RELATION OF THE ORE DEPOSITS OF THE SOUTHERN ROCKY MOUNTAIN REGION TO THE COLORADO PLATEAU

DISCUSSION

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In his excellent paper, Dr. Butler[2] has brought out the salient features of the relations of the Colorado Plateau to the bordering mountain areas, and has advanced a general hypothesis to account for the relations found. He states: "Can it be reasonably inferred then that the concentric folding around the northern portion of the Colorado Plateau had its origin in the collapse of a bordering basin of sedimentation? * * * It would seem that the primary cause was one that affected a very large area and that within this area the degree of folding in individual basins was dependent on the stage of weakness that they had reached. * * * All basins, however, were points of weakness, though of different degree, and responded in different degree to the wide-spread cause of the Tertiary revolution." With these ideas the writer is in hearty accord. In the paper, however, the relations found on the southern and southwestern borders of the Colorado Plateau were not sufficiently discussed. Why should the demarcation between plateau and mountains be so distinct in Arizona? As contrasted to this, why should the southern limits of the plateau in New Mexico be so vague? In both places, there is an apparent lack of geosynclinal basins at all comparable to those found on the eastern, northern and western borders of the Plateau. In Arizona, the mountain and plateau provinces are separated along a distinct line, quite similar to the lines of demarcation in Utah, southern Wyoming and Colorado. In New Mexico,

[1]Geologist, Arizona Bureau of Mines.
[2]Butler, B. S., Relation of the ore deposits of the Southern Rocky Mountain region to the Colorado Plateau: Proc. Colo. Sci. Soc. Vol. 12, pp. 23-36, 1929.

there is no distinct boundary. Why should this be so? In the following paragraphs, a tentative explanation, based on the same general hypothesis advanced by Dr. Butler, will be offered to account for the seeming discrepancies.

In the following discussion, by the term geosyncline is meant an area of the crust of the earth on which has been deposited a relatively great thickness of sediments, whether as a continuous process or not. It is assumed that in these areas, the deposition at various geologic times, more or less interrupted by minor uprisings, has had the effect of causing a zone of weakness in these areas due to repeated downwarping, or to be in itself the result of an inherent zone of weakness. The position of the sea-ways into these basins is not held to be important to the structural problem under consideration. The ultimate effect at the initiation of the Tertiary revolution is alone stressed. The writer does not suppose that the Plateau region was a persistent land mass, surrounded at all times by a basin of deposition, but rather that it was prevailingly a positive area, and that at different times, during the Paleozoic and Mesozoic, basins of deposition were present on its margins. It is maintained that at the time of Tertiary revolution, this positive area was surrounded by basins of deposition, which formed a more or less continuous belt of weakness around it.

SEDIMENTATION IN SOUTHERN ARIZONA, SOUTHERN CALIFORNIA AND NORTHWESTERN MEXICO

No evidence exists in the mountain province of Arizona of a deep geosyncline during Paleozoic time. (Physiographically, as outlined by Ransome[3], and as here and hereafter referred to, the state is divided into plateau, mountain, and desert provinces.)

In the northwestern part of the mountain area, extending from Boulder Canyon to Payson, a distance of about 220 miles, any Paleozoic sediments, if they were ever deposited,

[3]Ransome, F. L., The copper deposits of Ray and Miami, Ariz.; U. S. Geol. Surv., Prof. Paper No. 115, p. 27, 1919.

have been entirely removed by erosion. Lindgren[4] has presented evidence that a part of this area, in the Bradshaw Mountains, probably never was covered.

At Payson, only a thin skin of lower Paleozoic sediments exists. Here the base of the section was formed, in part, of an extremely resistant pre-Cambrian quartzite series.[5]

At Roosevelt Lake, the section, including the Apache series, possibly in part pre-Cambrian, measures about 2,600 feet with Cambrian, Upper Devonian, Mississippian, and Pennsylvanian represented.[6]

At Globe and Ray, the section is similar to that at Roosevelt Lake, and measures 2,640 feet.[7]

At Morenci, the section is very thin, and together with the overlying upper Cretaceous, measures about 1,100 feet, with the Apache series missing.[8]

In the Catalina Mountains, the same general section obtains as at Globe and Roosevelt Lake, and measures about the same.[9]

At Bisbee,[10] and in the neighboring ranges in the southeast corner of the state, the Paleozoic section, including Upper Cambrian, Upper Devonian, Mississippian and Pennsylvanian, measures about 5,000 feet. Above this, without marked angular uncomformity, are from 4,000 to 5,000 feet of Comanche beds. The section in this part of the state is the thickest of any measured, but does not compare with the sections found in Western Utah, the Wyoming basin, Denver basin, and Raton basin.

In none of the foregoing sections are any beds found higher than Pennsylvanian, except at Morenci and the southeastern corner of the state. In the Chiricahua Mountains, on

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[4]Lindgren, Waldemar, Ore deposits of the Jerome and Bradshaw Mountains quadrangles, Arizona; U. S. Geol. Surv. Bull. No. 782, pp. 11-13, 1926.

[5]Wilson, E. D., Proterozoic Mazatzal quartzite of central Arizona; Pan-American Geologist, vol. 38, pp. 229-312, 1922.

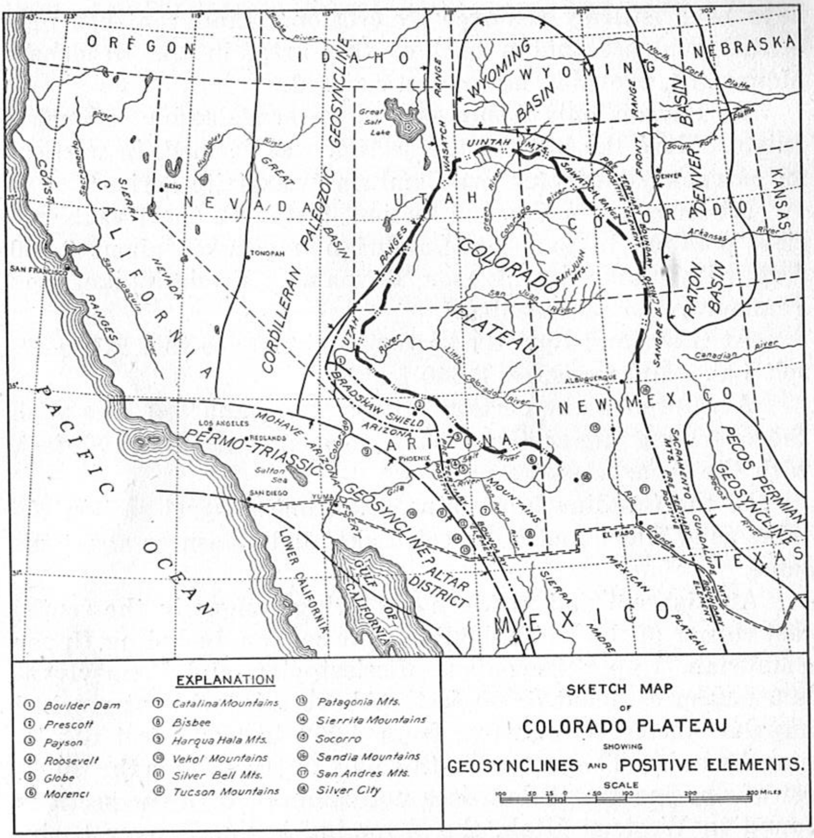
[6]Ransome, F. L., Some Palezoic sections in Arizona and the correlation; U. S. Geol. Surv., Prof. Paper, No. 98, p. 150, 1916.

[7]Op. Cit. pp. 39-50.

[8]Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Arizona; U. S. Geol. Surv., Prof. Paper No. 43, 1905.

[9]Darton, N. H., Résumé of Arizona Geology; Ariz. Bur. of Mines, Bul. No. 119, p. 292, 1925.

[10]Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona; U. S. Geol. Surv., Prof. Paper No. 21, pp. 27-73, 1904.



the border of New Mexico, the Paleozoic section includes Permian. Very little angular unconformity exists in this area between Paleozoic and Comanche beds, although the evidence points to a large erosional unconformity, with the development of large-throw normal faults during the interval, such as the Dividend fault at Bisbee.[11]

On the southwest border of the mountain province, and throughout the desert province of Arizona, the Altar district of Northwest Mexico, and the southern end of the Mohave

[11]Ransome, F. L., Op. cit. pp. 85-104.

desert of California, conditions are markedly different. The Paleozoic sediments, where found, are extremely metamorphosed. In the Buckskin, Harcuvar, and Harquahala Mountains, remnants of Paleozoic sediments are found, intensely folded, almost completely marmorized beds, occurring with interbedded schists, quartzites and slates. Fossils are rare, but such as have been found have been identified as Paleozoic.[12]

Remnants of marble and quartzite occur at numerous places in the deeply eroded desert ranges to the south. Further southeast, in the Vekol and Silver Reef Mountains, thick Paleozoic sections, intensely faulted, folded, and metamorphosed, have been measured.[13]

In the Silver Bell, Santa Rita, and Patagonia Mountains, erosion remnants of much marmorized, folded, and faulted Paleozoic beds are found, the sequence corresponding generally to the Bisbee section. In the Tucson, Waterman, and Sierrita ranges, a large part of the sediments found have yielded a sparse Permian (Kaibab) fauna.[14]

From the Altar district, Mexico, specimens have been brought to the Arizona Bureau of Mines, containing abundant marine Triassic fossils. Thick Paleozoic sections have also been reported from some of the ranges in this district, but no study of the area has yet been made.

To the west of the Colorado River, in the Mohave Desert ranges in California, the state geological map shows remnants of highly metamorphosed Paleozoic sediments. Thick sections are reported from the vicinity of Redlands. None of these sections have been studied in detail. The trends of the mountains in Southern California and in the Altar district are northwest to east-west, corresponding to the trends in the desert and mountain provinces of Arizona.

Sedimentation in New Mexico

In New Mexico, the eastern edge of the Colorado Plateau is marked in the north-central part of the state by the Sangre

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[12]Darton, N. H., Résumé of Arizona Geology; Ariz. Bureau of Mines Bul. No. 119, pp. 218, 220, 221, 222, 223, 1925.
[13]Darton, N. H., Op. cit. pp. 75-78, 264, 269, 287, 288.
[14]Darton, N. H., Op. cit. pp. 75-78.

de Cristo Mountains. West of the Sangre de Cristo axis, the Plateau has no distinct boundary. It merges gradually with the northern extension of the basin and range province to the south, characterized by long narrow anticlinal folded mountains and wide intermountain valleys, with north-south axes. This basin-range province merges at the south with the intermountain central plateau of Mexico.

To the east of the Sangre de Cristo range is the Mesozoic Raton geosynclinal basin. West of the Sangre de Cristo axis, and extending south to the Mexico-Texas border, thin stratigraphic sections are the rule. In the north the first sediments to appear are Pennsylvanian. Interrupted partly continental deposits occur, ranging in age from Pennsylvanian to upper Cretaceous, including Permian, Triassic, Jurassic, and upper Cretaceous. In the south, sedimentation started in upper Cambrian time and continued with many breaks through Comanche time, including Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian, and Comanchian. To the east of the basin and range area, in the southeastern part of the state, a moderate Permian geosyncline exists, formed largely of red beds and gypsiferous limestones. Darton[15] has measured numerous sections throughout the state, some of which are given below.

Socorro section, Pennsylvanian to upper Cretaceous, 4,320 feet.

Sandia Mountains section, Pennsylvanian to upper Cretaceous, 3,000 feet.

San Andreas Mountains section, Ordovician to Permian, 2,374 feet.

Silver City Section, Ordovician to Comanche, 4,640 feet.

The sediments met with, except where locally altered by intrusions, are as fresh and unaltered as those found in the flat-lying Grand Canyon section of the Colorado Plateau region. Certainly no geosyncline exists in western New Mexico.

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[15]Darton, N. H., "Red Beds," and associated formations in New Mexico; U. S. Geol. Surv., Bull. No. 794, pp. 66, 94, 184-191, 341-342, 1928.

AGE OF POST-PALEOZOIC—PRE-COMANCHE UPLIFT

The evidence as to the exact age of this uplift in the southern Rocky Mountain area, and especially that part south and southwest of the Colorado Plateau, is meagre. The principal line of evidence is the character of the sediments found in the southern part of the Plateau, assuming derivation from land masses to the south. After the deposition of the Permian Kaibab limestone, there was a gentle uplift in the Plateau, accompanied by very little erosion. The next beds to be deposited were the lower Triassic Moencopie fine sands and silts. These silts are of extraordinary comminution. They could not have been derived from high ground, but must have been deposited from extremely sluggish streams, rising and flowing over a nearly level low-lying land to the south. Immediately above the Moencopie beds are the lower or middle Triassic Shinarump and Chinle formations, composed of conglomerates and coarse sandstones containing abundant silicified fragments of mountain-growing trees. Above the Chinle formation was deposited a series of highly cross-bedded even-grained sandstones of probable eolian derivation, of Jurassic age. This basal Mesozoic series on the Plateau would suggest a probable gentle uplift of the area to the south during late Permian and early Triassic, followed in lower or middle Triassic by an intense mountain building period. The age of the uplift would appear, therefore, to be somewhat earlier than the first Sierra Nevada disturbance in California.

TENTATIVE HYPOTHESIS

The following suggested causes of the formation of the mountains bordering the Plateau on the southwest, and the absence of demarcation of the Plateau on the south, are suggestive only. The final solution will have to await careful study for confirmation. The sparse evidence given above, merely suggests the possible solutions offered in the following paragraphs.

The first of these hypotheses is that the positive Plateau element was much larger in pre-Tertiary time, and included a large part of the southeast portion of Arizona, all of southwest New Mexico, and probably a part of the present intermountain central Mexico highland. The absence of pre-Tertiary folding in this area, and the similarity throughout, of thin much-interrupted Paleozoic and Mesozoic sediments, are the principal lines of evidence.

The second hypothesis is that a deep Permo-Triassic geosyncline was developed in southwestern Arizona; in the Altar district, Sonora, Mexico; and in southern California. It is presumed that the long axis of this trough was northwest to east-west, and that seaway was through to the Pacific in the vicinity of Los Angeles. It is further assumed that during lower Triassic time the sediments in this trough were folded into a mountain chain, the thrust being to the northeast against the positive pre-Tertiary Plateau element. Erosion then proceeded and continued to the initiation in upper Cretaceous or early Tertiary time of the Tertiary revolution. At the outbreak of this world-wide disturbance, the old Triassic mountain range had been base leveled, and most of the sediments stripped from it. The line of weakness of the older geosynclines still existed, and the Tertiary mountain-building forces tended still further to crumple the edges of the geosynclinal down-warped troughs. This last revolution was so much more violent than the preceding ones that the tendency was to build up mountains at the expense of the more positive elements. In Arizona, the result was the formation of the present fault-block mountain ranges out of the border of the older plateau element, parallel to the older Triassic mountain chain. The new border of the plateau was partly fixed by the existence of a strong positive shield extending from Boulder Canyon to Payson, similar to the Front Range—Sangre de Cristo shield forming the eastern border of the present plateau in Colorado and northern New Mexico. The site of the Triassic mountains was again subjected to mild mountain-building forces, resulting in the basin range fault block or anticlinal block mountains of the Arizona, northwestern Mexico, and southern California desert province.

Renewed erosion in the desert ranges has stripped off all but occasional remnants of the folded sediments of the old geosyncline.

On the southern border of the Colorado Plateau, in New Mexico, the absence of any marked down-warped geosynclinal basins, except the relatively moderate Permian Red Bed basin to the southeast, prevented, during the Tertiary revolution, the formation of any major mountain masses. Here the plateau merges gradually into the gently folded anticlinal mountain chains and cuestas characteristic of the high intermountain plateau of central Mexico.

The hypotheses outlined in the preceding paragraphs are suggestive only, and are presented, in this discussion, for what they are worth, as a basis for future investigation. Proof of the existence of the postulated Permo-Triassic geosyncline will depend on the result of a careful stratigraphic study in the Altar district, and in southern California.

The above hypotheses appear to the writer to explain best not only the causes of the prevailing northwest trend of the Arizona, Altar, and southern California mountain ranges, but also the cause of the deeper erosion in the desert province than in the mountain province of Arizona.

The accompanying sketch map will aid in following the discussion.

The writer is indebted to Mr. E. D. Wilson, and Mr. R. E. S. Heineman, of the Arizona Bureau of Mines, and to Dr. B. S. Butler, for criticisms and suggestions.

Oct. 14, 1929, Tucson, Ariz.