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DEPARTMENT OF THE INTERIOR

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UNITED STATES

GEOLOGICAL SURVEY

No. 19

NOTES ON THE STRATIGRAPHY OF CALIFORNIA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

ADVERTISEMENT.

[Bulletin No. 19.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

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"That whenever any document or report shall be ordered printed by Congress, there shall be printed in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

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ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth Annual Report is in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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The following are in press, viz:

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. ix, 338 pp. 35 pl.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. —, — pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. —, — pp. 46 pl.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

Lake Bonneville, by G. K. Gilbert.

Sauropoda, by Prof. O. C. Marsh.

Stegosauria, by Prof. O. C. Marsh.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of ANNUAL REPORTS or MONOGRAPHS.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient size. To facilitate this each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 19 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of Troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Vanhise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°, 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Dr. C. A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by J. M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization, etc., by Arnold Hague and J. P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Dr. C. A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

Numbers 1 to 6 of the Bulletins form Volume I, and numbers 7 to 14 Volume II. Volume III is not yet complete.

The following are in press, viz:

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. — pp. 5 pl. Price — cents.

22. On New Cretaceous Fossils from California, by Charles A. White, M. D. 1885. 8°. — pp. 5 pl. Price — cents.

STATISTICAL PAPERS.

A fourth series of publications having special reference to the mineral resources of the United States is contemplated.

Of that series the first has been published, viz:

Mineral Resources of the United States, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

The second volume of this series, Mineral Resources 1883 and 1884, is in preparation and will soon be put to press.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE or MONEY ORDER, should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

WASHINGTON, D. C., *May* 25, 1885.

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J. W. POWELL DIRECTOR

NOTES

ON THE

STRATIGRAPHY OF CALIFORNIA

BY

GEORGE F. BECKER

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1885

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NOTES ON THE STRATIGRAPHY OF CALIFORNIA.

By George F. Becker.

Introductory.—A complete examination of the Coast Ranges of California can hardly be undertaken by the Geological Survey for some years to come, consistently with the plans at present formed. The detailed study of certain small areas in these ranges, however, raised a number of questions as to the age and stratigraphical relations of the various series of beds, which it seemed necessary to answer as well as circumstances permitted. Having reached certain conclusions, for the most part on structural grounds, it became indispensable for me to obtain the co-operation of an expert paleontologist. At my solicitation, and with the approval of the director, Dr. C. A. White consented to visit the field with me. He passed several months of the summer of 1884 in studying my collections and the occurrence of fossils in place with reference to the points at issue. His results appear in Bulletin No. 15, that and this being complementary to one another. I had the great satisfaction of finding that Dr. White was led from a purely paleontological position to conclusions entirely accordant with those at which I had already arrived on structural grounds. His long experience as a general geologist also made his agreement with me as to the structural indications a welcome confirmation of my opinions. These studies, in conjunction with many observations made by earlier workers on the Pacific Coast, particularly those of the State Geological Survey of California, under Prof. J. D. Whitney, have led to some seemingly well established general conclusions of interest. The more purely geological results will be presented in the following pages, in the imperfect form in which alone it will be possible to give them until an immense amount of additional work shall have been done.

Metamorphism in the Coast Ranges.—Throughout the Coast Ranges of California there occur large irregular areas of rocks in the condition ordinarily regarded as metamorphic. They are characterized lithologically by the presence of serpentine (perhaps accompanied by some other magnesian minerals) or silica, or both. Of the secondary

nature of the silicification there can be no doubt, since the quartz and opal occur mainly in the form of veins and stringers, for the most part occupying tiny cracks in the rock. The serpentine was also regarded as an alteration-product by Professor Whitney and his assistants, and with this opinion I am compelled to agree, after a careful study of the phenomena, both structural and microscopic, the details of which will be published on another occasion. Where the stratification of the metamorphic rocks is not obliterated, they are seen to be greatly disturbed, having been sometimes broken up into a chaotic mass of fragments, since cemented by silica or serpentine, and sometimes thrown into sharp plications. In the latter class of cases it is often clear that plication has not been effected by flexure, but by innumerable fractures, the resulting fragments often averaging less than one-quarter inch cube. These particles were retained in approximately their original position by mutual pressure, and have been recemented by silica. The most striking instances of this character are seen among thin-bedded rocks, either sandstones or sandy shales, and such are remarkably frequent in this series; indeed they might be said to be characteristic of it, though occasionally met with in formations which appear to be later than the most important era of metamorphism.[1]

Besides the rocks referred to above, the Coast Ranges include others which have been subjected to more or less complete alteration. Thus along the shore of Carmelo Bay, Miocene schists have been locally changed to a cindery mass, as if by the action of heat, but these rocks bear no resemblance to the serpentinized and silicified material just described. More or less complete induration is common even in the most recent rocks of the coast, and oxidation and impregnations with calcite and gypsum occur abundantly in rocks of all ages. In the present paper, however, the term metamorphism, unless specially qualified, must be understood to refer to serpentinization, silification, and associated changes.

AGE OF THE METAMORPHIC ROCKS OF THE COAST RANGES.—Rocks of the metamorphic series often pass over into unaltered beds under such circumstances as to preclude a doubt that they are of the same age; but unfortunately the unchanged strata seldom contain determinable fossils, and only a small number of occurrences are known in which the age can be satisfactorily established by direct evidence. In addition to these cases, however, there is a considerable amount of tolerably satisfactory indirect evidence available, when all the circumstances are taken into consideration. The neighborhood of Knoxville, Napa County, affords an excellent opportunity for the study of the metamorphic rocks. This region has also been mapped and examined in detail as a portion of a series of studies which, with abundant illus-

[1] The peculiarity of these thin-bedded, plicated, metamorphic rocks was observed and frequently referred to by Professor Whitney.

trations, will appear hereafter. A section across the north fork of Davis Creek, a little north of the Reed mine, a short distance from Knoxville, shows that the ravine occupies an eroded anticlinal of which the western portion is highly metamorphic, while the eastern consists in part of highly fossiliferous strata, containing *Aucella* of two varieties, with other molluscan remains. A map of the region shows that the strike of the unaltered strata throughout is tolerably constant, but that areas of metamorphic and unaltered rocks, the latter nearly all containing a few fossils, are interspersed in the most irregular manner. While the passage from metamorphosed to fresh rock is usually rather sudden, there are also clear cases of transition. The whole structure and the stratigraphical relations are such as to preclude every supposition except that the metamorphic rock is an alteration product of the same beds which contain *Aucella* and the accompanying fossils. These fossils, and these only, occur over a strip of country several miles in length, in which Knoxville is the only town. Dr. White and I have therefore agreed to call these characteristic beds the Knoxville group. Their age, as may be seen from Dr. White's bulletin, is near the limits of the Jurassic and the Cretaceous, and it is not quite certain to which they belong, if indeed they are not intermediate or transitional.

Close to the Manzanita gold and quicksilver mine on Sulphur Creek, in Colusa County, the metamorphic rocks contain impressions of *Aucella Piochii*, and close by are beds of limestone full of *Rhynconella Whitneyi*.[2] The metamorphic rocks of this region are serpentinized and silicified, and the thin-bedded strata show the characteristic contortions accompanied by a fine network of veins of silica. At Mount Diablo, too, there is abundant proof of the Knoxville age of the metamorphic rock. Professor Whitney, writing before Mr. W. M. Gabb had made his final divisions of the California Cretaceous, mentions the occurrences at Mount Diablo as conclusive of the Cretaceous age of the metamorphic rocks, but without enumerating the associated fossils. From an examination of the fossil localities in Mr. Gabb's work, however, it appears certain that these were *Aucella*, etc. An examination which Dr. White and I undertook for the purpose shows that in Bagley Creek, about a mile from the summit, *Aucella* occurs abundantly close to the edge of metamorphosed strata; indeed, in partially metamorphosed strata conformable with those extremely altered, and in structural relations to them, which clearly indicate the same age. My assistant, Mr. H. W. Turner, subsequently found a series of beds, some of which had escaped action and contained *Aucella*, though inclosed on both sides by highly metamorphic strata. Mr. Gabb also mentions[3] an *Aucella* locality near the New Almaden mine which I have not thus far been able to identify.

[2] These specimens were determined by direct comparison with specimens in the collection of the State survey. The figure given in Pal. Cal., Vol. II, Plate XXXIV, is incorrect in important particulars.

[3] Pal. Cal., Vol. II, p. 247.

So far as is known, that part of the country consists of metamorphic rocks overlain by Miocene strata, and there can be little doubt that the *Aucella* beds belong to the metamorphic series. Alcatraz Island, close to San Francisco, consists of metamorphic sandstone and shales not distinguishable from those of San Francisco or of Mount Diablo. Here Major Elliott discovered an *Inoceramus*, considered by Mr. Gabb and Dr. White as establishing the Cretaceous age of these rocks, though indecisive of the portion of this formation to which they should be referred. The above comprise all the instances known in which the age of the silicified and serpentinized metamorphic rocks is directly determinable by paleontological evidence.

Of other cases of alteration of rocks known not to belong to the Knoxville beds I have already mentioned the very remarkable but utterly different change in the Miocene strata near Monterey. In the Arroyo de la Penitencia above Alum Rock, near San José, there is also an area of altered Miocene sandstones referred to by Professor Whitney.[4] The rock here is much indurated and is full of veins of calcite. No objection can be made to its description as metamorphic by Professor Whitney, but it is not serpentinized and silicified, and does not partake of the characteristics so strongly marked in the highly metamorphosed rocks of the Knoxville group. On the other hand, there are plenty of rocks of this group no more altered than the Miocene of the Arroyo de la Penitencia and some areas still less modified. The Tertiary of the Arroyo has been subjected to influences seemingly identical with those which have affected portions of the Knoxville beds, but not to those which have produced in the older strata the characteristic serpentinization and silification. Professor Whitney also refers[5] twice to altered beds in the San Francisquito Pass, which, indeed is to the south of the Coast Ranges as usually defined. In the first reference he states that "this belt of metamorphic is referred by us to the Cretaceous formation, from general analogy rather than from any direct evidence of fossils." In the second reference they are mentioned as "Miocene rocks turned upon edge and so much metamorphosed as to be converted into mica slate." No statement of the means of determination of the age of these beds accompanies this remark, which, however, occurs in a brief summary of the geology of the Coast Ranges. Whatever the evidence may be upon which the change of reference was made, it can have little bearing upon the age of the metamorphics in the central Coast Ranges, nor is serpentinization referred to as forming a part of the phenomena.

So far as is known, therefore, no beds in the Coast Ranges of California younger than the Knoxville group have experienced the peculiar magnesian and silicious metamorphism so characteristic of these ranges. No fossils antedating the Knoxville period have anywhere been discov-

[4] Geol. Cal., Vol. I, p. 51.

[5] Geol. Cal., Vol. I, p. 196. Aur. Grav., p. 19.

ered in the Coast Ranges. For the most part it would seem that rocks indistinguishable in habitus from the Knoxville group rest directly upon the granite. In the Gavilan Range, however, an extremely crystalline limestone is the lowest sedimentary formation.[6] It is so highly metamorphosed where thus far seen as to offer no hope of fossils, and its general appearance is such as to suggest a far greater age than the Jurassic. Nothing of the kind is known to exist between this point and Clear Lake. A portion, at least, of the characteristic metamorphism of the Coast Ranges took place before the beginning of the Chico period. Metamorphic pebbles are common in the Chico conglomerates, but these are usually wholly silicious. This is in no way inconsistent with their having been derived from areas of metamorphosed Knoxville beds, for serpentine is easily abraded and easily decomposed, so that it readily escapes redeposition. These pebbles might also, however, have been derived from some earlier metamorphic area not now exposed. But in the Wallala[7] beds, a series extending along the coast from near Fort Ross at least to Wallala, and which Dr. White regards as probably prior to the Chico, serpentine pebbles from the adjoining metamorphic area are tolerably abundant. This area is a large one and no Knoxville fossils have been found as yet near Wallala, but the metamorphic is continuous with that of Colusa and Napa Counties, where we know that the magnesian metamorphism involved the Knoxville beds. These pebbles, then, are probably of Knoxville age. New Idria lies at the southern extremity of the Mount Diablo range, which takes its name from its most northerly peak. The range is essentially a metamorphic ridge flanked by inclined strata not altered. The metamorphic axis can be followed almost continuously, and perhaps quite so, but while at the northern end the metamorphic rocks are certainly of Knoxville age, at the southern end the externally indistinguishable material contains, so far as known, only a few indeterminable plant remains. It appears to me almost beyond reasonable doubt that the metamorphic of New Idria includes Knoxville beds.

Similarity of lithological and physical character may, I think, be given too much weight in geological diagnosis. I cannot conceive, for example, that any degree of similarity between the rocks of California and those of Switzerland should properly be considered as even tending to prove the age of either. I go farther, and refuse to regard the metamorphism of the rocks of Butte County as necessarily contemporaneous with that of the strata of Napa County in spite of external similarity. On the other hand, within properly limited areas, observations show that the same fauna is associated with similar rocks; while if it were impracticable to draw any conclusions as to age, except where

[6] Cf. Dr. Antisell's paper in Pacific Railroad Survey, Vol. VII.

[7] This name is variously spelled Gualala, Guadala, Walhalla and Wallala. The last is the spelling adopted by the Coast and Geodetic Survey after careful scrutiny and consideration.

the rock is fossiliferous, or where absolute continuity with fossiliferous localities, uninterrupted by faults, could be proved, geological mapping would be impossible. In California great use can be made of resemblances. Thus the Téjon strata of New Idria are mostly heavy bedded sandstones of a peculiarly light color, which there distinguishes them from the tawny Chico sandstones. Both are fossiliferous there as also near Mount Diablo, where, at a distance of 125 miles from New Idria, they preserve the same external characteristics. Similarly, the Knoxville beds of Knoxville and Mount Diablo are externally indistinguishable and, in their typical development, even when unaltered, very different from most of the later rocks.

Excepting the peculiar limestones of the Gavilan Range, there is no occurrence known in the Coast Ranges which suggests the presence of beds older than the Knoxville. Such may nevertheless be included in the metamorphic series, and may have undergone upheaval and metamorphism at the same date. There is also a possibility that older rocks not only exist, but were metamorphosed before the deposition of the Knoxville, so that the metamorphic areas in contact with the Wallala beds on the coast and with the Chico strata at New Idria may conceivably be earlier than the Knoxville. Even this supposition, which, in the absence of any evidence tending to it, seems rather far-fetched, would have no effect on the conclusions drawn in this paper, unless it could be maintained, not only that such was the case, but also that the violent upheaval and metamorphism which followed the Knoxville left the supposed older areas undisturbed. This would conflict with all analogy.

It is, perhaps, worth while to note that as a rule the character of the topography of the areas occupied by Shasta rocks differs widely from that of regions in which only the more recent beds are laid bare. In the metamorphic areas the valleys usually occupy anticlinals, though the erosion appears to have been partially controlled by the extent of the metamorphism.[8] Such surfaces necessarily indicate extremely prolonged exposure. On the other hand, where the surface is occupied by rocks of the Chico or later groups, erosion has often approximately followed the bedding.

The foregoing facts and the necessary inferences from them appear to justify the statement that the silicified and serpentinized metamorphic rocks of the Coast Ranges include a portion of the Knoxville beds, and do not include any portion of the Chico or of the Wallala series, while if there were pre-Knoxville rocks within the metamorphic areas they must have undergone at least a fresh disturbance at the time when the Knoxville beds were broken up and metamorphosed.

NONCONFORMITY BETWEEN THE KNOXVILLE BEDS AND THE CHICO.—Had the proof of this nonconformity been a simple matter, it could not have escaped attention of some one of the several able geol-

[8] Cf. Dana's Manual, p. 750.

ogists who have done more or less work in the Coast Ranges. The difficulty is in part due to the rarity of fossils in the older groups over a great portion of the area in question, which often leaves the observer without absolute proof of the age of the rocks about him; but the main obstacle arises from the complexity of structure. Few geological phenomena are more striking than a nonconformity where the overlying strata are nearly horizontal, the underlying rocks greatly inclined and the exposure tolerable. This combination is rare in the Coast Ranges, and no such case is known where the Shasta and Chico beds meet. The post-Miocene uplift traced by Professor Whitney has folded, faulted, and broken the later Cretaceous and the Tertiary rocks as well as the earlier strata upon which they were unconformably deposited, so that it is usually far from easy to make out the effects ascribable to the earlier and later disturbances respectively, and still more difficult to prove that no explanation except that of a nonconformity before the Chico will account for the facts. I believe that the structural evidence to be presented amounts to a demonstration of this nonconformity, but even after having delayed publication for a considerable time in order to secure more data, the proof, though convincing, is less abundant than I could wish it. The paleontological argument for this nonconformity is a very strong one, as will be seen from Dr. White's paper, but I had detected the gap before he joined me and while in ignorance that an hiatus existed in the succession of organic forms. The evidence will, therefore, be presented here chiefly from a purely structural standpoint.

In the neighborhood of the New Idria mine the metamorphic rocks have been greatly disturbed, while the Chico strata though tilted at a high angle are remarkably regular. Owing to the steepness of the contact, however, I was unable to find any exposures showing both series together from which thoroughly satisfactory inferences could be drawn as to the relations of the underlying and overlying rocks. I therefore resorted to a study of the exposures of each separately, for which the region offers unusual facilities. It was found possible to follow single strata of the Chico uninterruptedly for a large part of a mile, and in favorable cases to recover the croppings with substantial certainty after passing intervals covered with detritus, by the aid of lithological peculiarities combined with topographical indications and the strikes observed at the exposures.[9] The contact with the metamorphic rocks was also laid down and a great number of dips were observed in the metamorphic area. In order to eliminate the irregularities due to the varied topography of the lines of croppings, and the contact as laid down on the map, each line of croppings was reduced to its intersection with a plane of the mean altitude of these croppings, following the in-

[9] This would have been excessively difficult, if not impossible, but for the aid afforded by an almost ideally good contour map on a scale of 800 feet to the inch prepared for me by Mr. J. D. Hoffmann.

dication of the local dips. The results showed that the Chico strata are parallel in strike and thrown into extremely gentle undulations, while the metamorphic area is a mere shattered mass. The contact has approximately the same general direction as the Chico beds, but does not entirely coincide with their strike. It is a rough line, but not rougher than one which would represent the vertical section of an ordinary sea-bottom near the coast. The dip of the Chico strata decreases as the distance from the contact increases.

This structure either represents a nonconformity or else the metamorphism and accompanying disturbances occurred after the deposition of the Chico beds but ended sharply at a certain line. It might at first sight seem impossible that an area several miles in width should be crumpled, broken quite as thoroughly as a representative area of the Archæan along the eastern coast, and further for the most part converted into serpentine and chert, but that both mechanical and chemical action should cease abruptly at a given line. Nevertheless instances of which the above might pass for a description actually occur and are perhaps more frequent in the Coast Ranges than elsewhere. All geologists who have visited this region are aware of the very irregular distribution of the metamorphic areas and it has already been pointed out that, for example at Knoxville and at Mount Diablo, the metamorphic passes over into unaltered or very slightly altered Knoxville beds suddenly, though under circumstances which preclude the supposition that the adjoining areas represent different formations. There are, however, significant differences between these occurrences and the conditions at New Idria. The limits of metamorphism in areas consisting of Knoxville beds, however sharp they may be, are exceedingly irregular, the outline being substantially independent of stratification, cutting strata more often than following them, and presenting all sorts of convolutions. There are almost invariably also outlying areas of metamorphic rock and included masses of unaltered rock. Furthermore at least here and there are distinct transitions between unaltered and metamorphic rock. At New Idria, on the other hand, a section of the contact normal to the surface extends over at least several miles (as far as it was followed) in a tolerably straight line. There are no outlying patches of metamorphic rocks; the included masses of comparatively unaltered rock seem wholly different from the Chico strata above them and, though there is a considerable alteration of a portion of the overlying mass, this alteration is not of the same character as the magnesian and silicious metamorphism of the underlying rock; nor could I find any distinct case of transition. Finally, in the Chico conglomerates a part of the pebbles seem entirely to resemble the silicified or jaspery portions of the present metamorphic area while a few appear both macroscopically and microscopically identical with the serpentinized rocks of Knoxville age.

Some further evidence of the relation of the two series was found a few miles to the southeast of New Idria, where a branch of Cantua Creek cuts through a portion of the range. Here the heavy-bedded, tawny Chico sandstones, lying at an angle of about 45°, cap the hills which are intersected by the brook, while in the bed of the stream the thin-bedded metamorphic strata stand vertically. No actual contact, however, could be found, the interval being covered with detritus.

There seems no reasonable explanation of the structure at and near New Idria, except by the existence of a non-conformity. Though the evidence may seem less satisfactory than that which would be presented by an ideal exposure, it is derived from the correlation of the structural evidence along the contact for miles, and in this respect is superior to any but the very best local exposures of unconformable contacts; for every geologist must have observed cases where unconformable exposures were closely simulated by local faults. Could it be proved that the underlying mass is of greater age than the Knoxville the evidence would nevertheless indicate a non-conformity between the Chico and the Knoxville, unless it could be shown that the convulsion which has so marvelously crushed the Knoxville beds, at least from Clear Lake to the neighborhood of New Almaden, was unfelt at New Idria, while the comparatively gentle post-Miocene upheaval certainly extended throughout the Coast Ranges of California and Oregon.

Mount Diablo and the surrounding country consist of a core of metamorphic rock inclosed nearly or quite quaquaversally by rock of Chico and Tertiary age. The core is highly contorted, and for the most part is in an extremely metamorphosed condition, though here and there it is comparatively fresh, and in some cases contains *Aucella* and associated fossils. The overlying Chico, Téjon, and Miocene strata are tilted, but otherwise comparatively undisturbed. Over wide areas these three series seem to be perfectly conformable, nor is there any case known on the Pacific coast where there seems any ground for suspecting a non-conformity within these limits. Mr. H. W. Turner, my assistant, spent several days in this region, collecting fossils from various beds and searching for some exposure in which the relations of the Knoxville beds and the Chico could be well made out. The result was negative, no exposure being detected from which a non-conformity could be established beyond a question. On the other hand, the structure is much more easily accounted for by supposing a non-conformity to exist than by assuming conformity. The upturned edges of the more recent strata form long, smooth curves enveloping the plicated and metamorphosed core, and nowhere was there any metamorphism in the strata identified as Chico. The pebbles of the Chico conglomerates were metamorphic, but entirely silicious, and neither distinctly the same as the core of the mountain nor essentially different.

From about a mile south of Fort Ross northward for an unknown distance the sea-coast of California is formed by a terrace separated from

the beach by cliffs.[10] The rock exposed on these cliffs and at croppings on the terrace is composed of soft tawny sandstones, like those of the Chico, dark shales, and coarse conglomerates. The sandstone predominates. About a mile north of Wallala several fossils were found, and careful search at many points to the southward disclosed a few more from the same beds. These Dr. White regards as probably older than the Chico, but younger than the Knoxville group. At the chief fossil locality, near Wallala, the shells were found in part in sandstones and in part in the matrix of a conglomerate the pebbles of which are serpentine and other metamorphic rocks (exactly similar to those of typical metamorphic areas of Knoxville and Mount Diablo) and granite. The metamorphic pebbles are considered as valid evidence that the metamorphism and accompanying disturbances took place before these Wallala beds were deposited.

At the southern extremity of this terrace, below Fort Ross, there is a sharp contact between the Wallala beds and the metamorphic serpentinized rock which extends from this point to below the Russian River, if not to the Golden Gate. Passing back into the hills, the Wallala beds are found capping the first range of elevations opposite portions of the shore which are composed of the metamorphic rocks. I believe no one could examine this locality without being convinced that the Wallala beds rest unconformably upon the metamorphic, nor could any one pass inland from the mouth of the Russian River to Knoxville without feeling sure that the metamorphic is uniform in character and substantially continuous, though occasionally masked by eruptive rocks and possibly by a few patches of unaltered strata.

There is furthermore much indirect structural evidence that a nonconformity must exist between the Knoxville beds and the Chico. The exposures at Mount Diablo show that there, at least, no deposits were formed between the Knoxville and the Chico. Were the fauna of the Wallala beds more decisive as to age, it might therefore at once be maintained that during the Wallala period the Knoxville beds of Mount Diablo must have been above water. But this argument is not necessary. Upon the Chico lies the Téjon (I omit the Martinez[11] as a mere subdivision), and next follows the Miocene. The stratigraphical relations, as

[10] This terrace appears to me beyond question a raised beach. A careful comparison of its topography with that of the beaches more or less exposed at low tide showed a correspondence in character seemingly perfect. Still better evidence was the discovery of rock in place on the terrace at two points separated by several miles, in which were unmistakable *Pholas* borings indistinguishable from those frequent at the present water-level. Some of them were filled with hardened earth which had preserved their interior surfaces perfectly smooth. One locality was by estimation about 100 feet above tide water, the other more than double this elevation. As is well known, there have been differences of opinion as to the character of the terraces on the California coast.

[11] This name has crept into geological literature under the entirely incorrect form Martiñez.

well as organic forms, show a continuous sedimentation and a continuity of life between the Chico and Téjon. Between the Téjon and Miocene there is nowhere any suggestion of a non-conformity.[12] Near New Idria and at Mount Diablo, for example, the Miocene seems as strictly conformable with the Téjon as this with the Chico. So, too, along the flank of the Sierra Nevada, both Chico and Miocene remain almost perfectly horizontal. There is, in fact, evidence that the country was sinking at the period of time which separates the two eras. Had there been a great upheaval, accompanied by intense metamorphism, between the Téjon and the Miocene, it seems impossible not only that no trace of a non-conformity between these beds should have been detected, but also that no Chico or Téjon strata should have been found metamorphosed. But somewhere between the end of the Knoxville and the beginning of the Miocene there was a great upheaval, accompanied by silicious and magnesian metamorphism and followed by enormous erosion; for at many points the unaltered Miocene rests unconformably upon the metamorphic rocks. This I have observed on San Bartolo Creek and in the valley of the San Benito, to which the other is tributary. Professor Whitney found the Miocene resting unconformably upon the metamorphic between the Guadalupe Mine and Forbes's Mill, also near McCartysville,[13] as well as north of the Golden Gate;[14] for instance, near Tomales,[15] while, in speaking of the neighborhood of Suscol, he says[16] "it is probable that the most extensive disturbances of the Cretaceous, as also the larger portion of the metamorphic action upon it, had taken place before the Tertiary marine and volcanic beds were deposited."

There being nothing whatever to indicate any upheaval between the Téjon and the Miocene, this indirect evidence alone is sufficient to establish the fact of a non-conformity between the close of the Knoxville and the beginning of the Chico. Add to this the direct evidence at New Idria and Fort Ross, and to this again the paleontological evidence of an hiatus in the organic succession, probably amounting to the entire period represented by the sum of all the Cretaceous rocks of the country east of the Rocky Mountains, and it appears to me that the conclusion is irresistible. The precise time at which the Knoxville strata were upheaved and metamorphosed cannot be determined from any known facts. It must have been long before the first of the Wallala beds were deposited, and still longer before the opening of the Chico period. In the absence of any strata intermediate in age between the Knoxville and the Wallala beds it seems more probable that the upheaval took place soon after the close of the Knoxville period than at a later date or neither long before nor long after the Neocomian.

[12] Professor Whitney (Aur. Grav., p. 26) writes: "The Miocene and the Cretaceous seem everywhere to be conformable with each other." The Cretaceous here referred to is, of course, the Téjon.

[13] Geol. Cal., 1, p. 69. [14] *Id.*, p. 79. [15] *Id.*, p. 83. [16] *Id.*, p. 103.

IDENTITY OF THE MARIPOSA AND KNOXVILLE BEDS.—The gold belt of California, as hitherto traced out by miners and geologists, is an area of peculiar form. From Mariposa County to Nevada City, in Nevada county, a distance of about 150 miles, the belt is a strip of country nearly parallel to the crest of the Sierra, and about 30 miles in width. To the northward of Nevada City it rapidly widens, becoming at the same time less well defined. To the north it is finally terminated by extensive lava fields, while towards the northwest the country gradually loses its auriferous character as the coast is approached. Within the gold-bearing region three fossiliferous areas are known to exist. From the McCloud River to Pence's Ranch extends a belt of highly metamorphic limestone containing Carboniferous fossils. At Genesee Valley the State survey found fossils regarded as Triassic. Both of these localities are far removed from the narrow strip of country lying along the foot-hills from Mariposa to Nevada, and which is often known as the gold belt proper. In this narrow portion of the auriferous area, though the rocks are for the most part highly metamorphosed, a number of fossils have been found belonging to *Aucella*, *Belemnites*, etc., which are discussed in Dr. White's paper. Meek first described these fossils[17] and ascribed them to the Jurassic chiefly on the ground that *Aucella* "is, so far as is known, entirely confined to the Jurassic rocks."

Previous to the discovery of fossils on the Mariposa estate in the series which I shall call the Mariposa beds, Professor Whitney and his associates had collected in the Coast Ranges *Belemnites*, a shell determined as *Inoceramus Piochii*, and some others from the strata which I have entitled the Knoxville beds in this paper. Mr. Gabb described them as Cretaceous forms.[18] Some years after Mr. Meek had referred the Mariposa beds to the Jurassic, Mr. Gabb redescribed *Inoceramus Piochii* as *Aucella Piochii*,[19] a change of genus which I understand to be unquestionably correct. This correction would seem to have been of evident importance to the stratigraphy of the State, for through it the fauna of a large part of the known rocks supposed to belong to the Shasta group of the Cretaceous acquired the strongest resemblance to that of the Jurassic of Mariposa County. Indeed there seems scarcely room left for a distinction; if *Aucella* is distinctively Jurassic, the *Aucella*-bearing beds of the Coast Ranges must be members of that system, while if these *Aucella* beds are Cretaceous, *Aucella* is not a distinctively Jurassic genus even in the State of California, and Mr. Meek's principal reason for assigning the Mariposa beds to the Jurassic loses its validity.[20] Professor Whitney states that while the Mesozoic age of the

[17] Geol. Cal., Vol. I, p. 477.

[18] Pal. Cal., Vol. I.

[19] Pal. Cal., Vol. II.

[20] This argument first suggested itself to me on a preliminary visit to Knoxville, two years since. From an inquiry on the subject addressed to Dr. White through one of our colleagues, eventually resulted his visit to this coast.

Mariposa beds is proved by their fossils the pre-Cretaceous age of these strata is demonstrated from their stratigraphical relations. Professor Whitney has indeed shown that Cretaceous strata rest unconformably[21] upon the upturned edges of the auriferous slates along the foot-hills of the Sierra at several points; but I find no record of any such bed so low as the Knoxville group.[22] All the fossils recorded in this position are Chico. This does not indeed preclude the possibility that the Mariposa beds are Jurassic, and the *Aucella* beds of the Coast Ranges Cretaceous, for the former might have been above water during the Shasta epoch. But were Cretaceous strata containing the so-called *Aucella Piochii* to be found resting in a nearly horizontal position upon the Mariposa beds, it would prove not only that the genus had persisted from Jurassic into Cretaceous times, but that in essentially the same locality the genus was represented immediately after a great and wide-spread upheaval by a species nearly or quite indistinguishable from one which had inhabited it prior to this convulsion and the attendant metamorphism. Zoölogists would probably think such a survival very strange if it could be proved, and very improbable unless the proof were ample.

On the other hand, if the Mariposa beds are considered as equivalent to the Knoxville beds of the Coast Ranges, the non-conformity between the Chico beds and those of Mariposa is the same which has been traced in the preceding pages as existing in the Coast Ranges. Dr. White, after examination of Meek's types and new and better specimens which we collected together, is unable to draw any specific distinction between the *Aucella* of the Mariposa beds, and that of the Knoxville beds. Were it otherwise the upheaval and metamorphism of the two series would still be referable to nearly the same period, and would be presumptively simultaneous.

The lithological resemblance of the rocks of the Mariposa estate to those of many portions of the metamorphic rocks of Knoxville age is very strong. There is a similar prevalence of thin-bedded strata which silicification and serpentinization are equally the predominant characteristics. Plication and fracture are less noticeable than in the Coast Ranges. One geologist has maintained that the fossiliferous rocks of this locality did not form an integral portion of the auriferous series. Neither Dr. White nor I was able to see any ground for this assertion. The fossiliferous rocks are metamorphic like the whole series; they have the same dip and strike; they are unquestionably auriferous, gold

[21] I am perfectly satisfied of the existence of this non-conformity, though the localities where the Chico beds have been found resting on the upturned edges of the auriferous slates are not near those in which Mesozoic fossils have been found in the older rocks. The Chico beds, where they occur along the foot-hills, have suffered little if at all from the post-Miocene uplift in the Coast Ranges and are nearly horizontal. The Mariposa beds are almost vertical.

[22] The shell from Tuscan Springs recorded, Geol. Cal., Vol. I, p. 207, as *Inoceramus Piochii*, is redetermined as a *Mytilus* in Pal. Cal., Vol. II, p. 191.

quartz veins occurring between fossil-bearing strata and not simply near them. In short we could see no means of separating the strata containing shells from the remainder of the immense thickness of similar and apparently conformable slates.

RELATION OF THE CASCADES TO THE SIERRA AND THE COAST RANGES OF CALIFORNIA.—It seemed highly desirable to institute some slight comparison between the California ranges and the Cascades. For this purpose we visited Roseburg, Oregon, and made several trips into the mountains. These are evidently underlain by granite, which forms a great portion of the stream pebbles, though we met none of this rock in place. In a great number of localities we found upturned, crumpled, silicified, and metamorphosed rocks exactly similar to those of Mount Diablo, but our search for *Aucella* was not rewarded. Upon the metamorphic rocks lie non-conformably somewhat tilted unaltered sandstones. These are certainly Miocene, for though we found no fossils ourselves, Dr. White examined extensive collections of Miocene shells in entirely similar rock collected by the Rev. Thomas Condon, who gave us full information as to their occurrence in precisely similar positions but somewhat north of Roseburg. Overlying the sandstones are large areas of volcanic rocks.[23]

In the section made by the Columbia River no metamorphic rock or granite appears, but at least the southern portion of the range has a foundation similar to that of the California ranges and probably due to the same upheaval. Dr. White points out that since Chico fossils occur to the east of the Cascades the site of the Cascades was at least in part covered by the western sea. This, however, is no objection to the proposition just made, for the interior of Oregon may have been a gulf similar to the present Gulf of California.

OTHER MESOZOIC BEDS.—The Horsetown beds, as it seems convenient to call the group which occurs near Cottonwood Creek, Shasta County, so far as known are confined to that locality, and their relation to the Knoxville series is unknown. The solution is very probably to be found in the eastern Coast Ranges in Tehama County, but this region is not known to have been geologically explored, and it probably will not be examined until a special study of the Coast Ranges as a whole is undertaken. The Horsetown beds are somewhat altered, but at the points visited by Dr. White and myself do not show the characteristic serpentinization and silicification of the metamorphosed Knoxville beds. It cannot by any means be asserted definitely, however, that they were not involved in the upheaval and metamorphism which took place after the Knoxville and before the Wallala period, because much of the Knoxville series is also little altered. On the other hand,

[23] In an answer to an inquiry, Prof. Joseph Le Conte states that his remarks concerning the lower portion of the Cascade range in the Am. Jour. of Science, 3d s., Vol. VII, p. 177, were not from personal observation. He there suggested that the Cascades were a continuation of the Sierra.

the Horsetown beds rest unconformably upon the auriferous slates of that region, which are of unknown age, though apparently continuous with the Carboniferous of Pence's Ranch. Professor Whitney detected this nonconformity, though expressing the result in somewhat guarded terms.[24] The mining operations which have since been prosecuted have so exposed the rocks as to leave no room for any possible difference of opinion. The slates upon which the Horsetown beds lie are somewhat peculiar, and differ physically from those of the Mariposa beds, showing a very thin cleavage and a peculiar silver-gray luster. They give to the eye an impression of great geological age.

Genesee Valley, in Plumas County, is the only known locality west of the crest of the Sierra at which Triassic fossils have been discovered. The fossiliferous rocks seem to belong to the Jura-Trias area of Nevada, and this reference is strengthened by topographical considerations, for though Genesee Valley lies to the westward of the highest crests of the Sierra in this latitude, it lies to the east of a lower range, which is more directly in the line of the general trend of the Sierra. This neighborhood is auriferous, but, as already explained, gold is disseminated through a very wide area north of Nevada County. Dr. White and I did not visit Genesee Valley, its geographical position being such as not to conflict with any of our conclusions.

PALEOZOIC ROCKS OF CALIFORNIA.—Dr. Trask long since showed that Carboniferous limestones make up the McCloud Range, which stretches along the McCloud River; and near Pence's Ranch, in Butte County, Professor Whitney's party found similar limestones also fossiliferous and clearly of the same age. Professor Whitney infers, on lithological grounds, that the more westerly limestones of the gold belt further south may also be Carboniferous.

Near Baird post-office, on the McCloud River, a considerable area of granite occurs about half a mile west of the fossiliferous limestone. The interval is occupied by extremely metamorphosed sandstones, in which my party failed to find any trace of fossils. These sandstones underlie the limestone, and are probably older, but there is no evidence to show whether they belong to the Carboniferous or to some preceding formation. To the northwest of Baird thin-bedded, plicated, metamorphic shales occur, bearing a strong resemblance to those of the Knoxville series in central California. Their structure and position are such as to suggest nonconformity with the Carboniferous, but, owing to the difficulties of traversing the country, we were unable to test this relation satisfactorily in a hasty visit to the neighborhood. Not a trace of a fossil could be found even in the least altered portions of the shales, and their age is therefore entirely uncertain, the lithological resemblance to the Knoxville group amounting to a mere suggestion at such a distance from well-ascertained members of that series.

[24] Geol. of Cal., Vol. I, p. 321.

Near Pence's Ranch the shales are auriferous as well as certainly Carboniferous, at least in part. They also come in contact with Chico beds, which lie horizontally upon their upturned edges. The slates have a considerable similarity to those of the Mariposa group, and furthermore they are nearly vertical and strike in nearly the same direction as those of the gold belt proper. The question therefore at once arises whether their upheaval and metamorphism is ascribable to the same period as the uplift and alteration of the Mariposa and Knoxville beds. This is a subject which can be discussed only tentatively until a great amount of detailed work has been done in a somewhat unpromising field; but it is not too early to make some suggestions.

I think it may be asserted, as a result of all the geological work done from the Rocky Mountains to the Pacific, that there has been throughout geological time a definite tendency in the structural development of this area. The geologists of the fortieth parallel exploration showed that a fault began upon the west flank of the Wahsatch in the Archæan, the same fault which Mr. Gilbert has traced as still in progress. The last-named geologist has also detected a similar fracture on the east side of the lower portion of the Sierra. The eastern portion of the Great Basin was lifted above the surface of the ocean after the close of the Carboniferous, the western portion of the same area followed before the Cretaceous, and at one or both of these epochs the country was laterally compressed, an action no doubt closely connected with the progress of the great faults. About the time of the Neocomian, California experienced an east and west compression, and again following the Miocene was an uplift throwing the horizontal strata of the coast into north and south folds. From the Wahsatch to the Pacific Coast there thus appears to have been a recurrent, if not a constant tendency to lateral compression, in substantially one and the same direction. Now Dr. White points out that an extraordinary difference has existed between the marine fauna of the Pacific Coast and that of the waters east of the Sierra from a time prior to the Cretaceous onward, and hence that a land barrier must throughout have occupied substantially the position of the Sierra Nevada, which must therefore have experienced repeated upheavals to compensate for constant erosion. There are also said to be some paleontological grounds for supposing at least a partial separation of these areas during the Carboniferous. This supposition is in entire accord not only with the structural analogies of the region but with the detailed observations of Mr. Clarence King[25] and his colleagues, who were led to infer the existence of a continental area during the Paleozoic west of long. 117°30′, lat. 40°. Such a range as the Sierra, though partaking in the general compression and movement of the whole country, must offer a tremendous resistance, and at any one of the active periods during which the physical conditions permitted

[25] Systematic Geology, p. 534.

contortion of strata along the western flank of the Sierra, these must have been driven against the barrier until they could yield no more. Thus if a pile of cloths were compressed from their edges (as in Hall's famous experiment) with enormous energy, they would be forced into plications so sharp that the dip at any point would be nearly vertical. It seems to follow that at different upheavals, some of them perhaps as yet untraced, strata to the west of the great Sierra may have been driven into the nearly vertical position of the gold slates and their original stratigraphical relations completely obscured. I do not consider it certain, therefore, or even probable that the Carboniferous slates near Pence's Ranch first assumed their present position subsequently to the Knoxville period. It may be that they have stood nearly as now ever since the Carboniferous of Utah was raised above water, while the slates of Horsetown, of the age of which nothing is known, so far as I can see, may possibly owe their vertical dip to still earlier convulsions.

The Carboniferous slates of Pence's Ranch are serpentinoid, and, though distinctions between them and the metamorphosed Knoxville beds might perhaps be drawn, they are very similar. But just as it seems to me that successive upheavals may have produced similar results, I think the association of a certain uplift with a particular series of chemical changes in an argument for the supposition that analogous dynamical conditions might lead to molecular changes of the same kind. It seems therefore not at all impossible that both upheaval and metamorphism at Pence's Ranch were in the main earlier phenomena than those traced in the Coast Ranges. If so, their effect must have been felt throughout a great portion of California, though the results may have long since been obliterated. On the other hand, the post-Knoxville disturbance must have been felt at Pence's Ranch, though its effects may have been trifling as compared with those of earlier convulsions.

THE COAST RANGES MEMBERS OF THE WESTERN CORDILLERA SYSTEM.—As has already been stated, I am unable to see any reason for dissenting from Professor Whitney's opinion that the fossiliferous beds of Mariposa form an integral portion of the modern Sierra Nevada Range. It seems simply impossible that they should have assumed their present vertical position with a strike parallel to the crest, and that they should have been profoundly modified by chemical action except under conditions of disturbance amply sufficient to have brought about essential modifications of the whole range. That there were at the time, or at least had been previously, mountains in nearly the same position does not impair the claim of this addition to be considered as much a part of the modern Sierra as any older portion. If the conclusions thus far stated are accepted, it follows at once that subsequent to the close of the Knoxville, but long before the beginning of the Chico, both the Sierra and the Coast Ranges experienced an upheaval. This was in all probability not the first in the line of the Sierra and very possibly did not actually originate the Coast Ranges, but for the latter it is the first distinctly

traceable movement. It is conceivable that within the limits of time indicated two upheavals should have taken place, one affecting only the Sierra, the other only the Coast Ranges; but the probability of this alternative will scarcely be seriously maintained. The earlier determinable portion of the Coast Ranges must therefore be considered as due to the same disturbance which added the gold belt proper to the Sierra Nevada. There is much probability that a portion at least of the Cascade Range was elevated and metamorphosed at the same time. The relationship thus established is brought out more clearly by a comparison of the history of the ranges so far as it can be traced.

Both the Sierra Nevada and the Coast Ranges were above water and underwent erosion during the interval between the Knoxville and the Chico epochs. Both ranges also sank just before the beginning of the Chico, admitting the ocean over a great part of the Coast Ranges and over considerable areas at the base of the Sierra. Both appear to have risen partially before the Téjon, particularly toward the north; at least, the rocks of this epoch, so far as is known, are confined to the southern extremity of the Sierra and to the Coast Ranges south of Martinez. A subsidence would appear to have taken place before the Miocene; rocks of this age extending along the Sierra far to the north of the Téjon localities, while in the Coast Ranges they lie directly upon the metamorphic at a great number of points, clearly indicating a lower general level than during the preceding epoch. During the Pliocene very little of either range was below water.

Not only was an important uplift of the Sierra Nevada contemporaneous with the first known upheaval of the Coast Range, but, even with the imperfect information at command, it is clear that the successive fluctuations of level of the country since the close of this disturbance have affected these ranges substantially in the same manner, and I cannot but conclude that the new facts brought forward necessitate the reference of the Sierra Nevada and the Coast Ranges to a single mountain system. The Coast Ranges are, and probably always have been, of less altitude than the great Sierra, and they have consequently been more extensively immersed, just as would be the case if both were now to sink any given number of thousand feet. Between the Miocene and Pliocene periods the Coast Ranges also suffered disturbances, in which at least the western base of the Sierra seemed not to have shared. The Sierra, too, has undergone some faulting in which neither the Coast Ranges nor the Basin Ranges have shared; but these differences do not appear to me sufficient to counterbalance the important coincidences in the history of the ranges.

In portions of the Cascades the Miocene rests directly upon the metamorphic as it so often does in the California Coast Ranges, but to the east of the Cascades Chico beds occur, showing that the range was at least broken through at certain points. I greatly incline to the belief,

however, that this range is structurally one of the northern continuations of the united Coast Ranges and Sierra Nevada, though but a portion of it may have emerged from the sea at the same time as the more southern ranges. The great valley of California was evidently covered by water in comparatively recent times, as eastern Oregon was in the Chico, and as the Gulf of California is now. Dr. White points out that the occurrence of fossils of the eastern zoölogical province west of the Sierra Madre, shows that the peninsula of California was at one time the line of the barrier between the eastern and western seas. This appears to me conclusive, and yet there is much remaining to be settled as to the relations between the Sierra and the ranges from Arizona southward. They may still turn out to belong to a single system, though at some time the eastern members of the chain may have been broken sufficiently to admit the ocean while the western ranges were intact, just the reverse of the present condition.

The views taken in the foregoing pages have a perhaps not inconsiderable advantage in more closely harmonizing the topography and geology of the west coast. Any good topographical map of the Western United States seems to indicate some such structural relations as those which have been presented here from a geological point of view. Or conversely, if the conclusions reached are accepted, it appears that just as comparatively small fissures, such as are met in mines, are almost never simple, but branch or divide and meet again while following one dominant course, so the great lines of disturbance which have determined the geographical features of a large portion of the country unite, divide, and throw out shoots with an irregularity in detail underlying which a dominant tendency is clearly perceptible. I do not believe that such a system could have come into existence piecemeal, but rather that all its main outlines originated, like the great Wahsatch fault, long before the earliest of our fossiliferous strata.

SAN FRANCISCO, CALIFORNIA, *February*, 1885.

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