Stratigraphy and Nomenclature of Some Upper Cretaceous and Lower Tertiary Rocks in South-Central Wyoming

By J. R. GILL, E. A. MEREWETHER, *and* W. A. COBBAN

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Regional stratigraphic studies and ammonite zonation are used in interpreting complex intertonguing and subtle facies changes in rocks of Late Cretaceous and early Tertiary age

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By J. R. GILL, E. A. MEREWETHER, and W. A. COBBAN

ABSTRACT

Upper Cretaceous rocks described and correlated in this report are the Steele Shale, Mesaverde Group (consisting of the Rock River Formation (new name), Haystack Mountains Formation (new name), Allen Ridge Formation, Pine Ridge Sandstone, and Almond Formation), Lewis Shale, Fox Hills Formation, Medicine Bow Formation, and the lower part of the Ferris Formation. The lower Tertiary rocks described consist of the upper part of the Ferris Formation of Paleocene age and the overlying Hanna Formation of late Paleocene and Eocene age.

The oldest unit investigated, the Steele Shale, consists of 2,300–3,800 feet of dark-gray marine shale that contains limestone concretions, beds of bentonite as much as 5 feet thick, and thin layers of siltstone and very fine grained sandstone. It becomes sandy upward and grades into the overlying Mesaverde Group.

The Mesaverde Group, in the Rawlins-Medicine Bow area, consists of the following formations, from oldest to youngest: Haystack Mountains Formation, Allen Ridge Formation, Pine Ridge Sandstone, and Almond Formation. The Haystack Mountains Formation comprises a sequence of mostly shallow-water marine sandstone and shale that thins southwestwardly across south-central Wyoming from 2,550 to 850 feet. It contains three persistent ridge-forming sandstone members interpreted as beach and barrier-bar deposits. The oldest member, Tapers Ranch Sandstone (new name), is 270 feet thick and forms the base of the formation. The second member, O'Brien Spring Sandstone (new name) is 220 feet thick and lies 1,350 feet below the top of the formation. The Hatfield Sandstone Member, as much as 167 feet thick, lies 450 feet below the top.

Nonmarine sandstone, shale, and carbonaceous beds largely make up the Allen Ridge Formation, but some sandstone and shale of brackish-water and marine origin are included. The Allen Ridge is conformable with the underlying Haystack Mountains Formation. It is as much as 1,500 feet thick. It intertongues with the Rock River Formation, and in the Laramie Basin area, it is replaced by that formation.

Disconformably overlying the Allen Ridge Formation is the Pine Ridge Sandstone, a white to light-gray nonmarine sandstone 60–450 feet thick. The formation contains carbonaceous shale and impure coal, and ordinarily forms a conspicuous tree-covered ridge.

The Almond Formation, 30–575 feet thick, conformably overlies the Pine Ridge Sandstone. It is a sequence of sandstone, shale, and coal, representing fluviatile, brackish-water, and nearshore marine environments of deposition.

In the southeastern part of the area (Laramie Basin), the Mesaverde Group consists of the Rock River Formation and Pine Ridge Sandstone. The Rock River is a 1,500-foot-thick sequence of nonresistant sandstone and sandy shale of shallow-water marine origin. It grades eastward into the dominantly nonsandy Pierre Shale.

In southeastern Wyoming, the Mesaverde Group is conformably overlain by the Lewis Shale. The Lewis, 2,200–2,600 feet thick, is chiefly dark-gray marine shale but contains sandy units. In the Hanna Basin, the Lewis is divided into three parts by the Dad Sandstone Member, which is as much as 1,400 feet thick.

The Fox Hills Formation conformably overlies the Lewis Shale. It is chiefly ridge-forming yellowish-gray to light-brown shallow-water marine sandstone and ranges in thickness from less than 200 to more than 700 feet.

The Medicine Bow Formation, 3,000–6,500 feet thick, rests conformably on the Fox Hills. Lenticular beds of sandstone, siltstone, and shale, and persistent beds of coal make up the formation. Most of the formation is nonmarine, but the lower part contains brackish-water beds.

The Ferris Formation, of nonmarine origin, conformably overlies the Medicine Bow and is divisible into two parts. The lower part, 1,100 feet thick, consists of conglomeratic sandstone, sandstone, siltstone, and shale. The conglomeratic beds contain small well-rounded pebbles of resistant rocks such as chert and quartzite. The upper part, about 5,400 feet thick, is finer grained than the lower part and consists of sandstone, shale, and coal.

The Hanna Formation unconformably overlies the Ferris or older formations. It is as much as 7,000 feet thick and consists of nonmarine conglomerate, sandstone, shale, and coal. The conglomerates contain large cobbles of locally derived rocks.

The names Foote Creek and Dutton Creek, recently proposed by H. J. Hyden, Harry McAndrews, and R. H. Tschudy (1965), are abandoned. The Foote Creek is a remnant of the Medicine Bow Formation, and the Dutton Creek is part of the Hanna Formation.

INTRODUCTION AND ACKNOWLEDGMENTS

Regional stratigraphic and paleontologic studies and detailed geologic mapping in south-central Wyoming have demonstrated the need for revision of the stratigraphic nomenclature for the rocks of Late Cretaceous age. The ammonite zonation of the Upper Cretaceous rocks in the Western Interior established by Cobban provides a framework for regional stratigraphic studies and can be used in interpreting the complex intertonguing and subtle facies changes within these rocks. In this report we describe some of these complexities and attempt to make the nomenclature more compatible with that used in adjacent areas.

We acknowledge the assistance of Drs. D. L. Blackstone, Jr., and R. S. Houston, of the University of Wyoming, in reviewing this report and in discussing pertinent stratigraphic and nomenclature problems. G. H. Horn, M. W. Reynolds, and R. H. Tschudy, of the U.S. Geological Survey, also provided valuable assistance. N. F. Sohl, of the U.S. Geological Survey, identified the marine gastropod collections.

HISTORICAL BACKGROUND

SOUTHWESTERN COLORADO

In 1875, W. H. Holmes studied the geology of the San Juan district in southwestern Colorado and contiguous parts of New Mexico, Utah, and Arizona. He recognized sedimentary rocks of Cretaceous age and determined their thickness to be about 5,000 feet (Holmes, 1877, p. 242). He called the lowermost Cretaceous rock unit the Dakota Sandstone, or No. 1, following the nomenclature of Meek and Hayden (1862, p. 419; for a summary of Hayden's nomenclature, see Cobban and Reeside, 1952, p. 1014). Holmes thought that the overlying marine shale and minor limestone, 1,200–1,500 feet thick, represented Hayden's units 2 and 3 and part of unit 4 (the Fort Benton Group, Niobrara division, and Fort Pierre Group). Holmes (1877, p. 245) named stratigraphically higher nonmarine and marine rocks the Mesa Verde Group, in which he recognized a threefold division—an upper escarpment sandstone, a middle coal group, and a lower escarpment sandstone. He did not name an overlying 400- to 800-foot-thick marine shale, but he called the next higher massive marine sandstone the Pictured Cliffs Group. Holmes (1877, p. 243, pl. 15) equated the marine shale and overlying Pictured Cliffs Group with Cretaceous units 4 and 5 of Hayden (Fort Pierre Group and Fox Hills beds).

The thick marine shale unit between the Dakota Sandstone and the Mesa Verde (Holmes, 1877) was named the Mancos Shale by Cross (1899) for exposures near the town of Mancos, Colo., north of Mesa Verde National Park. The marine shale between the Mesa Verde and the Pictured Cliffs Sandstone was named the Lewis Shale by Cross and Spencer (1899) for exposures near Fort Lewis, Colo., east of Mesa Verde National Park. The current spelling of the name Mesaverde was apparently introduced by Cross and Spencer in 1899.

In 1919, A. J. Collier investigated the coal deposits in Holmes' middle coal group of the Mesa Verde south of the town of Mancos in the region of Mesa Verde. Collier (1919, p. 296) recognized Holmes' threefold division of the Mesaverde and designated the upper escarpment sandstone as the Cliff House Sandstone, the middle coal group as the Menefee Formation, and the lower escarpment sandstone as the Point Lookout Sandstone and referred the three new formations to the Mesaverde Group.

NORTHWESTERN COLORADO

Geologists of the King and the Hayden Surveys mapped Cretaceous sedimentary rocks in Routt County, northwestern Colorado, and adopted the stratigraphic classification previously established in the upper Missouri River region by Meek and Hayden (1862, p. 419). The classification used in the Missouri River region, based on lithology and fossils, was applied to Cretaceous rocks throughout much of the Rocky Mountain region. Nomenclature used by these surveys is as follows (adapted from Fenneman and Gale, 1906, p. 18):

Tertiary		
Cretaceous	6. Laramie	
	5. Fox Hills	Montana Group
	4. Pierre	
	3. Niobrara	Colorado Group
	2. Benton	
	1. Dakota	

The early geologists generally assumed that the main Cretaceous coal-bearing units were in the Laramie and that the minor coal-bearing units were in the Dakota. This assumption resulted in the inclusion of the main coal-bearing rocks of northwestern Colorado in the Laramie Formation.

In 1905, Fenneman and Gale studied the Yampa coal field of Routt County where they recognized marine and nonmarine Cretaceous rocks, about 8,000 feet thick, overlying the Dakota Sandstone. They (1906, p. 17–31) were unable to apply the classification and nomenclature used previously in the area and believed that the established nomenclature was incorrect and only generally relevant. Concerning this problem they stated (p. 19):

> Below the Laramie and above the Dakota the succession of formations as summarized in the foregoing table is not applicable to the Yampa field except in a most general and indefinite way. In the Montana group the Fox Hills sandstone and the Pierre shale are not found as distinct formation or lithologic units, and similarly the Colorado group cannot be said to be composed of the Niobrara limestone and the Benton shale as distinguished in other fields. Moreover, the line between the Montana and Colorado groups also becomes an indefinite or abitrary boundary as the distinction between Pierre and Niobrara is lost. There is, however, a certain fossil fauna which has been recognized as characteristic of the Montana formation, and similarly a lower fauna which is as characteristic of the Colorado. It is, however, more convenient and logical to drop the grouping as Colorado and Montana and adopt a new basis for subdivision of the combined stratigraphic interval thus represented. This has already been done by the geologists who have worked in southwestern Colorado [Cross, 1899], where the succession shows such marked similarity to that of the Yampa field that the names there adopted have been incorporated in this report.

In summary, Fenneman and Gale recognized a thick unit of marine shale containing fossils of Benton and Niobrara age overlying the Dakota Sandstone and underlying a thick unit of marine sandstone and shale containing a fauna of Pierre and Fox Hills age; this latter unit grades upward into nonmarine rocks including coal, and these, in turn, are overlain by a thick body of marine shale. Fenneman and Gale acknowledged the apparent homotaxic equivalence of these beds to the Cretaceous sequence in southwestern Colorado and, therefore, introduced the names Mancos Shale, Mesaverde Formation, and Lewis Shale into northwestern Colorado. In regard to the introduction of the names, Fenneman and Gale (1906, p. 28) stated "and the name is provisionally adopted as in the case of the Mancos shale and Mesaverde formation, in the expectation that future geologic work will definitely establish the correlation between the two."

The equivalence of the Mesaverde and Lewis of northwestern and southwestern Colorado anticipated by Fenneman and Gale has not been confirmed. Geologic investigations in western Colorado clearly demonstrate a lack of continuity between the Mesaverde and Lewis at their type localities and the Mesaverde and Lewis of northwestern Colorado and Wyoming. Reeside (1924, p. 18) stated that the Lewis Shale of the northern areas was definitely not the same age as the Lewis of the San Juan district. More recently, Weimer (1959, p. 11) has shown a similar relationship.

At its type locality in southwestern Colorado, the Mesaverde Group is a thick unit of marine sandstone and nonmarine rocks. It thins northeastward, becomes finer grained, and finally loses its identity within the Mancos Shale. At the latitude of Montrose, Colo., the entire Mesaverde Group is represented by the middle part of the Mancos Shale, and the overlying Lewis Shale is an indistinguishable part of the Mancos (Dickinson, 1965). In this area the Mancos is overlain by the Pictured Cliffs Sandstone, which in northwestern Colorado becomes the basal part of the Mesaverde as defined by Fenneman and Gale (1906) and by others. The Lewis Shale of the Yampa district of northwestern Colorado is not represented by marine rocks in western and southwestern Colorado.

In 1912 and 1913, Hancock (1925) investigated the geology and coal resources of the Axial and Monument Butte quadrangles in Moffat County in northwestern Colorado. He divided the Mesaverde into the Iles and the overlying Williams Fork Formations and elevated the Mesaverde to group status (Hancock, 1925, p. 13–14). Publication of the report formally describing these two new formations was delayed, and the names first appeared in the U.S. Geological Survey Press Memorandum 16037, October 1, 1923.

SOUTH-CENTRAL WYOMING

While examining coal deposits in east-central Carbon County, Wyo. (fig. 1), in 1906, Veatch (1907) recognized a thick succession of Upper Cretaceous rocks. The main difference between these rocks and Upper Cretaceous rocks of northwestern and southwestern Colorado was the presence of formations of the Colorado and Montana Groups in Wyoming, units that had been indistinct or unrecognizable in the southern areas. Veatch (1907, p. 246) assigned the Dakota, Benton, and Niobrara Formations to the Colorado Group and the Pierre, Mesaverde, and Lewis Formations to the Montana Group. Overlying the Montana Group was the "Lower Laramie," a thick sequence of Cretaceous nonmarine rocks. Veatch's Benton, Niobrara, and Pierre Formations are probably equivalent to Fenneman and Gale's Mancos Shale (1906), and the Mesaverde and Lewis Formations in each area are approximately equivalent. Regarding the use of the name Pierre in Wyoming, Veatch (1907, footnote on p. 246) stated:

> It is the belief of Dr. T. W. Stanton that the Mesaverde and part of the Lewis also belong to the Pierre, as that formation is developed east of the Rocky Mountains. A local name will therefore probably be applied to this lowest division of the Montana in this region.

The name Steele Shale was introduced by Darton, Blackwelder, and Siebenthal (1910, p. 10), to replace Pierre as used by Veatch (1907). Their description follows:

> The lower portion of the Montana group in the Laramie Basin consists of about 3,000 feet of dark shale with some thin beds of sandstone and numerous nodular concretions, mostly sandy. These rocks are believed to represent the Steele shale, named for the type locality, Fort Steele, on the North Platte River.

In 1918, Bowen reported on the stratigraphy of the Hanna Basin. He described the Steele Shale as a 4,000-foot-thick dark-gray shale with interbedded sandstone and shaly sandstone, some of which forms conspicuous ledges near the top of the formation (Bowen, 1918, p. 229). He described the Mesaverde Formation as 2,700 feet thick and divisible into three members. The upper member consists of whitish sandstone interbedded with gray and carbonaceous shale and thin irregular beds of coal. The middle member is composed of brown to gray sandstone, carbonaceous shale, and thin irregular beds of coal; it contains a fresh- and brackish-water fauna. The lower member is gray to white sandstone and gray shale; it lacks coal and contains a marine fauna. Bowen apparently redefined the upper and lower boundaries of the Mesaverde of Veatch and included some of the lower part of the Mesaverde in the Steele Shale (Veatch, 1907, p. 246; Bowen, 1918, p. 229).

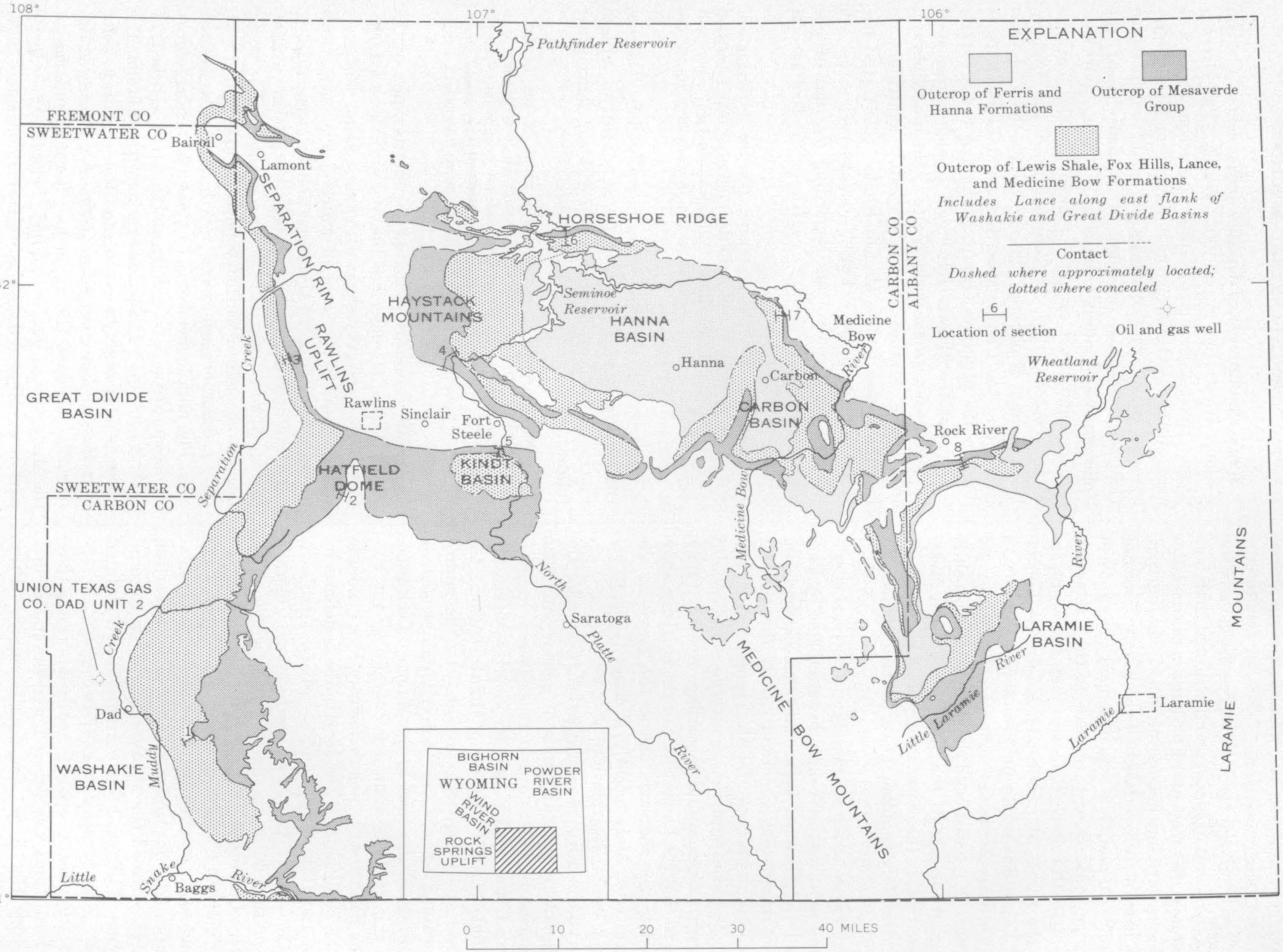

FIGURE 1.—Index geologic map of south-central Wyoming showing location of measured sections. Geology modified from Love, Weitz, and Hose (1955).

In south-central Wyoming, the Lewis Shale and overlying "Lower Laramie" were reported by Veatch (1907, p. 246–249) to consist of marine and continental rocks, respectively. Bowen (1918, p. 228–230) substituted the name Medicine Bow Formation for the "Lower Laramie." Dobbin, Bowen, and Hoots (1929, p. 22–24) described a unit of interbedded marine and nonmarine rocks, 400–500 feet thick, between the Lewis and Medicine Bow and reassigned most of these rocks from the upper part of the Lewis to the basal part of the Medicine Bow. They correlated this transitional unit plus an uppermost part of the Lewis Shale with the Fox Hills Sandstone of eastern Wyoming. The Fox Hills had been named in South Dakota by Meek and Hayden (1862, p. 419). Dobbin and Reeside (1929, p. 21–23) also recognized the transitional rocks and stated that they were of Fox Hills age. Dorf (1938, p. 4–6) redefined the Medicine Bow assigning the basal 400± feet in the Hanna Basin to the Fox Hills Formation.

Bowen (1918, p. 228) also named the Ferris Formation of questionable Tertiary age and the Hanna Formation of Tertiary age. Most subsequent workers in the area have used the nomenclature of Bowen (in Dobbin, Bowen, and Hoots, 1929, p. 17–26).

The names Foote Creek and Dutton Creek were introduced by Hyden, McAndrews, and Tschudy (1965) for rocks of Late Cretaceous and Tertiary age in the northern part of the Laramie Basin and southern part of the Carbon Basin. Geologic investigations in the area since then indicate that these rocks are remnants of the Medicine Bow and Hanna Formations, respectively.

SUMMARY

Nomenclature established for rocks of Late Cretaceous age in southwestern Colorado should not have been extended into northwestern Colorado, eastern Utah, and Wyoming. Although the stratigraphic sequences are homotaxically equivalent, the Mesaverde Formation and Lewis Shale are not laterally continuous among the areas. It would be desirable to abandon the names Mesaverde and Lewis away from their type localities, but their general use for more than 60 years makes such a change impractical. A reasonable solution, based on regional geologic studies, is to redefine the Mesaverde as a group and establish within it lesser stratigraphic units that are widely mappable and laterally continuous (table 1). A similar approach was used by Hancock (1925, p. 13–14) in defining the Iles and Williams Fork Formations of the Mesaverde Group in northwestern Colorado, by Spieker and Reeside (1925, p. 440); in defining the Star Point Sandstone, Blackhawk Formation, and Price River Formation of the Mesaverde Group in eastern Utah, and by Sears (1926, p. 16); in treating the Blair and Rock Springs Formations, the Ericson Sandstone, and the Almond Formation of the Mesaverde Group in southwestern Wyoming.

We propose a revision of the stratigraphic nomenclature for some of the rocks of Late Cretaceous age in the area of the Rawlins uplift and the Hanna, Carbon, and Laramie Basins in southern Wyoming. These revisions are based on regional stratigraphic and faunal studies and on detailed geologic mapping.

In the area of this report we herein elevate the Mesaverde Formation to the Mesaverde Group and establish and accept the following formations within the Mesaverde Group in the Hanna and Carbon Basins (in ascending order): Haystack Mountains Formation, Allen Ridge Formation, Pine Ridge Sandstone, and Almond Formation (fig. 2). The Haystack Mountains Formation consists of thick and persistent units of marine sandstone separated by thick units of marine shale. Three of the sandstone units have been mapped locally and are designated as members of the Haystack Mountains Formation. They are, in ascending order: Tapers Ranch, O'Brien Spring, and Hatfield Sandstone Members. The Hatfield Sandstone Member was proposed by Hale (1961, p. 134) and is herein adopted. The Allen Ridge Formation, proposed by Bergstrom (1959, p. 114) for the dominantly nonmarine part of the Mesaverde underlying the Pine Ridge Sandstone, is herein adopted. Dobbin, Hoots, Dane, and Hancock (1929, p. 134) first described the Pine Ridge Sandstone as a member of the Mesaverde Formation. We herein elevate it to formation status. The Almond Formation, first described by Schultz (1907, p. 260) is southwestern Wyoming as the Almond coal group, was later called by Sears (1926, p. 16) the Almond Formation of the Mesaverde Group. This formation conformably underlies the Lewis Shale in much of southern Wyoming. The name Almond is hereby extended from southwestern Wyoming into the area of this study.

In the Laramie Basin the Mesaverde Group consists of the Pine Ridge Sandstone and a thick underlying unit of shallow-water marine sandstone and shale. We propose that the latter unit be named the Rock River Formation (fig. 2). The thick and distinctive marine rocks of the Rock River Formation grade westward into the mainly nonmarine rocks of the Allen Ridge Formation. The lateral transition between the two formations is in the northern part of the Laramie Basin.

The name Lewis Shale is retained in southern Wyoming even though the formation is neither correlative with, nor lithologically the same as, the type Lewis Shale of southwestern Colorado. The name is perpetuated only because of long-established usage in the region. In its upper part the Lewis Shale contains a wide-

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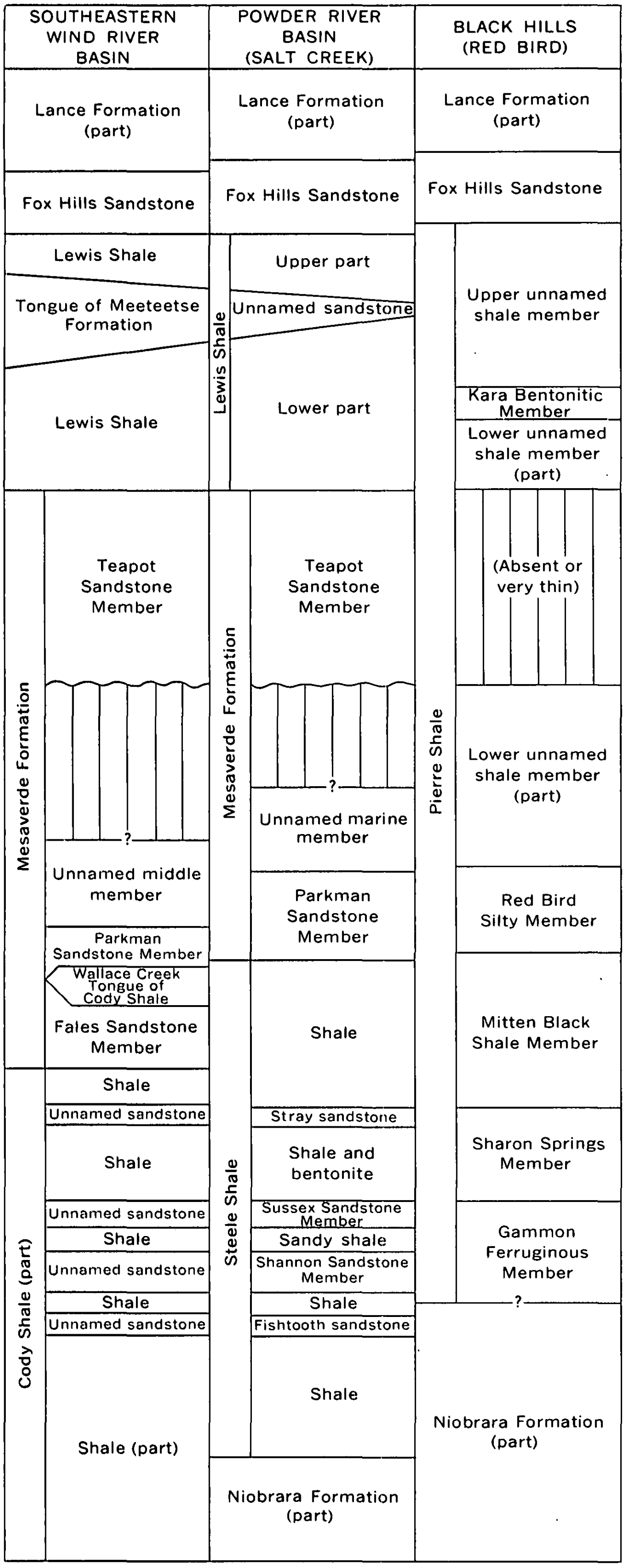
TABLE 1.—*Correlation of Upper Cretaceous rocks in south-central Wyoming and*

UPPER CRETACEOUS STAGES AND SUBSTAGES		WESTERN INTERIOR AMMONITE ZONES	ROCK SPRINGS UPLIFT			HANNA BASIN			LARAMIE BASIN (ROCK RIVER)	
Maestrichtian	Lower	29 *Discoscaphites nebrascensis*	Lance Formation (part)			Medicine Bow Formation (part)			Medicine Bow Formation (part)	
		28 *Hoploscaphites nicolletii*								
		27 *Sphenodiscus (Coahuilites)*				Fox Hills Formation			Fox Hills Formation	
		26 *Baculites clinolobatus*	Fox Hills Sandstone			Lewis Shale	Upper part		Lewis Shale	Upper part
		25 *Baculites grandis*	Lewis Shale				Dad Sandstone Member			Unnamed sandstone
		24 *Baculites baculus*					Lower part			Lower part
Campanian	Upper	23 *Baculites eliasi*	Mesaverde Group	Almond Formation		Mesaverde Group	Almond Formation			
		22 *Baculites jenseni*								
		21 *Baculites reesidei*		Ericson Sandstone	Upper part		Pine Ridge Sandstone		Mesaverde Group	Pine Ridge Sandstone
		20 *Baculites cuneatus*								
		19 *Baculites compressus*								
		18 *Didymoceras cheyennense*			?					
		17 *Exiteloceras jenneyi*								?
		16 *Didymoceras stevensoni*								Rock River Formation
		15 *Didymoceras nebrascense*					Allen Ridge Formation	Unnamed marine member		
		14 *Baculites scotti*								
		13 *Baculites gregoryensis*								
		12 *Baculites perplexus*			? Middle part		Haystack Mountains Formation	Upper unnamed member	Steele Shale	
		11 *Baculites* sp. (smooth)			?			Hatfield Sandstone Member		
		10 *Baculites asperiformis*			Lower part			Middle unnamed member		
		9 *Baculites mclearni*								
	Lower	8 *Baculites obtusus*		Rock Springs Formation				O'Brien Spring Sandstone Member		
		7 *Baculites* sp. (weak flank ribs)						Lower unnamed member		
		6 *Baculites* sp. (smooth)						Tapers Ranch Sandstone Member		
		5 *Scaphites hippocrepis* III		Blair Formation		Steele Shale				
		4 *Scaphites hippocrepis* II								
		3 *Scaphites hippocrepis* I	Baxter Shale (part)						?	
Santonian	Upper	2 *Desmoscaphites bassleri*		Airport Sandstone Member of Smith (1961)		?			Niobrara Formation (part)	
		1 *Desmoscaphites erdmanni*				Niobrara Formation (part)				

nearby areas



spread unit of sandstone and shale called the Dad Sandstone Member by Hale (1961, p. 136). This name is herein adopted.

At the top of the Lewis Shale or at the base of the overlying Medicine Bow Formation is a thick unit composed mainly of sandstone. Rocks of this unit are transitional from marine shale of the underlying Lewis to nonmarine rocks of the overlying Medicine Bow Formation and include shallow-water marine sandstone and marine to nonmarine siltstone and shale. The name Fox Hills Formation is used for these rocks.

The Medicine Bow Formation of Late Cretaceous age, named and described in the Hanna Basin, is mostly restricted to the Hanna and Carbon Basins. The name is herein used as originally defined. The Ferris Formation of Late Cretaceous and early Tertiary age and the Hanna Formation of Tertiary age were defined in the Hanna Basin and are herein adopted as originally proposed.

The Foote Creek Formation of Late Cretaceous and early Tertiary age and the Dutton Creek Formation of Tertiary age are exposed along the northern margin of the Laramie Basin and the southern margin of the Carbon Basin. Recent studies of the lithology and age of these rocks have shown them to be correlative with parts of the Medicine Bow and Hanna Formations. For reasons given in this report on pages 45–46, we commend that the names Foote Creek and Dutton Creek be abandoned.

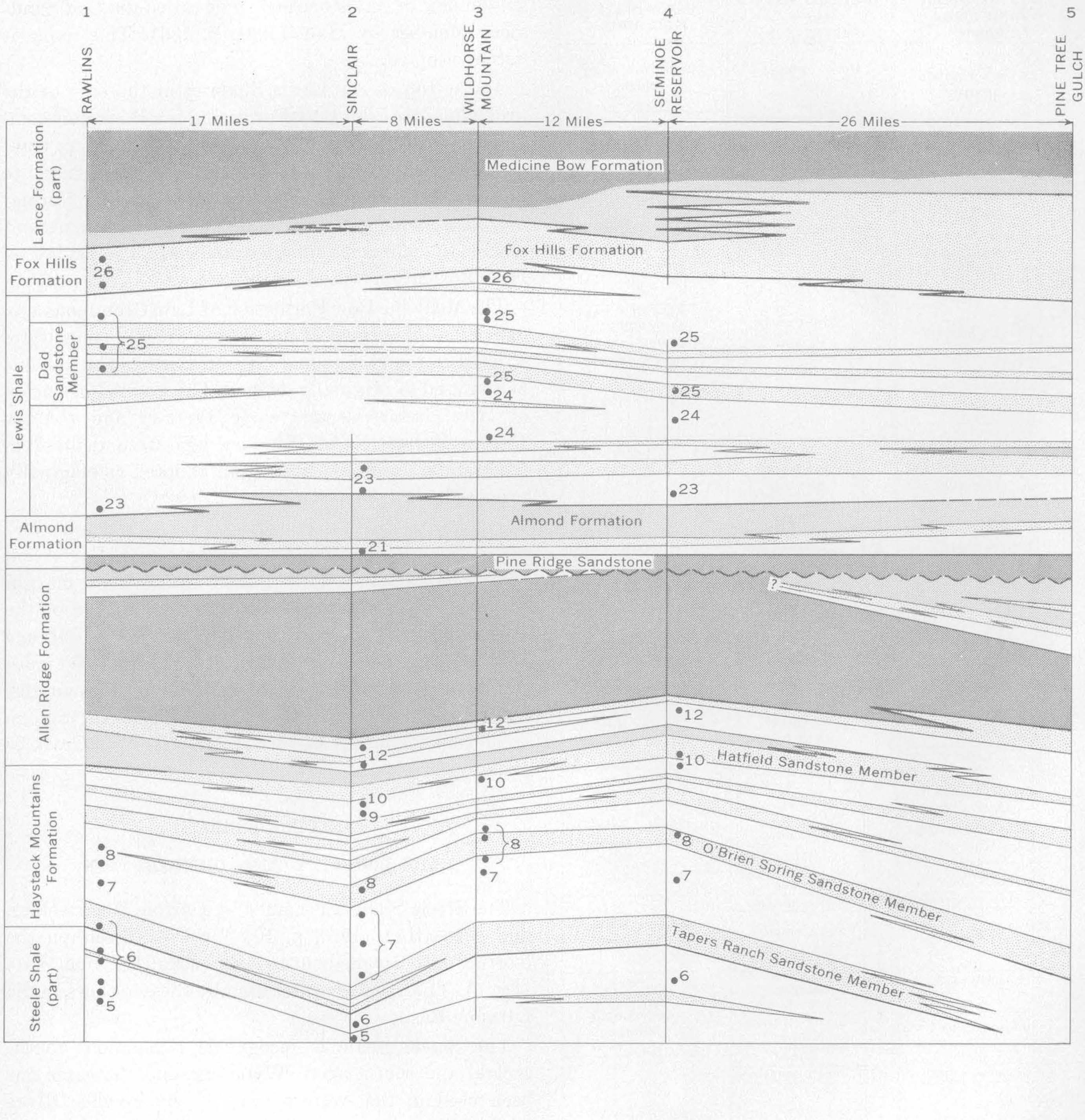
STEELE SHALE

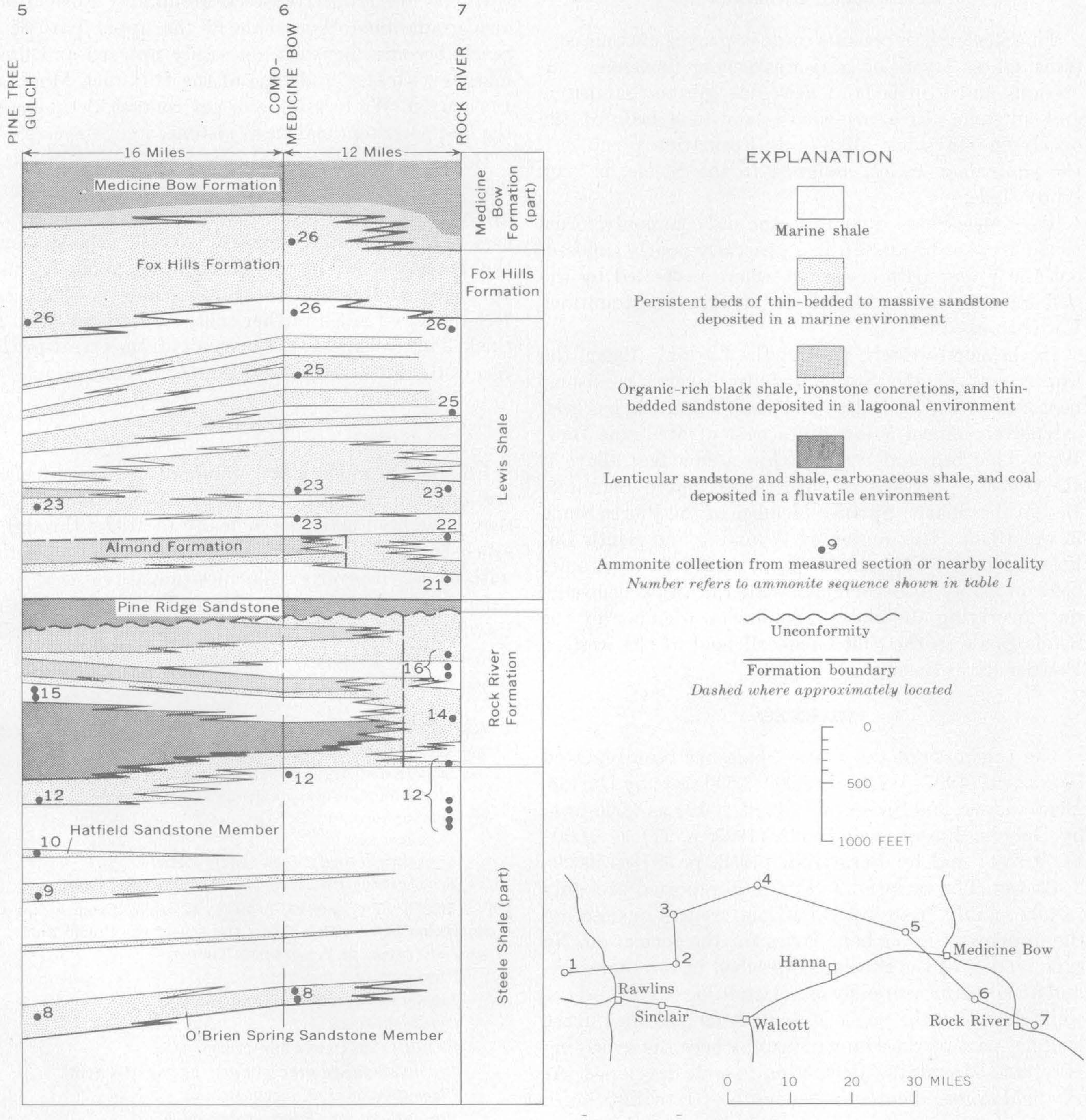
TYPE LOCALITY AND DISTRIBUTION

The Steele Shale was named by Darton, Blackwelder, and Siebenthal (1910, p. 10) for Fort Steele on the North Platte River, about 15 miles east of Rawlins, Wyo. (fig. 1). The name was first used by these authors in the Laramie Basin.

The Steele Shale is recognized throughout south-central and southeastern Wyoming, and the name has been used in the western part of the Powder River Basin in northeastern Wyoming. In areas where the underlying Niobrara Formation is poorly developed or not recognized, the marine shale unit beneath the Mesaverde is called Cody Shale. The Cody is equivalent to the Carlile Shale, Niobrara Formation, and Steele Shale.

FIGURE 2.—*Stratigraphic diagram showing intertonguing relations*





of Upper Cretaceous rocks in south-central Wyoming

LITHOLOGIC CHARACTER

The Steele Shale consists of dark-gray shale that contains sparse layers of gray-weathering limestone concretions and thin beds of very fine grained sandstone and siltstone. In areas where sandstone beds of the overlying Haystack Mountains Formation pinch out, the equivalent facies, assigned to the Steele, is very sandy shale.

The Steele Shale is nonresistant and commonly forms broad areas of low relief. It is generally poorly exposed, but the upper part crops out where protected by the cliff-forming sandstone of the Haystack Mountains Formation.

In the northwestern part of the Laramie Basin, the upper part of the Steele includes several persistent bentonite beds. One bed, as much as 5 feet thick, has been extensively mined a few miles west of Medicine Bow, Wyo. This bed and those within a few feet above it are probably correlative with the Ardmore Bentonite Bed in the Sharon Springs Member of the Pierre Shale in the Black Hills region of Wyoming and South Dakota (Gill and Cobban, 1966a, p. A10). The bentonite beds probably also correlate with the thick bentonite unit overlying the Sussex Sandstone Member of the Steele Shale in the Salt Creek oil field of the western Powder River Basin.

THICKNESS

The thickness of the Steele Shale has been reported by Veatch (1907, p. 246) as 3,000–3,500 feet; by Darton, Blackwelder, and Siebenthal (1910, p. 10) as 3,000 feet; by Dobbin, Bowen, and Hoots (1929, p. 17) as 4,000–5,000 feet; and by Bergstrom (1953, p. 59) as 2,600–3,200 feet. The variation in thickness reported probably results mainly from individual preferences in selecting the upper and lower boundaries for the formation. No type section of the Steele is described in the literature, and none was measured by us. Electric logs of oil and gas wells show that the Steele is about 2,400 feet thick in the western part of the Hanna Basin, where the overlying Haystack Mountains Formation is well developed. At Hatfield dome, about 10 miles south of Rawlins, Smith (1965, pl. 3) reported the Steele to be about 3,800 feet thick. In the Rock River area of the Laramie Basin, the formation is about 2,300 feet thick.

RELATION TO ADJACENT FORMATIONS

The contact of the Steele Shale with the underlying Niobrara Formation is gradational. It is located at the change from the gray shale of the Steele to the yellowish-orange-weathering calcareous shale of the upper part of the Niobrara. The contact of the Steele Shale with the overlying Haystack Mountains Formation is also gradational. The shale of the upper part of the Steele becomes increasingly sandy upward and finally merges with the sandstone of the Haystack Mountains Formation. We locate the upper contact at the base of the first persistent marine sandstone.

Both the upper and lower boundaries of the Steele rise stratigraphically eastward, and the formation grades laterally into the lower part of the Pierre Shale east of the Laramie Mountains. In the type section of the Haystack Mountains Formation, about 11 miles northeast of Rawlins, the Steele Shale is about 2,400 feet thick; 22 miles farther south, it is about 3,800 feet thick. This thickness change results from a stratigraphic rise in the Steele-Haystack Mountains contact.

FOSSILS

Fossils are moderately abundant in limestone concretions and thin sandy beds of the Steele Shale, and they have been collected at many localities throughout southern Wyoming. The best documented collections with respect to stratigraphic position are those of Smith (1965, p. 21–23) from the Hatfield dome area south of Rawlins in Carbon County. Fossils from these collections, which were identified and the names herein updated by W. A. Cobban, are as follows:

USGS D3293. SE¼ sec. 24, T. 19 N., R. 87 W. From a limestone concretion layer 415 ft below the top of the Steele Shale.
- *Inoceramus* cf. *I. proximus* Tuomey
- *Pteria linguaeformis* (Evans and Shumard)
- *Cymbophora* sp.
- *Thyasira* sp.
- *Baculites obtusus* Meek (early form)
- *Trachyscaphites praespiniger* Cobban and Scott

USGS D3290. SE¼ sec. 12, T. 19 N., R. 88 W. From a limestone concretion layer 405 ft below the top of the Steele Shale.
- *Inoceramus* cf. *I. proximus* Tuomey
- *Pteria* sp.
- *Lucina subundata* Hall and Meek
- *Cymbophora* sp.
- *Baculites* sp. (weak flank ribs)
- *Trachyscaphites praespiniger* Cobban and Scott
- *Placenticeras* cf. *P. meeki* Boehm
- *Placenticeras* cf. *P. intercalare* Meek

USGS D3048. NW¼ sec. 34, T. 19 N., R. 86 W. From a limestone concretion layer 702 ft below the top of the Steele Shale
- *Inoceramus* sp.
- *Pteria* sp.
- *Ostrea* sp.
- *Baculites* sp. (weak flank ribs)
- *Placenticeras* cf. *P. meeki* Boehm

USGS D3047. NE¼ sec. 34, T. 19 N., R. 86 W. From a limestone concretion layer 702 ft below the top of the Steele Shale.
- *Inoceramus* sp.
- *Baculites* sp. (weak flank ribs)

USGS D3046. SW¼ sec. 35, T. 19 N., R. 86 W. From a limestone concretion layer 912 ft below the top of the Steele Shale.
Inoceramus sp.
Pteria n. sp.
Baculites sp. (weak flank ribs)
Trachyscaphites praespiniger Cobban and Scott

USGS D3291. NE¼ sec. 26, T. 19 N., R. 87 W. From a limestone concretion layer 1,736–1,750 ft below the top of the Steele Shale.
Lucina subundata Hall and Meek
Baculites aff. *B. aquilaensis* Reeside

USGS D3054. NE¼ sec. 23, T. 19 N., R. 88 W. From a limestone concretion layer 2,320 ft below the top of the Steele Shale.
Inoceramus cf. *I. proximus* Tuomey
Ostrea sp.
Glyptoxoceras sp.
Scaphites hippocrepis (DeKay)

USGS D3053. NW¼ sec. 14, T. 19 N., R. 88 W. From a limestone concretion layer 2,332 ft below the top of the Steele Shale.
Inoceramus cf. *I. proximus* Tuomey
Pteria cf. *P. linguaeformis* (Evans and Shumard)
Ostrea n. sp.
Drepanochilus sp.
Baculites sp.
Glyptoxoceras sp.
Haresiceras montanaense (Reeside)
Scaphites hippocrepis (DeKay) I

USGS D3095. Center of the N½ sec. 23, T. 19 N., R. 88 W. From a limestone concretion layer 2,747 ft below the top of the Steele Shale.
Ostrea sp.
Baculites sp.
Scaphites hippocrepis (DeKay) I

USGS D3051. NW¼ sec. 26, T. 19 N., R. 88 W. From clayey limestone concretion layer 3,565 ft below the top of the Steele Shale.
Uintacrinus socialis Grinnell
Ostrea congesta Conrad
Inoceramus cf. *I. balticus* Boehm
Baculites thomi Reeside
Desmoscaphites bassleri Reeside

AGE AND CORRELATION

The fauna listed above from the Steele Shale in the Hatfield dome area, south of Rawlins, is common to the Telegraph Creek and Eagle Formations and the lower part of the Claggett Formation of central Montana (Cobban and Reeside, 1952, p. 1019–1020). In the area north and northeast of Rawlins, the top of the Steele is older and apparently does not contain beds younger than about the middle part of the Eagle; beds in the lower part of the overlying Haystack Mountains Formation contains late Eagle and Claggett fauna.

The upper part of the Steele Shale in the area north of Rawlins correlates with the upper part of the Mancos Shale of northwestern Colorado, the upper part of the Blair Formation of southwestern Wyoming, the upper part of the Cody Shale in the Wind River Basin of central Wyoming, and the Steele Shale of the western Powder River Basin of northeastern Wyoming (table 1). The lower contact of the Steele rises stratigraphically toward the east.

MESAVERDE GROUP AND MESAVERDE FORMATION

Rocks in south-central Wyoming formerly called Mesaverde Formation, and hereafter referred to as the Mesaverde Group (table 1), are divided into the following formations, in ascending order: Haystack Mountains Formation, Allen Ridge Formation, Pine Ridge Sandstone, and Almond Formation. The Mesaverde Group conformably overlies, and laterally intertongues at the base with, the Steele Shale. It conformably underlies, and laterally intertongues at the top with, the Lewis Shale (fig. 2).

In the southeastern part of the area (Laramie Basin), the Mesaverde Group comprises the Rock River Formation and the Pine Ridge Sandstone. The absence of the Haystack Mountains, Allen Ridge, and Almond Formations is due to the eastward change in facies from rocks typical of these formations to marine beds of the Steele and Lewis Shales (fig. 2).

The name Mesaverde Formation is still applied to a thick sequence of shallow-water marine and nonmarine beds in the Powder River, Bighorn, and Wind River Basins of Wyoming. Regional stratigraphic studies indicate that the formation is composed of several widespread and distinctive units that can be recognized in each of the basins. Some of these units, such as the Teapot and Parkman Sandstones, are formal members of the Mesaverde Formation, but other equally distinctive units are unnamed.

In the southeastern part of the Wind River Basin, Barwin (1959, p. 141) named the lower regressive tongue of the Mesaverde Formation the Phayles Reef Member and later modified the name to Phayles Member (Barwin, 1961, p. 174). We reexamined Barwin's area and type section in the SW¼ sec. 4, T. 33 N., R. 87 W., and found that the correct spelling of "Phayles" is Fales, as shown on the Garfield Peak 7½-minute quadrangle map. Inasmuch as "Phayles" is not a well-established and repeatedly published name, we are accepting the correct spelling of Fales.

Marine rocks overlying the Fales were called the Wallace Creek Tongue of the Cody Shale (Barwin, 1959, p. 142). The type section of the Wallace Creek is also in the SW¼ sec. 4, T. 33 N., R. 87 W. The Wallace Creek Tongue of the Cody and the Fales Member of the Mesaverde are distinctive stratigraphic units in the southeastern part of the Wind River Basin and are herein adopted as formal stratigraphic units for that area.

FIGURE 3.—Haystack Mountains Formation exposed along the west side of the Haystack Mountains in sec. 18, T. 24 N., R. 86 W., Carbon County, Wyo. tr, Tapers Ranch Sandstone Member; ob, O'Brien Spring Sandstone Member; ha, Hatfield Sandstone Member; hm, top of Haystack Mountains Formation.

HAYSTACK MOUNTAINS FORMATION

TYPE SECTION AND DISTRIBUTION

The Haystack Mountains Formation receives its name from an imposing range of hills that occupies the west half of TS. 22–23 N., R. 86 W., Carbon County, Wyo. (fig. 3). These hills, called the Haystack Mountains, form the rugged elevated surface along the east side of the Rawlins Northwest 7½–minute quadrangle, the southern part of the Wild Horse Mountain 7½–minute quadrangle, and the western part of the Lone Haystack Mountain 7½–minute quadrangle.

The type section of the Haystack Mountains Formation was measured a short distance west of the place where the Seminoe road passes through the canyon of the North Platte River, about 6 miles north of the town of Sinclair (fig. 1). The section was measured by plane-table and tape in the NE¼NE¼ sec. 22, NE¼ sec. 23, and SE¼SE¼ sec. 14, T. 22 N., R. 86 W., Carbon County (Sinclair 7½–minute quadrangle). The upper part of the underlying Steele Shale was measured in the N½SW¼ sec. 7, T. 22 N., R. 86 W. (Rawlins Northwest 7½–minute quadrangle).

Three new distinctive members of the Haystack Mountains Formation are recognized and mapped in this area (table 1; fig. 2). These members are, in ascending order: Tapers Ranch Sandstone, O'Brien Spring Sandstone, and Hatfield Sandstone. The name Tapers Ranch is taken from Tapers Ranch in the S½ sec. 3, T. 24 N., R. 86 W. (Wild Horse Mountain 7½-minute quadrangle), and the name O'Brien Spring is taken from O'Brien Spring located in the SW¼ sec. 9, T. 24 N., R. 86 W. (Seminoe Dam Southwest 7½-minute quadrangle). Both members are moderately well exposed in the vicinity of these two localities, but they are best developed and exposed at the locality of the type Haystack Mountains Formation which is designated the type section of the two new members.

The Hatfield Sandstone was named a member of the "lower (marine) Mesaverde" by Hale (1961, p. 130–134) for exposures along the flanks of Hatfield dome south of Rawlins. The name is here adopted as the youngest named member of the Haystack Mountains Formation. Inasmuch as a type section was not given by Hale, we designate as the principal reference section the exposure of the Hatfield Sandstone Member on the west side of Hatfield dome in the NE¼NE¼ sec. 18, T. 19 N., R. 88 W., Carbon County, Wyo. (Bridger Pass 15–minute quadrangle) (figs. 1, 4).

The Haystack Mountains Formation is a widespread and distinctive unit that can be recognized along the east margins of the Great Divide and Washakie Basins, on the flanks of the Rawlins uplift, and in the Hanna and Carbon Basins (fig. 1). The upper part of the formation is present along the Colorado-Wyoming boundary east of Baggs, Wyo. It is not recognizable in the Laramie Basin because of a facies change from ridge-forming sandstones to soft sandy shale. Rocks in the Laramie Basin that are equivalent to the Haystack Mountains Formation are part of the Steele Shale. The dominant source for the marine sandstones of the Haystack Mountains Formation seems to have been from

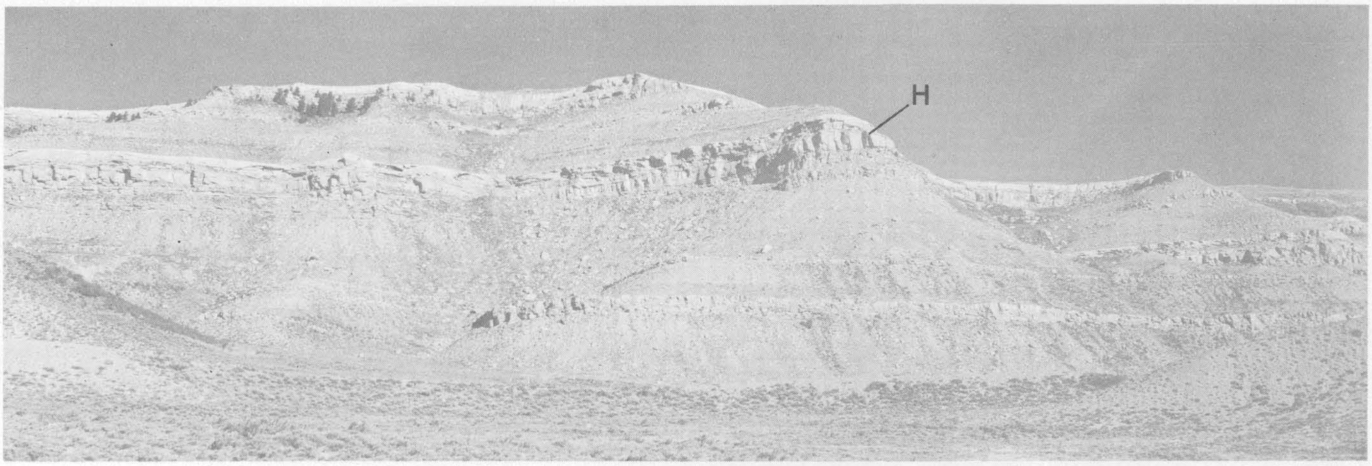


FIGURE 4.—Haystack Mountains Formation at the principal reference section of the Hatfield Sandstone Member, sec. 18, T. 19 N., R. 88 W., Carbon County, Wyo. The Hatfield Sandstone Member (H) crops out in the middle of the slope.

the north and northwest inasmuch as brackish-water strata occur in association with these beds in that direction.

LITHOLOGIC CHARACTER

The Haystack Mountains Formation is thick and lithologically diverse, consisting mainly of thick units of marine sandstone, deposited in nearshore and offshore enviroments, interbedded with thick units of marine shale, deposited in deeper water environments. The sandstone of marine origin in the type section generally is pale yellowish gray, very fine to fine grained, very thin to thin bedded, and commonly burrowed. Sandstone units generally have a gradational base and are as much as 275 feet thick. Units of marine shale range in thickness from about 25 to 700 feet. The shale is gray to brownish gray and consists mostly of clay and sandy clay. The shale contains fossiliferous concretions in varying abundance, and these may be rusty-weathering ironstone, limestone, or argillaceous sandstone.

At the type section the formation contains eight ledge-forming sandstone beds, three of which are laterally persistent and locally mapped. The three units are designated members of the Haystack Mountains Formation. The uppermost of the members is the Hatfield which is the most diagnostic and useful for correlation. It crops out about 450 feet below the top of the formation north of Sinclair. The Hatfield consists of pale-yellowish-gray cliff-forming sandstone about 167 feet thick at the principal reference section on Hatfield dome. At this locality, it is overlain by a unit of brackish-water and shallow-marine carbonaceous shale, siltstone, and sandstone, about 100 feet thick. At the type section of the Haystack Mountains Formation, the Hatfield is a cliff-forming marine sandstone, about 120 feet thick, that is overlain by rocks of brackish-water origin about 55 feet thick. The Hatfield Sandstone Member at the type section of the Haystack Mountains Formation is mostly very fine grained, thin bedded, and crossbedded, and it is gradational with the underlying marine shale. The Hatfield Sandstone Member probably originated as a marine beach and barrier-bar deposit.

The O'Brien Spring Sandstone Member crops out about 1,350 feet below the top of the Haystack Mountains Formation north of Sinclair. It consists of pale-yellowish-gray very fine grained and fine-grained thin-bedded sandstone (fig. 5) about 220 feet thick, that forms a prominent cliff (fig. 6). The lower part of the member grades into the underlying marine shale. The sandstone contains abundant *Ophiomorpha*, a fossil crustacean burrow indicative of a shallow-water marine environment.

The Tapers Ranch Sandstone Member is the basal sandstone of the Haystack Mountains Formation and, at the type section north of Sinclair, is about 270 feet thick. The member consists of grayish-green fine- to coarse-grained glauconitic thin-bedded sandstone containing laminae of dark-gray sandy shale. At the type section, a unit about 50 feet thick of gray sandy shale containing laminae of sandstone crops out about 75 feet above the base of the member. The member has a gradational base. The Tapers Ranch Sandstone Member probably originated in an environment of deeper water than either the Hatfield or the O'Brien Spring.

THICKNESS

The Haystack Mountains Formation ranges in thickness from 2,550 feet at the type section to 850 feet at Hatfield dome. This thinning toward the southwest results from facies changes in the lower part of the formation; sandstone at the type section grades into shale at Hat-

367-863 O—70——3

FIGURE 5.—Thin-bedded character of the O'Brien Spring Sandstone Member of the Haystack Mountains Formation at its type section in the NE¼ sec. 23, T. 22 N., R. 86 W., Carbon County, Wyo.

field dome. In secs. 2, 3, and 11, T. 24 N., R. 89 W., at Separation Rim, the formation is 930 feet thick. The thickness difference between this locality and the type section to the east results from different interpretations of the base of the Mesaverde Group. North from Separation Rim, the Haystack Mountains Formation thins to a featheredge, partly by depositional thinning and facies change to nonmarine rocks and partly by uplift and erosion before deposition of the Pine Ridge Sandstone and the Lewis Shale (Reynolds, 1966). The formation thins eastward and is not present in the central part of the Laramie Basin.

RELATION TO ADJACENT FORMATIONS

The contact of the Haystack Mountains Formation with the underlying Steele Shale is conformable and gradational. The basal sandstone of the Haystack Mountains grades into sandy shale in the upper part of the Steele.

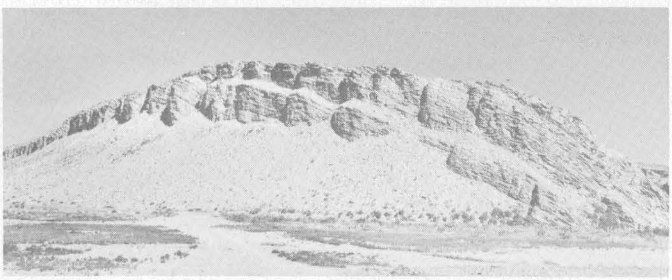


FIGURE 6.—O'Brien Spring Sandstone Member of the Haystack Mountains Formation at its type section in the NE¼ sec. 23, T. 22 N., R. 86 W., Carbon County, Wyo.

The marine shale members of the Haystack Mountains Formation are genetically tongues of the Steele Shale. The units of marine sandstone in the Haystack Mountains Formation, if traced laterally eastward and southward, lose their identity within equivalent parts of the Steele Shale.

The contact of the Haystack Mountains Formation with the overlying Allen Ridge Formation is sharp and conformable. It is generally located by a change from marine sandstone to carbonaceous shale or coal. The upper part of the Haystack Mountains Formation may locally contain a few beds of carbonaceous shale, but the lower part of the Allen Ridge Formation does not contain beds of marine sandstone. The contact of the two formations represents a change from a mainly shallow-marine environment to a brackish-water or fluviatile environment. The contact descends stratigraphically to the west and northwest.

FOSSILS

Fossils are moderately abundant in the sandstone and shale of the Haystack Mountains Formation. Those in the shale are commonly enclosed in calcareous, sandy, or iron-rich concretions and rarely occur individually. Fossils are generally sparse in the sandstone units but are locally abundant on the upper surfaces of a few sandstone beds. The following sequence of index ammonites was established from scattered localities in the Haystack Mountains Formation:

Baculites perplexus (youngest)
asperiformis
mclearni
obtusus
sp. (weak flank ribs)
sp. (smooth) (oldest)

Additional fossils are listed with the descriptions of the measured sections.

AGE AND CORRELATION

At the type section the Haystack Mountains Formation contains fossils indicative of late Eagle, Claggett, and early Judith River ages (Gill and Cobban, 1966a, pl. 4; Cobban and Reeside, 1952, p. 1019–1020). The Tapers Ranch Sandstone Member contains an undescribed smooth baculite which is also found in the Shannon Sandstone Member of the Steele Shale in the Powder River Basin and which is restricted to rocks of late Eagle age. The thick shale overlying the Tapers

Ranch Sandstone Member contains an undescribed baculite that has weak flank ribs. This species, which is indicative of a very late Eagle age, has also been found in the shale between the Shannon and Sussex Sandstones Member in the Powder River Basin. The O'Brien Spring Sandstone Member contains *Baculites obtusus*, a guide fossil to rocks of early Claggett age. This member has the appearance and fossils of the Sussex Sandstone Member of the Steele Shale in the Powder River Basin. Ammonites have not been collected from the Hatfield Sandstone Member, but they were collected from the underlying and overlying shale. The Hatfield apparently was deposited during the time of *B. asperiformis* or early during the time of *B. perplexus*. This indicates a late Claggett or early Judith River age for these rocks.

The Hatfield Sandstone Member and the overlying rocks of brackish-water origin resulted from a widespread regression of the sea in southern Wyoming, northwestern Colorado, and northeastern Utah. This regression was followed by an advance of the sea represented by the marine rocks of the uppermost part of the Haystack Mountains Formation. In the southern part of the Wind River Basin, regressive deposits comparable to the Hatfield Sandstone Member are represented by the Fales Member of the Mesaverde Formation, and transgressive deposits equivalent to the uppermost part of the Haystack Mountains Formation are represented by the Wallace Creek Tongue of the Cody Shale.

The regression of the sea that resulted in the deposition of the Hatfield Sandstone Member and the overlying brackish-water beds is represented in northwestern Colorado and in the Book Cliffs area of eastern Utah and western Colorado by the Castlegate Sandstone. The marine shale overlying the Castlegate Sandstone is called the Buck Tongue of the Mancos Shale and is equivalent to the uppermost part of the Haystack Mountains Formation. The Buck Tongue was described by Fisher (1936, p. 15) in the Book Cliffs coal field and, more recently, by Cullins (1968) in the Rangely area of northwestern Colorado.

TYPE AND REFERENCE SECTIONS

The following type and reference sections are descriptions of the lithology and fossil content of the Haystack Mountains Formation at three widely separated localities. The Horseshoe Ridge reference section was measured by the late A. D. Zapp, but the section has been reexamined and additional fossils have been collected by us.

Type section of the Haystack Mountains Formation and its O'Brien Spring and Tapers Ranch Sandstone Members

[Measured with planetable and tape by J. R. Gill and R. L. Fleisher, August 1966. Fossils identified by W. A. Cobban. Measured in the NE¼NE¼ sec. 22, NE¼ sec. 23, and SE¼SE¼ sec. 14, T. 22 N., R. 86 W., Carbon County, Wyo. (Sinclair 7½-minute quadrangle), loc. 4, fig. 1.]

	Feet
Allen Ridge Formation:	
36. Sandstone and shale interbedded; sandstones are lenticular, nonpersistent, and weather brown; shales are gray to brown and locally carbonaceous; ironstone concretions common. Unit is dominantly fluviatile in origin	1,475
35. Shale, brown to black, carbonaceous to lignitic	50
Total Allen Ridge Formation	1,525
Haystack Mountains Formation:	
Upper unnamed member:	
34. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded; contains clay pebbles and *Ophiomorpha;* forms ledge	15
33. Sandstone and shale interbedded, greenish-gray to yellowish-gray; sandstone in beds 0.1–1 ft thick; forms slope	34
32. Shale, gray; contains a few thin beds of sandstone in lower 20 ft	85
USGS D5573, from near base of this unit in the SE¼ sec. 6, T. 23 N., R. 86 W.: *Lingula subspatulata* Hall and Meek; *Pinna* sp.; *Inoceramus* sp.; *Oxytoma* sp.; *Syncyclonema*? sp.; *Modiolus* sp.; *Cymella montanensis* (Henderson); *Clisocolus*? sp.; *Ethmocardium* sp.; *Tellina* sp.; *Baculites perplexus* Cobban; *Hoploscaphites* sp.; *Placenticeras* sp.	
31. Shale, medium-gray	15
30. Sandstone, pale-yellowish-gray, fine-grained, medium- to thin-bedded with some low-angle crossbeds; contains local masses of brown-weathering concretionary sandstone near top. *Ophiomorpha* abundant	65
29. Sandstone and shale interbedded; sandstone is pale yellowish gray and in beds 0.5–2 ft thick. Unit forms a slope and contains a layer of orange-brown-weathering sandstone concretions in middle and locally at top	65
USGS D5553, from top of unit in the SE¼NE¼NE¼ sec. 30, T. 22 N., R. 85 W.: *Nucula* sp.; *Inoceramus* sp.; *Cymbophora* sp.; *Baculites* sp.	

Type section of the Haystack Mountains Formation and its O'Brien Spring and Tapers Ranch Sandstone Members—Continued

Haystack Mountains Formation—Continued

Upper unnamed member—Continued

	Feet
29. Sandstone and shale interbedded—Con.	
USGS D3347, from same level as above in the NW¼NE¼NE¼ sec. 30:	
Inoceramus subcompressus Meek and Hayden	
Cymbophora sp.	
Baculites cf. *B. perplexus* Cobban	
28. Shale, medium- to dark-grayish-brown; contains a few ironstone concretions	25
USGS D5550:	
Discinid brachiopod (attached to oyster)	
Ostrea sp.	
Nucula sp.	
27. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded; low-angle crossbeds	5
USGS D5549:	
Nucula sp.	
Ostrea sp.	
26. Shale, medium- to dark-brownish-gray, carbonaceous in part; forms slope. At base a 1-ft-thick bluish-gray carbonaceous shale overlain by a 0.5-ft-thick impure coal	65
25. Sandstone, light-gray, very fine grained; contains a 1-ft-thick lignitic shale in middle. Persistent unit but variable in thickness	4
24. Shale, dark-grayish-brown to brownish-gray; locally carbonaceous at base; jarositic on bedding planes	50
Total upper unnamed member	428

Hatfield Sandstone Member:

	Feet
23. Sandstone, pale-yellowish-gray, fine-grained, medium- to thick-bedded at base, thin-bedded at top with low-angle crossbeds; contains abundant *Ophiomorpha* in middle; forms cliff	115
22. Sandstone and shale interbedded; sandstone is pale yellowish gray, fine grained, and in beds 1–2 ft thick; shale is bluish gray and sandy. Unit forms slope	35
Total Hatfield Sandstone Member	150

Middle unnamed member:

	Feet
21. Shale, dark-gray, soft; contains a layer of orange-weathering concretions at top	160
USGS D6086, from 40 to 50 ft below top in the NE¼SE¼ sec. 30, T. 24 N., R. 86 W.:	
Calcareous worm tube	
Bryozoan	
Ostrea sp.	
Baculites asperiformis Meek	
USGS D5564, from 80 ft below top in the NE¼NW¼ sec. 7, T. 23 N., R. 86 W.:	
Bryozoan	
Cymella montanensis (Henderson)	
Baculites mclearni Landes	

Type section of the Haystack Mountains Formation and its O'Brien Spring and Tapers Ranch Sandstone Members—Continued

Haystack Mountains Formation—Continued

Middle unnamed member—Continued

	Feet
20. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded; soft at base and harder and cliff forming above; contains in middle dark-brown-weathering sandstone concretions 1.5 ft thick and 10 ft in diameter; upper few feet contains abundant glauconite and a few iron-replaced fossils	95
USGS D6266, from top of unit:	
Baculites mclearni Landes	
19. Sandstone, like unit 20, soft; forms low ridge; contains at top dark-brown-weathering sandstone concretions 1 ft thick and 6 ft in diameter	40
18. Shale, medium-dark-gray	40
17. Sandstone, pale-yellowish-gray, fine-grained, soft	25
16. Sandstone, like unit 17, glauconitic; weathers in 2 low benches; contains abundant *Ophiomorpha* and at top dark-brown-weathering sandstone concretions 2 ft thick and 8 ft in diameter	65
15. Shale, gray, sandy; weathers yellowish gray; contains sparse rusty-brown-weathering limestone concretions; forms valley	85
14. Sandstone, pale-yellowish-gray, fine-grained, cliff former; contains a few *Ophiomorpha*	80
13. Shale, medium-dark-gray; poorly exposed but contains a 1-ft-thick bentonite at base	170
Total Middle unnamed member	760

O'Brien Spring Sandstone Member:

	Feet
12. Sandstone, light-gray, very fine grained, clayey, soft	45
USGS D5571, from 20 ft below top in the SE¼NE¼ sec. 7, T. 23 N., R. 86 W.:	
Baculites obtusus Meek	
11. Sandstone, pale-yellowish-gray, fine grained; in beds 0.1–1 ft thick; weathers light brown in lower part and light gray at top; contains dark-brown sandstone concretions and abundant *Ophiomorpha*. Base poorly exposed here, but in other areas it is gradational with underlying shale	175
Total O'Brien Spring Sandstone Member	220

Lower unnamed member:

	Feet
10. Shale, medium-gray, soft; forms broad valley; contains orange-brown-weathering gray limestone concretions in the upper part and red-weathering ironstone concretions in lower part	675
USGS D6100, from 50 ft below top in the NW¼NW¼ sec. 31, T. 24 N., R. 86 W.:	
Inoceramus sp.	
Baculites obtusus Meek	

Type section of the Haystack Mountains Formation and its O'Brien Spring and Tapers Ranch Sandstone Members—Continued

	Feet
Haystack Mountains Formation—Continued	
Lower unnamed member—Continued	
10. Shale, medium-gray, soft—Continued	
USGS D5548, from 80 ft below top on line of section:	
Baculites sp. (weak flank ribs)	
USGS D363, from 270 ft below top:	
Baculites sp. (weak flank ribs)	
USGS D2994, from 600 ft below top:	
Baculites sp. (weak flank ribs)	
USGS D364, from 655 ft below top:	
Baculites sp. (weak flank ribs)	
9. Sandstone and shale interbedded; weathers yellowish gray and forms slope	40
USGS D2993, 20 ft below top:	
Baculites sp.	
Total lower unnamed member	715
Tapers Ranch Sandstone Member:	
8. Sandstone, pale-greenish-gray, medium- to coarse-grained, thin-bedded with low-angle crossbeds, calcareous, glauconitic, ridge forming; contains some reddish-brown iron cement	8
7. Sandstone, grayish-green to light-yellowish-gray, fine-grained; contains thin laminae and beds of gray shale with the thicker beds of shale forming slopes covered with thin plates of sandstone	60
6. Sandstone, gray, fine-grained to very fine grained, clayey, thin-bedded with shale laminae; cleaner and glauconitic in upper part; contains some iron cement; upper part forms a ridge and basal part forms a slope	78
5. Shale, medium-dark-gray, sandy; contains some sandstone laminae; poorly exposed	50
4. Sandstone, pale-yellowish-gray to dark-gray, glauconitic; contains small dark chert granules and limonite-cemented shale pebbles. Upper part medium to coarse grained and very glauconitic, weathering to a brown cliff; lower part clayey and slope forming	75
Total Tapers Ranch Sandstone Member	271
Total Haystack Mountains Formation	2,544
Steele Shale (part):	
3. Shale, medium- to dark-gray, sandy; contains a few layers of gray sandy limestone concretions in upper part and red-weathering ironstone concretions in lower part	180
2. Sandstone and shale interbedded; weathers pale yellowish gray; sandstone in beds about 0.1 ft thick or less; forms low ridge	8

Type section of the Haystack Mountains Formation and its O'Brien Spring and Tapers Ranch Sandstone Members—Continued

	Feet
Steele Shale (part)—Continued	
1. Shale, medium-dark-gray, soft; contains limestone concretion layers 600 ft and 20 ft below top	600
USGS D5547, from 20 ft below top:	
Baculites sp. (smooth)	
USGS D5554, from 600 ft below top:	
Anisomyon sp.	
Baculites sp.	
Scaphites hippocrepis (DeKay) III	
Haresiceras natronense Reeside	
Total Steele Shale measured	788

Reference section of the Haystack Mountains Formation

[Measured by A. D. Zapp, September 1961. Fossils identified by W. A. Cobban. Measured on the north side of Horseshoe Ridge in the SE¼ sec. 36, T. 25 N., R. 84 W., Carbon County, Wyo. (Seminoe Dam Southeast 7½-minute quadrangle), loc. 6, fig. 1.]

	Feet
Allen Ridge Formation:	
34. Sandstone and shale interbedded; lenticular ridge-forming units deposited in a fluviatile environment. Thickness estimated from the topographic map	1,120
Total Allen Ridge Formation (approximate)	1,120
Haystack Mountains Formation:	
Upper unnamed member:	
33. Sandstone, pale-yellowish-gray, fine-grained, massive, soft; weathers light gray to white	40
32. Shale, dark-gray; contains several 0.2- to 0.5-ft-thick ledges of hard calcareous siltstone 40–45 ft above base	200
USGS D3323, from shale:	
Inoceramus subcompressus Meek and Hayden	
Ethmocardium sp.	
Baculites perplexus Cobban	
Placenticeras cf. *P. intercalare* Meek	
31. Shale, dark-gray, somewhat carbonaceous; may be nonmarine	3
30. Sandstone, pale-yellowish-gray, very fine grained, hard; cliff former; in beds about 0.5 ft thick; contains abundant oysters	20
29. Shale, brownish-gray; appears nonmarine	13
28. Sandstone, pale-yellowish-gray, very fine grained to fine-grained, upper surface a coquina of clams	5
27. Shale, dark-brownish-gray	22
26. Sandstone, yellowish-gray, very fine grained, thin-bedded, very hard; contains abundant burrows, trails, and oysters	2
25. Shale, dark; appears nonmarine	28
24. Sandstone, pale-yellowish-gray, fine-grained, massive; contains abundant *Ophiomorpha* at top	8

Reference section of the Haystack Mountains Formation—Con.

	Feet
Haystack Mountains Formation—Continued	
Upper unnamed member—Continued	
23. Shale, purplish-brown, silty; appears nonmarine	7
Total upper unnamed member	348
Hatfield Sandstone Member:	
22. Sandstone, light-gray, fine-grained, iron-stained 110–140 ft above base; forms massive ledge	140
21. Shale and siltstone interbedded, dark-gray; increasing amounts of thin beds of sandstone in upper part	18
20. Sandstone, dull-gray, massive, very resistant; contains abundant scattered round phosphate nodules and baculites at top	30
USGS D3322:	
Inoceramus sp.	
Ostrea sp.	
Baculites asperiformis Meek	
Total Hatfield Sandstone Member	188
Middle unnamed member:	
19. Shale, dark-gray; contains large orange-weathering limestone concretions in middle; some thin sandstones in lower 5 ft	152
USGS D4770, from concretions:	
Oxytoma nebrascana (Evans and Shumard)	
Ostrea sp.	
Modiolus sp.	
Baculites asperiformis Meek	
Hoploscaphites n. sp.	
18. Sandstone, gray, fine-grained to very fine grained; clayey and soft in lower part, cleaner and harder in upper 6 ft; contains *Ophiomorpha*	30
17. Siltstone and shale, gray; weathers yellowish gray	80
16. Sandstone, pale-yellowish-gray, fine-grained; ridge forming for the most part; lower 80 ft and intervals 80–95 and 105–120 ft above base are soft and may contain some shale. Sandstone in the interval 35–55 ft above the base is clayey and forms a topographic depression	132
15. Shale, dark-gray	235
Total middle unnamed member	629
O'Brien Spring Sandstone Member:	
14. Sandstone, gray, very fine grained, clayey; upper half massive and very concretionary, top iron cemented and rarely exposed	145
USGS D3321, from 75 ft above base:	
Baculites obtusus Meek	
USGS D3320, from 5 ft above base:	
Inoceramus sp.	
Baculites aff. *B. obtusus* Meek	
Total O'Brien Spring Sandstone Member	145

Reference section of the Haystack Mountains Formation—Con.

	Feet
Haystack Mountains Formation—Continued	
Lower unnamed member:	
13. Shale, brownish-gray, silty to sandy; transitional with overlying sandstone; contains brown-weathering gray limestone concretions	170
12. Shale, black, clayey; contains abundant layers of ferruginous limestone or ironstone concretions	320
USGS D3319, from 15 ft below top:	
Inoceramus sp.	
Baculites sp. (weak flank ribs)	
USGS D3318, from 150 to 170 ft above base:	
Inoceramus cf. *I. balticus* Boehm	
Baculites sp. (weak flank ribs)	
Placenticeras sp.	
USGS D3317, near base:	
Inoceramus cf. *I. balticus* Boehm	
Baculites sp. (weak flank ribs)	
Placenticeras sp.	
11. Shale, gray, sandy and silty, poorly exposed	165
Total lower unnamed member	655
Tapers Ranch Sandstone Member:	
10. Sandstone, pale-yellowish-gray, very fine grained to fine-grained, clayey, soft; a few thin ledge formers. Some beds are glauconitic	240
9. Sandstone, brownish-gray, very fine grained to fine-grained, thin-bedded; clayey and soft in middle; contains a scattering of dark chert granules and pebbles to 0.1 ft in diameter. Some beds are very glauconitic	60
Total Tapers Ranch Sandstone Member	300
Total Haystack Mountains Formation	2,265
Steele Shale (part):	
8. Shale, dark-gray; contains a few very fine grained thin sandstone beds; unit is transitional into the overlying sandstone. Lower 45 ft contains several discontinuous ledges of tan-weathering silty limestone with many crushed baculites	328
USGS D3316, from limestone concretions 60 ft above base:	
Baculites sp. (smooth)	
7. Shale and siltstone interbedded, very dark gray; contains large septarian concretions	95
6. Sandstone, grayish-green, very glauconitic, hard; contains a scattering of dark chert granules	2
5. Sandstone, greenish-gray, very fine grained, glauconitic, clayey	105

Reference section of the Haystack Mountains Formation—Con.

Steele Shale (part)—Continued	Feet
4. Shale, mostly covered; contains some massive siltstone near and at the top	870
USGS D3315, from shale 330 ft above base: *Inoceramus* cf *I. proximus* Tuomey; *Baculites aquilaensis* Reeside	
3. Sandstone, greenish-gray, fine-grained with some very fine grained beds; thin-bedded becoming massive in upper part; contains abundant trails and ripple marks on bedding planes. Capped by a 5-ft-thick bed of banded silty limestone	80
2. Covered; appears to be shale	125
1. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded; capped by a 5-ft-thick bed of banded silty limestone	55
Total Steele Shale measured	1,660

Principal reference section of the Hatfield Sandstone Member of the Haystack Mountains Formation

[Measured by J. R. Gill and G. A. Bergman, August 1967, with plane-table and Jacob's staff. Fossils identified by W. A. Cobban. Measured on the west side of Hatfield dome in the NE¼NE¼ sec. 18 and in the center and NW¼NW¼ sec. 17, T. 19 N., R. 88 W., Carbon County, Wyo. (Bridger Pass 15-minute quadrangle), loc. 2, fig. 1.]

	Feet
Allen Ridge Formation:	
64. Sandstone and shale interbedded; lenticular ridge-forming units deposited in a fluviatile environment; thickness not measured.	
Haystack Mountains Formation:	
Upper unnamed member:	
63. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded; upper part weathers light gray; contains large orange-weathering sandstone concretions in lower part	17
62. Shale, gray, sandy	15
61. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded; contains *Ophiomorpha*	2
60. Shale, gray; contains sandstone laminae	8
59. Sandstone, like unit 61	2
58. Shale, gray	14
57. Sandstone, like unit 61	2
56. Shale, gray; contains some thin beds of sandstone; poorly exposed	22
55. Sandstone, pale-yellowish-gray, very fine grained to fine-grained; in beds 0.2–2 ft thick in lower part becoming massive in upper part; contains a layer of pale-orange sandstone concretions in lower part	75
54. Shale, olive-gray, poorly exposed	40
53. Sandstone, pale-yellowish-gray, fine-grained; contains *Ophiomorpha*	1
52. Shale, olive-gray	1
51. Sandstone, like unit 53; contains abundant *Ophiomorpha* and iron-cemented shale pebbles	34
50. Shale, olive-gray; contains thin-shelled oysters	23
49. Sandstone, like unit 53	5
48. Shale, olive-gray to brownish-gray; contains ironstone concretions	8

Principal reference section of the Hatfield Sandstone Member of the Haystack Mountains Formation—Continued

Haystack Mountains Formation—Continued Upper unnamed member—Continued	Feet
47. Siltstone, pale-yellowish-gray, laminated, carbonaceous; contains many burrows	4
46. Shale, brownish-gray, flaky; contains ironstone concretions	5
45. Sandstone, pale-yellowish-gray, fine-grained; weathers light gray; contains large *Ophiomorpha*	2
44. Shale, like unit 46	4
43. Siltstone, like unit 47	5
42. Shale, like unit 46	10
41. Siltstone, like unit 47	2
40. Shale, brown, carbonaceous	1
39. Siltstone, light-brown, carbonaceous, laminated; contains burrows in upper part	9
38. Shale, reddish-brown to black, carbonaceous	4
37. Sandstone and siltstone, interbedded, light-yellowish-gray, very fine grained, ripple-laminated	5
36. Shale, olive-gray, poorly exposed; contains ironstone concretions	15
35. Shale, black, lignitic	1
34. Sandstone, light-gray to brownish-gray, medium-grained, slightly carbonaceous	5
33. Sandstone, pale-yellowish-gray, fine-grained; contains *Ophiomorpha*	8
32. Shale, reddish-brown, carbonaceous, poorly exposed	11
31. Sandstone, like unit 33	6
30. Sandstone, light-gray, medium-grained; contains abundant oysters	2
29. Shale, olive-gray	3
28. Shale, dark-brown, carbonaceous	2
27. Siltstone, black, coaly	1
Total upper unnamed member	374
Hatfield Sandstone Member:	
26. Sandstone, pale-yellowish-gray, fine-grained; weathers yellowish gray to light gray; lower 20 ft in beds 0.5–2 ft thick; upper part forms massive cliff with a slight reentrant 45 ft from top. Contains shale pebbles and *Ophiomorpha*	97
25. Shale, gray, sandy, poorly exposed	30
24. Sandstone, like unit 26, thin-bedded	30
23. Sandstone and shale; weathers yellowish gray	10
Total Hatfield Sandstone Member	167
Espy Tongue of Hale (1961):	
22. Shale, gray, sandy	65
21. Limestone concretion; weathers orange	1.5
USGS D6363: *Baculites* sp.	
20. Shale, grayish-brown, flaky	20

Principal reference section of the Hatfield Sandstone Member of the Haystack Mountains Formation—Continued

	Feet
Haystack Mountains Formation—Continued	
Espy Tongue of Hale (1961)—Continued	
19. Shale, grayish-brown, flaky; contains sandstone laminae in upper 2 ft	15
USGS D6362: *Ostrea albertensis* Landes	
18. Sandstone, yellowish-gray, very fine grained, lower 25 ft clayey and friable; contains 6 layers of orange-weathering sandstone concretions 2 ft thick and 6 ft in diameter. Upper 30 ft is glauconitic and contains iron-cemented nodules with fossils	55
USGS D6361, from top of unit: Calcareous worm tube; *Inoceramus* sp.; *Ostrea russelli* Landes; *Ethmocardium ursaniense* Landes; *Cymbophora* sp.; *Baculites* cf. *B. asperiformis* Meek	
17. Shale, gray, sandy; weathers light gray	25
16. Sandstone, pale-yellowish-gray, fine-grained; weathers light brown	6
USGS D6360, from base of sandstone: *Nucula*? sp.; *Modiolus* sp.; *Crenella* n. sp.; *Ethmocardium ursaniense* Landes; *Cymbophora* sp.	
15. Shale, gray, sandy	19
14. Sandstone, pale-yellowish-gray, very fine grained; capped by a 3-ft-thick bed of medium-grained crossbedded sandstone containing abundant *Ophiomorpha*	12
13. Shale, dark-gray, flaky	17
12. Sandstone, pale-yellowish-gray, very fine grained, ripple-laminated; contains at base siltstone concretions 1.5 ft thick and 1.5 ft in diameter	21
11. Shale, gray, flaky; weathers light gray to pale yellowish gray	35
Total Espy Tongue of Hale (1961)	291.5
Deep Creek Sandstone of Hale (1961):	
10. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded; weathers yellowish gray to dusky yellow in lower part and light gray to light brown in upper part; contains a few burrows	40
Total Deep Creek Sandstone of Hale (1961)	40
Total Haystack Mountains Formation (rounded)	870
Steele Shale (part):	
9. Shale, gray, upper part sandy	100
8. Bentonite, light-greenish-gray, nonswelling	1
7. Shale, gray, poorly exposed	75

Principal reference section of the Hatfield Sandstone Member of the Haystack Mountains Formation—Continued

	Feet
Steele Shale (part)—Continued	
6. Shale, gray, poorly exposed; contains at top tan-weathering silty limestone concretion 0.5 ft thick and 1.5 ft in diameter	150
5. Shale, gray, with thin laminae of very fine grained sandstone; contains at top a layer of calcareous sandstone concretions 0.5 ft thick and 1.5 ft. in diameter. Unit is equivalent to the top of the O'Brien Spring Sandstone Member of the type Haystack Mountains Formation and to Cow Creek Member of the Steele Shale of Hale (1961)	35
USGS D6359, from sandstone concretions: Calcareous worm tube; *Inoceramus* sp.; *Cymbophora* cf. *C. holmesi* (Meek); *Baculites obtusus* Meek	
4. Shale, gray, sandy; contains thin sandstone laminae, a few gray limestone concretions, and at top a 0.2-ft-thick bentonite bed	20
3. Bentonite and yellow fibrous calcite	1
2. Shale, gray, slightly sandy, poorly exposed	100
1. Sandstone and shale interlaminated; forms small ridge	30
Total Steele Shale measured (rounded)	510

ROCK RIVER FORMATION

TYPE SECTION AND DISTRIBUTION

The Rock River Formation of the Mesaverde Group is named herein for exposures in the SE¼ sec. 8, SW¼ sec. 9, and NW¼ sec. 16, T. 20 N., R. 76 W., about 2 miles southeast of the town of Rock River, Albany County, Wyo. The Rock River Formation is mainly confined to the Laramie Basin and consists of alternating beds of hard and soft fossiliferous sandstone of marine origin. The formation is generally poorly exposed and about one-third of the formation is concealed at the type section. The covered intervals probably contain nonresistant sandstone, but they might consist of soft sandy shale.

Darton and Siebenthal (1909, p. 36–37) first described these beds in the Rock River area and related them to the lower part of the Montana Formation. Equivalent rocks in the southern part of the Laramie Basin were called the Mesaverde Formation (Darton and others, 1910, p. 10).

The Rock River Formation crops out beneath the Pine Ridge Sandstone and overlies the Steele Shale along the west margin of the Laramie Basin. The formation grades eastward into the marine Pierre Shale and does not occur east of the Laramie Range. Westward, the Rock River Formation grades into the dominantly nonmarine rocks of the Allen Ridge Formation. One or more thin tongues of the Rock River Formation can be identified in the upper part of the Allen Ridge in the southeastern part of the Carbon Basin.

LITHOLOGIC CHARACTER

The Rock River Formation consists of soft sandstone and a few beds of soft sandy shale deposited in a marine environment. The sandstone weathers light gray to light brown and is generally very fine to fine grained and thin bedded to massive. Locally, the sandstone is shaly and crossbedded. Large brown-weathering fossiliferous sandstone concretions are abundant in some beds. These concretions are harder than the enclosing rocks and form low ridges where they are numerous. The formation is generally poorly exposed, except for the harder concretionary layers.

THICKNESS

The maximum known thickness of the Rock River Formation, 1,565 feet, is at the type section. The formation has not been measured at other localities, but it apparently thins to the east and south. This thinning accompanies a facies change from shallow-water marine sandstone to deeper water marine shale.

RELATION TO ADJACENT FORMATIONS

The basal sandstone of the Rock River Formation grades into the sandy shale of the underlying Steele Shale. The contact between the two formations is selected where the rocks are dominantly sandstone above and dominantly shale below. The Rock River Formation grades laterally eastward into marine shale of the Pierre and westward into mainly nonmarine rocks of the Allen Ridge.

The Rock River Formation appears to be overlain unconformably by nonmarine rocks of the Pine Ridge Sandstone. In the Rock River area, we have little evidence to indicate an angular unconformity at the base of the Pine Ridge, but Davis (1966) had sufficient data from this area to propose a disconformity. Gill and Cobban (1966b) described a widespread unconformity at the base of the equivalent Teapot Sandstone Member of the Mesaverde Formation in northern Wyoming, and Reynolds (1966, 1967) has reported an unconformity at the base of the Pine Ridge Sandstone along the east margin of the Great Divide Basin.

FOSSILS

Marine invertebrate megafossils are abundant at several levels in the Rock River Formation. Stanton (Stanton and Knowlton, 1897, p. 138–141) identified many mollusks from rocks now included in the Rock River Formation. Most of these (with their names updated) and many others are listed in the type section. The fossils reveal that the lowest part of the Rock River lies in the uppermost part of the zone of *Baculites perplexus*, and that the formation extends up through the zone of *Didymoceras stevensoni* and probably a little higher. One very fossiliferous sandstone (unit 22 of type section) contains *Trigonia* and other fossils characteristic of the Gulf Coast Cretaceous.

AGE AND CORRELATION

The Rock River Formation is of Judith River and early Bearpaw age. It correlates with about the middle part of the Pierre Shale to the east and with the upper part of the Mitten Black Shale Member, the Red Bird Silty Member, and the lower part of the lower unnamed member of the Pierre Shale in the southern Black Hills (Gill and Cobban, 1966a, pl. 4). The Rock River is equivalent to the Parkman Sandstone Member and overlying unnamed marine member of the Mesaverde Formation in the western Powder River Basin (table 1). It correlates and intertongues with the Allen Ridge Formation in the Hanna and Carbon Basins and is equivalent to the Iles Formation of northwestern Colorado.

TYPE SECTION

The type section of the Rock River Formation was measured by G. R. Scott and W. A. Cobban, and fossils collected from the formation were identified by Cobban and N. F. Sohl. A description of the type section follows.

Type section of the Rock River Formation

[Measured with a Jacob's staff by G. R. Scott and W. A. Cobban, May 1957. Measured about 2.5 miles southeast of Rock River in the S½ N½ and NE¼SE¼ sec. 8, NW¼NW¼SW¼ sec. 9, and NW¼ NW¼ sec. 16, T. 20 N., R. 76 W., Albany County, Wyo. (Rock River 7½-minute quadrangle), loc. 8, fig. 1.]

Pine Ridge Sandstone:
41. Sandstone, whitish-gray, fine-grained, massive; forms conspicuous tree-covered bluff. Not measured.

Rock River Formation:	Feet
40. Concealed	39
39. Sandstone, light-gray, soft; in massive beds separated by darker shale partings	140
USGS D1390, from 60–90 ft above base: *Inoceramus* sp. *Ostrea russelli* Landes (bored)	
38. Sandstone, light-brown, soft, massive; contains some harder concretionary shaly sandstone that weathers darker brown. A few *Ophiomorpha*	30
37. Sandstone, gray, soft, shaly; uppermost few feet harder and somewhat carbonaceous; some parts of unit concretionary	103

Type section of the Rock River Formation—Continued

Rock River Formation—Continued	*Feet*
36. Sandstone, light-brown, soft; contains darker brown-weathering concretionary sandstone and, at top, a ridge-forming bed of closely spaced sandstone concretions 1–2 ft thick and as much as 8 ft in diameter, commonly crowded with large *Inoceramus*	61

USGS D1391, from top of unit:
- Membraniporoid bryozoan (attached to *Inoceramus*)
- *Inoceramus* cf. *I. shikotanensis* Nagao and Matsumoto
- *Baculites* sp.

USGS D1389, from rest of unit:
- *Inoceramus convexus* Hall and Meek
- *Ostrea* sp.
- *Tellina* sp.
- *Baculites* sp.
- *Placenticeras* sp.
- *Eutrephoceras* sp.
- *Ophiomorpha* sp.
- Reptilian bones

35. Sandstone, light-gray and light-brown, very fine grained, soft; contains closely spaced large dark-brown-weathering fossiliferous sandstone concretions that are commonly 3–4 ft thick and 8–10 ft in diameter. Unit forms a conspicuous ridge	10

USGS D1388, from concretions:
- Membraniporoid bryozoans (on inocerams)
- *Inoceramus convexus* Hall and Meek
- *Pteria linguaeformis* (Evans and Shumard)
- *Ostrea* cf. *O. russelli* Landes
- *Ostrea* cf. *O. plumosa* Morton
- *Cymella montanensis* (Henderson)
- *Lucina* sp.
- *Tellina* sp.
- *Cymbophora* sp.
- *Goniochasma* sp.
- *Drepanochilus nebrascensis* (Evans and Shumard)?
- *Euspira*? sp.
- *Serrifusus* n. sp.
- *Anisomyon borealis* (Morton)
- *Baculites crickmayi* Williams
- *Didymoceras stevensoni* (Whitfield)
- *Solenoceras* n. sp.
- *Hoploscaphites* sp.
- *Placenticeras intercalare* Meek
- Crustacean
- Fish scales and teeth
- Carnivorous dinosaur tooth

34. Sandstone, light-brown, soft, very fine grained	20
33. Sandstone, gray, very fine grained, soft, shaly; uppermost 1–2 ft is harder and forms a low ridge	24

Type section of the Rock River Formation—Continued

Rock River Formation—Continued	*Feet*
32. Sandstone, like unit 33; contains gray- and brown-weathering sandy fossiliferous limestone concretions. Thickness estimated	30

USGS D1387:
- *Micrabacia americana* Meek and Hayden
- Calcareous worm tubes
- Echinoid fragment
- *Dysnoetopora demissa* (White)
- *Websteria*-like bryozoan
- Pyriporoid bryozoan (on inocerams and ammonite living chambers)
- *Solemya* n. sp.
- *Perrisonota* sp.
- *Nucula* cf. *N. planimarginata* Meek and Hayden
- *Nucula* (*Pectinucula*) sp.
- *Yoldia*? cf. *Y.*? *evansi* (Meek and Hayden)
- *Nemodon sulcatinus* (Evans and Shumard)
- *Limopsis* sp.
- *Gervillia* aff. *G. recta* Meek and Hayden
- *Inoceramus convexus* Hall and Meek
- *Pteria linguaeformis* (Evans and Shumard)
- *Oxytoma* aff. *O. nebrascana* (Evans and Shumard)
- *Ostrea* cf. *O. plumosa* Morton
- *Syncyclonema hallii* Gabb
- *Chlamys nebrascensis* Meek and Hayden
- *Anatimya* n. sp.
- *Vetericardia*? sp.
- *Tenea circularis* (Meek and Hayden)
- *Cuspidaria* cf. *C. moreauensis* (Meek and Hayden)
- *Cuspidaria* cf. *C. variabilis* Warren
- *Cymbophora* sp.
- *Dentalium* cf. *D. pauperculum* Meek and Hayden
- *Dentalium*? sp.
- *Acmaea occidentalis* (Hall and Meek)
- *Atira*? *nebrascensis* (Meek and Hayden)
- *Drepanochilus nebrascensis* (Evans and Shumard)
- *Euspira obliquata* (Hall and Meek)
- *Serrifusus* aff. *S. dakotensis* (Meek and Hayden)
- *Cryptorhytis cheyennensis* (Meek and Hayden)
- *Nonactaeonina attenuata* (Meek and Hayden)
- *Oligoptycha* sp.
- *Acteon* sp.
- *Anisomyon borealis* (Morton)
- *Baculites crickmayi* Williams
- *Didymoceras stevensoni* (Whitfield)

Type section of the Rock River Formation—Continued

Rock River Formation—Continued

32. Sandstone, like unite 33—Continued
    USGS D1387—Continued
    Solenoceras n. sp.
    Hoploscaphites n. sp.
    Placenticeras intercalare Meek
    Crustacean

	Feet
31. Concealed. Thickness estimated	280
30. Shale, gray, silty; contains hard gray limestone concretions at top	8.5
29. Sandstone, dark-olive-brown, fine-grained; contains tan-weathering clay pebbles and forms a low ridge	3
28. Sandstone, soft, massive; weathers tan	5
27. Bentonite, light-gray; contains tan fibrous calcite	.5
26. Sandstone, soft, massive; weathers tan	80
25. Sandstone, dark-olive-brown, fine-grained, more or less thick bedded and firm; forms a ridge	4
24. Sandstone, soft, massive; weathers tan	57
23. Sandstone, brownish, soft, massive; contains large darker brown weathering fossiliferous sandstone concretions commonly 2 ft thick and 5 ft in diameter. Uppermost 1 ft, which is hard and ledge forming, locally contains clay pellets	28

USGS D1401, from throughout unit:
- Calcareous worm tube (attached to baculite)
- *Dysnoctopora demissa* (White)
- *Pteria linguaeformis* (Evans and Shumard)
- *Oxytoma* sp.
- *Ostrea russelli* Landes (common in upper few feet of unit)
- *Syncyclonema? simplicius* Conrad?
- *Modiolus* sp.
- *Cymella montanensis* (Henderson)
- *Ethmocardium* sp.
- *Legumen ellipticum* Conrad
- *Cymbophora* sp.
- *Drepanochilus* sp. (immature)
- *Arrhoges (Latiala)* aff. *A. (L.) lobata* Wade
- *Euspira* sp.
- *Graphidula* cf. *G. alleni* (White)
- *Serrifusus?* sp.
- *Ellipsoscapha* sp.
- *Oligoptycha* sp.
- *Baculites* n. sp.
- *Didymoceras* sp.
- *Oxybeloceras* sp.
- *Placenticeras* sp.

	Feet
22. Sandstone, gray, soft, massive; locally contains large brown-weathering sandstone concretions usually 2 ft thick and 4 ft in diameter and smaller brownish-gray very fossiliferous sandy concretions. Top is locally baculite-bearing brown-weathering concretions containing comminuted pelecypods	27

Type section of the Rock River Formation—Continued

Rock River Formation—Continued

22. Sandstone, gray, soft, massive—Continued
    USGS D1400, from throughout unit:
- Calcareous worm tubes (attached to baculites)
- *Dysnoctopora demissa* (White)
- *Nemodon* n. sp.
- *Pinna lakesi* White
- *Inoceramus* cf. *I. convexus* Hall and Meek
- *Pteria linguaeformis* (Evans and Shumard)
- *Oxytoma* cf. *O. nebrascana* (Evans and Shumard)
- *Ostrea russelli* Landes
- *Pycnodonte* cf. *P. mutabilis* (Morton)
- *Trigonia* cf. *T. eufaulensis gabbi* Stephenson
- *Syncyclonema? simplicius* Conrad?
- *Limatula* sp.
- *Anatimya doddsi* Henderson
- *Cymella montanensis* (Henderson)
- *Astarte* sp.
- *Protodonax* n. sp.
- *Ethmocardium* n. sp.
- *Legumen ellipticum* Conrad
- *Tenea parilis* Conrad?
- *Tellina* cf. *T. munda* Stephenson
- *Leptosolen* sp.
- *Senis* sp.
- *"Corbula"* n. sp.
- *Dentalium* sp.
- *Baculites* n. sp.
- *Didymoceras* sp.
- *Anapachydiscus* n. sp.
- *Menuites* n. sp.
- *Placenticeras* n. sp.
- *Ophiomorpha*
- Fish bones, scales, and teeth
- Reptilian bones

	Feet
21. Sandstone, light-gray; forms series of small ledges of crossbedded sandstone separated by shaly sandstone. Top 2 in. is a conglomerate of phosphatic pebbles and oyster fragments in tan concretionary siltstone	14.2
20. Sandstone, gray and tan, soft	16
19. Sandstone, gray, soft; at top are brownish-gray hard silty concretions about 1 ft thick	74
18. Sandstone, gray and tan, fine-grained, soft; contains harder limonitic layers	32
17. Sandstone, light-gray, fine-grained, soft; lower part thin bedded and upper part more massive; contains harder masses of tan-weathering concretionary sandstone and some brown carbonaceous partings	162

USGS D1399, from 95–110 ft above base:
- *Inoceramus subcompressus* Meek and Hayden
- *Ostrea* cf. *O. subtrigonalis* Meek and Hayden
- Shark teeth

Type section of the Rock River Formation—Continued

	Feet
Rock River Formation—Continued	
16. Siltstone, gray; contains large tan-weathering silty poorly fossiliferous limestone concretions	3
15. Concealed. Thickness estimated	150
14. Sandstone, tan, soft, massive; exposed in railroad cut	30
13. Sandstone, tan, soft, massive; contains a few tan-weathering small silty limestone concretions. Bench mark S318 located here	20
USGS D1398, from concretions:	
Inoceramus subcompressus Meek and Hayden	
Baculites perplexus Cobban (transitional to *Baculites gregoryensis* Cobban)	
12. Concealed. Thickness estimated	85
11. Sandstone, tan, fine-grained	30
Total Rock River Formation (rounded)	1,565
Steele Shale (part):	
10. Concealed. Thickness estimated	75
9. Shale, dark-gray; contains gray limestone concretions and some baculites	15
USGS D3197:	
Pyriporoid bryozoan	
Membraniporoid bryozoan	
Inoceramus sp.	
Baculites perplexus Cobban	
8. Shale, dark-gray; contains a few iron-stained limestone concretions	85
7. Shale, dark-gray; contains a few iron-stained limestone concretions and, at top, small masses of "tepee-butte limestone"	27.5
USGS D1396, from top:	
Pyriporoid bryozoan (in living chambers)	
Inoceramus sp.	
Baculites perplexus Cobban	
6. Shale, gray, sandy to silty; contains 7 harder layers of tan-weathering very fine grained shaly sandstone as much as 1 ft thick	72
5. Shale, dark-gray; contains a few small rusty ferruginous concretions and, in upper part, a thin layer of bentonite with gray fibrous calcite	35
USGS D1395:	
Pyriporoid bryozoans (in living chambers)	
Inoceramus sp.	
Baculites perplexus Cobban	
Placenticeras sp.	
4. Shale, dark-gray; contains thin rusty ferruginous concretions and sparse layers of tan shaly sandstone	13
3. Shale, dark-gray; contains thin rusty ferruginous concretions	80
USGS D1394:	
Pyriporoid bryozoan	
Membraniporoid bryozoan	

Type section of the Rock River Formation—Continued

	Feet
Steele Shale (part)—Continued	
3. Shale, dark-gray—Continued	
USGS D1394—Continued	
Inoceramus subcompressus Meek and Hayden	
Baculites perplexus Cobban	
2. Shale, dark-gray; contains rusty-weathering thin shaly, sandy concretions, and tan shaly layers of sandstone	30
1. Shale, dark-gray; contains a few thin layers of shaly very fine grained tan-weathering sandstone	30+
Total Steele Shale measured (rounded)	460

ALLEN RIDGE FORMATION

PRINCIPAL REFERENCE SECTION AND DISTRIBUTION

Bergstrom (1959, p. 114) applied the name Allen Ridge Formation to a 1,200-foot-thick sequence of rocks underlying the Pine Ridge Sandstone and overlying the Steele Shale along the northeast flanks of the Hanna Basin northeast of Medicine Bow. Bergstrom's description consists of a composite columnar section accompanied by brief remarks regarding the lithology of the formation. The name was apparently derived from the ridge adjacent to the now-abandoned Allen Station on the Union Pacific Railroad; no topographic feature by this name is shown on the topographic map of the area (Saddleback Hills 15-minute quadrangle). According to Bergstrom, part of the Allen Ridge Formation was measured in sec. 9, T. 22 N., R. 79 W., which is near Allen Station, and part was measured in Pine Tree Gulch in sec. 18, T. 23 N., R. 79 W. We were unable to recover Bergstrom's section at these localities, but we measured a complete section of the Allen Ridge and adjacent formations along the north and south sides of Pine Tree Gulch in the S½NE¼ sec. 19, T. 23 N., R. 79 W., Carbon County (figs. 1 and 7, loc. 7) here designated the principal reference section.

We obtained much the same thickness as was reported by Bergstrom (1,255 compared to 1,200 ft), but we differ radically in our interpretation of rock units composing the formation. We found the formation to consist of a lower nonmarine unit of fluviatile sandstone, shale, and carbonaceous beds about 685 feet thick, a middle unit consisting of 195 feet of marine shale and sandstone, and an upper unit 375 feet thick consisting dominantly of rocks of brackish-water origin. Bergstrom apparently considered the entire Allen Ridge Formation to be nonmarine.

The Allen Ridge Formation of the Mesaverde Group is a widespread and distinctive unit that can be recognized throughout much of south-central Wyoming. It

FIGURE 7.—Allen Ridge Formation at its principal reference section in Pine Tree Gulch in the NE¼ sec. 19, T. 23 N., R. 79 W., Carbon County, Wyo. Contact with the underlying massive sandstone of the Haystack Mountains Formation is shown on the right side of the photograph, and the contact with the overlying Pine Ridge Sandstone is shown on the extreme left side of the photograph.

is the main ridge-forming part of the Mesaverde around the margins of the Carbon and Hanna Basins and the Rawlins uplift, and it is an important part of the Mesaverde along the east margins of the Great Divide and Washakie Basins. In the northwestern part of the Laramie Basin, the Allen Ridge intertongues on a grand scale with marine sandstone and shale of the Rock River Formation. At Rock River the facies change is complete, and the entire sequence of beds equivalent to the Allen Ridge Formation is represented by rocks of the Rock River Formation. The Allen Ridge Formation is not present elsewhere in the Laramie Basin.

LITHOLOGIC CHARACTER

At its principal reference section, the Allen Ridge Formation is a diverse lithologic unit. The lower part of the formation is a thick sequence of ridge-forming fluviatile sandstones and shales that weather distinctive shades of brown and rusty brown. These colors contrast sharply with the yellowish-gray-weathering sandstones of the underlying Haystack Mountains Formation. The fluviatile sequence is about 685 feet thick and contains many beds of carbonaceous shale and numerous ironstone concretions but very little coal.

This nonmarine sequence is interrupted in the eastern part of the Hanna Basin by marine strata which are included in the Allen Ridge, but which connect laterally with the Rock River Formation (fig. 2). This unnamed marine member consists of 115 feet of fossiliferous marine shale and siltstone and 80 feet of marine sandstone containing abundant *Ophiomorpha* (fig. 8). It is overlain by reddish-brown-weathering carbonaceous shale, a shallow-water marine sandstone, and a thick unit of dark-brownish-gray ironstone-bearing shale. These beds are nonresistant, poorly exposed, and generally form a valley. They were apparently deposited close to the sea, perhaps in a lagoon or in some other brackish-water environment. The marine member and the overlying marginal marine beds change character in a west and northwest direction because they grade into nonmarine beds typical of the lower part of the Allen Ridge.

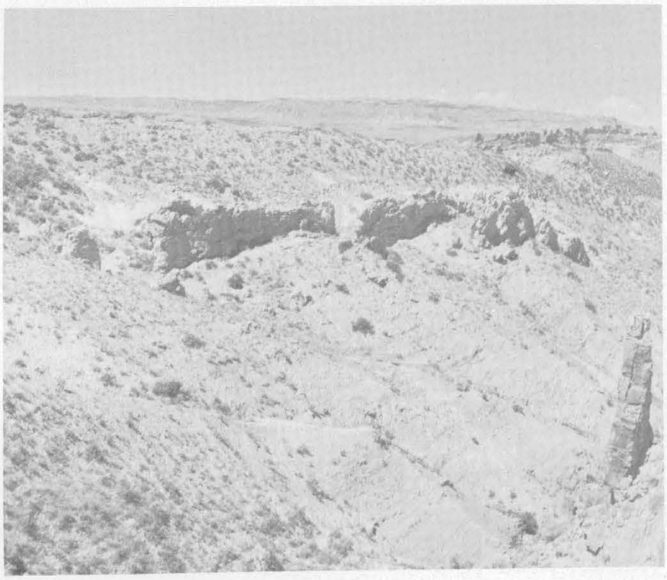


FIGURE 8.—Outcrop of an unnamed marine member in the upper part of the Allen Ridge Formation at Pine Tree Gulch, in the NW¼SE¼ sec. 19, T. 23 N., R. 79 W., Carbon County, Wyo.

Along the east edge of the Great Divide and Washakie Basins, the entire Allen Ridge Formation is composed of nonmarine beds, except for a small area west of the town of Rawlins, where thin shallow-water marine sandstones crop out in the upper part of the formation (M. W. Reynolds, oral commun., 1968).

THICKNESS

The Allen Ridge Formation ranges in thickness from a featheredge in the northern part of the Laramie Basin to 1,255 feet at its principal reference section on the northeast flank of the Hanna Basin; it is as much as 1,500 feet thick in the Haystack Mountains north of Sinclair; and it ranges in thickness from 0 to about 1,275 feet on the northeast flank of the Great Divide Basin. This variation in thickness is due in part to uplift and erosion before deposition of the Pine Ridge Sandstone, uplift and erosion in early Lewis time, and possibly in part to depositional thinning. The geologic history of the Upper Cretaceous rocks of this area is discussed in detail by Reynolds (1966, 1967).

RELATION TO ADJACENT FORMATIONS

The Allen Ridge Formation conformably overlies the Haystack Mountains Formation. The contact is sharp and is marked by the abrupt change from fine-grained yellowish-gray-weathering marine sandstone below to carbonaceous shale or locally fluviatile channel sandstone above. The contact with the overlying Pine Ridge Sandstone probably is unconformable. This unconformity is difficult to document at most localities, but regional stratigraphic and faunal studies strongly suggest its presence (Gill and Cobban, 1966b). This unconformity exists on the northeast flank of the Great Divide Basin, as shown by detailed mapping by Reynolds (1966, 1967).

Except for minor marine tongues, the Allen Ridge Formation is the landward facies of the marine Rock River Formation that borders it to the east. To the northwest and west the Allen Ridge Formation probably merges into the main mass of the nonmarine Mesaverde Group. In the southern Wind River Basin and in the Rock Springs uplift, as shown by stratigraphic studies, rocks equivalent to the Allen Ridge probably have been removed by pre-Teapot or pre-Pine Ridge erosion.

FOSSILS

Fossils in the nonmarine part of the Allen Ridge Formation are scarce. Bone fragments were found at a few localities in the Haystack Mountains, and two collections of invertebrates were obtained from widely separated localities in the Hanna Basin. Invertebrate fossils from the basal part of the Allen Ridge were collected in the SW¼SE¼ sec. 29, T. 24 N., R. 86 W., and were identified by W. A. Cobban as follows:

USGS D6084:
Campeloma sp.
Tulotomops cf. *T. laevibasalis* Yen

The second collection, which came from a 5-foot-thick channel sandstone that crops out 550 feet above the base of the Allen Ridge Formation in the center of the NE¼ sec. 19, T. 23 N., R. 79 W., is listed in the principal reference section.

The marine tongue included as a part of the Allen Ridge Formation at the principal reference section contains abundant marine fossils at 20 and 70 feet above the base; these are listed in the section.

AGE AND CORRELATION

Inasmuch as the Allen Ridge Formation is dominantly nonmarine in most localities, it is difficult to relate the unit to the Western Interior Late Cretaceous ammonite sequence, except by comparing it with fossiliferous lateral marine equivalents such as the Rock River Formation. At the principal reference section, the top of the underlying Haystack Mountains Formation contains *Baculites perplexus*, and we infer that the lower part of the Allen Ridge was probably deposited late in the range span of this ammonite. *Didymoceras nebrascense* occurs in the lower part of the marine tongue that overlies nonmarine rocks of the lower part of the Allen Ridge. A comparison of time-equivalent strata at Rock River shows that these nonmarine beds were deposited during the range span of *B. gregoryensis* and *B. scotti*.

Similarly, comparison of the Rock River section with the Allen Ridge section indicates that the marginal marine beds above the unnamed marine member were probably deposited during, or somewhat later than, the range span of *Didymoceras stevensoni*.

The Allen Ridge Formation is Judith River and early Bearpaw in age (Gill and Cobban, 1966a, pl. 4) in comparison with the central Montana section. The formation correlates with the Rock River Formation of the Laramie Basin, the Parkman Sandstone Member and the lower part of the unnamed marine member of the Mesaverde Formation of the western Powder River Basin, and the Iles Formation of the Mesaverde Group of northwestern Colorado. We are uncertain of the correlation of the Allen Ridge with rocks of the Mesaverde Group in the Rock Springs uplift and in the southern part of the Wind River Basin.

PRINCIPAL REFERENCE SECTION

Inasmuch as we were unable to recover Bergstrom's original section (1959), we designate the following as the principal reference section for the Allen Ridge Formation.

Principal reference section of the Allen Ridge Formation

[Measured in July 1967 with planetable and tape by J. R. Gill and R. L. Fleisher. Fossil identifications by W. A. Cobban and N. F. Sohl. Measured on the north and south sides of Pine Tree Gulch in the NE¼ sec. 19, T. 23 N., R. 79 W., Carbon County, Wyo. (Saddleback Hills 15-minute quadrangle), loc. 7, fig. 1.]

Pine Ridge Sandstone:

57. Sandstone, light-gray, fine-grained, high-angle crossbeds; contains thin laminae of dark-brown to black carbonaceous shale; forms ridge that supports a moderate growth of pine trees; weathers white. Not measured.

Allen Ridge Formation:

Upper part:

56. Shale, dark-brownish-gray; contains abundant ironstone concretions; poorly exposed on line of section but moderately well exposed a quarter of a mile to south along south side of Pine Tree Gulch — 180
55. Sandstone, yellowish-gray to pale-yellow, fine- to medium-grained; weathers in three ledges 1–2 ft thick at base, middle, and top; contains small *Ophiomorpha* — 46
54. Shale, medium- to dark-brown, carbonaceous, flaky, poorly exposed — 80
53. Sandstone, pale-yellowish-gray, fine- to medium-grained, thin-bedded at base, massive at top; capped by a 1-ft-thick bed of brown-weathering sandstone — 25
52. Shale, reddish-brown, very carbonaceous, abundant limonite plates and a few ironstone concretions; sandy in upper part — 43

Total upper part — 374

Unnamed marine member:

51. Sandstone, pale-yellowish-gray, fine- to medium-grained, lower part ledge forming, upper part soft; contains *Ophiomorpha* — 80
50. Shale, siltstone and sandstone, dark-gray to dull-olive, soft; sandstone and siltstone laminae are cemented with limonite; poorly exposed on line of section but well exposed a quarter of a mile to south — 115

USGS D5000, from limonite concretions 20 ft above base:

Yoldia? evansi (Meek and Hayden)
Nucula sp.
Inoceramus aff. *I. turgidus* Anderson
Pteria linquaeformis (Evans and Shumard)
Oxytoma sp.
Ostrea sp.
Goniomya americana Meek and Hayden
Lucina sp.
Tenea sp.
Tellina munda Stephenson
Corbula sp.
Baculites sp.
Didymoceras cf. *D. nebrascense* (Meek and Hayden)

Principal reference section of the Allen Ridge Formation—Continued

Allen Ridge Formation—Continued

Unnamed marine member—Continued

50. Shale, siltstone and sandstone—Continued

USGS D5001, from 70 ft above base:

Serpula sp.
Dysnoetoporoid bryozoan
Inoceramus cf. *I. pertenuis* Meek and Hayden
Oxytoma sp.
Ostrea sp.
Syncyclonema sp.
Pholadomya sp.
Protocardia? sp.
Cymella montanensis (Henderson)
Tellina munda Stephenson
Corbula sp.
Acmaea? parva (Meek and Hayden)
Acmaea? cf. *A. occidentalis* (Meek and Hayden)
Cerithioderma? sp.
Tuba n. sp.
Aporrhais aff. *A. biangulata* (Meek and Hayden)
Euspira obliquata (Hall and Meek)
Gyrodes sp.
Morea sp. (only apex preserved but it belongs in the *cancellaria* rather than *marylandica* species group)
Bellifusus sp. (immature)
Graphidula cf. *G. alleni* (White)
Acteon sp.
Oligoptycha sp.
Baculites sp.
Didymoceras nebrascense (Meek and Hayden)
Placenticeras intercalare Meek
Fish scales

Total unnamed marine member — 195

Lower part:

49. Sandstone, pale-yellowish-gray, fine-grained, hard; weathers dark reddish brown; contains a few limonite nodules in lower part and masses of concretionary-weathering sandstone in upper part — 30
48. Shale, light-gray, interbedded with brown carbonaceous shale; contains a few light-yellowish-weathering beds of soft lenticular sandstone. A 1-ft-thick bed of carbonaceous shale at top and a layer of reddish-brown-weathering ironstone concretions 3 ft below top — 106
47. Sandstone, pale-yellowish-gray, fine-grained, crossbedded, lenticular; forms ridge — 5

USGS D4759:

Anodonta propatoris White
Plesielliptio sp.
Fusconaia? sp.
Sphaerium sp.
Viviparus sp.

Principal reference section of the Allen Ridge Formation—Continued

	Feet
Allen Ridge Formation—Continued	
Lower part—Continued	
46. Shale, light- to medium-gray, sandy; contains thin lenses of soft sandstone with layers of limonite cement and 2 thin beds of carbonaceous shale in upper part	45
45. Sandstone, moderate-yellow-brown, fine-grained, lenticular; forms ridges; contains numerous limonite nodules	3
44. Shale, light-gray, sandy; contains numerous layers of iron-cemented siltstone or silty ironstone. Three 1–ft-thick beds of carbonaceous shale in upper part	29
43. Sandstone, pale-yellowish-gray, fine-grained; crossbedded, lenticular; weathers brown and forms ridge	7
42. Shale, as in unit 44; contains a few carbonaceous streaks	21
41. Sandstone, as above	23
40. Shale, gray and brown interbedded; in part carbonaceous	59
39. Sandstone, pale-yellowish-gray, fine-grained, crossbedded, lenticular; forms ridge; contains 1.5–ft-thick by 3–ft-diameter dark-yellowish-orange sandstone concretions at base	14
38. Shale, like unit 40; contains some thin beds of soft sandstone	23
37. Sandstone, like unit 39, except very fine grained	5
36. Shale, like unit 40, contains ironstone concretions	15
35. Sandstone, pale-yellow, very fine grained, thin-bedded, soft; numerous layers are cemented with limonite	9
34. Shale, light-gray to reddish-brown interbedded; in part carbonaceous; contains thin lenticular beds of sandstone	22
33. Sandstone, pale-yellowish-gray, fine-grained, very lenticular; weathers brown and forms ridge	3
32. Shale, like unit 34	29
31. Sandstone, like unit 33; contains limonite-cemented shale pebbles	35
30. Shale and sandstone interbedded; light-gray shale interbedded with reddish-brown carbonaceous shale and lenticular beds of reddish-brown-weathering sandstone. Unit capped by a 4–ft-thick bed of carbonaceous shale	73
29. Sandstone, like unit 33; weathers dusky yellow	2
28. Shale, like unit 34; contains ironstone concretions; soft	23
27. Sandstone, like unit 33	3
26. Shale, gray; contains thin ironstone layers	2
25. Shale, dark-brown, carbonaceous	3
24. Sandstone, dark-yellowish-orange, very fine grained, thin-bedded	2
23. Shale, light-gray; contains thin beds of soft sandstone and carbonaceous shale, soft. A layer of ironstone concretions 0.8 ft thick and 1.5 ft in diameter in middle of unit	15
22. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded; numerous rusty-brown-weathering limonite-cemented layers. Capped by a 1.5–ft-thick bed of hard reddish-brown-weathering sandstone	6
21. Shale, reddish-brown, carbonaceous. Interbedded with light-gray sandy shale; forms valley	35
20. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded, lenticular; weathers dark yellowish orange	9
19. Shale, as above	30
Total lower part	686
Total Allen Ridge Formation	1,255
Haystack Mountains Formation:	
Upper unnamed member:	
18. Sandstone, pale-yellowish-gray, fine-grained; forms massive cliff; contains *Ophiomorpha*	70
17. Sandstone and shale interbedded; dominantly sandstone in beds 0.1–6 ft thick; shale in beds less than 0.1–1 ft thick; forms valley between 2 cliff-forming sandstones	70
16. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded at base to massive at top; abundant limonite-replaced shale pebbles in lower part; contains numerous partially oxidized small pyrite nodules	70
USGS D5580, from lower part of unit: *Baculites perplexus* Cobban	
15. Sandstone and shale; weathers yellowish gray; poorly exposed	175
14. Covered; appears to be dark-gray sandy shale	230
Total upper unnamed member	475
Hatfield Sandstone Member:	
13. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded, in beds 0.1–0.4 ft thick, locally cemented with iron and containing fossils; forms ridge	55
USGS D5579: Pyriporoid bryozoan; *Inoceramus subcompressus* Meek and Hayden; *Baculites asperiformis* Meek?; *Hoploscaphites* sp.; *Placenticeras* sp.	
Total Hatfield Sandstone Member	55

Principal reference section of the Allen Ridge Formation—Continued

	Feet
Haystack Mountains Formation—Continued	
Middle unnamed member:	
12. Covered; appears to be dark-gray shale	225
11. Sandstone, as above; forms massive ridge	185
USGS D5578:	
Inoceramus sp.	
Baculites mclearni Landes	
10. Covered; appears to be dark-gray shale	370
9. Shale and sandstone interbedded, gray, soft, poorly exposed; contains thin beds of coarse-grained glauconitic sandstone with dark phosphate pebbles 50 ft below top	60
USGS D5577, from 50 ft below top:	
Baculites sp. (phosphatized)	
8. Shale, gray, sandy; weathers yellowish gray; poorly exposed	280
USGS D5576, float 190 ft above base of unit:	
Baculites cf. *B. mclearni* Landes	
7. Shale, poorly exposed; contains a few thin beds of sandstone	280
6. Covered; appears to be sandy shale	210
Total middle unnamed member	1,610
O'Brien Spring Sandstone Member:	
5. Sandstone, pale-yellowish-gray, very fine grained, clayey, soft in lower part becoming slightly resistant in upper part; contains thin beds of sandy shale and sparse limestone concretions; poorly exposed	250
USGS D4757, from 150 ft above base of unit:	
Cymbophora holmesi (Meek)	
Baculites obtusus (Meek)	
4. Bentonite, light-gray, slightly swelling	5
3. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded, soft; capped by a 0.3-ft-thick bed of green glauconitic silica-cemented sandstone	70
Total O'Brien Spring Sandstone Member	325
Total Haystack Mountains Formation (rounded)	2,600
Total Mesaverde Group measured (rounded)	3,860
Steele Shale:	
2. Shale, medium-dark-gray, sandy	175
1. Bentonite, like unit 4; contains a 0.2-ft-thick silicified sandstone at base	2

PINE RIDGE SANDSTONE

TYPE LOCALITY AND DISTRIBUTION

The Pine Ridge Sandstone was designated the upper member of the Mesaverde Formation and was named by Dobbin, Hoots, Dane, and Hancock (1929, p. 140) for the exposure on Pine Ridge about 2 miles southeast of the town of Rock River in the northern part of the Laramie Basin, but they did not measure a section at this locality. The section we measured on Pine Ridge is considered in this report as the principal reference section for the unit. In this report we elevate the Pine Ridge Sandstone from a member of the Mesaverde Formation to a formation in the Mesaverde Group.

The Pine Ridge Sandstone is the most conspicuous formation in the Mesaverde Group. It is a white to light-gray nonmarine sandstone, more resistant and lighter colored than the adjacent formations, and generally crops out as a distinctive tree-covered ridge. The formation can be recognized along the west and north margins of the Laramie Basin, throughout the Carbon and Hanna Basins, and along the east flank of the Great Divide Basin. It is exposed on the northeast side of the Washakie Basin near Rawlins, but has not been identified on the southeast side of the basin near the Wyoming-Colorado State line.

LITHOLOGIC CHARACTER

The Pine Ridge Sandstone in much of south-central Wyoming consists mainly of pale-yellowish-gray very fine grained to fine-grained sandstone that weathers very light gray to white. It includes beds of light-gray carbonaceous siltstone, sandy carbonaceous shale, and thin beds of impure coal. Many bedding surfaces are stained or cemented with iron oxide. High-angle crossbedding that resembles torrential bedding is a striking feature on many outcrops. Some of the sandstone beds in the formation are closely jointed. These joints and the adjacent rock have been cemented with secondary silica resulting in a raised boxwork pattern on weathered surfaces.

In most areas, sandstones of the Pine Ridge are fine grained, except where the formation has cut deeply into the underlying rocks. In these areas the grain size of the Pine Ridge (called Teapot Sandstone Member of the Mesaverde by earlier workers) reaches granule-pebble conglomerate size (Reynolds, 1967, p. D26).

THICKNESS

The Pine Ridge Sandstone is 83 feet thick at the principal reference section (fig. 9). It apparently thins toward the east, grading into shallow-water marine sandstone. This change cannot be observed in the Laramie Basin but has been seen in the Teapot Sandstone Member (coextensive with the Pine Ridge) of the Mesaverde Formation in the southern Powder River Basin. The Pine Ridge Sandstone is as much as 450 feet thick in the northwestern part of the Rock Creek oil field in the northwestern part of the Laramie Basin (Dobbin and others, 1929, p. 140), and it ranges in

FIGURE 9.—Pine Ridge Sandstone at its principal reference section in the NE¼SW¼NW¼ sec. 16, T. 20 N., R. 76 W., Albany County, Wyo. Valley to the right side of the area shown in photograph is cut in the Lewis Shale, and sage-covered slope to the left is formed by the Rock River Formation.

thickness from 250 feet along the east margin of the Hanna Basin to about 70 feet in the Kindt Basin south of Sinclair (Davis, 1966, p. 68).

On the northeast flank of the Great Divide Basin, the Pine Ridge is 60–205 feet thick. Reynolds (1967, p. D24) attributed this variation to depositional thinning, to intertonguing with the generally overlying Almond Formation, and to local truncation beneath the Lewis Shale. Regionally, the Pine Ridge is a thin widespread unit of sandstone deposited by meandering streams upon an uplifted and eroded surface of nonmarine and marine rocks. South of Rawlins, along the east margin of the Washakie Basin, the Pine Ridge Sandstone has lost its characteristic blanketlike character and is probably represented by thick channel-filling sandstones that grade laterally into rocks of Allen Ridge lithology.

RELATION TO ADJACENT FORMATIONS

The nonmarine Pine Ridge Sandstone is thought to rest unconformably on the Rock River Formation in the Laramie Basin and on the Allen Ridge Formation in the Hanna Basin. The basal beds of the Pine Ridge fill channels in the underlying rocks at many places, but the relief on this erosion surface can be determined at few localities. Apparently, much of central Wyoming was subjected to regional uplift and erosion before the deposition of the Pine Ridge Sandstone and the coextensive Teapot Sandstone Member of the Mesaverde (Gill and Cobban, 1966b). Local areas of intense pre-Pine Ridge folding and erosion in south-central Wyoming were described by Reynolds (1966, 1967), and an unconformable relationship between the Pine Ridge and older rocks in south-central Wyoming was recorded by Davis (1966, p. 60–62).

The Pine Ridge Sandstone is one of the major regressive tongues of the Mesaverde Group and represents an eastward retreat of the strand. The formation probably thins and changes eastward, first to a shallow-marine unit and then to a part of the Pierre Shale. Following deposition of the Pine Ridge, the sea again advanced westward, and mud of the Lewis Shale was deposited. In the Laramie Basin, the Lewis rests conformably on the Pine Ridge Sandstone; but in the Carbon, Hanna, Great Divide, and Washakie Basins farther west, the Pine Ridge is conformably overlain by, and interfingers with, coal beds, brackish-water shale, and nearshore-marine sandstone. The name Almond Formation is applied to these rocks which represent the barrier bar or barrier island and lagoonal deposits along the western shore of the advancing Lewis sea. In the western part of south-central Wyoming, where the uppermost strata of the Pine Ridge Sandstone interfinger with the basal beds of the Almond, the contact of the two formations is placed between the light-gray-weathering nonmarine sandstone and the overlying yellowish-gray to brown-weathering sandstone or dark-gray brackish-water shale. The sandstone of the lower part of the Almond, although similar to the sandstone of the upper part of the Pine Ridge at many localities, commonly contains burrows of marine and brackish-water organisms. The shale of the lower part of the Almond, in contrast with the shale of the upper part of the Pine Ridge, contains brackish-water fossils and generally occurs in thicker units.

AGE AND CORRELATION

The age of the Pine Ridge has been extrapolated from the ages of overlying and underlying marine rocks because only poorly preserved plant fossils have been found in the formation. The youngest marine fossils in the underlying Rock River Formation, from 270 feet below the top, include *Didymoceras stevensoni*. From the known range span of this species at other localities, it appears that the uppermost part of the Rock River Formation could have been deposited during the time of the next younger index ammonite, *Exiteloceras jenneyi*.

The lower part of the Lewis Shale, overlying the Pine Ridge Sandstone in the Rock River area, contains *Baculites reesidei*. This ammonite is separated from *Exiteloceras jenneyi* by, from oldest to youngest, the zones of *Didymoceras cheyennense*, *B. compressus*, and *B. cuneatus* in other areas in the Rocky Mountain region. It is possible that the Pine Ridge Sandstone was deposited during the time span of these three zones, but it is improbable because of the unconformity at the base of the formation. The marine equivalent of the Teapot Sandstone Member of the Mesaverde Formation in the Powder River Basin contains *B. reesidei* (Gill and Cobban, 1966b, p. B21–B24). We believe the Teapot to be coextensive with the Pine Ridge and, consequently, that the Pine Ridge was deposited early in the time of *B. reesidei*. This would indicate that the Pine Ridge Sandstone is of middle Bearpaw age (Gill and Cobban, 1966a, pl. 4).

The Pine Ridge Sandstone correlates with an unnamed sandstone unit in the upper part of the Pierre Shale at Horse Creek east of the Laramie Range and with an unnamed sandstone and shale sequence below the Larimer and Rocky Ridge Sandstone Members of the Pierre Shale along the east side of the Front Range in Colorado (Scott and Cobban, 1959, p. 129). It probably also correlates with the lower part of the Williams Fork Formation of the Mesaverde Group in northwestern Colorado and with the Teapot Sandstone Member of the Mesaverde Formation in the western Powder River Basin, eastern Wind River Basin, and Bighorn Basin of Wyoming. The Pine Ridge Sandstone probably is coextensive with the upper part of the Ericson Sandstone of the Rock Springs uplift; the two formations have similar lithologies, and both underlie the Almond Formation.

PRINCIPAL REFERENCE SECTION

The following section, measured about 2 miles southeast of the town of Rock River in the area where the formation was named, is herein designated the principal reference section.

Principal reference section of the Pine Ridge Sandstone

[Measured with a Jacob's staff by J. R. Gill in June 1968. Measured about 2¾ miles southeast of the town of Rock River in the NE¼SW¼NW¼ sec. 16, T. 20 N., R. 76 W., Albany County, Wyo. Loc. 8, fig. 1.]

	Feet
Lewis Shale:	
18. Shale, dark-gray to black; not measured.	
Pine Ridge Sandstone:	
17. Sandstone, light-gray, very fine grained, very thin bedded; contains some yellow iron stain	1.0
16. Shale, reddish-brown, carbonaceous	2
15. Sandstone, like unit 17	9
14. Shale, dark-brown to black, coaly in middle; level of prospect pit	15.8
13. Sandstone, pale-yellowish-gray, fine-grained; forms cliff; contains high-angle crossbeds and weathers light gray; weathered surfaces have a boxwork pattern, in part	20.5
12. Coal, black, impure	1.4
11. Shale, dark-brown to black, carbonaceous to coaly	2.0?
10. Sandstone, like unit 13	4.0
9. Shale, dark-brown, carbonaceous, silty; contains a 1-ft-thick siltstone layer in middle	3.5
8. Coal, black, impure	2.8

Principal reference section of the Pine Ridge Sandstone—Continued

	Feet
Pine Ridge Sandstone—Continued	
7. Claystone, light-olive-gray, carbonaceous, very silty	5.0
6. Sandstone, like unit 13, but in beds 1-ft thick; contains some yellow iron stain	4.5
5. Shale, brown to black, coaly in upper foot	4.0
4. Sandstone, like unit 13, but slightly carbonaceous	2.4
3. Shale, olive-gray, carbonaceous	4.5
2. Sandstone, pale-yellowish-gray, fine- to medium-grained, hard; abundant plant and root remains	.8
Total Pine Ridge Sandstone (rounded)	83.0
Rock River Formation (part):	
1. Sandstone, very light gray, very fine grained, soft, clayey; becomes dusky yellow at top	75
Rock River Formation measured	75

ALMOND FORMATION

TYPE LOCALITY AND DISTRIBUTION

The Almond Formation was first called the "Almond coal group" of the Mesaverde Formation by Schultz (1907, p. 262) and later called the Almond Formation of the Mesaverde Group by Sears (1926, p. 16). Neither geologist designated a type locality nor measured a type section. We assume that the name was derived from the Almond stage station near Point of Rocks, in the SW¼ sec. 27, T. 20 N., R. 101 W., Sweetwater County, Wyo. We measured a section nearby, in sec. 25, where the Almond is about 585 feet thick and consists of two parts. The lower part, 180 feet thick, consists of fluviatile sandstone, shale, and coal. The upper part, 405 feet thick, consists of marine shale, shallow-water marine sandstone, and lagoonal or brackish-water rocks. The upper part interfingers with the overlying Lewis Shale, and the lower part is in sharp contact with the underlying Ericson Sandstone.

The Almond Formation is well exposed along the flanks of the Rock Springs uplift and extends eastward in the subsurface through the Great Divide and Washakie Basins. The Almond crops out along the east margins of these basins and is also exposed in the Hanna and Carbon Basins to the east. The Almond Formation is a sequence of fluviatile, brackish-water, and nearshore marine rocks that conformably overlie the Pine Ridge Sandstone and conformably underlie, and intertongue with, the Lewis Shale in south-central Wyoming.

LITHOLOGIC CHARACTER

In south-central Wyoming, the Almond Formation consists of a thick sequence of sandstone, shale, and minor coal. Sandstone constitutes one-half to one-third of the formation. It is pale yellowish gray to dusky yellow, weathers various shades of brown, and is very fine grained and thin bedded. Locally, the sandstone contains *Ophiomorpha*, which is evidence of a shallow-water marine depositional environment, and abundant oysters and other fossils from a brackish-water depositional environment. These sandstone units may represent barrier-bar or barrier-island deposits marginal to the Lewis Sea. The formation also contains a few sandstone units probably of fluvial origin. The sandstone beds of the Almond seem to increase in thickness and number seaward (east and southeast).

Shale units in the Almond are, in a regional sense, tongues of the Lewis Shale and likewise increase in thickness and number to the east and southeast. The Almond contains two types of shale. The first is dark gray to olive gray and devoid of ironstone concretions but, locally, contains limestone concretions with marine fossils. Units of this shale thin to the west and northwest and regionally are tongues of the Lewis Shale. The second and more typical type is brownish gray to brownish black, carbonaceous to coaly, and contains many ironstone concretions with abundant oysters and other brackish-water fossils. This shale was probably deposited in a restricted marine or brackish-water environment, possibly behind barrier-bars or islands. In the extreme northwestern part of the area, on the northeast flank of the Great Divide Basin, fluviatile sandstone and shale form the basal part of the Almond (M. W. Reynolds, oral commun., 1968).

THICKNESS

The thickness of the Almond Formation varies considerably in south-central Wyoming. The formation generally thins toward the east and southeast. The thinning results from an increase in number and thickness of marine shale units and from the nonpersistence, in an eastward direction, of the shallow-water marine sandstone units chosen to identify the Almond-Lewis contact. As the sandstone units beneath the Almond-Lewis contact pinch out and the marine shale units in the upper part of the Almond thicken to the east and southeast, the contact is selected progressively lower in the rock sequence.

Where the Almond Formation crops out along the northwestern margin of the Laramie Basin, it consists of 30–40 feet of interbedded carbonaceous shale, shallow-marine sandstone, and lenticular coal. The Almond is about 575 feet thick along the south margin of the Hanna Basin near the Elk Mountain anticline. In this area the Almond contains two tongues of marine shale—a lower tongue, 215 feet thick, and an upper tongue, 75 feet thick. The remainder of the formation consists of slightly carbonaceous shale containing abundant ironstone concretions, interbedded sandstone and carbonaceous shale, and beds of shallow-water marine sandstone. About 28 miles northeast of this area, in the southern Haystack Mountains, the Almond is about 600 feet thick (fig. 10). Remnants of marine tongues are represented there by shallow-water marine sandstones and shales containing abundant brackish-water fossils. This lithology is described in reference section 1 of the Almond Formation.

Along the northeast flank of the Great Divide Basin in the Lamont-Bairoil area, the Almond ranges in thickness from 0 to 365 feet. This variation resulted from depositional thinning on a growing Late Cretaceous fold and from erosion along a local unconformity at the top of the formation (M. W. Reynolds, oral commun., 1968).

RELATION TO ADJACENT FORMATIONS

Dark-gray-weathering shale and sandstone of the lower part of the Almond are conformable with, and alternate with, lighter colored sandstone of the upper part of the Pine Ridge Sandstone. In some areas the contact is sharp, and in others it is arbitrarily located within gradational rocks. The Almond Formation is generally conformable with, and grades laterally into, the partly younger Lewis Shale. This contact is generally placed at the top of a shallow-marine sandstone unit that overlies dark-colored brackish-water and fluviatile beds and underlies a marine shale unit. The Almond Formation in south-central Wyoming was deposited along the margins of the expanding Lewis Sea, which accounts for the large-scale intertonguing of the two formations.

FOSSILS

The Almond Formation contains marine and brackish-water faunas. The brackish-water fossils are mainly associated with carbonaceous shale and ironstone concretions, but reeflike beds of oysters occur with some of the shallow-water marine sandstones. The marine fossils are in limestone concretions, within tongues of marine shale, or in shallow-marine sandstones.

At Rock River the part of the Lewis Shale that is equivalent to the Almond of the western areas contains the following index ammonites, from oldest to youngest: *Baculites reesidei*, *B. jenseni*, and *B. eliasi*. Of these forms, *B. reesidei* and *B. eliasi* have been found in marine rocks of the Almond at several places. *B. jenseni* has not been reported in the Almond, probably because

FIGURE 10.—Shallow-water marine sandstones and brackish-water shales in the lower part of the Almond Formation near reference section 1, sec. 12, T. 22 N., R. 85 W., Carbon County, Wyo. Dip slope to right is formed by the Pine Ridge Sandstone. Looking east.

the rocks representing this fossil zone are of brackish-water origin in much of the area.

In the southern part of the Hanna Basin, in the NW¼SW¼ sec. 27, T. 21 N., R. 81 W., Carbon County, the following fossils were collected from 280 feet above the base of the Almond:

USGS D6272:
- Calcareous worm tube
- *Solemya*? sp.
- *Nuculana* sp.
- *Yoldia*? *evansi* (Meek and Hayden)
- *Breviarca* sp.
- *Inoceramus* sp.
- *Oxytoma* sp.
- *Ethmocardium* sp.
- *Anisomyon centrale* Meek
- *Baculites reesidei* Elias

Additional fossils are listed in reference sections 1 and 2 for the Almond Formation.

AGE AND CORRELATION

The Almond Formation in south-central Wyoming was deposited during the time range of three ammonites, in ascending order, *Baculites reesidei*, *B. jenseni*, and the early part of *B. eliasi*. The type Almond in the Rock Springs uplift took longer to accumulate; it appears to encompass the preceding zones plus the younger zone of *B. baculus*. The presence of these fossils indicates that the Almond Formation is of late Bearpaw age (Gill and Cobban, 1966a, pl. 4).

The Almond correlates with the lower unnamed shale member and the Kara Bentonitic Member of the Pierre Shale in the eastern Powder River Basin, with the lower part of Meeteetse Formation of the western Bighorn and Wind River Basins, and with the upper part of the Williams Fork Formation of the Mesaverde Group in northwestern Colorado. It also correlates with the lower part of the Lewis Shale in the Laramie Basin and with the upper part of the Pierre Shale east of the Laramie Mountains.

REFERENCE SECTIONS

The two following reference sections were measured about 11 miles apart and document the southerly (seaward) change in the lithology of the Almond Formation.

Reference section 1 of the Almond Formation

[Measured in July 1967 with planetable and tape by J. R. Gill and G. A. Bergman. Fossils identified by W. A. Cobban. Measured in the SW¼SE¼SW¼ and the SW¼NE¼ sec. 12, T. 22 N., R. 85 W., Carbon County, Wyo. (Lone Haystack Mountain 7½-minute quadrangle), loc. 4, fig. 1.]

	Feet
Lewis Shale:	
40. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded to massive, friable to cliff-forming; contains 3 layers of large brown-weathering sandstone concretions	180
USGS D5258, from near top of unit:	
Baculites eliasi Cobban	
39. Shale, olive-gray, flaky; becomes sandy in upper part; contains 4 layers of rusty-weathering septarian limestone concretions in the lower 30 ft. Middle of unit contains 2 beds of bentonite less than 0.5 ft thick	70
38. Shale, light-olive-gray; weathers yellowish gray; persistent bed of red-weathering septarian limestone concretions at top	30
Total Lewis Shale measured	280
Almond Formation:	
37. Sandstone and shale interbedded; weathers yellowish gray; soft; nonpersistent layer of brown-weathering sandstone concretions at top	25
USGS D6263:	
Calcareous worm tube	
Cymbophora? sp.	
Gastropods	
Baculites eliasi Cobban	
Hoploscaphites sp. (with aptychus)	
36. Shale, reddish-brown, carbonaceous	7
35. Coal, black, impure	1.5
34. Sandstone, pale-yellowish-gray, very fine grained; thin bedded at base and massive at top	5
33. Shale, brownish-gray, flaky, poorly exposed; contains tabular masses of orange-weathering ironstone and cone-in-cone limestone concretions. Upper 10 ft consists of reddish-brown carbonaceous shale	60
USGS D6262, from 20 ft below top:	
Corbicula sp.	
USGS D6261:	
Crassostrea glabra (Meek and Hayden)	
Corbicula? sp.	
32. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded, ripple-laminated; contains small vertical burrows	4
31. Shale, dark-brownish-gray; grades into coaly shale at top	2
30. Shale, dark-yellowish-orange	0.5
29. Sandstone as above	8
USGS D6264:	
Panopea? sp.	
Corbula undifera (Meek)	
28. Shale, brownish-gray; olive gray and sandy in upper 10 ft; contains 3 layers of red-weathering ironstone concretions	55
USGS D6261:	
Crassostrea glabra (Meek and Hayden)	
Corbicula? sp.	

Reference section 1 of the Almond Formation—Continued

	Feet
Almond Formation—Continued	
27. Sandstone, yellowish-gray to dusky-yellow, fine- to medium-grained, ridge-forming; contains abundant oyster shells and invertebrate burrows. Locally contains brown-weathering cross-bedded sandstone concretions at 10 ft above base	18
26. Shale, dark-brownish-gray; contains abundant oyster shells and *Ophiomorpha*	25
25. Sandstone, like unit 27	5
24. Shale, like unit 26, but sandy	13
23. Sandstone, like unit 27	2
22. Shale, olive-gray; weathers to a yellowish-gray slightly bentonitic surface; contains 4 layers of oyster-bearing ironstone concretions	35
21. Shale, brownish-black, flaky; abundant jarosite and selenite in lower part; contains 6 layers of small ironstone concretions	37
20. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded	2
19. Shale, dark-gray; ironstone concretion layer at top	10
18. Shale, black, very carbonaceous	4
17. Shale, brown, carbonaceous, silty; contains a 0.4-ft-thick bed of pale-yellowish-gray very fine grained sandstone at top	4
16. Sandstone, grayish-yellow to dusky-yellow, fine-grained, thin-bedded, cliff-forming; contains small U-shaped burrows and small *Ophiomorpha*	17
15. Sandstone and shale interbedded; contains a 1-ft-thick bed of carbonaceous shale at top	10
14. Sandstone, like unit 16	10
13. Shale, dark-gray, flaky; contains at 10 ft above base a 0.4-ft-thick by 1.5-ft-wide orange-weathering lens of limestone with cone-in-cone structure	20
12. Shale, brownish-gray to brownish-black; contains 2 layers of ironstone concretions. Upper 10 ft is reddish-brown carbonaceous shale	29
11. Sandstone and shale interbedded; grades into overlying sandstone	10
10. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded, cliff-forming; contains many smooth burrows and a few *Ophiomorpha*	60
9. Sandstone, dusky-yellow to yellowish-gray, fine-grained, massive; stained with yellow limonite	8
8. Sandstone, dusky-yellow to light-gray, fine-grained, thin-bedded, ripple-marked; contains burrows	9
7. Shale, dark-brown, poorly exposed; contains a few thin layers of sandstone	15
6. Sandstone, yellowish-gray, fine-grained, thin-bedded; lower part weathers dusky yellow and upper part weathers light gray; contains burrows	12
5. Shale, dark-brown; contains ironstone concretions	37
4. Sandstone, yellowish-gray, very fine grained; weathers light gray	2
3. Shale, like unit 5	10

Reference section 1 of the Almond Formation—Continued

Almond Formation—Continued

	Feet
2. Sandstone, yellowish-gray to pale-yellowish-gray, fine-grained, thin-bedded to massive, cliff-forming; weathers light gray; contains large *Ophiomorpha* in upper part	25
1. Shale, reddish-brown, carbonaceous	11
Total Almond Formation	608

Pine Ridge Sandstone. Not measured.

Reference section 2 of the Almond Formation

[Measured by J. R. Gill and G. A. Bergman, August 1967. Fossils identified by W. A. Cobban. Measured in the C SE¼ and the SE¼SW¼ sec. 3, T. 20 N., R. 85 W., Carbon County, Wyo. (Savage Ranch 7½-minute quad.), loc. 5, fig. 1.]

	Feet
Lewis Shale (part):	
54. Shale, dark-gray, poorly exposed; contains highly fractured brown-weathering silty limestone concretions at 100 and 180 ft above base	180
USGS D6305, from top of unit: *Baculites eliasi* Cobban	
Total Lewis Shale measured	180
Almond Formation:	
53. Sandstone, yellowish-gray, fine-grained; cemented with iron; contains abundant oysters	4
USGS D6310: *Crassostrea glabra* (Meek and Hayden)	
52. Shale, reddish-brown to yellowish-gray; upper 2 ft very carbonaceous	9
51. Shale, black, coaly	2
50. Sandstone, pale-yellowish-gray, very fine grained, ripple-laminated	4
49. Shale, dark- to brownish-gray, flaky; contains a layer of ironstone concretions at 10 and 15 ft above base	36
48. Sandstone, pale-yellowish-gray, fine-grained, soft	5
47. Sandstone, like unit 48; contains numerous oyster shells	2
USGS D6309: *Crassostrea glabra* (Meek and Hayden)?	
46. Sandstone, pale-yellowish-gray, fine-grained; soft in lower part and more resistant near top; at 60 ft above base are orange-weathering sandstone concretions 2 ft thick and 4 ft in diameter; contains *Ophiomorpha*	75
45. Shale, olive-gray at base becoming dark gray at top	10
44. Sandstone, pale-yellowish-gray, fine-grained, soft	3
43. Shale, dark-gray to black, flaky; contains a layer of ironstone concretions at 10 ft above base and at top	22
42. Siltstone, pale-yellowish-gray, ripple-laminated	10
41. Covered; appears to be shale; weathers yellowish gray	17

Reference section 2 of the Almond Formation—Continued

Almond Formation—Continued

	Feet
40. Shale and sandstone interbedded; sandstone in beds less than 0.2 ft thick weathering yellowish gray to moderate orange with much iron stain; outcrop weathers light reddish brown	15
USGS D6308: *Inoceramus* sp.	
39. Shale, olive- to brownish-gray	13
38. Sandstone, pale-yellowish-gray, fine-grained; weathers light yellow to yellowish gray; contains *Ophiomorpha*	12
37. Shale, dark-gray, poorly exposed	10
36. Sandstone, like unit 38, but very thin bedded	4
35. Shale, reddish-brown to black, carbonaceous	4
34. Sandstone like unit 38, but contains at 18 ft above base sandstone concretions 2 ft thick and 12 ft in diameter	28
33. Covered; probably shale	20
32. Shale, medium-gray, platy; contains a few ironstone concretions	30
31. Sandstone, yellowish- to light-gray, thin-bedded; soft at base and hard at top; weathers light gray	8
30. Covered; appears to be shale	4
29. Sandstone, like unit 38, but contains large *Ophiomorpha*	8
28. Sandstone, like unit 38, but thin to medium bedded; forms cliff	4
27. Shale, brownish-gray, carbonaceous	.5
26. Sandstone, like unit 38, but thin bedded to massive; forms cliff	18
25. Sandstone, light-brown, fine-grained, very thin bedded; contains thin laminae of brownish-gray carbonaceous shale	7
24. Sandstone, pale-yellowish-gray, very fine grained, lenticular	3
USGS D6307: *Inoceramus* sp.	
23. Sandstone, light-brown, very fine grained; interlaminated with brownish-gray carbonaceous shale; muddled bedding	10
22. Siltstone, pale-yellowish-gray; very thin bedded at base to massive at top; contains laminae of carbonaceous shale	10
21. Claystone, medium-light-gray	2
20. Sandstone, like unit 23; weathers light yellow	3
19. Shale, dark-gray	.5
18. Siltstone, like unit 22	.5
17. Shale, dark- to brownish-gray; weathers splintery	2.5
16. Sandstone, pale-yellowish-gray, fine-grained, thin-bedded; local iron-cemented masses of sandstone in upper part	10
USGS D6306: *Inoceramus oblongus* White	
15. Claystone, dark- to brownish-gray	2.5
14. Sandstone, yellowish-gray, fine-grained; in beds 0.1–1.5 ft thick	11
13. Claystone, medium-light-gray	1

Reference section 2 of the Almond Formation—Continued

Almond Formation—Continued	
12. Sandstone, like unit 14	4
11. Coal, black, impure	1.5
Total Almond Formation	446
Pine Ridge Sandstone:	
10. Sandstone, light-brown, very fine grained; in beds 0.05–0.1 ft thick; contains abundant carbonaceous fragments and carbonaceous shale to impure coal laminae; weathers dusky yellow to light gray	17
9. Shale, brownish-gray, carbonaceous	7
8. Sandstone, like unit 10	6
7. Claystone, dark-brownish-gray, carbonaceous	3
6. Sandstone, like unit 10	4
5. Shale, dark-gray; ironstone concretionary layer at base	4
4. Sandstone, like unit 10	13
Total Pine Ridge Sandstone	54
Allen Ridge Formation:	
3. Shale, medium-dark-gray to brownish-gray; contains several thin layers of sandstone and siltstone	24
2. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded and ripple-marked. Weathers dusky yellow to light gray; contains some U-shaped burrows	4
1. Sandstone and shale interbedded, not measured and described in detail	1,325
Total Allen Ridge Formation (rounded)	1,350
Total Mesaverde Group measured (rounded)	1,850

LEWIS SHALE

TYPE LOCALITY AND DISTRIBUTION

The Lewis Shale was named by Cross and Spencer (1899) for exposures of a thick marine shale near Fort Lewis, east of Mesa Verde National Park in southwestern Colorado. The Lewis Shale of southwestern Colorado is neither an extension of, nor the same age as, the Lewis Shale of south-central Wyoming. The name is retained in Wyoming only because of long-established usage in the region. (See p. 3 and 5.)

Rocks assigned to the Lewis Shale are widely distributed in Wyoming. The Lewis is recognized in the Laramie, Carbon, Hanna, Great Divide, Washakie, Powder River Basins, eastern part of the Bighorn and Wind River Basins, and around the Rock Springs uplift. In eastern Wyoming, rocks equivalent to the Lewis Shale are in the upper part of the Pierre Shale.

LITHOLOGIC CHARACTER

The Lewis Shale of south-central Wyoming consists of 2,200–2,600 feet of shale, siltstone, and sandstone. Much of the variation in thickness may result from differences in opinion as to the placement of the upper and lower contacts of the formation. Both the overlying Fox Hills Formation and the underlying Almond Formation intertongue with the Lewis Shale on a regional scale. In the northern part of the Laramie Basin, the Lewis Shale contains many thick beds of sandstone that are either tongues of the Fox Hills Formation or offshore marine units deposited marginal to the Almond Formation. In this area, Hyden (1965) and McAndrews (1965) included the nonresistant sandstones of the Fox Hills with the Lewis Shale for mapping. Where this procedure was followed, the Lewis Shale may contain more than 50 percent sandstone.

Sandstone of the Lewis is very fine to medium grained, thin bedded to massive, and pale yellowish gray to brown. It is generally nonresistant, but where concretionary, it forms ridges that can be traced for many miles (fig. 11). Sandstone units in the lower part of the Lewis commonly contain molluscan fossils and *Ophiomorpha.* The middle and upper parts of the formation contain a distinctive and widespread unit of interbedded sandstone and sandy shale that ranges in thickness from 300 to at least 700 feet. This unit is assigned in this report to the Dad Sandstone Member of the Lewis Shale.

The shale of the Lewis is dominantly dark gray to olive gray, silty to sandy, and nonresistant, and, locally, contains fossiliferous limestone or siltstone concretions.

FIGURE 11.—Fossiliferous sandstone concretions weathered from a soft friable sandstone in the lower part of the Lewis Shale, in the NW¼ sec. 6, T. 22 N., R. 79 W., Carbon County, Wyo. These distinctive concretions can be traced along the entire east side of the Carbon and Hanna Basins.

A distinctive unit of black shale several hundred feet thick forms the basal part of the Lewis in the northern part of the Laramie Basin (fig. 12). The siltstone of the Lewis is yellowish gray, nonresistant, and poorly exposed.

The Lewis Shale is almost entirely marine in origin. The shale of the Lewis represents a marine depositional environment but may contain a few thin units of brackish-water origin. The sandstone in the formation contains *Ophiomorpha* in places and was probably deposited in nearshore marine environments.

A distinctive unit of interstratified sandstone and shale occurs in the middle and upper parts of the Lewis Shale in south-central Wyoming. In the Washakie Basin, these rocks were called the Dad Member of the Lewis by Hale (1961, p. 136–137) and were described as follows:

> Approximately seven miles due west in the Dad area, wells have drilled a total of 2,300 feet of Lewis but disclose a series of sandstones and minor shales 1,000–1,400 feet thick which divides the Lewis into upper and lower shale units. This sandy member is here called the Dad member of the Lewis shale for typical development in the Union Texas Gas Company Dad Unit 2 well between 6,385 feet and 7,805 feet. This well is located in sec. 13, T. 16 N., R. 93 W.

We have examined the Lewis Shale along the east margin of the Washakie Basin and can identify the Dad Sandstone Member in this and adjacent areas. The Dad Sandstone Member is much thinner where exposed than in the subsurface at the Dad Unit well 2. We measured a reference section of the Dad Member in the NW¼NE¼SW¼ sec. 28, T. 15 N., R. 91 W., Carbon County, and determined the thickness to be about 585 feet. The Dad Sandstone Member can be traced northward along the east margin of the Washakie and Great Divide Basins, where it has been mapped as the lower part of the Lance Formation (Love, and others, 1955). Ten miles northwest of Rawlins, the Dad is 735 feet thick. (See reference section of the Lewis Shale.)

The Dad Sandstone Member of the Lewis Shale is actually a tongue of the Fox Hills Formation. It can be traced from near Rawlins northward along the east margin of the Great Divide Basin, where the upper shale unit of the Lewis grades into sandstone and the underlying sandstone beds of the Dad grade into rocks of the Fox Hills Formation (M. W. Reynolds, oral commun., 1968).

The Dad Sandstone Member occurs throughout the Hanna (fig. 13) and Carbon Basins and is a thick unit of poorly exposed sandstone in the northern part of the Laramie Basin. The Dad Member probably is a result of an uplift in central Wyoming and consequent increase in the amount of sediment deposited in the Lewis Sea. In the western part of the Powder River Basin, regressive deposits of sandstone, shale, and coaly rocks in the upper part of the Lewis Shale represent the same tectonic event that caused deposition of the Dad Sandstone Member. Similar rocks divide the Lewis Shale into two parts in the southeastern part of the Wind River

FIGURE 12.—Dark shale of the lower part of the Lewis Shale exposed along the Platte River, in the NE¼SW¼ sec. 11, T. 20 N., R. 85 W., Carbon County, Wyo.

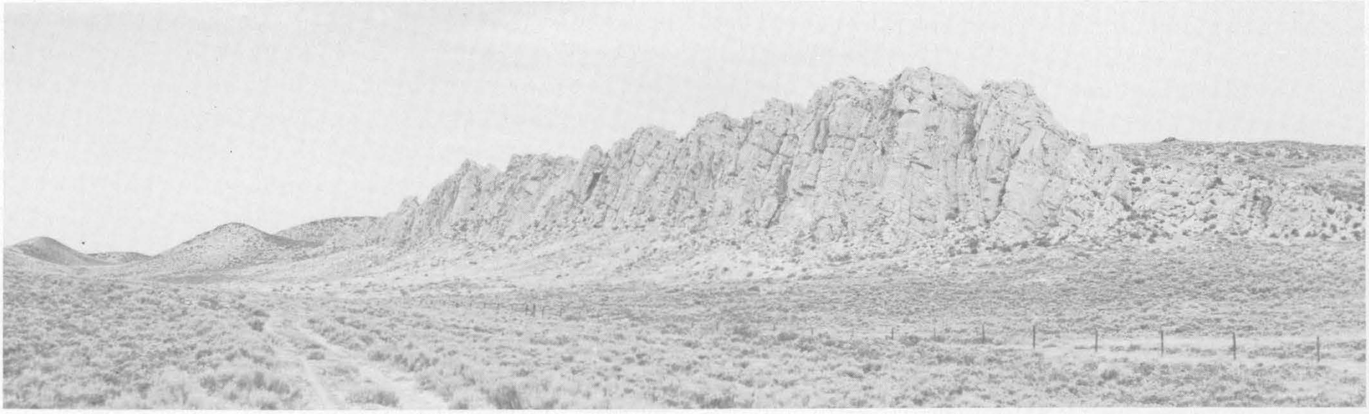


FIGURE 13.—Cliff-forming sandstone of the Dad Sandstone Member of the Lewis Shale, in the SW¼ sec. 14, T. 20 N., R. 83 W., Carbon County, Wyo.

Basin. In this area these rocks are called the Meeteetse Formation (Rich, 1962, p. 469–479). Abundant fossils from many localities are evidence that the Dad Sandstone Member of the Lewis Shale, the regressive sandstone tongue in the upper part of the Lewis of the Powder River Basin, and the Meeteetse Formation in the Wind River Basin were deposited during the range of *Baculites grandis*.

THICKNESS

The thickness of the Lewis Shale is not easily determined at most localities because the formation is poorly exposed. Rocks of the Lewis Shale are nonresistant, and the contract with the overlying Fox Hills Formation is transitional and poorly exposed. Most previous workers have included the soft sandstones of the Fox Hills with the Lewis Shale (for example, Hyden, 1965; Davidson, 1966), and this assignment causes the thickness of the Lewis to be excessive when compared to its thickness in areas where the Fox Hills is recognized. Davidson (1966, p. 26) reported that the Lewis is 3,900 feet thick in the northeastern part of the Hanna Basin. He included the Fox Hills in the Lewis, and in this area the Fox Hills is more than 700 feet thick. Davidson (1966, p. 26) also reported that the Lewis is 3,000 feet thick at Mill Creek in the southwestern part of the Laramie Basin, but he included an unknown thickness of the Fox Hills with the Lewis. Hyden (1965) showed the Lewis to be about 2,500 feet thick in the northern part of the Laramie Basin, but he also included an unknown thickness of the Fox Hills in the Lewis.

The maximum thicknesses of the Lewis that we have measured are 2,600 feet on the southeast flank of the Carbon Basin and 2,300 feet on the northwest side of the Hanna Basin. These and other measurements are evidence that the Lewis thins from south-central Wyoming in a north and northwest direction. The Lewis is about 2,300 feet thick near Rawlins (see reference section), but, where traced northward along the east flank of the Great Divide Basin, it thins owing to facies changes and nondeposition. Thirty miles north of Rawlins, near Bairoil, the lower part of the Lewis Shale is absent because of nondeposition; the upper part changes facies and is represented by beds assigned to the Fox Hills and Lance Formations (M. W. Reynolds, oral commun., 1968).

RELATION TO ADJACENT FORMATIONS

The Lewis Shale gradationally overlies the Almond Formation in the area of this report, except in the Laramie Basin where it rests sharply on the Pine Ridge Sandstone. Locally, as in the Lamont area (fig. 1), the Lewis Shale rests unconformably on beds as old as the Cody Shale (Reynolds, 1966). The Lewis also grades into the overlying sandstone of the Fox Hills Formation. At this contact, sandy shale of the Lewis merges gradually into the clayey sandstone of the Fox Hills. Northward and northwestward thinning of the Lewis is associated with a facies change from marine shale to the south to nearshore marine sandstone and to fluviatile deposits to the north.

FOSSILS

The Lewis Sea sustained a large and varied invertebrate marine fauna. Large collections of fossils from many localities show that the Lewis Shale was deposited in the eastern part of the area during the range of six successive ammonite zones. These ammonites are listed below, with the youngest species at the top:

Baculites clinolobatus
grandis
baculus
eliasi
jenseni
reesidei

Many other invertebrate fossils were found in association with these ammonites, and some of these are listed in the reference section of the Lewis.

AGE AND CORRELATION

In comparison with the classic Cretaceous section of central Montana, the Lewis Shale of the Laramie Basin is equivalent to the uppermost Bearpaw Shale, the Fox Hills Sandstone, and the lower part of the Hell Creek Formation. The Lewis Sea remained in south-central Wyoming after receding from central Montana; consequently, the upper part of the Lewis Shale in the report area is equivalent to nonmarine rocks of the Hell Creek Formation in central Montana.

The Lewis Shale correlates with the Meeteetse Formation of the western Wind River and Big Horn Basins and with the upper unnamed shale member of the Pierre Shale in the eastern Powder River Basin (Gill and Cobban, 1966a, pl. 4). The Lewis is equivalent to the Almond Formation and the Lewis Shale of the Rock Springs uplift and approximately equivalent to the Lewis Shale of northwestern Colorado.

REFERENCE SECTIONS

Two reference sections are described. One is the principal reference section for the newly adopted Dad Sandstone Member of the Lewis, and the other is a reference section of the Lewis Shale and Fox Hills Formation in the western part of the report area.

Principal reference section of the Dad Sandstone Member of the Lewis Shale

[Measured with planetable and Jacob's staff by J. R. Gill and G. A. Bergman, August 1967. Measured on the south side of Wild Cow Creek from the SW¼SW¼NW¼ sec. 27 to the NW¼NE¼SW¼ sec. 28, T. 15 N., R. 91 W., Carbon County, Wyo. (Baggs 15-minute quadrangle), loc. 1, fig. 1.]

	Feet
Lance Formation:	
19. Shale, dark-brown to black, carbonaceous to lignitic	30
18. Sandstone, light-gray, very fine grained, upper part cemented with limonite; weathers white	4
17. Shale, gray, slightly carbonaceous; weathers light gray	5
Total Lance Formation measured	39
Fox Hills Formation:	
16. Sandstone, pale-yellowish-gray, very fine grained; contains a 1-ft-thick layer of highly fractured siltstone concretions overlain by a light-brown- to gray-weathering sandstone concretion 4 ft thick and 20 ft in diameter	70
15. Shale, gray, very sandy, soft; weathers yellowish gray	40

Principal reference section of the Dad Sandstone Member of the Lewis Shale—Continued

Fox Hill Formation—Continued	
14. Sandstone, pale-yellowish-gray, soft; contains local lenses 4 ft thick by 30 ft in diameter of light-brown-weathering concretionary sandstone	40
Total Fox Hills Formation	150
Lewis Shale:	
Upper part:	
13. Shale and sandstone interbedded; shale dominant; sandstone in thin beds 0.1–0.4 ft thick; weathers yellowish gray	110
12. Shale, olive-gray, flaky, sandy near top	220
Total upper part	330
Dad Sandstone Member:	
11. Sandstone, pale-yellowish-gray, very fine grained, soft; contains shale pebbles in lower part and a 0.3-ft-thick bed of platy-weathering siltstone at base	60
10. Shale, olive-gray, sandy; weathers yellowish-gray	15
9. Sandstone, pale-yellowish-gray, very fine grained, soft; contains at top light-brown-weathering sandstone concretions 4 ft thick and 8 ft in diameter	25
8. Shale, olive-gray, sandy; contains a few sandstone laminae in middle part; weathers yellowish gray	150
7. Sandstone and shale, yellowish-gray, soft; contains local masses of concretionary sandstone 2–3 ft in diameter	40
6. Sandstone, pale-yellowish-gray, very fine grained; contains some tuberous-shaped and cannonball-like concretions as much as 1.5 ft in diameter; forms low ridge	40
5. Shale, gray; weathers yellowish gray; contains a few thin beds of fine-grained soft sandstone	105
4. Sandstone, pale-yellowish-gray, very fine grained; contains brown-weathering cannonball concretions 1.5 ft in diameter and large concretionary masses 8 ft thick by 20 ft in diameter	50
3. Shale, gray, sandy; weathers light gray	20
2. Sandstone, pale-yellowish-gray, very fine grained, soft; upper part poorly exposed and may contain some thin beds of sandy shale; contains some thin tabular masses of concretionary sandstone	80
Total Dad Sandstone Member	585
Lower part:	
1. Shale, gray, sandy; weathers grayish yellow; contains 2 thin layers of yellow limestone concretions 50 ft below top; thickness not measured.	

Reference section of the Fox Hills Formation and Lewis Shale (including Dad Sandstone Member)

[Measured with planetable and Jacob's staff by J. R. Gill and G. A. Bergman. Fossils identified by W. A. Cobban. Measured on the north side of Indian Springs Creek starting in the SW¼SW¼ sec. 13 and ending in the SE¼SE¼ sec. 14, T. 22 N., R. 89 W., Carbon County Wyo. (Rawlins Peak 15-minute quadrangle.)]

	Feet
Lance Formation:	
40. Shale and sandstone interbedded; sandstone beds are thin and lenticular; shale beds are carbonaceous	30
USGS D6334, from 10 ft above base of unit:	
Corbicula fracta (Meek)	
39. Shale, dark-brown to black, carbonaceous	3
38. Coal, lignitic, black	1.2
Total Lance Formation measured	34.2
Fox Hills Formation:	
37. Sandstone, pale-yellowish-gray, very fine grained, massive; weathers yellowish gray; contains some concretionary masses	33
36. Shale and sandstone interbedded, soft; weathers yellowish gray; contains local concretionary ledges of brown-weathering sandstone as much as 2 ft thick	32
35. Sandstone, pale-yellowish-gray, very fine grained; contains *Ophiomorpha*	1
USGS D6333:	
Crassostrea sp.	
Pholadomya n. sp.	
Tancredia? sp.	
Ethmocardium n. sp.	
Legumen sp.	
Cymbophora sp.	
Baculites sp.	
34. Shale, gray, sandy	8
33. Shale, dark-brown, carbonaceous	4
USGS D6332:	
Crassostrea sp.	
32. Coal, lignitic, impure, black	1
31. Sandstone, pale-yellowish-gray, concretionary at base, soft at top; weathers light gray; contains *Ophiomorpha*	51
30. Sandstone and shale, interbedded in equal amounts, soft; weathers yellowish gray	31
29. Sandstone, pale-yellowish-gray, very fine grained, concretionary at top	11
Total Fox Hills Formation	172
Lewis Shale:	
Upper part:	
28. Shale, gray, silty to sandy, sandier toward top; weathers yellowish gray; contains three layers of siltstone concretions	67
27. Sandstone, pale-yellowish-gray, very fine grained; weathers yellowish gray; top locally contains large masses of concretionary sandstone	22

Reference section of the Fox Hills Formation and Lewis Shale (including Dad Sandstone Member)—Continued

Lewis Shale—Continued	
Upper part—Continued	
26. Shale and sandstone; weathers yellowish gray; contains orange-brown-weathering sandstone concretions 5 ft thick and 15 ft in diameter	55
25. Shale, medium-dark-gray; weathers dark gray; contains sparse gray limestone concretions in middle	33
24. Sandstone, yellowish-gray to dusky-yellow, fine-grained, soft; contains numerous concretions and *Ophiomorpha* in upper part. Probably represents a northward thickening tongue of the Fox Hills Sandstone	85
USGS D6248:	
Crassostrea glabra (Meek and Hayden)	
23. Shale and sandstone interbedded, soft; weathers yellowish gray	55
22. Siltstone and shale interbedded; weathers yellowish gray; contains local lenslike concretionary masses of orange-brown-weathering siltstone in upper part	81
21. Shale, dark-gray; forms dark band on outcrop; contains a 0.1-ft-thick bentonite overlain by a thin layer of dark-gray limestone concretions	37
USGS D6331, from limestone concretion:	
"Inoceramus" fibrosus (Meek and Hayden)	
Baculites sp.	
USGS D5588, from this level in the S½SW¼ sec. 6, T. 21 N., R. 88 W.:	
"Inoceramus" fibrosus (Meek and Hayden)	
Lucina sp.	
Baculites cf. *B. clinolobatus* Elias	
Hoploscaphites sp.	
20. Shale, yellowish-gray, very sandy; contains small limestone concretions at top	20
USGS D6330:	
Baculites sp.	
19. Shale, medium-gray; weathers light gray; contains a 0.1-ft-thick bentonite with fibrous calcite at 6 ft below top (this bentonite is about 2 ft thick a few miles to the south)	70
Total upper part	525
Dad Sandstone Member:	
18. Sandstone, yellowish-gray to pale-yellowish-gray, very fine grained, soft, friable; contains randomly distributed 5-ft-thick by 10 ft in diameter masses of concretionary sandstone	56
17. Shale, gray, sandy; contains thin laminae of sandstone	34

Reference section of the Fox Hills Formation and Lewis Shale (including Dad Sandstone Member)—Continued

Lewis Shale—Continued	
Dad Sandstone Member—Continued	
16. Shale, gray; weathers light gray; contains thin siltstone laminae cemented with limonite	89
15. Siltstone, gray; weathers yellowish gray	50
14. Sandstone, light- to dusky-yellow, glauconitic, fine-grained, soft; contains sandstone concretions 8 ft thick and 15 ft in diameter	77
USGS D6629:	
Ostrea sp.	
Arctica? sp.	
13. Shale, light-gray, sandy in upper half; weathers yellowish gray	69
12. Sandstone, yellowish-gray, fine-grained, soft; contains thin laminae of shale	10
11. Shale, gray, sandy; weathers pale yellowish gray to light gray	70
10. Sandstone, yellowish-gray to dark-yellowish-orange, fine-grained, soft, friable; contains abundant burrows and near top fossiliferous sandstone concretions 1.5 ft thick and 3 ft in diameter	45
USGS D6328, from top of unit:	
Micrabacia sp.	
Calcareous worm tube	
Bryozoan	
"*Inoceramus*" *fibrosus* (Meek and Hayden)	
Pteria linguaeformis (Evans and Shumard)	
Ostrea russelli Landes	
Pecten sp.	
Anomia sp.	
Modiolus galpiniana (Evans and Shumard)	
Pholadomya n. sp.	
Goniomya americana Meek and Hayden	
Drepanochilus sp.	
Baculites grandis Hall and Meek	
Discoscaphites sp.	
9. Poorly exposed. Appears to be sandy shale with numerous thin beds of sandstone	110
8. Sandstone and sandy shale interbedded, pale-yellowish-gray, thin-bedded, ripple-laminated; weathers in light-brown concretionary and slabby ledges 2–5 ft thick	115
Total Dad Sandstone Member	725
Lower part:	
7. Shale, poorly exposed, sandy; 15 ft above base is a layer of limestone concretions	250
USGS D6327:	
"*Inoceramus*" *fibrosus* (Meek and Hayden)	
Baculites sp.	
6. Sandstone, pale-yellowish-gray, very fine grained; weathers concretionary locally	5
5. Shale, gray, sandy, poorly exposed	45

Reference section of the Fox Hills Formation and Lewis Shale (including Dad Sandstone Member)—Continued

Lewis Shale—Continued	
Lower part—Continued	
4. Sandstone, pale-yellowish-gray, very fine grained, thin-bedded; locally concretionary	15
3. Shale, gray, poorly exposed	405
2. Shale, dark-gray, flaky; contains several layers of dark-reddish-brown-weathering limestone concretions, some of which are septarian	340
USGS D6326, from 50 ft above base:	
Baculites eliasi Cobban	
Total lower part	1,060
Total Lewis Shale	2,310
Almond Formation (part):	
1. Sandstone, yellowish-gray to grayish-yellow, fine- to medium-grained, thin-bedded; contains many oysters in lower 10 ft and abundant *Ophiomorpha* in upper part	25
USGS D6325:	
Crassostrea glabra (Meek and Hayden)	

FOX HILLS FORMATION

TYPE LOCALITY AND DISTRIBUTION

The Fox Hills Formation was named by Meek and Hayden (1862, p. 419) for exposures of siltstone and sandstone on Fox Ridge between the Grand and Moreau Rivers in central South Dakota. The name has been used in South Dakota, North Dakota, Montana, Wyoming, and Colorado for rocks that are transitional with the underlying marine shale of the Pierre and Lewis and with the overlying fluviatile beds of the Hell Creek, Lance, and Medicine Bow Formations.

Early geologists (for example, Dobbin, Bowen, and Hoots, 1929, p. 23) recognized rocks equivalent to the Fox Hills in south-central Wyoming but included them in either the upper part of the Lewis Shale or the lower part of the Medicine Bow Formation. Dorf (1938, p. 6) assigned the name Fox Hills Formation to the marine sandstone and marine to nonmarine shale that had previously been included in the lower part of the Medicine Bow Formation. We accept Dorf's assignment for the area of this report and have identified the Fox Hills in the Hanna, Carbon, and Laramie Basins.

LITHOLOGIC CHARACTER

The Fox Hills Formation consists dominantly of thick units of friable sandstone but includes units of shale. Sandstone units are pale yellowish gray, very fine to fine grained, weather yellowish gray to light brown, and commonly contain fossiliferous sandstone concretions. They are thin bedded to massive, crossbedded and ripple bedded, and generally nonresistant, but locally they are well cemented and cliff forming. The shale units are olive gray to dark gray, mainly sandy, nonresistant, and generally poorly exposed. Thin units of carbonaceous shale containing brackish-water fossils or thin impure beds of coal crop out in some areas. *Ophiomorpha* is common in the sandy rocks, and oysters are locally abundant in beds of sandstone or shale.

THICKNESS

The Fox Hills ranges in thickness from less than 200 feet along the east side of the Great Divide and Washakie Basins to at least 700 feet along the east side of the Carbon Basin near Medicine Bow; at other localities it may be thicker. We interpret the differences in thickness to be a result of different rates of subsidence and sediment delivery. In areas of maximum thickness, the rates of sedimentation and subsidence were probably about equal; consequently, the strandline was nearly stationary for a long period of time. Where the Fox Hills is thin, the strandline probably retreated seaward at a relatively rapid rate.

RELATION TO ADJACENT FORMATIONS

The sandstone of the Fox Hills Formation intertongues with the marine shale of the Lewis and with the brackish-water and fluviatile shale and sandstone of the Medicine Bow Formation. The Fox Hills represents a transitional depositional environment between a deeper water marine environment and the lagoonal and continental environments. The formation resulted from the deposition of sediments in shallow marine, barrier bar, and beach environments as the Cretaceous sea withdrew from the area of the northern Rocky Mountains.

The contact between the Lewis and Fox Hills is progressively lower in the section in a north and northwest direction because the marine shale of the Lewis is replaced laterally by the shallow-water marine sandstone of the Fox Hills. The lower contact of the Fox Hills Formation is placed at the horizon below which the rocks are predominantly marine shale. The upper contact is located at the horizon above which the rocks are predominantly of fresh- and brackish-water origin, including coal and carbonaceous shale, and below which the rocks are predominately of marine origin. These criteria are similar to those proposed by Lovering, Aurand,, Lavington, and Wilson (1932, p. 702) for the recognition and delineation of the Fox Hills in northeastern Colorado.

FOSSILS

The Fox Hills Formation contains a shallow-water marine fauna consisting of a large variety of clams and snails. In the area of this report it also contains three distinctive types of ammonites which are *Baculites clinolobatus*, *Sphenodiscus* (*Coahuilites*) sp., and *Discoscaphites* sp. *Baculites clinolobatus* is an index ammonite found in the upper part of the Pierre Shale in eastern Wyoming, South Dakota, and eastern Colorado where the Fox Hills is younger than in south-central Wyoming. The following three collections of fossils, identified by W. A. Cobban and N. F. Sohl, are representative of the fauna of the Fox Hills in south-central Wyoming:

USGS D5538. NE¼SE¼ sec. 16, T. 21 N., R. 79 W., Carbon County.

From 215 ft below the top of the Fox Hills Formation.

Lingula sp.
Nucula planimarginata Meek and Hayden
Oxytoma nebrascana (Evans and Shumard)
Clamys nebrascensis (Meek and Hayden)
Crenella sp.
Astarte sp.
Clisocolus sp.
Protocardia rara (Evans and Shumard)
Legumen sp.
Tellina sp.
Dentalium sp.
Euspira sp.
Ellipsoscapha sp.
Cylichna volvaria (Meek and Hayden)
Oligotycha concinna (Hall and Meek)
Baculites sp.
Aptychus

USGS D5539. SE¼NW¼ sec. 21, T. 21 N., R. 79 W., Carbon County.

From the middle and upper parts of the Fox Hills Formation.

Dysnoetopora demissa (White)
Lingula nitida (Meek and Hayden)
"*Inoceramus*" *fibrosus* (Meek and Hayden)
Pseudoptera n. sp.
Oxytoma nebrascana (Evans and Shumard)
Ostrea sp.
Ethmocardium sp.
Protocardia subquadrata (Evans and Shumard)
Venerid pelecypod
Legumen ellipticum (Conrad)
Gyrodes? sp.
Baculites clinolobatus Elias
Discoscaphites sp.

USGS D5540. SW¼NW¼ sec. 11, T. 21 N., R. 79 W., Carbon County.

From 30 ft above the base of the Fox Hills Formation.

Bryozoan
Lingula nitida Meek and Hayden
Gervillia sp.
"*Inoceramus*" *fibrosus* (Meek and Hayden)
Pseudoptera n. sp.
Syncyclonema sp.
Pholadomya n. sp.
Ethmocardium n. sp.
Protocardia subquadrata (Evans and Shumard)
Venerid pelecypod
Legumen ellipticum Conrad
Tellina sp.
Cymbophora warrenana (Meek and Hayden)
Gyrodes? sp.
Baculites sp.
Sphenodiscus sp.

AGE AND CORRELATION

The Fox Hills in south-central Wyoming is oldest in the northern and northwestern part of the area and was probably deposited during the range span of *Baculites grandis* or possibly during the time of *B. baculus*. In the central and southeastern part of the area, the Fox Hills was deposited within the range span of *B. clinolobatus*. Nowhere in the area is it as young as at the type locality in South Dakota (Gill and Cobban, 1966a, p. A35).

The Fox Hills Formation of this area is not necessarily equivalent in age, but it correlates lithologically with the Fox Hills of North and South Dakota, Montana, and eastern Colorado. It also correlates lithologically with the Fox Hills of the Rock Springs uplift and with the Fox Hills of the Powder River Basin in Wyoming. It is equivalent to beds in the lower part of the Lance Formation in northwestern Colorado, as mapped by Bass, Eby, and Campbell (1955), and to the Lion Canyon Sandstone Member of the Williams Fork Formation, in the area of Meeker, Colo., as mapped by Hancock and Eby (1930).

MEDICINE BOW FORMATION

The Medicine Bow Formation is a thick unit of continental beds that were deposited during and after withdrawal of the Cretaceous sea from south-central Wyoming. Bowen (1918) named and described the formation from exposures along the North Platte River near the mouth of the Medicine Bow River in the western part of the Hanna Basin (fig. 1). The usage of the term "Medicine Bow Formation" is restricted to the Hanna, Laramie, and Carbon Basins. At the type locality and in adjacent areas, the Medicine Bow is about 6,200 feet thick and consists of fluviatile sandstone, siltstone, and shale with persistent beds of coal in the lower part. We have studied these rocks in detail only in the northwestern part of the Hanna Basin; consequently, our descriptions in this report are more limited than for the underlying Cretaceous rocks.

Marine sandstone and shale included by early workers in the upper part of the underlying Lewis Shale were placed by Dobbin, Bowen, and Hoots (1929, p. 22–24) in the Medicine Bow Formation. Dobbin and Reeside (1929, p. 21–23) recognized that these rocks represent the transition from conditions of marine deposition to continental deposition and determined them to be of Fox Hills age. Later, Dorf (1938, p. 4–6) redefined the Medicine Bow Formation and restricted the several hundred feet of marine beds at the base of the formation to the Fox Hills Formation. We concur with Dorf's redefinition.

We have not measured a complete section of the Medicine Bow, but are in general agreement with the description given by Bowen (1918, p. 229–230) and by Dobbin, Bowen, and Hoots (1929, p. 23–24). A brief description by the latter authors follows:

> The Medicine Bow formation ranges from 4,000 to 6,200 feet in thickness and consists of yellow, gray, and carbonaceous shale, beds of coal, and gray and brown sandstone. * * * The lower part of the formation is made up of massive to cross-bedded brown sandstones, which usually form a conspicuous group of ledges and contain numerous beds of coal. These sandstones are overlain by an intermediate group of dark-colored shales and thin-bedded fine-grained brown sandstones, with some beds of massive white sandstone. The sandstones at the top of the formation are coarse, massive, friable, and easily eroded and are interbedded with thick beds of dark-gray shale.

The Medicine Bow Formation seems to be conformably overlain by coarse-grained to conglomeratic sandstone beds of the Ferris Formation. In the type locality of the Ferris, in the central part of the Hanna Basin, coarse-grained sandstone of the upper part of the Medicine Bow grades upward into pebble-bearing sandstone beds of the Ferris. Locally, along the east side of the Hanna and Carbon Basins, the Medicine Bow Formation is overlain in angular unconformity by the Hanna Formation (fig. 14).

The Medicine Bow Formation is of Late Cretaceous age, as was suggested by Bowen (1918, p. 230), Dobbin and Reeside (1929, p. 22), Dorf (1938, p. 6), and Knowlton (1911, p. 369; 1914, p. 328). Dobbin, Bowen, and Hoots (1929, p. 23) considered that most of the Medicine Bow Formation and the lower 1,000 feet of the Ferris Formation represented the Lance Formation of eastern Wyoming. Dorf (1940, p. 223, 233) correlated the Medicine Bow with the Lance, the Hell Creek Formation of Montana and the Dakotas, and the Laramie

FIGURE 14.—Rocks of the Hanna Formation resting unconformably on the lower part of the Medicine Bow Formation in the southeastern part of the Carbon Basin, in the SE¼SE¼ sec. 20, T. 21 N., R. 79 W., Carbon County, Wyo.

Formation of Colorado. The Medicine Bow probably is equivalent to only major parts of the previously named units, as Dobbin, Bowen, and Hoots suggested, because the lower part of the Ferris Formation, which conformably overlies the Medicine Bow, is also of Late Cretaceous age (Brown, 1943, p. 81–82; 1962, p. 21).

Numerous fossil collections from the Medicine Bow Formation by earlier workers in the area include fresh- and brackish-water invertebrates, ceratopsian dinosaur remains, and plants. The geographic and stratigraphic position of many of these earlier collections cannot be determined accurately. During the course of the present study, invertebrate fossils were collected from the Medicine Bow Formation in the Carbon Basin and eastern part of the Hanna Basin, as well as from the lower and middle parts of the formation near the west margin of the Hanna Basin (Seminoe Dam SW 7½-minute quad.). Representative fossil collections from Carbon County, identified by W. A. Cobban, follow.

From middle part of Medicine Bow Formation:

USGS D6607. SW¼NW¼ sec. 26, T. 24 N., R. 85 W. (western Hanna Basin).
- *Proparreysia* sp.
- *Tulotomops thompsoni* (White)
- *Campeloma nebrascensis whitei* Russell
- *Lioplacodes* aff. *L. tenuicarinata* (Meek and Hayden)

USGS D6611. NE¼SE¼ sec. 33, T. 24 N., R. 85 W.
- *Proparreysia holmesiana* (White)
  - cf. *verrucosiformis* (Whitfield)
- *Plethobasis aesopiformis* (Whitfield)

USGS D6612. NE¼NW¼ sec. 24, T. 24 N., R. 85 W.
- *Anodonta* aff. *A. propatoris* White
- *Plesielliptio postbiplicata* (Whitfield)
- *Teredina laramiensis* (Whitfield)
- *Tulotomops thompsoni* (White)
- *Lioplacodes* aff. *L. tenuicarinata* (Meek and Hayden)
- *Campeloma nebrascensis whitei* Russell
- *Physa reesidei* Stanton

From lower part of Medicine Bow Formation:

USGS D5618. Center of the N½ sec. 1, T. 22 N., R. 80 W. (eastern Hanna Basin).
- *Plesielliptio postbiplicata* (Whitfield)
- *Tulotomops thompsoni* (White)
- *Lioplacodes* sp.
- *Campeloma nebrascensis whitei* Russell
- *Cassiopella turricula* White

USGS D5544. SE¼NE¼ sec. 21, T. 21 N., R. 79 W. (Carbon Basin).
- *Sphaerium* sp.
- *Tulotomops thompsoni* (White)
- *Lioplacodes* sp.

From S½NE¼ sec. 1, T. 22 N., R. 80 W.:

USGS D6241. (eastern Hanna Basin).
- Calcareous worm tube
- *Crassostrea* sp.

USGS D6242. 240 ft above D6241.
- *Corbicula* cf. *C. planumbona* Meek

USGS D6243. 30 ft above D6242.
- *Corbula* cf. *C. mactriformis* Meek and Hayden
- *Unio* sp.
- Gastropods

USGS D6244. 60 ft above D6243.
- *Corbula subtrigonalis* Meek and Hayden

USGS D6245. 215 ft above D6244.
Corbula cf. *C. mactriformis* Meek and Hayden
Goniobasis sp.
Viviparus sp.
USGS D6246. 40 ft above D6245.
Plesielliptio sp.
Tulotomops thompsoni (White)
Campeloma nebrascensis var. *whitei* Russell
USGS D6247. 45 ft above D6246.
Plesielliptio cf. *P. postbiplicata* (Whitfield)
Tulotomops thompsoni (White)
Campeloma nebrascensis var. *whitei* Russell
Lioplacodes cf. *L. tenuicarinata* (Meek and Hayden)
USGS D6080. NE¼NE¼ sec. 18, T. 24 N., R. 84 W. (western Hanna Basin).
Crassostrea glabra (Meek and Hayden)

FOOTE CREEK AND DUTTON CREEK FORMATIONS

The names Foote Creek and Dutton Creek were recently introduced in the northern part of the Laramie and southern part of the Carbon Basins by Hyden, McAndrews, and Tschudy (1965). The names were used on several geologic quadrangle maps. The Foote Creek Formation was proposed for as much as 400 feet of interbedded fine-grained sandstone, carbonaceous shale and siltstone, and coal. The Foote Creek (basal Medicine Bow Formation of this report) was reported to be of Late Cretaceous and Paleocene age and to conformably overlie the Lewis Shale (Hyden and others, 1965, p. K1). The Dutton Creek Formation (Hanna Formation of this report) was proposed for 200–500 feet of interstratified conglomerate, fine- to coarse-grained sandstone, mudstone, carbonaceous shale, and coal. The Dutton Creek is of late Paleocene age and unconformably overlies the Foote Creek. These new formation names were used for rocks shown on the current Wyoming State geologic map (Love and others, 1955) as the Medicine Bow and Hanna Formations.

The Foote Creek Formation at the type section, about 12 miles west of the town of Rock River, conformably overlies the Fox Hills Formation, which was included by Hyden, McAndrews, and Tschudy (1965, p. K7) in the Lewis Shale. At this locality the Foote Creek contains a thick unit of marine sandstone in its lower part and is transitional with the underlying Fox Hills. The thickness of the Foote Creek at this locality is 228 feet, and its lithology and fossil content are the same as those of the Medicine Bow Formation in nearby areas. At the type section of the Foote Creek a coal bed, about 7 feet above the base, contains spores and pollen typical of the Hell Creek, Lance, and Medicine Bow Formations of Late Cretaceous age (Hyden and others, 1965, p. K5). The beds a few feet above the coal contain *Crassostrea glabra* (Meek and Hayden), a fossil oyster typical of the transitional rocks in the upper part of the Fox Hills and lower part of the Medicine Bow.

The Paleocene age of the Foote Creek was determined from plant microfossils in core samples of carbonaceous shale and coal. The core was recovered from a hole 12 miles southeast of the type section of the formation. The coal-bearing rocks penetrated by the drill are about 160 feet thick and were interpreted by Hyden, McAndrews, and Tschudy (1965, p. K8) as part of the Foote Creek Formation resting conformably on the Lewis Shale. We believe these beds are a fine-grained facies of the Hanna Formation. Excellent and well-preserved pollen assemblages were obtained from five beds in the lower part of the Foote Creek and all are of late Paleocene age (R. H. Tschudy, oral commun., 1968). The lowest bed from which pollen was collected and identified is 15 feet above the Lewis Shale.

The basal part of the Foote Creek Formation (Medicine Bow of this report) at the type section contains Late Cretaceous plant microfossils, but the basal part of the Foote Creek (Hanna Formation of this report) at the locality of the drill hole contains plant microfossils now considered to be late Paleocene instead of Paleocene in age.

In the center of the Hanna Basin, about 20 miles northwest of the type section of the Foote Creek Formation, rocks of Late Cretaceous age (the lower part of the Medicine Bow) are separated from rocks of late Paleocene age (the lower part of the Hanna Formation) by as much as 13,000 feet of strata. This thickness contrasts with the reported maximum thickness of 400 feet between similar rocks of Late Cretaceous and late Paleocene (late Paleocene, R. H. Tschudy, oral commun., 1968) age in the Foote Creek Formation (Hyden and others, 1965, p. K3). A major unconformity at the base of the Hanna Formation has been described and mapped by Dobbin, Bowen, and Hoots (1929, p. 25 and pl. 27). The Hanna Formation lies unconformably on the Ferris Formation and transgresses across all underlying formations at least down to the Cloverly and possibly down to Precambrian granite (Dobbin, Bowen, and Hoots, 1929, p. 25). We believe that the Foote Creek Formation, reportedly of Late Cretaceous to late Paleocene age (Hyden and others, 1965, p. K5), encompasses this unconformity.

Rocks mapped as Foote Creek by Hyden and McAndrews (1967) along the east margins of the Hanna and Carbon Basins (T L Ranch 7½-minute and Saddleback Hills 15-minute quarangles) are at one place remnants of the basal Medicine Bow and at other places a fine-grained coal-bearing facies of the Hanna Formation. We have examined the local unconformity at the base of the Foote Creek Formation, reported by Hyden, McAndrews, and Tschudy (1965, p. K4), and conclude that the unconformity is not local and that the rocks above it are a fine-grained facies of the Hanna

Formation. Rocks as thick as 16,000 feet may be represented by the unconformity at this locality. In most other quadrangles mapped by Hyden and others in the northern part of the Laramie Basin, the name Foote Creek has been applied to remnants of the lower part of the Medicine Bow Formation.

We believe that the Dutton Creek Formation of late Paleocene age is a coarse-grained conglomeratic facies of the Hanna Formation and that the name "Hanna" should be reinstated for these rocks. Locally, the Dutton Creek is the basal unit of the Hanna which grades laterally into a fine-grained facies, as can be demonstrated in the northern part of the T L Ranch quadrangle. Where the lower part of the Hanna is fine grained, the Dutton Creek crops out higher in the Hanna Formation.

Our reevaluation of the stratigraphic and paleontologic data from rocks of Late Cretaceous and early Tertiary age in the Hanna, Carbon, and Laramie Basins results in the conclusion that the Foote Creek and Dutton Creek Formations have been incorrectly interpreted. The stratigraphic sequence exposed along the southeast margin of the Carbon Basin was reexamined in the company of H. J. Hyden, and it was concluded that the rocks assigned to the Foote Creek Formation belong in the lower coal-bearing part of the Medicine Bow Formation and in the coal-bearing fine-grained parts of the Hanna Formation.

The Foote Creek Formation as a formal stratigraphic name is abandoned in accordance with the wishes of Mr. Hyden before his untimely death. This action is taken because the lower part of the Medicine Bow Formation and the fine-grained facies of the Hanna Formation, although similar in appearance, can now be recognized. The two formations can be identified on the basis of lithology and are separated by a large unconformity. The two units are, in addition, of different ages—Late Cretaceous and late Paleocene. Inasmuch as most of the rocks mapped as Foote Creek are now recognized as remnants of the lower part of the Medicine Bow Formation, we recommend that the name Medicine Bow be reinstated for formal usage in this area. The Dutton Creek Formation represents one of the many coarse-grained tongues of the Hanna Formation; consequently, to avoid a duplication of names, the Dutton Creek is abandoned and the Hanna is reinstated.

FERRIS FORMATION

The Ferris Formation was named by Bowen (1918, p. 230–231) from exposures between the old Ferris Ranch on the North Platte River (sec. 33, T. 23 N., R. 84 W.) and a hilltop to the east (sec. 28, T. 23 N., R. 83 W.). The formation is about 6,500 feet thick in the type locality. It consists of a thick sequence of continental rocks that can be divided into two parts: a lower unit of Late Cretaceous age which is about 1,100 feet thick and composed of conglomeratic sandstone, sandstone, and shale, and an upper unit of Paleocene age which is about 5,400 feet thick and composed of gray, brown, and yellow sandstone and many thick beds of coal. The two units appear to be conformable, although their lithologies are markedly different.

The conglomerate of the lower unit is generally dark. It contains pebbles as much as 1 inch in diameter composed of black, red, and yellow chert, red and gray quartzite, and sparse rhyolite and quartz latite porphyry (Bowen, 1918, p. 230). Some of the siliceous pebbles contain Paleozoic fossils. The pebbles apparently do not consist of rocks exposed locally in mountains adjacent to the basin. Bone fragments are common in the conglomerates, and some have been identified by C. W. Gilmore as *Triceratops*, which indicates a correlation between the basal part of the Ferris and the Lance Formation (Bowen, 1918, p. 231). Plant microfossils collected by us from the dark-brown shales in the lower unit of the Ferris were examined by R. H. Tschudy, who said (written commun., 1967): "Sample D4085 yielded a characteristic late Cretaceous assemblage including the genera *Proteacidites* and *Aquilapollenites*. There is no doubt concerning the age of this sample."

The upper unit of the Ferris differs from the lower unit in being much thicker, in containing numerous persistent beds of coal, and in its lack of conglomerate or conglomeratic sandstone. Plant microfossils collected from about the middle of the upper unit were examined by R. H. Tschudy, who stated (written commun., 1967): "The few fossils identified indicate a Paleocene age for the samples. The absence of *Monipites tenuipolus* suggests early rather than late Paleocene."

The Ferris Formation conformably overlies coarse-grained sandstones of the Medicine Bow Formation and unconformably underlies locally derived conglomerate or conglomeratic sandstone of the Hanna Formation. In the type locality of the Ferris, in the west-central part of the Hanna Basin, an angular relation between the two formations is not apparent. Possibly in the central part of the Hanna Basin, the Ferris and Hanna Formations are virtually conformable, as suggested by Knight (1961, p. 162). A marked angular unconformity separates the two formations along the east side of the Hanna and Carbon Basins. The unconformity is well exposed in sec. 14, T. 22 N., R. 80 W., 2 miles north of the old town of Carbon.

In the northern part of the Hanna Basin, Dobbin, Bowen, and Hoots (1929, pl. 27) mapped the Hanna unconformably overlying the Ferris. Knight (1961, p. 155–164) measured two sections in the area and found no evidence of an angular unconformity, and he did not differentiate the Ferris and the Hanna. We have examined the area and conclude that the map of Dobbin, Bowen, and Hoots is incorrect. The Hanna Formation overlies a part of the Medicine Bow Formation; the intervening upper part of the Medicine Bow and the Ferris have been removed by pre-Hanna erosion. This accounts for the thinness of the Medicine Bow (3,950 ft instead of 6,500 ft a few miles to the west). We, like Knight, did not see a measurable angular unconformity at the base of the conglomeratic sequence, but it may have been overlooked in exposures on the edges of vertical beds.

The Ferris crops out in the Hanna and Carbon Basins, but the original areal extent of the formation is not known. Bowen (1918, pl. 66) showed that the Ferris is at least 4,600 feet thick in places along the east flank of the Hanna Basin. Probably the formation was also deposited in the Laramie Basin. The presence of locally derived conglomerate in the basal part of the overlying Hanna Formation and a marked angular unconformity at the base of this unit indicate that the Hanna and Carbon Basins started to form during the early or middle Paleocene. Knight (1953, p. 67) reported a locally derived conglomerate in the lower part of the Medicine Bow Formation, in the southwestern part of the Laramie Basin, and he concluded that the Medicine Bow Mountains were elevated sufficiently in Cretaceous time to expose rocks of Precambrian age.

HANNA FORMATION

The Hanna Formation was named by Bowen (1918, p. 231) from exposures north and west of the town of Hanna (fig. 1). Neither Bowen (1918, p. 231), who proposed the formation, nor Dobbin, Bowen, and Hoots (1929), who first mapped it, designated a specific type locality and described a type section. We have studied the formation only in the Hanna and Carbon Basins, and our descriptions are limited to general lithology, fossil content, and the relation with adjacent formations.

The Hanna Formation of continental origin consists of conglomerate, sandstone, shale, and coal. Bowen (1918, p. 231) reported that the formation was about 7,000 feet thick, but sections measured subsequently by Knight (1961, p. 159–161) on the north flank of the Hanna Basin and our field observations lead us to believe that the Hanna may be as much as 13,500 feet thick.

Bowen reported (1918, p. 231) that the Hanna Formation was "highly feldspathic" and composed of conglomerate, conglomeratic sandstone, sandstone, shale, and many thick beds of coal. The conglomerate is distributed throughout the formation, but is most abundant in the lower half. The pebbles in the conglomerate are, in general, light colored and consist of chert, granite, quartzite, sandstone, Mowry Shale, and conglomerate from the Cloverly Formation. The pebbles of granite, quartzite, Mowry Shale, and conglomerate are believed to represent nearby exposures of these rocks. The conglomerates of the Hanna differ from those of the Ferris in color and in the size and composition of the clasts. Apparently, the conglomerates of the Ferris were derived from a distant source and those of the Hanna from a nearby source. The basal unit of the Hanna is generally composed of coarse conglomerate but may locally be finer grained.

The Hanna Formation unconformably overlies the Ferris Formation in much of the area, but locally along the margins of the basins it rests on rocks as old as Precambrian age (fig. 15). Bowen (1918, p. 232) estimated that the unconformity at some localities represented the removal of rocks more than 20,000 feet thick. On the south flank of the Hanna Basin the Hanna and older formations are unconformably overlain by beds named the North Park Formation of Miocene age by Dobbin, Bowen, and Hoots (1929, p. 26) and undivided Pliocene and Miocene rocks by Weitz and Love (1952).

Knight (1961, p. 160) mapped unnamed continental rocks of Eocene age in the northern part of the Hanna Basin and demonstrated that this unit was in angular unconformity with the underlying Hanna and older formations at the basin margin. He further reported that the rocks of Eocene age became conformable with the underlying rocks as they were traced basinward. Plant microfossils collected by H. J. Hyden in the lower part of Knight's Eocene sequence in the SE¼ sec. 16, T. 22 N., R. 81 W., Carbon County, were examined by R. H. Tschudy, who stated (written commun., 1963) "USGS D3232A. Assemblage includes specimens of *Tiliaepollenites* and is of late Paleocene or early Eocene age." Plant microfossils collected by us from higher in the unit in the center of the SW¼ sec. 34, T. 24 N., R. 81 W., were described by Tschudy as follows (written commun., 1967): "USGS D4088. Assemblage includes the genera *Carya*, *Juglans*? *Tiliapollenites*, and *Platycarya*, and is of Eocene age." Knight's Eocene unit was originally mapped as part of the Hanna by Dobbin, Bowen, and Hoots (1929, pl. 27), but the demonstrated mappability of the unit (Knight, 1961, p. 160) and the unconformity at its base lead us to conclude that it should be excluded from the Hanna and perhaps included in the Wind River Formation as Knight suggested.

The fossils in the Hanna Formation consist of well-preserved leaves, spores and pollen, invertebrates, and

FIGURE 15.—Hanna Formation (Th) unconformably overlying the Lewis Shale (Kle) in the northeastern part of the Hanna Basin, in the NE¼NW¼ sec. 10, T. 23 N., R. 80 W., Carbon County, Wyo. Sandstones of the Almond Formation (Ka) crop out in the area shown in the lower left corner of the photograph, and the soft shales of the Lewis form the valley in the foreground.

vertebrates. The vertebrate remains described by Bowen (1918, p. 231) "include fish scales, fragments of turtle shells, and a fragmentary mammalian jaw identified by J. W. Gidley as a creodont, probably *Claeonodon*, which may belong to either the Fort Union or Wasatch." Bowen also reported that invertebrates from the Hanna were identified by T. W. Stanton and correlated with those of the Fort Union and Wasatch Formations. The plant fossils found by Bowen were referred to the Fort Union by F. H. Knowlton.

We collected plant microfossils from two localities in the lower part of the formation in the eastern part of the Carbon and Hanna Basins. These collections were described by R. H. Tschudy as follows (written commun., 1967):

USGS D4089. NW¼ sec. 10, T. 23 N., R. 80 W., Carbon County. Lower part of Hanna Formation.

Sparse assemblage, but the presence of *Momipites tenuipolus* Anderson and the absence of Cretaceous and Eocene species indicate that this sample is of late Paleocene age.

USGS D3939. NE¼SE¼SE¼ sec. 20, T. 21 N., R. 79 W., Carbon County. Lower part of Hanna Formation.

Good assemblage of well-preserved fossils, including *Pistillipollenites*, of late Paleocene age.

The age of the Hanna remains in some doubt. The upper part of the underlying Ferris Formation is of early Paleocene age and the overlying unnamed sequence mapped by Knight (1961) is of possibly latest Paleocene and early Eocene age. Fossils from the Hanna indicate a late Paleocene age, but the formation may be as old as late early Paleocene or middle Paleocene in the center of the Hanna Basin.

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