

## DISCUSSION

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This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

### *PHYSIOGRAPHIC CONDITIONS AND COPPER ENRICHMENT.*

*Sir:*—The interesting article by Professor W. W. Atwood on "The Physiographic Conditions at Butte, Montana, and Bingham Canyon, Utah, when the Copper Ores in these Districts were Enriched," as published in a recent number of this journal, represents one of the few attempts that have been made to correlate physiographic history with the development of metallic veins. As stated by the author, it was preceded several years ago by a somewhat similar article by Mr. J. B. Umpleby, regarding a district in central Idaho. Although addressed primarily to economic geologists, Mr. Atwood's paper raises anew an old question that has been discussed for years by S. F. Emmons, Powell, Willis, Daly, Lindgren, Calkins, and others—the ages of the existing features of Rocky Mountain topography. On reading this latest contribution one is likely to miss the essential fact that this is distinctly a debatable and indeed debated group of questions. I therefore avail myself of the well-appreciated opportunity offered by the "Discussion" column of this journal, to point out some of the considerations on the other side of the controversy.

During some ten or twelve field seasons in the Rocky Mountains, including districts immediately adjacent to those discussed

by Mr. Atwood, I have studied many of the same phenomena, but have reached different conclusions on several points. Some of these questions I have already discussed in print elsewhere,<sup>1</sup> but since many readers of ECONOMIC GEOLOGY may not have seen the articles, it may be well to restate here very briefly those considerations which apply to the case in hand.

From his observations Mr. Atwood was led to agree with some of his predecessors that the tops of many mountains in western Montana and central Idaho represent an ancient peneplain, and that this plain was cut during the Eocene period. Granting the existence of the peneplain, it seems to me that the Eocene age of it is far from satisfactorily established. The evidence given by Mr. Atwood in support of this hypothesis is that there are broad deep-branching valleys below the peneplain level, and that these valleys are now partly filled with Oligocene and Miocene sediments. Perhaps he omitted some pertinent facts bearing on these questions. At any rate I find nothing in his paper to indicate that he considered two other possibilities, viz.: (a) that the Tertiary deposits were folded or faulted downward below the base-level of erosion, and among masses of harder rock; that this mosaic was afterward planed off, and that the broad valleys were subsequently excavated on the outcrops of the Tertiary formations solely because of their relative weakness; or (b) that early in the Tertiary period these valleys were excavated, were afterward filled with Oligocene and Miocene sediments and the entire region was thereafter reduced to a peneplain at a level considerably above the bottoms of the original valleys, but below the tops of the aggradation plains. I think it must be admitted that either of these chains of events (or some combination or variety of them) would have brought about conditions similar (although not identical) to those described by Mr. Atwood. These hypotheses are illustrated by the diagrams, Figs. 20, 21 and 22.

<sup>1</sup> "The Old Erosion Surface in Idaho: a Criticism," *Jour. of Geol.*, Vol. XX., 1912, pp. 410-414.

"Post-Cretaceous History of the Mountains of Central Western Wyoming," *Jour. of Geol.*, Vol. XXIII., pp. 193-207.

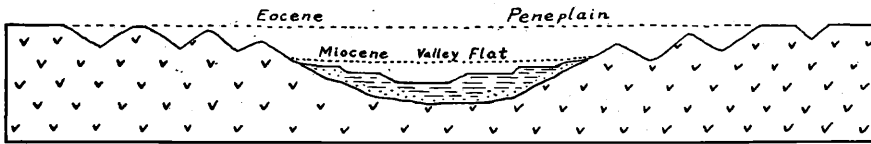


FIG. 20. An Eocene plain cut across folded Cretaceous and older rocks. Later broad and deep valleys were excavated and then partly filled with Oligocene and Miocene sediments. In still more recent time streams have partly dissected the filling. (Essentially Mr. Atwood's conception.)

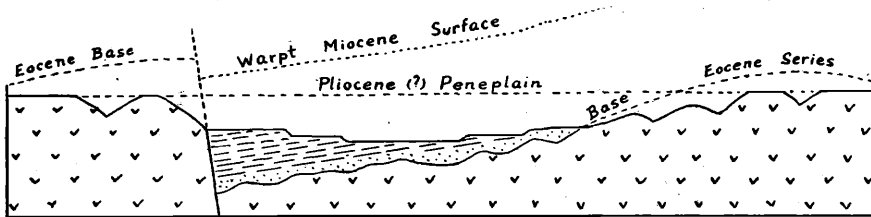


FIG. 21. An early Tertiary surface, either plain or hilly, on which a thick series of Tertiary sediments was deposited. Afterward the region was gently folded and faulted so that the Tertiary beds were left alternately above and below base-level. In post-Miocene times a period of comparative quiescence permitted the cutting of a plain over the entire district, but some of the weak Tertiary deposits were preserved because they were far below base-level. In consequence of a later uplift streams rapidly excavated and planed the Tertiary deposits down to a new base-level and at the same time carved canyons and ravines in the harder rocks adjacent.

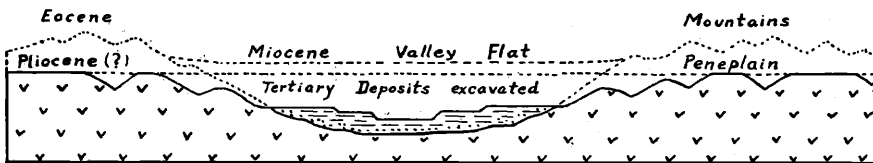


FIG. 22. A broad, deep valley was excavated early in the Tertiary period and then more or less completely filled with Oligocene and Miocene deposits. The region was thereafter reduced to a peneplain, but a part of the Tertiary deposits were so far below base-level that they could not be removed. Subsequent rejuvenation of the region permitted the streams to intrench the Tertiary beds quickly and reduce them to a new plain, while the harder rocks adjacent were carved into mature topography with occasional remnants of the peneplain. On this hypothesis deformation of any kind is eliminated.

It is not necessary, however, to leave the question of age in doubt among three or more possibilities. Both Umpleby and Atwood describe the summit peneplain as being approximately level, although varying gradually from 6,000 feet to 8,000 feet, and in Idaho to 10,000 feet above sea-level. It can be reconstructed, according to Mr. Atwood, by "lifting certain tilted blocks, straightening out some warped surfaces and filling the great intermontane troughs in the old peneplain" (page 707). It appears, however, that these places of warping and faulting are somewhat exceptional, and on the whole remnants of the peneplain stand nearly everywhere at the elevations above mentioned. On the other hand the early Tertiary sediments, which are supposed to have been deposited in valleys excavated out of the peneplain, are in many parts of Montana, Wyoming, and Idaho considerably deformed. It is common to find them tilted at angles of 5, 10, and 15 degrees. In a number of places folds with dips ranging from 25 to 50 and even 80 degrees have been found. In many places the beds have been broken by faults, and of these some have displacements of as much as 10,000 feet. Some of these facts are stated in Mr. Atwood's paper, but there are many more instances in print. It is difficult to see how any Eocene peneplain could retain an approximately horizontal attitude and nearly uniform elevation over a large part of two or more states, while sediments that have been subsequently deposited upon it were tilted, folded, and faulted to this extent.

It is well worth noting also that abundant evidence is being brought to light from time to time indicating that the existing topographic features of large areas have been produced almost entirely within the Pleistocene period. Such facts come from California, the Rockies, the Colorado plateau, Alaska, the Alps, and from many widely scattered regions over the globe. Indeed, on such general grounds it may fairly be doubted whether there is anywhere in existence a topographic feature as old as the Eocene and perhaps not older than the Miocene, excepting, of course, such ancient topographies as have been recently exhumed by the removal of later deposits.

These considerations lead me to think that the peneplain not only is not proven to be of Eocene age, but that the evidence is rather in favor of believing that it was carved after the mild de-formative movements which followed the deposition of the Mio-cene sediments. In this connection it is significant that during the last twenty years peneplains of post-Miocene age have been reported from many other parts of the Cordilleran province by such men as Willis, Ball, Huntington, Davis, Robinson, Ransome and even by Mr. Atwood himself.

Therefore, while it is possible that an Eocene peneplain exists in western Montana and vicinity, the presumptions are against it, and we have a right to demand of its advocates more convincing evidence than they have yet presented.

ELIOT BLACKWELDER.

#### *PHYSIOGRAPHIC CONDITIONS AND COPPER ENRICHMENT.*

*Sir:*—Mr. Blackwelder has kindly submitted to me the above statement and asked that I have my reply appear, if possible, in the same number of your magazine.

The question at issue is the age of the summit peneplain in western Montana and eastern Idaho, adjoining the district studied by Mr. Blackwelder in Wyoming. I regret now that I did not treat this question more fully, and debate the alternative hypotheses which Mr. Blackwelder has urged, and which I considered while at work in the field.

In Mr. Blackwelder's figure No. 1 he has shown what is essentially my conception of the physiographic evolution. It should be remembered, however, that the troughs in which the Oligocene and Miocene sediments rest were not developed so much by stream erosion as by the warping and faulting of the peneplain. In considering the alternative hypotheses I should like to make the following points:

1. If the Oligocene and Miocene sediments were present at the peneplain horizon before the faulting and deformation by warping took place, should not some one of us who have been at work

in this portion of the Rocky Mountains have found remnants of those sediments upon that peneplain surface?

2. I found no evidence, in the region I examined, indicating that a peneplain had been developed upon the surface of the Oligocene and Miocene sediments. Such evidence should, I believe, be present if the peneplain is of post-Miocene age. Mr. Umpleby has reported that lake-shore features cut during Miocene times about the margin of Miocene deposits yet remain. This would not be so if the region examined by him had been peneplained after the close of the lake period.

3. The deformation of the Tertiary sediments is granted, as Mr. Blackwelder states, in my paper, but this deformation came, I believe, in association with a late Tertiary period of mountain growth when, through arching and renewed faulting, the mountains of today received essentially their present elevation.

4. The field evidence which I think will be most helpful in this whole discussion, and which I may not have called sufficient attention to in my article, comes from the distribution of the Oligocene and Miocene sediments, shown in Fig. 52, page 710, of my original article. The Tertiary sediments involved in this problem rest not only in the intermontane troughs, but, in a number of instances, they cross the mountain ranges where they rest in passes cut several hundred feet below the even crest line of the mountains. I would refer to localities Nos. 23, 26, 27, 31, and 32, in Fig. 52 of the original article. In Fig. A of Plate XXXIV. in the original article a view of Beaverhead Range from the southwest is shown. The crest line is a portion of the old summit peneplain. A little to the right of the center is the pass now used by the railroad and located where the number 26 is on Fig. 52. The Tertiary sediments rest at higher and higher elevations on the two sides of the mountains until they partially fill the pass. In this pass these sediments are at least 200 feet thick, and have very evidently been uplifted in the late Tertiary period of mountain growth when this range attained its present altitude. They rest in a saddle, astride the mountain range. The pass in which these sediments are is certainly an old stream

course through this range. The base below the Tertiary sediments is at least 500 feet below the old summit peneplain which appears at either side of the pass in the crest of the range. Was not the notch cut after the uplifting of the peneplain and before the Oligocene and Miocene sediments which rest in it were deposited? Therefore, is not the age of the notch pre-late Oligocene? The peneplain was uplifted before the notch was cut, and it was certainly developed before it was uplifted, therefore, I again come to the conclusion that the peneplain in the region I studied must be pre-late Oligocene, and I believe it was developed by the close of Eocene time. This is not an isolated example. Remember, there are five similar cases within the region studied, and I see no way to avoid that sequence of events in the physiographic history and that geologic dating of the age of the summit peneplain.

I take pleasure in agreeing with Mr. Blackwelder in the belief that our relief features in the Cordilleran provinces of North America are exceedingly young. I hope others will believe that certain peneplains that I have described are of very late Tertiary age. I believe that most of the great canyons in our western mountains and high plateaus have been excavated during and since the Pleistocene time. However, I am not convinced that there are no topographic features in existence as old as the Eocene sediments, and the more I think of the physiography of the western portion of the continent, the more firmly I believe that there has been variety in the relief of that portion of the continent throughout post-Cretaceous time. I have given up the thought that there was one period of widespread peneplanation when the entire Cordilleran region was near to base level, and now favor the working hypothesis that while certain regions were high, others were low, and the relief has been different in degree, yet of the same general type that we now have in the Cordilleran provinces.

WALLACE W. ATWOOD.