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SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY, 1927

CEPHALOPODS FROM THE LOWER PART OF THE CODY SHALE OF OREGON BASIN, WYOMING

By John B. Reeside, Jr.

INTRODUCTION

It is the purpose of this paper to record the cephalopods contained in a collection of invertebrate fossils from the lower part of the Cody shale in Oregon Basin, Wyo., a topographic subdivision of the western part of the great synclinal area known generally as the Big Horn Basin. The collection was made by Edwin Binney, jr., during the course of a study of the oil and gas resources of this area and comes from secs. 6, 19, 31, and 33, T. 51 N., R. 100 W. The stratigraphic position is in a zone from 720 to 820 feet above the sandstone that forms the uppermost member of the Frontier formation as it is recognized in the region. Collections made from the Cody shale 200 feet above this sandstone and in the sandstone itself show that a closely related fauna extends down to that horizon.

The stratigraphic section in Oregon Basin is described in a published paper by Hewett [1] and in a manuscript by Binney.[2] The Cretaceous rocks include at the base the Cloverly formation, followed in succession by the Thermopolis shale, Mowry shale, Frontier formation, Cody shale, Mesaverde formation, and Meeteetse formation. Above the Meeteetse lies the Lance formation, assigned with doubt to the Tertiary; then, unconformably, the Fort Union formation, of Eocene age.

The Cody shale is 2,200 to 2,500 feet thick in Oregon Basin. In the upper 350 feet a fauna of Eagle (lower Campanian) age was collected near Shoshone River by Hewett, including such species as *Inoceramus lobatus* Goldfuss, *Scaphites hippocrepis* (De Kay), and *Scaphites aquilaensis* Reeside. A middle zone 1,200 to 1,400 feet thick has not yielded diagnostic fossils. The lower part contains the fauna listed in this paper.

Mr. W. O. Hazard made the photographs of the specimens shown in the plates, and Miss Frances Wieser retouched the figures and assembled the plates.

[1] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyoming: U. S. Geol. Survey Prof. Paper 145, 1926.

[2] Binney, Edwin, jr., dissertation presented to the faculty of Yale University in candidacy for the degree of Doctor of Philosophy, 1925.

THE FAUNA AND ITS RELATIONS

The fossils collected by Mr. Binney from the zone 720 to 820 feet above the upper sandstone of the Frontier formation constitute a fairly varied fauna, though many of the species are yet undescribed. The complete list is as follows:

Vermes:
- Serpula sp.

Pelecypoda:
- Inoceramus umbonatus Meek and Hayden.
  - exogyroides Meek and Hayden.
  - aff. I. acutiplicatus Stanton.
  - sp. undescribed aff. I. barabini Morton.
- Pteria gastrodes Meek.
- Ostrea sp.
- Modiola sp. undescribed aff. M. meeki Evans and Shumard.
- Pholadomya papyracea Meek and Hayden.
- Crassatellites sp. undescribed.
- Corbula nematophora Meek.

Gastropoda:
- Gyrodes conradi Meek.
- Turritella sp. undescribed aff. T. whitei Stanton.
- Anchura sp.
- Fusus sp. (sp. undescribed?).
- Fasciolaria sp. undescribed.
- Volutoderma, probably several undescribed species related to V. dalli and V. ambigua Stanton.
- Cinulia sp. undescribed aff. C. concinna Hall and Meek.
- Anisomyon sp. undescribed.

Cephalopoda:
- Eutrephoceras sp.
- Phlycticrioceras oregonense Reeside, n. sp.
- Baculites asper Morton.
  - codyensis Reeside, n. sp.
  - sp.
- Binneyites parkensis Reeside, n. gen. and sp.
- Scaphites ventricosus Meek and Hayden.
  - ventricosus var. stantoni Reeside, n. var.
  - ventricosus var. depressus Reeside, n. var.
  - ventricosus var. oregonensis Reeside, n. var.
  - ventricosus var. interjectus Reeside, n. var.
  - vermiformis Meek and Hayden.
  - vermiformis var. binneyi Reeside, n. var.
- Placenticeras pseudoplacenta Hyatt.
- Mortoniceras shoshonense Meek.
  - shoshonense var. crassum Reeside, n. var.

Crustacea:
- Balanid barnacle, young form?

At 200 feet above the upper sandstone of the Frontier formation in the NE. ¼ SE. ¼ sec. 32, T. 52 N., R. 100 W., a rudistid much like "*Radiolites*" (*Durania?*) *austinensis* Roemer was collected by Mr. Binney, and near the top of the Frontier formation as interpreted by him, in sec. 32, T. 51 N., R. 100 W., he found *Inoceramus deformis* Meek, *Inoceramus* aff. *I. acutiplicatus* Stanton, and *Pinna* aff. *P. lakesi* White.

The association of species shown in these collections from the lower part of the Cody shale and the upper sandstone of the Frontier formation identifies a faunal zone that occurs in the Niobrara formation of the Great Plains and contiguous areas; in the middle of the Mancos shale of New Mexico, Utah, and Arizona, and in the upper part of the Colorado formation of Montana. Such species as *Inoceramus umbonatus*, *I. exogyroides*, *I. deformis*, *Scaphites ventricosus*, and *S. vermiformis* are among the most useful guide fossils for this particular faunal zone in the Cretaceous of the Interior Province. The fossils also show that the Frontier formation as identified in the Big Horn Basin includes younger rocks than are included in the typical Frontier of Lincoln County, Wyo., where the entire formation is pre-Niobrara and probably pre-Carlile in age.

Some of the species in that they support strongly the correlation usually made of the Niobrara formation and its faunal equivalents in North America with the European Coniacian (Emscherian). The coiled *Inoceramus umbonatus* Meek and Hayden and *I. exogyroides* Meek and Hayden are very close allies of *I. involutus* Sowerby. *Phlycticrioceras oregonense* is very close to *Phlycticrioceras* ("*Ancyloceras?*") *douvillei* Grossouvre. *Mortoniceras shoshonense* Meek is close to *M. bourgeoisi* D'Orbigny.

The cephalopods described in this paper include, as the list above shows, representatives of 7 genera, under which are placed 10 species and 6 varieties. One genus is new, *Binneyites*. The species of *Scaphites* have not been minutely described before and have been in need of amplified treatment. *Mortoniceras shoshonense* has been recorded only by Meek's original description and figure but is here described and figured in detail from Mr. Binney's material and other specimens from near-by localities.

SYSTEMATIC DESCRIPTIONS OF THE CEPHALOPODS

Family NAUTILIDAE Owen

Genus EUTREPHOCERAS Hyatt

Eutrephoceras includes nautiloids with subglobose, involute shells; whorl nephritic in cross section throughout life, changing but little; umbilicus closed; siphuncle generally dorsad of the center of the whorl. Shells usually smooth except for fine longitudinal lines on the venter and growth lines parallel to the aperture. Sutures nearly straight, having shallow elements—ventral lobe, broad ventrolateral saddle, lateral lobe, second lateral saddle, umbilical lobe, and a broad, obtusely pointed dorsal lobe.

Species of this genus are not very sharply differentiated, especially in the sort of material usually available—broken internal casts. There is, however, a consistency in the form of the cross section of the whorl and the maximum size attained that permits a separation into specific groups that are limited in geographic distribution and in stratigraphic range.

Eutrephoceras sp.

Plate 1, Figures 1–4

A single small but well-preserved septate internal cast is the only representative of the genus in the collection.

Shell stout, well rounded; maximum size unknown. Stages up to 10 or 12 millimeters in diameter globose; succeeding stages to a diameter of 30 millimeters, somewhat higher but still stout. The proportions of height to width of the cross section of the whorl are as 4 to 5.

Surface of shell unknown. Sutures as in the generic description.

This small specimen, although insufficient as a basis for the founding of a new species, seems to be different from species now known in the Interior Province. From *E. dekayi* (Morton) of Meek,[3] which occurs in the upper part of the Pierre shale, it differs in proportions, the ratio of height to width of the cross section of the whorl of *E. dekayi* being 3 to 4; from *E. alcesense* Reeside,[4] of the Eagle sandstone, it differs also in the proportions of the whorl, the ratio of height to width of the cross section in *E. alcesense* being 6 to 7.

Occurrence: Cody shale, about 800 feet above base, in sec. 6, T. 51 N., R. 100 W., Wyo.

Family LYTOCERATIDAE Neumayr

Subfamily MACROSCAPHITINAE Hyatt

Genus PHLYCTICRIOCERAS Spath

This genus was proposed by Spath[5] for the reception of a group of aberrant ammonites. The specimens figured in the literature and those available to the writer leave some important features of the genus in doubt, but the characters shown indicate such differences as to deserve separation from other members of the family. Spath, indeed, proposes to make the genus the basis for a new family, Phlycticrioceratidae.

[3] Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, pp. 496–498, pl. 27, figs. 1, 2, 1876.

[4] Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 7, pl. 1; pl. 2; pl. 3, figs. 1–5; pl. 5, figs. 1, 2, 1927.

[5] Spath, L. F., On new ammonites from the English chalk: Geol. Mag., vol. 63, p. 80, 1926.

Spath, in his definition, merely cites *Ancyloceras douvillei* Grossouvre as the genotype and notes the "median crest" as the distinguishing feature. The genus may be defined more fully as follows:

Shell elongated, tubular, apparently lying in a single plane with whorls widely separated; coiling irregular, parts of shell nearly straight, parts much curved. It is not yet known whether the coiling is like that of *Hamites* or like that of *Ancyloceras*. Ribs simple and bearing on the siphonal line a high, sharp tubercle and on each ventrolateral shoulder a lower, rounded tubercle; constrictions at intervals bordered by ribs larger than the other ribs. Suture has two lateral lobes, deeply bifid, and three lateral saddles, also bifid, on each side between the siphonal and antisiphonal lobes.

This genus is related to *Hamites* Parkinson in suture and form of the shell, so far as may be inferred from material in hand, but differs in the possession of the median-ventral nodes. The shell might well have the form of *Ancyloceras* D'Orbigny but differs very sharply in suture, for it has bifid instead of trifid lobes; and it differs from *Helicoceras* D'Orbigny in having the coil in a plane instead of a helicoid.

Ancyloceras? douvillei Grossouvre,[6] the genotype, from the uppermost Coniacian; probably *Hamites* cf. *H. angustus* Dixon of Schlüter,[7] which Grossouvre believed to be identical with his species; possibly *Hamites trinodosus* Geinitz[8] from Kieslingswald; and the species described below complete the list of known or possible members of the genus.

Phlycticrioceras oregonense Reeside, n. sp.

Plate 1, Figures 5–18

This species is based on nine specimens from five localities, one in Oregon Basin, four elsewhere. The three specimens from Oregon Basin are figured, and the best characterized is taken as the type. The whorl has a high pentagonal cross section with flanks and inner side flattened. Ventrolateral shoulders angular, dorsolateral shoulders rounded. The proportions of the height to width of the cross section are about as 3 to 2. Septate and unseptate fragments have the same form. Aperture unknown.

Sculpture of relatively low, straight, simple ribs, which pass entirely around the shell, inclined somewhat posteriorly as they pass outward on the whorl, weak or nearly obsolete on the inner (dorsal) side, strongest on the outer (ventral) side. The ribs are broadly rounded and about equal in width to the concave interspaces. On the ventrolateral shoulders they rise into a low, sharp circular tubercle and on the siphonal line into a high tubercle, slightly elongated parallel to the siphon. Each fifth or sixth interspace deepened to make a definite constriction, with the bordering ribs somewhat elevated above the other ribs.

This species is very close to the genotype, which seems to be more compressed and to have the constrictions at greater intervals—differences which may prove not to be of great significance when larger collections are available. No recorded American species are liable to confusion with it, for none have the median row of nodes. Of American species referred to *Ancyloceras*, as was *P. douvillei*, *Ancyloceras jenneyi* Whitfield,[9] which Hyatt[10] assigns to his genus *Exiteloceras* but which is probably a species of *Neancycloceras* Spath, has a suture similar to that of *P. oregonensis* in its bifid lobes and saddles, is similar in costation, and is coiled in a single plane but bears only two rows of nodes. *Ancyloceras tricostatum* Whitfield[11] is very different and belongs to *Didymoceras* or *Nostoceras* Hyatt.[12] *Ancyloceras? uncum* Meek and Hayden[13] is also very different and is assigned by Hyatt[14] to *Exiteloceras*.

The specific name is derived from Oregon Basin, Wyo., from which the type came.

Occurrence: Cody shale 800 feet above Frontier formation, sec. 6, T. 51 N., R. 100 W., in Oregon Basin, Wyo.; Cody shale 350 feet above base, sec. 24, T. 58 N., R. 97 W., near Frannie, Wyo., and sec. 22, T. 7 S., R. 23 E., 5 miles southeast of Bridger, Mont.; lower middle Mancos shale, NE. ¼ sec. 4, T. 19 S., R. 14 E., and 1 mile east of Desert station, Emery County, Utah.

Genus BACULITES Lamarck

Baculites includes ammonites with a minute, closely coiled initial stage, which passes quickly into a straight, staff-like stage maintained throughout the remainder of the shell and increasing slowly in diameter with age. The usual specimens available are fragments of this staff-like, gently tapering part. Cross section of whorl subtriangular, oval, or subcircular. Living chamber large; aperture with long, straight rounded extension on the siphonal side and lateral sinus. Surface smooth, or with low rounded ribs parallel to the aperture, or with nodes on the flanks. Suture with six saddles and six lobes, bifid except for the antisiphonal lobe.

[6] De Grossouvre, Albert, Les ammonites de la craie supérieure, p. 254, pl. 35, fig. 8; text figs. 88, 89, 1894.

[7] Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 106, pl. 32, figs. 6, 7, 1871.

[8] Geinitz, H. B., Das Quadersandsteingebirge, pl. 3, fig. 4, 1850.

[9] Whitfield, R. P., Paleontology of the Black Hills, in Newton, Henry, and Jenney, W. P., Report on geology and resources of the Black Hills of Dakota, p. 452, pl. 16, figs. 7–9, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

[10] Hyatt, Alpheus, Phylogeny of an acquired characteristic: Am. Philos. Soc. Proc., vol. 32, p. 577, 1894.

[11] Whitfield, R. P., op. cit., p. 45, pl. 15, figs. 7, 8.

[12] Hyatt, Alpheus, op. cit., p. 574.

[13] Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 409, pl. 21, figs. 1a, 1b, 1876.

[14] Hyatt, Alpheus, op. cit., p. 577, 1894.

Baculites asper Morton

Plate 1, Figures 19–24; Plate 2, Figures 1–5

1830. *Baculites asper* Morton, Am. Jour. Sci., 1st ser., vol. 23, p. 291.

1834. *Baculites asper* Morton, Synopsis of the organic remains of the Cretaceous group in the United States, p. 43, pl. 1, figs. 12, 13; pl. 13, fig. 2.

[For complete synonymy see Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 151, p. 13, 1927.]

B. asper Morton includes small shells with broadly ovate cross section; distant, rounded nodes on the antisiphonal half of the flanks; and rather weak undulations on the siphonal side that have only faint connection with the rounded nodes. Suture relatively simple, with little-incised rounded elements.

Various forms with other characters, such as arcuate nodes, tapered cross section and more or less acute siphonal margin, compressed cross section, and large size, do not properly belong to the species, though such forms have been assigned to it by several authors. The distribution is wide, and the range of the species, in the proper application of the name, appears to be through the late Colorado and early Montana horizons (Emscherian to lower Campanian), though there is some uncertainty because of lax use of the name.

The specimens described in this paper are typical in every respect, and one of them is especially notable in preserving a complete living chamber. This is proportionately shorter than in several other species which the writer has seen but shows very well the siphonal and antisiphonal extensions of the aperture.

Baculites codyensis Reeside, n. sp.

Plate 2, Figures 6–19

This species belongs to a group of baculites marked by the possession of relatively close-set strong arcuate nodes on the antisiphonal half of the flank. Members of the group are often designated *B. anceps* Lamarck in the literature, but inasmuch as other characters of specific value are ignored in this assignment and as *B. anceps* in its proper conception is probably limited to the Maestrichtian of Europe, new names are desirable.

Shell small for the genus, the largest individuals reaching about 20 millimeters in diameter; taper comparatively rapid; cross section well rounded, ovate much as in *B. asper*. Surface shows numerous fairly prominent, arcuate nodes on the antisiphonal half of the shell, each of which corresponds to one or more ill-defined inclined ribs on the siphonal margin. The nodes are distinct on the smallest individual available for examination—5 millimeters in diameter. The suture shows relatively simple elements, rounded and little incised, with the anomalous feature that the saddle dividing the siphonal lobe is itself divided by a single, pointed marginal lobe on the siphonal line.

B. codyensis is much like *B. asper* Morton in form and size, but its close-set, arcuate nodes are quite unlike the distant rounded nodes of *B. asper*. There are individuals, however, which show a tendency toward the type of ornamentation shown by *B. asper*, and it is possible that large collections might include a series of intermediate forms connecting the two species. *B. codyensis* differs from *B. aquilaensis* Reeside [15] in its smaller size and much stouter cross section. It is not, however, as stout as *B. aquilaensis* var. *obesus* Reeside.[16] *B. anceps* var. *obtusus* Meek,[17] of a late Montana horizon, has much heavier and more prominent ribs.

Occurrence: Cody shale 800 feet above base, sec. 6, T. 5 N., R. 100 W., Wyo.; upper (Niobrara) part of Colorado formation, Cow Creek 13 miles above the mouth, in the Judith region, Mont.; middle (Niobrara) part of Mancos shale near Desert station, Emery County, Utah.

Baculites sp.

A single specimen (Yale Peabody Museum catalogue No. 6406) of a baculite larger than *B. asper* and *B. codyensis* is contained in the collection. It is much crushed, and details are not well preserved, so that it does not retain essential characters, but it seems to record the presence in the fauna of a baculite attaining a diameter of more than 30 millimeters. It was apparently smooth or nearly smooth and had a deeply dissected suture.

Another specimen (Yale Peabody Museum catalogue No. 6412), with a length of 18 millimeters and cross section measuring 8.5 by 5 millimeters, is oval but more compressed than either *B. asper* or *B. codyensis* and shows no trace of nodes or ribs. It probably represents an undescribed species, but the material in hand is not sufficient basis for a new name. The suture is like that of the two species named—of relatively simple, rounded, little-incised elements.

Family BINNEYITIDAE Reeside, n. fam.

Genus BINNEYITES Reeside, n. gen.

A single nearly complete specimen of a small ammonite from the SW. ¼ NE. ¼ sec. 6, T. 51 N., R. 100 W., in Oregon Basin, in the Cody shale 775 feet above the base, and a smaller broken specimen from sec. 24, T. 58 N., R. 97 W., near Frannie, in the Cody shale 400 feet above the base, present such a combination of characters as to deserve separation as a new genus. The features shown include a much compressed discoid shell with subparallel flanks, truncated venter bor-

[15] Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 12, pl. 6, figs. 11–13; pl. 8, figs. 1–14, 1927.

[16] Idem, p. 12, pl. 10, figs. 1–18.

[17] Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 406, text figs. 57–60, 1876.

dered by subangular shoulders, and very small umbilicus. Whorls with flanks smooth except for latest part of shell, which shows low falciform ribs; and with distant, elongated and inclined nodes on the ventrolateral shoulders. Suture with simple elements; ventral lobe small, first lateral saddle long and very narrow, simple; first lateral lobe broad, asymmetrically bifid; second lateral saddle broad, high, bifid; second lateral lobe long, narrow, asymmetrically bifid; other elements small, simple.

The relations of this genus are difficult to determine. The writer has in hand several specimens of a small undescribed ammonite of Turonian age that appears to be a species of *Heterotissotia* Peron.[18] The external features are exceedingly close to those of *Binneyites*, but the sutures of the two forms have nothing in common. Some of the Triassic genera, such as *Cordillerites*,[19] show some resemblance to *Binneyites*, but it is probable that the similarities are purely superficial. In this respect the genus resembles the Cenomanian *Flickia* Pervinquière,[20] which finds its closest analogues in the Triassic. For the present the writer proposes to set *Binneyites* apart in a separate family, though it may be possible in the future to connect this genus with other groups.

The genus is named for Edwin Binney, jr., who made the collection containing the genotype.

Binneyites parkensis Reeside, n. sp.

Plate 3, Figures 1–10

Adult shell much compressed, involute, discoid; flanks flat, subparallel; venter truncate, very gently arched. Earliest whorls seen, at diameter of 2 millimeters, stout, well rounded; half a whorl later, at a diameter of 3 millimeters, the flanks are flattened and the shell is a stout disk; about half a whorl later, at a diameter of 5 millimeters, the whorl is still more compressed and much like the later whorls except that the venter is well rounded and not distinctly truncate. At a diameter of about 10 millimeters the venter is bordered by subangular shoulders, which continue to the end of the shell. The proportions of the whorl are shown in the cross section of the type, Plate 3, Figure 4. The living chamber occupies more than five-eighths of the last whorl but probably very little more; it is slightly scaphitoid. Aperture not preserved, but the latest growth lines suggest that it is sigmoid, with probably a short ventral lappet. Umbilicus very small with abrupt subangular shoulder and perpendicular inner wall.

Whorls have smooth flanks from a diameter of 2 to 15 millimeters. From 15 to 26 millimeters, the last stage preserved, constituting mostly the unseptate part of the shell, low irregular ribs pass radially from the umbilicus to the middle of the flank, then curve gently forward, backward, and finally forward to the border of the venter, making a shallow sigmoid curve. On the margins of the venter low indistinct nodal swellings appear at a diameter of about 2.5 millimeters. These quickly become low elongated nodes, with the longer axis inclined forward at an angle of about 30° to the plane of coiling of the shell, and are present on all the stages seen. There are seven of these nodes on the first half of the last whorl and twelve on the latter half, each corresponding to a rib on the flank; they are more closely spaced toward the end of the shell. On the venter obscure ribs arched gently forward connect the nodes.

The adult suture shows a simple ventral lobe; a very narrow, simple first lateral saddle, in width about half that of the ventral lobe; a broad, somewhat asymmetrical and simple, bifid first lateral lobe in width 1½ times that of the ventral lobe and of equal length; a high, bifid second lateral saddle about as broad as the first lateral lobe and with several small marginal lobes; a long, narrow second lateral lobe, asymmetrically bifid, about three-fourths the width of the ventral lobe and considerably longer; remaining elements of the suture small and in a nearly straight line inclined to the radius. The suture at a diameter of 2.5 millimeters shows the ventral lobe large; the first lateral saddle about as large as the first lateral lobe and both smaller than the ventral lobe; the second lateral saddle and lobe not conspicuous. At a diameter of 4.5 millimeters the features of the suture have approached somewhat those of the adult, though the first lateral lobe is about equal in size to the ventral lobe, and the second lateral lobe is small. At a diameter of 9 millimeters the suture is very much like that of later stages except that the first lateral saddle is a bit wider proportionately.

The specific name is derived from Park County, Wyo., in which the type locality occurs.

Family COSMOCERATIDAE Zittel

Subfamily SCAPHITINAE Meek

Genus SCAPHITES Parkinson

Scaphites has been used in a broad sense by many students and made to include several rather different groups of forms. Some of these were separated as subgenera or sections long ago. Nowak[21] in recent years has again called attention to the separateness of some of the groups and proposed new names In its stricter sense *Scaphites* includes only the close relatives of *S. aequalis* Sowerby, the genotype. The am-

[18] Peron, M., Les ammonites du crétacé supérieur de l'Algérie: Soc. géol. France Mém. 17, p. 81, 1896.

[19] Hyatt, Alpheus, and Smith, J. P., The Triassic cephalopod genera of America: U. S. Geol. Survey Prof. Paper 40, p. 110, pl. 2, figs. 1–3, 1905.

[20] Pervinquière, Léon, Études de paléontologie tunisienne, pt. 1, Céphalopodes des terrains secondaires, p. 212, 1907.

[21] Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, pp. 547–588, 1912; Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrgang 1915, No. 3, pp. 56–57, 1916.

monites of this genus have the characteristic form—a normal coil of septate whorls and the last living chamber partly unrolled; whorls stout, umbilicus small, sculpture of straight ribs beginning in the umbilicus and passing with increasing height to the margin of the venter, where they split into two or more ventral ribs; there are also intercalated ventral ribs, and there may be definite nodes at the ventrolateral ends of the primary ribs; the suture consists of moderately incised elements, decreasing gradually in size from the median plane to the line of involution; lobes trifid in the earliest stages but usually bifid in the adult. Nowak called this group *Holcoscaphites*, but Parkinson's name should be retained in a restricted sense.

The writer has in another paper [22] reviewed the scaphites as a group, and to that paper the reader is referred for an extended statement.

Scaphites ventricosus Meek and Hayden

Plate 3, Figures 11–18; Plate 4, Figures 1–4

1862. *Scaphites ventricosus* Meek and Hayden, Acad. Nat. Sci. Philadelphia Proc., vol. 14, p. 22.

1876. *Scaphites ventricosus* Meek and Hayden. Meek, U. S. Geol. Survey Terr. Rept., vol. 9, p. 425, pl. 6, figs. 7, 8.

1894. *Scaphites ventricosus* (part) Meek and Hayden. Stanton, U. S. Geol. Survey Bull. 106, p. 186, pl. 44, figs. 8–9; pl. 45, fig. 1 [not pl. 44, fig. 10].

1898. *Scaphites ventricosus* (part) Meek and Hayden. Logan, Kansas Univ. Geol. Survey, vol. 4, p. 476, pl. 104, figs. 8, 9; pl. 105, fig. 1 [not pl. 104, fig. 10].

1899. *Scaphites ventricosus* Meek and Hayden. Stanton, U. S. Geol. Survey Mon. 32, p. 636.

1903. *Scaphites ventricosus* Meek and Hayden. Douglass, Carnegie Mus. Annals, vol. 2, No. 1, p. 8.

Meek's description is as follows:

Shell attaining a medium or larger size, oval, ventricose, broadly rounded over the periphery; inner turns closely involute, deeply embracing, and composing a large portion of the entire bulk; deflected portion very short; umbilicus very small and deep; aperture transversely sublunate or reniform, being deeply sinuous and but slightly disconnected from the inner turns on the inner side; surface ornamented with costae that pass nearly straight over the periphery, where they are of uniform size, excepting their gradual enlargement with the volutions, while on the sides of the last or outer volution, about every fifth or sixth one is larger and more prominent than the intermediate ones, which latter do not extend inward to the umbilical margin.

The septa, as made out from the specimen represented by our figures 8, *a*, *b* (which is believed to be the inner volutions of this species, as represented by figures 7, *a*, *b*), are provided with deeply divided lobes and sinuses. Siphonal lobe longer than wide and bearing on each side of its very slender body three branches, the two terminal of which are slightly larger than the succeeding lateral ones, and each unequally bifid and digitate; first lateral sinus as large as the siphonal lobe, very narrow at its base, and profoundly divided at its extremity into two unequal branches, of which the one on the siphonal side is larger than the other, and, like the latter, deeply bifid, with sinuous and obtusely digitate margins; first lateral lobe as wide as the siphonal lobe but somewhat shorter and provided with two nearly equal, bifurcating, and digitate terminal branches; second lateral sinus not more than half as long and little more than half as wide as the first and somewhat similarly divided and subdivided; second lateral lobe about half as long and wide as the first, but tripartite at the extremity, the divisions being nearly equal and digitate; third lateral sinus small and merely provided with two nearly equal terminal branches, with more or less sinuous margins; third lateral lobe hardly more than half as large as the second and bearing two very short, digitate terminal divisions. Between the last-mentioned lobe and the umbilicus there is a minute tridigitate lobe, very similar to the auxiliary lobe of the third lateral sinus but smaller.

The individuals here referred to this species agree very closely in form, sculpture, and suture with Meek's type specimen. Additional details of the early stages not given in Meek's description are afforded by the material in hand. The protoconch is similar to that of many other ammonites. The whorls are stout and are well rounded from the earliest stages to the end of the adult shell, the relative depression of the whorl increasing, however, in the latest stages. Up to a diameter of perhaps 3 millimeters the shell is smooth; then the ventral ribs appear as low rounded swellings passing straight across the venter, about 20 in number on the first sculptured whorl. These ventral ribs join near the umbilicus to form perhaps 10 obscure straight primary ribs. On succeeding whorls the same type of sculpture is present, though the ribs become higher and more numerous. The smaller specimen figured shows on the whorl ending at a diameter of 30 millimeters 50 ventral ribs and 19 umbilical ribs, and the larger specimen shows on the last septate whorl nearly 70 on the venter and 20 near the umbilicus. The ribs increase by forking and also by intercalation. The uncoiled living chamber bears relatively coarser ribs than the septate whorls. There is no suggestion of nodes in any of the specimens. An interesting feature of the larger specimen figured is the presence over the siphuncle of a faint rounded ridge which is continued out on the living chamber where the siphuncle is absent. The suture shows the characteristics of a normal *Scaphites* (s. s.) in that the first lateral lobe is in the earliest stages distinctly unsymmetrical, though it does not show a clearly trifid division, and then becomes symmetrically bifid. The second lateral lobe is clearly trifid at a diameter of 5 millimeters and in the later stages approaches a bifid form. The elements of the suture show a gradual decrease in size from the median plane of the shell to the line of involution both for the external and internal parts.

The characteristic features of *Scaphites ventricosus* are its stout, evenly rounded whorls, relatively fine ribs throughout the shell, and lack of nodes.

Hyatt [23] proposed to make this species the type of a new genus, *Anascaphites*, but the writer believes that

[22] Reeside, J. B., jr., The scaphites, an Upper Cretaceous ammonite group: U. S. Geol. Survey Prof. Paper 150-B, pp. 21-40, 1927.

[23] Hyatt, Alpheus, Cephalopoda, in Eastman, C. R., Textbook of paleontology by Karl von Zittel, vol. 1, p. 572, 1900.

the sequence of form, the sculpture, and the development of the suture prove it a *Scaphites* in the strict sense of the name and that *Anascaphites* must be abandoned. Hyatt did not define his group other than to cite the type species, and no one has yet accepted his usage.

The species is of widespread occurrence in the Interior Province of the Cretaceous and is one of the valuable guide fossils for late Colorado (Niobrara) time. It does not occur in beds of Benton age, as restricted to pre-Niobrara time, though Meek and others have cited it as a Benton species.

Scaphites ventricosus Meek and Hayden var. stantoni Reeside, n. var.

Plate 3, Figures 19–20; Plate 4, Figures 5–10

1894. *Scaphites ventricosus* (part) Meek and Hayden. Stanton, U. S. Geol. Survey Bull. 106, p. 186, pl. 44, fig. 10 [not pl. 44, figs. 8, 9; pl. 45, fig. 1].

1898. *Scaphites ventricosus* (part) Meek and Hayden. Logan, Kansas Univ. Geol. Survey, vol. 4, p. 476, pl. 104, fig. 10 [not pl. 104, figs. 8, 9; pl. 105, fig. 1].

This variety is proposed to include forms like that figured by Stanton in Plate 44, Figure 10, of his paper on the Colorado fauna, the original of which will serve as the type specimen for the variety. It is a more slender shell than the typical form of the species and has finer ribs, though in general aspect and in suture it is like the typical form. The last separate whorl with a maximum diameter of 40 millimeters shows 80 ventral ribs and about 25 primary ribs. None of the individuals in hand attain much more than half the size of typical *S. ventricosus*, possibly owing to the mere accidents of collecting. Should small size prove a constant feature it will form another character of the variety.

The type specimen figured by Stanton comes from Devils Slide, Cinnabar Mountain, Mont. Several specimens are in the collection from Oregon Basin and from other localities in the Interior Province of the Cretaceous.

Scaphites ventricosus Meek and Hayden var. depressus Reeside, n. var.

Plate 5, Figures 6–10

The variety is marked chiefly by the greater depression of the whorls, the shell being 52 millimeters wide at a diameter of 50 millimeters, whereas in the typical form it is 44 millimeters wide at a diameter of 50 millimeters. The living chamber is not known, but a complete shell would be as large as the typical form of the species. The ribs are fine—about 75 ventral ribs on the last whorl of the type (diameter of 50 millimeters) and 19 umbilical ribs.

Scaphites ventricosus Meek and Hayden var. oregonensis Reeside, n. var.

Plate 6, Figures 11–15

This variety is marked by possessing relatively fine and relatively sharp ribs rather than threadlike rounded ribs; on the living chamber the umbilical ribs stand high and sharp and at the margin of the venter reach their greatest height in an incipient node. It resembles somewhat in sculpture and form the geologically younger species *Desmoscaphites bassleri* Reeside,[24] which has sharp, well-developed nodes at the margin of the venter. It differs from *D. bassleri* in its stouter whorls and lack of a real node and is also different in suture. In its general aspect it is still a *S. ventricosus*. The specimens in hand are small, though this might not be a constant feature in a larger collection.

Scaphites ventricosus Meek and Hayden var. interjectus Reeside, n. var.

Plate 5, Figures 1–5

This variety is much like the type in its general aspect and in suture, but the primary ribs are relatively higher and rise into an incipient or even clearly defined node at the margin of the venter. In this character it approaches *Scaphites vermiformis* Meek and Hayden (see below), but it differs in having more numerous ribs on the venter of the living chamber—four or more to each umbilical rib—and, so far as the specimens in the writer's hands show, in attaining a larger size.

One of the specimens figured is from the banks of Missouri River, 4 or 5 miles below the mouth of Marias River, Mont.; the other is one of several specimens from Oregon Basin, Wyo.; a third locality is in the NE. ¼ NW. ¼ sec. 30, T. 56 N., R. 97 W., on the Garland anticline, Wyo.

Scaphites vermiformis Meek and Hayden

Plate 6, Figures 9–10

1852. *Scaphites vermiformis* Meek and Hayden, Acad. Nat. Sci. Philadelphia, vol. 14, p. 22.

1876. *Scaphites vermiformis* Meek and Hayden. Meek, U. S. Geol. Survey Terr. Rept., vol. 9, p. 423, pl. 6, fig. 4.

1894. *Scaphites vermiformis* Meek and Hayden. Stanton, U. S. Geol. Survey Bull. 106, p. 183, pl. 44, fig. 3.

1898. *Scaphites vermiformis* Meek and Hayden. Logan, Kansas Univ. Geol. Survey, vol. 4, p. 474, pl. 104, fig. 3.

1910. *Scaphites vermiformis* Meek and Hayden. Grabau and Shimer, North American index fossils, p. 176, fig. 1427c.

Meek's description is as follows:

Shell under medium size, ovate-subdiscoidal in form; umbilicus very small; inner regularly coiled volutions closely involute, deeply embracing, and composing a rather large portion of the entire shell; deflected part very short, so as only to be slightly disconnected from the inner turns at the aperture, which is a little contracted and quadrato-subcircular in outline, with a slightly sinuous inner margin; surface ornamented by numerous straight costae, which are rather small and nearly regular on the inner volutions but become more distant and larger, as well as much more prominent, on the inner half of each side of the body portion, where they each support a prominent node at the outer end, so arranged that those on opposite sides generally alternate; costae all passing

[24] Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 16, pl. 21, figs. 17-21; pl. 22, figs. 8-12, 1927.

nearly straight across the periphery, on which they are of nearly uniform size, with the exception of the irregular enlargement with the whorls.

The nodes mentioned above are directed out at right angles to the sides of the shell and, like the costae, become again smaller toward the aperture. Most of the large costae bifurcate at the nodes on the body part of the shell, but their number is also increased by the intercalation of others between. Where they thus branch at the nodes on one side, the two divisions crossing over the periphery from the point of bifurcation never both connect at a node on the opposite side, but in most cases one and sometimes each division terminates between two of the nodes on the other side.

The septate portion of the only specimen of this species in the collection being highly crystalline, the structure of its septa can not be very clearly traced out. The siphonal lobe, however, can be seen to be a little longer than wide, with a rather narrow body, provided with three branches on each side, the upper pair of which are small and nearly simple, while the next pair are longer and each bifid, and the terminal pair (which are larger than the second) are each ornamented by three small pointed branchlets, or digitations, on the outer side. The first lateral lobe is somewhat irregularly tripartite, the lateral divisions being bifid and sharply digitate, while the terminal, which is not exactly central, is longer than the others, and has about five pointed digitations, or sharp, nearly or quite simple branchlets. The first lateral sinus can be seen to be deeply divided at the extremity into two nearly equal branches. The second lateral sinus can also be so far traced as to show that it is not more than about one-third as large as the first, nearly as long as wide, and regularly tripartite; and this is as far as the structure of the septa can be made out from the specimen.

This species is distinguished by the possession of coarse, rather sharp ventral ribs—two to each umbilical rib—and a row of high, sharp conical nodes along the margins of the venter of the living chamber—one node for each primary rib. It is moderately compressed and apparently a consistently small shell for the genus. The suture is not well preserved on any of the specimens available to the writer but is definitely a normal suture for *Scaphites* s. s.—bifid adult lobes and a gradual decrease in size from the median plane. It is connected with *S. ventricosus* Meek and Hayden by *S. ventricosus* var. *interjectus* Reeside, n. var. The type specimen came from the later (Niobrara) part of the Colorado formation at Chippeway Point, on Missouri River, Mont.

The species is widespread in the Interior Province of the Cretaceous and, like its frequent associate *S. ventricosus*, is one of the most useful guide fossils for late Colorado (Niobrara) time. It does not occur in beds of Benton age as now conceived, though Meek and others have cited it as a Benton form.

Scaphites vermiformis Meek and Hayden var. binneyi Reeside, n. var.

Plate 6, Figures 1–8

This variety differs from the typical form in the greater depression of the whorls and the greater length of the living chamber. Its general aspect, sculpture, and suture are essentially the same as in the typical form.

Subfamily PLACENTICERATINAE Hyatt

Genus PLACENTICERAS Meek

The writer, in another paper,[25] has discussed at some length the genus *Placenticeras*. As there defined it has the following characters:

Shell large, discoidal, involute, compressed. Whorls stout and rounded in earliest stages; at a diameter of a few millimeters becomes higher than wide in cross section, with flattened venter; all later stages to a large diameter high, compressed, with narrow channeled venter bordered by sharp continuous or nodose keels or with narrow flat venter. Very large adults of most species have compressed whorls with narrowly rounded venters, though in a few species the senile whorls are stout, even quadrate in cross section. Umbilicus narrow in typical forms, about one-seventh the diameter of the shell, with rounded shoulder, gentle inner slope in the young and steep in the later stages. Stout species have a relatively wider umbilicus. Sculpture weak; faint ribs in the very young stages and none or only low, obscure coarse ribs in the later stages. Surface marked by sigmoid striae. Tubercles when present not usually strong nor numerous. Suture in adult has three prominent lateral lobes and six or seven smaller lateral lobes.

Placenticeras pseudoplacenta Hyatt

Plate 2, Figures 20–21

1894. *Placenticeras placenta?* (part) Stanton, U. S. Geol. Survey Bull. 106, pl. 39, fig. 1 [not figs. 2, 3].

1903. *Placenticeras pseudoplacenta* Hyatt, U. S. Geol. Survey Mon. 44, p. 216, pl. 43, figs. 3–11; pl. 44.

Hyatt did not anywhere offer a real diagnosis of this species, though from his figures and casual remarks it may be deduced that he had in mind a moderately stout shell, with height of the whorl about twice the width, flanks of whorl flattened in younger stages, very gently arched in later stages; narrow umbilicus; venter moderately broad, about as in *P. planum* Hyatt and *P. stantoni* Hyatt; nodes and ribs inconspicuous or absent at all stages; suture with first three lobes and first three saddles subequal; all the parts of the suture short, very solid, and only moderately incised; fourth lateral lobe much shorter than the third.

A single fragment of a species of *Placenticeras* preserving part of three successive whorls presents characters that ally it strongly with *P. pseudoplacenta* Hyatt but also with *P. planum* Hyatt.[26] It resembles the former species in the general form and proportions of the cross section of the whorl—height about twice the width—though the flanks are a little more rounded than in the type; in the absence of tubercles; and in

[25] Reeside, J. B., jr., A comparison of the genera *Metaplacenticeras* Spath and *Placenticeras* Meek: U. S. Geol. Survey Prof. Paper 147, pp. 1–5, 1926.

[26] Hyatt, Alpheus, Pseudoceratites of the Cretaceous: U. S. Geol. Survey Mon. 44, p. 202, pl. 33, figs. 2–4; pl. 34, 1903.

the degree of incision and proportions of the suture except for the first lateral saddle, which should be nearly equal in size to the second and third saddles but is instead nearly twice as wide. It resembles the second species in the gently rounded rather than flattened flanks and in the wide first lateral saddle; it differs in the absence of tubercles, somewhat stouter whorl—ratio of height to width as 2 to 4 as against 2 to 5—and abrupt drop in size of the fourth lateral lobe with respect to the third lateral lobe.

None of the other species of *Placenticeras* are very close to this: *P. syrtale* (Morton) and its allies have prominent nodes; *P. meeki* Boehm (=*P. whitfieldi* Hyatt) and its allies have a more compressed shell and much more intricate suture, *P. placenta* (De Kay) and its allies have a suture of different proportions and greater incision.

Hyatt seems to have allowed some latitude with respect to the width of the first lateral saddle, so it seems best to assign the present specimen to *P. pseudoplacenta*. It is not the variety *occidentale* Hyatt,[27] which is like the typical form in lacking conspicuous tubercles but which has a different suture—more complicated with the lobes and saddles unequal—so much so that the writer doubts that the variety *occidentale* really belongs to the species.

Family PRIONOTROPIDAE Zittel

Genus MORTONICERAS Meek

Mortoniceras embraces ammonites with compressed discoid shells, wide umbilicus, subquadrate cross section of the whorls; external border broad, bearing a low rounded keel bordered by shallow furrows, which in turn are bordered externally by a row of elongated tubercles; ribs straight, simple or bifurcated, and ornamented by tubercles. Sutures of few elements—siphonal lobe, three lateral lobes, and antisiphonal lobe; first lateral lobe about as long as the siphonal lobe but much longer than the second and third; first lateral lobe bifid.

Meek [28] chose *Ammonites vespertinus* Morton as the genotype, believing it identical with *Ammonites texanus* Roemer. Later students accept the latter as the true genotype.

Mortoniceras shoshonense Meek

Plate 6, Figures 16–23; Plate 7, Figures 1–11; Plate 8, Figures 1–4

1876. *Mortoniceras shoshonense* Meek, U. S. Geol. Survey Terr. Rept., vol. 9, p. 449, pl. 6, figs. 3 a, 3 c, 6 b.
1894. *Mortoniceras shoshonense* Meek. Stanton, U. S. Geol. Survey Bull. 106, pp. 179, 180, pl. 43, figs. 1, 2.
1898. *Mortoniceras shoshonense* Meek. Logan, Kansas Univ. Geol. Survey, vol. 4, p. 471, pl. 103, figs. 1, 2.

Meek's original description is as follows:

Shell compressed-discoidal, with umbilicus apparently nearly or quite twice as wide as the outer whorl; volutions very narrow, with dorsoventral and transverse diameters equal, and section subquadrangular, those within scarcely one-sixth embraced by the succeeding turn; costae each mainly represented by two nodes, the inner of which is low, compressed, and elongated, so as to extend from near the umbilical margin about halfway across the sides, while the outer near the peripheral margins is more prominent, rounded, and directed laterally; keel less prominent than the row of compressed nodes on each side about halfway between it and the rounded nodes along the margins of the periphery; compressed nodes on the periphery of each inner turn covered by the succeeding volution, the inner margin of which is indented by the rounded lateral nodes of that next within.

Septa moderately approximated; siphonal lobe oblong, about once and a half as long as wide, with small, short, nearly parallel, serrated terminal branches and three or four very short, digitate and simple branchlets and points on each side; first lateral sinus wider than the siphonal lobe (which it equals in length), unequally bipartite at the anterior end, both divisions being digitate and the larger one on the siphonal side deeply bifid; first lateral lobe somewhat longer but narrower than the siphonal and having its terminal division deeply bifid and its lateral margins bearing a few very nearly simple branchlets; second lateral sinus scarcely more than half as wide as the first and much shorter on the umbilical side, unequally bifid or trifid at the end, with more or less sinuous margins; second lateral lobe only about half as long and wide as the first and trilobate, with the small middle division emarginate at the end; third lateral sinus a little shorter and narrower than the second, with a bipartite end and serrated margins; third lateral lobe nearly as long as the second but narrower and irregularly tridentate at the end; antisiphonal lobe about as long as the first lateral but narrower, with a few short nearly simple, lateral divisions and a tridentate posterior extremity.

Meek's type is a small part only of a whorl but is sufficiently well characterized to define the species, as may be seen from Meek's excellent figures.[29] The specimens from Oregon Basin and other material in the writer's hands permit the following additional details of description, which Meek's specimen did not afford:

The shell in the earliest stages has a stout discoid form but quickly becomes compressed discoid. At the earliest diameter seen, 3.5 millimeters, the whorl is subcircular in cross section. A whorl later, at a diameter of 7 millimeters, the cross section has become slightly higher than wide and still evenly rounded. A half whorl later, at a diameter of 10 millimeters, it is 4 millimeters high, 3.5 millimeters wide, and helmet-shaped. A fourth whorl later, at a diameter of 13 millimeters, it is approaching a subquadrate form. In the course of the succeeding whorl it becomes quadrate, higher than wide, a form maintained in all the later stages known—that is, up to a diameter of 150 millimeters. The umbilicus is wide through all stages—a little less than half of the diameter; umbilical wall steep, umbilical shoulder rounded but well defined. Living chamber in specimens available for examination incomplete but occupying more than a half whorl. Aperture not preserved.

The whorl at a diameter of 3.5 millimeters is smooth; at 5 millimeters the low rounded siphonal keel has

[27] Idem, p. 217, pl. 45, figs. 1, 2.

[28] Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 448, 1876.

[29] Meek, F. B., op. cit., pl. 6, figs. 3a, 3c, 6b.

appeared; at 7 millimeters radial welts appear on the outer border of the flanks; at 10 millimeters the median keel is accompanied on each side by a faint rounded ridge, and the ventrolateral welts have become distinct rounded nodes and are connected with the umbilical shoulder by a low rounded rib. At 13 millimeters the faint ridges bordering the median keel have broken into distinct nodes—one to each rib, the ventrolateral nodes are still more distinct and the umbilical part of the rib has become more prominent and nodelike. At a diameter of 18 to 20 millimeters the ventral nodes have become elongated parallel to the median keel, and the general aspect of the shell is much like that of the larger adult. In subsequent stages (up to a diameter of 150 millimeters) the high point of the umbilical node moves outward nearly to the middle of the flank and is elongated radially; the ventrolateral node is subconical; the ventral node is much elongated parallel to the keel; the keel itself becomes relatively less and less conspicuous. The ribs are simple and nearly straight at all stages; there are none intercalated and none divide. There are from 19 to 22 ribs to each whorl in the specimens in hand, the number varying but little with the stage of growth.

The external suture retains about the same proportions from the earliest stage seen, at 3.5 millimeters, throughout the later stages. There are numerous variations in small details. The first lateral lobe in the early stages has a single terminal branch but becomes blunt and rounded in the later stages.

The chief specific characters of *M. shoshonense* are the simple ribs bearing three nodes, one on the flank elongated radially, one on the ventrolateral margin and subconical, one on the venter elongated parallel to the keel. From other American species it is separated easily. *M. texanum* (Roemer)[30] and its allies, *M. lasswitzi* Yabe and Shimizu[31] and *M. roemeri* Yabe and Shimizu,[31] also *M. delawarense* (Morton)[32] and its ally, *M. omeraense* Reeside,[33] have five nodes on each rib. *M. bourgeoisi* Grossouvre var. *americana* Lasswitz[34] has a node on the middle of the flank in addition to the umbilical and ventrolateral nodes and has nothing to do with either *M. shoshonense* or *M. bourgeoisi.* Other species named by Lasswitz are likewise easily separable. *M. crenulatum* Anderson[35] does not belong to *Mortoniceras,* for it has crenulated keel, much inclined ribs, and long spines. It is possibly a *Prionotropis. M. worthense* Adkins[36] belongs to some other genus, probably *Inflaticeras* Stieler. *M.? vermilionense* Meek[37] is probably a *Prionotropis* and at any rate lacks the conspicuous nodes and straight ribs of *M. shoshonense.* Poorly preserved and fragmentary specimens of *Mortoniceras* collected by L. W. Stephenson from a tongue of the Austin chalk of Texas (4 miles north of Broadway, Lamar County, and 2 miles east-northeast of Savage, Fannin County) have four or five rows of tubercles and are therefore distinct from *M. shoshense.* Among European species it is closest to *M. bourgeoisi* (D'Orbigny emended by Grossouvre),[38] from which it differs in acquiring the tubercles at a much earlier stage and in the more external position of the inner tubercle, though the resemblance otherwise is very great.

Occurrence: *M. shoshonense* is known from only a small area in north-central Wyoming. Meek's type is said to have come from the head of Wind River valley and was collected by F. V. Hayden while a member of Raynolds's expedition to explore the upper Missouri country. The other specimens known to the writer all came from the northern part of Big Horn Basin, from localities near the towns of Cody, Greybull, and Frannie, Wyo.

Mortoniceras shoshonense Meek var. crassum Reeside, n. var.

Plate 8, Figures 5–15

This variety differs from the typical form in its coarser sculpture, somewhat stouter whorls, and somewhat greater involution. The general characteristics of the sculpture are the same, and there are no conspicuous differences in suture.

The specimens in hand are from the same localities as the typical form.

[30] Roemer, Ferdinand, Die Kreidebildungen von Texas, p. 31, pl. 3, figs. 1 a–c [not figs. 1 d–e], 1852.

[31] Yabe, Hisakatsu, and Shimizu, Saburo, A note on the genus *Mortoniceras:* Japanese Jour. Geology and Geography, vol. 2, p. 30, 1923.

[32] Morton, S. G., Synopsis of the organic remains of the Cretaceous group in the United States, p. 37, pl. 2, fig. 5, 1834.

[33] Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 38, pl. 42, figs. 3, 4; pl. 43, figs. 1, 2, 1927.

[34] Lasswitz, Rudolf, Die Kreide-ammoniten von Texas: Geol. und pal. Abh., n. ser., vol. 6, Heft 4, p. 252, pl. 8, fig. 1, 1904.

[35] Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., vol. 2, No. 1, p. 125, pl. 1, figs. 17, 18, 1902.

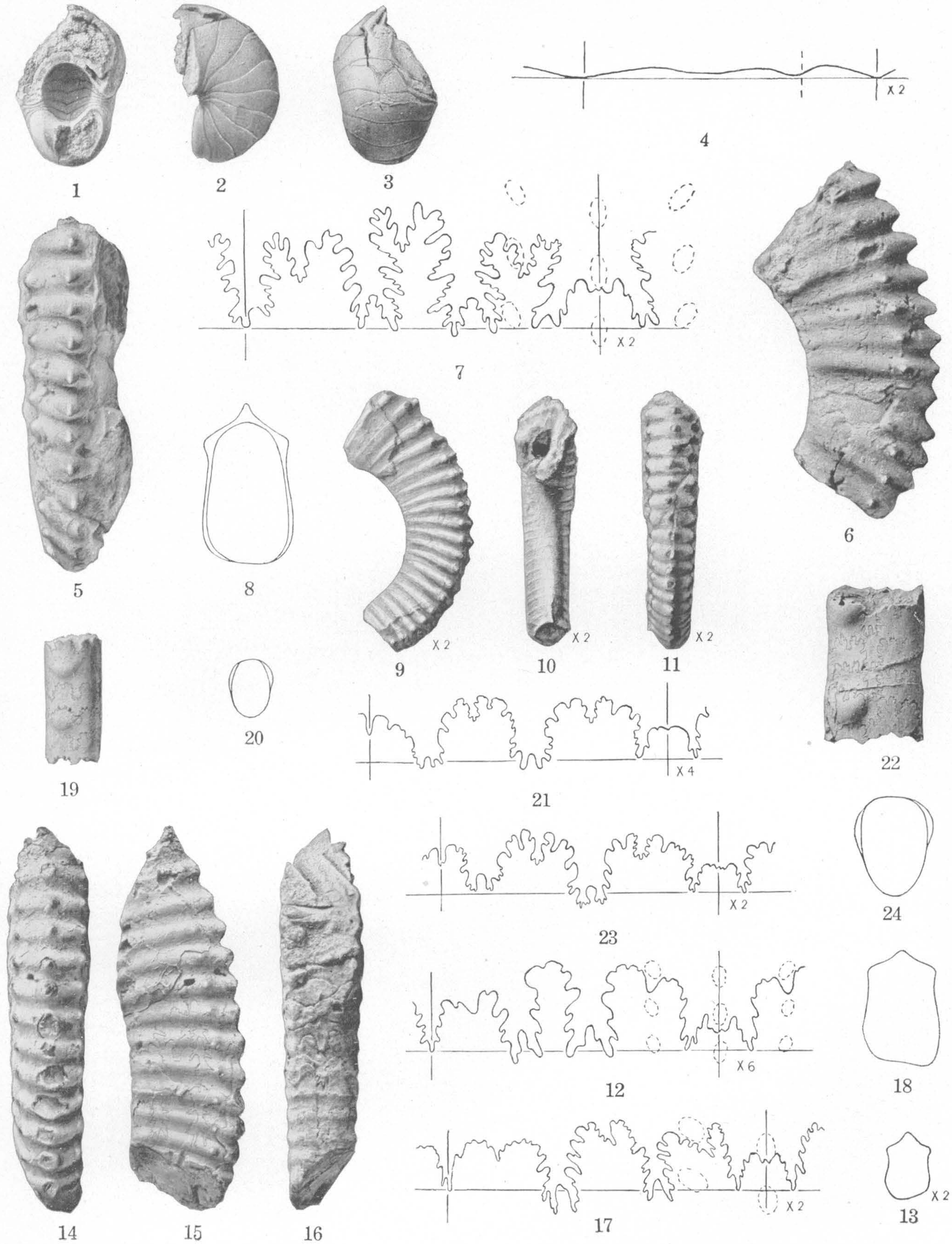
[36] Adkins, W. S., The Weno and Pawpaw formations of the Texas Comanchean: Texas Univ. Bull. 1856, p. 91, pl. 1, figs. 6–10, 18–19, 26; text fig. 12, 1920.

[37] Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 450, pl. 7, fig. 2, 1876.

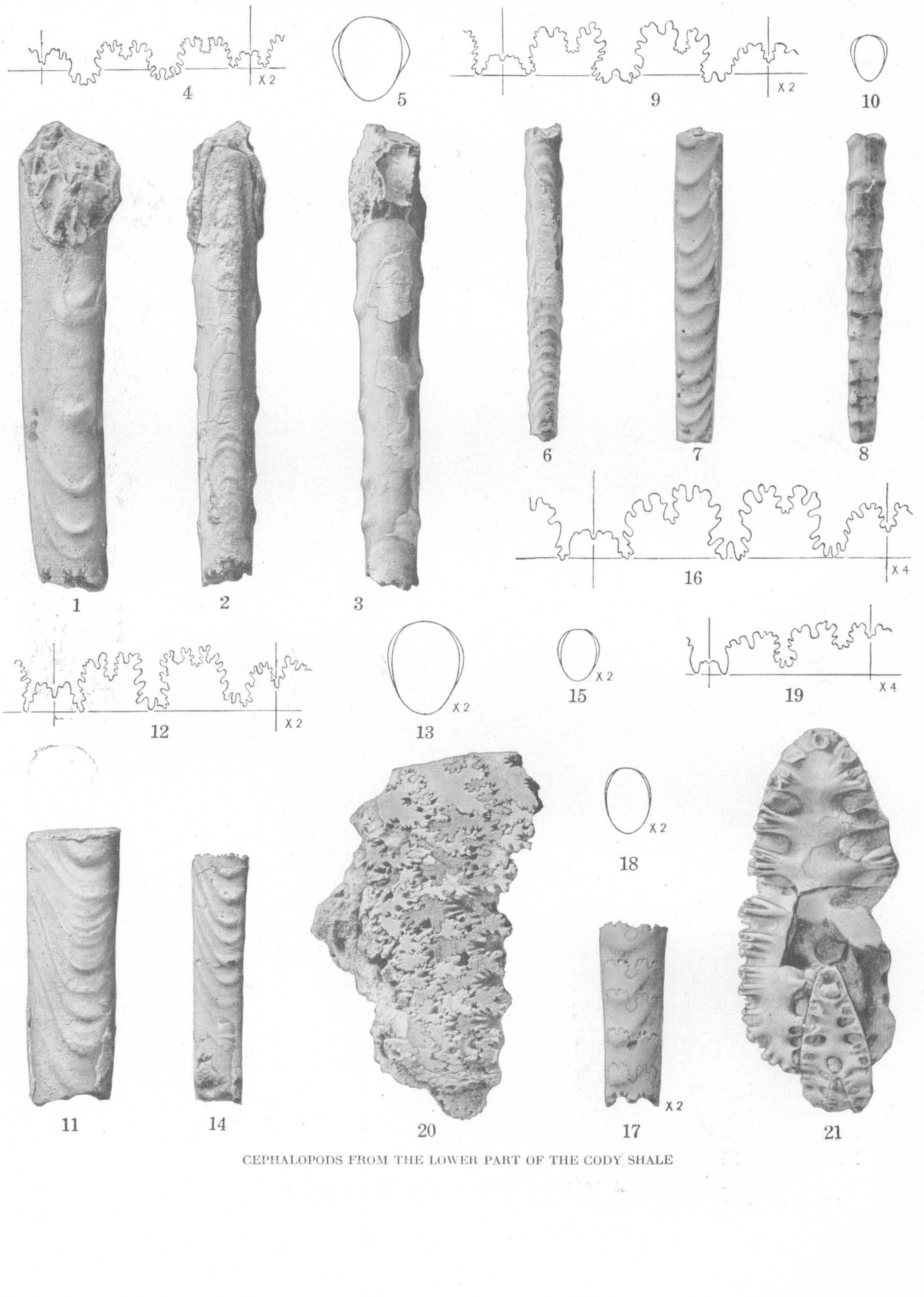
[38] De Grossouvre, Albert, Les ammonites de la craie supérieure, p. 73, pl. 13, fig. 2; pl. 14, figs. 2, 5, 1894.

PLATES 1–8

PLATE 1



CEPHALOPODS FROM THE LOWER PART OF THE CODY SHALE



CEPHALOPODS FROM THE LOWER PART OF THE CODY SHALE

PLATE 2

Page

FIGURES 1–5. *Baculites asper* Morton, side, siphonal, and antisiphonal views, suture, and cross section of a cast representing a complete living chamber. Cody shale, 800 feet above base, sec. 6, T. 51 N., R. 100 W., Wyo. Yale Peabody Mus. catalogue No. 6415 ---- 4

FIGURES 6–19. *Baculites codyensis* Reeside, n. sp. Cody shale, 800 feet above base, sec. 6, T. 51 N., R. 100 W., Wyo. Yale Peabody Mus. catalogue No. 6408 ---- 4

6–10. Siphonal, side, and antisiphonal views, suture and cross section of type specimen, a septate internal cast with some fragments of shell adhering.

11–13. Side view, suture, and cross section of a large septate internal cast.

14–16. Side view, cross section, and suture of a septate internal cast with more closely set ribs.

17–19. Side view, cross section, and suture of a small septate internal cast.

FIGURES 20–21. *Placenticeras pseudoplacenta* Hyatt, side and end views of an internal cast. Cody shale, 800 feet above base, sec. 6, T. 51 N., R. 100 W., Wyo. Yale Peabody Mus. catalogue No. 6413 ---- 8

PLATE 3

Page

FIGURES 1–10. *Binneyites parkensis* Reeside, n. gen. and sp. 5

1–5. Side, rear, and front views, cross section, and suture at 15 millimeters diameter, of the type, an internal cast. Cody shale 775 feet above base, SW. ¼ NE. ¼ sec. 6, T. 51 N., R. 100 W., Oregon Basin, Wyo. Yale Peabody Mus. catalogue No. 6420.

6–10. Side and front views, suture at 2.5 millimeters diameter, suture at 4.5 millimeters diameter, suture at 9 millimeters diameter, of an internal cast. Upper part of Colorado group (lower part of Cody shale), sec. 24, T. 58 N., R. 97 W., Wyo. U. S. Nat. Mus. catalogue No. 73268.

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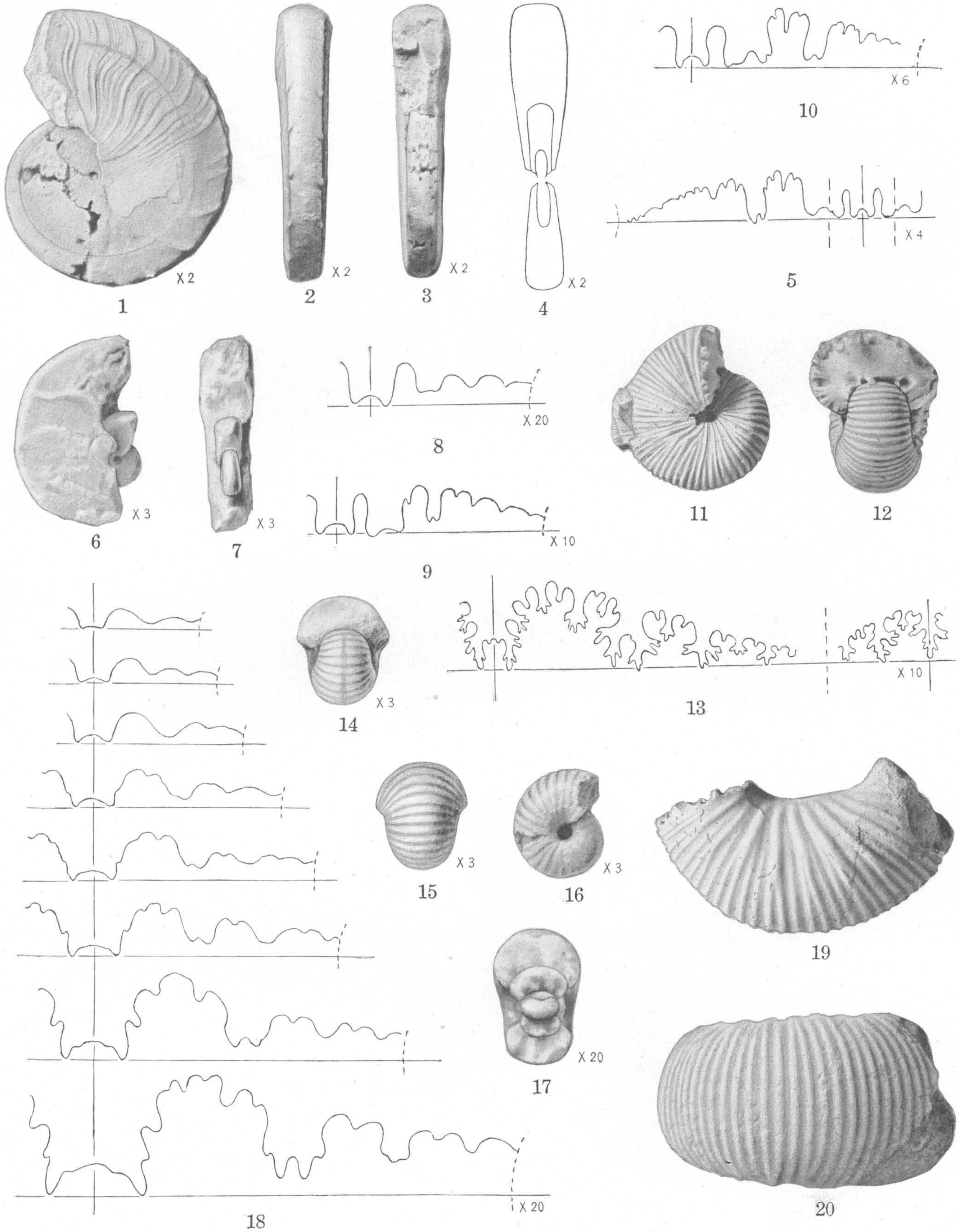
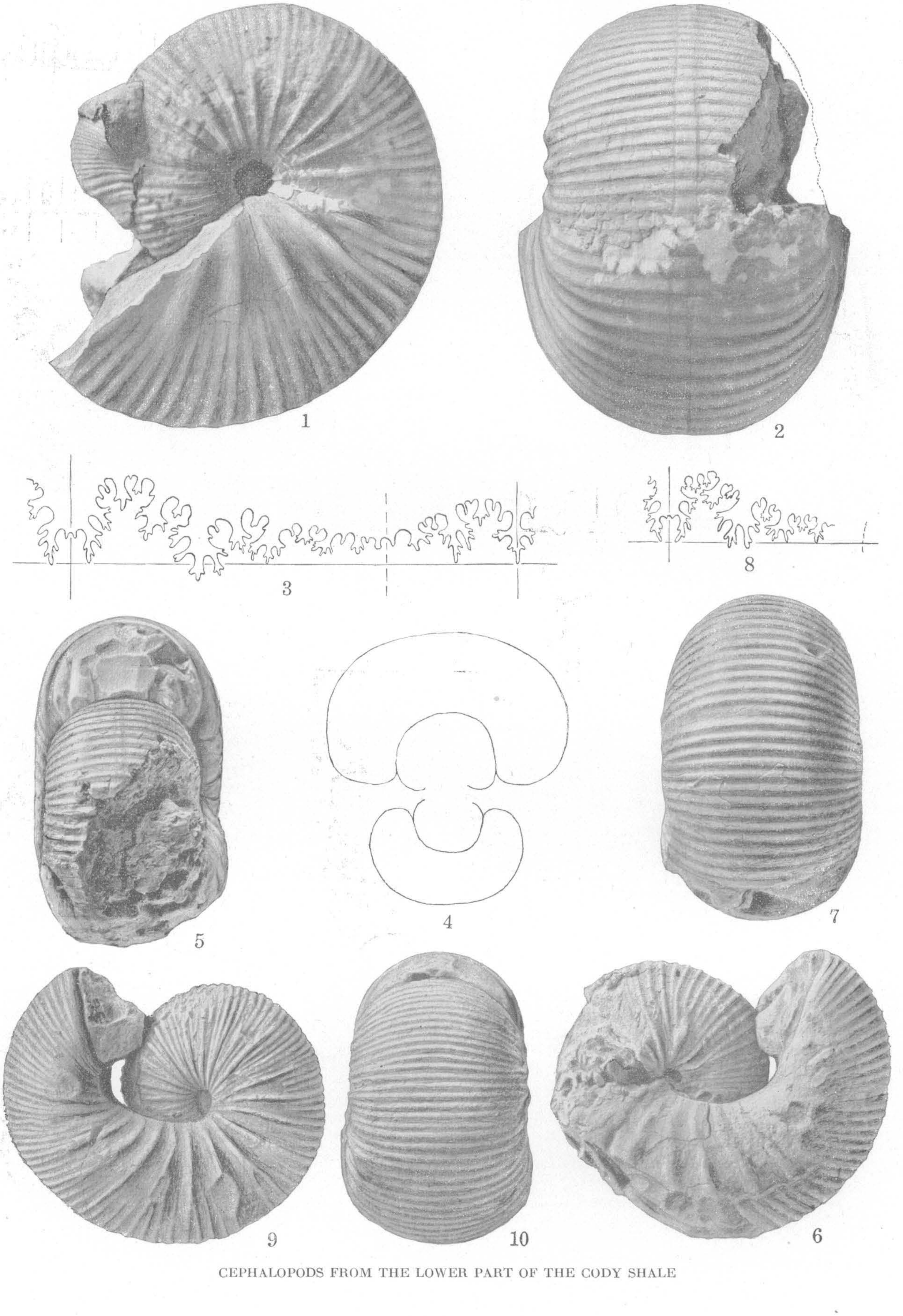


CEPHALOPODS FROM THE LOWER PART OF THE CODY SHALE



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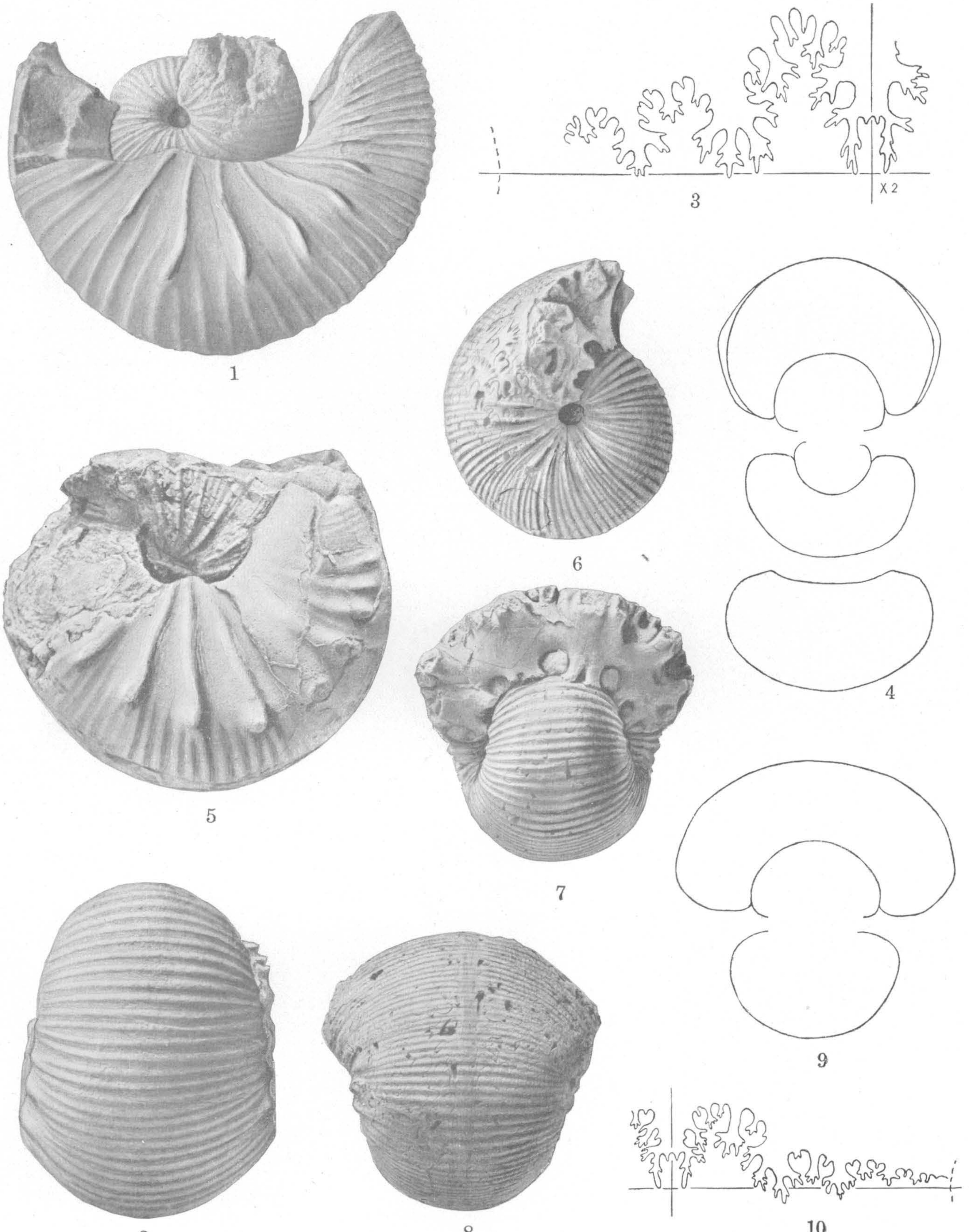
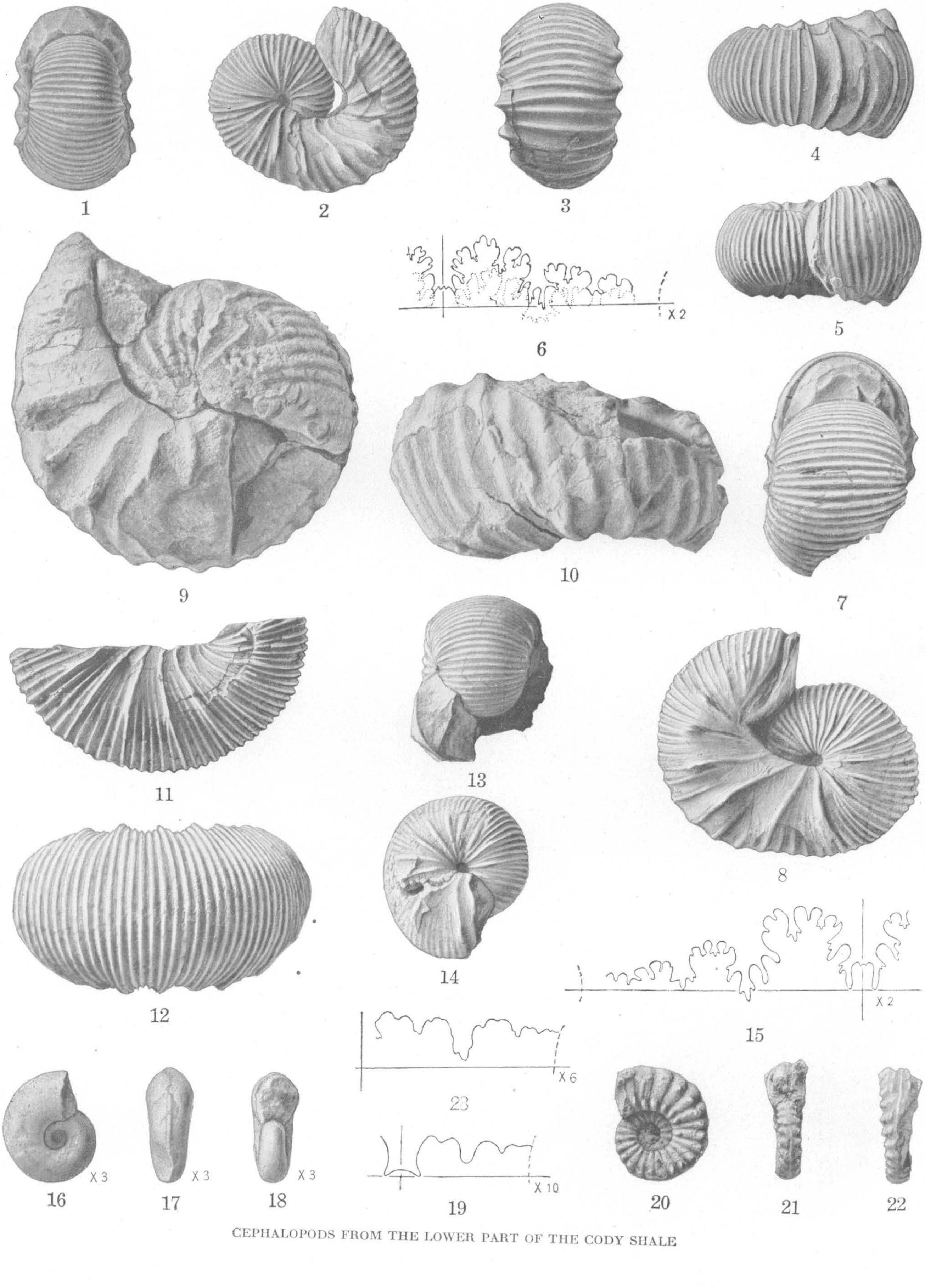


CEPHALOPODS FROM THE LOWER PART OF THE CODY SHALE



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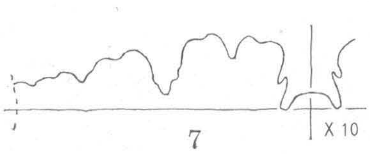

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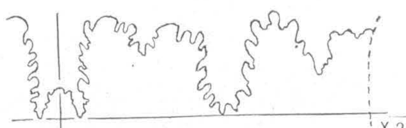

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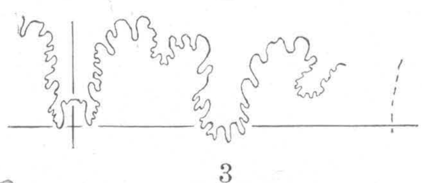

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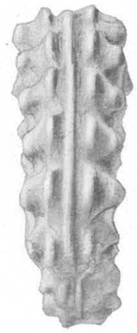

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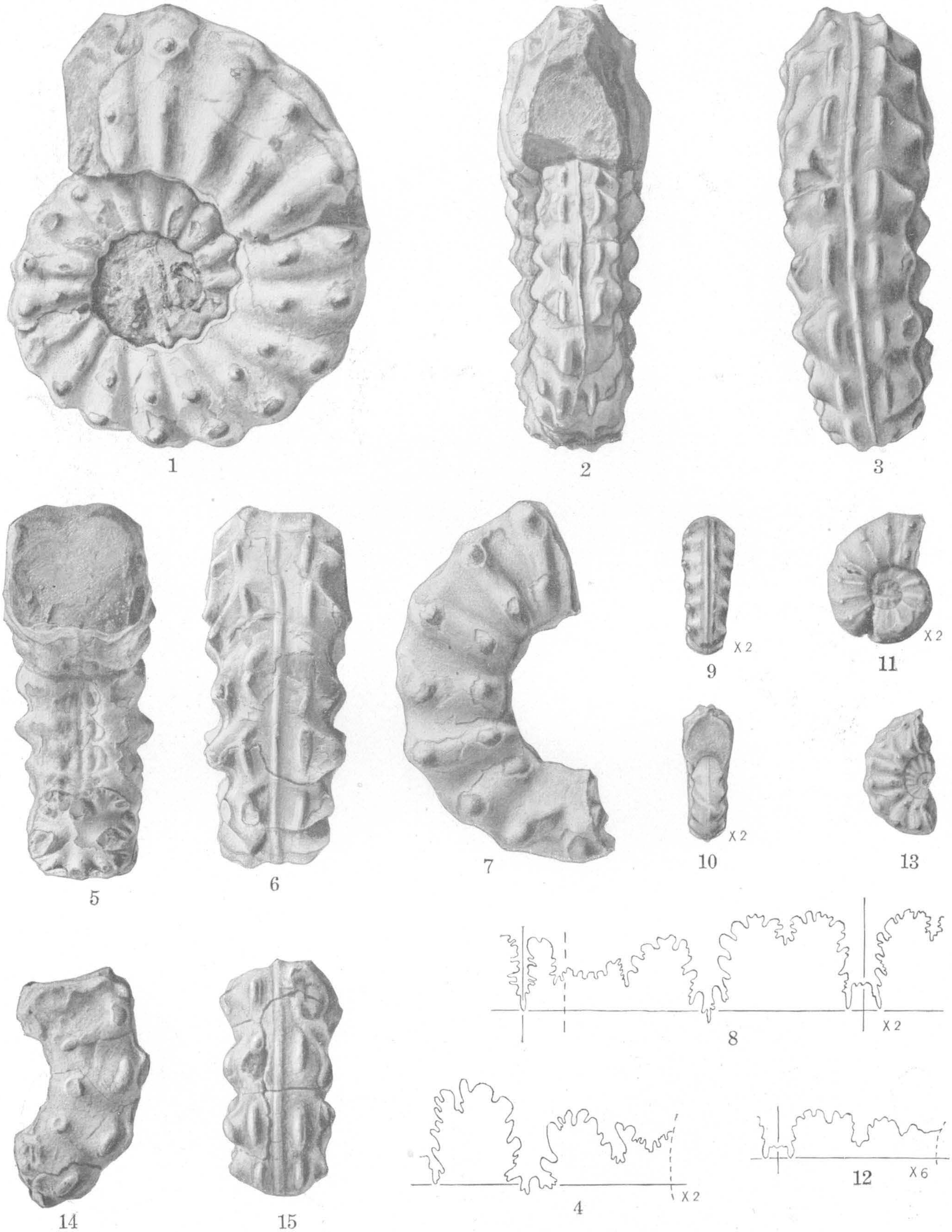
CEPHALOPODS FROM THE LOWER PART OF THE CODY SHALE



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THE SCAPHITES, AN UPPER CRETACEOUS AMMONITE GROUP

By John B. Reeside, Jr.

INTRODUCTION

This paper presents a summary of the principal publications dealing with the scaphites, an estimate of the generic divisions proposed, and a catalogue of the species recorded in the literature available to the writer.

The scaphites are an especially important group of ammonites because of their wide distribution and relative abundance in many of the Upper Cretaceous faunas of the world. In some areas the succession of species affords a more useful basis for faunal subdivision of the strata than any other single group of fossils, and in many other areas it is a very valuable auxiliary to the other groups. A fairly satisfactory intercontinental correlation has been based on the scaphites alone.

The literature dealing with the scaphite group includes a large part of the papers that describe Upper Cretaceous cephalopods, though many such papers do not treat the scaphites to any greater extent than to describe or record species and do not enter into the more general questions of classification and phylogeny.

The writer realizes, from the errors in the delimitation and chronologic assignment of American species noted in the works of European writers, that he assumes a considerable risk of falling into similar errors in attempting to deal with European species with which he has little or no first-hand acquaintance. He has had the temerity to essay in the appended catalogue of species a decision between conflicting statements in the European literature, both as to identity and as to chronologic assignment of various species, and bespeaks a kindly indulgence for such errors as may be included.

TAXONOMIC HISTORY OF THE SCAPHITES

Parkinson [1] in 1811 applied the name *Scaphites* to "a fossil concamerated shell, commencing with spiral turns, the last of which, after being elongated, is reflected back toward the spiral part." He figured an example of the genus which was afterward referred to the species *aequalis* Sowerby, thereby making this species the genotype.

[1] Parkinson, James, Organic remains of a former world, vol. 3, p. 145, pl. 10, fig. 10, 1811.

For many years afterward all forms of Mesozoic cephalopods that began with a normal ammonitic coil, departed from it, and bent back again to form a hook without leaving the original plane of coiling were referred to *Scaphites* Parkinson, though it was recognized by many students that such species as *ivanii* Puzos differed notably from the genotype. D'Orbigny,[2] for example, separated the species known in 1840 into two sections:

> Elongati, whose spire is composed of nonembracing whorls, completely uncovered, and whose crook is very long. (*S. ivanii.*)
>
> Breves, whose spire is composed of embracing whorls, almost entirely covered, and whose crook is very short. (*S. aequalis, compressus, constrictus, hugardianus.*) [Translated.]

With the advance in knowledge of ammonites, due to the labors of numerous students, and the resultant efforts to arrive at a classification expressive of genetic relationship, various assignments have been given to the scaphites by different authors—indeed, are still given—for there is by no means complete agreement concerning the problems involved.

Neumayr [3] in 1875 considered the scaphites, with the exception of *S. ivanii*, to be a natural group and on the form of the aptychus and presence of auxiliary lobes in the suture to belong to the perisphinctid stem. On the form of the inner whorls he considered the group to have been derived from *Olcostephanus* Neumayr.

Meek [4] in 1876 discussed in detail the genus *Scaphites*, referring it as the sole genus to the family Scaphitidae Meek but not indicating any relationship to other groups. He had already [5] proposed the subgenus *Discoscaphites* to include certain forms that presented differences from the typical species, and he now proceeded to further elaboration. Meek proposed the subgenus *Macroscaphites* for the group of *Scaphites ivanii* Puzos, and it has been considered since under that name by most students as entirely distinct from the scaphites. He restricted *Scaphites*, in its

[2] D'Orbigny, Alcide, Paléontologie française, 1st ser., Terrain crétacé, vol. 1, p. 514, 1840.

[3] Neumayr, Melchior, Die Ammoniten der Kreide und die Systematik der Ammonitiden: Deutsche geol. Gesell. Zeitschr., vol. 27, p. 924, 1875.

[4] Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, pp. 413–417, 1876.

[5] Meek, F. B., A preliminary list of fossils collected by Dr. Hayden in Colorado, New Mexico, and California: Am. Philos. Soc. Proc., vol. 11, p. 429, 1870.

narrower sense, to the rank of a subgenus with three sections—(*a*) group of *Scaphites aequalis* Sowerby, with coiled part relatively small, narrow umbilicus, round venter, and a single row of nodes, if any, on the margin of the living chamber; (*b*) group of *Scaphites nodosus* Owen, with coiled part relatively large, deflected part short, venter more or less flattened, with a row of nodes on the margin, and a second row of nodes near the umbilicus; (*c*) group of *Scaphites trinodosus* and *S. tridens* Kner, with three rows of nodes on the rounded periphery. Under the subgenus *Discoscaphites* Meek proposed to place two sections—(*a*) group of *Scaphites conradi* Morton, with narrow umbilicus, coiled part forming most of the much compressed shell, flattened periphery, and four to nine rows of nodes on each flank, the outer row being the largest; (*b*) group of *Scaphites cheyennensis* Owen, much like section *a* but with relatively wide umbilicus and little-deflected body chamber. Meek in his specific descriptions includes in *Discoscaphites* species that do not possess the numerous rows of nodes, relying on other characters for the assignment. He remarks that some of his groups might appropriately be made separate genera.

Zittel [6] in 1885 placed the genus *Scaphites* under the Stephanoceratidae of Neumayr but apparently was doubtful of its exact relationship, for he separated the discussion of this genus and *Crioceras* Léveillé from that of the other members of the family by a rule. Zittel put into *Scaphites* "with the exception of *Macroscaphites*, whose suture agrees completely with *Lytoceras*, * * * all uncoiled Cretaceous ammonites distinguished by a hook-shaped, reflected living chamber, and whose suture shows auxiliary lobes." [Translated.]

H. Douvillé,[7] according to Grossouvre,[8] assigned *Scaphites* on the basis of the sutures to the family Pulchellidae Douvillé and compared the young of certain species to *Stoliczkaia dispar* (D'Orbigny) Neumayr. Douvillé, because of the presence of tubercles on the shell, rejected an assignment to the family Lytoceratidae Neumayr favored by some students on account of the bifid lobes of the adult suture.

Grossouvre [9] in 1894 placed the genus in his family Acanthoceratidae on the basis of the suture and the sculpture. He consolidated Douvillé's two groups Pulchellidae and Acanthoceratidae and therefore followed Douvillé in his assignment. Grossouvre included in the genus

forms which in youth resemble *Stoliczkaia dispar*, have a narrow umbilicus, embracing whorls, rounded on the periphery, ornamented with simple ribs which increase on the external region of the flanks by intercalation or by bifurcation. The last whorl separates from the others, forms a straight part, then bends back into a crook in such a way that the coiled part faces the mouth; the latter is ordinarily a little contracted, supplied with a ventral apophysis, dorsal apophysis, and sometimes lateral lappets. On the straight part and the bend, the ornamentation is often modified and becomes nodose; this character is especially accentuated in the latest forms. [Translated.]

Logan [10] in 1899 discussed *Scaphites*, accepting the genus as a member of the Stephanoceratidae and regarding it as a progressive rather than a decadent or retrogressive group, because the sutures do not show degeneration but progression if it is assumed that the later scaphites descended from the earlier. Logan studied the ontogeny of *Scaphites nodosus* Owen and thought he saw in it evidence of a development through *Anarcestes*, *Tornoceras*, *Glyphioceras*, *Gastrioceras*, *Paralegoceras*, and *Pronorites*. Later stages he thought to resemble *Scaphites warreni*, and at the end of the fourth whorl the adult *nodosus* form is reached.

Hyatt [11] in 1900 accepted the genera *Scaphites* Parkinson and *Discoscaphites* Meek and proposed *Anascaphites* with *Scaphites ventricosus* Meek and Hayden as the genotype and *Jahnites* with *Scaphites geinitzi* D'Orbigny var. *binodosus* Roemer of Jahn [12] as the genotype. Hyatt gave no diagnoses of the genera but assigned them to the family Scaphitidae Meek and placed them between the family Macroscaphitidae Hyatt and the family Lytoceratidae Neumayr. Hyatt defined the family as follows:

Two or more rows of tubercles developed in the ephebic or gerontic stage; costae continuous across the venter; aperture evenly constricted on the sides and with a slight, broad rostrum on the venter, caused by a recession of the lateral curves. There is a dorsal lappet, but this is long and bent only in *Jahnites*. The young and sometimes ephebic stages of *Scaphites* possess the costae, form, and general aspect of *Pachydiscus*, and there are species transitional between them.

J. P. Smith [13] in 1901 expressed the opinion that the genus *Scaphites* is polyphyletic and that some of the species seem to have come from a *Hoplites*-like ancestor, though others have larval stages similar to those of *Lytoceras* and *Baculites* and probably have a common origin with them.

W. D. Smith [14] in 1905 published the results of his work on the young stages of *Scaphites nodosus* Owen and *S. condoni* Anderson. He does not accept Logan's views on the derivation of *Scaphites*, holding that the sutures alone are insufficient proof of derivation, and does not see the resemblances which Logan

[6] Zittel, K. A., Handbuch der Palaeontologie, vol. 2, p. 480, 1885.

[7] A definite citation is not given but is probably Douvillé, Henri, Notes pour le cours de paléontologie professé à l'École de mines en 1889–1890, given a limited circulation in 1890.

[8] De Grossouvre, Albert, Les ammonites de la craie supérieure: Carte géol. France Mém., Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 238, 1894.

[9] Idem, p. 238.

[10] Logan, W. N., Contributions to the paleontology of the Upper Cretaceous series: Field Mus. Nat. Hist. Pub. 36, Geol. ser., vol. 1, pp. 207–211, pls. 22, 23, 1899.

[11] Hyatt, Alpheus, Cephalopoda, in Eastman, C. R., Textbook of paleontology by Karl von Zittel, 1st ed., vol. 1, p. 572, 1900.

[12] Jahn, Jaroslav, Ein Beitrag zur Kenntniss der Fauna der Priesener Schichten der böhmischen Kreideformation: K.-k. geol. Reichsanstalt Jahrb., vol. 41, pp. 179–184, text figs. 1–5, 1892.

[13] Smith, J. P., The larval coil of *Baculites*: Am. Naturalist, vol. 35, p. 45, 1901.

[14] Smith, W. D., The development of *Scaphites*: Jour. Geology, vol. 13, pp. 635–654, 1905.

finds. He likewise considers the genus a degenerate group, not progressive, because it unrolls, has a reduced number of sutural elements, and is spinose in many species. Smith finds from his study of the form of the whorls, sculpture, and sutural characters that "the *Scaphites nodosus* group is to be considered as having come from some member of the Stephanoceratidae." [15] The young of this species show a development from a triaenidian first lateral lobe to a dicranidian, and there is a constriction at the end of the first whorl. Regarding the group of *Scaphites condoni*, Smith, from the character of the young stages, believes it to have a common ancestor with *Baculites* and *Lytoceras*, or with *Baculites* to have descended from *Lytoceras*. He says: "The likeness of the young stages of *S. condoni* * * * to the young of *Baculites* and *Lytoceras* is more in the general aspect of the shell rather than in any specific characters." [16] The *condoni* group differs from the *nodosus* group chiefly in having bifid lobes throughout, whereas in the *nodosus* group the first lateral lobe of the suture is supposed to develop from a trifid to a bifid form, and in having a wide umbilicus and suppressed ribs as compared with the narrow umbilicus and prominent ribs of the *nodosus* group. The genus therefore, according to Smith, is polyphyletic, the degenerate, phylogerontic descendant of several stocks.

Pervinquière [17] in 1907 considered scaphites of the type of *Scaphites aequalis* Sowerby on the basis of form, sculpture, and suture to have been derived from *Olcostephanus* Neumayr or *Holcodiscus* Uhlig, thus reverting to the opinion of Neumayr. He rejected an attachment to the Lytoceratidae because of the presence of several auxiliary lobes in the external suture and several lobes in the internal suture, and to *Stoliczkaia* Neumayr because of the form of the young. For the group like *Scaphites cunliffei* Forbes, Pervinquière favored an assignment to the Lytoceratidae. *Scaphites cunliffei* has a discoid form, a wide umbilicus, a suture whose first lateral lobe passes directly from the simple to the bifid stage, and a first whorl with a constriction like that of *Baculites* and *Lytoceras*. The features antagonistic to the assignment are the strong sculpture, at least in comparison with *Lytoceras*, and the presence of several internal lobes in the suture. Pervinquière noted that some of the species of *Discoscaphites* Meek have a discoid form and wide umbilicus, but he was unwilling to accept Meek's name because the development of the American forms was not known. He was unwilling also to include in it *S. cunliffei* because the living chamber of the *cunliffei* group had not been found.

[15] Smith, W. D., op. cit., p. 648.

[16] Idem, p. 651.

[17] Pervinquière, Léon, Études de paléontologie tunisienne, pt. 1, Céphalopodes des terraines secondaires, p. 116, Paris, 1907.

Yabe [18] in 1910 proposed the genus *Yezoites* to include scaphites with a suture possessing a single-pointed internal lobe and a very high internal saddle next to it. The external suture, form, and other characters are like those of the normal scaphites. Yabe considered the internal suture to be the most significant criterion in determining the relationship of scaphites. He rejected Hyatt's classification, primarily because of the lack of elaboration of the genera. The full diagnosis of *Yezoites* is as follows:

Shell as in *Scaphites* Parkinson, consisting of more or less widely umbilicate spiral whorls and of a free, at first straight and then reflected last whorl. Border of the aperture either only thickened or with a constriction and lateral lappets. The external part of the suture as in *Scaphites;* the internal part with high saddle and small notches in it.

Here belong three species, from the *Scaphites* beds of Hokkaido, which may be grouped in two sections:

1. Umbilicus of the spiral whorls mostly covered by the flanks of the loose whorl; border of the aperture simply thickened.

2. Umbilicus of the spiral whorls entirely open; border of the aperture with constriction and lateral lappets. [Translated.]

Yabe did not assign a systematic position to either *Scaphites* or *Yezoites*.

Nowak [19] in 1911 reviewed briefly the work of many previous students of the scaphites. He did not consider *Yezoites* Yabe a valid genus, believing from the work of Pervinquière and W. D. Smith, cited above, that a high internal saddle may be present in groups that by other characters give strong evidence of different derivation. Nowak expressed no opinion as to the ideas of Meek and Hyatt regarding *Scaphites*. Contrary to Yabe's opinion, Nowak believed that although the form of internal suture should not be neglected in studying scaphites, as has so often been done, it is not the most important criterion but must be considered in conjunction with the form of the shell, the sculpture, and the external suture. The primary feature to be considered in determining relationship is the ontogenetic development as a whole. Nowak compared *Scaphites aequalis* Sowerby, *S. tridens* Kner, and *S. constrictus* Sowerby with the representatives of other genera and concluded that at least three evolutionary series are represented, similar only in possessing an abnormal living chamber—the group of *S. aequalis*, derived from *Holcostephanus;* the group of *S. tridens*, derived from *Acanthoceras;* and the group of *S. constrictus*, derived from *Hoplites*. For these groups Nowak proposed the names *Holcoscaphites*, *Acanthoscaphites*, and *Hoploscaphites*, respectively. The diagnoses of these genera given by

[18] Yabe, Hisakatsu, Die Scaphiten der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, pp. 159-174, pl. 15, 1910.

[19] Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. Sci. Cracovie Bull. internat., année 1911, sér. B, pp. 547-588, 1912.

Nowak will perhaps present in briefest possible form his reasons for their institution:

Genus *Holcoscaphites*.—Shell with narrow umbilicus; umbilicus broader in youth, narrower in age; whorls stout, last living chamber abnormal. The sculpture of the normal whorls, especially in the young stages, like *Holcostephanus*. [That is, the ribs pass without nodes from the umbilicus, end at the edge of the venter with a nodose thickening, and then split into weaker secondary ribs. Later the ribs of the venter and flank are equal.] Lobes and saddles in external part [of suture] gradually smaller from the outside [of the whorl] inward; the same in the internal part but in the opposite direction. The bifid lobes develop out of trifid; the internal lobe trifid. Species: *H. hugardianus* D'Orbigny, *aequalis* Sowerby, *geinitzi* D'Orbigny, *fritschi* Grossouvre, *geinitzi* var. *lamberti* Grossouvre (Jahn), ?*compressus* D'Orbigny, *auritus* Schlüter, *hippocrepis* De Kay, cf. *meslei* Grossouvre (Pervinquière), *inflatus* Roemer, *texanus* Roemer, *nodosus*, Owen, and most of Yabe's species.

Genus *Acanthoscaphites*.—Whorls always somewhat higher than wide, last living chamber abnormal. Sculpture consists of straight or only slightly bent ribs; in youth there are principal ribs which begin at the umbilicus with a nodose thickening and pass over the venter to the other side and auxiliary ribs which are intercalated between these on the venter. Later the auxiliary ribs become longer and, like the principal ribs and the umbilical nodes, disappear. In adult specimens there are [ventral] nodes. The suture possesses an external lobe, two lateral lobes, and one to two auxiliary lobes. The external lobe is longest; next in length comes the first lateral, which is bifid; the trifid second lateral and the following lobes are strikingly shorter than the first lateral. Three internal saddles, the first highest and broadest, the others progressively smaller. The bifid lobes develop out of trifid. Lobes and saddles strongly incised. Species: *A. tridens* Kner, ?*gibbus* Schlüter, *roemeri* D'Orbigny, *cunliffei* Forbes, ?*ornatus* Roemer. Species falling within this genus are certainly much more numerous, but their suture lines are mostly unknown.

Genus *Hoploscaphites*.—Flat forms with involute whorls; the umbilicus in youth broader, then narrower. Sculpture consists of arched ribs, which at the middle of the flank and on the venter are bent forward; they fork at different heights on the flank without forming nodes. Increase in the number of ribs occurs also by intercalation. Suture consists of an external lobe, two lateral lobes, and two to three auxiliary lobes. The first lateral lobe is usually highest, the external lobe next, and then the second lateral lobe, which reaches scarcely one-third the height of the first lateral lobe. The first internal saddle small and narrow, the second very broad and higher than the first. The lobes and saddles are not much divided and incised. The bifid lobes have arisen from trifid lobes. Species: *H. rochatianus* D'Orbigny, ?*africanus* Pervinquière, *thomasi* Pervinquière, ?*aquisgranensis* Schlüter, ?*monasteriensis* Schlüter. *pungens* Binckhorst, *constrictus* Sowerby.

Whether scaphites do not occur also in other ammonite genera and families may be established only by further investigation, [Translated.]

J. P. Smith [20] in 1913 accepted the genera *Scaphites* Parkinson, *Discoscaphites* Meek, and *Jahnites* Hyatt, placing them in the subfamily Scaphitinae Meek of the family Cosmoceratidae Zittel. He gives a diagnosis of the subfamily only, as follows:

Whorl closely coiled in youth, opening out at maturity into a hook-shaped body chamber. Form robust, thick-set, involute, surface highly ornamented with ribs and knots. Septae finely digitate, usually with several auxiliary lobes.

Frech [21] in 1915 sought to group the scaphites of the European and American Cretaceous into form groups characteristic of the successive zones and exhibiting a progressive increase in size and in complexity of sculpture from the older beds to the younger. The form groups do not imply community of descent. Frech makes out a case of nearly perfect parallelism between the two sides of the Atlantic, proposing to unite under the same names a number of species previously separated. His grouping is as follows:

1. Group of *S. aequalis*. Small species with threadlike ventral ribs and fewer but stronger lateral ribs: *S. aequalis*, *geinitzi*, *larvaeformis*, *warreni*, and *warreni* var. *silesiaca*. Cenomanian and Turonian.
2. Group of *S. vermiformis*. Medium-sized species with coarse sculpture whose lateral ribs end in nodes: *S. lamberti*, *meslei*, *kieslingswaldensis*, *vermiformis*. Emscherian and lower Senonian.
3. Group of *S. binodosus*. Forms with two rows of lateral nodes on each flank and with ventral ribs, which are partly obliterated: *S. binodosus*, *inflatus*, *binodosus* (*nodosus*) var. *brevis*, var. *quadrangularis*, var. *plenus*. Lower Senonian. Possibly also *S. gibbus* of the upper Senonian.
4. Group of *S. constrictus* (*Discoscaphites*), presenting only slight modifications from the *binodosus* group. Compressed forms with narrow venter and high sides; dichotomous lateral ribs on the inner whorls, two rows of nodes on the living chamber (umbilical and external), in some species accompanied by suppression of the ribs.

   (*a*) Ribs on the septate whorls; living chamber smooth except for two rows of nodes: *S. hippocrepis*, *aquisgranensis*. Lower Senonian.

   (*b*) Ribs on the septate and unseptate whorls; the two rows of nodes irregularly developed, in some species distinct throughout (*S. compressus* Roemer), in others with umbilical row suppressed (*S. constrictus*, *roemeri*, *conradi*, *abyssinus*). Middle and upper Senonian.
5. Group of *S. pulcherrimus*, with three to four rows of nodes on each flank, one row on the ventral margin; numerous ribs. Upper Senonian.

   (*a*) Most species have the four rows of nodes (*S. spiniger*, *pulcherrimus*), though some have more numerous *Trachyceras*-like rows of nodes (*S. cheyennensis*, *spinosissimus*).

   (*b*) One species, reaching the largest size, has between the two rows of lateral nodes a third row of less numerous but very strong nodes in the plane of symmetry (*S. tridens*).

Nowak [22] in 1916 dealt with the importance of the scaphites in the subdivision of the Upper Cretaceous. He disagreed with Frech as to the desirability of Frech's form groups, because the similarities used by Frech are largely superficial and take no account of genetic relationships. Nodes appear in different groups at different times and with different intensity, and the maximum development occurs at different times. Nowak considered the high point of develop-

[20] Smith, J. P., Ammonoidea, in Eastman, C. R., Textbook of paleontology by Karl von Zittel, vol. 1, 2d ed., p. 670, 1913.

[21] Frech, Fritz, Ueber Scaphites: Centralbl. Mineralogie, Jahrg. 1915, No. 18, pp. 553–568; No. 21, pp. 617–621, 1915.

[22] Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. Geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, pp. 56–67, 1916.

ment to have come in his *Holcoscaphites* in the Cenomanian, in his *Acanthoscaphites* in the middle of the *Mucronatus* zone (upper Campanian), and in his *Hoploscaphites* in the very late Cretaceous (Maestrichtian). Some of the species of *Acanthoscaphites* reach much larger size than any of the later *Holcoscaphites*.

Concerning the relation between the European and American species, Novak added to the *aequalis* group, besides *S. larvaeformis* Meek and Hayden and *S. warreni* Meek and Hayden, *S. gillisi* Anderson, *S. klamathensis* Anderson, *S. condoni* Anderson, and the Emscherian *S. vermiformis* Meek and Hayden. Nowak did not accept Frech's consolidation of *S. binodosus* Roemer and *S. nodosus* Owen but assigned *S. nodosus* var. *plenus* Meek to *S. tridens* Kner var. *quadrispinosus* Geinitz, and *S. nodosus* var. *quadrangularis* Meek and Hayden to *S. roemeri* D'Orbigny. He did not accept Frech's combination of *S. roemeri* D'Orbigny and *S. nicolleti* Meek nor of *S. inflatus* Roemer and *S. nodosus* Owen var. *brevis* Meek. He accepted the identity of *S. conradi* var. *intermedius* Meek with *S. constrictus* and also assigned to it *S. nicolleti* Meek, *S. mandanensis* (Morton), and *S. abyssinus* (Morton). Nowak on the basis of the scaphites and other fossils correlated the American Fox Hills sandstone with the Maestrichtian and the upper part of the Pierre shale with the upper Campanian, a more definite correlation than that made by Frech.

In tabular form Nowak's grouping is as follows:

Distribution of the scaphites according to J. Nowak

Age		Holcoscaphites	Acanthoscaphites	Hoploscaphites
Senonian.	Maestrichtian.			constrictus, tenuistriatus. [=nicolleti, conradi intermedius, mandanensis, abyssinus.] cheyennensis. conradi.
	Campanian.		cunliffei. tridens, trinodosus. [=nodosus plenus.] roemeri. [=nodosus quadrangularis.] pulcherrimus. spiniger.	monasteriensis. gibbus.
		inflatus.		aquisgranensis.
	Santonian.	hippocrepis.		binodosus.
Coniacian-Emscherian.		meslei. lamberti.		potieri. arnaudi.
Turonian.		auritus. geinitzii [=gillisi]. warreni. larvaeformis. vermiformis.		
Cenomanian.		aequalis [=? condoni]. [=pseudoaequalis.]		?rochatianus. ?africanus.
Upper Gault. [Vraconian.]		hugardianus.		

Spath [23] in 1922 recognized Nowak's three genera as valid. He suggested that possibly some Campanian members of the genera *Hoploscaphites* and *Acanthoscaphites* have been derived from a group of desmoceratids to which he gave the name *Menuites* Spath (including *Ammonites menu* Forbes, *A. stüri* Redtenbacher, *A. portlocki* Sharpe). He believed that other late Senonian scaphites now included in Nowak's genera have come from the group of *Hoplites vari* Schlüter (*Hoplitoplacenticeras* Paulcke).

The writer, in recent papers,[24] has accepted Nowak's divisions of the scaphites as valid, though not accepting his names *Holcoscaphites* and *Hoploscaphites* (see below, p. 27), and has proposed *Desmoscaphites* to include scaphites with the following features: Shell of moderate size with stout, well-rounded whorls; umbilicus small; sculpture on earlier whorls of stout rounded ribs, which increase both by forking and by intercalation and are more or less arched forward on the venter, and whose orderly sequence is interrupted by six to eight constrictions per whorl; sculpture on later whorls without constrictions and finer; suture has large siphonal lobe, first lateral saddle about same size as siphonal lobe and unsymmetrically trifid, first lateral lobe a little shorter than the siphonal lobe and symmetrically trifid, remaining elements small. *Desmoscaphites*, on the basis of the constrictions on the early whorls and the suture, is believed to have come from a desmoceratid stock.

[23] Spath, L. F., On the Senonian ammonite fauna of Pondoland: Roy. Soc. South Africa Trans., vol. 10, pp. 123, 136, 1922.

[24] Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, pp. 20–21, 1927; Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, pp. 5–6, 1927.

PRESENT STATUS OF THE GROUP

The summary of the more important papers relating to the scaphites given above shows that, *Macroscaphites* not included, nine generic names have been proposed:

Scaphites Parkinson, 1811.
Discoscaphites Meek, 1870.
Anascaphites Hyatt, 1900.
Jahnites Hyatt, 1900.
Yezoites Yabe, 1910.
Holcoscaphites Nowak, 1912.
Acanthoscaphites Nowak, 1912.
Hoploscaphites Nowak, 1912.
Desmoscaphites Reeside, 1927.

Scaphites Parkinson was sufficiently comprehensive in its original definition to include all the later names and has the species *aequalis* Sowerby as the genotype. (See pl. 10, figs. 13–15.)

Discoscaphites Meek was established on the basis of the compressed form of the shell and the presence of numerous rows of nodes on the ribs, though in the actual application of the name by Meek species without nodes on the flanks were included in the genus. The genotype is the species *conradi* Morton. (See pl. 9, figs. 2–7.)

Anascaphites Hyatt was defined only by the citation of the species *ventricosus* Meek and Hayden as the genotype. It is a very stout shell, without nodes but with numerous relatively fine, sharp ribs, and attains a large size for the group. The writer [25] has studied and described typical examples of the species and believes that the suture, the various stages in the development of the shell, and the adult features ally it closely with *Scaphites aequalis* and that it does not deserve generic rank. (See pl. 10, figs. 1, 2.)

Jahnites Hyatt was based on *Scaphites geinitzi* D'Orbigny var. *binodosus* Roemer as elaborated by Jahn, who found it to have a relatively long, bent dorsal lappet, apparently the fundamental character which Hyatt had in mind in establishing the genus. (See pl. 10, fig. 3.) However, a dorsal lappet occurs in species of seemingly distinct derivation, differing in them only in length. The species *ventricosus, warreni, stantoni, nodosus, nicolleti* and some European species show a distinct dorsal lappet, bent much as Jahn's figures show it, though shorter. The feature is therefore hardly of generic value.

Yezoites Yabe was based on scaphites like *S. aequalis* in most characters but possessing an internal suture with a long single-pointed dorsal lobe; a very high, somewhat dissected saddle next to it; and a small second internal lobe and saddle. The species *planus* Yabe was used by Yabe as the chief basis for his discussion and is to be taken as the genotype. (See pl. 10, figs. 4–9.) As Nowak has shown, the distinctive features occur in scaphites that from other characters seem to have had differing derivations, and it is unwise to ignore everything but the internal suture in seeking generic characters.

Holcoscaphites Nowak was founded upon *Scaphites aequalis*, which, though not so designated, must be taken as the genotype. It includes chiefly smaller shells with narrow umbilicus; stout whorls; ribs that form a nodose thickening or actual node at the margin of the venter and split into finer ribs on the venter; suture with parts gradually smaller from the median plane of the shell to the line of involution and with bifid lateral lobes in the adult stages derived from trifid embryonic lobes; suture only moderately incised. (See pl. 9, fig. 1.) This generic group certainly appears to be valid, but inasmuch as *Scaphites* Parkinson was previously founded on the same genotype it is not in accord with the usual practice to drop the earlier name, which should rather be restricted to the scope of the later definition. This group should therefore be designated *Scaphites* Parkinson emended. It is interesting to note that this restricted genus has nearly the compass of Meek's section *a* of *Scaphites* s. s. (See p. 22.)

Acanthoscaphites Nowak, founded on the species *tridens* Kner, includes shells that generally attain a large size for the group, with whorls somewhat higher than wide; ribs straight, with nodose thickening near the umbilicus, intercalated secondary ribs, and in the adults lateral and ventral nodes; suture with long external lobe, long bifid first lateral lobe, and much shorter second lateral and auxiliary lobes; three internal saddles, decreasing regularly from the dorsal lobe to the line of involution; bifid lobes in the adult suture developed from trifid embryonic lobes; suture much incised. (See pl. 11, figs. 1, 2.) This generic group appears to be valid. Meek long ago had set it apart as his sections *b* and *c* of *Scaphites* s. s. (See p. 22.)

Hoploscaphites Nowak, founded on the species *constrictus* Sowerby, includes compressed shells with involute whorls, mostly of moderate size for the group; ribs curved, increasing in number by intercalation and by forking; nodes few or numerous on the flanks; suture usually with first lateral lobe longest, external lobe next in length, and second lateral and auxiliaries much shorter; first internal saddle narrow, second wide; suture only moderately incised; bifid lobes in the adult arise from trifid embryonic lobes. (See pl. 9, figs. 8–10.) This group also seems to be valid, but inasmuch as Nowak puts into it all of Meek's species of *Discoscaphites*, it seems to the writer that Meek's earlier name has

[25] Reeside, J. B., jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, pp. 6–7, pls. 1–8, 1927.

precedence. There appears to be no doubt that Nowak is correct in associating the discoscaphites with his *Hoploscaphites*, and as Frech previously had used the generic name *Discoscaphites* for the species *constrictus*, the usage of the name for the whole group may be considered established.

Desmoscaphites Reeside, with the species *bassleri* Reeside as the genotype, includes moderately large shells with constrictions on the early whorls and with a symmetrically trifid first lateral lobe in the adult suture. It is therefore distinct from the other divisions and is a valid genus. (See pl. 10, figs. 10–12.)

Of the nine names proposed there are, in short, four apparently valid. These designate four genera, which represent three families and four subfamilies:

Stepheoceratidae:
- Scaphitinae:
  - *Scaphites* Parkinson (*Holcoscaphites* Nowak, *Anascaphites* Hyatt, *Jahnites* Hyatt, *Yezoites* Yabe).

Desmoceratidae:
- Silesitinae:
  - *Desmoscaphites* Reeside.

Cosmoceratidae:
- Hoplitinae:
  - *Discoscaphites* Meek (*Hoploscaphites* Nowak).
- Acanthoceratinae:
  - *Acanthoscaphites* Nowak.

The following assignment of species to generic groups is based for the European species largely on Nowak's assignments and for the American species in part on Nowak's assignments but in larger part on long-accepted assignments and comparisons such as those made by Meek. Whether all the forms customarily placed in the species *nodosus* Owen belong to *Acanthoscaphites* may be doubted, but this comprehensive species needs extensive revision before much can be said of it with confidence, and in the meanwhile it may be left as Nowak assigned it.

Scaphites: aequalis, aequalis var. turonensis, aquilaensis, aquilaensis var. costatus, aquilaensis var. nanus, auritus, compressus?, condoni, condoni var. appressus, evolutus, formosus, fritschi, geinitzi, geinitzi var. intermedia, gillisi, gracilis, hilli, hippocrepis, hippocrepis var. crassus, hippocrepis var. pusillus, hippocrepis var. tenuis, hugardianus, inermis, inflatus, kieslingswaldensis, kingianus, klamathensis, lamberti, larvaeformis (Meek and Hayden), larvaeformis (Frech), leei, leei var. parvus, levis, meriani?, meslei, mullananus, obliquus, peroni, peroni var. inornatus, perrini, planus (Roman and Mazeran), planus (Yabe), planus var. gigas, pseudoaequalis, puerculus, puerculus var. teshioensis, rochatianus, roguensis, semicostatus, septemcostatus, similaris, similis, stantoni, tenuicostatus, texanus, thomasi, ventricosus, ventricosus var. stantoni, ventricosus var. depressus, ventricosus var. oregonensis, ventricosus var. interjectus, vermiformis, vermiformis var. binneyi, warreni, warreni var. silesiaca, yonekurai, yokoyamai.

Desmoscaphites: bassleri, novimexicanus.

Discoscaphites: abyssinus, africanus?, angulatus, aquisgranensis, arnaudi, binodosus, cheyennensis, conradi, conradi var. gulosus, conradi var. intermedius, conradi var. petechialis, constrictus, constrictus var. crassus, constrictus var. quiriquinensis, constrictus var. vulgaris, diversesulcatus, gibbus, haugi?, iris?, mandanensis, monasteriensis, nicolleti, niedzwiedzkii, nodosus (Lopuski)?, potieri, pungens, tenuistriatus, verneuilli?.

Acanthoscaphites: cunliffei, nodosus (Owen), nodosus var. brevis, nodosus var. plenus, nodosus var. quadrangularis, pulcherrimus, quadrispinosus, reesidei?, roemeri (D'Orbigny), spiniger, subglobosus?, tridens, tridens var. bispinosus, trinodosus, trispinosus, varians.

Unassigned "Scaphites": brahminicus, idoneus?, ornatissimus, ornatus, pavana, plicatellus, pygmaeus, roemeri (Brauns), spinosissimus, tuberculatus, verrucosus, worthensis?.

CATALOGUE OF THE SPECIFIC NAMES APPLIED TO SCAPHITES

The following catalogue of the specific names applied to scaphites includes all that the writer has met in a perusal of the literature at his disposal. For some of the species no generic assignment is given, owing to the facts that the data given in the literature are insufficient and that the writer lacks adequate material on which to base a conclusion.

Synonyms and abandoned names are shown in italics; valid names are shown in heavy-face type.

abyssinus (Morton) Meek. **Discoscaphites.**
- *Ammonites abyssinus*, Morton, S. G., Description of some new species of organic remains of the Cretaceous group of the United States: Acad. Nat. Sci. Philadelphia Jour., vol. 8, p. 209, pl. 10, fig. 4, 1841.
- *Scaphites abyssinus*, Meek, F. B., and Hayden, F. V., Smithsonian check list, 1860.
- *Scaphites* (*Discoscaphites*) *abyssinus*, Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 441, pl. 35, figs. 2, 4, 1876.
- Fox Hills sandstone. [Maestrichtian.]

aequalis Sowerby. **Scaphites.**
- Sowerby, James, Mineral conchology of Great Britain, vol. 1, p. 53, pl. 18, figs. 1–3, 1813.
- Cenomanian.

aequalis Sowerby var. **turonensis** Roman and Mazeran. **Scaphites.**
- Roman, Frédéric, and Mazeran, Pierre, Monographie paléontologique de la faune turonienne du bassin d'Uchaux et de ses dépendances: Mus. hist. nat. Lyon Archives, vol. 12, Mém. 2, pp. 12–13, pl. 4, figs. 10–14, 1920.
- Turonian.

africanus (Pervinquière). **Discoscaphites?**
- *Scaphites africanus*, Pervinquière, Léon, Études de paléontologie tunisienne, pt. 1, Céphalopodes des terraines secondaires, p. 123, pl. 4, figs. 34, 35, 1907.
- *Hoploscaphites? africanus*, Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 566, 1912.
- Cenomanian.

?andoorensis (Stoliczka) Kossmat.
- *Ammonites andoorensis*, Stoliczka, Ferdinand, Fossil Cephalopoda of the Cretaceous rocks of southern India, Ammonitidae, vol. 1, p. 94, pl. 47, fig. 3, 1865.
- *Scaphites? andoorensis*, Kossmat, Franz, Untersuchungen über die südindische Kreideformation: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 11, p. 139, pl. 17, fig. 3, 1897.
- Upper Trichinopoly [Santonian?].

angulatus (Lopuski). **Discoscaphites.**
Scaphites angulatus, Lopuski, Geslaw, Contribution à l'étude de la faune crétacée du plateau de Lublin: Soc. sci. Varsovie Compt. rend., année 4, pt. 3, p. 136, pl. 3, figs. 8–10, 1911.
Maestrichtian.
[=*Hoploscaphites constrictus* var. *tenuistriatus* according to Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 586, 1912.]

aquilaensis Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 25, pl. 18, figs. 15–27; pl. 19, figs. 1–7, 1927.
Lower Campanian.

aquilaensis Reeside var. **costatus** Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 25, pl. 19, figs. 8–13, 1927.
Lower Campanian.

aquilaensis Reeside var. **nanus** Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151. p. 26, pl. 19, figs. 14–21; pl. 20, figs. 1–6. 1927.
Lower Campanian.

aquisgranensis (Schlüter) Frech. **Discoscaphites.**
Scaphites aquisgranensis, Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 81, pl. 24, figs. 7–9, Cassel, 1871.
Hoploscaphites? aquisgranensis (Schlüter), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 566, 1912.
Scaphites (*Discoscaphites*) *aquisgranensis* (Schlüter), Frech, Fritz, Ueber *Scaphites:* Centralbl. Mineralogie, Jahrgang 1915, No. 21, p. 555, 1915.
Lower Quadratenkreide [Lower Campanian].

arnaudi (De Grossouvre). **Discoscaphites.**
Scaphites arnaudi, De Grossouvre, Albert, Les ammonites de la craie supérieure: Carte géol. France Mém. Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 242, pl. 32, fig. 8, 1894.
Hoploscaphites arnaudi (De Grossouvre), Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 66, 1916.
Middle Coniacian.

auritus Schlüter. **Scaphites.**
Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 77, pl. 23, figs. 5–11, Cassel, 1871.
Scaphitenpläner. [Turonian.]

aff. **auritus** Schlüter.
Burckhardt, Carlos, Faunas cretácicas de Zumpango del Río: Inst. geol. México Bol. 33, pp. 95, 96, pl. 22, figs. 5–10, 1919.
Turonian.

auritus Fritsch and Schloenbach (not Schlüter). See *fritschi* De Grossouvre.

bassleri Reeside. **Desmoscaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 16, pl. 21, figs. 17–21; pl. 22, figs. 8–12, 1927.
Santonian.

binodosus (Roemer). **Discoscaphites.**
Scaphites binodosus, Roemer, F. A., Die Versteinerungen des norddeutschen Kreidegebirge, p. 90, pl. 13, fig. 6, 1841.
Hoploscaphites binodosus (Roemer), Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 66, 1916.
Upper marl at Dülmen. [Santonian according to Nowak.]

brahminicus (Stoliczka) Kossmat.
Ammonites brahminicus, Stoliczka, Ferdinand, Fossil Cephalopoda of the Cretaceous rocks of southern India, Ammonitidae, vol. 1, p. 169, pl. 81, fig. 7, 1865.
Scaphites brahminicus, Kossmat, Franz, Untersuchungen über die südindische Kreideformation: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 11, p. 137, 1897.
Upper Trichinopoly (?) beds. [Coniacian-Santonian?]

cheyennensis (Owen) Meek. **Discoscaphites.**
Ammonites cheyennensis, Owen, D. D., Description of new and imperfectly known genera and species of organic remains, collected during the geological surveys of Wisconsin, Iowa, and Minnesota, p. 578, pl. 7, fig. 2, 1852.
Scaphites cheyennensis, Meek, F. B., and Hayden, F. V., Smithsonian check list, p. 23, 1864.
Scaphites (*Discoscaphites*) *cheyennensis*, Meek, F. B., Preliminary paleontological report: U. S. Geol. Survey Terr. Second Ann. Rept., p. 297, 1872; Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 437, pl. 35, fig. 3, 1876.
Fox Hills. [Maestrichtian.]

compressus D'Orbigny. **Scaphites?**
D'Orbigny, Alcide, Paléontologie française, 1st ser., Terrain crétacé, vol. 1, p. 517, pl. 128, figs. 4, 5, 1841.
Craie chloritée. [Senonian?]

aff. **compressus** (D'Orbigny) Bonarelli and Nágera.
Bonarelli, Guido, and Nágera, J. J., Observaciones geológicas en las inmediaciones del Lago San Martín (Territorio de Santa Cruz): Ministerio de Agricultura (Argentina), Dirección general de minas, geología é hidrología, Bol. 27, ser. B, p. 28, 1921.

compressus Roemer (not D'Orbigny). See *roemeri* D'Orbigny.

comprimis Owen. [=*Scaphites nicolleti* (Morton).]
Owen, D. D., Description of new and imperfectly known genera and species of organic remains collected during the geological surveys of Wisconsin, Iowa, and Minnesota, p. 580, pl. 7, fig. 4, 1852.

condoni Anderson. **Scaphites.**
Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 111, pl. 2, figs. 58–63, 1902.
Lower Chico. [Cenomanian.]

condoni Anderson var. **appressus** Anderson. **Scaphites.**
Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 112, pl. 2, figs. 64–66, 1902.
Lower Chico. [Cenomanian.]

conradi (Morton) Meek. **Discoscaphites.**
Ammonites conradi, Morton, S. G., Synopsis of the organic remains of the Cretaceous group of the United States, p. 39, pl. 16, figs. 1, 3, 1834.
Scaphites conradi, D'Orbigny, Prodrome de paléontologie, p. 214, 1850.
Scaphites (*Discoscaphites*) *conradi* (Morton), Meek, F. B., A preliminary list of fossils collected by Dr. Hayden: Am. Philos. Soc. Proc., vol. 11, p. 429, 1871; Preliminary paleontological report: U. S. Geol. Survey

conradi (Morton) Meek. **Discoscaphites**—Continued.
Terr. Second Ann. Rept., p. 297, 1872; Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 430, pl. 36, fig. 2, 1876.
Fox Hills sandstone. [Maestrichtian.]

conradi (Morton) var. **gulosus** Morton. **Discoscaphites.**
Ammonites conradi var. *gulosus*, Morton, S. G., Synopsis of the organic remains of the Cretaceous group of the United States, p. 39, pl. 16, fig. 2, 1834.
Scaphites conradi var. *gulosus*, Gabb, W. M., Synopsis of the Mollusca of the Cretaceous formations, p. 32, 1861.
Scaphites (Discoscaphites) conradi var. *gulosus*, Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 432, pl. 36, fig. 1, 1876.
Fox Hills sandstone. [Maestrichtian.]

conradi (Morton) var. **intermedius** Meek. **Discoscaphites.**
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 433, pl. 34, fig. 3, 1876.
Fox Hills sandstone. [Maestrichtian.]

conradi (Morton) var. **petechialis** Morton. **Discoscaphites.**
Ammonites conradi Morton var. *petechialis*, Morton, S. G., Synopsis of the organic remains of the Cretaceous group in the United States, p. 39, pl. 16, fig. 1, 1834.
Scaphites conradi Morton var. *petechialis* Morton, Gabb, W. M., Synopsis of the Mollusca of the Cretaceous formations, p. 32, 1861.

constrictus (Sowerby) Frech. **Discoscaphites.**
Ammonites constrictus, Sowerby, James, Mineral conchology of Great Britain, p. 189, pl. 184 A, fig. 1, 1817.
Scaphites constrictus D'Orbigny, Alcide, Paléontologie française, 1st ser., Terrain crétacé, vol. 1, p. 522, pl. 129, figs. 8–11, 1841.
Hoploscaphites constrictus (Sowerby), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 580, text figs. 15, 16, 1912.
Scaphites (Discoscaphites) constrictus (Sowerby), Frech, Fritz, Ueber *Scaphites:* Centralbl. Mineralogie, Jahrg. 1915, No. 18, p. 554, 1915.
Maestrichtian.

constrictus (Sowerby) var. **crassus** Lopuski. **Discoscaphites.**
Lopuski, Geslaw, Contribution à l'étude de la faune crétacée du plateau de Lublin: Soc. sci. Varsovie Compt. rend., année 4, pt. 3, p. 134, pl. 2, figs. 5, 6; pl. 3, figs. 1, 2, 1911.
Maestrichtian.

constrictus (Sowerby) var. **quiriquinensis** Wilckens.
Wilckens, Otto, Revision der Fauna der Quirquiná-Schichten: Neues Jahrb., Beilage-Band 18, pp. 189–193, p. 17, figs. 3–8, 1904.
Senonian. [Campanian?]

constrictus (Sowerby) var. **tenuistriatus** Kner. See *tenuistriatus* Kner.

constrictus (Sowerby) var. **vulgaris** Nowak. **Discoscaphites.**
Hoploscaphites constrictus (Sowerby) var. *vulgaris*, Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 583, pl. 32, fig. 6; pl. 33, figs. 8–12, 1912.
[Campanian?]

costatus Mantell. [=*Scaphites aequalis* Sowerby.]
Mantell, G. A., Geology of Sussex, pl. 22, figs. 3–12, 1822.

cottae (Roemer).
Ammonites cottae Roemer, F. A., Die Versteinerungen des norddeutschen Kreidegebirges, p. 86, pl. 13, fig. 4, 1840.
Scaphites cottae Gümbel, C. W., Geognostische Beschreibung des Königreiches Bayern, vol. 2, p. 764, 1868.
[=*Scaphites binodosus* according to Fritsch, Anton, and Schlönbach, Urban, Cephalopoden der böhmischen Kreideformation, p. 42, 1872.]
[=*Scaphites auritus* according to Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 77, 1872.]
[=*Scaphites geinitzi* according to De Grossouvre, Albert, Recherches sur la craie supérieure, pt. 1, Stratigraphie générale, fasc. 2, p. 652, 1901.]

cunliffei (Forbes) Nowak. **Acanthoscaphites.**
Ammonites cunliffei, Forbes, Edward, Fossil invertebrates of south India: Geol. Soc. London Trans., 2d ser., vol. 7, p. 109, pl. 8, fig. 2, 1845.
Scaphites cunliffei, Stoliczka, Ferdinand, India Geol. Survey Records, vol. 1, p. 35, 1868.
Acanthoscaphites cunliffei (Forbes), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 565, 1912.
Valudayur beds. [Upper Campanian.]

cuvieri Morton [=*Scaphites hippocrepis* (DeKay) Morton].
Morton, S. G., Description of two new species of fossil shells of the genera *Scaphites* and *Crepidula:* Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 109, pl. 7, fig. 1, 1828.

diversesulcatus (Alth). **Discoscaphites.**
Ammonites diversesulcatus, Alth, Alois, Geognostisch-palaeontologische Beschreibung der nächsten Umgebung von Lemberg: Naturw. Abh. (W. Haidinger), vol. 3, pt. 2, No. 9, p. 204, pl. 10, fig. 28, 1850.
[=*Hoploscaphites constrictus* var. *tenuistriatus* according to Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 586, 1911.]
[=*Scaphites roemeri* according to Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 89, 1871.]
[Maestrichtian.]

evolutus Pervinquière. **Scaphites.**
Pervinquière, Léon, Sur quelques ammonites du crétacé algérien: Soc. géol. France Mém. 42, p. 25, pl. 2, figs. 3–9, 1910.
Cenomanian.

?*falcifer* Gümbel.
Gümbel, C. W., Geognostische Beschreibung des bayrischen Alpengebirge, p. 574, 1861.
[=*Scaphites constrictus* Sowerby according to Böhm, Johannes, Die Kreidebildungen des Furbergs und Sulzbergs bei Siegsdorf in Oberbayern: Palaeontographica, vol. 38, p. 48, 1891.]

formosus Yabe. **Scaphites.**
Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 166, pl. 15, fig. 8, 1910.
[Cenomanian.]

fritschi De Grossouvre. **Scaphites.**
Scaphites auritus, Fritsch, Anton, and Schlönbach, Urban, Cephalopoden der böhmischen Kreideformation, p. 44, pl. 13, figs. 9, 11, 14, 15; pl. 14, fig. 12, 1872.

fritschi De Grossouvre. **Scaphites**—Continued.
Scaphites fritschi, De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 243, 1894.
[Turonian?]

geinitzi D'Orbigny. **Scaphites.**
D'Orbigny, Alcide, Prodrome de paléontologie, p. 214, 1850.
Turonian.

geinitzi D'Orbigny var. *binodosus* Roemer of Fritsch and Schloenbach (not *S. binodosus* Roemer). See *lamberti* De Grossouvre.

geinitzi D'Orbigny var. **intermedia** Scupin. **Scaphites.**
Scupin, Hans, Die Löwenberger Kreide und ihre Fauna: Palaeontographica, suppl. 6, pt. 2, p. 98, 1913.
Priesenerschichten. [Turonian.]

aff. **geinitzi** D'Orbigny. **Scaphites.**
Burckhardt, Carlos, Faunas cretácicas de Zumpango del Río: Inst. geol. México Bol. 33, p. 93, pl. 22, figs. 1–4, 1919.
Turonian.

aff. **geinitzi** Jahn, not (D'Orbigny) Schlüter. **Scaphites.**
Burckhardt, Carlos, Faunas cretácicas de Zumpango del Río: Inst. geol. México Bol. 33, p. 96, pl. 22, fig. 12, 1919.
Turonian.

gibbus (Schlüter). **Discoscaphites.**
Scaphites gibbus, Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 87, pl. 26, figs. 6–9, 1871.
Hoploscaphites gibbus (Schlüter), Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 66, 1916.
Mucronatenkreide. [Maestrichtian.]

gillisi Anderson. **Scaphites.**
Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 110, pl. 3, figs. 85–88, 1902.
Lower Chico. [Cenomanian.]

gracilis Yabe. **Scaphites.**
Yabe, Hisakatsu, Zur Stratigraphie und Paläontologie der oberen Kreide von Hokkaido und Sachalin: Deutsche geol. Gesell. Zeitschr., vol. 61, p. 421, 1909.
Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 166, pl. 15, figs. 9, 10, 1920.
[Cenomanian.]

haugi (De Grossouvre). **Discoscaphites?**
Scaphites haugi, De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 244, pl. 31, fig. 5, 1894.
Middle Campanian.

hilli Adkins and Winton. **Scaphites.**
Adkins, W. S., and Winton, W. M., Paleontological correlation of the Fredericksburg and Washita formations in north Texas: Texas Univ. Bull. 1945, p. 36, pl. 7, figs. 3–6, 1919.
Lower beds of Pawpaw formation (upper Washita). [Cenomanian.]

hippocrepis (DeKay) Morton. **Scaphites.**
Ammonites hippocrepis, DeKay, J. E., Report on several fossil multilocular shells from the State of Delaware: New York Lyceum Nat. Hist. Annals, vol. 2, pp. 273–277, pl. 5, fig. 2, 1827.
Scaphites hippocrepis, Morton, S. G., Synopsis of the organic remains of the Cretaceous group in the United States, p. 41, pl. 7, fig. 1, 1834.
Merchantville clay of New Jersey. [Lower Campanian.]

hippocrepis (DeKay) var. **crassus** Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 23, pl. 17, figs. 6–15, 1927.
Lower Campanian.

hippocrepis (DeKay) var. **pusillus** Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 23, pl. 17, figs. 1–5, 1927.
Lower Campanian.

hippocrepis (DeKay) var. **tenuis** Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 23, pl. 16, figs. 11–16, 1927.
Lower Campanian.

hugardianus D'Orbigny. **Scaphites.**
D'Orbigny, Alcide, Paléontologie française, 1st ser., Terrain crétacé, vol. 1, pp. 521, 525, 1841.
Upper Gault. [Vraconian.]

? **idoneus** (Stoliczka) Kossmat.
Ammonites idoneus, Stoliczka, Ferdinand, Fossil Cephalopoda of the Cretaceous rocks of southern India, Ammonitidae, vol. 1, p. 64, pl. 34, fig. 1, 1865.
Scaphites? idoneus, Kossmat, Franz, Untersuchungen über die südindische Kreideformation: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 11, p. 139, 1897.
Upper Trichinopoly beds. [Santonian?]

inermis Anderson. **Scaphites.**
Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 113, pl. 3, figs. 74–77, 1902.
[= *Yezoites puerculus* (Jimbo) Yabe according to Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 170, 1910.]
Chico formation. [Cenomanian.]

inflatus Roemer. **Scaphites.**
Roemer, F. A., Die Versteinerungen des norddeutschen Kreidegebirges, p. 90, pl. 14, fig. 3, 1841.
Upper marl at Dülmen. [Lower Campanian according to Nowak.]

iris (Conrad). **Discoscaphites?**
Scaphites iris, Conrad, T. A., Observations on a group of Cretaceous fossil shells found in Tippah County, Miss., with descriptions of fifty-six new species: Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 3, p. 335, pl. 35, fig. 23, 1858.
[Ripley formation, Campanian or Maestrichtian.]

kieslingswaldensis Langenhan and Grundey. **Scaphites.**
Langenhan, Alwin, and Grundey, Max, Das Kieslingswalder Gestein: Jahresbericht des Glatzer Gebirgsvereins, vol. 10, p. 9, pl. 1, fig. 1, 1891. [Publication not seen.]
Emscherian-Coniacian.

kingianus Stoliczka. **Scaphites.**
Stoliczka, Ferdinand, Fossil Cephalopoda of the Cretaceous rocks of southern India, Ammonitidae, vol. 1, p. 169, pl. 81, fig. 7, 1865.
Ootator beds. [Cenomanian.]

klamathensis Anderson. **Scaphites.**
Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 115, pl. 3, figs. 78–81, 1902.
[Cenomanian.]

lamberti De Grossouvre. **Scaphites.**
Scaphites geinitzi D'Orbigny var. *binodosus* Roemer, Fritsch, Anton, and Schloenbach, Urban, Cephalopoden der böhmischen Kreideformation, p. 43, pl. 14, fig. 13, 1872.
Scaphites lamberti, De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 24, pl. 32, figs. 1, 5, 1894.
Lower and middle Coniacian.

larvaeformis Meek and Hayden (not Frech). **Scaphites.**
Meek, F. B., and Hayden, F. V., Descriptions of new organic remains collected in Nebraska Territory in the year 1857 by Dr. F. V. Hayden: Acad. Nat. Sci. Philadelphia Proc., vol. 10, p. 58, 1859.
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 418, pl. 6, fig. 6, 1876.
Carlile shale. [Upper Turonian.]

larvaeformis Frech (not Meek and Hayden). **Scaphites.**
Frech, Fritz, Über *Scaphites:* Centralbl. Mineralogie, Jahrg. 1915, No. 21, p. 556, fig. 2, 1915
Turonian.

leei Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 26, pl. 20, figs. 17–22; pl. 21, figs. 1–7, 1927.
Lower Campanian.

leei Reeside var. **parvus** Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 27, pl. 21, figs. 8–16, 1927.
Lower Campanian.

levis Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 26, pl. 20, figs. 7–16, 1927.
Lower Campanian.

mandanensis (Morton) Meek. **Discoscaphites.**
Ammonites mandanensis Morton, S. G., Description of sone new species of organic remains of the Cretaceous group of the United States: Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, p. 208, pl. 10, fig. 2, 1841.
Scaphites mandanensis (Morton) Meek, F. B., and Hayden, F. V., Descriptions of new fossil species of Mollusca collected by Dr. F. V. Hayden in Nebraska Territory: Acad. Nat. Sci. Philadelphia Jour., vol. 8, p. 281, 1857.
Scaphites (*Discoscaphites*) *mandanensis* (Morton), Meek, F. B., Preliminary paleontological report: U. S. Geol. Survey Terr. Second Ann. Rept., p. 297, 1872; Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 443, pl. 35, fig. 1, 1876.
Fox Hills sandstone. [Maestrichtian.]

meriani Pictet and Campiche. **Scaphites?**
Pictet, F. J., and Campiche, G., Description des fossiles du terrain crétacé des environs de Sainte Croix, pt. 2: Matériaux pour la paléontologie suisse, sér. 3, Mon. 2, p. 16, pl. 44, 1861.
Upper Greensand [Cenomanian].

meslei De Grossouvre. **Scaphites.**
De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 239, pl. 32, figs. 4, 7, 1894.
Lower and middle Campanian.

monasteriensis (Schlüter). **Discoscaphites.**
Scaphites monasteriensis, Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 91, pl. 27, figs. 6, 7, 1871.
Hoploscaphites monasteriensis (Schlüter), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 566, 1912.
Mucronatenkreide. [Maestrichtian.]

moreauensis Owen. [=*Discoscaphites cheyennensis* (Owen) Meek.]
Owen, D. D., Description of new and imperfectly known genera and species of organic remains, collected during the geological surveys of Wisconsin, Iowa, and Minnesota, p. 579, pl. 8, fig. 7, 1852.
Fox Hills sandstone. [Maestrichtian.]

mullananus (Meek and Hayden) Stanton. **Scaphites.**
Ammonites mullananus, Meek, F. B., and Hayden, F. V., Description of new Cretaceous fossils from Nebraska Territory collected by the expedition sent out by the Government under the command of Lieut. John Mullan: Acad. Nat. Sci. Philadelphia Proc., 1862, pp. 23–25.
Ammonites? mullananus, Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, pp. 607–609, pl. 8, figs. 1a–c, 1876.
Scaphites mullananus, Stanton, T. W., The Colorado fauna: U. S. Geol. Survey Bull. 106, p. 187, pl. 44, figs. 2–4, 1893.
[Upper part of Colorado group, Coniacian.]

multinodosus Von Hauer (1858, not Von Hauer 1866).
Von Hauer, Franz, Über die Cephalopoden der Gosauschichten: Beitr. Paläontographie Oesterreich, vol. 1, p. 9, pl. 1, figs. 7, 8, 1858.
[=*Scaphites constrictus* D'Orbigny according to De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 248, 1894.]
[Maestrichtian?]

multinodosus Von Hauer (1866, not Von Hauer 1858).
Von Hauer, Franz, Neue Cephalopoden aus den Gosaubilden der Alpen: K. Akad. Wiss. Wien Sitzungsber., vol. 53, p. 7, pl. 1, figs. 7, 8, 1866.
[=*Scaphites pulcherrimus* Roemer according to De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 251, 1894.]

nebrascensis Owen. [=*Discoscaphites conradi* (Morton) Meek.]
Owen, D. D., Description of new and imperfectly known genera and species of organic remains, collected during the geological surveys of Wisconsin, Iowa, and Minnesota, p. 577, pl. 8, fig. 3; pl. 9, fig. 2; 1852.

nicolleti (Morton) Meek. **Discoscaphites.**
Ammonites nicolleti, Morton, S. G., Description of some new species of organic remains of the Cretaceous group of the United States: Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, pt. 2, pt. 209, pl. 10, fig. 3, 1842.

nicolleti (Morton) Meek. **Discoscaphites**—Continued.
Scaphites nicolleti (Morton), Meek, F. B., and Hayden, F. V., Descriptions of new fossil species of Mollusca collected by Dr. F. V. Hayden in Nebraska Territory: Acad. Nat. Sci. Philadelphia Jour., vol. 8, p. 281, 1857.
Scaphites (*Discoscaphites*) *nicolleti* (Morton), Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 435, pl. 34, figs. 2, 4, 1876.
Fox Hills sandstone. [Maestrichtian.]

niedzwiedzkii (Uhlig). **Discoscaphites.**
Uhlig, Victor, Bemerkungen zur Gliederung der karpathischen Bildungen: K.-k. geol. Reichsanstalt Jahrb., vol. 43, p. 220, fig. 2, 1894.
[=*Scaphites constrictus* var. *niedzwiedzkii* according to Wisniowski, Thaddeus, Über die obersenone Flyschfauna von Leszczny: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 20, p. 104, 1907.]
Senonian. [Maestrichtian?]

nodosus (Owen) Nowak (not Lopuski). **Acanthoscaphites.**
Scaphites nodosus, Owen, D. D., Description of new and imperfectly known genera and species of organic remains, collected during the geological surveys of Wisconsin, Iowa, and Minnesota, p. 581, pl. 8, fig. 4, 1852.
Acanthoscaphites nodosus (Owen), Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 63, 1916.
Upper Pierre shale. [Upper Campanian.]

nodosus (Owen) var. **brevis** Meek. **Acanthoscaphites.**
Scaphites nodosus Owen var. *brevis*, Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 426, pl. 25, fig. 1, 1876.
Upper Pierre shale. [Upper Campanian.]

nodosus Owen var. *exilis* Meek and Hayden. [=*Scaphites nodosus* var. *quadrangularis* Meek and Hayden.]
Meek, F. B., and Hayden, F. V., Descriptions of new lower Silurian (Primordial), Jurassic, Cretaceous, and Tertiary fossils collected in Nebraska by the exploring expedition under the command of Capt. W. F. Raynolds: Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 420, 1862.

nodosus (Owen) var. **plenus** Meek and Hayden. **Acanthoscaphites.**
Meek, F. B., and Hayden, F. V., Descriptions of new organic remains from the Tertiary, Cretaceous, and Jurassic rocks of Nebraska: Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 177, 1861.
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 429, pl. 26, fig. 1, 1876.
[=*Acanthoscaphites tridens-quadrispinosus* according to Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 59, 1916.]
Upper Pierre shale. [Upper Campanian.]

nodosus (Owen) var. **quadrangularis** Meek and Hayden. **Acanthoscaphites.**
Meek, F. B., and Hayden, F. V., Descriptions of new lower Silurian (Primordial), Jurassic, Cretaceous, and Tertiary fossils collected in Nebraska by the exploring expedition under the command of Capt. W. F. Raynolds: Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 420, 1862.

nodosus (Owen) var. **quadrangularis** Meek and Hayden. **Acanthoscaphites**—Continued.
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 428, pl. 25, figs. 2–4, 1876.
[=*Acanthoscaphites roemeri* (D'Orbigny), according to Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 63, 1916.]
Upper Pierre shale. [Upper Campanian.]

nodosus Lopuski (not Owen). **Discoscaphites?**
Scaphites nodosus, Lopuski, Geslaw, Contribution à l'étude de la faune crétacée du plateau de Lublin: Soc. sci. Varsovie Compt. rend., année 4, pt. 3, p. 122, 1911.
Maestrichtian.

novimexicanus Reeside. **Desmoscaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 17, pl. 11, figs. 1–4, 1927.
Santonian.

obliquus Sowerby. **Scaphites.**
Sowerby, James, Mineral conchology of Great Britain, vol. 1, p. 53, pl. 18, figs. 1, 2, 1813.
Cenomanian.

ornatissimus D'Orbigny.
D'Orbigny, Alcide, Prodrome de paléontologie, p. 214, 1850.
Senonian [of D'Orbigny].

ornatus (Roemer) Nowak (not Gümbel). **Acanthoscaphites?**
Scaphites ornatus, Roemer, F. A., Versteinerungen des norddeutschen Kreidegebirges, p. 91, pl. 13, fig. 8, 1841.
Acanthoscaphites? ornatus (Roemer), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 565, 1912.
Lower marl at Lemförd. [Campanian?]

ornatus Gümbel (not Roemer).
Gümbel, C. W., Geognostische Beschreibung des bayrischen Alpengebirge, p. 576, 1861.
[=*S. constrictus* Sowerby according to Böhm, Johannes, Die Kreidebildung des Furbergs und Sulzbergs bei Siegsdorf in Oberbayern: Palaeontographica, vol. 38, p. 48, 1891.]

pavana (Forbes) Kossmat.
Ammonites pavana, Forbes, Edward, Fossil invertebrates of South India: Geol. Soc. London, ser. 2, vol. 7, p. 110, pl. 7, fig. 5, 1846.
Scaphites pavana, Kossmat, Franz, Untersuchungen über die südindische Kreideformation: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 11, p. 138, 1897.
[=*S. cunliffei* var. *pavana* according to Pervinquière, Léon, Études de paléontologie tunisienne, pt. 1, Céphalopodes des terrains secondaires, p. 124, 1907.]
Valudayur beds. [Campanian.]

peroni Pervinquière. **Scaphites.**
Pervinquière, Léon, Sur quelques ammonites du crétacé algérien: Soc. géol. France Mém. 42, p. 26, pl. 2, figs. 10–13, 1910.
Cenomanian.

peroni var. **inornatus** Pervinquière. **Scaphites.**
Pervinquière, Léon, Sur quelques ammonites du crétacé algérien: Soc. géol. France Mém. 42, p. 26, pl. 2, figs. 14–16, 1910.
Cenomanian.

perrini Anderson. **Scaphites.**
Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 114, pl. 2, figs. 71–73, 1902.
Lower Chico. [Cenomanian.]
[=*Yezoites perrini* according to Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 172, pl. 15, figs. 28, 29, 1910.]

planus Roman and Mazeran (not Yabe). **Scaphites.**
Roman, Frédéric, and Mazeran, Pierre, Monographie paléontologique de la faune turonienne du bassin d'Uchaux et de ses dépendances: Mus. hist. nat. Lyon Archives, vol. 12, Mém. 2, p. 13, pl. 4, figs. 15–17, 1920.
Turonian.

planus Yabe (not Roman and Mazeran). **Scaphites.**
Scaphites planus, Yabe, Hisakatsu, Zur Stratigraphie und Paläontologie der oberen Kreide von Hokkaido und Sachalin: Deutsche geol. Gesell. Zeitschr., vol. 6, p. 415, 1909.
Yezoites planus, Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 167, pl. 15, figs. 11–18, 1910.
[Cenomanian.]

planus Yabe var. **gigas** Yabe. **Scaphites.**
Yezoites planus var. *gigas*, Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 167, pl. 15, fig. 19, 1910.
[Cenomanian.]

plicatellus Roemer.
Roemer, F. A., Versteinerungen des norddeutschen Kreidegebirges, p. 91, pl. 13, fig. 7, 1841.
Lower marl at Lemförd. [Campanian?]

potieri De Grossouvre. **Discoscaphites.**
Scaphites potieri, De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 242, pl. 22, fig. 3, 1894.
Lower and middle Campanian.

pseudoaequalis Yabe. **Scaphites.**
Yabe, Hisakatsu, Zur Stratigraphie und Paläontologie der oberen Kreide von Hokkaido und Sachalin: Deutsche geol. Gesell. Zeitschr., vol. 61, p. 415, 1909.
Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 163, pl. 15, figs. 1–3, 1910.
[Cenomanian.]

puerculus Jimbo. **Scaphites.**
Scaphites puerculus, Jimbo, K., Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido: Paleont. Abh. (Dames & Kayser), vol. 6, pt. 3, p. 37, pl. 5, fig. 4, 1894.
Yezoites puerculus, Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 170, pl. 15, figs. 20–22, 1910.
[Cenomanian.]

puerculus Jimbo var. **teshioensis** Yabe. **Scaphites.**
Yezoites puerculus var. *teshioensis*, Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 170, pl. 15, figs. 23–27, 1910.
[Cenomanian.]

pulcherrimus (Roemer) Nowak. **Acanthoscaphites.**
Scaphites pulcherrimus, Roemer, F. A., Versteinerungen des norddeutschen Kreidegebirges, p. 91, pl. 14, fig. 4, 1841.

pulcherrimus (Roemer) Nowak. **Acanthoscaphites—Con.**
Acanthoscaphites pulcherrimus (Roemer), Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 63, 1916.
Lower marl. [Upper Campanian.]

pungens (Binckhorst). **Discoscaphites.**
Ammonites pungens, Binckhorst, J. T., Monographie des gastéropodes et des céphalopodes de la craie supérieure du Limbourg, Classe des céphalopodes, p. 32, pl. $5a_3$, figs. 1 a–d, 1861.
Scaphites pungens, De Grossouvre, Albert, Description des ammonitides du crétacé supérieur du Limbourg belge et hollandais et du Hainaut: Mus. roy. hist. nat. Belgique Mém., vol. 4, p. 37, pl. 11, fig. 1, 2, 1908.
Hoploscaphites pungens (Binckhorst), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 566, 1912.
Maestrichtian.

pygmaeus Holzapfel.
Holzapfel, Eduard, Die Mollusken der aachener Kreide, Abt. 1, Cephalopoda und Glossophora: Palaeontographica, vol. 34, p. 63, pl. 7, fig. 19, 1888.
Lower Senonian. [Lower Campanian.]

quadrispinosus (Geinitz) Nowak. **Acanthoscaphites.**
Scaphites quadrispinosus, Geinitz, H. B., Das Quadersandsteingebirge in Deutschland, p. 116, pl. 7, fig. 2; pl. 8, fig. 2, 1850.
[=*Scaphites tridens* Kner according to Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 94, 1871.]
[=*Acanthoscaphites tridens* Kner var. *quadrispinosus* Geinitz, according to Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, Teil 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 577, 1912.]
[Upper Campanian.]

reesidei (Wade). **Acanthoscaphites?**
Scaphites reesidei, Wade, Bruce, The fauna of the Ripley formation on Coon Creek, Tenn.: U. S. Geol. Survey Prof. Paper 137, pp. 183–184, pl. 61, figs. 3–7, 1926.
Ripley formation. [Upper Campanian.]

reniformis Morton.
Scaphites reniformis Morton, S. G., Supplement to the "Synopsis of the organic remains of the ferruginous sand formation of the United States": Am. Jour. Sci., 1st ser., vol. 23, p. 291, 1833.
Scaphites reniformis Morton, S. G., Synopsis of the organic remains of the Cretaceous group of the United States, p. 42, pl. 2, fig. 6, 1834.
[=*Scaphites hippocrepis* according to Gabb, W. M., Synopsis of the Mollusca of the Cretaceous formation: Am. Philos. Soc. Proc., vol. 8, p. 33, 1861.]

rochatianus D'Orbigny. **Scaphites.**
D'Orbigny, Alcide, Prodrome de paléontologie, p. 147, 1850.
Cenomanian.

roemeri (D'Orbigny) Nowak (not Brauns). **Acanthoscaphites.**
Scaphites compressus, Roemer, F. A., Versteinerungen des norddeutschen Kreidegebirges, p. 91, pl. 15, fig. 1, 1841.
Scaphites roemeri, D'Orbigny, Alcide, Prodrome de paléontologie, p. 214, 1850.
Acanthoscaphites roemeri (D'Orbigny), Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 62, 1916.
Upper Campanian.

roemeri Brauns (not D'Orbigny).
Scaphites binodosus, Roemer, F. A., Die Quadratenkreide des Sudmerberges bei Goslar: Palaeontographica, vol. 13, p. 197, pl. 32, fig. 9, 1865.
Scaphites sp., Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, pl. 23, fig. 23, 1871.
Scaphites roemeri, Brauns, A., Über den Sudmerberg bei Ocker: Zeitschr. ges. Naturwiss., 1875, p. 342, pl. 8, figs. 4, 5.
Emscher. [Coniacian.]

roguensis Anderson. **Scaphites.**
Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 112, pl. 2, figs. 67–70, 1902.
Lower Chico. [Cenomanian.]

semicostatus Roemer. **Scaphites.**
Roemer, F. A., Die Kreidebildungen von Texas, p. 35, pl. 1, fig. 5, 1852.
Austin chalk. [Coniacian.]

septem-costatus Cragin. **Scaphites?**
Cragin, F. W., A contribution to the invertebrate paleontology of the Texas Cretaceous: Texas Geol. Survey Fourth Ann. Rept., pt. 2, p. 241, 1893.
Eagle Ford shales. [Turonian.]

similaris Stoliczka. **Scaphites.**
Scaphites aequalis, Stoliczka, Ferdinand, Fossil Cephalopoda of the Cretaceous rocks of southern India, p. 167, pl. 81, fig. 46, 1865.
Scaphites similaris, Stoliczka, Ferdinand, India Geol. Survey Records, vol. 1, p. 36, 1868.
Ootatoor. [Cenomanian or Turonian.]

similis Whitfield. **Scaphites.**
Whitfield, R. P., Gastropoda and Cephalopoda of the Raritan clays and greensand marls of New Jersey: U. S. Geol. Survey Mon. 18, p. 267, pl. 44, figs. 1, 2, 1892.
Merchantville clay. [Lower Campanian.]

spiniger (Schlüter) Nowak. **Acanthoscaphites.**
Scaphites spiniger, Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 82, pl. 25, figs. 1–7, 1871.
Acanthoscaphites spiniger (Schlüter), Nowak, Jan, Zur Bedeutung von *Scaphites* für die Gliederung der Oberkreide: K.-k. geol. Reichsanstalt Verh., Jahrg. 1916, No. 3, p. 67, 1916.
Mucronatenkreide. [Upper Campanian.]

spinosissimus Frech.
Frech, Fritz, Über *Scaphites:* Centralbl. Mineralogie, Jahrg. 1915, p. 564, fig. 12, 1915.
Upper *Mucronatus* zone. [Upper Campanian.]

stantoni Reeside. **Scaphites.**
Reeside, J. B., jr., The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U. S. Geol. Survey Prof. Paper 151, p. 23, pl. 17, figs. 16–21; pl. 18, figs. 1–7, 1927.
Lower Campanian.

stephanoceroides Yabe.
Yabe, Hisakatsu, Zur Stratigraphie und Paläontologie der oberen Kreide von Hokkaido und Sachalin: Deutsche geol. Gesell. Zeitschr., vol. 61, p. 442, 1909.
[=*Yezoites perrini* according to Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 172, 1910.]

striatus Mantell (not Kner). [=*Scaphites aequalis* Sowerby.]
Mantell, G. A., Geology of Sussex, pl. 22, figs. 14, 15, 1822.

striatus Kner (not Mantell).
Kner, Rudolph, Versteinerungen des Kreidemergels von Lemberg und seiner Umgebung: Naturw. Abh. (W. Haidinger), vol. 3, pt. 2, No. 1, p. 10, 1850.
[=*Scaphites aequalis* Sowerby according to Alth, Alois, Geognostisch-palaeontologische Beschreibung der nächsten Umgebung von Lemberg: Naturw. Abh. (W. Haidinger), vol. 3, pt. 2, No. 9, p. 206, pl. 10, fig. 31, 1850.]
[=*Scaphites roemeri* D'Orbigny according to Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 90, 1871.]
[=*Hoploscaphites constrictus* var. *tenuistriatus* (Kner) according to Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, Teil 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 585, 1912.]
Maestrichtian.

stüri Redtenbacher.
Scaphites? stüri, Redtenbacher, Anton, Cephalopodenfauna der Gosauschichten in den nordöstlichen Alpen: K.-k. geol. Reichsanstalt Abh., vol. 5, Heft 5, p. 129, pl. 30, fig. 10, 1873.
[=*Menuites stüri* according to Spath, L. F., On the Senonian ammonite fauna of Pondoland: Roy. Soc. South Africa Trans., vol. 10, p. 123, 1922.]

subglobosus (Whiteaves). **Acanthoscaphites?**
Whiteaves, J. F., Report on the Invertebrata of the Laramie and Cretaceous rocks of the vicinity of the Bow and Belly Rivers and adjacent localities in the Northwest Territory: Contr. Canadian Paleontology, vol. 1, p. 52, pl. 7, figs. 3, 8, 1885.
[=*Scaphites mullananus?* according to Stanton, T. W., The Colorado formation and its invertebrate fauna: U. S. Geol. Survey Bull. 106, p. 189, 1893.]
Bearpaw shale. [Upper Campanian.]

tenuicostatus Pervinquière. **Scaphites.**
Pervinquière, Léon, Sur quelques ammonites du crétacé algérien: Soc. géol. France Mém. 42, p. 28, pl. 2, figs. 17–19, 1910.
Middle Cenomanian.

tenuistriatus (Kner). **Discoscaphites.**
Kner, Rudolph, Versteinerung des Kreidemergels von Lemberg und seiner Umgebung: Naturw. Abh. (W. Haidinger), vol. 3, pt. 2, No. 1, p. 10, pl. 1, fig. 5, 1850.
[=*Scaphites constrictus* var. *tenuistriatus* according to De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 249, 1894.]
[=*Hoploscaphites constrictus* var. *tenuistriatus* according to Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 585, 1912.]
[Maestrichtian?]

cf. **teshioensis** (Yabe) Burckhardt.
Burckhardt, Carlos, Faunas cretácicas de Zumpango del Río: Inst. geol. México Bol. 33, p. 97, pl. 22, fig. 11, 1919.
Turonian.

texanus Roemer. **Scaphites.**
Roemer, F. A., Die Kreidebildungen von Texas und ihre organischen Einschlüsse, p. 35, pl. 1, fig. 4, 1852.
Austin chalk. [Emscherian.]

thomasi Pervinquière. **Scaphites.**
Pervinquière, Léon, Études de paléontologie tunisienne, pt. 1, Céphalopodes des terraines secondaires, p. 121, pl. 4, figs. 30, 31, 1907.
Cenomanian.

tridens (Kner) Nowak. **Acanthoscaphites.**
Scaphites tridens, Kner, Rudolph, Versteinerungen des Kreidemergels von Lemberg und seiner Umgebung: Naturw. Abh. (W. Haidinger), vol. 3, pt. 2, No. 1, p. 10, pl. 2, fig. 1, 1850.
Acanthoscaphites tridens (Kner), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 570, pl. 32, fig. 4; pl. 33, figs. 27, 29, 1912.
[Upper Campanian.]

tridens (Kner) var. **bispinosus** Nowak. **Acanthoscaphites.**
Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 577, pl. 32, figs. 1–3, 1912.
[Upper Campanian.]

trinodosus (Kner) Nowak. **Acanthoscaphites.**
Scaphites trinodosus, Kner, Rudolph, Versteinerungen des Kreidemergels von Lemberg und seiner Umgebung: Naturw. Abh. (W. Haidinger), vol. 3, p. 2, No. 1, p. 11, pl. 2, fig. 2, 1850.
[=*Scaphites tridens* according to Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide, p. 95, 1871.]
[=*Acanthoscaphites tridens* var. *trinodosus* according to Nowak, Jan, Untersuchungen über die Cephalopoden, der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B. p. 576, 1912.]
[Upper Campanian.]

trispinosus (Geinitz) Nowak. **Acanthoscaphites.**
Scaphites trispinosus, Geinitz, H. B., Das Quadersandsteingebirge, p. 116, pl. 7, figs. 1 a–b, 1850.
[=*Acanthoscaphites tridens* var. *trispinosus* according to Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 578, 1912.]
Upper Campanian.

tuberculatus Giebel.
Giebel, Naturw. Ver. Halle Jahresber., 1849, p. 20. [Original publication not seen.]
[=*Scaphites compressus* Roemer (*S. roemeri* D'Orbigny) according to Frech, Fritz, Über *Scaphites:* Centralbl Mineralogie, Jahrg. 1915, No. 18, p. 556, text fig. 14, 1915.]
[Upper Campanian?].

varians (Lopuski) Nowak. **Acanthoscaphites.**
Scaphites varians, Lopuski, Geslaw, Contribution à l'étude de la faune crétacée du Plateau de Lublin: Soc. sci. Varsovie, Compt. rend., année 4, p. 137, pl. 4, figs. 1–3, 1911.
[*Ancanthoscaphites tridens* var. *varians* (Lopuski), Nowak, Jan, Untersuchungen über die Cephalopoden der oberen Kreide in Polen, pt. 2, Die Skaphiten: Acad. sci. Cracovie Bull. internat., année 1911, sér. B, p. 578, pl. 33, figs. 1–3, 1912.
Upper Campanian.

ventricosus Meek and Hayden. **Scaphites.**
Meek, F. B., and Hayden, F. V., Descriptions of new Cretaceous fossils from Nebraska Territory: Acad. Nat. Sci. Philadelphia Proc., vol. 14, p. 22, 1863.
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 425, pl. 6, figs. 7, 8, 1876.
Upper Colorado formation. [Coniacian.]

ventricosus Meek and Hayden var. **stantoni** Reeside. **Scaphites.**
Reeside, J. B., jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, p. 7, pl. 3, figs. 19, 20; pl. 4, figs. 5–8, 1927.
Cody shale (Coniacian).

ventricosus Meek and Hayden var. **depressus** Reeside. **Scaphites.**
Reeside, J. B., jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, p. 7, pl. 5, figs. 6–10, 1927.
Cody shale (Coniacian).

ventricosus Meek and Hayden var. **oregonensis** Reeside **Scaphites.**
Reeside, J. B., jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, p. 7, pl. 6, figs. 11–15, 1927.
Cody shale (Coniacian).

ventricosus Meek and Hayden var. **interjectus** Reeside. **Scaphites.**
Reeside, J. B., jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, p. 7, pl. 5, figs. 1–5, 1927.
Cody shale (Coniacian).

vermicosus (Shumard) Adkins. [Misprint for *Scaphites verrucosus* Shumard?]
Adkins, W. S., The Weno and Pawpaw formations of the Texas Comanchean: Texas Univ. Bull. 1856, p. 84, 1918.

vermiculus Shumard.
Shumard, B. F., Description of new Cretaceous fossils from Texas: St. Louis Acad. Sci. Trans., vol. 1, p. 594, 1860
White, C. A., Contributions to invertebrate paleontology, No. 2, Cretaceous fossils of the Western States and Territories: U. S. Geol. and Geog. Survey Terr. Twelfth Ann. Rept., pt. 1, p. 39, pl. 18, fig. 8, 1883.
[=*Macroscaphites* according to Meek, B. F., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 419, 1876.]

vermiformis Meek and Hayden. **Scaphites.**
Meek, F. B., and Hayden, F. V., Descriptions of new Cretaceous fossils from Nebraska Territory: Acad. Nat. Sci. Philadelphia Proc., vol. 14, p. 22, 1863.
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 423, pl. 6, fig. 4, 1876.
Upper Colorado formation. [Coniacian.]

vermiformis Meek and Hayden var. **binneyi** Reeside. **Scaphites.**
Reeside, J. B., jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, p. 8, pl. 6, figs. 1–8, 1927.
Cody shale. (Coniacian.)

verneuili (D'Orbigny) De Grossouvre. **Discoscaphites**
Ammonites verneuili, D'Orbigny, Alcide, Paléontologie française, Terrain crétacé, Céphalopodes, p. 329, pl. 98, figs. 3–5, 1840.
Scaphites verneuilli, De Grossouvre, Albert, Les ammonites de la craie supérieure: Recherches sur la craie supérieure, pt. 2, Paléontologie, p. 253, pl. 26, fig. 2, 1894.
Upper Campanian.

verrucosus Shumard.
Shumard, B. F., Descriptions of new Cretaceous fossils from Texas: Boston Soc. Nat. Hist. Proc., vol. 8, p. 189, 1862.
Navarro formation. [Campanian.]

warreni Meek and Hayden. **Scaphites.**
Meek, F. B., and Hayden, F. V., Descriptions of new organic remains from the Tertiary, Cretaceous, and Jurassic rocks of Nebraska: Acad. Nat. Sci. Philadelphia Proc., 1860, p. 177.
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 420, pl. 6, fig. 5; text figs. 61–63, 1876.
Carlile shale. [Upper Turonian.]

warreni Meek and Hayden var. **silesiaca** Frech. **Scaphites.**
Scaphites lamberti, Leonhard, Richard, Die Fauna der Kreideformation in Oberschlesien: Palaeontographica, vol. 44, p. 61, pl. 6, figs. 7, 8.
Scaphites warreni var. *silesiaca*, Frech, Fritz, Über *Scaphites:* Centralbl. Mineralogie, Jahrg. 1915, No. 21, p. 557, figs. 6, 8.
[Turonian.]

?worthensis Adkins and Winton. [*Macroscaphites*?]
Adkins, W. S., and Winton, W. M., Paleontological correlation of the Fredericksburg and Washita formations in north Texas: Texas Univ. Bull. 1945, p. 36, pl. 7, figs. 1, 2, 1919.
Lower Washita. [Cenomanian?]

wyomingensis Meek. [=*S. warreni* Meek and Hayden.]
Meek, F. B., Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 421, pl. 13, figs. 5–7, 1876.

yonekurai Yabe. **Scaphites.**
Yabe, Hisakatsu, Zur Stratigraphie und Paläontologie der oberen Kreide von Hokkaido und Sachalin: Deutsche geol. Gesell. Zeitschr., vol. 61, p. 421, 1909.
Yabe, Hisakatsu, Die Scaphiten aus der Oberkreide von Hokkaido: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, p. 165, pl. 15, figs. 4–7, 1910.
[Cenomanian?]

yokoyamai Jimbo. **Scaphites.**
Jimbo, K., Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido: Paleont. Abh., vol. 6, No. 3, p. 37, pl. 5, fig. 3, 1894.
[Cenomanian?]

LIST OF SPECIES ARRANGED BY MAJOR CHRONOLOGIC DIVISIONS

Below is a list of species arranged by major chronologic divisions. A query (?) indicates doubt as to age. Under each division the species in group *a* are American; those in group *b* extra-American.

Maestrichtian:
(*a*) abyssinus, cheyennensis, conradi, conradi var. gulosus, conradi var. intermedius, conradi var. petechialis, ?iris, mandanensis, nicolleti.
(*b*) angulatus, constrictus, constrictus var. crassus, constrictus var. vulgaris, diversesulcatus, gibbus, monasteriensis, niedzwiedzkii, nodosus (Lopuski), tenuistriatus.

Upper Campanian:
(*a*) nodosus (Owen), nodosus var. brevis, nodosus var. plenus, nodosus var. quadrangularis, reesidei, subglobosus, verrucosus.
(*b*) ?compressus, ?constrictus var. quiriquinensis, cunliffei, haugi, ?ornatus, pavana, ?plicatellus, pulcherrimus, quadrispinosus, roemeri (D'Orbigny), spiniger, spinosissimus, tridens, tridens var. bispinosus, trinodosus, trispinosus, tuberculatus, varians, verneuilli.

Lower Campanian:
(*a*) aquilaensis, aquilaensis var. costatus, aquilaensis var. nanus, hippocrepis, hippocrepis var. crassus, hippocrepis var. pusillus, hippocrepis var. tenuis, leei, leei var. parvus, levis, similis, stantoni.
(*b*) aquisgranensis, inflatus, meslei, potieri.

Santonian:
(*a*) bassleri, novimexicanus.
(*b*) ?andoorensis, binodosus, ?idoneus.

Coniacian:
(*a*) mullananus, semicostatus, texanus, ventricosus, ventricosus var. depressus, ventricosus var. interjectus, ventricosus var. oregonensis, ventricosus var. stantoni, vermiformis, vermiformis var. binneyi.
(*b*) arnaudi, ?brahminicus, kieslingswaldensis, lamberti, roemeri (Brauns).

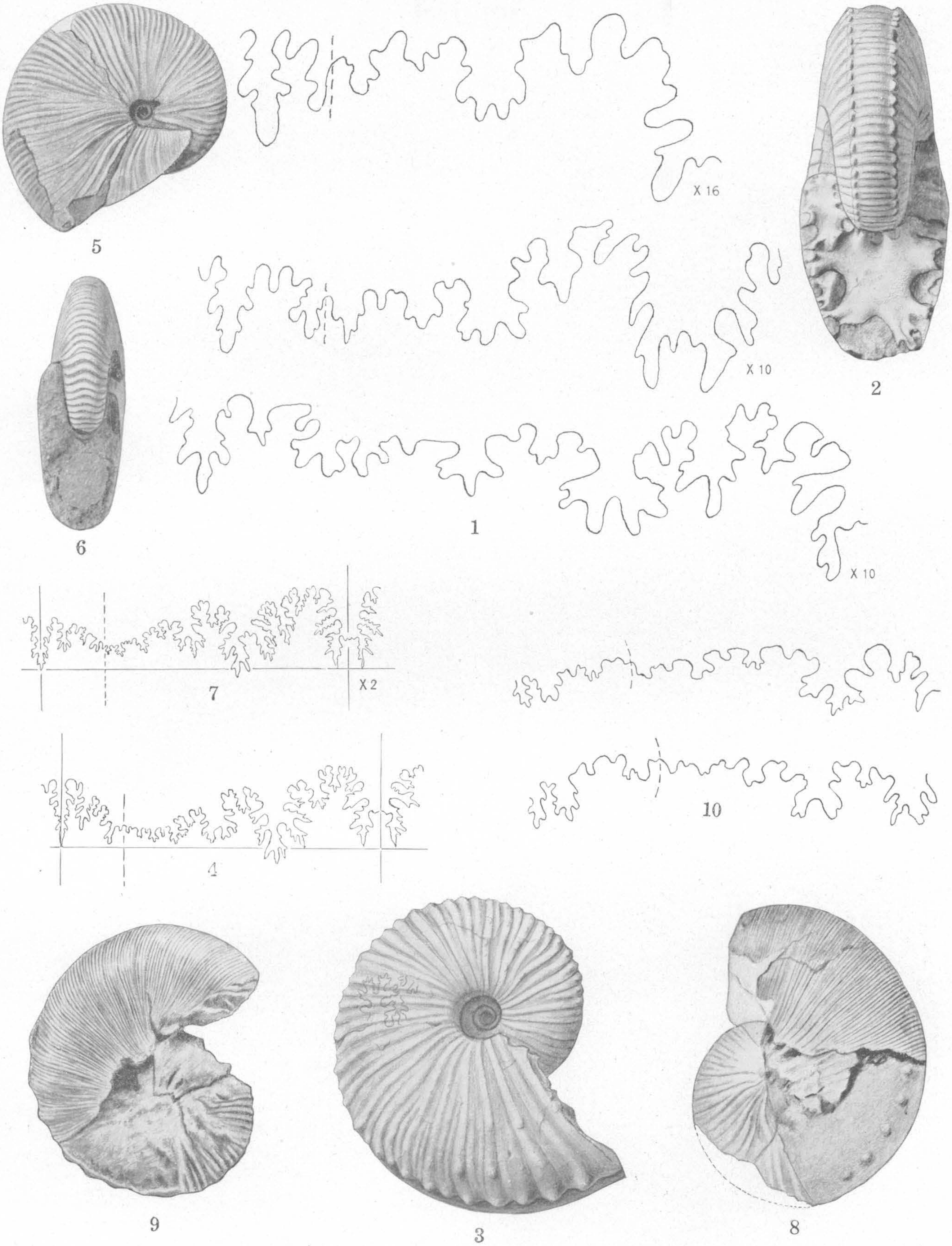
Turonian:
(*a*) larvaeformis, septemcostatus, warreni.
(*b*) aequalis var. turonensis, auritus, ?fritschi, geinitzi, geinitzi var. intermedius, planus (Roman and Mazeran), warreni var. silesiaca.

Cenomanian:
(*a*) condoni, condoni var. appressus, gillisi, hilli, inermis, klamathensis, perrini, roguensis.
(*b*) aequalis, africanus, evolutus, formosus, gracilis, kingianus, obliquus, peroni, peroni var. inornatus, planus (Yabe), planus var. gigas, pseudoaequalis, puerculus, puerculus var. teshioensis, rochatianus, similaris, tenuicostatus, thomasi, yonekurai, yokoyamai.

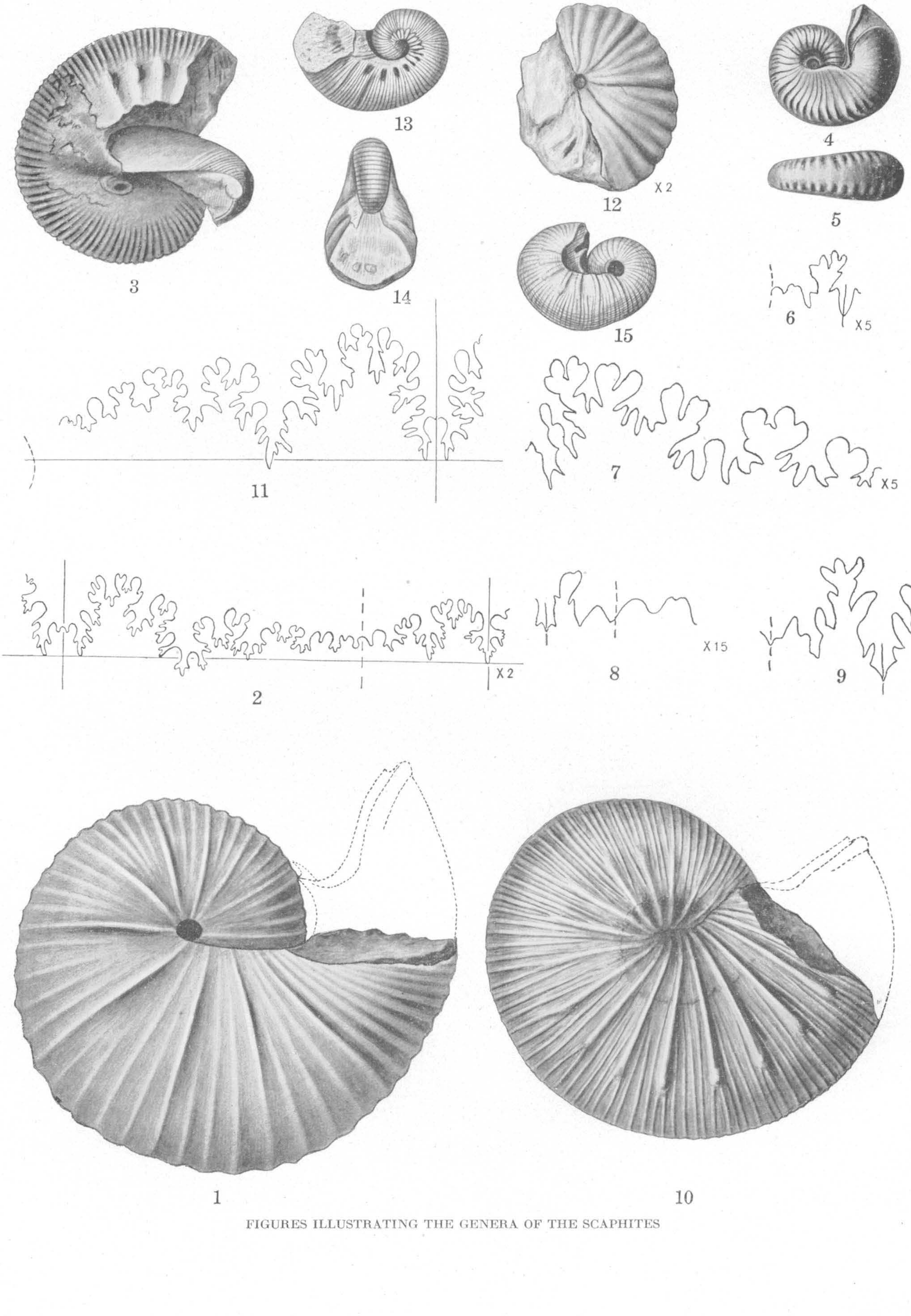
Upper Gault:
(*b*) hugardianus.

PLATES 9–11

PLATE 9



FIGURES ILLUSTRATING THE GENERA OF THE SCAPHITES



FIGURES ILLUSTRATING THE GENERA OF THE SCAPHITES

PLATE 10

Page

FIGURE 1. *Scaphites ventricosus* Meek and Hayden, from upper part of Colorado formation at Chippewa Point, near Fort Benton, Mont.; side view, after Meek, U. S. Geol. Survey Terr. Rept., vol. 9, pl. 6, fig. 7b, 1876. Hyatt's type of *Anascaphites* ---- 22, 26

FIGURE 2. *Scaphites ventricosus* Meek and Hayden, from Cody shale in sec. 6, T. 51 N., R. 100 W., Wyo.; suture of a typical specimen ---- 22, 26

FIGURE 3. *Scaphites geinitzi* D'Orbigny var. *binodosus* Roemer, from Priesen, near Laun, Bohemia; side view, after Jahn, K.-k. geol. Reichsanstalt Jahrb., vol. 41, text fig. 3, p. 181, 1892. Hyatt's type of *Jahnites* ---- 22, 26

FIGURES 4, 5. *Scaphites planus* Yabe, from vicinity of Opiraushibets, Province of Teshio, Hokkaido, Japan; side and peripheral views, after Yabe, Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, vol. 23, pl. 15, figs. 15a,b, 1910. Referred to *Yezoites* by Yabe ---- 23, 26

FIGURES 6, 7. *Scaphites planus* Yabe, from same locality as Figures 4 and 5; dorsal and ventral sutures, after Yabe, op. cit., pl. 15, figs. 17, 18, 1910. Referred to *Yezoites* by Yabe ---- 23, 26

FIGURE 8. *Scaphites puerculus* Jimbo, from same locality as Figures 4 and 5; dorsal suture with part of ventral suture, after Yabe, op. cit., pl. 15, fig. 22, 1910. Referred to *Yezoites* by Yabe ---- 23, 26

FIGURE 9. *Scaphites* sp., from Lenentz, Laun, Bohemia; dorsal suture, after Yabe, op. cit., pl. 15, fig. 30, 1910. Referred to *Yezoites* by Yabe ---- 23, 26

FIGURES 10–12. *Desmoscaphites bassleri* Reeside, from the Telegraph Creek formation in sec. 27, T. 1 S., R. 30 E., Mont.; side view and suture of adult and side view of early whorls ---- 25, 27

FIGURES 13, 14. *Scaphites aequalis* Sowerby; from the Greensand of Yeovil, England; side and peripheral views of the type specimen, after Sowerby, Mineral conchology of Great Britain, pl. 18, figs. 1, 2, 1813 ---- 21, 26

FIGURE 15. *Scaphites aequalis* Sowerby, from Dorsetshire, England; side view of the genotype specimen, *Scaphites* of Parkinson; after Parkinson Organic remains of a former world, pl. 10, fig. 10, 1811 ---- 21. 27

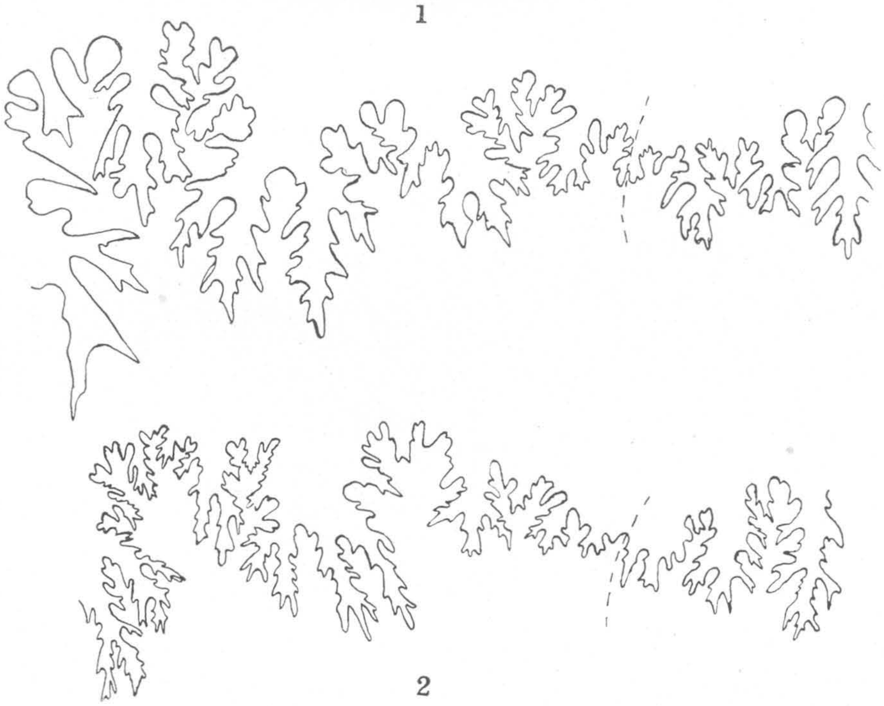
PLATE 11

Page

FIGURE 1. *Acanthoscaphites tridens* (Kner) Nowak, var. *trispinosus* Geinitz, from Porszna, Poland; side view, after Nowak, Acad. sci. Cracovie Bull. internat., année 1911, sér. B, pl. 32, fig. 5, 1912 ---- 24, 27

FIGURE 2. *Acanthoscaphites tridens-trinodosus* (Kner) Nowak, from Kierniczki, Poland; two sutures, after Nowak, op. cit., text figs. 8, 9, p. 572, 1912 ---- 24, 27

1



2

FIGURES ILLUSTRATING THE GENERA OF THE SCAPHITES

A SECTION OF THE KAIBAB LIMESTONE IN KAIBAB GULCH, UTAH

By L. F. Noble

INTRODUCTION

Of the Paleozoic formations in the plateau province of Arizona and Utah the Kaibab limestone, the youngest formation of the succession, is perhaps the best known. It is probably the most widely distributed Paleozoic formation in the province, its outcrops covering a large part of northern Arizona and appearing at many places in southern Utah. In southern Nevada, beyond the western boundary of the province, it is exposed in several mountain ranges, in one of which it extends to the border of California. At the Grand Canyon it is one of the chief elements in the landscape, constituting the surface of the Kaibab and Coconino Plateaus, through which the deepest part of the canyon is cut, and forming the first cliffs that drop away at the rim of the canyon. Its abundant fossil fauna and its position at the top of the Permian series beneath a widespread unconformity of erosion furnish interesting problems for the paleontologist and stratigrapher. At many places it is of considerable economic importance for the deposits of gypsum and lime that it contains.

The Kaibab limestone was named by Darton,[1] who states:

> The upper limestone of the Carboniferous in northern Arizona has heretofore been known as the "Aubrey" limestone, but as Aubrey has now been adopted by the United States Geological Survey for the group of which this limestone forms a part, a distinct name is required for it. Accordingly Kaibab has been selected, from the Kaibab Plateau, on the north side of the canyon, which is capped by the formation in typical development over a very large area.

Inasmuch as the formation not only makes the entire surface of the Kaibab Plateau but is magnificently exposed in cross section in the wall of the Grand Canyon all around the south end of the plateau, the name given to it by Darton is eminently appropriate. Curiously, however, although the Kaibab Plateau is the type locality for the Kaibab limestone, no detailed section of the formation has been made anywhere in the plateau. Consequently no type section of the formation is on record.

During a stratigraphic reconnaissance of the region north of Colorado River in Arizona and Utah in the summer of 1922,[2] Prof. H. E. Gregory and I had occasion to visit the Kaibab Plateau, and I took the opportunity to obtain a section of the Kaibab limestone in this, the type locality. Our search in the plateau for a place where unquestionably all the formation is exposed was rewarded in Kaibab Gulch, 8 miles southwest of the abandoned settlement of Paria. Kaibab Gulch, which lies in Utah about 6 miles north of the Arizona boundary, is a deep canyon cut entirely across the northern part of the Kaibab Plateau. The gulch enters the plateau abruptly from the west, crosses it in a course that is slightly south of east, and emerges at the point where the strata along the eastern margin of the plateau depart from their horizontal attitude and dip eastward in the east Kaibab fold. Here, where the gulch crosses the fold, a magnificent section of the Kaibab limestone with a part of the Hermit shale below it and a part of the Moenkopi formation above it is exposed along the bed of the stream.

So far as we could ascertain the region around and just north of Kaibab Gulch is the only area within or along the borders of the Kaibab Plateau where both the upper and the lower contacts of the Kaibab limestone are exposed. Elsewhere the characteristic red shale and sandstone that are unmistakably recognizable as belonging to the lower part of the overlying Moenkopi formation have been removed by erosion, so that it is impossible to tell how much of the top part of the Kaibab limestone remains. Owing to this uncertainty the many fine exposures of the limestone in the cliffs of the Grand Canyon around the south end of the plateau and the exposures in the escarpment of the west Kaibab fault along the western border of the plateau are considered inappropriate for a type section, although many of these exposures reveal the beds of the formation in every detail from the base upward and are far more accessible than the exposures in Kaibab Gulch. The section in Kaibab Gulch is therefore proposed as the type section of the Kaibab limestone, because it is the only section in the type area that is known to be complete.

The location of the section in Kaibab Gulch and of other sections of the Kaibab limestone and the formations immediately above and below it that have been measured within a radius of 90 miles of the Kaibab Gulch section is shown on Figure 1. The distance and direction of each section from Kaibab Gulch, the formations included in each, and the report in which each measurement appears, if published, are given in a table below the map.

Kaibab Gulch is shown on the Kanab topographic map published by the United States Geological Survey, but its name is not printed on the map. It may be identified as a deep canyon coming from the west

[1] Darton, N. H., A reconnaissance of parts of northern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, p. 28, 1910.

[2] Gregory, H. E., and Noble, L. F., Notes on a geological traverse from Mohave, Calif., to the mouth of San Juan River, Utah: Am. Jour. Sci., 5th ser., vol. 5, pp. 229-238, 1923.

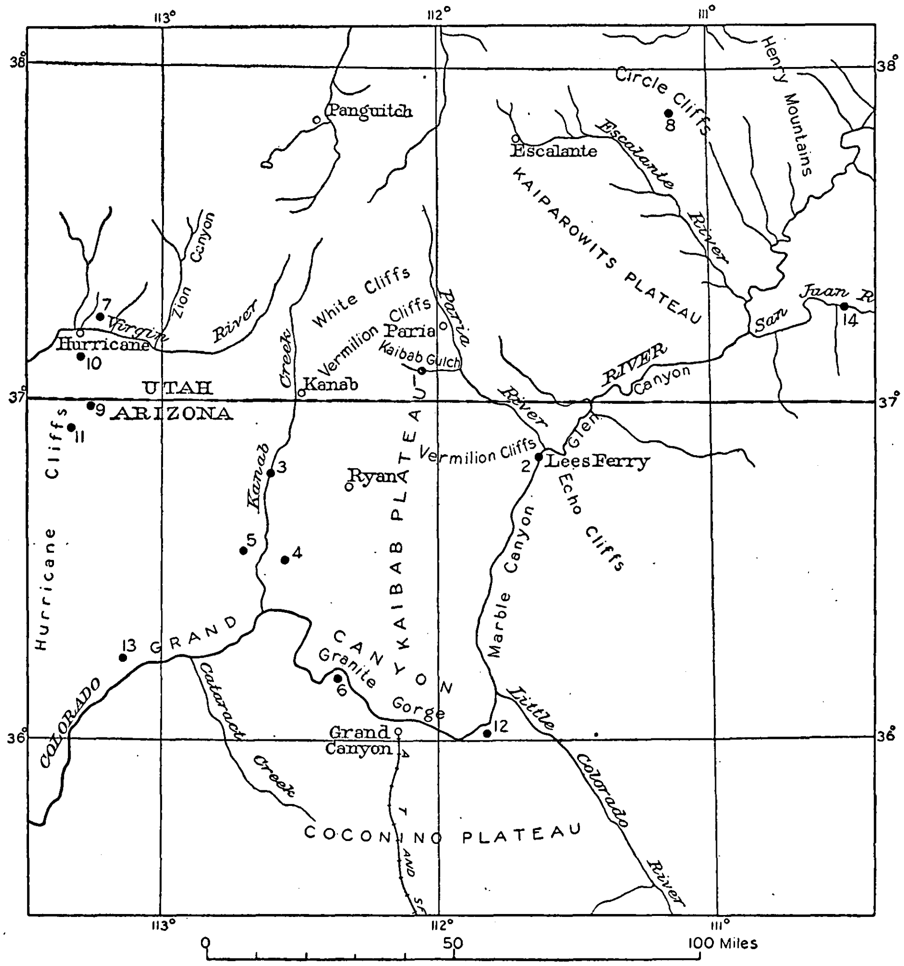


FIGURE 1.—Index map of parts of Utah and Arizona showing location of columnar section (dot numbered 1) in Kaibab Gulch given in Plate 12 and location of other sections of Carboniferous and Triassic strata in the area covered by the map. The location of each section is designated by a numbered dot

and intersecting the eastern boundary of the quadrangle at a point 6 miles north of the southeast corner.

SECTION IN KAIBAB GULCH

The section measured in Kaibab Gulch includes the entire exposed thickness of the Kaibab limestone, a small part of the overlying formation, and a part of the underlying formation. The overlying formation, as elsewhere in the Grand Canyon region, is the Moenkopi. The underlying formation, however, is not the one that is found in contact with the Kaibab limestone elsewhere. At all other places in the Grand Canyon region where its lower contact is exposed the Kaibab rests upon the Coconino sandstone, but at Kaibab Gulch it rests upon the Hermit shale, the formation next older than the Coconino. The absence of the Coconino sandstone is a unique feature of the section. The contacts of the Kaibab limestone with the overlying Moenkopi formation and with the underlying Hermit shale are shown in Plate 13, *A*, *B*, and *C*.

No. on map	Locality	Approximate distance from Kaibab Gulch (miles)	Direction from Kaibab Gulch	Formations measured	Author and report
1	Kaibab Gulch, Kaibab Plateau			Moenkopi formation (base), Kaibab limestone (Coconino sandstone absent), Hermit shale (top)	Noble, L. F., this report.
2	Lees Ferry, Colorado River	30	S. 52° E.	Moenkopi and overlying Mesozoic formations, Kaibab limestone, Coconino sandstone.	Longwell, C. R., Miser, H. D., Moore, R. C., Bryan, Kirk, and Paige, Sidney, Rock formations in the Colorado Plateau of southeastern Utah and northern Arizona: U. S. Geol. Survey Prof. Paper 132, p. 16, 1923.
3	Canyon of Kanab Creek, 22 miles south of Kanab.	38	S. 56° W.	Kaibab limestone (base), Coconino sandstone, Hermit shale (top).	Noble, L. F., and Gregory, H. E., unpublished data.
4	Jumpup Canyon, near Kanab Creek	50	S. 38° W.	Kaibab limestone (base), Coconino sandstone, Hermit shale, Supai formation (top).	Noble, L. F., this report.
5	Hacks Canyon, near Kanab Creek	53	S. 46° W.	Kaibab limestone, Coconino sandstone, Hermit shale, Supai formation (top).	Reeside, J. B., jr., and Bassler, Harvey, Stratigraphic sections in southwestern Utah and northwestern Arizona: U. S. Geol. Survey Prof. Paper 129, p. 69, 1922.
6	Bass trail, Grand Canyon	65	S. 17° W.	Kaibab limestone, Coconino sandstone, Hermit shale, Supai and underlying Paleozoic formations.	Noble, L. F., A section of the Paleozoic formations of the Grand Canyon at the Bass trail: U. S. Geol. Survey Prof. Paper 131, pp. 23–73, 1922.
7	Virgin River Canyon. Four sections designated 9, 10, 11, and 12 by the authors.	68	N. 81° W.	Moenkopi formation (base), Kaibab limestone (top).	Reeside, J. B., jr., and Bassler, Harvey, op. cit., pp. 72–73.
8	Circle Cliffs	70	N. 43° E.	Kaibab limestone, Coconino (?) sandstone (top).	Longwell, Miser, Moore, Bryan, and Paige, op. cit., pp. 20–21.
9	Rock Canyon. Two sections designated 6 and 7 by the authors.	70	S. 84° W.	Moenkopi formation (base), Kaibab limestone, Coconino (?) sandstone, Supai (?) formation (top).	Reeside, J. B., jr., and Bassler, Harvey, op. cit., pp. 70–71.
10	Hurricane Cliff, 6 miles south of Hurricane. Section designated 8 by the authors.	72	N. 89° W.	Moenkopi formation (base), Kaibab limestone, Coconino (?) sandstone, Supai (?) formation (top).	Idem, pp. 71–72.
11	Hurricane Cliff, 18 miles south of Hurricane. Section designated 4 by the authors.	75	S. 80° W.	Kaibab limestone (base), Coconino sandstone and Supai formation (undifferentiated).	Idem, p. 70.
12	Cedar Mountain, Grand Canyon	75	S. 10° E.	Shinarump conglomerate, Moenkopi formation, Kaibab limestone (top).	Noble, L. F., op. cit. (Prof. Paper 131), pp. 71–72.
13	Toroweap Canyon, near Grand Canyon.	85	S. 47° W.	Kaibab limestone, Coconino sandstone, Hermit shale, Supai formation.	Reeside, J. B., jr., and Bassler, Harvey, op. cit., pp. 69–70.
14	San Juan River, near Zahns Camp	85	N. 81° E.	Moenkopi and overlying Mesozoic formations (Kaibab limestone absent), Coconino sandstone.	Longwell, Miser, Moore, Bryan, and Paige, op. cit., p. 17.

The columnar section (pl. 12) shows diagrammatically the topographic profile of the beds, their sequence and general lithology, and the subdivisions into which the writer has grouped them. The number at the right of each bed or set of beds in the columnar section is the number used to designate the same bed or set of beds in the detailed section given in the text. In the columnar section the strata are represented as horizontal, but actually they dip eastward at angles ranging from 10° to 20°. The section was measured in a traverse along the bed of the gulch by ascending the walls to measure each set of strata at the place where it was best exposed, then locating at the next favorable place the stratum last measured and resuming measurement at that stratum. The length of the traverse necessary to obtain the complete section, following the windings of the gulch, was about a mile. The measurements were made with a Locke level. They are not as accurate as they would have been if the strata were horizontal and were exposed in a single vertical section, as in the wall of the Grand Canyon; nevertheless the windings of the gulch afforded so many exposures in cliff faces parallel with the strike that the writer believes the error was not great.

The section is given below in two forms—a general section showing the major subdivisions and a detailed section with comments on the several beds. The Moenkopi formation was measured and described by Professor Gregory; the Kaibab limestone and the Hermit shale by me.

Section in Kaibab Gulch

General section

	Feet
Moenkopi formation (Lower Triassic):	
Dark reddish-brown shale and thin-bedded sandstone with here and there a thin irregular bed of conglomerate at the base. All higher Moenkopi strata have been removed by erosion	12
Unconformity.	
Kaibab limestone (Permian):	
A. Very irregular beds of coarse breccia-conglomerate, interstratified with buff shale and calcareous sandstone and capped by massive beds of buff limestone. The limestone forms a strong cliff; the shales and sandstones form a slope broken by irregular cliffs of breccia	77
B. Massive gray crystalline limestone, cherty and fossiliferous, containing a bed of sandstone in the middle and passing at top into alternating beds of chert and buff earthy limestone. The beds of gray crystalline limestone form strong cliffs; the alternating beds of chert and buff limestone above the gray limestone form a steep ledgy slope	326
C. Buff and reddish fine-grained sandstone, poorly consolidated and irregularly bedded, interstratified with beds of sandy breccia and travertine; forms slope	150
Kaibab limestone (Permian)—Continued.	
D. Massive buff siliceous limestone, cherty and somewhat fossiliferous, containing some calcareous sandstone near the middle and a well-defined bed of hard fine-grained buff cross-bedded sandstone near the base. All beds except the calcareous sandstone in the middle of the member form strong cliffs	119
E. Alternating beds of arenaceous limestone and irregularly bedded fine-grained buff sandstone. One thin bed of limestone, in the middle of the member, is very fossiliferous. The member forms a steep ledgy slope, broken by small cliffs	45
	717
Hermit shale (Permian):	
Red sandy shale and fine-grained massive friable red sandstone, which exhibits concretionary structure; base of formation concealed; beds form slope	55

Detailed section

	Feet
Moenkopi formation:	
1. Sandstone, dark reddish-brown, thin bedded, each bed consisting of overlapping laminae; foliation surfaces show abundant mud cracks and ripple marks; weathering forms "slab talus"	3
2. Shales, dark reddish brown, very unevenly bedded, sun baked, glistening foliation surfaces	4
3. Conglomerate, gray and brown, composed essentially of flat pebbles of limestone and red shale; in some places forms a definite bed 4 to 8 inches thick; in other places lenses of conglomerate are embedded in yellow lime shale and brown sandy shale through a vertical distance of 3 to 5 feet; in still other places the conglomerate is underlain or even replaced by thin layers or aggregates of quartz. Contact with underlying limestone is sharp and somewhat uneven; appears to represent a surface of erosion	⅓–5
	12
Unconformity.	
Kaibab limestone:	
A. 1. Massive buff limestone containing a little chert; fossiliferous, but all forms seen were too poorly preserved to be determinable; weathered surfaces of the rock feel sandy or gritty	2
2. Chert	½
3. Massive buff limestone like No. 1; contains many cavities, formed probably by the solution of fossils. Calcite fills many cavities and occurs in veins. Fossils occur sparingly, but all those seen were too poorly preserved to be determinable. Chert not abundant	12
4. Chert and sand	1
5. Massive buff limestone like No. 3; appears to form one solid bed	9

Kaibab limestone—Continued.

	Page
A. 6. Buff shale, soft, sandy, and very thinly laminated. The laminae are wavy and many are as thin as paper; some are reddish. A few layers of calcareous sandstone averaging one-fourth inch thick are interbedded with the shale	2
7. Dense fine-grained sandy buff limestone	½
8. Buff shale, like No. 6; basal 4 feet consists entirely of sandy mud; upper 3 feet contains a few ½-inch layers of fine-grained calcareous buff sandstone	7
9. Massive bed of coarse breccia; forms strong cliff; rests upon an uneven surface, which exhibits considerable relief, the breccia bed ranging in thickness from 4 to 14 feet in a horizontal distance of 100 feet. Most of the breccia fragments are chert but some are limestone and sandstone; they are of all sizes up to 6 inches in diameter; all are angular. The matrix is buff sand	4–14
10. Irregular bed consisting partly of sandy breccia and partly of calcareous sandstone. Contacts with overlying and underlying beds are uneven	1–4
11. Buff calcareous sandstone with thin partings of shale at the bottom and lenses of chert at the top; bedding planes wavy	5
12. Massive buff calcareous sandstone; thickness ranges from 1 to 3 feet in a horizontal distance of 100 feet	1–3
13. Greenish sandy shale; laminae wavy; thickness ranges from 1 to 3 feet in a horizontal distance of 100 feet. Contacts with overlying and underlying beds uneven	1–3
14. Conglomerate composed of chert and sandstone fragments embedded in a matrix of sand, which exhibits gnarly, contorted structure; thickness ranges from 1 to 3 feet in a horizontal distance of 100 feet. Contacts with overlying and underlying beds uneven	1–3
15. Irregular bed composed entirely of hard chert. Contacts with overlying and underlying beds uneven, wavy	1
16. Partly concealed interval forming a gentle débris-covered slope; the few outcrops consist of buff soft calcareous sandstone	10
	77
B. 1. Buff crystalline limestone forming a small cliff	2
2. Beds of buff earthy limestone alternating with beds composed almost entirely of chert nodules; much of the chert is white. The alternations are very regular, the limestone beds averaging 6 inches in thickness and the chert beds 3 inches. The beds form a ledgy slope. This unit resembles alternating beds of chert and calcareous sandstone that occur at the top of the Kaibab limestone in the southern rim of the Grand Canyon near Cedar Mountain (locality 12: see fig. 1)	55

Kaibab limestone—Continued.

	Feet
B. 3. Very fossiliferous, very cherty, gray to buff crystalline limestone. The chert is in large lumps, which are scattered irregularly through the rock and most of which are several inches in diameter. The bedding planes of the limestone are obscure, but the beds appear to be very thick, some as much as 20 feet. The rock forms an almost vertical cliff. This unit resembles and corresponds in position to the Kaibab beds that form pinnacles of erosion at many places along the north rim of the Grand Canyon	85
4. Chert and fine-grained sand forming a ledge	10
5. Very massive bed of hard, dense, fine-grained buff sandstone, practically a quartzite; forms strong cliff; weathered surfaces exhibit cross-bedded structure; contains a few tiny rounded pebbles, the largest of which does not exceed a quarter of an inch in diameter; otherwise the rock resembles in composition the Coconino sandstone of the Kaibab division of the Grand Canyon. The cement appears to be all siliceous. The sandstone rests with wavy, uneven contact upon a bed of chert and sand	14
6. Very cherty, very fossiliferous, gray crystalline limestone, weathering buff; forms strong cliffs. The beds of limestone average about 5 feet in thickness and are separated by beds of chert and sand, most of which are less than 1 foot thick, but some of which are as much as 4 feet. Chert occurs throughout the limestone in nodules and in bands. Cavities lined with quartz crystals are fairly abundant. The fauna of the unit is of the familiar normal Kaibab type (the "*Productus ivesi* fauna")	140
7. Gray crystalline limestone in massive beds, separated by thin beds of sandstone with wavy, irregular contacts; forms strong cliff; contains a small quantity of chert in bands and nodules. Fossils and cavities lined with quartz crystals occur sparingly. The limestone beds average 4 feet in thickness	20
	326
C. 1. Soft sandstone; bedding contorted. Contacts with overlying and underlying beds are uneven, wavy	1
2. Gray crystalline limestone, texture sugary	1
3. Irregularly bedded hard sandy limestone; under surface very uneven; this and the two overlying beds make small cliffs	3
4. Soft buff contorted sandstone; contains lenses of red shale averaging less than an inch thick; makes a slope and alcove; outcrops partly concealed	15
5. Irregularly bedded porous sandy limestone seamed with calcite; the rock is in part travertine; bedding wavy throughout; rests upon an uneven surface; forms a cliff	7

Kaibab limestone—Continued.	Feet
C. 6. Soft buff sandstone; bedding exceedingly contorted; contains a few brecciated beds and some sandy travertine; rests upon an irregular surface; forms a slope and alcove	8
7. Gray sandy limestone, in part travertine; makes a small cliff	3
8. Beds of breccia and travertine interstratified with irregularly bedded yellowish-buff sandstone; make a cliff. The upper 2 feet is entirely travertine. The breccia consists of sandstone fragments of all sizes up to 4 feet in diameter embedded in a matrix of contorted calcareous sand. All beds are very irregular and in all of them the bedding is contorted and wavy	8
9. Beds of breccia and soft sandstone like No. 8; make a slope; much of the breccia resembles fanglomerate	17
10. Brownish-buff fine-grained calcareous sandstone in beds up to 1 foot thick; almost a limestone	6
11. Reddish sandstone; forms slope; outcrops partly concealed	3
12. Buff hard fine-grained sandstone, composed of tiny transparent quartz grains, which sparkle in the sunlight; material resembles that of the Coconino sandstone of the Grand Canyon; forms a small cliff	2
13. Reddish soft fine-grained sandstone	8
14. Buff to brown porous calcareous brecciated sandstone seamed with calcite; largely travertine; forms a small cliff	2
15. Red soft sandstone; bedding gnarly and contorted; outcrops largely concealed	15
16. Buff to brown calcareous sandstone seamed with calcite; forms small cliff; bedding irregular, gnarly	2
17. White soft fine-grained sandstone; bedding irregular, gnarly; rests upon a wavy surface exhibiting relief of a foot or more in a distance of 50 feet	2
18. Red soft fine-grained sandstone; outcrops largely concealed	12
19. Breccia; angular fragments of sandstone, shale, limestone, and chert of all sizes up to several feet in diameter embedded in a matrix of gnarled and contorted yellowish-buff sand. Much of the deposit is cemented with carbonate of lime and exhibits the characteristic porous structure of travertine	5
20. Largely concealed; the few outcrops seen consist of brownish-buff soft sand	12
21. Gnarly buff calcareous sandstone	3
22. Concealed; probably soft sandstone	12
23. Breccia in travertine, like No. 19	3
	150
D. 1. Platy gray limestone in beds averaging one-fourth inch thick	4
2. Dense siliceous buff limestone in beds ranging from 1 to 3 feet thick. Bands of chert nodules abundant	10

Kaibab limestone—Continued.	Feet
D. 3. Dense siliceous limestone like No. 2; forms two massive beds each 9 feet thick; contains many cavities lined with quartz crystals; contains also nodules of chert, but the chert is not conspicuously abundant	18
4. Massive arenaceous limestone exhibiting gnarly contorted bedding on weathered surfaces	7
5. Buff arenaceous limestone or calcareous sandstone forming a single massive bed; bedding planes level and even. This and the five overlying beds of D unite in forming a sheer high cliff	12
6. Soft calcareous sandstone; bedding irregular, gnarly; forms alcove	10
7. Arenaceous limestone; most beds exhibit faint cross-bedding on weathered surfaces, but some exhibit gnarly bedding; makes a steep ledgy slope	16
8. Buff limestone in massive beds from 6 inches to 4 feet thick; forms a strong cliff; weathered surfaces feel sandy or gritty. Thin platy partings of calcareous sandstone separate most of the beds. The limestone contains a large amount of chert, most of which is in rounded masses or nodules of all sizes up to a foot in diameter, but some of it occurs in bands. Fossils, chiefly large brachiopods, are abundant, and the rock contains many cavities formed by the solution of fossils. Most of the cavities are lined with quartz crystals. This limestone resembles the massive siliceous limestone in the lower part of the Kaibab at Bass trail, Grand Canyon	22
9. Massive bed of chert; forms an alcove	1
10. Massive bed of hard fine-grained buff sandstone; forms strong cliff. The rock is vesicular, and weathered surfaces are cavernous. Basal 3 feet strongly and conspicuously cross-bedded; remainder of bed contorted, gnarly. The sand grains consist of quartz and are tightly packed together; most of them are transparent and rounded. The cementing material appears to be carbonate of lime, but some of it may be silica. The rock sparkles in the sunlight like the typical Coconino sandstone of the Grand Canyon. The lower part of the bed contains lenses of fine conglomerate, whose constituent pebbles are tiny sheaflike aggregates of radially disposed quartz crystals. Most of these aggregates are less than a quarter of an inch in diameter, but some are as much as 1 inch. They appear to represent weathered quartz geodes	9
11. Buff shaly sandstone, soft, poorly exposed; forms alcove	2
12. Gray crystalline limestone in massive beds ranging from 4 inches to 2 feet thick. Rock hard and more or less vesicular; forms strong cliff	8
	119

Kaibab limestone—Continued.	Feet
E. 1. Buff gnarly sandstone; soft; forms alcove; weathered surfaces are cavernous. The basal 2 inches of the bed is a conglomerate consisting of chert fragments that average a quarter of an inch in diameter	8
2. Alternating beds of buff sandy shale in paper-thin laminae and buff chert. One chert bed is 6 inches thick	2
3. Buff hard fine-grained arenaceous limestone or calcareous sandstone; seamed with calcite; exhibits faint cross-bedded structure on weathered surfaces	2
4. Lumpy and gnarly fine-grained sandstone; soft; forms alcove	½
5. Buff hard fine-grained arenaceous limestone or calcareous sandstone; seamed with calcite; forms a cliff	2
6. Alternating beds of gray chert and buff sand. The chert beds average an inch thick; some of them are composed of solid chert, others are bands of elongated nodules	2
7. Buff hard fine-grained arenaceous limestone or calcareous sandstone; forms cliff	2
8. Irregularly bedded buff soft fine-grained sandstone; structure contorted and gnarly	5
9. Sandy buff crystalline limestone; hard; weathers into nodular lumps; very fossiliferous, but all fossils seen were too poorly preserved to be determinable	½
10. Buff calcareous shale	½
11. Sandy buff limestone, somewhat cherty; fossiliferous but fossils very poorly preserved	½
12. Soft lumpy sandstone, very irregularly bedded; largely a conglomerate or breccia of sandstone lumps embedded in a matrix of churned-up sand	3
13. Buff sandy calcareous shale	1
14. Yellowish-buff hard fine-grained evenly bedded sandstone	2
15. Buff soft fine-grained sandstone; bedding gnarly and contorted	5
16. Buff fine-grained hard arenaceous limestone or calcareous sandstone; laminae very thin, horizontal; makes a small cliff	1
17. One-inch parting of calcareous shale in paper-thin laminae.	
18. Arenaceous limestone or calcareous sandstone, like No. 16	2
19. Two-inch parting of calcareous shale, like No. 17.	
20. Arenaceous limestone or calcareous sandstone, like No. 16	1
21. Same kind of rock as No. 20, but even more thinly laminated	1
22. Arenaceous limestone or calcareous sandstone, like No. 16	2
23. Six-inch parting of calcareous shale, like No. 17.	
24. Arenaceous limestone or calcareous sandstone, like No. 16	1
	45
Total thickness of Kaibab limestone	717

Hermit shale:	Feet
1. Buff and greenish-buff slightly sandy clay shale containing stringers of gypsum. Brownish streaks of limonite occur along the stringers and between laminae of the shale. Some of the gypsum stringers are as much as half an inch thick. The shale resembles a consolidated playa mud.	
2. Greenish-buff massive fine-grained sandstone exhibiting marked concretionary structure; in weathering splits off in concentric shells along the concretionary surfaces; differs only in color from the concretionary red sandstone (3) lying beneath it. The greenish-buff sandstone (2) and the topmost foot of the underlying red sandstone (3) appear to constitute a sort of mud-ball conglomerate	1
3. Very fine grained massive red sandstone, essentially a consolidated sandy mud; exhibits marked concretionary structure and weathers into rounded surfaces or into huge balls that shell off in layers, like an onion. This concretionary structure is exactly like that characteristic of the upper part of the Hermit shale in the Kaibab division of the Grand Canyon. The material of which the sandstone is composed does not differ in any respect from that which constitutes the shale and sandstone beds of the Hermit shale in the Grand Canyon. The sandstone contains a few buff streaks, but the difference in color bears no relation to bedding. The rock exhibits no partings or bedding planes and is not cross-bedded	7
4. Very massive bed, like No. 3; upper portion contains buff streaks and blotches	22
5. Red sandy shale; not conspicuously different from the overlying sandstone in composition but is laminated and soft, whereas the sandstone exhibits no bedding planes and is relatively compact	7
6. Massive red concretionary sandstone, like No. 3	3
7. Red soft sandy shale, like No. 5	8
8. Massive red concretionary sandstone, like No. 3	4
	55

Talus, extending downward to the bed of Kaibab Gulch and concealing all underlying rocks.

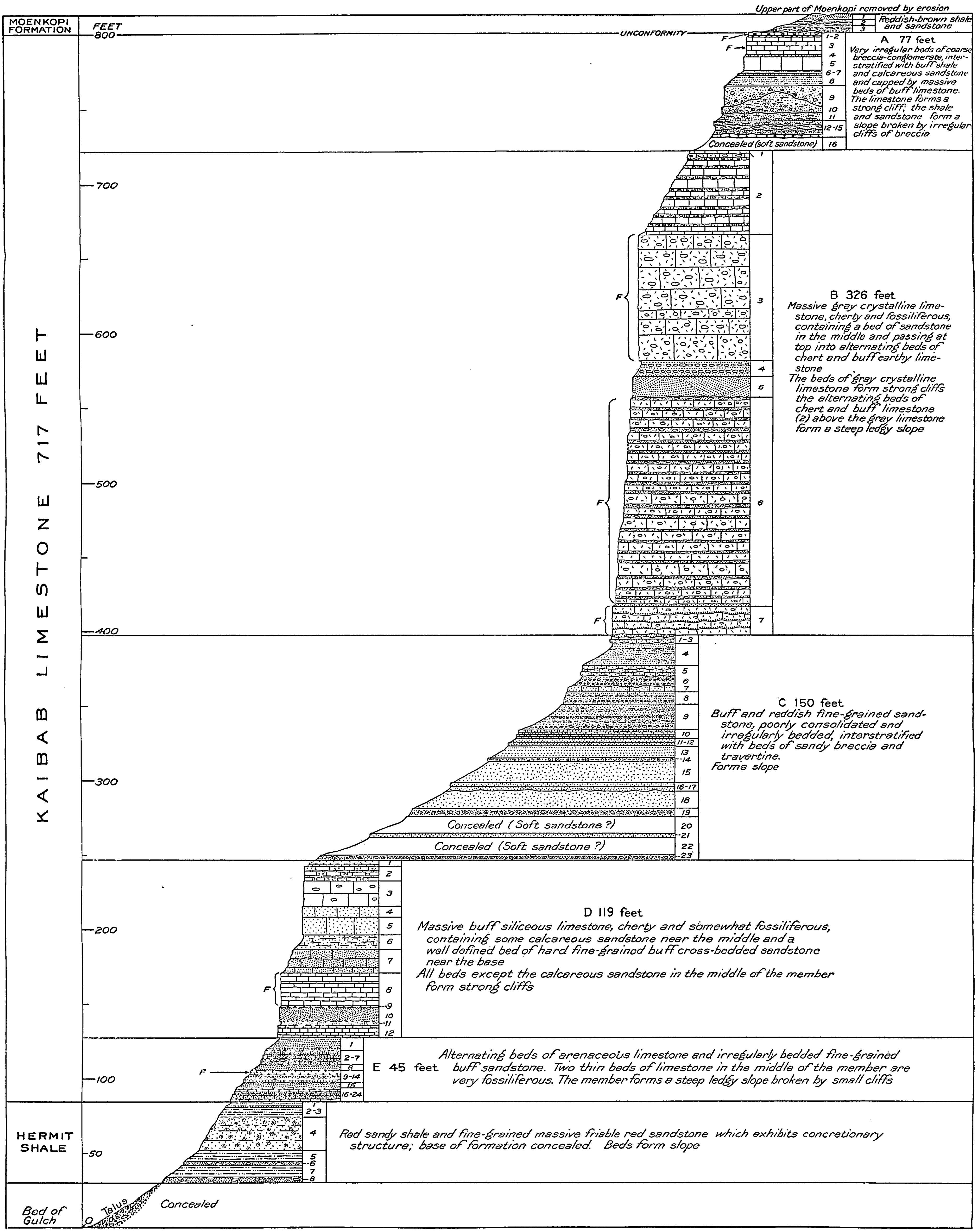
COMPARISON WITH OTHER SECTIONS

SECTION AT BASS TRAIL

In 1916 I measured a detailed section of the Paleozoic formations of the Grand Canyon at the Bass trail, in the Shinumo region, to supersede the generalized and inadequate reconnaissance section given in my report on the Shinumo quadrangle.[3] This detailed section is described in a report published in 1922.[4] The part of it that includes the Kaibab limestone, Coconino sandstone, and Hermit shale is reprinted below for comparison with the section in Kaibab Gulch. The locality (No. 6, fig. 1) is 65 miles southwest of Kaibab Gulch.

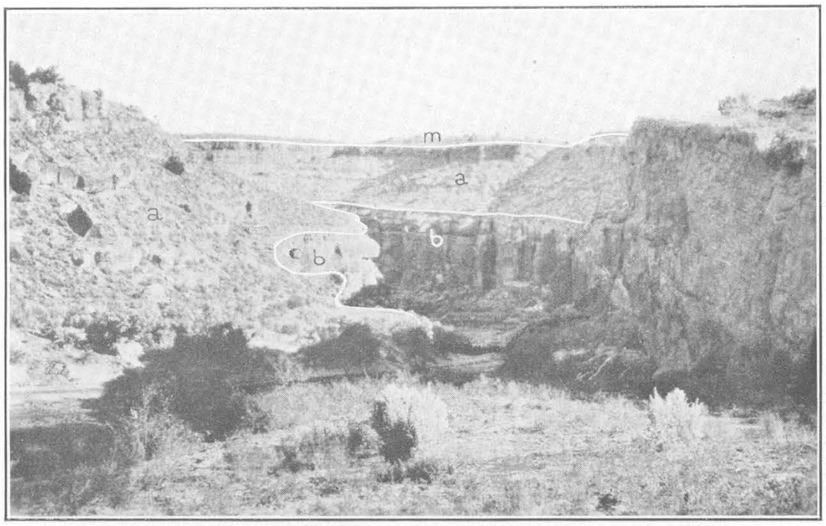
[3] Noble, L. F., The Shinumo quadrangle, Grand Canyon district, Ariz.: U. S. Geol. Survey Bull. 549, pp. 60–73, 1914.

[4] Noble, L. F., A section of the Paleozoic formations of the Grand Canyon at the Bass trail: U. S. Geol. Survey Prof. Paper 131, pp. 23–73, 1922.



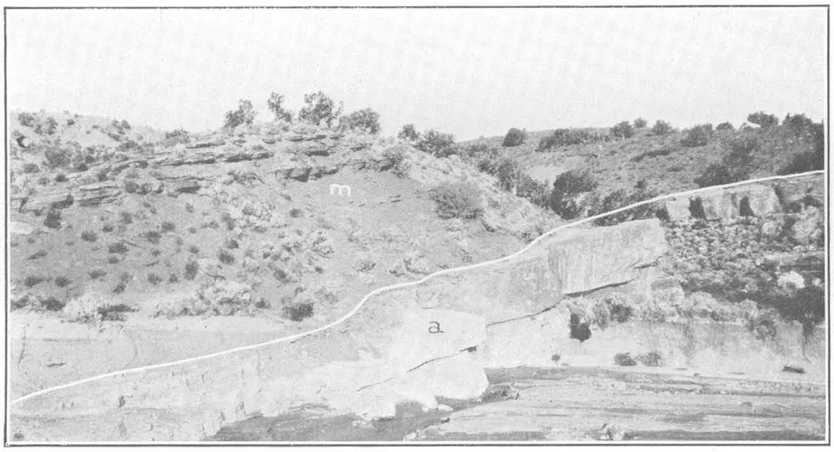
COLUMNAR SECTION OF THE KAIBAB LIMESTONE IN KAIBAB GULCH, UTAH

With a part of the overlying Moenkopi formation and of the underlying Hermit shale



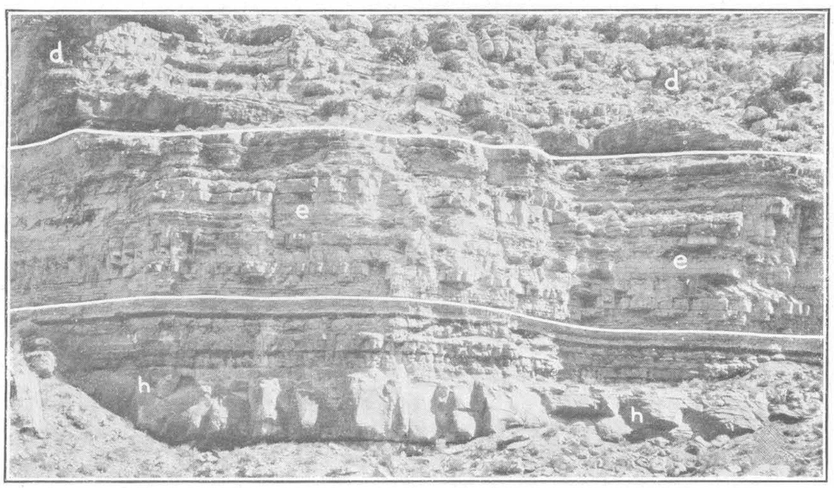
A. KAIBAB GULCH, UTAH, LOOKING WESTWARD UP THE GULCH FROM A POINT NEAR THE MOUTH

m, Moenkopi formation; a, b, subdivisions A and B of Kaibab limestone. The strata dip toward the observer, and the bed of the gulch descends in the same direction but at a lower angle, so that successively lower strata are encountered in ascending the gulch. The summit of the Kaibab limestone (shown in *B*) is crossed at the mouth of the gulch, and the base (shown in *C*) about a mile above the mouth. Thus a traverse of the bed of the gulch yields a complete section of the formation



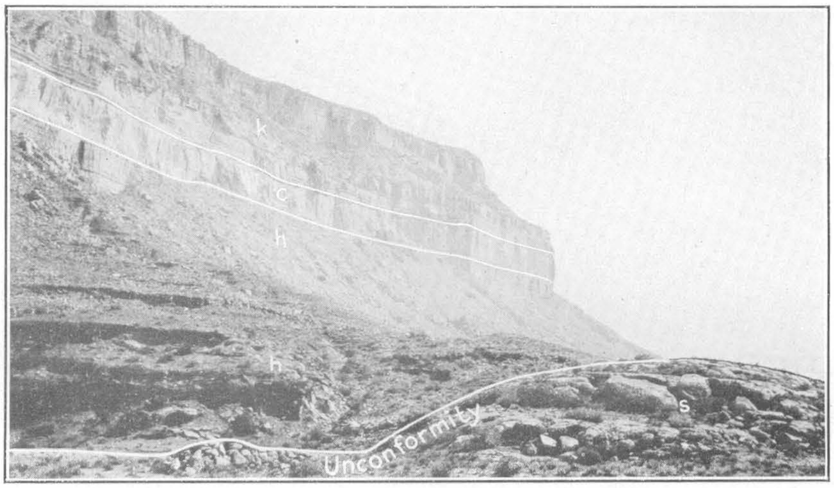
B. CONTACT BETWEEN MOENKOPI FORMATION AND KAIBAB LIMESTONE AT THE MOUTH OF KAIBAB GULCH

m, Moenkopi formation; a, limestone at top of subdivision A of Kaibab limestone

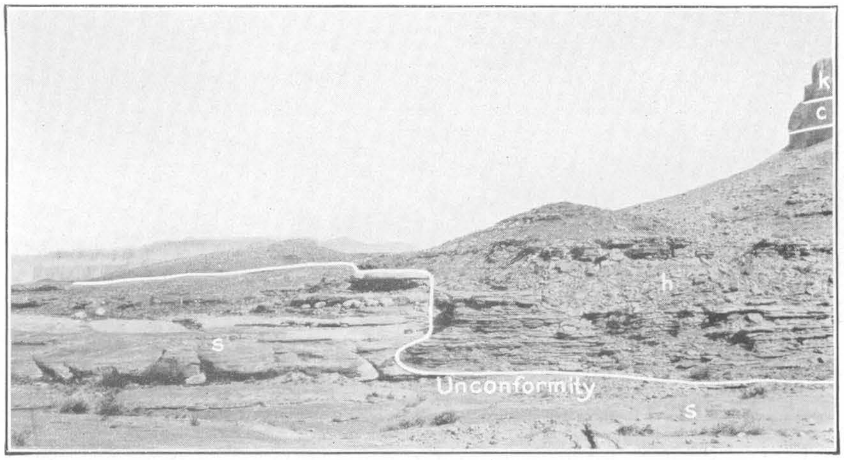


C. CONTACT BETWEEN KAIBAB LIMESTONE AND HERMIT SHALE IN KAIBAB GULCH

d, e, Subdivisions D and E of Kaibab limestone; h, Hermit shale



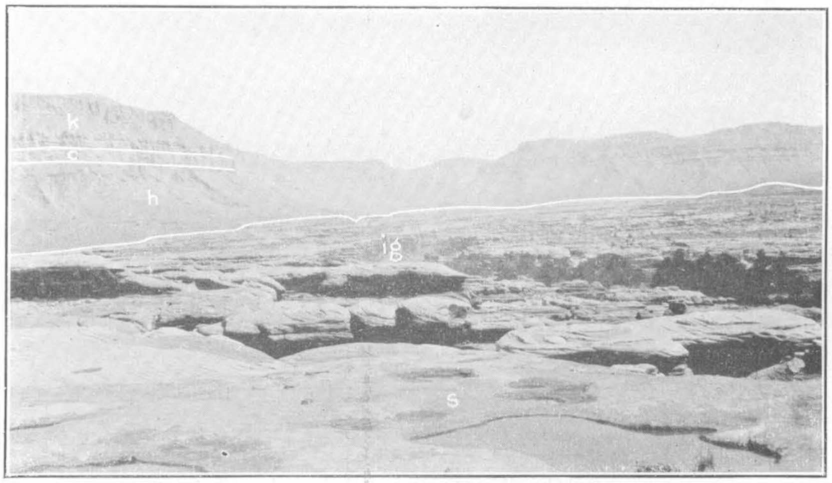
A



B

A, B. UNCONFORMITY BETWEEN HERMIT SHALE AND SUPAI FORMATION IN CANYON OF LOWER KANAB CREEK NEAR JUMPUP CANYON, UTAH

k, Kaibab limestone; c, Coconino sandstone; h, Hermit shale; s, Supai formation. In *A* the hill of sandstone of the Supai formation in the lower right corner projects 30 feet above the base of the Hermit shale in the hollow at the left of the hill. In *B* the base of the Hermit shale in the steep-sided hollow at the right is 40 feet below the summit of the sandstone of the Supai formation at the left of the hollow



C. CANYON OF LOWER KAIBAB CREEK, UTAH

Looking south near mouth of Jumpup Canyon, showing broad platform ("The Esplanade") on the summit of the Supai formation at the horizon of the unconformity shown in *A* and *B*. k, Kaibab limestone; c, Coconino sandstone; h, Hermit shale; s, Supai formation; ig, inner gorge of Kanab Creek. In structure, composition, and mode of weathering the cross-bedded sandstone at the top of the Supai sandstone shown in the view is strikingly similar to the Navajo sandstone exposed in Glen Canyon of Colorado River. A water pocket in the sandstone of the Supai is shown in the lower right corner

Section at Bass trail

General section

	Feet
Kaibab limestone (Permian):	
A. Gray crystalline limestone, very fossiliferous and somewhat cherty, passing at base and top into alternating beds of very cherty limestone and buff calcareous sandstone; forms cliffs and steep slopes	292
B. Buff and reddish fine-grained sandstone, poorly consolidated and irregularly bedded, containing beds of sandy breccia near top; forms slope	136
C. Buff sandstone and limestone in alternating beds, passing at top into massive siliceous limestone; upper portion forms a strong cliff; central portion forms cliffs and ledges; lower portion forms a slope	134
	562
Coconino sandstone (Permian):	
Pale-buff, uniformly fine-grained sandstone, characterized by cross-bedding on a huge scale; presents the appearance of a single massive bed; forms the strongest and highest cliff in the upper wall of the canyon	330
Hermit shale (Permian):	
Deep brick-red sandy shale and fine-grained friable sandstone; characterized in upper portion by concretionary structure; beds form slope	332
Unconformity.	

Detailed section

	Feet
Kaibab limestone:	
A. 1. Limestone, buff, compact; effervesces strongly with dilute hydrochloric acid; caps a small cliff on the rim of the Grand Canyon at the head of Bass trail. Bass Camp, on the Coconino Plateau, at the head of the trail, is built on this stratum. Higher beds, which form the surface of the plateau just east of the camp, are not included in this section	2
2. Limestone, buff, siliceous; texture compact, chalky; contains small cavities lined with tiny crystals	6
3. Sandstone, buff, fine grained, calcareous; effervesces with acid	5
4. Alternating thin beds of variegated chert and fine-grained calcareous sandstone	25
5. Limestone, gray, crystalline, very cherty, fossiliferous. The chert occurs in nodules and in bands; in places it constitutes half of the rock. Aside from the abundance of chert the limestone resembles No. 6	40
6. Limestone, gray, hard, crystalline, somewhat cherty, very fossiliferous; effervesces strongly with acid. Beds differ greatly in thickness; some are a few inches thick, others several feet. The chert occurs in scattered nodules and in bands but is not a conspicuous feature of the rock	126
7. Alternating beds of fine-grained buff calcareous sandstone, buff limestone, and chert; form small conspicuous cliff	10
8. Limestone, gray, hard, crystalline, somewhat cherty, fossiliferous; resembles No. 6	60
Kaibab limestone—Continued.	
A. 9. Sandstone, lemon-buff, fine grained, calcareous; bedding irregular, gnarly; forms a gentle slope covered in most places by talus	10
10. Limestone, thin bedded, very cherty; effervesces with acid. The chert constitutes more than half of the rock and occurs in parallel bands whose average thickness is 2 inches	8
	292
B. 1. Sandstone, buff, massive, fine grained, calcareous; effervesces weakly with acid	4
2. Breccia composed chiefly of angular fragments of evenly bedded buff fine-grained sandstone embedded in a matrix of fine lemon-buff sand; contains a few fragments of siliceous limestone. The fragments range in diameter from less than an inch to more than 4 feet. The contact of the breccia with the underlying sandstone is wavy and irregular, exhibiting in places inequalities of several feet	17
3. Sandstone, buff, fine grained, friable. The component grains are quartz, as in other sandstones of the Kaibab, but are very loosely cemented, so that the rock crumbles to sand when struck with the hammer	1
4. Sandstone, like No. 3 but bright red	2
5. Buff sandstone, like No. 3	8
6. Bright-red sandstone, like No. 4	2
7. Lemon-buff sandstone, like No. 3	5
8. Bright-red sandstone, like No. 4; contains a 1-inch layer of pale-green sandstone in the central part	7
9. Sandstone, lemon buff, fine grained, friable; bedding irregular, gnarly; contact with underlying sandstone slightly wavy and irregular	3
10. Sandstone, bright red, shaly; bedding gnarly; contact with underlying breccia wavy and irregular, exhibiting inequalities of 2 feet or more	3
11. Breccia composed of angular fragments of fine-grained sandstone averaging 4 inches in diameter. Very little matrix between the fragments. The contact with the underlying sandstone is irregular, exhibiting inequalities of several feet	4
12. Reddish-buff loosely consolidated fine-grained sandstone in indistinct but fairly even beds, some of which display gnarly structure; forms débris-covered slope; exposures poor. The upper 3 feet of the sandstone is bright red and thinly laminated	12
13. Sandstone, like No. 12, but more compact, forming a weak cliff; gnarled and twisted structure very pronounced; color lemon-buff to reddish buff	10
14. Sandstone, like No. 12, very soft, forming a gentle slope that is covered nearly everywhere by talus; no good exposures obtainable; white, lemon-buff, greenish, and bright red; in some places the color is in blotches or streaks; in other places a single color characterizes each bed	58
	136

Kaibab limestone—Continued.	Feet
C. 1. Limestone, buff, dense, siliceous; in heavy, massive beds; forms a strong cliff; contains much chert in bands and nodules and many small cavities lined with crystals of quartz or calcite. In appearance the rock suggests silicified chalk. Some beds effervesce weakly with acid	48
2. Limestone, like No. 1 but in thinner beds (1 foot or less), which are separated by thin partings of buff fine-grained shaly sandstone; forms a steep ledgy slope	12
3. Limestone like No. 1; forms a cliff	16
4. Shaly sandstone, lemon-buff, soft, thin bedded, fine grained; makes alcove under overhanging cliff of No. 3	2
5. Limestone, buff, in heavy beds with thin sandy partings; not notably siliceous; effervesces strongly with acid; forms cliff	8½
6. Shaly sandstone, like No. 4; makes alcove under overhanging cliff of No. 5	3
7. Limestone, like No. 5 but in thinner beds (1 or less); forms slope	11
8. Limestone, buff, dense, siliceous, in heavy beds; contains many crystal-lined cavities apparently formed by the solution of brachiopods; does not effervesce with acid	5½
9. Limestone, like No. 7, in beds separated by very thin partings of sand	5
10. Sandstone, buff, fine grained	5
11. Limestone, like No. 7, but in a single bed	1½
12. Sandstone, buff, fine grained	6
13. Limestone, buff, siliceous, fossiliferous; does not effervesce with acid; contains many small cavities lined with calcite crystals	1½
14. Alternating beds of lemon-buff fine-grained sandstone and buff limestone; beds average 3 inches thick	6
15. Limestone, buff, not notably siliceous; effervesces strongly with acid	½
16. Sandstone, lemon-buff, fine grained	2
17. Sandstone, red, fine grained. The base of this layer truncates inclined laminae of the underlying Coconino sandstone, which dip 15° S	½
	134
Coconino sandstone: Pale-buff fine-grained sandstone, cross-bedded on a huge scale; appears like single massive bed; forms highest cliff in upper wall of canyon. The base of the sandstone is marked by an abrupt change from buff sandstone to underlying red shale, and the contact is an even line. In places the under surface of the sandstone shows impressions of sun cracks. For 25 feet above the base the cross bedding is on a small scale, and horizontal layers alternate with cross-bedded layers; then the coarse cross-bedding begins and continues upward until the sandstone is truncated by the level base of the Kaibab	330
Hermit shale:	
1. Sandstone, red, soft, fine grained, massive, with a thin layer of green shale at the top. Exhibits well-marked concretionary structure; the concretions are spheroidal forms which range from half an inch to 4 feet in diameter and consist of the general mass of the rock; in weathering the rock splits off in concentric shells along the concretionary surfaces	5

Hermit shale—Continued.	Feet
2. Sandstone, fine grained, massive; resembles the Coconino sandstone in texture and composition but is not cross-bedded; lower half buff; upper half red with buff blotches	6
3. Concretionary sandstone, like No. 1, in massive layers	16
4. Shale, deep red, thinly laminated, sandy	24
5. Beds of soft massive concretionary red sandstone like No. 1 alternating with thinner beds of deep-red shale like No. 4; sandstones and shales not conspicuously different in composition	28
6. Shale, deep red, sandy	16
7. Sandstone, pink, hard, very fine grained; contains cracks and cavities filled with crystals of calcite (dog-tooth spar); rock itself does not effervesce with acid; forms small prominent cliff	6
8. Shale, soft, brick-red, thinly laminated, sandy	28
9. Sandstone, brick-red, friable, massive; forms weak cliff	2
All underlying beds of shale are like No. 8; all underlying beds of sandstone like No. 9. The beds designated shale and sandstone actually differ little in composition; both consist essentially of sandy mud colored red by a strong ferritic pigment. The beds designated sandstone are massive and relatively compact, as contrasted with the beds designated shale, which are thinly laminated and soft. Both types of rock are friable.	
10. Shale, containing beds of massive friable sandstone near the top	33
11. Sandstone in massive beds; contains a 1-foot layer of shale in the middle part; forms weak cliffs	8
12. Shale	11
13. Sandstone; forms weak cliff	10
14. Shale	33
15. Alternating lenticular beds of intraformational conglomerate and red fine-grained sandstone averaging 1 foot in thickness; beds display indistinct sun cracks and rain prints; form weak cliff. The conglomerate consists chiefly of flattened pebbles of fine-grained sandstone or sandy shale less than 1 inch in diameter, embedded in a matrix of red sandy mud but contains some nodular or concretionary fragments of limestone	6
16. Shale	11
17. Sandstone	3
18. Shale	40
19. Sandstone	2
20. Shale	6
21. Sandstone; forms weak cliff	5
22. Shale	16
23. Sandstone; forms weak cliff	5
24. Shale	12
	332

A comparison shows that the section at Kaibab Gulch and the section at the Bass trail are remarkably alike, notwithstanding the fact that they are 65 miles apart. The major subdivisions of the Kaibab limestone seen at the Bass trail are at once recognizable in the section at Kaibab Gulch, each subdivision at either place consisting of beds that are similar in lithology and succession and exhibit a similar topographic profile to those that make up the corresponding subdivision at the other place. Many beds at corresponding horizons in the two localities are lithologically identical. The chief differences between the two sections are the absence of the Coconino sandstone at Kaibab Gulch and the fact that the topmost subdivision of the Kaibab limestone (subdivision A of the Kaibab Gulch section) apparently is not represented at the Bass trail. Moreover, all the subdivisions of the Kaibab are somewhat thicker at Kaibab Gulch than they are at Bass Canyon, and most of them include a somewhat greater variety of beds.

There can be no reasonable doubt that the 55 feet of red shale and sandstone exposed beneath the Kaibab limestone in Kaibab Gulch is equivalent to a part of the Hermit shale of the Bass Canyon section. The evidence upon which this correlation is based is the peculiar and distinctive character of the beds at the top of the Hermit shale. At the Bass trail, as may be seen in the detailed section, many beds in the upper 79 feet (units 1 to 5) of the Hermit shale exhibit a well-marked concretionary structure that appears only on weathered surfaces of the rock. A similar structure is characteristic of the upper part of the formation at other localities where I have examined it in detail—at Hermit Basin, the type locality;[5] and at Jumpup Canyon in the valley of lower Kanab Creek. (See p. 54.) Inasmuch as the localities are widely separated, it is evident that the concretionary structure is a persistent and widespread feature of the upper part of the Hermit shale. Now the red sandy shale and sandstone beneath the Kaibab limestone in Kaibab Gulch are identical in composition and appearance with the rocks that constitute the Hermit shale at the Bass trail and at the type locality in Hermit Basin, and they exhibit the concretionary structure just described. They can not possibly represent the Coconino sandstone, a buff cross-bedded sandstone, whose appearance and lithologic character are distinctive and unmistakable, and they do not resemble the rocks characteristic of the upper part of the Supai formation, which are chiefly hard cross-bedded sandstones. I have therefore assigned them to the Hermit shale and correlated them with the upper part of that formation as exposed at the Bass trail. The thickness of the Hermit shale at Kaibab Gulch is of course unknown, because the base is not exposed there.

The series of beds that constitutes subdivision C, the lowest subdivision of the Kaibab limestone at the Bass trail, corresponds closely in lithology, succession, and topographic expression to the series that constitutes subdivisions D and E of the section at Kaibab Gulch and is almost certainly its stratigraphic equivalent. When I measured the section at the Bass trail I could have divided subdivision C into two units, which in lithology and topographic profile would be as distinct from each other as subdivisions D and E at Kaibab Gulch. The lower part of subdivision C at the Bass trail consists of beds 9 to 17, described in the detailed section (p. 48). This series of alternating sandstone and limestone, which is 28 feet thick at the Bass trail, closely resembles the series of alternating sandstone and limestone that constitutes subdivision E at Kaibab Gulch and is 45 feet thick. At both localities the sandstones range from buff and pink to a peculiar shade of lemon-yellow and are fine-grained, soft, and for the most part thinly laminated, and the limestones are buff, thin bedded, and more or less siliceous. In general the sandstones are somewhat more irregularly bedded at Kaibab Gulch than at the Bass trail, and the limestones are rather more sandy, but these differences are not essential. At both localities these beds form a slope which is in strong topographic contrast with the cliffs formed by the massive limestone above them. In view of all these facts I have correlated the slope-forming part of subdivision C at the Bass trail with subdivision E at Kaibab Gulch.

At the Bass trail a thin bed of very fossiliferous limestone (No. 13) occurs in the lower middle part of the slope-forming unit of subdivision C. At Kaibab Gulch two very thin beds of similar fossiliferous limestone (Nos. 9 and 11), separated by a 6-inch parting of calcareous shale, occur in the lower part of subdivision E. No other beds in the two units appear to contain fossils at either locality. Although the distance between the localities is much too great for correlation of individual thin beds, the occurrence of the fossiliferous beds at approximately the same horizon in the two sections suggests that these fossiliferous beds are stratigraphically equivalent and serves further to emphasize the lithologic similarity of the two sections.

The upper part of subdivision C at the Bass trail consists of beds 1 to 8 described in the detailed section (p. 48), is 106 feet thick, and is composed almost entirely of limestone. The topmost bed (No. 1) is a massive buff siliceous limestone containing bands and nodules of chert and many small cavities lined with crystals of quartz or calcite. This bed, which is 48 feet thick, is very hard and forms a strong cliff. Below it is a bed (No. 2) composed of layers of similar limestone separated by thin partings of shaly sandstone. This bed, which is 13 feet thick, forms a steep ledgy slope. Below the slope-forming bed is a set of beds (Nos. 3 to 8) consisting chiefly of massive buff cherty and vesicular limestone like No. 1 but including a few thin interbedded layers of sand-

[5] Noble, L. F., A section of the Paleozoic formations of the Grand Canyon at the Bass trail: U. S. Geol. Survey Prof. Paper 131, pl. 19, 1922.

stone. This set of beds, 46 feet thick, makes a series of cliffs broken at intervals by narrow ledges at the horizons where partings of sand occur.

Subdivision D of the Kaibab Gulch section, like the cliff-forming unit at the Bass trail just described, consists chiefly of limestone that makes strong cliffs, includes also a few beds of sandstone, and is 119 feet thick. Most of the limestone is similar in composition and appearance to that which constitutes the cliff-forming unit at the Bass trail, for it is buff, massive, siliceous, more or less cherty, and vesicular, containing many small cavities lined with quartz crystals. Indeed, the limestones are so alike at both localities that, aside from differences in thickness, the lithologic description of any one of beds 2, 3, or 8 at Kaibab Gulch might be applied without change to any one of beds 1, 3, or 8 at the Bass trail.

Accordingly I have correlated the upper or cliff-forming unit of subdivision C at the Bass trail with subdivision D at Kaibab Gulch. Although the distance between the localities makes definite correlation of individual beds impossible, it is probable that the limestone bed, No. 1, which makes a cliff at the top of the cliff-forming unit of subdivision C at the Bass trail, is roughly equivalent to the limestone beds, Nos. 1 to 5, which make a cliff at the top of subdivision D at Kaibab Gulch; that the underlying slope-forming bed of limestone and shaly sandstone, No. 2, at the Bass trail is roughly equivalent to the slope-forming beds of calcareous sandstone and arenaceous limestone, Nos. 6 and 7, at Kaibab Gulch; and that the lower cliff-forming beds of limestone and sandstone, Nos. 3 to 8, at the Bass trail are roughly equivalent to the similar cliff-forming beds, Nos. 8 to 12, at Kaibab Gulch.

The only rock in subdivision D at Kaibab Gulch that has no counterpart in the corresponding unit at the Bass trail is a 9-foot bed of hard fine-grained buff sandstone, No. 10, which lies 10 feet above the base of the subdivision. A peculiar feature of this sandstone is the occurrence in it of lenses of fine conglomerate whose constituent pebbles are tiny sheaflike aggregates of radially disposed crystals. The basal 3 feet of the sandstone is strongly cross-bedded, whereas the upper 6 feet exhibits gnarly, contorted bedding. The radial aggregates of quartz crystals appear to be confined to the cross-bedded lower part of the sandstone. Where free from conglomerate the cross-bedded sandstone at first sight resembles the typical Coconino sandstone of the Grand Canyon—so much so that, when I first encountered blocks of the sandstone in talus in the bed of Kaibab Gulch, I thought that they were fragments of the Coconino sandstone and that I should therefore find the Coconino below the base of the Kaibab higher up the gulch. However, when I traced the fragments to their source and found the parent bed (No. 10) in the Kaibab limestone at a horizon more than 50 feet above the base of beds lithologically similar to Kaibab beds that overlie the Coconino at the Bass trail, it was evident that the bed could not possibly represent the Coconino sandstone. Closer inspection showed that it differs from the Coconino of the type locality in that the sand grains are bound together by calcareous cement, whereas the cementing material of the typical Coconino is siliceous. Moreover it is vesicular, whereas the Coconino sandstone is compact and massive. Nor are streaks of conglomerate known to occur in the Coconino, one of whose distinctive features in the type locality is its uniform fineness of grain.

Subdivision B of the Kaibab limestone at the Bass trail, 136 feet thick, is composed entirely of sandstone and is the most sharply defined unit of the formation in the Kaibab division of the Grand Canyon. The sandstone is soft and friable, so that everywhere the subdivision makes a gentle slope, in contrast with the cliffs and steep slopes formed by the overlying and underlying limestone subdivisions. At most places the sandstone exhibits reddish and yellowish hues, which contrast strikingly with the grays and pale buffs of the adjacent limestone. The lithologic character of the subdivision, moreover, is peculiar and distinctive. Much of the sandstone exhibits a gnarly, contorted structure, which appears to be a form of cross-bedding. Wavy, irregular contacts separate many of the beds. Local unconformities are common. Interbedded with the sandstone are irregular beds of sandy breccia, which, although they do not occur everywhere at the same horizon, are a constant feature of the subdivision wherever it is exposed. At some places in the Kaibab division the breccia consists of angular fragments of sandstone and other rocks in an irregularly bedded matrix of sandy material, resembles a coarse fanglomerate, and is clearly of detrital origin; at other places it has the appearance of rock that has been brecciated in place, either by pressure or by the beds caving in and breaking because some soluble material, perhaps gypsum, was leached out of them. In places the breccia is associated with deposits of travertine. At some places, although not at the Bass trail, lenses of sandy red shale are interbedded with the sandstone and breccia.

Subdivision C at Kaibab Gulch, 150 feet thick, occupies the same position in the Kaibab limestone that subdivision B occupies at the Bass trail. It consists of soft slope-making beds of sandstone and sandy breccia that exhibits all the distinctive characteristics just described and is a no less sharply defined unit than subdivision B. Unquestionably, therefore, subdivision B at the Bass trail is the stratigraphic equivalent of subdivision C at Kaibab Gulch. As may be seen in the detailed sections there is no essential difference in the lithology of the two subdivisions. In general, the beds at Kaibab Gulch are more calcareous than those at the Bass trail, for they include beds of travertine and a few beds of limestone. Lenses of red shale occur at Kaibab Gulch but not at the Bass trail. However, beds of red shale, travertine, and sandy limestone similar to those at Kaibab Gulch occur in subdivision B at places in the Grand Canyon not far from the Bass trail.

The sandstone breccia unit just described is certainly a widespread and persistent member of the Kaibab limestone. Its presence at Kaibab Gulch, as well as throughout the Kaibab division of the Grand Canyon, indicates that it underlies all the Kaibab Plateau. It is exposed at many localities in a wide region west and northwest of the Kaibab Plateau, as is shown in the sections of the Kaibab limestone measured by Reeside and Bassler.[6] It is present in the region around Cataract Creek, as shown in a section measured by Newberry.[7] The origin of this member of the Kaibab is an interesting problem, for although the member is overlain and underlain by fossiliferous limestones that are unquestionably marine, some lithologic features suggest that not all parts of it are of marine origin. The beds of travertine at Kaibab Gulch, for example, are indistinguishable in appearance from certain beds of fresh-water limestone that occur in Tertiary deposits of the desert region of California and Nevada, notably at Callville Wash, in southern Nevada, and in the Death Valley region of California. The presence of breccia beds resembling fanglomerate is suggestive, as is also the presence of red shale. Some of the shale exhibits sun cracks. West of the Kaibab Plateau the member contains beds of gypsum at many horizons, as is shown in the sections measured by Reeside and Bassler and by Newberry. A section that I measured at Jumpup Canyon, near Kanab Creek, where the member contains a great deal of gypsum, is given on pages 54–57, for comparison with the section at Kaibab Gulch. Similar occurrences of gypsum are very common in Tertiary and Quaternary beds of the Great Basin region that are certainly not marine. On the other hand, beds of fossiliferous marine limestone occur in the upper part of this sandstone breccia member at Jumpup Canyon not far above beds that contain gypsum, and in different parts of the region gypsum occurs in other members of the Kaibab that contain fossiliferous marine limestone.

Subdivision A at the Bass trail, 292 feet thick, is composed chiefly of gray crystalline fossiliferous cherty limestone but includes beds of calcareous sandstone. The chert is exceedingly abundant in this subdivision throughout the Grand Canyon region, and it is to this feature that the Kaibab limestone owes the old name "cherty limestone," given to it by the early geologic explorers. At the Bass trail the chert is most abundant near the base and top of the subdivision; near the top it forms a conspicuous set of beds (No. 4) composed of almost solid layers of chert alternating with layers of calcareous sandstone. This set of alternating beds is present and easily recognizable everywhere in the Kaibab division of the canyon. The limestone beds in the middle part of the subdivision (Nos. 5, 6, and 8) are exceedingly fossiliferous, and the fauna of beds 6 and 8, at least, is the so-called "*Productus ivesi*" fauna of the "normal Kaibab" type[8] and not the upper "*Bellerophon* limestone" fauna of the Kaibab. Whether bed 5 or the overlying beds at the top of the subdivision at the Bass trail contain the "*Bellerophon*" fauna or the "*Productus ivesi*" fauna has not been determined. The subdivision as a whole is a strong cliff maker, and its topographic profile is a succession of cliffs and steep slopes.

Subdivision B at Kaibab Gulch, 326 feet thick, consists of beds that differ in no essential particular from those that constitute subdivision A at the Bass trail; they are composed chiefly of massive gray crystalline limestone, which is fossiliferous and cherty. As in A at the Bass trail, the limestones in the middle of subdivision B at Kaibab Gulch (beds 3 and 6) are very fossiliferous, and bed 6, at least, contains the "*Productus ivesi*" fauna; as in A, the chert becomes particularly abundant near the top of the subdivision, where it forms a set of beds alternating with earthy limestone layers (No. 2), which are a counterpart of the alternating chert and calcareous sandstone beds (No. 4) near the top of A. Like A, the entire subdivision is a cliff maker. Disregarding a few feet of beds at the base and top of A at the Bass trail whose correlation is uncertain, the subdivision is undoubtedly the stratigraphic equivalent of B at Kaibab Gulch.

Although it is not possible definitely to correlate individual beds in the two sections owing to the distance that separates the localities, it seems probable that beds 5 to 10 of the Bass trail subdivision are together roughly equivalent to beds 3 to 7 of the Kaibab Gulch subdivision; and that bed 4 at the Bass trail, consisting of alternating layers of chert and calcareous sandstone, is equivalent to bed 2 at Kaibab Gulch, consisting of a similar set of alternating layers of chert and sandy limestone. It is possible, however, that bed 5 at the Bass trail is also all or in part equivalent to bed 2 at Kaibab Gulch. Bed 5 at Kaibab Gulch, a hard quartzitic cross-bedded sandstone, appears to have no counterpart in the section at the Bass trail. The correlation of beds 1, 2, and 3 at the top of subdivision A at the Bass trail is altogether uncertain; they may be equivalent to beds at the summit of B

[6] Reeside, J. B., jr., and Bassler, Harvey, Stratigraphic sections in southwestern Utah and northwestern Arizona: U. S. Geol. Survey Prof. Paper 129, pp. 58–59, 69–77, 1922.

[7] Newberry, J. S., Report upon the Colorado River of the West, explored in 1857–58 by Lieut. J. C. Ives, pt. 3, Geological Report, 1861.

[8] Reeside, J. B., jr., and Bassler, Harvey, op. cit., pp. 66–67.

at Kaibab Gulch, but it is conceivable that they, together with some overlying beds exposed on the Coconino Plateau that are not included in the Bass trail section, are equivalent to a part of A, the topmost subdivision of the Kaibab limestone at Kaibab Gulch.

SECTIONS MEASURED BY REESIDE AND BASSLER IN SOUTHWESTERN UTAH AND NORTHWESTERN ARIZONA

In 1919 J. B. Reeside, jr., and Harvey Bassler made a stratigraphic reconnaissance of southwestern Utah and northwestern Arizona in the course of which they measured 22 detailed sections of the Paleozoic and Mesozoic rocks at separate localities scattered over this wide region. These sections are described in a report published by the Geological Survey in 1922.[9] Most of the sections include a part of the Kaibab limestone, and many of them include all of it. The location of all these sections that lie within a radius of 85 miles of Kaibab Gulch is shown in Figure 1. These sections are by far the most important contribution to the study of the formation that has been made. As summarized and discussed by Reeside and Bassler they constitute the standard section to which all sections of the Kaibab limestone in the neighboring region must be referred for comparison and correlation.

The general section of the Kaibab limestone for the area studied by Reeside and Bassler is summarized as follows:

Section of Kaibab limestone

	Feet
5. Harrisburg gypsiferous member: Gypsum, shale, and limestone, with platy chert. Locally the "*Bellerophon* limestone" at top	0–280±
4. Upper limestone member: Massive cliff-forming cherty gray limestone	185–455
3. Upper slope-forming member: Soft beds resembling basal member	80–285
2. Lower limestone member: Massive gray limestone with much chert	150–230
1. Lower slope-forming member: Gypsum, gray and yellow shale, soft gray sandstone, and some thin-bedded dark-drab limestone	0–100

The writers state:[10]

In most of the exposures seen in our work the Kaibab limestone shows a fivefold topographic and lithologic division—(1) a lower soft member consisting of gypsum, gray and yellow shale, soft gray sandstone, and subordinate amounts of thin-bedded dark-drab limestone; (2) a lower cliff-forming member of gray massive limestone with much brown to black concretionary chert; (3) an upper soft member with much the same character as the lower one; (4) an upper massive cliff-forming limestone which is similar to the lower one but contains more chert and which from Bright Angel Creek to southwestern Utah shows towerlike erosion forms along its upper cliff face; (5) a topmost member, less resistant than the underlying beds and highly variable in composition and thickness, consisting of shale, gypsum, and limestone. The limestone of the top member is at some places arenaceous, at others partly silicified, at still others filled with masses of light-colored chert that breaks into flat platy fragments; at many places the upper layers contain many small angular fragments of chert. In color it is light gray, yellowish brown, pink, and rarely a sugary white. The sandstone is gray to yellow, calcareous, and locally gypseous—that is, it has a gypsum cement. The shale may be gray, yellow, or rarely red. It is usually gypseous and in some places sandy.

These divisions of the Kaibab limestone vary much in thickness from point to point, and it seems unlikely that exactly the same beds enter into the same divisions at all localities. * * *

The topmost member (5) is composed of peculiar and characteristic rocks. It may be recognized, in spite of its variability, wherever it occurs, and as it is a definite unit between the upper cliff-forming limestone of the Kaibab and the basal beds of the Moenkopi formation it is here named the Harrisburg gypsiferous member, from its occurrence in the Harrisburg dome, 8 miles east of St. George. A section measured here shows a thickness of 280 feet. This member may be absent from some of the sections examined, but in others it reaches a thickness of nearly 300 feet. It is apparently the same unit as that designated "Super-Aubrey beds" by Huntington and Goldthwait. The uppermost limestone beds locally contain an abundance of a species of *Bellerophon* and are the "*Bellerophon* limestone" of some of the earlier geologists.

The section of the Kaibab limestone at Kaibab Gulch shows a fivefold topographic and lithologic division comparable to the fivefold division of the general section for southwestern Utah and northwestern Arizona just described, and it appears highly probable that the subdivisions of the section at Kaibab Gulch are equivalent to the subdivisions of Reeside and Bassler's general section, although the correlation of A, the topmost subdivision at Kaibab Gulch, is more uncertain than that of the other four. Inasmuch as the nearest section measured by Reeside and Bassler (locality 5, fig. 1) is 53 miles from Kaibab Gulch and all the other sections more than 68 miles distant, it is hardly to be expected that equivalent subdivisions would correspond in all details of lithology and contain exactly the same beds. Nevertheless, in a broad way, they correspond remarkably—as closely, indeed, as the subdivisions at the Bass trail correspond with those at Kaibab Gulch; so that correlation can be made with at least as much confidence as that between the Bass trail and Kaibab Gulch sections.

Subdivision E, the basal slope-making unit at Kaibab Gulch, which consists chiefly of soft sandstone and includes thin beds of limestone, some shale, and a thin bed or two of sandy breccia, is almost certainly the correlative of No. 1, the "lower slope-forming member" of Reeside and Bassler, composed of gypsum, gray and yellow shale, soft sandstone, and thin-bedded limestone. Like subdivision C, which is composed of soft sandstone, sandy breccia, and shale similar to those which occur in E, the unit contains gypsum west of the Kaibab Plateau in the region studied by Reeside and Bassler but does not contain it at Kaibab Gulch nor in the Kaibab division of the Grand Canyon.

Subdivision D, which constitutes the lower cliff-making unit of the Kaibab limestone at Kaibab

[9] Reeside, J. B., jr., and Bassler, Harvey, op. cit.
[10] Idem, p. 58.

Gulch and consists chiefly of massive siliceous cherty limestone of a distinctive type, is certainly roughly equivalent to No. 2, the "lower cliff-forming member" ("lower limestone member") of Reeside and Bassler, which consists of similar limestone.

Subdivision C, the sharply defined slope-making unit in the middle of the Kaibab at Kaibab Gulch, which is composed of soft sandstone, sandy breccia, and travertine, is the equivalent of No. 3, the "upper slope-forming member" of Reeside and Bassler, which, like No. 1, consists of soft sandstone, shale, and thin-bedded limestone and includes beds of gypsum. Subdivision C does not contain gypsum at Kaibab Gulch; nevertheless its correlation with No. 3 is definitely established, for at Jumpup Canyon (locality 4, fig. 1), on the border of the region studied by Reeside and Bassler, where I measured a section of the Kaibab limestone (p. 54), the equivalent unit contains many beds of gypsum interstratified with beds of soft sandstone, breccia, and shale that are lithologically identical with the beds of sandstone, breccia, and shale that constitute subdivision C at Kaibab Gulch.

Subdivision B, the upper cliff-making member of the Kaibab at Kaibab Gulch, is composed of the type of rock that is most commonly associated with the name Kaibab limestone in the minds of geologists who have worked in the plateau region—the massive gray or buff cherty fossiliferous limestone that is conspicuously exposed in the cliffs under the rim of the Grand Canyon in the Kaibab and Coconino Plateaus. All the lower half of the subdivision contains fossils of the typical "*Productus ivesi*" fauna in great abundance. Fossils are almost as abundant at many horizons in the upper half, but unfortunately I did not determine whether they represent the "*Productus ivesi*" fauna or the higher "*Bellerophon*" fauna. No. 4, the "upper limestone member" (or "upper massive cliff-forming member") of Reeside and Bassler, consists, like subdivision B, of the familiar cherty limestone which "from Bright Angel Creek to southwestern Utah shows towerlike erosion forms along its upper cliff face." The abundant fossils that it contains represent the "*Productus ivesi*" fauna. In all probability the whole of subdivision B is equivalent to No. 4, although it is barely possible that the upper part of B, the character of whose fauna has not been determined, may represent a part of the Harrisburg member of Reeside and Bassler. The beds in the upper half of B, however, do not at all suggest those of the Harrisburg member in lithology and order of succession, notwithstanding the fact that the Harrisburg member is an exceedingly variable unit.

Subdivision A at Kaibab Gulch, which consists at the top of massive buff limestone and contains at the base very irregular beds of coarse breccia-conglomerate interstratified with shale and soft sandstone, apparently represents No. 5, the Harrisburg gypsiferous member of Reeside and Bassler, which, as shown by those writers, occupies the stratigraphic position of A and which, although exceedingly variable in lithology, consists at many places of rocks very similar to those that constitute subdivision A. The fact that the Harrisburg member contains gypsum in the region studied by Reeside and Bassler, whereas A at Kaibab Gulch does not contain it is not at all inconsistent with the lithology of A. As I have already shown, two other subdivisions of the Kaibab limestone, C and E, which are gypsiferous west of the Kaibab Plateau are not gypsiferous at Kaibab Gulch, but they contain at Kaibab Gulch beds of sandy breccia, soft sandstone, and shale. Similar beds of breccia, sandstone, and shale are interstratified with the gypsum at many of the places west of the Kaibab Plateau where the subdivisions are gypsiferous. Accordingly this association appears to be significant; in other words, the breccia, sandstone, and shale beds in A at Kaibab Gulch are what would be expected at a horizon where gypsum occurs at other localities.

I have tentatively correlated subdivision A at Kaibab Gulch with the Harrisburg member of Reeside and Bassler and have included it in the Kaibab limestone. Nevertheless the possibility exists that it belongs at the base of the Triassic Moenkopi formation, for it may represent a basal member of the Moenkopi that occurs here and there in the region studied by Reeside and Bassler, contains Triassic fossils, and has been named by them the Rock Canyon conglomeratic member. This member of the Moenkopi is described as follows:[11]

> The basal discontinuous unit [of the Moenkopi formation] is an exceedingly variable assemblage of shale, limestone, gypsum, conglomerate, and a minor amount of sandstone. To this unit we have given the name Rock Canyon conglomeratic member, from Rock Canyon, 5 miles north of Antelope Spring, Ariz. A detailed section at this locality [locality 9, fig. 1] is given on page 70 (section 6). The limestone is gray to pink, is usually coarse, and contains chert fragments. The shale may be gray, yellow, or red. The conglomerate is made up of limestone and chert boulders, locally as much as 3 feet in diameter but usually less than a foot, in a limestone cement and occurs in very irregular beds, which may lie at any stratigraphic level in the basal unit. Locally the included limestone fragments are angular and the material is really a breccia, though at most points observed they are rounded or only subangular. Locally this basal member is absent, as the sections show, and the lower red beds of the Moenkopi formation rest directly on limestones containing Kaibab fossils. At the head of Rock Canyon a great gash 700 feet wide and 250 feet deep has been cut into the Kaibab and filled with a confused mass of limestone, shale, gypsum, and conglomerate. This mass contains thin veins of asphaltite and zones impregnated with asphaltic material.

In lithology subdivision A corresponds as well to the Rock Canyon member of the Moenkopi just described as it does to the Harrisburg member of the

[11] Reeside, J. B., jr., and Bassler, Harvey, op. cit., p. 60.

Kaibab, as may be seen by comparing the detailed section of subdivision A (pp. 43–44) with Reeside and Bassler's detailed section of the Rock Canyon member at the type locality and with their section of the Harrisburg member at the narrows of Virgin River.[12] Both these sections, like the section at Kaibab Gulch, consist at the base of irregular beds of breccia and conglomerate, soft sandstone or shale, and limestone or chert, which pass up into gray and buff limestones. The correlation of subdivision A therefore remains uncertain and can be settled only by determination of the fossils that the subdivision contains. Fossils are fairly abundant in the limestone at the top of the subdivision, but all those that I saw were too obscure or too poorly preserved to be determinable, and I had not time to search carefully for better specimens. A systematic search at Kaibab Gulch would undoubtedly yield determinable material, which would establish definitely the correlation of the subdivision.

SECTION IN JUMPUP CANYON

During the eary part of our stratigraphic reconnaissance in the summer of 1922 Professor Gregory and I measured an incomplete section of the Kaibab limestone, Coconino sandstone, and Hermit shale in Jumpup Canyon, a tributary gorge that enters the lower canyon of Kanab Creek from the east at a point about 6 miles north of the junction of Kanab Creek with Colorado River. The section is interesting because it shows in detail the lithology of the slope-making unit of the middle Kaibab (the correlative of subdivision C at Kaibab Gulch, of B at the Bass trail, and of No. 3 of Reeside and Bassler) at a place where the unit contains gypsum; because it shows in detail the lithology of the Hermit shale at a place where that formation is extraordinarily thick and calls attention to the presence in the canyon of lower Kanab Creek of an unconformity at the base of the Hermit shale similar to the unconformity that is well displayed at the type locality of the formation in the canyon of Hermit Creek in the Grand Canyon; and because it affords data concerning the thinning of the Coconino sandstone northward of Kanab Creek. The section is therefore included in this report for comparison with the section at Kaibab Gulch, although in the Kaibab limestone at Jumpup Canyon only the unit mentioned above was measured in sufficient detail to make the section of much value for comparison with the standard sections of the region.

Jumpup Canyon is shown on the Kaibab topographic map published by the United States Geological Survey, but the name of the canyon is not printed on the map. It may be identified as the first large gorge that enters the canyon of Kanab Creek from the east above the junction of Kanab Creek and Colorado River. The location of the section is shown on figure 1 (locality 4). It is roughly 50 miles southwest of Kaibab Gulch, 25 miles northwest of the Bass trail, and 10 miles southeast of Hacks Canyon, where the nearest section of Reeside and Bassler was measured (locality 5, fig. 1). It is not far from the general locality on Kanab Creek where Walcott measured the section shown in columnar form in my report on the Paleozoic rocks of the Grand Canyon,[13] but inasmuch as Walcott's section is a composite section measured along 25 miles of Kanab Canyon between Shinumo Canyon and Colorado River, the writer does not know just what parts of Walcott's section were measured near Jumpup Canyon.

Subdivision C of the Hermit shale and subdivision A of the Supai formation were measured by Professor Gregory in Jumpup Canyon at different places 1 to 4 miles above the junction of Jumpup Creek with Kanab Creek. The Kaibab limestone, Coconino sandstone, and subdivisions A and B of the Hermit shale were measured by me in the walls of Jumpup Canyon at different places 4 to 7 miles above the mouth of Jumpup Creek.

Section in Jumpup Canyon

General section

	Feet
Kaibab limestone:	
Summit of formation not exposed.	
A. Massive gray fossiliferous cherty limestone, forming strong cliffs and steep slopes. Not examined in detail nor measured, but exposed thickness appears to exceed 250 feet	250+
B. Gypsiferous member: Yellowish-buff and pinkish fine-grained sandstone, poorly consolidated and irregularly bedded, interstratified with beds of gypsum and gypsiferous shale; contains near the top beds of sandy breccia and a few thin beds of fossiliferous gray limestone; forms a gentle slope	161
C. At the base buff sandstone and limestone in alternating beds, passing up into massive siliceous buff limestone, fossiliferous and cherty, which constitutes the greater part of the subdivision and makes strong cliffs	172±
Coconino sandstone: Fine-grained buff sandstone, cross-bedded throughout; forms a sheer cliff	90
Hermit shale:	
A. Alternating beds of red sandy shale and fine-grained massive friable sandstone; form a slope; many beds exhibit concretionary structure	44
B. Alternating beds of red shale and sandstone, forming a slope; beds do not exhibit concretionary structure but otherwise are like A	450
C. Alternating beds of red shale and sandstone; like B in composition, but the sandstone beds are rather more massive and resistant than those of B, so that the subdivision forms a ledgy slope broken by weak cliffs and exhibits a profile distinctly steeper than that of B	307
	801

[12] Idem, p. 75.

[13] Noble, L. F., A section of the Paleozoic formations of the Grand Canyon at the Bass trail: U. S. Geol. Survey Prof. Paper 131, pl. 19, 1922.

Unconformity, obscure at the place in Jumpup Canyon where this section was measured, because the surface of erosion exhibits no relief there, but very distinct at many localities 1 to 5 miles away, where the surface of erosion exhibits a relief of 40 feet or more in distances of a few hundred feet.

Supai formation:

A. Upper cliff-making member: Violently and persistently cross-bedded fine-grained hard calcareous sandstone in heavy, massive beds, which everywhere form strong cliffs; pale red to pale yellowish red, contrasting with the prevailing deep red of the Hermit shale. Partings of red sandy shale or platy red sandstone separate many beds of the massive cross-bedded sandstone. The summit beds of this cliff-making subdivision of the Supai form the floor of a broad platform in Jumpup Canyon and throughout the lower canyon of Kanab Creek; this platform is the Esplanade of the western Grand Canyon. Thickness of subdivision not measured, probably about 400 feet.

Detailed section

Kaibab limestone:	Feet
A. Massive gray fossiliferous cherty limestone, forming strong cliffs. Not measured.	
B. 1. Concealed; probably yellow sandstone; makes slope	5
2. Gray limestone in beds averaging 6 inches thick; makes small cliff	4
3. Concealed; probably yellow sandstone; makes slope	5
4. Dense fossiliferous gray limestone forming small cliff	2
5. Yellowish breccia, base concealed. The breccia consists of fragments of sandstone and limestone embedded in a matrix of yellow sand	6
6. Dense fossiliferous gray limestone	1
7. Breccia like No. 5	5
8. Concealed. The few outcrops seen are very soft fine-grained yellowish sandstone	24
9. Massive gypsum	4
10. Yellowish-buff sandy shale, largely concealed; contains at least three 6-inch beds of massive gypsum	15
11. Massive gypsum	8
12. Pinkish sandy shale, partly concealed; contains several 1-foot beds of massive gypsum	16
13. Gypsum containing a small amount of whitish shale and exhibiting very thinly laminated structure	22
14. Gypsiferous yellowish sandy shale, containing three 6-inch beds of massive gypsum	11
15. Massive gypsum, containing a small amount of yellow sand	5
16. Sandy shale impregnated with gypsum and cut by many tiny stringers of gypsum	16
17. Soft whitish-buff fine-grained sandstone in beds averaging 4 inches thick; probably a calcareous sandstone; largely concealed, but many beds of the sandstone appear to be separated by layers of gypsiferous shale. Outcrops are covered by puffy, gypsiferous soil	12
	161

Kaibab limestone—Continued.	Feet
C. 1. Pale-buff arenaceous limestone in two 2½-foot beds, which are separated by a thin parting of shaly sandstone. Forms cliff	5
2. Pale-buff arenaceous limestone, containing lenses, bands, and nodules of chert that become less abundant toward the top. Weathered surfaces of the rock feel gritty and exhibit a faint thinly laminated structure. Forms a steep ledgy slope	8
3. Dense siliceous buff limestone in massive beds, some of which appear to be more than 20 feet thick, fossiliferous and cherty; contains many cavities. The chert occurs in lenses, bands, and nodules and in some beds is very abundant. The limestone forms strong cliffs. Not examined closely nor measured. Thickness estimated roughly	135±
4. Buff fine-grained sandstone. No bedding planes observable. Rather soft; forms an alcove under the high cliffs of No. 3	5½
5. Three 1-foot beds of dense siliceous buff limestone separated by two 2-inch layers of sandy shale. The bottom bed of limestone rests upon a wavy, irregular surface, which exhibits vertical inequalities of a foot or more in a distance of 100 feet	3½
6. Whitish-buff dense fine-grained sandstone. No bedding planes observable	2½
7. Hard dense fine-grained buff crystalline limestone in four beds ranging in thickness from 6 inches to 2 feet	4½
8. Reddish soft sandstone, partly concealed. No bedding planes observable. The sand grains resemble those of the underlying Coconino. The base of the bed truncates with level, even contact the inclined wedges of the underlying Coconino sandstone	8
	172

Coconino sandstone: Fine-grained buff sandstone, cross-bedded throughout. Forms a sheer cliff. At the point where this section was measured one inclined wedge is nearly as thick as the entire formation. The laminae of the wedges dip south or southwest. Contact with underlying shale level, even	90

Hermit shale:	
A. 1. Greenish sandy shale (typical playa mud)	1
2. Fine-grained white sandstone	5
3. Red sandy shale, exhibiting concretionary structure on weathered surfaces	3
4. Red sandstone	5
5. Concretionary red shale, like No. 3	6
6. Reddish-buff calcareous sandstone	2
7. Red shale	2
8. Reddish-buff calcareous sandstone	5
9. Concretionary red shale, like No. 3	4
10. White sandstone, fine grained, calcareous, massive	3
11. Concretionary red shale, like No. 3	8
	44

Hermit shale—Continued.

		Feet
B. 1.	Massive fine-grained friable red sandstone	3
2.	Sandy red shale	3
3.	Sandstone, like No. 1	7
4.	Shale, like No. 2	4
5.	Sandstone	4
6.	Shale	5
7.	Sandstone	4
8.	Shale	5
9.	Sandstone	12
10.	Shale	17
11.	Sandstone	5
12.	Shale	11
13.	Sandstone	4
14.	Shale	8
15.	Sandstone	6
16.	Shale	6
17.	Sandstone	11
18.	Shale	19
19.	Sandstone	1
20.	Shale	3
21.	Sandstone	1
22.	Shale	1
23.	Sandstone	1
24.	Shale	5
25.	Sandstone	4
26.	Shale	5
27.	Sandstone	2
28.	Shale	7
29.	Sandstone	9
30.	Shale	10
31.	Sandstone	3
32.	Shale	1
33.	Sandstone	5
34.	Shale	8
35.	Sandstone	3
36.	Shale	6
37.	Sandstone	1
38.	Shale	5
39.	Sandstone	1
40.	Shale	7
41.	Sandstone	1
42.	Shale	5
43.	Sandstone	3
44.	Shale	23
45.	Sandstone	5
46.	Shale	5
47.	Sandstone	6
48.	Shale	12
49.	Sandstone	5
50.	Shale	18
51.	Sandstone	4
52.	Shale	17
53.	Sandstone	5
54.	Shale; contains greenish bands at intervals	59
55.	Sandstone	4
56.	Shale; basal 2 inches greenish	5
57.	Sandstone	2
58.	Shale	3
59.	Sandstone	3
60.	Shale	5
61.	Sandstone	2
62.	Shale	4
63.	Sandstone	2
64.	Shale	24
65.	Sandstone	5
		450

[All beds below this point were measured and described by H. E. Gregory]

		Feet
C. 1.	Hard massive buff to red calcareous sandstone; contains greenish blotches; forms small cliff	4
2.	Sandy red shale containing greenish spots and layers	8
3.	Red sandstone, hard, lumpy; weathers into knobs; forms vertical cliff. The rock is composed of fine uniform quartz grains bound together by calcareous cement, cross-bedded. Thickness estimated	40
4.	Red shale or thin-bedded sandstone; breaks into small chunks of hardened sand or mud; shows worm trails and mud pellets; includes several greenish-white sandy bands; has mica sprinkled on surface; forms slope	35
5.	Red sandstone, massive, chunky	2
6.	Like No. 4; includes four greenish-white sandy bands	42
7.	Red sandstone, chunky	2
8.	Red shale, lumpy, nodular, uneven, sandy; forms flat slope	20
9.	Red sandstone, massive; forms cliff	2
10.	Red sandy shale; forms slope	38
11.	Red sandstone, unevenly bedded; forms two layers the bottoms of which are white and exhibit mud cracks, mud holes, worm trails, etc	12
12.	Red, unevenly bedded shaly sandstone or sandy shale, lumpy and friable with no apparent change in texture or composition; forms two shale slopes and two broken cliffs	55
13.	Red friable sandstone	6
14.	Red shaly sandstone with greenish-white spots	8
15.	Red sandstone, uniformly fine-grained; roughly separated into three beds, cross-bedded	10
16.	Red mud shale, plastered against uneven under surface of No. 15	1
17.	Red shale or sandstone; weathers into thin sandy shales like mud in arid stream. Greenish-white streaks of thinly laminated shale make three parting planes. Beds are very uneven; contacts wavy	22
		307

Supai formation:

		Feet
A. 1.	Sandstone, calcareous; weathers into hoodoo forms; exhibits greenish-white streaks, blotches, and dots. The rock is cross-bedded, and the sand grains are uniform in size and very small. In texture and color it is exactly like No. 4, below	4
2.	Light-red sandstone, composed of quartz grains bound together with calcareous cement; forms two massive beds separated by crumbly sandstone; has amorphous lumps of limestone	11

Supai formation—Continued.	Feet
A. 3. Calcareous cross-bedded sandstone, like No. 1. Texture and color like No. 4	5
4. Sandstone, light red to yellow-red; makes striking contrast with dark-red Hermit and white Coconino, which appear on same valley wall; everywhere makes strong cliffs. The sandstone is roughly arranged in beds 10 to 50 feet thick, whose appearance is strikingly like that of the Navajo sandstone. Parting planes are marked by nothing or by lenses and short beds of sandstone and sandy shale that resemble the sandstone and shale of the Chinle formation. Nearly all beds are cross-bedded tangentially and angularly. The component sand grains are surprisingly uniform in size and composition and are mostly quartz with lime cement; all grains are almost microscopic; a few red specks are garnet. This cliff-making sandstone unit (No. 4) with the three overlying beds (Nos. 1, 2, and 3) is the rock that floors the Esplanade throughout the canyon of Kanab Creek and in the neighboring Grand Canyon. It constitutes the upper cliff-making subdivision of the Supai, and its steep profile is everywhere in sharp contrast with the gentler profile of the overlying Hermit and underlying Supai beds. At most places in the Canyon of Kanab Creek the surface of the Esplanade lies at the top of No. 4, but at some places it lies at the top of one of the overlying beds, 1, 2, or 3; the surfaces of all four beds weather into water pockets. An all-day search in Jumpup Canyon failed to reveal a place where the cliffs of No. 4 could be descended; consequently this unit could not be examined in detail nor measured. Thickness estimated; may be as much as	400

Subdivision A of the Supai formation on lower Kanab Creek does not differ essentially in composition from A, the corresponding cliff-making subdivision of the Supai at the Bass trail. Like that subdivision, it forms the resistant unit which underlies the Esplanade and determines its floor. The sandstone of which the unit is chiefly composed is, however, much more violently and persistently cross-bedded at Kanab Creek than it is at the Bass trail and appears to form thicker and more massive beds. In composition it is astonishingly like the Navajo sandstone, which I studied later in the Glen Canyon region of Colorado River, and under erosion assumes forms like those assumed by the Navajo sandstone. Some of the bedding is of the "gnarled" or "contorted" type.

Along Kanab Creek just below the mouth of Hacks Canyon I was able to examine some of the beds in the upper part of B, the underlying subdivision of the Supai, but I could not examine the subdivision in detail, as it was impossible at the time to descend along Kanab Creek, owing to high water. I was interested to find, in the upper part of B, beds of limestone conglomerate similar to a bed that occurs in subdivision B in the Kaibab division of the Grand Canyon.[14] One bed is 20 feet thick, and another, higher in the subdivision, is 1 foot thick. The lower bed occurs at approximately the horizon at which the similar bed occurs at the Bass trail. The rock strikingly resembles the "saurian conglomerate" of the Chinle formation, which I had opportunity later to examine in the Vermilion Cliffs. The occurrence of the distinctive beds of conglomerate at Kanab Creek indicates that they are a persistent feature of the Supai over a wide area, for they occur also in the Aubrey cliff near Seligman as well as throughout the Kaibab division of the Grand Canyon. Further study of the Supai formation will be necessary to determine the stratigraphic significance of these conglomerate beds; it is conceivable that they mark a widespread zone of unconformity within the formation or at any rate a datum plane that will prove useful for correlation.

The unconformity that separates the Hermit shale from the Supai formation in Kanab Canyon is an exact counterpart of the unconformity which separates these formations in the Kaibab division of the Grand Canyon and which I have described in another paper.[15] In Kanab Canyon as in the Grand Canyon it is so clear at some places that it may be recognized at a glance and so obscure at other places that it can not be detected. The unconformity lies at or just above the general level of the Esplanade, the platform developed on the hard summit beds of the Supai. Along the east side of Kanab Canyon, between the mouth of Hacks Canyon and Jumpup Canyon, it is clearly exposed for a distance of 3 or 4 miles and is unmistakable. The surface of erosion exhibits considerable relief; in places channels 40 feet deep have been eroded in the Supai beds. These hollows are filled with the Hermit shale. At places residual hills of Supai, 30 feet or more high, project into the Hermit shale. The photographic views in Plate 14 show some of these details of the unconformity. Near the mouth of Jumpup Canyon where the section given above was measured, the unconformity could not be detected, notwithstanding the fact that good exposures of it appear in the canyon of Kanab Creek a mile away. It is therefore possible that some of the beds assigned to the base of the Hermit shale in the sections are Supai beds, although it is improbable from the observed stratigraphic position of the unconformity at places not more than a mile away that the base of the Hermit lies much higher than the position assigned to it in the section. All the beds in the section that are assigned to the Supai, at any rate, are unquestionably

[14] Noble, L. F., A section of the Paleozoic formations of the Grand Canyon at the Bass trail: U. S. Geol. Survey Prof. Paper 131, p. 61, 1922.

[15] Idem, pp. 63–64.

Supai. I experienced a similar difficulty in determining the base of the Hermit shale at the Bass trail, where the unconformity is also obscure.

Although the unconformity just described appears to be a widespread feature in the Grand Canyon region, as is indicated by its presence in Kanab Canyon as well as in the Kaibab division of the Grand Canyon, it probably does not mark any great or significant time interval, for subdivision A of the Supai below the unconformity as well as the Hermit shale above it is believed to be of Permian age. Inasmuch as the unconformity coincides roughly with the general level of the Esplanade or lies just above it, the Esplanade might be regarded as an exhumed and now more or less dissected erosion surface of Permian time.

At Jumpup Canyon I divided the Hermit shale into three subdivisions, A, B, and C, for convenience in measuring the section. These subdivisions have no particular stratigraphic significance, because the formation is essentially a unit in lithology, all parts of it consisting of similar material—sand and red sandy mud, which form alternating beds of sandstone and sandy shale. Other geologists might subdivide the same section differently or might not subdivide it at all. For example, the subdivisions into which Reeside and Bassler [16] have divided the formation at Hacks Canyon and those into which Walcott [17] has subdivided it along Kanab Creek do not correspond with those into which I have subdivided it at Jumpup Canyon, although the three sections are essentially similar in lithology. Subdivision A of the Hermit shale at Jumpup Canyon differs from other subdivisions of the formation at that locality only in that many beds in it exhibit a peculiar concretionary structure on weathered surfaces that does not appear in the other subdivisions. Subdivision C differs from A and B only in that the beds of which it is composed are rather more massive than those of A and B, so that the subdivision exhibits a somewhat steeper topographic profile than the other subdivisions.

In lithology the section of the Hermit shale at Jumpup Canyon does not differ in any essential respect from the sections of that formation at the Bass trail and at the type locality in Hermit Basin.[18] At Jumpup Canyon, as at these other localities, the upper part of the formation is marked by concretionary structure, and the Hermit beds exposed at Kaibab Gulch (see p. 46) evidently represent this concretionary part of the formation. The most noteworthy feature of the Hermit shale at Jumpup Canyon is its great thickness (800 feet) as contrasted with its thickness at the Bass trail (332 feet) and at Hermit Basin (317 feet), from which it is evident that the formation maintains at least as far as Kanab Canyon the steady increase in thickness northwestward that it exhibits in the Kaibab division of the Grand Canyon. The fact that the Coconino sandstone thins steadily in the same direction (see below) is in accordance with the observation [19] that in the Kaibab division of the Grand Canyon the thickness of the Coconino is everywhere in inverse ratio to that of the underlying Hermit. The significance of this relation is not known.

The three subdivisions, A 1, A 2, and A 3 of the Aubrey group in Walcott's composite section along Kanab Creek [20] correspond in lithology and in aggregate thickness (775 feet) to the Hermit shale (801 feet) at Jumpup Canyon and undoubtedly represent that formation. Walcott's underlying subdivision B, composed of massive cross-bedded sandstone (315 feet thick) undoubtedly represents subdivision A of the Supai in the section at Jumpup Canyon.

The upper 550 feet, at least, of the beds classed as Supai in Reeside and Bassler's section at Hacks Canyon,[21] and perhaps a part of the underlying beds, are Hermit shale.

In our traverse down Kanab Creek from Fredonia to Jumpup Canyon we had an opportunity to trace the Coconino sandstone continuously for 20 miles in the eastern wall of Kanab Canyon—from the point where it first appears in the bed of Kanab Creek to the mouth of Jumpup Canyon. We found that between these points the sandstone thins steadily northward, its thickness diminishing from 90 feet at Jumpup Canyon to 15 feet in the bed of Kanab Creek (locality 3, fig. 1). Throughout this long exposure in Kanab Canyon the Coconino appears to be one bed, made up of cross-bedded wedges, not several beds; and this bed is continuously traceable from Jumpup Canyon into the thick bed that constitutes the formation in the Kaibab division of the Grand Canyon, the type locality of the Coconino sandstone. West of Kanab Canyon, however, the Coconino, as identified by Reeside and Bassler,[22] consists of several members, and it is uncertain whether one or all of these members should be correlated with the single massive bed that represents the formation at the type locality. Near Ryan, 25 miles northeast of Jumpup Canyon in the general direction of Kaibab Gulch, the Coconino is exposed in the escarpment along the West Kaibab fault. Here, as seen from a distance of a mile, it appears to be about 25 feet thick and, as at Jumpup Canyon, to constitute a single bed. It rests upon beds of Hermit shale whose exposed thickness appears to be at least 600 feet.

The facts just noted show that the Coconino must wedge out to the vanishing point somewhere between the localities on Kanab Creek and at Ryan, where it

[16] Reeside, J. B., and Bassler, Harvey, op. cit., p. 69.
[17] Noble, L. F., op. cit., pl. 19.
[18] Idem, pp. 64–65.
[19] Noble, L. F., op. cit., p. 67.
[20] Idem, pl. 19.
[21] Reeside, J. B., jr., and Bassler, Harvey, op. cit., p. 69.
[22] Idem, p. 57.

has decreased, respectively, to 15 and 25 feet, and Kaibab Gulch, where it is absent.

The Coconino-Hermit contact is a well-marked spring horizon in Jumpup Canyon and other tributary gorges of Kanab Canyon, just as it is throughout the Kaibab division of the Grand Canyon and along the western border of the Kaibab Plateau. Evidently the Hermit shale is much more impervious than the Coconino sandstone and offers everywhere a barrier to percolation. This relation may be worthy of consideration, for it is conceivable that fuller knowledge of the thickness and distribution of the Coconino in the plateau country will reveal geologic structure favorable for the accumulation of underground water above the contact in sufficient quantity to be recoverable by wells.

In a broad way the units into which the Kaibab limestone is divisible at Jumpup Canyon exhibit the distinctive features of lithologic character, succession, and topographic expression that corresponding units of the formation display at Kaibab Gulch, at the Bass trail, and in the region studied by Reeside and Bassler, so that the section at Jumpup Canyon may be correlated confidently with these other sections. Subdivisions A, B, and C at Jumpup Canyon are obviously equivalent, respectively, to subdivisions A, B, and C at the Bass trail. Apparently beds 4, 5, 6, 7, and 8 of C, the alternating beds of sandstone and limestone at the base of the Kaibab at Jumpup Canyon, are equivalent to subdivision E at Kaibab Gulch and to No. 1, the "lower slope-forming member," of Reeside and Bassler; and beds, 1, 2, and 3 of C at Jumpup Canyon, composed of massive buff siliceous limestone, are equivalent to subdivision D at Kaibab Gulch and to No. 2, the "lower limestone member," of Reeside and Bassler, which are composed of limestone of this distinctive type.

Subdivision B, the gypsiferous member of the Kaibab at Jumpup Canyon, is certainly equivalent to C at Kaibab Gulch and to No. 3, the "upper slope-forming member," of Reeside and Bassler. The section of this unit at Jumpup Canyon affords a connecting link between the sections at Kaibab Gulch and the Bass trail, where the unit contains no gypsum, and the sections in the region studied by Reeside and Bassler, where it is composed chiefly of gypsum. At Jumpup Canyon the unit not only contains the characteristic beds of breccia, soft sandstone, and shale that constitute it at Kaibab Gulch and Bass Canyon and the beds of gypsum that are characteristic of it in the sections of Reeside and Bassler but contains also, in its upper part, beds of fossiliferous limestone interstratified with the distinctive sandy breccia. Subdivision C at Jumpup Canyon, which I did not measure, is the familiar cherty limestone member of the Kaibab and is the correlative of a part, at least, of B at Kaibab Gulch and of No. 2, the "upper limestone member," of Reeside and Bassler. In all probability No. 5, the overlying Harrisburg member of Reeside and Bassler, with which I have tentatively correlated subdivision A at Kaibab Gulch, is represented by beds on the Kaibab Plateau along the rim of Jumpup Canyon, but I did not have an opportunity to examine these beds.

SECTION NEAR LEES FERRY

Near Lees Ferry, 30 miles southeast of Kaibab Gulch, the following section (No. 3, fig. 1) was measured by Bryan:[23]

Section near Lees Ferry

	Feet
Moenkopi formation: Red sandy shale and thin-bedded sandstone with seams of gypsum; in places has beds of red and gray sandstone 2 to 6 feet thick and in one locality 12 feet of gypsiferous limestone at the top. Base generally 1 to 10 feet of chert conglomerate	500±
Unconformity.	
Kaibab limestone: Yellow limestone with many more or less rounded nodules of chert	250
Coconino sandstone: Gray cross-bedded massive sandstone	300
Unconformity (?).	
Hermit (?) shale: Red shale and sandstone Unconformity (?) (not observed). Supai formation: Red shale with beds of blue limestone	500±

Bryan's section of the Kaibab limestone is not sufficiently detailed to afford a basis for determining what part of the Kaibab at Kaibab Gulch is represented at Lees Ferry. As described by Bryan the Kaibab limestone at Lees Ferry consists entirely of cherty limestone; this limestone might represent that of either subdivision B or subdivision D at Kaibab Gulch or both. Subdivision C at Kaibab Gulch, the well-defined soft sandstone and breccia member of the middle Kaibab, does not appear to be represented at Lees Ferry. Its absence there seems surprising, for Lees Ferry is much nearer Kaibab Gulch than any other locality from which a measured section of the Kaibab has been published. One would expect to find at least as close a correspondence between the Kaibab Gulch and Lees Ferry sections as between the Kaibab Gulch and Bass trail sections, which are more than twice as far apart. The absence of the Coconino sandstone at Kaibab Gulch and its presence at Lees Ferry, only 30 miles away, where it is 300 feet thick, is even more surprising. The Kaibab limestone, moreover, is only a little more than one-third as thick at Lees Ferry as it is at Kaibab Gulch. These differences in thickness serve further to emphasize the contrast between the sections at the two localities.

[23] Longwell, C. R., Miser, H. D., Moore, R. C., Bryan, Kirk, and Paige, Sidney, Rock formations in the Colorado Plateau of southeastern Utah and northern Arizona: U. S. Geol. Survey Prof. Paper 132, p. 16, 1923.

SECTION IN THE CIRCLE CLIFFS

In the Circle Cliffs, 70 miles northeast of Kaibab Gulch, the following section (No. 8, fig. 1) was measured by R. C. Moore: [24]

Section in Circle Cliffs

	Feet
Moenkopi formation.	
Kaibab limestone:	
Yellow dolomitic limestone in massive, evenly bedded ledges; weathers in large angular blocks pitted by solution; part contains many dendrites of manganese oxide and concretions of a mineral resembling wad; contains fossils; forms resistant cap of prominent bench	37
Light-yellow soft dolomitic massive limestone, filled with angular fragments of chert; weathers in smooth slope; exposed	15
Soft light creamy-yellow thin to medium bedded limestone; weathers in slope; partly concealed	37
White very sandy limestone, rounded sand grains scattered rather evenly; weathers in thick ledges	34
White medium to coarse grained massive sandstone; rounded quartz grains in a lime matrix	19
White very sandy limestone; rounded sand grains scattered rather evenly; weathers in thick ledges; forms bench	21
	163
Coconino (?) sandstone: White medium to coarse grained moderately soft massive sandstone; rounded quartz grains in a lime matrix; breaks into irregular blocks on weathering; exposed	73

At the Circle Cliffs, as at Lees Ferry, it is impossible with any degree of assurance to correlate the section in detail with the section at Kaibab Gulch. The fossiliferous and cherty limestones in the Circle Cliffs section, which, as shown by Moore,[25] contain the typical "*Productus ivesi*" fauna, might represent either the limestones of subdivision B at Kaibab Gulch or those of subdivision D. Sandstones occur in all the subdivisions of the Kaibab at Kaibab Gulch, and any of them except those in subdivision A might represent sandstones in the Circle Cliffs section. The sandstone assigned to the Coconino at the Circle Cliffs appears to differ somewhat from the Coconino of the type locality in the Kaibab division of the Grand Canyon; the grains of sand, as described by Moore, are medium to coarse, whereas in the type locality they are uniformly fine; and the cementing material is calcareous at Circle Cliffs, whereas it is siliceous at the type locality. However, these differences are not necessarily significant in view of the distance that separates the sections.

SECTION NEAR ZAHNS CAMP, SAN JUAN RIVER

In a section measured by H. D. Miser [26] at Zahns Camp on San Juan River (No. 14, fig. 1), 85 miles east of Kaibab Gulch, the Kaibab limestone is entirely absent and the Moenkopi formation rests upon the Coconino sandstone.

[24] Longwell, C. R., and others, op. cit., pp. 20-21.
[25] Idem, p. 9.
[26] Idem, p. 17.

CONTRAST WITH SECTIONS EAST OF KAIBAB PLATEAU

The sections at Lees Ferry, Zahns Camp, and the Circle Cliffs, which lie, respectively, southeast, east, and northeast of Kaibab Gulch, present a striking contrast with the sections that lie south, southwest, and west of Kaibab Gulch in the degree of certainty with which they can be correlated in detail with the Kaibab Gulch section. As shown in this report, the members of the Kaibab limestone in the section to the south, southwest, and west are represented by members at Kaibab Gulch that are immediately recognizable as equivalent units, whereas correlation of the members of the Kaibab at Kaibab Gulch with those in the sections to the southeast, east, and northeast is difficult if not impossible, and in the section at Zahns Camp the Kaibab limestone is not represented at all. It is therefore evident that the Kaibab limestone experiences much greater changes in lithology in the region immediately east of the Kaibab Plateau than it does over a very wide region west of the plateau. The fact that, as described by Longwell,[27] the formation as far west as the Muddy Mountains in Nevada consists of units corresponding closely to the four lowest subdivisions at Kaibab Gulch indicates that its comparative uniformity west of the Kaibab Plateau is widespread indeed.

The absence of the Coconino sandstone from the section at Kaibab Gulch taken in connection with its thinning almost to the vanishing point up Kanab Creek, its presence as a thin bed (25 feet thick) overlying the Hermit shale on the West Kaibab fault at Ryan, and its thickness of 300 feet near Lees Ferry (measured by Bryan) and of 250 to 650 feet, increasing southeastward, in the Kaibab division of the Grand Canyon, appears to mark the Coconino as a well-defined lentil that wedges out northward from the type locality in the Kaibab division and disappears in the region around Kaibab Gulch. (See fig. 1.) Accordingly the presence at Kaibab Gulch of massive cross-bedded sandstone (bed 10 of subdivision D) in the lower part of the Kaibab but above fossiliferous limestone (beds 9 and 11 of subdivision E) suggests the possibility that sandstone assigned to the Coconino in the Circle Cliffs region northeast of Kaibab Gulch may form a part of the Kaibab, if the name Coconino sandstone is restricted to the single definite bed that represents the formation in the type locality. It is conceivable also that the Coconino and Kaibab interfinger in the Circle Cliffs region.

[27] Longwell, C. R., Geology of the Muddy Mountains, Nev.: Am. Jour. Sci., 5th ser., vol. 1, p. 48, 1921.

SEDIMENTARY ROCKS OF THE SAN RAFAEL SWELL AND SOME ADJACENT AREAS IN EASTERN UTAH

By James Gilluly and John B. Reeside, Jr.

INTRODUCTION

Eastern Utah is a part of the Colorado Plateau province, a land of naked rocks, of canyons, buttes, mesas, and cliffs. Exposures of bedrock are almost ideal, and the rocks over large areas lie with only slight inclinations, though a few laccolithic mountain masses and a few abrupt folds vary the general simplicity of the structure. Nevertheless, the paucity of fossiliferous strata and some astonishing lateral changes in the sediments have occasioned misinterpretation of even the most persistent lithologic units, and considerable uncertainty has existed as to correlation between the different sections and as to the appropriate nomenclature. Continuous tracing is of course the most satisfactory means of effecting such correlations, though very closely spaced stratigraphic sections will suffice to give useful and sometimes complete answers to the questions involved. The present paper serves to record stratigraphic data obtained, in part by detailed work and in part by more or less isolated observations, in the portion of the Plateau province which includes the San Rafael Swell and some contiguous districts. The results of earlier investigators are interpreted in the light of these recent data, and an effort is made to present briefly the available information on the stratigraphy of the region treated.

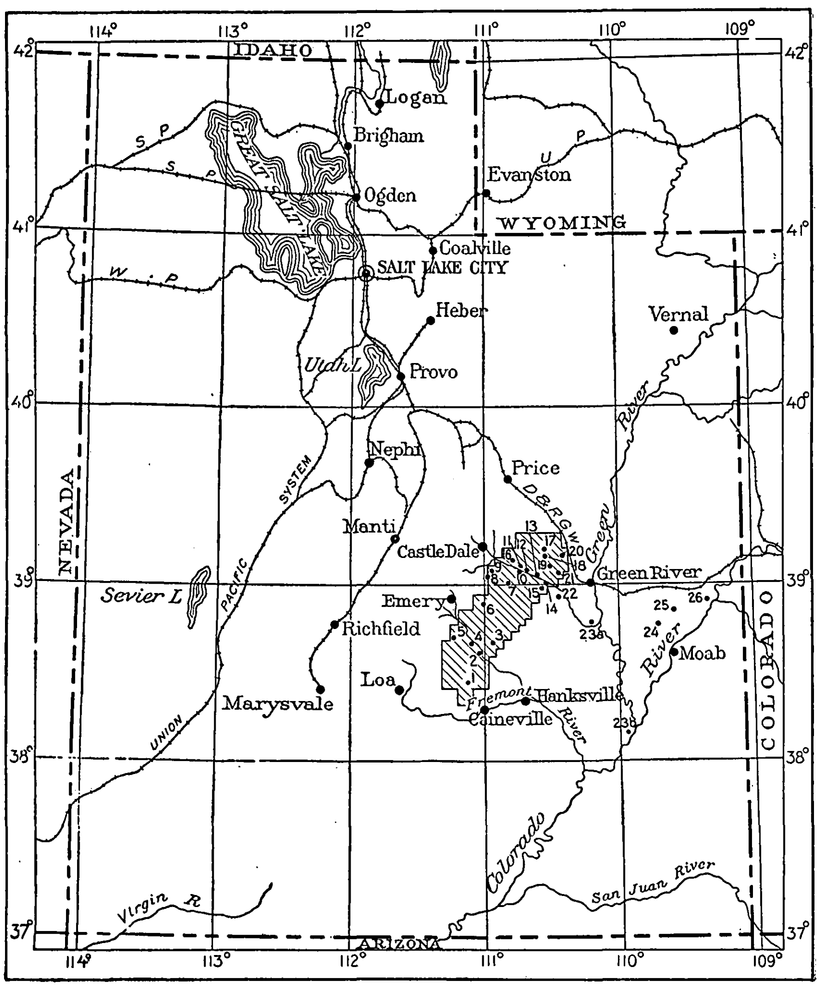


Figure 2.—Index map of Utah, showing location of numbered stratigraphic sections given on pp. 82–110. Shading indicates area of detailed map accompanying a paper on the economic geology of the San Rafael Swell (U. S. Geol. Survey Bull. —, in preparation)

In connection with a study of the oil possibilities of the San Rafael Swell, its entire area except part of the eastern margin was mapped by plane table in detail in 1924 and 1925. This work was begun by E. M. Spieker but shortly afterward was taken over and continued to its completion by Mr. Gilluly. Small areas near Cisco and Crescent were also visited. Mr. Reeside spent several weeks studying the stratigraphy of the Swell in 1924 and visited parts of it again in 1925.

The correlation of the strata of the Colorado Plateau is of great value in deciphering the paleogeographic relations of the region and, because of the recognized influence of paleogeographic conditions on the accumulation of oil and gas, it is of considerable economic importance as well. Accordingly, the areas intervening between Cisco and the San Rafael Swell were studied by the writers jointly for two weeks in 1925 and a week in 1926. As the Green River Desert region had been mapped by Emery [1] in 1917 and much of the country east of Green River by Lupton [2] in

[1] Emery, W. B., The Green River Desert section, Utah: Am. Jour. Sci., 4th ser., vol. 46, pp. 551–577, 1918.

[2] Lupton, C. T., Oil and gas near Green River, Utah: U. S. Geol. Survey Bull. 541, pp. 115–134, 1914.

1912, and as the exposures are very complete and the topography such as to emphasize the stratigraphic divisions the work was greatly facilitated, and considerable confidence is felt in the correlations here made between the Swell and the mouth of Dolores River. The interpretation of the lateral variations of the different units and the correlations arrived at are shown in Plate 15.

PREVIOUS WORK

Dutton,[3] Gilbert,[4] and Powell,[5] in connection with the early surveys of the plateau province, described adjacent districts and only incidentally mentioned the San Rafael Swell and Green River Desert area. More recent work by Cross,[6] Lupton,[7] Dake,[8] Lee,[9] Emery,[10] Prommel,[11] Moore,[12] and Longwell and others[13] deals directly with its stratigraphic problems. Papers on neighboring areas by many writers have been consulted in making correlations and will be referred to in the appropriate places.

TOPOGRAPHY

The San Rafael Swell is an elongate oval area, surrounded by a rim of inward-facing, almost vertical cliffs. From the top of the cliffs the surface slopes outward in all directions, gently on the west toward Castle Valley and on the north toward the Uinta Basin and more steeply on the south and east toward Fremont River and the Green River Desert. The Green River Desert lies largely on the north and west slopes of a huge but gentle uplift centering near the Blue Mountains. South of the Swell are the Henry Mountains, a group of smoothly rounded masses projecting high above the general surface. West of these mountains lies the Waterpocket Fold, a district remarkably resembling the San Rafael Swell in topography. The north end of this fold is the southern extremity of the area here discussed. To the west the region is bounded by one of the High Plateaus, the Wasatch Plateau, whose top reaches altitudes of 9,000 to 11,000 feet. From the north end of the Wasatch Plateau the much lower escarpment of the Book Cliffs continues eastward to and beyond the Colorado State boundary and the limits of the area described in this paper. South of the Book Cliffs, east of Green River, and north of the La Sal Mountains is a large district showing only minor topographic features rising above the general surface of the plateau.

Over most of the area drainage channels are deeply incised, and to speak of a "general plateau surface" is justified only in dealing with the very largest topographic units. In detail, the country is dissected by an intricate maze of nearly or quite impassable canyons and dotted with buttes and mesas of gigantic dimensions. The local topography is governed in minute detail by the rock structure. Massive sandstones form steep ledges or even-topped benches, and softer shales weather into slopes. Drainage is carried through the thick sandstones by narrow and vertical-walled canyons; through the shales by wider valleys with gentler side slopes. Structural terraces along the watercourses, due to the erosion of soft beds from the nearly flat-lying resistant beds, are a prevailing feature. (See pl. 16.)

SEDIMENTARY ROCKS

GENERAL FEATURES

The rocks exposed in the districts discussed in this paper range in age from Pennsylvanian to Upper Cretaceous. The most widely exposed formations are those of the Triassic and Jurassic systems. Pre-Triassic beds come to the surface in the area locally called Sinbad, within the San Rafael Swell, in the Waterpocket Fold, and in the canyons of Colorado River and its eastern tributaries. A band of Cretaceous beds crops out about the edges of the district—on the south between the Swell and the Henry Mountains; on the west and north in Castle Valley, the Wasatch front, and the Book Cliffs and the adjacent lower plateau.

A few dikes and sills in the southwestern part of the San Rafael Swell are the only igneous rocks in the area, though igneous rocks are prominent in the near-by La Sal, Blue, and Henry Mountains and in the southern High Plateaus. None of the igneous bodies are described in this paper.

Sandstones overwhelmingly predominate in all the formations older than the Mancos shale. The Triassic and Jurassic rocks, the main concern of this paper, are mostly nonfossiliferous and are probably in large part of continental origin.

A generalized section of the rocks exposed in the San Rafael Swell is given in the accompanying table. The correlation with more easterly areas is discussed in detail only for the formations included between the Chinle and Morrison, and is shown diagrammatically in Plate 15.

[3] Dutton, C. E., Report on the geology of the High Plateaus of Utah, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

[4] Gilbert, G. K., Report on the geology of the Henry Mountains, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1877.

[5] Powell, J. W., Exploration of the Colorado River of the West, 1875.

[6] Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, pp. 634–679, 1907.

[7] Lupton, C. T., Oil and gas near Green River, Utah: U. S. Geol. Survey Bull. 541, pp. 115–134, 1914; Gypsum along the west flank of the San Rafael Swell, Utah: U. S. Geol. Survey Bull. 530, pp. 221–231, 1913; Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, 1916.

[8] Dake, C. L., The horizon of the marine Jurassic of Utah: Jour. Geology, vol. 27, pp. 634–646, 1919; The pre-Moenkopi unconformity of the Colorado Plateau: Jour. Geology, vol. 28, pp. 61–74, 1920.

[9] Lee, W. T., Early Mesozoic physiography of the southern Rocky Mountains: Smithsonian Miscellaneous Coll., vol. 69, No. 4, 1918.

[10] Emery, W. B., op. cit.

[11] Prommel, H. W. C., Geology and structure of portions of Grand and San Juan Counties, Utah: Am. Assoc. Petroleum Geologists Bull., vol. 7, No. 4, pp. 384–399, 1923.

[12] Moore, R. C., Stratigraphy of a part of southern Utah: Am. Assoc. Petroleum Geologists Bull., vol. 6, No. 3, pp. 199–227, 1922.

[13] Longwell, C. R., Miser, H. D., Moore, R. C., Bryan, Kirk, and Paige, Sidney, Rock formations in the Colorado Plateau of southeastern Utah and northern Arizona: U. S. Geol. Survey Prof. Paper 132, pp. 1–25, 1923.

General section of rock formations in the San Rafael Swell, Utah

System	Series	Group and formation	Thickness (feet)	Character	Remarks
Quaternary.		Alluvium and terrace gravel.		Sandy clay, sand, and gravel in alluvial fans; terrace gravels on benches along streams.	
		Unconformity			
Cretaceous.	Upper Cretaceous.	Mancos shale.	4,000 ±	Gray marine shale, sandy beds in lower part, rather persistent sandstone members about 200 feet above the base and 600 feet above the base.	
		Dakota (?) sandstone.	0–55	Conglomerate; coarse and fine sandstone, in places quartzitic; gray and greenish clay.	
		Unconformity			
Cretaceous (?).	Lower Cretaceous (?).	Morrison formation.	415–847	Clay and shale, variegated, dominantly green-gray, maroon, and mauve; gray sandstone and conglomerate, very lenticular, massive, and cross-bedded; such lenses especially numerous toward the base, where they form the Salt Wash sandstone member; subordinate thin lenticular limestones; a rather persistent conglomerate 250 to 350 feet below the top.	McElmo, except basal part, of Cross;[a] McElmo of Emery;[b] Upper McElmo of Lupton[c,d] and Dake.[e] At base is Salt Wash sandstone member of Lupton,[c] Emery,[b] and Dake.[e]
		Unconformity			
Jurassic.	Upper Jurassic.	San Rafael group: Summerville formation.	125–331	Thin-bedded chocolate-colored sandstone; earthy red-brown sandstone and shale; some gypsum, and a little limestone in some sections.	According to W. T. Lee,[f] probably basal McElmo at type locality; basal part of McElmo of Cross[a] and middle part of McElmo of Lupton;[c,d] part of lower McElmo of Dake[e] included in Navajo by Emery.[b]
		San Rafael group: Curtis formation.	76–252	Green-gray conglomerate and shale, and gray heavy-bedded sandstone.	Included in Navajo by Emery;[b] Salt Wash of Lupton.[d]
		Unconformity			
		San Rafael group: Entrada sandstone.	265–844	Thin-bedded red shale and sandstone at the base; heavy, massive red-brown earthy sandstone above; weathers into rounded forms and steep cliffs.	Upper La Plata sandstone of Cross;[a] included in Navajo sandstone by Emery;[b] "varicolored sandstone and shales" of Longwell and others;[g] included in McElmo of Lupton,[c,d] in lower McElmo (Sundance?) of Dake.[e]
		San Rafael group: Carmel formation.	170–650	Dense limestone and buff and red sandstone at the base; toward the top dominantly red and green shale with thin sandstones and heavy beds of gypsum.	Base of McElmo of Lupton;[d] included in "marine Jurassic" of Dake[e] and Lee;[h] Todilto (?) formation of Emery;[b] "gypsiferous shales and sandstones" of Longwell and others;[g] middle La Plata of Cross[a] and Paige.[i]
		Unconformity (?)			
Jurassic (?).		Glen Canyon group: Navajo sandstone.	440–540	Tan to light-gray massive cross-bedded calcareous sandstone, with a few thin local limestones.	Gregory's usage;[j] lower La Plata of Cross;[a] included in Wingate sandstone by Emery.[b]
		Glen Canyon group: Todilto (?) formation.	44–240	Red-brown sandstones, green and red shale, and shale conglomerate, irregularly interfingering and channeled.	Included in Wingate sandstone by Emery.[b]
		Glen Canyon group: Wingate sandstone.	360–400	Buff to tan, pink, and dark-gray massive cross-bedded limy sandstone, with a few thin lenses of limestone. In most places stained red by wash.	Gregory's usage;[j] lower part of Wingate sandstone of Emery;[b] Upper Dolores sandstone of Cross.[a]
		Unconformity			
Triassic.	Upper Triassic.	Chinle formation.	141–225	Green and red micaceous sandstone and thin red-brown shales; limestone conglomerate; variegated marl; all lenticular, channeled, and interfingering.	Lower Dolores of Cross.[a]
	Upper (?) Triassic.	Shinarump conglomerate.	70–178	Cross-bedded lenticular conglomerate, sandstone, clay, and shale; interfingering. Much silicified wood. Quartz and chert pebbles predominate in the conglomeratic portions.	
		Unconformity			
	Lower Triassic.	Moenkopi formation.	735–850	Green-gray pyritic shale; gypsiferous green and red shale; red micaceous ripple-marked sandstone; gray to buff sandstone; red sandstone. Very limy throughout. A massive, persistent light-gray marine limestone and sandstone member 140 to 200 feet above the base and 40 to 150 feet thick—the Sinbad limestone member.	
		Unconformity			
Carboniferous.	Permian.	Kaibab limestone.	0–85	Light-gray to cream-colored cherty limestone; some oölite; somewhat sandy in places.	Present only in patches in San Rafael Swell; only uppermost part of typical Kaibab.
		Coconino sandstone.	715	White to buff sugary, friable to hard massive cross-bedded quartz sandstone of uneven grain. Some grit toward the base, and the lowest 40 feet largely limestone. Base not exposed.	May include chronologic equivalents of part of typical Kaibab limestone, typical Coconino sandstone, Hermit shale, and part of Supai formation.

[a] Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, p. 641, 1907.
[b] Emery, W. B., The Green River Desert section, Utah: Am. Jour. Sci., 4th ser., vol. 46, pp. 551–577, 1918.
[c] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bull. 541, pp. 115–133, 1914.
[d] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, pp. 19–26, 1916.
[e] Dake, C. L., The horizon of the marine Jurassic of Utah: Jour. Geology, vol. 27, pp. 634–646, 1919.
[f] Lee, W. T., personal communication.
[g] Longwell, C. R., and others, Rock formations of the Colorado Plateau in southern Utah and northern Arizona: U. S. Geol. Survey Prof. Paper 132, pp. 1–23, 1923.
[h] Lee, W. T., Early Mesozoic physiography of the southern Rocky Mountains: Smithsonian Misc. Coll., vol. 69, No. 4, 1918.
[i] Paige, Sidney, The La Plata group in the plateau country (unpublished), read before the Am. Assoc. Adv. Sci., December, 1924, Washington, D. C.
[j] Gregory, H. E., The geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, 1917.

PRE-TRIASSIC ROCKS

The exposed rocks older than Triassic are of entirely different facies in the eastern and western parts of the area here described. The western facies was studied in considerable detail in the Waterpocket Fold and at numerous localities in the San Rafael Swell. Observations on the eastern facies in the canyons of Colorado River and its tributaries near and east of Moab were so meager and so cursory that the writers will not attempt in this paper any extended comparison with the rocks of the San Rafael Swell.

COCONINO SANDSTONE

In the western localities the rocks exposed below the Triassic are designated here the Coconino sandstone and the Kaibab limestone. The Coconino is a massive, highly cross-bedded buff to white sandstone, at some places blotched irregularly with red and brown. The thick beds are unbroken by shale. It is dominantly lime-cemented and somewhat friable but nevertheless stands in nearly vertical cliffs whose intricate jointing is characteristic. The grain is uneven but chiefly fine. The basal 40 feet of the thickest exposure in the San Rafael Swell, in the Black Box Canyon of San Rafael River, is chiefly limestone and may belong to an older but conformable formation rather than the Coconino sandstone, though no decisive evidence on this point was obtained. No determinable fossils have been found in the sandstone, and correlation with the type Coconino sandstone, of Permian age, is based upon the apparently conformable stratigraphic position beneath the Kaibab limestone and upon the lithology. In the Circle Cliffs, at Lees Ferry, and in the Grand Canyon district (the type region of the Coconino sandstone and Kaibab limestone) similar lithologic units occur with identical relations—a limestone formation conformably above a sandstone. It is true that it is not possible to trace the formations between the San Rafael Swell, Cataract Canyon, the Circle Cliffs, and Lees Ferry and the Grand Canyon and that there may be question as to the lateral changes in lithology and the chronologic equivalence of the similar units. As noted on the table, the Kaibab limestone in the San Rafael Swell is only the very latest part of the formation as it is represented in the type area, and some part of the Coconino sandstone of the San Rafael Swell may therefore be of the age of the typical Kaibab limestone. Near the junction of Green and Colorado Rivers, United States Geological Survey field parties collected Permian fossils from limestones at the base of beds that grade laterally within a few miles into the Coconino sandstone of Cataract Canyon. Under these fossiliferous beds a red, nearly barren zone several hundred feet thick rests conformably on the top of beds assigned to the Goodridge formation and containing fossils of Pennsylvanian (Hermosa) age. These facts suggest that the lithologic unit designated Coconino sandstone in the San Rafael Swell and Cataract Canyon may contain time equivalents of part of the Supai formation, the Hermit shale, the Coconino sandstone, and the Kaibab limestone of the Grand Canyon region. The name is in use, however, and it seems best for the present, at least, to continue using this name as a convenient designation for the lithologic unit, without implying chronologic identity with the typical Coconino sandstone.

The greatest thickness measured in the San Rafael Swell is 715 feet in the Black Box Canyon of San Rafael River, in the north end of the Swell. The base is not exposed here nor at any other point in the region described by the writers. In Cataract Canyon the sandstone measures nearly 1,000 feet, according to Longwell, Miser, Moore, Bryan, and Paige,[14] who state further that it "has been traced by B. S. Butler, F. L. Hess, H. E. Gregory, C. R. Longwell, and H. D. Miser practically the entire distance from Cataract Canyon to the San Juan oil field by way of White Canyon."

The Coconino thins to the south and west of this region. In the Grand Canyon district it is 250 to 350 feet thick, and Reeside and Bassler [15] and Longwell [16] have shown that still farther to the west it thins yet more and finally is inseparable from the westward equivalent of the underlying Supai formation.

KAIBAB LIMESTONE

Conformably above the Coconino sandstone in the Waterpocket Fold and in parts of the San Rafael Swell lies the Kaibab limestone. Fossils collected by Powell [17] and Newberry [18] near the confluence of the Green and the Colorado were interpreted some years ago by G. H. Girty [19] as probably indicating the presence in that district of a formation equivalent to the "Aubrey" limestone (Kaibab). More recent data confirm this probability, as the highest marine fossils in collections made by Geological Survey parties and examined by Mr. Girty [20] contain the same species as the older collections, though no limestone comparable to the Kaibab limestone of the San Rafael Swell has been found at the top of the section. The Kaibab limestone was not seen in Elaterite Basin by either Emery [21] or the writers, nor is it reported by any of the geologists who have worked along Cataract Canyon, on San Juan River, or in the Henry Mountains. It is present only in thin patches in the San Rafael country, being cut out at many places by the pre-Triassic unconformity.

[14] Longwell, C. R., and others, op. cit., p. 8.
[15] Reeside, J. B., jr., and Bassler, Harvey, Stratigraphic sections in southwestern Utah and northwestern Arizona: U. S. Geol. Survey Prof. Paper 129, p. 57, 1922.
[16] Longwell, C. R., The geology of the Muddy Mountains, Nev., with a section to the Grand Wash Cliffs, in western Arizona: Am. Jour. Sci., 5th ser., vol. 1, p. 47, 1921.
[17] Powell, J. W., op. cit., pp. 88-92.
[18] Newberry, J. S., Report of expedition from Santa Fe, N. Mex., to the junction of the Grand and Green Rivers of the Great Colorado of the West, in 1859, p. 98, Washington, 1876.
[19] Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, pp. 670-674, 1907.
[20] Girty, G. H., oral communication.
[21] Emery, W. B., op. cit.

The maximum thickness of the Kaibab limestone measured in the San Rafael Swell is 85 feet, and it ranges from this thickness down to a thin film. In the Circle Cliffs it is 163 feet thick,[22] at Lees Ferry 250 feet,[23] in the Grand Canyon 400 to 600 feet,[24] and in southwestern Utah and northwestern Arizona 775 to 1,050 feet.[25] Evidently the Kaibab limestone thins to the northeast.

As the Coconino sandstone thickens northeastward, and as the Kaibab limestone lies upon it with an apparently conformable contact, it seems probable that the limestone thins almost wholly by the lateral gradation of the limy (Kaibab) facies into the sandy (Coconino) facies. That this may not be the sole reason for the thinning is indicated by the erosional unconformity below the Moenkopi formation in the San Rafael Swell—an unconformity remarkably well shown in a multitude of canyons on Sinbad and clearly seen as an irregular, rolling surface, in some places rising so as to leave a notable thickness of Kaibab limestone and in others sinking so that the basal chert conglomerate of the Moenkopi formation rests directly on the clean sandstone of the Coconino. There can be no question of the relief on this surface, as the Kaibab remnants are separated by wide areas over which they are absent. It is manifest, therefore, that some of the Kaibab limestone has been removed and that in some part the eastward thinning of the Kaibab is due to pre-Triassic erosion.

Yet it is likely that this erosion in a broad view was not very great, for fossils collected from the Kaibab limestone near the head of Black Box Canyon of San Rafael River were determined by G. H. Girty to belong probably to the widespread *Bellerophon* zone, a relatively thin but persistent zone at the top of the Kaibab in the Grand Canyon district and adjacent regions to the north and west of it. Mr. Girty's report is as follows:

The fauna of lot 5472 has obvious Paleozoic affinities and shows relationships to the fauna of the Manzano group and that of the Phosphoria formation. The fauna of lot 5476 is in many respects peculiar, for it consists largely of mollusks, with a notable rarity though not complete absence of brachiopods. Some of the pelecypods of this fauna, which are represented in greater variety and perfection in other collections, are peculiar, and they apparently represent genera new to the Carboniferous. Nevertheless the Paleozoic age of the fauna seems well assured through the presence of such types as *Composita* and *Euphemus*. This is apparently the horizon which has sometimes been called the "*Bellerophon* limestone" and has been regarded as marking the top of the Paleozoic.

5472. Head of Black Box Canyon of San Rafael River. Kaibab, just below lower Moenkopi:

Pustula aff. P. montpelierensis.	Schizodus sp.
Pustula nevadensis?	Aviculipecten sp.
Composita sp.	Lima? sp.
Edmondia aff. E. gibbosa.	Myalina aff. M. perattenuata.
Parallelodon sp.	Griffithides sp.

5476. Head of Black Box Canyon of San Rafael River. Coquina limestone of Kaibab, just below lower Moenkopi shale:

Sponge?	Pleurophorus? sp.
Batostomella? sp.	Anatina? sp.
Composita mexicana?	Plagioglypta canna.
Nucula levatiformis.	Bucanopsis modesta.
Leda obesa?	Euphemus subpapillosus.
Schizodus? sp.	Sphaerodoma sp.

The Weber quartzite and overlying Park City formation of the Uinta Mountain region present a lithologic sequence similar to that of the Coconino sandstone and Kaibab limestone of the San Rafael Swell, and the similarity is somewhat strengthened by the presence in the upper (Phosphoria) part of the Park City of a few species that are also present in the Kaibab, such as *Plagioglypta canna*, *Leda obesa*, and *Euphemus subpapillosus*. In both regions the next higher formation is the marine Lower Triassic.

On the other hand, many students of the Uinta region believe that there is an unconformity within or beneath the Park City formation and that the Weber quartzite is proved by the included fossils to be all of Pennsylvanian age. If the Coconino sandstone is of Permian age, as seems probable in spite of the lack of paleontologic evidence, the similarity of the two sections is therefore merely superficial. It is possible that the top of the Weber quartzite as it is defined at some places is Permian [26] and that some part of the Coconino sandstone of the San Rafael Swell is contemporaneous, but it seems more likely that they are of different ages. The unconformity above the Kaibab formation has no recognized counterpart above the Park City formation, and the Park City is possibly somewhat younger than the Kaibab. At any rate a positive correlation between the San Rafael Swell and the Uinta Mountain region is not indicated by the evidence now available.

Concerning the relations between the Coconino and Kaibab formations of this paper and the Tensleep sandstone and the overlying Phosphoria formation of central Wyoming even less may be affirmed, though again the two regions show the similar condition of a sandstone formation followed by a limestone formation, and that in turn by Triassic beds. The Phosphoria likewise has some species in common with the Kaibab of the San Rafael Swell.

PRE-TRIASSIC UNCONFORMITY

The unconformity at the base of the Triassic, mentioned above, is a striking feature in the San Rafael Swell and one of major importance in the geologic

[22] Longwell, C. R., and others, op. cit., p. 21.

[23] Idem, p. 16.

[24] Noble, L. F., The Shinumo quadrangle, Grand Canyon district, Ariz.: U. S. Geol. Survey Bull. 549, p. 70, 1914.

[25] Reeside, J. B., and Bassler, Harvey, op. cit., pp. 69–76.

[26] Girty, G. H., oral communication.

history of the whole plateau province. Many workers in the Southwest have recognized it, and it has now been traced through much of southern Utah, northern New Mexico, northern Arizona, and eastern Nevada.[27] Yet, although the unconformity is exceedingly widespread, it occurs over large areas close to the same stratigraphic horizon, and if it is true, as has been suggested,[28] that the Coconino and Kaibab grade laterally one into the other, the unconformity is not necessarily of much importance structurally over the plateau province as a whole—that is, it does not indicate a period of orogenic activity.

TRIASSIC SYSTEM

LOWER TRIASSIC SERIES

MOENKOPI FORMATION

Distribution and topographic expression.—The Moenkopi formation lies at the base of the Triassic section over most of the plateau province. It crops out over wide areas in the Waterpocket Fold, the San Rafael Swell, Elaterite Basin, and the canyons of other deeply incised tributaries of Green River.

Over most of this area the Moenkopi formation is exposed in badland topography or in steep slopes beneath the resistant cap of Shinarump conglomerate. Some thick sandstones, however, crop out as ledges, and in the San Rafael Swell the details of the form of the huge Sinbad Dome are beautifully shown in the flexures of a very massive limestone—the Sinbad limestone member—which forms the surface rock over probably four-fifths of Sinbad.

Lithology and thickness.—On the west side of the San Rafael Swell the Moenkopi formation is 735 to 850 feet thick and consists of dominantly red-brown micaceous ripple-marked sandstones, gray lenticular sandstones, and maroon shales, all extremely variable laterally. It includes also, about 200 feet above the base of the formation, a fairly persistent member of thick-bedded light-gray sandy limestone and sandstone, 40 to 150 feet thick, here named the Sinbad limestone member, from its excellent exposures in Sinbad. Near San Rafael River the part of the formation above the Sinbad member has few red strata, and the shales are pyritic and exhibit a dominantly greenish-gray hue in marked contrast with the usual coloring. This gray facies interfingers with the red facies and passes directly into it. Discontinuous gypsum beds occur near the base of the formation in places but are nowhere conspicuous in the Swell. Although the formation appears to be more sandy in the south than in the north, no equivalent of the DeChelly (?) sandstone lentil [29] was recognized.

The Moenkopi is only 585 feet thick at Temple Mountain, on the east flank of the Swell, and 356 feet thick in Elaterite Basin, according to the measurements of Emery.[30] The Sinbad limestone member is represented about 140 feet above the base at Temple Mountain but is not present in Elaterite Basin.

Conditions of deposition.—The irregular lenticular sandstones, the recurrence of mud cracks, clay pellets in sandstones, uniform micaceous beds, and rapid variations, vertically and laterally, all point to continental conditions of deposition for the greater part of the formation. But in the lower part the long, even bedding lines, the good sorting of material, and the association with the unquestionably marine Sinbad limestone member indicate that this portion is of marine origin, at least in the San Rafael Swell.

The green-gray pyritic carbonaceous shales of the local area in the northwestern part of the Swell, though they have not yielded fossils, probably represent delta-pool conditions where much sulphur accumulated. This facies is not confined to the part of the formation below the marine limestone but in this local area, near Window Blind Butte and the mouth of Buckhorn Wash, extends to the very top, and it is probable that here all the Moenkopi is marine. A similar, probably local replacement of normally red strata by gray strata has been noted [31] on Vermilion Creek in Moffat County, Colo., where the Woodside and Thaynes (?) formations contain only gray beds, though not far to the west they are so red as to justify the name Flaming Gorge given to the exposures on Green River by Powell. A second locality of gray beds replacing red in the Woodside and Thaynes (?) formations was noted by Messrs. Spieker and Reeside on the south flank of Blue Mountain in T. 4 N., R. 102 W., Colorado. A second locality in the Moenkopi formation, reported by E. T. McKnight, is adjacent to Green River a few miles above its junction with the Colorado. Probably marine strata occur at many other places in the San Rafael Swell, but fossils are rare, if present at all, and it is believed that most of the Moenkopi of this region is continental.

Local unconformities are present within the formation; one notable example may be seen in the cliff face at Tan Seeps, in Sinbad. None of these appear

[27] Gilbert, G. K., op. cit., p. 8. Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Ariz.: Am. Jour. Sci., 3d ser., vol. 20, pp. 221–225, 1880. Ward, L. F., Status of the Mesozoic floras of the United States: U. S. Geol. Survey Mon. 48, p. 19, 1905. Robinson, H. H., The San Franciscan volcanic field: U. S. Geol. Survey Prof. Paper 76, p. 24, 1913. Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, pp. 362–364, 1917; General stratigraphic break between Pennsylvanian and Permian in western America [abstract]: Geol. Soc. America Bull., vol. 28, pp. 169–170, 1917. Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, p. 21, 1917. Shimer, H. W., Permo-Triassic of northwestern Arizona: Geol. Soc. America Bull., vol. 30, p. 494, 1919. Dake, C. L., The pre-Moenkopi (pre-Permian?) unconformity of the Colorado Plateau: Jour. Geology, vol. 28, pp. 66–74, 1920. Longwell, C. R., The pre-Triassic unconformity in southern Nevada: Am. Jour. Sci., 5th ser., vol. 10, pp. 93–106, 1925. Longwell, C. R., and others, op. cit., p. 9. Reeside, J. B., jr., and Bassler, Harvey, op. cit., pp. 60–61.

[28] Longwell, C. R., and others, op. cit., pp. 8–9.

[29] Miser, H. D., Geologic structure of San Juan Canyon and adjacent country, Utah: U. S. Geol. Survey Bull. 751, pp. 122–123, 1925. Gregory, H. E., op. cit., pp. 31–33.

[30] Emery, W. B., op. cit., pp. 558–559.

[31] Sears, J. D., Geology and oil and gas prospects of part of Moffat County, Colo., and southern Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 751, pp. 281, 284, 1925.

to be of any considerable extent, being normal local features in a continental deposit.

Age and correlation.—The correlation of the Moenkopi formation of the San Rafael Swell with the type Moenkopi of the Navajo Reservation is based upon its lithologic character, its stratigraphic position between unmistakable Kaibab limestone and Shinarump conglomerate, and fossil collections made from the Sinbad limestone member. The fossils were submitted to G. H. Girty for determination. He reports as follows:

The three lots, 5473, 5474, 5475, display the same fauna, the one which in the Grand Canyon section was at first called Permian, in the Wasatch section "Permo-Carboniferous," and in the Idaho section Lower Triassic. An abrupt and impressive faunal change marks the transition from Permian to Triassic in all these sections, and the higher fauna is now generally recognized as of Mesozoic age.

The table below shows the species found.

Fossils of the Moenkopi formation

	5473	5474	5475
Echinoid spines	----	----	×
Pleuromya? sp	×	×	×
Pleuromya? n. sp	×	×	×
Edmondia? sp., several	----	----	×
Myophoria n. sp	×	----	×
Myacites inconspicuus	×	----	----
Entolium n. sp	×	----	×
Aviculipecten sanrafael n. sp	×	----	×
Aviculipecten sanrafael, several varieties	----	----	×
Aviculipecten occidaneus?	×	----	×
Aviculipecten thaynesianus	×	----	----
Aviculipecten sp. indet	×	----	×
Myalina n. sp., several	×	----	×
Bakewellia? n. sp	----	----	×
Pteria? sp	----	----	×
Astartella forresteri	×	----	×
Pleurophorus n. sp	----	----	×
Pleurophorus sp	----	----	×
Laevidentalium? n. sp	×	----	×
Natica lelia	×	----	×
Natica lelia var	----	----	×
Naticella sp	----	----	×
Holopea sp	----	----	×
Aclisina? sp	×	----	×
Bulimorpha n. sp	×	----	×
Sphaerodoma? n. sp	----	----	×
Zygopleura n. sp	----	----	×
Meekoceras gracilitatis?	----	----	×
Meekoceras? sp	----	----	×
Ostracoda, indeterminate	----	----	×

5473. 200 yards up Red Canyon from its junction with San Rafael River. Sinbad limestone member of Moenkopi formation. Collected by James Gilluly.

5474. Half a mile south of head of Black Box, San Rafael River. Sinbad limestone member of Moenkopi formation. Collected by James Gilluly.

5475. Black Box, San Rafael River. Basal zone of Sinbad limestone member of Moenkopi formation. Collected by James Gilluly.

As Mr. Girty's statement shows, the marine fossils of the Moenkopi formation of the San Rafael Swell permit a very satisfactory correlation with the group that includes the Woodside, Thaynes, and Ankareh formations of the western Uinta Mountain region, now accepted widely as Lower Triassic, though long thought to be Permian. In the eastern Uinta Mountains [32] there is doubt as to the identity of the Ankareh formation, but it seems at least very likely that the Woodside and Thaynes formations are represented even though paleontologic evidence is still lacking. Farther northeast, in Wyoming, the Chugwater formation seems to be the most likely representative of the Lower Triassic, though paleontologic evidence is restricted to pelecypods of doubtful affinities and to the single gastropod *Natica lelia*, all contained in a limestone in the upper part of the formation.

UPPER (?) TRIASSIC SERIES

SHINARUMP CONGLOMERATE

Distribution and topographic expression.—One of the most remarkable formations of the plateau province is the Shinarump conglomerate. It is present over nearly all the region from western New Mexico [33] to southeastern Nevada [34] and northward to the north end of the San Rafael Swell. It is not definitely recognizable in western Colorado nor in the Uinta Mountains, unless it is represented by the siliceous conglomerate at the base of the Ankareh (?) formation which rests unconformably upon the Thaynes (?) formation in the eastern Uinta region,[35] though there is at the present time very little evidence other than the structural relations of the beds. It is possible that the Ankareh (?) is merely an introductory phase of the Nugget sandstone and much later than the Shinarump.

The topographic expression of the Shinarump is strong. It lies between two formations of relatively unresistant material that break down into slopes, between which the Shinarump, though not really an extremely hard formation, has the relief of one. It forms vertical cliffs capping steep Moenkopi slopes, and from its top the weak Chinle formation has at many places been swept for considerable distances, leaving wide conglomerate-capped terraces and mesas characteristic of the formation. Even where the Shinarump is only 30 or 40 feet thick, the wall it offers is in many places unscalable for miles.

Lithology and thickness.—The Shinarump lies unconformably on the Moenkopi, its conglomerates and sandstones resting in the hollows of the uneven Moenkopi surface. Whether this unconformity is angular as well as erosional is not certain. The thinning of the Moenkopi eastward from the south end of the San Rafael Swell may conceivably be due to original thinning of the formation or to angular unconformity.

[32] Sears, J. D., op. cit., p. 284. Reeside, J. B., jr., Notes on the geology of Green River Valley between Green River, Wyo., and Green River, Utah: U. S. Geol. Survey Prof. Paper 132, pp. 48, 49, 1923.

[33] Gregory, H. E., op. cit., p. 38.

[34] Longwell, C. R., Geology of the Muddy Mountains, Nev., with a section to the Grand Wash Cliffs in western Arizona: Am. Jour. Sci., 5th ser., vol. 1, pp. 39–62, 1921.

[35] Sears, J. D., op. cit., p. 284. Reeside, J. B., jr., op. cit., pp. 40, 43, 49.

At the southwest end of the Swell, on Muddy Creek, the thickness is 735 feet. At Temple Mountain, on the southeast reef, Emery measured 585 feet and in Elaterite Basin only 356 feet. No system of variations is apparent in northeastern Arizona and northwestern New Mexico with which this progressive eastward thinning of the Moenkopi can be checked. It is certainly presumptive evidence of pre-Shinarump beveling in this region, however.

Throughout the San Rafael Swell and Green River Desert the Shinarump conglomerate is rarely missing where the beds at its horizon are exposed, yet it almost nowhere exceeds 200 feet in thickness and in the greater part of the exposures ranges between 30 and 100 feet.

Its lithologic character is not such as to suggest this remarkable persistence. Everywhere the Shinarump is clearly recognizable as an interfingering series of lenticular gritty sandstones, conglomerates, clean sandstones, variegated mudstones, and even shales—a series cut by hundreds of channel unconformities within itself and composed of lenses which thicken and thin with bewildering rapidity. Despite its local variations, its continuity is essentially unbroken in the western part of the district here discussed. In this area the conglomeratic facies is perhaps less striking than it is farther south, for in many of the exposures the formation is hardly more than a coarse sandstone. The principal pebbles in the conglomerates are white and yellow quartz, black chert, yellow quartzite, and subordinate dense gray limestone, all well rounded and set in a matrix of quartz sand. Silicified and carbonized wood is almost invariably present in this area, as it is through the entire province. Mud balls are numerous. Carnotite and other uranium minerals occur at certain places, notably at Temple Mountain, on the southeast flank of the Swell, where the deposits were mined during the World War.

Conditions of deposition.—The numerous lateral and vertical variations of the Shinarump conglomerate and its apparently conformable position beneath the Chinle formation, which is definitely continental, point to a continental origin for the Shinarump conglomerate also. The evidence is not conclusive, but the improbabilities that arise on a postulate of marine origin seem so great that the evidence cited appears sufficient. A marine transgression extending over 100,000 square miles (the minimum areal extent of the Shinarump conglomerate) would be expected to leave offshore sediments and marine fossils. The only suggestion of such fossils is a collection of pelecypods found by Gregory in the Shinarump at Beautiful Valley, Ariz., one of which was interpreted by T. W. Stanton as "almost certainly marine." [36] This specimen has a carditoid aspect quite unlike that of any nonmarine shells previously recorded from western North America. It is, however, like shells of the genus *Diplodon*, lately described from the nonmarine Triassic Newark group of the eastern United States and has been recently assigned to that genus.[36a] The other specimens are fragmentary and of little value but could be parts of shells of *Unio*, a fresh-water form. This isolated occurrence therefore affords little ground for overthrowing the lithologic evidence in favor of a continental origin, yet a final conclusion must be postponed until further evidence is available.

Age and correlation.—No reports of diagnostic fossils from the Shinarump have been published, but its fossil wood has Upper Triassic affinities,[37] and cycad foliage of Upper Triassic aspect was collected by R. C. Moore [38] near Waterpocket Wash, Garfield County, Utah. The Chinle has furnished Upper Triassic vertebrates and fresh-water invertebrates, and it is probable that the Shinarump is the "basal conglomerate" of the sedimentation which was continued in the Chinle and, like that formation, is of Upper Triassic age.

Correlation with areas outside the plateau province seems impossible at present. The Shinarump probably lenses out to the east beneath the overlap of the Chinle formation, so that the "saurian conglomerate" of the San Juan Mountains, though similarly placed, being the basal member of the Dolores formation of that region, is not the equivalent of the Shinarump.

UPPER TRIASSIC SERIES

CHINLE FORMATION

Distribution and topographic expression.—The Chinle formation is exposed in the San Rafael Swell, in the Waterpocket Fold, in Elaterite Basin and neighboring canyons, and along the Colorado above the junction with Green River. It is undoubtedly equivalent to the lower part of the Dolores formation of the San Juan Mountains, the upper sandstone of that unit probably being the equivalent of the Wingate sandstone of the plateau.

It is typically exposed in steep slopes between the ledge of Shinarump conglomerate and the base of the Wingate sandstone.

Lithology and thickness.—The Chinle formation is apparently conformable upon the Shinarump conglomerate. It is a series of green-gray sandstones, micaceous red-brown sandstones, variegated marls, limestone conglomerates, and maroon shales, all very lenticular and interfingering with one another, though the individual units are considerably more persistent than those in the Shinarump conglomerate. The bedding is rather irregular, and few of the sandstones exceed 5 feet in thickness. Individual beds that can be followed for more than half a mile are exceptional. The sandstones all contain pellets of shale; the shales

[36] Gregory, H. E., op. cit. (Prof. Paper 93), p. 41.

[36a] Reeside, J. B., jr., Two new unionid pelecypods from the Upper Triassic: Washington Acad. Sci. Jour., vol. 17, pp. 476–478, figs. 1–2, 1927.

[37] Gregory, H. E., op. cit., p. 41.

[38] Berry, E. W., Cycads in the Shinarump conglomerate of southern Utah: Washington Acad. Sci. Jour., vol. 17, pp. 303–307, figs. 1–5, 1927.

have mud-cracked, curled surfaces at many horizons; and these features, combined with the lateral variability of the formation, point to a continental origin. Silicified tree trunks like those in the Shinarump conglomerate are very common.

The Chinle formation ranges in thickness from 141 to 225 feet in the San Rafael Swell and is 300 feet thick in Elaterite Basin, according to Emery.[39] These thicknesses are all notably less than those shown in the country to the south. In the Henry Mountains the formation ("Shinarump, division a," of Gilbert [40]) is 300 feet thick, in the Circle Cliffs 475 feet, and along San Juan River from 830 to 1,182 feet,[41] but in all these localities it is notably more shaly than within the region here discussed. The Chinle formation is continental in origin. Possibly the source of the sediment lay to the north, so that the coarser material was deposited on the nearer part of the basin of deposition while most of the finer was carried farther to the south. It might well be that in a basin of continental deposition a very great thickness of fine detritus might accumulate in the deeper part while a much thinner body of coarser sediment was being deposited on the marginal portions. Especially is this probable in basins where a large fraction of the contributed sediment is in a finely divided state and in those where the area of deposition encroaches gradually upon the original area of denudation. This matter has been elucidated by Lawson [42] for the bolson deposits, but a priori the principle involved appears to the writers as being of very general application. The lithology of the Chinle does not appear to be that of a fanglomerate but rather more characteristic of flood-plain or swamp deposits, but it is suggested that the relations between distribution of thickness and coarseness of sediments of the one may apply with some modifications to the other as well. Later erosion may have stripped off more of the coarser deposits than of the finer, so that the variations in thickness are not necessarily altogether depositional.

There is a marked unconformity at the top of the Chinle in the San Rafael Swell. Cracks in the upper surface are filled to depths of 6 or 8 feet with sands of the overlying Wingate; and fragments of shale and chunks of sandstone of the Chinle are incorporated in the basal beds of the Wingate sandstone. The upper surface of the Chinle formation is slightly rolling when viewed in the large, and its members are cut off at low angles, a truncation which is visible on close inspection.

That this unconformity is not everywhere prominent if, indeed, it is everywhere present, is seen from the references to its uncertainty by Emery,[43] Gregory,[44] and Reeside and Bassler,[45] but the definite evidence seen in the San Rafael Swell is corroborated by observations made elsewhere by Dutton,[46] Gilbert,[47] and Lee.[48]

The unconformity between the Dolores and La Plata in the San Juan Mountains described by Cross [49] is not valid evidence of a break between Chinle and Wingate, as thought by Gregory,[50] because, if Cross's correlation of the upper sandstone of the Dolores with the Wingate sandstone (called Vermilion Cliff by Cross) is correct, that unconformity lies at the top of the Wingate instead of at the base. This matter is further discussed below.

The evidence for the Upper Triassic age of the Chinle has been summarized by Gregory.[51] No new data bearing on this question were obtained by the writers.

JURASSIC (?) SYSTEM

GLEN CANYON GROUP

Throughout the plateau country the most prominent formations present are the group of massive sandstones that rest upon the Chinle formation. To these sandstones the name Glen Canyon group has been given by Gregory and Moore,[52] a name that for some areas replaces the term La Plata "group" and for other areas is applied for the first time as a name for the sandstone assemblage as a whole. The name is derived from the excellent exposures of the rocks in Glen Canyon of Colorado River, Kane County, Utah, and adjacent areas in Arizona. In the Navajo country the group is ordinarily divisible into three units—a thick cross-bedded, dominantly red sandstone at the base, a similar massive sandstone, chiefly tan or white, at the top, and a middle thinner-bedded unit of red shales, lenticular sandstones, and limestones, which is, in most localities, much more limy than the sandstones it separates. The upper and lower divisions were named by the early explorers the White (or Gray) Cliff and Vermilion Cliff groups, respectively, and have been recognized widely by many workers since. The middle thin-bedded division has received less notice until more recently, largely because it is not everywhere developed.

In southwestern Utah the group is not so readily divisible but forms a single unbroken unit, in which

[39] Emery, W. B., op. cit., p. 563.

[40] Gilbert, G. K., op. cit., p. 6.

[41] Longwell, C. R., and others, op. cit., pls. 1 and 2, pp. 6 et seq.

[42] Lawson, A. C., The epigene profiles of the desert: California Univ. Dept. Geology Bull., vol. 9, pp. 23-48, 1915.

[43] Emery, W. B., op. cit., p. 563.

[44] Gregory, H. E., op. cit. (Prof. Paper 93), p. 48.

[45] Reeside, J. B., jr., and Bassler, Harvey, op. cit., p. 64.

[46] Dutton, C. E., Report on the geology of the High Plateaus of Utah, p. 148, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

[47] Gilbert, G. K., op. cit., p. 9.

[48] Lee, W. T., oral communication.

[49] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Engineer Mountain folio (No. 171), p. 7, 1910, and several other folios.

[50] Gregory, H. E., op. cit. (Prof. Paper 93), p. 48.

[51] Idem, pp. 46-47.

[52] Gregory, H. E., and Moore, R. C., manuscript report on geology of southern Utah and northern Arizona.

there is no consistent coloring but which varies capriciously from red to white, though red is more common in the lower part and white in the upper part.[53]

To the east, where the divisions are more marked,[54] Gregory [55] has applied names to distinguish them. For the lower massive division Dutton's name Wingate sandstone was adopted. The name Todilto formation was chosen for the thinner-bedded middle division, and Navajo sandstone for the upper massive division. The name Todilto was originally used for the thin middle division of limestone and sandstone in Todilto Park, N. Mex., and its applicability in more westerly areas to which the division can not be traced continuously is based on the position of the beds to which it is applied, between accepted Wingate and Navajo sandstones.

Lee [56] has suggested that the type Todilto is probably later than the so-called White Cliff of the Henry Mountains, a suggestion to which Emery [57] agreed and which was certainly not excluded by the scanty amount of detailed work which had been done in the intervening areas at that time.

WINGATE SANDSTONE

Distribution.—The Wingate sandstone is widely distributed. It is present in the San Rafael Swell, southeastward into western Colorado, and wherever beds at its horizon are exposed over all of northwestern New Mexico, northeastern Arizona, and southern Utah. It has been traced by Gregory and Moore [58] into the single massive sandstone at Zion Canyon, which includes equivalents of both Wingate and Navajo sandstones, and it is with little doubt represented in the Jurassic sandstone in southern Nevada described by Longwell.[59] (See pl. 17, *A*, *B*.)

Thickness.—In the Navajo country the Wingate sandstone ranges from 30 to 450 feet in thickness.[60] In the Circle Cliffs it averages 300 feet.[61] In the Henry Mountains it is the lower part of the 500 feet of the so-called Vermilion Cliff group measured by Gilbert.[62] In the San Rafael Swell the measurements range between 360 and 400 feet. According to Emery [63] the massive member at the base of his Wingate sandstone in Elaterite Basin is 375 feet thick.

The Orange Cliffs of the upper Colorado Valley are made by this massive sandstone, capped by a hard ledge at the base of the thin-bedded Todilto (?) formation. The sandstone becomes thinner in this direction, being 210 feet thick near Courthouse mail station on the road between Moab and Thompsons, 250 to 275 feet in Salt Valley, and 250 feet near the mouth of Dolores River. Sections and photographs by Coffin [64] show its continuation, with comparable thickness, up Dolores River to the south and in Sinbad and Paradox Valley. Mr. Reeside, in company with C. E. Dobbin, visited Sinbad and Paradox Valley in 1926 and agrees with this interpretation.

Lithology.—Throughout the western part of the San Rafael Swell the Wingate sandstone is very massive, with few or no partings of shaly material between the beds. Most of the strata are highly cross-bedded on a very large scale and in a most irregular manner, though not a few are characterized by slabby fractures and even bedding. The grain is uniformly fine, no silt occurs except in a few lenticular beds, and almost no mineral but quartz is present except for the few thin lenses of limestone. These limestones are largely silicified, and none observed exceed 2 feet in thickness. The cement of the sandstone is nearly everywhere lime, commonly not very firm.

Toward the east the beds appear to become less massive. A 340-foot cliff of Wingate at the mouth of Buckhorn Wash is divisible into only four beds, and in Salt Valley the average bed is only about 12 feet thick. The shale partings are very thin in Salt Valley, but only a few miles to the east, at the mouth of Dolores River, the average bed, except the one massive unit that forms the uppermost 40 feet, is only 3 to 8 feet thick, and the layers are nearly everywhere separated by shale partings not more than an inch thick. This thin bedding is not prominent, however, in the western Colorado localities discussed by Coffin.

The color of the Wingate cliff is nearly everywhere red. At many places this is not at all an original hue but is due to wash from the maroon shale lenses in the overlying Todilto (?) formation. Where the dip is steep and the shales have been swept back some distance from the lip of the cliff, the sandstone may be buff or gray. However, in many places the color is an original pink, somewhat darkened on weathering. On the whole this formation is reddish as compared with the overlying Navajo—a distinction which long ago gave rise to the name Vermilion Cliffs and whose validity is somewhat emphasized by the local name Orange Cliffs applied to the ledges of this formation from the mouth of Green River eastward.

Conditions of deposition.—The origin of the Wingate sandstone has long been a subject of interest in the geology of the plateau. The conditions that permitted the deposition over such tremendous areas of

[53] Reeside, J. B., jr., and Bassler, Harvey, op. cit., p. 63.

[54] Butler, B. S., The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, p. 82, 1920. Dake, C. L., op. cit., p. 638.

[55] Gregory, H. E., op. cit., pp. 50–59.

[56] Lee, W. T., Early Mesozoic physiography of the southern Rocky Mountains: Smithsonian Misc. Coll., vol. 69, No. 4, pp. 13, 14, 1918

[57] Emery, W. B., op. cit., pp. 568–570.

[58] Gregory, H. E., and Moore, R. C., op. cit.

[59] Longwell, C. R., Geology of the Muddy Mountains, Nev.: Am. Jour. Sci., 5th ser., vol. 1, p. 46, 1921.

[60] Gregory, H. E., op. cit. (Prof. Paper 93), p. 54.

[61] Moore, R. C., Stratigraphy of a part of southern Utah: Am. Assoc. Petroleum Geologists Bull., vol. 6, p. 217, 1922.

[62] Gilbert, G. K., op. cit., pp. 6–7.

[63] Emery, W. B., op. cit., p. 565.

[64] Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, pp. 48–55, 1921.

such thick masses of uniform fine sand, including in the western exposures so few thin beds, are indeed difficult to picture. The remarkable large-scale tangential cross-bedding and the absence of fossils, except a few dinosaur tracks, fit well the character of a desert dune deposit. The considerable amount of indisputably water-laid material and the limestone pans are explicable, if such an origin is assumed, as due to wash during storms and to deposition in playas in periods of high ground-water level. The thinner bedding toward the east seems to require deposition in water, and the shale partings there confirm this inference. Whether these waters were marine, brackish, or fresh, however, no evidence known to the writers appears to disclose.

Age and correlation.—Opinion as to the age of the Wingate sandstone has fluctuated from a general assignment to the Triassic to about the same agreement on the Jurassic. The information upon which to decide this question has been eagerly sought for more than 40 years, and hardly any more pertinent data are available to-day than at the time of the early explorers. Cross [65] assigned the Wingate (his so-called Vermilion Cliff sandstone) to the Triassic, on the basis of the Triassic fossils in the Dolores and the correlation of his Vermilion Cliff with the upper sandstone portion of that formation. Recent work has emphasized the significance of the unconformity between the Chinle and the Wingate to which Gilbert [66] called attention long ago, and, if the correlation of Cross is correct, this unconformity occurs between the fossiliferous beds of the Dolores and the base of the sandstone member. Accordingly the fossils can not be considered as proving the Triassic age of the so-called Vermilion Cliff—the present Wingate sandstone. Gregory's assignment of the Wingate to the Jurassic, on the other hand, was due to his interpretation of it as the lower part of the La Plata sandstone of the San Juan Mountain region.[67] As this correlation is almost certainly incorrect, the inference of Jurassic age derived from the assignment of the La Plata to the Jurassic period fails. The question is discussed at length on pages 72-73, after the description of the Navajo sandstone, for both formations are closely involved, and the data available are similar for both.

The correlation of the Wingate sandstone of this district with that of surrounding regions is based largely on (1) its distinctive lithology and position between the equally distinctive Chinle formation and the overlying thin-bedded Todilto (?); (2) the tracing of the Wingate from the Navajo country to the Waterpocket fold by Gregory and Moore, to the north end of the Fold by Moore, and thence throughout the San Rafael Swell by the present writers. The correlation of the Wingate sandstone, thus verified as a continuous unit from northern Arizona to San Rafael River, with the lower massive member of Emery's Wingate in Elaterite Basin is based on its lithologic character and its position above the Chinle. Variable thickness of the member without any unconformity at the top is mentioned by Emery as an argument against the classification of it as a formation, but this argument loses much weight in view of the possible irregularities because of the unconformity at the base and fails completely in the face of the actual tracing of the outcrop over so wide an area. Although mapping of the unit was not carried up the Colorado from the mouth of Green River, the clear-cut features of the lithology permit no doubt of the identity of the sandstone of the Orange Cliffs at Elaterite Basin with that at Moab. From Moab it was traced without any break as far as the mouth of Dolores River. The work of Coffin extends its continuity from a locality a few miles southeast of this point as far as Paradox Valley. In view of the correlation offered by Cross [68] between Colorado River and the type section of the Dolores formation in the San Juan Mountain country, it seems that the Wingate is to be definitely correlated with the upper sandstone member of the Dolores formation and not with the lower part of the La Plata, as has been long assumed in spite of Cross's early work.

TODILTO (?) FORMATION

Distribution and topographic expression.—The name Todilto was applied by Gregory [69] to a limestone resting on the Wingate sandstone in Todilto Park, N. Mex. In the region northwest of the type locality and separated from it by areas in which younger beds only are exposed, Gregory applied Todilto to a unit which contained thin-bedded sandstone, shale, and minor beds of limestone and which he believed to occupy a place in the sequence of formations identical with that of the typical Todilto limestone. No work has been done in later years to substantiate this correlation, and there is at the present time some doubt that it is correct. In this paper the name Todilto is therefore applied with a query to the unit of sandstone and shale in the northern exposures. The Todilto (?) formation, as thus defined, is widely distributed, though it has not been recognized in the Vermilion Cliffs near Lees Ferry nor in southwestern Utah. It has been traced from the San Juan River region to Rainbow Bridge through Cataract Canyon and to the Henry Mountains by Miser, Paige, and Longwell [70] and northward along the Waterpocket Fold by Moore.[71] The formation is well developed in the San Rafael

65 Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, p. 636, 1907.

66 Gilbert, G. K., op. cit., p. 9. Dutton, C. E., op. cit., p. 148. Emery, W. B., op. cit., p. 563. Gregory, H. E., op. cit. (Prof. Paper 93), p. 48. Reeside, J. B., jr., and Bassler, Harvey, op. cit., p. 64

67 Gregory, H. E., op. cit., p. 51.

68 Cross, Whitman, and Howe, Ernest, Red beds of southwestern Colorado and their correlation: Geol. Soc. America Bull., vol. 16, pp. 472-473, 1905.

69 Gregory, H. E., op. cit. (Prof. Paper 93), pp. 55-56.

70 Longwell, C. R., and others, op. cit., p. 12.

71 Moore, R. C., op. cit., p. 218.

Swell (see pl. 17, *C*), in the Green River Desert, and up Colorado River from the mouth of Green River. It was recognized between Moab and Monticello and in Salt Valley and was traced to the east by the writers as far as the mouth of Dolores River. It is unquestionably present well southeast of this point, as is seen from the descriptions and photographs by Coffin.[72]

Throughout this area the Wingate sandstone typically stands in a nearly vertical wall, the top of which is a resistant, very limy sandstone. This is the lowest member of the thinner-bedded, somewhat shaly sandstones and occasional limestones of the Todilto (?) formation. In most localities only the lower member is very resistant, so that it caps the Wingate cliffs; the upper parts are softer and weather down quickly, leaving benches beneath the overlying cliffs of the Navajo sandstone.

Thickness and lithology.—In the Navajo country the Todilto (?) formation is as much as 200 feet in thickness.[73] Moore measured 125 to 215 feet of Todilto (?) in the Circle Cliffs,[74] Longwell assigns a thickness of 249 feet to it near Trachyte Creek,[75] and in the San Rafael Swell it ranges in thickness from 44 to 240 feet and averages probably about 120 feet. Toward the east it averages about the same, being 150 feet thick (measured by Emery) in Elaterite Basin, 120 feet near Courthouse mail station on the Moab-Thompsons road, 75 to 100 feet in Salt Valley, and about 200 feet near the mouth of Dolores River.

The Todilto (?) formation differs but little in composition from the Navajo and the Wingate. It is thinner bedded, however, is exceedingly variable, and carries many lenses of clean well-laminated shale, usually red. Limestones occur locally, though they are hardly more numerous in the Todilto (?) than in the Navajo and Wingate. Shale pellets and angular chunks of shale are very common in the sandstone beds.

The contact of the Todilto (?) formation with the Wingate sandstone in most of the western localities is abrupt rather than transitional, but the impression was gained, as the beds were traced toward the east, that the Todilto lithology is increasingly difficult to differentiate sharply from that of the Wingate sandstone, and in the upper Dolores Valley the two were not differentiated by Coffin [76] but were both included in the upper sandstone of the Dolores formation.

The upper boundary of the Todilto (?) is also difficult to determine in some localities. Usually there is a rather definite change from the more or less parallel bedding of the Todilto (?) to the irregular cross-bedding of the Navajo sandstone, but the Navajo in its variations locally approaches in bedding that of the Todilto (?), and at many places it would be difficult to select any except an arbitrary boundary through a distance of 50 feet, or even more. It is the opinion of the writers that deposition was essentially continuous from the base of the Wingate to the top of the Navajo, with only such breaks as inevitably accompany continental deposition and only such erosion as would be expected in local variations of streams.

Conditions of deposition.—From the irregular, lenticular form of the beds, the interfingering shale, sandstone, and shale conglomerate, the presence of mud cracks, and numerous unquestionable scoured and filled channels, the origin of the Todilto (?) formation is ascribed with considerable confidence to deposition by rapidly shifting currents. Whether these currents were in rivers or tidal channels is somewhat uncertain. The only fossils found in the formation in Arizona have been dinosaur tracks and in the San Rafael Swell a small indeterminate pelecypod in sec. 16, T. 20 S., R. 13 E., west of Cottonwood Springs. The tracks probably favor a continental origin for the formation; the pelecypod may be marine or nonmarine. Near Moab, Utah, A. A. Baker [77] has recently collected several species of *Unio* that indicate with certainty deposition of the formation in fresh water in that area. The question is therefore unsettled, though a continental origin seems much more probable.

Age and correlation.—The dinosaur tracks found by Gregory in Arizona were determined by Lull [78] to be not older than uppermost Triassic. The shells found by Mr. Baker near Moab belong to long-ranging types that might be found at many horizons from Upper Triassic upward. No other data are available for this formation as distinct from the associated Wingate and Navajo sandstones, and the age of the group is discussed after the description of the Navajo.

Emery [79] noted this zone in the Green River Desert, but as he believed that its variable distance above the base of the Wingate (as shown by his Elaterite Basin and Temple Mountain sections) precluded the possibility of its representing the Todilto of the Navajo country, he included it in the Wingate. The evidence of the unconformity beneath the Wingate has been strengthened by numerous observations since that time, and the irregularities in thickness seem thereby sufficiently explained.

That the thin-bedded zone—the Todilto (?) formation—resting upon the Wingate is at a somewhat variable distance above the base is indeed the fact. Yet if the mass of lenticular sandstones and shales constituting the Todilto (?) is considered a fluviatile deposit between two series of dune sands, such variation is to be expected and offers no bar to the con-

72 Coffin, R. C., op. cit., pp. 48-50.
73 Gregory, H. E., op. cit. (Prof. Paper 93), pp. 55-56.
74 Moore, R. C., op. cit., p. 205.
75 Longwell, C. R., and others, op. cit., pl. 2.
76 Coffin, R. C., op. cit., pp. 48, 50.
77 Oral communication.
78 Gregory, H. E., op. cit. (Prof. Paper 93), p. 56.
79 Emery, W. B., op. cit., pp. 565-567.

ception of the unit as a formation. The point that seems most important is the continuity of a zone of deposits by shifting currents, perhaps tidal but probably fluviatile, between two deposits, which, whatever their origin, were surely laid down under fairly similar conditions that were widely different from those of the intermediate zone. The question whether this intermediate series is everywhere of exactly the same age seems not a crucial one in view of the wide areas over which it is unbroken, and if its beds are homotaxial rather than synchronous in deposition, it seems still to merit recognition as a distinct formation, with an important place in the geologic history of the plateau country.

Toward the southeast the Todilto (?) is clearly recognizable in western Colorado, where it is included by Coffin [80] in the Dolores. The thin-bedded sandstones just above his massive Dolores sandstone are almost certainly equivalent, at least in the lower part, to the Todilto (?) formation of southeastern Utah, though they may also include a small part of the Navajo at the top.

NAVAJO SANDSTONE

Distribution and topographic expression.—The Navajo sandstone is one of the most widespread formations of the plateau country. It was named from its prominent development in the Navajo Reservation but has been traced to the west and north and has been recognized as making up the White Cliffs of southern Utah. It is present in the walls of Glen Canyon, the Echo Cliffs, the Waterpocket Fold, and the Henry Mountains. The Navajo forms a cliff completely encircling the San Rafael Swell (see pl. 18) and is exposed in many canyons through the Green River Desert and up Colorado River to the eastern border of Utah. In Colorado it is identifiable as the "Lower La Plata" of Coffin,[81] and farther south it occurs in the type La Plata of the San Juan Mountain region.[82]

Through most of this area the Navajo forms a very characteristic topography, marked by huge domes and rounded masses where the overlying rocks are soft or have been removed and by sheer cliffs many scores of feet high where they are resistant. These cliffs and domes are among the most prominent features of the country and give much of the picturesque grandeur for which plateau scenery is so famous.

Lithology and thickness.—The lower contact of the Navajo sandstone is in most places definite, though locally gradational, as water-laid material is common in the sandstone and in places occurs at the base; that is, conditions characteristic of Todilto (?) deposition persisted longer in some places than in others.

Cross-bedding on a large scale is typical; a bed 100 feet or more thick may show no true bedding but only long lines of tracery descending at angles as high as 30° with the true bedding and curving at the base into parallelism with it. Some angular cross-bedding is also present, as well as a subordinate amount of even, parallel lamination, but the dominant and striking feature of the sandstone, here as elsewhere, is the large-scale tangential bedding.

The individual laminae differ but very slightly in grain, the bedding being apparently brought out by a scattering of slightly coarser grains over the surface of normal laminae. Nearly all the grains are quartz, though some agate and a little feldspar are present. Toward the top of the formation in the San Rafael Swell there is in many places an interrupted zone of lenticular limestones, though isolated limestone lenses occur at many other horizons also. The limestone zone is typically expressed in the topography as a wide bench, above which the "beehive" domes of the upper Navajo rise and below which the cliffs fall vertically to the upper bench of the Todilto (?) formation. One zone of sporadic pebbles 2 or 3 inches in diameter was found on the wedge between Buckhorn Wash and San Rafael River, but it is apparently almost unique. The pebbles are quartz, highly polished and faceted—perfect examples of "dreikanter."

In the southwesterly exposures the Navajo is described as white; in the Navajo Reservation it is red. In the San Rafael Swell it is dominantly gray to tan but in places red. Toward the east the principal color is gray, though in places the formation is white. The cement is calcite, locally stained with iron oxide.

Conditions of deposition.—The Navajo has been considered a typical eolian deposit by many writers since the first suggestion of this origin by Gregory. Indeed, it seems difficult to conceive of any other mode of deposition for this tremendous mass of sand. The cross-bedding, cutting itself off at all angles apparently without system; the texture, a scattering of larger grains over wide surfaces of smaller; the well-rounded grains; and the absence of silt are all reconciled with this theory, though none of these features can be said to constitute proof in itself. The presence of the dreikanter mentioned above also accords with this view. The limestone lenses unquestionably bespeak the existence of some basins, probably ephemeral, in which water stood, and there is evidence in the even stratification of many beds that many clastic members of the sandstone were also deposited from water. This would, of course, be expected in any desert dune country, for the torrential rains of such a region would surely leave traces of their reworking of some dune sand and its deposition in interdune depressions.

Age and correlation.—No fossils have ever been reported from the Navajo sandstone. Its age can accordingly not be definitely determined but must be judged by its general stratigraphic relations. Whatever the age of the Navajo, it is closely bound up with

[80] Coffin, R. C., op. cit., p. 50.
[81] Idem, pp. 61–76.
[82] Lee, W. T., U. S. Interior Dept. Mem. for the Press, Mar. 30, 1926.

the Wingate and Todilto. Tracing over wide regions in the plateau by Moore,[83] Gregory,[84] Miser,[84] Lee,[84] and the writers, although disclosing local unconformities within the Todilto (?) formation and at its base, has led to complete agreement that the three sandstones are a unit of deposition and that these unconformities are all attributable to such minor fluctuations in the streams depositing the Todilto (?) formation as would be expected in any fluviatile deposit. Emery so minimized the importance of the Todilto (?) formation that he recognized no break between the base of the Wingate and the top of the Navajo but referred the entire thickness to the Wingate sandstone.[85] Toward the east no pre-La Plata (post-Todilto) unconformity was recognized by Coffin north of Paradox Valley, though to the south of that locality evidence of at least local erosion was found.[86] Cross[87] found an unquestionable unconformity between his Dolores and La Plata formations in the San Juan Mountains, but the evidence cited by him seems not to exclude completely the explanation that the La Plata overlaps the Dolores formation, for it thins remarkably in the direction of the mountains, as does also the Dolores, perhaps owing to nondeposition. This hypothesis is not advanced very confidently, however, for the San Juan Mountain area has been an active orogenic center at several periods, so that unconformities present there may well be absent in the comparatively inactive regions to the west. It is certain, at any rate, that in southwestern Utah there is no unconformity in the thick mass of sandstone—well shown, for example, at Zion Canyon—into which both Wingate (Vermilion Cliff and "upper Dolores massive sandstones" of Cross) and Navajo (White Cliff and lower La Plata of Cross) have been traced.[88]

Above the Navajo sandstone lies the fossiliferous marine Upper Jurassic zone of Utah. With the fossils of the Chinle formation also taken into account, the age of the entire Glen Canyon group is fixed as later than some part of the Upper Triassic and earlier than some part of the Upper Jurassic. The question where to draw the Jurassic-Triassic boundary thus presents a dilemma. If the boundary is placed at the base of the Wingate sandstone it is necessary to assume continuous deposition between the two periods in the San Juan Mountain region, for there is no evidence of a stratigraphic break beneath the massive sandstone of the Dolores formation present in that region and believed to be equivalent to the Wingate. If the prominent unconformity at the base of the La Plata sandstone of the San Juan Mountains is selected as a boundary the conditions are reversed; the unconformity of the plateau province is in the midst of the Upper Triassic, and sedimentation was continuous across the Triassic-Jurassic boundary in such areas as the Zion Canyon region and essentially continuous in the San Rafael Swell. On the whole it seems that there is no present basis for any categoric location of this boundary. The Glen Canyon group may be Jurassic or Triassic; the probabilities slightly favor the Jurassic age of most of it, as indicated here by assignment to the Jurassic with a question.

Of the regions north of those mentioned here only the Uinta Mountain region and central Wyoming seem to offer a correlative of the Glen Canyon group. In the Uinta Mountain region the Nugget sandstone is similar in lithology and in position beneath the marine Upper Jurassic Twin Creek limestone, though there is no evidence available to show what part of the Glen Canyon group the Nugget may represent. In central Wyoming a much thinner sandstone, usually included in the Sundance formation as a basal member, suggests in many features that it may be equivalent to the Nugget sandstone and to some part of the Glen Canyon group.

JURASSIC SYSTEM

SAN RAFAEL GROUP

Above the Navajo sandstone is the long-recognized marine Upper Jurassic succession, here named the San Rafael group, from its splendid exposures in the San Rafael Swell. It is divisible into four formations, described below as the Carmel, Entrada, Curtis, and Summerville formations, in ascending order.

CARMEL FORMATION[89]

Distribution and topographic expression.—The Carmel formation is the lowest formation of the group. It has been traced from southwestern Utah, where it was first observed by Gilbert, with few interruptions around the south end of the High Plateaus, along the Waterpocket Fold,[90] in the Henry Mountains,[91] along Glen Canyon,[92] and throughout the San Rafael Swell. In the eastern part of the Green River Desert no fossils have been found in the Carmel formation, nor have any been reported from it in the neighborhood of Bluff, though the formation is recognizable there. Traced to the east it is represented by thin-bedded sandstones and shales which are correlated[93] with the middle limy member of the La Plata sandstone of the San Juan Mountains. It is recognizable on the west side of the High Plateaus near Salina (where it is saliferous), Manti, and Thistle, and it is, in part at least, represented farther north in the Uinta and Wasatch Mountains by the Twin Creek limestone.

The lower part of the formation is in most places very limy and resistant, capping vertical cliffs of the Navajo (pl. 18, *A*) and extending in wide esplanades beneath the slopes of the weak shales in the upper

[83] Moore, R. C., op. cit., pp. 216–217.
[84] Oral communication.
[85] Emery, W. B., op. cit., p. 565.
[86] Coffin, R. C., op. cit., pp. 71–72.
[87] Cross, Whitman, and Hole, A. D., U. S. Geol. Survey Geol. Atlas, Engineer Mountain folio (No. 171), 1910. See also Cross, Whitman, folios 57, 60, 130, 153.
[88] Gregory, H. E., and Moore, R. C., op. cit. Reeside, J. B., jr., and Bassler, Harvey, op. cit., p. 64.

[89] This formation is named from Mount Carmel, Utah, where Gilbert first recorded it, by H. E. Gregory and R. C. Moore (op. cit.).
[90] Gregory, H. E., and Moore, R. C., oral communications. Dake, C. L., op. cit., p. 637.
[91] Gilbert, G. K., op. cit., p. 6.
[92] Paige, Sidney, oral communication.
[93] Lee, W. T., U. S. Interior Dept. Mem. for the Press, March 30, 1926.

part. Where little limestone is present, however, the formation is swept from the upper surface of the Navajo, which is left as a terrace.

Lithology and thickness.—Measurements of thickness of the Carmel formation range in the San Rafael Swell from a maximum of 650 feet near the junction of Last Chance and Starvation Creeks, on the west flank, to 170 feet at Black Dragon Canyon and 95 feet (described as Todilto (?) by Emery) near Temple Mountain, on the east flank. At the mouth of San Rafael River it is 95 feet; near Courthouse mail station, 47 feet; in the Salt Valley anticline, 60 feet. It is represented by only a thin shaly zone at the mouth of Dolores River, but at Bluff it is 50 feet thick.[94]

The lower contact of the Carmel is an apparently smooth or only slightly rolling surface. The basal beds are nearly everywhere very limy buff to greenish-yellow sandstones, evidently composed of reworked sand from the Navajo sandstone. Its parallel, even bedding cuts off the steep cross-bedding of the Navajo over wide surfaces, but whether an unconformity is represented is impossible to determine, because of the irregular bedding of the Navajo. Above the buff sandy basal beds there is in many places a few feet of light-gray limy shale, and then a series of gray fossiliferous sandy limestones which reach thicknesses approaching 100 feet in places along the west side of the Swell. Elsewhere they are much thinner, and for considerable distances east of the Swell the limestone facies is not present, though the middle calcareous member of the La Plata sandstone of western Colorado is very probably at this horizon. The fossils are confined to the limy phase in the Swell, but none have been reported from the limestones of the La Plata of Colorado.

Where the formation is thickest the basal limestones pass upward into a series of gray, orange-red, and greenish shales, with much gypsum in highly contorted beds and massive strata as much as 40 feet thick. Anhydrite occurs in some of the limestones, and some salt is present in the formation along Muddy River and in the western part of the Swell. The well-known salt deposit near Salina is almost surely in equivalent beds.

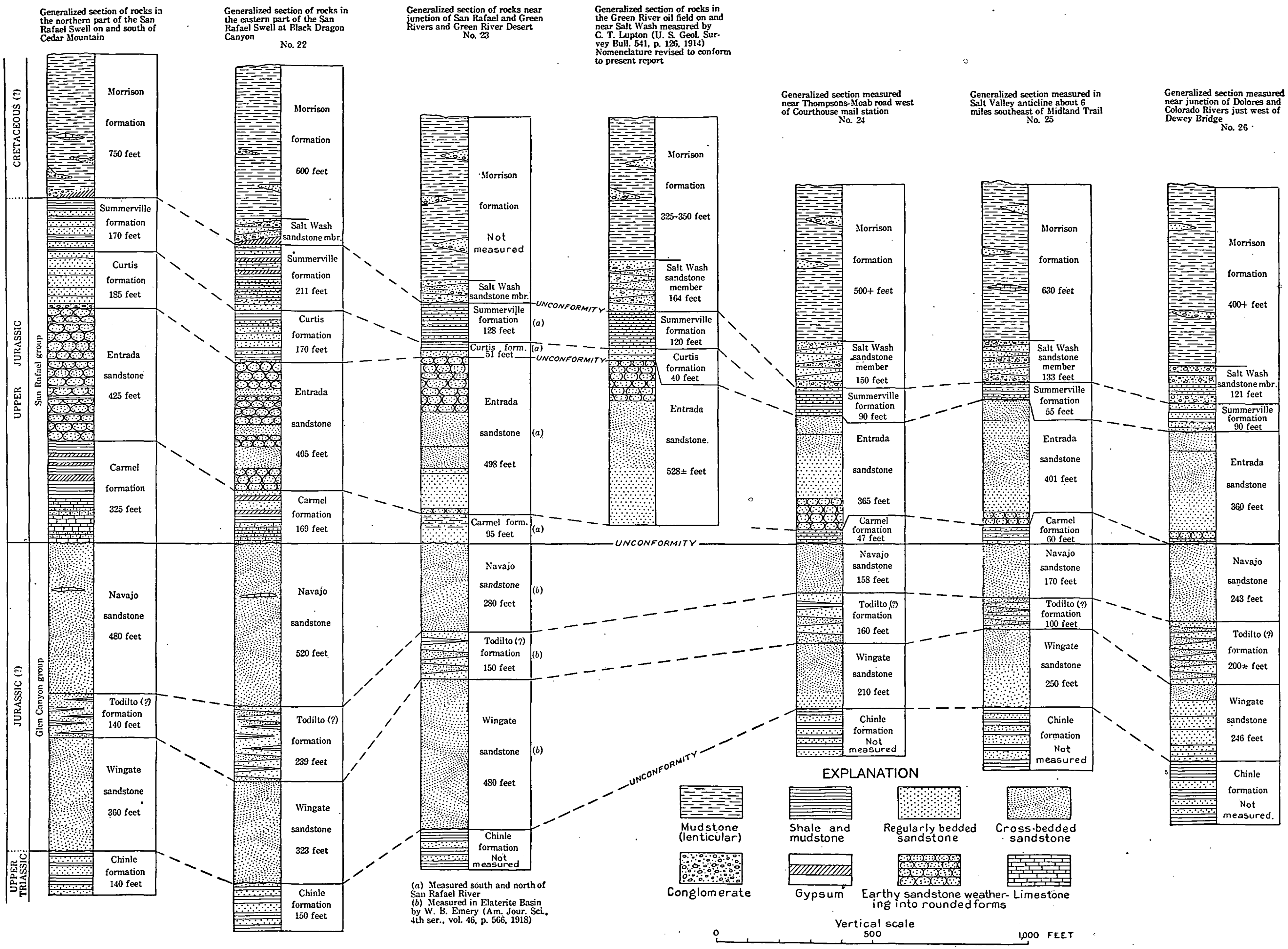
The thinner facies of the Carmel formation in and east of the Green River Desert is a series of thin shaly brown and gray sandstones and red sandy shales, with a few gypsum lenses and a little limestone. Along the Waterpocket Fold the series is very gypsiferous, and this facies is more persistent than the limy one.

In the eastern localities the boundary with the conformably overlying Entrada sandstone is difficult to draw. There is a highly contorted zone of red-brown earthy sandstone with minor amounts of interbedded red shale which is to be placed either at the top of the Carmel formation or at the base of the Entrada sandstone. The contortions (shown in pls. 18, *C*, and 19, *A*) are surely depositional features, possibly due to subaqueous erosion and flow. The bedding both above and below the contorted zone is even and horizontal, proving the absence of angular unconformity. In the opinion of the writers most of this zone is better included in the Entrada sandstone, as it is dominantly and stone, and it is so included in the accompanying sections and charts. Some observers, however, would perhaps be inclined to draw the boundary between the Carmel and Entrada formations at the top of the zone. Either assignment appears permissible, in the opinion of the writers, as the two formations appear to be conformable and to represent continuous deposition. The division into two units is quite arbitrary, is made purely for the purpose of emphasizing the lithologic differences, and is not believed to have important significance in the geologic history of the region.

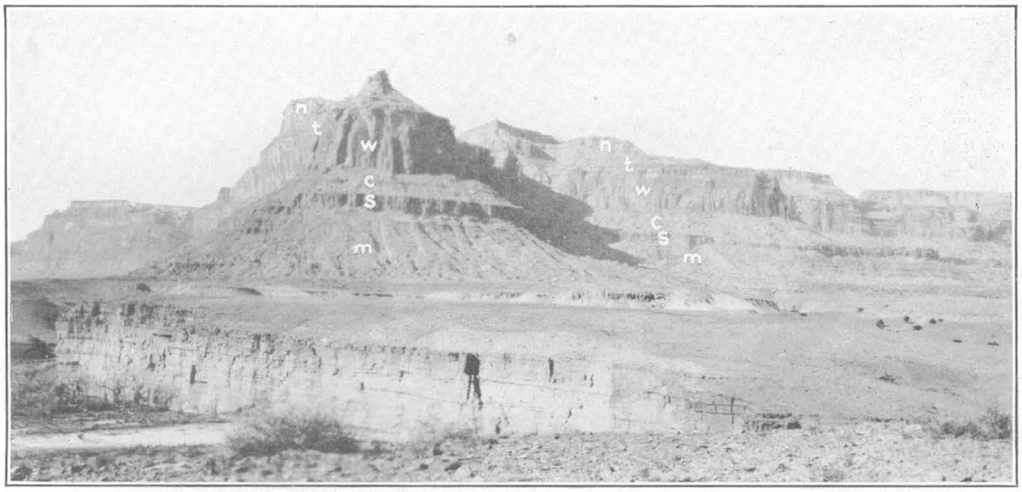
[94] Longwell, C. R., and others, op. cit., pl. 1.

Conditions of deposition.—The marine origin of the limestone facies of the Carmel formation is clearly proved by the inclusion of abundant marine fossils. Very shaly limestones closely associated with the fossiliferous sandy limestones contain nodules of anhydrite, and at least one on the west flank of the Swell is traceable directly into a shaly anhydrite zone. Much of the gypsum, though by no means all, in the upper, noncalcareous part of the formation is cavernous and contorted on a scale which must imply volume changes of considerable amount, a feature that would seem to point to derivation of at least some of the gypsum from anhydrite. The association with salt mentioned above, though not conclusive, also points to deposition in lagoons by evaporation of marine waters. The interbedded shales are very even, and there are few abrupt variations in lithology, so that no support is given by the lithology to a hypothesis of deposition in an interior basin. The hypothesis of marine origin is further favored by the apparently conformable contact with the overlying Entrada formation, whose deposition in marine waters, although not yet established by the finding of fossils, seems probable from the character of its stratification and lithology. No dogmatic statement appears warranted, but the hypothesis of a marine origin of the entire Carmel formation in the San Rafael Swell area seems to be the most workable. The thinner, more variable shales and sandstones of the more easterly regions of the Green River Desert, Moab, and Salt Valley may represent deposits in the fluctuating margin of such a salt lagoon, and the disappearance of the formation at the mouth of Dolores River and the recurrence of thin-bedded limy material in the middle of the La Plata sandstone of Colorado would accord with erosion and continental deposition in those districts. All this is speculative in the extreme, but such data as are at present available seem to agree with it fairly well.

Age and correlation.—The age of the Carmel formation has long been recognized on the basis of many fossil collections as Upper Jurassic. In the course of the work covered by this report fossils were collected from the limestones of the lower part of the formation in many parts of the area. These fossils are listed in the accompanying table, together with others collected some years ago by Robert Forrester and not yet noted in the literature.

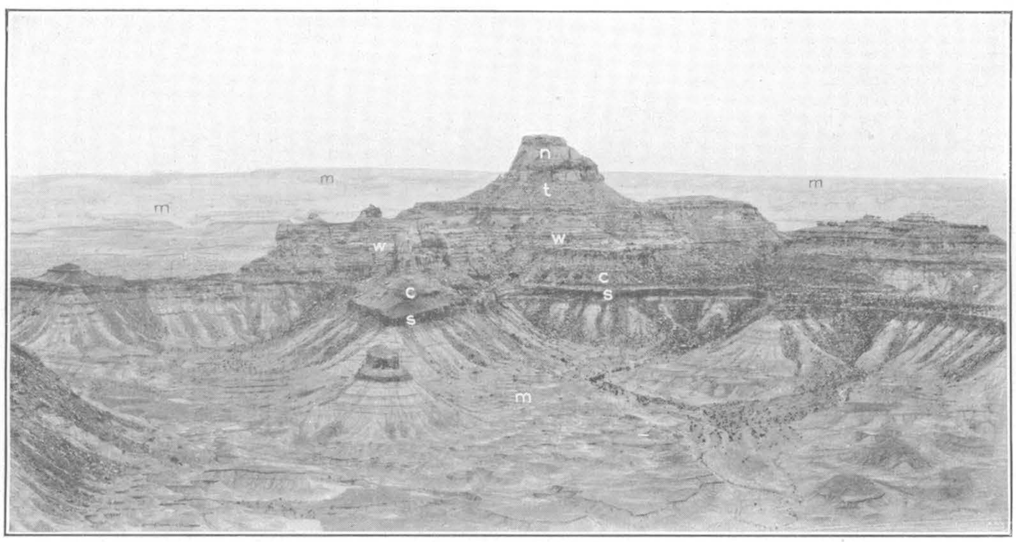


GENERALIZED COLUMNAR SECTIONS OF THE JURASSIC AND JURASSIC (?) ROCKS OF SOUTHEASTERN UTAH



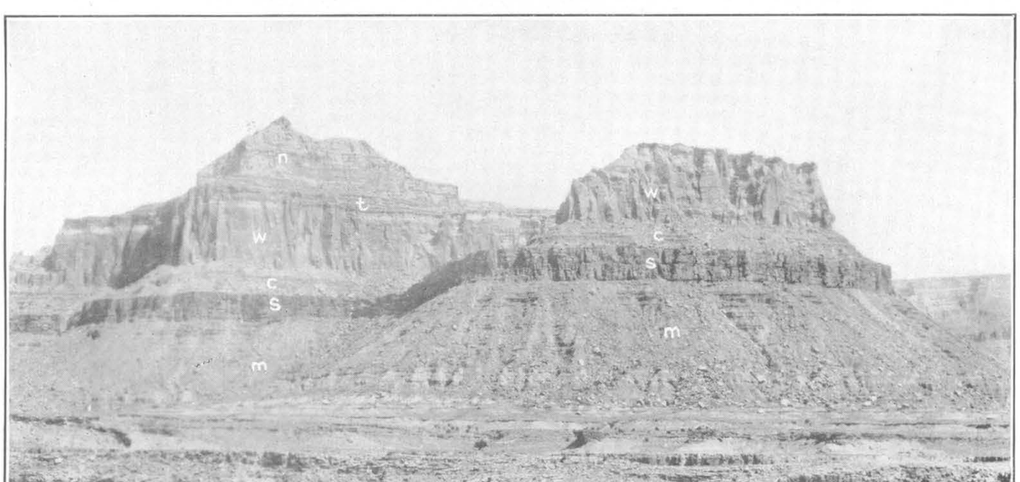
A. VIEW LOOKING NORTHWEST FROM POINT NEAR HEAD OF BLACK BOX OF SAN RAFAEL RIVER, SAN RAFAEL SWELL, UTAH

The cliff against which the river runs is made by the Sinbad limestone member of the Moenkopi formation. The slope above is made by the upper part of the Moenkopi formation. m, Upper part of the Moenkopi; s, Shinarump conglomerate; c, Chinle formation; w, Wingate sandstone; t, Todilto (?) formation; n, Navajo sandstone



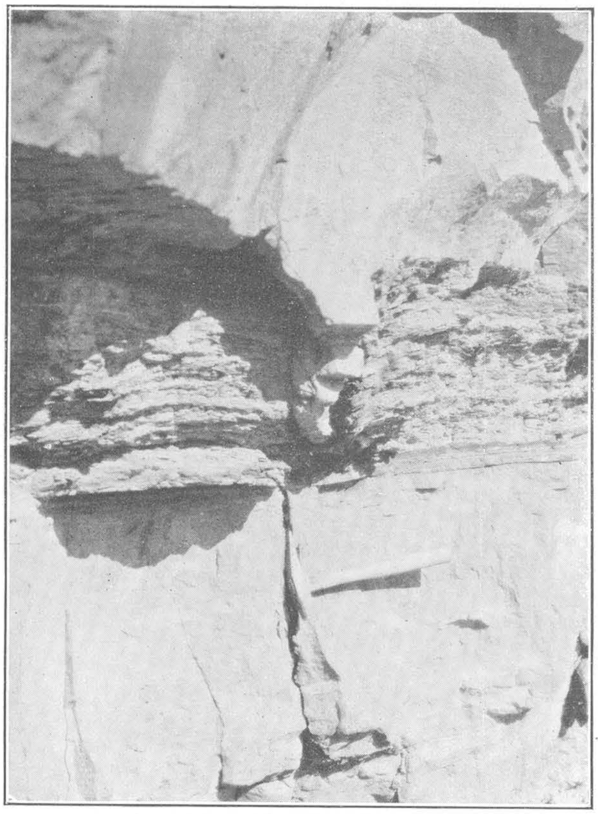
B. VIEW LOOKING SOUTH FROM THE REEF AT MOUTH OF BUCKHORN WASH, SAN RAFAEL SWELL

Window Blind Butte and, in the distance, Sinbad Plateau. m, Moenkopi formation; s, Shinarump conglomerate; c, Chinle formation; w, Wingate sandstone; t, Todilto (?) formation; n, Navajo sandstone. Photograph by E. M. Spieker

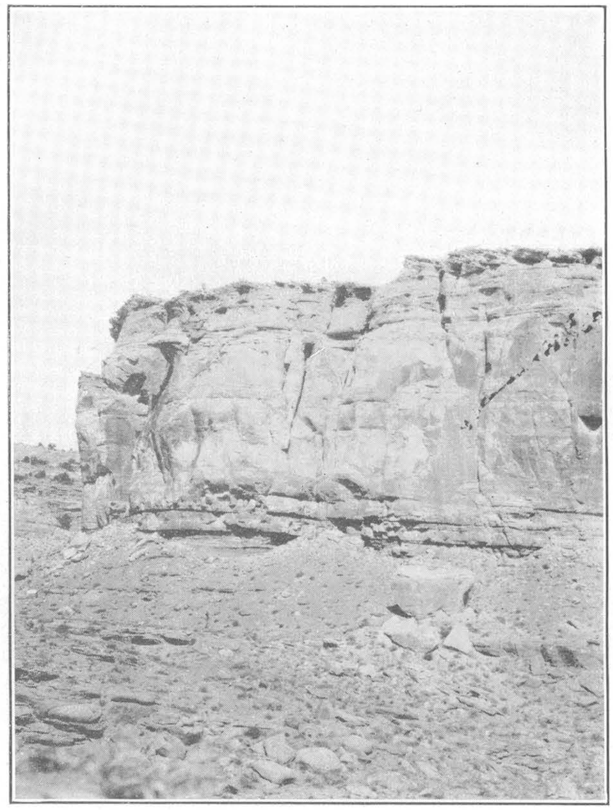


C. VIEW LOOKING NORTHEAST FROM MOUTH OF RED CANYON, SAN RAFAEL SWELL

m, Moenkopi formation; s, Shinarump conglomerate; c, Chinle formation; w, Wingate sandstone; t, Todilto (?) formation; n, Navajo sandstone

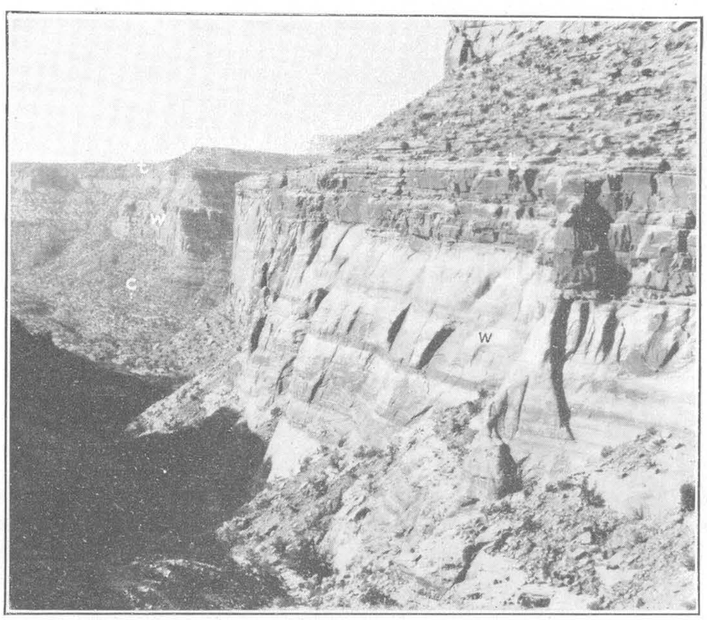


A. UNCONFORMITY, CHANNEL IN CHINLE SHALE FILLED BY SANDSTONE OF THE WINGATE SANDSTONE



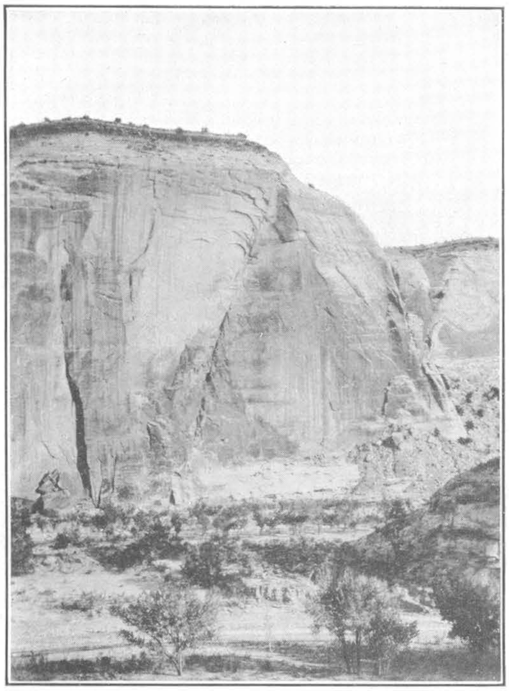
B. WINGATE SANDSTONE, RESTING ON CHINLE FORMATION NEAR COURTHOUSE MAIL STATION ON THOMPSONS-MOAB ROAD, UTAH

Cliff 210 feet high



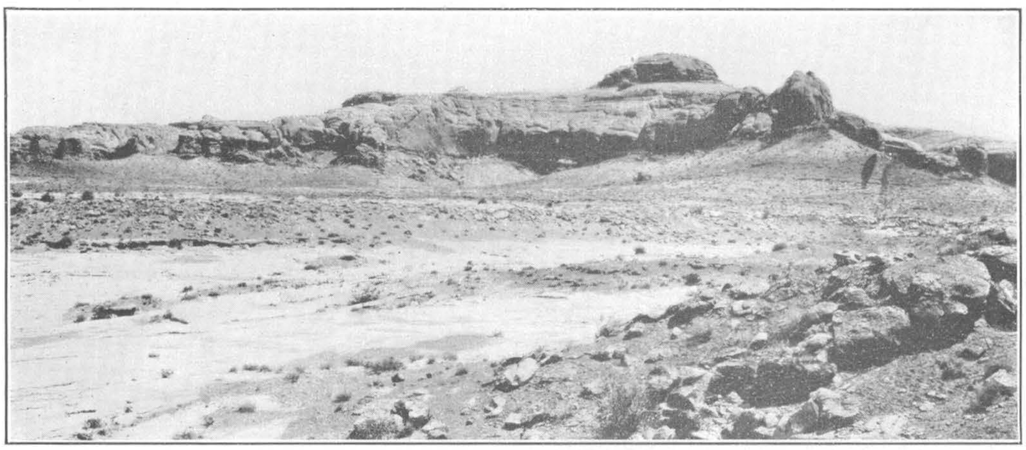
C. TYPICAL OUTCROP OF TODILTO (?) FORMATION NEAR HEAD OF SPRING CANYON, NORTHERN PART OF SAN RAFAEL SWELL, UTAH

c, Chinle formation; w, Wingate sandstone; t, Todilto (?) formation



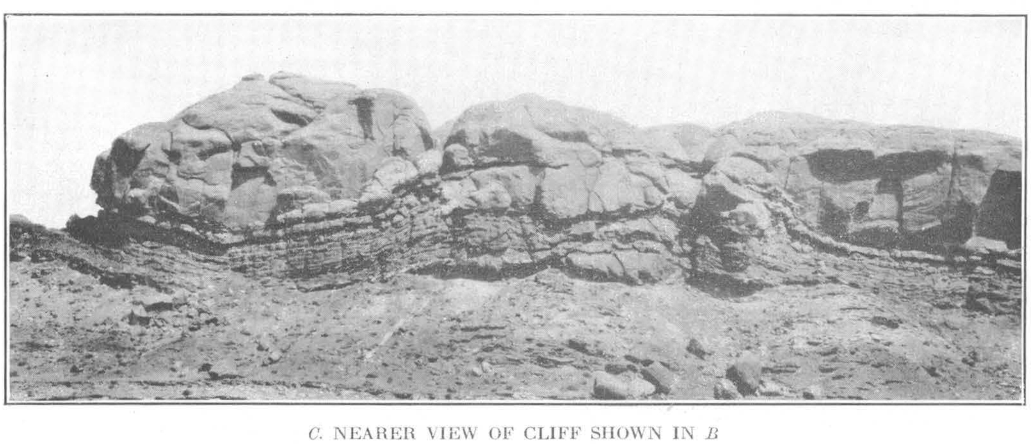
A. CLIFF OF NAVAJO SANDSTONE, CAPPED BY BASAL LIMESTONE BEDS OF CARMEL FORMATION ON SALT WASH, NORTHWESTERN PART OF SAN RAFAEL SWELL, UTAH

Top of Todilto (?) formation barely visible near right just above creek. Thickness of Navajo, 485 feet



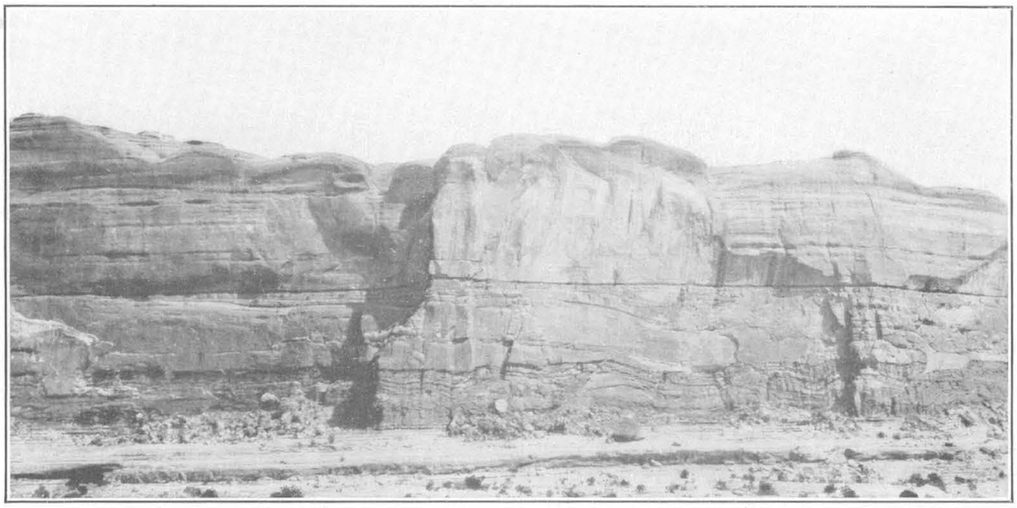
B. VIEW TAKEN 2 MILES SOUTH OF SAN RAFAEL-GREEN RIVER JUNCTION, UTAH

Navajo sandstone forms white patch in left foreground; slope is made by soft shale and sandstone of the Carmel formation. The rounded cliff exposes the lower 325 feet of the Entrada sandstone



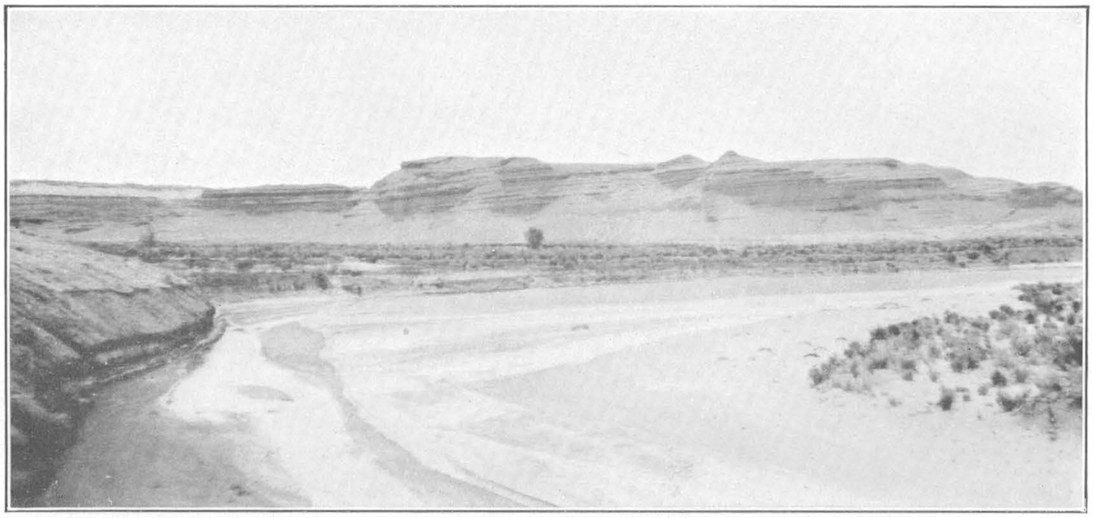
C. NEARER VIEW OF CLIFF SHOWN IN *B*

Shows contorted bedding at base of Entrada sandstone above slope made by Carmel formation



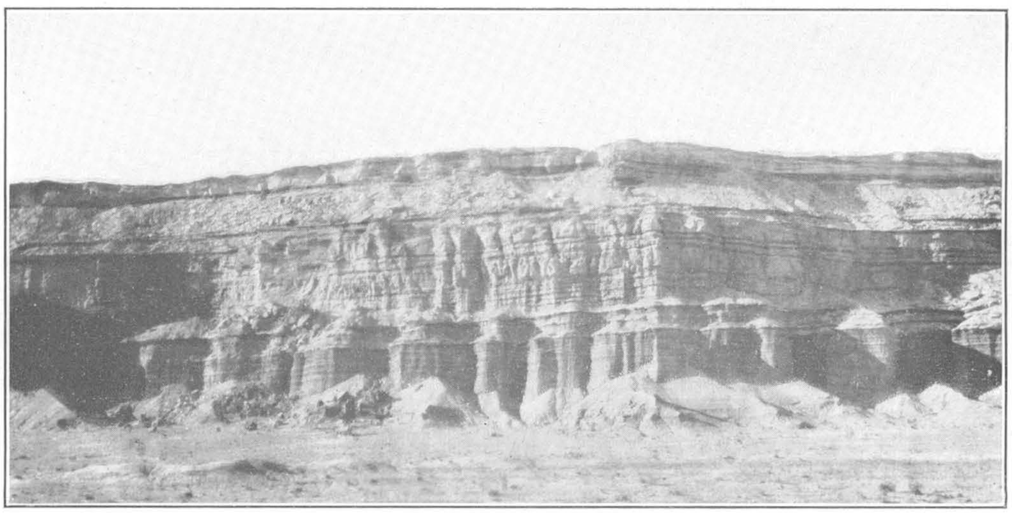
A. VIEW NEAR COURTHOUSE MAIL STATION, THOMPSONS-MOAB ROAD, UTAH

Bench in foreground made by Navajo sandstone; thin shaly zone (not prominent) at foot of cliff composed of Carmel formation; the cliff, which shows remarkable contorted bedding at the base, is made of Entrada sandstone, of which about 320 feet is here shown



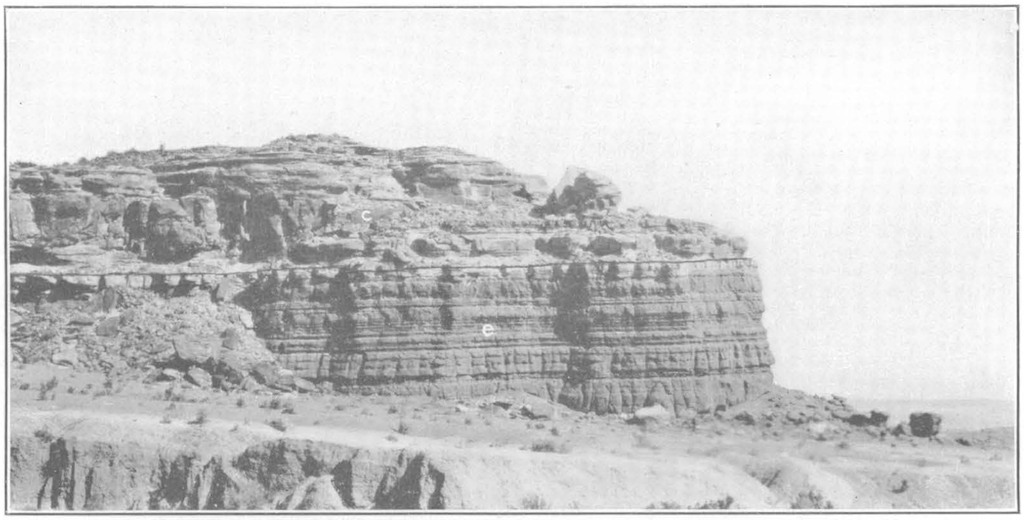
B. VIEW ON MUDDY RIVER AT THE MOUTH OF SALT GULCH, WEST FLANK OF SAN RAFAEL SWELL, UTAH

Cliff in distance is made of Entrada sandstone, here represented by its soft, earthy facies



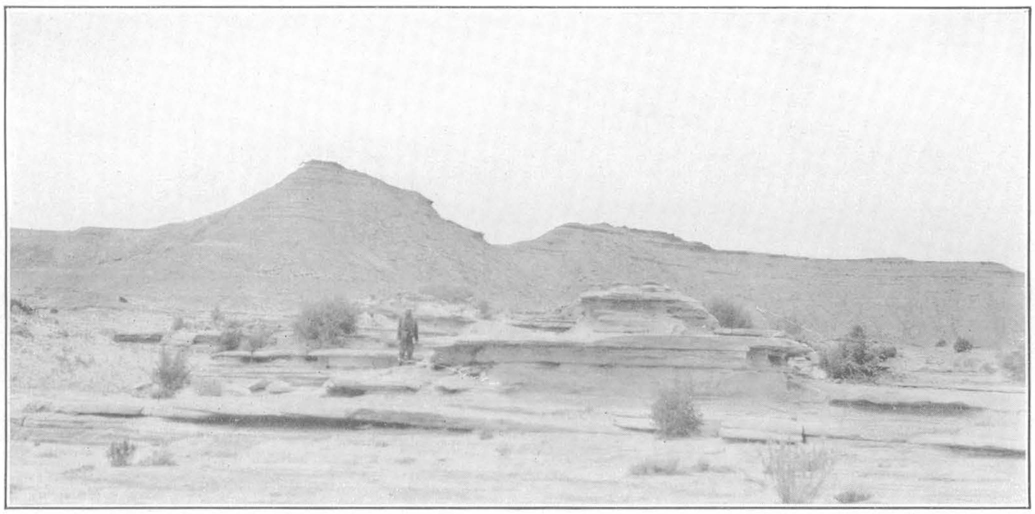
C. THE RED LEDGE, BETWEEN BUCKHORN FLAT AND SAN RAFAEL RIVER, WEST FLANK OF SAN RAFAEL SWELL

Earthy facies of Entrada sandstone forms the cliff, capped by basal sandstone of Curtis formation, which forms the light band at the crest

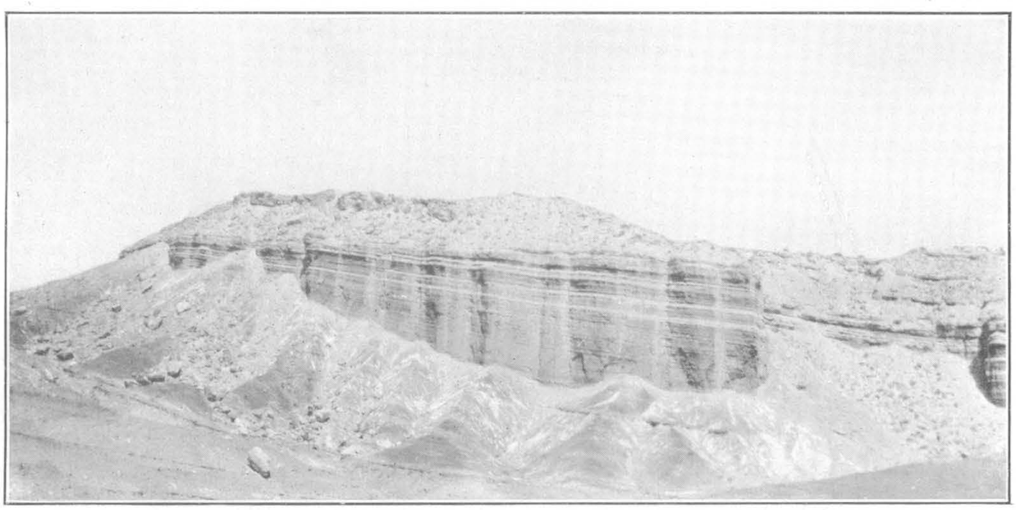


A. CLIFF AT MOUTH OF HORN SILVER GULCH, WEST FLANK OF SAN RAFAEL SWELL, UTAH

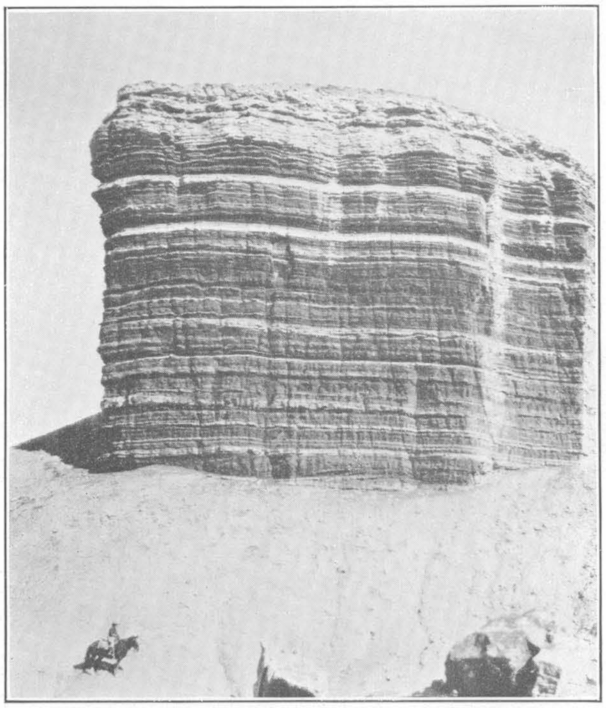
e, Earthy facies of Entrada sandstone, showing characteristic spheroidal weathering; c, concretionary sandstones at the base of the Curtis formation



B. ROUNDED CONCRETIONARY MASSES IN SANDSTONE OF CURTIS FORMATION IN FOREGROUND, SLOPE OF SUMMERVILLE FORMATION ABOVE, NEAR DRUNK MAN'S POINT, WESTERN PART OF SAN RAFAEL SWELL

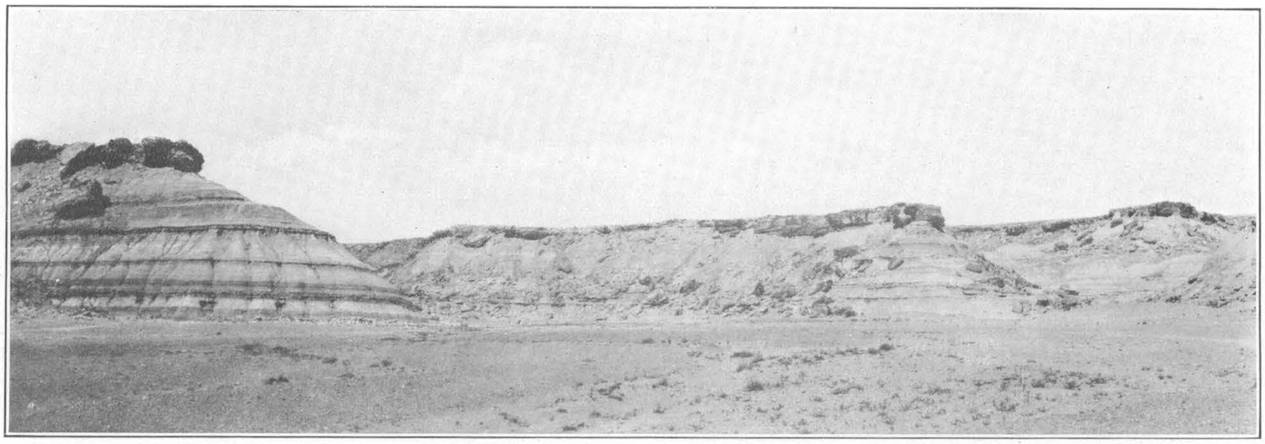


C. UNCONFORMITY BETWEEN EVENLY BANDED SHALES AND SANDSTONES OF THE SUMMERVILLE FORMATION AND THE IRREGULAR GYPSUM, SANDSTONES, AND CLAYS OF THE OVERLYING MORRISON FORMATION, COTTONWOOD SPRINGS WASH, NORTHEASTERN PART OF SAN RAFAEL SWELL

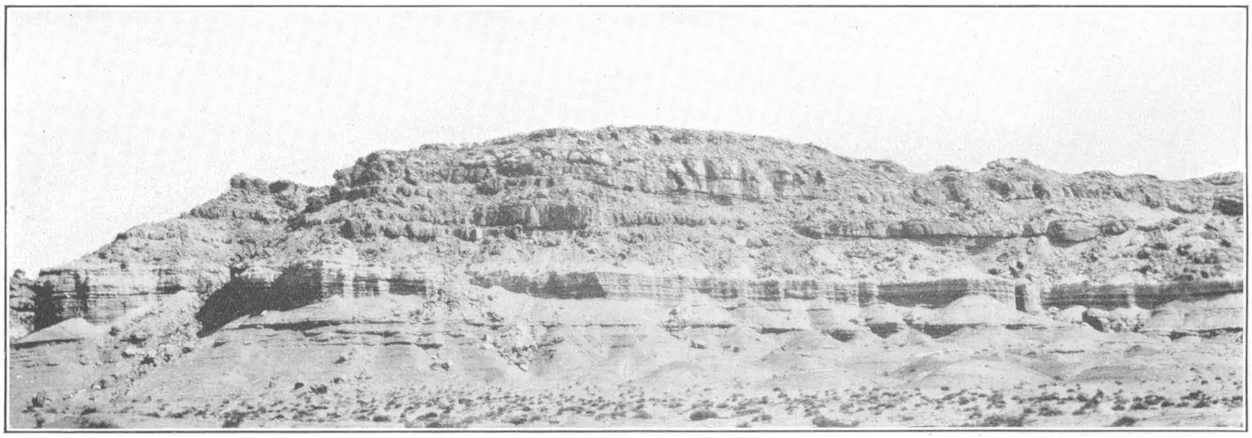


A. BUTTE OF SUMMERVILLE FORMATION NEAR CREST OF WOODSIDE ANTICLINE, NORTHEASTERN PART OF SAN RAFAEL SWELL, UTAH

Capped by white gypsum of the base of the Morrison formation. The white bands in the face of the cliff are sandstones of the Summerville



B. VARIEGATED CLAY AND SANDSTONE OF MORRISON FORMATION, BUCKHORN FLAT, WESTERN PART OF SAN RAFAEL SWELL, UTAH



C. SALT WASH SANDSTONE MEMBER OF MORRISON FORMATION UNCONFORMABLY OVERLYING GYPSUM, SHALES, AND THIN SANDSTONES OF SUMMERVILLE FORMATION, WOODSIDE ANTICLINE, NORTHEASTERN PART OF SAN RAFAEL SWELL

Photograph by E. M. Spieker

Fossils of the Carmel formation

	Lot 1	Lot 2	6280	6281	6282	6284	12555	12556	12557	12558	12560	12570	12581	12582	12835	12839	12840	12841	12842
Serpula sp. undet				×															
Pentacrinus asteriscus Meek and Hayden		×																	
Pinna kingi Meek	×			×															
Gervilia sp. (n. sp.?)	×																		
Ostrea engelmanni? Meek								×											
Ostrea strigilecula White	×	×	×	×	×		×	×	×		×	×				×	×	×	×
Ostrea sp. undet						×													
Trigonia quadrangularis Meek				×	×			×				×	×		×	×	×		
Trigonia montanaensis Meek							×	×	×		×			×					×
Trigonia n. sp. aff. T. americana Meek							×												
Trigonia sp. undet				×	×	×				×									
Camptonectes pertenuistriatus Hall and Whitfield	×			×	×														
Camptonectes stygius White			×	×		×	×			×				×			×	×	×
Camptonectes extenuatus Meek and Hayden							×	×				×	×		×				
Camptonectes bellistriatus? Meek and Hayden												×							
Camptonectes sp. undet		×							×		×								
Plicatula n. sp							×												
Lima (Plagiostoma) occidentalis Hall and Whitfield	×																		
Lima sp. undet	×																		
Modiola subimbricata Meek	×																×		
Modiola sp. (n. sp.?)	×																		
Pleuromya subcompressa (Meek)	×																		
Pleuromya newtoni? (Whitfield)															×				
Pleuromya kingi (Meek)	×																		
Pleuromya sp. undet				×															
Pholadomya kingi Meek										×									
Pholadomya sp. undet				×		×							×						
Cyprina? sp. undet		×		×		×													
Astarte? sp. undet	×				×														
Tancredia inornata (Whitfield)					×								×						
Dosinia sp. undet												×	×		×	×	?		
Corbula? sp							×												
Dentalium? subquadratum Meek							×		×		×								
Neritina? phaseolaris White			×	×															
Lyosoma powelli White														×					
Cardioceras cf. C. distans Whitfield							×												

Lot 1, unnumbered. Ten miles below Castledale, Utah, on San Rafael River. Collected by Robert Forrester.

Lot 2, unnumbered. Eight miles west of Cliff Siding, Emery County, Utah; 175 feet above base. Collected by Robert Forrester.

6280. Big Holes, Emery County, Utah; in lower 30 feet. Collected by Robert Forrester.

6281. Coal Wash, Emery County, Utah; in lower 30 feet. Collected by Robert Forrester.

6282. Devils Canyon, Emery County, Utah; in lower 30 feet. Collected by Robert Forrester.

6284. North of Salt Wash, Emery County, Utah; in lower 30 feet. Collected by Robert Forrester.

12555. The Wedge, 2 miles south of Fullers Bottom, Emery County, Utah; 6 to 12 feet above base. Collected by W. H. Newhouse.

12556. The Wedge, between Buckhorn Wash and San Rafael River, Emery County, Utah; 10 feet above base. Collected by D. J. Fisher.

12557. San Rafael River below Fullers Bottom; 18 feet above base. Collected by W. H. Newhouse.

12558. San Rafael River, below Fullers Bottom; 15 feet above base. Collected by W. H. Newhouse.

12560. San Rafael River, below Fullers Bottom; 17 feet above base. Collected by W. H. Newhouse.

12570. Two miles west of Lost Spring, on Saleratus Wash, Emery County, Utah; in an oolite 100 feet above base. Collected by John B. Reeside, jr.

12581. One and one-half miles west of Lost Spring, on Saleratus Wash, Emery County, Utah; in lower part. Collected by E. M. Spieker.

12582. Buckhorn Flat, Emery County, Utah; about 100 feet above base. Collected by E. M. Spieker.

12835. Cottonwood Springs Wash, sec. 10, T. 20 S., R. 13 E., Emery County, Utah; 68 feet above base. Collected by James Gilluly.

12839. Cottonwood Springs Wash, sec. 35, T. 19 S., R. 13 E., Emery County, Utah; 40 feet above base. Collected by James Gilluly.

12840. Cottonwood Springs Wash, sec. 33, T. 19 S., R. 13 E., Emery County, Utah; at base. Collected by James Gilluly.

12841. Salt Wash Canyon, sec. 25, T. 20 S., R. 9 E., Emery County, Utah; 16 feet above base. Collected by James Gilluly.

12842. Salt Wash Canyon, sec. 25, T. 20 S., R. 9 E., Emery County, Utah; 21 feet above base.

There is no doubt that this fauna is Upper Jurassic and that all the species also occur in the Sundance formation of Wyoming. Similar collections, with a few other species, have been reported by Howell and Gilbert,[95] Dake,[96] Emery,[97] and Lupton [98] from various parts of Utah, though some of them may include also fossils from beds as late as the Curtis formation, described on pages 78–79.

The correlation of the marine Jurassic of Utah has long been a matter of controversy. Cross [99] pointed out the fact that there are three great sandstone units in the neighborhood of the La Sal Mountains, the lowest forming part of the Dolores formation and equivalent to the Wingate sandstone, which he called Vermilion Cliff, and the upper two forming the La Plata sandstone and equivalent, in his opinion, to the White Cliff sandstone of Powell, now known as Navajo. As the marine Jurassic lies above the Navajo it is thereby assigned to a place later than the La Plata sandstone as thus interpreted. Other writers found, over most of the Colorado Plateau, only the two sandstone units of Powell, with which Cross had correlated his three sandstones, and assumed a correlation of these two units with the two divisions of the La Plata of Cross. This assignment again placed the marine Jurassic above the La Plata sandstone and correlated the thin-bedded zone between the two sandstones with the middle La Plata of Cross; that is, the Wingate, Todilto, and Navajo formations were thought to be equivalent to the La Plata sandstone and to form the La Plata "group."[1] The later work of Coffin [2] and Lee [3] and the tracing from the San Rafael Swell to Moab by the writers has shown that the lower sandstone (Wingate) is part of the Dolores formation, as Cross said; that the upper sandstone (Navajo) is the middle sandstone of Cross, the lower La Plata only; and that the marine Jurassic includes, by a marked lateral change in lithology, the thin-bedded middle zone and upper sandstone of Cross, the middle and upper La Plata. Emery [4] was nearly correct in his interpretation of the relations eastward from the Green River Desert, in which he called the present Carmel formation middle La Plata and the present Entrada sandstone upper La Plata, though wrong, as pointed out by Dake [5] and as shown above, in classifying the present Carmel formation as the equivalent of Gregory's Todilto and in lumping the Navajo, Todilto (?), and Wingate formations as a unit under the name Wingate sandstone. In the following table the correlations based on the tracing and measurements of the present report are compared with those of the writers cited above.

[95] Howell, E. E., U. S. Geog. and Geol. Expl. W. 100th Mer. Rept., vol. 3, p. 281, 1875. Gilbert, G. K., idem, pp. 159, 174.
[96] Dake, C. L., op. cit., p. 636.
[97] Emery, W. B., op. cit., p. 568.
[98] Lupton, C. T., op. cit. (Bull. 628), p. 24.
[99] Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, pp. 634–679, 1907.
[1] Gregory, H. E., op. cit., p. 52 and elsewhere. Dake, C. L., op. cit., p. 637. Lee, W. T., Smithsonian Misc. Coll., vol. 69, No. 4, p. 12. Moore, R. C., op. cit., p. 216.
[2] Coffin, R. C., op. cit.
[3] Lee, W. T., oral communication.
[4] Emery, W. B., op. cit., p. 567.
[5] Dake, C. L., op. cit., pp. 644–646.

ENTRADA SANDSTONE

Distribution and topographic expression.—Immediately succeeding the shales and gypsum of the Carmel formation, with apparent conformity, is a thick series of earthy sandstones and subordinate shales, here named the Entrada formation, from their strong development on Entrada Point, in the northern part of the San Rafael Swell.

The Entrada sandstone is present around the Swell, in the Waterpocket Fold, northeast of the Kaiparowits Plateau, in the Henry Mountains, and along San Juan River, as well as in the Green River Desert and farther east in western Colorado. It constitutes a lower part of the "Flaming Gorge group" of Gilbert,[6] is the lower part of the "Upper Jurassic sandstone" of Moore,[7] and is part of the "varicolored sandstones and shales" discussed by Longwell, Miser, Moore, Bryan, and Paige.[8]

There are two general types of topography in which the formation is displayed. Where it is clean and well sorted it stands in steep cliffs with rounded shoulders and in huge domes, such as are so characteristic of the Navajo sandstone. Where it is more earthy or less well cemented it crops out in a steep slope, though in many places it weathers down much like a shale.

Lithology and thickness.—The thickness of the Entrada sandstone is variable. At the type locality it is 312 feet, but toward the south it increases greatly. At Muddy River, on the west flank of the Swell, it is 844 feet, and Moore found 1,430 feet in the Circle Cliffs, though he probably includes at the top a few feet of strata equivalent to the Summerville formation. To the east of the Swell the thickness is more nearly constant for many miles, being 405 feet at Black Dragon Canyon, 498 feet at the mouth of San Rafael River, 375 feet near Courthouse mail station, 401 feet in Salt Valley, and 360 feet at the mouth of Dolores River.

There are two lithologic facies of the formation. Both consist dominantly of sandstone, but the one exposed to the east of the Swell is composed largely of clean well-sorted material, and the more westerly facies is somewhat finer grained and silty. Gilbert's description of the "Flaming Gorge group," a larger unit in which the equivalents of the Entrada greatly preponderate, applies very well to the Entrada sandstone over most of the San Rafael Swell.[9]

The rock of the Flaming Gorge group is of a peculiar character. It is ordinarily so soft that in its manner of weathering

[6] Gilbert, G. K., The geology of the Henry Mountains, pp. 6–7, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1877.
[7] Moore, R. C., op. cit., pp. 219–221.
[8] Longwell, C. R., and others, op. cit., p. 14.
[9] Gilbert, G. K., op. cit., p. 6.

Correlation of the stratigraphic subdivisions of this paper with the classifications of previous workers in the region

Age	Gregory, 1917; Navajo country	Gilbert, 1877; Henry Mountains	Moore, 1922; Circle Cliffs	Gilluly and Reeside, 1926; southeastern Utah	Dake, 1919; Waterpocket fold	Cross, 1907, and Paige, 1924	Emery, 1918; Green River Desert	Longwell and others, 1923; southeastern Utah
Upper Cretaceous.	Dakota sandstone.	Henrys Fork group.	Dakota sandstone.	Dakota sandstone (locally absent).	Dakota sandstone (locally absent).	Dakota sandstone.	Dakota sandstone.	Dakota sandstone.
Cretaceous(?).	McElmo formation.	Flaming Gorge group.	McElmo formation.	Morrison formation.	McElmo group: Upper McElmo.	McElmo formation.	McElmo formation.	McElmo formation.
				Salt Wash sandstone member.	Salt Wash member.		Salt Wash member.	
			"Upper	Summerville formation.	Lower McElmo (Sundance?).		La Plata group: Navajo sandstone.	Varicolored sandstones and shales [Curtis not present].
	Hiatus.		Not present.	Curtis formation.		Hiatus.		
Upper Jurassic.	Undifferentiated McElmo and Navajo.		Jurassic sandstone."	Entrada sandstone.		La Plata group: Upper La Plata.		
			"Gypsiferous zone."	Carmel formation.		Middle La Plata.	(?) Todilto (?) formation. (?)	Gypsiferous shales and sandstones.
	La Plata group: Navajo sandstone.	Gray Cliff group.	La Plata group: Navajo sandstone.	(?) Navajo sandstone.	La Plata group: Navajo sandstone.	Lower La Plata.	Wingate sandstone.	Navajo sandstone.
Jurassic(?).	Todilto formation.	Vermilion Cliff group.	Todilto formation.	Todilto formation.	Todilto formation.	Dolores formation: Vermilion Cliff sandstone.		Todilto formation.
	Wingate sandstone.		Wingate sandstone.	Wingate sandstone.	Wingate sandstone.			Wingate sandstone.
Upper Triassic.	Chinle formation.	Shinarump, "division a."	Chinle formation.	Chinle formation.	Dolores formation.	Lower Dolores.	Chinle formation.	Chinle formation.

it appears to be a shale. It is eroded so much more rapidly than the Henry's Fork conglomerate above it that the latter is undermined and always appears in the topography as the cap of a cliff. Nevertheless, it is not, strictly speaking, a shale. The chief product of its weathering is sand, and wherever it can be examined in an unweathered condition it is found to be a fine-grained sandstone, massive and cross laminated like those of the Gray and Vermilion Cliffs but devoid of a firm cement. In a number of localities it has acquired, locally and accidentally, a cement, and it is there hardly distinguishable from the firmer sandstones which underlie it.

The chief modification this description requires is that the sandstones are really not free from silt but contain a good deal. This is readily swept away by the winds, however, and is not seen in the talus from the formation. Its presence gives the sandstones a peculiar character, so that they weather like a granite into bosses and rounded forms—a most characteristic feature of the formation. The term "earthy sandstone" seems best to describe the rock.

To the east of the Swell the Entrada sandstone becomes much less earthy and better cemented, taking on the appearance of the underlying Navajo and Wingate sandstone. At the mouth of San Rafael River it forms huge domes 325 feet high, but the bedding is nearly parallel at a number of horizons within this thickness, and the earthy character of the basal 30 feet and the 140 feet overlying the domes shows the affinities with the San Rafael Entrada which the stratigraphic position would indicate.

Farther east the earthy character is even less prominent but is still seen in a 15-foot zone included as the base of the formation at the mouth of Dolores River, though it might perhaps be assigned to the Carmel formation. This basal earthy portion is in many places highly contorted, as described on page 74, in a manner difficult to explain, for the overlying and underlying strata are well exposed and undisturbed. This contorted character is a constant feature of the base of the formation over the plateau east of the San Rafael Swell and is seen at points so widely separated as Bluff, Dry Valley, and Salt Valley, as well as at the places already mentioned. Lee [10] has recognized this zone still farther south in northern New Mexico.

Although the Entrada sandstone is massive and thick bedded in the western localities, it contains many shaly layers a few inches thick and exceedingly persistent. The partings between the thick beds are as a rule very even and traceable over wide areas. Toward the east it is more massive, though there also the even bedding divisions are continuous for long distances.

Conditions of deposition.—The Entrada sandstone in the western areas is almost surely entirely water-laid. The even bedding and continuity of single zones seems to point to a marine origin, though this inference is not yet confirmed by fossil evidence. Toward the east, also, it is largely water-laid, though it there appears to be more highly and variably cross-bedded as well as cleaner and less silty, and some beds suggest an eolian origin, or at least conditions comparable to those prevailing in Navajo time.

Age and correlation.—The Upper Jurassic age of the Entrada formation is proved by its position between fossiliferous strata of that time. It is correlated with the Upper Jurassic sandstone of the Circle Cliffs and is equivalent to a part of the group in southern Utah called "varicolored sandstones and shales" by Longwell and others. In the San Rafael Swell it is part of the "McElmo formation" of Lupton [11] and was included (with some overlying beds) in the Navajo by Emery.[12] Traced toward the east it is found to be the zone in Dry Valley and near Moab called "Upper La Plata" by Cross.[13] Dake [14] follows Gilbert [15] in referring the sandstone to the "Flaming Gorge group," adding that this is practically equivalent to the "McElmo" of more recent writers. Prommel [16] called the corresponding strata in the Salt Valley anticline "Upper Navajo sandstone" and referred them to the La Plata "group," but, as is now known from tracing, they occur above the true Navajo, though equivalent to the upper part of the La Plata sandstone of Colorado.

CURTIS FORMATION

General character.—In the San Rafael Swell an erosional unconformity displaying irregularities of as much as 50 feet in height occurs at the top of the Entrada sandstone. Resting on this channeled surface is the Curtis formation, here named from its excellent exposures on Curtis Point, near the head of Cottonwood Springs Wash, on the northeast side of the Swell. It is a series of greenish-gray glauconitic conglomerates, sandstones, and shales and contains Upper Jurassic fossils.

Distribution and topographic expression.—About the north end of the San Rafael Swell and well down the west side the Curtis formation forms the crest of a cliff and the dip slope behind it. Farther south the conglomeratic facies of the formation becomes less prominent and the whole formation thins greatly, so that in the south end of the Swell, south of Starvation Creek, it forms a hardly noticeable shoulder in the steep slopes above the Entrada formation, while in the north end of the Waterpocket Fold it is a thin greenish-gray shaly sandstone which lenses out completely a short distance to the south. To the east of the Swell also it becomes more shaly and, though still present as a ledge former near the mouth of San Rafael River,

[10] Lee, W. T., U. S. Dept. Interior Mem. for the Press, March 30, 1926.

[11] Lupton, C. T., Oil and gas near Green River, Utah: U. S. Geol. Survey Bull. 541, pp. 125–126, 1914; Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, pp. 21, 23–24, 1916.

[12] Emery, W. B., op. cit., pp. 570–572, 1918.

[13] Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15 pp. 644–651, 1907.

[14] Dake, C. L., op. cit., pp. 644–646.

[15] Gilbert, G. K., op. cit., p. 6.

[16] Prommel, H. W. C., op. cit., pp. 387, 392.

is no longer recognizable near Courthouse mail station, where its horizon is exposed. The formation is not known east or south of the extreme localities mentioned, and so far as known it is a restricted phase of the marine Jurassic.

Lithology and thickness.—The Curtis formation, unlike most of the other strata of the plateau, may be identified usually by color alone. All its members have a peculiar greenish-gray color on fresh fracture, due to the glauconite contained in them. Weathering causes them to turn brownish, but very dark colors are not common.

At or near the base there is commonly from 3 to 20 feet of conglomerate, containing well-rounded pebbles as much as 1½ inches in diameter, mostly varicolored chert and flint, in a gritty matrix. Most of the formation, however, is a fine sandstone, in beds from 6 inches to 3 or 4 feet thick, cross-bedded and ripple marked throughout and commonly containing sporadic pellets of green shale. (See pl. 20, *B*.) Lime cement with some iron is irregularly distributed, and the sandstones commonly weather into biscuit-like or loglike forms owing to this differential cementation and to exfoliation. The shales that make up most of the upper part of the formation are well laminated, flaky, and limy.

The Curtis formation is 193 feet thick at the type locality and 252 feet at Summerville Point, at the north end of the Swell. Down the west side of the Swell it diminishes to 166 feet at Horn Silver Gulch and to 76 feet just south of the junction of Last Chance and Starvation Creeks. At Sand Creek, in the northern part of the Waterpocket Fold, it is very shaly and was estimated as about 40 feet thick. The formation was not noted by Moore [17] in his work near the Circle Cliffs. Just across Fremont River from Hanksville it is about 70 feet thick, but the formation is not recognizable in the description of the stratigraphy of the Henry Mountains by Gilbert.

At Black Dragon Wash the Curtis formation is 170 feet thick; near the mouth of San Rafael River, 50 feet. It is probably represented by the 40 feet of "sandstone, red below and gray above, very calcareous; contains many small nodules," described by Lupton [18] in his section of the "McElmo" formation on Salt Wash. It is not recognizable at any of the more easterly points visited by the writers.

Conditions of deposition.—The fossils collected from the Curtis formation at several places in the San Rafael Swell prove its marine origin. Its narrow areal distribution and its upper gradational boundary with the Summerville formation, which is much more widespread, seem to indicate that it never extended as a distinct deposit much farther south and east. Nothing definite is known of its northern or western limits.

[17] Moore, R. C., oral communication.

[18] Lupton, C. T., Oil and gas near Green River, Utah: U. S. Geol. Survey Bull. 541, p. 126, 1914.

Certainly its coarse basal facies and the ripple marks throughout the formation afford convincing evidence that it is a shallow-water deposit. The presence of its pebbles in crevices in the upper surface of the Entrada seems to point to its origin as a basal conglomerate, deposited by the sea encroaching on a land surface.

Age and correlation.—The assignment of the Curtis formation to the Upper Jurassic is based upon the fossils shown in the following table, mostly collected in the northern part of the Swell:

Fossils of the Curtis formation

	12568	12569	12571	12576	12579
Cidaris sp	×	×	----	----	×
Pentacrinus asteriscus Meek and Hayden	×	×	----	----	×
Eumicrotis curta Hall	----	×	----	----	----
Ostrea strigilecula White	×	×	----	----	×
Camptonectes stygius White	×	----	----	----	----
Tancredia inornata (Whitfield)	----	----	----	×	----
Ammonite, indeterminable	----	----	×	----	----

12568. Saleratus Creek, 1 mile south of Lost Springs, in Saleratus Wash, Emery County, Utah; lower part of formation. Collected by E. M. Spieker.

12569. One mile north of Lost Spring, Emery County, Utah; highest grit, about middle of formation. Collected by E. M. Spieker.

12571. Lost Spring, Emery County, Utah. Collected by E. M. Spieker.

12576. One mile north of Lost Spring, Emery County, Utah; 5 feet below top of formation. Collected by John B. Reeside, jr.

12579. Humbug Wash, Emery County, Utah; base of formation. Collected by John B. Reeside, jr.

The species named above, like those of the Carmel formation, all occur in the Sundance formation of Wyoming, and it seems assured that the time of at least the lower three formations of the San Rafael group is included in the interval represented by the Sundance formation. It is not yet possible, however, to say precisely what parts of the San Rafael group are represented in the marine Upper Jurassic deposits of southwestern and central Utah, nor in the Twin Creek limestone of the Uinta Mountain region.

It should be noted that the Curtis formation on the west flank of the Swell was called the Salt Wash sandstone member of the "McElmo" by Lupton.[19] The true horizon of the Salt Wash sandstone member, as shown by detailed mapping and sections in the intervening areas between the west flank of the Swell and the type locality of the member, is 335 feet higher, the 8-foot conglomerate of Lupton's measured section being the equivalent of the true Salt Wash.

SUMMERVILLE FORMATION

Distribution and topographic expression.—In the San Rafael Swell the Curtis formation passes upward with a gradational boundary into the even-bedded

[19] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, p. 25, 1916.

red and white sandstones and maroon shales of the Summerville formation, so named from its excellent exposures on Summerville Point, just southeast of the head of Summerville Wash, in the north end of the Swell. This formation has a much greater areal extent than the Curtis and is found in the Waterpocket Fold,[20] in the Henry Mountains, and throughout the region between the Swell and the mouth of Dolores River, wherever beds at its horizon are exposed. Very similar beds occur in Dry Valley and just north of Bluff, but detailed mapping would be required before exact equivalence can be confidently affirmed. It is ordinarily exposed in a steep slope, though in some places in a vertical cliff capped by the conglomeratic Salt Wash sandstone member of the overlying Morrison ("McElmo") formation. The zone of thin alternations of shale and sandstone weathers in rounded slopes that resemble those of shale badlands in appearance but are so hard and so thickly covered with small sandstone fragments that it is very difficult to maintain one's footing on even moderate slopes.

Thickness and lithology.—The type section of the Summerville formation includes 163 feet of thin alternating beds of chocolate-colored gypsiferous mudstone and well-laminated sandstone, with some red clays toward the base. Even bedding is not so characteristic as it is in the Woodside anticline, on the northeast flank of the Swell, but the beds are fairly persistent and regular. To the south the formation increases in thickness for some distance, being 258 feet thick at Horn Silver Gulch and 331 feet near Drunk Man's Point. Still farther south it thins considerably, so that near the junction of Starvation and Last Chance Creeks it is only 184 feet thick. The formation is not everywhere evenly laminated but contains a series of lenticular sandstones and shales of very irregular thickness, though the group as a whole changes only gradually from place to place. No measurement was made at Sand Creek, in the northern part of the Waterpocket Fold, but the formation was estimated to be much thinner there, perhaps only 100 feet thick. Eastward from the northern part of the Swell the formation is on the average somewhat thinner than in the type locality, being 128 feet thick in the Woodside anticline, 125 feet on Cottonwood Springs Wash in sec. 34, T. 19 S., R. 13 E. (unsurveyed), 210 feet at Black Dragon Wash, on the east side of the Swell, and 125 feet near the junction of San Rafael and Green Rivers. Strata 120 feet thick just below the Salt Wash sandstone member of Lupton's Salt Wash section[21] appear to represent the Summerville. Near Courthouse mail station about 60 feet of the Summerville formation rests directly upon the Entrada, the Curtis not being recognizable there. In similar manner at Salt Valley 55 feet of the Summerville, and near Dolores River 90 feet, is present directly above the Entrada sandstone.

In these more easterly localities the bedding resembles that in the southerly exposures in the Swell—that is, it is marked by interlensing thin sandstones and maroon mudstones and shales. Chalcedony concretions are present over the entire area of exposure of the Summerville, and bedded gypsum is likewise very common though not persistent.

Conditions of deposition.—In the north end of the Swell the Summerville formation appears to represent deposition in rather quiet shallow waters, but it is ripple-marked and sun-cracked throughout, and its sandstones contain pellets of the interbedded shales. The apparent conformity with the marine Curtis formation renders it probable that the Summerville likewise was deposited in an arm of the sea, though the gypsum beds, as well as the shallow-water features just mentioned, seem to indicate lack of free access thereto. Both to the south and to the east, however, the irregular lenticular nature of the sandstones seems to point to continental deposition, perhaps on a flat shelving plain whose lower portion was covered by the shallow marine water in which were deposited the even sediments of the northern San Rafael Swell. This conception would agree with the general evidence tending to show that the Jurassic sea retreated toward the northwest.

The chalcedony concretions are undoubtedly secondary for the most part. Perhaps they are to be accounted for by vadose circulating waters during the exposure of these beds prior to the deposition of the unconformably overlying Salt Wash sandstone member of the Morrison formation.

Age and correlation.—The conformable relation of the Summerville with the Curtis formation, which is of known Upper Jurassic age, together with the unconformity at the top beneath the Morrison formation (pl. 20, *C*), whose Cretaceous age is questioned, renders it probable that the Summerville formation likewise belongs to the Upper Jurassic. No fossils have yet been found upon which to base a more unequivocal assignment.

Correlation with beds in other areas must remain very tentative in view of the absence of fossils, the unconformity just above the Summerville, and the rapid lateral variations of the overlying Morrison. It is possible that the sandstones of the "lower McElmo" of Coffin[22] (the "carnotite beds") represent equivalents of the Summerville in western Colorado, though they may possibly lie in the Salt Wash sandstone member of the Morrison formation.

[20] Moore, R. C., oral communication.

[21] Lupton, C. T., Oil and gas near Green River, Utah: U. S. Geol. Survey Bull. 541, p. 126, 1914.

[22] Coffin, R. C., op. cit., pp. 77-97

CRETACEOUS (?) SYSTEM

LOWER CRETACEOUS (?) SERIES

MORRISON FORMATION

Lower contact.—There is an unconformity, both angular and erosional, at the top of the Summerville formation. (See pls. 20, *C*, and 21, *C*.) The angular discordance of the beds above and below is not everywhere apparent, and at no point observed in the San Rafael Swell does it exceed 4°, though in the Henry Mountains a divergence of approximately 8° was observed on the road between Hanksville and the Granite ranch, on the northeast foothills of Mount Ellen. However, the erosional unconformity is everywhere present. An unconformity at this horizon has been suggested by Emery [23] and Dake.[24]

Lithology and thickness.—The Morrison formation consists of mudstones and clays of variegated colors (pl. 21, *B*), with many channel conglomerates, sandstones, and lenticular limestones and at least locally some volcanic ash. On the east flank of the Swell, in the Green River Desert, and to the east there is at the base of the formation a variable thickness, ranging from about 50 feet to 200 feet or more, of thick lenticular conglomeratic sandstones with subordinate interbedded shales and mudstones—the Salt Wash sandstone member. (See pl. 21, *C*.) To the west and south this member rapidly diminishes in thickness and in the southwestern part of the Swell is present only at irregular intervals. These variations are almost surely due solely to variations in original deposition, as the lenticular nature of the individual beds of the conglomerate is very evident, and the interbedded mudstones are identical with those of the higher parts of the Morrison.

The mudstones of the Morrison formation are of various colors, as is usual with the unit elsewhere. Green, gray, white, maroon, purple, red, and many other colors are represented in irregular and discontinued development. Most of the mudstones are limy, and lenticular limestones occur here and there at several horizons within them.

In the northern part of the San Rafael Swell a persistent conglomerate from 3 to 40 feet thick containing many rounded pebbles of black chert occurs about 250 to 300 feet below the top, but it was not observed as a continuous bed either to the south or to the east. Lenses of similar conglomerate, however, recur to the east, though not at a constant horizon. Lee [25] believed that in the region from Moab eastward conglomerates similar to these may correspond to the basal conglomerate of the Cloverly formation of Wyoming and should be grouped with overlying highly colored shades and still higher beds of sandstone and locally coal-bearing strata as the Dakota (?) formation. He interprets the conglomerates in that region to be unconformable on the older beds and the overlying strata to be unbroken. The inconstancy of the conglomerates, the identical character of the overlying and underlying highly colored mudstones, and the practical impossibility of recognizing a dividing plane where the conglomerate is absent have led to the inclusion of the beds in the Morrison for the San Rafael Swell, especially as dinosaur bones were seen in the most persistent of these conglomerates. The designation Dakota (?) is applied in this paper only to the strata immediately beneath the Mancos shale and unconformably above the highly colored shales.

The thickness of the Morrison formation varies greatly, both because of original irregularities of deposition and because of the notable unconformity at the top. East of the Woodside anticline, in the northern part of the Swell, it is 725 feet thick; at Horn Silver Gulch, on the west flank, 847 feet. Just south of Willow Springs Draw, on the west flank, it is only 415 feet thick, and it was estimated to be of about the same thickness in the north end of the Waterpocket Fold.

Near Green River the Morrison includes, according to the measurements of Lupton,[26] 475 to 525 feet of strata, for the lower 700 feet of his "McElmo formation" constitutes the San Rafael group of the present report. In the Salt Valley anticline 640 feet of the Morrison is exposed.

Conditions of deposition.—The Morrison formation has long been considered an example of a flood-plain deposit, laid down by aggrading, wandering streams. On this hypothesis the lenticular conglomerates and sandstones represent old stream channels; the mudstones represent the deposits away from the main channels; and the limestones are believed to be freshwater pond deposits. All the fossil evidence seems to harmonize with this interpretation as thoroughly as the physical evidence, and it is here accepted.

Age and correlation.—The Morrison is assigned with question by the Geological Survey to the Cretaceous system. Many vertebrate remains were seen in the area, but only one collection was made. This was examined by C. W. Gilmore, who furnished the following information:

> The fossil bones apparently belong to one individual and are identified as pertaining to the well-known genus *Diplodocus*. *Diplodocus* belongs to that group of dinosaurs known as the sauropods, which contains the largest ones known. The genus is not known outside of the Morrison formation, so the presumption is that these bones come from equivalent beds.

The limestone layers at places contain poorly preserved shells. One collection, made on Humbug Wash from limestones in mudstones between the lenses of conglomeratic sandstone of the Salt Wash member,

[23] Emery, W. B., op. cit., p. 573.

[24] Dake, C. L., op. cit., p. 646.

[25] Lee, W. T., U. S. Dept. Interior Mem. for the Press, March 30, 1926.

[26] Lupton, C. E., Oil and gas near Green River, Utah: U. S. Geol. Survey Bull. 541, p. 124, 1914.

contains a *Unio* much like the Morrison *Unio nucalis* Meek and calcareous tubes of an undetermined organism, perhaps an annelid.

As the fauna of the formation as observed in this area is similar to that of the type Morrison formation and the lithology is practically identical, the name Morrison formation is here applied to the strata. Previously the beds have formed part of the "McElmo" formation, but that name is abandoned here because the "McElmo" formation probably contains at the type locality [27] beds equivalent to the Summerville formation and more particularly because the term "McElmo" has been used by several authors to include, in different parts of the plateau province, (1) all the strata between the base of the Carmel formation and the base of the Dakota sandstone, (2) the beds between the base of the Entrada and the base of the Dakota, and (3) the beds between the top of the Entrada and the base of the Dakota. Such confusion has greatly impaired the usefulness of the name.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

DAKOTA (?) SANDSTONE

Distribution and topographic expression.—The Dakota (?) sandstone is present around most of the northern part of the San Rafael Swell, where the beds at its horizon are exposed, but toward the south it becomes less prominent and is absent near Caineville and at many of the southwestern exposures along the Swell. To the east it is nearly everywhere present within the area covered by this study.

The Dakota (?) sandstone invariably crops out either as a cuesta or as a mesa, for it is interbedded with weak mudstones and shales.

Stratigraphy.—The Dakota (?) sandstone rests unconformably on the eroded surface of the Morrison formation. In places it is lacking entirely; in places it may reach as much as 60 feet in thickness; everywhere it is extremely variable in constitution. It is ordinarily a rather friable buff to brown conglomerate, containing well-rounded pebbles of white, brown, black, and red quartz and chert in a matrix of coarse-grained cross-bedded sandstone. In some places it is very firmly cemented with silica and is a quartzite; but in most exposures it is cemented with lime, in places rather loosely.

Age and correlation.—Richardson collected typical Dakota plants from the sandstone near Elgin and near Woodside.[28] These fix the age of the beds as in the early part of the Upper Cretaceous, but although the stratigraphic succession and lithology are similar to those of beds widely accepted as Dakota, the likelihood of differences in age at so great distances from the original Dakota locality and the difference of opinion as to how much shall be included under the name make it seem best to apply a question mark to the correlation.

MANCOS SHALE

The Mancos shale overlies the Dakota (?) sandstone with apparent conformity, usually with transitional contact. It crops out over a large area in Castle Valley, the broad plain south of the Book Cliffs and north of the Henry Mountains. It is everywhere a soft, easily eroded formation and forms wide valleys with badland slopes leading back to steep cliffs which are formed by resistant sandstone members within the shale or overlying it.

The relations of the Mancos shale and the overlying rocks in the region of Castle Valley and the Wasatch Plateau have been recently summarized.[29] Only casual attention was given to them in the present work, as only negligible areas of Mancos were included in the district mapped.

LOCAL SECTIONS

The measured sections on which the much generalized descriptions and the interpretations given above are largely based are presented in detail below. The localities are shown by corresponding numbers on Figure 2.

1. *Section 2 miles south of junction of Starvation and Last Chance Creeks, in southern part of San Rafael Swell, Utah*

	Feet
Morrison formation: Gypsum and limy sandstones of various colors, conglomerate at base.	
Unconformity; surface scoured into hollows 4 feet deep, in which occurs the conglomerate at the base of the Morrison.	
Summerville formation:	
1. Sandstone, chocolate-red, shaly; thin bedded (average 1 inch), well laminated in the large but irregularly in the hand specimen; interbedded with some thin green-gray sandstone as much as 4 inches thick; much seamed with gypsum, which is probably all secondary	184
Curtis formation:	
2. Sandstone, green-gray, glauconitic, gritty; becomes shaly toward the top; firmly cemented at base, softer above; gradation to Summerville through about 4 feet of interbedded red-brown and green-gray sandstone	76
Unconformity, not obviously angular; sharp lithologic change; upper surface of the Entrada sandstone bleached to a depth of about 6 inches.	
Entrada sandstone:	
3. Sandstone, red-brown, shaly, in beds as much as 20 feet thick, alternating with poorly bedded lumpy chocolate-brown sandy shale in beds as much as 18 inches thick; the whole weathers in a horizontally fluted cliff, in which the individual beds are traceable for very long distances	299

[27] Lee, W. T., oral communication.

[28] Richardson, G. B., Reconnaissance of the Book Cliffs coal field: U. S. Geol. Survey Bull. 371, p. 14, 1909.

[29] Spieker, E. M., and Reeside, J. B., jr., Cretaceous and Tertiary formations of the Wasatch Plateau, Utah: Geol. Soc. America Bull., vol. 36, No. 3, pp. 435–454, 1925.

Entrada sandstone—Continued.	Feet
4. Sandstone, red-brown, massive, cross-bedded; weathers in rounded exfoliating masses and forms a strong ledge	14
5. Chocolate-brown sandy shale and thin cross-bedded micaceous shaly sandstone; beds about 4 inches thick; stands in a horizontally fluted cliff	23
6. Sandstone, shaly, massive, cross-bedded, resistant; weathers in a strong rounded ledge traceable for long distances	2
7. Sandstone and shale, like No. 3, except that there are no sharp divisions between the more sandy and the less sandy beds and the sandstones weather into "stone babies" and rounded masses; much seamed with secondary gypsum	337
Total Entrada sandstone	675

Apparent conformity.

Carmel formation:	Feet
8. Mudstone, orange-brown, very soft; with some interbedded green silt and much selenite veining	8
9. Silt, light green, and gypsum, containing seams of white and nodules of red-brown selenite; forms an irregular ledge with some interbedded lavender shale at some places; thickness variable	2
10. Shale, light green, soft; forms slope	6½
11. Silt, light green, and shale, banded with gypsum; forms low ledge	29
12. Shale, light grayish green, limy, with some slightly ripple-bedded shaly limestone	41½
13. Interbedded green and chocolate-red gypsiferous silt and mudstone, much seamed with selenite; forms a slope	6½
14. Mudstone, reddish brown, poorly consolidated	1
15. Silt, grayish green, and gypsum	½
16. Mudstone, like No. 14	2
17. Shale, light grayish green, limy, with some thin alabaster gypsum beds in a 4-foot zone about the middle of the member	27½
18. Silt, like No. 15, except that there is more gypsum in nodules toward the base	3
19. Shale, like No. 12	2
20. Gypsum, in some places with light-green silt, elsewhere constituting the entire unit	3
21. Shale, light green; gypsiferous, containing many seams of selenite averaging half an inch to 1 inch thick; bedding contorted, highly folded; upper 1 to 4 feet a continuous ledge	11
22. Shale, light greenish gray, limy	15½
23. Gypsum, white; forms a ledge	1
24. Silt, light grayish green, gypsiferous	1
25. Shale, grayish green, limy, interbedded with shaly limestone; forms a slope	10
26. Limestone, light greenish gray finely laminated; weathers into thin plates; forms a low ledge	1
27. Shale, light greenish gray, with seams of gypsum as much as half an inch thick	2½
28. Silt, reddish brown	1½
29. Silt, light yellowish green and grayish green, with some limy shale	17½
30. Silt, like No. 28	1
31. Silt and shale, like No. 29	2
32. Limestone, light greenish gray, less shaly toward the top; weathers in thin plates	5

Carmel formation—Continued.	Feet
33. Gypsum (alabaster)	1
34. Shale, light green, limy; weathers light yellowish green	5
35. Silt, light greenish yellow; gypsiferous, grading toward the top into white gypsum with subordinate silt	36½
36. Gypsum, white	3
37. Silt, light grayish green, gypsiferous; shaly in places	3
38. Gypsum, white, including a minor amount of light greenish-gray limestone	3
39. Silt, light yellowish green and reddish brown, gypsiferous	8
40. Gypsum and limestone, like No. 38	5
41. Gypsum, white, resistant; forms a ledge	7
42. Silt, greenish yellow and reddish brown; gypsiferous, especially toward the top	1
43. Silt, reddish brown and brick-red, gypsiferous	7½
44. Limestone, light greenish gray, somewhat shaly, partly replaced (?) by gypsum	4½
45. Limestone, light greenish gray to bright yellow, somewhat sandy, ripple-marked; gypsum along joint planes; weathers in thin platy slabs in lower part	27
46. Limestone, light and dark gray, massive, blocky, ledge-forming	1½
47. Limestone, light and dark gray, thin bedded, platy; forms slope	3
48. Limestone, like No. 46	6½
49. Limestone, resistant, banded light gray and light yellow	2
50. Limestone, gray, weathering brownish yellow; platy, cross-bedded on a small scale in lower and upper parts; middle massive; forms resistant ledge	34
51. Mudstone, reddish brown, soft	1
52. Limestone, gray, thinly laminated, soft	1
53. Limestone, light greenish gray, sandy; ripple-marked and ripple-bedded; platy, except upper 5 feet, which forms massive ledge	22½
54. Limestone, very light gray, slabby, nonresistant	3
55. Limestone, white, ledge-forming; in places somewhat sandy; irregular in thickness	3
56. Sandstone, greenish gray, fine grained, limy; lower 1 to 4 feet finely laminated, ripple-bedded; middle part weathers in rounded forms; upper part massive, forms irregular ledge	23
57. Silt, green and yellow, unconsolidated	5
58. Sandstone, bright yellow, limy, soft	5
59. Shale, sandy, light green	1
60. Sandstone, like No. 58	1
61. Sandstone, white to light yellow, limy, fine grained, soft; forms a slope except uppermost 2 feet	11½
62. Shale, light greenish gray and yellowish	½
63. Sandstone and mudstone, yellow to brown, soft to hard; forms variable ledge and slope	4
64. Mudstone, chocolate-colored, with some light greenish gray shale at base	1
65. Sandstone, light gray, massive, fine grained, limy; forms ledge	1
66. Mudstone, like No. 57	2
67. Sandstone, light greenish gray, fine grained, thinly laminated, ripple-bedded, lime-cemented; ledge former but variable along exposure	1

Carmel formation—Continued.	Feet
68. Mudstone, maroon to dark gray, flaky	½
69. Sandstone, gray to yellow, fine grained, hard, sugary; reworked Navajo sandstones, cross-bedded on a small scale	2½
Total Carmel formation	449½

Unconformity.
Navajo sandstone.

2. *Section on cliffs south of Muddy River, in southwestern part of Sinbad, San Rafael Swell, Utah*

Wingate sandstone:	Feet
1. Sandstone, buff to yellow, fine grained, limy, friable, highly cross-bedded	300+

Unconformity, marked by channeled surface, into the depressions of which the overlying sandstone is deposited.

Chinle formation:	
2. Shale, green, sandy, not very well laminated; top surface shows channeling to depth of 1 foot or more	3
3. Sandstone in beds 2 to 3 feet thick; red-brown except top foot, which is green; earthy; weathers in rounded forms	11
4. Mudstone, limy, variegated purple and maroon, indistinctly laminated; forms a slope	13½
5. Sandstone, gray, limy, fine grained, ripple-marked, thin bedded; lenticular, not persent in section 100 yards away	5
6. Lower part mudstone, blocky, limy, in nearly vertical cliff; checks into small angular fragments; upper part alternately more and less shaly mudstone containing particles of grit and fragments of green shale	62
7. Basal part shale, maroon, well laminated; upper part variegated mudstone like upper part of No. 6 and even earthy sandstone	38
8. Sandstone, shaly, well bedded, olive-green, passing upward into well-laminated biotite-bearing sandstone which is cross-bedded at high angles; thins to less than 1 foot within 100 yards along the exposure	4½
9. Sandstone, greenish gray, highly cross-bedded, coarse grained; contains shale pellets	1
10. Shale, olive-green, flaky, somewhat sandy	1
11. Sandstone, like No. 9	1
12. Shale, like No. 10	1½
Total Chinle formation	141½

Contact apparently conformable.

Shinarump conglomerate:	
13. Conglomerate, extremely variable, cross-bedded; pebbles largely of quartzite, white quartz, and white, black, gray, and cream-colored chert as much as three-fourths inch in diameter; matrix a coarse sandstone with much mudstone locally (probably transported as mud balls). Along the exposure the conglomerate is everywhere a cliff; in some places it is all in one bed; in others it occurs in many 2 to 3 foot beds separated by mudstone lenses. Carbonaceous material is abundant	58
14. Mudstone, green, sandy	7
15. Mudstone, shaly, mottled purple and green, showing slickensides on a small scale in nearly every plane; forms a ledge	10
16. Mudstone, very limy, mottled purple, green, and yellow; contains some angular fragments of yellow quartz a quarter of an inch or less in diameter	23

Shinarump conglomerate—Continued.	Feet
17. Shale, variegated green, brown, ocher, and purple; color changes unrelated to bedding; forms a smooth slope	16
Total Shinarump conglomerate	114

Unconformity, smooth surface, sharply cutting between decidedly different lithologic types. No angular discordance is discernible.

Moenkopi formation:	
18. Alternating thin beds of red-brown micaceous shale and fine-grained limy red-brown micaceous sandstone, very well bedded; thick sandstones at 16–19, 32–36, 205–208, and 212–217 feet above the base. Gypsum nodules occur in some of the sandstones, and seams of selenite are very common. Individual beds are traceable for long distances—the sandstones as ledges, the shales as rounded sunken surfaces	291
19. Sandstone, very limy, cross-bedded, in 6-inch beds; contains some shale partings and some 2-inch gypsum seams near the base; forms a persistent ledge	6½
20. Shale, maroon, flaky, evenly bedded, with a few thin limy sandstone beds at 12 to 14 feet from the base	21
21. Sandstone, micaceous, very limy; forms a strong persistent ledge, ripple-marked and cross-bedded throughout	6½
22. Shale, micaceous, evenly bedded, with subordinate shaly sandstones that weather into rounded forms; much selenite in seams	46
23. Alternating shale and sandstone, like No. 18, except that the heavy sandstones occur between 27 and 30 feet above the base and in the top 4 feet of the unit	47½
24. Sandstone, red-brown, ripple-marked, very evenly bedded, micaceous; upper foot slabby; persistent ledge former	5½
25. Shale and sandstone, like No. 18, but without heavy sandstones	21
26. Sandstone, like No. 24	2
27. Shale, red-brown, slightly sandy, micaceous	½
28. Sandstone, like No. 24	1
29. Shale, like No. 27	2½
30. Sandstone, like No. 24	25½
31. Alternating shale and sandstone, like No. 18	41
Sinbad limestone member:	
32. Limestone, gray, ripple-marked, sandy, cross-bedded; lower half in one bed, upper part in beds 6 inches or less in thickness	6½
33. Shale, green-gray to blue-gray, well laminated; no sand present	1
34. Limestone, like No. 32	8½
35. Shale, like No. 33	6½
36. Limestone, gray; weathers to cream-colored or yellow; in beds 2 inches to 3 feet thick; slightly sandy, somewhat cross-bedded; vuggy and cherty in places, especially toward the top, where the nodules lie in layers parallel to the bedding; some thin shale partings 1 to 2 inches thick; oolitic to dense, fossiliferous at a few horizons; silicified in places; contains blebs of asphalt. Usually in one vertical ledge, but locally in a series of vertical steps	68½

Moenkopi formation—Continued.

Sinbad limestone member—Continued. | Feet

37. Sandstone, green-gray, limy, petroliferous, shaly, with a few partings of green shale; a number of selenite seams, and some gypsum nodules at the base; becomes sandier upward; at 12 feet above the base becomes a red-brown earthy, limy sandstone, well bedded, ripple-marked, micaceous, very fine grained. Weathers into ledge below and rounded slope above. Partings of red-brown shale, mottled with green, begin at 27 feet above base and increase to top of unit, though the sandstone facies predominates ... 62

Total Sinbad limestone member ... 153

38. Sandstone, shaly, tan; limy, increasingly so toward top; ripple-marked and ripple-bedded throughout; thin bedded, more shaly and less shaly beds alternate in slopes and subordinate ledges; one 2-inch bed of very black petroliferous sandstone 33 feet above the base; in upper part, gypsiferous yellow-brown shale alternates with the sandstone; a 3-foot bed of very clean blue-green shale occurs 3 feet above the base ... 39

39. Conglomeratic sandstone and conglomerate in beds 1 inch to several feet thick; pebbles, largely of milk-blue chert derived from the Kaibab, greatest diameter noted, 1 inch ... 4

40. Sandstone, shaly, containing chert particles; interbedded with sandy green-gray limy micaceous shale ... 9

41. Sandstone, gray, gritty, quartzose, cross-bedded; variable along exposure; contains pebbles like those of No. 23 except that greatest size is three-eighths inch; also waterworn asphalt grains ... 1 to ½

42. Shale, green-gray, gypsiferous, sandy ... ½

43. Sandstone, like No. 41 ... 1 to ½

44. Sandstone, tan, gritty; very thin bedded, with some thin sandy shale; weathers in a slope ... 6½

45. Conglomerate, like No. 39 ... ½

46. Sandstone, green-gray, shaly, very limy; contains chert particles and is not conglomeratic; interbedded with micaceous sandy shale ... 2½

Total Moenkopi formation ... 734

Unconformity, irregular erosion surface with apparent relief of about 10 feet in an area of 2 or 3 acres.

Kaibab limestone: Top bed is a very limy sandstone, gray with some black; weathers into rounded forms.

3. Section near The Tanks, in southern part of Sinbad, San Rafael Swell, Utah

Feet

Moenkopi formation: Chert conglomerate, containing much silt and passing upward into gypsiferous shale.

Erosional unconformity with relief of 40 feet in a few acres of exposure.

Kaibab limestone: Chiefly cream-colored to gray sandy limestone with many shaly nodules, crinoid fragments, and milk-blue chert nodules as much as 1½ inches in diameter; beds 1 to 4 feet thick. Part near top is less sandy and darker gray and shows cleavage facets of calcite as much as one-eighth inch in diameter. Basal 10 feet a fine-grained, limy sandstone, somewhat shaly, passing laterally and vertically into the limestone facies. No sharp lithologic change within the formation ... 69

Feet

Contact, apparently transitional and indefinite within 2 feet.

Coconino sandstone: Sandstone, commonly gray to white but blotched with yellow-brown and rarely maroon; fine grained, sugary; the quartz grains clean, rounded to subrounded, with many "frosted" surfaces; highly cross-bedded and jointed without any apparent system; exposed ... 50+

4. Section on Muddy River, San Rafael Swell, Utah, between mouth of Salt Gulch and mouth of Willow Springs Wash

Curtis formation (basal part): | Feet

1. Conglomerate of pebbles of gray chert, jasper, flint, gray limestone, and green chert, rather well rounded, ranging from one-sixteenth inch to 1½ inches in diameter; matrix of green-gray glauconitic sandstone ... 2

Unconformity, slightly wavy; the material below cracked and bleached for a few inches and sharply different from that above.

Entrada sandstone:

2. Mudstone, chocolate-brown, slightly sandy, with some ripple-bedded sandstone ... 14
3. Sandstone, red-brown, massive, ripple-bedded ... 1½
4. Sandstone, shaly, ripple-marked, soft; forms a slope ... 3
5. Sandstone, shaly, massive, concretionary ... 4
6. Sandstone, soft, red-brown, with subordinate chocolate-colored mudstones; indistinctly bedded; weathers into a slope like shale ... 16
7. Sandstone, red-brown, earthy, massive; weathers into "stone babies"; not well exposed ... 142
8. Sandstone, fine to coarse grained, ripple-marked and cross-bedded; purple, green-gray, chocolate-brown; seamed with gypsum; forms a strong persistent ledge ... 11½
9. Mudstone, chocolate-brown, sandy, soft, indistinctly bedded; forms a slope broken by subdued ledges of slightly more sandy beds ... 33
10. Sandstone, red-brown, fine grained, somewhat shaly, ripple-bedded; gritty in parts, almost approaching a fine conglomerate; cross-bedded, somewhat lenticular; forms an irregular ledge ... 2½
11. Sandstone, brick-red and gray, thin bedded, ripple-bedded, alternating with chocolate-brown mudstone and shale in beds about 3 inches thick; upper 12 feet massive, poorly bedded and slightly contorted ... 68
12. Sandstone, massive, very gypsiferous; forms a ledge ... 2½
13. Silt, dark chocolate-brown, soft, sandy ... 4
14. Sandstone, shaly, massive, limy, seamed somewhat with selenite; toward top almost a sandy gypsum; forms a ledge ... 6
15. Sandstone, brick-red and gray, thin bedded, ripple-bedded, alternating with chocolate-brown mudstone and shale in beds averaging 3 inches in thickness except for a 2-foot sandstone ledge 16 feet from the base ... 48

Entrada sandstone—Continued.	Feet
16. Gypsum (alabaster), sandy; forms a ledge, though friable; selenite common in seams	1½
17. Sandstone, soft, friable; red-brown, earthy, fine grained, cross-bedded; weathers in rounded forms	3½
18. Sandstone, brick-red and gray, thin bedded, ripple-bedded, alternating with chocolate-brown mudstone and shale in thin beds	24
19. Gypsum, like No. 16	2½
20. Series of alternating beds of poorly bedded red silty sandstone, forming ledges, and dark chocolate-brown blocky, shaly sandstone which forms niches; a few ½-inch limestones. Each individual layer is poorly bedded but persistent, giving the cliff the appearance of the edges of the leaves of a book	12
21. Gypsum like No. 16	2
22. Alternating beds like No. 20	19
23. Sandstone, red-brown, massive; forms a slope	32
24. Sandstone, red-brown, massive; forms a ledge	10
25. Sandstone, dark red-brown, shaly; bedding apparent and very even when viewed in the large but invisible in the hand specimen; a very gypsiferous zone at 42 feet above the base	61
26. Concealed by valley fill	155
27. Sandstone, light brick-red, ledge-forming, can be traced for miles	29
28. Sandstone, dominantly brown, but with some gray shaly layers; gypsiferous, soft, friable; weathers into a banded slope like a shale; at places along strike stands in cliffs	136
Total Entrada sandstone	843½

Contact conformable; a sharp lithologic change only at this horizon.

Carmel formation:	Feet
29. Gypsum, orange-red, porous, silty	3½
30. Silt, red-brown, with some purple shale and much secondary gypsum	3
31. Sandstone, shaly, red-brown; forms a ledge	½
32. Shale, green-gray, flaky	10½
33. Gypsum, pink, with some green silt and chert	½
34. Silt, red-brown, passing into green-gray shale	3½
35. Gypsum, porous, impure, and green silt with much secondary chert	½
36. Shale and sandstone, greenish gray, ripple-bedded, lenticular	5
37. Gypsum and silt, like No. 35	1
38. Shale and sandstone, like No. 36	10
39. Silt, red-brown, gypsiferous	7
40. Gypsum, impure, with much green silt; bedding highly contorted	4½
41. Silt, red-brown at base, passing up into greenish-gray flaky, somewhat sandy shale, with some ripple-bedded lenticular sandstone at about 25 feet above the base	31
42. Gypsum, impure, banded with green silt; some pink selenite crystals	6

Carmel formation—Continued.	Feet
43. Shale, green, alternating with a minor amount of chocolate-brown silt; some selenite seams	5
44. Alternating green sandstone and shale, thin bedded, ripple-bedded throughout; shale predominant. Ripples trend N. 60° E., of current type and indicating current from west	19
45. Silt, chocolate-brown, unconsolidated	2
46. Gypsum, contaminated with much red and green silt	1
47. Shale, greenish gray, well laminated, with some lenses of sandstone	1½
48. Sandstone, limy, thin bedded (average one-fourth inch), oscillation-ripple marked throughout (trend N. 40° E.)	1
49. Shale, greenish gray; with subordinate very thin sandstone lenses; ripple-bedded throughout	11
50. Sandstone, friable, poorly bedded, oscillation-ripple marked, somewhat shaly; contains both light and dark mica and includes a few thin lenses of greenish shale	20
51. Shale, green, maroon, and chocolate-brown, alternating	6½
52. Gypsum, impure, with much green silt and secondary jasper	1½
53. Silt, red	9
54. Shale, green	7
55. Gypsum, impure, with green and red silt and jasper crusts	2½
56. Silt, reddish brown, gypsiferous	2
57. Gypsum, pink, impure	1
58. Shale, green	6
59. Gypsum, greenish, impure, with green silt and some pink selenite	2½
60. Shale, green	4½
61. Gypsum, like No. 59	1
62. Shale, green	9
63. Gypsum with much interbedded green shale	1
64. Shale, green	2
65. Alternating gypsum, green-gray rippled sandstone, and subordinate flaky green-gray shale; more gypsiferous in upper part	7
66. Shale, green, becoming sandier upward and passing into poorly bedded shaly sandstone at the top	51
67. Gypsum, snow-white, mottled with small aggregates of greenish and red silt; many selenite seams 1 inch thick cutting across and parallel to the bedding planes	4½
68. Shale, greenish, with some blue; highly gypsiferous and seamed with selenite	18
69. Gypsum, impure, largely reddish brown with some green, persistent	6
70. Shale, green, with some soft greenish-yellow fine-grained sandstone; about 70 per cent shale	32
71. Gypsum, impure, with irregular beds of green limestone and shale at the base; a layer of soft yellow shaly unconsolidated sand 10 to 12 feet above the base; white gypsum containing pockets of yellow sand above that to top of member	28
72. Shale, lenticular, greenish gray, flaky	2

Carmel formation—Continued.	Feet
73. Sandstone, yellow, soft, fine grained, very friable except at the top; weathers a peculiar yellow-brown	1
74. Gypsum, spongy, crystalline, white, with much yellow clay and silt distributed through it	11
75. Shale and shaly limestone, greenish gray, veined with gypsum along and across the bedding; passes completely into limestone within 100 feet along exposure and then into gypsum 150 feet farther on	3½
76. Shale, greenish gray, limy, with some secondary gypsum	7½
77. Gypsum, largely pink selenite, streaked with green silt	1½
78. Silt, unconsolidated, red-brown, highly gypsiferous	5
79. Shale, green-gray, limy, seamed with greenish gypsum, especially near the top	7
80. Gypsum (alabaster) containing isolated crystals of selenite as much as three-eighths inch long; thickness variable	3–7½
81. Mudstone, reddish brown, much fractured and jointed; cracks filled with fibrous selenite, at some places 2½ inches thick, associated with jasper crusts; some greenish shale and sandstone in upper part	12
82. Gypsum (impure alabaster) with shale streaks and selenite, as in No. 80	5
83. Shale, green	3½
84. Gypsum, like No. 82	6
85. Shale, limy, platy, very thin bedded	13
86. Sandstone, greenish gray, fine grained, ripple-bedded, with some green silt along the bedding surfaces; finely laminated in upper part; forms ledge	2½
87. Shale, gray, limy, platy, weathering almost white, and thin lenses of ripple-bedded greenish-gray sandstone, increasing upward. Unit seamed with selenite, some of which has altered to chert	22
88. Limestone, variable; in places oolitic, in places dense or sandy, even a shaly sandstone; passes from one phase to the other both across and along the bedding; forms a strong ledge, the top 8 feet being a persistent dense limestone; breaks into slivers usually, though locally platy; fossiliferous; *Trigonia* and *Camptonectes* especially plentiful	78
89. Gypsum and green-gray sandy shale and sandstone, greatly contorted on a small scale, especially around gypsum nodules in the shale and sandstone; about 25 per cent gypsum	2
90. Sandstone, greenish gray, weathering brown, shaly, very fine grained, poorly bedded; weathers into rounded forms. Some subordinate layers of clean sandstone show cross-bedding on a small scale	12
91. Sandstone, gray, clean, mostly limy but siliceous in places, thin bedded, cross-bedded on a small scale; forms strong ledge	2½

Carmel formation—Continued.	Feet
92. Shale, greenish gray, micaceous, unctuous, and some subordinate thin lenses of greenish-gray limy ripple-bedded sandstone	9
93. Conglomerate or breccia, largely of flint pebbles but with some clear and some milky quartz 1 inch in largest dimension, poorly sorted; unit cavernous but firmly cemented	½
94. Gypsum, impure, yellowish gray, with much limestone and shale; somewhat spongy in texture	2½
95. Sandstone, reddish brown, fine grained; soft, almost unconsolidated in lower part; gray and slightly better cemented above	18
96. Sandstone, yellowish gray, very irregularly bedded and including pockets of maroon shale; soft at base, harder and better bedded toward top, a hard, limy greenish-gray ledge 2½ feet thick	12½
97. Sandstone, shaly, poorly bedded; weathers into rounded forms below and slabs above; persistent limy zone at top	14
98. Sandstone, blue-gray weathering dark brown; hard, limy, somewhat shaly but resistant; beds about 2 inches thick	3
99. Shale, dark blue-gray, carbonaceous, with some thin, very limy ripple-bedded lenticular sandstones and sandy limestones; some reddish-brown iron concretions near the base; shale constitutes 85 per cent of unit	7
100. Limestone (a coquina in places) and shale, alternating in beds about 2 inches thick; some rill marks in the limestone, which is very vuggy	1
101. Shale, greenish gray, carbonaceous, well laminated, almost black on fresh exposure, weathering with dark reddish-brown streaks	1
102. Limestone, dense, very hard, with some shale containing red calcite blebs; forms a strong ledge; fossiliferous; *Trigonia* and *Camptonectes* especially common	2
103. Shale, green-gray, carbonaceous, limy, in some places slightly sandy; blocky in lower part, platy above; forms a slope	7½
104. Sandstone, dark reddish brown, limy, varying to sandy limestone and in some places a clean, dense purple limestone, extremely fossiliferous; forms a strong persistent ledge	2½
105. Limestone, gray, dense in some places, oolitic in others; very hard; forms a ledge; fossiliferous, locally almost a coquina	1
106. Shale, limy, gray, varying to soft, well-laminated shaly limestone; fossiliferous; forms a slope	4
107. Shale, sandy, greenish gray, varying to thin-bedded soft sandstone; both limy and veined with selenite; fossiliferous; forms a slope	2½
108. Sandstone, evenly bedded, fine grained, tan, limy, very resistant; forms a ledge; composed of reworked Navajo sandstone	11
Total Carmel formation	648–652½

Unconformity, cutting cross-bedding of Navajo sharply.

5. Section of Dakota (?) sandstone and Morrison formation in terrace 2 miles south of Willow Springs Wash, west flank of San Rafael Swell, Utah

Mancos shale.

Apparent conformity.

	Feet
Dakota (?) sandstone:	
1. Sandstone, yellow-gray, cross-bedded, ripple-marked, gritty; in two beds separated by 3 feet of dark-gray carbonaceous shale	13
Unconformity; contact a scoured surface.	
Morrison formation:	
2. Mudstone, purple variegated with white, bluish gray, maroon, and reddish brown; contains many small lenses of nodular silicified limestone, caliche-like zones, and thin sandstone lenses, some conglomeratic, none over 2 feet thick and a few scores of feet wide	189
3. Conglomerate and sandstone, brownish gray, very hard, lenticular	8
4. Mudstone, like No. 2, rather limy; at 46 and 55 feet above the base nodular jasper lenses 1 foot thick	124½
5. Chert and jasper, nodular; interbedded with bentonitic (?) clay and poorly bedded light-gray coarse sandstone, which is only partly cemented	5½
6. Mudstone, dominantly purple, gray, and maroon; contains some thin nodular silicified limestone, a few thin lenticular sandstones, and at 12 feet above the base a persistent 2 to 4 foot limestone	86
7. Sandstone of lenticular "channel" type; very limy and cherty	1–5
Total Morrison formation	414–418

Summerville formation: Thin-bedded orange-red shaly sandstone and sandy shale with some interbedded thin gray limy sandstones.

6. Section in gulch southwest of Drunk Man's Point, San Rafael Swell, Utah

	Feet
Summerville formation (part):	
1. Alternating thin-bedded lilac to brick-red clays and soft gray sandstone	18
Curtis formation:	
2. Sandstone, gray, soft; forms a slope except the bottom 6 inches, which is platy and forms a ledge; some thin dark-green cross-bedded sandstones and a little purple shale are interbedded; upper 3 inches contains shale pellets	11
3. Sandstone, green-gray, soft except for a basal ledge-forming bed	6
4. Sandstone, green-gray, soft, with a few harder beds but no ledges; forms slope	11½
5. Sandstone, green-gray, concretionary, limy; forms ledge	1
6. Sandstone, light greenish gray, soft, nonpersistent	8
7. Sandstone, green-gray, weathering brown, ripple-bedded, very hard and limy, concretionary; forms a ledge	1
Curtis formation—Continued.	
8. Sandstone, green-gray, weathering brown, medium to coarse grained, massive; bedding indistinct, with some ripple-marked surfaces; weathers into biscuit-shaped limy masses; contains some carbonaceous seams, and a rather resistant 4-foot bed about 30 feet above the base; cross-bedding more evident above this bed than below it	88
9. Sandstone, shaly, greenish gray, soft, much cross-bedded; true bedding irregular, rarely evident; carbonaceous, especially along certain seams; secondary seams of selenite common; some rusty strata interbedded	9½
10. Sandstone, green-gray, very hard, firmly cemented, medium grained; contains pellets of green shale as much as 1 inch long and three-eighths inch thick and much carbonized vegetable matter; forms ledge	3½
11. Sandstone, greenish gray, fine grained, blocky; no evident bedding	2½
12. Shale, green-gray, poorly laminated; limy, with some concretions and many selenite seams; some thin ripple-bedded sandstone lenses as much as three-fourths inch thick	5
13. Sandstone, massive, silty, cross-bedded throughout, lime-cemented, some secondary gypsum seams; carbonaceous in places	4
14. Shale, greenish gray, and lenticular ripple-bedded sandstone alternating in thin beds; unit sandier toward the top	6
15. Sandstone, very limy, ripple-bedded; upper half forms a ledge; lower half soft and slightly shaly; not persistent	1½
16. Shale, green-gray, in places concretionary, containing many beds about half an inch thick of lenticular cross-bedded fine gray sandstone. This unit grades into sandstone within a quarter of a mile along the exposure	15
Total Curtis formation	173½

Unconformity; surface of Entrada sandstone covered with veneer of pebbles of black chert and gray limestone, which are somewhat embedded in the sandstone in places; the surface was exposed to weathering and then reconsolidated. Contact surface strikes N. 7° E. and dips 3½° W.

Entrada sandstone: Sandstone, red-brown, earthy, massive, thick bedded, strike N. 20° E., dip 2½° W., exposed to level of Salt Gulch, at least 400 feet.

7. Section in Saddle Horse Canyon, San Rafael Swell, Utah

Navajo sandstone: Sandstone, buff to yellow-gray, massive; cross-bedded on a very large scale; forms vertical cliff.

Transitional contact.

	Ft.	in.
Todilto (?) formation:		
1. Shale, green, very sandy	1	
2. Sandstone, white to greenish gray, much cross-bedded; contains a few shale pellets, shale lenses, and small limonite concretions	4	3
3. Shale, green, passing by gradation into No. 2	3	6
4. Sandstone, greenish gray, hard, in one bed; ripple-marked throughout, cross-bedded on a very minute scale; contains flakes of shale		8

Todilto (?) formation—Continued.	Ft.	in.
5. Shale, maroon, clayey		6
6. Sandstone, like No. 4		6
7. Shale, green at base, passing up into maroon; flaky		8
8. Sandstone, buff, tangentially cross-bedded; weathers into benches and slopes—the benches made by thin laminæ containing small shale particles and spherical limy nodules one-sixteenth to one-fourth inch in diameter	12	6
9. Sandstone, white and tan, containing green shale pellets; coarse grained, ripple-marked and ripple-bedded throughout	2	2
10. Sandstone, pink, very micaceous, thin bedded; top surface channeled with a relief of more than a foot	8	
11. Sandstone, white, very micaceous, ripple-marked throughout, cross-bedded, with chiefly angular but some tangential cross-bedding at angles as great as 28°; contains many comminuted fragments of green shale	2	
12. Shale parting, green		2
13. Sandstone, pink, in beds averaging 6 to 8 inches thick with thinner bedding at bottom and top	5	
14. Sandstone, in alternating laminae of pale red and white, carrying small fragments of green shale; fine grained, cross-bedded; has a very limy layer with hummocky surface about 6 inches below the top; top 6 inches a micaceous shale conglomerate with shale pebbles as much as 2 inches in diameter, though the average is about three-eighths inch	6	
15. Shale, maroon, slightly sandy	1	
16. Sandstone, light red, with a few partings of maroon shale; carries pellets and flakes of allochthonous green shale; top 2 inches bleached white	2	
17. Shale, maroon, like No. 15		6
18. Sandstone, of the channel type, torrentially cross-bedded, and containing flakes of green shale as large as 2 inches by three-eighths of an inch; extremely variable along the strike; very resistant; forms a ledge	2	6
19. Sandstone; lower 40 feet massive, gray, coarse grained, tangentially cross-bedded, containing large flakes of muscovite and a few shale pellets, which lie at all angles to the bedding, though prevailingly parallel to it. The massive sandstone passes into red micaceous very thin-bedded sandstones and above them through much cross-bedded material carrying flakes of green shale into well and evenly bedded, dominantly light brick-red sandstone with alternating white bands a quarter of an inch to 10 inches thick. This red and white sandstone is rather friable and contains fragments of a green mineral, quartz, magnetite, sporadic mica, and some chlorite with very little silt; in uppermost 15 feet lamination is poorer and ferruginous and limy concretions occur	87	6
20. Sandstone, brick-red, bleached green along joints and in uppermost foot; very micaceous, very fine grained, extremely thin bedded but well bedded; ripple-marked on a small scale. The unit is cut out by scour within a quarter of a mile in one direction from the point of measurement and within 2,000 feet in the other, the sandstone above descending in both directions; bedding surfaces in the uppermost foot continuous from the normal red to the green weathered layers, though the green layers are somewhat brecciated from weathering		9
21. Sandstone, white, friable; has a surficial pink tinge due to wash from upper part of Todilto (?) formation; contains throughout pellets of green shale ranging from those of microscopic size to pieces 3 inches by half an inch; these weather out on the surfaces and leave pits; bedding thick, somewhat thinner at bottom; unit shows angular cross-bedding at angles as high as 17° and some tangential cross-bedding. In basal part of unit the sand is interlaminated with shale and there are channels as much as 5 feet deep cut in unit 22. At 15 feet above base a short lens of green shale and at same horizon a shale conglomerate with chunks 6 inches long. Unit forms a persistent ledge crowning the Wingate sandstone cliff for miles	31	
22. Shale, green, flaky, persistent; ranges in thickness from 2 feet to 2 inches	1	
Total Todilto (?) formation	181	5

Contact shows some channeling, but no observable angular unconformity.

Wingate sandstone:	Ft.	in.
23. Sandstone, buff, cross-bedded; massive, except for a few thin water-laid beds; forms sheer cliff	139	
24. Sandstone, gray, in one cliff-forming bed with tangential cross-bedding	34	
25. Sandstone, soft, thin bedded, almost laminated; alternating yellow-gray and light red in thin lenses; contains bands of cone-in-cone calcite	7	
26. Sandstone, buff; massive, with tangential cross-bedding	43	6
27. Sandstone, white, thin and thick bedded, softer than most of the formation; forms a distinct bench	12	
28. Sandstone, buff, with tangential cross-bedding cut off at all angles; almost certainly wind-laid	73	
29. Sandstone, buff, thick bedded, calcareous, with some subordinate thin-bedded water-laid material. A few thin lenses of dense cherty limestone occur on the opposite side of the canyon at this horizon but do not appear on the near side	11	
30. Sandstone, gray-buff, composed of rounded grains; cross-bedded very irregularly on a large scale; a typical dune deposit	30	6
Total Wingate sandstone	350	

	Ft.	in.
Unconformity, channeled surface.		
Chinle formation:		
31. Clay shale, light blue-green, passing up into green sandstone in 2-inch beds and shale, capped by a 2-inch bed of bright-green sandstone	7	2
32. Shale, flaky, dark red; contains no sand; a thin band of green shale at the base	3	6
33. Sandstone, red, containing shale pellets as much as 1 inch in diameter, ripple-marked throughout, cross-bedded. This bed increases to about 15 feet in thickness within 300 feet along the outcrop	4	
34. Limestone conglomerate; contains fragments of green and red shale and sandstone	1	3
35. Shale, maroon, micaceous, with the mica along the bedding planes	5	3
36. Sandstone, red, in beds one-sixteenth to one-fourth inch thick, ripple-bedded and cross-bedded throughout; very micaceous	5	
37. Shale and sandstone, the shale brick-red; the sandstone green and very subordinate, no bed thicker than about 1 inch, except for a 1-foot sandstone ledge at 11 feet from the base. This member lenses out completely within 300 feet along the outcrop	20	
38. Sandstone, gritty, containing shale pellets; the lower 2 feet massive and red, then a red shale parting, and the upper foot thin bedded and red, with 1 inch of green-gray sandstone at the top	3	
39. Shale, brick-red	3	
40. Sandstone, gritty, at some places all one bed, at others in 6-foot to 8-foot beds; contains conglomerate lenses composed of limestone pebbles half an inch long, micaceous green sandstone fragments 1 inch long, and shale pellets and flakes as much as 3 inches long; a green mineral prominent; forms a persistent ledge	18	
41. Sandstone, dark greenish gray, weathering purple; blocky, limy, extremely fine grained, massive; weathers into mammillary forms; upper contact wavy, the irregularities as much as 3 inches in height	3	
42. Alternating green sandstone and brick-red shale, becoming more limy upward	9	
43. Sandstone, greenish gray, in beds less than one-sixteenth inch thick, very fine grained, ripple-marked and cross-bedded throughout; individual beds lens in and out very rapidly, 6-inch beds disappear within 8 feet; some angular and some tangential cross-bedding present; bedding is much contorted and bends down as much as 3 inches beneath limy lumps; manganese dendrites common	2	
44. Shale; lower third dark green, weathering to purple, almost black; upper two-thirds brick-red, weathering brown-red; very limy throughout	25	6
45. Sandstone, mottled brick-red and green, the green color apparently confined to walls of fractures; very fine grained, very limy; massive, forms ledge; passes upward by gradation into No. 44	7	
46. Shales and sandstone, brick-red; the shale blocky, somewhat sandy, very calcareous, and in beds three times as thick as the sandstone beds	2	

	Ft.	in.
Chinle formation—Continued.		
47. Sandstone, very fine grained, very hard, limy		8
48. Sandstone and shale, alternating; about 80 per cent sandstone, dark brown and chocolate-red, thin bedded, ripple-marked, limy; 20 per cent maroon shale	6	
49. Sandstone, green-gray, rippled, and cross-bedded		4
50. Shale, maroon	2	
51. Sandstone, red, micaceous, fine grained, cross-bedded; at the top weathers gray, and contains green flakes resembling chlorite and muscovite, the muscovite flakes as much as one-sixteenth inch long; one lens with beds less than half an inch thick, all the rest thick bedded. At 50 feet away along the strike, this sandstone and the underlying conglomerate, No. 52, are one bed of sandstone with a thin conglomerate lens in the middle, the whole 6 feet thick	3	
52. Conglomerate; contains quartz grains; very limy, subangular and well-rounded pellets of red shale nearly three-fourths inch in maximum diameter; much crystalline calcite; and a few chert pebbles; beds 2 to 6 inches thick; unit locally massive	2	
53. Shale, maroon in distant view, reddish chocolate-colored in the hand specimen; biotitic, muscovitic, slightly sandy; broken at 3, 5, and 18 feet above the base by sandstone beds 8 inches to a foot thick	29	3
54. Sandstone, green-gray, stained somewhat with limonite; hard, ripple-marked, slabby, in beds one-eighth to one-fourth inch thick; contains rose quartz, muscovite, and magnetite	2	2
55. Shale, green-gray, flaky; slightly sandy, with a few thin gray sandstones—one bed 3 inches thick, with shale flakes in it as much as 2 inches long, cross-bedded and rippled. This sandstone on fresh fracture is mottled gray and brown (the brown from limonite) and contains quartz, muscovite, and a green mineral as common constituents	5	
Total Chinle formation	169	1
Contact apparently conformable.		
Shinarump conglomerate:		
56. Sandstone, gray, medium grained, thick bedded, siliceous, resistant	8	
57. Conglomerate, dark brown, extremely hard and well cemented with silica and lime; pebbles as much as 4 by 2 inches but averaging half an inch in diameter, predominantly of well-rounded white chert with milky quartz, gray crystalline limestone, opaline silica, brown chert, rose quartz, jasper, flint, gray sandstone, and green shale in angular fragments. Rock breaks across the pebbles at many places and forms a strong ledge. Many plant and bark fragments as much as several inches in length, some carbonized, are present, and carnotite stains are associated with the siliceous and carbonized wood	9	6
58. Shale, green-gray, flaky, without sand, and with broken carbonized plant remains	5	6

Shinarump conglomerate—Continued.	Ft.	in.
59. Sandstone lens, gray, massive; thins out laterally	6	
60. Conglomerate, like No. 57	1	6
61. Sandstone, gray, weathering light brown; massive, grading into No. 62	5	
62. Conglomerate, like No. 57, grading up into No. 61	2	
63. Sandstone, like No. 57, but with fewer and smaller pebbles	5	
64. Shale, gray, nearly a clay; forms a slope	9	
65. Sandstone, gray, like No. 61	2	
66. Sandstone and conglomerate alternating; varies much laterally and vertically; beds average perhaps 3 feet in thickness; top 6 inches is thin bedded and shows ripple marks and cross-bedding. Unit forms a strong ledge	9	6
67. Sandstone, medium to fine grained, made up largely of quartz and some black grains not determinable with the hand lens; somewhat softer than the beds above and below	3	8
68. Sandstone, gritty, with sporadic pebbles of same sort as in No. 57, cross-bedded at angles with the true bedding as high as 20°, well cemented, somewhat mottled with brown on gray, highly variable along the strike	1	6
69. Conglomerate, only partly consolidated, many pieces of silicified wood 4 inches or less in diameter and pebbles like those in No. 57. A white efflorescence as much as half an inch thick occurs at the top and bottom of this member and also in reticulating veinlets through it	2	2
Total Shinarump conglomerate	70	4
Unconformity; surface wavy, with a relief of about 6 inches in a length of 10 feet.		
Moenkopi formation:		
70. Shale, gray and purple; a persistent zone seen throughout the area just below the Shinarump conglomerate, not typical of Moenkopi lithology, but here assigned to that formation	10	
71. Sandstone, red, typical Moenkopi, not measured.		

8. *Section on west flank of San Rafael Swell near Horn Silver Gulch, in secs. 35 and 36, T. 20 S., R. 8 E., Utah*

Mancos shale.		
Dakota (?) sandstone:	Ft.	in.
1. Grit, gray, limy, cross-bedded, with iron concretions up to 1 foot in diameter; and conglomerate of small rounded to subangular pebbles of black and white chert, white and rose quartz, and clay in a slightly gritty matrix; forms a persistent ledge, above which the Mancos shale begins	26	
Morrison formation:		
2. Mudstone, variegated, light gray, blue-gray, and greenish gray	96	
3. Sandstone, slightly gritty, light gray, slightly friable, lime-cemented; subrounded grains of rose quartz, white quartz, and biotite make up the rocks; lenses out within 200 yards	3	6
4. Mudstone, very poorly laminated, light gray, gypsiferous	42	

Morrison formation—Continued.	Ft.	in.
5. Conglomerate lens, disappears within half a mile in one direction and 300 feet in the other; very little sandstone present	4	
6. Shale and clay, dominantly light gray banded with purple and mauve and with numerous 4-inch bands of dense blue-gray nodular limestone; forms a slope strewn with limestone and silicified limestone balls derived from these beds	93	
7. Conglomerate, with lenses of sand constituting as much as a third of the unit; persistent; contains well-rounded pebbles of flint with some jasper and brown chert, averaging three-eighths inch in diameter but as large as 2½ inches. Thickness varies by inclusion of lenses of shale and clay at some places and increases locally to 20 feet	6	
8. Shale and clay, variegated indigo-gray, light gray, and maroon; with some thin limestones, as in No. 6	66	
9. Limestone, green-gray, dense; much silicified, with chert lenses roughly parallel to the bedding and following joints, the chert evidently a weathering product; the bed is a lens disappearing within 100 yards along the strike	3	6
10. Clay, variegated gray, purple, red, and brown, with purple, maroon, white, and gray marl, brick-red shale, and sandstone in a few thin lenses 6 inches to 1 foot thick and rarely over 200 feet long, though at the corresponding horizon 100 yards away there are several thick sandstones which lens out before reaching this section	134	6
11. Sandstone, slightly gritty, cross-bedded; very lenticular, exposure less than 150 feet long	1	6
12. Marl, white	7	6
13. Clay, purple, limy, varying to slightly clayey limestone	9	
14. Shale and clay, variable, purple, micaceous, gypsiferous, passing along the strike into sandstone; fractured, with a white material resembling bentonite along the cracks and apparently interbedded with the clay	2	
15. Clay, white, brick-red, and purple, with a few thin limestones; passes upward into dead-white marl with a few shaly maroon limestones; under the microscope the clay proves to be an altered volcanic ash, approaching bentonite in structure	31	6
16. Sandstone, lenticular, grayish red, fine grained, irregular; contains lumps of marl and clay	1	6
17. Clay, red	9	
18. Clay, gray, with a bench of purple limestone at 15 feet from the base and a few thin sandstone lenses	22	
19. Marl, purple, containing limestone lumps	1	
20. Clay, gray-green, with lenticular thin sandstones and an 8-inch limestone	21	
21. Channel sandstone, cross-bedded, conglomeratic, with a siliceous cement; base irregular, with a relief of 2½ feet in a short distance; dinosaur bones at the top. Capping a winding ridge, the sandstone lens, nowhere over 100 yards wide, can be traced with northeast trend for miles and is clearly a fossil stream channel	9	6

Morrison formation—Continued.

	Ft.	in.
22. Clay, light green-gray; at 7 feet above the base a persistent 6-inch ledge of blue-gray limestone, weathering brown	48	
23. Limestone, shaly, gray, weathering brown	1	6
24. Clay, gray	51	
25. Sandstone, conglomeratic, like No. 21; extremely variable along its northeast trend and lenticular across it; thins out and disappears in about an eighth of a mile along its course in one direction from the point of measurement, though it continues in the other for a long distance	13	6
26. Clay, gray with some purple; contains some lumpy marl weathering brownish purple	34	
27. Channel sandstone, like No. 21 but lensing out in both directions along its trend	13	9
28. Clay, gray, like No. 26; contains a 3-inch sandstone at 16 feet above the base	23	6
29. Channel sandstone, very lenticular; like No. 21 but not persistent; as much as 6 feet thick and lensing completely out within 500 feet	2	
30. Clay, light green-gray, pinkish gray, purple-gray, and tan; very subordinate shaly limestone and brown marl	6	
31. Channel sandstone with grit lenses; lenticular, although this horizon is sandy for long distances; some of the conglomerate pebbles are three-fourths inch in diameter, though the average is much less; a thin short lens of sandy marl 11 feet above the base	14	
32. Sandstone, white, friable; poorly bedded, somewhat shaly, lenticular, vanishing within a few score feet	1	6
33. Clay, blue-gray, becoming sandier upward and passing into No. 32	3	
34. Sandstone, like No. 32	1	3
35. Clay, gray, with some shaly limestone and thin sandstone lenses 4 inches thick and 30 feet long	16	6
36. Sandstone, cross-bedded, conglomeratic, pebbles as much as a quarter of an inch in diameter, largely of flint and gray chert	4	
37. Clay, like No. 30	21	
38. Limestone lens, nodular, sandy, with small chert pebbles scattered through it; thickens to 1½ feet and then lenses out in a short distance		6
39. Clay, gypsiferous, gray	4	
40. Gypsum (alabaster), with thin seams of green clay, contorted perhaps by hydration of the gypsum; contains jasper chert crusts of irregular shape as much as 2 inches in length, some with hollow centers filled with crystalline quartz; lower 10 feet forms a ledge, the upper part a slope	24	
Total Morrison formation	847	

Unconformity, angular and erosional; the gypsum cuts down across the bedding of the red shale and sandstone of the Summerville formation as much as 3 feet in 30 feet of outcrop.

Summerville formation: Sandstone and micaceous shale, alternating in thin beds seamed with secondary gypsum.

9. *Section in gulch north of Horn Silver Gulch, in secs. 28–29, T. 20 S., R. 9 E., San Rafael Swell, Utah*

	Ft.	in.
Curtis formation (part): Conglomerate of pebbles of gray sandstone as much as 1½ inches long and well-rounded chert pebbles in a green-gray sandstone matrix, cross-bedded and interfingering with thin shales.		
Unconformity, angular and erosional.		
Entrada sandstone:		
1. Sandstone, green and red, top part scoured and checked, containing pebbles of chert and shale; a consolidated soil	3	
2. Shale, green, flaky		2
3. Sandstone, shaly, massive, limy; weathers in rounded forms	9	
4. Shale, maroon, with a few thin lenses of green-gray sandstone	7	6
5. Sandstone, red-brown, very shaly and soft, thin bedded; top few inches bleached green-gray	6	
6. Sandstone, clean, very fine grained, cross-bedded and ripple-marked		2
7. Shale, maroon, with a few lenses of very fine grained green-gray sandstone one-eighth to one-sixteenth inch thick	1	3
8. Sandstone, mostly red-brown but green at top and bottom; a 2-foot subdued ledge at the base, shaly and thin bedded above	11	
9. Shale, maroon	1	
10. Sandstone, shaly, red except the top, which is bleached	7	
11. Sandstone, red-brown except for gray bleached zone at the bottom; upper 3 feet is shaly and thin bedded, forming a slope; remainder massive	15	3
12. Clay, purple, limy		6
13. Sandstone, red-brown except at the top, where it is greenish gray; massive and weathers in rounded forms like a granite	4	6
14. Sandstone, red-brown, very silty, massive; forms a bench	20	
15. Shale parting		1
16. Sandstone, red-brown, massive, soft and silty but forms a bench	9	6
17. Sandstone, thin bedded; forms a slope	3	
18. Sandstone, massive, like No. 14	55	
19. Sandstone, very soft and shaly, brown-red	3	
20. Sandstone, dark red, with cavities containing calcite and chert	1	6
21. Sandstone and shale, thin bedded, extremely wavy, limy; contains crusts of red chert in geodes and along fractures	2	
22. Sandstone, like No. 14	6	
23. Sandstone, dark red, thick bedded except 1 foot of shaly material at the top	28	6
24. Shaly sandstone with much red chert in crusts and geodes	1	
25. Sandstone, like No. 14, except that the upper foot is a strong ledge	4	6
26. Sandstone, red-brown, poorly bedded, ripple-marked; cross-bedded; top surface hummocky; uppermost 2 feet forms a ledge; remainder shalier	5	
27. Sandstone, light gray, ripple-marked, fine grained	2	6
28. Sandstone, shaly, red-brown; contains a ledge of green-gray cross-bedded, current-rippled cleaner sandstone; coarse grained, with some large well-rounded quartz grains and fine chert, almost a fine grit	12	

Entrada sandstone—Continued.

	Ft.	in.
29. Sandstone, red-brown, mostly shaly but with a 2-foot ledge at the top	13	
30. Sandstone, brownish gray, shaly, poorly bedded, gypsiferous; lenticular, thinning within a few feet along the strike	2	
31. Shale, very thin bedded, micaceous, slightly sandy; contains some greenish gray and some red sandstone, poorly bedded, soft, limy	10	
32. Sandstone, gray-brown, gypsiferous, limy; very irregular lower boundary, with relief of 1 foot in 10 feet, perhaps due to variable cementation but not to channeling; forms a ledge	2	
33. Sandstone, shaly, dark red-brown, thin bedded, lenticular	9	6
34. Sandstone, brown-gray, gypsiferous, shaly, cross-bedded; in thin irregular beds 1 inch thick but weathers as one massive layer	6	6
35. Shale parting		8
36. Sandstone, gypsiferous, shaly, cross-bedded; like No. 34	1	6
37. Shales, micaceous, chocolate-brown, in beds from 6 to 18 inches thick; alternating with green-gray sandstone in beds less than 2 inches thick, ripple-marked, cross-bedded, lenticular; gypsum seams, largely parallel to the bedding, as much as three-eighths inch thick, are abundant in the upper part	13	
38. Sandstone, gray, thin bedded, cross-bedded, with gypsum seams, lenses out along the bedding	2	6
39. Sandstone, red, thin bedded, shaly, with numerous seams of secondary gypsum; cross-bedded and ripple-marked throughout	62	6
40. Shale, dark brown, micaceous, slightly sandy		2
41. Sandstone, white, coarse grained, capped by silicified platy layer; forms a very persistent ledge		6
42. Sandstone, red, thin bedded, apparently thick bedded toward the top	26	6
43. Sandstone, white, ripple-marked, cross-bedded, medium grained; contains large plates of biotite and also selenite crystals in cavities; forms a small ledge		3
44. Sandstone, soft, red, thin bedded, with much secondary gypsum	116	
45. Concealed interval interpreted as the basal part of the formation, as the next outcrops are gypsum beds typical of the Carmel formation	32	
Total Entrada sandstone	518	6

Carmel formation.

10. *Section on south side of Sawtooth Butte, San Rafael Swell, Utah*

Chinle formation (part):

	Ft.	in.
1. Shale, maroon, micaceous; contains a number of thin lenses of green-gray ripple-marked fine-grained, extremely micaceous sandstone	5	

Contact displays no angular discordance or notable erosion.

Shinarump conglomerate:

	Ft.	in.
2. Sandstone, conglomeratic at the top, and shale; beds very lenticular and much channeled; unit shows tangential and angular cross-bedding; forms a strong ledge. Beds of conglomerate and sandstone from 6 inches to 3 feet thick, very hard, with lime cement; pebbles of the conglomerate include quartz, chert, green shale, and fine sandstone. Shale lenses green, very lenticular, well laminated; contain rounded quartz pebbles around which the laminae are curved	7	
3. Shale, micaceous, maroon except the top 6 inches, which is green	8	
4. Sandstone, thin bedded, cross-bedded, medium grained; increases to 4 feet in thickness in 100 feet along the strike; forms strong ledge	2	
5. Sandstone, gray, medium grained, with silicified wood; thin parting of red shale in the middle	5	6
6. Conglomeratic sandstone, medium gray, with much dark mineral (biotite?) in the sand; cross-bedded, with laminae of alternating coarse and fine sand with sporadic pebbles of black chert, and red, white, and colorless quartz as much as 1½ inches in diameter. Upper surface irregular, relief of 6 inches in a length of 6 or 8 feet. A persistent layer at the top contains chunks of shale as large as 6 by 6 inches by 1 foot	2	3
7. Conglomerate; pebbles of quartz and limestone 1½ inches or less in diameter in a matrix of coarse granular sandstone	2	6
8. Clay, limy, lumpy, approaching a marl; dark blue except top 1½ feet which is greenish gray	13	6
9. Grit, light gray, weathering reddish brown, cross-bedded; individual beds not persistent, averaging 6 inches thick and 30 feet long; very hard, cemented with both calcite and silica; forms a ledge	1	
10. Shale parting, green		6
11. Grit, like No. 9	2	6
12. Grit, reddish brown except where leached and and blotched with white and green; unconsolidated, the sand grains about one-sixteenth inch in diameter and largely white, colorless, and rose quartz; contains much clay, which seems to be in transported lumps and breaks with very brilliant fracture surfaces; upper surface irregular	3	
13. Sandstone, with angular quartz grains, very light pinkish gray, cross-bedded; decidedly lenticular, pinching out in 50 feet; forms a ledge	1	
14. Grit, not well consolidated, micaceous, with some shale particles; purple-gray, somewhat mottled	1	3
15. Sandstone, very light gray, fine grained, very limy; forms a ledge	4	
16. Clay, sandy, nodular, in lumps about the size of an egg; purple, mottled with blue and brown, probably colored by manganese and iron; wavy, irregular upper surface	21	6

Shinarump conglomerate—Continued.	Ft.	in.
17. Sandstone, reddish brown spotted with gray, limy and ferruginous; in concretionary masses 1 foot by 2 inches; largely quartz, stained with some yellow mineral	6	
18. Clay, sandy; purple at a distance, mottled gray on close view, with some yellow mineral stains	5	
19. Conglomerate, very carbonaceous, not very well cemented; chiefly of coarse angular quartz with some gray detrital calcite, some carbonized wood fragments as large as 2 by 7 inches, some detrital asphaltite with stringers of red mineral fragments and some thin shale lenses with plant remains	13	
20. Shale, black, carbonaceous, gypsiferous, with carbonized wood fragments and leaves and some yellow mineral stain	3	
21. Shale, fine-grained sandstone, and medium-grained sandstone, in interfingering lenses as much as 4 inches thick; much carbonized wood and sedimentary asphaltite; sand grains and asphaltite particles largely angular	2	
Total thickness of Shinarump conglomerate	104	6

Contact with no angular discordance nor marked erosion.

Moenkopi formation: Shales and sandstones, gray, ripple-marked, limy, with small fragments of carbonized wood.

11. *Section at mouth of Buckhorn Wash, San Rafael Swell, Utah*

Wingate sandstone: Sandstone, tinged with green at the base for 2 feet, above which it is buff; stained red on the surface with wash; massive, cross-bedded, with only 8 or 10 bedding planes in over 350 feet of strata.

Unconformity. The lower few feet of the overlying formation is shaly and lenticular, in some places occupying scoured channels in the lower beds. There is no evidence in the San Rafael Swell of any diastrophism having occurred in the interval between the deposition of the Chinle and that of the Wingate formation.

Chinle formation:	Ft.	in.
1. Shale, limy, green and purple; showing scour, filling with sand, and later scour and filling with shale		4
2. Sandstone, greenish gray, ripple-marked, very micaceous, very limy; with a few shaly lenticular partings; shale flakes numerous	8	6
3. Shale, mottled greenish gray and chocolate-brown, well laminated; mud cracks evident		2
4. Sandstone, greenish gray, ripple-marked		2
5. Shale, like No. 3, much squeezed	2	
6. Sandstone, brick-red, becoming green-gray upward; limy and shaly; weathering into rounded forms	3	
7. Sandstone, green-gray, mud-cracked, ripple-marked; some shale pellets along bedding planes and some thin shale partings; the shale pellets reach 3 by 1 by one-fourth inch in size	1	6
8. Shale, maroon, with a few lenses as much as 2 inches thick of ripple-marked and rill-marked thin-bedded greenish-gray sandstone	3	

Chinle formation—Continued.	Ft.	in.
9. Sandstone, tan, fine grained, with some shale partings and numerous shale flakes one-half by one-half by one-eighth inch in maximum size; micaceous, limy, thin bedded, cross-bedded; forms a strong ledge, except the top 3 feet, which is very thin bedded and nonresistant	12	
10. Shale, red-brown, micaceous, and thin bedded ripple-bedded sandstone, alternating	1	6
11. Sandstone, greenish gray, very limy, with calcite along the fractured surfaces; ripple-bedded, rill-marked; containing many small shale pellets; upper surface mud-cracked	1	
12. Shale and sandstone, alternating, red-brown except along some joints, where they are leached to greenish-gray; sandstone micaceous, ripple-marked, cross-bedded; shale blocky, poorly laminated	2	6
13. Sandstone, green-gray, hard, limy, ripple-marked and rill-marked; calcite along joint surfaces; contains animal borings one-eighth to one-sixteenth inch in diameter	1	
14. Shale and sandstone, like No. 12	3	6
15. Sandstone, reddish gray at base, greenish gray at top; very fine grained, ripple-bedded, very limy; contains shale pellets as much as a quarter of an inch in diameter; forms a small ledge	2	
16. Sandstone, shaly, greenish gray; lenses out in 8 feet	1	6
17. Sandstone, reddish gray; massive in some places, one-fourth inch bedding in others; ripple-marked, mud-cracked, micaceous; forms ledge	3	
18. Mudstone, very sandy, chocolate-brown, micaceous	4	6
19. Shale conglomerate, containing angular fragments of shale as large as 2 by 4 by 6 inches, very micaceous along certain bedding surfaces; passes upward into an apparently massive but really thin-bedded ripple-marked, rill-marked greenish-gray sandstone with several shale conglomerate lenses whose shale fragments are less than 2 inches in diameter; in some places weathers into rounded forms, in others into thin plates due to the rippling; forms a ledge	12	
20. Shale, maroon, micaceous, lenticular; fades out laterally; upper surface scoured	1	6
21. Sandstone, red-brown, micaceous, shaly, cross-bedded, ripple-marked, mud-cracked, lenticular, with some interbedded shale; contains animal trails and borings as much as three-sixteenths inch in diameter	1	
22. Shale, maroon, micaceous, well laminated	11	
23. Sandstone, greenish, mottled with light red in places; contains fragments of green shale one-half by one-eighth inch scattered throughout; mud-cracked, rill-marked; thin bedded in lower part (one-eighth to one-fourth inch bedding), massive above, where it weathers into rounded forms; much calcite along joint surfaces; forms a ledge	16	6

Chinle formation—Continued.

	Ft.	in.
24. Shales, green-gray, purple, and maroon, all well laminated; some are micaceous and have sheen, perhaps due to desiccation; mud-cracked; about one-fifth of bed is dark reddish-gray, fine-grained ripple-bedded sandstone, in lenses one thirty-second to one-fourth inch thick	4	
25. Sandstone, greenish gray, very limy, micaceous, ripple-marked, massive; lower contact is irregular, owing to reworking of No. 26; forms a ledge	1	
26. Limestone conglomerate, mottled purple and ash-gray, with some drab; limestone pebbles light gray and purple, the largest 2 inches in length; matrix a limy sandstone; whole bed forms cliff, weathers into nodular forms, and is much fractured and jointed	6	
27. Marl, red-brown, soft, slightly sandy, becoming sandier upward and containing some sand lenses; weathers into a slope	5	
28. Limestone, nodular, shaly, passing upward into red-brown, slightly sandy marl, fractured and colored green along the cracks; checked and cracked into parallelopipeds; forms a ledge	4	
29. Shale, brick-red, with subordinate brown sandstone lenses as much as 2 inches thick, passing upward into blocky, very limy massive fine-grained red shaly sandstone, mottled with green along the numerous joints; above lower 10 feet marl predominates, containing, in the upper few feet, nodules of dense purple crystalline limestone from the size of a pea to that of a walnut; unit forms a slope	21	
30. Sandstone, drab, weathering light greenish gray; cross-bedded both angularly and tangentially; unit in one bed at this point, but 10 feet away along the strike it is all thin bedded; farther on it is interbedded with shale; forms a ledge	2	
31. Sandstone, reddish brown, thin bedded, ripple-bedded, with some greenish-gray lenses half an inch to 3 inches thick; interbedded with maroon micaceous shale; unit is 70 per cent sandstone; forms slope	5	
32. Sandstone, red-brown, blotched with green due to leaching; thinly laminated, ripple-marked, cross-bedded, very fine grained; weathers into small curved plates about a quarter of an inch thick; forms a ledge	3	6
33. Shale, brick-red, weathering chocolate-brown	7	6
34. Sandstone, drab, weathering light greenish gray, medium grained; carries muscovite, biotite, and magnetite but consists chiefly of rounded quartz; very limy, ripple-marked; in one massive blocky bed forming a ledge	1	9
35. Shale, maroon, micaceous, with many glistening surfaces, perhaps indicating desiccation	14	
Total Chinle formation	167	11

Contact a very uneven surface with a relief of 15 to 20 feet within 100 yards.

Shinarump conglomerate: Coarse to fine grained limy cross-bedded ledge-forming sandstone with sporadic quartz pebbles which become less numerous upward.

12. *Section of Wingate sandstone in Cane Wash, San Rafael Swell, Utah*

	Ft.	in.
Todilto (?) formation:		
1. Sandstone, buff, in beds 5 to 10 feet thick, separated by thinner-bedded zone of alternating buff sandstone and green shale. The heavier sandstones are cross-bedded tangentially at steep angles, and in some places the bedding is much contorted as if by slumping due to water scour. Local shale conglomerates of chunks as much as 8 inches long arranged at all angles to the bedding, as well as thin green shale lenses as much as 12 feet long, formed in place, prove that this series was at least in part deposited in water	30+	
Contact gradational.		
Wingate sandstone:		
2. Sandstone, tangentially cross-bedded; very dark brown, nearly black, with impregnated petroleum	21	
3. Shale, green, well laminated, persistent for some distance		2
4. Sandstone and shale conglomerate; the angular shale chunks, arranged at all angles to the bedding, reach sizes of 1 foot by 5 inches by one-half inch, but most of the fragments are about a quarter of an inch long	5	6
5. Green shale and sandstone, containing much muscovite and chlorite, gypsiferous, thin bedded, very well laminated, lenticular, grades upward into No. 4	2	
6. Sandstone, buff, with a few black layers showing spots of asphalt (?) stain	71	
7. Sandstone, with tangential cross-bedding on a large scale, dominantly buff, but with much black, the cross-bedding surfaces separating the two colors	15	
8. Sandstone, mostly black but in part buff, with tangential cross-bedding dipping S. 80° E., S. 30° W., and N. 55° E., in various parts of the bed; some small black iron concretions at the top	39	
9. Sandstone, buff and black, in part tangentially cross-bedded and in part horizontally bedded; rippled surfaces and contorted bedding common. The cross-bedding is indicated by the scattered slightly larger grains of quartz on surfaces of finer material	4	6
10. Sandstone, white, with lenses of black material, sharply cut off on horizontal surfaces by tangential cross-bedding in different directions	1	
11. Sandstone, black with subordinate buff; tangential cross-bedding	4	
12. Sandstone, buff, with a few black bands, not noticeably cross-bedded	12	6
13. Sandstone, black and buff, tangentially cross-bedded; forms a strong ledge	6	6
14. Sandstone, buff, with very subordinate black bands in lower part; tangentially cross-bedded, the planes dipping N. 60° W., S. 10° W., and N. 65° E	20	
15. Sandstone, black, interbedded with buff; tangentially cross-bedded; varies somewhat in thickness but is persistent laterally	13	

Wingate sandstone—Continued.	Ft.	in.
16. Sandstone, buff, massive, with only two true bedding planes, one at 20 feet, the other at 83 feet above the base; strong tangential cross-bedding with the planes dipping in so many directions that no system is apparent; forms a bench	95	
17. Sandstone, light red, separable from No. 18 only by the color differences; tangentially cross-bedded at high angles; not persistent for more than 300 feet	10	6
18. Sandstone, buff, tangentially cross-bedded at high angles, the cross-bedding planes dipping S. 60° E., S. 40° W., and N. 20° E.; true bedding surfaces rare, one at 3 feet, one at 10 feet, and one at 23 feet above the base being the only breaks in an otherwise massive member	44	
(Beds 16, 17, and 18 are all deeply pitted with solution cavities, ranging in size from very small pits to hollows 3 feet in diameter, which apparently start along bedding surfaces but are not controlled by them in their development.)		
Total Wingate sandstone	364	8
Unconformity (?); contact shows only slight channeling.		
Chinle formation (part):		
19. Shale and thin sandstone, green, well bedded		6
20. Sandstone, buff, massive, limy, medium to fine grained, composed of quartz and an unidentified dark mineral; cross-bedded tangentially	3	
21. Sandstone, ripple-bedded, green-gray; and shale, well bedded, green.		

13. *Section of Moenkopi formation at north end of San Rafael Swell, Utah*

[Units 1 to 26 measured at mouth of Red Canyon; remainder north from head of Black Box Canyon]

	Feet
Shinarump conglomerate: Conglomerate and coarse sand; forms a vertical ledge.	
Contact shows no noticeable angular or erosional unconformity.	
Moenkopi formation:	
1. Clayey sand and sandy clay, 80 to 90 per cent sand; soft, forms slope	20
2. Sandstone, mottled gray and red, the red perhaps due to wash; very fine grained, composed chiefly of well-rounded quartz sand, mostly colorless, with sporadic large frosted glassy grains and some mica; flaggy in the middle, with a shale parting, but massive at top and bottom	24
3. Shale, dark red-brown, micaceous; very well laminated, ripple-marked and mud-cracked	2
4. Mudstone, chocolate-brown, with a few thin bands of green-gray sandy shale and red and green micaceous gypsiferous sandstone; secondary seams of gypsum as much as 1 inch in thickness	11
5. Sandstone, red-brown, flaggy, micaceous	5
6. Mudstone and sandstone, like No. 4	6
7. Sandstone, red-brown, limy, massive, ledge-forming	4
8. Mudstone and sandstone, like No. 4	16
9. Sandstone, like No. 5	4
10. Mudstone and sandstone, like No. 4	79

Moenkopi formation—Continued.		Feet
11. Sandstone, like No. 7		10
12. Mudstone and sandstone, like No. 4		25
13. Sandstone, like No. 7		4
14. Mudstone and sandstone, like No. 4		15
15. Sandstone, like No. 7		3
16. Sandstone and mudstone, like No. 4		9
17. Sandstone, like No. 7		5
18. Mudstone and sandstone, like No. 4		61
19. Sandstone, dark gray, weathering light gray, micaceous; contains black, brown, and green grains, some of them perhaps hydrocarbons; concretionary, in beds half an inch to 4 inches thick with a few thin shale partings		42½
20. Shale, chocolate-brown to brick-red, micaceous, containing a few thin lentils of hard limy gypsiferous sandstone; the finer material darker than the coarser; 6-inch ledge of gray sandstone 64 feet above the base		126
21. Sandstone, red-brown, ripple-bedded, limy, micaceous, quartzose, with heavy iron stain; forms a strong ledge		9
22. Sandstone, buff at the bottom, brick-red above, with a wavy boundary between the colors; thin bedded except for one 2-foot blocky massive bed; lime-cemented, symmetrically ripple-marked		37
23. Shale, green-gray, micaceous, gypsiferous, well laminated; includes thin lentils of sandstone which constitute about 10 per cent of the member		21
24. Sandstone, gray, fine grained, shaly, gypsiferous, limy, ripple-marked; beds separated by green-gray well-laminated shale, which makes up about a fourth of the material at the base but is less abundant toward the top		27
25. Sandstone, brown-gray on fresh fracture, weathering dark brown, massive, fine grained, lime-cemented, cross-bedded on a small scale; weathers to a semiplaty débris but forms a strong ledge		9
26. Sandstone like No. 22, with about the same distribution of the colors		36
Sinbad limestone member:		
27. Limestone with a minor amount of sandstone, the two phases not sharply separated and passing gradually one into the other; the sandstone micaceous but not well bedded; the limestone dense, light gray to buff, stylolitic, containing dendrites of manganese and numerous rounded grains of quartz one-sixteenth of an inch in diameter; pelecypods and cephalopods abundant in some layers; unit contains oolite-like grains of asphalt	19	
28. Sandstone, gray, weathering brown, fine grained, micaceous, with calcite cement; massive, cross-bedded; weathers into thin plates and has a shaly parting in the middle	15	
29. Limestone, massive, dirty purplish gray, weathering light gray; dense, in part crystalline; breaks in irregular angular fragments; strongly petroliferous; very fossiliferous, brachiopods and mollusks numerous	11½	
Total Sinbad limestone member		45½

Moenkopi formation—Continued.

	Feet
30. Shale, buff-yellow, limy and sandy; contains some edgewise conglomerate and is seamed and veined with gypsum; contorted on a small scale; forms a slope	7
31. Shale, gray, slightly sandy, gypsiferous, making up three-fourths of the unit; alternates in thin beds with dark-gray sandstone, weathering medium gray, ripple-bedded by symmetrical ripples 1½ inches long, and weathering into platy fragments. Except for dominantly sandy zones between 60 and 90 feet and between 120 and 130 feet above the base, no sandy beds exceed a few inches in thickness. The unit as a whole is soft, a slope former	146
32. Sandstone, buff-brown, limy, thin bedded, ripple-bedded, seamed with gypsum; fine grained, with about 30 per cent brown grains; forms a ledge	2½
33. Sandstone, yellowish-stained gypsum, and shale; the sandstone friable, of the type of No. 6	24½
34. Sandstone, light gray, thin bedded, fine grained, friable, limy; composed dominantly of white quartz with scattered grains of limonite; weathers into platy fragments	1½
35. Gypsum, yellow, interbedded with blue-gray well-laminated micaceous limy, sandy shale, which makes up about one-third of the unit	2
Total Moenkopi formation	839½

Unconformity, not well exposed.
Kaibab limestone.

14. *Section in Black Box Canyon, San Rafael River, San Rafael Swell, Utah*

Kaibab limestone.
Contact apparently conformable.
Coconino sandstone:

	Feet
1. Sandstone, white to buff, sugary, in beds from 1 to 15 feet thick, cross-bedded, very uneven grained; gritty and definitely water-laid at the base, finer grained upward; very much jointed and weathering like an igneous rock, owing to the jointing and the inconspicuous bedding. The canyon receives its name from the prominent coating of desert varnish on the cliffs formed by this unit	662
2. Sandstone, buff, very limy, sugary and friable; gritty, with rounded grains of quartz and feldspar as much as one-eighth inch in diameter, set in a finer-grained matrix	3
3. Sandstone, buff, very limy at base, less so at the top; grades into No. 2 without a sharp break; fine grained, with much mica and some thin limestone lenses at the base	22
4. Limestone, buff, with some buff sandstone, largely massive, with some parts thin bedded; varies from sandstone to limestone along the strike, with some shaly material in both types; a 6-inch zone of limestone conglomerate 6 feet above the exposed base; quartz and calcite-filled geodes numerous, and some limonite pseudomorphs after pyrite; exposed to water's edge	26
Total Coconino sandstone exposed	713

15. *Section half a mile south of the head of Black Box Canyon of San Rafael River, San Rafael Swell, Utah*

	Feet
Moenkopi formation: Conglomerate, fine to coarse, with many angular and subangular chert and quartz pebbles; in 1-foot lenses, locally recurring in two beds 1 to 1½ feet thick separated by 5 feet of buff gypsiferous shale.	
Erosional unconformity, with a relief of about 15 feet in an area of 5 acres. The conglomerate occurs only in the hollows, the higher points being covered with green-gray gypsiferous shale. In some of the depressions a gritty white clay occurs, probably being derived from the decomposition of the Kaibab limestone in pre-Moenkopi time.	
Kaibab limestone:	
1. Limestone, light gray to cream-colored, weathering dark to light gray, containing some limy sandstone beds 1 to 9 feet thick which grade into true limestone; surface pitted; contains abundant nodules which range from half an inch to 5 inches in diameter, though mostly about an inch, and which are chert on the outside, lined with crystalline milky quartz, and filled at the center with large calcite crystals. Toward the middle of the unit iron concretions are numerous, their sharp angular outlines in strong contrast with the mammillary surfaces of the quartzose nodules. Thickness varies owing to erosion surface at the top	61–76
2. Sandstone, gray, weathering nearly white; massive, in two or three beds; very limy, micaceous; very unevenly granular, grains one-sixteenth inch in maximum diameter	5
3. Limestone, sandstone, and shale, thin bedded and interfingering; the limestone practically all altered to white, chalky-appearing chert, with scattered gray nodules as much as 3 inches in diameter; the limestone beds average half an inch in thickness; the shale and sandstone lenses are thinner, averaging perhaps a quarter of an inch, though a few are as much as 4 inches thick; some angular chert in these thicker layers is perhaps clastic, but the whole bed is so checked and broken that it may have been formed in place	3–4½
Total Kaibab limestone	69–85½

Contact gently rolling; conformity probable but uncertain.
Coconino sandstone: Sandstone, heavy bedded, cross-bedded, white, sugary.

16. *Section on south side of Cedar Mountain, in sec. 10, T. 19 S., R. 11 E., San Rafael Swell, Utah*

Entrada sandstone (part): Sandstone, maroon, fine grained, gypsiferous, cliff former.
Carmel formation:

	Ft.	in.
1. Gypsum, green, bedded, with much selenite veining; forms a ledge	4	
2. Sand, green-gray	1	6
3. Sand, maroon, with gypsum veins and layers	3	
4. Gypsum, green stained	1	
5. Shale and sandstone, sandier upward; green	5	3
6. Sand, maroon, much veined with secondary selenite	2	
7. Gypsum, white		10
8. Sand, red and green, gypsiferous, unconsolidated	1	
9. Gypsum, white		3
10. Shale, green	4	3
11. Sand, red, gypsiferous	2	6
12. Gypsum, clean white, bedded	1	6
13. Sand, gypsiferous, red	3	9

Carmel formation—Continued.	Ft.	in.
14. Gypsum, massive	5	
15. Shale, green	11	6
16. Sand, red, gypsiferous	2	6
17. Gypsum		6
18. Shale, gray-green, sandier toward the top	32	6
19. Gypsum	2	
20. Sandstone, gray, gypsiferous, thin bedded	4	
21. Gypsum		4
22. Shale, green	4	
23. Sand, red, gypsiferous	1	6
24. Shale and thin sandstone; gray, flaky, ripple-marked; thin gypsum parting at the top	21	6
25. Sand, maroon, shaly	1	
26. Gypsum, clean white alabaster, massive	5	3
27. Sand, maroon, shaly, soft	1	
28. Gray shale and sandstone, alternating; interbedded gypsum bands 4 feet above the base; much secondary selenite along cracks	6	
29. Gypsum, green-white	3	
30. Sand, green-gray, highly gypsiferous; a few black grains disseminated through it	1	
31. Sand, red, highly gypsiferous	1	6
32. Sand, like No. 30	1	
33. Gypsum, white, soft, pure; forms a flat bench	5	
34. Gypsum, interbedded with gray dense crystalline limestone in lenses from a quarter of an inch to 30 feet long and from paper-thin to 2 inches in thickness; the gypsum very clean and hard; no limestone in the upper 10 feet, which forms a persistent ledge	16	9
35. Clay, gray-green and chocolate-red, highly gypsiferous	1	6
36. Gypsum, clean white, practically free from silt		10
37. Sandstone, gray, gypsiferous, very soft and friable	2	6
38. Clay, red, very gypsiferous, slightly sandy	7	
39. Shales and sandstones, gray; highly micaceous, some biotite flakes one-eighth inch long; clean gray quartz sand and gray clay, with secondary gypsum seams as much as 1 inch in thickness	6	
40. Gypsum (alabaster), stained green; weathers cavernous and hummocky; bedding apparent on distant view but not prominent in detail; fibrous seams of selenite as much as 1¼ inches thick cut diagonally across the bedding but more commonly lie parallel to it; forms a ledge	6	3
41. Sandstone, green-gray, fine grained, ripple-marked, cross-bedded, composed of rounded grains of quartz; upper 8 feet massive and cut by many gypsum seams as much as half an inch thick, which have a tendency to follow the bedding planes but cut across them at places; the fibers of gypsum are neither parallel to the bedding nor perpendicular to the walls of the veinlets; some of the veinlets show comb structure, and most of them die out downward but upward enlarge into nodules of alabaster gypsum as much as 1 inch thick and 3½ inches long; these nodules are flattened roughly parallel to the bedding; forms a ledge	20	9
42. Limestone, oolitic, containing shell fragments		2
43. Shale, drab	3	

Carmel formation—Continued.	Ft.	in.
44. Limestone, shaly, gray, hard, thin bedded, platy; breaks into chips one-eighth to one-half inch thick and 3 to 5 inches across; forms a ledge	3	6
45. Limestone, massive, gray, very dense, blocky; irregular leached cavities numerous in the middle part; forms a persistent ledge; a few fossils in the upper part	1	10
46. Shale, hard, limy; drab, weathering creamy gray; in beds one-fourth to one-half inch thick, slabby, ripple-marked; sandy to varying degree, in the upper part approaching a sandstone	32	
47. Sandstone, gray, platy, fossiliferous; breaks into shelly fragments 2 to 6 inches across, one-eighth to 1 inch thick; forms a strong ledge	6	
48. Sandstone, thin bedded, ripple-marked, cross-bedded; in small lenses one-eighth to 1 inch thick and three-fourths to 4 inches long; the top 1 foot unconsolidated sand; forms a slope	7	
49. Sandstone, very limy, buff; oolitic at the top, with coarser grains as much as one-eighth inch in diameter; variable between the limy and the sandy facies by gradation along the bed, not by discontinuous lensing	2	6
50. Limestone, shaly, changing upward to a sandy, limy shale, greenish gray, weathering buff; forms a slope	15	6
51. Limestone, light gray, dense, breaking with conchoidal fracture; somewhat sandy in the middle, shaly and platy at the top; fossiliferous throughout; forms a strong ledge	5	6
52. Conglomeratic limestone, containing numerous chert pebbles as much as three-eighths inch in diameter and small, nearly spherical gray oolites; *Camptonectes*, *Trigonia*, and *Ostrea* numerous		2
53. Limestone, blocky; massive at both top and bottom, with a thin-bedded shaly zone in the middle; *Camptonectes*, *Trigonia*, and *Ostrea* abundant, lie at many places at right angles to the bedding; one shell observed with valves vertical and umbo down	3	6
54. Sandstone, greenish gray, extremely limy; in paper-thin to 4-inch beds, ripple-marked, tangentially cross-bedded; has a 2-inch parting of green shale at the top; forms a ledge	2	2
55. Shale, greenish gray, slightly sandy, not very well laminated; contains some soft gray thin-bedded fine-grained ripple-marked cross-bedded limy sandstone toward the top; uppermost 1 foot sandstone; forms a slope	11	9
56. Sandstone, fine grained, gray, weathering drab; contains lenses of dense gray ripple-marked limestone, weathering white; beds from paper-thin to 3 inches in thickness; oscillation ripples on top, wave length 6 inches, amplitude half an inch	5	1
57. Shale, from greenish gray to almost black, slightly sandy, not very well laminated; contains some thin lenses of sandstone; forms a slope	4	9

Carmel formation—Continued.	Ft.	in.
58. Sandstone, buff, weathering brown, the upper part much stained with desert varnish; very hard and limy; at some places massive, at others in one-half to 6 inch beds; cross-bedded and ripple-marked throughout; fine grained, consisting chiefly of white quartz grains; some of the beds with high concentration of dark minerals, among them biotite; forms a very persistent ledge	5	9
59. Sandstone, buff, weathering light brown, fine grained, very limy, probably chloritic; and shale, dominantly greenish gray with some thin maroon bands, especially toward the bottom, well laminated, flaky, and pure; interbedded in lenses 1 foot long and 3 inches thick; unit variable, ripple-marked throughout	2	8
60. Sandstone, red, possibly owing to wash from the overlying beds, as fresh fracture shows green-gray with only a few red blotches; extremely limy, vuggy; fractured surfaces show broad facets of calcite; beds a quarter of an inch to 5 inches thick; two chocolate-red shale partings 2 inches thick in the upper part; very fossiliferous, in part approaching a coquina; forms a ledge	3	
61. Parting of red and green shale		2
62. Sandstone, maroon, grading into limestone; fine grained, largely recrystallized; contains prolate-spheroidal red oolites from 0.25 to 0.75 millimeter in diameter and very irregular in distribution, also vugs of calcite; shows facets of calcite on fracture; alternates with beds of shale one-quarter to 3 inches thick, decidedly ripple-marked, and lensing in and out along the strike; fossils abundant, including *Ostrea*, *Camptonectes*, and *Trigonia*	2	4
63. Shale and sandstone, alternating in beds one-sixteenth to 1 inch in thickness; the sandstone yellow-gray, weathering brown; the shale green with a brown tinge, making up 70 per cent of unit; the upper surface of the unit ripple-marked	1	
64. Sandstone, yellow, weathering brown; in beds 1 to 3 inches thick; composed of fine-grained clean white and pink quartz sand; stained by limonite and manganese; hard, very limy, showing facets of calcite on fracture surfaces; forms a ledge		10
65. Shale, blocky, greenish, with limonite stains along the bedding planes and around incipient concretionary centers; very limy; contains muscovite but no sand		8
66. Sandstone, yellow, weathering brown, very fine grained, shaly, rather friable, with a few thin shale partings through the bed	1	6
Total Carmel formation	324	10

Unconformity; rolling surface, rather broadly irregular.

Navajo sandstone: Sandstone, buff, massive, cross-bedded; exposed to a thickness of 30 feet.

17. *Type section of the Entrada sandstone at Entrada Point, northern San Rafael Swell, Utah*

	Feet
Curtis formation: Conglomerate of chert pebbles in a green gray sandstone matrix.	
Erosional unconformity, shown in a rolling surface of low relief.	
Entrada sandstone:	
1. Sandstone, reddish chocolate-colored, becoming gray toward the top; thinly laminated, cemented by lime	5
2. Sandstone, chocolate-red, medium grained, massive; weathers into rounded forms	8
3. Sandstone, chocolate-brown; mostly laminated, massive in places	3½
4. Sandstone, chocolate-brown, medium to fine-grained, massive; weathers into rounded forms	13
5. Sandstone, light red, coarse, gritty	2
6. Shales, red, weathering gray, sandy, thin bedded	1½
7. Sandstone, chocolate-red, fine grained, massive, cross-bedded	2
8. Shale, green-gray, well laminated, alternating in thin layers with red, gray-green, and gray sandstones; unit sandier toward the top	2½
9. Sandstone, chocolate-red, fine grained, massive; forms a bench; in the upper 4 feet many angular and subrounded fragments of fine-grained green-gray sandstone, ranging from half an inch to 15 inches in length, disposed at all angles to the bedding	29
10. Sandstone and shale; sandstone micaceous, mottled red and green; shale sandy and chocolate-red	5½
11. Sandstone, chocolate-red, massive, fine grained, cross-bedded in thin laminae	4
12. Sandstone, fine grained, and shale, variegated	2
13. Sandstone, chocolate-red, massive, fine grained; weathers into rounded forms	14
14. Sandstone, chocolate-red, thin bedded, medium to fine grained	15
15. Sandstone, chocolate-red, very fine grained, variable along the strike; massive, cliff-forming in some places, terraced in others; cemented with lime	22
16. Sandstone, chocolate-red, bleached green in places; thin bedded, fine grained; upper surface channeled	11
17. Sandstone, gray, cross-bedded tangentially; medium grained, with coarser grains near the base; almost surely water-laid; forms a ledge	30
18. Sandstone, light gray, fine grained	2
19. Sandstone, red, fine grained, massive; forms a cliff	18
20. Sandstone, chocolate-brown, thin bedded, medium to fine grained	7
21. Sandstone, chocolate-red, in beds from 2 to 8 inches thick	5
22. Shale, chocolate-red, well laminated	1
23. Sandstone, gray, red in places, medium grained, massive; concretionary toward the top	3
24. Shale, micaceous, and sandstone, thin bedded, chocolate-brown to red, with greenish streaks through it	3

Entrada sandstone—Continued.	Feet
25. Sandstone, light gray to pink, medium grained, massive; with discontinuous shaly partings; cemented with lime	5
26. Sandstone, dark brown, thinly laminated; weathers like shale	2
27. Sandstone, chocolate-brown, cross-bedded, massive, fine grained; upper and lower surfaces irregular	5
28. Sandstone, chocolate-brown with a few gray bands, coarse grained at the base, medium grained above, friable	30
29. Sandstone, gray and yellow, in thick beds showing contorted cross-bedding, composed largely of white quartz, dark and light mica, loosely cemented with lime, somewhat friable and with a shale parting at 7½ feet above the base	11
30. Sandstone, reddish brown, medium grained, massive, cross-bedded toward the top; the upper surface rolling, with a relief of 1 foot; weathers into rounded forms	22
31. Sandstone, gray, mottled, thin bedded, shaly	7
32. Sandstone, reddish brown, medium grained	1
33. Sandstone, greenish gray, shaly, fine grained; contains many red grains, probably of agate	20
Total Entrada sandstone	312

Carmel formation.

18. *Section of Summerville and Curtis formations at Summerville Point, near head of Summerville Wash, northern San Rafael Swell, Utah*

Morrison formation (part):	Feet
1. Clay, chocolate-colored, containing many lumps of gypsum as much as 4 inches in diameter; passes, by a zone 6 inches thick, into a gray shaly sand containing some carbonaceous matter	4
Unconformity, not prominent.	
Summerville formation (type section):	
2. Sandstone, chocolate-colored, thin bedded	2
3. Clay, with several thin sandstones	4½
4. Sandstone, thin bedded, cross-bedded, ripple-marked, micaceous	2
5. Clay, sandy, chocolate-colored	2
6. Sandstone, gray, fine grained, minutely cross-bedded and showing current-rippling	3
7. Clay, sandy, chocolate-colored; interbedded with gypsum; with well-laminated brown sandstones in beds less than 2 inches thick and gray sandstones in beds less than 1 inch thick; clay greatly predominates, becoming more sandy toward the top; the sandstone ledges give a banded "pipe-organ" appearance when the cliff is viewed from a distance	103
8. Gypsum, chocolate-colored mottled with green; weathering in gnarled, lumpy shapes	¼
9. Clay, chocolate-colored; interbedded with talc-like gray silt, with thin limy chocolate-colored sandstone in beds nowhere over 2 inches thick and usually thinner	32
10. Sandstone, chocolate-colored, very fine grained, very limy, breaking with conchoidal fracture	1
11. Clay, reddish, interbedded with thin limy green-gray sandstone, mostly very thin-bedded but with some layers 8 inches thick	14
Total Summerville formation	163¾
Transitional boundary.	
Curtis formation:	
12. Limestone, sandy, gray, weathering brown; contains many geodes lined with chalcedony, rock crystal, and calcite	¾
13. Sandstone, gray, weathering brown, fine grained, very limy; with thin-bedded zones 5 to 10 feet apart between which the bedding is massive; contains many small black grains (biotite?) and green grains	73½
14. Sandstone, green-gray, medium grained; green grains numerous; bedding irregular, ripple-marked; cross-bedded, breaking into smooth slabs along the planes; more massive toward top and weathering into large disks; contains thin lentils of chlorite-bearing shale	124½
15. Sandstone, green-gray, very limy; coarse, nearly a grit, with well-rounded grains; green grains numerous and clay balls as large as 2 by 1½ inches by three-fourths inch, usually containing carbonaceous material	1
16. Sandstone, greenish gray, weathering brown, fine to medium grained; beds from one-eighth inch to 18 inches thick, irregularly cemented; cross-bedded; clay fragments sparingly scattered throughout, in places associated with carbonaceous material	20
17. Sandstone, medium grained, containing angular clay flakes usually parallel to the bedding; carbonaceous material in irregular lenses	1
18. Sandstone, with some shale, thin bedded, irregularly bedded, fine grained	12½
19. Sandstone and shale, in alternating lenses	2
20. Shale, gray-green, well laminated	14
21. Conglomerate of black, brown, and red chert pebbles one-fourth inch in maximum diameter	⅔
22. Shale, green-gray, clayey, well laminated	½
23. Conglomerate, cross-bedded at angles as great as 30° with the true bedding; same types of pebbles as in unit 21, but more scattered	1
24. Sandstone, gray	1
Total Curtis formation	252½

Unconformity; erosion and angular discordance of 4°.
Entrada sandstone: Sandstone, red, thin bedded.

19. *Section on Curtis Point, Saleratus (Lost Springs) Wash, sec. 34, T. 19 S., R. 13 E., San Rafael Swell, Utah*

Morrison formation (part):	Ft.	in.
1. Sandstone lens, channel type.		
2. Limestone, crystalline, gray, containing much nodular jasper, shattered and veined like septaria; beds about 7 inches thick	4	
Unconformity not apparent at this point.		
Summerville formation:		
3. Sandstone, gray, fine grained; in part massive, weathering brown; in part thin bedded, weathering brick-red; interbedded with chocolate-colored sandy clay; a 6-inch bed of jasper at top; forms a slope	5	6
4. Sandstone, gray, weathering brown, fine grained, limy, thin bedded, ripple-bedded, containing some small clay pellets, variable along strike; forms a subdued ledge	2	
5. Mudstones, somewhat sandy, chocolate-colored; with many 1 to 2 inch beds of cross-bedded calcareous chocolate-brown sandstone	75	6

Summerville formation—Continued.	Ft.	in.
6. Sandstone, gray, weathering chocolate-colored; rather fine, well-rounded grains, some black and some red; massive bed	1	4
7. Mudstone, chocolate-colored, with many thin ledges of very limy sandstone, mostly chocolate-colored but with some green-gray and constituting about 10 per cent of the unit; many balls of gypsum as large as baseballs weather out and are strewn over the surface	23	6
8. Mudstone, sandy, green-gray; passes upward into a variable series of green-gray thin-bedded calcareous, very fine-grained sandstone; highly calcareous gray sandstones which form low ledges; and at about the middle of the unit red sandy clays	17	6
Total Summerville formation	125	4

Curtis formation (type section):	Ft.	in.
9. Sandstone, green-gray, weathering brown; very limy, fine grained, thin, platy; cross-bedded in 6-inch layers between heavier layers of slightly coarser, less limy sandstone, which does not weather brown	21	
10. Sandstone, green-gray, medium grained; weathers in rounded forms due to exfoliation and differential cementation	40	6
11. Sandstone, green-gray, fine grained, friable; clay pellets and loglike iron-stained concretions at various horizons; forms steep ledgy slope	24	
12. Sandstone, green-gray, weathering brown; much carbon at some horizons, clay pellets at others; weathers into rounded forms as in No. 10 and forms ledge	20	
13. Sandstone, green-gray, of fine-grained quartz with some black and green grains; thin bedded, lenticular; interfingers with lenses of green gritty sandstone, which weathers buff, contains many red grains as well as the green and black, and is cross-bedded throughout, with individual beds 4 inches to 2 feet thick; unit forms vertical cliff, capped by projecting ledge	10	6
14. Grit, green-gray, with sporadic pebbles; cross-bedding not as general as in the lower beds and with planes dipping north; 2-inch shale parting in the middle; lenses out within 100 yards	2	2
15. Shale, green-gray, flaky	5	
16. Conglomerate, green-gray, of pebbles of brown, gray, and white chert, and jasper as much as half an inch in diameter but mostly less than a quarter of an inch; very limy; cross-bedded, with planes dipping south at angles as great as 22°, directly opposite to the dip in No. 14	3	
17. Shale, like No. 15	15	6
18. Conglomerate, like No. 16, containing echinoid spines	1	
19. Shale, green-gray, flaky	2	6
20. Conglomerate, like No. 16, but with cross-bedding on a smaller scale; within 100 yards to the north base cuts downward and unit is 12 feet thick	4	6
21. Shale parting, dark gray		6

Curtis formation (type section)—Continued.	Ft.	in.
22. Grit, grains nearly all smaller than wheat grains		6
23. Shale, slightly sandy, dark gray, fissile	7	6
24. Sandstone, gray, weathering buff; limy, with a few thin shale lenses	4	9
25. Shale, sandy, dark gray; includes thin lenses of well-bedded rippled fine-grained limy sandstone which make up about 25 per cent of the member; carbonaceous toward the top	7	
26. Sandstone, buff, massive, fine grained, limy	3	
27. Sandstone, limy, clayey, fine grained, mouse-colored, with red tinge here and there; alternates with sandy shale of the same color; the sandstone especially predominant at bottom and top; gypsiferous in upper part	20	
28. Shale, gray and green-gray, with a little red along some beds; well laminated		8
Total Curtis formation	193	4
Erosional unconformity.		
Entrada sandstone (part):		
29. Sandstone, red, thin bedded, very fine grained	10+	

20. *Section on east flank of Woodside anticline, San Rafael Swell, secs. 17 and 18, T. 19 S., R. 14 E., Utah*

Dakota (?) sandstone:	Feet
1. Grit, ill exposed, at base of Mancos shale	2
Morrison formation:	
2. Clay, variegated yellow, cream-colored, chocolate-colored, bluish gray, greenish gray, brick-red, etc.; contains discontinuous bands of gritty medium-gray limestone which weather dark brown. The limestones contain sporadic grains, one-sixteenth to one-eighth inch in diameter, of jasper and black chert and smaller grains of translucent quartz; seams of secondary calcite common	25
3. Sandstone, light gray, fine grained, with calcareous cement, cross-bedded, much stained with desert varnish; conglomerate at base containing pebbles as much as 3 inches in diameter of clay, chert, limestone, and jasper	11
4. Shale, marly, medium gray with greenish cast	20
5. Limestone, dense but badly shattered; medium gray with greenish tinge and some lilac-red spots; much iron stain along joints; grades upward into a dirty-purplish shaly limestone	6
6. Clay, variegated, like No. 2; limy bands have considerable secondary calcite	33½
7. Sandstone, light gray, fine grained, with limy cement, cross-bedded; conglomeratic at base, with pebbles of limestone, chert, and jasper; much desert varnish on surface	5
8. Clay, variegated, like No. 2; contains a parting of fine-grained thin-bedded greenish limy sandstone made up largely of quartz and jasper	28¼
9. Sandstone, light gray, much cross-bedded; contains several bands of fine conglomerate, cemented with silica; pebbles as much as 1 inch in diameter but mostly about three-eighths inch, chiefly black and gray chert with a few of firm clay including grains of secondary quartz (apparently weathered igneous rock); unit contains also a clay parting at 13½ to 17 feet above base; much desert varnish	18

Morrison formation—Continued.	Ft.	in.
10. Clay, variegated, like No. 2; the gritty limestone bands in places give way to a calcareous grit or a limestone conglomerate with chert pebbles as much as 1 inch in diameter, in part angular, in part smoothed, of many colors; unit weathers into steep slopes covered with jagged pebbles	64	
11. Sandstone, lenticular, like No. 9	3	
12. Clay, like No. 10	18½	
13. Limestone, medium gray, lenticular but more extensive than usual as it is traceable for over half a mile; contains much secondary bluish-white chert, calcite, and rock crystal; weathers into nodular masses from 6 inches to 1 foot across and in places makes a slight bench	4½	
14. Clay, like No. 10	52	
15. Grit and conglomerate, cemented firmly with silica; in places fractures across the pebbles, in places limy with secondary calcite along fractures; lower 4 feet a fine conglomerate with brown, gray, green, white, red, and black chert pebbles averaging three-eighths inch in diameter, and limestone and sandstone pebbles as much as 3 inches in diameter; upper 5 feet a grit which blends with the lower part, very irregular in thickness, and bearing much desert varnish	9	
16. Clay, like No. 2 except that limestone lenses are confined to the upper part	25½	
17. Sandstone, light gray, limy; grains about 0.25 millimeter in diameter, of translucent quartz with some muscovite and a few dark minerals; massive, breaking into angular joint blocks about 1 foot on a side; in part firmly cemented; stained on outcrop by blotches of limonite	5	
18. Conglomerate, cemented with silica, largely of chert pebbles, but with some pebbles of sandstone as much as 4 by 2 inches; layers of cross-bedded sandstone and grit as much as 4 feet thick included; stream-bedded throughout. This is the conglomerate capping Cedar Mountain and forming the prominent hogback west of the Denver & Rio Grande Western Railroad south of Woodside, Utah	19	
19. Shale, limy, greenish gray	3	
20. Clay, purplish on close view, bluish gray at a distance; rather flaky toward the top, approaching a shale in fissility but breaking into angular fragments	4½	
21. Conglomerate, mottled purple and gray, with limestone pebbles as much as 1¼ inches in diameter	½	
22. Clay, drab to green-gray; weathers into steep slopes	45	
23. Sandstone, light gray, with some limonite stain; tangentially cross-bedded; lime-cemented, very friable	3	
24. Clay, gray, with faint greenish-yellow tinge	8½	
25. Sandstone, light gray, weathering drab to brown, friable, lime-cemented, thin bedded, cross-bedded; varies in constitution along strike, at some places gritty and containing subrounded grains as much as one-eighth inch in diameter of gray chert, jasper, and translucent quartz; at other places shaly	2½	

Morrison formation—Continued.	Ft.	in.
26. Clay, drab or gray, with faint greenish-yellow tinge, soft, structureless	16	
27. Sandstone, medium gray, generally friable, lime-cemented, cross-bedded; grains 1 to 2 millimeters in diameter, many coated with limonite; contains small lenses of quartzite and at base a fine conglomerate of clay and chert pebbles	5½	
28. Clay, light greenish gray	19	
29. Sandstone, light gray, limy; cross-bedded, with planes inclined as much as 32° to the true bedding, and no consistent direction apparent; grains about 0.75 millimeter in diameter, chiefly of well-rounded clear quartz, with some jasper and brown chert; clay pellets up to 1.5 millimeters in diameter at bottom of ripples	12	
30. Clay, variegated, dominantly light greenish gray with tinges of red	9	
31. Limestone, dark green, dense, cherty	1	
32. Clay, like No. 30	21	
33. Sandstone, dark green, calcareous, friable, very lenticular	1	
34. Shale, variegated, somewhat fissile	3	
35. Sandstone, lenticular, dark green	½	
36. Clay, like No. 30	3½	
37. Limestone, light, greenish gray, dense, siliceous	1½	
38. Clay, like No. 30	19	
39. Limestone, very dense, green-gray; weathers into nodular forms; much stained with limonite, probably impure	1	
40. Clay, like No. 30	6	
41. Clay and sandstone, alternating; the clay of the type of No. 30; the sandstone limy, greenish gray, weathering brown, in cross-bedded lenses half an inch to 10 inches thick, averaging 4 inches. The unit is about 80 per cent clay and 20 per cent sandstone, and a short distance away one of the sandstone lenses reaches a thickness of 4 feet	14	
Salt Wash sandstone member:		
42. Sandstone, light gray; fine, nearly pure quartz sand cemented by lime; beds as much as 12 feet thick; cross-bedding common, and in the cross-bedded parts, especially toward the top, some layers of fine grit or even fine conglomerate; clay in partings and seams as much as 1 foot thick, especially near the base, constituting 20 per cent of entire unit; unit weathers into a limonite-stained friable rock in rounded forms and makes a strong bench half a mile wide	74	
43. Clay, light medium gray with slight greenish cast, in part variegated; polished pebbles ("gastroliths") on this slope	11	
44. Sandstone, light gray, friable on weathering; largely medium grained; contains a few clay pellets as much as a quarter of an inch in diameter	2½	
45. Clay, like No. 43	6	

Morrison formation—Continued.	Feet
Salt Wash sandstone member—Continued.	
46. Clay, like No. 43, and sandstone, like No. 44. The sandstone constitutes about one-third of the unit, in ledges 6 inches to 2 feet or more thick, weathering light brown; very hard, probably cemented with silica; 11 feet above the base of unit a 1-foot bed of quartzitic grit containing grains of jasper, rock crystal, brown, green, and black chert; sandstone at top of the unit makes a bench 50 feet wide	27
47. Clay, light medium gray with a greenish cast, but in part variegated with a dirty purplish tinge; probably limy	7
48. Clay, like No. 47, and limestone. Limestone constitutes one-third of the unit, medium gray, weathering dark gray, in some places brown; dense, in ledges as much as 1 foot thick. No fossils noted here, but fragmentary gastropods occur elsewhere at this horizon	18½
49. Gypsiferous clay, mainly green-gray, with many seams of fibrous white secondary gypsum; near top a few thin sandstone layers	11
50. Gypsiferous sandstone, grading upward into No. 49; greenish gray, friable, with much secondary fibrous gypsum; apparently a resistant stratum, as it caps a rather extensive bench	15
51. Gypsum, massive and fibrous; contaminated with clay and sand; cherry-red, pink, and white; forms a strong ledge	5½
Total Salt Wash sandstone member	177½
Total Morrison formation	724¾

Unconformity not apparent, though elsewhere a low angular discordance and some erosion are visible at this horizon.

Summerville formation:	Feet
52. Sandstone, dirty brick-red, friable, clayey, gypsiferous; upper 2 feet with fibrous white secondary gypsum in numerous seams nearly parallel to the bedding planes	4½
53. Mudstone, limy, sandy, brownish red with chocolate-brown tinge at close range, brick-red in distant view; massive, nonfissile, breaking into angular fragments, and weathering in part into ellipsoidal masses; contains some thin bands which range in texture from dense medium-gray limestone to coarsely crystalline pinkish or white calcite and which weather into nodules and irregular fragments covering the slope; many of these nodules cherty	1
54. Sandstone, medium gray with a greenish cast, very thin bedded, fine grained, clayey, lime-cemented; includes some red mudstone partings	1
55. Mudstone, like No. 53	3

Summerville formation—Continued.	Feet
56. Sandstone, like No. 54	1½
57. Mudstone, like No. 53	1
58. Sandstone, like No. 54	½
59. Mudstone, like No. 53	8½
60. Sandstone, like No. 54	1½
61. Mudstone, like No. 53, with about 10 per cent sandstone	16
62. Sandstone, like No. 54	4
63. Mudstone, like No. 53	8
64. Sandstone, like No. 54	3
65. Mudstone, like No. 53	8
66. Sandstone, like No. 54	3
67. Mudstone, like No. 53, but a few thin sandstone beds of a medium greenish-gray color, like No. 54	5½
68. Sandstone, like No. 54	4
69. Mudstone, like No. 67, except that the sandy ledges are confined to the upper part	27
70. Limestone, medium gray with red cast, finely crystalline, ripple-marked on upper surface	½
71. Mudstone, approaching a shale in fissility in some places and containing some thin sandstone beds. None of the mudstones above this unit carry more than a few per cent of limestone; in this there is more lime, perhaps 10 per cent	21
72. Limestone, brownish red, dense; contains stringers of quartz sandstone and seams as much as one-eighth inch thick of fibrous gypsum; weathers dark brown; forms a ledge	1
73. Mudstone, like No. 53	1
74. Limestone, like No. 72	½
75. Mudstone, like No. 53	3
Total Summerville formation	128
Curtis formation:	
76. Sandstone, medium gray with slight greenish tinge, weathering rich medium brown; very fine grained, fairly well cemented with lime; beds as much as 6 inches thick, with partings of shale of same color; ripple-marked; composed largely of quartz with some black and some red minerals; contains vugs and cavities lined with jasper, milky chalcedony, and rock crystal. Some of the vugs occur in limestone lenses which reach 6 inches in thickness and several feet in length	128

21. *Section in Cottonwood Springs Draw, sec. 10, T. 20 S., R. 13 E., San Rafael Swell, Utah*

Curtis formation (part):	Feet
1. Sandstone, gray, medium grained, lime-cemented; massive except for a few thin beds toward the top	3½

Unconformity, not strongly expressed here, but 1 mile to the west an angular discordance of 4° and erosional irregularities.

Entrada sandstone:	Feet
2. Sandstone, chocolate-brown, very massive; in general fine grained but gritty in the lower foot or so and containing subangular grains of gray, red, and yellow quartz and some biotite (?); weathers into rounded ledges and cliffs	49
3. Sandstone, buff, fine to medium grained, the larger grains well rounded, many of red quartz, some of blue	11½

Entrada sandstone—Continued.	Feet
4. Sandstone, chocolate-brown, shaly, thin bedded, micaceous; composed principally of red and yellow quartz grains; some dark, possibly carbonaceous streaks toward the middle and top of the unit	3
5. Sandstone, chocolate-brown, massive, fine grained; forms a ledge	4
6. Sandstone, chocolate-brown, friable, medium to fine grained, with sporadic large well-rounded quartz grains; 2-inch parting, at about the middle, of fine-grained cross-bedded gray sandstone with many yellow and red quartz grains	8
7. Sandstone, gray, massive, hard, medium grained, lime-cemented; composed of well-rounded white quartz grains with a few of red	1½
8. Sandstone, clayey, chocolate-brown; incloses lenses half an inch to 4 inches thick of very fine grained gray biotite-bearing lime-cemented thin-bedded and cross-bedded sandstone marked by current ripples of small size; lenses make up about 30 per cent of the rock	11½
9. Sandstone, chocolate-brown, massive, medium to fine grained, lime-cemented; contains some muscovite and a few large yellow quartz grains; forms a rounded slope	17½
10. Sandstone, clayey, chocolate-brown, with subordinate thin lenses of friable gray sandstone	4½
11. Sandstone, massive, gray, medium fine grained; composed chiefly of well-rounded white quartz grains, with some biotite; weathers yellow-gray in a rounded ledge	5½
12. Sand, gray, alternating with friable thin-bedded gray sandstone of fine grain; weathers to a slope	13½
13. Sandstone gray, massive; well-rounded sand grains, chiefly white, yellow, and red quartz, subordinate; black, green, and blue grains; weathers into rounded shapes ("stone babies") several feet long; forms a ledge	12
14. Sandstone, in three thin beds, medium grained, limy, fairly hard	2
15. Sandstone, gray, weathering yellow-gray; thin bedded, with a more massive zone at the top; composed of well-rounded white quartz, with sporadic yellow and red quartz, biotite, and some scattered specks of limonite	29
16. Sandstone, chocolate-brown, massive, lime-cemented; fine grained but with a few coarse, well-rounded grains	6
17. Sandstone, chocolate-brown, friable; basal 2 feet very friable, shaly, and red; above this, three very hard, well-cemented 1-foot beds composed of white and brown subangular quartz grains	19
18. Sandstone, brown, medium grained, composed of subangular quartz with much dark mica; in two heavy beds with 6-inch shaly parting between	2½
19. Sand, shaly, slightly gypsiferous; includes at intervals of 3 and 5 feet three beds of friable chocolate-brown sandstone, about 8 inches thick, forming ledges in the slope made by the unit as a whole	14

Entrada sandstone—Continued.	Feet
20. Shale, sandy, gray, gypsiferous, becoming more sandy upward; uppermost foot nearly a sandstone	8
21. Sandstone, gray, friable, medium coarse grained, finer toward top; made up chiefly of rounded and subangular quartz grains; cross-bedded, planes dipping generally southeast; in beds about 4 feet thick; forms a gentle slope	19
22. Sandstone, gray, weathering yellow-gray, chocolate-red in upper part, sugary, very friable, lime-cemented, cross-bedded, massive, medium to coarse grained; largely of white quartz, with some red and yellow; forms vertical cliff	24
Total Entrada sandstone	265

Contact gradational.

Carmel formation:	Feet
23. Shale, chocolate-brown, becoming sandier toward top	9½
24. Shale, maroon, gypsiferous	2½
25. Gypsum, clean	4½
26. Shale, chocolate-red, with gypsum beds as much as 1 foot thick distributed throughout	11
27. Gypsum, clean	3
28. Clays, greenish gray, gypsiferous	5
29. Gypsum, clean, white	2
30. Shales, green-gray and red, gypsiferous	16
31. Concealed, probably gypsiferous clay and shale	35
32. Sandstone, gray, thin, platy; shows symmetrical ripples, with wave length 2½ inches, amplitude one-fourth to one-half inch, and crest trending generally N. 75° E.	2
33. Shale and sandstone, gray, in very thin alternations	8
34. Gypsum, white weathering yellow	3½
35. Shale, red at base, tan toward top, highly gypsiferous	8½
36. Gypsum (alabaster)	1
37. Sandstone and shale, alternating; chocolate-brown, with some clean maroon clays	11
38. Sandstone, blocky at base and thin, platy, highly micaceous toward top	½
39. Shale, sandy, chocolate-red	2½
40. Shale, slightly sandy	2
41. Sandstone, very shaly, green-gray, thin bedded, platy	2½
42. Sandstone, gray, weathering yellow-brown, medium grained, composed chiefly of subrounded quartz, cross-bedded at top; forms strong ledge	3½
43. Sandstone, shaly, light gray, ripple-bedded	10
44. Concealed	2
45. Sandstone, gray, fine grained, very limy, concretionary; cross ripples form a rhombic pattern on surfaces	7
46. Shale, slightly sandy, gray, soft	3½
47. Limestone, gray, shaly, fossiliferous	½
48. Sandstone, gray, thin bedded, platy, limy, with many grains of a black mineral (biotite?); makes low slope	9½
49. Sandstone, shaly at base, green-gray, fine grained, in beds 1 to 3 feet thick at base, thin bedded and flaggy toward the top; symmetrical ripple bedding throughout; forms strong ledge	19

Carmel formation—Continued.	Feet
50. Sandstone, greenish drab, very fine grained, dense; shaly and thin bedded toward base, cleaner and more massive in the middle, platy toward top (beds one-sixteenth inch thick); somewhat variable along the strike	10½
51. Limestone, gray, dense; usually platy but at some places blocky	2½
52. Shale, very limy, blocky, hard	2½
53. Limestone, gray, dense, massive, very hard; contains calcite-incrusted geodes; many fossils, especially oysters	1¼
54. Shale, green, soft, unctuous	⅜
55. Limestone, chocolate-brown; partly oolitic, partly dense, crystalline; beds one-fourth inch to 6 inches in thickness; contains oysters and other fossils	5
56. Sandstone, green, with a 1-foot chocolate-brown bed toward middle, separated by sharp but wavy boundaries; flaggy and cross-bedded toward top, massive and blocky in lower 2 to 3 feet	6
57. Shale, green to tan, blocky, gypsiferous, very limy, sandy toward top; upper surface wavy, with relief of 2 inches; basal 4 inches dark brown from limonite	2–2½
58. Sandstone, shaly at base, gypsiferous, green, weathering brown, biotite or chlorite plentiful, fine grained, very limy; very irregular upper surface suggesting wave form	2½
59. Shale, green, fissile, containing sandstone lenses 8 to 10 inches thick; lower bedding planes follow irregularities of lower surfaces, but upper planes smooth out and are regular; much secondary gypsum, in seams cutting across the bedding	1–2½
Total Carmel formation	219–221
Unconformity (?), wavy surface, with relief of 1½ feet and wave length 3 to 8 feet. Apparently there is here no reworked Navajo sandstone in the basal part of Carmel formation, as is usual elsewhere.	
Navajo sandstone:	
60. Sandstone, tan, massive, tangentially cross-bedded on large scale	400+

22. *Section at Black Dragon Canyon and Straight Wash, San Rafael Swell, Utah*

[Beds 1 to 6 measured east of Straight Wash Canyon; remainder along Black Dragon Wash]

	Feet
Morrison formation: Thick white alabaster gypsum beds at base, followed by conglomeratic "channel" sandstones and varicolored mudstones, marls, and shales.	
Unconformity, a channeled irregular surface in the hollows of which the overlying gypsum was deposited.	
Summerville formation:	
1. Shale, sandy, thin bedded, dark reddish brown; contains many thin lenses of greenish-gray sandstone, especially in the upper part, and many beds of pinkish-white alabaster gypsum as much as 6 inches thick; crusts of red chert, probably secondary, weather out on the slope; unit much seamed with secondary selenite veins	63
2. Gypsum, a massive greenish-white alabaster; a persistent bed	2½
3. Shale, sandy, dark red-brown, with a few gray sandstones 2 inches thick in the lower part; ripple-marked; above a horizon 65 feet from the base, nodules and beds as much as 6 inches thick of pink gypsum occur at 6-foot intervals to the top of the unit; in the upper 50 feet much more sandy than shaly—in fact, a blocky thin-bedded shaly sandstone, much seamed with secondary selenite; crusts of red chert strewn over the slope, as in No. 1	146
Total Summerville formation	211
Curtis formation:	
4. Shale and sandstone, alternating, green-gray, thin bedded; dominantly sandstone below and shale above and passing by gradation into the overlying Summerville formation	47
5. Sandstone, green-gray, weathering brown, lime-cemented, friable, massive, very thick bedded, cross-bedded, ripple-marked; includes some angular shale fragments and weathers into concretionary bosses and "biscuits"	65
6. Shale, green-gray, glauconitic, in layers chiefly less than 2 inches thick though as much as 6 inches, ripple-marked and separated by thin-bedded sandstone; the sandstone constitutes perhaps 5 per cent of the bulk of the unit	58
Total Curtis formation	170
Erosional unconformity with relief of several feet.	
Entrada sandstone:	
7. Sandstone, massive, earthy, red-brown; over 50 feet in one bed, the rest thick bedded but with shaly partings a few inches thick	84
8. Sandstone, yellow-gray, tangentially cross-bedded	11
9. Sandstone, earthy, red-brown, with many thin maroon sandy shale zones; weathers into "bobbins"	25
10. Sandstone, yellow, highly cross-bedded, even grained but somewhat earthy, especially in upper part	7
11. Sandstone, at base shaly and thinly, poorly bedded but passing upward into earthy, exfoliating ("bobbin weathering") type; buff in lower 3 feet, red-brown above	19
12. Sandstone, red-brown, earthy at base, buff and clean above; weathers in rounded forms, tangentially cross-bedded, especially in upper part; a green shale parting 17 feet above base	26
13. Sandstone, shaly, yellow-brown, interlensing with clean maroon shale; average lens 2 inches or less in thickness; wavy surfaces and ripple marks throughout	2½
14. Sandstone, yellow-gray and tan, tangentially cross-bedded, limy, friable; a few thin partings of maroon shale and green sandy shale; except for the shale the unit is of the type characteristic of the Navajo sandstone	31½
15. Shale, maroon, clean, well laminated	1½
16. Sandstone, yellow-gray, tangentially cross-bedded, limy, friable; uppermost 6 inches shaly	6

Entrada sandstone—Continued. Feet

17. Sandstone, red-brown, earthy, limy, containing at several horizons well-bedded red-brown shale a few inches thick. The unit is a series of more shaly and less shaly beds, poorly bedded, contorted and rippled throughout — 35½
18. Sandstone, shaly, micaceous, drab, weathering buff; very poorly bedded — 8½
19. Sandstone, like No. 14 — 75
20. Sandstone, red-brown, earthy, limy, massive, irregularly bedded; contains some very irregular lenses of green shale fragments; bedding in the large slightly contorted; weathers into "bobbins" — 73

Total Entrada sandstone — 405½

Carmel formation:

21. Gypsum and green-gray shaly sandstone, highly contorted and inseparably mixed owing to slumping — 32
22. Gypsum, white alabaster — 2
23. Sandstone, like No. 20 except that it is less massive; checks into angular fragments the size of a pea — 5
24. Gypsum, white alabaster — 1½
25. Sandstone, like No. 23 — 8
26. Gypsum, white alabaster — 2
27. Sandstone, earthy, like No. 23 — 18
28. Sandstone, gray, earthy, obscurely bedded at base; some sandy shale in the middle of the member; greenish gray, platy, ripple-marked and ripple-bedded toward the top; sharp lithologic change at top, transition at base; weathers into rounded forms — 19
29. Sandstone, gray with greenish tinge, limy at base, passing up into fine-grained sandy limestone; cross-bedded and ripple-marked throughout; platy at top — 6
30. Limy shale, somewhat sandy, not well bedded, varies laterally and across the bedding into true limestone and passes upward by gradation into No. 29; poorly exposed — 26
31. Sandstone, yellow, with lenses of gray shaly limestone; ripple-marked and cross-bedded; becomes more limy upward and is a true limestone in upper 3 feet; forms a ledge — 21
32. Sandstone, buff, very limy, fine grained, poorly bedded; very shaly in middle; weathers in rounded forms toward the top; ripple-marked throughout; forms a slope — 18
33. Limestone, gray with purple bands in lower part, all purple toward the top; beds 2 inches to 1 foot thick, slabby; usually dense but sandy in some places; very fossiliferous, *Camptonectes* and *Trigonia* especially common; forms a strong ledge — 2½
34. Sandstone, red-brown, evenly bedded, fine grained, very limy; beds half an inch to 3 inches thick; passes into No. 33 by gradation, and along strike into a sandy limestone — 3
35. Sandstone, red-brown, fine grained, earthy; weathers into a notch, and passes by gradation into No. 34 — 5

Total Carmel formation — 169

Possible unconformity. Feet

Navajo sandstone:

36. Sandstone, massive, light gray, even grained, with both tangential and angular cross-bedding — 520

Todilto (?) formation:

37. A series of poorly bedded, thin to medium bedded pink sandstones, weathering white to light gray and containing a few beds and many thin partings of finely laminated chocolate-colored sandy shale and brown sandstone. Both upper and lower boundaries are transitional and indefinite — 239

Wingate sandstone:

38. Sandstone, very thick bedded, light gray to red-brown, weathering brown; beds average 6 to 15 feet thick, but all resemble one another, and parting planes do not appear to be significant — 323

Unconformity.

Chinle formation: Top member is chocolate-colored earthy sandstone, in upper part varying to mudstone, soft, poorly exposed; forms a slope.

23. *Section in Green River Desert near mouth of San Rafael River, Utah*

Feet

Morrison formation: Varicolored shales and mudstones, and conglomeratic "channel" sandstone lenses.

Unconformity; angular discordance not evident but a very sharp, widespread lithologic change.

Summerville formation:

1. Limestone, sandy, gray, containing irregular masses of reddish chert and geodes lined with crystalline quartz; forms a very widespread bench — 2
2. Alternating shaly sandstone and mudstone, chocolate-brown and red-brown; includes some thin beds of greenish-gray sandstone; thin bedded and ripple-marked throughout — 70
3. Mudstone and shaly sandstone, chocolate-colored, interbedded with orange-red silt and forming a fairly conspicuous band traceable for some distance — 12
4. Shale, alternating grayish green and chocolate-colored, with a few thin purple beds, grading into sandy shale, shaly sandstone, and greenish-gray thin-bedded sandstone in upper part — 12
5. Mudstone, somewhat laminated but not a shale, chocolate-brown and orange-colored, with a few thin beds of greenish-gray sandstone — 7
6. Shale, very thin bedded, chocolate-colored, greenish-gray, and some purple; chocolate-colored mudstone; and some thinly laminated grayish-green sandstone — 25

Total Summerville formation — 128

Curtis formation:

7. Shale, sandy shale, and thinly laminated ripple-bedded sandstone, greenish-gray; includes a few thin beds of chocolate-colored and purple shale of the type of the Summerville formation; upper foot forms a continuous sandstone ledge — 18
8. Sandstone, very thin bedded, greenish gray, shaly, with greenish-gray sandy shale and subordinate chocolate-colored shale, shaly mudstone, and concretionary ripple-bedded greenish-gray sandstone; a zone 2 to 3 inches thick of purple carbonaceous shale about 8 feet above the base — 20

Curtis formation—Continued.	Feet
9. Sandstone, reddish brown, shaly, thin bedded, even bedded, soft; weathers in low slope	11
10. Sandstone, red-brown, limy, even bedded, very hard; forms persistent strong ledge capping Entrada cliff and cutting across irregularities in the Entrada	2
Total Curtis formation	51

Unconformity; strike N. 45° E., dip 2° NW., above; strike N. 45° W., dip 1° NE. below.

Entrada sandstone:	
11. Sandstone, earthy, red-brown; weathers into "bobbins"; beds 2 to 5 feet thick with very thin maroon shale partings continuous in the large, though individual beds vary noticeably in thickness; cross-bedded obscurely on a small scale. From a distance contortion of bedding is noticeable, the contortion being cut off smoothly beneath the ledge at the base of the Curtis formation	142
(Part of section above this horizon measured in cliffs 4 miles north of the San Rafael River crossing of Elaterite Basin road, and remainder 2 miles south of the crossing. Some uncertainty exists as to the identity of the base of bed 11 with the top of bed 12, the uppermost horizon south of the river, but the error is probably less than 20 feet and almost certainly not over 40 feet.)	
12. Sandstone, clean; the lower 3 feet thin bedded but passing up into massive, highly cross-bedded pinkish sandstone, which weathers into rusty-brown domes and arches	126
13. Sandstone, clean, yellow to tan, weathering brown; thin bedded in lower few feet but very thick bedded above; tangentially cross-bedded; forming domes in upper part	88
14. Sandstone, clean, massive, only slightly cross-bedded, almost surely water-laid	111
15. Sandstone, earthy, somewhat limy; weathers into "bobbins"; highly irregular contorted bedding so that both upper and lower boundaries vary in position nearly 20 feet; average thickness about	31
Total Entrada sandstone	498

Carmel formation:	
16. Shale, gray, mostly pure but with slight amounts of sand in some layers and a few thin beds of earthy sandstone intercalated	12
17. Sandstone, gray to buff, weathering very light gray, limy, rather clean, composed of well-rounded sand grains but with some small chert fragments and many mud pellets; very irregularly bedded, with some mud cracks and ripple marks; forms a ledge	3
18. Sandstone, red-brown, earthy, soft, irregularly bedded, with some platy layers and subordinate red-brown shale; some thin brown-stained but really clean gray sandstones as much as 6 inches thick occur but are not prominent or numerous; forms a slope	29
19. Sandstone, gray, limy, stained brown by wash; forms a ledge	1½
20. Sandstone, red-brown, earthy, somewhat platy in some places	4½

Carmel formation—Continued.	Feet
21. Sandstone, gray, very limy, very irregularly cross-bedded; nodular chert and gypsum common; forms a strong ledge	1
22. Sandstone, red-brown, limy, in part platy, in part earthy and irregularly bedded; forms a slope	13
23. Sandstone, gray, stained red-brown, very limy; contains many mud pellets; top and bottom are wavy surfaces, but the bed is not notably lenticular; forms a ledge	1½
24. Sandstone, red-brown, earthy, except toward top, where it is cleaner and platy; forms a slope	11
25. Sandstone, gray, limy, cross-bedded and irregularly bedded; weathers into nodular shapes and forms continuous ledge over a wide area	1½
26. Sandstone, red-brown; earthy, in some places almost a sandy mudstone; unevenly bedded, lime-cemented; weathers in a slope, with a few subordinate clean red sandstone ledges which weather brown	18
Total Carmel formation	95

Unconformity, an even surface separating very distinct lithologic types.

Navajo sandstone, traced from Miller Canyon, about 15 miles to the south (east of Keg Springs); exposed---- 200±

24. *Section west of Thompsons-Moab road, 2¾ miles south of Courthouse mail station, Utah, just west of big fault which brings the Morrison formation into contact with the Moenkopi formation*

Summerville formation (not measured).

Unconformity.

Entrada sandstone:	Feet
1. Sandstone, white, clean, not prominently cross-bedded, probably water-laid; covers very wide dip slopes both here and east of the fault to and beyond Salt Valley; thickness can not be measured here; estimated	50±
2. Sandstone, massive, gray, weathering red-brown; clean, except for a few small lenses of "bobbin" sandstone, and forming arches and domes; not prominently cross-bedded; stands here in vertical cliff in which some of the bedding-planes can be followed for a few hundred yards, but none are persistent nor do the beds above and below them differ in composition. Alidade measurement	207
3. Shale, maroon, very evenly bedded, extremely persistent; can be followed for miles. Above this zone the bedding is even and regular; below it, contorted and very irregular	2½
4. Sandstone, red-brown, earthy; weathers into bobbins and rounded forms; bedding very highly contorted, the top cut off sharply by No. 3; a few thin discontinuous bands of red-brown shale constitute perhaps 1 per cent of the unit; forms very steep rounded slopes and vertical cliffs. Alidade measurement	105½
Total Entrada sandstone	365±

Carmel formation:	
5. Sandstone, white, limy, very much cross-bedded and hummocky on surfaces; lenses out along the exposure	10

Carmel formation—Continued.	Feet
6. Sandstone, red-brown, shaly, thin bedded, cross-bedded, ripple-marked, soft; forms a slope; lenticular with very hummocky upper surface having relief of about 2 feet	11
7. Sandstone, white, limy, very much cross-bedded and irregularly bedded, ripple-marked, lenticular	9
8. Sandstone, red-brown, very shaly, thin bedded, cross-bedded, ripple-marked, soft; forms slope; lenticular, nonpersistent	17
Total Carmel formation	47
Unconformity.	
Navajo sandstone:	
9. Sandstone, gray to buff, clean, quartzose; very thick and even bedded; weathers in large rounded masses but not into "bobbins" or "stone babies"	41
10. Sandstone, gray, thick bedded, highly cross-bedded; contains a few thin partings of shaly ripple-marked even-bedded sandstone, nowhere thick enough to conceal the dominantly tangential cross-bedding of the unit as a whole	117
Total Navajo sandstone	158
Todilto (?) formation:	
11. Sandstone, gray; a 2-foot hard cross-bedded ledge at base followed by thin-bedded ripple-marked sandstone, cross-bedded on a small scale and including a few red shale partings; unit transitional to the Navajo sandstone	13
12. Sandstone and shale, irregularly interbedded, dominantly soft shaly micaceous maroon sandstone with a minor amount of clean maroon shale and clean gray sandstone	30
13. Sandstone, red to gray, in beds 1 to 3 inches thick, limy, ripple-marked, cross-bedded throughout; includes some very discontinuous lenses of red limestone and of shale conglomerate; red shaly partings are very numerous, and the whole mass is very lenticular, so that thicknesses of individual beds vary much along the outcrops; local unconformities numerous but probably insignificant	76
14. Sandstone, gray, in beds about 3 feet thick, cross-bedded, containing some green shale partings; forms a strong ledge	19
15. Sandstone, red to gray, fine grained, ripple-bedded, in beds about 2 inches thick; forms a persistent bench, and passes gradually into No. 14	22
Total Todilto (?) formation	160
Wingate sandstone:	
16. Sandstone, gray, in beds 1 to 2 inches thick at top and bottom but 7 to 8 feet thick in middle, where it is highly cross-bedded; ripple-marked, very irregularly bedded; no sharp boundaries above or below; much thinner bedded than usual for the Wingate sandstone	91
17. Sandstone, pink to buff, composed of clean quartz; unevenly bedded at base, with some red-brown shale in bulbous, discontinuous lenses and passing upward into clean sandstone, very highly cross-bedded and probably wind-laid	97

Wingate sandstone—Continued.	Feet
18. Sandstone, red-brown, earthy, ripple-marked, fine grained, very limy, containing many discontinuous beds of dark red-brown shale about 2 inches thick; weathers in much modified "stone babies"; upper surface ripple-marked	6
19. Sandstone, buff to pink, in beds about 3 inches thick in lower part, and in beds as much as 6 feet thick in upper part; ripple-marked; many green shale pellets and green sandy lenticular mudstone partings between the beds	16
Total Wingate sandstone	210

Unconformity; rippled and mud-cracked surface, channels in which are filled by the basal Wingate sandstone.

Chinle formation: Red-brown mudstones, limestone conglomerate, green-gray shale and thin-bedded micaceous red-brown sandstone, the sandstone forming the top bed, which is 3 feet thick.

25. *Section in Salt Valley, about 6 miles south of road from Thompsons to Green River, Utah*

Dakota (?) sandstone:	Feet
1. Sandstone, white and light gray, containing at the base a conglomerate with black chert pebbles. The sandstone is carbonaceous and ferruginous, is much stained with limonite, and forms a strong ledge	9
2. Shale and sandstone; the lower 15 feet in layers less than 1 foot thick of interbedded sandstone and shale, in which *Halymenites* and plant impressions are common, but no carbonaceous matter was seen; above the basal 15 feet the member consists dominantly of gray shale with only thin sandstone lenses	51
3. Conglomerate, cross-bedded, containing yellow, black, white, and gray chert pebbles as much as three-fourths inch in diameter	10
Total Dakota (?) sandstone	70
Unconformity.	
Morrison formation:	
4. Clay, light gray with a green tinge, typical of the Morrison and containing marly layers, limestone nodules, and some grit lenses	68
5. Gritty sandstone, of which the lower 50 feet passes into clay within a few hundred feet laterally. Half a mile away this unit consists of only 8 feet of coarse light-gray sandstone, conglomeratic at the top and persistent for some distance; pebbles in the conglomerate are black chert and limestone	58
6. Clay, variegated, maroon, gray, and purple, with more gray toward the base and more maroon toward the top, the maroon color stronger than is usual in the Morrison; unit contains many grit and sandstone lenses, more numerous and thicker in the upper 50 feet; much chert and mottled chalcedony strewn over the surface and in place	337
7. Conglomeratic grit and conglomerate, light gray, containing many black, orange, white, and gray chert pebbles; a fairly persistent bed	22
8. Alternating red shale and thin gray sandstone, not well exposed	22
9. Channel sandstone, rather gritty and with some shale lenses in places	17

Morrison formation—Continued.	Feet
10. Interval mostly concealed, with some maroon and green shales exposed	41
11. Persistent gritty channel sandstone, containing pebbles as much as a quarter of an inch in diameter	13
12. Sandstone, gray, thin bedded, ripple-marked, cross-bedded, and interbedded red shale	17
13. Channel sandstone, gray	18
14. Variegated shale, with a sandy marl containing green shale lumps at the top and with interfingering drab shale lenses, limestone, and grit	14
15. Coarse channel sandstone	8
16. Variegated gray and purple sandy mudstone	5
Total Morrison formation	640
Unconformity, not prominent.	
Summerville formation:	
17. Poorly exposed red and green sandstone and shale, with limy and siliceous lumps on the surface; forms a slope	34
18. Grit, hard, fine grained, cross-bedded, white	2
19. Sandstone, red, somewhat shaly, thin bedded, medium grained	6
20. Sandstone, white, hard, fine grained	2
21. Sandstone, light yellow-gray, somewhat friable, thin bedded, poorly bedded, medium grained	11
Total Summerville formation	55
Unconformity.	
Entrada sandstone:	
22. Sandstone, white, massive in upper 50 feet, thin bedded in lower 20 feet; cross-bedded, fine grained, very limy toward the base	70
23. Sandstone, massive, brick-red, decidedly cross-bedded, strongly jointed, weathering into chimneys and alcoves; a few shale pockets present; sandstone somewhat shaly at the base, upper part clean and well-sorted	290±
24. Sandstone, red-brown, thick bedded, weathering into rounded masses and containing irregular shale pockets	41
Total Entrada sandstone	401±
Carmel formation:	
25. Interval largely concealed, probably mostly shale but with massive 6-foot sandstone at the top and at least one nodular bed of calcareous gypsum about 2 feet thick	60
Navajo sandstone:	
26. Sandstone, light buff to gray, cross-bedded at high angles, very massive	170
Todilto (?) formation and Wingate sandstone, not measured separately:	
27. Sandstone, massive, thick bedded, cross-bedded; bedding roughly parallel, probably water-laid throughout; some beds 12 feet thick, others as little as 1 foot; a few carry conglomerate of shale fragments as much as 6 inches long; at top a massive cross-bedded calcareous sandstone, red and gray, 12 feet thick; color of whole unit streaked red and light gray	350

Shale slope about 30 feet high to base of exposure.

26. *Section one-half to 1 mile below Dewey Bridge, on Colorado River just below the mouth of Dolores River, Utah*

	Ft.	in.
Morrison formation: Variable series 121 feet thick of gritty ripple-marked cross-bedded sandstones in beds as much as 8 feet thick, interbedded with red and green sandy shale. This series capped by a 20-foot gray sandstone ledge, followed by several hundred feet of variegated mudstones and channel sandstones.		
Unconformity.		
Summerville formation:		
1. Sandstone, irregularly bedded, red-brown, shaly, very limy in places; dense purple limestone; nodular limestone; and some red-brown shale. Nodules of lime and crusts of chert are common on the slope. In the upper part a few lenses of limy fine-grained irregularly bedded white sandstone, ranging in thickness from 2 feet to a few inches within short intervals. The unit forms a slope	47	
2. Sandstone, gray, gritty, of clean quartz with grains of gray and white chert and flint one-sixteenth inch in maximum diameter; a few lenses of shale and some shale pellets; thickness and bedding vary along the strike; very limy, hard, and forming a persistent ledge	8	6
3. Mudstone, red, sandy, micaceous, with thin lenses of green-gray sandstone, nowhere over half an inch thick; a number of thin lenses and one persistent 2-inch bed of dense pink sandy limestone are present; the upper surfaces show mud cracks and curled shale fragments, indicating with certainty exposure to the air	1	6
4. Sandstone, pink, quartzose, slightly earthy, and very limy; contains flakes of green shale at the bottom and has wavy contact, both at bottom and top; thickness somewhat variable; forms a persistent ledge	2	
5. Shale, sandy, reddish brown, with a very sharp, even separation from the gray sandstone of the Entrada formation below; contains many thin lenses of gray limy ripple-marked cross-bedded fine-grained sandstone with pellets of green shale; unit about 60 per cent shale, though not perfectly exposed	31	6
Total Summerville formation	90	6
Unconformity.		
Entrada sandstone:		
6. Sandstone, gray, all in one bed; highly cross-bedded, with tangential type of bedding throughout; composed of clean quartz with lime cement	57	
7. Shale parting, maroon, very persistent, can be traced as far as the stratigraphic horizon is visible, several miles		1

	Ft.	in.
Entrada sandstone—Continued.		
8. Sandstone, pink below, gray above; dominantly even bedded in lower half, highly cross-bedded and very thick-bedded like the upper half of the Navajo sandstone	268	
9. Sandstone, nodular, earthy, very irregularly and obscurely bedded, containing many bulbous lenses of red-brown mudstone; both boundaries extremely indefinite and variable; tongues of the overlying clean sandstone penetrate into the upper surface of this unit, but there is apparently no significant unconformity. Basal 10 feet of this unit may be the Carmel formation	36	
Total Entrada sandstone	361	
Unconformity (?).		
Navajo sandstone:		
10. Sandstone, clean, quartzose, with lime cement, pink in places but mainly gray, highly cross-bedded, the bedding cutting off at all angles and without apparent system	127	
11. Limestone, dense, silicified; a short lens, vanishing within less than 100 feet in one direction, concealed in the other	1	6
12. Sandstone, white, weathering buff, fine grained, clean, hard, well cemented, and containing many small pellets of green shale at the base; cross-bedded regularly up to about 28 feet above base and very irregularly above that horizon; a 5-inch parting of maroon shale 5 feet above the base and several very thin partings of green shale in the lower 15 feet of the unit; this part is cut out down the dip by bed 13, owing to evident local erosional unconformity	115	
Total Navajo sandstone	243	6
Todilto (?) formation:		
13. Sandstone, red, very shaly; thin bedded, with a few lenses of limy sandstone as much as 1 foot thick; mud-cracked and ripple-marked throughout; in places a sandy, poorly laminated shale; upper surface channeled; forms a slope	31	
14. Sandstone, pink, weathering red-brown; in beds 6 inches to 10 feet thick, lensing into one another and not persistent over long distances; contains thin, irregular lenses of red-brown sandy shale, mudstone, and shale conglomerate, but these are all subordinate to the sandstone	165±	
Total Todilto (?) formation	196±	
(Section continued on left bank of the Colorado half a mile downstream.)		
Wingate sandstone:		
15. Sandstone, pink, weathering dark red-brown, fine grained, lime-cemented, in beds mostly 3 to 8 feet thick, ripple-marked; cross-bedding not prominent except in a few layers; maroon shale partings, 1 inch or less in thickness, separate the heavy beds of clean sandstone; upper 40 feet in one massive, highly cross-bedded unit without partings and capping an abrupt cliff	246	
Chinle formation: Red shales, sandstones, and limestone conglomerates, forming below the Orange Cliffs a slope to river level.		

THE POCONO FAUNA OF THE BROAD TOP COAL FIELD, PENNSYLVANIA

By George H. Girty

INTRODUCTION

Marine invertebrate fossils are extremely rare in the Pocono formation of Pennsylvania, although they are found in rocks of equivalent age that occur in the northwestern part of the State. Because such occurrences are rare and because the one near Saxton was recorded many years ago, somewhat special interest attaches to the fauna from the Broad Top coal field which is described in the following pages. The stratigraphy of this region has been discussed by a number of authors, notably by Ashburner,[1] Stevenson,[2] White,[3] and, more recently, Reger.[4] My own knowledge of the subject is of the superficial sort that is incidental to a brief visit for the purpose of collecting specimens. In this particular province, therefore, I shall restrict myself to an abstract from the work of others; if more detail is desired, the original reports just cited will furnish it.

The Pocono of this region as described by White, consists of "coarse, sometimes pebbly, greenish-gray, characteristically false-bedded, more or less massive sandrocks, interstratified with thinner gray shales, like those of the Productive coal measures but without workable coal beds." In two measured sections the thickness of the Pocono was determined at about 1,150 feet, and the formation was subdivided into an upper division, which contained little or no red shale, and a lower division, which contained considerable red shale, ending below in a massive gray sandstone of great thickness. In its stratigraphic relations the Pocono of this region is underlain by rocks referred to the Catskill formation and overlain by rocks referred to the Mauch Chunk.

The Pocono invertebrates considered in this report were collected at four localities—Shoups Run Gap, Riddlesburg Gap, Great Trough Creek Gap, and Sideling Hill tunnel, more fully described on page 123 under the locality numbers 3547, 3548, 3549, and 5438. The Shoups Run section has been described by White and also by Reger. The Riddlesburg Gap section likewise has been described by White and by Reger. The section in Great Trough Creek Gap has not been described, so far as I am aware, nor am I able to supply the deficiency. The section at Sideling Hill tunnel has been the subject of some controversy, chiefly, however, in the way of harmonizing the observations of different authors. White and Reger both describe it.

The fossiliferous rock in all four sections is a dark, almost black shale, not of the fissile type but hard and blocky. The faunas also, like the rock which contains them, are essentially identical, and it seems probable that all came from a single bed and a common horizon in the Pocono of this region. This is the view of Reger, who collected some of the fossils described in this report. This shale, according to him, has a thickness of 75 feet or more, and in different sections it occurs from 500 to 670 feet below the top of the Pocono.

Although representing but four localities, my collections number no less than nine, for they are the work first of David White, then of myself, and lastly of Mr. Reger. Fossils are abundant as to number but poor as to variety. The collections differ but little save in the abundance or scarcity of certain forms, whether they were made at the same locality by different collectors or at different localities, and it seems probable that the fauna here described constitutes almost the entire Pocono fauna of this region, comprising certainly all the common species and many of the rare ones. The following table shows the occurrence of the known fauna, consisting of 20 species, at the four localities represented by my collections:

Distribution of the Pocono fauna at the four localities represented

	3547 (Shoups Run)	3548 (Riddlesburg)	3549 (Trough Creek)	5438 (Sideling Hill)
Scarphiocrinus kirkianus	×	×	------	------
Spirorbis sp	×	×	------	------
Stenopora? sp	×	×	×	------
Lingulidiscina newberryi?	×	×	×	×
Rhipidomella huntingdonensis	×	×	×	------
Schuchertella chemungensis	×	×	×	×
Chonetes acutiliratus	×	×	×	×
Camarotoechia aff. C. contracta	×	×	×	×
Cranaena sp	------	------	×	------
Spirifer compositus	×	×	×	------
Nucula aff. N. houghtoni	------	×	------	------
Palaeoneilo concentrica	×	×	×	×
Leda aff. L. spatulata	×	------	×	×
Cypricardinia consimilis	×	×	×	×
Glossites? sp	------	×	×	------
Pleurotomaria aff. P. hickmanensis.	×	×	×	------
Loxonema sp	------	------	×	------
Orthoceras sp	------	------	×	------
Cytherellina? sp	------	------	×	×
Kirkbya? sp	×	------	------	------

[1] Ashburner, C. A., Pennsylvania Second Geol. Survey Rept. F, p. 206, 1878.
[2] Stevenson, J. J., idem, Rept. T_2, p. 62, 1882.
[3] White, I. C., idem, Rept. T_3, p. 77, 1885.
[4] Reger, D. B., Pocono stratigraphy in the Broad Top Basin of Pennsylvania: Geol. Soc. American Bull., vol. 38, pp. 397-410, 1927.

The specimens from the Pocono of the Broad Top coal field are, as I have already had occasion to point out, but poorly preserved. They have been described as fully as their condition would permit and figured so far as figures promised to be of value. Of the 20 species cited in the table, 2 have received no descriptive treatment in the text. These are the ostracodes. These shells are scarcely determinable even generically when they are known only as internal molds, for their distinctive characters are not present on the inside of the shell. Furthermore, in the ostracodes of the present collection, which are both few and ill preserved, even the internal characters are shown less faithfully than they would be in shells which were of larger size, which were preserved in a matrix of finer material or which had not been subjected to compression. Nothing could be said about them that would be sufficiently important or sufficiently precise to deserve record, and even the generic references, which were made at my request by P. V. Roundy, are uncertain.

Synonymic lists are almost an essential part of any work in descriptive paleontology that offers claims to completeness. For the present report, in view of its small size and conservative treatment made necessary by the very nature of its subject matter, it has seemed adequate to cite but a few works—those especially that were in reference to each species authentic and that set up, as it were, the model to which the Pocono shells were thought to conform.

The Pocono fauna listed above is a varied one in the sense that many classes of invertebrate animals are represented in it. It is, however, essentially a brachiopod fauna in the sense that that group is represented overwhelmingly by individuals. The discinoid, the *Rhipidomella*, the *Schuchertella*, the *Chonetes*, and the *Camarotoechia* are all very abundant, though they may be abundant in one collection and relatively rare in another. The only pelecypod that at all rivals these forms, though it rivals them but remotely, is the *Palaeoneilo*, with *Cypricardinia* still farther in the rear. It is notable also that a large gastropod, one of the Pleurotomarias, is by no means rare.

This fauna is somewhat remarkable in that each genus is represented by but a single species. It is true that unless the species of any particular genus were conspicuously unlike, they could hardly be distinguished among these specimens most of which are poorly preserved as molds and have been flattened and deformed by the folding of the rocks wherein they lie; but there is little reason to believe that really distinct species have on this account failed of recognition.

This fauna is far more remarkable for another reason than for the one just mentioned. It is, one can hardly doubt, of Carboniferous age, yet it lacks, all but entirely, two genera that more than any others abound in our Carboniferous faunas—*Productus* and *Spirifer*. A Carboniferous fauna without a single productoid (except, of course, *Chonetes*) and without a single spiriferoid (except a very rare and very peculiar species of *Spirifer*) is indeed an anomaly. This is so true that the Carboniferous age of this fauna, though it is very probable on broader grounds, is but slenderly supported by the evidence of the fauna itself. Except for a few types that have more distinctly Carboniferous affinities, it might almost as well be Devonian. If one were bent on selecting a fauna of cryptic aspect, he could hardly do better than to pick out a discinoid, a *Rhipidomella*, a *Schuchertella*, a *Chonetes*, and a *Camarotoechia* of the generalized, nondescript type that these specimens belong to. The most distinct Carboniferous evidence, perhaps, is found in the *Scaphiocrinus*, the *Palaeoneilo*, and the *Cypricardinia*, and that evidence, such as it is, is in a measure confirmed by the *Rhipidomella*, *Schuchertella*, *Chonetes*, and *Camarotoechia* (more as generic than as specific citations), inasmuch as our early Carboniferous faunas, especially those of eastern type as represented in the Waverly rocks of Ohio, Kentucky, and Pennsylvania, usually abound in shells belonging to those genera and more or less akin to these Pocono species. The same is true, however, though not equally true, of the later faunas of Devonian age. At the same time those late Devonian faunas, no less than the early Carboniferous ones, contain normally a rich and varied representation of spiriferoid and productoid shells.

A scientific paper ordinarily comprises a statement of facts, more or less new, and a statement of inferences derived from them, more or less logical; and papers of the present sort state facts of generic and specific identification and inferences as to geologic age and correlation. Whatever vague inferences I have dared have already been set down, and such value as the present paper may hope to sustain will rest largely on the record of facts appearing in the descriptions and figures that follow. Little—indeed, so far as I know, nothing—has yet been done toward describing our Pocono faunas, especially those of the more northern and more typical extension of the rocks identified as Pocono. As this paper is a beginning, though but a small one, in a subject about which little is known, it can not but have value as a record of fact, and perhaps it could not, without some background, look to going far in the way of inference and conclusion.

DESCRIPTION OF SPECIES

Scaphiocrinus kirkianus Girty, n. sp.

Plate 22, Figures 1, 2

Three specimens of this species are available for study, all preserved as external molds. One specimen comprises part of the dorsal cup and about 1.5 centimeters of column; another consists of a group of well-preserved arms, unfortunately dissociated from the dorsal cup; the third, of which both halves of the mold were collected, affords views of the crown as oriented from the anterior radius and posterior interradius. A small fragment of the stem is attached, and the ventral tube, as well as portions of the arms, are preserved. This specimen has been chosen as the type, although details of arm and stem structures have been taken from the others.

The crown of the type specimen has a length over all of 46 millimeters, measured from the base of the cup to the tip of the ventral tube. The dorsal cup measures 10 millimeters in height. It is subfusiform in shape, with a maximum diameter at the arm bases of about two-thirds of its height. There is no sign of surface ornamentation on the cup plates. The infrabasals are pentagonal in outline, with a height of 2.6 millimeters and a maximum breadth of about 1.7 millimeters. The basals are relatively large, having an average height of about 4.4 millimeters and a maximum breadth of about 2.8 millimeters. The radials have an approximate average height of 3 millimeters and are about as wide as high. The articulating facets are concentric in outline and take up nearly three-fourths of the upper faces of the radials. Below the facet the radial develops a thickened shoulder. Plate RA is pentagonal in outline, resting on the upper inner faces of the two basals below, abutting to the right on the right posterior radial and to the left on plate X. Above it supports plate rt.

The posterior side of the ventral tube is shown only in its proximal portion, and the distal part is shown in the anterior view. The basal portion of the tube as shown is composed of fairly large plates irregularly alined. They are ornamented by strong radiating ridges. In the distal portion of the tube the plates are arranged regularly in vertical rows so that the juxtaposed raised and rounded median portions of the plates stand out sharply as long, rounded ridges.

The arms of the type specimen are relatively small for the size of the crinoid. This may be due to their having been broken off and regenerated. The arm ossicles are longer than wide and unite with slightly gaping sutures. The arm bifurcates once on the second primibrach. Thereafter long, slender ramules are given off on alternate sides from each second brachial. The ramules in turn bifurcate by regular dichotomy, there being at least three divisions. In the main arms, and in the ramules as well, the ventral groove is covered by two alternating rows of small pentagonal covering plates.

The stem is pentagonal in section, with well-defined nodes and internodes.

Owing to the somewhat loose usage of generic names for American Inadunata it is difficult accurately to assign this species to a genus. It shows nothing, however, that would cause its exclusion from *Scaphiocrinus* as now defined. Within that genus there are no species, however, with which it is closely comparable.

I take pleasure in naming this crinoid after my colleague, Dr. Edwin Kirk, and in acknowledging my indebtedness to him. He furnished the description essentially as it is presented above, but, out of consideration for the bibliographer, requested me not to attach his name to it as author. I regret the request, although I can not but accede to it.

Spirorbis sp.

A number of small coiled shells of the type commonly referred to *Spirorbis* have been observed in some of the collections, and, as they are inconspicuous, others doubtless have been overlooked. Of those observed most were attached to *Cypricardinia consimilis*, but some to *Rhipidomella huntingdonensis*. The specimens occur as molds and have been completely flattened. The larger ones have a diameter of almost 2 millimeters. The surface is smooth so far as can be seen.

Stenopora? sp.

This form, which is rather rare, has an incrusting growth and is found especially on *Lingulidiscina newberryi* and *Cypricardinia consimilis*. The colonies are of small extent and in thickness somewhat less than 1 millimeter as a maximum. They are preserved as molds, the fossil itself having been dissolved away and only the mud-filled chambers remaining. To judge by the rounded shape of the minute columns representing the zooecia and by their distances apart, the walls were rather thick; and to judge by the general appearance of the columns the zooecia were without diaphragms and the walls were marked by constrictions. The shape and spacing of the columns somewhat suggest that we have here a *Leioclema*, or even a *Fistulipora*, and, indeed, doubtful evidence of mesopores has been noted. The shape of the columns (round instead of petaloid), their spacing, and their annulated markings would seem to indicate that the species, if not a *Stenopora*, is more likely to be a *Leioclema* than a *Fistulipora*.

Lingulidiscina newberryi (Hall)?

Plate 22, Figures 3–15

1867. *Discina newberryi* Hall, New York Geol. Survey, Paleontology, vol. 4, p. 25, pl. 1, figs. 10a,b; 11a–e. Waverly group, Cuyahoga Falls and Akron, Ohio.

1892. *Orbiculoidea newberryi* (Hall). Hall and Clarke, idem, vol. 8, pt. 1, p. 130, pl. 4F, fig. 18. Waverly group, Cuyahoga Falls, Ohio.

1897. *Lingulidiscina newberryi* (Hall). Schuchert, U. S. Geol. Survey Bull. 87, p. 261.

Numerically at least discinoids play an important part in the Pocono fauna of the Broad Top coal field, and they occur in especial abundance at station 3547. In their present estate their characters are these:

In size they reach a diameter of 27 millimeters, though many are considerably smaller. In outline they range from nearly circular to strongly elliptical.

The brachial valve ranges from low to rather high in convexity and the apex may almost overhang the posterior margin or be well forward from it, perhaps as much as one-half of a radius. The anterior side is commonly somewhat inflated so that the apex appears to point backward.

The pedicle valve varies in outline like the brachial valve, from circular to elliptical. It is nearly flat except for a strongly introverted cicatrix.

The surface markings consist of the usual widely spaced narrow, threadlike lirae, of which about 10 occur in a distance of 5 millimeters. These are, however, confined to the more central parts and give place on the outer parts to striae of growth which are rather strong and rather regular but quite different from the spaced lirae. This change appears to be more marked in the brachial valve.

It is obvious at once that these specimens have been distorted by compression and that much of the existing variation must be ascribed to that cause. It seems safe to infer that the original outline was essentially circular instead of elliptical, as in so many of the specimens. The elevation of some of the brachial valves must have been high, for it is fairly high even in their present condition and could scarcely have been lower originally. In many of these specimens the lower part of the shell on the posterior side spreads out abruptly from a steep descent above, as if through compression this side had buckled and been doubled inward. The effect of this process would be to make the height of the valve appear lower and the apex more nearly marginal than it was originally. On the other hand, compression might affect this valve in a different way so as to flatten it out, with the result that the height would seem lower and the apex more central in position, while radiating cracks would appear in it. This condition also has been observed, and it seems not improbable that much of the variation shown both in the height of the valve and in the position of the apex can be attributed to the different ways in which the shell yielded to compression or the different directions in which the compression was applied. It can hardly be denied, however, that part of the variation may have been original. Originally, according to my estimate, the height of this valve was rather great, the apex was situated one-fourth of a diameter more or less in front of the posterior margin, the slope from the apex forward was rather convex, and the slope from the apex backward was flat or gently concave.

The effect of compression on the pedicle valve, except as it changed the outline, would be less pronounced, because this valve was more nearly flat originally, and less important, because the specific characters reside chiefly in the other valve.

In its original condition this species must have had much the configuration of *L. newberryi*, although in some specimens the height of the brachial valve appears to have been greater. The apex is at present much more nearly marginal in many specimens, and it may have been originally so in some. *L. newberryi* attained an equal size, some specimens being over 25 millimeters in diameter.

I at one time identified this form as *Oehlertella pleurites* Meek, and if no allowance is made for distortion, certain specimens resemble that species rather closely. Even in its present condition, however, the brachial valve is more highly convex, and if it were restored as I should restore it, the convexity would be much greater and the apex considerably farther from the posterior margin. I can hardly imagine a shell having the configuration shown by Meek's figures so transformed by any process of distortion as closely to resemble most of the shells in my collection. These differences do not exist to the same extent if other illustrations are consulted than those given by Meek, for Hall and Clarke figure two brachial valves whose apices, though equally close to the posterior margin by projection, appear to rise higher above it than in the figure given by Meek.

A generic difference even may exist between the Pocono form and *Oehlertella pleurites*, inasmuch as I refer my form to "*Orbiculoidea*," whereas Meek's has been made the type of the subgenus *Oehlertella*. The smaller characters of the pedicle valve are not well shown by my specimens, but I believe that they did not possess a marginal notch for the passage of the pedicle, as in *Oehlertella*. The compression which all these specimens have undergone seems to have caused many of the pedicle valves to part along the line of the pedicle scar, which appears like a narrow crack penetrating the shell from its circumference well toward the center. Other specimens show the deep cicatrix with edges joined even to the circumference; still others show the pedicle scar in the usual form, but with a slight marginal deflection.

It would seem to me quite natural that the disturbance or irregularity caused in "*Orbiculoidea*" by the development of the pedicle tube and the great cicatrix which it produced superficially should be expressed in some specimens by a deflection at the margin of the valve. The essential point is not whether such a deflection existed, but whether it served as a pedicle opening. The great pedicle scar of "*Orbiculoidea*" would seem to be connected with the development of this pedicle tube and its very oblique direction. I should expect a much less striking manifestation if the pedicle issued from a notch on the margin, and the presence of a deep cicatrix may in my judgment be taken as indicating the presence also of an oblique pedicle tube, if no contradictory evidence appears. Although the details are not shown by my specimens, the structure indicated seems to be that of "*Orbiculoidea,*" but naturally nothing positive can be said on this point.

Some of my specimens also resemble *Discina connata* of Walcott, but Walcott's species resembles Meek's rather closely, and the Pocono form did, I believe, present much the same differences in its original condition from the one as from the other.

Rhipidomella huntingdonensis Girty, n. sp.

Plate 22, Figures 16–23

Shell rather large, though mostly under 37 millimeters in width. Shape broadly subcircular, with the transverse diameter distinctly greater than the longitudinal.

Pedicle valve of rather low convexity, being nearly flat over most of its surface and owing its capacity in large measure to the inflected parts along the cardinal border; more or less depressed down the middle. Hinge line about one-half the greatest width. Cardinal area rather low, suberect.

On the interior this valve has a rather large, deeply impressed flabelliform muscular area reaching about halfway, or a little more, to the anterior margin. The muscular area is divided into two lobes (the diductors) by a median ridge which is a continuation of the ridges defining the muscular imprints, and in its backward course this median ridge itself divided about halfway to the beak so as partly to inclose a small heart-shaped scar formed by the two adductors.

The brachial valve is more convex than the other, though it is by no means gibbous. It appears to have a distinct median sinus which is narrower than the broad, gentle deflection of the pedicle valve.

The muscular imprints of the brachial valve are scarcely appreciable. Where best seen they take a multilobate, probably a quadrilobate form. A pair of grooves (ridges on internal molds), one on each side and some distance apart, define a central area having a vaguely cordate shape, and these are sharply reflexed toward the side at the posterior end. The most obvious internal feature is a low rounded ridge which extends about half the length of the valve and becomes stronger toward its posterior end, where through a general thickening of the shell near the cardinal margin it coalesces with the cardinal process and the dental sockets.

The surface is marked by the usual fine radial lirae, of which about three, measured from crest to crest, occur in 1 millimeter at the anterior margin of mature shells. In addition to the punctae, these shells had pores (spines?) of two sizes. Those of the larger size are confined to the crests of the lirae and resemble overarching scales or the bases of spines that have been broken off. They extend obliquely backward from the outer surface but do not completely penetrate the shell except possibly in the marginal region. They commonly emerge at intervals along the varices of growth, but they occur elsewhere as well, and on the cardinal angles of the pedicle valve they are especially large and closely arranged. In that region they resemble large tubules piercing the shell obliquely. My specimens do not show the fact conclusively, but these groups of large pores are apparently confined to the pedicle valve and do not occur upon the cardinal angles of the brachial valve. The small pores are much more numerous than the large ones, much more thickly and more indiscriminately strewn, for they occur on the sides as well as on the top of the lirae. The surface is also marked by fine, regular incremental striae and by rather numerous but not very strong or regularly arranged varices of growth.

I have not been able to locate this form satisfactorily in any described species. *R. oweni* at once suggests itself in this connection but is also at once dismissed. Not only are the muscular imprints of that species much smaller, but the shell is generally somewhat wider, and the pedicle valve rarely shows those tubules, or so many or so large, that I have described as occurring near the cardinal border of the present form.

R. pennsylvanica Simpson appears to be similar in many ways (though it is not very satisfactorily known), and it invites comparison because of its geographic distribution. It is, on the other hand, said to belong with a fauna apparently different from this one and also somewhat older. It does not reach so large a size and is apt to be relatively narrower. *R. pennsylvanica* is described as having a slight fold down the middle of the pedicle valve, corresponding to a slight sinus in the brachial valve, whereas no such elevation is present in the Pocono shell, which instead shows a broad, shallow concave deflection from side to side. This character, however, and some of the others are more or less inferential, as the Pocono specimens are all deformed by pressure to a greater or less extent. Specimens from northwestern Pennsylvania, supposed to belong to *R. pennsylvanica,* show a larger and less deeply impressed scar in the pedicle valve and somewhat coarser liration.

R. burlingtonensis is likewise a similar species, but aside from its remote geographic position and its association with a fauna very unlike the Pocono fauna, even if possibly of the same geologic age, it appears to show some proper differences. Owing to their different preservation, however, these shells can not be satisfactorily compared in several details. The beak of the pedicle valve in *R. burlingtonensis* is not only more elevated but it projects well beyond the hinge line. In the present form, on the contrary, the umbonal region is much less gibbous and projects scarcely at all, even if allowance is made for the effects of compression. Nor does one find among specimens of *R. burlingtonensis* as many individuals that are wider than long or any that are relatively as wide as one finds in the specimens from the Pocono fauna.

The species most likely to prove similar to or even the same as this is *R. pulchella* of Herrick. Herrick's description is too general to permit comparisons in a number of important characters, and the specimens of *R. pulchella* in my collection are equally unfavorable. They are preserved in sandstone, and the original shell has been reduced to an ocherous film so that it is possible to make out neither the character of the muscular imprints nor the details of shell structure and sculpture.

These appear to be the most closely related of our Mississippian species, and the Pocono form can not be exactly identified with any of them. Differences of a similar nature and equally pregnant can be found if Devonian shells are brought into comparison. The two Hamilton species, *Orthis vanuxemi* and *O. penelope*, are more comparable than are the orthoids of the Chemung fauna, and of the two mentioned, *O. penelope* more than *O. vanuxemi*. If it is necessary to distinguish the present form from *R. penelope*, the most conspicuous difference perhaps is the tubular character of the lirae in that form which gives them the interrupted appearance mentioned by Hall.

Schuchertella chemungensis Conrad.

Plate 22, Figures 24–28

1867. *Streptorhynchus chemungensis*. Hall, New York Geol. Survey, Paleontology, vol. 4, p. 67, pl. 10, figs. 1–26. Chemung group, New York.

1892. *Orthothetes chemungensis*. Hall and Clarke, idem, vol. 8, pt. 1, p. 255, pl. 10, fig. 9; pl. 11A, fig. 14. Hamilton group, western New York, Chemung group, southwestern New York.

Shells belonging to the genus *Schuchertella* are very abundant in the Pocono formation of Huntingdon County, but like the other fossils found there they have suffered much from distortion, so that some characters desirable or even necessary for close identification can not be determined with precision.

Some specimens are as wide as 45 millimeters, or even wider, this dimension being much greater than their length. The cardinal angles appear to have been rounded and the general shape more or less elliptical.

The pedicle valve is of low convexity and owes its elevation chiefly to the height of the cardinal area, the upper surface being almost flat. In many specimens this surface is gently concave, especially over the posterior half, but, on the other hand, the parts adjacent to the beak may be somewhat inflated. The cardinal area probably had a slight backward inclination from the hinge and in some it slopes backward rather strongly; in still others, however, it is at present nearly perpendicular to the plane of the shell edge. In height the cardinal area measures on the average about 5 millimeters (along its surface) in mature specimens but sometimes distinctly more. Compression may have modified the original height and slope considerably. The width of the delthyrium is generally about 5 millimeters, but this dimension has suffered change from compression that is difficult to allow for. From what has been said it will be apparent that this valve varies not a little in its configuration, some specimens being distinctly irregular and distorted, others quite regular, and some having a moderately high area, others a distinctly higher.

On the inside this valve developed no median septum and no well-marked dental plates, though the margins of the delthyrium are thickened into stout dental pillars. The muscular imprints must originally have been faint, and at present scarcely any trace of them remains.

The brachial valve is of rather low convexity, in some specimens very low indeed, though the umbonal region is apt to be slightly inflated and the parts adjacent to the cardinal angles rather broadly depressed.

On the interior this valve is without any appreciable muscular scars. Two short, thin socket plates are directed outward from the umbo at a very acute angle to the hinge margin and are connected with the cardinal process, which extends somewhat backward but chiefly upward.

The surface is marked by slender radial lirae separated by interspaces of about the same width. The lirae are subequal or, as new ones are introduced, obscurely alternating, and about 10 occur in 5 millimeters. This number, however, is subject to variation, originally through introduction of new lirae, subsequently through compression, which has spread out some specimens and pressed together others. The usual concentric crenulations are also present, but on the specimens seen they show more clearly between the lirae than upon them.

In so far as I have been able to determine, these shells can not be adequately distinguished from *S. chemungensis*, and, but for their faunal association, might as well be cited under that species as under any other. They may belong to *S. fernglenensis* or to *S. ruber*, which have the disadvantage as compared with *S. chemungensis* of coming from a remote area and a different fauna, though a fauna perhaps not very different in geologic age. Of the forms occurring in the Waverly group of Ohio, some probably belong to the same species as this, but *S. desiderata*, from the Cuyahoga shale of Medina County, is apparently distinct by reason of its much more gibbous brachial valve. Some of these Waverly forms have been identified as *Hemipronites crenistria* Phillips and others (or possibly the same ones) were at one time said by Hall to be identical with *S. chemungensis*. As typical *crenistria* belongs to a different genus from these common Waverly shells, being indeed taken as the genotype of *Schellwienella*, it is no longer possible to accept an identification which had little to recommend it but the weight of authority. Thus a reference of the Pocono form to *S. chemungensis* is not only probable but represents almost the only practicable course, except introducing a new name for a type which in its present preservation is hardly if at all distinguishable from that species.

Chonetes acutiliratus Girty, MS.

Plate 23, Figures 1–4

Shells belonging to the genus *Chonetes* are extremely abundant in the Pocono formation of the Broad Top coal field, but their proper disposition is difficult because in characters vital to a close identification few of the associated forms have suffered more than these. The specimens, which occur as molds in shale, have been considerably deformed by compression, which has affected not only their shape and convexity but also the details of their sculpture. The sculpture has been still further obscured where the matrix happens to have been of a sandy character and also where the surface has been covered by a ferruginous deposit, as it has been in many specimens. The characters here set down, therefore, are more or less inferential.

Some specimens are rather large, as much as 17 millimeters in width, but a space of 10 to 14 millimeters covers most of them. The original shape appears to have been deeply semicircular, with the length rather more than commonly great in proportion to the width; in some specimens at present it even exceeds the width, but this is clearly due to distortion. The sides are long and subparallel, in direction nearly perpendicular to the hinge line, with cardinal angles very slightly extended perhaps in some specimens and possibly rounded in others.

The pedicle valve appears to have been rather highly arched for the genus; the curvature of the brachial valve, on the other hand, seems to have been rather low. The cardinal spines are slightly oblique and rather numerous; eight or nine to a side can sometimes be counted on internal molds, but only five or six were functional—that is, projections from the shell and not merely tubes embedded in it.

The radial costae appear to have been angular, with relatively broad, rounded striae between. They number about 10 to 13 in 3 millimeters, usually 11 or 12. No character, perhaps, has been more modified by fossilization than this, for specimens that have been flattened by pressure from above present too few lirae in a measured distance, and those that have been squeezed together by pressure from the side present too many. Some specimens which appear to come under the former category present only eight or nine costae in 3 millimeters. Some external molds show distinct though fine concentric striae, which appear to be in the nature of growth lines rather than crenulations. Varices of growth also are there, but they are neither numerous nor conspicuous.

The angular character of the costae, the broad intercostal spaces, and the concentric markings of growth lines rather than crenulations are apparently significant characters of this form and tend to ally it with a *Chonetes* which I have described in manuscript under the name *Chonetes acutiliratus* and of which the types were found in the Bedford shale of Ohio. Most of the other characters are also in agreement except the spines, which appear to be more numerous in the Pocono shell; they are not, however, well shown in the Bedford one. With the characters which it appears to possess, this form can not belong to *C. illinoisensis*, or any of its allies, much less to *C. logani* or any species allied to it. Nor does it belong to *C. michiganensis*, with characteristic specimens of which it has been compared, though the two are certainly related. Material such as is furnished by these beds, however, is not susceptible of satisfactory identification.

Camarotoechia aff. C. contracta (Hall)

Plate 23, Figures 5–8

1867. *Rhynchonella* (*Stenocisma*) *contracta*. Hall, New York Geol. Survey, Paleontology, vol. 4, p. 351, pl. 55, figs. 26–39. Chemung group, New York; Meadville and Bradford, Pa. Waverly group, Licking County, Ohio.

1892. *Camarotoechia contracta* (Hall). Hall and Clarke, idem, vol. 8, pt. 2, p. 192, pl. 57, figs. 28–32, 49. Hamilton group, Cardiff, N. Y. Chemung group, New York.

Rhynchonellas belonging to the genus *Camarotoechia* are extremely abundant, but though almost innumerable specimens are contained in my collections, very few of them show the characters necessary to their identification. The full number of costae can but rarely be ascertained, and still more rarely their distribution upon the sides of the shell and on the fold and sinus. The total number of plications can sometimes be computed if not counted in full, and if the brachial valve is taken as a standard, the total number appears to range from 12 to 24, with the number 18 recurring more often perhaps than any other. Even if the total number can be counted, however, the specimens are mostly so distorted by compression that the limits of the fold and sinus are not determinable. Nevertheless, the facts can still be ascertained in some cases, and the following combinations occur: Four plications on the fold with four on each side; five on the fold with five on each side; and six on the fold with six on each side, this perhaps being the combination most commonly met with. Still other combinations occur, such as four on the fold and seven on each side; five on the fold and six (or seven) on each side; or eight on the fold and five on each side. It will be remarked that combinations making a total of 18 are especially common. Individual counts may be in error owing to the character of the fossils, but the general statement foregoing is probably not far afield. As to size, a few very large specimens have a length of 17 millimeters, but most measure from 10 to 15 millimeters. The shape, as now exhibited, varies almost indefinitely, but originally to all appearances it offered no unusual features and was subtriangular, subovate, and subquadrate in different specimens, with the width greater than the length. In their general appearance the specimens at present show the greatest contrasts, for if they have been pinched together laterally the shape is much elongated and the plications are thin, crowded, and high, whereas if they have been flattened out the shape is very wide and the plications large, broad, and low.

The variation in original characters which is suggested rather than shown by these specimens is greater than I would wish to assign to a single species, though not greater than has sometimes been assigned to species of this genus. A subdivision of the specimens, however, would have to be carried out along quite arbitrary lines and would leave most of them undetermined and most of the remainder determined with doubt. On the whole, this form seems to stand rather close to *C. contracta*, which is not only common in the Chemung but has also been identified by Hall in the Waverly group of Ohio. The total number of plications in *C. contracta* is given as 16 to 20, with commonly 4 on the fold. Some of my specimens would in their original state hardly be distinguishable from *C. contracta*, but the more persistent condition seems to be represented by shells with 6 plications on the fold and 6 on the sides, so that the less common arrangement here is the prevailing one in *C. contracta* and vice versa. The identification suggested is unsatisfactory, but for the present it must rest at that. If the basic arrangement of the plications for this form is taken as 6 on the fold and 6 on the sides I know of no Mississippian species which approaches it as closely as *C. purduei* var. *agrestis*. Though characters proper to the shells themselves may suggest such an identification, considerations of regional development and faunal association seem much opposed to it. The same objection holds against *C. elegantula*, the number and arrangement of whose costae can apparently be duplicated in some at least of my specimens.

Cranaena sp.

This type is represented by a single specimen flattened in shale. It is small, measuring but 11 millimeters in length and 7 millimeters in width, and of an ovate shape, widest below the middle. The apparent outline may not be the true one, however, for a pronounced sulcus due to interrupted growth seems to indicate a greater width and a more pentagonal shape. The shell structure is punctate. Internally septal plates are lacking in the brachial valve, but there is a suggestion of a hinge plate supporting crural arms after the manner of the genus *Cranaena*.

Spirifer compositus Girty, n. sp.

Plate 23, Figures 9–11

Shell small, strongly transverse. Cardinal angles rounded so that the greatest width occurs somewhat anterior to the hinge line. Of the few specimens observed none are much over 20 millimeters in width.

Pedicle valve subconical. Cardinal area rather high, rather well defined, gently arched, and somewhat inclined backward from the hinge line. Foramen triangular and unusually wide, apparently occupying nearly a third of the hinge line. Sinus broad and fairly well defined. Surface marked by rather coarse, strong plications, of which about 10 occur on the lateral slopes and 2 in the sinus. In the interior 2 thin strongly diverging dental plates can be seen, but no transverse plate across the open delthyrium.

The brachial valve corresponds in character to the pedicle valve as described, being strongly transverse, rounded at the hinge line, and of low convexity. The fold is broad, sharply defined, and moderately elevated. The plications are rather large and fairly strong. Ten or 11 occur on the lateral slopes, and 3 on the fold.

The surface is marked by concentric striae, which are rather coarse, rather regular, but not very sharp. Covering the whole is a sculpture of fine, regularly arranged elongated papillae, creating an appearance almost exactly like that characterizing the genus *Syringothyris*.

This species is represented by but few specimens and the preservation of these is adverse to an accurate description. Some of the characters noted above are therefore of doubtful authenticity. The description of the pedicle valve was drawn up from one specimen and that of the brachial valve from another, each from a different collection. Should any question arise as to the two valves being conspecific, the pedicle valve may be considered the typical one.

This pedicle valve, though even now rather highly convex, has been compressed from above and somewhat obliquely from the right. The effect has been to reduce the height of the cardinal area and cause it to be more arched and more tilted backward. To some extent the definition of the cardinal area and the unusual width of the delthyrium may have been affected by this general deformation. The limits of the sinus are also not altogether clear, because the shape of the valve and the height of the plications have been altered unsymmetrically owing to the oblique direction of compression. As determined by the strength of the plications in the median region, the sinus is of moderate width and contains but two costae, which is the number that it should contain in order to agree with the brachial valve referred to the same species. This does not, however, check up exactly with evidence furnished by the disposition of the dental plates, which are, one may suppose, symmetrically placed and consequently available for determining corresponding plications on opposite sides of the median line. On this evidence the sinus might contain four plications instead of two, and they would be of unequal size.

Although this pedicle valve is an internal mold, it clearly shows the character of the surface markings, except in the umbonal region. These consist of minute elongated pustules arranged quincuncially so as to lend the surface the "twilled-cloth" sculpture exemplified in the syringothyroid shells. The brachial valve, though also an internal mold, does not show these markings at all. A small piece of the external mold, however, does preserve them, though with not quite the same appearance. The linear arrangement of the pustules is more apparent, though their independent character is shown by the presence of small spinules represented by minute rounded punctures in the matrix.

Spirifer compositus is remarkable in several ways. As is well known, the Spirifers of the Carboniferous are in a broad way distinguished from those of the Devonian by having a plicated fold and sinus. Now, the plications in the fold and sinus of every species that I can recall follow a uniform course of development. The fold and sinus begin as simple deflections of the shell along the median line; then the fold gradually becomes divided by a median groove at the same time that a median rib develops in the sinus. Other ribs are added symmetrically, so that those within the sinus always make up an odd number and those upon the fold always an even number. In this species the plan is reversed, the fold showing an odd number of plications and the sinus an even. The sculpture also is paradoxical for the normal Carboniferous Spirifers. Normal Carboniferous Spirifers having a plicate fold and sinus almost invariably show finely reticulate surface markings composed of delicate radial lirae crossed by delicate lamellose transverse lirae. One set of markings may strongly predominate, but rarely if ever is the other wholly indistinguishable. In this species apparently we find a quite different type of sculpture, one which is very common among Devonian Spirifers and which has been brought over into the Carboniferous especially by the syringothyroid shells. It is so alien to the ordinary Carboniferous Spirifers, however, as to be almost a generic character of *Syringothyris*. Sculpture comparable to that of *Spirifer compositus* is not entirely unknown even among our Carboniferous Spirifers. I figured as *Reticularia subrotundata* a shell from the Madison limestone, which of course I now know to belong to an altogether different group of Spirifers that has a surface in general effect extremely similar to this, though the two species are very different in configuration. That form has the configuration of *S. rostellatus*, or, indeed, of the species to which it was originally referred. Another form that possesses somewhat similar surface characters is one from the Leadville limestone of Colorado, which in my report upon those faunas I distinguished merely by the formula *Spirifer* sp. *b*. *Spirifer* sp. *b* outwardly resembles the early Mississippian Spiriferinas, such as *Spiriferina solidirostris*, but it does not possess a median septum in the pedicle valve nor probably a punctate shell structure. The surface is thickly covered by fine spinules; in this it resembles *Spirifer compositus*, as it does also in general configuration, although it differs conspicuously in having the fold and sinus incompletely divided, and divided in the customary way with an even number of plications on the fold and an odd number in the sinus. In configuration, of course, *Spirifer* sp. *b* is widely different from the form that I identified as *Reticularia subrotundata*. Thus apparently this rare type of surface marking is manifested in several distinct groups of Carboniferous Spirifers as determined by their configuration. Whether this sculpture, though similar in appearance, is really identical in plan is a matter for further verification. Though the effect is much the same, the surface of "*R. subrotundata*" when closely examined appears to be covered with minute indentations which must be a feature of the superficial layer alone, inasmuch as the shell is impunctate. Little indentations, however, must be separated by minute projections, and little spinules must be separated by minute indentations, while the spinules, if torn off with the matrix, would tend to leave little pits. With specimens that are indifferently preserved the distinction just made, which is so easily visioned, is in fact very difficult to recognize.

Nucula aff. N. houghtoni Stevens

1858. *Nucula houghtoni* Stevens, Am. Jour. Sci., 2d ser., vol. 25, p. 262. Marshall group, Battle Creek, Mich.

1855. *Nucula houghtoni* Stevens. Hall, New York Geol. Survey, Paleontology, vol. 5, pt. 1, Lamellibranchiata, pt. 2, p. 323, pl. 45, figs. 29–31. Waverly group, Newark and Richfield, Ohio; Battle Creek and Hillsdale, Mich.

The identification of this species is probably more precarious than that of any other cited in this Pocono fauna, for not only are the specimens few and ill preserved, but one can hardly doubt that when the early Mississippian Nuculas of the Michigan-Ohio area are carefully studied there will be much shifting of synonymy and of nomenclature. The species that must be considered here are *N. houghtoni* Stevens, *N. sectoralis* Winchell, and *N. stella* Winchell, all from the Marshall sandstone of Michigan, and *N. iowensis* White and Whitfield, from the Kinderhook group of Burlington, Iowa, which is regarded by Hall as a synonym of *N. houghtoni*.

N. sectoralis may be dismissed as soon as mentioned. Under that species Winchell included shells belonging to both *Nucula* and *Schizodus*, and unfortunately the type specimen of *N. sectoralis* is of the latter genus. Stevens did not figure *N. houghtoni*, and his description is of such a character as to require close study for the identification of his species among the Nuculas of the Marshall fauna, even if it can be satisfactorily identified at all. I suspect that the *Nucula* content of *N. sectoralis* should actually come under *N. houghtoni*. As so much legitimate doubt surrounds the interpretation of *N. houghtoni*, it is unfortunate that Hall went so far as to place *N. iowensis* in synonymy. Hall seems to have interpreted *N. houghtoni* on the basis of specimens from Ohio, especially from Newark. His identification is quite possibly correct. Its status is, perhaps, such that, while the confirmatory evidence is by no means strong, the negative evidence is still weaker. Regarding the identity of *N. iowensis* with *N. houghtoni*, as understood by Hall, there may well arise some question. Weller has figured two of the original specimens of *N. iowensis*, and at first sight one would be inclined to say that both did not belong to the same species. It must be borne in mind, however, that the fossils figured by Weller are internal molds and that the shell of *Nucula* is thick and massive along the hinge border, so that if this thickness happened to be included in the outline of one drawing but not in that of the other the disparity that is at present so striking could be in large measure discounted. Specimens of *N. iowensis* from the original locality, in my possession, are largely intermediate in shape between Weller's two figures. As to the identity of *N. iowensis* with *N. houghtoni*, then, as interpreted by Hall, the marked difference in size (*N. iowensis* is much the smaller) and the pronounced difference in faunal association create an a priori improbability. On the other hand, Hall's figures differ from one another sufficiently and Weller's figures differ from one another sufficiently so that by selection the two species might be made to appear quite similar or quite different, according as one might wish. The differences between favorable specimens of the two species are, I would judge, less than the differences between the two typical specimens of *N. iowensis*. Hall may have been correct both in identifying his Ohio shells with *N. houghtoni* and in regarding them at the same time as referable to *N. iowensis*. No contradictory judgment, at all events, seems at present justified.

Now, Herrick has identified three species of *Nucula* in the Waverly rocks of central Ohio—*N. stella*, *N. houghtoni*, and *N. iowensis*. It is difficult to see any material difference between his figures of *N. iowensis* and *N. stella*, but his *N. houghtoni* appears to be something distinct from either. One would be inclined to say that his *N. stella* and *N. iowensis* belong to one species and *N. houghtoni* to another, and that his *N. houghtoni*, in spite of its much smaller size, is the same as Hall's *N. houghtoni* from the same region. If Herrick's *N. iowensis* is distinct from his *N. houghtoni*, as seems probable, the identification with *N. iowensis* is in contradiction to Hall's conclusion that *N. iowensis* and *N. houghtoni* are the same. Neither of Herrick's forms, not even the one he identifies as *N. stella*, is seemingly referable to that species, for *N. stella* is a much broader form with subcentral beaks.

The Pocono shells here considered, some of which may not be Nuculas at all, have characters of size and shape that ally them with typical *N. iowensis* and with *N. houghtoni* as that species is represented by Herrick's figures, but they are much smaller than the figures of *N. houghtoni* given by Hall or than the dimensions given in Stevens's description. Even were *N. houghtoni* and *N. iowensis* to prove distinct, it would be impossible to determine which the present shells more closely resemble.

Palaeoneilo concentrica (Winchell)

Plate 23, Figures 12–18

1862. *Cardinia concentrica* Winchell, Acad. Nat. Sci. Philadelphia Proc. for 1862, p. 413. Marshall group, Jonesville, Mich.

1865. *Sanguinolites concentrica* Winchell, idem for 1865, p. 128. Marshall group, Hillsdale, Mich.

These shells are rather abundant in the collections studied; nevertheless, they have been so deformed by pressure that they can be described or identified only in a broad way. Some are two and one-half times as long as they are high, while others, apparently belonging to the same species, are only one and one-half times; the one form is, of course, very transverse, the other much more compact and strikingly different in appearance. These differences, however, are largely accidental and it seems clear that this form belongs to a rather well-defined group of Palaeoneilos, of which the Hamilton species *P. emarginata* is a good example. It is characterized by being elongate transversely, by having a deep emargination in the lower part of the posterior outline, and by showing rather strong, lamellose, regularly spaced concentric costae.

Though apparently belonging to the same group of Palaeoneilos, the Pocono species appears to differ regularly from *P. emarginata* in having a shallower sulcus on the postumbonal slope and in having the umbonal ridge more rounded, that structure in fact never becoming sharp and angular as it does in *P. emarginata*. The Pocono shell is apparently more nearly related to one from the Marshall sandstone which Winchell described as *Cardinia concentrica*. Winchell later cited the species under *Sanguinolites*, and Herrick may have intended to transfer it to *Palaeoneilo*, where it really belongs, for he figured but did not describe a "*Palaeoneilo concentrica* var.," which bears, however, no close relationship to *P. concentrica* unless, as may actually be the fact, he was dealing with a young specimen. Winchell published no figures of *Cardinia concentrica*, but an unpublished figure, not to mention the type specimen and other specimens available for study, show very clearly where the species belongs. A decision as to whether or not the Pocono form is actually and closely identical with *P. concentrica* would depend in large measure upon one's estimate of the original shape from the present distorted specimens. No one, however, can doubt that the relationship is close.

This type of *Palaeoneilo* has not often been cited from our Mississippian rocks, though it is probably more common there, at least in the Waverly rocks of Ohio and Pennsylvania, than this fact would suggest. *P. parallela*, which was described by Hall and Whitfield, but unfortunately never figured, apparently belongs in this group, and so may also some of the shells figured by Hall as *P. sulcatina* Conrad. *P. sulcatina* itself is clearly a different species. If one may form an opinion from Hall's figures alone, without examining a series of specimens, he has included more than one species under *P. sulcatina*, his Figure 43 with its pronounced sinus being of the present group, the others more like true *sulcatina*. His *P. truncata* also is a species closely related to *P. concentrica*. Herrick makes *P. truncata* a synonym of *Sanguinolites marshallensis*, but *S. marshallensis* is quite a different thing, probably a *Sphenotus*. Consequently, *P. truncata* appears to be a valid species, at least so far as *S. marshallensis* is concerned, and Herrick's citation of *P. marshallensis* belongs with *P. truncata*, or at least with the present group of *Palaeoneilo*. Herrick has in fact figured a number of forms mostly as distinct species or varieties of *Palaeoneilo* that seem to be on the border line of this group. They may prove to be young or imperfect or abnormal specimens of some known species, or they may not belong to *Palaeoneilo* at all. In fact, young specimens of the form here under consideration (as at locality 5438) are broadly rounded behind, lacking a strong sulcus posterior to the umbonal ridge as well as a pronounced emargination in the lower part of the posterior outline corresponding to it. The shape of these young specimens resembles that of *P. concentrica* var. or *P. curta* or *P. elliptica*, all of Herrick. The size is comparable to that of *P. curta* or to that of the small figure of *P. elliptica*, for the length is less than 10 millimeters. Another specimen from the same locality, still young but larger than the last (it is 15 millimeters long), has the sulcus and the sinus well developed, and the growth lines show that it had much the same shape at a stage considerably younger. The younger specimen especially referred to has been compressed, although the fact is not at all obvious.

Leda aff. L. spatulata Herrick

Plate 23, Figures 19, 20

1888. *Nuculana (Leda) spatulata* Herrick, Denison Univ. Sci. Lab. Bull. 3, p. 79, pl. 9, fig. 11. Waverly group, Licking County, Ohio.

1888. *Leda saccata.* Herrick, idem, p. 108, pl. 9, fig. 12. Waverly group, Licking County, Ohio.

1888. *Nuculana* sp. Herrick, idem, p. 107, pl. 7, fig. 35. Waverly group, Licking County, Ohio.

These specimens are few as well as imperfect, and they might be compared with several other species belonging in other geologic periods as aptly as with *Leda spatulata*. Some of the specimens are more slender and transverse than Herrick's figure, but they have clearly been compressed in such a manner as to produce that effect. On the other hand, one specimen is much less transverse and much more compact, without showing evidence of compression. However, a specimen of *Cypricardinia consimilis* on the same slab and oriented in the same direction is so much deformed as to be almost circular, and the great contrast between the associated *Leda* and others can be accounted for by the same process.

These shells might equally well be compared with *Leda similis* Herrick, and indeed it is difficult to see wherein any difference lies between *L. similis* and *L. spatulata*. Herrick suggests that *L. similis* is the same species that Hall figured under the name *L. pandoriformis* Stevens. This seems, indeed, very likely, as the two figures agree in shape almost to a hair. We do not at present know and perhaps never shall know what species Stevens wished to designate by *L. pandoriformis*, as his description lacks precision on many points. To avoid possible confusion, inasmuch as we already have another name available, it would seem wise to discontinue *L. pandoriformis* until something more definite is known as to its characters.

Cypricardinia consimilis Hall

Plate 23, Figures 21, 22

1885. *Cypricardinia consimilis* Hall, New York Geol. Survey, Paleontology, vol. 5, Lamellibranchiata, pt. 2, p. 486, pl. 79, figs. 18–21; pl. 96, fig. 3. Waverly group, Licking and Medina Counties, Ohio; Warren, Pa.

These shells, though abundant, have been quite as much deformed by pressure as those referred to *Palaeoneilo concentrica*, and quite as definitely they do not yield to close identification. The variation which they show in the proportion of length and width is at present very great, but it can be ascribed largely to distortion by pressure.

This is a large species for the genus and belongs to a rather well-marked type, distinguished perhaps more by its robust size than by characters of greater moment. Many specimens in the present collection equal though but few exceed a width of 20 millimeters. The shape must have been very similar to that of *Cypricardinia consimilis*, though the size is considerably less, Hall's figures showing a width of 30 millimeters.

The most conspicuous and in many specimens the only surface marking consists of rather strong concentric striae disposed at fairly regular intervals. These are very different from the striae of the associated

Palaeoneilo concentrica, as they are not connected with the development of lamellose ridges but instead define somewhat imbricating plates. My specimens also show, though none distinctly, fine radiating striae that are interrupted by the concentric ones but are continued outward from one band to another in the same general direction. These markings appear sometimes as raised lines separated by wide interspaces, sometimes as rounded lirae separated by incised lines, but one can hardly doubt that they were originally essentially the same.

That this form is more than probably identical with *C. consimilis* could hardly be maintained with distorted specimens such as these; equally would it be impossible to show that this was a different species. Furthermore *C. consimilis* appears to be the only species known from the same general faunal province and the same general geologic age which this one closely resembles.

Glossites? sp.

Plate 23, Figure 23

This form is rare, only three specimens having been collected, and even these lack assurance of belonging to the same species. They constitute a rather large species (over 30 millimeters in length) of an elongate-ovate shape, widest back of the middle and with beaks strongly anterior yet by no means terminal. In one specimen an oblique and fairly distinct sulcus defines a lobe anterior to the beak. This configuration is less well marked in the others. The umbonal ridge is broadly rounded and does not form a distinct feature

The surface in general effect is nearly smooth. It is, however, marked by innumerable fine incremental striae, among which here and there occur others more pronounced, due to intermittent growth. One specimen especially but all three in some degree have the appearance of being finely pitted or finely papillose, especially in the umbonal region.

The generic position and still more the specific relations of this form are conjectural only. It might apparently be included under *Glossites* or under *Spathella* without running counter to any of the facts at present known. It resembles Hall's figures of *G. amygdalinus*, from the Kinderhook group at Burlington, Iowa, and also his figures of *G. lingualis* and *G. depressa*, from the Chemung group. It likewise resembles the figures of *Spathella ventricosa*, from the Kinderhook group at Burlington, given by the same author. The dual expression of the Pocono shells thus suggested is attributable to their more or less distorted condition, which has lent them a diverse appearance.

Pleurotomaria aff. P. hickmanensis Winchell

Plate 23, Figures 24–26

1869. *Pleurotomaria hickmanensis* Winchell, in Safford, Geology of Tennessee, p. 445. [Maury shale], Hickman and Maury Counties, Tenn.

1870. *Pleurotomaria hickmanensis* Winchell, Am. Philos. Soc. Proc., vol. 11, p. 257. Waverly group, Hickman County, Tenn.

This pleurotomarioid is not rare in the Pocono collections if all the specimens referred here are of one species, although on this head their very diverse appearance warrants some doubt. All are preserved in the same way, merely as partings in the shaly matrix, the shell itself having totally disappeared, together with the cavity which would have been left by its dissolution. Some specimens appear to show only the internal characters and are entirely smooth; one or two exhibit external markings, crisply expressed; but most show external markings in a subdued and modified form. The sculpture has furthermore been more or less disguised by compression, which has tended to obscure some features and exaggerate others. The same process has also distorted the shape, and all the specimens are otherwise more or less imperfect.

The shell is a rather large one, and the diameter of the final volution must in some specimens have been as much as 25 millimeters, or even more. The shape as a whole was probably subglobose or somewhat ovate, with the height of the spire less than that of the body whorl. The whorls were apparently well rounded and not deeply embracing, so that the suture was much depressed. The curvature of the volutions was interrupted by a pronounced though not high carina, situated above the middle. The slit band is located on or rather forms the carina. It has projecting edges and is marked by strong, regular lunettes which are apparently (in the best specimens, at least) intersected by a revolving line traversing the middle of the band. The surface of the volution above the band and also below it is reticulated by a series of relatively strong, coarse transverse and spiral lirae. The revolving lirae are irregular in size and distribution; small ones here and there lend a conspicuously alternating effect. Some of the lirae are wider and others narrower than the interval between. The transverse lirae have the appearance of being fascicles of growth lines. They are not quite as strong as the revolving ones and not quite as far apart, but they are more regularly disposed. Their course is almost direct, but they are gently curved both above and below the band, with the convex side toward the aperture. The intersections of the two sets of lirae form nodes, which in certain lights are conspicuous.

The surface characters just described are taken from a well-preserved fragment in lot 3549. Another specimen has similar sculpture but fainter and apparently finer. This specimen has been compressed laterally, however, so that the revolving lirae would be brought closer together.

Some of the characters above ascribed to these specimens are open to more or less question, and the identification of the species is correspondingly qualified. Comparisons may fairly be limited to species that are of similar character and that occur in the same faunal province. *P. hickmanensis* may not be regarded as coming from the same faunal province, but it appears to be closely comparable in many of its own characters. The differences that can be discovered (from Winchell's description alone) may be accidental or not particularly material. The slit band on his species is well defined without forming a distinct carina; on mine the band forms a distinct though not strong carina on the best specimen, though on others the carina is more or less suppressed. *P. hickmanensis* is said to be marked by revolving lines. Transverse lines are not mentioned, but the revolving lines are described as nodose, suggesting that transverse lines may originally have been present. In the Pocono form the transverse lines are present and they produce nodes at their intersection with the revolving ones, although this sculpture varies in appearance with the conditions of preservation. *P. vadosa* (from the limestone of Kinderhook age (Rockford limestone) at Rockford, Ind.) can hardly be regarded as of the same faunal province, except that Winchell, in Michigan and Ohio, and Herrick, in Ohio, have identified specimens under that name. Hall's description without a figure and Herrick's figure without a description (especially as Herrick's identification is quite questionable) do not afford an adequate basis for comparison. My form may perhaps be compared with either of those others in size and shape, but not in sculpture. *P. huronensis*, though probably a *Pleurotomaria*, is a quite different species, suggesting the Pennsylvanian *P. carbonaria* but having the revolving ridges fewer, coarser, and more widely spaced. *P. textiligera* (which I do not regard as the same as *P. mississippiensis*) is a similar though not the same form. The whorls of the Pocono shells are apparently more rounded, the suture more depressed, and the sculpture on a larger scale.

Loxonema sp.

The single specimen here under consideration is of the type commonly referred to *Loxonema*, though the characters that would verify the reference or assign the specimen to some quite unrelated genus are not shown. In brief, this is a good-sized shell, composed of many volutions which have but a narrow contact zone and form a very elongated cone. The specimen is so much compressed that the whorls are strongly oblique and the largest, measured obliquely, is over 10 millimeters in diameter. No surface characters are shown, and the whorls may have been marked by the sigmoidal lirae of *Loxonema* or, on the other hand, by revolving lirae, as in the genera *Cyclonema* and *Aclisina*.

Orthoceras sp.

This type, which is represented by a single very poor specimen, deserves only passing notice. The upper end probably shows part of the chamber of habitation; the lower end is apparently divided into shallow chambers. The partitions are represented on the macerated and flattened specimen by grooves, so as to create a certain resemblance to the genus *Cycloceras*, although the features are really reversed, the constrictions being narrow and the annulations broad. About five chambers occur to the diameter, which was about 7 millimeters where the measurement was made, but the specimen appears to have been compressed in the direction of its axis, this process shortening its length and producing irregular transverse wrinkles. The original dimensions, therefore, were probably somewhat different.

REGISTER OF LOCALITIES

3547. Pocono formation. In cut of the Huntingdon & Broad Top Mountain Railroad, on the west side of Shoups Run, 1½ miles southeast of Saxton, Pa.

3548. Pocono formation. In cut of Huntingdon & Broad Top Mountain Railroad, east side of Raystown branch of Juniata River, about 2½ miles north of Riddlesburg, Pa.

3549. Pocono formation. Great Trough Creek Gap in Terrace Mountain, 4 miles east of Marklesburg, Pa.

5438. Pocono formation. South end of Sideling Hill tunnel of East Broad Top Railroad, Huntingdon County, Pa.

PLATES 22–23

PLATE 22

Page

FIGURES 1, 2. *Scaphiocrinus kirkianus* Girty, n. sp. ---- 112

1. Squeeze made from an impression in shale. Station 3547.
2. Squeeze made from the counterpart of the same impression.

FIGURES 3–15. *Lingulidiscina newberryi* Hall? ---- 113

3, 4. Two views of a small brachial valve somewhat compressed and considerably exfoliated. Station 3547.

5, 6. Two views of a small brachial valve which probably retains much of its original shape. Station 3547.

7, 8. Two views of an internal mold of a crushed specimen. Station 3547.

9. Impression of a pedicle valve. The concentric lamellae which are well shown, stand at somewhat wider intervals than in typical specimens. The pedicle scar apparently occurs at the break that passes inward from the lower left-hand margin. Station 3548.

10. A pedicle valve, crushed and exfoliated. Station 3547.

11. Another pedicle valve compressed in the opposite direction. Station 3547.

12, 13. Two views of a large brachial valve, distorted and exfoliated. Station 3547.

14, 15. Two views of an exfoliated brachial valve. It appears to have been compressed vertically so that the original outline is unchanged, but the height is reduced. Station 3547.

FIGURES 16–23. *Rhipidomella huntingdonensis* Girty, n. sp. ---- 115

16. Impression of a pedicle valve showing the large flabelliform diductor scars surrounding the small cordate adductors Station 3549.

17. Internal mold of a brachial valve, distorted by pressure. Station 3547.

18. A pedicle valve retaining the shell but somewhat crushed. Station 3549.

19. Dorsal view of a large specimen retaining both valves. Station 3549.

20, 21. Dorsal and ventral views of a specimen in which the two valves are retained pressed together. Station 3549.

22. Part of an external mold showing minute surface characters. The small elevations are the plugs of matrix that filled the tubules or "spines," which are not to be confused with the finely punctate shell structure. It has not been practicable to represent these plugs in the drawing in quite the number and diversity of the original. Station 3549.

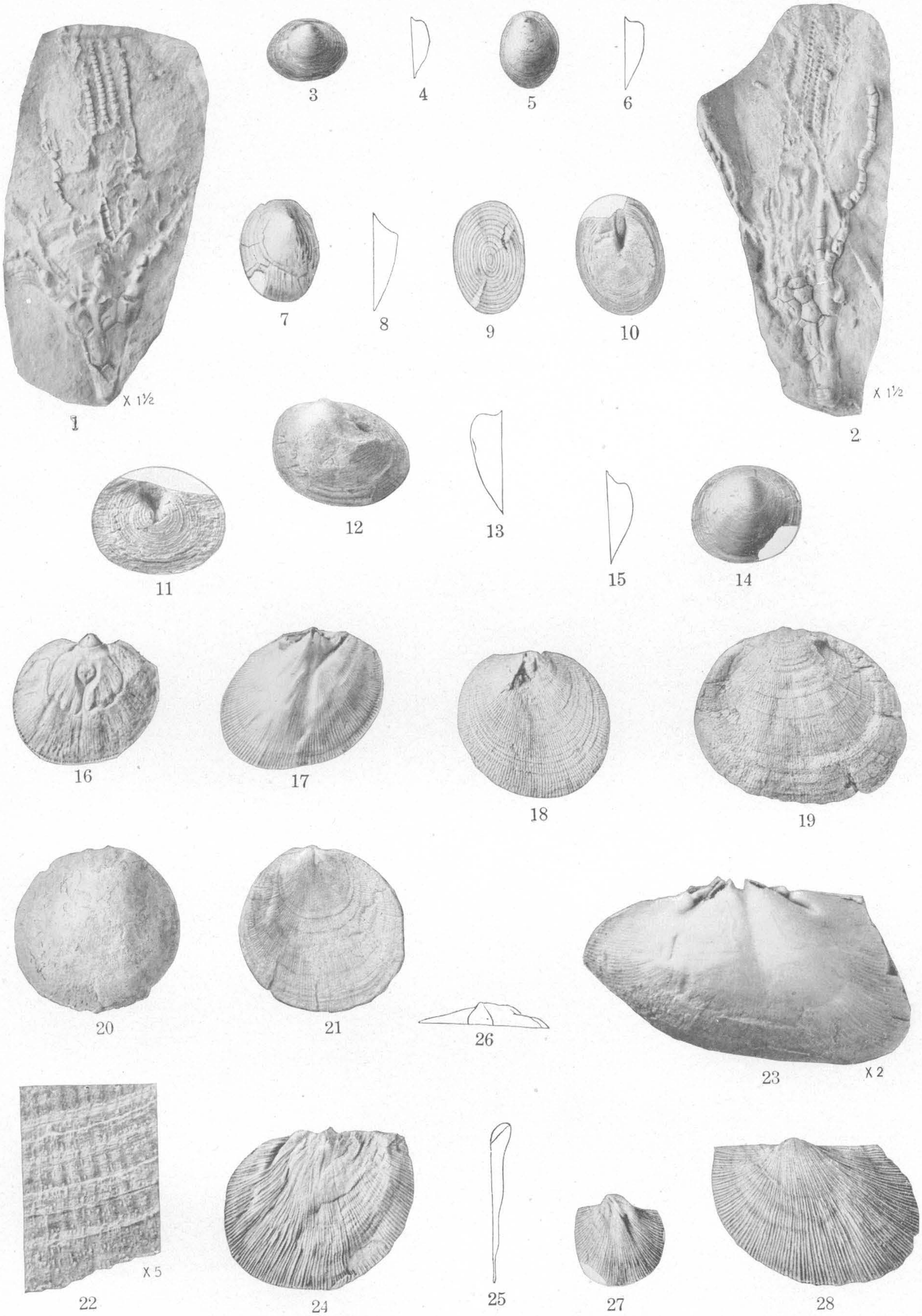
23. Internal mold of a brachial valve showing some details of structure, ×2. Station 3548.

FIGURES 24–28. *Schuchertella chemungensis* Conrad ---- 116

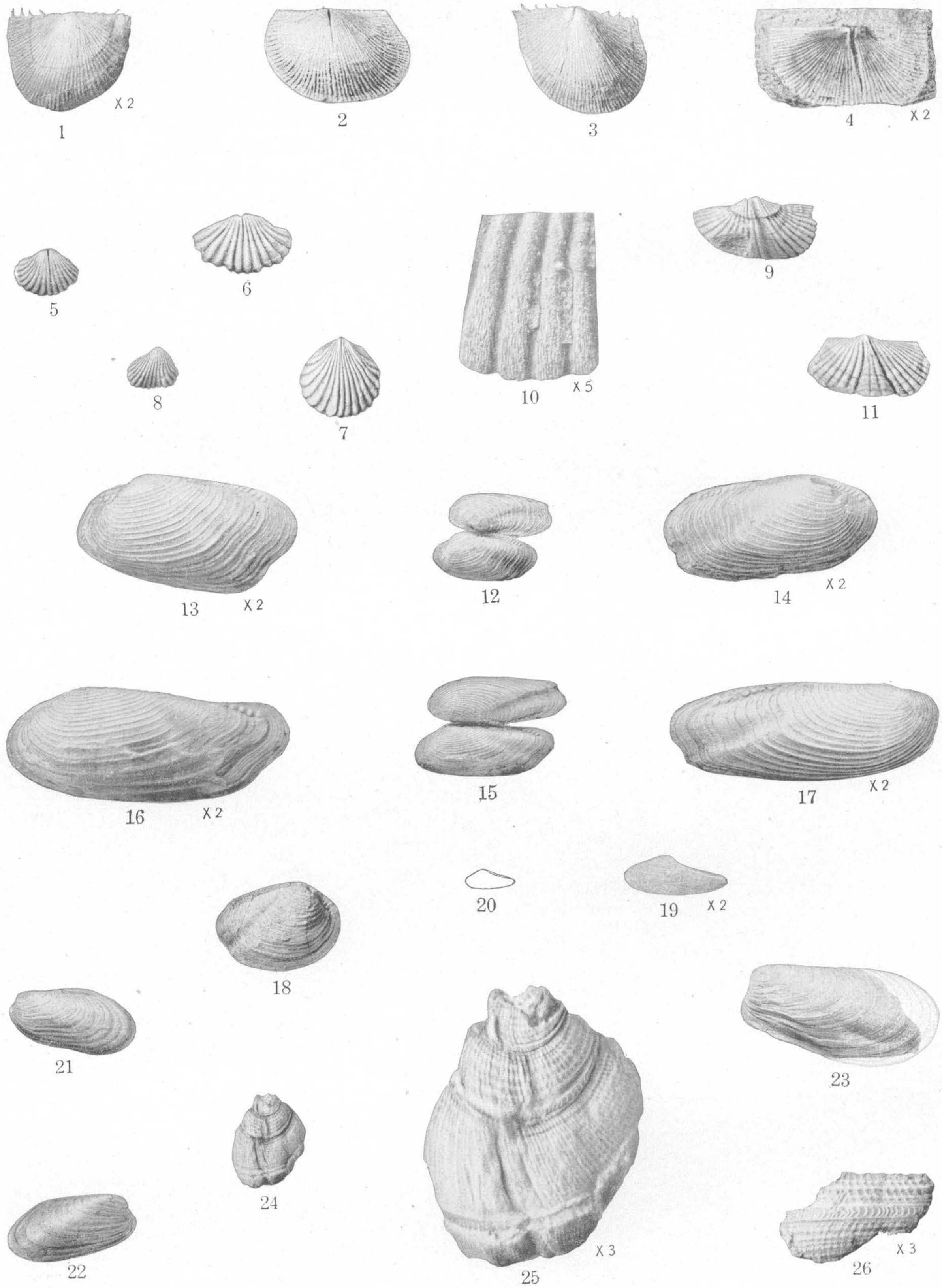
24–26. Three views of an internal mold of a pedicle valve. Station 3547.

27. Internal mold of a small pedicle valve which has an uncommonly high cardinal area strongly inclined backward. This configuration is probably in large part original. Station 3549.

28. Impression of a brachial valve. Station 3547.



FOSSILS FROM THE POCONO FORMATION OF THE BROAD TOP COAL FIELD, PENNSYLVANIA



FOSSILS FROM THE POCONO FORMATION OF THE BROAD TOP COAL FIELD, PENNSYLVANIA

PLATE 23

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FIGURES 1–4. *Chonetes acutiliratus* Girty, n. sp. 117

1. Squeeze of a gibbous pedicle valve. Station 3549.
2. Internal mold of a pedicle valve. Station 3549.
3. Squeeze of a pedicle valve. Station 3549.
4. A testiferous brachial valve whose curvature has been exaggerated by compression. Normally the curvature is much lower. Station 3549.

FIGURES 5–8. *Camarotoechia* aff. *C. contracta* Hall. 117

5. Impression of a small brachial valve which has about 18 plications, 4 on the fold and 7 on each side. Station 3549.
6. Impression of a brachial valve which has about 14 plications, 4 on the fold and 5 on each side. Station 3547
7. Impression of a large brachial valve of which the whole number of plications is uncertain as well as their distribution. Apparently the fold bears 5 and the lateral slopes 6. Station 3549.
8. Impression of a small pedicle valve which has 4 plications in the sinus and 7 on each side. Station 3549.

FIGURES 9–11. *Spirifer compositus* Girty, n. sp. 118

9. Impression of a pedicle valve. Station 3547.
10. Part of the surface of the same specimen, $\times 5$.
11. Impression of a brachial valve. Station 3547.

FIGURES 12–18. *Palaeoneilo concentrica* Winchell. 120

12–14. A specimen retaining both valves, with views of the separate valves enlarged to 2 diameters. Station 3547.

15–17. Three similar views of another specimen. Station 3547. The shape in every instance has been more or less altered by compression.

18. A specimen whose natural proportions have been greatly altered by compression. Station 3547.

FIGURES 19, 20. *Leda* aff. *L. spatulata* Herrick. 121

19, 20. A left valve, natural size and enlarged. Station 3547.

FIGURES 21, 22. *Cypricardinia consimilis* Hall. 121

21, 22. Left and right valves, both somewhat distorted. Station 3547.

FIGURE 23. *Glossites?* sp. 122

23. Left valve of a shell of doubtful affinities. Station 3549.

FIGURES 24–26. *Pleurotomaria* aff. *P. hickmanensis* Winchell. 122

24, 25. Side view of a flattened impression. Station 3549.

26. Fragment of another specimen, probably belonging to the same species which has sharply defined sculpture. Station 3549.

NOTES ON PLEISTOCENE FAUNAS FROM MARYLAND AND VIRGINIA AND PLIOCENE AND PLEISTOCENE FAUNAS FROM NORTH CAROLINA

By Wendell C. Mansfield

INTRODUCTION

In June, 1920, I visited two Pleistocene localities in St. Marys County, Md.—one at Wailes Bluff, in the low cliffs on the left bank of Potomac River about 1 mile above Cornfield Point; the other at Langleys Bluff, on the bay shore about 5½ miles south of Cedar Point. (See pls. 24, 25.) The main object of the trip was to collect additional fossil pyramidellid mollusks, which were subsequently turned over to Dr. Paul Bartsch, of the United States National Museum, for study, but other mollusks were also collected from each locality. In June, 1925, I again visited both localities, in company with L. W. Stephenson and Willis P. Popenoe, and made small collections.

In 1925 I obtained considerable fossil material from five localities along and near Neuse River in Craven County, N. C., ranging over a distance of 10 to 15 miles below New Bern, and one lot from a locality about 10 miles northeast of Beaufort. In 1918 J. A. Cushman made several collections of fossil material in Craven County, and the faunas at two of his stations are considered in this paper.

This paper describes the stratigraphic sections at each of the several localities, lists the species (exclusive of the pyramidellid mollusks) collected from each stratum, treats briefly the significance of the faunas, and, finally, seeks to establish as accurately as possible the age relations of these faunas in the deposits in Maryland and North Carolina.

I wish to express my appreciation to the authorities of the United States National Museum for the use of the facilities of that institution, and to L. W. Stephenson, of the United States Geological Survey, for his helpful suggestions. Dr. Mary J. Rathbun, of the United States National Museum, identified the Crustacea from the Wailes Bluff locality, and Dr. E. W. Berry, of Johns Hopkins University, identified a fossil cone from North Carolina. Dr. Albert Mann, diatomist, of the Carnegie Institution of Washington, identified the diatoms.

PLEISTOCENE LOCALITIES IN MARYLAND

HISTORICAL SUMMARY OF THE GEOLOGY OF WAILES BLUFF AND LANGLEYS BLUFF, ST. MARYS COUNTY, MD.

The localities of Wailes Bluff and Langleys Bluff, in St. Marys County, Md., attracted attention early in the history of Coastal Plain geology. Conrad[1] paid special attention to the Wailes Bluff locality (Cornfield Harbor) and in his publication describes the locality and lists the fossil species. Later he gave a section at Wailes Bluff, described the fauna, and listed the species from this locality.[2] His description of the section and the fauna is quoted as follows:

Section near the mouth of Potomac [*Wailes Bluff*]

Elevation, 15 feet

Sand and gravel.
Ostrea virginiana, *Mytilus hamatus* (estuary deposit), sand, 1 foot thick.
Clay with *Pholas costata*, *Mactra lateralis*, *Arca transversa*, *Solecurtus caribaeus*, etc. (marine deposit), 8 feet above tide.

About 3 miles above the low sandy point which forms the southern extremity of the western peninsula of Maryland, the bank of the Potomac rises to an elevation of about 15 feet at its highest point. The fossils are visible in this bank one-fourth of a mile in uninterrupted extent. The inferior stratum is a lead-colored clay, containing great numbers of *Mactra lateralis* (Say), a common recent bivalve of the coast, which in many instances appear in nearly vertical veins, having evidently fallen into fissures in the clay. *Pholas costata* is also abundant, and each individual remains in the position in which the living shell is usually buried in the mud—that is, vertical, with the anterior or short side pointing downward. They are very fragile and can rarely be procured entire. Over the clay reposes a bed of *Ostrea virginiana* in sand, in places a foot in thickness. It is nearly horizontal, varying from a height of 4 to 8 or 10 feet above high-water mark. The fossils of this locality, with two exceptions, are common recent species of the Atlantic coast, and in some instances the original colored markings remain upon the shells. Were it not for the occurrence of *Gnathodon cuneatus*, *Mytilus hamatus*, and *Arca ponderosa*, the group would not vary from that now inhabiting the coast as

[1] Conrad, T. A., On the geology and organic remains of a part of the Peninsula of Maryland: Acad. Nat. Sci. Philadelphia Jour., vol. 6, pp. 205–230, 1830.

[2] Conrad, T. A., Observations on a portion of the Atlantic Tertiary region, with a description of new species of organic remains: Nat. Inst. Promotion of Science Proc., Bull. 2, pp. 189–191, 1842.

far north as Massachusetts; but the presence of these three bivalves indicate that a climate equivalent to that of Florida prevailed when the shells of this locality were living in the sea. I have before alluded to the peculiar and highly important distribution of the existing *Gnathodon*, burrowing in myriads in the mud flats near Mobile and confined to the estuaries of the Gulf of Mexico. An occasional waterworn valve in the deposit on the Potomac, above described, seemed to indicate that the species lived in that river in the upper Tertiary period. This conjecture was converted into certainty by an exploration of the shore farther north, which resulted in discovering a bed composed exclusively of the *Gnathodon*, on the land of Mr. Ebb, above the mouth of St. Marys River. This bed, except that the shells are smaller, is precisely similar to those which line the bay shore near Mobile. The valves of the shells are frequently connected, and there can be no doubt that here was the spot where they lived and were embedded; that this was a region of sand flats bared at low tide, the water brackish, as it is now; and that the deposit near the mouth of the Potomac was of the same period but more directly communicating with the ocean.

Dall [3] states, in referring to the Cornfield Harbor clays, that they have generally been referred to the Pleistocene, but it is possible that further research will show them to be upper Pliocene.

In the more recent volume by Shattuck, Clark, and others [4] on the Pliocene and Pleistocene of Maryland, however, the Wailes Bluff and Langleys Bluff localities are assigned to the Talbot formation (Pleistocene), and their faunal contents are described and figured.

In previous publications the species from each of the different layers in these sections are not fully listed separately, although the upper bed, which is packed with oysters, is mentioned in several reports.

WAILES BLUFF

STRATIGRAPHIC SECTION

Wailes Bluff (pl. 24) rises about 15 feet above the beach sand, and the section given below is clearly exposed at all times on its face. The waves at this point are eating into the land and gradually destroying it along a distance of about half a mile.

Section at Wailes Bluff, St. Mary's County, Md.

		Feet
4.	Unfossiliferous buff sand and gravel	6–8
3.	Mainly coarse to fine grained angular quartz sand packed with *Ostrea virginica*	1–3
	Probably slight unconformity.	
2.	Bluish clay	0–1
1.	Mainly greenish compact clay mixed with a small amount of quartz sand and a few quartz boulders	4–5

The base of bed 1 is not exposed, but comparison with the similar section at Langleys Bluff, on the bay shore, suggests that this bed may rest upon Miocene deposits at a slight depth below sea level. The material in the upper part of bed 1 consists of shell fragments mingled with well-rounded quartz pebbles and fragments of lignitic material, and its upper surface is somewhat irregular. Nearly vertical pockets, the original openings of which may have been made by some boring crustacea or mollusks, are filled chiefly with *Mulinia lateralis*. In the lower part of this bed the valves of the mollusks are usually attached indicating deposition in quiet water, but in the upper part they are detached, indicating more agitated conditions of the water.

Bed 2 varies in thickness from place to place and is not everywhere present; it may be considered a part of bed 1. This bed contains *Rangia cuneata* and many shells of *Venus mercenaria*.

Bed 3 is composed almost entirely of *Ostrea virginica*. The contact between this bed and the clay on which it rests is not horizontal but undulates through a vertical distance of 2 feet or more in a horizontal distance of 20 yards along the beach. In places the materials of this bed penetrate those of the underlying bed, indicating that the oyster bed occupied a depression in the underlying bed and subsequently was covered with reworked sediments of this lower bed.

FAUNAL LIST

Station 8932, Wailes Bluff, left bank of Potomac River, about 1 mile above Cornfield Point. From lower part of section, beds 1 and 2. Collected by W. C. Mansfield.

[a=Abundant, c=common, r=rare]

Mollusca

Acteocina canaliculata (Say). c.
Mangilia cerina (Kurtz and Stimpson). c.
Busycon canaliculatum (Linnaeus). c.
Busycon caricum (Gmelin). r.
Alectrion trivittata (Say). a.
Ilyanassa obsoleta (Say). a.
Columbella (Astyris) lunata (Say). a.
Urosalpinx cinereus (Say). c.
Eupleura caudata (Say). a.
Epitonium lineatum (Say). a.
Epitonium aff. E. denticulatum (Sowerby). r.
Crepidula plana Say. c.
Crepidula fornicata (Linnaeus). c.
Polynices duplicatus (Say). a
Nucula proxima Say. c.
Leda acuta (Conrad). c.
Yoldia limatula Say. r.
Arca transversa Say. a.
Arca ponderosa Say. c.
Ostrea virginica Gmelin. c.
Pandora gouldiana Dall (1 valve).
Venus mercenaria Linnaeus. c.
Callocardia morrhuana Linsley. r.
Tagelus gibbus (Spengler). c. (Occurs at the top of bed 1.)
Tellina tenera Say? r.
Macoma balthica (Linnaeus). r. (One fragment.)
Ensis directus Conrad. r.
Rangia cuneata (Gray). r. (Mainly from bed 2, just below oyster bed.)
Mulinia lateralis (Say). a.
Corbula contracta Say. r.
Barnea (Scobina) costata (Linnaeus). a.

[3] Dall, W. H., A table of North American Tertiary horizons correlated with one another and with those of western Europe, with annotations: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, p. 336, 1898.

[4] Maryland Geol. Survey, Pliocene and Pleistocene, 1906.

Crustacea

[Identified by Dr. Mary J. Rathbun, of the United States National Museum]

Callinectes sapidus Rathbun. (Range in Recent fauna: Cape Cod to Texas.)
Cancer irroratus Say. (Range in Recent fauna: Labrador to South Carolina.)
Chloridella empusa (Say). (Range in Recent fauna: Vineyard Sound to Texas.)

Station 8933. From oyster bed, or bed 3, at Wailes Bluff. Collected by W. C. Mansfield.

[a=Abundant, c=common, r=rare]

Mollusca

Ilyanassa obsoleta (Say). r.
Urosalpinx cinereus (Say). c.
Epitonium lineatum (Say). (One specimen.)
Crepidula fornicata (Linnaeus). a.
Polynices duplicatus (Say). (One specimen.)
Ostrea virginica Gmelin. a.
Mytilus clava Meuschen. a.
Venus mercenaria Linnaeus. c.
Macoma balthica (Linnaeus). r.
Mya arenaria Linnaeus. a.
Rangia cuneata (Gray). (One fragment taken at lower contact and may belong to bed beneath.)
Corbula contracta Say. (One specimen.)

Additional species, aside from the pyramidellid, from Wailes Bluff, described in the volume of the Maryland Geological Survey on the Pliocene and Pleistocene, comprise the following:
Terebra dislocata (Say).
Cumingia tellinoides (Conrad).
Macoma calcarea (Gmelin).
Petricola pholadiformis Lamarck.
Aligena elevata (Stimpson).
Unio complanatus (Solander).

LANGLEYS BLUFF

STRATIGRAPHIC SECTION

Langleys Bluff (pl. 25), which is about 25 feet high and one-third to one-half mile long, exhibits the section given below, but some parts of it are obscured by a growth of vegetation.

Section at Langleys Bluff, St. Marys County, Md.

	Feet
Pleistocene:	
5. Unfossiliferous cross-bedded buff sand and gravel with a seepage of water along the base	4–15
4. Uniformly deposited unfossiliferous dark-gray sandy clay with a pebbly band at the base	2
3. Oyster zone, sediments with a few small pebbles. No unconformity was observed between this bed and the underlying one	0–1
2. Fossiliferous compact bluish sandy clay containing sandy pockets or filled borings. A thin oyster zone occurs at the base. In this bed are a few pebbles, the largest of which are 3 inches in diameter, and smoothly waterworn cobbles, which are most abundant at the contact with the underlying Miocene	6–8
Unconformity.	
Miocene:	
1. Sandy clay with Miocene (St. Marys) fossils	0–3

FAUNAL LIST

Station 8934. Langleys Bluff, Chesapeake Bay, about 5½ miles south of Cedar Point. From the lowermost Pleistocene bed, or bed 2. Collected by W. C. Mansfield.

[a=Abundant, c=common, r=rare]

Acteocina canaliculata (Say). a.
Mangilia cerina (Kurtz and Stimpson). r.
Busycon caricum (Gmelin). c.
Busycon canaliculatum (Linnaeus). c.
Alectrion trivittata (Say). a.
Ilyanassa obsoleta (Say). r.
Columbella lunata (Say). r.
Eupleura caudata Say. a.
Epitonium lineatum (Say). c.
Polynices duplicatus (Say). a.
Crepidula plana Say. c.
Leda acuta (Conrad). c.
Nucula proxima Say. r.
Arca transversa Say. c.
Ostrea virginica Gmelin. c.
Venus mercenaria Linnaeus. c.
Mulinia lateralis (Say). a.
Rangia cuneata (Gray). r.
Barnea (Scobina) costata (Linnaeus). c.

From the oyster bed, or bed 3. Collected by W. C. Mansfield.
Ostrea virginica Gmelin.
Venus mercenaria Linnaeus.

Additional species from Langleys Bluff, described in the volume of the Maryland Geological Survey on the Pliocene and Pleistocene, comprise the following:
Mya arenaria Linnaeus.
Tagelus gibbus (Spengler).
Unio complanatus (Solander).

ANALYSIS OF THE FAUNAS

WAILES BLUFF

The fauna in beds 1 and 2 of the section is in the main typically littoral marine, with a slight admixture of brackish-water forms, and is somewhat similar to the Recent fauna described by Henderson and Bartsch,[5] obtained chiefly from the shallow waters on the inner side of Chincoteague Island, Va. The material of both beds indicates a muddy bottom inhabited by a fauna that thrives best in comparatively quiet, shallow water protected from the rough breakers of the sea. Neither the material nor the fauna suggests an open sea. The fauna as a whole suggests a temperature about the same as that of the water along the coast in the same latitude at the present day, or perhaps a little warmer. None of the species indicate a colder condition with the exception of *Aligena elevata* (Stimpson) and *Macoma calcarea* (Gmelin), which are recorded by the Maryland Geological Survey from Wailes Bluff. I did not find the two species at Wailes Bluff, nor are they in the United States National Museum collections from this locality.

[5] Henderson, J. B., and Bartsch, Paul, Littoral marine mollusks of Chincoteague Island, Va.: U. S. Nat. Mus. Proc., vol. 47, pp. 411-421, 1914.

The figured specimen of *Aligena elevata* in the collection of the Maryland Geological Survey from Wailes Bluff was examined by me and is correctly identified. *Macoma calcarea* was identified from the fragments of the shell, but I have not seen these fragments. Both species are distinctly northern forms and do not occur on our coast this far south.

The species of mollusks listed are all represented somewhere in the Recent faunas except an *Epitonium*, which may be a new species and may not be represented in the Recent fauna. Nearly all are living somewhere on the coast from Cape Cod southward to Florida and on the Gulf. *Ostrea virginica* is smaller in size and proportionally wider than the representatives of the same species that occur abundantly in the bed above. *Arca ponderosa*, originally described by Say from the Recent fauna of Florida, where it is represented by many individuals, is abundant. This species is living on the present coast from Cape Cod to Florida, but the warmer waters south of Cape Hatteras appear to be a more favorable habitat.

In the upper part of bed 1 and bed 2 *Rangia cuneata* is associated with *Venus mercenaria*, which suggests a slight freshening of the water. The Recent geographic range of *Rangia cuneata*, as noted by other writers, is along the Gulf, from Alabama westward. There it lives in both salt and brackish water, but it thrives best in the brackish water.

Two species—*Yoldia limatula*, which ranges in the Recent fauna from Arctic seas to Cape Hatteras, and *Callocardia morrhuana*, which ranges from Prince Edward Island to North Carolina—indicate that the fauna lived in a temperature cooler than that which prevails to-day south of Cape Hatteras.

The uppermost fossiliferous bed, or bed 3, carries many individuals of *Ostrea virginica*, *Mytilus clava*, and *Mya arenaria*. The two species last mentioned were not obtained from beds 1 and 2. *Ostrea virginica* is large and elongate and has a modern aspect. *Mytilus clava*, which is usually associated with *Ostrea virginica* in both its fossil and its Recent occurrences, has a geographic range from Cape Cod to Nicaragua and Porto Rico. *Mya arenaria* is now living from Greenland to Beaufort, N. C. It also occurs at the mouth of Potomac River, but it is not abundant in Chesapeake Bay.

Kellogg [6] describes the habitat of this species as follows:

> In describing the conditions which are necessary for the existence of clams on natural beds it may be well to note the fact that, within certain very wide limits, clams appear to do equally well in water which is very salt or nearly fresh. Not only is this true, but they may be transplanted from one locality to another where the salinity is very different without being affected adversely.

[6] Kellogg, J. L., Conditions governing existence and growth of the soft clams (*Mya arenaria*): U. S. Comm. Fish and Fisheries Rept. for 1903, p. 200, 1905.

The fauna of the upper fossiliferous bed, or bed 3, therefore could have lived in brackish water, and considerable evidence points to such an environment.

LANGLEYS BLUFF

The Pleistocene fauna from bed 2 at Langleys Bluff is similar to that in beds 1 and 2 at Wailes Bluff. Bed 3 carries many individuals of *Ostrea virginica* and a few of *Venus mercenaria*. This bed is present only for a short distance in the bluff, and where it is absent bed 4 rests on bed 2. No specimens of *Mya arenaria* or *Mytilus clava* were obtained by the writer from this upper fossiliferous bed (No. 3), but *Mya arenaria* is reported from Langleys Bluff by the Maryland Geological Survey in its volume on the Pliocene and Pleistocene. This bed may or may not represent the oyster bed at Wailes Bluff, but the two beds must differ in age only slightly, if at all.

Only two valves of *Rangia cuneata* were obtained from Langleys Bluff, and they were taken from bed 2.

COMPARISON OF LOCALITIES IN MARYLAND WITH LOCALITIES IN VIRGINIA

Shattuck,[7] in commenting on the deposits at Wailes Bluff, says:

> The lower portion carrying the marine organisms points to salt-water conditions and contains remains of sea animals which live to-day along the Atlantic coast. * * * Later, however, it would appear that a barrier beach was constructed, shutting off a portion of the sea bed which had formerly been occupied by marine animals and gradually allowing it to be transformed from salt-water conditions to those of brackish water. In this brackish-water lagoon the fauna changed to that found along our estuaries to-day, and huge oysters flourished and left behind them a deposit of shell rock. With the bar advancing landward, this lagoon was gradually filled up with sand and gravel and finally obliterated.

Shattuck finds no indication of an appreciable lapse of time between the deposition of the oyster bed and that of the underlying clay bed, and I am inclined to agree with his interpretation. The faunal change and the irregular contact between the two beds probably indicate a minor unconformity.

Clays of Talbot age at several places in Virginia, whether carrying a brackish-water fauna, plant remains, or peaty material, appear to be approximately contemporaneous with each other and probably are contemporaneous with the clay that carries the littoral or brackish-water fauna at Wailes Bluff and Langleys Bluff in Maryland. This relationship was especially noted in exposures on the right bank of lower Rappahannock River in Virginia, between Taft post office and Mosquito Point. Here a peat bed or a clay bed carrying either oysters or *Rangia cuneata* reposes upon the Yorktown Miocene and crops out at the same level along the bluff.

[7] Shattuck, G. B., The Pliocene and Pleistocene deposits of Maryland: Maryland Geol. Survey, Pliocene and Pleistocene, p. 132, 1906.

If these clays that carry a brackish-water fauna or plant remains or peaty material in Virginia are approximately contemporaneous with the clays that carry a littoral or brackish-water fauna at Wailes Bluff and Langleys Bluff in Maryland, it would appear that the overlying beds in the two areas, composed of cross-bedded sand and gravel and occasional boulders, are approximately contemporaneous.

At Wailes Bluff the line of separation between the oyster bed and the gravel and sand above is a sharp one. Shattuck [8] states that there is no indication of an appreciable lapse of time at this point. I have noted a sharp line of demarkation between the clay that carries a brackish-water fauna, or vegetable remains, and the overlying sand and gravel at several exposures in Virginia. Only two are mentioned here.

In the bluff on the right bank of Rappahannock River about 2 miles above Tappahannock a cypress stump bed crops out along the beach and is overlain by a bed of considerably cross-bedded sand and gravel with boulders at the base.

In the bluff on Godfrey Bay, on the left bank of Piankatank River, a bed of carbonaceous material carrying many shells of *Rangia cuneata* is exposed about 2 feet above the beach. This bed is overlain by sand and pebbles. The height of the bluff is 15 to 20 feet.

On the other hand, exposures have been observed in which the evidence of an unconformity at the contact between the beds that carry vegetable or other organic remains and the gravel and cross-bedded sand is not convincing. At one place on the left bank of Rappahannock River, between Taft post office and Mosquito Point, an exposure near water level reveals a bed of gravel between peat beds.

It would then appear that the contact between the beds that carry either a littoral or brackish-water fauna or vegetable remains and the overlying cross-bedded sand and gravel, although it appears to be unconformable in some exposures and less so in others, does not represent an appreciable lapse of time.

PLIOCENE AND PLEISTOCENE LOCALITIES IN NORTH CAROLINA

HISTORICAL SUMMARY

In 1835 H. B. Croom [9] gave an account of organic remains obtained from marl pits dug on the estate of Lucas Benners, on the north bank of Neuse River 16 miles below New Bern, N. C. The pits were dug to a depth of about 25 feet, and their bottoms were about 10 feet below the water level of the river. Croom gives a list of genera, comprising mainly mollusks, obtained from this marl, and mentions bones and teeth of fishes and land animals. He was informed that the remains of the land animals were taken from depths of 20 to 25 feet below the surface. The same year Conrad [10] published a list of 66 species of mollusks received from H. B. Croom, which were taken from the marl pits on Mr. Benners's plantation. Of these species seven had not been found by Conrad in the Recent fauna. The beds were referred to the "Newer Pliocene." Conrad compares this fauna with the fossiliferous material found in Maryland near the mouth of Potomac River [Wailes Bluff].

Later Conrad [11] listed 34 species from the same pits. He states that his "medial and upper Tertiary" are in juxtaposition here. He was informed that the bones of land animals were above the "medial Tertiary," being mixed with the upper Tertiary, which he calls "Pleistocene or post-Pliocene." In referring to the state of preservation of these bones Conrad [12] writes:

> These remains are nearly all waterworn, black, and silicified and have evidently been transported from a distance, probably carried by ice down the ancient Neuse and dropped among the shells of the upper Tertiary period.

It appears from Conrad's later list of molluscan species from the marl pits on Benners's plantation that the specimens were taken from the upper part of the pits. Conrad [13] correlates this stratum on Neuse River with beds of "*Gnathodon*" on Potomac River, in Maryland, and refers it to the post-Pliocene.

In 1885 Holmes [14] described the occurrence of fossil cypress stumps overlain by shell marl on the southwest bank of Neuse River 10 to 12 miles below New Bern. This section is evidently the same as the section described on page 134 of this paper, and the shell marl mentioned by Holmes probably corresponds to the shell marl from which my collection No. 10896 was taken.

Dall [15] proposed the name Croatan beds to include those beds which are found on the estuary of Neuse River. He lists the species and analyzes the fauna from the Croatan beds, as obtained by Charles W. Johnson on Neuse River at Mr. Mallison's place,[16] 13 miles below New Bern, and at the mouth of Slocum Creek, 15 miles below New Bern. The Mallison section is evidently the same as section 3, described on page 134 of this paper, and the Slocum Creek section is the same as section 4, described on page 135. From these beds Dall reports 80 out of 96 recognized species as also occurring in the Recent fauna, or 83 per cent

[8] Idem, p. 132.

[9] Croom, H. B., [Organic remains found in the marl pits in Craven County, N. C.:] Am. Jour. Sci., 1st ser., vol. 27, pp. 168-171, 1835.

[10] Conrad, T. A., Observations on the Tertiary strata of the Atlantic coast: Am. Jour. Sci., 1st ser., vol. 28, pp. 104-111, 280-282 (see pp. 109, 110), 1835.

[11] Conrad, T. A., Observations on a portion of the Atlantic Tertiary region, with a description of new species of organic remains: Nat. Inst. Promotion of Science Proc., Bull. 2, pp. 191-192, 1842.

[12] Idem, p. 191.

[13] Idem, p. 177.

[14] Holmes, J. A., *Taxodium* (cypress) in North Carolina Quaternary: Elisha Mitchell Sci. Soc. Jour., vol. 2, pp. 92, 93, 1885.

[15] Dall, W. H., Contributions to the Tertiary fauna of Florida, with especial reference to the Miocene Silex beds of Tampa and the Pliocene beds of the Caloosahatchie River: Wagner Free Inst. Sci. Trans., vol. 3, pt. 2, pp. 209, 213-217, 1892.

[16] Idem, p. 205.

Recent. The fauna is referred to the Pliocene but is regarded as younger than the Waccamaw Pliocene. Dall's list of the Croatan fauna, as will be shown later, includes both characteristic Pliocene and Pleistocene species.

Miller,[17] in 1912, described a section at Riverdale Wharf, on the right bank of Neuse River 9 miles below New Bern, the upper 12 to 15 feet of which he referred to the Pleistocene and the lower 4 to 5 feet to the Pliocene (Waccamaw). He says:[18]

> The lower part of this section is undoubtedly Pliocene or Pleistocene, but fossils that are represented by casts are not distinctive. However, it is probable that the strata belong to the same period as those exposed at Slocum Creek, and probably will be found to be of Pliocene age.

In referring to the fossiliferous blue clays that crop out below and a little above water level a short distance above the mouth of Slocum Creek, Miller says:

> It is probable they form a part of the upper Pliocene. Sufficient work in the determination of the fossils has not as yet been done to definitely settle this point, and for that reason they are retained in the Pliocene, where they have formerly been placed.

In referring to the fossil organisms listed by Conrad in his two publications and obtained from the Lucas Benners estate, on the north bank of Neuse River 16 miles below New Bern, Stephenson [19] writes:

> The large percentage of recent forms enumerated in both lists indicates the Pleistocene age of the bed.

In referring to the beds which furnished the fossils that were obtained from the marl pits on the northern shore of Neuse River 16 miles below New Bern, Hay [20] writes:

> It is not improbable that the deposit which furnished these fossils belongs to the earliest Pleistocene stage, the Nebraskan.

Berry [21] gives an account of what is known of the Pleistocene flora of North Carolina and the conclusions that may legitimately be derived from it. *Pinus serotina* [22] Michaux is reported from the Pamlico formation [Chowan?], below New Bern, Neuse River, Craven County, N. C. *Taxodium distichum* [23] (Linnaeus) L. C. Richard is reported from the Pamlico formation [Chowan?] below New Bern. This locality evidently is the same as that of section 2, in the next column.

[17] Miller, B. L., The Coastal Plain of North Carolina; the Tertiary formations: North Carolina Geol. and Econ. Survey, vol. 3, pp. 253, 254, 1912.

[18] Idem, p. 254.

[19] Stephenson, L. W., The Coastal Plain of North Carolina; the Cretaceous, Lafayette, and Quaternary formations: North Carolina Geol. and Econ. Survey, vol. 3, p. 289, 1912.

[20] Hay, O. P., The Pleistocene of North America and its vertebrated animals from the States east of the Mississippi River and from the Canadian provinces east of longitude 95°: Carnegie Inst. Washington Pub. 322, p. 359, 1923.

[21] Berry, E. W., Pleistocene plants from North Carolina: U. S. Geol. Survey Prof. Paper 140, pp. 97-117, pls. 45-57, 1926.

[22] Idem, p. 105.

[23] Idem.

STRATIGRAPHIC SECTIONS

The following sections were measured on the right bank of Neuse River:

1. *Section at Riverdale Wharf, 9 miles below New Bern, N. C.*[24]

	Feet
Pleistocene: Laminated alternating layers of drab clay and sand, poorly exposed	12–15
Pliocene (Waccamaw) [Croatan sand of this report]:	
Indurated ferruginous sandstone containing many small quartz pebbles, few larger than a pea in size. The rock contains many fossil casts of *Pecten*, *Ensis*, *Leda*, *Cardium*, and other forms. The rock varies in the amount of induration. Exposed about	4
Compact drab clay, poorly exposed	½–1

2. *Section near residence of W. B. Flanner, about 10 miles below New Bern, N. C.*

[By W. C. Mansfield]

	Feet
Loamy soil	2
Pleistocene (Chowan? formation):	
Laminated, gray to reddish medium-grained sand	4
Compact, laminated gray clay with thin partings of sand. Contains impressions of shells	4
Gray clayey sand	4
Very fossiliferous grayish sand. Many individuals of *Mulinia lateralis* present throughout, and *Rangia cuneatà* is present in the lower 1 foot (collection 10896 [25])	8
?Unconformity:	
Truncated cypress stumps, 6 to 8 feet in diameter, embedded in dark carbonaceous clay	4
	26

3. *Section about 11 miles below New Bern, N. C.*

[By W. C. Mansfield]

	Feet
Sandy soil	2
Pleistocene:	
Laminated reddish sand and clay, with a water seepage at the base	6
Gray clayey sand	8
Very fossiliferous fine-grained gray sand (collection 10895)	4
Unconformity.	
Pliocene (Croatan sand):	
Concretionary, ferruginous coarse sand and gravel, carrying corals and mollusks (collection 10895*a*)	0–2

About 100 yards downstream from section 3 many individuals of *Rangia cuneata* were scattered along the shore, but none were observed in place in the section.

About 1 mile below section 3, at a place locally called "Shell Slough," many Pliocene shells are scattered along the beach, of which *Mulinia congesta* is the most abundant (collection 10894).

[24] North Carolina Geol. and Econ. Survey, vol. 3, p. 253, 1912.

[25] Tertiary locality numbers above 10000 are recorded in the U. S. Geological Survey station books and on the specimens in the form $\frac{1}{896}$ (=10896).

4. *Section about 15 miles below New Bern and half a mile below the mouth of Slocum Creek*

[By W. C. Mansfield]

	Feet
Sandy soil	2
Pleistocene:	
Partly slumped laminated clay and sand, in which no fossils were observed	12–14
Gray plastic clay	2
Unconformity.	
Pliocene (Croatan sand):	
Shell bed, the upper part of which is highly oxidized and contains coarse sand and pebbles (collection 10893)	2–4

FOSSIL LOCALITIES

The fossil material from North Carolina was collected by me at the following stations:

10896. Neuse River, right bank, about 10 miles below New Bern, near the residence of W. B. Flanner. Taken from the bed in section 2 that directly overlies the truncated cypress stumps.

10897. Marl pile from pit on Brice Creek, about 1½ miles west of Croatan station.

10895. Neuse River, right bank, about 11 miles below New Bern; upper fossiliferous bed in section 3.

10895*a*. Same section as the preceding but taken from the lowest bed exposed.

10894. Neuse River, right bank, about 12 miles below New Bern, locally known as "Shell Slough." Fossils scattered along the beach.

10893. Neuse River, right bank, about 15 miles below New Bern, about 3 miles above Cherry Point, and half a mile below the mouth of Slocum Creek, section 4.

10892. Open land project about 10 miles northwest of Beaufort and 6 miles from North River. Marl thrown out of lower part of wide ditches constructed for drainage. The surface of the terrace is about 11 feet above sea level, and the marl came from about 8 feet below the surface.

Stations at which fossil material was collected from Craven County, N. C., in 1918 by Joseph A. Cushman:

8167. From pits 10 to 12 feet in depth on the John L. Roper property, 3 miles southwest of Riverdale.

8168. Blue shell marl from pits on the Ballinger farm, close to Croatan station

GEOLOGIC RANGE OF SPECIES FROM THREE LOCALITIES

The following table shows the number of species from beds at three localities in North Carolina which represent the different epochs from the Miocene to the Recent and also the number which occur either at Wailes Bluff or Langleys Bluff, Md., and at Simmons Bluff, Yonges Island, S. C. In determining the occurrence of species at Yonges Island, S. C., I have consulted the collection deposited in the United States National Museum and the table by Pugh.[26]

[26] Pugh, G. T., Pleistocene deposits of South Carolina, a thesis submitted to the faculty of Vanderbilt University for a degree of Doctor of Philosophy, Nashville, Tenn., 1905.

Geologic range of species of mollusks and corals

Station	Number of forms considered	Miocene	Pliocene	Pleistocene	Recent	Wailes Bluff and Langleys Bluff below oyster bed	Simmons Bluff, Yonges Island, S. C.
10892, 10 miles northwest of Beaufort.	30	9 and 2 queried	18 and 3 queried	30	30	12	22
10896, Neuse River, 10 miles below New Bern.	39	13 and 2 queried	29 and 2 queried	38 and 1 queried	38	22	31
10893, Neuse River, 15 miles below New Bern.	42	23 and 1 queried	39 and 1 queried	29 and 1 queried	27 and 1 queried	13	24

AGE AND STRATIGRAPHIC RELATIONS OF THE STRATA

PLIOCENE DEPOSITS

The fauna listed by Dall[27] from his Croatan beds at Slocum Creek and at Mallisons evidently includes a mixture of both characteristic Pliocene and Pleistocene species. A few species in the list that I regard as characteristic Pleistocene forms are *Ilyanassa obsoleta* (Say), *Urosalpinx cinereus* Say, *Arca ponderosa* Say (typical), *Arca pexata* Say, and *Anatina* [*Labiosa*] *canaliculata* (Say). Some of the species in his list that are believed to occur not later than Pliocene are *Drillia tuberculata* Emmons, *Ostrea meridionalis* Heilprin = *O. sculpturata* Conrad, *Carditamera arata* Conrad, and *Mactra* [*Mulinia*] *congesta* Conrad.

As it is undesirable to apply the name Croatan to a group of beds part of which are of Pliocene and part of Pleistocene age, I propose to restrict the name to those beds on and near Neuse River which are of Pliocene age.

The Pliocene was observed by me in three of the sections examined on the right bank of Neuse River. (See fig. 3.) I infer that the basal 3 to 4 feet in Miller's section[28] at Riverdale Wharf, on the right bank of Neuse River 9 miles below New Bern, also belongs, as he placed it, in the Pliocene. The Pliocene beds consist chiefly of coarse ferruginous more or less fossiliferous sand that rises to an observed maximum height of about 4 feet above the beach. The name Croatan sand is therefore appropriate. The Pliocene stratum is unconformably overlain by the Pleistocene deposits. The contact of the Pliocene with the Pleistocene deposits was observed in two exposures—one about 11 miles below New Bern (section 3) and the other about 15 miles below New Bern (section 4).

The fossil collection from station 10893, 15 miles below New Bern, contains mainly Pliocene species.

[27] Dall, W. H., op. cit., pp. 209, 213–217.

[28] Miller, B. L., op. cit., p. 253.

A few Pleistocene species, which are believed to have fallen from the overlying Pleistocene beds, are included in the list. (See stratigraphic section 4.) The following species collected there which are believed to have lived not later than the Pliocene include *Busycon caricum* Gmelin var., *Ilyanassa irrorata* (Conrad), *Urosalpinx* sp. aff. *U. perrugatus* Conrad, *Crassinella duplinana* Dall, *Cardita arata* Conrad, *Chama striata* Emmons, *Venus rileyi* Conrad, *Gemma trigonia* Dall, *Mulinia congesta* Conrad (not typical), *Septastraea crassa* (Holmes).

A collection of fossils was obtained from a marl pile thrown out of a pit dug in Brice Creek, about 1½ miles west of Croatan station (station 10897). This fauna indicates a mixture of Pliocene and Pleistocene species.

Two collections were obtained from Craven County, N. C., at stations 8167 and 8168, by Joseph A. Cushman. At station 8167 the material was obtained from pits on the John L. Roper property, 3 miles southwest of Riverdale. According to notes furnished by Mr. Cushman, the section here consists of 4 feet of soil, sandy Pleistocene, underlain by a bluish marl 6 to 8 feet in thickness, extending down to a reddish marl that carries abundant oyster shells [*Ostrea sculpturata*]. At station 8168 the fossil material was obtained from a blue shell marl in pits on the Ballinger farm, close to Croatan station. The fauna at both stations is similar to that at my station 10897 and also indicates a mixture of Pliocene with a few Pleistocene species.

PLEISTOCENE DEPOSITS

I have assigned all the deposits above the Pliocene examined by me on the right bank of Neuse River, except the loamy top soil, to the Pleistocene. These deposits below the top soil may represent the Chowan formation of the Pleistocene. These deposits include the cypress stump bed and the fossiliferous bed that immediately overlies it and also the poorly fossiliferous beds exposed in the upper part of the bluffs. These deposits were observed in exposures 10, 11, and 15 miles below New Bern. (See stratigraphic sections 2, 3, and 4.) At the exposures 11 and 15 miles below New Bern the bed that carries a littoral Pleistocene fauna rests upon the Pliocene deposit. At the exposure 10 miles below New Bern this same bed is underlain by a cypress stump bed, thus indicating that the Pleistocene material occupies a shallow depression in the surface of the Pliocene.

The age of these deposits is probably late Pleistocene. The table on page 135 has been compiled to show the geologic time range of the species in outside formations. Of 39 species obtained from the bed that immediately overlies the cypress stump bed 10 miles below New Bern, represented by collection 10896, all except one queried form are represented in the Pleistocene, 38 are known in the Recent fauna, 22 in Pleistocene clay either at Wailes Bluff or at Langleys Bluff, Md., and 31 are believed to occur at Simmons Bluff, Yonges Island, S. C.

Another collection was obtained about 10 miles northwest of Beaufort, N. C., at station 10892. In constructing a ditch or canal for drainage the marl had been thrown out and left on both sides of the ditch. The surface of the terrace here is about 11 feet above sea level. The top of the marl is about 8 feet below the surface. These fossils came from the Pamlico formation or terrace. In the table compiled to show the geologic time range of species in outside formations, out of 30 species considered, all are represented in the Recent fauna, 12 occur in the Pleistocene clays, either at Wailes Bluff or at Langleys Bluff, Md., and 22 are believed to occur at Simmons Bluff, Yonges Island, S. C. The age of the fauna is late Pleistocene.

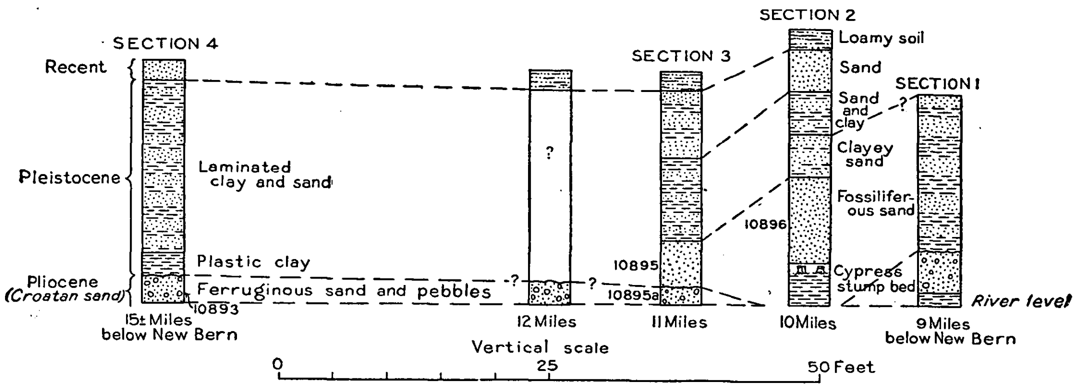


FIGURE 3.—Detailed columnar sections of Pliocene and Pleistocene strata along Neuse River, N. C.

PHYSICAL CONDITIONS ATTENDING THE DEPOSITION OF THE MATERIAL

The irregular contact between the Pliocene and Pleistocene beds on Neuse River below New Bern indicates that they are unconformably related. The episode that preceded the submergence of the land and the deposition of the Pleistocene beds appears to have been one of uplift and erosion. During this period of erosion stream channels were cut in the Pliocene surface, after which the land was lowered sufficiently to permit the accumulation of Pleistocene deposits upon the irregular Pliocene surface. The cypress stump bed probably occupies a stream-cut channel.

The succession of the deposits as shown in stratigraphic section 2, about 10 miles below New Bern, affords a basis for inferring the physical conditions which prevailed during the deposition of the Pleistocene beds. The sequence of the beds from the base of the cliff upward consists of truncated cypress stumps embedded in a dark carbonaceous clay, gray sand carrying in the lower part a mixed littoral and brackish-water fauna and in the upper part a typical littoral fauna, and, finally, poorly fossiliferous sand and clay.

The cypress stumps indicate fresh water. Concerning the distribution of the Recent bald cypress, *Taxodium distichum* Richard, Sargent [29] writes:

River swamps usually submerged during several months of the year, low wet banks of streams, and the wet depressions of pine barrens from southern Delaware southward near the coast to the shores of Mosquito Inlet and Cape Romano, Fla.

Dr. Albert Mann, diatomist, of the Carnegie Institution of Washington, identified the more prevalent species of diatoms taken from this cypress-stump bed. The following list of species, showing their abundance, and the remarks that follow are furnished by Doctor Mann:

[v. c.=Very common; c.=common; f.=frequent; s.=scarce]

Cymbella lanceolata (Ehrenberg) Kuetzing. f.
Eunotia major (W. Smith) Rabenhorst. f.
Navicula brasiliensis Grunow. f.
Navicula cuspidata Kuetzing. s.
Navicula elliptica Kuetzing. s.
Navicula formosa Gregory, var. s. (A marine species.)
Navicula maculata (Bailey) Cleve. f. (A marine species.)
Navicula nobilis (Ehrenberg) Kuetzing, var. approaching N. dactylus (Ehrenberg) A. Schmidt. c.
Navicula (Stauroneis) phoenicenteron, var. gracilis, S. gracilis W. Smith. s.
Navicula transversa A. Schmidt. s.
Nitzschia scalaris W. Smith. v. c. (Outnumbers all the others.)
Rhopalodia gibba (Ehrenberg) O. Müller. c.

[29] Sargent, C. S., Manual of the trees of North America, p. 72, 1905.

The material is a brown peaty mud, with considerable plant detritus, and the diatoms make up 5 to 10 per cent of the mass. They prove it to be a comparatively recent fresh-water deposit, though it contains a few forms that are unmistakably marine or brackish. This fact suggests that when the diatoms flourished the locality was close enough to the sea for tidal inflow to penetrate and thereby affect the diatom flora. Although this inference is warranted, it must be understood to be merely an inference.

Sponge spicules are also rather abundantly present. I am no authority on these structures, but I am pretty certain that, although the great majority are fresh-water forms, a few are marine, thus strengthening the inference as to the tidal inflow of the sea water.

It would be unsafe to attempt a comparison between this material and other subfossil deposits of similar latitude, such as the Pleistocene bed of the "Walker Hotel" swamp, Washington, D. C. Although a number of species are present in both they are common forms that have persisted from late geologic strata up to the present day and are in no sense indicative of any particular formation.

The fauna in the material that overlies the cypress stump bed indicates an invasion of the sea. The invasion of saline waters appears first to have destroyed the cypress forest, after which the advancing waves beveled off the upper part of the swamp deposit, leaving the large cypress stumps embedded in the carbonaceous clay. The presence of *Rangia cuneata* at and near the base of the fossiliferous sand that overlies the swamp deposit indicates brackish-water conditions at first, followed by a more typical littoral marine condition. The succeeding deposits above the fossiliferous sand, although of marine origin, are almost barren of organic remains. Just what caused the diminution of the fossil remains the writer is unable to explain.

PRESENT GEOGRAPHIC RANGE OF RECENT SPECIES FROM THREE OF THE FOSSIL LOCALITIES

The following table shows the present geographic distribution of those species at three of the fossil localities, which range upward to the Recent. I have ascertained the geographic distribution by consulting Dall's tables [30] and the collections of Recent mollusks in the United States National Museum.

[30] Dall, W. H., A preliminary catalogue of the shell-bearing marine mollusks and brachiopods of the southeastern coast of the United States, with illustrations of many new species: U. S. Nat. Mus. Bull. 37, 1889.

Present geographic distribution of Recent species from three fossil localities

Station	Number of forms considered	Cape Hatteras and northward	Cape Hatteras, northward and southward	Cape Hatteras and southward	Off North Carolina coast	West coast of Florida and Gulf Mexico
10892, 10 miles northwest of Beaufort	29	0	19	9	----------	1
10896, Neuse River, 10 miles below New Bern	37	1	28	6	1	1
10893, Neuse River, 15 miles below New Bern	28	1	20	7	----------	----------

CONDITIONS OF TEMPERATURE INDICATED BY THE FAUNAS

The fauna in collection 10893, which represents mainly Pliocene species, shows that out of 28 Recent species, 20 are now living both north and south of Cape Hatteras, 7 are living at and south of Cape Hatteras, and 1 (*Yoldia limatula*) is living at and north of Cape Hatteras. This distribution indicates that the temperature of the water in which they lived was no colder than that off the coast at Cape Hatteras to-day, and there is a suggestion that the water may have been a little warmer.

The Pleistocene fauna in the bed above the cypress stumps, represented by collection 10896, shows that out of 37 Recent species, 28 are now living both north and south of Cape Hatteras, 6 are living at and south of Cape Hatteras, 1 (*Yoldia limatula*) is living at and north of Cape Hatteras, and 1 is living on the west coast of Florida and in the Gulf of Mexico. This fauna suggests the presence of slightly cooler water than that which prevailed in Pliocene time but affords no positive evidence that the fauna could not have lived on the shores in the vicinity of Cape Hatteras to-day.

The fauna obtained from the Pamlico formation, represented by collection 10892, contains no species now living exclusively north of Cape Hatteras. Nine are found at and south of Cape Hatteras. This fauna could have lived under present conditions of temperature in the same latitude.

CORRELATION OF THE DEPOSITS IN MARYLAND AND NORTH CAROLINA

The accompanying table shows the occurrence and geologic range of species from the localities in Maryland and North Carolina and also a locality on Yonges Island, S. C., inserted for comparison. Only those species that occur at localities either in Maryland or North Carolina are recorded from Yonges Island.

Species of fossils from localities in Maryland, North Carolina, and South Carolina and their geologic range

	North Carolina									Maryland		South Carolina	Geologic range			
	Pliocene		Pliocene with admixture of Pleistocene				Pleistocene									
	10894. 12 miles below New Bern	10895a. 11 miles below New Bern	10893. 15 miles below New Bern	8167. 3 miles southwest of Riverdale	8168. Near Croatan	10897. 1½ miles west of Croatan	10896. 10 miles below New Bern	10895. 11 miles below New Bern	10892. 10 miles northwest of Beaufort	Wailes Bluff	Langleys Bluff	Yonges Island	Miocene	Pliocene	Pleistocene	Recent
MOLLUSKS																
Gastropods																
Acteocina canaliculata (Say)			×				×	×		×	×	×	×	×	×	×
Terebra concava (Say) var							×	?				×			×	×
Terebra dislocata (Say)				×			×	×	×	[a]×		×	×	×	×	×
Drillia tuberculata (Emmons) var.?				×	×								?	×		
Mangilia cerina (Kurtz and Stimpson)							×	×		×	×	×		×	×	×
Marginella limatula Conrad			×	×	×	×						×	×	×	×	×
Olivella mutica (Say)					?	?		×	×			×	×	×	×	×
Oliva sayana Ravenel			×						×			×	×	×	×	×
Busycon canaliculatum (Linnaeus)			×				×		×	×	×	×		×	×	×
Busycon caricum (Gmelin) var			×		×									×	?	
Busycon caricum (Gmelin)						×	×	×	×	×	×	×			×	×
Alectrion consensa (Ravenel)				×										×	×	×
Alectrion trivittata (Say)			×				×	×	×	×	×	×		?	×	×
Alectrion acuta (Say)			×				×	×				×		×	×	×
Alectrion vibex (Say)						×								×	×	×
Ilyanassa obsoleta (Say)			×				×	×		×	×	×			×	×
Ilyanassa irrorata (Conrad)			×	×	×									×		
Anachis obesa C. B. Adams			×				×	×						×	×	×
Anachis obesa C. B. Adams var				×	×									×		
Anachis avara Say var.? (Young)							×									
Anachis avara Say var				×										×		
Astyris lunata (Say)			×	×			×	×		×	×	×		×	×	×
Urosalpinx cinereus (Say)				×				×		×		×			×	×
Urosalpinx sp				×										×		
Urosalpinx sp. aff. U. perrugatus Conrad			×			×								×		
Coralliophila n. sp. ?				×										×		
Eupleura caudata (Say)						?	×			×	×	×		×	×	×
Epitonium lineatum (Say)							×			×	×	×		×	×	×
Epitonium aff. E. denticulatum (Sowerby)										×						
Seila adamsii (H. C. Lea)			×	×	×	×						×	×	×	×	×
Vermicularia spirata Philippi			×	×				×					×	×	×	×
Crepidula fornicata (Linnaeus)	×		×	×	×	×	×		×	×		×	×	×	×	×
Crepidula plana Say			×				×		×	×	×	×	×	×	×	×
Polynices duplicatus (Say)			×		×		×	×	×	×	×	×	×	×	×	×
Natica pusilla Say? (Young)			×													
Sinum perspectivum (Say)			×				×		×			×		×	×	×
Vitrinella (Episcynia) multicarinata Stimpson				×									×	×	×	×
Fissuridea alternata Say	×		×									×		×	×	×
Teinostoma sp								×								
Adeorbis? sp							×									

[a] Recorded here by the Maryland Geol. Survey in the volume on the Pliocene and Pleistocene.

Species of fossils from localities in Maryland, North Carolina, and South Carolina and their geologic range—Continued

	North Carolina									Maryland		South Carolina	Geologic range			
	Pliocene		Pliocene with admixture of Pleistocene				Pleistocene									
	10894. 12 miles below New Bern	10895a. 11 miles below New Bern	10893. 15 miles below New Bern	8167. 3 miles southwest of Riverdale	8168. Near Croatan	10897. 1½ miles west of Croatan	10896. 10 miles below New Bern	10895. 11 miles below New Bern	10892. 10 miles northwest of Beaufort	Wailes Bluff	Langleys Bluff	Yonges Island	Miocene	Pliocene	Pleistocene	Recent
MOLLUSKS—Continued																
Pelecypods																
Nucula proxima Say			×	×	×	×	×	×		×	×	×	×	×	×	×
Yoldia limatula Say						?	×			×		×			×	×
Yoldia limatula Say var.			×	×	×									?	?	?
Leda acuta (Conrad)	?		×	×	×	×	×	×		×	×	×	×	×	×	×
Arca (Noëtia) ponderosa Say (typical)							×		×	×		×			×	×
Arca (Noëtia) ponderosa var.			×													
Arca (Noëtia) limula Conrad, grading toward A. ponderosa Say			×													
Arca (Noëtia) limula Conrad var.	×		×	×	×	×										
Arca (Argrina) campechensis var. pexata Say							×								×	×
Arca (Argrina) campechensis Gmelin var.?									×						×	×
Arca (Cunearca) incongrua Say									×			×			×	×
Arca (Scapharca) transversa Say (large and robust form)									×					×	×	×
Arca (Scapharca) transversa Say (light form)						×	×	×		×	×	×		×	×	×
Arca (Scapharca) subsinuata Conrad			×	×										×	×	
Arca (Scapharca) sp. aff. A. subsinuata Conrad	×					×										
Arca (Scapharca) n. sp. aff. A. plicatura Conrad	×		×	×	×	×										
Arca (Scapharca) plicatura Conrad var.			×													
Arca sp. aff. A. compyla Dall	×					×										
Arca n. sp.?			×													
Arca (Fossularca) adamsii (Shuttleworth)						×							×	×	×	×
Ostrea virginica Gmelin			×		×	?			×	×	×	×	?	×	×	×
Ostrea sculpturata Conrad				×		×							×	×		
Anomia simplex D'Orbigny			×		×	×	×	×	×			×	×	×	×	×
Pecten gibbus Linnaeus									×			×		×	×	×
Pecten gibbus Linnaeus var.			×													
Pecten n. sp. aff. P. eboreus Conrad		×														
Plicatula marginata Say?					×	×		×								
Mytilus clava Meuschen=M. hamatus Say										[b] ×				×	×	×
Pandora trilineata Say							×	×				×	?	×	×	×
Pandora gouldiana Dall										×					×	×
Crassinella lunulata (Conrad)			×	×				×	?			×	×	×	×	×
Crassinella sp. cf. C. mactracea Linsley					×	×										
Crassinella duplinana Dall		×	×										×	×		
Cuna? n. sp.?			×													
Cardita floridana Conrad								×	×			×		×	×	×
Cardita arata (Conrad)	×		×		×	×							×	×		
Venericardia tridentata Say			×	×	×	×		×	×			×	×	×	×	×
Venericardia perplana Conrad					×								×	×	×	×
Venericardia perplana var. abbreviata Conrad			×	×									×	×		
Chama macerophylla Gmelin									×						×	×
Chama striata Emmons			×										×	×		
Phacoides (Bellucina) waccamawensis Dall					×	×								×		
Phacoides (Bellucina) sp. cf. P. amiantus Dall								×								
Phacoides (Parvilucina) multilineatus Tuomey and Holmes				×	×	×		×				×	×	×	×	×
Divaricella sp.									×							
Diplodonta sp. cf. D. caloosaensis Dall		×	×													
Diplodonta punctata Say							×	×							×	×
Bornia n. sp.? aff. B. lioica Dall								×								
Rochefortia planulata aff. var. fragilis Verrill and Bush			×				×	×						×	×	×
Sportella protexta (Conrad)				×								×	×	×	×	×
Sportella constricta (Conrad)					×		×	×					×	×	?	
Aligena elevata (Stimpson)										[a] ×		×			×	×
Cardium robustum Solander			×				×	×				×		×	×	×
Chione cancellata Linnaeus				×		×			×			×		×	×	×
Venus rileyi Conrad			×	×									×	×		
Venus mercenaria Linnaeus				[a] ×			×		×	×	×	×	?	?	×	×
Venus campechiensis var. quadrata Dall									×						×	×
Callocardia sayana (Conrad)					×	×							×	×		
Callocardia morrhuana Linsley										×					×	×
Gemma purpurea H. C. Lea									×						×	×
Gemma magna Dall			×		×			×					×	×	×	
Gemma trigona Dall			×										×	×		
Petricola pholadiformis Lamarck										[a] ×		×			×	×
Tellina tenera Say										[a] ×						
Tellina sayi Deshayes			×				×	×				×		×	×	×
Tellina sp. a aff. T. sayi Deshayes									×							
Tellina sp. b aff. T. sayi Deshayes								×								
Macoma calcarea (Gmelin)										[a] ×					×	×
Macoma balthica Linnaeus										×		×			×	×
Cumingia tellinoides (Conrad)										[a] ×		×			×	×
Abra aequalis (Say)							×	×				×	×	×	×	×
Abra aequalis (Say) var.			×	×	×	×		×								
Donax variabilis Say									×			×			×	×
Tagelus divisus Spengler							×							×	×	×
Tagelus gibbus (Spengler)										×	[a] ×	×	×	×	×	×
Ensis directus Conrad			×				×	×	×	×		×	×	×	×	×
Spisula procera Solander									×						×	×
Spisula subparilis Conrad, grading toward S. similis Say			×										×	×		
Mulinia lateralis Say (heavy form)									×					?	×	×
Mulinia lateralis Say (light form)							×	×		×	×	×	×	×	×	×
Mulinia congesta (Conrad) (not typical)	×		×	×	×	×							×	×		
Rangia cuneata (Gray)							×		×	×	×			×	×	×
Rangia clathrodonta Conrad				×									×	×		

[a] Recorded here by the Maryland Geol. Survey in the volume on the Pliocene and Pleistocene.

[b] Obtained only from bed 3, or oyster bed.

Species of fossils from localities in Maryland, North Carolina, and South Carolina and their geologic range—Continued

	North Carolina									Maryland		South Carolina	Geologic range			
	Pliocene		Pliocene with admixture of Pleistocene				Pleistocene									
	10894. 12 miles below New Bern	10895a. 11 miles below New Bern	10893. 15 miles below New Bern	8167. 3 miles southwest of Riverdale	8168. Near Croatan	10897. 1½ miles west of Croatan	10896. 10 miles below New Bern	10895. 11 miles below New Bern	10892. 10 miles northwest of Beaufort	Wailes Bluff	Langleys Bluff	Yonges Island	Miocene	Pliocene	Pleistocene	Recent
MOLLUSKS—Continued																
Pelecypods—Continued																
Anatina canaliculata (Say)							×					×			×	×
Paramya subovata Conrad							×						×	×	×	×
Mya arenaria Linnaeus										[b] ×	[a] ×	×	×		×	×
Corbula contracta Say			×		×		×	×	×	×		×		×	×	×
Corbula inaequalis Say			×	×	×	×							×	×		
Barnea (Scobina) costata (Linnaeus)										×	×	×		×	×	×
Martesia sp. cf. M. cuneiformis Say							×					×				
CORAL																
Septastraea crassa (Holmes) [c]		×	×	×									×	×		
CRUSTACEA																
Callinectes sapidus Rathbun										×			×		×	×
Cancer irroratus Say										×						×
Chloridella empusa (Say)										×						×
PLANT																
Pinus serotina Michaux [d]							×									

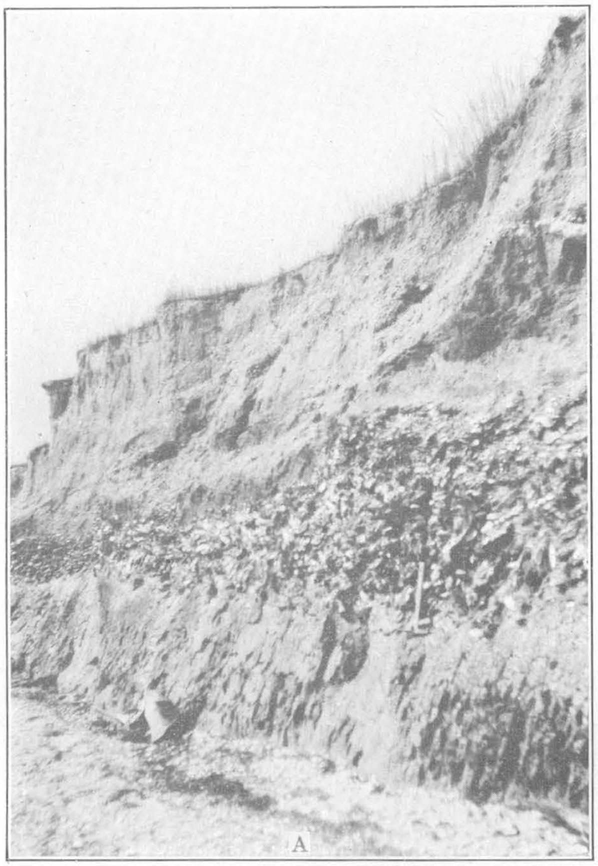
[a] Recorded here by the Maryland Geol. Survey in the volume on the Pliocene and Pleistocene.
[b] Obtained only from bed 3, or oyster bed.
[c] Identified by J. E. Hoffmeister at stations 10893 and 10895*a*.
[d] Identified by E. W. Berry, probably from cypress stump bed.

Pliocene.—The fauna of the Croatan sand is approximately equivalent to both the fauna of the Waccamaw formation in North Carolina and South Carolina and to the faunas of the Nashua marl and the Caloosahatchee marl in Florida.

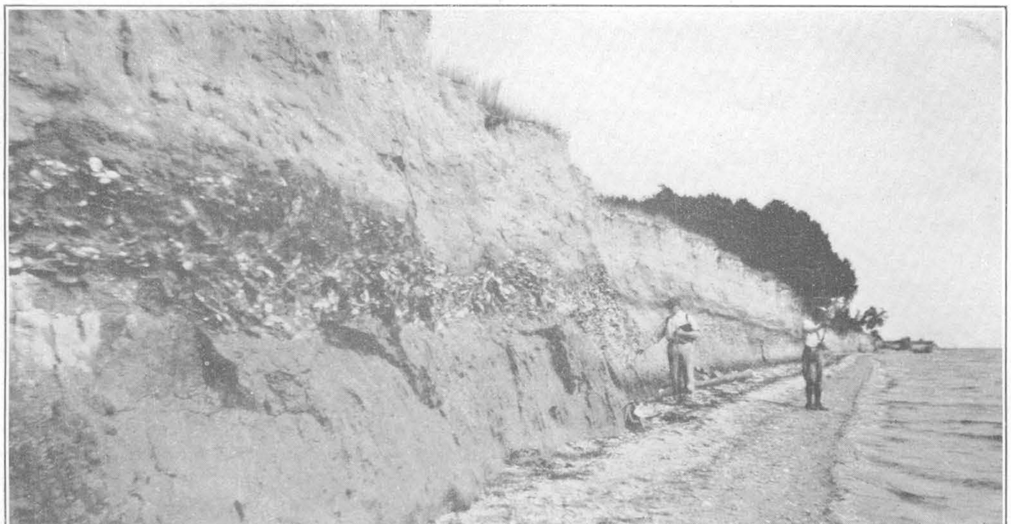
Pleistocene.—The littoral and brackish-water faunas along the Neuse, in North Carolina, represented by collections 10896 and 10895, appear to be equivalent in age to the fauna below the oyster bed at Wailes and Langleys Bluffs, Md., and to the fauna at Rose Bluff, Fla. It is probably a little older than the fauna of Simmons Bluff, Yonges Island, S. C.

The fauna from the Pamlico formation, represented by collection 10892, is probably of about the same age as the fauna of Simmons Bluff, Yonges Island, S. C. The fauna of Simmons Bluff contains a number of species—some of which are represented by many individuals—which are absent in my collections. A few of these species are *Tritonidea cancellata* Conrad, *Strombus pugilis* Linnaeus, *Dosinia discus* Reeve, *Tellidora cristata* Recluz, and *Tellina alternata* Say.

The fauna of Simmons Bluff indicates warmer water than that of the Pleistocene fauna in collection 10892, as might be expected from its more southern position.



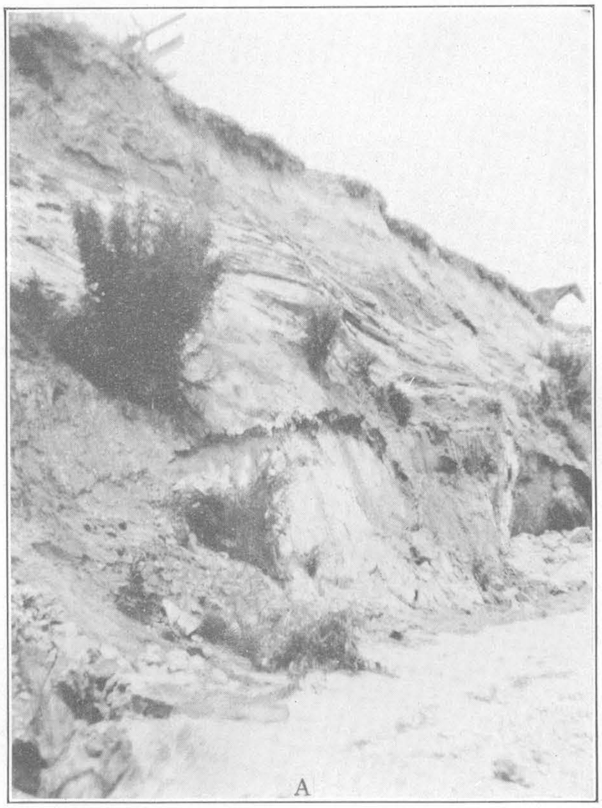
A. CONTACT OF OYSTER BED AND UNDERLYING CLAY BED, INDICATED BY HEAD OF HAMMER



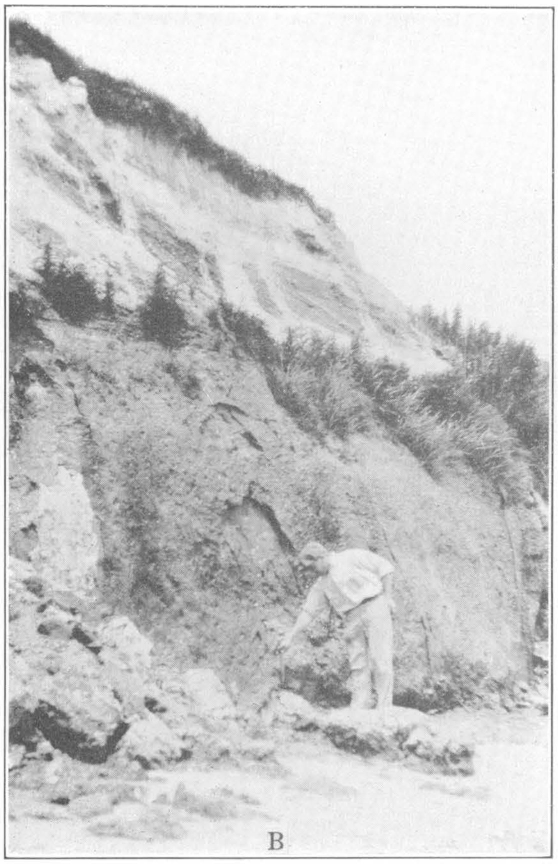
B. VIEW OF EASTERN END OF BLUFF

Sag in oyster bed at place indicated by man standing near bluff

WAILES BLUFF, ST. MARYS COUNTY, MD.

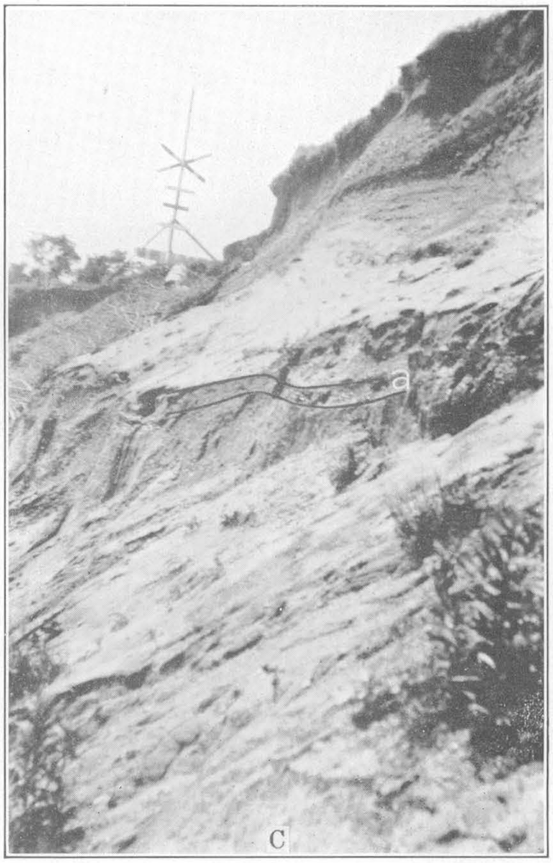


A, FOSSILIFEROUS PLEISTOCENE CLAY OVERLAIN BY CROSS-BEDDED SAND AND GRAVEL



B. CONTACT OF MIOCENE WITH OVERLYING PLEISTOCENE

Indicated by head of hammer



C. UNDULATING UPPERMOST PLEISTOCENE CLAY BED

Indicated by "a"

LANGLEYS BLUFF, ST. MARYS COUNTY, MD.

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