The Chinle (Upper Triassic) and Sundance (Upper Jurassic) Formations in North-Central Colorado

By G. N. PIPIRINGOS, W. J. HAIL, JR., *and* G. A. IZETT

CONTRIBUTIONS TO STRATIGRAPHY

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A description of hitherto unreported or little-understood stratigraphic and paleontologic details of marine Jurassic and Upper Triassic rocks of a scantily studied area

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By G. N. PIPIRINGOS, W. J. HAIL, Jr., and G. A. IZETT

ABSTRACT

The Chinle Formation (Upper Triassic) and Sundance Formation (Upper Jurassic) have been studied in 11 stratigraphic sections along the flanks of the Park Range near Kremmling, north-central Colorado. The Chinle at Elk Creek on the west side of the Park Range is about 127 feet thick and is divided into a lower conglomerate to sandy siltstone member, a middle silty claystone member, and an upper sandstone and siltstone member. To the east the Chinle is truncated beneath an unconformity at the base of the Canyon Springs Sandstone Member of the Sundance Formation, and the Chinle is absent a few miles west of Kremmling on the east flank of the Park Range. The lower and middle members of the Chinle reappear north of Kremmling between the Lazy Bear Ranch and McMahon Reservoir. North of McMahon Reservoir the Chinle is truncated by the Canyon Springs Sandstone Member.

The Chinle rests on Triassic and Permian red beds on the east side of the Park Range and on rocks lithologically similar to the red beds on the west side of the range.

The Sundance Formation is about 260 feet thick at Elk Creek on the west flank of the Park Range. It thins eastward to about 55 feet at Tyler Mountain and thickens northward to about 230 feet at Frantz Creek. The Sundance is divided in ascending order into the Canyon Springs Sandstone, Lak(?), Pine Butte, and Windy Hill Sandstone Members. The Canyon Springs is equivalent to the Entrada Sandstone, and the Pine Butte Member is equivalent to the lower part of the Curtis Formation of northwest Colorado.

INTRODUCTION

Marine Jurassic rocks and Triassic red beds that lie below the Morrison Formation of Late Jurassic age are exposed discontinuously along both the east and west sides of the Park Range near Kremmling in north-central Colorado (figs. 1, 2). (For convenience of discussion, the area shown in fig. 1 will be referred to in this report as the Kremmling

area.) The upper part of this sequence is here divided into four thin but widespread units that correspond in lithology, fossil content, and stratigraphic position to named members of the Upper Jurassic Sundance Formation of south-central Wyoming. Underlying red beds comprise the Triassic Chinle Formation and older rocks. This paper describes the Upper Triassic and marine Jurassic rocks exposed in the Kremmling area and gives the reasons for their correlation with named units in southern Wyoming or western Colorado. Upper Triassic and Upper Jurassic rocks described in this report have received scant attention from previous workers; references to these rocks have been of a general nature, or incidental to investigations of areas marginal to north-central Colorado, or incidental to the study of overlying or underlying stratigraphic units. Consequently, the principal contributions of this report are (1) detailed descriptions of the lithologies and fossil content of 11 stratigraphic sections, (2) the calling of attention to surprisingly rapid facies and thickness changes, particularly in the Sundance Formation, and (3) the correlation of the various stratigraphic units within the study area and with similar stratigraphic units in southeastern Wyoming and in the southwesternmost part of the Kremmling area.

The Jurassic and Triassic rocks in Colorado, mainly west of the Park Range, have been studied by Heaton (1933, fig. 4, p. 115), Lovering and Johnson (1933, p. 357), Baker, Dane, and Reeside (1936, p. 18, 28, figs. 3, 6), Donner (1949, p. 1229–1230), Poole and Stewart (1964), and others. The rocks in North Park have been studied by Beekly (1915) and those in Middle Park by Jenkins (1957).

Work reported here was done mostly in 1963. Information was gathered by studying 11 stratigraphic sections, which are described on pages N16 to N34 and are located in figure 1. Correlation and facies changes of stratigraphic units are shown in figure 3. W. B. Cashion, A. A. Bookstrom, and C. S. V. Barclay helped measure the sections. Regional correlations reported here are supported by geologic mapping in Middle Park, Colo., by Izett (1968) and in North Park, Colo., by W. J. Hail, Jr. (1965), and by regional stratigraphic studies in southern Wyoming and northern Colorado by Pipiringos (1968).

Fossils collected during the study are listed in table 1 according to age. I. G. Sohn identified the ostracodes, R. A. Scott identified the plant microfossils, and R. W. Imlay identified the pelecypods.

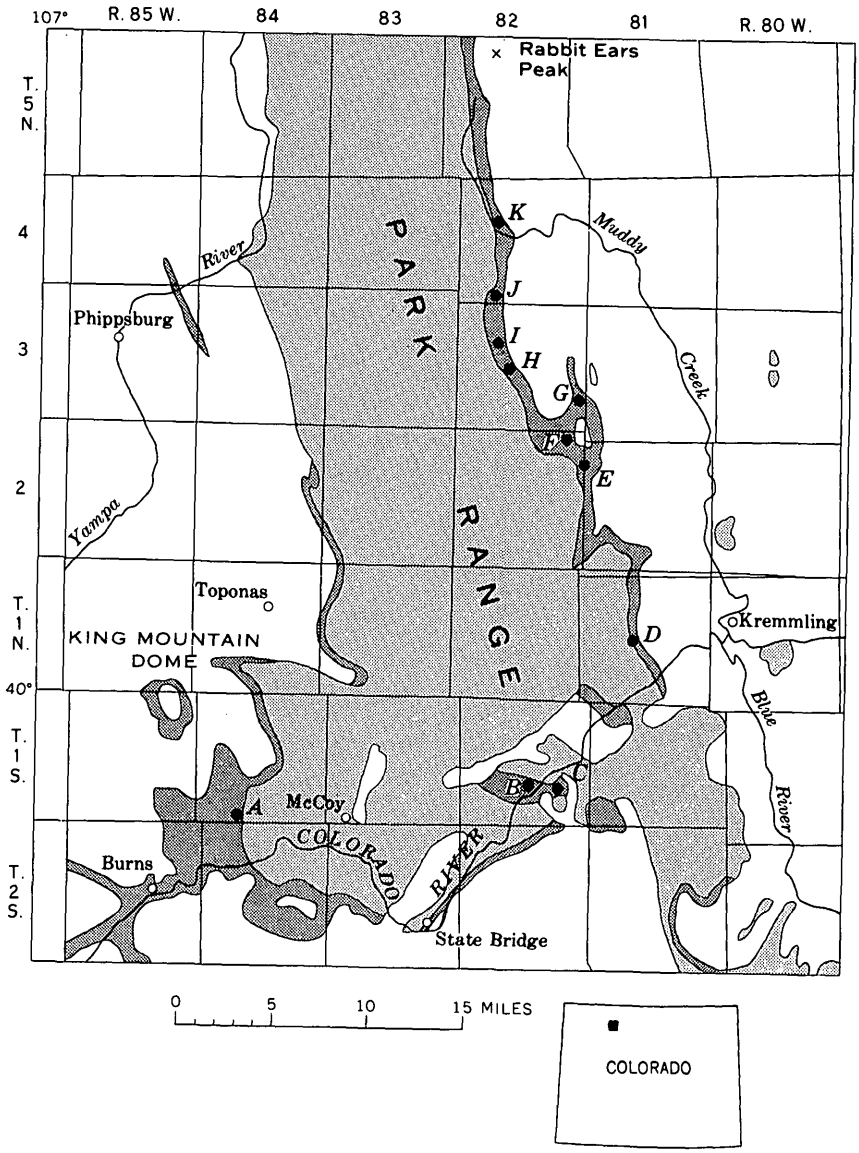

FIGURE 1.—Map of north-central Colorado showing location of stratigraphic sections: *A*, Elk Creek; *B*, Radium SW; *C*, Radium SE; *D*, Kremmling; *E*, Lazy Bear; *F*, Snowshoe Ranch; *G*, Tyler Mountain; *H*, McMahon Reservoir; *I*, McMahon Reservoir, north; *J*, Frantz Creek; and *K*, Barber Basin, Light stipple, pre-Triassic rocks; dark stipple, Triassic and Jurassic rocks; unpatterned, post-Jurassic rocks. Geology and base from "Geologic Map of Colorado" (Burbank and others, 1935), modified by W. J. Hail, Jr., 1964.

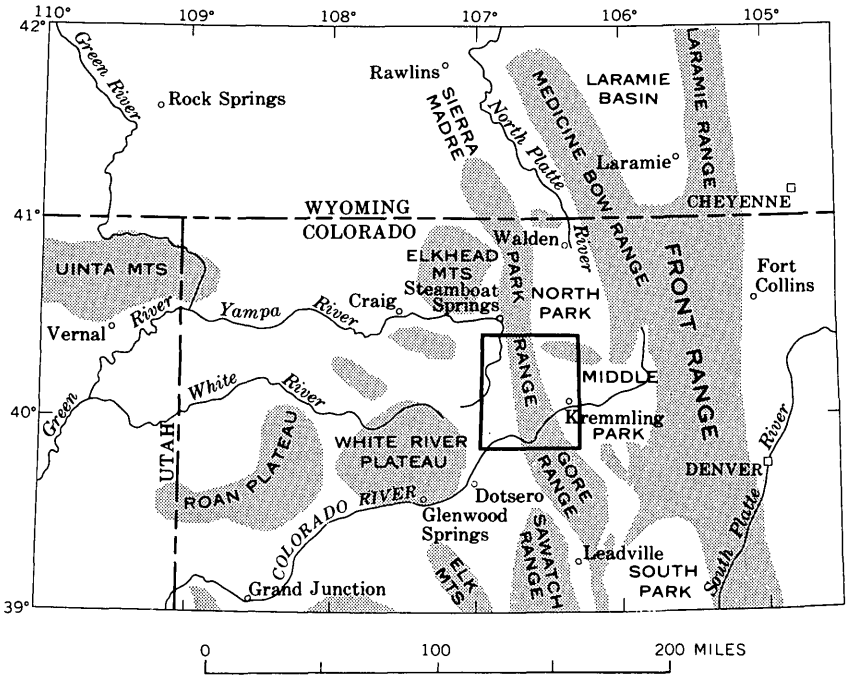

FIGURE 2.—Map showing some geographic features of northwestern Colorado and adjacent parts of Utah and Wyoming. Heavy line indicates area of figure 1.

TABLE 1.—*Late Jurassic fossils collected from the Sundance Formation in north-central Colorado*

Collection	Stratigraphic section (in fig. 1)	Stratigraphic position above base of member (feet)	Fossil identification
		Windy Hill Sandstone Member	
		[Ostracodes, identified by I. G. Sohn]	
FC–1	*B.* Radium SW	7–8.5	*Darwinula*? sp. *Bisulcocypris-Theriosynoecum* group sp.
		Pine Butte Member	
		[Pelecypods, identified by R. W. Imlay]	
FC–2	*A.* Elk Creek	6–13	*Lopha* sp.
3	do	4–5	*Grammatodon*? sp., *Tancredia*? sp.
4	*B.* Radium SW	8	*Vaugonia conradi* (Meek and Hayden). *Quenstedtia* cf. *Q. planulata* (Whitfield and Hovey). *Tancredia* sp.
5	*F.* Snowshoe Ranch	6–8.5	*Pleuromya*? sp., *Pronoella*? sp. *Vaugonia* cf. *V. conradi* (Meek and Hayden).
6	*G.* Tyler Mountain	0–5	*Vaugonia conradi* (Meek and Hayden).

TABLE 1.—*Late Jurassic fossils collected from the Sundance Formation in north-central Colorado*—Continued

Collection	Stratigraphic section (in fig. 1)	Stratigraphic position above base of member (feet)	Fossil identification
		Pine Butte Member	
		[Ostracodes, identified by I. G. Sohn]	
FC-7	*I.* McMahon Reservoir N-	10-11	Virtually same assemblage as FC-8 but much more poorly preserved.
8	do	5-6	*Drawinula sp.* *Bisulcocypris-Theriosynoecum* group spp. with 1 and 2 sulci. Genus or genera indeterminate, large smooth.
9	*J.* Frantz Creek	0-10	Same assemblage as FC-8; many of the specimens are squashed.
		Lak(?) Member	
		[Plant microfossils, identified by R. A. Scott]	
FC-10	*J.* Frantz Creek	23-28	*Caytonipollenites* sp., *Classopollis* sp. *Eucommiidites* sp., *Taugaepollenites* sp. *Monosulcites* sp., *Klukisporites* sp.
		Canyon Springs Sandstone Member	
		[Pelecypods, identified by R. W. Imlay]	
FC-11	*F.* Snowshoe Ranch	20-25 (estimated)	*Vaugonia conradi* (Meek and Hayden).

CHINLE FORMATION

The Chinle Formation, which is exposed on both sides of the Park Range in the Kremmling area, ranges in thickness from 0 to 127 feet and is divisible into a lower conglomeratic sandstone and sandy siltstone member, a middle silty claystone and clayey siltstone member, and an upper sandy siltstone member. On the east side of the Park Range, the Chinle Formation rests with erosional unconformity on red sandstone and siltstone of Triassic and Permian age (secs. *E* and *J*), and on the west side of the range, it rests on a sequence of red beds whose age has been considered Permian by some geologists and Permian and Triassic by others. The Chinle is overlain with a slight angular unconformity by Jurassic rocks. Previously the Chinle has been generally lumped with the Chugwater on the east side of the Park Range.

The lower part of the lower member consists principally of light-gray sandstone and conglomeratic sandstone. The upper part consists principally of sandy siltstone, generally banded or mottled gray and pale red to grayish purple. Black iron oxide nodules mostly less than 1 inch in diameter are characteristic of the lower member. The two major lithologies locally are interbedded and grade into each other laterally and vertically. In most places the lower member forms small cliffs and slopes interrupted by rounded strong to weak ledges.

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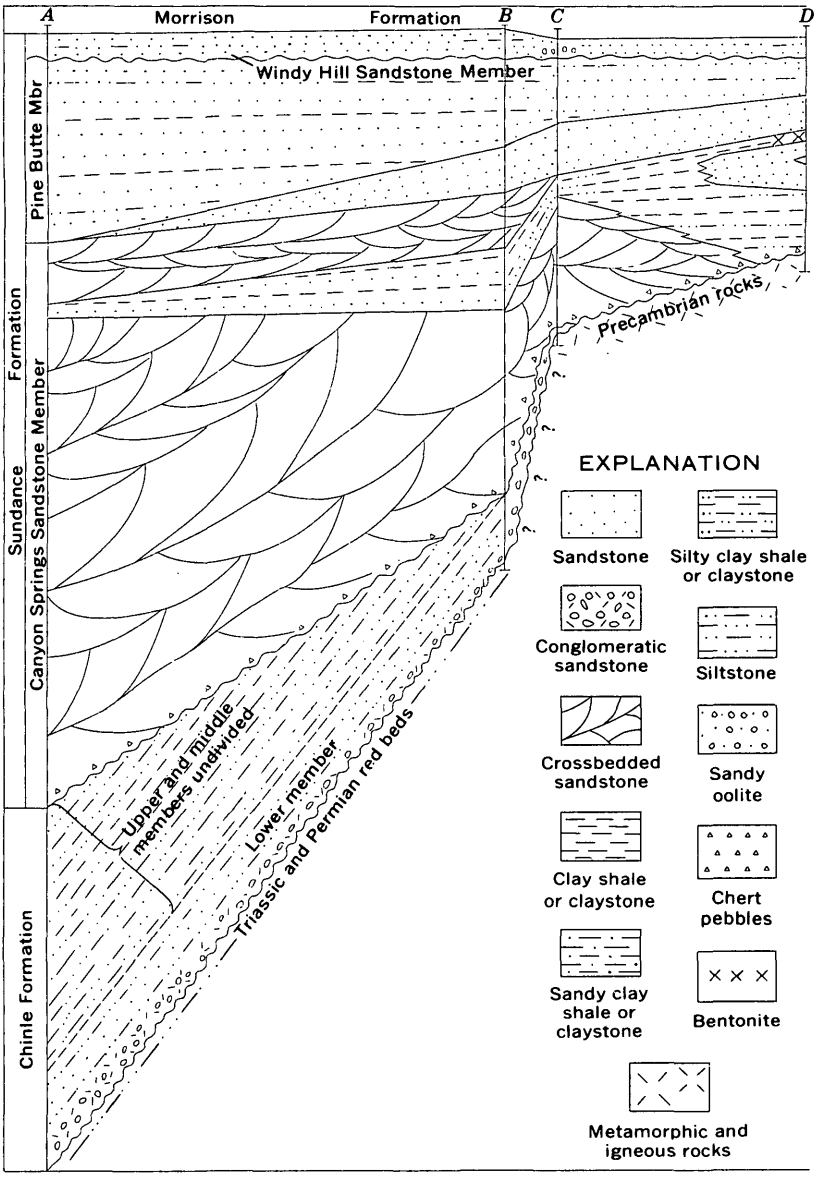

FIGURE 3.—Restored section showing correlation and facies changes of Triassic and Jurassic rocks in north-central Colorado. Location of sections *A–K* shown in figure 1. Lithologies greatly generalized.

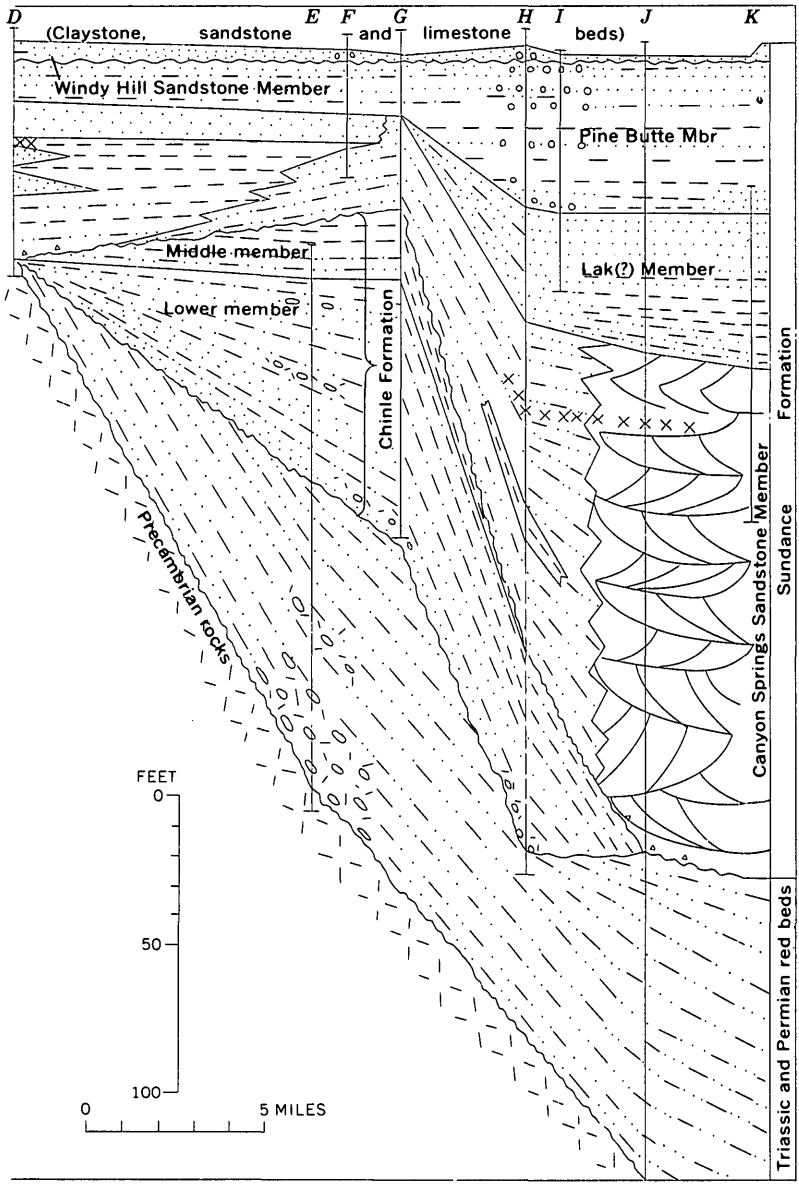

FIGURE 3.—Continued.

The lower member is thickest on the east side of the Park Range, in the Lazy Bear-Tyler Mountain area (secs. *E* and *G*, fig. 1), but is absent in sections less than 10 miles to the south (sec. *D*) and to the north in the Frantz Creek-Barber Basin area (secs. *J* and *K*). On the west side of the Park Range, the lower member is about 35 feet thick at Elk Creek (sec. *A*) and 21 feet thick in the vicinity of Radium, Colo. (sec. *B*). It is thinner at section *C*, also near Radium, but there it is thinned by faulting.

Fossils were not found in the lower member of the Chinle along the Park Range, but inasmuch as the lower member is lithologically similar to the basal Gartra Member and overlying mottled member of the Chinle Formation in the Uinta Mountains, Utah (Poole and Stewart, 1964), and to the Brynt Draw Member of the Popo Agie Formation in Wyoming, (Pipiringos, 1968, p. D15) its age is assumed to be Late Triassic. The two units in the lower member in the Park Range represent one continuous period of deposition of alternating conglomerate, conglomeratic sandstone, sandstone, and sandy siltstone beds that do not warrant subdivision.

The middle member consists of claystone that is somewhat sandy or silty in the lower part. It is mostly grayish to purplish red but contains some yellowish-orange bands. The middle member characteristically weathers to a slope that separates ledgy beds in both the upper and lower members. At Tyler Mountain (sec. *G*) it is 23 feet thick, but is unconformably overlain by Jurassic rocks. At the Lazy Bear section (*E*), faults prevent measurement of the total thickness, but it is at least 10 feet. At Elk Creek (units 5 and 6, sec. *A*) rocks equivalent to the member almost certainly are present but they are not shown separately from the upper member because at this locality the contact between the members is not obvious. At Snowshoe Ranch (sec. *F*) the middle member is presumed to be present below the base of the measured section, and at the McMahon Reservoir sections (*H*, *I*) it is concealed if present. It is absent at all the other sections, probably because it has been eroded away. The middle member grades into the underlying lower member through an interval of 1–2 feet.

Fossils were not found in the middle member, but its stratigraphic position and lithology are similar to those of the ocher siltstone member of the Chinle of the Uinta Mountains in Utah (Poole and Stewart, 1964) and the Lyons Valley Member of the Popo Agie Formation in Wyoming (Pipiringos, 1968, p. D15–D16). Therefore, it is assumed to be of Late Triassic age.

The upper member of the Chinle Formation consists of reddish-brown slope-forming siltstone beds alternating with ripple-laminated tightly lime-cemented ledge-forming siltstone beds. It occurs only at

the Elk Creek section (*A*, beds 7–11), where it is about 33 feet thick, but is not readily separated from the middle member; consequently, at this locality the upper and middle members of the Chinle are undivided. The upper part, however, is correlated by lithologic features and stratigraphic position with the upper member of the Chinle Formation as mapped by Kinney (1955, p. 69) in the Uinta Mountains and with the Bell Springs Member of the Nugget Sandstone in Wyoming (Pipiringos, 1968, p. D16–D17) and it is considered on this basis to be of Late Triassic age.

The presence of the lower and middle members of the Chinle on the east side of the Park Range (fig. 3) suggests that an embayment of the formation extended from southern Wyoming or northern Utah southeastward or eastward into north-central Colorado. The shape of this embayment, however, cannot be outlined on the basis of present information.

SUNDANCE FORMATION

The Sundance Formation in south-central Wyoming consists of, in ascending order, the Canyon Springs Sandstone, Stockade Beaver Shale, Hulett Sandstone, Lak, Pine Butte, Redwater Shale, and Windy Hill Sandstone Members (Pipiringos, 1968, p. D18–D25).

The Sundance has been traced from Wyoming into the northern part of north-central Colorado to a point about 9 miles north of Steamboat Springs on the west side of the Park Range, and to a point on the east side of Sheep Mountain, about 11 miles northwest of Walden on the east side of the Park Range. In both areas, the Sundance comprises, in ascending order, the Canyon Springs Sandstone, the Pine Butte, the Redwater Shale, and the Windy Hill Sandstone Members. Mapping by W. J. Hail, Jr. (1965), indicates that, because of poor exposure, the Redwater Shale and the Pine Butte Members cannot be traced from the northwestern corner of North Park southward along the east side of the Park Range into the study area. Furthermore, reconnaissance along the west side of the range suggests that it is equally unfeasible to trace these members from the vicinity of Steamboat Springs southward into the western part of the study area (G. L. Snyder, oral commun., 1967). Fortunately, the Sundance in the Kremmling area is fossiliferous; correlations based partly on the fossils and partly on lithology, stratigraphic position, and regional stratigraphic relations suggest that the Redwater pinches out at some point north of the Kremmling area, but that the Pine Butte persists southward.

The Sundance Formation in the Kremmling area (fig. 1) is exposed on both sides of the Park Range. It ranges in thickness from 54 feet at Tyler Mountain (sec. *G*) to 259 feet at Elk Creek (sec. *A*) and is

divisible into four members. The basal member is the Canyon Springs and the uppermost member is the Windy Hill, but the correlation of the two medial members is less certain. Detailed stratigraphic studies of the lower part of the Sundance Formation in areas north of the Kremmling area show that the Stockade Beaver and the Hulett of southern Wyoming change facies southward and do not extend into north-central Colorado. The two medial members, therefore, are correlated with the overlying Lak and Pine Butte Members of the Sundance Formation of southeastern Wyoming.

Rocks exposed on the west side of the Park Range near Burns (sec. *A*, fig. 1) and here assigned to the Canyon Springs Sandstone and the Pine Butte Members of the Sundance Formation correlate with the Entrada Sandstone and Curtis Formation, respectively, of Baker, Dane, and Reeside (1936, p. 28, fig. 6, loc. 16).

CANYON SPRINGS SANDSTONE MEMBER

The Canyon Springs is 166 feet thick at Frantz Creek and 60 feet thick in a partial exposure at Barber Basin (secs. *J* and *K*, fig. 1). At these places it consists of massive to obscurely crossbedded very fine grained yellowish-white or pink sandstone that forms rounded cliffs and ledges. This lithology, color, and topographic expression are normal for this member throughout most of southeastern Wyoming and northwestern Colorado. At the Frantz Creek section (*J*) the member rests unconformably on the Triassic and Permian red beds. At the Barber Basin section (*K*) the uppermost few feet of the Canyon Springs contains borings made by organisms that probably were introduced with the advent of the sea in which the overlying rocks were deposited.

Along the east side of the Park Range south of Frantz Creek, the Canyon Springs is completely exposed at Tyler Mountain and Kremmling (secs. *G* and *D*), partly exposed at localities *H* and *F*, and completely concealed at localities *I* and *E*. The member is only 33 feet thick in the complete section at Tyler Mountain (sec. *G*), but is 79 feet thick in the partial section at McMahon Reservoir (sec. *H*).

At McMahon Reservoir only the basal few feet and the upper 30 feet are typical of the Canyon Springs in some nearby areas; the intervening part (beds 6–10, sec. *H*) consists principally of reddish-orange ledgy sandstone containing thin beds of greenish-gray, gray, and dark-gray clay shale and a thin bed of greenish-gray bentonite. Farther south, at Tyler Mountain (sec. *G*), the Canyon Springs consists almost entirely of reddish-orange silty clayey sandstone that greatly resembles bed 9 of the McMahon Reservoir section. At Snowshoe Ranch less than 2 miles south of Tyler Mountain, the upper part

of the red sandstone sequence is replaced laterally by shale and sandstone containing marine pelecypods (sec. *F*, beds 2 and 3). Near Kremmling (sec. *D*) the lateral change from red beds to normal marine shale and sandstone is complete, and the Canyon Springs consists entirely of shaly sandstone and siltstone interbedded with green clay shale. A bed of bentonite 12 feet below the top of the sequence is identical in appearance, and in its association with greenish-gray clay shale, with the bentonite in the McMahon Reservoir section (*H*). Bentonitic clay shale was found at only one other locality—Frantz Creek (sec. *J*, bed 3).

The facies change just described is duplicated in reverse (fig. 3) on the west side of the Park Range. Only the lower part of the Canyon Springs has the faint crossbedding to massive bedding normal for the member at section C, but 1.5 miles farther west the lower half of the upper part also has this normal appearance and lithology (sec. *B*). At the farthest west section (*A*) considered here, the Canyon Springs is entirely a massive to obscurely crossbedded sandstone except for a thin shaly bed in the upper part.

Although the Canyon Springs east of the Park Range varies greatly from section to section, two key beds are persistent enough to tie the sections together. The bentonite and bentonitic clay shale beds already described help correlate the Frantz Creek, McMahon Reservoir, and Kremmling sections (*J*, *H*, and *D*). Similarly, a light-gray to light-yellowish-brown sandstone at the top of the Canyon Springs serves to tie together the Radium, Kremmling, and Snowshoe Ranch sections (*B*, *C*, *D*, and *F*).

The base of the Canyon Springs everywhere examined rests unconformably on the underlying rocks. At Elk Creek (sec. *A*) and at the sections near Radium and Kremmling (secs. *B*, *C*, and *D*), chert pebbles clearly mark the base. At Frantz Creek (sec. *J*) the chert pebbles are small and inconspicuous, but the basal inch of the member is notably gritty (bed 2, sec. *J*). At Tyler Mountain (sec. *G*), the only other section where the basal contact of the Canyon Springs is exposed, the contact is an abrupt change from the bentonitic grayish-red claystone in the Chinle Formation to the pale-reddish-brown very fine grained sandstone in the Canyon Springs Member of the Sundance.

At a locality about 3 miles southwest of Burns, Colo. (fig. 1), the Entrada Sandstone (Baker and others, 1936, p. 28, fig 6, loc. 16) contains chert pebbles at the base, unconformably overlies the Chinle, and grades up into the Curtis. Its lithology and its stratigraphic and structural relations to the overlying and underlying rocks are identical with those of the Canyon Springs at Elk Creek (sec. *A*, fig. 1) with which it is here correlated.

Imlay (1947, table 1) considers both the Canyon Springs of Wyoming and the Entrada Sandstone of Utah and Colorado to be of Callovian Age. At the Snowshoe Ranch (sec. *F*) bed 2 contains *Vaugonia conradi* (Meek and Hayden). This pelecypod has not been reported from beds younger than the Pine Butte Member which is probably middle or late Callovian in age (member B of Pipiringos, 1953, p. 34; 1957, p. 22–23).

LAK(?) MEMBER

In the northern part of the area, at sections *H*, *I*, *J*, and *K*, there occurs a sequence of rocks consisting of light- to yellowish-gray limy silty clayey sandstone and gray to yellowish-gray clay, shale, claystone, and siltstone which is tentatively interpreted to be a facies of the Lak Member of the Sundance Formation of Wyoming and is here referred to as the Lak(?) Member. The Lak at its type section (Black Hills, Wyo.), and throughout much of eastern, central, and south-central Wyoming, consists principally of red siltstone and sandstone, although locally it is yellowish gray. The red facies has been traced southward as far as Big Sandstone Creek on the west flank of the Sierre Madre (northern extension of the Park Range of Colorado) about 7 miles north of the Wyoming-Colorado State line. The Lak(?) is absent from outcrops along the Park Range between this point and the northern part of the Kremmling area (fig. 1), and the Lak(?) of the Kremmling area, therefore, has not been traced into the main body of the member to the north in Wyoming. Correlation with the Lak is based almost entirely on its stratigraphic position—above the Canyon Springs and beneath the Pine Butte Members of the Sundance.

The Lak(?) ranges in thickness from 37 feet at McMahon Reservoir (sec. *H*) to 47 feet at Frantz Creek (sec. *J*). At the three northernmost sections (*I*, *J*, and *K*) it is predominantly gray, and, although it is sandier and more yellowish gray at McMahon Reservoir (sec. *H*), its position in all four sections beneath the Pine Butte and above the Canyon Springs leaves little doubt about its correlation among these localities. It is not present at Tyler Mountain (sec. *G*); presumably it thins and pinches out in the area between sections *H* and *G*.

At Barber Basin, Frantz Creek, and McMahon Reservoir (secs. *K*, *J*, and *H*) the Lak(?) grades downward into the Canyon Springs Sandstone Member. The contact is marked by only a slight change in lithology, by a change from soft slopes characteristic of the Lak(?) to more resistant slopes and rounded ledges in the Canyon Springs, and by the presence of bottom-dweller borings (beds 4 and 1, secs. *J* and *K*, respectively) in the upper few feet of the Canyon Springs.

The Lak(?) grades both upward into the Pine Butte Member and

downward into the Canyon Springs Member, both of which are of Callovian Age.

Pollen and spores of vascular land plants were collected from bed 7 of the Frantz Creek section (table 1, FC–10). None of the forms is specifically identifiable and all were easily carried by wind; thus they are diagnostic neither of age nor of environment of deposition.

PINE BUTTE MEMBER

The Pine Butte Member of the Sundance Formation in the Kremmling area is present in all the sections examined and consists of interbedded sandstone, siltstone, clay shale, and limestone. The member is only 13 feet thick at Kremmling (sec. *D*), but thickens northward to 48 feet at the McMahon Reservoir (sec. *H*). It is about 62 feet thick at Elk Creek (sec. *A*). The member grades downward into the Lak(?) but is unconformably overlain by the Windy Hill Sandstone Member.

The Pine Butte in the Kremmling area contains abundant glauconite, oolitic limestone, and oolitic sandstone. Such sedimentary features in southern Wyoming are common in the Redwater Shale, less common in the Windy Hill Sandstone, and least common in the Pine Butte Members of the Sundance Formation (Pipiringos, 1953, p. 34; 1957, p. 11; 1968, p. D23). The Pine Butte does not contain thin platy ripple-imbricate limy sandstone beds marked with furrowed bottom-dweller trails that are characteristic of the Pine Butte of Wyoming. These comparisons suggest possible correlation of the Pine Butte in the Kremmling area with the Redwater Shale Member in Wyoming.

The following stratigraphic and paleontologic features, however, strongly suggest that the Pine Butte of north-central Colorado more likely correlates with the Pine Butte of Wyoming:

1. The Redwater Shale Member in south-central Wyoming consists of four distinct and persistent lithologic units. In ascending order, these are a lower siltstone, a lower shale, an upper siltstone, and an upper shale (Pipiringos, 1968, p. D23, fig. 3). By contrast, the Pine Butte of the Kremmling area does not show orderly superposition of lithologic units nor does any one lithologic sequence within the member persist laterally for any great distance.
2. The basal contact of the Redwater is unconformable, whereas the basal contact of the Pine Butte in the Kremmling area is gradational.
3. In southeastern Wyoming, progressively older units of the Redwater are truncated southeastward, and the vanishing edge of the lower siltstone unit trends southwestward across the southern part of the Laramie Basin, Wyo., into and across the northern part of North Park, Colo. Extrapolation of this trend suggests

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that the zero line passes a few miles north of Steamboat Springs, Colo. Consequently, although it is not impossible that the Redwater extends southward into the Kremmling area, it seems improbable; more likely the Redwater has been truncated and it is the Pine Butte that extends into the study area.

4. Absence of the furrowed bottom-dweller trails from the Pine Butte of the study area is fortuitous inasmuch as they are abundant in equivalent rocks near Burns, Colo., about 7.5 miles southwest of stratigraphic section A.
5. Absence from the Pine Butte in the Kremmling area of belemnites, certain ammonites, the pelecypods *Camptonectes bellistriatus* and *Astarte packardi*, and other fossils such as are abundant in the Redwater is significant, inasmuch as these forms are likewise absent from the Pine Butte of Wyoming (Imlay, 1947, p. 259–263; Pipiringos, 1957, p. 22–24).
6. Identification of the Pine Butte Member in the Kremmling area is based mainly on the presence of *Vaugonia conradi* (Meek and Hayden), which is the only species of *Vaugonia* recognized to date in the Pine Butte of Wyoming; it is unknown from the Redwater. A form previously identified as *Trigonia sturgisensis*? (Whitfield and Hovey, 1906) in Wyoming (Pipiringos, 1953, p. 34; 1957, p. 22, 23) has since been determined by R. W. Imlay to be *Vaugonia conradi* (Meek and Hayden).

This species occurs in beds as old as Bajocian (early Middle Jurassic) (Imlay, 1964, p. C30) and as young as middle or late Callovian, but has not been found in rocks of Oxfordian Age in Wyoming or adjacent States (Imlay, 1964; written commun., 1966). Whereas ammonites are scarce in the Callovian rocks of Wyoming and adjacent States, *Vaugonia conradi* is common. Consequently, the latter, in many areas, may prove to be very useful in differentiating beds of Callovian Age from beds of Oxfordian Age.

Specifically unidentifiable ostracodes from beds 3 and 5 of the McMahon Reservoir north section (*I*) and from bed 10 of the Frantz Creek section (*J*) were referred by I. G. Sohn (written commun., 1964) to the genus *Darwinula*, to genera in the *Bisulcocypris-Theriosynoecum* group, and to an indeterminate large smooth genus or genera (table 1, FC–7, 8, 9). These fossils could not be used for dating the rocks, but Sohn (written commun., 1964) remarked, "The only element lacking to make this a typical Morrison assemblage is *Theriosynoecum wyomingense* (Branson)." Sohn further stated, "No Foraminifera were found. The ostracodes are all of the fresh-water type; some of the genera can tolerate brackish-water, but none is found in marine sediments except near shore where specimens can be washed in from

a fresh-water habitat. The abundance of individuals would rule out transport to a marine environment. It is noteworthy that no chara were observed; these are normally present in Morrison sediments * * *."

The ostracodes occur in unit 5, section *I*, which contains marine pelecypods and is overlain by glauconitic oolitic beds, one of which (bed 12, sec. *I*) contains echinoid spines. This indicates marine deposits are intercalated with fresh-water deposits of Callovian Age. Apparently the ostracodes persisted with but little change into Morrison time (probably Kimmeridgian).

The Curtis Formation (Baker and others, 1936, p. 28, fig. 6, loc. 16) contains marine Jurassic fossils including the furrowed bottom-dweller trails that are characteristic of the Pine Butte of Wyoming. The formation grades down into the Entrada (Baker and others, 1936, pl. 20*A*) and is sharply overlain by beds equivalent to the Windy Hill Sandstone Member. The lithology and faunal content (except the furrowed trails of the Curtis) and its stratigraphic and structural relations to the underlying and overlying rocks of this locality are nearly identical with those of the Pine Butte at Elk Creek (sec. *A*, fig. 1) with which it is here correlated.

WINDY HILL SANDSTONE MEMBER

The Windy Hill Sandstone Member of the Sundance is present throughout the area. It consists of light-greenish-gray amorphous-lime- and crystalline-calcite-cemented ripple-marked sandstone beds, which weather to slabby grayish-yellow ledges, and locally interbedded grayish-green clayey siltstone beds, which weather to form reentrants and slopes. Locally the member is sparsely oolitic and glauconitic, and at section *I* (bed 14) it contains salt crystal casts. Its thickness ranges from 1 foot at the McMahon Reservoir north (sec. *I*) to 10 feet at Radium (sec. *B*). Throughout the area the Windy Hill rests sharply and apparently unconformably on the Pine Butte, and it grades upward into the Morrison Formation.

In most sections the lithology and weathering characteristics of the member are closely similar to those of the Windy Hill of southeastern Wyoming (Pipiringos, 1968, p. D23–D24). Locally, as at the Radium SW section (*B*), the member is atypical and correlation with the Windy Hill at adjacent localities is based principally on stratigraphic position. Except for ripple marks it lacks most of the lithologic and weathering characteristics, and in addition it contains ostracodes, which have not been reported form this member elsewhere.

Bed 13 of section *B* contains ostracodes (table 1, FC–1) that appear to be similar to those found in the Pine Butte (I. G. Sohn, written commun., 1964).

The age of the Windy Hill in Wyoming is probably Kimmeridgian. Regionally, the member truncates underlying units of Oxfordian Age and grades up into the Morrison (Pipiringos, 1953, p. 34; 1957; p. 24; 1968, p. D23–D25, fig. 3).

STRATIGRAPHIC SECTIONS

Locations of stratigraphic sections are shown in figure 1. Fossil collections are identified by the numbers FC–1, FC–2, and so forth; fossils identified in each collection are listed in table 1.

In the descriptions that follow, the term "unit" is applied to an interval that contains more than one rock type.

SECTION A.—*Elk Creek*

[In Leadville quadrangle, Army Map Service (A.M.S.), near Elk Creek about 4.5 miles west of McCoy, Colo., in the SW¼ sec. 33, T. 1 S., R. 84 W., and in the NW¼ sec. 4, T. 2 S., R. 84 W.; beds strike N. 30° W., dip 5° SW. Measured by G. N. Pipiringos and A. A. Bookstrom, July 1963]

	Feet
Morrison Formation (in part):	
23. Mostly siltstone, gray-green, clayey, limy; makes slope capped by thin ledge of greenish-gray and reddish-brown silty clayey limy sandstone	3
Sundance Formation:	
Windy Hill Sandstone Member:	
22. Sandstone, light-gray, light-yellowish-brown-weathering, fine-grained, well-sorted, tightly lime-cemented; bedding surfaces show trails of crawling organisms; ripple marked; forms slabby ledge	2
21. Siltstone, grayish-green, clayey; makes slope	3
20. Sandstone, like bed 22; contains scattered medium grains of quartz; ripple marked, makes ledge	4
Thickness of Windy Hill Sandstone Member	9
Unconformity.	
Pine Butte Member:	
19. Sandstone, greenish-gray, very fine grained, fairly well sorted, silty and clayey, slightly limy; contains a few scattered glauconite grains and marine pelecypod fragments; a ledge 0.4 ft thick, 7 ft below top, contains obscure tubular scaphopod? casts; forms ledgy slope	18
18. Sandstone, like bed 19; no fossils; weathers to thin plates; makes ledgy cliff	31
17. Sandstone, like bed 19; contains a few limy nodular concretions, carbonaceous debris; has contorted bedding; contains pelecypods (FC–2), especially abundant in top 3 ft; forms slope	8
16. Sandstone, like bed 19; contains marine pelecypod fragments near top (FC–3); forms blocky projecting ledge	5
Thickness of Pine Butte Member	62

SECTION A.—*Elk Creek*—Continued

Sundance Formation—Continued

	Feet
Canyon Springs Sandstone Member:	
15. Sandstone, moderate-orange-pink, very fine grained, locally limy, well-sorted; contains orange and black chert grains; massive; contains a platy-fissile grayish-green clayey zone 5 ft thick 20–25 ft below top; forms rounded ledges	68
14. Sandstone, like unit 15; weathers yellowish gray; makes rounded ledges	61
13. Sandstone, like unit 15	41
12. Sandstone, like unit 15; base of unit marked by zone of black limy schist pebbles as much as 2.5 in. long; forms rounded ledges	18
Thickness of Canyon Springs Sandstone Member	188
Thickness of Sundance Formation	259

Unconformity.

Chinle Formation:

Upper and middle members undivided:	
11. Siltstone, pale-red, tightly lime-cemented, ripple-laminated at top 1 ft; forms massive rounded ledge	9
10. Siltstone, pale-reddish-brown, and grayish-red silty claystone; contains a few grayish-red lime-cemented siltstone pebbles; forms slope	4
9. Siltstone, pale-reddish-brown, tightly lime-cemented; forms rounded ledge	16
8. Claystone, grayish-red, very silty; forms slope	2
7. Limestone, light-gray, dolomitic; makes square-faced ledge that weathers to thin plates	2
6. Siltstone, moderate-reddish-brown, clayey, slightly limy, micaceous; subfissile to blocky; forms slope	31
5. Claystone, reddish-purple, silty; forms slope containing 0.5-ft-thick ledge 9 ft above base; ledge is pale-reddish-purple slightly clayey laminated micaceous siltstone	28
Thickness of upper and middle members undivided	92
Lower member:	
4. Siltstone, dark-reddish-brown, mixed with dark-reddish-brown silty sandy claystone and greenish-gray fine-grained sandstone; unit is especially sandy in lower 10 ft; forms slope interrupted by projecting ledge of limestone pebble conglomerate 5 ft below top and thin sandstone ledge in lower part	20
3. Sandstone, mottled light-gray and grayish-red, medium- to coarse-grained, poorly sorted, contains a few chert pebbles; forms rounded ledges	12

SECTION A.—*Elk Creek*—Continued

	Feet
Chinle Formation—Continued	
Lower member—Continued	
2. Sandstone, light-gray, coarse-grained, with quartz, chert, and quartzite pebbles as much as 1 in. in diameter; upper 2 ft contains grayish-purple shale and makes slope; basal 1 ft makes projecting ledge	3
Thickness of lower member	35
Thickness of Chinle Formation	127
Unconformity.	
Triassic and Permian red beds (in part):	
1. Siltstone, reddish-brown and grayish-red in top 5 ft, micaceous, subfissile; forms slope containing thin ledges	100+

SECTION B.—*Radium SW*

[In Leadville quadrangle (A.M.S.), across the graded road 0.5 mile southwest of Radium, Colo., in the SW¼NW¼ sec. 27, T. 1 S., R. 82 W.; attitude of beds ranges from N. 5° E., 11° NW. at base of Chinle Formation to N. 11° E., 14° NW. at base of upper part of Entrada Sandstone and averages about N. 7° E., 13° NW. Measured by G. N. Pipiringos and A. A. Bookstrom, July 1963]

Morrison Formation (in part):	
18. Limestone, olive-gray, aphanitic; weathered surfaces show fine laminae of algal(?) origin; forms hard ledge	1
17. Sandstone, greenish-white, very fine to fine-grained, tightly lime-cemented; makes hard ledge separated by partings of soft sandstone	7
16. Sandstone, greenish-gray, very clayey; forms soft slope	4
15. Claystone, greenish-gray and dark-purplish-gray, silty; forms slope	20
14. Sandstone, light-gray, very fine grained; interbedded with medium-gray dense aphanitic limestone; forms rounded ledge	1
Partial thickness of Morrison Formation	33
Sundance Formation:	
Windy Hill Sandstone Member:	
13. Sandstone, light-gray, very fine grained, well-sorted, slightly limy, orange and black chert grains; middle of unit contains a 1.5-ft-thick bed of medium-gray poorly laminated claystone that contains ostracodes (FC–1); forms slope	4
12. Sandstone, light-gray, very fine grained, well-sorted, slightly limy, porous; contains varicolored chert and quartzite grains; middle 2 ft forms a slope capped by a 1-ft-thick ledge; basal 3 ft makes a massive to platy ledge; locally ripple marked	6
Thickness of Windy Hill Sandstone Member	10

SECTION B.—*Radium SW*—Continued

	Feet
Unconformity.	
Pine Butte Member:	
11. Clay shale, medium-gray; forms slope	2
10. Sandstone, light-gray, yellowish-gray-weathering, very fine grained, well-sorted, limy; forms slope with ledges at top and bottom	8
9. Sandstone, light-gray, very fine grained, limy, clayey; forms slope	7
8. Sandstone, light-gray, very fine grained; basal 2 ft contains medium-gray shale partings; two thin ledges at 3 and 5 ft below top contain marine pelecypod fragments and casts throughout (FC–4); unit forms slope capped by 3-ft-thick fossiliferous ledge	13
Thickness of Pine Butte Member	30
Canyon Springs Sandstone Member:	
7. Sandstone, light-gray, white- and pink-weathering, fine-grained, limy, clayey, friable; forms slope	17
6. Sandstone, like bed 7 but obscurely crossbedded; forms massive cliff	18
5. Clay shale, very light green and very dusky red, limy, silty; contains glauconitic aggregates, chlorite and biotite flakes; shale is interbedded with very thin green and red clayey to silty sandstone beds; makes chippy slope	21
4. Sandstone, light-gray, grayish-orange-weathering, fine-grained, well-sorted, weakly lime-cemented, friable; contains chert granules 2 ft above base; 0.2 mile to west the basal foot of unit contains pebbles as much as 6 mm in diameter; forms massive rounded cliff	60
Thickness of Canyon Springs Sandstone Member	116
Thickness of Sundance Formation	156
Unconformity.	
Chinle Formation:	
Lower member:	
3. Sandstone, siltstone, and claystone. Lower third of unit is mottled grayish-purple silty sandy claystone mixed with light- to medium-gray sandstone; claystone is swelling clay; silt and sand grains float in claystone matrix; micaceous. Upper two-thirds of unit is pale-reddish-brown-weathering sandstone and siltsone. Unit forms slope	18
2. Sandstone, light-gray, gritty, slightly limy; contains a few chert and quartzite grains and a few scattered reddish-brown siltstone fragments; forms ledge	3
Thickness of Chinle Formation	21

SECTION B.—*Radium SW*—Continued

Unconformity.

Triassic and Permian rocks (in part):	Feet
1. Siltstone, grayish-red, micaceous (chlorite and white mica), clayey, subfissile; forms slope	20+

SECTION C.—*Radium SE*

[In Leadville quadrangle (A.M.S.), along the road 1.5 miles southeast of Radium, Colo., in the SW¼NE¼ sec. 26, T. 1 S., R. 82 W.; attitude of beds ranges from N. 45° W., vertical dip at base of Canyon Springs Sandstone Member to N. 68° W., 70° SW. in the Windy Hill Sandstone Member. Measured by G. N. Pipiringos and A. A. Bookstrom, July 1963]

Morrison Formation (in part):	Feet
19. Limestone, grayish-brown, smooth, has faint algallike laminae; lower part is sandy and clayey; upper part makes projecting ledge, lower part makes slope	2
18. Sandstone, pink and green, very fine grained, very clayey, limy; makes slope	2
17. Sandstone, grayish-white, very fine to fine-grained; has chalky calcite matrix; contains 1-ft-thick shale parting 5 ft below top; unit makes moderately projecting slabby ledge	12
16. Claystone, red and green; interbedded with thin sandstone and limestone beds; unit forms ledges and slopes	9
15. Sandstone, greenish-gray, very fine grained, limy; grades downward into sandy grayish-pink limestone; upper part of unit forms slabby ledge, lower 2 ft makes hard square-faced ledge	3
14. Siltstone, greenish-gray, clayey, slightly micaceous; contains ostracodes; forms slope	2
Partial thickness of Morrison Formation	30

Sundance Formation:

Windy Hill Sandstone Member:

13. Sandstone, light-greenish-gray, very fine grained, silty, clayey, laminated, glauconitic, oolitic; upper part has bottom-dweller trails on bedding planes; lower part is ripple marked and weathers grayish yellow; forms slabby ledge	7

Unconformity.

Pine Butte Member:

12. Shale, grayish-green, silty, sandy, limy; forms slope	1
11. Sandstone, light-greenish-gray, very fine to fine-grained, limy, hard; makes square-faced ledge	6
10. Sandstone, light-greenish-gray, very fine-grained, limy, silty, clayey, glauconitic; has wavy laminations; forms slope	3
9. Sandstone, light-greenish-gray, very fine grained, limy, slightly micaceous; forms ledge	6

SECTION C.—*Radium SE*—Continued

Sundance Formation—Continued

	Feet
Pine Butter Member—Continued	
8. Sandstone, like bed 10, but platy; interbedded with thin beds of gray shale in middle and laminated reddish-brown siltstone in lower part; hard square-faced ledge 1 ft thick 0.5 ft below top of unit	6
Thickness of Pine Butte Member	22
Canyon Springs Sandstone Member:	
7. Sandstone, reddish-brown, very fine grained, clayey; locally cut out by greenish-gray limy very fine grained sandstone that makes a square-faced ledge	2
6. Sandstone, light-brown, very fine-grained, well-sorted, massive; makes rounded ledge	27
5. Siltstone, greenish-gray, clayey, sandy, shaly, laminated, micaceous, limy; contains sparse glauconite; forms slope	7
4. Sandstone, light-gray to pink, very fine grained; crossbedded; quartz granules and pebbles are concentrated in lower 2 ft; a few quartz, chert, and quartzite granules are scattered throughout; forms rounded ledges	31
Thickness of Canyon Springs Sandstone Member	67
Thickness of Sundance Formation	96

Unconformity.

Chinle Formation (in part):

3. Claystone, mottled grayish-purple and light-gray, silty and sandy; bed is highly sheared	2

Fault.

2. Siltstone, moderate-reddish-brown, slightly clayey, micaceous; resembles lithology of older red beds; bed is highly sheared	5

Unconformity.

Precambrian:

1. Gneiss.

SECTION D.—*Kremmling*

[In Kremmling quadrangle, about 4.5 miles southwest of Kremmling, Colo., on north side of an irrigation ditch in the center of the N½N½ sec. 21, T. 1 N., R. 81 W.; beds strike N. 12° W. and dip 13° NE., except units 8–12 which strike N. 15° W. and dip 30° NE. Measured by G. N. Pipiringos and C. S. V. Barclay, June 1963]

Morrison Formation (in part):	Feet
16. Sandstone, thin-bedded; interbedded with clay shale; topmost bed is a 2-ft-thick grayish-brown limestone; thin conglomeratic sandstone bed in middle of unit contains fragments of limestone similar to topmost bed; unit forms ledges and reentrants	20
15. Sandstone, white and yellow, thin-bedded; interbedded with gray clay shale, claystone, and limestone; sandstone is similar to that in unit 11; unit forms ledges and reentrants	9

SECTION D.—*Kremmling*—Continued

	Feet
Morrison Formation (in part)—Continued	
14. Claystone, greenish-gray and light-pinkish-gray; makes slope; topmost 0.5 ft is dense gray sandy limestone that makes ledge	1.5
13. Sandstone, light-gray, very fine grained, slightly limy; interlayered with greenish-gray waxy clay shale; appears transitional between units 14 and 12; unit forms slopes and ledges	2.5
Partial thickness of Morrison Formation	33
Sundance Formation:	
Windy Hill Sandstone Member:	
12. Sandstone, pale-yellowish-orange, very fine grained, clean, well-sorted, slightly limy, ripple-marked; greenish-gray clayey shaly siltstone near middle of unit; sandstone forms ledges separated by siltstone reentrants	4.5
11. Sandstone, pale-yellowish-orange, very fine grained, clean, well-sorted, slightly limy, ripple-marked; light-gray shaly silty limy claystone in upper half foot; unit forms ledge	3
Thickness of Windy Hill Sandstone Member	7.5
Unconformity.	
Pine Butte Member:	
10. Siltstone and very fine grained sandstone; both light greenish gray, limy, clayey, micaceous; contains some bottom-dweller trails; middle part of unit forms ledges, rest of unit forms slopes	5
9. Sandstone, light-greenish-gray, very fine grained; contains casts of marine pelecypods and bottom-dweller trails; forms rounded ledge	2
8. Sandstone, light-greenish-gray, yellowish-brown-weathering, very fine grained, clayey; forms slopes and ledges	6
Thickness of Pine Butte Member	13
Canyon Springs Sandstone Member:	
7. Sandstone, light-yellowish-brown, very fine grained, slightly clayey; basal 1 ft contains vuggy calcite aggregates; forms ledges	12
6. Bentonite, white, waxy, mixed with some light-greenish-gray silty sandstone and clay shale; forms slope	1
5. Sandstone, light-yellowish-brown, very fine grained, clayey, locally limy, shaly; forms slope	2
4. Sandstone, light-yellowish-brown, very fine grained, calcite-cemented, well-sorted, fairly clean, massive; has shale partings; grades laterally into shale; contains ripple marks and bottom-dweller trails and borings; unit forms rounded ledge	17

SECTION D.—*Kremmling*—Continued

Sundance Formation—Continued

Canyon Springs Sandstone Member—Continued

	Feet
3. Siltstone, very light greenish gray, well-sorted, limy, slightly clayey; upper part is more clayey and shaly and is mottled purple; contains a few thin beds of light-gray calcite-cemented sandstone; unit forms slopes and thin ledges	14
2. Partly covered; light-gray, micaceous, limy sandstone, contains granules and pebbles near base. Most granules are white, some are black, and some are pink chert; pebbles are light-gray chert. Thin bedded; forms slope	5
Thickness of Canyon Springs Sandstone member	51
Thickness (rounded) of Sundance Formation	71

Unconformity.

Precambrian:

1. Biotite gneiss and migmatite.

SECTION E.—*Lazy Bear*

[In Gore Pass quadrangle, about 9.5 miles northwest of Kremmling, Colo., on north side of a road leading to the Lazy Bear Ranch (formerly the Lone Cow Ranch) in the NE¼NW¼ sec. 7 and the SE¼SW¼ sec. 6, T. 2 N., R. 81 W.; beds strike N. 40° W. and dip about 2½° SW. Measured by G. N. Pipiringos and W. J. Hail, Jr., September 1963]

Sundance Formation, not measured; base of exposure is in fault contact with beds similar to those in unit 12.

Chinle Formation (in part):

Middle member:

13. Claystone, grayish-red and yellowish-orange, weathers to popcorn surface, soft and sticky when wet; top is in fault contact with beds similar to those in unit 12; forms slope	10+

Lower member:

12. Sandstone, mottled light-gray and grayish-purple, very coarse grained, poorly sorted, granulitic, arkosic; contains thin partings of grayish-purple silty sandy claystone; forms rounded ledges and slopes; ledge at top	44
11. Siltstone and claystone, grayish-purple; mixed with fine-grained mottled poorly sorted sandstone and swelling claystone; shaly in basal few feet; contains black iron oxide nodules 3 ft above base; unit forms badland topography	25
Thickness of lower member	69
Partial thickness of Chinle Formation	79+

SECTION E.—*Lazy Bear*—Continued

Unconformity.

Triassic and Permian red beds:	Feet
10. Siltstone and shale; upper part is reddish-brown limy siltstone; lower part is reddish-brown shale with thin platy limy siltstone ledges; unit forms slopes and ledges	6
9. Siltstone, reddish-brown, slightly clayey, limy, micaceous (biotite, chlorite, and white mica); forms ledgy slope	35
8. Claystone, reddish-brown, subfissile, interlaminated with thin siltstone layers; unit forms ledges and slopes	10
7. Siltstone, like bed 9; contains greenish-gray arkosic bed at top; unit forms ledges and slopes	10
6. Siltstone, like bed 9; contains a 1.5-ft-thick ledge at top and a 0.5-ft-thick ledge in middle	8
5. Siltstone, like bed 9; interbedded with a few 1-in.-thick layers of conglomerate; topmost 0.5 ft makes ledge	13.5
4. Sandstone, reddish-brown, very coarse to fine-grained, poorly sorted, clayey and silty, micaceous, conglomeratic; fragments are as much as 4 in. long and are especially abundant in a zone 3–5 ft above base; forms slopes and rounded ledges	15
3. Siltstone, reddish-brown, slightly clayey, slightly limy, micaceous, laminated; forms slope	1
2. Sandstone, reddish-brown, very coarse to fine-grained, conglomeratic, arkosic, poorly sorted; makes rounded ledge	2.5
Thickness of Triassic and Permian red beds	101

Unconformity.

Precambrian:

1. Crystalline rocks.

SECTION F.—*Snowshoe Ranch*

[In Gore Pass quadrangle, about 10.5 miles northwest of Kremmling, Colo., along a road in the NW¼NW¼ SE¼ sec. 1, T. 2 N., R. 82 W.; beds strike N. 10° E., dip 40° SE. Measured by G. N. Pipiringos and W. B. Cashion, September 1957]

Morrison Formation (in part):	Feet
14. Sandstone, light-gray, clear- to chalky-calcite-cemented, glauconitic(?), well-sorted, massive friable; forms rounded ledge	15
13. Claystone, greenish-gray and red, limy, sandy near top, blocky; forms slope	2
Partial thickness of Morrison Formation	17

Sundance Formation (in part):

Windy Hill Sandstone Member:

12. Sandstone, light-gray, fine-grained, calcite-cemented, fairly clean, well-sorted, sparsely oolitic; forms ledge; sharp contact with unit 11	2.5

SECTION F.—*Snowshoe Ranch*—Continued

Sundance Formation (in part)—Continued

Unconformity.

	Feet
Pine Butte Member:	
11. Claystone, medium-gray, sandy, subfissile, limy; forms slope	4
10. Claystone, medium-gray, silty, subfissile, limy; forms slope; overlain by laminated silty sandstone that forms a weak ledge; unit is fossiliferous	2.5
9. Sandstone, light-gray, very fine grained, locally limy, interbedded with medium-gray limy shale; contains gray sandy nodular limestone bed 0.5 ft thick at base; sandstone contains marine pelecypod casts (FC–5); unit forms ledge	2.5
8. Claystone, yellowish-gray, limy, sandy, chunky; forms slope	1
7. Sandstone, yellowish-gray, very fine to fine-grained, chalky-calcite-cemented; makes weak inconspicuous ledge	1
6. Claystone, yellowish-gray, limy, silty, chunky; forms slope	1
5. Sandstone, grayish-yellow, very fine to fine-grained, tightly calcite-cemented; forms a platy, ripple-marked ledge	1
4. Claystone, yellowish-gray, limy, silty, chunky; forms slope	2
Thickness of Pine Butte Member	15
Canyon Springs Sandstone Member (in part):	
3. Sandstone, yellowish-gray, very fine-grained, limy, sparsely glauconitic; forms slope	9.5
2. Sandstone, light-gray, very fine to fine-grained, cemented with chalky to clear calcite; interbedded with gray-green shale; unit forms ledgy slope; sandstone contains marine pelecypods (FC–11)	2
1. Sandstone, moderate-reddish-orange, silty, limy, fairly soft; contains a few limy nodules; topmost few feet are green; forms slope; base concealed	8+
Partial thickness of Canyon Springs Sandstone Member	19.5+
Partial thickness (rounded) of Sundance Formation	37+

SECTION G.—*Tyler Mountain*

[In Gore Pass quadrangle, about 11.5 miles northwest of Kremmling, Colo., on southwest side of Tyler Mountain on north side of Deer Creek in the NW¼SE¼ sec. 25, T. 3 N., R. 82 W.; beds nearly horizontal. Measured by G. N. Pipiringos, W. J. Hail, Jr., G. A. Izett, and C. S. V. Barclay, June and September 1963

	Feet
Sundance Formation:	
Windy Hill Member:	
18. Sandstone, pale-yellowish-gray, yellowish-orange-weathering, fine-grained, limy; contains a few rounded medium chert grains; bedding surfaces are ripple marked; freshly fractured surfaces show calcite cleavage faces; contact with Morrison Formation not exposed; forms slabby ledge	3

SECTION G.—*Tyler Mountain*—Continued

Sundance Formation—Continued
Unconformity.

	Feet
Pine Butte Member:	
17. Sandstone, light-gray, very fine grained, friable, well-sorted, fairly clean, locally ripple marked, massive; contains a few shale partings; topmost 8 ft are covered; contains marine pelecypods in basal 5 ft (FC–6); unit forms rounded ledges and reentrants	18
Canyon Springs Sandstone Member:	
16. Sandstone, moderate-reddish-orange, very fine grained, silty and clayey, limy, laminated; slope is littered with ripple-laminated platy chips of sandstone; forms soft slope	29
15. Sandstone, pale-reddish-brown to yellowish-gray, very fine grained, tightly lime-cemented, laminated; forms slabby ledge	4
Thickness of Canyon Springs Sandstone Member	33
Thickness of Sundance Formation	54

Unconformity.
Chinle Formation (in part):

Middle member:	
14. Claystone, grayish-red with pinkish-gray bands, bentonitic, smooth, waxy, weathers to popcorn surfaces; makes soft deeply weathered slope	19
13. Claystone, light-yellowish-orange, sandy, bentonitic; makes slope	1
12. Siltstone, pale-reddish-brown, very clayey, very sandy; makes slope	3
Thickness of middle member	23
Lower member (in part):	
11. Claystone, dusky-red, locally mottled light-gray, silty, sandy, blocky; contains black iron oxide nodules; forms slope	3.5
10. Sandstone, gray to purplish-red, very fine grained, tightly lime-cemented; makes hard square-faced ledge	3
9. Claystone, sandy; and clayey sandstone; mottled purplish black to grayish purple; forms slope	26
8. Sandstone, mottled purple, yellow, and red, fine- to coarse-grained, conglomeratic, poorly sorted; contains claystone and siltstone fragments as much as 10 mm long; arkosic; upper part cross laminated; upper part makes slope, lower 1.5 ft makes prominent ledge	3.5
7. Claystone, sandy, and clayey sandstone; mottled purplish black and grayish purple; forms slope	3
6. Sandstone, mottled pale-reddish-brown, grayish-purple, and pale-yellowish-orange, fine- to coarse-grained, poorly sorted; contains clay galls and chips, arkosic; forms ledge	1

SECTION G.—*Tyler Mountain*—Continued

	Feet
Chinle Formation (in part)—Continued	
Lower member (in part)—Continued	
5. Claystone, mottled like bed 6, silty and very sandy, micaceous, laminated to blocky; forms slope and platy ledges	10
4. Sandstone, mottled like bed 6, fine-grained, silty and clayey, not well-sorted, fairly well indurated; contains trail casts and borings; forms ledge	1
3. Sandstone, mottled like bed 6, fine-grained, silty, poorly sorted, blocky; interbedded with silty shale; unit forms ledges	15+
Partial thickness of lower member	66+
Partial thickness of Chinle Formation	89+
2. Covered; contact of Chinle with Triassic and Permian red beds concealed in this interval [1]	56
Triassic and Permian red beds (top and bottom not exposed, thickness estimated):	
1. Siltstone, reddish-brown, micaceous, locally laminated; contains thin beds of reddish-brown sandstone; unit forms slopes and ledges	80+
Unconformity.	
Precambrian crystalline rocks.	

SECTION H.—*McMahon Reservoir*

[In Gore Pass quadrangle, at north end of McMahon Reservoir about 15 miles northwest of Kremmling, Colo., in the SW¼NE¼ and the SE¼NW¼ sec. 21, T. 3 N., R. 82 W.; beds 1-14 strike N. 38° W. and dip 13° NE., beds 15-21 strike N. 28° E. and dip 46° SE. Measured by G. N. Pipiringos, A. A. Bookstrom, and C. S. V. Barclay, June 1963]

	Feet
Morrison Formation (in part):	
22. Limestone, gray, very sandy, cherty; forms ledge	2
21. Claystone, green, subfissile; forms slope	10
Partial thickness of Morrison Formation	12
Sundance Formation:	
Windy Hill Sandstone Member:	
20. Sandstone, light-greenish-gray, mottled red in lower part, very fine grained, limy, glauconitic, sparsely oolitic; contains a few laminations of greenish-gray shaly siltstone; upper 0.5 ft forms ledge, rest forms slope	5.5

[1] At a locality about 0.7 mile southeast of the Tyler Mountain section along the road near a steel gate in the SE¼NE¼NE¼ sec. 36, T. 3 N., R. 81 W., the lower part of the lower member consists of quartz granules and pebbles in a coarse quartzose sandstone matrix and is about 10 ft thick. It overlies the Triassic and Permian red beds and is overlain by about 5 ft of purple and gray siltstone and sandstone beds whose top is concealed. Consequently, the minimum thickness of the Chinle in this area is about 105 ft. The maximum thickness is about 125 ft (exposed Chinle plus unit 2).

SECTION H.—*McMahon Reservoir*—Continued

Sundance Formation—Continued

Unconformity.

	Feet
Pine Butte Member:	
19. Sandstone, light-gray, very fine grained, slightly limy, slightly glauconitic, oolitic(?), well-sorted, fairly clean; stained with iron oxides 3.5 to 4.5 ft below top; makes slope	10
18. Sandstone, greenish-white, very fine to fine-grained, weakly calcite-cemented; contains shaly partings in lower part; lower part forms slopes, upper part forms weak ledges; thin weak ledges at top and bottom of unit are oolitic	15
17. Claystone, medium-gray, very sandy, very limy, crudely fissile; contains ostracodes; makes slope	7
16. Sandstone, light-gray, fine-grained, calcite-cemented well-sorted, contains abundant white chalky ooliths; top 0.2 ft makes ledge, rest forms slope	8
15. Limestone, light-olive-gray, dense, slightly sandy; contains ostracodes; no fissility apparent, but edges of bed weather to an irregularly bladed appearance parallel to bedding; makes weak ledge	.5
Offset northward on limestone in unit 15. About 200 ft north, there is a 1-ft-thick oolitic sandstone bed about 23 ft above the limestone. The slope between the limestone and the oolitic sandstone is mostly covered and consists in part of greenish-gray clayey, silty limy sandstone locally mottled pale red. About 100 feet still farther north, the limestone contains a few ostracodes and occurs 5–7 below a thin oolitic sandstone bed; the limestone grades downward into unit 14.	
14. Slope, mostly covered; upper half is light-gray highly calcareous claystone that contains ostracodes; lower half is medium-gray fine-grained sandstone that is calcite cemented, oolitic; contains large glauconite pellets and grades downward into unit 13	5
13. Limestone, light-greenish-gray, oolitic, sandy; contains large glauconite pellets and fragments of *Camptonectes;* forms prominent ledge	2.5
Thickness of Pine Butte Member	48
Lak(?) Member:	
12. Sandstone, light-gray, yellow-gray-weathering, fine-grained, silty, limy, glauconitic, friable; makes rounded slope	37
Canyon Springs Sandstone Member:	
11. Sandstone, moderate-reddish-orange, fine-grained, well-sorted, limy; contains well-rounded quartz grains and a few magnetic dark mineral grains; friable; forms slope; middle third of unit is covered	30
10. Clay shale, greenish-gray, bentonitic; basal 0.3 ft is greenish-gray bentonite	1

SECTION H.—*McMahon Reservoir*—Continued

	Feet
Sundance Formation—Continued	
Canyon Springs Sandstone Member—Continued	
9. Sandstone, moderate-reddish-orange; except beds of top few feet which are gray and yellow; very fine grained, silty, clayey, limy, friable; contains magnetic dark mineral grains; contains a few 1-in.-thick layers of brown silty and sandy clay shale in lower 10 ft; unit forms ledges and slopes	30
8. Sandstone, moderate-reddish-orange to light-brown, very fine to fine-grained, well-sorted, firmly calcite-cemented to friable; contains magnetite and some other dark mineral grains; thin-bedded, forms platy ledge	2
7. Claystone, light-greenish-gray, limy, slightly sandy and silty, crudely fissile, laminated to blocky; forms slope	6
6. Sandstone, light-greenish-gray locally mottled pink and yellow, very fine grained, limy silty, thin-bedded to finely laminated, varvelike; interbedded with greenish-gray shale near base; platy to papery, fissile throughout; some bedding surfaces are irregularly pustulate, especially near base; unit forms slope	8
5. Sandstone, moderate-reddish-orange, very fine grained, well-sorted, limy, massive; contains well-rounded medium- to coarse-size quartz grains; friable, clean; base of exposure is at creek level on the east side of Red Dirt Creek	2+
Partial thickness of Canyon Springs Sandstone Member	79+
Partial thickness (rounded) of Sundance Formation	170+
4. Covered by alluvial deposits; contact between Sundance Formation and Chinle Formation concealed; position of this contact shown in figure 3 is arbitrary	68
Chinle Formation (in part):	
Lower member (in part):	
3. Sandstone, silty sandstone, sandy siltstone, interbedded; the sandstone is light gray, coarse grained to pebbly, quartzose; the silty sandstone and the sandy siltstone are pale red to dusky red, mottled pinkish gray, noncalcareous, clayey, poorly sorted; the silty sandstone is fine to medium grained; entire unit is friable and makes a short steep slope in the west bank of a meander of Red Dirt Creek; top and bottom of unit are concealed	20+
Offset to northwest on west side of Red Dirt Creek in the NE¼SE¼NW¼ sec. 21, T. 3 N., R. 82 W.	
2. Sandstone, pinkish-gray, very coarse to fine-grained, quartzose; contains a few chert and quartzite granules and pebbles; forms weak crossbedded slabby ledge that grades up into lithology like that of unit 3; top concealed	3+
Partial thickness of lower member of Chinle Formation	23+

SECTION H.—*McMahon Reservoir*—Continued

Unconformity.

Triassic and Permian red beds (in part):	Feet
1. Clay shale, moderate-reddish-brown, silty, sandy, noncalcareous, micaceous, laminated; forms slope; sharp contact with bed 2; base concealed	20+
Partial thickness of Triassic and Permian red beds	20+

SECTION I.—*McMahon Reservoir, north*

[In Gore Pass quadrangle, about 16 miles northwest of Kremmling, Colo., about 1 mile north of McMahon Reservoir near the center W½NW¼ sec. 16, T. 3 N., R. 82 W.; beds strike N. 34° W. and dip 13° NE. Measured by W. J. Hail, Jr., and G. N. Pipiringos, September 1963]

Morrison Formation (in part):	Feet
16. Limestone, medium-gray; shows concentric algal structures; contains charophyte oogonia; forms ledge; stratigraphically higher beds concealed	0.5
15. Covered interval	2
Partial thickness of Morrison Formation	2.5

Sundance Formation (in part):

Windy Hill Sandstone Member:

14. Sandstone, light-gray, light-brown-weathering, very fine grained, well-sorted; calcite cemented; fractured surfaces show calcite cleavage faces; ripple marked; salt crystal casts on under side of bedding surfaces; forms slabby ledge — 1

Unconformity.

Pine Butte Member:

13. Sandstone, light-gray, fine-grained, slightly limy, oolitic; interbedded with gray calcareous claystone; unit forms slope — 1
12. Limestone, light-gray, sandy, oolitic; contains large glauconite pellets and fragments of echinoid spines; forms prominent ledge and ridge; base concealed — 10

Offset 200 feet southeast across stream.

11. Sandstone, yellowish-gray, very fine grained, well-sorted, clean, limy, glauconitic, oolitic; contains light-olive-gray claystone layers; unit forms partly covered slope — 10
10. Sandstone, light-gray, fine-grained, slightly limy; contains abundant white chalky ooliths and a few dark mineral grains; friable; forms weak rounded ledge — 2
9. Sandstone, light-gray, very fine grained, well-sorted, clean, cemented with chalky calcite, oolitic; top 0.5 ft is fine-grained and makes weak rounded ledge; lower part is soft and forms partly covered slope — .5
8. Limestone, light-greenish-gray, very sandy, contains biotite and other dark minerals; upper part is smooth, medium gray — .5

SECTION I.—*McMahon Reservoir, north*—Continued

	Feet
Sundance Formation—Continued	
Pine Bute Member—Continued	
7. Sandstone, light-greenish-gray, yellowish-gray-weathering, limy; contains biotite and other dark minerals; basal 1 ft contains beds of medium-gray sandy calcareous clay shale; unit forms slope	9
6. Limestone, light-greenish-gray, yellowish-gray-weathering, very sandy; contains biotite flakes and other dark minerals; contains a shaly sandstone parting near base; unit makes a weak slabby ledge	1.5
5. Shale, light-greenish-gray; contains ostracodes (FC–7); interbedded with clayey silty sandstone that contains marine pelecypods; unit forms ledges and slopes	4
4. Sandstone, very light greenish gray, fine-grained, calcareous, abundantly oolitic; contains clay galls; grades downward into sandy light-gray dense limestone with smooth conchoidal fractures; unit forms rounded ledge	1
3. Shale, light-olive-gray; calcareous; contains ostracodes (FC–8); includes two thin light-gray silty and sandy limestone beds; unit forms slope	5
2. Sandstone, very light greenish gray, very fine grained, glauconitic, limy, ripple-marked, thin-bedded, cherty; forms ledge	1
Thickness of Pine Butte Member	50
Lak(?) Member (in part):	
1. Sandstone, light-gray to yellowish-gray, very fine grained, cemented with chalky calcite, glauconitic, well-sorted, friable; forms soft smooth slope; base concealed	26+
Partial thickness of Sundance Formation	77+

SECTION J.—*Frantz Creek*

[In Lake Agnes quadrangle, about 18 miles northwest of Kremmling, Colo., in the NE¼NW¼SE¼ sec. 32, T. 4 N., R. 82 W.; beds strike about north and dip 10° E. Measured by W. J. Hail, Jr., and G. N. Pipiringos, September 1963]

	Feet
Morrison Formation (in part):	
18. Limestone, gray, calcareous; middle is shaly and makes reentrant between two ledges	1
17. Claystone, medium-gray, calcareous, chunky; contains ostracodes; makes slope	5
Partial thickness of Morrison Formation	6

SECTION J.—*Frantz Creek*—Continued

Sundance Formation:

Windy Hill Sandstone Member: *Feet*

16. Sandstone, grayish-yellow, very fine grained, cemented with chalky calcite, ripple-marked; makes weak slabby ledge--- 1

Pine Butte Member:

15. Clay shale, greenish-gray mottled purple, calcareous, crudely fissile; makes slope---------- 4
14. Sandstone, yellowish-gray, very fine grained, calcareous, glauconitic; beds in upper 2 ft contain grayish-green shale partings, middle is shaly, basal 1 ft is grayish white; unit makes slope interrupted by weak ledges---------- 7
13. Sandstone, like unit 14; central part makes slope---------- 3
12. Covered---------- 2
11. Sandstone, grayish-yellow, very fine grained, cemented with chalky calcite, friable; makes slope---------- 1
10. Clay shale, light-greenish-gray, limy, irregularly fissile, laminated; bottom-dweller trails along bedding planes; contains ostracodes (FC–9); limy parts form thin ledges------ 10

Thickness of Pine Butte Member---------- 28

Lak(?) Member:

9. Sandstone, light-gray, very fine grained, well-sorted, slightly limy, glauconitic, fairly well indurated; makes slope, basal 1 ft makes ledge---------- 14
8. Sandstone, light-yellowish-brown, very fine grained, well-sorted, slightly limy; makes slope---------- 5
7. Claystone, olive-gray, limy, crudely fissile; plant microfossils (FC–10); forms slope---------- 5
6. Sandstone, brownish-yellow, very fine grained, limy; upper part forms slope, lower 1 ft forms ledge---------- 5
5. Claystone, gray, limy, crudely fissile, hard; forms slope----- 10
4. Siltstone, gray, limy, sparsely glauconitic, biotitic; interbedded with yellowish-gray limy silty sandstone; bottom-dweller burrow casts common; unit forms ledges and slopes; grades downward into unit 3---------- 8

Thickness of Lak(?) Member---------- 47

Canyon Springs Sandstone Member:

3. Sandstone, buff and moderate-reddish-orange, calcareous, friable; gradational downward into bed 2; contains a bed of green bentonitic clay shale 0.1 ft thick about 15 ft below top; unit forms steep slope---------- 164

SECTION J.—*Frantz Creek*—Continued

	Feet
Sundance Formation—Continued	
Canyon Springs Sandstone Member—Continued	
2. Sandstone, light-gray, very fine grained, calcareous, well-sorted, friable; basal 1 in. is biotitic, platy, gritty, and shaly and contains quartz, quartzite, and chert pebbles as much as 0.2 in. in diameter and iron oxide at the base	2
Thickness of Canyon Springs Sandstone Member	166
Thickness of Sundance Formation	242
Unconformity.	
Triassic and Permian red beds:	
1. Siltstone, moderate-reddish-brown, some parts bleached gray, clayey, sandy, calcareous, micaceous, thin-bedded; claystone partings are noncalcareous, unit forms chippy slope, contact with bed 2 is sharp; basal 10 ft concealed; contact with Precambrian approximately at creek level	100
Thickness of Triassic and Permian red beds	100
Unconformity.	
Precambrian granite.	

SECTION K.—*Barber Basin*

[In Lake Agnes quadrangle, about 20.5 miles northwest of Kremmling, Colo., at north end of Barber Basin in the NE¼SW¼NE¼ sec. 17, T. 4 N., R. 82 W.; beds strike N. 10° W. and dip 11° NE. Measured by W. J. Hail, Jr., and G. N. Pipiringos, September 1963]

	Feet
Sundance Formation (in part):	
Pine Butte Member (in part):	
8. Sandstone, yellowish-orange, very fine grained, poorly sorted, silty, limy, glauconitic; makes reentrants and slopes broken by ledges of coquinal sandstone similar to bed 7; top of unit concealed	5+
7. Sandstone, yellowish-orange, very fine grained, cemented by chalky calcite, glauconitic, cherty, contains *Camptonectes* and *Ostrea* shell fragments; forms square-faced ledge	4
Partial thickness of Pine Butte Member	9+
Lak(?) Member:	
6. Sandstone, yellowish-gray, clayey; forms slope	19
5. Claystone, yellowish-gray, silty, calcareous, crudely fissile; contains scattered lenses of platy limy glauconitic sandstone; unit forms slope	3
4. Sandstone, yellowish-gray, very fine grained, calcareous, clayey, silty, glauconitic; forms slope	3
3. Claystone, yellowish-gray, silty, calcareous, crudely fissile; forms slope; grades downward into bed 2	16

SECTION K.—*Barber Basin*—Continued

	Feet
Sundance Formation—Continued	
Lak(?) Member—Continued	
2. Siltstone, yellowish-gray, calcareous, clayey, sparsely glauconitic; forms slope; grades downward into bed 1	2
Thickness of Lak(?) Member	43
Canyon Springs Sandstone Member:	
1. Sandstone, fine-grained, well-sorted, clean, friable; a few percent chert and quartzite grains; upper part is gray with pink bands, lower part is orange pink with light-gray bands; beds of top few feet weather yellow and contain burrow casts; unit forms slope; base concealed	60+
Partial thickness of Sundance Formation	112+

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