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AGE OF THE HIGH EROSION SURFACE IN THE WYOMING RANGES

by

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CONTENTS

ILLUSTRATIONS

ABSTRACT

Although absolute evidence is lacking, it is possible to date approximately the age of the high erosion surface which is preserved in the Uinta, Beartooth, Bighorn and Wind River ranges in Wyoming. The evidence of a climatic change toward greater aridity in the Great Plains substantiates the Lower Miocene epirogeny postulated by Eardley. The distribution and character of Tertiary sediments seem to suggest that the surface was formed just prior to this uplift. Papers by Bradley on the Uinta Mountains, and by Bevan on the Beartooth Mountains, indicate the same approximate age for the surface in these regions. The Wind River-Sweetwater Plateau surface described by Bauer, the Medicine Bow-Laramie surface described by Blackwelder, and the surface of southwestern Idaho described by Mansfield may, with suggested modifications, be fitted into the general picture of a late Oligocene-lower Miocene high erosion surface.

THE PROBLEM

Geologists have long recognized the presence of a high erosion surface in the Wind River and other ranges of Wyoming. Agreement on its existence is almost unanimous, but as yet there is a diversity of opinion concerning its age. A review of the literature indicates that authors have variously assigned all ages from Late Eocene to Late Pliocene to its stages of maximum development. Blackwelder, Branson, Love, (1937) and Atwood and Atwood (1938, pp. 957-978) have favored a Pliocene age for the Wind River "peneplain", whereas Bradley, Baker (1912, p. 73), and Bauer favor an earlier age. Mansfield, Mackin, and Bevan have also indicated earlier ages for the surfaces in other ranges.

The time required to form an extensive graded surface varies in length depending upon various factors such as the climate, the stream gradients, and the resistance of the bedrock to weathering. It is evident, therefore, that some portions of a large surface may reach grade before others, and that interruptions of the erosional cycle may occur over parts of the surface before others. It does not seem possible, nor is it very significant to the geologic history, to decide, for example, whether the age of a surface is Late Eocene or Early Oligocene. It is, however, of great importance for an understanding of the post-Cretaceous history of Wyoming to be reasonably certain whether the high erosion surface, so strikingly developed in the Wind River, Bighorn, Uinta, Beartooth, and other ranges in Wyoming, is Eocene, Miocene, or Pliocene. It is also possible that the high surfaces in the several ranges did not reach the stage of maximum development at the same time, but from a comparative study of the several ranges Eardley (personal communication) believes there cannot be a great age difference.

DESCRIPTION OF SURFACE WHERE BEST DEVELOPED

Wind River Range

The dissected surface which is developed along the crest of the Wind River Range has been called the "Summit peneplain", the "Wind River peneplain", and the "Freemont surface" by various writers. It is best developed in the northern part of the range east of Indian Pass, at Goat Flat and at Horse Ridge (Westgate and Branson, 1913, p. 146). Remnants of the surface consist of numerous tabular, flat-topped areas which occur in the central portion of the range in an area 20 to 30 miles wide. From the highest remnants at 12,500 feet the surface slopes gently eastward to the edge of the crystallines and the Bighorn dolomite at about 10,000 feet. In the southern part of the range the elevations vary from 9,000 to 8,500 feet (Bauer, 1934, p. 694). Blackwelder reconstructs the surface as a "region reduced largely to flatness but with subdued mountains and hills with a relief of less than 1,500 feet near the divide, i.e., a state of early old age" (Blackwelder, 1915, p. 194).

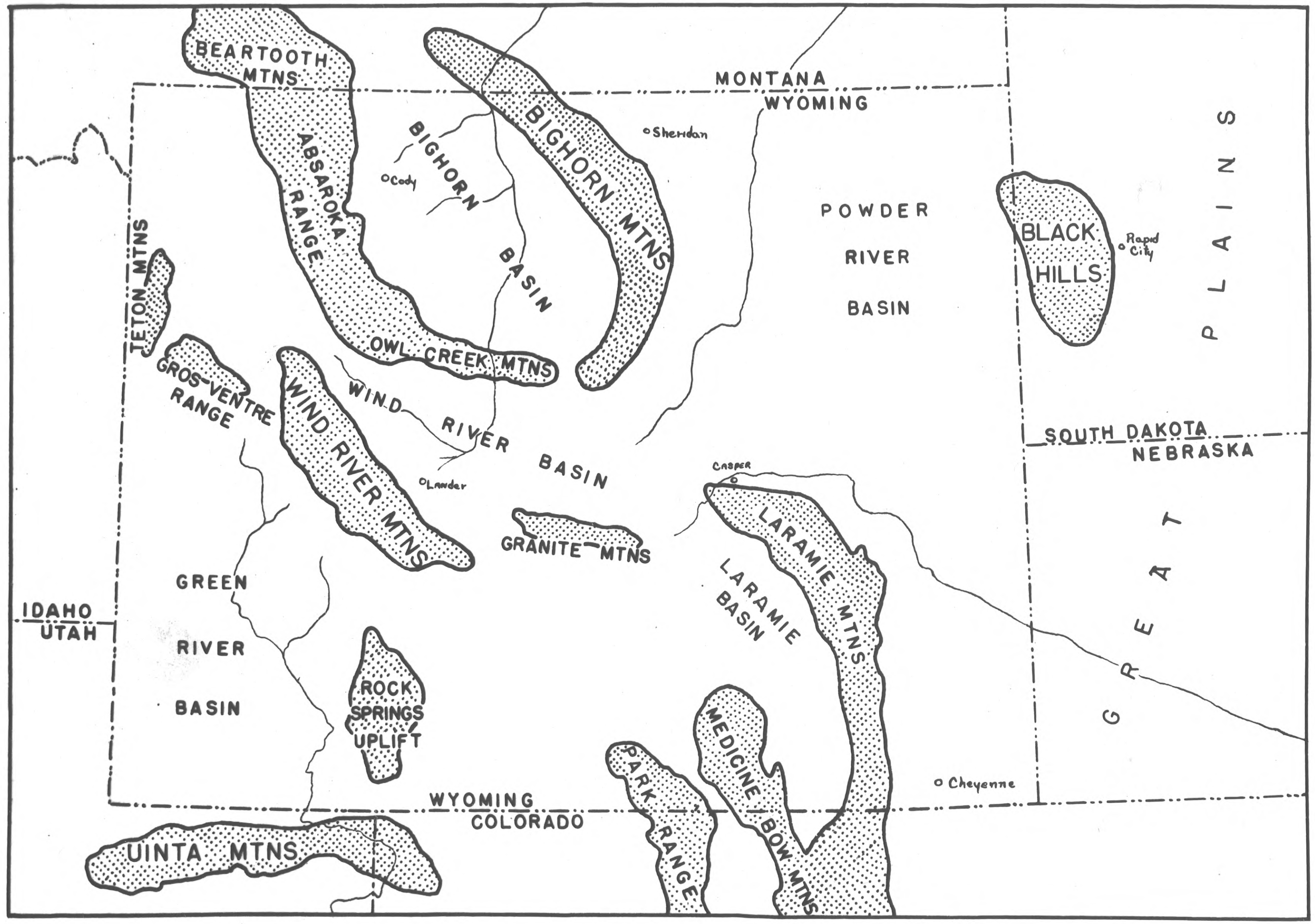


FIGURE I INDEX MAP OF THE WYOMING RANGES AND BASINS

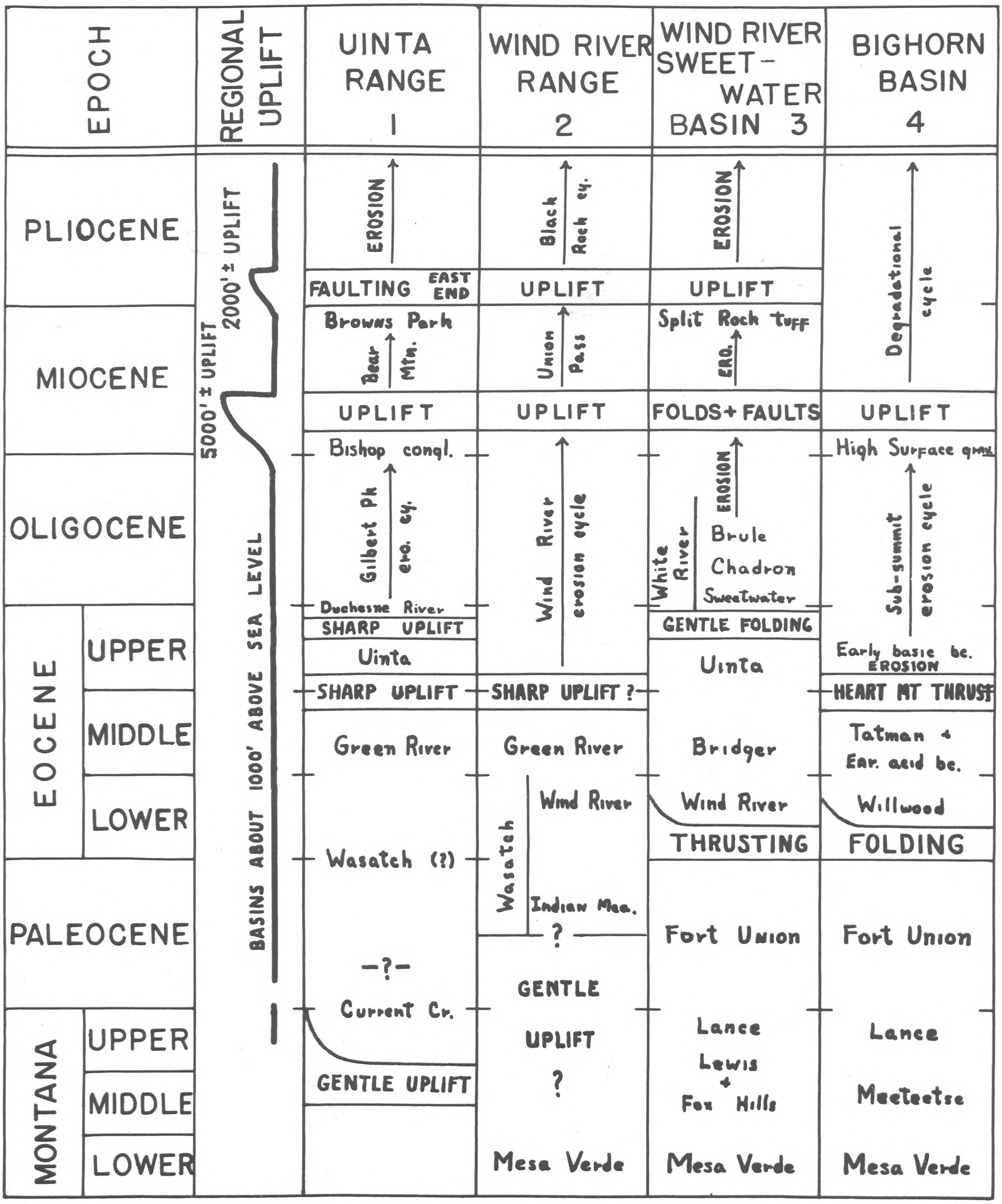


FIGURE 2 CORRELATION CHART OF DEFORMATIONAL, DEPOSTTIONAL, AND EROSIONAL EVENTS OF THE WYOMING RANGES AND BASINS

Chart prepared by A. J. Eardey from (1) Walton, 1944, and Bradley, 1936; (2) Love, 1937, and Blackwelder, 1915; (3) Love, 1937, Hares, 1946, and Tourtelot, 1946; and (4) Hewett, 1926, Pierce, 1942, Van Houten, 1944, and Mackin, 1937.

The surface truncates both hard and soft members of the Archean complex. It does not, however, extend beyond the Paleozoic formations, and no known Tertiary sediments rest upon it or are beveled by it. Branson and Branson (1941, p. 143) have described a deposit of fanglomerates along the northeast front of the mountains near Dinwoody Creek which is believed to be cut by the surface. It occurs at an elevation of 7,500 feet and rests on tilted Triassic and later Paleozoic beds. These gravels, the Burnt Gulch conglomerate, are supposedly of Miocene or Pliocene age, but there is no fossil evidence. The age assigned to them seems to be based on the assumption that they were formed just prior to the Wind River "peneplain", which the authors believe to be Pliocene. It is unfortunate that there is no fossil evidence of the age of these beds.

No mention of a gravel veneer on the surface is made in the literature.

Beartooth Mountains

Arthur Bevan reports the presence of two surfaces, the Summit peneplain and the Subsummit peneplain, in the Beartooth Mountain region (1925, pp. 563-587). The best remnants of the older surface, the Summit peneplain, are found along the main axial divide north of the Wyoming boundary. They consist of tabular peaks and broad flattish ridges which extend for about 20 miles along the axis of the range and for about 8 miles perpendicular to it. The elevation of the surface ranges from 12,850 (Granite Peak) to approximately 12,000 feet. No information was given on the type of surface mantle, if any.

The surface is younger than the Beartooth overthrust which in part may be contemporaneous with the post-Middle Eocene Heart Mountain overthrust (Bevan, 1925, p. 573). It is older than the Subsummit "peneplain". Its absolute age cannot be determined by local evidence, such as beveled Tertiary beds. However, on the basis of several lines of suggestive evidence, to be discussed later, Bevan has assigned it an Oligocene age.

Bighorn Mountains

To date there is only a small amount of information available on the upland surface of the Bighorn Mountains. On the northern third and southern third of the range, sedimentary beds form areas which extend along the axis of the range with a width of 10 to 20 miles at uniform elevations of 9,000 and 8,000 feet, respectively (Fenneman, 1931, p. 160). Since this surface closely corresponds to the dip of the beds, it is uncertain whether peneplanation has occurred. In the central third of the range an extensive upland, broken by granite ridges, is developed. Darton (1900) implies that it is an exhumed surface upon which the sediments were deposited. The presence of flat tracts of Tertiary boulder beds on this surface at elevations of 8,000 to 9,000 feet suggests that this exhumed (?) surface might very well have been stripped of its sediments and modified during Tertiary time. This would explain what Darton (1900, plate XXIII) terms a "High Plain of Supposed Tertiary Deposits on Summit of Divide in Bighorn Mountains".

Uinta Mountains

Bradley (1936, p. 163) has described several surfaces on the north flank of the Uinta Mountains. The highest surface, the Gilbert Peak, ranges from an elevation of 13,000 feet along the crest of the mountains (illustrated by Goslin and Cold Spring Mountains and the area west of Gilbert Peak) to 7,300 feet at its lowest point southwest of Aspen Mountain. Remnants, which are correlated by accordance in elevation and similarity of surface covering, have been identified more than 30 miles out in the Green River basin. It is a "broad, generally smooth plain" with a gradient of 55 feet to the mile in the basin and 400 feet to the mile along the crest where it becomes a "hilly post-mature surface" with rounded hills that rise as much as 1,000 feet above the surface (Bradley, 1936, p. 171).

As may be seen in figure 3, the Gilbert Peak surface truncates rocks from pre-Cambrian to latest Eocene in age, even without a break where it crosses from hard quartzites to soft Tertiary mudstones. Rich (1910, p. 607) reports that the surface bevels certain parts of the Rock Spring Dome without regard to the underlying beds which have dips as

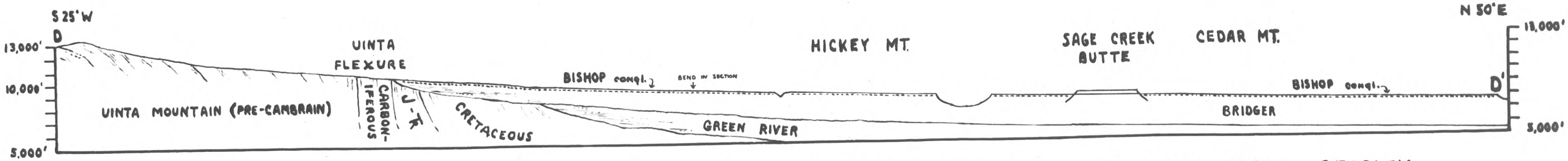


FIGURE 3 PROFILE SHOWING REMNANTS OF GILBERT PEAK SURFACE. ADAPTED FROM BRADLEY.

high as 35 degrees. For the most part, the surface is covered with the Bishop conglomerate which is as much as 200 feet thick in places. The conglomerate consists of poorly sorted boulders and gravels derived from the Uinta Mountains. In most localities the boulders are six to twelve inches in size, being somewhat smaller away from the mountain and larger on the mountain flanks.

Inasmuch as no fossils have been found in the Bishop conglomerate, its age cannot be definitely stated. Since the surface is older than the Browns Park formation (late Miocene or early Pliocene) Bradley has given its age as Oligocene or Miocene.

The lack of a soil mantle and the presence of the boulder and gravel veneer, and the fact that the limestone island-mounts rise more abruptly from the surface than do those of quartzite (Bradley, 1936, p. 176) suggest that the Gilbert Peak surface was formed during a semi-arid climate. These facts, as well as the decreasing gradients toward the basin, suggest that the surface had a pediment type of origin.

Other localities

No high surfaces equivalent to the Wind River surface are reported in the Granite Mountains, the Owl Creek Mountains (Fanshawe, 1939, pp. 1439-1490), or the Gros Ventre Range (Fenneman, 1931, p. 168). A surface is present in only two small areas in the Teton Range (Blackwelder, 1909, p. 201). The surfaces of Medicine Bow and Laramie ranges and the surface in southwestern Idaho will be discussed only briefly in this paper.

CLIMATE DURING TERTIARY

General statements

Since the physiographic features of an area are the indirect result of the climatic conditions, it would seem imperative to make a brief survey of the early Tertiary climates. It would be inexcusable to postulate the formation of a pediment slope during an epoch when fossil evidence indicates humid conditions.

Unfortunately deposits containing fossil plants and animals are not always ideally situated. Post-Eocene fossils are absent in central and western Wyoming; thus, the climate for these ages can only be inferred from the fossil evidence of the Great Plains. Conversely, the lack of Eocene deposits in the Great Plains necessitates the deduction of its climate from the evidence obtained in the basin deposits to the west.

Eocene climate

The nature of the Eocene climate is clearly indicated by fossils from deposits in the Wind River, Bighorn, and Green River basins. Fossil remains of palm trees and large crocodiles denote a warm, humid climate (Scott, 1937, p. 103). A forested region is indicated by the Eocene species of the horse, Eohippus, which was a browsing animal. Roland Brown (1934, p. 45) reports that the Green River flora (Middle Eocene) indicates a "warm, temperate, well-watered environment". These beds, now at elevations of 5,000 to 7,000 feet above sea level are believed to have been deposited at much lower elevations. Bradley (1929, p. 89) postulates an original elevation of the floors of the basins of deposition of about 1,000 feet above sea level. Mackin, (1937, p. 819) has suggested that erosion may have more or less kept pace with the differential early Laramide movements, so that no high land masses were developed in Wyoming during early Tertiary time, at least not more than 3,000 or 4,000 feet above the basin floors.

Oligocene climate

The nature of the Oligocene climate is not clear. It was a period of gradual change from the Eocene humid climate to the Miocene semi-arid climate. The disappearance of the palm trees and large crocodiles indicates a definite change to somewhat cooler conditions (Scott, 1937, pp. 106-107).

Fossil evidence of the camels, horses and "rhinos" indicates specialization toward a semi-arid climate which favored the replacement of the forests by semi-open country with grasslands. There was a sudden loss of primates and titanotheres. However, no actual climatic change seems to have occurred between the Eocene and Oligocene. Many Eocene forms continued through Lower Oligocene, but by Middle Oligocene the climate had become drier, so that many large animals, especially the large herbivorous and carnivorous became extinct (Hibbard, personal communication). This greater aridity is indicated by the land turtle and a greater number of terrestrial lizards, including Heloderm and Rhineura. Aeolian deposits have been postulated in the Oligocene of the Great Plains, but since catfish remains have been found in these so-called aeolian beds, their wind transported origin is doubtful, and therefore they are of doubtful value as climatic indicators (Hibbard, personal communication).

Although an increase of aridity probably took place throughout the Oligocene, the presence of wild turkey, insectivores, and Leptauchenia (a small aquaric oredon) indicates that the region could not have been completely dry. It is, therefore, suggested that the climate of the Upper Oligocene was one of wet and dry seasons.

Since the Oligocene fossil evidence occurs only in the Great Plains, it is inferred that such a fauna also existed to the west in the region of the Wyoming basins and ranges. The type of vegetation on the old upland slopes may have been grass or small brush. Perhaps by the end of the Oligocene most of the vegetation had disappeared.

The cause of the Oligocene climatic change is not definitely known, but evidence seems to indicate that such a change occurred throughout the western United States (Chaney, 1939, p. 357). However, mountain ranges to the west may have exerted locally a modifying influence.

Miocene climate

Osborn (1910, p. 241) states that "no geologic or life break occurs in America to separate Oligocene from Miocene". In the Great Plains the lowermost Miocene flood plains were downcutting and reworking the Oligocene material. The resulting 30 to 40 feet of beds make age determinations difficult. However, fossil evidence at the close of the Lower Miocene indicates a definite climatic change toward aridity (Hibbard, personal communication). It is well established that the Miocene species of the horse, Merychippus, had long crowned teeth which were adapted to grinding the tough, harsh grasses developed by a semi-arid climate.

The sudden change to a more arid climate during Miocene suggests that a major uplift occurred at that time in the mountains to the west. Eardley (1947) has postulated a regional uplift of approximately 5,000 feet during Lower Miocene. Since present-day examples of semi-arid conditions resulting from the influence of high mountains exist in the western United States, it would not seem erroneous to postulate a similar effect by the Wyoming Ranges during the Miocene, inasmuch as their date of elevation closely corresponds with the appearance of a definite climatic change in the Great Plains.

ORIGIN OF THE SURFACE

Concept of pediment theory

The general concept of a pediment is a gently inclined plain which extends from an abrupt mountain face to a marginal basin. The junction of the mountain front and the pediment has been called the "knick point". In an area of youthful topography it would be an angular junction. As the mountain front retreats, the knick point would retreat correspondingly. It would be found at higher elevations and would have a smaller junction angle. As the erosional cycle nears completion, the pediment would extend almost to the summits of the mountains, which would now be represented by rounded, mature hills. Throughout its development the lower portion of the pediment grades into the marginal basin. Its elevations become higher as the sediments accumulate. Even when the uplands have been reduced to a mature topography with gradients of 500 to 300 feet per mile, fine sediments may still be deposited in the central portions of the basin where the gradients may be as low as 50 feet per mile.

During the last stages in the formation of a pediment, an extensive surface is present, although the difference in elevations between the mountain summits and the central portions of the basins may be as much as 5,000 to 7,000 feet when large areas are involved. The upper portion of the surface would be formed on the upland by streams of degradation, whereas the lower portion would be formed on soft sediments by streams of aggradation.

Pediments are generally best developed in semi-arid or arid regions. This may be due to the sparsity of vegetation which leaves the surface exposed to weathering and erosional action of torrential storms. As a result of the climate, pediments are also characterized by a veneer of gravel rather than a surface covering of soil.

Gilbert Peak surface as a pediment

Bradley (1936, p. 163) believes that the Gilbert Peak surface in the Uinta Mountains is a pediment slope, and that the Bishop conglomerate is a pediment veneer, both of which were formed under semi-arid conditions. He states that the bedrock is unaltered (1936, p. 174), which would indicate that no soil was present when the conglomerate was deposited.

The climatic evidence indicates that during early Oligocene the surface would have been formed under humid conditions, while during late Oligocene and Miocene it reached its mature stage of development under semi-arid conditions. Such a sequence would not be seen in the field since the final pediment type of erosion would destroy the work of all earlier erosion. The final result would appear as if all erosion had been accomplished under semi-arid conditions.

Since it appears that during the last stages of the formation of the Gilbert Peak surface the pediment type of erosion prevailed, it would seem correct to postulate that a similar situation occurred in the other ranges. There is no reason to assume that the nearby Freemont surface on the Wind River range was formed under different conditions if a similarity in age is postulated. Bradley, in fact, has suggested that the Gilbert Peak surface extended across the Green River basin to the Wind River surface in the Wind River range.

EVIDENCE OF PRE-MIOCENE AGE

Significance of climate

Not only do the climatic conditions give an indication of the type of surface formed, but they become very important factors for dating the surface. As was previously shown, they indicate that a major regional uplift occurred during Lower Miocene. Such an uplift has been postulated by Eardley (1947). The formation of the high erosion surface must have been accomplished either prior to this movement or at some much later date, since it could not have been formed during or immediately after a major uplift. If the surface were formed at a later date, such as Pliocene, it would necessarily be at rather high elevations, since the continued aridity of the Great Plains does not indicate a wide-scale reduction of the mountains. A slight change toward a more humid climate would be expected if the mountains were leveled, but the fossil evidence does not indicate any such change. Since it is difficult to understand how the constant base level, needed for the formation of any surface, could be maintained at high elevations, it is believed that a wide-scale erosional and depositional surface could not have been formed during the Pliocene. Therefore, a pre-uplift age is postulated. Further evidence supporting the formation of this surface during Oligocene with its maximum development in the lowermost Miocene will be presented.

Sedimentary evidence

As previously indicated, the lack of Eocene deposits in the Great Plains and the proposed elevation for the deposition of the Green River beds suggests that the mountain ranges in Wyoming did not bear the same relationship to the Great Plains during the Eocene as today. Since the Eocene detritus from Wyoming was carried northward to Montana rather than directly eastward, it is suggested that the differences in elevation were not as great as today. The Oligocene sediments in the Great Plains and in the Laramie region are fine-grained. It was not until the Miocene that they became coarser. The material carried onto the Great Plains today is similar in size to that of the Miocene rather than the Oligocene (Hibbard, personal communication). Mackin (1937, p. 892) states that the Miocene and Pliocene detritus was of a coarse nature. These facts support the belief that the Wyoming ranges were of a lower relief and lower elevation during the Oligocene than at any time since then.

The distribution of sediments in the Wyoming region requires some consideration. Eocene deposits are found extensively in all the basins, while Oligocene deposits are limited to the Yellowstone-Absaroka region and a region along the southern portions of the Wind River basin.

If a late age is postulated for the surface, it becomes difficult to explain the absence of deposits for the intervening epochs. If the erosional cycle did not reach its completion until Pliocene, highlands and lowlands must have existed prior to this time. It, therefore, would seem that Miocene and Oligocene sediments should have been deposited in great thickness. However, since none have been preserved, their former existence is somewhat doubtful.

Although the weakness of this type of evidence is recognized, it must be noted that an Upper Oligocene-lowermost Miocene age for the surface adapts itself to the facts. The sparsity of Oligocene deposits is explained by the fact that the region was becoming subdued, and the greater part of the sediments were deposited in the Great Plains. Post-Oligocene deposits are not found because of the continued erosion that has occurred since the regional uplift of Lower Miocene time.

Beartooth Range

Bevan (1925, p. 578) has assigned an Oligocene age to the "summit peneplain" in the Beartooth Range. Although he states that its age cannot be positively established, he has indicated several lines of evidence suggestive of this age. An upper and lower age limit are established by the "sub-summit peneplain" (Pliocene (?)) and the Beartooth overthrust (post-Middle Eocene). At the southern ends of Bridger and Big Belt ranges of south-central Montana, there are Middle Miocene and Lower Miocene beds which are apparently deposited upon a "gently undulating plain" (Bevan, 1925, p. 576).

Although there is no means of correlation, it is highly significant that such a surface had developed by late Oligocene. Bevan also suggests that the "summit peneplain" may be partially contemperaneous with the Oligocene (?) plain on Cypress Hills in the northern Great Plains (1925, p. 578).

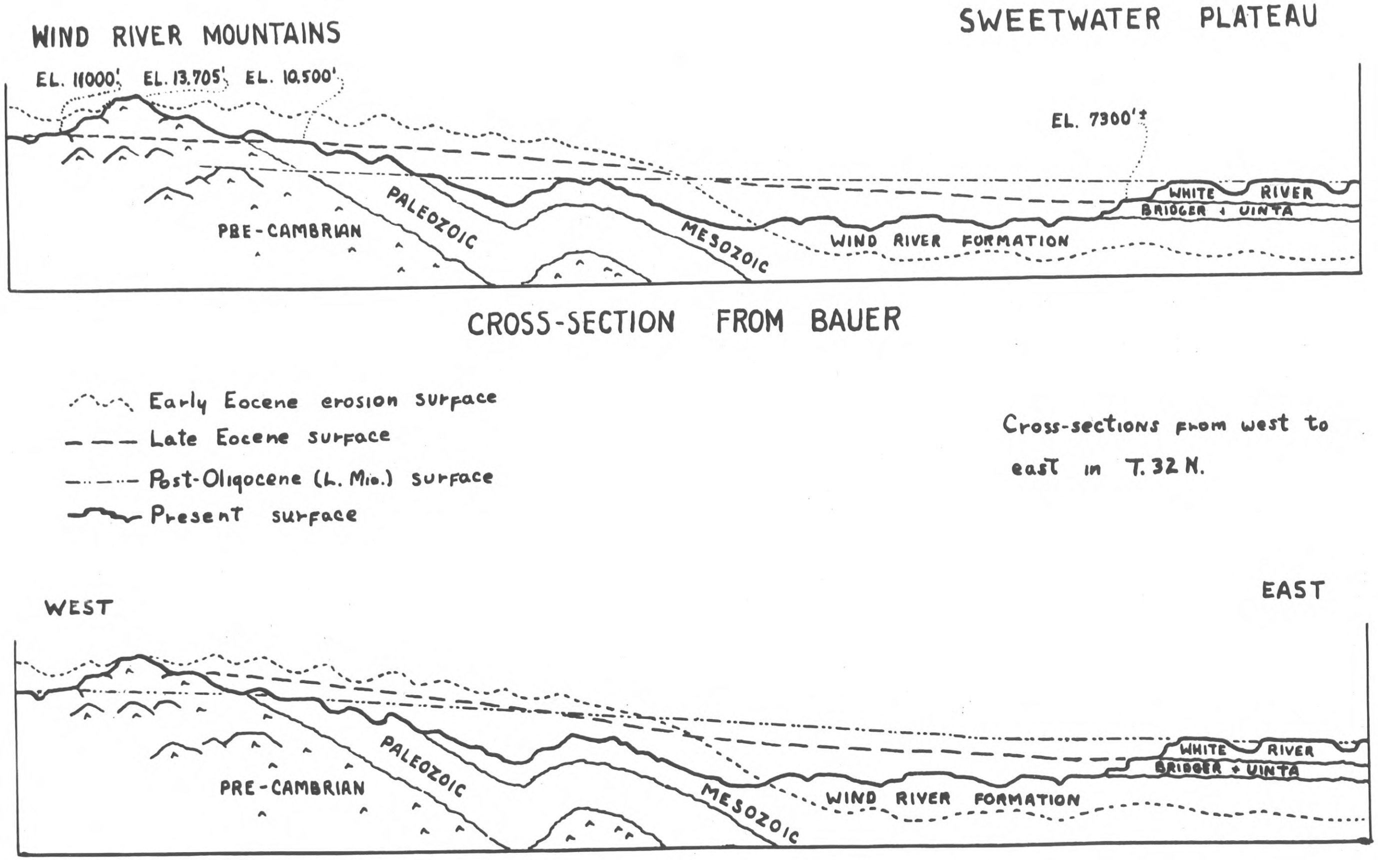
Uinta and Bighorn Ranges

As previously stated, Bradley has assigned an Oligocene or Miocene age to theBishop conglomerate which would also represent the age of the Gilbert Peak surface on the north flanks of the Uinta Mountains. This is based on the Miocene or early Pliocene age of the younger Browns Peak formation.

Age relationships for the surface on the Bighorn Mountains were not available.

Granite Range and Sweetwater Plateau

Although remnants of a surface are not found on the Granite Range, this area along with the Sweetwater Plateau requires some consideration. Bauer (1934 and 1940) also postulates low elevations during the Eocene and a general uplift in early Miocene. He believes that the Granite Range lagged behind in this general uplift to the extent of 2,500 to 3,500 feet, thus preserving the soft Oligocene sediments (1940, p. 326). He is convinced that a "widespread plain of erosion and deposition was developed in central Wyoming in the Late Eocene" (1940, p. 325). He reports that such a surface is preserved beneath the White River beds in the Sweetwater Plateau.



MODIFIED CROSS-SECTION

FIGURE 4 INTERPRETATIONS OF PRESENT POSITIONS OF EROSION SURFACES IN THE WIND RIVER - SWEETWATER REGION

The existence of such a surface is not of primary importance since it seems evident that the following epoch was also one of highland erosion and basin deposition. If a surface had been formed by the end of the Eocene, the slight uplift of the Oligocene would not prevent the formation of a more extensive surface during the Oligocene. Bauer (1940, p. 327) states that "since the Oligocene was a period of aggrading streams in this region, it is likely that by the close of the Oligocene even these peaks (Granite Mountains) had been buried by the sediments from the west". Thus not only is a surface at the close of the Oligocene suggested, but an explanation is presented for the lack of a cut surface on the Granite Mountains. In the case of the proposed Eocene surface, it is difficult to explain the absence of a cut surface, since the Granite Mountains are now surrounded by either Oligocene or Miocene sediments which overlie the horizon of the Eocene surface.

Bauer's cross section,(1934, p. 690) reproduced in figure 3, shows a late Eocene surface at the base of the White River formation and a post-Oligocene surface at its top. As may be seen in figure 3, it is this author's contention that the post-Oligocene rather than the late Eocene surface correlates with the surface on the nearby Wind River Mountains.

Other regions

The Laramie and Medicine Bow Ranges and the region of southwestern Idaho will not be discussed in this paper to any great length, although surfaces are known to be present. Information concerning the former region is lacking, and there is a great controversy in regard to the age of the surface in the latter region.

Blackwelder (1909, p. 444) reports the presence of a Pliocene "peneplain" in the Laramie region. However, it is interesting to note that the lower age limit, mid-Miocene, for the surface seems to be based upon the "mid-Tertiary" formations over which the surface seems to pass (1909, p. 434). These "mid-Tertiary formations" apparently are the Chadron and Brule clays and the Arikaree conglomerate, which were assigned Oligocene and early Miocene ages respectively. Since the Chadron and Brule clays have now been assigned earlier ages, and since the coarse Arikaree lies unconformably on finer sediments, further investigations may show that this surface could be of lowermost Miocene age.

The age of the Snowdrift "peneplain" and other related surfaces in Idaho has been the subject of much discussion in the literature. Although Mansfield (1927, pp.14-17) places the age as Eocene, he can show only that it is older than the Miocene uplift. The fact that Mansfield proposes no geologic events during the Oligocene suggests that he assumes the surface was in existence during this epoch. Eardley (1944, p. 864 and pp. 877-878) reviews the problem and concludes that the surface was completed in lowermost Miocene. He infers that a similar relationship between the surface and basin-like deposits exists in north-central Wasatch. Here, the Norwood tuff (lower Oligocene) which, along with older beds, was slightly folded before the formation of the surface, is found occupying depressions below the high erosion surface.

THE PLIOCENE THEORY

Blackwelder believes that the Wind River "peneplain" is of Pliocene age. Although he states that by the end of the Oligocene, there were "broad, flat graded plains" (1915, p. 111), he feels that the accumulation of thick sedimentary deposits during the Eocene and Oligocene makes the formation of a surface prior to the mid-Miocene deformation impossible. (1915, p. 202). This reasoning seems incorrect to the author, since the Oligocene sediments which have been preserved are not thick or widespread. Since great quantities of these beds are not known to have existed, it seems erroneous to assume that a depositional cycle occurred throughout the Oligocene. It is agreed that the surface was formed after the deposition of the Oligocene beds, but Blackwelder has found it necessary to assign a Pliocene age to the Wind River "peneplain" since he has not recognized a time interval before the uplift. It is also important to note that with a pediment type of surface, the deposition of sediments may occur in the basin even during the last stages of its development, so that a graded surface, part erosional and part depositional, is formed.

Blackwelder's "mid-Tertiary" deformation which expressed itself in faulting and folding has been questioned by Eardley (personal communication), since more recent work has shown that some of the "mid-Tertiary" faults are late Laramide thrusts. Thus, the earlier dating for the faulting and folding and the Lower Miocene dating for a regional uplift, would seem to necessitate a re-examination of the Pliocene theory by its exponents.

A line of reasoning followed by several researchers in the Wyoming ranges and Basins that leads to a Pliocene or early Pleistocene age of the high erosion surface is as follows: The subsummit surface is at 8,500-9,000 feet in the Gros Ventre Range, the Blackrock surface is at 7,500 feet and the Circle surface is at 6,500 feet. The Blackrock is covered with Illinois (?) drift, and the Circle with early Wisconsin (?) drift. Therefore, the Blackrock and Circle surfaces are dated as mid-Pleistocene and late Pleistocene respectively. Since the period of time between the Blackrock and Circle is so small, it seems logical to assign a similar length of time between the Blackrock and subsummit "peneplain". The later would, therefore, be Pleistocene or late Pliocene.

The error in this reasoning has been found by Eardley in the Hoback Range and Jackson Hole region where the following events occurred. After the subsummit surface had formed it was deeply dissected but numerous remnants remained. Then, high-angle faulting occurred, which was followed by deposition of early (?) and late Miocene conglomerates in the fault trough. This was followed by erosion below the upper surface of accumulation of the conglomerates to form the next conspicuous surface. The subsummit surface, therefore, predates the Miocene or at least the late Miocene in this region. Where faulting has not occurred, the surfaces need to be re-examined in the light of detailed mapping and all available facts.

Summary

An upper Oligocene-lowermost Miocene age is postulated for the high erosion surface preserved in the Wyoming ranges on the basis of the following suggestive evidence. Successive Tertiary fauna and flora indicate that the climatic conditions became progressively drier from Eocene to Pliocene. A marked change toward greater aridity in Lower Miocene is correlated with the regional uplift. The coarseness of the later gravels in the Great Plains and the elevations necessary to maintain the dryness of the Great Plains suggests that the high erosion surface was not formed after this uplift. The fineness and sparseness of the Oligocene deposits are interpreted, as was shown in figure 2, as an indication that the erosional surface was being formed at that time.

The surfaces in the various ranges can each be shown to have the same approximate age without distortion of the available facts. Bradley reports that the Gilbert Peak surface on the north flanks of the Uinta Mountains is a pediment slope which was formed in the Oligocene or Miocene, and Bevan dates the erosion surface in the Beartooth Range as Oligocene. The surface on the Wind River Range can be correlated with the top of the Oligocene beds in the Sweetwater Plateau region.

Acknowledgments

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