DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Professional Paper 108—L

STRATIGRAPHY OF THE HANNA BASIN, WYOMING

BY

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Published May 7, 1918

Shorter contributions to general geology, 1917
(Pages 227–235)

WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

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STRATIGRAPHY OF THE HANNA BASIN, WYOMING.

By C. F. Bowen.

INTRODUCTION.

Carbon County, Wyo., has attracted the attention of geologists since the days of the territorial surveys under King, Hayden, and Powell. During this earlier work all the rocks (except the North Park formation) overlying the uppermost beds of marine origin were grouped in a single formation, for which the name Laramie was proposed.

As the result of his work in the Hanna Basin (see fig. 31) in 1906, Veatch [1] subdivided this group of rocks into two formations, which he designated "Lower Laramie" and "Upper Laramie," and made the statement that the two were separated by an unconformity that involved the removal of 20,000 feet of rocks.

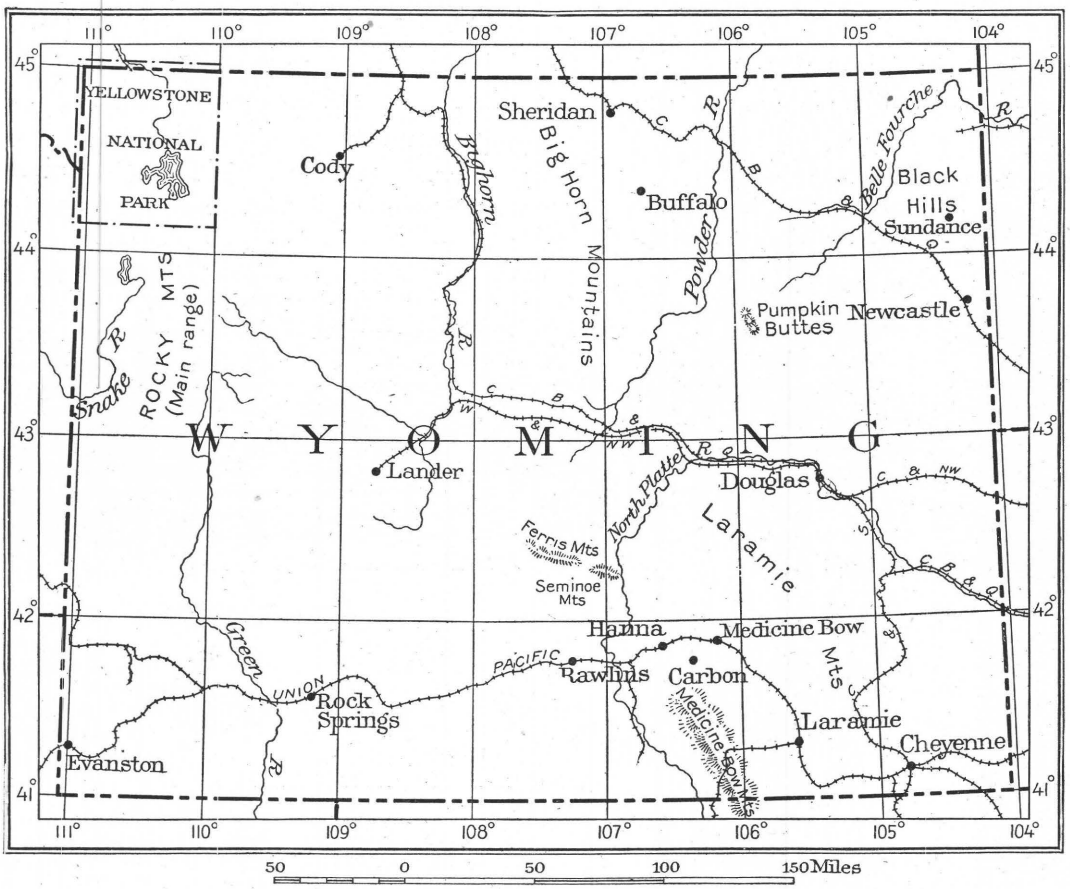

FIGURE 31.—Key map showing location of Hanna Basin, Wyo.

[1] Veatch, A. C., Coal in east-central Carbon County, Wyo.: U. S. Geol. Survey Bull. 316, p. 246, 1906; The origin and definition of the term Laramie: Jour. Geology, vol. 15, pp. 526–549, 1907.

Veatch's upper formation became the type of the "Upper Laramie formation," and the flora which it yielded was adopted as a standard for purposes of comparison in other fields.

It is the purpose of the present paper (1) to show that the "Upper Laramie" as defined by Veatch consists of two formations separated by a marked unconformity; (2) to show that this unconformity is the one which he regarded as representing the erosion of 20,000 feet and referred to the base of the "Upper Laramie formation"; (3) to present the facts so far as they can now be interpreted for and against the existence of an unconformity at the horizon indicated by Veatch; and (4) to offer some suggestions as to the source of the material which goes to make up the enormous thickness of continental deposits of this era.

STRATIGRAPHY.

GENERAL SECTION.

The formations exposed in or immediately adjacent to the area under consideration range in age from Cambrian (?) to probably Miocene. Those in the upper part of the section—that is above the base of Veatch's "Lower Laramie"—are of chief interest and will be described somewhat in detail; the underlying formations will be referred to but briefly. The sequence and general character of the Mesozoic and Cenozoic formations are shown in the following table:

Mesozoic and Cenozoic formations in Hanna Basin, Wyo.

System.	Formation.	Thickness (feet).	Characteristics.
Quaternary.	Alluvium.		Worked-over material from surrounding formations.
	Terrace gravel.	0–25±	Waterworn pebbles of older sedimentary and crystalline rocks.
	North Park formation.	0–400±	Whitish unconsolidated sand and clay with thin intercalated beds of limestone in some places; conglomeratic at base.
.....	Unconformity.....		
Tertiary.	Hanna formation.	7,000±	Alternating beds of dark-gray, yellowish, and carbonaceous shale; white, gray, and brown sandstones, massive to thin bedded and commonly cross-bedded; conglomerates and conglomeratic sandstones containing pebbles of chert, granite, quartzite, sandstone, Mowry shale, Cloverly conglomerate, etc. (these conglomerates are distributed throughout the section but are most abundant in the lower half), and numerous beds of coal. Contains fossil bones of vertebrates, fresh-water shells, and an abundance of leaves.
.....	Unconformity.....		
Tertiary (?).	Ferris formation.	6,500±	Light-colored, dark-gray, and carbonaceous shale; buff to brown sandstone; in places extremely cross-bedded and showing great irregularity of deposition and numerous beds of coal. Pockets, lenses, and thin beds of conglomerate composed of pebbles of older rocks are distributed through a zone about 1,000 feet thick at the base of the formation. Contains fresh-water invertebrates, land plants, and bones of vertebrates.
Cretaceous.	Medicine Bow formation.	6,200±	Light-colored to gray carbonaceous shale; gray to brown sandstone showing cross-bedding, ripple marks, and other features of irregular deposition; and thin irregular beds of coal. Fresh and brackish water, invertebrates, land plants, and bones of vertebrates.
	Lewis shale.	3,300±	Predominantly dark-gray shale with thin intercalated beds of shaly sandstone and some beds of light-colored massive to heavy-bedded sandstone. Near the top of the formation is a persistent ledge-making gray sandstone about 270 feet thick. Marine.

Mesozoic and Cenozoic formations in Hanna Basin, Wyo.—Continued.

System.	Formation.	Thickness (feet).	Characteristics.
Cretaceous.	Mesaverde formation.	2,700	An upper member of whitish sandstone alternating with gray and carbonaceous shale with a conspicuous resistant white sandstone at the top; contains thin irregular beds of coal in some places. A middle member of brown to gray sandstone, gray carbonaceous shale, and thin irregular beds of coal; differs from upper member in its prevailingly brown color; fresh and brackish water fauna. A lower member of gray to white sandstone and gray shale; contains a marine fauna and is not coal bearing.
	Steele shale.	4,000±	Dark-gray shale with intercalated beds of sandstone and shaly sandstone, some of which form conspicuous ledges near top of formation. Shale contains concretions of calcareous sandstone, dark limestone, and white crystalline calcite. Marine fauna.
	Niobrara formation.	370±	Calcareous shale with considerable intercalated white crystalline calcite at top and bottom.
	Carlile shale.	200	Dark-gray to black shale with some thin sandy layers.
	Frontier formation.	700	An upper member composed of thick beds of sandstone alternating with thinner beds of shale and a lower member composed of dark-gray shale.
	Mowry shale.	170	Fissile shale, dark brown on fresh surface but weathering to silver gray or white.
	Thermopolis shale.	140	Dark-gray shale with thin sandy layers.
	Cloverly formation.	231	An upper member of sandstone, a middle member of shale, and a lower member of conglomeratic sandstone.
Cretaceous (?).	Morrison formation.	350	Shale, mostly gray or greenish, alternating with sandy shale and sandstone. Contains bones of dinosaurs.
Jurassic.	Sundance formation.	85	Chiefly green, olive, and drab shales with a few thin intercalated beds of sandstone.
Triassic.	Chugwater formation.	1,000−	Chiefly red shale with intercalated red, buff, and yellow sandstone.

For stratigraphic study the most important of the formations given in the table are the Mowry shale, the Frontier, and the Mesaverde, because they possess characteristics which render them valuable as horizon markers. This is especially true of the silver-gray fish-scale shale of the Mowry.

MEDICINE BOW FORMATION.

Above the highest marine formation—the Lewis shale—is a mass of continental deposits, divisible into four formations having a maximum thickness of more than 20,000 feet. For the lowest of these formations the name

Medicine Bow is here proposed, because the formation is best exposed and most easily studied along both sides of North Platte River at the mouth of the Medicine Bow. The Medicine Bow formation is the equivalent of the "Lower Laramie" as defined by Veatch. The latter term is not applicable, for the "Upper Laramie," in the sense in which that term was originally used, is not of Laramie age. As the relation of the Medicine Bow formation to the Laramie of the Denver Basin can not be determined by field relations, and as paleontologists are not agreed as to the relation of the fossil remains found in the two formations, the use of the unqualified term "Laramie" is not advisable, and it is thought that confusion may be avoided by the use of an entirely new name for the formation hitherto called "Lower Laramie."

The Medicine Bow formation rests conformably on the Lewis and consists of an alternating succession of shale and massive to thin-bedded, ripple-marked, and cross-bedded sandstones, with several beds of coal in the lower third of the formation. The massive and thick-bedded sandstones are commonly somewhat coarser than the thin-bedded varieties and in some places contain clay balls and an occasional pebble the size of a pea.

Microscopic examination shows that the sandstone is composed of fragments of quartz, quartzite, feldspar, chert, schist, volcanic rocks, limestone, and other minor constituents. In other words, it has been derived from both sedimentary and igneous rocks. The grains show considerable variation in the degree of sorting and rounding, but on the whole are decidedly angular. One section showed well-rounded grains, 20 per cent; subangular grains, 35 per cent; angular grains, 45 per cent. These proportions suggest that the grains are chiefly the result of mechanical disintegration and rapid transportation with little or no subsequent reworking.

The formation contains remains of fresh and brackish water invertebrates, land plants, and bones of vertebrates. The plants are regarded by F. H. Knowlton as of the same age as the plants of the Laramie of the Denver Basin. The invertebrates are considered by T. W. Stanton to belong to the fauna of the Lance formation. The bones belong in part to the ceratopsians, but no specimens have been found that are sufficiently diagnostic for even generic determination.

FERRIS FORMATION.

The Medicine Bow formation is terminated above by a conglomeratic zone taken as the base of the Ferris formation, so named because it is best exposed from the old Ferris ranch, on North Platte River, eastward to the top of the hill north of "Middle Ditch" at its junction with "Big Ditch." As defined the Ferris formation is approximately equivalent to the lower half of the "Upper Laramie" of Veatch. The conglomerate at the base of the Ferris formation ranges through an interval of about 1,000 feet, in which massive sandstone, more or less conglomeratic, alternates with non-conglomeratic sandstone and shale. The conglomerate is sparingly developed at the base of the zone but increases in amount upward. It is succeeded by an alternating series of sandstone and shale containing numerous beds of coal. The maximum thickness of the formation is about 6,500 feet.

Both the matrix and the pebbles of the conglomerate consist of materials of the same kind as make up the sandstone of the underlying Medicine Bow formation. The pebbles consist mainly of chert and white quartz or quartzite; then follow in about the order named red and gray quartzite, porphyries, and conglomerate, with subordinate amounts of other constituents. Three facts impress the student of this conglomerate: (1) It is made up of only the most resistant kinds of rock; (2) it is lacking in several kinds of rock now exposed in the surrounding mountains—for example, granite, limestone, sandstone, Cloverly conglomerate, and Mowry shale; (3) it contains materials that seem to be foreign to this region, namely, quartzite, porphyry (quartz latite), and rhyolite. These features lead to the inference that the conglomerate and also the associated sandstone were derived from some distant source rather than from the near-by mountains. This inference has an important bearing on the unconformities discussed on pages 231–234.

The Ferris formation contains fresh-water invertebrates, land plants, and bones of vertebrates. The shells and plants, which are found chiefly above the conglomerate zone, are

regarded as of Fort Union age, whereas the vertebrate remains, thus far found only in the conglomeratic zone, consist of bones of turtles, indeterminable fragments of ceratopsians, and a few specimens that have been identified by C. W. Gilmore as *Triceratops*. The bones of *Triceratops* tend to show that the basal part of the formation should be correlated with the Lance of Wyoming and Montana and the Denver formation of the Denver Basin. There is, however, no conclusive proof of an unconformity below the bone horizon in the Hanna Basin, as there is said to be in the Denver Basin.

HANNA FORMATION.

For the upper part of the "Upper Laramie" as defined by Veatch the name Hanna formation is proposed, because the formation is well exposed to the west and north of the town of Hanna and yields all the coal mined at that place. The Hanna formation rests unconformably on the Ferris formation. A conglomeratic sandstone marks its base, above which conglomerate, sandstone, shale, and coal beds alternate to the top of the formation, some 7,000 feet above the base.

This formation differs from the Ferris in being highly feldspathic, in being conglomeratic throughout, and in the fact that the conglomerate contains an abundance of local material, notably granite, Mowry shale, and Cloverly conglomerate. The relative abundance of these constituents varies from place to place in accordance with the character of the surrounding rocks. Thus near outcrops of the Mowry shale and the underlying Cloverly those rocks constitute most of the pebbles, near outcrops of granite that rock is the most abundant material in the conglomerate, and in the center of the basin granite, sandstone, and conglomerate pebbles are associated with chert, white quartz, quartzite, etc.

This formation contains an abundance of plant remains, all of which are referred to the Fort Union by Mr. Knowlton. The invertebrates are also regarded by Mr. Stanton as chiefly indicative of Fort Union age, though species found near the top are said to resemble the Wasatch fauna. Only a few fragmentary remains of vertebrates have thus far been found in this formation. They include fish scales, fragments of turtle shells, and a fragmentary mammalian jaw identified by J. W. Gidley as a creodont, probably *Claenodon*, which may belong to either the Fort Union or Wasatch.

NORTH PARK FORMATION.

The North Park formation rests unconformably on the underlying rocks. This formation consists of conglomerate, unconsolidated sand and marl, and local thin beds of limestone. A peculiarity of the formation is that in many places its surface is thickly strewn with boulders of white, vitreous quartzite as much as 2 feet in diameter, but none of these have ever been found actually embedded in the formation.

No fossils have been found in the North Park, and its age is therefore largely a matter of conjecture, but it is thought to be Miocene.

STRUCTURE.

FOLDING AND FAULTING.

Folding is the dominant structural feature of the Hanna Basin, though faulting has occurred to some extent. A characteristic of the folds is that they are all oversteepened toward the west or southwest.

All the rocks up to and including the Ferris formation seem to have been equally deformed and were folded, faulted, and deeply eroded before the deposition of the Hanna formation. After the deposition of this formation there was another disturbance, which followed chiefly the lines of the earlier movements and served to emphasize the features of structure already produced. By this disturbance the Hanna formation was tilted in some places into a vertical position and was locally faulted. A third disturbance seems to have taken place subsequent to the deposition of the North Park formation, for this formation is now tilted in some places 40° or more.

UNCONFORMITIES.

Perhaps the most interesting structural problem in the field relates to the occurrence and magnitude of the unconformities. There are certainly two and possibly three unconformities present. The highest of these is at the base of the North Park formation, which overlaps all other formations in the field.

The next lower unconformity is that at the base of the Hanna formation, formerly assigned to the base of the Ferris formation. It represents the removal of more rather than less than the 20,000 feet assigned by Veatch.

The existence of this unconformity is demonstrated by the following field relations: (1) There is a marked angular discordance between the underlying and overlying formations; (2) the Hanna formation transgresses all the underlying formations at least down to the Cloverly and possibly down to the granite; (3) the Hanna formation has been less intensely deformed than the underlying formations; (4) the conglomerate at the base of the Hanna formation has clearly been derived from all the underlying rocks and is chiefly of local origin.

That this unconformity is the one assigned by Veatch to the base of his "Upper Laramie" is evident from the following considerations: (1) It is the most conspicuous break in the field; (2) it is the only unconformity present at some of the typical places observed by Veatch, the lower beds being there cut by overlap; (3) the Ferris formation nowhere transgresses the "Lower Laramie" and overlaps older rocks, as was postulated by Veatch; (4) all the rocks between the Medicine Bow ("Lower Laramie") and North Park were included by Veatch in a single formation.

Veatch's mistake was a natural one to make in rapid reconnaissance work. In the eastern part of the basin, where the unconformity is most evident, the conglomerate of the Ferris formation is either cut out by overlap or is directly overlain by the conglomerate of the Hanna formation, all the intervening strata being eroded. These relations were not detected in a rapid examination, but are perfectly clear when studied and mapped in detail.

On the west side of the basin the two conglomerates are separated by a stratigraphic interval of nearly 6,000 feet and by a horizontal distance of 5 to 7 miles. In that area Veatch appears to have recognized only the lower of the two conglomerates and to have unhesitatingly correlated it with the unconformity he saw farther east.

The next question that arises is regarding the significance of the conglomerate at the base of the Ferris formation. It has been held that, because this conglomerate is made up in part of pebbles containing Paleozoic fossils, it necessarily represents a period of uplift and erosion between the deposition of the Medicine Bow and that of the Ferris formation ("Upper Laramie" and "Lower Laramie") sufficient to expose the Paleozoic rocks. This would naturally follow if it could be proved that Paleozoic rocks did not contribute materials to the underlying formation or that the pebbles of the conglomerate came from a different source than the sand and clay of the underlying formation. As previously stated, microscopic study shows that the constituents of this conglomerate are all represented in the sandstone of the Medicine Bow formation. This seems to indicate that both were derived from the same source and that Paleozoic rocks contributed material to the Medicine Bow formation, as well as to the conglomerate above it. It is therefore not necessary to assume a great interval of uplift and erosion between the periods of deposition of the two formations to account for the Paleozoic pebbles in this conglomerate any more than it is necessary to assume a great interval of uplift and erosion to account for each of the successive conglomerates in the Hanna formation, or the conglomerates of earlier formations, such as the Beckwith in Uinta County and the Frontier (?) at Coalville, Utah. The presence of Paleozoic pebbles in these conglomerates, as well as in the Cloverly, is proof that the Paleozoic formations had been exposed somewhere in the region at least since the beginning of the Cretaceous period. That is, in so far as the evidence furnished by the conglomerate alone is concerned, it seems to the writer that there is no more argument for assuming an unconformity between the Ferris and Medicine Bow formations than there is for assuming an unconformity at the base of each of the conglomerates in the Beckwith, Frontier, and Hanna formations. Each of these conglomerates contains pebbles of Paleozoic rocks.

It is recognized, however, that a conglomerate indicates a more or less pronounced change in conditions of sedimentation. This change could be accomplished by a rejuvenation of the streams of an already existing land mass, by climatic changes, or by a combination of these and possibly other causes. The point made here is that the existence of a conglomerate is not positive proof of a great un-

conformity. This is especially true of a conglomerate occurring in the midst of a great mass of continental deposits that have the same lithologic character throughout—conditions entirely different from those presented by a conglomerate that separates two marine deposits or one deposit of marine origin and another of continental origin.

The field relations of the Ferris conglomerate and the underlying formation show (1) that the two have been equally deformed; (2) that there is no angular discordance between them either in the Hanna Basin or in other areas where both are present; (3) that the Ferris formation is nowhere known to transgress the Medicine Bow formation and overlap older rocks; (4) that, as previously indicated, the conglomerate seems to have been derived from the same source as the Medicine Bow; (5) that there appears to be a gradual transition from the Medicine Bow formation to the Ferris formation. The contact between the two is not sharply defined, coarse sandstone of the Medicine Bow being followed by grits in which a few small pebbles occur, and these giving place higher up to pockets, lenses, and thin beds of conglomerate, which are finally succeeded by thick beds of sandstone that are conglomeratic throughout. Interbedded in this transition zone are several beds of dark-gray shale, some of which attain a thickness of 30 feet.

This transition zone is very significant, occurring in all areas where both the Medicine Bow and Ferris formations or their equivalents are present. In the southern part of the Great Divide Basin it is, according to Smith,[1] 800 feet thick and consists chiefly of clay with interbedded thin rusty-brown sandstone, which becomes increasingly conglomeratic toward the top. In the northern part of the Great Divide Basin, according to the same author, the transition zone is still thicker.

Similar conditions in the Little Snake River field are described by Ball and Stebinger.[2]

This thick transition zone between the assumed unconformity and the principal conglomeratic zone supposed to represent it seems to the writer to be a fatal objection to the idea of an unconformity. It is difficult to conceive of a basal conglomerate occurring several hundred feet above the base it is assumed to represent. These conditions lead to the inference that no unconformity exists between the two formations.

The arguments in favor of an unconformity are (1) the conglomerate at the base of the Ferris formation, which, if the above reasoning is sound, has no weight; (2) a considerable thinning of the Medicine Bow formation in some places, which is partly offset by the fact that the Lewis and Mesaverde show just as great variations in thickness within as short distances; and (3) the fact that at the base of the Evanston formation of Uinta County, correlated with the Hanna at Carbon, there is an unconformity which has been assumed to represent the interval between the Medicine Bow ("Lower Laramie") and Ferris ("Upper Laramie") epochs.

The question now arises whether the Evanston formation should be correlated with the Ferris or with the Hanna formation. There are three lines of evidence which suggest that it should be correlated with the Hanna. (1) The flora of the Evanston is said to correspond to that obtained from the old town of Carbon, which in all probability came chiefly if not entirely from the Hanna formation and therefore tends to support the correlation of the Evanston with that formation; (2) the Evanston is conformable with the overlying Wasatch, a relation which is not known to exist between the Wasatch and older rocks in any other place in southern Wyoming; (3) the relation of the Evanston to the Adaville ("Lower Laramie") is largely a matter of inference, for it nowhere rests on the Adaville, and some of those most familiar with the Evanston section now believe that the Adaville formation, formerly thought to represent the "Lower Laramie," is really Mesaverde.

It seems to the writer, therefore, that the weight of evidence so far as it can now be interpreted is opposed to the existence of a great unconformity at the base of the Ferris formation, but it is freely admitted that more detailed field work over wider areas is necessary to decide this question. It is of course possible that a considerable unconformity near the margin of the ancient land mass from which the sediments were derived may give place to

[1] Smith, E. E., The eastern part of the Great Divide Basin coal field, Wyo.: U. S. Geol. Survey Bull. 341, p. 224, 1907.

[2] Ball, M. W., and Stebinger, Eugene, The eastern part of the Little Snake River coal field, Wyo.: U. S. Geol. Survey Bull. 381, p. 190, 1910.

apparent conformable relations at a considerable distance from that place. But it is still a fact that unconformity between the Fort Union and Wasatch is the most widespread and significant break that had been produced up to that time since the beginning of the Cretaceous period.

SOURCE OF THE MATERIAL.

The source of the enormous amount of sediment represented in these continental deposits is an interesting problem.

For the Hanna formation it can be stated with considerable confidence that the material was derived from all the underlying formations and is of more or less local origin.

For the underlying formations the case is not so simple. Even if it could be demonstrated that the Ferris formation is of local derivation, it would still be necessary to explain the source of the 6,200 feet of the Medicine Bow formation to which the immediately underlying rocks did not contribute. A study of at least all the Cretaceous formations is therefore necessary to throw light on the problem.

A few suggestions may be offered by comparing the sections in the accompanying chart (Pl. LXVI). These sections extend from the east side of the Hanna Basin westward through Rawlins, Rock Springs, and Evanston to Coalville, Utah. In constructing them the Mowry shale was taken as a datum plane. To consider first the sandstone formations, these sections show that from east to west the Mesaverde and Frontier thicken regularly, the materials become coarser with pronounced development of conglomerate in the Frontier and with slight indications of conglomerate in the upper part of the Mesaverde, and there is a marked development of coal in both formations.

The 700-foot interval represented by the Morrison and Cloverly near Medicine Bow is represented by the several thousand feet of Bear River and the upper part of the Beckwith in Uinta County. Although individual units of this group can not be exactly correlated, their upper and lower limits are definitely fixed, the upper by the Mowry shale and the lower by the Jurassic (Sundance and Twin Creek) formations, which are correlated with each other by their marine faunas.

The Beckwith includes many beds of coarse sandstone and conglomerate containing pebbles of Paleozoic rocks, and the Bear River is coal bearing. There is no coal in this interval in the Medicine Bow area, and the conglomerate of the Cloverly is composed almost entirely of small pebbles of black chert rarely exceeding half an inch in diameter. These pebbles show by their fineness and thorough assortment that they have been transported for long distances.

Of the shale formations the Lewis thins from east to west—that is, in the direction in which the sandstones thicken. The Mowry and the Hilliard and Steele shales, however, do not. The westward thickening of the Mowry is doubtless due to the fact that it is coarser and contains a considerable amount of interbedded sandstone in its western part. The Hilliard also carries large lenses of sandstone in Uinta County, but its apparent thickening toward the west may be due to the difficulty of accurately determining its thickness because of lack of exposures, inability to measure dips except in the overlying and underlying formations, and the possibility that its boundaries have not been drawn at the same horizon in the several fields.

The evidence of these sections seems to indicate that all the Cretaceous formations up to the top of the Lewis were derived from a western source.

As the Medicine Bow formation, or its equivalent the "Lower Laramie," rests conformably on the Lewis and shows some tendency to become coarser westward, as indicated by its slightly conglomeratic character in places in the Rock Springs field, the inference is that it was derived from the same source as the underlying formations.

The fact that the Ferris formation seems to be more closely related to the Medicine Bow both lithologically and structurally than to the overlying formation, together with the evidence that the conglomerate came from some distant source, would seem to indicate that this formation also came from the west. This view is somewhat strengthened by the fact that pebbles of quartzite occurring in the conglomerate are similar to the quartzite in the Uinta Mountains.

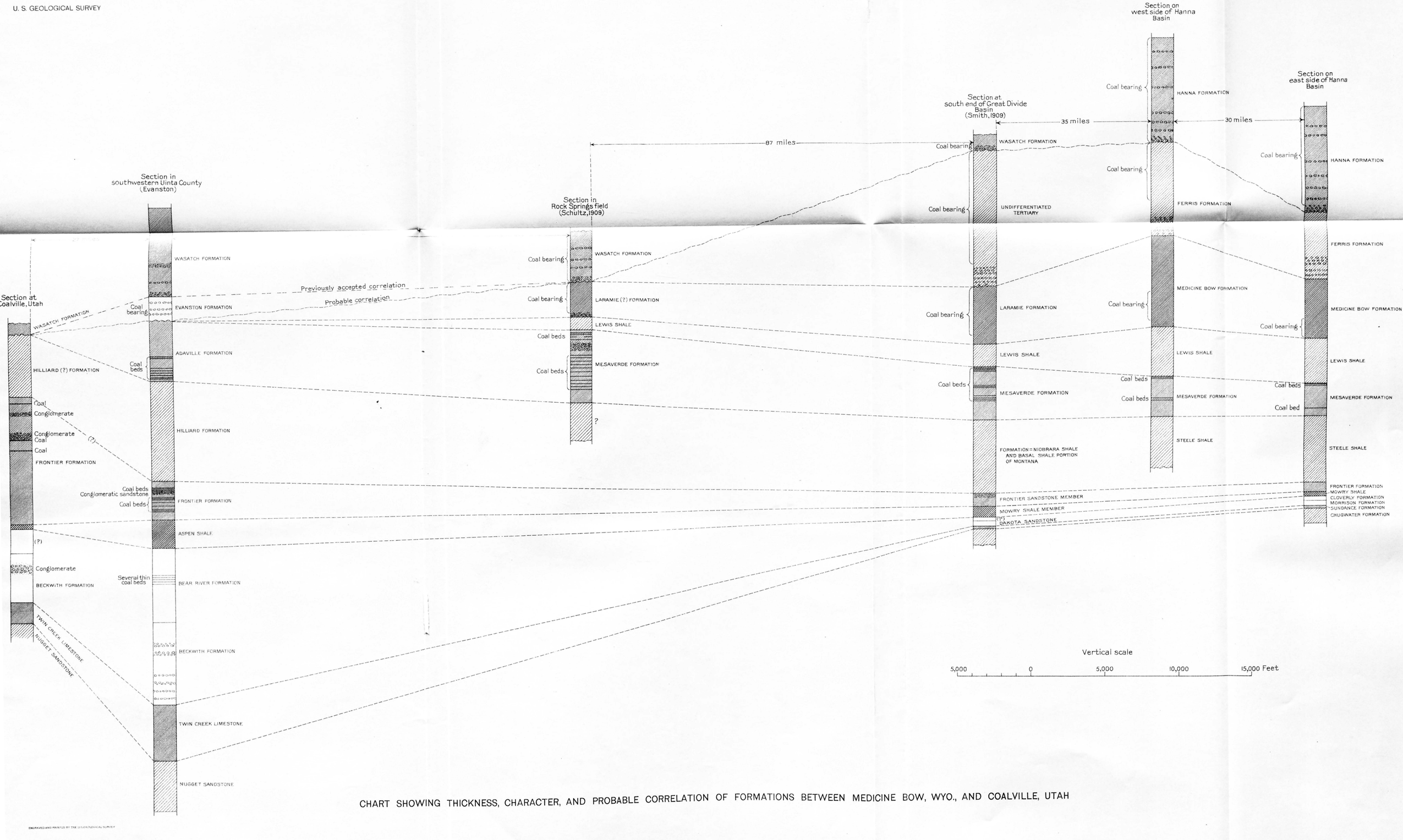

CHART SHOWING THICKNESS, CHARACTER, AND PROBABLE CORRELATION OF FORMATIONS BETWEEN MEDICINE BOW, WYO., AND COALVILLE, UTAH

ENGRAVED AND PRINTED BY THE GEOLOGICAL SURVEY

CONCLUSION.

By way of summary it may be said that the great break, as indicated by structural and field relations, occurs at the base of the Hanna formation; that this formation is the equivalent of the Wasatch of the Great Divide Basin and Rock Springs fields; that the structural and field relations do not suggest an unconformity at the base of the Ferris formation; that Paleozoic rocks contributed to the sedimentary formations from at least the beginning of Cretaceous time; and that the sediments seem to have been derived from the west or southwest.