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UPPER CRETACEOUS AND TERTIARY FORMATIONS OF THE WESTERN PART OF THE SAN JUAN BASIN COLORADO AND NEW MEXICO

BY

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AND

FLORA OF THE ANIMAS FORMATION

BY

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UPPER CRETACEOUS AND TERTIARY FORMATIONS OF THE WESTERN PART OF THE SAN JUAN BASIN OF COLORADO AND NEW MEXICO.

By John B. Reeside, Jr.

SUMMARY OF THE PAPER.

This paper presents the results of studies in the Upper Cretaceous and Tertiary formations of the San Juan Basin of Colorado and New Mexico. It includes a more or less detailed description of the formations, a geologic map of the area, and columnar sections. The formations described are the Dakota sandstone, Mancos shale, Mesaverde group (Point Lookout sandstone, Menefee formation, and Cliff House sandstone), Lewis shale, Pictured Cliffs sandstone, Fruitland formation, Kirtland shale with Farmington sandstone member, McDermott formation (the lower part of the Animas formation as heretofore defined), Ojo Alamo sandstone, Animas formation (restricted), Nacimiento group (Puerco and Torrejon formations), and Wasatch formation (including "Tiffany beds" of Granger at base).

Some of the conclusions reached in the paper are as follows:

The Mancos shale contains successive faunas like those of the Greenhorn limestone, the Carlile shale, the Niobrara formation, and the basal part of the Pierre shale of the region east of the Rocky Mountains.

The Mesaverde group in southern and central San Juan County, N. Mex., represents the same time interval as the upper part of the Mancos shale, the Mesaverde group, and the Lewis shale near Durango, Colo.

The Pictured Cliffs sandstone, Fruitland formation, and Kirtland shale may be traced with essentially the same characteristic features around the entire west side of the basin. They appear to represent the same time interval everywhere.

The lower part of the beds with andesitic débris hitherto included in the Animas formation is much older than the Animas formation and is separated from the overlying beds by an erosion interval. For these lower beds the name McDermott formation is herein introduced, and the name Animas formation is restricted to the beds above the break.

The Ojo Alamo sandstone and at least the lower part of the Animas formation as restricted in this paper are of nearly the same age and overlie the most widespread stratigraphic break in the whole series of beds described.

The Puerco formation is probably of the same age as the upper part of the Animas formation, though possibly later than any part of the Animas formation now present.

The Torrejon formation overlaps the Puerco formation northward and is in turn overlapped by the Wasatch formation.

The Laramie formation of the Denver Basin has no recognizable equivalent in the region, beds with Montana fossils being directly followed by beds containing a flora that Knowlton correlates with the Denver flora. The post-McDermott hiatus appears to represent all of Laramie time.

The Wasatch formation in the southern part of the San Juan Basin apparently succeeds the Torrejon formation unconformably, the hiatus representing early Wasatch deposits which to the north were called "Tiffany beds" by Granger. In the northern part of the basin the Torrejon formation grades without interruption into the Wasatch formation.

INTRODUCTION.

Many papers on the geology and paleontology of the San Juan Basin have been published, some of them written in the earliest days of exploration in the region. Much of the work done, however, was of a strictly reconnaissance type and left many problems to be solved by later and more detailed observation. It is the purpose of this paper to summarize the earlier knowledge of the stratigraphy and to present some of the results of later work that contribute to its better interpretation.

The San Juan Basin, in the larger sense of that term, includes the roughly rectangular region that extends from Durango, Colo., on the north, to Gallup, N. Mex., on the south, a distance of 125 miles, and from the Great Hogback on the west to Gallina, N. Mex., on the east, a distance of 100 miles. The southern third of this large basin is occupied by nearly flat-lying rocks of the Mesaverde group, and the northwest corner, in the Mesa Verde, is occupied by the flat-lying rocks of the Mesaverde group. The northern two-thirds of the basin, excluding the Mesaverde, is occupied by concentric inward-dipping bands of outcrop of the formations above the Mesaverde group. This northern two-thirds of the basin therefore approaches more nearly the ideal conception of a simple structural basin and may be considered the San Juan Basin proper. It is with the western part of this narrower San Juan Basin only that this report deals. (See fig. 1.)

The later data presented in this paper that concern the part of the San Juan Basin lying in New Mexico were gathered during the course of a study designed primarily to obtain detailed information regarding the coal resources of San Juan County. The work was begun in 1915 by C. M. Bauer, assisted by H. R. Bennett and the writer. Papers by Mr. Bauer, C. W. Gilmore, T. W. Stanton, and F. H. Knowlton[1] on the stratigraphy and paleontology of the area studied were published in 1916. The work was continued during parts of the field seasons of 1916, 1917, 1920, and 1923 by the writer, assisted in 1916 by F. R. Clark, in 1917 by Harvey Bassler, and in 1920 by C. E. Dobbin. A paper by Mr. Bauer and the writer[2] embodies the economic data obtained during four seasons, and another by Mr. Gilmore[3] describes reptilian remains obtained in 1916.

The later data presented in this paper that concern the part of the San Juan Basin lying in Colorado were gathered by M. A. Pishel in his examination of the Red Mesa quadrangle in 1913, by J. H. Gardner in his examination of the Ignacio quadrangle in 1909, and by the writer in 1920 and 1921. The writer had the assistance in 1920 of T. C. Hopkins and in 1921 of Q. D. Singewald.

The writer is indebted to various colleagues for advice and assistance. Mr. Whitman Cross has forwarded both the field work and the office work in many ways. His interest in the geologic problems of the region has been a constant stimulation, and his wide knowledge has been freely placed at the writer's service. He has read the completed manuscript and made many very helpful criticisms and suggestions and has examined and commented on the lithologic specimens collected. Mr. F. H. Knowlton has identified the fossil plants and supplied lists of species and comments on them, Mr. C. W. Gilmore has identified the reptilian fossils, and Mr. J. W. Gidley the mammalian fossils. These gentlemen have also read parts of the manuscript and offered suggestions for its improvement.

Free use has been made of all the published and unpublished data available to the writer, and for this use due credit is given in the appropriate places.

The geologic map (Pl. I) includes material derived from several sources. The main body of the map is original. A strip on the north side showing the formations beneath the Pictured Cliffs sandstone is taken from Gardner's unpublished map of the Ignacio quadrangle. A patch in the northwest corner is taken from the La Plata folio. A strip in Colorado on the west side showing the formations beneath the Pictured Cliffs sandstone is taken from Pishel's unpublished map of the Red Mesa quadrangle. Much of the part of Chaco Valley shown is taken from Bauer's published map,[4] and a strip on the extreme west side is taken from Gregory's map of the Navajo country.[5]

The area examined more or less in detail during the course of the field work extends from the east side of the Ignacio quadrangle westward to the edge of the Red Mesa quadrangle, southwestward across the Red Mesa quadrangle to the Colorado-New Mexico boundary, and thence southward across the middle half of San Juan County, N. Mex., to the south side, an area approximately 100 miles long and 45 miles wide. The detailed work extended also across the southern part of the eastern fourth of San Juan County, and much of the rest of this eastern strip was covered in rapid reconnaissance, such geographic locations as were made being based on the reconnaissance topographic map of the Largo quadrangle, which covers the area. Reconnaissance trips without mapping were made eastward from the Ignacio quadrangle to Pagosa Junction, Colo., to trace the Fruitland, Kirtland, Animas, and overlying formations eastward; and into the area between Escavada Wash and Medio Arroyo, in Sandoval County, N. Mex.,

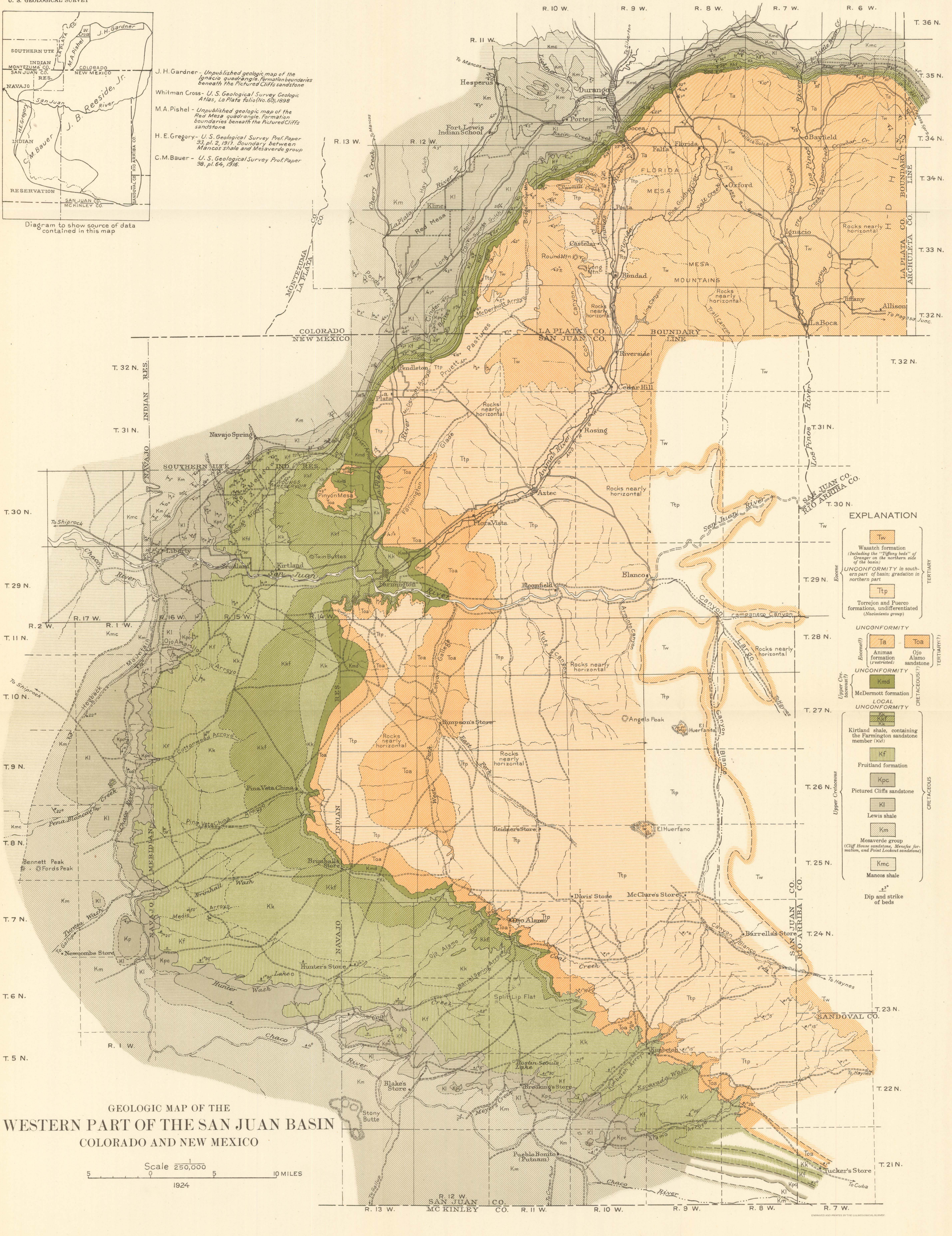
[1] Contributions to the geology and paleontology of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 98, pp. 271-353, 1916.

[2] Bauer, C. M., and Reeside, J. B., jr., Coal in the central and eastern parts of San Juan County, N. Mex.: U. S. Geol. Survey Bull. 716, pp. 155-237, 1921.

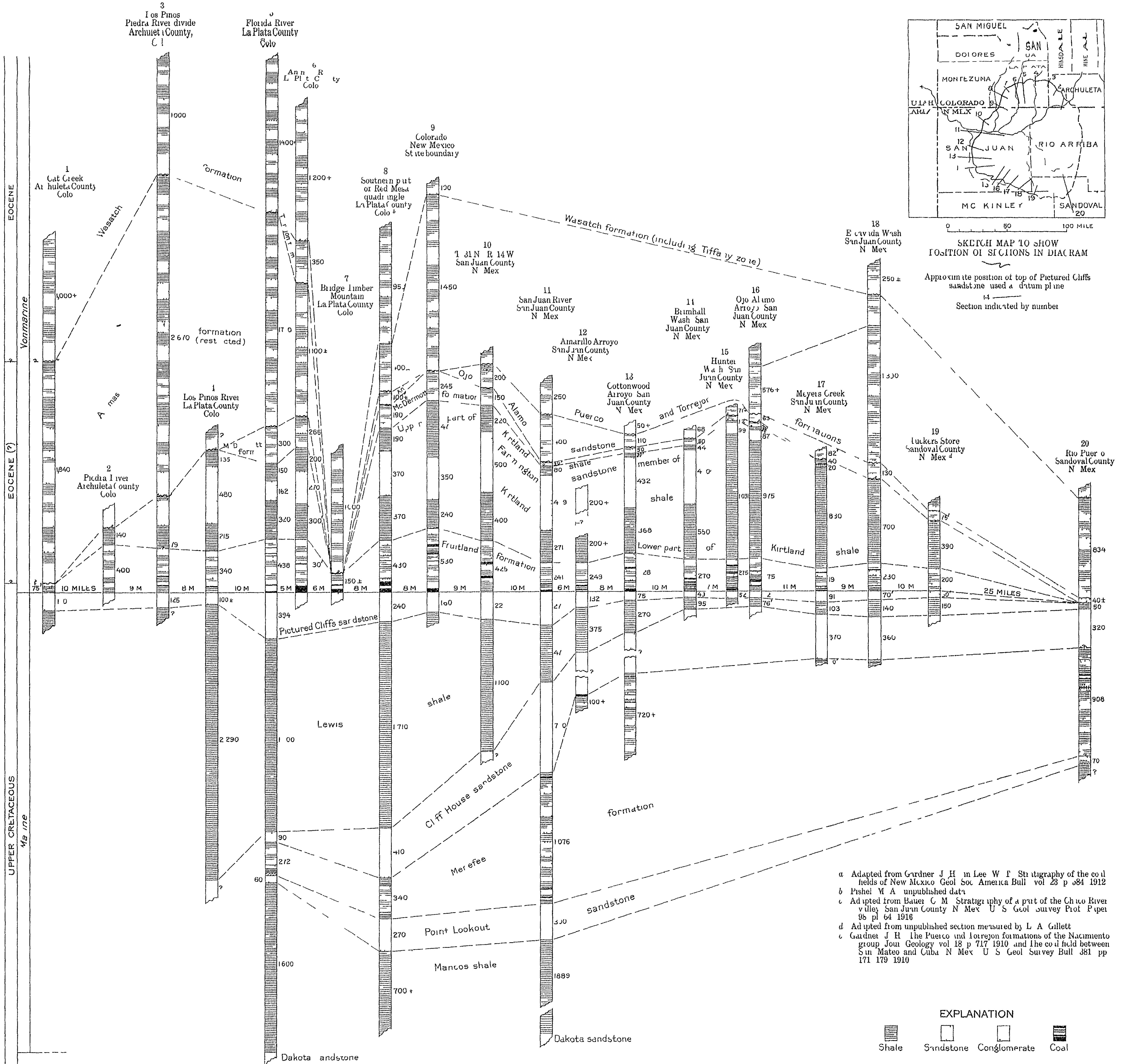
[3] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, 1919.

[4] Bauer, C. M., Stratigraphy of a part of the Chaco River Valley: U. S. Geol. Survey Prof. Paper 98, pl. 64, 1916.

[5] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, pl. 2, 1917.



GEOLOGIC MAP OF THE
WESTERN PART OF THE SAN JUAN BASIN
COLORADO AND NEW MEXICO



COLUMNAR SECTIONS OF FORMATIONS AROUND MARGIN OF SAN JUAN BASIN, COLORADO AND NEW MEXICO principally to trace the Ojo Alamo sandstone eastward. The general position of the area studied is shown in Figure 1.

The geographic features of the region have been described at varying length in the papers by Bauer, Gregory, and others, references to which may be found in the bibliography. These descriptions need not be repeated here other than to say that most of the region is in every way typical of the semiarid Southwest, though the northern edge approaches closely enough to the foothills of the San Juan and La Plata mountains to receive a greater rainfall and support a denser vegetation of plants that require more moisture.

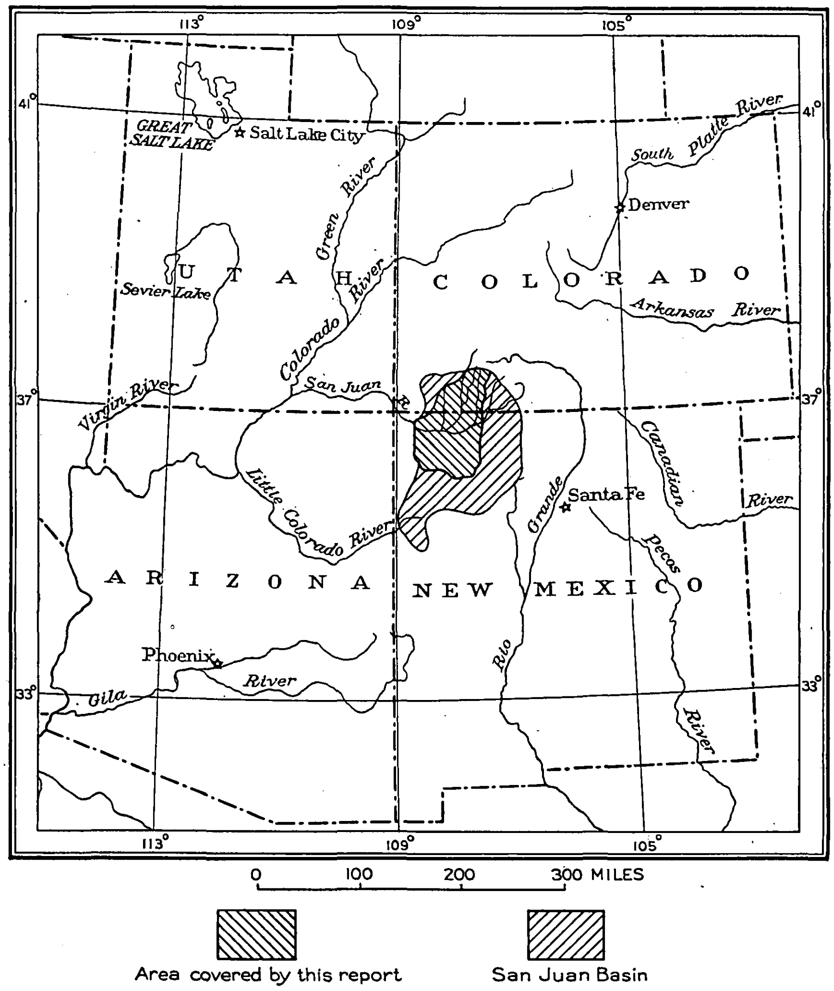


FIGURE 1.—Index map showing location of San Juan Basin and area covered by Plate I.

STRATIGRAPHY.

GENERAL SECTIONS.

The rocks of the San Juan Basin described briefly in the subjoined table and at greater length in the succeeding pages of this paper include sediments of Upper Cretaceous and Tertiary age. Older Mesozoic rocks not described here occur around the border of the basin, and within it there are small bodies of igneous rock of somewhat uncertain age though probably Tertiary. The area also includes gravel mesas, river terraces, and alluvium of Quaternary age, which are not described here. The writer's attention has been given chiefly to the formations from the Lewis shale to the Torrejon formation, inclusive. The Mancos shale was examined at only a few places, the Mesaverde group as a whole only near San Juan River in the Great Hogback and on Animas River near Durango. The base of the Wasatch formation has been the upper limit of study over much of the area examined, though in Colorado some time was spent on this formation, especially on Granger's "Tiffany beds," at its base.

Cretaceous and Tertiary formations of the western part of the San Juan Basin, in Colorado and New Mexico.

System.	Series	Formation.	Character.	Thickness.[a] 1	2	3	4
Tertiary.	Eocene.	Wasatch formation.	Massive, persistent gray to brown resistant conglomeratic sandstone interbedded with variegated shale; red shale abundant. In the extreme northern rim of the basin variegated shale chiefly, with beds of coarse arkose that contain an abundance of pink feldspar. Fluviatile. The "Tiffany beds" of Granger are the basal part of the formation in the northern part of the basin but are not differentiated in lithology; they are not known in the southern part of the basin.	1, 000+	900+	(?)	250+
		Unconformity in the southern part of the basin; conformity in the northern part.[b]					
		Nacimiento group. Torrejon and Puerco formations undifferentiated.	In the north, lenticular gray to brown conglomeratic resistant sandstone interbedded with red and gray shale; underlain by gray and greenish-gray shale and soft white to yellow conglomeratic sandstone. In the south, light-gray shale with some red layers and some soft whitish sandstone, underlain by gray to black shale with rare red bands, soft white sandstone, and soft yellow sandstone with concretions. Fluviatile. The faunas of these two formations are interpreted to demand a hiatus between them, but none has been definitely recognized yet. The Puerco formation is believed to be confined to the southern part of the basin.	0	400–1, 450	(?)	1. 140
Unconformity.							
Tertiary (?).	Eocene (?).	Animas formation (restricted) to north. (Contemporaneous with Ojo Alamo sandstone to south.)	At base coarse beds with weathered and waterworn andesitic débris and pebbles of siliceous rocks. Remainder of formation shale and sandstone with much andesitic débris and occasional beds of fine conglomerate. Whole formation pistachio-green to tan, with very rare reddish layers. Fluviatile.	2, 670	100	0	0
		Ojo Alamo sandstone[c] to south. (Contemporaneous with Animas formation to north.)	Gray to brown coarse sandstone containing lenses of siliceous pebbles and lenses of variegated shale. Fluviatile.	0	0	400	130
Unconformity.							
Cretaceous (?).	Upper Cretaceous (?).	McDermott formation.	In the north, andesitic tuff and tuffaceous sandstone and shale, mostly purple, with a small amount of conglomerate of pebbles of siliceous rocks. The proportion of purely volcanic material decreases southward, and in the south the whole formation consists of variegated shale and brown sandstone with a minor amount of volcanic débris. Heretofore included in Animas formation in the north.	266–300	190–245	40	40

[a] 1, Eastern La Plata County, Colo.; 2, northern San Juan County, N. Mex., and southern La Plata County, Colo.; 3, central San Juan County N. Mex. (San Juan River); 4, southern San Juan County, N. Mex.

[b] Unconformity present only where lower part ("Tiffany" zone) of Wasatch formation is absent.

[c] The Animas formation and Ojo Alamo sandstone are not known to touch anywhere, and their mutual relations are not certainly known, but they are believed to be contemporaneous, at least in part.

Cretaceous and Tertiary formations of the western part of the San Juan Basin, in Colorado and New Mexico—Con.

System.	Series	Formation.		Character.	Thickness. 1	2	3	4
Local unconformity.								
Cretaceous.	Upper Cretaceous.	Kirtland shale.		Light-gray to blue-gray shale, with some black carbonaceous and brown shale and soft white sandstone. Fluviatile.	0–135	190–475	110	0
				Farmington sandstone member; gray to brown indurated sandstone lenses separated by gray shales. Thins southward from San Juan River. Fluviatile.	480	350	455	0
				Shale and soft sandstone like those of upper member. Fluviatile.	215	240–370	271	700
		Fruitland formation.		Gray sandy shale, gray-white cross-bedded soft sandstone, brown indurated sandstone, carbonaceous shale and coal. Of fresh and brackish water origin.	340	430–530	241	230
		Pictured Cliffs sandstone.		Buff to light-yellow and gray sandstone interbedded in the lower part with thin gray shale. Marine.	125	160–240	275	70
		Lewis shale.		Greenish-gray and dark-gray sandy shale with occasional lenses of brown sandy limestone and buff concretions. Marine.	2, 290	[d] 1, 710	475	140
		Mesaverde group.	Cliff House sandstone.	Yellow to red-brown sandstone with some sandy shale. Some beds massive, cliff-forming. Marine.	[e] 90	[d] 390	750	369
			Menefee formation.	Gray shale, with some sandstone and coal. Coal beds grouped near top and base of formation; barren interval between. Rocks of fresh and brackish water origin, with only a few marine beds.	[e] 272	[d] 356	1, 076	(?)
			Point Lookout sandstone.	Massive buff or cream-colored to red-brown sandstone. Marine.	[e] 60	[d] 274	300	(?)
		Mancos shale.		Dark-gray and drab sandy shale, with Tocito sandstone lentil, 35 feet thick, about 735 feet above base. Marine.	1, 800	2, 000±	1, 889	(?)
		Dakota sandstone.		Brown sandstone with some shale lenses and coal; cherty conglomerate at base.	250	200±	200±	(?)

[d] Unpublished data collected by M. A. Pishel in the Red Mesa quadrangle, Colo.
[e] From section on Florida River measured by J. H. Gardner. See Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 187, 1917.

Correlation of previous usage of formation names with that in this paper.

New Mexico.

Holmes, 1877.[a]	Shaler, 1907.[b]	Gardner, 1909.[c]	Brown, 1910.[d]	Sinclair and Granger, 1914.[e]	Bauer, 1916.[f]	Bauer and Reeside, 1920.[g]	This paper.
Canyon Largo series of Newberry.	Wasatch (?).	Wasatch formation.	[Not described]	Wasatch.	[Not described.]	Wasatch formation.	Wasatch formation (including the "Tiffany beds" of Granger in lower part).
	Puerco marl.	Torrejon formation.	? Puerco formation.	Torrejon formation.	Wasatch formation (near Ojo Alamo).	Formation undetermined.	Torrejon and Puerco formations.
		?			Torrejon and Puerco formations.	Torrejon and Puerco formations.	
		Puerco formation.		Puerco formation.			
			Unnamed conglomerate.	Ojo Alamo beds.	Wasatch formation near San Juan River; Ojo Alamo sandstone near Ojo Alamo.	Ojo Alamo sandstone south of Pinyon Mesa.	Ojo Alamo sandstone.
"Puerco marls" of Cope.		Laramie formation.	Ojo Alamo beds.		Kirtland shale, including the Farmington sandstone member.	Ojo Alamo sandstone north of Pinyon Mesa; Kirtland shale, upper part, south of Pinyon Mesa.	McDermott formation.
? Laramie (?) group (Upper coal group).	Laramie formation.		?	?		Kirtland shale, including the Farmington sandstone member.	Kirtland shale, including the Farmington sandstone member.
					Fruitland formation.	Fruitland formation.	Fruitland formation.
Pictured Cliffs group.					Pictured Cliffs sandstone.	Pictured Cliffs sandstone.	Pictured Cliffs sandstone.

Sand shale group.	Lewis shale.	Lewis shale.	[Not described]	[Not described]	Lewis shale.	Lewis shale.	Lewis shale.
Upper escarpment sandstone. Middle coal group. Lower escarpment sandstone.	Mesaverde formation.	Mesaverde formation.			Mesaverde formation.	Cliff House sandstone. Menefee formation. Point Lookout sandstone.	Cliff House sandstone. Menefee formation. Point Lookout sandstone.
Colorado.	Mancos shale.	Mancos shale.			Mancos shale.	Mancos shale.	Mancos shale.

[a] Holmes, W. H., Geology of the San Juan district: U. S. Geol. and Geog. Survey Terr. Ninth Ann. Rept., for 1875, p. 244, 1877.
[b] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, pp. 378–379, 1907.
[c] Gardner, J. H., The coal field between Gallina and Raton Spring, N. Mex.: U. S. Geol. Survey Bull. 341, p. 338, 1909.
[d] Brown, Barnum, The Cretaceous Ojo Alamo beds of New Mexico, with description of the new dinosaur genus *Kritosaurus:* Am. Mus. Nat. Hist. Bull., vol. 28, pp. 267–274, 1910.
[e] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, N. Mex.: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 297–316, 1914.
[f] Bauer, C. M., Stratigraphy of a part of the Chaco River valley, San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 98, pp. 273–278, 1916.
[g] Bauer, C. M., and Reeside, J. B., jr., Coal in the middle and eastern parts of San Juan County, N. Mex.: U. S. Geol. Survey Bull. 716, p. 162, 1920.

Correlation of previous usage of formation names with that in this paper—Continued

Colorado.

Cross, 1899.[a]	Schrader, 1906.[b]	Taff, 1907.[c]	Shaler, 1907.[d]	Gardner, 1909.[e]	Gardner, 1912.[f]	Granger, 1917.[g]	This paper.
			Wasatch (?).		Wasatch formation.	Wasatch and Tiffany beds.	Wasatch formation (including "Tiffany beds" of Granger in lower part.
			?	Later Tertiary rocks.	?	?	
	Tertiary.	[Not described.]	Puerco marl.		Animas formation with coarse lentil at base.		Torrejon formation.
							Animas formation.
[Not present.]			Animas formation.	Animas formation (Tertiary).			McDermott formation.
	?	?					(Local.)
	Laramie (?) formation.	Laramie formation.	Laramie formation.	Laramie formation.	"Laramie" formation with Pictured Cliffs sandstone member near base.		Kirtland shale with Farmington sandstone member.
							Fruitland formation.
						[Not described.]	Pictured Cliffs sandstone.
Lewis shale.	Lewis shale.	Lewis shale.	Lewis shale.	Lewis shale.	Lewis shale.		Lewis shale.
Mesaverde formation.	Mesaverde formation.	Mesaverde formation.	Mesaverde formation.	Mesaverde formation.	Mesaverde formation.		Cliff House sandstone. Menefee formation. Point Lookout sandstone.
Mancos shale.	Mancos shale.	Mancos shale.	Mancos shale.	Mancos shale.	Mancos shale.		Mancos shale.
Dakota sandstone.	[Not mentioned.]	Dakota sandstone.	Dakota sandstone.	Dakota sandstone.	Dakota sandstone.		Dakota sandstone.

[a] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, La Plata folio (No. 60), pp. 4–5, 1899.
[b] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 285, pp. 241–257, 1906.
[c] Taff, J. A., The Durango coal district, Colo.: U. S. Geol. Survey Bull. 316, pp. 322–323, 1907.
[d] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, pp. 378–379, 1907.
[e] Gardner, J. H., The coal field between Durango, Colo., and Monero, N. Mex.: U. S. Geol. Survey Bull. 341, pp. 352–353, 1909.
[f] Gardner, J. H., in Lee, W. T., Stratigraphy of the coal fields of northern central New Mexico: Geol. Soc. America Bull., vol. 23, pp. 584–589, 1912. Also in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 185–187, 1917.
[g] Granger, Walter, Notes on Paleocene and Lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. Hist. Bull., vol. 37, p. 829, 1917.

DAKOTA SANDSTONE.

The Dakota sandstone is the basal formation of the Upper Cretaceous series of the region. The writer examined it at only one locality, near Durango, Colo., where it consists of variable gray to brown cross-bedded sandstone, with a cherty conglomerate at the base; it contains also shale lenses and beds of impure coal. Its thickness is about 250 feet. At many other localities its thickness is reported to range from 200 to 250 feet. The contact with the Mancos shale is transitional. The relation of the Dakota sandstone of this region to that of distant regions is not well known. It may represent a greater or lesser time interval than the typical Dakota sandstone.

MANCOS SHALE.

Type locality and distribution.—The Mancos shale was so designated by Cross[6] from the exposures near the town of Mancos, Colo. The name has since been applied extensively. Shaly strata in the lower part of the Upper Cretaceous as far away as central Utah, northern Colorado, northeastern Arizona, and north-central New Mexico have been grouped together as Mancos shale. Along the west side of the San Juan Basin the formation underlies a broad area between the Mesaverde group and the Dakota sandstone. On the north side the belt of outcrop is narrower but is marked as a pronounced valley between the underlying Dakota sandstone and the overlying Mesaverde group.

Lithologic character.—The Mancos shale at the type locality, near Mancos, Colo., consists of soft dark-gray or nearly black shale with thin lenses and concretions of limestone.[7] The writer examined the entire thickness of the Mancos shale on Animas River near Durango, Colo., where it is a gray to very dark marine shale with a few thin layers of gray sandstone near the top and some layers of impure limestone near the base. It contains ferruginous yellow-brown concretions at many horizons. On Chaco and San Juan rivers near the Hogback the upper two-thirds of the formation is exposed and was examined. The uppermost part is much like that on Animas River, consisting of gray shale with some thin beds of sandstone. The remainder of the upper two-thirds is gray shale with a number of zones of yellow-brown calcareous concretions and some zones of platy gray, rather soft sandstone that weathers like shale. Beneath this upper two-thirds, about 735 feet above the base of the formation, appears a notable bed of sandstone, 35 feet thick, brown, coarse, cross-bedded, containing lenses of pebbles of chert and quartz as much as half an inch in diameter, and resistant enough to make a cliff. It is known as the Tocito sandstone to the petroleum geologists who have mapped the region for oil companies, though sometimes also called by them Frontier sandstone. In this report it will be called the Tocito sandstone lentil of the Mancos shale. The name is derived from the outcrops of the sandstone near the Tocito trading post, in San Juan County, N. Mex. Only a small thickness of the beds beneath this sandstone is visible at the surface, but a well drilled to the Dakota sandstone shows that the lower third of the Mancos is gray to nearly black shale. The writer examined hurriedly the Tocito sandstone and the underlying beds at a locality 25 miles southwest of that just described, near Beautiful Mountain. Here the Tocito forms a hogback ridge and the gray to nearly black shale beneath it contains some calcareous layers and some sandy layers.

The Mancos shale is easily eroded and at most localities in the western part of the San Juan Basin makes a pronounced valley between the ridge of Dakota sandstone and that of the sandstones of the Mesaverde group.

Thickness in San Juan Basin and adjacent regions.—The Mancos shale at the type locality is 1,200 feet thick. Farther north, near Telluride, Colo.,[8] it reaches a thickness of 2,000 feet. The formation is 1,800 feet thick at Durango and is said by Gardner[9] to be 1,600 feet thick on Florida River, Colo., and by Shaler[10] to be 1,000 to 1,400 feet thick in San Juan County, N. Mex. The last-mentioned figure is about the thickness one might expect in San Juan County by a comparison of the

[6] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Telluride folio (No. 57), p. 4, 1899.

[7] Cross, Whitman, op. cit., p. 4.

[8] Cross, Whitman, op. cit., p. 4.

[9] Gardner, J. H., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 187, 1917.

[10] Shaler, M. K., A reconnaissance of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, p. 378, 1907.

thicknesses and the relative positions of some of the faunal zones. However, logs of wells drilled on the Southern Ute Indian Reservation near the southwest corner of sec. 31, T. 32 N., R. 13 W., show that the thickness there is approximately 2,000 feet, and a section measured by the writer in sec. 19, T. 29 N., R. 16 W., supplemented by the logs of wells drilled at the same locality, shows a thickness of about 1,880 feet. Possibly the two areas are nearer the center of the basin and the thickness is greater because of greater subsidence of the basin during deposition. In the Rio Grande valley southwest of the San Juan Basin the thicknesses as given by Lee [11] show a considerable range—1,000 to 2,400 feet—and several important sandstone members occur within the shales. To the west, in Arizona, Gregory [12] found 550 feet as the thickness at Salakhai Mesa, 565 feet at Chilchinbito, and 620 feet at Lolomai Point. In Socorro County, N. Mex., to the south of the area here considered, there is an essentially marine series, 2,080 feet thick, of yellow sandstone and drab and yellow sandy shale with a few beds of clay and several beds of coal, described by Winchester [13] as the Miguel formation. It occupies apparently the approximate position of the Colorado part of the typical Mancos shale and is overlain by a fresh-water series, lithologically similar to the Miguel formation and named the Chamiso formation, which seems to occupy the position of the Montana part of the typical Mancos shale and an undetermined amount of the later beds. The Chamiso formation bears coal and fossil plants of Montana age and is 1,850 feet thick.

Relation to adjacent formations.—The contact of the Mancos shale with the overlying Point Lookout sandstone is conformable—in fact, it is one of gradual transition, and a dividing plane must be arbitrarily chosen. The lower contact where seen in the Ignacio quadrangle is likewise transitional.

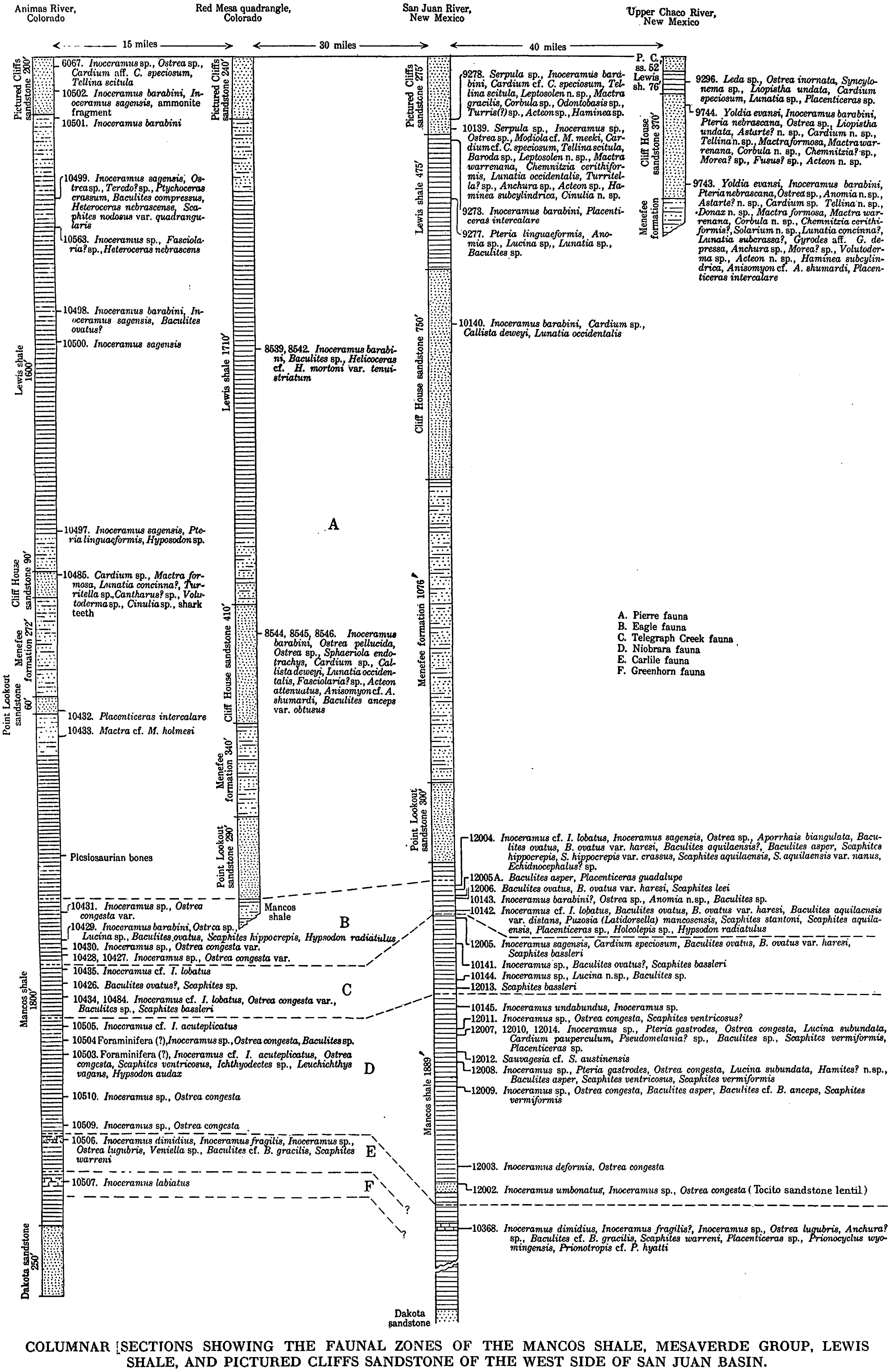
Fossils.—Eighteen collections of fossils were made from the Mancos shale in New Mexico, seventeen from the upper two-thirds and one from the lower third. Nineteen collections were made in Colorado, scattered throughout the formation. The species identified in these lots are listed in the accompanying table and also in Plate III.

Several distinct and widespread faunas are represented in these collections. For want of better names they may for the present be designated by the names of the formations in which they are especially well developed and characteristic. These faunas are, in ascending order, the Greenhorn fauna, the Carlile fauna, the Niobrara fauna, the Telegraph Creek fauna, the Eagle fauna, and the Pierre fauna. A rather widespread fauna at the base of the Mancos shale has been reported from the general region but was not observed by the writer. It contains such species as *Gryphaea newberryi* Stanton, *Metoicoceras whitei* Hyatt, and *Exogyra columbella* Meek.

[11] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 174, 1917.

[12] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, p. 74, 1917.

[13] Winchester, D. E., Geology of Alamosa Creek valley, Socorro County, N. Mex.: U. S. Geol. Survey Bull. 716, pp. 5-8, 1920.



COLUMNAR SECTIONS SHOWING THE FAUNAL ZONES OF THE MANCOS SHALE, MESAVERDE GROUP, LEWIS SHALE, AND PICTURED CLIFFS SANDSTONE OF THE WEST SIDE OF SAN JUAN BASIN.

Fossils of the Mancos shale.

Greenhorn fauna.

	10507
Inoceramus labiatus Schlotheim	×

Carlile fauna.

	10368	10506	10644
Inoceramus dimidius White	×	×	×
Inoceramus fragilis Meek and Hayden	?	×	---
Inoceramus sp.	×	×	---
Ostrea lugubris Conrad	×	×	×
Veniella sp. undetermined	---	×	---
Anchura? sp.	×	---	---
Baculites cf. B. gracilis Shumard	×	×	---
Scaphites warreni Meek and Hayden	×	×	---
Placenticeras? sp.	×	---	---
Prionocyclus wyomingensis Meek	×	---	---
Prionotropis cf. P. hyatti Stanton	×	---	---
Prionotropis loewianus White	---	---	×
Ptychodus sp.	---	---	×

Niobrara fauna.

	10145	10503	10504	10505	10509	10510	12002	12003	12007	12008	12009	12010	12011	12012	12014
Inoceramus undabundus Meek and Hayden	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Inoceramus cf. I. acutiplicatus Stanton	---	×	---	×	---	---	---	---	---	---	---	---	---	---	---
Inoceramus umbonatus Meek and Hayden	---	---	---	---	---	---	×	---	---	---	---	---	---	---	---
Inoceramus deformis Meek	---	---	---	---	---	---	---	×	---	---	---	---	---	---	---
Inoceramus sp., very large, thick-shelled	---	---	×	---	×	×	×	---	×	×	---	×	×	---	×
Inoceramus sp. undetermined	×	---	---	---	---	---	---	---	---	---	×	×	---	---	---
Pteria gastrodes Meek	---	---	---	---	---	---	---	---	---	×	---	×	---	---	×
Ostrea congesta Conrad	---	×	×	---	×	×	×	×	×	×	×	×	×	---	×
Lucina subundata Hall and Meek	---	---	---	---	---	---	---	---	---	×	---	---	---	---	×
Cardium pauperculum Meek	---	---	---	---	---	---	---	---	---	---	---	---	---	---	×
Sauvagesia cf. S. austinensis Roemer	---	---	---	---	---	---	---	---	---	---	---	---	---	×	---
Pseudomelania? sp.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	×
Hamites? n. sp.	---	---	---	---	---	---	---	---	---	×	---	---	---	---	---
Baculites asper Morton	---	---	---	---	---	---	---	---	---	×	×	---	---	---	---
Baculites cf. B. anceps Lamarck	---	---	---	---	---	---	---	---	---	---	×	---	---	---	---
Baculites sp. undetermined	---	---	×	---	---	---	---	---	---	×	---	×	---	---	---
Scaphites ventricosus Meek and Hayden	---	×	---	---	---	---	---	---	---	×	---	---	?	---	---
Scaphites vermiformis Meek and Hayden	---	---	---	---	---	---	---	---	---	×	×	×	---	---	---
Placenticeras sp. undetermined	---	---	---	---	---	---	---	---	---	---	---	×	---	---	---
Ichthyodectes sp.	---	×	---	---	---	---	---	---	---	---	---	---	---	---	---
Leuchichthyops vagans Cockerell	---	×	---	---	---	---	---	---	---	---	---	---	---	---	---
Hypsodon audax Leidy	---	×	---	---	---	---	---	---	---	---	---	---	---	---	---

Telegraph Creek fauna.

	10141	10144	10426	10434	10435	10484	12005	12013
Inoceramus sagensis Owen	---	---	---	---	---	---	×	---
Inoceramus cf. I. lobatus Goldfuss	---	---	---	---	×	×	---	---
Inoceramus sp. undetermined	×	×	---	---	---	---	---	---
Ostrea congesta Conrad, depauperate variety	---	---	---	---	---	×	---	---
Lucina n. sp.	---	×	---	---	---	---	---	---
Cardium speciosum Meek and Hayden	---	---	---	---	---	---	×	---
Baculites ovatus Say	?	---	?	---	---	---	×	---
Baculites ovatus Say var. haresi Reeside MS.	---	---	---	---	---	---	×	---
Baculites sp. undetermined	---	×	---	---	---	×	---	---
Scaphites bassleri Reeside MS.	×	---	---	×	---	×	×	×
Scaphites sp. undetermined	---	---	×	---	---	---	---	---

Fossils of the Mancos shale—Continued.

Eagle fauna.

	10142	10143	10427	10428	10429	10430	10431	12004	12005A	12006
Inoceramus sagensis Owen								×		
Inoceramus barabini Morton		?			×					
Inoceramus cf. I. lobatus Goldfuss	×							×		
Inoceramus sp., thick-shelled form				×		×	×			
Inoceramus sp. undetermined			×							
Ostrea congesta Conrad, depauperate variety				×		×	×			
Ostrea sp. undetermined		×			×			×		
Anomia n. sp		×								
Lucina sp. undetermined					×					
Aporrhais biangulata Meek and Hayden								×		
Baculites ovatus Say	×				×			×		×
Baculites ovatus Say var. haresi Reeside MS	×							×		×
Baculites aquilaensis var. distans Reeside MS	×							?		
Baculites asper Morton								×	×	
Baculites sp. undetermined		×								
Puzosia (Latidorsella) mancosensis Reeside MS	×									
Scaphites hippocrepis (DeKay)							×	×		
Scaphites hippocrepis var. crassus Reeside MS								×		
Scaphites aquilaensis Reeside MS	×							×		
Scaphites aquilaensis var. nanus Reeside MS								×		
Scaphites stantoni Reeside MS	×									
Scaphites leei Reeside MS										×
Placenticeras guadalupe Roemer	?								×	
Echidnocephalus? sp								×		
Holcolepis? sp	×									
Hypsodon radiatulus Cockerell	×				×					

Pierre fauna.

	10433
Mactra cf. M. holmesi Meek	×

10141. 1 mile north of Shiprock road, just west of Great Hogback, in sec. 32, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 280 feet beneath top of Mancos shale.
10142. 1 mile north of Shiprock road, just west of Great Hogback, in sec. 32, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 160 feet beneath top of Mancos shale.
10143. 1 mile north of Shiprock road, just west of Great Hogback, in sec. 32, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 120 feet beneath top of Mancos shale.
10144. 2½ miles north of Shiprock road, just west of Great Hogback, in sec. 20, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 410 feet below top of Mancos shale.
10145. 2 miles north of Shiprock road, just west of Great Hogback, in sec. 29, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 500 feet beneath top of Mancos shale.
10368. 14 miles S. 20° W. from Shiprock Peak, in sec. 5 or 8, T. 9 N., R. 4 W. Navajo meridian, San Juan County, N. Mex. Horizon about 125 feet beneath the Tocito sandstone member of Mancos shale.
10426. 1 mile west of Durango, Colo., in SW. ¼ NW. ¼ sec. 30, T. 35 N., R. 9 W. Horizon 850 feet above base of Mancos shale.
10427. 1½ miles west of Durango, Colo., at center of SE. ¼ sec. 13, T. 35 N., R. 10 W. Horizon 950 feet above base of Mancos shale.
10428. 1½ miles west of Durango, Colo., in NE. ¼ SE. ¼ SE. ¼ sec. 24, T. 35 N., R. 10 W. Horizon 950 feet above base of Mancos shale.
10429. Same locality as 10428. Horizon 1,000 feet above base of Mancos shale.
10430. 2 miles west of Durango, Colo., at center of sec. 13, T. 35 N., R. 10 W. Horizon 970 feet above base of Mancos shale.
10431. Same locality as 10430. Horizon 1,100 feet above base of Mancos shale.
10433. At east edge of Durango, Colo., in NE. ¼ SE. ¼ sec. 29, T. 35 N., R. 9 W. Horizon 1,725 feet above base of Mancos shale.
10434. 2 miles west of Durango, Colo., at center of sec. 13, T. 35 N., R. 10 W. Horizon 800 feet above base of Mancos shale.
10435. Same locality as 10434. Horizon 900 feet above base of Mancos shale.
10484. 1½ miles west of Durango, Colo., in NW. ¼ SE. ¼ SE. ¼ sec. 13, T. 35 N., R. 10 W. Horizon 800 feet above base of Mancos shale.
10503. Animas River at mouth of Lightner Creek, Durango, Colo., in NE. ¼ NE. ¼ sec. 30, T. 35 N., R. 9 W. Horizon 600 feet above base of Mancos shale.
10504. Half a mile west of Durango, Colo., in SW. ¼ SE. ¼ sec. 19, T. 35 N., R. 9 W. Horizon 650 feet above base of Mancos shale.
10505. Same locality as 10504. Horizon 700 feet above base of Mancos shale.
10506. 1 mile northwest of Durango, Colo., in NW. ¼ SE. ¼ sec. 18, T. 35 N., R. 9 W. Horizon 300 feet above base of Mancos shale.
10507. 1 mile northwest of Durango, Colo., in SW. ¼ NE. ¼ sec. 18, T. 35 N., R. 9 W. Horizon 150 feet above base of Mancos shale.
10509. Half a mile northwest of Durango, Colo., in SW. ¼ sec. 17, T. 35 N., R. 9 W. Horizon 300 to 350 feet above base of Mancos shale.
10510. 1 mile northwest of Durango, Colo., in NE. ¼ sec. 18, T. 35 N., R 9 W. Horizon 400 to 450 feet above base of Mancos shale.
10644. 7 miles north of Bayfield, Colo., at center of sec. 5, T. 35 N., R. 6 W. Horizon 350 feet above base of Mancos shale.
12002. One-fourth mile south of Chaco River, just west of Great Hogback, near center of sec. 19, T. 29 N., R. 16 W., San Juan County, N. Mex. Horizon at top of Tocito sandstone.
12003. Half a mile south of Chaco River, just west of Great Hogback, in SE. ¼ NE. ¼ sec. 24, T. 29 N., R. 17 W., San Juan County, N. Mex. Horizon 50 feet above the Tocito sandstone.
12004. 4 miles north of Shiprock road, just west of Great Hogback, in SW. ¼ NE. ¼ sec. 20, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 75 feet beneath top of Mancos shale.
12005. Same locality as 12004. Horizon 190 feet beneath top of Mancos shale.
12005 A. Same locality as 12004. Horizon 90 feet beneath top of Mancos shale.
12006. Same locality as 12004. Horizon 115 feet beneath top of Mancos shale.
12007. 1½ miles north of Shiprock road, just west of Great Hogback, in NW. ¼ SW. ¼ sec. 25, T. 30 N., R. 17 W., San Juan County, N. Mex. Horizon 598 feet beneath top of Mancos shale.
12008. Same locality as 12007. Horizon 698 feet beneath top of Mancos shale.
12009. 2 miles north of Shiprock road, just west of Great Hogback, in NW. ¼ NW. ¼ sec. 31, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 788 feet beneath top of Mancos shale.
12010. Half a mile north of Shiprock road, just west of Great Hogback, in NW. ¼ NW. ¼ sec. 35, T. 30 N., R. 17 W., San Juan County, N. Mex. Horizon 598 feet beneath top of Mancos shale.
12011. 1½ miles north of Shiprock road, just west of Great Hogback, in NW. ¼ SW. ¼ sec. 25, T. 30 N., R. 17 W., San Juan County, N. Mex. Horizon 578 feet beneath top of Mancos shale.
12012. Same locality as 12011. Horizon 658 feet beneath top of Mancos shale.
12013. 2 miles north of Shiprock road, just west of Great Hogback, in NE. ¼ NE. ¼ sec. 30, T. 30 N., R. 16 W., San Juan County, N. Mex. Horizon 435 feet beneath top of Mancos shale.
12014. 3 miles south of Chaco River, just west of Great Hogback, in SE. ¼ SE. ¼ sec. 34, T. 29 N., R. 17 W., San Juan County, N. Mex. Horizon 598 feet beneath top of Mancos shale.

Age and correlation.—The Mancos shale at the type locality contains invertebrate faunas of Colorado age in the older part and Montana age in the younger part ("upper few hundred feet" [14]). The collections made near San Juan River, in San Juan County, N. Mex., and near Durango, Colo., agree in this respect with those reported from the typical Mancos shale. The lists given on page 11 show the presence in both sections of faunas known in the western interior only in the Eagle sandstone and the Telegraph Creek formation and their equivalents at the base of the Montana group. The species collected beneath this fauna show that the principal faunal zones of the Colorado group of the region east of the Rocky Mountains are all represented. The fossils show the presence of equivalents of the Graneros shale, Greenhorn limestone, Carlile shale, and Niobrara formation. (See Pl. III.) It is evident from the position of the basal Montana (Eagle) fauna that the Mancos shale includes younger beds on Animas River than on San Juan River, and that the formation, though a lithologic unit, does not everywhere represent the same time interval. The Eagle fauna occupies a zone from 700 to 1,000 feet beneath the top of the Mancos shale on Animas River but is immediately at the top of the shale on San Juan River. Farther southeast, as shown by collections made near Copper City, N. Mex., by J. H. Gardner, it occurs in the lower part of the Mesaverde group, apparently the equivalent of the Point Lookout sandstone. In a sense the top of the Mancos shale is progressively older southward from Durango, Colo., across the San Juan Basin. Beds with the lithology of the Mesaverde group replace older and older marine shales of the Mancos. This change continues beyond the San Juan Basin until eventually the whole time interval of the typical Mancos shale is represented by rocks like those of the Mesaverde group, as, for example, the Miguel formation and the lower part of the Chamiso formation in Socorro County, N. Mex. The writer has not noted any specific place in the field where a lateral transition of shale into sandstone can be traced, but it could hardly be possible that no such transition occurs. The Tocito sandstone lentil of the Mancos shale on San Juan River represents a type of sedimentation lacking to the north but more and more abundant toward the south.

The relation of the Mancos shale of the San Juan Basin to that of the more distant areas in northern Colorado, Utah, and Arizona is not yet accurately known, though the time interval covered is certainly in large part the same wherever the name is in use.

MESAVERDE GROUP.

Type locality and distribution.—The Mesaverde group was named by Holmes [15] from the typical exposures in the Mesa Verde, in Montezuma County, southwestern Colorado. Holmes described three divisions—the "lower escarpment sandstone," the "middle coal group," and the "upper escarpment sandstone." To these divisions Collier [16] gave the names Point Lookout sandstone, Menefee formation, and Cliff House sandstone, respectively, all derived from localities on or near Mesa Verde. The three formations of the group are not distinguished at many localities, but the name Mesaverde as a designation for a coal-bearing series in the upper part of the Upper Cretaceous has been very widely used—as far away from the type region as northern Wyoming. In the part of the San Juan Basin covered by this report the Mesaverde group forms a marked ridge or series of ridges, interrupted where the formation extends with low dip out into the Mesa Verde and where the rocks are gently inclined along the upper valley of Chaco River.

Lithologic character.—At the type locality the Point Lookout sandstone is a massive, cliff-forming gray to brown marine sandstone; the Menefee formation is a variable assemblage of sandstone and shale, with three groups of coal beds, and is of both marine and fresh-water origin; and the Cliff House sandstone is variable in character though essentially a massive marine sandstone. This general description of the three lithologic units may be applied around the entire western side of the San Juan Basin, though the exposures on Animas and Florida rivers show the three-fold division less clearly than those to the west.

[14] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, La Plata folio (No. 60), p. 4, 1899.

[15] Holmes, W. H., Geological report on the San Juan district: U. S Geol. and Geog. Survey Terr. Ninth Ann. Rept., for 1875, pl. 35, 1877.

[16] Collier, A. J., Coal south of Mancos, Montezuma County, Colo.: U. S. Geol. Survey Bull. 691, p. 296, 1919.

In Tps. 29 and 30 N., R. 16 W., just north of San Juan River, San Juan County, N. Mex., where the writer examined the Mesaverde group in greater detail than elsewhere, the typical description applies, though the gross thickness there is much greater than in the Mesa Verde. The Point Lookout sandstone at this locality is a cream-colored to red-brown massive, cliff-forming marine sandstone that stands out prominently above the softer Mancos shale. The Menefee formation is a group of gray to brown lenticular sandstones and gray to chocolate-brown and black carbonaceous shales and contains two groups of lenticular coal beds, one near the top and one near the base. The formation varies greatly along the strike and contains fossils indicating a fresh-water origin for some beds and a marine origin for others. The Cliff House sandstone consists of a thick yellow to brown massive sandstone bed underlain and overlain by thin sandstones and shale, all of marine origin.

South of San Juan River the formations seem to have much the same composition. The Cliff House sandstone, however, contains coal at some places, notably along Chaco River near the mouths of Brimhall Wash and Pina Veta China Arroyo. On Meyers Creek the Cliff House sandstone has its normal marine character and though thinner than at San Juan River is a purer sandstone unit.

The sections on pages 62–69 show in detail the lithologic character of the formations of the Mesaverde group.

Thickness.—At the type locality the Point Lookout sandstone is 250 to 300 feet thick, the Menefee formation 400 feet thick, and the Cliff House sandstone 400 feet thick, a total for the group of approximately 1,100 feet.

On Florida River, Colo., the Mesaverde group was found by Gardner[17] to be 422 feet thick. In his section the Point Lookout sandstone is probably represented by massive gray sandstone forming the lower 60 feet, the Menefee formation by the shale and coal beds forming the middle 272 feet, and the Cliff House sandstone by sandstone and shale of the upper 90 feet. In the Red Mesa quadrangle, Colo., Pishel[18] measured a section at a locality 20 miles southwest of Durango in which the Mesaverde group was found to be 1,020 feet thick. The Point Lookout sandstone appears to be 270 feet thick, the Menefee formation 340 feet, and the Cliff House sandstone 410 feet. Near the Colorado-New Mexico boundary, in T. 32 N., R. 14 W., N. Mex., the group is 1,200 to 1,300 feet thick, the Point Lookout sandstone being about 225 feet thick, the Menefee formation 700 to 800 feet, and the Cliff House sandstone over 200 feet. The sections near San Juan River given on pages 64–65, show the total thickness of the group to be over 2,100 feet and the thicknesses of the three formations in ascending order to be approximately 200 feet, 1,000 feet, and 750 feet, respectively. Only parts of the group were measured in southern San Juan County. These measurements indicated a thinning of the Cliff House sandstone to 370 feet. On Arroyo Torrejon Gardner[19] measured a section of the group that shows a thickness of 1,300 feet, of which the lower 70 feet may represent the Point Lookout sandstone, the middle 908 feet the Menefee formation, and the upper 320 feet the Cliff House sandstone. Lee's sections[20] of rocks farther southeast assigned to the Mesaverde show much variation in thickness, from more than 300 feet to more than 1,800 feet, due in part to erosion at the top of the formation and in part to uncertainty as to where the upper limit should be placed. In this area it is difficult to identify the three formations of the group. The Lewis shale is unidentified in the area, and likewise the Fruitland formation and Kirtland shale. In some sections the Mesaverde group as now conceived may include beds of the age of the Lewis, Fruitland, and Kirtland formations.

In general the Mesaverde group may be said to thin eastward from the type locality and to thicken southward.

Relation to adjacent formations.—The Mesaverde is conformable with the Mancos shale below and the Lewis shale above. It is separated from both by a zone of transition beds in which the formation boundary must be arbitrarily fixed.

[17] Gardner, J. H., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 187, 1917.

[18] Pishel, M. A., unpublished data.

[19] Gardner, J. H., Coal field between San Mateo and Cuba, N. Mex.: U. S. Geol. Survey Bull. 381, p. 178, 1910.

[20] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 171–222, 1917.

Fossils.—Four collections were made from the Cliff House sandstone in New Mexico and four in Colorado. One collection (U. S. G. S. locality 10432) was made from the Point Lookout sandstone. The species included in these collections are shown in the list below and in Plate III. It is noteworthy that these collections, while containing a number of species that occur in the typical Montana faunas of the western interior province, contain also a number that are not known in the typical faunas but are closely related to species that are common in the faunas of the Coastal Plain province. It would appear that some connection existed between the San Juan Basin area and the Coastal Plain which was not open to the other regions of the western interior. This feature was noted by Stanton[21] in the faunas of the Mesaverde group of the region southeast of the San Juan Basin.

[21] Stanton, T. W., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 218, 1917.

Fossils of the Mesaverde group.

	8544	8545	8546	9742	9743	9744	10140	10432	10485
Micrabacia americana Meek and Hayden				×					
Yoldia evansi Meek and Hayden					×	×			
Inoceramus barabini Morton	×		×		×	×	×		
Inoceramus sp. undetermined				×		×			
Pteria nebrascana Evans and Shumard	×				×				
Ostrea pellucida Meek and Hayden									
Ostrea sp. undetermined			×	×	×	×			
Anomia sp. undescribed					×				
Liopistha undata Meek and Hayden				×		×			
Astarte? sp. undescribed	×				×	×			
Sphaeriola cf. S. endotrachys Meek									
Tancredia americana Meek and Hayden	×			×					
Cardium (Ethmocardium) sp. undescribed		×	×	×	×	×	×		×
Cyprimeria? sp. undescribed	×			×					
Callista deweyi Meek and Hayden							×		
Tellina sp. undescribed					×	×			
Tellina equilateralis Meek and Hayden				×					
Donax? sp. undescribed				×	×				
Mactra formosa Meek and Hayden				×	×	×			×
Mactra warrenana Meek and Hayden					×	×			
Mactra? sp. undetermined				×					
Corbula sp. undescribed				×	×	×			
Chemnitzia cerithiformis? Meek and Hayden				×	×				
Chemnitzia? sp. undetermined						×			
Pseudomelania? sp. undetermined				×					
Solarium sp. undescribed					×				
Lunatia occidentalis Meek and Hayden			×	×			×		
Lunatia concinna? Meek and Hayden					×				×
Lunatia subcrassa? Meek and Hayden					×				
Gyrodes aff. G. petrosa Morton					×				
Turritella sp. undetermined									×
Anchura nebrascensis? Meek and Hayden				×					
Anchura sp. undetermined					×				
Morea? sp. undetermined					×	×			
Cantharus? sp. undetermined									×
Fusus cf. F. newberryi Meek and Hayden				×					
Fusus? sp. undetermined						×			
Pyrifusus sp. undetermined	×								
Fasciolaria? sp. undetermined			×						
Volutoderma, several undescribed species				×	×				×
Acteon attenuatus Meek and Hayden			×	×					
Acteon sp. undescribed					×	×			
Cinulia sp. undetermined									×
Haminea subcylindrica Meek and Hayden					×				
Anisomyon cf. A. shumardi Meek and Hayden	×				×				
Baculites anceps var. obtusus Meek	×	×	×	×					
Placenticeras intercalare Meek					×			×	
Shark teeth, undetermined									×

8544. 4 miles north of Kline, Colo., in NW. ¼ NW. ¼ sec. 14, T. 34 N., R. 12 W. Horizon in uppermost 100 feet of Cliff House sandstone. M. A. Pishel, collector.
8545. 4 miles northeast of Kline, Colo., in SE. ¼ SW. ¼ sec. 7, T. 34 N., R. 11 W. Horizon in uppermost 100 feet of Cliff House sandstone. M. A. Pishel, collector.
8546. 2 miles west of Kline, Colo., in NW. ¼ NE. ¼ sec. 33, T. 34 N., R. 12 W. Horizon in uppermost 100 feet of Cliff House sandstone.
9742. Satans Pass, 18 miles north of Thoreau, N. Mex. Loose blocks of upper sandstone of Mesaverde group.
9743. 3 miles east of Pueblo Bonito, N. Mex., in sec. 19, T. 2 N., R. 10 W. Horizon 40 feet above base of Cliff House sandstone, which is here about 350 feet thick.
9744. Mouth of Escavada Wash, on Farmington-Pueblo Bonito road about 4 miles northwest of Pueblo Bonito, in sec. 27, T. 22 N., R. 11 W. Horizon 50 feet below top of Cliff House sandstone.
10140. West side of NW. ¼ sec. 23, T. 30 N., R. 16 W., 3 miles north of Liberty, N. Mex. Horizon 200 feet beneath top of Cliff House sandstone.
10432. Half a mile east of Durango, Colo., in NE. ¼ SE. ¼ sec. 29, T. 35 N., R. 9 W. Horizon at extreme base of Mesaverde group.
10485. 1 mile south of Durango, Colo., in NW. ¼ SE. ¼ sec. 32, T. 35 N., R. 9 W. Horizon at extreme top of Mesaverde group.

Age and correlation.—The Mesaverde group typically has a flora and invertebrate faunas of Montana age. Although the writer collected practically no fossils from the Point Lookout and Menefee formations, the presence of Montana fossils beneath them in the Mancos shale and above them in the Cliff House sandstone shows that in the San Juan Basin also the whole group is of Montana age. The extreme variation in thickness from north to south, as shown in the columnar sections on Plate II, and the difference in the position of the boundaries with reference to a faunal plane such as that of the basal Montana fauna occurring in the Mancos shale, or to a stratigraphic plane such as the top of the Pictured Cliffs sandstone, make it very improbable that the Mesaverde group of the San Juan Basin represents everywhere the same time interval within the Montana group. The writer believes that the Mesaverde group on San Juan River represents the time interval of part of the Mancos shale, the Mesaverde group, and much of the Lewis shale of the section on Animas River. South of San Juan River, where the Lewis shale becomes much thinner even than on San Juan River, the top of the Cliff House sandstone may represent practically the same time of deposition as the very top of the Lewis shale along the north side of the San Juan Basin. It seems very probable that the Point Lookout sandstone and the Cliff House sandstone are really aggregates of successively overlapping beds which as a whole, with reference to a given chronologic plane, change their positions in the stratigraphic column from place to place. The Point Lookout sandstone in its northern exposures is younger than in its southern exposures; the Cliff House sandstone in its northern exposures is older than in its southern exposures. The writer has not noted any locality in the field where such an overlap and passage from one lithologic phase to another is observable, but the exposures are in general inadequate. That such a phenomenon can be shown in other and more favorable regions is well known, and it is almost certain that something of the sort occurs here.

The relations of the Mesaverde group to the beds so named south and east of the San Juan Basin are somewhat obscure. At some localities the zone of the basal Montana fauna is well known and occurs in either the top of the Mancos shale or the base of the Mesaverde group. The top of the formation, as noted on page 14, may, however, include beds as young as the Fruitland and Kirtland formations of the San Juan Basin.

The relations of the Mesaverde group to the beds similarly named in northern Colorado, Utah, and Wyoming are also not at all clear. Many more stratigraphic and faunal data are needed. In some parts of Wyoming the base of the Montana group is definitely known and the general relations of the Mesaverde group of those regions to the typical Mesaverde may be deduced, but not enough is yet known to make detailed comparisons possible. At some places there are no marine beds above the basal part of the Mesaverde, and most of the Mesaverde strata and the later beds are fresh-water deposits. It is quite likely that the Mesaverde at some of these localities is really nearer to the Fruitland and Kirtland formations in age than to the typical Mesaverde.

LEWIS SHALE.

Type locality and distribution.—The Lewis shale was named by Cross[22] from the exposures near the former Army post called Fort Lewis, in sec. 3, T. 34 N., R. 11 W., La Plata County, Colo. (See Pl. I.) The name has been used widely to designate the interval between those beds assigned to the Mesaverde and the fresh-water deposits of post-Montana age—in fact, it has been applied in regions as far away as northern Wyoming. The Lewis shale may be traced continuously some distance north from the type locality and except for some interruptions on the east side has been identified clear around the San Juan Basin. It has not been identified, if present, to the west, south, or east of the San Juan Basin.

Lithologic character.—The Lewis shale at the type locality is described by Cross as "a body of more or less sandy shales and clays with occasional thin layers of impure limestone or of concretionary masses at several different horizons." It maintains this character along the north side of the San Juan Basin, where it is a fairly homogeneous mass of dark-gray to greenish-gray shale, with some sandy layers, some limestone, and numerous calcareous concretions, some yellow and splintery, others

[22] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, La Plata folio (No. 60), p. 4, 1899.

blue-gray, dense, and tough. In New Mexico the Lewis is sandier than in Colorado, though containing layers of impure brown limestone and yellow limestone concretions.

Thickness.—Along the north side of the San Juan Basin the thickness ranges from 1,700 feet near the type locality [23] to 1,600 feet on Animas River near Durango [24] and 2,290 feet near Pine River, and is said at other places to reach 2,500 feet.[25] In New Mexico it is thinner. It has a thickness of 1,100 feet near Navajo Springs, and 475 feet at San Juan River and thins southward to Coal Creek, where it is 76 feet thick. It increases somewhat on the south side of the basin and maintains a thickness of 100 to 150 feet at most localities. Near Cuba it is said to be over 200 feet thick.[26] These variations are shown graphically in the sections in Plate II. The Lewis shale seems to thin southward along the west side of the San Juan Basin in about the proportion that the Mesaverde group thickens.

Relation to adjacent formations.—The contact of the Lewis shale with both the Cliff House sandstone and the Pictured Cliffs sandstone is one of gradual transition, and the fixing of specific boundaries is entirely arbitrary.

Fossils.—Bauer [27] obtained three collections of marine invertebrates from the Lewis shale. These and collections made by Lee,[28] Pishel, Gardner, and the writer at widely separated localities show that many characteristic Pierre species range through its entire thickness, notably species of *Inoceramus* and various cephalopods. The forms identified by T. W. Stanton in Bauer's and Pishel's collections and those collected by the writer are listed in the table below and in Plate III.

[23] Pishel, M. A., unpublished data.

[24] Gardner, J. H., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 187, 1917.

[25] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 285, p. 242, 1906.

[26] Gardner, J. H., The coal field between Gallina and Raton Spring, N. Mex.: U. S. Geol. Survey Bull. 341, p. 339, 1909.

[27] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, p. 273, 1916.

[28] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 190, 193, 1917.

Fossils of the Lewis shale.

	8539	8542	9273	9277	9296	10497	10498	10499	10500	10501	10563
Leda sp. undetermined	---	---	---	---	×	---	---	---	---	---	---
Inoceramus barabini Morton	---	×	×	---	---	---	×	---	---	×	---
Inoceramus sagensis Owen	---	---	---	---	---	×	×	×	×	---	---
Inoceramus sp. undetermined	---	---	---	?	---	---	---	---	---	---	×
Pteria linguaeformis Evans and Shumard	---	---	---	---	---	×	---	---	---	---	---
Ostrea inornata Meek and Hayden	---	---	---	---	×	---	---	---	---	---	---
Ostrea sp. undetermined	---	---	---	---	---	---	---	×	---	---	---
Anomia sp. undetermined	---	---	---	×	---	---	---	---	---	---	---
Syncyclonema sp. undetermined	---	---	---	---	×	---	---	---	---	---	---
Liopistha undata Meek and Hayden	---	---	---	---	×	---	---	---	---	---	---
Lucina sp. undetermined	---	---	---	×	---	---	---	---	---	---	---
Cardium speciosum Meek and Hayden	---	---	---	---	---	---	---	---	---	---	---
Teredo? sp. undetermined	---	---	---	---	×	---	---	×	---	---	---
Lunatia sp. undetermined	---	---	---	×	×	---	---	---	---	---	×
Fasciolaria ? sp. undetermined	---	---	---	---	---	---	---	---	---	---	---
Ptychoceras crassum Whitfield	---	---	---	---	---	---	---	×	---	---	---
Baculites ovatus Say	---	---	---	---	---	---	---	---	---	---	---
Baculites compressus Say	---	---	---	---	---	---	---	×	---	---	---
Baculites sp. undetermined	---	×	---	×	---	---	---	---	---	---	---
Helicoceras cf. H. mortoni var. tenuistriatum Meek and Hayden	×	---	---	---	---	---	---	---	---	---	×
Heteroceras nebrascense Meek and Hayden	---	---	---	---	---	---	---	×	---	---	---
Scaphites nodosus var. quadrangularis Meek	---	---	---	---	---	---	---	×	---	---	---
Placenticeras intercalare Meek	---	---	×	---	---	---	---	---	---	---	---
Placenticeras sp. undetermined	---	---	---	---	×	---	---	---	---	---	---
Hypsodon sp. undetermined	---	---	---	---	---	×	---	---	---	---	---

8539. 3 miles southeast of Kline, Colo., in sec. 18, T. 33 N., R. 11 W. Horizon a short distance above middle of Lewis shale, here 1,700 feet thick. M. A. Pishel, collector.

8542. 7 miles south of Kline, Colo., in NE. ¼ NW. ¼ sec. 11, T. 32 N., R. 12 W. Horizon a short distance above middle of Lewis shale, here 1,700 feet thick. M. A. Pishel, collector.

9273. 5 miles southeast of Liberty, N. Mex. Horizon near top of Lewis shale. Identified by T. W. Stanton. C. M. Bauer, collector.

9277. South side of San Juan River, opposite Liberty, N. Mex. Horizon at middle of Lewis shale, here 475 feet thick. Identified by T. W Stanton. C. M. Bauer, collector.

9296. 35 miles south of Farmington, N. Mex., at the mouth of Coal Creek. Horizon at middle of Lewis shale, here 76 feet thick. Identified by T. W. Stanton. C. M. Bauer, collector.

10497. 2 miles south of Durango, Colo., at center of NW. ¼ sec. 5, T. 34½ N., R. 9 W. Horizon 150 feet above base of Lewis shale.

10498. 2 miles south of Durango, Colo., in SE. ¼ NE. ¼ sec. 6, T. 34 N., R. 9 W. Horizon 700 feet beneath top of Lewis shale.

10499. 2 miles south of Durango, Colo., at center of sec. 6, T. 34 N., R. 9 W. Horizon 300 feet beneath top of Lewis shale.

10500. 4 miles southwest of Durango, Colo., in SE. ¼ NW. ¼ sec. 11, T. 34 N., R. 10 W. Horizon 800 feet beneath top of Lewis shale.

10501. 3 miles east of Durango, Colo., in SE. ¼ NW. ¼ sec. 23, T. 35 N., R. 9 W. Horizon at top of Lewis shale.

10563. 2 miles south of Durango, Colo., in SW. ¼ NE. ¼ sec. 6, T. 34 N., R. 9 W. Horizon 400 feet beneath top of Lewis shale.

Age and correlation.—At a number of localities the Lewis shale contains fossils of Montana age throughout its thickness. Within the San Juan Basin the thick Lewis shale of the north side of San Juan Basin is probably, as shown on page 16, essentially contemporaneous with the major upper part of the thick Mesaverde group of the west and south sides. There is, however, probably some part of the Mesaverde group that is older than any part of the Lewis shale, and likewise some part of the Lewis that is younger than any part of the Mesaverde, but the time of deposition of much of the two formations was the same. It is probable that the top of the Lewis shale varies but little in age from place to place. The difference between the faunas of the Mesaverde group and those of the Lewis may be explained as due to the difference in the sediments.

The time interval of the typical Lewis shale is unquestionably represented outside of the San Juan Basin by sediments that cover wide areas. It is impossible, however, to fix upon its equivalent exactly. In a general way it is synchronous with some part of the middle and upper portions of the Pierre shale east of the Rocky Mountains, but more exact correlation must wait upon a more detailed knowledge of the ranges of species within the Montana group. The so-called Lewis shale of various parts of Wyoming certainly is not the same as the Lewis shale of the San Juan Basin. In Wyoming at several localities the upper part of the formation contains a true Fox Hills fauna, later than the fauna of any part of the Lewis shale or the Pictured Cliffs sandstone of the San Juan Basin, and it does not fit the lithologic definition of the Lewis shale, because it contains at many places thick fresh-water deposits with coal beds and heavy sandstones.

PICTURED CLIFFS SANDSTONE.

Type locality and distribution.—The name Pictured Cliffs sandstone was first applied by Holmes [29] to the marine sandstone that crops out north of San Juan River a mile west of Fruitland, N. Mex. Holmes evidently restricted the name to the massive ledges and excluded the interbedded shale and sandstones beneath them which the writer believes should be put with them. The original description is as follows:

> Pictured Cliffs, 140 feet—40 feet of white sandstone; 60 to 80 feet yellowish-gray sandstone; beneath these 30 to 40 feet of brownish laminated sandstones.

A section measured by C. M. Bauer on the south side of the river several miles west of Holmes's locality is given on page 63. It shows the formation to include, besides the massive upper units, a lower part containing much shale. The upper part of the formation consists of white to red-brown sandstone, which forms a striking member of the stratigraphic series; the lower part is of yellow to brown sandstone interbedded with gray sandy shale; the whole is 281 feet thick. The Pictured Cliffs sandstone has been shown to be present entirely around the San Juan Basin. In all the sections given by Lee,[30] Schrader,[31] and Gardner [32] it may be identified at the base of the so-called "Laramie" around the north and east sides of the basin. The writer has traced it from a locality north of Pagosa Junction, Colo., around the west and south sides of the basin as far as the head of Chaco River.

The Pictured Cliffs sandstone has not been recognized outside of the San Juan Basin.

Lithologic character.—The lithologic character varies much in detail along the strike, though as a whole it is fairly similar everywhere. At the type locality and to the north it is a white to brown indurated conspicuous sandstone that forms a scarp where the dip is low and a ridge where it is high. To the south it is locally very light colored, with a rusty-brown crusty layer at the top, and at many places is not well indurated. Near Escavada Wash it is at most places a rather soft gray-white to yellow sandstone with dark-brown platy concretions and is poorly exposed but is locally well indurated, red-brown, and cliff forming. In the Ignacio quadrangle east of Durango, Colo., it is at most places composed of two heavy beds of sandstone, separated

[29] Holmes, W. H., Geology of the San Juan district: U. S. Geol. and Geog. Survey Terr. Ninth Ann. Rept., for 1875, pl. 35, p. 248, 1877.

[30] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 187, 191, 1917.

[31] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 285, p. 242, 1905.

[32] Gardner, J. H., Coal field between San Mateo and Cuba, N. Mex.: U. S. Geol. Survey Bull. 381, p. 171, 1910.

locally by shale and coal. The formation is the highest marine deposit of the region.

Thickness.—Near the type locality the formation, including the interbedded sandstone and shale of the lower part not originally included by Holmes, is 281 feet thick. Owing in part to the nature of the boundaries that must be drawn and in part to a real variation there is little regularity in the thickness at different places. In general the formation seems to thin eastward and southward from Florida River, Colo. It seems to be thin near Pine River, though the exposures are not good and it may be considerably thicker than the 100 feet that is visible. On the divide between Pine and Piedra rivers it is 125 feet thick, and on Cat Creek north of Pagosa Junction 150 feet. On the west side of the basin it decreases from 394 feet on Florida River [33] to 240 feet in the Red Mesa quadrangle [34] southwest of Durango. In New Mexico north of San Juan River it varies between 150 and 225 feet. South of San Juan River it decreases gradually until at the mouth of Hunter Wash it is about 50 feet thick. Beyond this point it varies between 75 and 100 feet. These thicknesses are shown graphically on Plate II.

Relation to adjacent formations.—The Pictured Cliffs sandstone passes by transition zones into both the Lewis shale below and the Fruitland formation above. The determination of the bounding planes is therefore purely arbitrary, though the lowest predominantly sandy units and the highest marine beds have furnished guides.

Fossils.—Invertebrate fossils have been collected at several localities from the Pictured Cliffs sandstone, and the fucoid *Halymenites major* Lesquereux is abundant at all exposures. Holmes noted fossils at the type locality. Other collections, made by Gardner, Bauer,[35] and the writer, are listed in the following table and in Plate III. Most of the specimens are casts or molds in a coarse sandstone and preserve few of the smaller details.

[33] Gardner, J. H., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 187, 1917.

[34] Pishel, M. A., unpublished data.

[35] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, p. 274, 1916.

Fossils of the Pictured Cliffs sandstone.

	6067	9278	10139	10502
Serpula sp. undetermined	---	×	×	---
Inoceramus barabini Morton	×	×	---	×
Inoceramus sagensis Owen	---	---	---	×
Inoceramus sp. undetermined	---	---	×	---
Ostrea sp. undetermined	×	---	×	---
Modiola cf. M. meeki Evans and Shumard	---	---	×	---
Cardium aff. C. speciosum Meek and Hayden	×	×	×	---
Tellina scitula Meek and Hayden	×	×	×	---
Baroda sp. undetermined	---	---	×	---
Leptosolen n. sp	---	?	×	---
Mactra gracilis Meek and Hayden	---	×	---	---
Mactra warrenana? Meek and Hayden	---	---	×	---
Corbula sp. undetermined	---	×	---	---
Chemnitzia cerithiformis Meek and Hayden	---	---	×	---
Lunatia occidentalis Meek and Hayden	---	---	×	---
Turritella sp. undetermined	---	---	×	---
Anchura sp. undetermined	---	---	×	---
Odontobasis? sp. undetermined	---	×	---	---
Turris? sp. undetermined	---	×	---	---
Acteon sp. undetermined	---	×	?	---
Haminea subcylindrica Meek and Hayden	---	---	×	---
Haminea sp. undetermined	---	×	---	---
Cinulia n. sp	---	---	×	---
Ammonite fragment	---	---	---	×

6067. 6 miles east of Durango, Colo., in sec. 17, T. 35 N., R. 8 W. Horizon near top of Pictured Cliffs sandstone. J. H. Gardner, collector. Identifications by T. W. Stanton.

9278. South bank of San Juan River in SW. ¼ SW. ¼ sec. 7, T. 29 N., R. 15 W., San Juan County, N. Mex. Horizon 40 feet above base of Pictured Cliffs sandstone. C. M. Bauer, collector. Identifications by T. W. Stanton.

10139. 6 miles northwest of Fruitland, N. Mex., in sec. 19, T. 30 N., R. 15 W. Horizon near base of Pictured Cliffs sandstone.

10502. 2 miles east of Durango, Colo., in SW. ¼ SE. ¼ sec. 27, T. 35 N., R. 9 W. Horizon at middle of Pictured Cliffs sandstone.

Age and correlation.—The Pictured Cliffs sandstone contains, as shown by the list given above, a littoral marine fauna of Montana age. It includes species of *Inoceramus* not known in the latest Montana fauna of other regions, such as that of the typical Fox Hills sandstone, and it completely lacks, so far as now known, the typical Fox Hills forms. There is no definite equivalent of the Pictured Cliffs sandstone known outside of the San Juan Basin, though the time interval is certainly represented by deposits at many places. The writer believes the Pictured Cliffs sandstone to vary but little in age throughout its known extent. It is relatively thin but essentially uniform in lithology and easily recognized. It therefore forms a valuable stratigraphic datum and has been used as such by the writer in drawing up the sections on Plates II and III.

FRUITLAND FORMATION.

Type locality and distribution.—The Fruitland formation was named by Bauer[36] from the settlement of that name on San Juan River, N. Mex. It includes the coal-bearing beds in the lower part of what was long designated "the Laramie formation" of the San Juan Basin, and it has been shown by the various students of the region to extend entirely around the basin, though the outcrop is covered at some points by Tertiary sediments. It has not been recognized definitely outside of the basin.

Lithologic character.—The Fruitland formation, though extremely variable in details, contains at all exposures the same sorts of rocks. It is of brackish and fresh water origin and is composed of gray to brown hard sandstone, gray-white soft sandstone, gray, brown, and black shale, and coal. In general it may be said that

> the formation consists of sandstone, shale, and coal, very irregularly bedded. In constitution the various beds range from shale to sandstone with every conceivable intermediate phase of sandy shale and shaly sandstone. The marked variation both laterally and vertically is shown at many places by the unequal resistance to weathering and consequent production of fantastic assemblages of pillars, knobs, "mushroom rocks," and other forms. This irregularity is most marked in the gray-white sandstone and gray sandy shale, but it affects to some degree the coal beds also. * * * The coal beds are distributed throughout the formation, but are more abundant and generally thicker in its lower portion. * * * The Fruitland formation is further characterized by the presence of large concretions of iron carbonate which weather dark brown or black. Many of these concretions have been converted by veins of crystallized barite into large septaria.[37]

The coal of the Fruitland formation in San Juan County, N. Mex., and many local details of the stratigraphy are described in the paper by Bauer and the writer.[38] The sections on pages 55–70, taken largely from that paper, show the constitution of the formation at several localities.

Thickness.—The Fruitland formation at the type locality is 241 feet thick. In Colorado and in New Mexico north of San Juan River it is consistently thicker. Only the basal part is present on Cat Creek north of Pagosa Junction, Colo., for the upper part was removed by erosion before the deposition of the Animas formation. Between Piedra and Pine rivers the thickness ranges from 350 to 400 feet.

In Gardner's section on Florida River[39] the Fruitland formation is 438 feet thick. In the Red Mesa quadrangle,[40] southwest of Durango, it is 430 feet thick. On La Plata River near the New Mexico-Colorado boundary the Fruitland beds are 530 feet thick, the greater thickness being due perhaps to a local longer duration of the deposition of sandy material, as the lower part of the overlying Kirtland shale is relatively thin. The Fruitland is 425 feet thick halfway between the State boundary and San Juan River and ranges between 250 and 325 feet at the river and south of it. A number of sections of the Fruitland formation are shown on Plate II.

Relation to adjacent formations.—The Fruitland formation passes into the underlying marine Pictured Cliffs sandstone by a zone of brackish-water sediments that contain coal beds. The most convenient plane of division is the top of the purely marine beds, which also at many localities is practically the base of the lowest coal bed. The Fruitland formation likewise grades upward continuously into the overlying Kirtland shale. It may be distinguished in the aggregate from the Kirtland shale in that it includes coal beds and indurated brown sandstone. Usually the highest of the sandstones has been taken as the top of the Fruitland formation and the overlying softer rocks have been assigned to the Kirtland shale. Such an arbitrary separation undoubtedly leads to the drawing of the bounding plane at slightly different positions stratigraphically at different places and may account for some of the variation in thickness recorded.

Fossils.—The Fruitland formation has yielded many fossils. These have been described by Gilmore, Osborn, Stanton, and

[36] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, p. 274, 1916.

[37] Bauer, C. M., and Reeside, J. B., jr., Coal in the middle and eastern parts of San Juan County, N. Mex.: U. S. Geol. Survey Bull. 716, p. 167, 1920.

[38] Idem, pp. 155–237.

[39] Gardner, J. H., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 187, 1917.

[40] Pishel, M. A., unpublished data.

Knowlton. The vertebrates[41] include the following:

Dinosauria:
- Pentaceratops sternbergii Osborn.
- Monoclonius?
- Carnivorous dinosaur.

Chelonia:
- Adocus sp.
- Aspideretes sp.
- Baëna nodosa? Gilmore.

Pisces:
- Lepisosteus sp.

The invertebrates[42] are of brackish and fresh water types, the former mainly from the lower beds. The invertebrate fauna includes

Ostrea glabra Meek and Hayden.
Anomia gryphorhynchus Meek.
  gryphaeiformis Stanton.
Modiola laticostata (White).
Unio holmesianus White.
  amarillensis Stanton.
  gardneri Stanton.
  reesidei Stanton.
  brachyopisthus White.
  baueri Stanton.
  brimhallensis Stanton.
  sp. cf. U. primaevus White.
Corbicula cytheriformis (Meek and Hayden).
Corbula chacoensis Stanton.
Panopea simulatrix Whiteaves?
Teredina neomexicana Stanton.
Neritina baueri Stanton.
Neritina (Velatella) sp.
Campeloma amarillensis Stanton.
Tulotoma thompsoni White.
Melania insculpta Meek?
Goniobasis? subtortuosa Meek and Hayden.
Physa reesidei Stanton.
Physa sp.
Planorbis (Bathyomphalus) chacoensis Stanton.

The known flora[43] of the Fruitland formation includes the following forms, beside much unstudied silicified wood:

Anemia hesperia Knowlton.
Anemia sp.
Sequoia reichenbachi (Geinitz) Heer.
  obovata? Knowlton.
Geinitzia formosa Heer.
Sabal montana Knowlton.
Sabal? sp.
Myrica torreyi Lesquereux.
Salix baueri Knowlton.
  sp. *a* Knowlton.
Quercus baueri Knowlton.
Ficus baueri Knowlton.
  curta? Knowlton.
  praetrinervis Knowlton.
  leei Knowlton.
  praelatifolia Knowlton.
  sp.
  rhamoides Knowlton.
  squarrosa Knowlton.
  sp.
  eucalyptifolia? Knowlton.
Laurus baueri Knowlton.
  coloradoensis Knowlton.
Nelumbo sp.
Heteranthera cretacea Knowlton.
Pterospermites undulatus Knowlton.
  neomexicanus Knowlton.
Ribes neomexicana Knowlton.
Carpites baueri Knowlton.
Phyllites petiolatus Knowlton.
  neomexicanus Knowlton.
Unassigned plant.

Age and correlation.—Owing to the similarity of the faunas and flora of the Fruitland formation to those of the overlying Kirtland shale the discussion of the age and correlation of the Fruitland formation is united with that of the Kirtland shale on page 24.

KIRTLAND SHALE.

Type locality and distribution.—The Kirtland shale was so named by Bauer[44] from a settlement on San Juan River, New Mexico, situated on the formation. The typical exposure extends up the San Juan from Kirtland to Farmington. Near Farmington the middle sandstone member of the Kirtland shale, described below, is very well exposed. It was named by Bauer the Farmington sandstone member. The formation has been traced around the west side of the San Juan Basin but is overlapped on the north side by the Animas formation and on the south side by the Ojo Alamo sandstone. Whether it can be recognized on the east side of the basin the writer can not say. It has not been recognized definitely outside of the San Juan Basin, though there are certainly sediments of the same age over wide areas.

Lithologic character.—At the type locality the Kirtland shale may be divided into three groups of beds forming distinct members, all

[41] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, p. 8, 1919. Osborn, H. F., A new genus and species of Ceratopsia from New Mexico, *Pentaceratops sternbergii*: Am. Mus. Nat. Hist. Novitates, No. 93, 1923.

[42] Stanton, T. W., Nonmarine Cretaceous invertebrates of the San Juan Basin: U. S. Geol. Survey Prof. Paper 98, p. 310, 1916.

[43] Knowlton, F. H., Flora of the Fruitland and Kirtland formations U. S. Geol. Survey Prof. Paper 98, p. 330, 1916.

[44] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, p. 244, 1916.

of fresh-water origin. The lower member consists mainly of gray shale with some brown and black carbonaceous layers and a minor amount of bluish, greenish, and yellow sandy shale and of soft, easily weathered gray-white sandstones, all irregularly bedded. The middle member contains many irregular lenses of sandstone, soft, gray, and unresistant below but hard, brown, and resistant above. This member was named the Farmington sandstone member by Bauer. The upper member, like the lower member, consists of shale and soft sandstone.

Southward from the typical locality the Farmington sandstone member thins and is completely replaced by soft beds between coal Creek and Kimbetoh Arroyo, the lower shale member thickening at its expense, while the upper shale varies but little. Northward from San Juan River the sandstone member and the upper shale member vary irregularly in thickness, and the lower shale changes little. The lithologic constitution of these members remains the same as at the typical locality.

The shaly parts of the Kirtland contain considerable barite in the form of small concretions and veins. Gypsum also is present as sheets in joint planes and as crystals, aragonite in rounded brown fibrous concretions, and siderite in concretions. Silicified wood is common. The shales weather into rounded billowy forms, and where erosion is rapid and the dip of the beds low they have formed extensive badlands. Where the dip is high the shale members form marked valleys.

The sandstones of the Farmington sandstone member are irregular, cross-bedded, and composed almost invariably of two parts—a lower, soft, easily eroded yellow to white sandstone containing clay pellets and locally sandstone balls of material like the matrix and reaching 4 inches in diameter, and an upper hard sandstone which is fine grained, dark gray on a fresh surface and dark ferruginous brown on weathered surfaces. These lenses are of small lateral extent, not reaching more than several hundred yards as a rule, and few of them exceed 20 feet in thickness. The writer has not anywhere found pebbles in the Farmington sandstone. The sandstones of the Farmington member make marked benches where the dip of the beds is low and a ridge where the dip is high.

A section at the type locality, measured by the writer for Mr. Bauer [45] in 1915, is given on pages 62–63 and will serve to show the general character of the formation, though the details vary greatly in a short distance along the strike.

Thickness.—The Kirtland shale shows considerable variation in thickness. Except in the region near Durango, Colo., the McDermott formation seems to be conformable with it and would indicate that the variations shown between Ojo Alamo, N. Mex., and Florida River, Colo., represent original differences in deposition. The thinning east of Ojo Alamo and east of Florida River is undoubtedly due to erosion. The formation appears to be 630 feet thick at Durango, Colo.,[46] 927 feet in the Red Mesa quadrangle, southwest of Durango,[47] 1,065 feet at the New Mexico-Colorado boundary, 1,120 feet halfway between the State boundary and San Juan River, 800 feet on San Juan River, then thickening gradually to a maximum of 1,180 feet on Hunter Wash and thinning thence southeastward to 700 feet on Escavada Wash and 390 feet near Tucker's store, in sec. 20, T. 21 N., R. 7 W. Still farther to the southeast, on Medio Arroyo, the Ojo Alamo sandstone and the Puerco and Torrejon formations overlap it completely.

On San Juan River the lower shale member is 271 feet thick, the Farmington sandstone member 459 feet, and the upper shale member 80 feet. Toward the south the lower shale member increases, in the sections measured, to 368 feet, 550 feet, and 1,031 feet and then decreases to 975 and 830 feet. In the same sections the Farmington sandstone member measures 432, 450, 99, 87, and 20 feet. The upper shale member ranges from 12 to 44 feet in thickness. North of San Juan River the lower shale member maintains at most places a thickness of 300 to 350 feet. The Farmington sandstone member, however, ranges from 162 to 480 feet and the upper shale member from 150 to 475 feet. These variations seem to

[45] Bauer, C. M., unpublished data.

[46] Gardner, J. H., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 187, 1917.

[47] Pishel, M. A., unpublished data.

indicate simply differences in sedimentation, as the beds form everywhere an unbroken sequence of deposits.

The sections on Plate II show graphically the variations in the thickness of the Kirtland shale and its subdivisions.

Relation to adjacent formations.—The contact of the Kirtland shale with the Fruitland formation is one of gradual transition. The character of the contact with the overlying McDermott formation, where that is present, is difficult to determine. In the Red Mesa quadrangle [48] Pishel with good reason believed it to be one of conformity, and so far as local evidence goes the same might well be true for the New Mexico area. At many localities it is difficult to find any but an arbitrary plane of separation. At others it is possible to draw a fairly plausible boundary, but one without any sign of an erosion interval. At one locality on the north side of Pinyon Mesa, N. Mex., a pebble-bearing sandstone at the base of the McDermott formation rests with sharp contact on a considerable thickness of characteristic Kirtland shale, and at Ojo Alamo, N. Mex., a coarse grit forms the base of the McDermott formation. Near Durango, Colo., the McDermott formation seems to rest on an eroded surface of Kirtland shale, with the contact sharply defined by the change in color and in lithology. Gardner believed the contact on Florida River to show an angular discordance, but the writer doubts its presence and would interpret the apparent difference as due to rapid change in the dip. As the McDermott formation contains in this region much very coarse andesitic detritus, it is possible that the sharp contact represents the beginning of torrential deposits laid down in connection with the volcanic eruptions, these deposits, though unconformable, being not very much later in age than the underlying shales. The contact with the Ojo Alamo sandstone on the south side of the basin and with the Animas formation on the north side, where the McDermott formation is absent, is clearly an erosional unconformity.

Fossils.—The Kirtland shale has yielded a number of collections of fossils, nearly all from New Mexico. These have been described by Gilmore, Stanton, and Knowlton. The fossils all indicate a fluviatile origin for the formation. The vertebrates [49] from the Kirtland shale include the following forms:

Dinosauria:
- Kritosaurus sp.
- Crested trachodonts.
- Carnivorous dinosaurs.
- Ceratops? sp.
- Armored dinosaur (Scelidosauridae).

Chelonia:
- Baena nodosa Gilmore.
- sp. undetermined.
- Neurankylus baueri Gilmore.
- Adocus bossi Gilmore.
- kirtlandius Gilmore.
- Plastomenus robustus Gilmore.
- sp. undetermined.
- Aspideretes sp.

Crocodilia:
- Crocodylus sp.
- Brachychampsa sp.

Pisces:
- Lepisosteus sp.
- Myledaphus sp.

The invertebrates [50] include the following forms:

Unio pyramidatoides Whitfield?
- baueri Stanton.
- sp. undetermined.

Viviparus sp.

The plants were described by Knowlton [51] in 1916 and include the following forms:

Geinitzia formosa Heer.
Salix sp.
Ficus praetrinervis? Knowlton.
- leei Knowlton.

A collection made in 1921 from the Farmington sandstone at U. S. G. S. locality 7494, in the SE. ¼ SW. ¼ sec. 13, T. 35 N., R. 7 W., 5 miles north of Bayfield, Colo., and examined by Mr. Knowlton, contains the following species:

Ficus curta Knowlton.
Phyllites petiolatus? Knowlton.
Several undescribed leaves.

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[48] Pishel, M. A., unpublished data.

[49] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, p. 8, 1919. The list given in Gilmore's paper includes the faunas of both the Kirtland and McDermott formations.

[50] Stanton, T. W., Nonmarine Cretaceous invertebrates of the San Juan Basin: U. S. Geol. Survey Prof. Paper 98, p. 310, 1916.

[51] Knowlton, F. H., Flora of the Fruitland and Kirtland formations: U. S. Geol. Survey Prof. Paper 98, p. 330, 1916. The list given in Knowlton's paper includes also species from the McDermott formation.

Age of Fruitland formation and Kirtland shale.—The Fruitland formation and Kirtland shale contain very closely related floras and faunas. Brown,[52] on the basis of the vertebrates, considered his Ojo Alamo beds, mostly included in the Kirtland shale of this paper, "to be synchronous with the Judith (Belly River) formation." The vertebrate remains of the Fruitland, Kirtland, and Ojo Alamo formations are said by Gilmore [53] to show

> beyond all question that they pertain to a fauna or faunas distinctly older than that of the Lance, and that such evidence as there is contributes to the support of Brown's contention that the Ojo Alamo sandstone is synchronous with the Judith River and Belly River formations as found in areas to the north.

Later, concerning other specimens collected from the Kirtland, Gilmore [54] says:

> They furnish corroborative evidence * * * that the Kirtland formation is of Montana age. * * * These specimens show a stage of development reached only in the Judith River and Belly River ceratopsians.

Osborn,[55] in interpreting the bearing of *Pentaceratops sternbergii* on the age of the Fruitland formation, states that it is intermediate between the Judith River and Belly River beds on the one hand and the Lance formation on the other.

The invertebrates are said by Stanton[56]

> to favor the assignment of the Fruitland formation to an epoch considerably later than Mesaverde and Judith River and possibly somewhat earlier than Lance. * * * The sequence from the base of the Fruitland up to the top of the Ojo Alamo, which is conformable, according to Mr. Bauer, may include the equivalents of everything from the Fox Hills to the Lance, inclusive.

The plant fossils are said by Knowlton[57] to justify the conclusion "that the Fruitland and Kirtland formations are of Montana age" and are closely related to the floras of the Vermejo formation and Mesaverde group.

It seems most logical, in the light of present knowledge, to consider both the Fruitland formation and the Kirtland shale as of late Montana age, possibly equivalent to the latest part of the Pierre shale and part of the Fox Hills sandstone of the region east of the Rocky Mountains. The possible relations of these formations to the Laramie formation of the Denver Basin are discussed on page 28.

McDERMOTT FORMATION.

Definition, type locality, and distribution.—The name McDermott formation is here introduced for a series of lenticular sandstones, shales, and conglomerates containing much andesitic débris and usually in part of purple color. The name is derived from McDermott Arroyo, in the Red Mesa quadrangle, southwestern La Plata County, Colo., and the exposures in secs. 18 and 19, T. 32 N., R. 11 W., adjacent to McDermott Arroyo, may be considered typical of the formation. A section measured at this locality is given on page 57 and shows the formation to be 328 feet thick. The formation appears to be conformable on the Kirtland shale and at the type locality is overlain unconformably by the Torrejon formation.

The McDermott formation may be traced from the type locality northeastward to the divide between Florida and Pine rivers, except in Bridge Timber Mountain, where it is covered by overlap of later beds. Farther east it was removed by erosion before the deposition of the Animas formation. Southward from the type locality the formation may be traced to a locality some miles beyond Ojo Alamo, N. Mex. Beyond this place it seems to have been eroded away during the interval preceding the deposition of the Ojo Alamo sandstone. The outcrop, therefore, extends virtually around the western half of the San Juan Basin.

The formation defined above is the lower part of the unit described by Cross [58] in 1892 from observations made by T. W. Stanton as the "andesitic beds on Animas River" and in 1896 from his own observations[59] as the "Animas River beds." It is the same unit as

[52] Brown, Barnum, Cretaceous-Eocene correlation in New Mexico, Wyoming, Montana, and Alberta: Geol. Soc. America Bull., vol. 25, p. 380, 1914.

[53] Gilmore, C. W., Vertebrate faunas of the Ojo Alamo, Kirtland, and Fruitland formations: U. S. Geol. Survey Prof. Paper 98, p. 281, 1916.

[54] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, p. 8, 1919.

[55] Osborn, H. F., A new genus and species of Ceratopsia from New Mexico, *Pentaceratops sternbergii*: Am. Mus. Nat. Hist. Novitates, No. 93, 1923.

[56] Stanton, T. W., Nonmarine Cretaceous invertebrates of the San Juan Basin: U. S. Geol. Survey Prof. Paper 98, p. 310, 1916.

[57] Knowlton, F. H., Flora of the Fruitland and Kirtland formations: U. S. Geol. Survey Prof. Paper 98, p. 331, 1916.

[58] Cross, Whitman, Post-Laramie deposits of Colorado: Am. Jour. Sci., 3d ser., vol. 44, pp. 25–27, 1892.

[59] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, pp. 217–219, 1896.

the Animas formation of Shaler[60] (1907) and Gardner[61] (1909). It forms the basal part of the Animas formation as later conceived by Gardner.[62] It is included in the upper part of the Ojo Alamo beds of Brown[63] (1910), in the uppermost part of the Kirtland shale of Bauer[64] (1916), and in the Ojo Alamo sandstone in part (north of Pinyon Mesa, N. Mex.) and the Kirtland shale in part (south of Pinyon Mesa) of Bauer and Reeside[65] (1921).

The McDermott formation has not been recognized outside of the San Juan Basin.

Lithologic character.—At the type locality the McDermott formation consists of an irregular assemblage of brown to yellow soft sandstone; gray-white coarse tuffaceous sandstone; purple, yellow, and bluish-gray tuffaceous shale; green to drab coarse conglomerate with matrix almost entirely of andesitic débris and pebbles and cobbles nearly all of weathered andesite; in the upper part of the formation conglomerate with rusty brown matrix and pebbles nearly all of siliceous, resistant rocks, such as quartz, quartzite, and chert. These pebbles are much like those in the Ojo Alamo sandstone described on page 29. Nearly all the finer-grained parts of the formation contain some volcanic débris, the purple shale particularly. Northward from the type locality the proportion of andesitic material in the formation increases. On Animas River it is composed of fairly pure and little weathered andesitic débris, predominantly purple. Some beds of it are very coarse indeed, masses several feet in diameter being common. East of Animas River notable beds of siliceous pebbles are present in the lower part of the formation, associated with yellow sandstone. Southward from the type locality the proportion of volcanic matter decreases. Beds of purely andesitic débris do not occur west of La Plata River in New Mexico, though sandstone, shale, and conglomerate with a notable amount of andesitic material in them mark the McDermott formation clearly in the region north of San Juan River. At San Juan River the McDermott formation is represented by thin irregular lenses of fine purple and green tuffaceous sandstone, coarse white sandstone with clay pellets, and purple and gray shale forming 30 feet of beds just beneath the Ojo Alamo sandstone. South of San Juan River the McDermott formation is a thin assemblage of brown sandstone and grit, gray-white sandstone, and purple and gray shale just beneath the Ojo Alamo sandstone. Except for the purple color of some of the beds this assemblage does not look greatly like the McDermott formation in Colorado. These beds, however, contain detritus from andesites.

The constitution of the McDermott formation at a number of localities is shown by the sections on pages 56–62.

Thickness.—The thickness of the McDermott formation is highly variable, owing in part to the arbitrary placing of the lower boundary at many localities, in part to erosion of the upper surface, and in part to a variation in the original thickness. In Colorado it is 200 to 400 feet thick at most localities. In northern San Juan County, N. Mex., it is thinner, ranging between 150 and 200 feet. It thins still more southward and is from 30 to 50 feet thick in the region south of San Juan River. Some of these variations are shown graphically in Plate II.

Relation to adjacent formations.—The contact of the McDermott formation with the Kirtland shale is discussed on page 23. It is conformable at many localities, though it seems to be unconformable locally. Over most of the exposure in the Ignacio quadrangle— that is, from Bridge Timber Mountain to the divide between Florida and Pine rivers—the McDermott formation is overlain by the Animas formation. On Animas River the contact is marked by an angular discordance and a sharp color contrast between the purple McDermott formation and the greenish to brown Animas formation. At most other localities the sharp change in color is evident though a discordance in dip or local evidence of erosion has not been detected. The lower beds of the Animas formation are

[60] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, pp. 322-323, 1907.

[61] Gardner, J. H., The coal field between Durango, Colo., and Monero, N. Mex.; U. S. Geol. Survey Bull. 341, pp. 352-353, 1909.

[62] Gardner, J. H., section on Florida River published in Lee, W. T., Stratigraphy of the coal fields of northern central New Mexico: Geol. Soc. America Bull., vol. 23, p. 585, 1912.

[63] Brown, Barnum, The Cretaceous Ojo Alamo beds of New Mexico, with description of the new dinosaur genus *Kritosaurus*: Am. Mus. Nat. Hist. Bull., vol. 28, pp. 267-268, 1910.

[64] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, p. 275, 1916.

[65] Bauer, C. M., and Reeside, J. B., jr., Coal in the middle and eastern parts of San Juan County, N. Mex.: U. S. Geol. Survey Bull. 716, pp. 162, 172, 1921.

usually coarse and composed largely of andesitic débris, but they differ from the McDermott formation in containing much more weathered detritus and more non-volcanic material. Eastward from the divide between Pine River and Piedra River the Animas formation is in contact with successively lower beds of the McDermott formation, the Kirtland shale, and part of the Fruitland formation, and the evidence of pre-Animas erosion is very clear. It is the writer's belief that the Animas formation is everywhere unconformable upon the McDermott formation and that there is, in fact, a notable gap at this contact. In Bridge Timber Mountain the basal Wasatch beds ("Tiffany beds" of Granger) overlap the McDermott formation and the Kirtland shale. Southwest of Bridge Timber Mountain a narrow strip of Animas formation is present between the outcrops of the McDermott formation and the "Tiffany" zone of the Wasatch and Torrejon formations, but it thins out within a few miles, and in sec. 5, T. 32 N., R. 11 W., the Torrejon formation rests directly on the McDermott formation. The basal part of the Torrejon here consists of light and dark gray shale with some thin, platy green sandstone and some thin brown sandstone. The lithologic contrast with the conglomerates, soft yellow sandy beds, and purple layers of the McDermott formation permits a ready separation. The effect of erosion is not very evident, but as the Animas and Ojo Alamo formations are unrepresented the Torrejon is unconformable on the McDermott formation. On Barker Arroyo, in New Mexico, the Ojo Alamo sandstone appears between the Torrejon formation and the McDermott formation and is the overlying unit as far south as the McDermott formation occurs. The contact is one of erosional unconformity. Angular discordance has not been noted anywhere, and at some localities, owing perhaps to a reworking of McDermott materials, it is difficult to determine logically a plane of division between the two formations. At many localities, however, the contact is a clean-cut line between pebble-bearing sandstone and shale without great irregularities, and at still other localities it is at the base of a conspicuous coarse basal conglomerate in the Ojo Alamo sandstone and is very sinuous. Southeastward from Ojo Alamo the Ojo Alamo sandstone very clearly transgresses across the McDermott formation (see Pl. II), and the evidence of erosion before Ojo Alamo time is plain. It is therefore likely that there is a hiatus between the McDermott formation and the Ojo Alamo sandstone wherever they are in contact. Not enough is yet known of the Ojo Alamo fauna, as shown on page 31, to determine whether it is very different from that of the McDermott, but the writer believes that there is a difference which will be established with further collecting.

The beds of siliceous pebbles in the McDermott formation present a special problem. No pebbles of any kind have been found in the formations between the Tocito sandstone lentil of the Mancos shale and the McDermott formation. Clay pellets and "mud balls" are common in some of the beds but no pebbles. The siliceous pebbles, therefore, appear very suddenly in the succession of strata. Their source has not been traced. Among them rocks probably as old as pre-Cambrian are represented and certainly as old as Carboniferous. Whether the rocks forming the pebbles had been uncovered by erosion on some land mass during a long period of time, perhaps all of Cretaceous time or longer, and only fine débris was transported until some change, with which the volcanic eruption is possibly to be connected also, increased the power of the streams to carry débris, or whether the uncovering and transportation of the material occurred between Kirtland and McDermott time, must be determined indirectly. The latter alternative would necessitate a great hiatus between Kirtland and McDermott time, which is not shown either by the fossils or by the structural relations of the formations. The writer believes that the presence of the siliceous pebbles requires some other explanation than that of a hiatus.

Fossils.—Near the type locality of the McDermott formation indeterminable bones of dinosaurs, fragments of turtle bone, and fossil wood have been collected at a number of localities, but no other fossils, In the Durango region several lots of plants have been collected, and south of San Juan River in New Mexico both plants and reptilian remains have been found.

The vertebrate fauna has been listed by Gilmore [66] and includes the following forms, all from New Mexico:

Dinosauria.
- Kritosaurus navajovius Brown.[67]
- Monoclonius sp.[67]
- Armored dinosaur (Scelidosauridae).
- Carnivorous dinosaur suggesting Dryptosaurus and Dynamosaurus.

Chelonia:
- Baëna nodosa Gilmore.

Pisces:
- Lepisosteus sp.

From the same region as the vertebrates just listed two lots of fossil plants were collected by Bauer. These were examined by Knowlton and the species described.[68] The species in the two lots are as follows:

6965. 1 mile east and a quarter of a mile north from Pina Veta China, N. Mex.:
- Pistia corrugata Lesquereux.
- Ficus leei? Knowlton.
- Fragments of a large leaf, probably Ficus sp.
- Unassigned plant suggesting Selaginella.

6966. 1 mile east and three-quarters of a mile north from Pina Veta China, N. Mex.; horizon at very top of McDermott formation:
- Palm (genus and species?).
- Onoclea neomexicana Knowlton.
- Asplenium neomexicanum Knowlton.
- Ficus leei Knowlton.
- Myrica? neomexicana Knowlton.
- Leguminosites? neomexicana Knowlton.
- Pterospermites sp.

Plants have been collected from four localities in the Durango region and have been examined by Knowlton, who finds the following species present:

Florida River, Colo.; horizon 211 feet above base of McDermott formation; J. H. Gardner, collector:
- Ficus planicostata Lesquereux.

West side of Animas River below Durango, Colo.; Whitman Cross and A. C. Spencer, collectors:
- Fern, new, genus?
- Sabalites sp.?
- Cyperacites sp.
- Ficus eucalyptifolia Knowlton.
    - denveriana? Cockerell.
- Quercus preangustiloba Knowlton.
- Grewiopsis sp.
- Cissus coloradoensis? Knowlton and Cockerell.
- Rhamnus cf. R. cleburni Lesquereux.

1964. East of ridge west of Animas River about 3 miles below Durango, Colo.; base of beds containing eruptive débris; Whitman Cross and A. C. Spencer, collectors:
- Cyperacites, sp.
- Canna? magnifolia Knowlton.
- Laurus socialis Lesquereux.
- Cinnamomum linifolium? Knowlton.
- Sequoia acuminata? Lesquereux.

7457. 4 miles south of Durango, Colo., in NW. ¼ SE. ¼ sec. 11, T. 34 N., R. 10 W., near base of McDermott formation; J. B. Reeside, collector:
- Salpichlaena sp. probably new but close to S. anceps (Lesquereux) Knowlton.
- Ficus sp.
- Laurus sp.
- Fragments of two or three other dicotyledons.

Age and correlation.—The dinosaur fauna listed above contains only forms considered to be of Montana age. *Kritosaurus* occurs in the Kirtland formation and is known elsewhere only in the Belly River formation. *Monoclonius* is not known in later beds than those of Montana age. The specimen of carnivorous dinosaur is most like a form from the Edmonton formation. *Baëna nodosa* occurs also in the Kirtland and Fruitland formations. The assemblage is therefore said by Gilmore [69] (see p. 24), following Brown, to indicate Montana age for the inclosing beds, or at least an earlier age than that of any beds with *Triceratops,* such as the Denver formation and the Lance formation. The fauna is certainly much like that of the Fruitland and Kirtland formations. Concerning the plants listed above, Knowlton says (see p. 77 of this volume):

> The bearing of this flora on the question of age is difficult of satisfactory or conclusive evaluation. * * * As the matter now rests, the plants undoubtedly favor placing the McDermott formation in the Cretaceous, but they are not conclusive.

The paleontologic evidence as to age is therefore somewhat conflicting, though more favorable to an association of the McDermott formation with the underlying beds than with later deposits. The McDermott formation is continuous between the Colorado area and the New Mexico area and is everywhere terminated by an erosion surface. The base, on the contrary, is a much less definite plane of separation. It seems to the writer, therefore, that the McDermott formation has much closer

[66] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, p. 8, 1919. The list given by Gilmore includes the McDermott fauna with the Kirtland fauna.

[67] Cited by Brown in his Ojo Alamo beds, but really coming from the present McDermott formation.

[68] Knowlton, F. H., Flora of the Fruitland and Kirtland formations: U. S. Geol. Survey Prof. Paper 98, p. 330, 1916. The list given includes the plants of the McDermott formation with those of the Kirtland shale.

[69] Gilmore, C. W., Vertebrate faunas of the Ojo Alamo, Kirtland, and Fruitland formations: U. S. Geol. Survey Prof. Paper 98, pp. 280–281, 1916.

relations to the underlying than the overlying beds, and that it should be placed in the Cretaceous. However, in view of the doubt that exists regarding its age this assignment is made with question in this paper.

The McDermott formation being, in the opinion just expressed, probably the highest conformable Cretaceous formation of the San Juan Basin, its relation to the Laramie formation of the Denver Basin comes into question. The Laramie formation is universally accepted as of post-Montana age, as it follows the Fox Hills sandstone, which by definition of the Montana group is the highest Montana formation. The highest marine beds of the San Juan Basin, those of the Pictured Cliffs sandstone, contain a fauna somewhat older than that of the Fox Hills sandstone. The beds above the Pictured Cliffs sandstone therefore must represent the time of possibly a small part of the Pierre shale and certainly the Fox Hills sandstone. Whether they include any deposits as late in time as the Laramie of the Denver Basin can be determined only by comparison of the respective faunas and floras. It has been stated on page 24 that the vertebrate fauna and the flora of the Fruitland and Kirtland formations are agreed as to the Montana age of the beds, and that the invertebrate fauna is less positive in its testimony, for though the fauna may be as old as Fox Hills it has much in common with that of the Laramie. The Laramie formation has yielded no determinable reptilian fossils, and the McDermott formation no invertebrates, so that a direct comparison can be based only on the floras. These have little in common and deny rather than affirm a close relationship, though the evidence is admittedly not conclusive. Unless in Laramie time dissimilar plants lived simultaneously in northeastern and southwestern Colorado the beds are not of the same age. If the evidence of the vertebrates of the McDermott formation and that of the plants are taken together it must be said that they lend some support to placing the McDermott formation even as low in the series as the Montana group, and that there is not now in hand any clear evidence of the presence in the San Juan Basin of an equivalent of the Laramie formation of the Denver Basin nor any evidence that it was ever present in the past. It seems much more likely that the post-McDermott hiatus represents all of Laramie time and the interval of the post-Laramie hiatus in the Denver Basin.

OJO ALAMO SANDSTONE.

Type locality and distribution.—The history of Ojo Alamo as a formation name has been traced in detail by Bauer.[70] It was first applied by Brown [71] to a reptile-bearing shale below a conglomerate on Ojo Alamo Arroyo near Ojo Alamo, N. Mex. Later Sinclair and Granger [72] found that at the same locality there were two conglomerates inclosing between them a shale with reptilian remains resembling those in the shale beneath the conglomerate. They considered the lower conglomerate to split the original shale of Brown into two parts, the upper inclosed between the lower conglomerate and a higher conglomeratic sandstone and the lower extending downward for an unknown but considerable thickness. They applied the name to the whole mass of sandstones, conglomerates, and shales. Bauer [73] showed that the lower conglomeratic sandstone of Sinclair and Granger when traced laterally became continuous with the upper by the pinching out of the included shale member and proposed to restrict the name Ojo Alamo to these conglomeratic beds and the shale between them, inasmuch as the trading post Ojo Alamo is situated on them, and to use the name Kirtland for the lower shale. It is in the sense proposed by Bauer that the name Ojo Alamo is used in this paper.

The Ojo Alamo sandstone may be defined as a conglomeratic sandstone containing one or more lenses of variegated shale and soft sandstone bounded below by an unconformable contact with the McDermott formation and above at the type locality by an unconformable contact with the Puerco formation. The section at the type locality given on page 68 shows it to be 86 feet thick.

The Ojo Alamo sandstone, so far as now known, is confined to New Mexico. It extends as the cap rock of a continuous ridge

[70] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, pp. 274–276, 1916.

[71] Brown, Barnum, The Cretaceous Ojo Alamo beds of New Mexico with description of the new dinosaur genus *Kritosaurus:* Am. Mus. Nat. Hist. Bull., vol. 28, pp. 267–274, 1910.

[72] Sinclair, W. J., and Granger, W. J., Paleocene deposits of San Juan Basin, N. Mex.: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 300–304, 1914.

[73] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, pp. 275–276, 1916.

from Pinyon Mesa, a few miles north of San Juan River, around the west and south sides of the San Juan Basin. It is concealed for some miles north of Pina Veta China but forms the cliff at the top of the bluffs near San Juan River, along the lower part of La Plata River, and it is the cap rock of Pinyon Mesa. A small remnant is present east of Barker Arroyo, but north of that locality it is cut out by the overlapping Torrejon formation. (See Pl. I.)

The pebbles contained in the conglomeratic portions of the Ojo Alamo sandstone are similar to those found in certain beds of the McDermott and Animas formations and include a highly varied assortment of resistant siliceous materials. Perhaps two-thirds are of jaspery quartz of a striking, brilliant red color; chert of various shades of brown, gray, and black; vein quartz; pink, white, and rarely gray quartzite, and hard brown sandstone. The

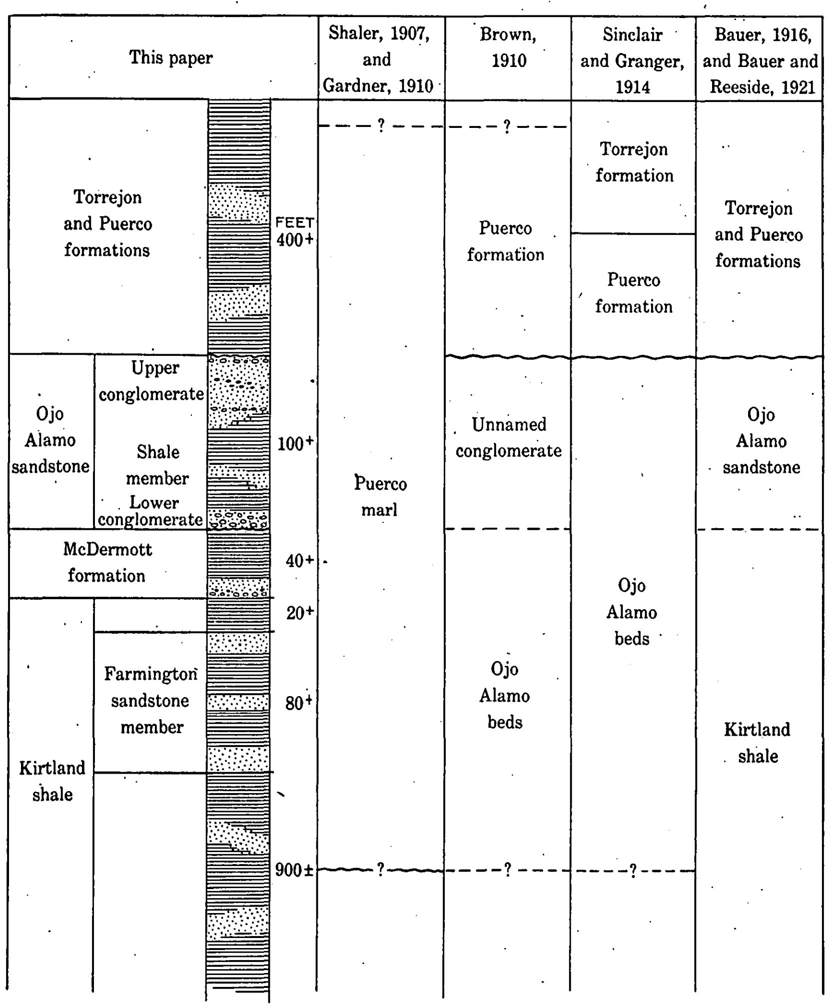

FIGURE 2.—Diagram showing the differences in naming of beds exposed near Ojo Alamo, N. Mex.

Lithologic character.—The Ojo Alamo sandstone is a white, gray, and brown resistant sandstone from medium to coarse-grained, containing lenses of well-rounded pebbles of various resistant siliceous materials and lenses of gray, greenish, and very rarely reddish shale interfingering with soft gray-white sandstone. Silicified logs are abundant locally, and the formation contains a few concretions of dark ferruginous sandstone.

remaining third includes silicified rhyolite, andesite, and other porphyries and rarely granite, gneiss, and schist. The pebbles are all well rounded, and many of them are chattermarked. They attain as great a size as 6 inches in diameter, though usually from 1 to 3 inches. Their source is as yet unknown, though possibly they came from the east or south rather than the north, for the types of rock abundant in the present-day river gravels derived from the north are lacking in the Ojo Alamo sandstone.

Sections at a number of localities are given on pages 61–70 and show the constitution of the formation in detail.

Thickness.—Near the type locality the formation is from 60 to 80 feet thick. To the south it increases somewhat in thickness locally, reaching 125 feet on Escavada Wash. A section at Tucker's store, 12 miles southeast of the locality on Escavada Wash, shows the thickness to be 75 feet. The Ojo Alamo sandstone may be traced eastward from Tucker's store as a nearly continuous sandstone ridge just beneath the beds assigned to the Puerco formation and overlapping with it across the Kirtland, Fruitland, Pictured Cliffs, and Lewis formations. It appears to vary little from its thickness at Tucker's store, though no careful measurements were made. To the north of the type locality the formation increases but little in thickness as far as Pina Veta China, where it is 91 feet thick. On the western slope of the Chaco-Gallego divide there are so few exposures between Pina Veta China and the bluffs south of San Juan River, a distance of 11 miles, that little can be determined. Along West Gallego Arroyo, however, exposures of the Ojo Alamo sandstone occur at many places from the head of the arroyo to its junction with the main arroyo and on down to San Juan River, where they are continuous with the exposures on that river. The exposures are so situated that the writer has no doubt of the continuity of the Ojo Alamo sandstone through the Chaco-Gallego divide from Pina Veta China to San Juan River. The fine exposures along this stream and its tributaries show a large increase in the thickness of the formation. In the triangular area between Animas and San Juan rivers the sandstone and its included shale units measure 400 feet in thickness. The lithologic constitution of this thicker phase of the formation differs from that of the typical phase only in the greater number of alternations of shale and conglomeratic sandstone, and although the increase in thickness is surprisingly great there is little room for doubt as to the identity of the formation with that at Ojo Alamo. In Pinyon Mesa, west of La Plata River, the thickness decreases to 200 feet, and within 5 miles to the northeast it is reduced to a vanishing edge between the McDermott formation and the overlying beds referred in this paper to the Torrejon formation. (See p. 36.) Still farther north thin beds of conglomerate composed of pebbles like those of the Ojo Alamo sandstone occur in the upper part of the McDermott formation and appear like a continuation of the Ojo Alamo sandstone. They occur, however, in an entirely distinct matrix and have been traced into beds of conglomerate that on Barker Arroyo lie beneath the thinning wedge of Ojo Alamo sandstone and are distinctly not a part of it. The Ojo Alamo sandstone thus thins, perhaps by erosion rather than by nondeposition, and in the region northeast of Barker Arroyo, which joins La Plata River about 9 miles north of Farmington, N. Mex., it disappears from the succession of rocks bordering the west of San Juan Basin.

Relation to adjacent formations.—The lower contact of the Ojo Alamo sandstone has been described on pages 23 and 26. It is one of erosional unconformity without notable discordance of dip except where it overlaps the older beds, as on Medio Arroyo. Gardner[74] has described the overlap at this place, though not differentiating the basal sandstone now known to be Ojo Alamo. The Ojo Alamo and overlying beds rest on the Fruitland and older formations with a difference in strike of nearly 90°. The dip is nearly the same for both formations, about 4°.

The upper contact of the Ojo Alamo is also an erosional unconformity. This is shown by a sinuous line of contact, sharply defined, a lithologic change from the conglomeratic sandstone of the Ojo Alamo sandstone to the variegated shale of the Puerco and Torrejon formations, and, as will be shown later, a complete change of fauna in passing from the Ojo Alamo sandstone to the Puerco formation.

Fossils.—The Ojo Alamo sandstone has afforded abundant but fragmentary remains of reptiles and a few poorly preserved remains of plants.

[74] Gardner, J. H., The coal field between San Mateo and Cuba, N. Mex.: U. S. Geol. Survey Bull. 381, p. 171, 1910; The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, p. 722, 1910.

The vertebrates described in the literature as derived from the Ojo Alamo sandstone have been listed by Gilmore [75] as follows:

Dinosauria:
- Kritosaurus navajovius Brown.
- Monoclonius sp.
- Armored dinosaur (Scelidosauridae).
- Deinodon?

Chelonia:
- Basilemys nobilis Hay.
- Adocus vigoratus Hay.
- Aspideretes vorax Hay.
  - fontanus Hay.
  - austerus Hay.
- Thescelus rapiens Hay.
- Compsemys sp.

Crocodilia:
- Crocodylus sp.

Pisces:
- Lepisosteus sp.

All the collections made up to the present time have come from places near the type locality, Ojo Alamo. The specifically identified forms, except *Kritosaurus navajovius*, were all collected by Brown in 1904 and by Gardner and Gidley [76] in 1908 near the type locality. The most significant species are *Monoclonius* sp. and *Kritosaurus navajovius*. *Monoclonius* sp. is cited on the evidence of a horn core collected by Brown. At the time of collecting the specimen Brown was applying the name Ojo Alamo to the shale (McDermott and Kirtland) beneath the conglomerates. Specimens representing primitive ceratopsian dinosaurs are known from four or five localities in the Kirtland shale, and Brown's own statement [77] of the occurrence of his materials is that "the vertebrate remains were numerous in several places from 30 to 100 feet below the conglomerate." It is fairly open to question, therefore, whether the horn core came from the Ojo Alamo sandstone or older beds. *Kritosaurus navajovius* is cited on the evidence of material collected by Sinclair and Granger [78] and identified by Brown. This material consisted of part of a trachodont maxillary and fragments of the skull. Inasmuch as Brown himself says that "even generic determination of isolated dinosaur teeth and bones must be considered a provisional reference," it seems fair to ask whether this material is determinable with certainty or should be referred merely to the trachodont dinosaurs until more material is available. The age assignment of the formation must rest in part on the dinosaur fauna, and the inclusion of determinations that are not surely founded is apt to lead to confusion. The remaining specimens now known whose stratigraphic position is unquestioned are mostly fragmentary, and though suggesting a varied fauna, are not sufficient for such definite assignment as should be used in correlation. These specimens include teeth of *Deinodon?;* dermal plates and a scapula of an armored dinosaur; part of the frill of a ceratopsian distinct from *Triceratops*, *Ceratops*, or *Monoclonius;* [79] vertebrae of a very large carnivorous dinosaur of the proportions of *Tyrannosaurus;* and a scapula and ischium of the large sauropod dinosaur *Alamosaurus sanjuanensis* Gilmore.[80] The last three were not included by Gilmore in the list given above.

Away from the type locality little vertebrate material has been found. A few poorly preserved dinosaur bones were seen by the writer near Kimbetoh Arroyo and a few scraps of turtle carapace near San Juan River.

Several small lots of fragmentary plants have been collected from the Ojo Alamo sandstone. These have been examined by F. H. Knowlton, who reports as follows:

6951. 3½ miles south of Pina Veta China, N. Mex.; horizon near base of Ojo Alamo sandstone. Material is a very hard fine-grained sandstone. Plants very fragmentary. There are two species with rather large leaves and a small, narrow *Salix*-like leaf. One of the large leaves is either a *Platanus* or an *Aralia*. If the former it might well be *Platanus aceroides* Goeppert or *Platanus raynoldsii* Newberry, but it is impossible to be certain. Both these are well-known Eocene (Fort Union, Denver, Raton, etc.) species. The other things can not be identified.

7373. 2 miles south of Farmington, N. Mex.; horizon 25 feet above the base of the Ojo Alamo sandstone, associated with a lens of impure lignite. This material is a soft clay shale well fitted to retain plant remains, and in fact the plants present are in the main beautifully preserved, but unfortunately they were so much

[75] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, p. 9, 1919.

[76] Gilmore, C. W., Vertebrate faunas of the Ojo Alamo, Kirtland, and Fruitland formations: U. S. Geol. Survey Prof. Paper 98, p. 279, 1916.

[77] Brown, Barnum, The Cretaceous Ojo Alamo beds of New Mexico, with a description of the new dinosaur genus *Kritosaurus*: Am. Mus. Nat. Hist. Bull., vol. 28, p. 268, 1910.

[78] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, N. Mex.: Am. Mus. Nat. Hist. Bull., vol. 23, p. 302, 1914.

[79] Gilmore, C. W., Reptilian faunas of the Torrejón, Puerco, and underlying Upper Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, pp. 65, 67, 1919.

[80] Gilmore, C. W., A new sauropod dinosaur from the Ojo Alamo formation of New Mexico: Smithsonian Misc. Coll., vol. 72, No. 14, 1922.

broken up before fossilization that it is now impossible to identify them with any degree of certainty. I note the presence of a peculiar fern that is probably an *Anemia*, but it can not be fixed with certainty. There are also at least two types of dicotyledonous leaves, a small one that seems to be a *Sapindus* of the type of *Sapindus affinis* Newberry (a Fort Union species) and a larger one that strongly suggests an undescribed species of *Ficus* from the Dawson arkose of Colorado.

Mr. Knowlton examined another collection made by Bauer from a locality very close to locality 7373, and his report on it [81] is repeated below:

This material is very fragmentary. It includes, apparently, two ferns, one *Pteris*-like and the other *Anemia*-like, but neither is sufficiently well preserved to be identified. There is also a monocotyledon that may be a palm ray or a large leaf of a sedge. The only dicotyledon present is a *Sapindus* not unlike a large leaflet of *S. angustifolia* Lesquereux, a Green River species. This lot appears to be Tertiary, but it is too fragmentary to place positively.

Age and correlation.—The Ojo Alamo sandstone, as noted above, has yielded a very imperfectly known fauna and a very small flora. The fauna has been correlated by Brown and by Gilmore with the Judith River and Belly River formations, of middle Montana age. (See p. 24.) The writer believes that of the two most significant forms cited as members of the fauna one probably came from older beds and the other is probably not determinable closely enough to afford a sure correlation. The remainder of the fauna is either entirely new or too fragmentary for precise identification. The known flora suggests Tertiary rather than Montana age, but is, like the fauna, too meager to permit even a comparison. In short, the paleontologic data now available are entirely inconclusive as to the age of the beds. Bauer [82] in 1916 accepted as actual the apparent conformity of the Ojo Alamo sandstone on the older beds in the area he studied and assigned the Ojo Alamo to the Cretaceous system. The presence of an overlap of Ojo Alamo across older beds and structural discordance near Medio Arroyo, the sharp change in lithology from the McDermott formation to the Ojo Alamo sandstone, and local evidence of erosion, even where there is no evidence of discordance otherwise, show the presence of an important hiatus between the pre-Ojo Alamo deposits and the Ojo Alamo sandstone. The similar position in the stratigraphic succession of the Ojo Alamo sandstone and the Animas formation (as shown on p. 25) and the fact that each formation in its area of occurrence carries the latest dinosaur remains known suggest that they are of very nearly the same age, or perhaps better that the lower part of the Animas formation and the Ojo Alamo sandstone are of the same age. The relations between the Ojo Alamo and Animas are treated more fully on page 34. The writer believes that both of these formations are later than Montana and Laramie and that both are equivalent to some part of the Denver, Raton, and Lance formations, the Animas formation, however, representing a longer time interval than the Ojo Alamo sandstone. In view of the wide differences in opinion expressed by various students as to the correct assignment of this whole group of related formations, the Ojo Alamo sandstone and Animas formation are herein classified as Tertiary (?).

ANIMAS FORMATION (RESTRICTED).

Type locality and distribution.—The writer here applies the name Animas to the greenish-gray and tan beds with much andesitic débris that on Animas River in the Ignacio quadrangle, Colo., lie unconformably upon the purple beds assigned to the McDermott formation and unconformably below the Torrejon formation. Andesitic beds on Animas River near Durango, Colo., were described without a specific name in 1892 by Cross,[83] quoting field observations by T. W. Stanton. He described the deposits at greater length in 1896, naming them the "Animas River beds"[84] and including the McDermott formation and part of the Animas formation as here distinguished. A complete section through both the McDermott and Animas formations was measured on Florida River by Gardner [85] in his work on the Ignacio quadrangle, though both were included under the designation Animas formation.

[81] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, p. 278, 1916.

[82] Idem, p. 275.

[83] Cross, Whitman, Post-Laramie deposits of Colorado: Am. Jour. Sci., 3d ser., vol. 44, pp. 25-27, 1892.

[84] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, pp. 217-219, 1896.

[85] Gardner, J. H., in Lee, W. T., Stratigraphy of the coal fields of northern central New Mexico: Geol. Soc. America Bull., vol. 23, pp. 584-587, 1912; also in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 185-186, 192, 1917.

The Animas formation is confined, so far as now known, to the northern rim of the San Juan Basin. The writer has traced its outcrop from the type locality southwestward into the Red Mesa quadrangle, a few miles southwest of Durango, Colo., where the formation wedges out. He has traced it also eastward to Pagosa Junction. Beds with andesitic débris are reported well beyond that locality and very likely are part of the Animas formation. Lee [86] found such beds at Dulce, N. Mex., and they are undoubtedly present at other localities.

Lithologic character.—The lower 300 feet of the Animas formation contains coarse conglomerates separated by shale and sandstone. All these beds are greenish gray to tan and contain much weathered andesitic material. The conglomerates contain many pebbles of quartz, quartzite, and chert and a few of nonandesitic igneous rocks, similar to those of the Ojo Alamo conglomerates, but consist predominantly of andesite. Above this 300-foot zone greenish-gray to tan shale and sandstone are the predominant rocks, though layers of fine conglomerate are also fairly common. All this upper part of the formation contains much andesitic detritus. Reddish bands occur locally but are not a common feature. The Animas formation contains throughout some vegetable débris, locally enough to form thin coal beds. This feature becomes more pronounced eastward from the type locality. On Cat Creek, near Pagosa Junction, a number of thin lenticular coal beds are present and fossil plants occur abundantly at many horizons. Sections of the Animas formation at several localities are given on pages 55–56.

Thickness.—On Animas River the formation is about 1,100 feet thick, though cut off above, as indeed it is everywhere else, by an unconformity, owing to the removal of an unknown amount of the original thickness. The section measured by Gardner on Florida River, referred to on page 32, shows a thickness of 1,800 feet for the formation—that is, exclusive of the part of his section assigned in this paper to the McDermott formation. The next complete section available is on the divide between Pine River and Piedra River in secs. 31 and 32, T. 35 N., R. 5 W., where the Animas formation is 2,670 feet thick. On Cat Creek, near Pagosa Junction, the Animas formation is 1,840 feet thick. Westward from the type locality the overlap of the Torrejon and Wasatch ("Tiffany" zone) formations gradually reduces the thickness of the part of the formation exposed until all is covered under Bridge Timber Mountain. In the Red Mesa quadrangle, a few miles to the west, scarcely 100 feet of the basal zone of the Animas formation is present. These thicknesses are shown graphically on Plate II.

Relation to adjacent formations.—The Animas formation is unconformable upon the McDermott formation. On Animas River there is angular discordance and a sharp color change. Elsewhere the color change is prominent, but no discordance has been noted. The Animas formation furthermore overlaps successively the McDermott formation, the Kirtland shale, and part of the Fruitland formation in the region between the Florida River-Pine River divide and Cat Creek, north of Pagosa Junction. Farther east beds with andesitic débris that are lithologically like the Animas formation are reported [87] to rest on still older rocks. It is highly probable that the base of the Animas is everywhere unconformable. The top of the Animas formation as now preserved is an extremely variable surface. Near Animas River the overlapping Torrejon formation covers up a large part of the formation and the Wasatch beds ("Tiffany" zone) cover the rest. There is no sign of interfingering or lateral gradation of Torrejon beds into Animas beds. East of Animas River the widespread Quaternary deposits in Florida Mesa and Oxford Mesa hide the older rocks over large areas but such exposures as are available show that the basal Wasatch beds ("Tiffany beds" of Granger) directly overlie the Animas formation, with a hiatus between representing at least the Torrejon formation. The contact is marked by a lithologic change without any marked local evidence of erosion. The greenish-gray shales and sandstones of the Animas formation are succeeded by a series of variegated shales and coarse arkoses with pink feldspars that has a distinctly different aspect.

[86] Lee, W. T. and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 190–191, 1917.

[87] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 190–191, 1917.

Fossils.—The Animas formation has yielded fragmentary and indeterminable dinosaur bones at several localities. A complete but indeterminable dinosaurian limb bone was reported [88] from the basal part of the formation near the divide between Pine and Piedra rivers.

Fossil plants have long been known—in fact, since the first recognition of the formation. Practically all the known collections from the Animas formation have been in the hands of F. H. Knowlton. The results of his study are contained in a paper describing the flora and discussing its relations to other floras, which forms a part of this volume (pp. 77–115).

Age and correlation.—The Animas formation must be correlated chiefly on the basis of its plant fossils, though the relations to adjacent formations and its lithologic constitution offer some aid. Knowlton says of the flora:

> On combining the Animas species found in the Denver, Raton, and Wilcox it appears that 33 species, or over 90 per cent of those having an outside distribution, are held in common and the conclusion is reached that the Animas formation is of the same age namely, Eocene Tertiary.

The similarity in lithology of the Animas and Denver formations led, as long ago as the time of first recognition of the formation, to a tentative correlation between them, though the later establishment of the occurrence in the Rocky Mountain region of beds of andesitic débris in rocks of Montana age weakens the force of such correlations unless they are supported by other evidence. The Animas formation is unquestionably unconformable on the McDermott formation and on the older beds and is separated from them, in the writer's belief, by a notable hiatus. It is overlain unconformably by the Torrejon formation and therefore must precede it in time. The relations between the Animas formation and the Ojo Alamo sandstone and the Puerco formation are not so clear. The Animas and the Ojo Alamo are nowhere in contact, their nearest outcrops being about 12 miles apart. The dinosaur fauna of the Animas and the flora of the Ojo Alamo are virtually unknown, and no paleontologic comparison can be made. Yet it is significant that each in its area contains the latest known dinosaur remains, each succeeds the McDermott formation unconformably, each overlaps the preceding formations eastward along the outcrop, and each contains beds of siliceous pebbles of similar but peculiar constitution. (See p. 29.) The andesitic material of the Animas formation appears to have been derived from the north, the site of the present mountains. The siliceous materials of both Animas and Ojo Alamo formations are unlike the rocks occurring in the present mountains and the débris brought down by the recent streams and must have been derived from some other source, possibly east or south of the San Juan Basin. Thus there probably were sediments coming in from two directions. In the south little andesitic débris reached the site of the present Ojo Alamo sandstone, and the deposits consist chiefly of sand, clay, and the siliceous pebbles. In the north much the greater part of the material is andesitic débris, but some of the siliceous material also reached the area during the early part of Animas time and is mixed with the andesitic matter in the lower beds of the Animas formation. The presence of such beds of pebbles has been used in other regions as an argument for a lapse of much time in the interval preceding their deposition. This argument is weak when applied to the San Juan Basin, because of the presence of identical beds in the McDermott formation, which also carries Cretaceous dinosaurs and plants. Possibly the Puerco formation also is equivalent in age to some of the upper beds of the Animas formation. The small flora of the Puerco (see p. 75) seems to support this view, but the very narrow distribution of the Puerco formation and the entire absence from the Animas formation of mammals, so far as present knowledge goes, renders such a correlation uncertain, though the writer has considered it (see p. 43) the best interpretation of the data now in hand.

It is the writer's belief, in short, that present evidence shows the Animas formation to be equivalent in time to some part of the Denver, Raton, and Lance formations outside of the San Juan Basin and to the Ojo Alamo sandstone and probably the Puerco formation within it.

[88] Gardner, J. H., unpublished data.

In view of the difference of opinion expressed by various writers as to the correct assignment of this whole group of related formations, the Animas formation is herein classified as Tertiary(?).

NACIMIENTO GROUP.

The history of the names Puerco and Torrejon has been traced in detail by Gardner [89] and Bauer.[90] The name Puerco was applied by Cope [91] in 1875 to the entire series of beds on Puerco River, now supposed to include both the Puerco and Torrejon formations. He did not at that time have fossils from these beds (nor have any been collected since). Later numerous fossils were found in the region west of Puerco River which were believed by Cope to have come from the equivalent of his Puerco beds and were described by him as the Puerco fauna. These fossils were later separated by Wortman [92] into two quite distinct faunas. For the beds yielding the younger fauna he proposed the name Torrejon from the exposures on Arroyo Torrejon, Sandoval County, N. Mex., retaining Cope's name Puerco for the beds yielding the older fauna. In these senses the names have been generally accepted since that time.

The Torrejon fauna is interpreted by most students of vertebrate paleontology to be a direct descendant of the Puerco fauna but is sufficiently different to demand the lapse of a long interval of time. As, in addition, the two faunal zones appear to be relatively close together stratigraphically at some localities and widely separated at others and as the area yielding the Torrejon fauna is much greater in extent than that yielding the Puerco fauna, it would seem necessary to assume the presence of a hiatus. However, owing to the great similarity in lithology and the restriction of the fossils to relatively narrow zones with a barren interval between, no break has been recognized in the field in the series of beds, even at the localities where both formations are known to be present.

Gardner [93] proposed to use the name Nacimiento, from the town of that name (better known as Cuba), as a group term to include the Puerco and Torrejon formations. It is a convenience where the two formations are not distinguished on maps and in discussions, and for that reason it is now retained, but as the two formations are almost entirely distinct in fauna and, as stated above, possibly separated by a hiatus, Sinclair and Granger [94] did not use the group term.

Inasmuch as the formations are not separated on the maps and other illustrations accompanying this paper, and as such a separation would be worth little if made, it may seem unnecessary to discuss them separately. However, for future convenience it has seemed worth while in the following description to assemble as far as possible the data for each formation by itself.

PUERCO FORMATION.

Distribution.—The Puerco formation as defined by its fauna is now known only in a small area extending from Escavada Wash to the head of the west fork of Gallego Arroyo, in southeastern San Juan County, N. Mex. The distance along the outcrop is about 35 miles. No fossils are known from the section on Puerco River near Cuba, whence the formation name was derived, and only Torrejon fossils from the beds on Arroyo Torrejon. In fact, as the Puerco formation is characterized only by its fossils, it is very doubtful whether or not the formation is really present at either of these localities. It is purely an assumption to apply either Puerco or Torrejon to the barren interval between the fossiliferous zones of the Puerco and Torrejon or to the lateral extension of the beds in this interval into localities where Puerco fossils are not known. The barren interval is rather thin on both Arroyo Torrejon and Puerco River, as shown by Sinclair and Granger,[95] modifying Gardner's sections, and may be later than the fossiliferous Puerco. North of the head of West Gallego Arroyo beds that seem in lithology and stratigraphic position to be

[89] Gardner, J. H., The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, pp. 702-713, 1910.

[90] Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, 276-277, 1916.

[91] Cope, E. D., Report on the geology of that part of northwestern New Mexico examined during the field season of 1784: Chief Eng. Ann. Rept. for 1875, pt. 2, appendix G1, pp. 1008-1017, 1875.

[92] Wortman, J. L., and Matthew, W. D., A revision of the Puerco auna: Am. Mus. Nat. Hist. Bull., vol. 9, p. 260, 1897.

[93] Gardner, J. H., The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, p. 714, 1910.

[94] Sinclair, W. J., and Granger, Walter, Paleocené deposits of the San Juan Basin: Am. Mus. Nat. Hist. Bull., vol. 33, p. 313, 1914.

[95] Idem, fig. 2.

the continuation of the fossiliferous Puerco beds are present in the divide between Chaco River and Gallego Arroyo as far as Pina Veta China, though no fossils have yet been found to show that these beds are really the Puerco formation. On San Juan and Animas rivers the beds just above the Ojo Alamo sandstone are not at all like the typical Puerco and have not yielded any mammalian fossils. There is a long interval without outcrops between Escavada Wash and Arroyo Torrejon and a similar lack of exposures between the head of West Gallego Arroyo and Pina Veta China and between Pina Veta China and San Juan River. The lateral relation of the beds immediately above the Ojo Alamo sandstone beyond these covered intervals to the known Puerco beds is therefore a matter of inference. It is possible that the Torrejon formation overlaps and conceals the Puerco formation over most of the San Juan Basin. This idea is suggested by the scanty distribution of the known Puerco beds and the demonstrated overlap northward of upper Torrejon over the lower Torrejon beds on Animas River, for if the overlap was progressive and began earlier in the south, the lower Torrejon beds south of San Juan River may have covered up the Puerco beds and were then themselves covered. (See p. 39.) It must be admitted that the presence of a barren zone as thick as the known Puerco fossiliferous zone at the base of some of the sections offers a possibility that in the future the Puerco fauna will be found of greater extent than is now known, though the differences in lithology and the fact that no fossils were found, even after careful search for them, make such an outcome seem unlikely now. The writer has preferred as a working hypothesis to consider the present available evidence as indicating an overlap of the Torrejon formation and a restriction of the Puerco formation practically to the area in which Puerco fossils are now known. Whether the Puerco formation, as limited by this hypothesis, was once much more widespread than the existing exposures there is little to indicate. If there really is a post-Puerco hiatus, the possibility of considerable erosion during the time represented by the break renders it likely that Puerco beds once covered a much larger area than at present.

Lithology and thickness.—On Escavada Wash and its branches the lower 250 feet of the series of beds which include the Puerco and Torrejon formations consists of a rather dark mass of lenticular light and dark gray shale with bands of purplish, bluish, black, and rarely red shale, intermingled with soft gray-white sandstone. Concretions and layers of blue-black manganitic sandstone and veins and concretions of barite occur commonly. The upper half of the lowermost 50 feet of these beds contains Puerco fossils, and this is the most southerly occurrence of the fauna. There is no consistent lithologic difference to separate the fossil zone from the adjacent beds. The next higher 500 feet consists of cream-colored to yellow and brown, fairly well indurated sandstone with reddish-brown concretions, the sandstone in layers 30 to 40 feet thick separated by greenish-gray and lead-gray shale and some soft white sandstone. These beds have yielded no fossils but were placed arbitrarily in the Puerco formation by Sinclair and Granger.[96] The next higher 459 feet includes much very dark slate-colored shale with two prominent and several fainter red bands. The lowest Torrejon fossils yet collected came from a horizon 75 feet above the base of this unit. There are therefore only 50 feet of proved Puerco beds in this section, though above these beds are some 775 feet of barren beds before the lowest horizon of Torrejon fossils is reached. The barren beds may equally well be Puerco or Torrejon.

Near Ojo Alamo the lower 150 feet of beds comprising the Puerco and Torrejon formations is a rather dark mass of shale and soft sandstone (see section on p. 67) much like the lowest beds on Escavada Wash. The lowermost 90 feet of this mass contains Puerco fossils. The next higher 240 feet consists of lighter-gray shale with bands of brown, olive, and some dark shale, soft gray-white sandstone, and a few layers of yellow and brown resistant sandstone. Torrejon fossils occur about 50 feet above the base of this unit. The proved Puerco beds in this section are therefore only 90 feet thick and are succeeded by a barren interval of about 110 feet.

96 Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 297-316, 1914.

At the head of the west fork of Gallego Arroyo only a partial section is exposed. Dark variegated shale, containing the northernmost occurrence of the Puerco fauna, rests on Ojo Alamo sandstone but is cut off above by recent erosion.

On Arroyo Torrejon the beds beneath the lowest Torrejon fossils and above the Ojo Alamo sandstone are yellowish and dark-gray sandy shale, variegated red, purple, drab, and white shale, and massive coarse tan sandstone.[97] They are 110 feet thick and have yielded no fossils. On Puerco River the beds beneath the horizon equivalent to that of the lowest Torrejon fossils on Arroyo Torrejon, as determined by Sinclair and Granger, are 179 feet thick. They are composed of massive coarse-grained brown sandstone, gray shale, and soft gray and tan sandstone [98] and have yielded no fossils. These barren beds may be Puerco in age but in this paper are considered as belonging to the Torrejon formation.

Near Pina Veta China a considerable exposure of variegated shale and soft sandstone very much like the fossiliferous beds at the head of West Gallego Arroyo and resting directly on the Ojo Alamo sandstone may be of Puerco age, but the beds have yielded no fossils to confirm such an assignment.

Near San Juan and Animas rivers the beds beneath the lowest level of Torrejon fossils are soft white to buff or brown pebble-bearing sandstones, separated by gray, olive, and brown shales. The pebbles of the sandstone beds are chiefly gray chert and quartz. These beds are about 150 feet thick and have yielded only a few scraps of turtles and a few poorly preserved plants. The lithology of these beds is quite different from that of the proved Puerco beds and that of the exposure near Pina Veta China. They may be of Puerco age but in this paper are included in the Torrejon formation.

Relation to adjacent formations.—The lower contact of the Puerco formation, with the Ojo Alamo sandstone, is one of lithologic contrast and erosional unconformity without discordance of dip. The conglomeratic sandstone of the older formation has an irregular upper surface upon which were laid the more even shaly strata of the Puerco. Even where the beds of doubtful age that succeed the Ojo Alamo sandstone contain conglomeratic beds they differ from the Ojo Alamo sandstone in lacking the abundant red elements present in the conglomerates of the older formation and also the varied igneous constituents.

The contact of the Puerco formation with the Torrejon formation is obscure. Each of these formations shows considerable variation in gross lithology when traced along the strike and is likewise highly variable in details. Nearly all the individual beds are lenticular and can be traced for only short distances, even in continuous exposures. Beds very similar in lithology occur in both formations, and isolated outcrops that afford only lithologic criteria can not be assigned with confidence. It is therefore impracticable, if not impossible, to designate on lithologic grounds any given horizon as the dividing plane between the Puerco and Torrejon formations. The fossils, as stated above, give some reason to believe that there is a time interval unrepresented by sediments between the formations. The interval between the fossil zones is very much thicker on Escavada Wash than it is near Ojo Alamo and if it could be shown to constitute part of the Puerco formation would lend strong support to the supposition of a post-Puerco erosion interval. As its age is, for the present at least, indeterminate, the evidence for such an interval must come largely from the faunal relations. Along Animas River in Colorado beds that rest unconformably upon the Animas formation have been traced by continuous exposures southward to the fossiliferous Torrejon beds near Cedar Hill, N. Mex. They are clearly the upper beds of the Torrejon and have therefore overlapped the remainder of the Torrejon formation, which is present on Animas River below Cedar Hill. It may be legitimately inferred that still farther south the lower Torrejon overlapped the Puerco beds and that the lack of Puerco fossils in the region between Aztec, N. Mex., and Pina Veta China or perhaps even the head of the west fork of Gallego Arroyo is really due to the absence of Puerco beds. There are at present no direct observations to support such a deduction except perhaps the difference in lithology between the beds that follow the Ojo Alamo on San Juan and Animas rivers and the Puerco beds farther south.

[97] Gardner, J. H., The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, p. 724, 1910.
[98] Idem, p. 717.

Fossils.—The Puerco formation contains a large vertebrate fauna. The latest full list of the mammals is that given by Matthew [99] in 1914, though a number of changes have been proposed since that date, chiefly in the publications of the American Museum of Natural History. The latest full list of the reptiles is that by Gilmore,[1] published in 1919. These lists in condensed form but without any essential change are given below. The abundance of mammals and the complete absence of dinosaurs are the distinguishing features.

Puerco mammals:
- "Neoplagiaulax" americanus Cope.
- Polymastodon taoensis Cope.
  - attenuatus Cope.
- Catopsalis foliatus Cope.
- Claenodon? protogonioides? Cope.
- Triisodon quivirensis Cope.
  - heilprinianus Cope.
  - gaudrianus Cope.
- Oxyclaenus cuspidatus Cope.
  - simplex Cope.
- Loxolophus hyattianus Cope.
  - priscus Cope.
  - attenuatus Osborn and Earle.
- Carcinodon filholianus Cope.
- Paradoxodon rutimeyeranus Cope.
- Protogonodon pentacus Cope.
- Wortmania otariidens Cope.
- Onychodectes tisonensis Cope.
  - rarus Osborn and Earle.
- Mioclaenus turgidunculus Cope.
- Oxyacodon agapetillus Cope.
- Periptychus coarctatus Cope.
- Ectoconus ditrigonus Cope.
- Conacodon entoconus Cope.
  - cophater Cope.
- Hemithlaeus kowalevskianus Cope.
- Anisonchus gillianus Cope.

Puerco reptiles and fish:
- Chelonia:
  - Compsemys parva Hay.
    - vafer Hay.
    - puercensis Gilmore.
  - Baena sp.
  - Adocus hesperius Gilmore.
  - Hoplochelys crassa (Cope).
    - bicarinata Hay.
    - laqueta Gilmore.
  - Plastomenus sp.

Puerco reptiles and fish—Continued.
- Chelonia—Continued.
  - Aspideretes sagatus Hay.
    - puercensis Hay.
    - reesidei Gilmore.
    - vegetus Gilmore.
    - quadratus Gilmore.
    - perplexus Gilmore.
  - Conochelys admirabilis Hay.
- Rhynchocephalia:
  - Champsosaurus australis Cope.
    - saponensis Cope.
- Loricata:
  - Crocodylus stavelianus Cope.
- Pisces:
  - Lepisosteus sp.

In a late paper Matthew [2] says of the Puerco fauna:

> It contains a large mammal fauna which is wholly unknown elsewhere. Multituberculates form a considerable element, but the major part is archaic placentals. There are no dinosaurs, but the crocodiles, rhynchocephalians, and turtles are of the same groups as those of the Judith and Lance and not perceptibly more advanced.

Plants are represented in the Puerco formation by fossil wood and by rather rare leaf impressions. One collection of leaves was made by Sinclair and Granger on Barrel Spring Arroyo and studied by F. H. Knowlton, who made the following report: [3]

> With a fair degree of probability I am able to identify the following species:
>
> Ficus occidentalis Lesquereux.
> Artocarpus sp. ined.
> Paliurus zizyphoides Lesquereux.
> Viburnum lakesii? Lesquereux.
> Platanus sp. cf. P. haydenii Newberry.
> Populus sp. cf. P. cuneata Newberry.
> Viburnum sp.?
> Fragments.
>
> The *Ficus*, *Paliurus*, and *Viburnum lakesii* are species of the Denver and Raton formations. The *Artocarpus* is the same, apparently, as an undescribed species from the Raton formation, while the others, if correctly identified, should indicate Fort Union.
>
> While I am not positive about it, so far as I can determine from the imperfect material available, the age indicated is that of the Denver or perhaps as late as Fort Union.

[99] Matthew, W. D., Evidence of the Paleocene vertebrate fauna on the Cretaceous-Tertiary problem: Geol. Soc. America Bull., vol. 25, pp. 383–385, 1914.

[1] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, pp. 9, 10, 1919.

[2] Matthew, W. D., Fossil vertebrates and the Cretaceous-Tertiary problem: Am. Jour. Sci., 5th ser., vol. 2, p. 218, 1921.

[3] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin: Am. Mus. Nat. Hist. Bull., vol. 33, p. 306, 1914.

A second collection was made by the writer from beds at the same horizon as that just described and at very nearly the same locality. This locality is 1 mile northeast of Ojo Alamo, N. Mex., and is almost at the top of the Puerco beds as here limited (U. S. G. S. plant locality 7495). Mr. Knowlton has examined this collection also (see p. 75) and concludes that "on the basis of the plants the Puerco formation is of Tertiary age and in the approximate position of the Denver, Raton, and Wilcox beds."

Age and correlation.—The age and correlation of the Puerco and Torrejon formations are set forth on page 43.

TORREJON FORMATION.

Distribution.—The Torrejon formation, as defined by its fauna, is known to extend from Arroyo Torrejon in Sandoval County, N. Mex., across the southern and western parts of the San Juan Basin almost to the Colorado-New Mexico boundary. The beds that contain the the fossils near Cedar Hill, in northern San Juan County, N. Mex., have been traced by continuous exposures along the Animas Valley about 12 miles into Colorado, where they rest directly upon the Animas formation. They represent, however, only the upper 300 to 400 feet of the Torrejon formation as fully exposed in New Mexico, these upper beds having overlapped the lower beds, which along Animas River below Cedar Hill are about 1,000 feet thick. The Torrejon formation has been traced also from New Mexico into the valley of McDermott Arroyo, in the southern part of the Red Mesa quadrangle, 8 or 10 miles west of Animas River. Mammalian fossils have not yet been found in the Torrejon formation in Colorado and its identification is dependent chiefly on the unquestioned tracing of continous outcrops. Eastward from Arroyo Torrejon the Torrejon formation has been followed by Gardner and by Sinclair and Granger to and beyond Puerco River.

Lithology and thickness.—At the type locality of the Torrejon formation the constituent beds are described by Gardner [4] as drab, gray, reddish, black, and yellow shale and soft gray and tan sandstone. Gardner's section, modified by Sinclair and Granger,[5] shows the thickness of the beds present between the Wasatch formation and the base of the lowest beds containing Torrejon fossils to be 240 feet. Beneath these beds is a barren zone 110 feet thick, which in turn rests on the Ojo Alamo sandstone. The horizon of the lowest fossil zone has been traced by nearly continuous exposures to Puerco River.[6] The beds above it there are described by Gardner [7] as including variegated shale; gray, yellowish, and dark shale; soft gray sandstone; and massive coarse brown sandstone. They are said by Sinclair and Granger, modifying Gardner's section, to be 660 feet thick, with a barren zone 179 feet thick beneath them. The barren basal zone is in this paper considered of Torrejon age.

On Escavada Wash and its branches, above the thick barren zone that succeeds the zone of Puerco fossils, a series of beds containing much very dark slate-colored shale with two prominent and several fainter red bands, lenses of soft gray-white sandstone, and some lenses of indurated brown sandstone, attains a thickness of 450 feet. Black, probably manganitic sandstone concretions and barite in veins and concretions, occur throughout but are more common in the lower part. A peculiar dense quartzitic sandstone with many impressions of plant stems occurs at many horizons. The lowest Torrejon fossils were found 75 feet above the base of this unit, and the highest near its top.

Above the dark shale on Escavada Wash is a group of beds that seem to lie upon the shale with sharp erosional contact. These beds, 250 feet thick, consist of dove-colored shale, lighter-gray sandy shale, and soft white sandstone. A few reddish bands occur near the top, and some nearly black bands are present. Lenses of resistant light-gray sandstone with scattered pebbles of dark chert and quartz were seen here and there. The series as a whole shows marked banding and is very distinct in its general light color from the underlying beds. The sharp basal contact has been traced beyond Alamo Arroyo on the south

[4] Gardner, J. H., The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, p. 724, 1910.

[5] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin: Am. Mus. Nat. Hist. Bull., vol. 33, fig. 2, 1914.

[6] Idem, fig. 2.

[7] Gardner, J. H., The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, p. 717, 1910.

and beyond Ojo Alamo on the north, a distance of some 30 miles in an air line. However, as the beds are very similar to beds farther north known to contain Torrejon fossils and as they seem to be no higher in the section than the exposures that contain Torrejon fossils near Angel Peak, they have been in this paper included in the Torrejon formation. Future paleontologic or other evidence may warrant a different assignment. It is possible that they represent the "Tiffany beds" of Granger, a faunal zone in the basal part of the Wasatch formation in Colorado (see p. 44), or that they are part of the typical Wasatch formation of the region, though their absence beneath the massive sandstones of the Wasatch farther east renders the latter possibility very unlikely. In the absence of fossils their assignment to the Torrejon is as reasonable as any other that can be made.

Near Ojo Alamo the barren interval above the Puerco fossiliferous zone is followed by 240 feet of beds that consist of gray shale with bands of brown, olive, and some very dark shale; soft gray-white sandstone; and a few layers of brown resistant sandstone containing rather rare pebbles of chert and quartz. (See section on p. 67.) Torrejon fossils are found in a thin zone 50 feet above the base of this unit. These beds contain also some dark, probably manganitic sandstone in layers and concretions, gray dense quartzitic sandstone with impressions of plant stems, and barite in veins and concretions. Above these beds lie the light-colored beds which have been traced from Escavada Wash (see p. 39), attaining here a thickness of 186 feet, though cut off above by recent erosion. At this locality these uppermost beds were left unassigned by Sinclair and Granger[8] but were assigned to the Wasatch formation by Bauer.[9]

On San Juan and Animas rivers the Ojo Alamo sandstone is immediately overlain by a succession of rather soft white to buff, in places rusty-brown conglomeratic sandstones separated by light-gray, dark-gray, olive, and brown shales, with which are associated some thin beds of fine-grained green sandstone and gray quartzitic sandstone. These beds are 600 to 700 feet thick. In their upper part are some indurated brown sandstones and a few reddish bands. These beds are succeeded by an equal thickness of beds in which indurated brown lenticular sandstones are abundant and are separated by gray shale, red and purple shale, and soft gray-white sandstone. The red shale is greater in proportionate amounts in the higher part. Near San Juan River the only fossils found in this whole series[10] are Torrejon fossils from horizons high up in the series. Along Animas River, however, Torrejon fossils from the exposures below and above Aztec, N. Mex., show that the beds above the lower 150 feet, approximately, of the series are of Torrejon age. The lower beds have not yielded mammalian fossils but in this paper are also included in the Torrejon formation.

In the Pruett Pastures, east of La Plata, N. Mex., the lower half of the series of beds assigned to the Torrejon formation lacks the olive shale shown on Animas River and has less soft yellow heavy-bedded sandstone. The general effect to the eye is that of a more marked banding of light and dark gray shaly beds. The upper half consists of brown sandstone and gray and red shale like that on Animas River. No fossils have been collected except indeterminate scraps of turtles, but by tracing around from Animas Valley it has been shown that the section contains the same beds as are present in Animas Valley.

The beds exposed on Animas River near Cedar Hill, N. Mex., which are fossiliferous, represent approximately the uppermost 300 feet of the Torrejon formation and consist of brown lenticular sandstone and variegated shale. The beds above them, identified in this paper as the "Tiffany beds" of Granger, are very similar, but the sandstones are persistent, especially the basal sandstone. The uppermost Torrejon beds and the "Tiffany" zone have been traced continuously northward along Animas River to a point beyond the mouth of Florida River. Here, however, a change takes place, the indurated sandstone being replaced by soft sandstone and

[8] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin: Am. Mus. Nat. Hist. Bull., vol. 33, p. 312, 1914.

[9] Bauer, C. M., Stratigraphy of a part of the Chaco River valley U. S. Geol. Survey Prof. Paper 98, p. 65, 1916.

[10] Granger, Walter, Notes on Paleocene and lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. Hist. Bull., vol. 37, pp. 823-826, 1917.

shale. It is very difficult to locate exactly in this mass of soft, variable rocks the accepted dividing plane between the Torrejon and the "Tiffany" zone, though its approximate position may be traced. The exposures are good enough to show the pinching out of the individual indurated sandstone beds, so that no doubt exists as to the change in lithology.

Relation to adjacent formations.—The contact of the Torrejon formation with the Puerco, as shown on page 37, is indefinite but is probably unconformable. Where the Puerco is presumably absent the lower contact of the Torrejon formation is one of lithologic change and erosional unconformity without marked discordance of dip. The upper contact, with Wasatch sandstone, is in the southern part of San Juan Basin also one of lithologic change and, locally, of distinct erosion but without notable discordance of dip. The soft beds assigned to the Torrejon are directly followed by the basal cliff-forming sandstone of the Wasatch. To the southeast, however, near Cuba, N. Mex., the Wasatch formation overlaps the Torrejon and Puerco formations and rests upon them and older rocks with marked discordance.[11] The contact between the Torrejon formation and the overlying beds has been followed by the writer in very rapid reconnaissance between the head of Kimbetoh Arroyo, near the southeast corner of T. 24 N., R. 8 W., and the divide between San Juan and Animas rivers. It is much less distinct toward the north owing to the appearance in the upper Torrejon of indurated brown sandstones resembling the overlying formation, and in fact near the State boundary a separation is very difficult. So far as is now known, only the true Wasatch fauna (with *Eohippus*, *Phenacodus*, *Coryphodon*, *Pachyaena*, etc.) is present in the southern part of the San Juan Basin. In Colorado the earlier "Tiffany" fauna (see p. 46) is present east of Pine River, and the lithologic zone containing it has been traced westward into the beds just above the Torrejon formation on Animas River. The presence of these beds with the "Tiffany" fauna, intermediate between that of the Torrejon formation and the Wasatch, their lithologic similarity to the Torrejon formation, and the apparent continuity of the strata, strongly suggest that sedimentation in the northern part of the basin was continuous from Torrejon time into Wasatch time and that there is no such break in the series as is apparently present in the southern part of the basin.

Fossils.—The Torrejon formation contains a large vertebrate fauna. The mammals were listed in 1914 by Matthew[12] and the reptiles in 1919 by Gilmore.[13] These lists are given below without change, though a number of changes have been proposed since 1914 in the list of mammals.

Torrejon mammals:
- "Neoplagiaulax" molestus Cope.
- Ptilodus mediavus Cope.
  - trovessartianus Cope.
- Polymastodon fissidens Cope?
- Didymictis haydenianus Cope.
- Claenodon corrugatus Cope.
  - ferox Cope.
  - protogonioides Cope.
- Sarcothraustes antiquus Cope.
- Goniacodon levisanus Cope.
- Microclaenodon assurgens Cope.
- Dissacus saurognathus Wortman.
  - navajovius Cope.
- Chriacus pelvidens Cope.
  - truncatus Cope.
  - baldwini Cope.
  - schlosserianus Cope.
- Tricentes subtrigonus Cope.
  - crassicollidens Cope.
- Deltatherium fundaminis Cope.
- Palaeoryctes puercensis Matthew.
- Pentacodon inversus Cope.
- Mixodectes pungens Cope.
  - crassiusculus Cope.
- Indrodon malaris Cope.
- Psittacotherium multifragum Cope.
- Conoryctes comma Cope.
- Tetraclaenodon puercensis Cope.
  - minor Matthew.
- Mioclaenus turgidus Cope.
  - lydekkerianus Cope.
  - lemuroides Matthew.
  - acolytus Cope.
  - inaequidens Cope.
- Protoselene opisthacus Cope.
- Periptychus carinidens Cope.
  - rhabdodon Cope.
- Anisonchus sectorius Cope.
- Haploconus lineatus Cope.
  - corniculatus Cope.
- Pantolambda bathmodon Cope.
  - cavirictus Cope.

[11] Gardner, J. H., The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, pp. 717, 721, 1910.

[12] Matthew, W. D., Evidence of the Paleocene vertebrate fauna on the Cretaceous-Tertiary problem: Geol. Soc. America Bull., vol. 25, pp. 383-385, 1914.

[13] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, pp. 9, 10, 1919.

Torrejon reptiles and fish:
- Chelonia:
  - Compsemys torrejonensis Gilmore.
    - parva? Hay.
  - Baena escavada Hay.
    - sp. undetermined.
  - Adocus substrictus (Hay).
    - onerosus Gilmore.
    - annexus (Hay).
  - Hoplochelys saliens Hay.
    - paludosa Hay.
    - elongata Gilmore.
  - Plastomenus acupictus Hay.
    - n. sp. ? undet.
    - sp.
  - Aspideretes singularis Hay.
    - sp.
  - Platypeltis antiqua Hay.
  - Amyda eloisae Gilmore.
- Serpentes:
  - Helagras prisciformis Cope.
- Rhynchocephalia:
  - Champsosaurus puercensis Cope.
- Loricata:
  - Crocodylus sp.
- Pisces:
  - Lepisosteus sp.

In a late paper Matthew [14] says of the Torrejon fauna:

> The Torrejon overlies the Puerco conformably and contains the same and some additional families of archaic mammals, both multituberculates and placentals. Some of the Puerco phyla can be followed through, apparently as direct descendents, and in these there is evidence of considerable evolutionary change, representing a considerable lapse of time.

Poorly preserved invertebrates have been reported from the Torrejon formation,[15] but the only species that have been studied are those described by White [16] under the following names:

- Unio rectoides White?
- Helix nacimientensis White.
  - adapis White.
- Pupa leidyi Meek?

Several lots of poorly preserved plants were collected by the writer from the indeterminate zone beneath the lowest horizon of Torrejon mammals in the region adjacent to San Juan and Animas rivers. As these beds are treated in this paper as part of the Torrejon formation, the results of the examination of these collections by F. H. Knowlton are given here.

> 7371. 3 miles south of Farmington, N. Mex.; horizon about 50 feet above the Ojo Alamo sandstone:
> - Atrocarpus pungens (Lesquereux) Hollick.
> - Rhamnus goldianus? Lesquereux.
> - Platanus aceroides Goeppert.
> - Paliurus zizyphoides? Lesquereux.
> - Liquidambar? cucharas? Knowlton, but much smaller.
> - Dombeyopsis obtusa? Lesquereux.
> - Quercus sp.
> - Fragments of several types of dicotyledons.
>
> This material is very difficult and unsatisfactory to study, for although in the individual specimens the outline and nervation are well preserved the specimens are so fragmentary that it is impossible to make the identifications positive. So far as the fragments go they could be referred to the species indicated with reasonableness, but without the whole or the major portion of a leaf it is unwise or at least unsafe to make positive determinations. I believe, however, that these remains have been allocated with a reasonable degree of certainty, and therefore they indicate undoubted Tertiary age and the approximate position of the Denver and Raton formations.
>
> The previously known position and distribution of the forms listed is as follows: *Artocarpus pungens* was described from specimens collected from the Denver formation at Golden, Colo., and has been found in the Wilcox deposits of Mississippi, Arkansas, and Louisiana. It occurs in the San Juan Basin in the Animas formation and probably in the Puerco formation. *Rhamnus goldianus* is a very abundant form in the Denver and has been reported in beds presumed to be of similar age at Silver Cliff, Colo. It is also found in the Raton formation of southeastern Colorado and questionably in the Laramie at Marshall, Colo., where it occurs in the highest beds referred to the Laramie. *Platanus aceroides* has a very wide distribution in the Tertiary and is not now recognized as occurring in older beds. It occurs in the San Juan Basin in the Animas formation. *Paliurus zizyphoides* was described from specimens found at Black Buttes, Wyo., in beds believed to be of post-Laramie age and was subsequently identified in the Denver at Golden, in the Raton of southern Colorado, and doubtfully in the Laramie at Erie, Colo. It occurs in the Puerco formation of the San Juan Basin. The identification of *Liquidambar*? *cucharas* is not very certain. It is based on one side of a leaf that is much smaller than the type of the species, which came from the Raton formation of southern Colorado. The form assigned to *Dombeyopsis obtusa* is also unsatisfactory. The type locality of this species is the Laramie of Colorado Springs, Colo. It was found later at several places in the Laramie, in the Denver at Golden and Sedalia, Colo., and in the Dawson near Colorado Springs.
>
> 7437. Near the center of sec. 18, T. 30 N., R. 12 W., about 7 miles northeast of Farmington, N. Mex.; horizon 100 feet above the top of the Ojo Alamo

[14] Matthew, W. D., Fossil vertebrates and the Cretaceous-Tertiary problem: Am. Jour. Sci., 5th ser., vol. 2, p. 218, 1921.

[15] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, New Mexico: Am. Mus. Nat. Hist. Bull., vol. 33, p. 313, 1914.

[16] White, C. A., On the relation of the Laramie molluscan fauna to that of the succeeding fresh-water Eocene and other groups: U. S. Geol. Survey Bull. 34, pp. 11, 12, 1886.

sandstone. This material is very fragmentary, yet it obviously contains a number of very distinct types. There is, for instance, what appears to have been a large leaf with a very thick midrib and thin remote secondaries. It suggests a *Ficus*, but there is no margin preserved. There is a small ovate-lanceolate, entire-margined leaf that has the size and shape of *Juglans schimperi* Lesquereux, a Green River species, but it has a different secondary nervation. There is also a small ovate, long-pointed leaf with a sharply serrate margin and three ribs from the base of the blade that might well be *Zizyphus meigsii* (Lesquereux) Berry, a well-known species in the Wilcox and Raton formations. If this material had been submitted without stratigraphic data I should not have hesitated to place it in the Tertiary, but beyond that it would be hazardous to venture an opinion.

Age and correlation of the Puerco and Torrejon formations.—The Puerco formation is distinctly later than the Ojo Alamo sandstone, as shown by the erosion interval between them and the nearly complete change in lithology and fauna. Its relation to the Animas formation is not so clear, as the two formations are widely separated geographically and as the Animas formation has yielded no mammals and the flora of the Puerco formation is very small. Fortunately the flora of the Puerco formation, even though small, contains enough confidently identified species to link it closely with the Animas flora and no contradictory species at all. Unless the flora of the Animas formation consists of long-lived, persistent species, it is probable that there is little difference in age between the upper part of the Animas formation and the Puerco formation. A suggestion that the Animas flora contains at least some long-ranging species is contained in the character of the flora of the beds near Animas and San Juan rivers interpreted in this paper to be basal Torrejon, and in the small flora collected from the "Tiffany beds" (the base of the Wasatch formation). The Puerco formation may therefore be later than the Animas formation. However, the probable unconformity of the Torrejon on the Puerco and the demonstrated unconformity of the Torrejon upon the Animas lend support to the flora in indicating that the upper part of the Animas and the Puerco are close together in age. An exact correlation must await further data.

The Torrejon formation is probably unconformable upon the Puerco and is certainly unconformable upon the Animas formation. It is therefore later in time than either of them.

The Puerco and Torrejon formations have both been almost universally regarded as of early Tertiary age, though it has been proposed at various times to include them in the Upper Cretaceous. The small flora of the Puerco formation is interpreted as indicating the age to be that of the Raton, Denver, and Wilcox formations, all accepted as Eocene. The faunas of the Puerco and Torrejon are marked by the abundance of primitive mammals, turtles, and crocodiles and by the absence of dinosaurs. Matthew [17] in 1914 compared the early mammalian faunas known in the Edmonton, Paskapoo, Lance, and Fort Union formations with those of the Puerco and Torrejon. At that time he presented the classic view that the Edmonton beds were the oldest and intermediate in age between Judith River and Lance; the Paskapoo and Lance nearly the same in age and still Cretaceous; the Puerco beds younger than Lance but older than Torrejon and Fort Union and of earliest Tertiary age. In a brief review in 1921 Matthew [18] changes his views somewhat, stating that

> The Puerco "Lower Paleocene" * * * may be as old as the Lance or older, although usually regarded as later. The Torrejon and Fort Union faunas, Upper Paleocene, are not much later than the Lance, and the phyletic evolution indicates that they are considerably later than the Puerco. The Tiffany and Cernaysian faunas show a still later stage of the Paleocene faunas.

In a more extended discussion published a few months later Matthew [19] says:

> The Torrejon and Fort Union are Upper Paleocene, correlated by the paleobotanists with the lower Thanetian of Europe (Gelinden and Sezanne).
>
> The Puerco, Lower Paleocene, is post-Senonian but may be as old as the Lance or older. The fauna shows it to be considerably earlier than the Torrejon-Fort Union, and the near relations in stratigraphy and flora between Lance and Fort Union are strongly against intercalating between them the very wide time gap which is involved by placing the Puerco as later than the Lance. If so, we must conclude that the latest dinosaur faunas were contemporary with the older Paleocene mammalian fauna, and that it is owing to some imperfectly known differences in facies that they are not found associated. Some indirect evidence in support of this view is afforded by the Paskapoo, in which Lance mammals and Paleocene placentals are found associated.

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17 Matthew, W. D., Evidence of the Paleocene vertebrate fauna on the Cretaceous-Tertiary problem: Geol. Soc. America Bull., vol. 25, pp. 381-402, 1914.

18 Matthew, W. D., The Cannonball Lance formation: Science, n. ser. vol. 54, pp. 27-29, 1921.

19 Matthew, W. D., Fossil vertebrates and the Cretaceous-Tertiary problem: Am. Jour. Sci., 5th ser., vol. 2, p. 220, 1921

In these later papers Matthew is in favor of assigning the Puerco and Torrejon together with the succeeding "Tiffany beds" to the Cretaceous, though frankly stating that the opinions of other vertebrate paleontologists are not fully in accord with his. He cites H. F. Osborn as adhering to the older view that the extinction of the dinosaurs, presumably at the end of the Lance, marks the end of Cretaceous time, and he also cites J. W. Gidley as accepting the view advocated by the paleobotanists that Tertiary time began with the deposits containing the related Fort Union, Lance, Denver, and Raton floras and their equivalents in other regions.

It seems to the writer that in a general way the time interval represented by the sediments of the Ojo Alamo sandstone and the Animas formation, the Puerco formation, and the Torrejon formation of the San Juan Basin is equivalent to that of the Raton formation of northeastern New Mexico and southeastern Colorado, to that of the Arapahoe and Denver formations of the Denver Basin, and to that of the Lance and Fort Union formations of Wyoming, Montana, and the Dakotas. In the San Juan Basin the first and most notable break in the stratigraphic and biologic succession comes at the base of the Animas and Ojo Alamo formations and affords a suitable place to draw a systemic boundary. Whether this horizon can be recognized and is the best place to draw the boundary in other regions depends on the premises accepted as the basis for a judgment, and the verdict will be quite different as rendered by different individuals honestly weighing the same data. The writer has not presumed to pass judgment on the widely varying opinions expressed by different authorities as to the proper location of the Cretaceous-Tertiary boundary in the Interior province of North America but has indicated the conflict in interpretation of the data by questioning the assignment of the Ojo Alamo and Animas formations to the Eocene, while at the same time correlating them with the Raton and Denver formations, whose age has been accepted by most writers as Eocene, and with the Lance, variously placed in the Cretaceous and Tertiary and by the United States Geological Survey doubtfully in the Tertiary.

WASATCH FORMATION.

Identification and distribution in San Juan Basin.—In San Juan County, N. Mex., the base of the Wasatch formation formed the upper boundary of the writer's field work. It was mapped only in the extreme southern and northern parts of the county, the region between having been examined only in rapid reconnaissance without mapping except for approximate locations on a very generalized topographic map. In Colorado all of the formation present in the Ignacio quadrangle was examined. Few details are available regarding the formation in New Mexico. It was first noted as such by Cope [20] in 1874. Collections made by Cope and others brought into his hands representatives of 20 genera of Wasatch fossils from the San Juan Basin.[21] Cope estimated the thickness of the Wasatch formation of New Mexico as 2,500 feet. Granger in 1912 examined the formation near Gallina and Cuba, N. Mex., and made collections of fossils. On the basis of this work he estimated the total thickness as 1,000 feet and recognized two faunal divisions, a lower division, called the "Almagre beds," containing *Eohippus* and *Anacodon* and consisting of red, gray, and ocherous shale and sandstone, and an upper division, called the "Largo beds," containing *Eohippus*, *Meniscotherium*, and *Ambloctonus* and consisting of lithologic materials similar to those of the lower unit but with more red coloring. Most of the fossils recorded from the Wasatch formation of the San Juan Basin seem to have come from the southeastern part of the basin. In Colorado, between Los Pinos and Piedra rivers in southeastern La Plata County, beds near the base of the Wasatch formation containing a fauna intermediate between that of the Torrejon and Wasatch formations were noted by Gidley and Gardner.[22] These beds have since been called by Granger [23] the "Tiffany beds." They are

[20] Cope, E. D., Report on the geology of that part of northwestern New Mexico examined during the field season of 1874: Chief Eng. Ann. Rept. for 1875, pt. 2, appendix G 1, pp. 1008-1017.

[21] Granger, Walter, Lower Eocene of New Mexico and Wyoming: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 201-207, 1914.

[22] Gidley, J. W., in Wegemann, C. H., Wasatch fossils in so-called Fort Union beds of the Powder River basin, Wyo., and their bearing on the stratigraphy of the region: U. S. Geol. Survey Prof. Paper 108, p. 59, 1918.

[23] Granger, Walter, Notes on Paleocene and lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. Hist. Bull., vol. 37, p. 829, 1917.

treated in this paper as a faunal zone of the Wasatch formation, as they are not different in lithology from the beds above and in fact are separable only by their fauna. This zone has been traced northward from the type locality in sec. 20, T. 33 N., R. 6 W., to the southern part of T. 35 N., R. 6 W., and eastward as far as Pagosa Junction. It undoubtedly extends beyond that locality, but how far has not been determined. In all this region it may be identified by its fossils as well as by tracing the beds. Westward from the type locality it has been traced by following the beds to the divide between Animas and La Plata rivers and southward for some miles into New Mexico. It has not, however, yielded fossils west or south of the type locality, and the identification has depended entirely on tracing outcrops and on lithologic comparisons. In the southern part of the San Juan Basin this faunal zone is apparently absent, and beds with only the typical Wasatch fauna have been observed. Just where between northern and southern San Juan County this zone wedges out has not been determined. In this region, the location of Newberry's "Canyon Largo series," the formation is very clearly displayed in Canyon Blanco and Canyon Largo, but little detailed information regarding it is available. The Wasatch formation occupies the central part and much of the eastern part of the basin, for it is reported to overlap the older beds at many points along the eastern border. It is, so far as known and with the exception of much later gravels, the latest formation now present in the San Juan Basin.

Lithologic character and thickness.—In southeastern San Juan County the part of the Wasatch formation seen comprises a massive, cliff-forming basal coarse sandstone, 50 feet thick, of copper-red color, containing lenses of pebbles of chert and quartz; overlain by 150 feet of light-gray and red shale and soft white sandstone, overlain in turn by another sandstone very much like the first. Higher than these beds, but some distance back from their outcrop, are similar shales and sandstones. The basal contact of the lower sandstone is not conspicuously irregular at most places, though locally it shows erosion. The lithologic contrast is sharp.

Along Blanco and lower Largo canyons the Wasatch is excellently exposed. Locally the lower 300 feet or so seems to be one continuous sandstone bed. Elsewhere there is a succession of sandstone and shale beds, the sandstones mostly red-brown and resistant, the shales gray and red with layers of soft white sandstone irregularly intermingled.

On the divide between San Juan and Animas rivers the Wasatch formation consists of a succession of sandstone and shale beds; the sandstone gray-white to copper-red, rather coarse, containing small pebbles of chert and quartz; and the shale variegated, purple and gray, with intermingled soft white sandstone. The lower layers of sandstone are heavier and more massive than the higher layers. Near Cedar Hill, N. Mex., the lower 700 feet of the Wasatch formation is exposed, and higher beds are visible off to the east.

In Colorado the phase of the Wasatch formation consisting of brown indurated sandstone and variegated shale persists for a few miles north of the State boundary. It passes then into soft, fine conglomerate, soft sandstone, usually arkosic, and variegated shale. The mass viewed from a distance is of a rather even dove-gray color, but closer inspection shows red, greenish, and gray tones in about equal amount. This material weathers into slopes as if it were all shale. This softer phase of the Wasatch formation has been traced eastward across the Ignacio quadrangle to the H-D Hills, which extend from R. 6 W. to Piedra River. Here the lower 400 feet of the Wasatch formation, containing near the base the "Tiffany" fauna, consists chiefly of variegated green, red, and gray shale with a minor amount of fairly well indurated arkose. The arkose contains pebbles of pink feldspar as much as three-fourths of an inch in diameter in a matrix of fine-grained greenish material. The higher beds consist of gray shale with some red bands, soft sandstone, and some rusty-brown indurated sandstone and arkosic conglomerate. Gardner's section [24] of the formation describes the lithology well, though the writer is not certain whether the base of the section coincides with the base as drawn in this paper. No mention is made by Gardner of the prominent arkoses which the writer places in the lower part of the Wasatch forma-

[24] Gardner, J. H., in Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 185, 1917.

tion, and these may lie below the beds measured by Gardner. The thickness is certainly as great as that given in his section. Partial sections at several places are given on pages 55–58.

Relation to adjacent formations.—In southern San Juan County there is a sharp lithologic change from Torrejon to Wasatch and near the Nacimiento Mountains an overlap of the Wasatch and an angular discordance.

The uppermost Torrejon in southern San Juan County contains little brown resistant sandstone, but toward the north more and more of such rock appears until the gross lithology is much like that of the overlying Wasatch formation. The Torrejon sandstones are thinner, shorter lenses and do not form as much of the bulk of the formation as those of the overlying beds. This hazy distinction has been used in mapping the base of the Wasatch formation in northern San Juan County. There is no sign of an erosion interval or discordance in dip. Even this lithologic distinction disappears a few miles north of the State line in Colorado, for the whole series present above the Animas formation passes laterally into soft materials in which no breaks have been discerned.

The Wasatch formation, therefore, appears to be conformable on the Torrejon formation in the northern part of the San Juan Basin and unconformable in the southern part.

Fossils.—The latest list of Wasatch fossils from the San Juan Basin is that given by Matthew[25] in 1909. It does not include the "Tiffany" fauna. Matthew's list is repeated below without any of the later changes or additions:

Pelycodus jarrovii Cope.
  tutus Cope.
  frugivorus Cope.
Cynodontomys angulatus (Cope).
Didymictis pretenus (Cope).
  leptomylus Cope.
Vulpavus sp.
Ambloctonus sinosus Cope.
Oxyaena lupina Cope.
  forcipata Cope.
  morsitans Cope.
Sinopa viverrina (Cope).
  strenua (Cope).
  multicuspis (Cope).
  hians (Cope).
Pachyaena ossifraga Cope.
Hyopsodus miticulus (Cope).
Diacodon alticuspis Cope.
  celatus Cope.
Esthonyx burmeisteri Cope.
  acer Cope.
  bisulcatus Cope.
  spatularia Cope.
?Sciuravus buccatus (Cope).
Calamodon simplex Cope.
  arcamoenus Cope.
  novomehicanus Cope.
Ectoganus gliriformis Cope.
Phenacodus primaevus Cope.
  astutus (Cope).
  flagrans (Cope).
  ?sulcatus Cope.
Meniscotherium terraerubrae Cope.
  chamense Cope.
  tapiacitis Cope.
Coryphodon lobatus Cope.
  elephantopus Cope.
  latidens Cope.
Heptodon singularis (Cope).
Systemodon tapirinus (Cope).
Eohippus validus Marsh.
  angustidens (Cope).
  cuspidatus (Cope).
  cristonensis (Cope).
Trigonolestes chacensis (Cope).

The "Tiffany" zone has yielded a fauna as yet only partly described. The specimens collected by Gidley and Gardner[26] in 1909 were listed by Gidley as follows:

Coryphodon sp.
Phenacodont intermediate between Phenacodus and Euprotogonia.
Hemiacodon (? n. sp.).
Nothodectes sp.
Miscellaneous unidentified teeth.

The species collected by Granger[27] in 1916, as given in a preliminary report, included

Periptychus n. sp.
Phenacodonts, 3 species.
?Dissacus.
?Chriacus.
Nothodectes sp.
Many undetermined small mammals.

The writer made two collections in 1921 from the "Tiffany" zone. These have been examined by Mr. Gidley, and his report is as follows:

[25] Matthew, W. D., Faunal lists of the Tertiary Mammalia of the West, in Osborn, H. F., Cenozoic mammal horizons of western North America: U. S. Geol. Survey Bull. 361, pp. 92-95, 1909

[26] Gidley, J. W., in Wegemann, C. H., Wasatch fossils in so-called Fort Union beds of the Powder River basin, Wyo., and their bearing on the stratigraphy of the region: U. S. Geol. Survey Prof. Paper 108, p. 59, 1918.

[27] Granger, Walter, Notes on Paleocene and lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. Hist. Bull., vol. 37, p. 828, 1917.

Near head of Crowbar Creek, 5½ miles east of Bayfield, Colo., in sec. 11, T. 34 N., R. 6 W.; horizon in lower 100 feet of "Tiffany" zone of Wasatch formation:

Psittacotherium sp., portion of anterior tooth (canine?).

Tetraclaenodon or Phenacodus, lower molar in fragment of jaw.

Cf. Tricentes sp., two molars in portion of a lower jaw.

These fossils are not sufficiently complete nor characteristic enough to make positive the determination of the horizon. *Psittacotherium*, *Tricentes*, and *Tetraclaenodon* are Torrejon genera, the first never having been reported outside this horizon. However, the phenacodont tooth so closely resembles a corresponding one in our collection from the "Tiffany beds" as to lead me to believe that the species from this locality represent this horizon.

One mile west of Carracas station, Colo., on the Denver & Rio Grande Western Railroad, at the edge of the hills north of the railroad; horizon in the lower 100 feet of the "Tiffany beds":

Tetraclaenodon cf. T. puercensis (Cope). Three teeth, p 4, m 1, and m 2 (broken), in a portion of a left lower jaw; a first left lower molar in a fragment of jaw; a left lower molar crown but little worn; a right lower premolar, p 3.

Tetraclaenodon cf. T. minor (Matthew). Two right lower molars, m 2 and m 3.

Phenacodus cf. P. primaevus Cope. A left first lower molar in portion of jaw containing roots of p 3 and p 4.

Nothodectes cf. N. gidleyi or new species. A left upper incisor larger than Matthew's type.

Creodont of the Claenodon type, genus and species not determined but probably new. A last right lower molar in portion of jaw.

The fragmentary condition of most of the specimens of this lot is such that absolute dependence can not be placed on the above identifications. However, there seems to be here a rather unexpectedly mixed fauna of Wasatch, Torrejon, and "Tiffany" species. This assemblage of species does not exactly agree with our former conception of the "Tiffany" fauna as known from the type locality, and this intermingling of true Wasatch and Torrejon species, if substantiated by larger collections, may modify our idea of a considerable time interval between these two horizons.

Some of the material collected by Granger in 1916 and not identified at the time of his preliminary report (see footnote, p. 46) has since been studied and described.[28] These species include the following:

Zanycteris paleocenus Matthew.
Nothodectes gidleyi Matthew.
Ectypodus musculus Matthew and Granger.
Peradectes elegans Matthew and Granger.
Leptacodon tener Matthew and Granger.
Xenacodon mutilatus Matthew and Granger.
Labidolemur soricoides Matthew and Granger.
Ignacius frugivorus Matthew and Granger.
Navajovius kohlhaasae Matthew and Granger.
Carpodaptes aulacodon Matthew and Granger.

Two collections of fossil plants were made from the "Tiffany" zone of the Wasatch formation. These were examined by F. H. Knowlton, who identified the following forms:

7454. 5 miles east of Ignacio, Colo., in the center of the NE. ¼ sec. 19, T. 33 N., R. 6 W.; near base of "Tiffany" zone of the Wasatch formation:

Aralia? sp.
Ficus sp.
Celastrinites cf. C. artocarpidioides Lesquereux, a Denver species.
Fragments of dicotyledons.

7455. At milestone 436, 1 mile south of Florida station on Denver & Rio Grande Western Railroad; near base of "Tiffany" zone of the Wasatch formation:

Ficus planicostata Lesquereux.
cf. F. denveriana Cockerell.
cf. F. schimperi Lesquereux.
Fragmentary dicotyledons.

Ficus planicostata has been reported both from the Laramie and from later beds; *Ficus schimperi* and *Ficus denveriana* from the Raton and Wilcox formations, the last from the Animas formation also. Mr. Knowlton (p. 76) says of these collections:

This material is so poorly identified that little can be said as to age determination. If the suggested identifications were authenicated there would be no hesitation in regarding it as approximating in age the Denver and Raton formations, and there is nothing in the collections that in any way militates against this conclusion.

Age and correlation.—The Wasatch formation of the San Juan Basin contains in the higher beds the fauna that in the stricter sense of the name is considered characteristic—that with "*Eohippus* and its associated forms, which include lemuroids, rodents, and artiodactyls."[29] It contains also in the basal "Tiffany" zone a fauna intermediate between that of the Torrejon and that of the younger Wasatch beds—intermediate in the sense that

[28] Matthew, W. D., A Paleocene bat: Am. Mus. Nat. Hist. Bull., vol. 37, pp. 569-571, 1917; The dentition of *Nothodectes:* Am. Mus. Nat. Hist. Bull., vol. 37, pp. 831-839, 1917. Matthew, W. D., and Granger, Walter, New genera of Paleocene mammals: Am. Mus. Nat. Hist. Novitates, No. 13, 1921.

[29] Granger, Walter, Notes on Paleocene and lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. Hist. Bull., vol. 37, pp. 829-830. 1917.

it associates genera known in the typical Torrejon but not in the typical Wasatch faunas and genera known in the typical Wasatch but not in the typical Torrejon. The typical Wasatch fauna is widespread in the Rocky Mountain region, and the beds that contain it are usually designated the Wasatch formation, though locally numerous names distinctive of faunal zones within the formation have been applied. The "Tiffany" fauna is known in the "Clark Fork beds" of the Wasatch formation in northwestern Wyoming. Matthew[30] says that the "Tiffany" zone

> is still faunally Paleocene, the mammals archaic placentals. The phyla that can be traced through show in some instances a considerable advance beyond the Torrejon, indicating considerable lapse of time, and are very close to the succeeding Wasatch horizons of the true Eocene. But in the Tiffany, as in the Torrejon, the modernized placental mammals, abundant in the overlying horizons of the Wasatch, are almost wholly absent. There is between Tiffany and true Eocene very little lapse of time but a great change of fauna. For various reasons impossible to present here I hold that the change is not explainable as due in any degree to difference in facies but must be due to migration.

The assignment of the typical Wasatch to the Eocene has never been questioned. Granger likewise placed his "Tiffany beds" in the Eocene, but Matthew, because of their relations to the Torrejon faunally, proposes to place them with the Torrejon, in the Cretaceous system.

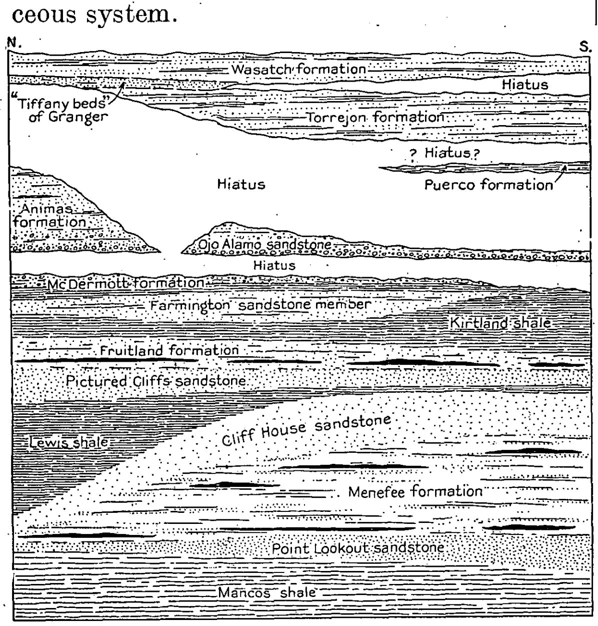

FIGURE 3.—Diagram showing the relations of the formations along the west side of the San Juan Basin.

[30] Matthew, W. D., Fossil vertebrates and the Cretaceous-Tertiary problem: Am. Jour. Sci., 5th ser., vol. 2, p. 218, 1921.

SUMMARY OF THE RELATIONS OF THE FORMATIONS WITHIN AND WITHOUT THE SAN JUAN BASIN.

The relations of the formations within the San Juan Basin to one another have been given in the descriptions of the individual units. These are summarized graphically in Figures 3 and 4. Figure 3 sets forth the relations as shown

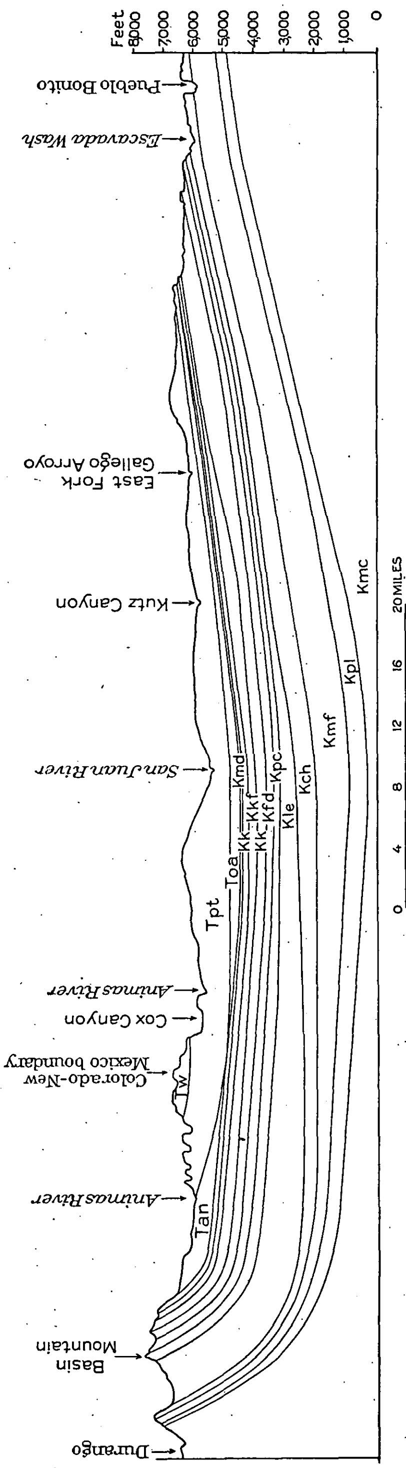

FIGURE 4.—Diagrammatic section across the San Juan Basin from Durango, Colo., to Pueblo Bonito, N. Mex. For explanation of symbols see Plate I.

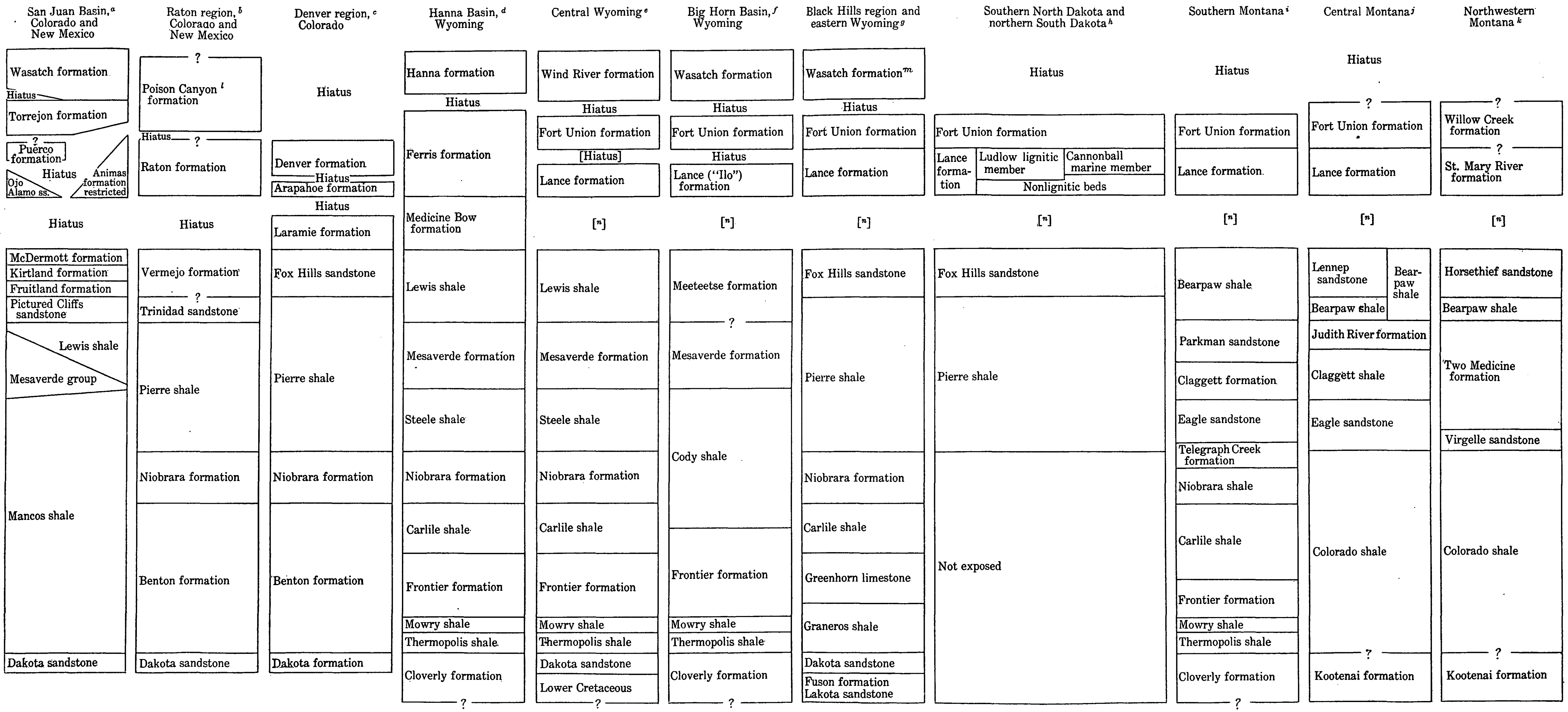

DIAGRAM SHOWING THE APPROXIMATE CORRELATION OF THE FORMATIONS OF SAN JUAN BASIN WITH THOSE OF OTHER REGIONS IN THE WESTERN INTERIOR.

As interpreted by John B. Reeside, jr.

[a] This paper.
[b] Adapted from Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, 1917.
[c] Adapted from Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, 1896.
[d] Adapted from Bowen, C. F., Stratigraphy of the Hanna Basin, Wyo.: U. S. Geol. Survey Prof. Paper 108, pp. 227-241, 1918.
[e] Adapted from Hares, C. J., Anticlines in central Wyoming: U. S. Geol. Survey Bull. 641, pp. 233-279, 1916.
[f] Adapted from Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 656, 1917.
[g] Adapted from various publications.
[h] Adapted from Lloyd, E. R., and Hares, C. J., Jour. Geology, vol. 23, pp. 524-547, 1915; and Winchester, D. E., Hares, C. J., Lloyd, E. R., and Parks, E. M., U. S. Geol. Survey Bull. 627, p. 16, 1916.
[i] Adapted from Thom, W. T., jr., Oil prospects in and near the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 736, pp. 35-53, 1922.
[j] Adapted from various publications.
[k] Adapted from Stebinger, Eugene, The Montana group of northwestern Montana: U. S. Geol. Survey Prof. Paper 90, pp. 61-68, 1915.
[l] The Poison Canyon and Raton formations may differ but little in age and may be simply varying phases of sedimentation: Lee, W. T., and Knowlton, F. H., op. cit., p. 61.
[m] Not present east of Salt Creek and Powder River fields of east-central Wyoming.
[n] Most geologists, including the authors cited, who have examined the formations of this region consider that no hiatus exists at this horizon. Others believe the absence of beds containing the Laramie flora to indicate a break in sedimentation. The writer can not account for the absence of such beds but nevertheless believes the evidence now available to show a transition without hiatus from pre-Lance to Lance deposition.

along the outcrop and as inferred from other data.

The relations of the formations of San Juan Basin to those of some of the other parts of the Western Interior are shown in Plate IV. Most of the correlations shown in this diagram are of long standing and need no special discussion.

A tentative correlation with the European time scale is given in Figure 5. The correlation of the Tertiary part of the section is based chiefly on the published correlations of the vertebrate paleontologists. The correlation of the Cretaceous part of the section is in large part of long standing.

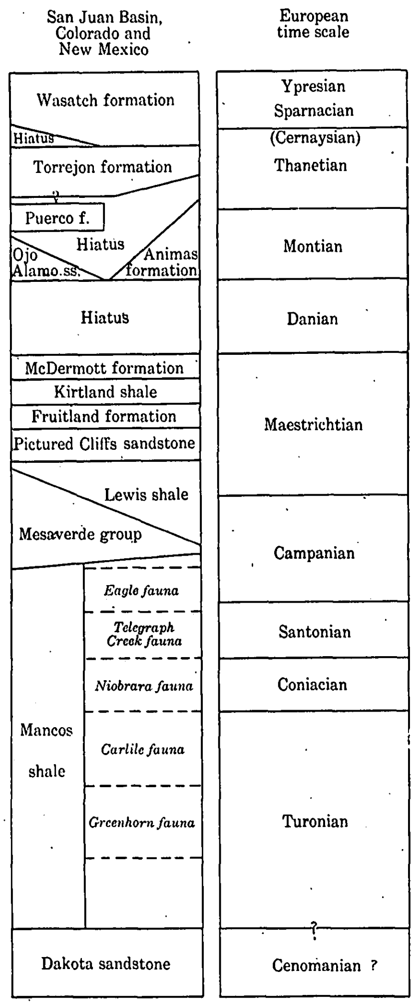

FIGURE 5.—Tentative correlation of the formations of the San Juan Basin with the European time scale.

PHYSICAL HISTORY OF THE WESTERN PART OF THE SAN JUAN BASIN FROM MANCOS TIME TO WASATCH TIME.

During Mancos time the San Juan Basin and the adjoining country were occupied by a sea in which the sediments that were being deposited were chiefly muds. The nearest shore of this sea seems to have been off to the southwest, in Arizona. Into the San Juan Basin itself little sand was brought except in the very early stages and at the time of deposition of the Tocito sandstone. In adjoining areas nearer to the shore, however, some beds of sand accumulated, especially south of San Juan County, and at some places there was even more sand than mud. These muds and sands are now represented by shales and sandstones containing marine fossils. The similarity of the fossils of this sea of Mancos time to those present in deposits within and east of the present Rocky Mountains and in deposits in the present Gulf coastal region indicate that the sea extended over the site of the present mountains and far beyond and was connected on the south with the waters in which the Cretaceous deposits of the Gulf region were being laid down.

Toward the end of Mancos time the sea began to withdraw from the area, probably toward the northeast. The sea in the south became shallower as the shore line approached, and more and more sand was deposited there until the deposits were all sand—the present Point Lookout sandstone. This set of conditions moved only gradually northward, and muds were still being deposited on the site of the north side of the present basin long after the sandy type of sedimentation had begun at the site of the south side of the basin, as is shown by the position of the fossil zones with reference to the change in lithology.

However, the conditions producing the sandy marine sediments did not persist long at any one place, for they were succeeded quickly from place to place by conditions of relative instability. The shallow waters in which the Point Lookout sandstone was deposited became shallower still, and a period began during which there were constantly changing swamps and lagoons—that is, actual shore conditions with the sea very near at hand. Muds and sand accumulated. At times only fresh water flooded the swamps and lagoons; at other times, marine waters. Around and in the swampy areas lived plants of many kinds, whose remains now form beds of coal and impressions of whose leaves occur in the sandstones. The beds formed when the water was fresh contain the remains of fresh-water animals; the beds formed when the sea came in contain the remains of marine animals. This mass of coal and hardened muds and sands, with both fresh-water and marine fossils, is the Menefee formation, evidently laid down near tide level.

This unstable period in the north was not very long relatively, for the sea ceased its retreat and began to return to the area it had previously occupied. There was again at each place, as the sea moved gradually southeastward, shallow water in which marine sands were laid down. These sands formed the Cliff House sandstone of to-day, which is therefore considerably younger in the south than in the north, and the conditions of the Menefee deposits persisted in the south long after the sea had returned to the northern part of the area. At this time also the sea must still have covered a great area, for the same species of fossils occur both in and far beyond the San Juan Basin. Some of these fossils occur elsewhere only in the region east of the Rocky Mountains and in the basins now inclosed by the mountains, and other species have their nearest relatives in the Gulf coastal region.

The shallow sea in which the sands of the Cliff House sandstone were accumulated became deeper as the shore line moved farther away to the southwest, and then muds chiefly were deposited. These muds were, of course, much thicker in the northern part of the basin than in the southern part, and indeed so gradual was the movement of the shore line that a considerable thickness of mud was formed in the north while Menefee and Cliff House sediments were still forming in the south. There was in fact but little mud deposited in the south and practically no change in conditions from those of the Cliff House sandstone. The muds of these deeper waters formed the Lewis shale of to-day.

There is, then, owing to this retreat and advance of the sea, a great wedge-shaped mass, chiefly of sandy rocks, whose thinner edge projects northeastward between the Mancos shale below and the Lewis shale above. The thick side of this wedge was being formed during the same time that the upper part of the Mancos shale, the thin part of the wedge, and practically all of the Lewis shale were forming. The wedge, made up of the three divisions, Point Lookout, Menefee, and Cliff House, constitutes the Mesaverde group of sediments.

After a time the sea became shallow again, the waters apparently withdrawing quickly from the whole area and leaving as they went a relatively thin but widespread mantle of sand containing the remains of marine animals. This near-shore deposit of sand formed the Pictured Cliffs sandstone, the last purely marine formation of the region, though a few later incursions of sea water during the deposition of the next higher formation are shown by the presence of shells of brackish-water animals.

The deposition of the Pictured Cliffs sandstone was followed by a relatively short period of unstable conditions like those represented by the Menefee formation. Swamps in which vegetable débris accumulated, occasional incursions of salt water which permitted oysters and brackish-water animals to thrive, and bodies of fresh water in which fresh-water animals lived are clearly recorded in the sediments and indicate a low, poorly drained coastal region. The shore line seems then to have passed on toward the east, for no more salt water reached the region, and rivers were the chief depositing agency. Highly variable beds of sand, sandy mud, and clay that show every indication of being flood-plain deposits were formed. For the first time since the beginning of the Upper Cretaceous, so far as present knowledge extends, dinosaurs became abundant in the region, and river turtles flourished. The complex of fresh and brackish water shales, sandstones, and coal beds containing a varied array of fossils, which now represents the muds and other deposits, is the Fruitland formation.

The deposition of the Fruitland formation was followed without interruption by that of a thick series of clays and sandy muds, which are now the Kirtland shale. In the south few layers of purer sand were deposited, but in the north the middle part of the series contains many lenses of sand, which now, hardened into sandstone, make up the Farmington sandstone member of the Kirtland shale. The formation shows many features to indicate that it was laid down on a river flood plain. The sediments suggest sluggish streams and a source that was not high enough to supply coarse materials. They contain plant fossils in the form of leaf impressions and logs, shells of fresh-water animals, and remains of fish, river turtles, and dinosaurs.

Upon the Kirtland shale was deposited a rather peculiar mass of sediments now included in the McDermott formation, an explanation of whose origin is perplexing. On the north side of the present basin this material consists largely of débris derived from eruptions of andesitic lava and ash, most of it of purplish color and little weathered. It contains beds of cobbles and boulders of andesite that must have required large, rapidly moving streams to transport them. At many localities there are also thin beds of pebbles of many sorts of hard, resistant siliceous rocks and beds of sandy and clayey matter associated with the beds of andesitic débris. The proportion of andesitic matter in the formation decreases southward in a very marked fashion, though some is present everywhere, and it seems quite clear that the andesitic débris came from the north, from some part of the region covered by the San Juan Mountains. The sources of the siliceous pebbles are unknown, though they can hardly be the same areas as those which yielded the andesitic débris, and moreover most of the rocks represented among the pebbles are not known in the present mountain region north of the San Juan Basin. We may conjecture with some reason that the land from which the pebbles were derived lay to the south or east rather than to the west, but at present there is little basis for a definite assertion as to its position or extent.

The sudden appearance of these beds of andesitic débris and of siliceous pebbles raises many questions. If they came from the same land masses that yielded the material of the pre-McDermott deposits why are they absent from these deposits and why do they appear suddenly? The similarity of the plant and animal fossils of the McDermott and Kirtland formations and the lack of any recognizable widespread break in the series of deposits constitute strong arguments against the assumption of a time interval between the formations. Yet the andesitic lava and ash had to be available for erosion, and, as the siliceous pebbles include rocks certainly as old as Carboniferous, and probably as old as pre-Cambrian, their sources had to be exposed and subject to erosion before the deposition of the McDermott formation began. If a long time had elapsed between the deposition of the Kirtland shale and that of the McDermott formation, there would have been time in this interval for the eruption, erosion, and transportation of the andesitic débris and for the uncovering, erosion, and transportation of the siliceous constituents. Such an interval would be a very logical and consistent explanation of most of the facts that have been observed. However, as neither the fossils nor the apparent physical features of the contact of the deposits warrant the deduction that any considerable time interval is represented, some other explanation must be offered.

Probably there were, near the end of Kirtland time, outbursts of andesitic lava and ash somewhere in the region to the north. With these eruptions came heavy rains that supplied the volume of water necessary to move the coarse materials now seen in the McDermott formation. The rapidity with which erosion and transportation followed the eruption of the material would account for its sudden appearance in the series of deposits and its relative freshness. There may have been going on some general change in the attitude of the land surface—some uplift or premonitory symptom of the period of mountain building that was to follow, of which the volcanic eruptions were one phase. That there is nothing unreasonable about the presence of andesitic outbursts in the Rocky Mountain region as early as this time is shown by the still older and even more extensive deposits of andesitic débris in the Livingston formation of the Livingston region, Montana. The supposition of some general change, furthermore, helps to explain the appearance of the siliceous pebbles. They could very well have been forming for a considerable period on a land mass not covered by Cretaceous sediments, or at least not covered at the end of Montana time and drained by streams that could not carry the pebbles as far as the San Juan Basin. Then, through the quickening of the streams by the volcanic rains or by the accumulated change in the attitude of the land, they were carried to their present locations at about the same time as the volcanic products reached the basin. The pebbles would easily have withstood long weathering and transportation. However it may have happened, the net result of the activities of McDermott time was the formation of a blanket of sediments, coarser and consisting chiefly of andesitic detritus on the site of the north side of the present San Juan Basin, and finer and with less volcanic matter southward until at its southernmost occurrence it is not strikingly different from the Kirtland shale, except for the purplish color of some beds. Plants continued to live in the region during McDermott time, and also dinosaurs, turtles, and crocodiles.

There is no important break in the series of deposits included in the Mancos shale and later formations up to the top of the McDermott formation. The formations pass each one into the next by a continuous gradation of shale into sandstone or sandstone into shale, except for the local erosion at the base of the McDermott formation. All the changes in the marine beds were caused by a shift of the shore line that brought the sandier near-shore sediments closer or placed them farther away. The cause of such shifts is open to dispute; it may possibly have been a worldwide rise or fall of the sea level, a rise or fall of the land in certain regions without material alteration of the general sea level, or the filling and sinking irregularly of the area that was receiving the sediments. The river-made sediments vary but little in general composition. The changes before the end of McDermott time seem to have occurred without sharp local disturbances. The deposition of the McDermott formation, however, ended with a change of considerable importance. The sediments of the San Juan Basin were uplifted enough to cause erosion to begin, and locally there was folding that tilted the beds. The folds that now delimit the north and west sides of the basin probably began to form at this time, though the movement continued at later times.

After the uplift and erosion that carried away parts of the older beds, volcanic outbursts to the north of the San Juan Basin again poured out andesitic lava and ash. There was apparently time for some weathering, and then a considerable thickness of this material, greenish gray in color, was brought southward by streams and spread out to form what we now call the Animas formation. In some places it lies across the uplifted and eroded edges of the older formation. In others erosion had not produced any large irregularities of the surface and the new materials lie so evenly upon the old that there is little local evidence of the interval represented at their contact. During the early part of the time when the beds of andesitic débris were forming other materials, largely nonvolcanic, were coming into the San Juan Basin from some other direction, through the action of streams. These materials were largely in the form of sand, but at times the currents were strong enough to transport large pebbles and cobbles, which are of siliceous composition and very like the pebbles of the McDermott formation. Some material of this sort is present in the Animas formation, but most of the sand and conglomerate beds formed from these nonvolcanic materials are in the Ojo Alamo formation.

The Ojo Alamo is not known anywhere to come into direct contact with the Animas formation, the areas of deposition not overlapping so far as now known, though of course we do not know what is present under the cover of later beds in the center of San Juan Basin. Whether these nonvolcanic materials were laid bare on an old land mass during a long period preceding their deposition or whether this erosion of a great thickness of rock occurred mostly during the interval following the deposition of the McDermott formation is not definitely known. The very similar material present in the McDermott formation suggests that the sources were the same and that erosion had proceeded far at the sources, even in McDermott time. If this is true, not so long a time interval between the McDermott formation and the succeeding beds is required as there would be if the erosion of the regions outside of the San Juan Basin contributing the sedimentary materials all took place in post-McDermott time. The erosion shown within the San Juan Basin and the change in flora from the McDermott to the Animas tend to show, however, that a fairly long period elapsed between Animas (and Ojo Alamo) and McDermott time. The Ojo Alamo sandstone, like the Animas formation, was at many places laid down on a surface with few irregularities and gives little evidence of any gap in sedimentation at its base. In the southeastern part of the San Juan Basin it was deposited across the eroded edges of the older rocks. In the region covered by the Ojo Alamo sandstone dinosaurs were numerous and varied in type. They were present also in the region covered by the Animas beds in early Animas time, but little else is known of them there. A variety of plants is known from the whole of the Animas formation, which shows that the flora was much like that occurring in the similar deposits on the east side of the present Rocky Mountains.

The deposition of the Animas and Ojo Alamo formations was followed by another period of local folding and erosion. Upon the surface thus formed were laid down by rivers the mud and sand that now constitute the Puerco and Torrejon formations. It is difficult to-day to interpret the history of Puerco and Torrejon time. The sediments of the Puerco formation did not cover a large area, so far as now known, but those of the Torrejon spread out much farther. In the region in which both occur they are so much alike that they can not be sharply separated. The Puerco beds, consisting chiefly of dark muds and constituting the lower part of the series of deposits, seem not to have had a wide extent—in fact, it would be pure conjecture to say that they much exceeded their present known area in the southwestern part of the San Juan Basin. They were deposited on an irregular surface of Ojo Alamo sandstone, though the unconformity is not a striking or conspicuous break. Possibly the Puerco beds were laid down contemporaneously with the later beds of the Animas formation, for they both contain the same species of plants. In the Puerco epoch mammals became for the first time abundant in the region, and there were also numerous river turtles and crocodiles. The dinosaurs had disappeared completely, and they appeared no more later. The Torrejon deposits must have covered practically the whole basin, for they may be traced around its south and west sides and reach the north side. Not the same sort of stuff was laid down everywhere, however. In the south chiefly muds were deposited, some of them sandy but with sand as only a minor part. Toward the north more pure sand was brought in and locally lenses of small pebbles in sand. This difference is accentuated to-day by the fact that the clayey muds and sandy muds formed soft rocks, while the purer sands formed hard, resistant sandstones. The Torrejon beds rest on the Puerco beds without a conspicuous break—in fact, they are not separable by any recognizable difference in lithology or structure. This feature is made more pronounced by the presence of a doubtful zone of sediments that may be either Puerco or Torrejon. There is reason, however, to believe that an interval not represented by sediments separated Puerco and Torrejon time. The Torrejon deposits in the present Animas Valley in Colorado were laid directly on the Animas beds, and it is possible, though indicated only by negative evidence, that they rest at other places directly on the Ojo Alamo sandstone. The mammals and reptiles that lived in Torrejon time, though similar to those of the Puerco, are sufficiently different to suggest the lapse of enough time to permit an evolutionary change to take place. There may have been, therefore, a gap between Puerco deposition and Torrejon deposition, but it can not yet be rigidly proved.

In the north the deposition of materials seems to have continued without interruption from Torrejon time through the interval represented by the "Tiffany" zone to true Wasatch time. There was no change in the sort of sediments that accumulated: they were river-formed muds and sands of much the same general type throughout. Some of the animals of Torrejon time lived on into "Tiffany" time, when the first Wasatch animals appeared. The fauna of the Torrejon beds therefore grades through that of the "Tiffany" zone into that of the unquestioned Wasatch. In the south no equivalent of the "Tiffany" zone has been found. There seems to have been an interval of erosion in this part of the area, and the Torrejon beds in San Juan County are followed sharply by the basal pebble-bearing sandstone of the Wasatch, and this in turn by alternating shale and sandstone. Near the Jemez Mountains there was some uplift, folding, and erosion after Torrejon time, and the Wasatch formation was deposited upon the upturned and eroded edges of the Torrejon and older beds. Apparently sediments were being laid down continuously on the north side of the basin while deformation and erosion were going on at the south side. How widely the Wasatch beds were originally distributed in this region is not clearly known, but they may have covered a very wide area and since been greatly reduced by erosion.

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LOCAL SECTIONS.

Section exposed along Cat Creek north of Pagosa Junction, Colo.

	Feet.
Wasatch formation:	
Brown sandstone and gray and reddish shale, thickness not determined.	
Sandstone, coarse, rusty brown arkosic	5
Shale, variegated, red, gray, green, with small dark-colored phosphatic concretions	65
Sandstone, coarse, arkosic, brown to greenish gray; has coarse feldspar pebbles locally	25
Shale, variegated, red, gray, and green; contains some soft argillaceous sandstone. The lower part of this shale contains the "Tiffany" fauna	305
Unconformity.	
Animas formation:	
Sandstone, greenish gray and green, fine grained, tuffaceous	30
Shale, greenish gray to tan, tuffaceous	70
Sandstone, green to tan, fine grained, tuffaceous	20
Shale, greenish gray to tan, tuffaceous	70
Sandstone, green to tan, fine grained, tuffaceous; contains plant remains	10
Shale, greenish gray to tan, with some soft sandstone; tuffaceous	120
Sandstone, greenish gray, fine grained, tuffaceous; contains plant remains	10
Shale, greenish to tan, with some soft sandstone; contains plant fragments	200
Sandstone, greenish gray, massive; some lenses of fine conglomerate present	40
Shale, greenish, with some sandstone lenses	20
Animas formation—Continued.	
Sandstone, fine, greenish, tuffaceous	15
Shale, greenish gray to tan, tuffaceous	85
Sandstone, fine grained, greenish gray, tuffaceous; contains plant remains	10
Shale, greenish gray to tan	30
Sandstone, fine grained, greenish gray to brown; contains plant remains	5
Shale, greenish gray	65
Sandstone, greenish gray, platy, tuffaceous; contains plant remains	5
Shale, greenish gray to tan, tuffaceous, and soft sandstone	285
Sandstone, greenish gray, tuffaceous	5
Shale and soft sandstone, tuffaceous, greenish gray	190
Conglomerate, pebbles, nearly all of greenish weathered andesite; matrix greenish andesitic débris; a few quartz and quartzite pebbles present; prominent ridge-forming unit; plant remains abundant	75
Shale and indurated sandstone, interbedded; all tuffaceous, greenish gray; some layers conglomeratic; plant remains abundant	260
Conglomerate, massive, greenish gray; pebbles of andesite with many of quartz, quartzite, and other rocks	25
Shale and thin sandstone, greenish gray, not well exposed	195
Total Animas formation	1,840
Unconformity.	
Fruitland formation:	
Sandstone, bluish gray, dense, medium grained; full of vegetable débris	6
Shale, gray	5
Shale, brown, carbonaceous	9
Coal bed	2
Shale, brown, carbonaceous	10
Coal bed	4
Shale, brown, carbonaceous	10
Sandstone, thin bedded, gray, medium grained	3
Shale, brown to black, carbonaceous	14
Sandstone, heavy bed, brown	4
Shale, brown, carbonaceous	2
Coal bed	3
Shale, brown, carbonaceous	4
Pictured Cliffs sandstone: Massive gray to brown marine sandstone	150
Lewis shale.	

Section on Pine River-Piedra River divide in secs. 29, 31, 32, T. 35 N., R. 5 W., Colo.

	Feet.
Wasatch formation:	
Top of formation eroded off.	
Sandstone, rusty brown, indurated, and gray shale, not well exposed; some beds of conglomerate with pebbles of pink feldspar, quartz, and chert. Lower 470 feet of this unit measured; remainder estimated to crest of divide	1,000

	Feet.
Wasatch formation—Continued.	
Arkose, coarse, with pebbles of pink feldspar as much as three-fourths of an inch in diameter in a fine greenish matrix; conglomeratic layers separated by thick layers of variegated red, green, and gray shale. The shale forms the bulk of the unit, but the arkose is resistant and more prominent. The lower part of this unit contains in this section the "Tiffany" fauna	390
Unconformity, shown by absence of Torrejon formation.	
Animas formation:	
Shale, greenish gray to tan, fairly well exposed	220
Sandstone, greenish gray	5
Shale, greenish gray to tan, poorly exposed	115
Sandstone, greenish gray, with andesitic débris, medium grained	10
Shale, greenish gray to tan; some sandstone included	780
Sandstone, greenish gray, with andesitic débris, platy	10
Shale, greenish gray to tan, fairly well exposed	270
Sandstone, green, thin, platy	2
Interval poorly exposed; probably all greenish shale and fine sandstone	370
Conglomerate; pebbles all of greenish andesite, as much as 1 inch in diameter	5
Interval poorly exposed; probably all greenish shale and fine sandstone	515
Conglomerate, rather fine; pebbles all andesite in tuffaceous matrix; greenish gray	5
Interval concealed	23
Sandstone, coarse, green, tuffaceous	10
Conglomerate, pebbles 2 to 4 inches in diameter and mostly of greenish andesite	10
Interval concealed	170
Sandstone, or grit, tuffaceous, greenish gray	10
Interval concealed	100
Sandstone, containing much fine andesitic débris and pebbles of andesite, greenish gray	40
Total Animas formation	2, 670
Unconformity.	
Kirtland shale and Fruitland formation, undifferentiated	795
Pictured Cliffs sandstone	125

Section of Animas and McDermott formations on Animas River 4 miles south of Durango, Colo.

	Feet.
Torrejon formation.	
Unconformity.	
Animas formation:	
Shale, sandstone, and fine conglomerate, greenish gray to tan; contains much weathered andesitic débris	850
Conglomerate, massive; pebbles and cobbles as much as 6 inches in diameter, of greenish andesite chiefly but with a considerable admixture of quartz, quartzite, etc.; greenish gray to brown	25
Shale, yellow, sandy, weathered; contains andesitic débris	30
Conglomerate, much like second unit above	10
Shale, yellow, sandy, much weathered; probably contains much fine andesitic débris	35
Conglomerate, much like second and fourth units above	25
Shale, greenish gray to tan, gritty; contains andesitic débris	55
Conglomerate, massive; pebbles and cobbles practically all of greenish andesite, 6 to 8 inches in diameter, with a few rare pebbles of other rocks; contains fossil logs	25
Tuff, green to buff; much of it about as coarse as sand but some parts really a fine conglomerate and here and there a little coarse conglomerate; material all weathered andesite. Some maroon bands near the top of the unit and some black carbonaceous shale	40
Conglomerate, massive; contains boulders as much as 3 feet in diameter though mostly cobbles 6 to 8 inches in diameter; poorly sorted; practically all of greenish andesite with very rare quartzite and sandstone	15
Total Animas formation	1, 110
Unconformity.	
McDermott formation:	
Shale, tuffaceous, or laminated tuff; purple to maroon, with a few gray streaks; a little fine conglomerate	40
Tuff, finely conglomeratic, massive, purple; weathers into angular fragments	28
Conglomerate, gray to purple, locally stratified; contains pebbles and cobbles of andesite mostly from 1 to 8 inches in diameter but a few as large as 18 inches; all subangular; matrix of same material as pebbles	15
Shale, tuffaceous, purple, laminated, alternating with layers of massive, nonlaminated volcanic débris	45
Sandstone, dense, bluish gray, finely and regularly laminated; breaks with conchoidal fracture; practically a porcellanite; weathers almost white	8
Tuff, purple, containing masses of andesite as much as 4 feet in diameter	100
Sandstone, yellow, coarse, containing volcanic detritus; near the base a thin shale	20
Total McDermott formation	256

	Feet.
Sharp contact, without angular discordance; may be an unconformity.	
Kirtland shale and Fruitland formation undifferentiated	1,200
Pictured Cliffs sandstone.	

Section along north side of NE. ¼ NW. ¼ sec. 5, T. 32 N., R. 11 W., La Plata County, Colo.

	Feet.
Torrejón formation:	
Beds above section mostly concealed, but some exposures of light-gray shale are visible.	
Shale, drab and yellow-brown	30
Shale and soft sandstone, light gray	30
Shale, drab and yellow-brown	40
Sandstone, fine, hard, bluish gray on fresh surface and dark reddish brown on weathered surface	3
Shale, drab and yellow-brown	40
Concealed interval, forming a valley, probably shale	240
Unconformity probably present though not observed.	
McDermott formation:	
Conglomerate of siliceous pebbles in a matrix of brownish andesitic tuff	2
Interval, largely concealed but apparently consisting of yellow-brown tuffaceous shale	84
Sandstone, gray-white, with lenses of siliceous pebbles; pebbles reach 3 inches in diameter	25
Beds below section concealed in valley; probably Kirtland shale.	

Section of McDermott formation at center of NW. ¼ SW. ¼ sec. 5, T. 32 N., R. 11 W., La Plata County, Colo.

	Feet.
Beds above section concealed; probably all in Torrejon formation.	
McDermott formation:	
Conglomerate of siliceous pebbles in a brown tuffaceous matrix; pebbles reach 2 or 3 inches in diameter	4
Shale, yellow, ashy	2
Conglomerate like that above	2
Shale, purple, tan, and drab, with thin sandstone layers	17
Sandstone, bluish gray, tuffaceous, in thin nodular layers separated by sandy shale of greenish-gray color; upper part of unit contains many cobbles of weathered andesite; some dinosaur bones, turtle bones, and silicified wood	33
Shale, purple, tan, and drab, with some thin sandstone layers, all containing débris from igneous rocks	22
Sandstone, gray, coarse, with siliceous pebbles	3
Shale, gray and purple	30
Beds below section concealed to the Farmington sandstone member of Kirtland shale. Probably in part Kirtland shale.	

Typical section of McDermott formation at south side of SW. ¼ NW. ¼ sec. 19, T. 32 N., R. 11 W., La Plata County, Colo.

	Feet.
Beds belonging to the Torrejon formation mostly concealed but with rare exposures of light-gray shale, gray-white soft sandstone, and some black carbonaceous shale and thin green sandstone.	
Unconformity.	
McDermott formation:	
Conglomerate of pebbles of bright-red jasper, red and white quartzite, chert, and rarely andesite; pebbles all chatter-marked and as large as 6 inches in diameter; matrix andesitic tuff	4
Shale, yellow-brown, sandy	60
Conglomerate like that above	2
Shale, purple and yellow, containing volcanic débris	32
Conglomerate, drab to green, composed of andesite pebbles, cobbles, and boulders as much as 1 foot in diameter and a sprinkling of small jasper, quartzite, and quartz pebbles; matrix andesitic tuff. Unit irregular along strike. Dinosaur and turtle bones in place	8
Shale, drab to purple, containing volcanic débris	40
Sandstone, light gray to white, containing pebbles of andesite and andesite débris	20
Sandstone, fine, soft, yellow-brown, capped by hard, thin platy greenish sandstone; loose fragments of dinosaur bone scattered on surface	15
Shale, purple, containing volcanic débris	10
Sandstone, gray-white, coarse	2
Shale, variegated, purple and blue-gray, containing volcanic débris	40
Concealed mostly but apparently occupied by sandy yellow-brown shale	85
Sandstone, gray-white, coarse, poorly exposed. Contains lenses of coarse grit and some small quartz and chert pebbles and also fossil logs	10
	328
Concealed to Farmington sandstone member of Kirtland shale; interval probably all Kirtland shale.	

Section of lower part of Wasatch formation and upper part of Torrejon formation near Cedar Hill, N. Mex., in secs. 31 and 34, T. 32 N., R. 10 W.

	Feet.
Wasatch formation:	
Top of formation eroded.	
Sandstone, gray-white to copper-red, coarse, hard, resistant, and shale, variegated purplish and dove-gray, with some soft, white sandstone; the hard sandstone layers thicker than the shale. East of the point of measurement perhaps 500 feet more of similar shale and sandstone beds are in sight	200

Wasatch formation—Continued.	Feet.
Sandstone, gray-white to copper-red, hard, resistant	30
Shale, variegated, purplish, dove-gray, with soft white sandstone	30
Sandstone, gray-white to copper-red, resistant	10
Shale, variegated	50
Sandstone, gray-white to copper-red, resistant	30
Shale, variegated	30
Sandstone, gray-white to copper-red, resistant	10
Shale, variegated purplish and dove-gray, with some soft white sandstone	70
Sandstone, massive, persistent, gray-white to copper-red, coarse; some parts of the rock a grit composed of grains as coarse as rice; many chert and quartz pebbles in the coarse layers; a few thin streaks with carbonaceous debris and stem impressions	145
Shale, dove-gray	20
Sandstone, massive, persistent, gray-white to copper-red, coarse, composed locally of quartz and jasper but usually of white quartz; contains scattered pebbles 1 inch or less in diameter	75
Torrejon formation:	
Clay shale, greenish gray, with some carbonaceous streaks	10
Sandstone, soft, gray-white, coarse	10
Shale, greenish gray, with carbonaceous bands near base	40
Sandstone, coarse, gray-white, containing pebbles	15
Shale, greenish gray, with carbonaceous bands; contains remains of turtles (*Hoplochelys* sp., *Compsemys* sp. *Adocus* sp., trionychid turtle)	40
Sandstone, coarse, gray-white to copper-red, resistant	15
Shale, variegated, wine-red, purple, gray, and white, with soft sandstone in thin beds	70
Sandstone, coarse, gray-white to copper-red, resistant	20
Shale, variegated, red, purple, gray, and white, and soft sandstone. Unit contains two local lenses of indurated brown sandstone. *Periptychus* sp. and *Hoplochelys* sp. near base	200
Beds below concealed by alluvium, etc.	

Section across Pruett pasture, in secs. 16, 22, and 26, T. 32 N., R. 12 W., San Juan County, N. Mex.

	Feet.
Wasatch sandstone: Sandstone, copper-red to gray, resistant; forming vertical unbroken faces and resting apparently without sinuous contact on the Torrejon below. Persistent along strike	100
Unconformity, if present at all, very obscure.	
Torrejon formation:	
Sandstone and shale. The sandstone copper-red to gray, lenticular, cross-bedded; lighter in color than Wasatch and softer, forming more rounded and broken ledges; in hand specimen coarse, friable, chiefly of quartz; contains many pebbles of chert, gray to black, and quartz 1 inch or less in diameter. Sandstones separated by shale, light gray and dark gray in lower half of unit but containing red bands in upper half like those near Cedar Hill	700
Shale and sandstone. The shale light gray, dark gray, sandy, and black, carbonaceous; the sandstone soft, yellowish and white. Unit contains few resistant beds, and outcrops are not numerous	700
Sandstone, brown, fine grained, platy, in gray and yellowish sandy shale	50
Unconformity.	
McDermott formation:	
Conglomerate of siliceous pebbles in a brown matrix containing volcanic débris	3
Shale, yellow-brown, sandy	40
Conglomerate composed of weathered andesite pebbles as much as 8 inches diameter in a matrix of andesitic débris. Unit very irregular in composition and thickness, greenish gray to drab; contains scattered dinosaur bones	15
Shale, variegated purple, white, and green; contains volcanic débris	74
Sandstone, white to yellow, coarse; contains volcanic débris; well indurated	15
Sandstone, soft, white to yellow, coarse, with some shale probably. Unit poorly exposed and may include some Kirtland shale in lower part	125
Beds below concealed to Farmington sandstone member of Kirtland shale.	

Section of McDermott formation on east bank of La Plata River in SW. ¼ SW. ¼ sec. 23, T. 32 N., R. 13 W., N. Mex.

	Feet.
Torrejon formation: Gray shale and soft gray sand-stone.	
Unconformity.	
McDermott formation:	
Conglomerate of siliceous pebbles in a hard dark-brown ferruginous matrix	2
Intervals with beds poorly exposed but apparently of brown, gray, and faintly purplish shale with some thin whitish sandstone. Dip difficult to determine and thickness here given may be excessive	170
Sandstone, greenish gray, pitted; contains volcanic débris	6
Sandstone, fine grained, white to yellow, with volcanic débris and scattered pebbles of siliceous materials	15

McDermott formation—Continued.

	Feet.
Sandstone, platy, gray, fine grained	2
Shale, variegated purple, gray, and greenish	34
Shale, yellow	17

Beds below concealed by wash; probably all Kirtland shale.

Section of McDermott formation in SW. ¼ SW. ¼ sec. 8, T. 31 N., R. 13 W., N. Mex.

[Thicknesses approximate.]

Beds above section concealed by wash, etc.

McDermott formation:

	Feet.
Shale, purple, with volcanic débris, and shale, sandy, brown and drab	40
Sandstone, gray-white, coarse, with volcanic débris and many pebbles of siliceous materials as much as 4 inches in diameter	5
Shale, variegated, purple, white, etc.; contains volcanic débris	60
Sandstone, brown, platy, hard	2
Shale, purple	10
Shale, sandy, greenish gray, brown, and purple	40
Sandstone, soft, gray-white to yellow, poorly exposed	50

Beds below concealed by terrace gravels; probably all Kirtland shale.

Section of McDermott formation at center of sec. 18, T. 31 N., R. 13 W., N. Mex.

Wash, wind-blown sand, etc., cover higher beds at this point, but along the strike light-gray and white soft sandstone and shale are exposed that are part of the Puerco and Torrejon succession.

Unconformity.

McDermott formation:

	Feet.
Sandstone, conglomeratic, limonitic, brown to black, well indurated; pebbles of quartz, jasper, volcanic rocks, and other siliceous resistant materials	1
Shale, drab	2
Sandstone, white to yellow, soft, fine-grained	18
Sandstone, gray-white, dense, resistant, containing many pebbles of siliceous materials (quartzite, jasper, chert, and volcanic rocks)	3
Shale, variegated purple, pink, and greenish gray; rather coarse in grain; contains volcanic débris	16
Sandstone, coarse, gray-white, argillaceous, soft; rather drab on fresh surface	8
Shale, dove-colored, not sandy, alternating irregularly with greenish-gray sandy shale	16
Sandstone, gray-white, medium grained	1
Shale, dove-colored, not sandy	9
Sandstone, gray-white, medium grained	1
Shale, dove-colored, not sandy	9
Shale, very sandy, greenish yellow and white, poorly exposed	10

McDermott formation—Continued.

	Feet.
Concealed interval, probably soft yellow sandstone	16
Shale, sandy, black, carbonaceous	4
Sandstone, soft, gray, nonresistant; pebbles on surface but none seen in place; contains some carbonaceous lenses and becomes yellow toward top; exposed	12

Concealed interval, extending to outcrop of Farmington sandstone member of Kirtland shale.

Section of McDermott formation in NW. ¼ NE. ¼ sec. 19, T. 31. N., R. 13 W., N. Mex.

Beds above section concealed by wash, wind-blown sand, etc., apparently basal part of Puerco and Torrejon succession.

McDermott formation:

	Feet.
Sandstone, hard, brown, filled with pebbles of siliceous materials as large as a man's fist	3
Shale and soft sandstone, gray and purple, tuffaceous	10
Sandstone, white to ecru, coarse, tuffaceous	10
Shale, variegated purple, gray, and brown, tuffaceous	50
Sandstone, gray-white to brown, coarse	40

Beds below section concealed under the valley extending to outcrop of Farmington sandstone member of Kirtland shale.

Section of Fruitland formation on divide between Barker Arroyo and Youngs Arroyo, San Juan County, N. Mex.

[Measured by Harvey Bassler.]

Kirtland shale.

Fruitland formation:

	Feet.
Shale and sandstone	80
Sandstone	5
Shale	20
Sandstone	10
Shale, carbonaceous in part	80
Coal, high in ash	1½
Shale, carbonaceous	2½
Coal bed with partings	1
Shale, carbonaceous	2
Coal bed with partings	4
Shale, carbonaceous	3
Coal	½
Shale, carbonaceous in part	75
Coal bed with partings	14
Shale and sandstone	125
Coal	2½
	426

Pictured Cliffs sandstone.

Section along north side of NW. ¼ sec. 1, T. 30 N., R. 14 W., N. Mex.

[Measured by Harvey Bassler.]

	Feet.
Ojo Alamo sandstone: Sandstone, massive, coarse grained, gray to brown, with streaks and lenses of coarse conglomerate of siliceous pebbles; top eroded; thickness present	45

Unconformity.
McDermott formation:

	Feet
Shale, greenish and gray	4
Sandstone, coarse, arkosic, soft, with some pebbles in lower part	23
Sandstone, coarse, soft, with pebbles of chert and jasper as much as 3 inches in diameter	1½
Shale, maroon	6
Sandstone, dense, gray, quartzose	1
Shale and sandstone, green and maroon	10
Sandstone, dense, fine, hard, with apparently some ash in its composition	1
Shale, green and maroon	5
Sandstone, coarse, with clay balls and shaly bands	7
Sandstone, coarse, soft, with pebbles of chert and quartz as much as 2 inches in diameter	3½
Sandstone and shale, maroon	25
Sandstone, soft, arkosic; weathers to gray and drab color; pink grains common; basal 6 feet weathers pisolitic	40
Sandstone, green, micaceous	½
Shale, gray, greenish, and maroon, and sandstone	37½
Sandstone, coarse, gray, arkosic; weathers to a buff color	15

Section at center of sec. 2, T. 30 N., R. 14 W., N. Mex.

Ojo Alamo sandstone: Sandstone, massive gray-white to copper-red, containing lenses of siliceous resistant pebbles; top eroded, thickness of part present	50
Unconformity.	
McDermott formation:	
Shale, drab and rusty brown	30
Sandstone, coarse, gray-white, indurated, with a thin purple shale layer near middle that contains volcanic débris	15
Sandstone, soft, gray-white, rather coarse grained; contains volcanic débris	30
Shale, variegated purple, green, and light gray; contains volcanic débris	40
Sandstone, soft, gray-white, coarse; contains volcanic débris	22
Shale, variegated purple, green, and gray, sandy; contains volcanic débris	22
Sandstone, soft, gray-white, coarse grained; no pebbles seen	10
Total McDermott formation	169
Kirtland shale.	

Section of McDermott formation on north side of Pinyon Mesa in NE. ¼ SW. ¼ sec. 2, T. 30 N., R. 14 W., N. Mex.

[Measured by C. E. Dobbin.]

Ojo Alamo sandstone.
Unconformity.
McDermott formation:

	Feet
Shale, gray and green, with one thin layer of purple	46
Shale, variegated red, purple, gray, green, and black, capped by a thin persistent layer of fine-grained sandstone; contains volcanic débris	6
Sandstone, gray, with some thin lenses of purple shale	17
Shale, purple, contains volcanic débris	6
Shale, yellow, with lenses of fine-grained yellow sandstone, containing volcanic débris	23
Beds beneath concealed by débris.	

Section of McDermott formation on north side of Pinyon Mesa in SE. ¼ SE. ¼ sec. 3, T. 30 N., R. 14 W., N. Mex.

Ojo Alamo sandstone.
Unconformity.
McDermott formation:

	Feet
Shale, gray and yellow	22
Shale, gray and purple, with thin sandstone at top	23
Sandstone, quartzitic	2
Shale, variegated purple, gray, and white, micaceous, with volcanic material	10
Shale, gray	40
Shale, purple, micaceous, with volcanic material	2
Shale, drab	13
Shale, yellow, sandy, grading downward into soft yellow sandstone	17
Shale, drab, with a 4-inch layer of indurated gray sandstone at top; appears to contain volcanic material	30
Sandstone, coarse, gritty, light gray, with volcanic material	6
Kirtland shale.	165

Section on north side of Pinyon Mesa at center of NE. ¼ sec. 10, T. 30 N., R. 14 W., N. Mex.

	Feet
Ojo Alamo sandstone: Sandstone, massive, cliff-forming, conglomeratic; light gray to copper-red; contains a few thin lenses of shale and many pebbles of siliceous rocks as much as 5 inches in diameter; top eroded, thickness of part remaining	50
Erosional unconformity.	
McDermott formation:	
Shale, gray to purple, with volcanic material	10
Sandstone, light gray, containing volcanic débris; rather resistant; forms ledge	10
Shale, light gray, grading upward into soft gray sandstone with purple and green streaks; contains volcanic material	33
Sandstone, soft, coarse, gray; contains volcanic material	10
Shale, purple and green; contains volcanic material	8
Sandstone, light gray, micaceous	2
Shale, purple and green, fine grained	14
Sandstone, green, micaceous	1
Shale, light gray, sandy, with some local lenses of soft yellow sandstone	30

McDermott formation—Continued.	Feet.
Sandstone, gray-white, soft, fine grained, irregular; a channel sandstone	5
Shale, light gray, sandy	18
Sandstone, coarse, gray to yellow, irregularly indurated; with lenses of small pebbles of chert and quartz, rounded to subangular, attaining three-fourths inch in diameter. Small lenses of carbonaceous shale and silicified logs present	10
Total McDermott formation	151

Kirtland shale:	
Light-colored mass of light-gray and greenish-gray shale and gray-white soft sandstone containing brown hard concretions; forms a valley	220
Sandstone, gray to brown, indurated, and gray shale, forming Farmington sandstone member of Kirtland	500
Shale, gray and greenish gray, soft gray-white sandstone; very irregularly bedded	400
Total Kirtland shale	1, 120

Fruitland formation:	
Shale and sandstone	80
Sandstone, brown	5
Shale, gray	20
Sandstone, brown	10
Shale, gray; carbonaceous in part	80
Coal bed	2
Shale, carbonaceous	2
Coal bed	1
Shale, carbonaceous	2
Coal bed	4
Shale, carbonaceous	3
Coal bed	6
Shale, gray; carbonaceous in part	75
Coal bed	14
Shale and sandstone, in part concealed	125
Coal bed	3
Total Fruitland formation	426
Pictured Cliffs sandstone	225
Lewis shale; details not noted	1, 100
Mesaverde group.	

Section on north side of Pinyon Mesa at center of sec. 10, T. 30 N., R. 14 W., N. Mex.

	Feet.
Ojo Alamo sandstone: Sandstone, massive, gray-white to copper-red, cross-bedded, coarse grained, with many lenses of pebbles of siliceous resistant materials. Upper 2 feet dark brown. No shale present. Apparently all of formation present though not covered by higher beds	200
Unconformity.	
McDermott formation:	
Sandstone, purple to nearly black; contains volcanic débris	20
Sandstone, soft, gray-white, rather coarse grained; contains volcanic material	28
Shale, purple	1
Sandstone, soft, gray-white, coarse grained; contains volcanic débris	29
Shale and sandstone, purple, green, gray, brown, varying rapidly in color and composition laterally and vertically; contains volcanic material	55
Sandstone, brown, soft, at places carbonaceous and well indurated	10
Total McDermott formation	143
Kirtland shale.	

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Section on west side of Pinyon Mesa in NW. ¼ NW. ¼ sec. 15, T. 30 N., R. 14 W., N. Mex.

[Measured by Harvey Bassler.]

Ojo Alamo sandstone:	Feet.
Sandstone, massive, coarse grained, gray to brown, with streaks and lenses of coarse conglomerate of siliceous materials. Pebbles as much as 5 inches in diameter	164
Shale, sandy, micaceous, gray to green	3
Sandstone, soft, coarse, with pebbles in lower part	23
Total Ojo Alamo sandstone	190
Unconformity.	
McDermott formation:	
Shale, highly colored	7
Sandstone, argillaceous, micaceous	2
Shale, gray	5
Sandstone, argillaceous	1
Shale, purple	25
Sandstone, greenish, argillaceous, thickness undetermined.	

Beds below are light-gray shale and soft arkosic sandstone down to the resistant sandstones of the Farmington member of the Kirtland shale.

Section on south side of Pinyon Mesa in SW. ¼ NW. ¼ sec. 24, T. 30 N., R. 14 W., N. Mex.

[Measured by C. E. Dobbin.]

	Feet.
Ojo Alamo sandstone: Sandstone, massive, gray-white to brown, coarse, cross-bedded; contains lines and lenses of coarse conglomerate of siliceous materials	100+
Unconformity.	
McDermott formation:	
Shale, yellow and green, sandy, with thin sandstone lenses	60
Sandstone, coarse grained, white, ashy, containing many pebbles of siliceous materials of dark color; differs from Ojo Alamo in lacking red pebbles	7
Shale, yellow, with one thin purple band	17
Shale, gray and green	22
Shale, variegated gray and purple, with 5-foot band of bright purple at top	17
Shale, gray, containing thin lenses of platy green sandstone	21
Shale, purple, sandy	2
Kirtland shale: Light-gray shale and soft gray-white sandstone.	

Section on La Plata River in SW. ¼ SW. ¼ sec. 28, T. 30 N., R. 13 W., N. Mex.

	Feet.
Ojo Alamo sandstone: Sandstone, massive, brown to gray, cliff-forming, with many pebbles of siliceous rocks as much as 6 inches in diameter	100+
Unconformity.	
McDermott formation:	
Shale, purple and gray, and soft gray, white, and yellow sandstone, varying rapidly both vertically and horizontally. One sandstone lens contains pebbles of dark chert and quartz	160
Beds immediately below concealed by alluvium.	

Section along San Juan River below Farmington, N. Mex.

	Feet.
Torrejon formation: Shale, olive and gray, with soft gray-white to yellow sandstone containing siliceous pebbles	250+
No break observed, though certainly present.	
Ojo Alamo sandstone:	
Sandstone, gray-white to yellow, massive, cross-bedded, indurated, medium grained; contains many siliceous pebbles as much as 2 inches in diameter	85
Shale, brownish, not persistent laterally	6
Shale, brown, carbonaceous, not persistent laterally	6
Sandstone, gray-white to yellow, massive, indurated, medium grained; contains siliceous pebbles as much as 2 inches in diameter and some limonitic crusts	57
Shale, greenish gray, sandy, not persistent laterally	23
Sandstone, indurated, gray-white to yellow, massive, cross-bedded; contains lines and lenses of pebbles of siliceous materials several inches in diameter and some limonitic crusts. A few thin, short shale lenses included	92
Shale, green, sandy, pinching out within a short distance laterally	28
Sandstone, massive, medium to coarse grained, gray-white to brown; contains lines and lenses of siliceous pebbles; pebbles as much as 6 inches in diameter. Unit forms cliff	100±
Total Ojo Alamo sandstone	397±
Unconformity, erosional.	
McDermott formation: Gray shale; purple shale containing volcanic débris; coarse gray-white soft sandstone; variable unit	30±
Kirtland shale.	
Upper shale member: Shale, yellowish, sandy, stained with limonite in irregular patches, and gray to drab shale, with platy dark-brown concretions 1 foot or less in diameter, alternating irregularly; dinosaur bone from horizon near top of unit	80±

Kirtland shale—Continued.

	Feet.
Farmington sandstone member:	
Sandstone, brown, massive, fine grained; contains lenses of grit with fine black chert and clay galls but consists mostly of quartz	15
Sandstone, friable, buff, stained locally by limonite	16
Shale, drab, sandy, locally carbonaceous	33
Shale, sandy, salmon-colored	5
Sandstone, brown, rather coarse, cross-bedded; contains crusts of limonite	12
Shale, drab, clayey, and light-brown sandy shale, alternating irregularly. Contains lenses of friable sandstone and dark-brown sandstone concretions	98
Sandstone, light brown, coarse, hard; fresh surface gray with fine white specks; much cross-bedded; locally pisolitic	4
Shale, drab, sandy	5
Sandstone, light gray, fine grained, friable, with a number of platy brown concretions; small limonitic crusts abundant	10
Shale, gray, sandy	8
Sandstone, fine grained, reddish brown on weathered surface, light gray on fresh surface, micaceous, massive, resistant; locally contains clay galls and ferruginous concretions; impressions of stems of plants and parallel-veined leaves abundant	4
Shale, light brown, sandy, with some drab streaks	19
Sandstone, reddish brown, fine grained, hard, with platy concretions of dark-brown sandstone; clay galls numerous; lower part lighter and softer	5
Shale, olive, sandy	22
Sandstone, reddish brown, fine grained, massive; fresh surface light gray	12
Shale, gray and buff, sandy, alternating irregularly and inclosing a few thin sandstones; gypsum present locally	84
Sandstone, reddish brown on weathered surface; mottled brown and white on fresh surface; massive, resistant unit	35
Shale, gray and buff, sandy, alternating at about 5-foot intervals with thin brown sandstones	28
Sandstone, yellowish, coarse, friable	19
Shale, gray, sandy	16
Sandstone, buff, friable, cross-bedded; dinosaur bone observed	9
Total Farmington sandstone member	459

Kirtland shale—Continued.	Feet.
Lower shale member:	
Shale, clayey; light gray on weathered surface, drab on fresh exposure; contains a few thin sandstone layers	14
Shale, sandy, chocolate-brown, filled with carbonized plant fragments; much gypsum in small crystals present	4
Sandstone, buff, friable; stained with limonite	2
Shale, drab, very sandy; a few dark sandstone concretions present	10
Shale, dark bluish-gray, stained along seams with limonite and containing gypsom on joint planes; plant fragments abundant	4
Shale, light gray	11
Shale, somewhat sandy, black to dark brown, filled with cumminuted plant fragments	2
Shale, sandy, micaceous, light gray on weathered surface, mottled drab and brown on fresh surfaces	13
Sandstone, shaly, yellowish, soft; contains large crystals of gypsum and scattered lignitic material; large concretions of platy dark-brown sandstone	10
Shale, light gray	20
Shale, black, carbonaceous	½
Shale, dark gray	18
Shale, dark brown, carbonaceous	½
Shale, light gray on weathered surface, drab on fresh surface	23
Shale, yellowish, sandy; perhaps really a soft sandstone; contains much disseminated gypsum and a few thin lenses of dark-green indurated shale	17
Sandstone, buff, soft, with a line of dark-brown platy concretions at top	5
Shale, yellowish, very sandy, grading upward into the unit above	16
Shale, black, carbonaceous, with much gypsum	1
Shale, gray to yellow, very sandy	6
Shale, chocolate-colored, with carbonized plant remains	2
Shale, gray to yellow, sandy	13
Shale, black, carbonaceous	1½
Shale, gray	5
Shale, brown, carbonaceous, with carbonized vegetable débris	2
Shale, drab, sandy in part	35
Shale, black, carbonaceous	1
Shale, drab, sandy	35
Total lower shale member	271
Total Kirtland shale	810

Fruitland formation:	Feet.
Sandstone, gray, fine grained, irregularly bedded	7
Shale, gray to black; contains fragments of carbonized wood and is streaked with limonite	8
Shale, light gray to drab, with limonite streaks; sandy in lower portion	11
Shale, sandy, light gray to buff	12
Sandstone, brown, friable; contains concretions of light-gray fine-grained sandstone	15
Shale, drab, sandy	1
Shale, brown, carbonaceous; contains plant fragments	2
Shale, light gray, sandy, with streaks of pearl-gray calcareous shale and drab platy sandstone concretions	14
Shale, dark brown, carbonaceous; contains plant fragments and gypsum in small flakes	7
Shale, light gray to drab	10
Sandstone, platy, fine grained, light greenish gray	20
Shale, light gray, sandy, locally carbonaceous	15
Shale, dark brown, carbonaceous; contains thin lenses of bone	6
Sandstone, light gray, fine grained and carbonaceous	18
Shale, gray to drab, with carbonaceous bands which are burned locally (probably coal bed elsewhere)	30
Sandstone, light gray, fine grained; contains lenses of carbonaceous shale; sandstone is cross-bedded and stained brown locally	25
Shale, brown to black, carbonaceous	3
Coal bed with partings	15
Shale, carbonaceous	2½
Bone	¼
Shale, brown	5
Coal	⅓
Shale, sandy, brown	5
Shale, light gray, sandy	2
Sandstone, greenish, cross-bedded	3½
Shale, brown	1
Sandstone, nearly white	6
Coal bed with parting	2
Total Fruitland formation	246

Pictured Cliffs sandstone:	
Sandstone, massive, buff on weathered surfaces, light yellow to white on fresh surfaces; contains many 2-inch nodules of limonitic sandstone and a few 18-inch concretions of dark-brown platy sandstone; *Halymenites* common	60
Sandstone, massive, cliff-forming; copper-red on weathered surfaces, light gray to yellow on fresh surfaces; quartzose, fine grained; contains a few large concretions with *Halymenites*	48

	Feet.
Pictured Cliffs sandstone—Continued.	
Shale, gray to brown, carbonaceous, sandy, in courses about 18-inches thick, separated by 12-inch layers of gray to yellow sandstone	42
Sandstone, yellow-brown on weathered surface, light gray on fresh surface, fine grained; a few large concretions of brown platy sandstone present	28½
Shale, sandy, gray to brown, interbedded with thin sandstones	11
Sandstone, yellow to brown on weathered surface, light gray on fresh surface, fine grained; contains large concretions of platy dark-brown sandstone; *Halymenites* present	22
Shale, drab	1½
Sandstone, fairly massive, light gray on fresh surface, brown on weathered surface	5½
Shale and sandstone, rapidly alternating. Shale dark gray, sandy; sandstone shaly, gray to brown. Fossils (locality 9278; see p. —) 36 feet above base of unit	57½
Sandstone, shaly, gray on fresh surface, brown on weathered surface, fine grained, cross-bedded; *Halymenites* present	5
Total Pictured Cliffs sandstone	281
Lewis shale: Gray sandy shale, containing some thin layers of arenaceous limestone; some large yellow septarian limestone concretions and some brown ferruginous concretions	450
Mesaverde group:	
Cliff House sandstone:	
Sandstone, heavy bed, reddish brown to buff	4
Shale, gray, sandy, with a few thin beds of sandstone	96
Sandstone, massive, heavy bedded, reddish brown to buff, with thin layers of shale separating the sandstone beds	330
Shale and sandstone, gray, interbedded. Sandstone in thin layers and more abundant in upper part of unit; some layers ripple marked	195
Concealed, probably sandy shale	73
Sandstone, soft, buff	8
Shale, sandy, gray	11
Sandstone, massive, pisolitic, dark brown on weathered surface, gray on fresh surface	33
Total Cliff House sandstone	750
Menefee formation:	
Shale, sandy, gray	6
Coal	7½
Shale, sandy, brown, carbonaceous	20
Coal bed with partings	10½
Shale, sandy, brown, carbonaceous	28

	Feet.
Mesaverde group—Continued.	
Menefee formation—Continued.	
Shale, soft, light colored, sandy	6
Shale, sandy, brown, carbonaceous	12
Shale, containing 18 beds of sandstone. The sandstone layers range in thickness from 3 to 12 feet but average 5 feet	619
Coal	1
Sandstone	15
Shale	25
Sandstone	7
Shale	8
Sandstone	30
Shale	125
Sandstone	35
Shale	1
Coal bed with partings	2½
Shale and sandstone	10
Coal	1
Shale	26
Sandstone	12
Shale	1
Coal	1
Shale	20
Coal bed with partings	9
Sandstone and shale	10
Coal	½
Shale and sandstone	5
Coal	1
Shale	21
Total Menefee formation	1, 076
Point Lookout sandstone:	
Sandstone	32
Shale, sandy	16
Sandstone, with some thin sandy layers	252
Total Point Lookout sandstone	300
Total Mesaverde group	2, 126
Mancos shale:	
Shale, gray, with a few yellow-brown calcareous concretions	430
Shale, gray, with many yellow-brown calcareous concretions; forms a marked lithologic zone	25
Shale, gray	105
Sandstone, concretionary, brown, calcareous	1
Shale, gray, sandy	38
Sandstone, concretionary, brown, calcareous	1
Shale, gray, sandy	48
Sandstone, concretionary, brown, calcareous	1
Shale, gray	85
Sandstone, soft, gray, laminated, argillaceous; contains many "worm track" surfaces	35
Shale, gray	20
Sandstone, concretionary, brown, calcareous	1

	Feet.
Mancos shale—Continued.	
Shale, gray	110
Sandstone, concretionary, brown, calcareous	1
Shale, gray; upper part somewhat sandy	130
Sandstone, brown	1
Shale, gray	85
Sandstone, rusty brown, coarse, sugary in grain; contains many scattered pebbles of chert and quartz as much as half an inch in diameter; locally bedded but mostly massive (Tocito sandstone lentil)	35
Shale, light gray to buff, with some hard layers, probably sandy; exposed	65
Shale, gray to black, as interpreted by drillers of wells on Hogback dome in sec. 19, T. 29 N., R. 16 W. Interval contains some thin sandstones not noted by drillers	672
Total Mancos shale	1, 889
Dakota sandstone	200±

Section in sec. 5, T. 9 N., R. 4 W. Navajo meridian, near Beautiful Mountain, San Juan County, N. Mex.

	Feet.
Shale, sandy, dark gray; Mancos shale.	
Sandstone, massive, light gray on fresh surface with carbonaceous streaks, red-brown on weathered surface; medium-grained; Dakota sandstone of Gregory (?); Tocito sandstone of oil geologists and this report	75±
Shale, drab, sandy on the whole but calcareous in some layers. Fossils abundant, particularly in resistant limy layers about 125 feet beneath top (locality 10368; see p. 11). Thickness not determined.	
Sandstone, light gray, coarse, quartzose; contains numerous impressions of plant stems and fragments. Only top exposed. May be Dakota sandstone or pre-Cretaceous.	

Section of Mesaverde group in T. 29 N., R. 16 W., N. Mex., where Chaco River cuts the Great Hogback.

[Measured by C. M. Bauer.]

	Feet.
Lewis shale.	
Mesaverde group:	
Cliff House sandstone:	
Shale and sandstone	60
Sandstone, brown, pitted	18
Shale, yellow, sandy	8
Sandstone, light gray, pink in places	6
Shale, blue and gray	5
Sandstone, yellow, massive in upper part, carrying a few thin beds of shale; *Halymenites major* in lower part	318
Shale, sandy, interbedded with yellowish sandstone layers, each about 1 foot thick	133
Sandstone, reddish brown, hard	10
Shale, blue-gray	40
Mesaverde group—Continued.	
Cliff House sandstone—Continued.	
Sandstone, massive, thin bedded on top, massive and nearly white below	25
Total Cliff House sandstone	622
Menefee formation:	
Shale, blue and gray, interbedded with lenses of buff sandstone. Shale beds are carbonaceous and contain thin streaks of coal	560
Sandstone, massive, light gray	20
Shale, gray, contains beds of sandstone 1 foot thick	30
Sandstone, light gray, massive	12
Shale, blue-gray, containing several carbonaceous streaks	92
Sandstone, massive	20
Shale, drab	5
Coal	1
Shale, carbonaceous, black	$\frac{1}{2}$
Shale, blue-gray, containing carbonaceous streaks	246
Sandstone, gray	10
Shale, gray	$\frac{1}{2}$
Coal	$\frac{1}{2}$
Shale, gray	7
Coal	2
Shale and sandstone, with thin beds of coal which are burned out	126
Total Menefee formation	1, 132
Point Lookout sandstone:	
Sandstone, light buff and cream-colored, massive	67
Sandstone, buff to brown, weathering red-brown	158
Shale and sandstone, thin bedded, yellowish gray	20
Total Point Lookout sandstone	245
Total Mesaverde group	2, 009
Mancos shale.	

Section of Pictured Cliffs sandstone in Ojo Amarillo Arroyo, San Juan County, N. Mex.

	Feet.
Fruitland formation: Sandstone, shale, and coal beds.	
Pictured Cliffs sandstone:	
Sandstone, buff to brown, soft, fine grained, cross-bedded, locally pisolitic; top is a limonitic crusty irregular layer; *Halymenites* abundant; crusts and nodules of limonitic	27
Sandstone, light brown, irregular; *Halymenites*	2
Shale, buff, sandy	5
Sandstone, well indurated; fairly coarse grained; weathered surface light coffee-brown and rough, pisolitic; fresh surface gray, blotched with limonitic spots; *Halymenites* very abundant	4

Pictured Cliffs sandstone—Continued.	Feet.
Sandstone, buff to white, locally stained by limonite; contains limonite nodules; rather soft and easily eroded; fresh surface light gray; *Halymenites* abundant	21
Shale, light yellow, limonitic	3
Sandstone, buff, soft, fine grained	3
Shale, sandy, light yellow to white, with many layers and streaks of limonitic sand; cross seams stained by iron	4
Shale, bluish gray, sandy, somewhat carbonaceous	4
Sandstone dark, red-brown, platy, fine grained; fresh surface dark gray mottled with brown; unit cross-bedded, irregular in thickness	5
Sandstone, buff to brown, fine grained, light gray on fresh surface, soft and easily eroded; contains small brown ferruginous nodules 1 to 2 inches in diameter	22
Shale, greenish gray, sandy, alternating with thin sandstones	30
Sandstone, gray, fine grained, platy, stained brown locally and carrying dark red-brown platy concretions as much as 1 foot in diameter; *Halymenites* present	2
	132

Lewis shale: Shale, gray, greenish gray, and drab, sandy.

Section of part of Mesaverde group 5 miles west of mouth of Cottonwood Arroyo, San Juan County, N. Mex.

	Ft.	in.
Cliff House sandstone: Sandstone, massive, light yellow, weathering pink	65	
Menefee formation:		
Shale, gray, carbonaceoous	15	
Shale, gray	12	
Coal	1	7
Bone		4
Shale, carbonaceous	2	3
Coal, weathered	3	8
Shale, carbonaceous	6	
Sandstone	4	
Shale	6	
Coal	2	8
Shale, gray	16	
Sandstone, hard, platy	4	6
Shale, carbonaceous	3	
Sandstone, forming cliff	22	
Shale, carbonaceous	3	
Coal	1	
Shale, carbonaceous	2	
Sandstone, pink	14	
Shale, gray, sandy	10	
Shale, dark gray, containing several 3-inch beds of coal	5	6
Shale, black, carbonaceous	4	6
Coal		10
Shale, dark gray	61	
Coal		3
Shale, carbonaceous	2	

Menefee formation—Continued.	Ft.	in.
Coal		5
Shale, dark gray	18	
Coal		10
Shale	12	
Sandstone	15	
Shale, gray, with carbonaceous streaks	21	
Coal	1	5
Shale, carbonaceous	3	
Sandstone	3	
Shale, carbonaceous	4	
Coal	1	2
Shale, carbonaceous	35	
Sandstone	5	
Shale, dark, carbonaceous	87	
Shale and sandstone in alternating thin beds	195	

Section of Fruitland formation in Cottonwood Arroyo, San Juan County, N. Mex.

[Measured by C. M. Bauer.]

Kirtland shale: Shale, light gray and yellowish, sandy, containing ferruginous concretions.

Fruitland formation:	Feet.
Sandstone, brown, platy	13
Shale, sandy, gray	31½
Sandstone, brown, cross-bedded and concretionary	5
Sandstone; contains iron-carbonate concretions	4
Sandstone, irregularly bedded and unequally indurated	8
Shale, gray, sandy, concretionary	28
Coal bed with partings	4½
Shale, carbonaceous	1
Shale, gray	15
Sandstone, buff to gray, cliff forming	20
Shale, carbonaceous	1
Shale, gray	35
Sandstone, gray, easily eroded	11½
Coal bed with partings	4
Shale, carbonaceous, brown and gray	12½
Sandstone, gray; contains lime concretions	4
Shale, sandy	8
Shale, brown, carbonaceous	1
Coal bed with partings	5½
Shale, carbonaceous	6
Sandstone, nearly white, soft, cross-bedded, streaked with limonite	15
Shale, gray, sandy	2
Coal, impure	1½
Ash (from burned coal)	⅔
Shale, gray	7½
Ash (from burned coal)	1
Shale, bluish gray, sandy	16
Sandstone, nearly white, soft; contains streaks of limonite one-fourth inch thick and in places irregular masses of brown cross-bedded sandstone	25
Coal	½
Shale, blue-gray, sandy	15½
Sandstone, shaly in places, light colored, platy	12

Fruitland formation—Continued.	Feet.
Shale, carbonaceous	$\frac{1}{3}$
Coal	$\frac{2}{3}$
Shale, sandy	5
Coal bed with partings	$4\frac{1}{2}$
Shale, sandy, carbonaceous	3
Pictured Cliffs sandstone.	
	$328\frac{2}{3}$

Section at head of Pina Veta China Arroyo, San Juan County, N. Mex.

[Measured by C. M. Bauer.[31]]

Puerco formation:	Feet.
Higher beds eroded off.	
Shale, gray	12
Shale, wine-red, irregular	3
Sandstone, soft, light yellow	4
Shale, blue-gray	$2\frac{1}{2}$
Erosional unconformity.	
Ojo Alamo sandstone: Sandstone, massive, cross-bedded, gray, white, yellow, and brown, with some splotches of vermilion, fairly resistant and ledge forming, coarse grained; contains pebbles of various siliceous, resistant materials as much as 6 inches diameter, comprising chert, chalcedony, quartz, quartzite, silicified wood, volcanic rocks, sandstone, gneiss, and schist; basal part here has no pebbles but toward middle of unit they are abundant	$91\frac{1}{2}$
Erosional unconformity.	
Kirtland shale [McDermott formation]: Shale, greenish gray, gray, and maroon; carbonaceous brown shale; and soft gray and yellow sandstone.	

Section of Pictured Cliffs sandstone in sec. 14, T. 8 N., R. 1 W. Navajo meridian, N. Mex.

	Feet.
Fruitland formation: Sandstone, shale, and coal.	
Pictured Cliffs sandstone:	
Sandstone, massive, white to copper-red on weathered surface, light gray, with yellow blotches, being the prevailing color; medium grained; fresh surface shows quartz, weathered feldspar, and small fragments of carbonized wood; locally contains carbonaceous streaks and gypsum; varies laterally in induration; *Halymenites* abundant	69
Shale, sandy, light gray to yellow; with some platy gray sandstone concretions	11
Sandstone, fairly coarse, with laminated concretions, dark gray, micaceous	3
Lewis shale: Shale, brown, dark gray, and drab, sandy; contains large platy sandstone concretions.	

[31] Shown diagrammatically in Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, pl. 70, Section H, 1916.

Section at head of Ojo Alamo Arroyo, T. 24 N., R. 11 W., N. Mex.

[Measured by C. M. Bauer and John B. Reeside, jr.]

Torrejon and Puerco formations:	Feet.
Crest of divide.	
Sandstone, yellow to brown, medium grained, ferruginous, soft; contains limonitic crusts	40
Shale, dark drab	8
Sandstone, yellow, soft, with limonitic crusts	15
Shale, dark gray to drab	6
Sandstone, yellow, soft, with brown limonitic crusts and some 2-foot concretions of dark-brown sandstone	16
Shale, dark drab	4
Sandstone, yellow, soft, with concretions of aragonite 1 foot or less in diameter	5
Shale, olive-green, sandy	8
Sandstone, yellow and brown, stained locally by limonite; soft and easily eroded; contains dark-brown sandstone concretions	83
Sandstone, dark-brown, ferruginous, coarse, well indurated	1
Break in section which may be traced for a number of miles, but which seems nevertheless to lie within the Torrejon formation.	
Shale, light greenish gray	6
Shale, light brown, sandy	4
Shale, light gray, greenish gray, and dark gray, irregularly intermingled	27
Sandstone, light gray, soft, alternating with greenish-gray sandy shale	20
Sandstone, light gray and brown, fairly hard and resistant	5
Shale, greenish gray, sandy, alternating with thin soft light-gray sandstones	12
Sandstone, light gray and brown, resistant, massive, micaceous, fine grained	$7\frac{1}{2}$
Shale, light gray, greenish gray, and dark gray, irregularly intermingled	25
Sandstone, light gray, soft, fine grained; has locally at the base a resistant layer of dense quartzitic sandstone	5
Shale, dark gray	21
Sandstone, soft, shaly, light gray with greenish streaks	10
Shale, gray and brown, mingled irregularly	13
Sandstone, soft, greenish gray, shaly	11
Shale, light and dark gray, mottled; probably horizon of Torrejon fossils collected by Sinclair and Granger[32]	10
Sandstone, brown, yellow, and white, mostly rather soft but containing local lenses of coarse grit with a ferruginous cement in which occur rounded chert and quartz pebbles as much as 1 inch in diameter. Laterally this sandstone thickens and is a prominent member of the section, but at the point of measurement it is thin	2

Torrejon and Puerco formations—Continued.	Feet.
Shale, dark gray	6
Sandstone, soft, shaly, micaceous, light brown, olive, and light gray, alternating in thin bands with wine-red, light-brown, and gray shale	31
Sandstone, olive-green, soft, shaly micaceous	4
Shale, dark gray, sandy, locally tinged with red	6
Sandstone, light gray, soft	1
Shale, dark gray with brownish streaks; has a faint reddish tinge in upper 2 feet	7½
Sandstone, soft, shaly, light gray to white; locally contains 1-foot beds of dense quartzitic sandstone which carry impressions of plant stems	10½
Shale, light gray, sandy	10
Shale, light and dark gray, irregularly intermingled	8
Sandstone, soft, light gray, grading into a dense resistant quartzitic layer	5
Shale, light gray, mottled locally by ferruginous brown	11
Sandstone, soft, whitish, fine grained	2
Shale, light gray, sandy	3
Sandstone, dense, fine grained, quartzitic, light gray to brown, vesicular and locally filled with impressions of plant stems	1
Shale, light gray, sandy; streaks of wine-red color near base; probably upper zone of Puerco fossils collected by Sinclair and Granger [32]	8
Sandstone, black to very dark greenish brown, micaceous, fine grained; cement manganitic; contains poor imprints of plant stems and leaves; thickness variable owing to concretionary character; probably horizon of plants collected by Sinclair and Granger [32]	3
Sandstone, soft, light gray to white; yellowish near top. Contains irregular lenses of gray shale and concretions of manganitic sandstone	38
Shale, dark gray, with some patches of white sand	7
Sandstone, soft, white, shaly, with one 6-inch streak of wine-red shale	10
Shale, greenish gray and wine-red	3½
Shale, light gray, sandy	1½
Shale, dark gray, carbonaceous	5½
Shale, light gray, sandy, with small barite concretions; probably lower zone of Puerco fossils collected by Sinclair and Granger [32]	13
Sandstone, gray, dense, quartzitic, with impressions of plant stems	1
Shale, black, carbonaceous, hard	3
Sandstone, soft, light gray to yellow, banded and blotched in upper part with red sandy shale	6½

Erosional unconformity.

Ojo Alamo sandstone:	Feet.
Sandstone, brown to yellow, cross-bedded, irregularly indurated; contains silicified logs and scattered pebbles	33½
Shale, sandy, light bluish green	7½
Shale, blue-gray	1
Sandstone, white, soft, cross-bedded, contains concretions of brown sandstone 8 to 10 inches in diameter	16½
Shale, wine-red, with irregular blotches of light-yellow sandy shale	3½
Sandstone, white, soft, with concretions of brown sandstone	6
Shale, blue-gray	3
Sandstone, white, soft	5½
Shale, gray, sandy	2
Conglomerate of siliceous pebbles several inches in diameter; matrix coarse white sand with rust-colored blotches	8
	86½

Unconformity.

McDermott formation:	
Shale, gray, purple, and greenish, and soft, argillaceous gray-white sandstone; contains andesitic débris	30
Sandstone, brown to gray, containing grit and fine conglomerate with fragments of andesite, quartz, quartzite, etc	10
Kirtland shale:	
Shale, gray	20
Farmington sandstone member; brown indurated sandstone and softer gray sandstone in lenses separated by gray shale	87
Shale, gray, soft gray-white sandstone; some carbonaceous shale, etc	975

Fruitland formation.

Section on branch of Ojo Alamo Arroyo northwest of Ojo Alamo, in or near sec. 6, T. 24 N., R. 11 W.

[Measured by C. M. Bauer.[33]]

Puerco formation:	Feet.
Shale, gray, sandy	3
Shale, dark colored	2½
Shale, blue-gray	4
Shale, wine-red, banded with yellow sandy layers	3
Shale, gray and yellow, banded, sandy, soft	4

Unconformity.

Ojo Alamo sandstone:	
Sandstone, light gray with yellowish spots and irregular brown indurated areas; unequally indurated and easily eroded; contains streaks and pockets of pebbles and large silicified logs, the latter enveloped in a coarse ferruginous grit	31½
Sandstone, coarse, brown, indurated, conglomeratic	6½
Sandstone, brown, soft, with scattered pebbles	5½

[32] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, N. Mex.: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 305–307, 14.

[33] Shown diagrammatically in Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, pl. 70, section N, 1916.

Ojo Alamo sandstone—Continued.	Feet.
Shale, sandy, light green, irregular in thickness and containing patches of white sandstone	10½
Sandstone, light colored, conglomeratic in basal 1 foot and in upper half; pebbles of many sorts of siliceous rocks	16½
	70½

Unconformity.
Kirtland shale: Shale, dark greenish gray and black, carbonaceous.

Section on Meyers Creek in T. 7 N., R. 11 W., San Juan County, N. Mex.

[Measured by C. M. Bauer.]

Kirtland shale: Shale, light gray, streaked with yellow and gray.

Fruitland formation:	Feet.
Sandstone, soft, gray, at base, capped by hard brown coarse-grained sandstone	4
Shale, gray, sandy, streaked with yellow; a few lenses of sandstone containing ferruginous concretions	42
Shale, black, carbonaceous	½
Shale, gray, sandy, banded with yellow, locally a soft gray concretionary sandstone	10
Shale, light gray, sandy	25
Shale, dark brown, carbonaceous	⅔
Shale, gray, with ferruginous concretions and barite	5½
Shale, black, carbonaceous	½
Sandstone, yellow, argillaceous	⅓
Shale, dark brown, carbonaceous	1½
Sandstone, argillaceous, gray, streaked with yellow; contains brown platy concretions of coarser sandstone and some aragonite concretions	12½
Coal	⅙
Sandstone, black, carbonaceous	½
Bone	1
Shale, sandy, containing lenses of brown and gray sandstone, ferruginous concretions with barite, and lenses of carbonaceous shale	32½
Sandstone, soft, gray with brown streaks; cross-bedded and platy at top	6
Shale, brown, carbonaceous, locally sandy	3
Coal bed with partings	4½
Shale, gray and yellow, sandy	10½
Shale, gray, sandy, and lenses of yellow concretionary sandstone	10
Sandstone, light gray, fine grained, unequally indurated; contains dark-brown sandstone concretions	7
Shale, dark brown, carbonaceous	½
Shale, dark gray; contains ferruginous concretions locally	5
Sandstone, light gray, cross-bedded; contains ferruginous concretions with barite; grades laterally into shale	7½
Coal bed with partings	5
Total Fruitland formation	196

Pictured Cliffs sandstone:	Feet.
Sandstone, light gray, soft, shaly; contains large concretions of brown sandstone and carbonaceous streaks; locally has a hard dark-brown layer at top	24
Sandstone, light brown, hard and platy; *Halymenites* abundant	4
Sandstone, yellow to white, medium grained, rather soft as a whole but with indurated masses that stick out as ledges in weathering; many of these ledges are stained brown by iron	61
Sandstone, hard, brown, platy, persistent layer	2
Total Pictured Cliffs sandstone	91

Lewis shale:	
Shale, sandy, yellowish, grading upward into the Pictured Cliffs sandstone	24
Sandstone, platy, brown, fine grained, discontinuous	4
Shale, light gray to greenish gray, sandy; contains two zones of yellow sideritic concretions	46
Sandstone, brown, platy, fine grained, discontinuous	2
Shale, light gray to greenish gray, sandy	27
Total Lewis shale	103

Mesaverde group:

Cliff House sandstone:	
Sandstone, copper-red, fine grained, not as massive as the underlying unit, but not thin bedded; *Cardium* aff. *C. speciosum*, *Inoceramus* sp., *Mactra* sp., *Halymenites* and other marine fossils profuse	51
Sandstone, almost white, coarse; stained brown locally by limonite; massive unit, though with lenses of gray shale near top; *Halymenites* abundant	65
Sandstone, light brown to copper-red, fine grained, massive; contains lenses of platy rusty-colored sandstone; *Halymenites* abundant	70
Sandstone in courses 1 to 3 feet thick, medium grained, uniform copper-red; *Halymenites* common	117
Sandstone, light brown to copper-red on weathered surface, yellow-brown to gray on fresh surface, medium grained, massive, contains thin lenses of coarse dark-brown ferruginous sandstone; *Halymenites* common	66
Total Cliff House sandstone	369

Menefee formation:	
Shale, brown, carbonaceous, locally sandy	14
Coal, impure	1½
Shale, brown, carbonaceous, locally sandy	40
Sandstone, light brown, medium grained; limonitic nodules common	15
Shale, brown, carbonaceous, sandy	12+

Section of Ojo Alamo sandstone in sec. 26, T. 23 N., R. 10 W., N. Mex.

[Measured by F. R. Clark.]

	Feet.
Ojo Alamo sandstone:	
Sandstone, coarse, dark brown, highly indurated; contains pebbles	7+
Sandstone, gray, fairly hard	7
Sandstone, gray and yellow, friable, coarse	28
Sandstone, gray, hard enough to form a ledge	7
Shale, bluish gray, local lens	8
Sandstone, coarse, gray, friable	10
Shale and sandstone, gray and yellow, with hard sandstone concretions	5
Sandstone, hard, dark, with clay pellets	1
Sandstone, white, quartzose, with pebbles locally	14
Shale, bluish gray, with some gypsum crystals	6
Sandstone, thin bedded, gray, with veinlets of barite	7
	100+

Unconformity.

Kirtland shale: Shale, bluish gray with barite and gypsum crystals.

Section of Ojo Alamo sandstone on a branch of Escavada Wash in sec. 3, T. 22 N., R. 9 W., N. Mex.

[Measured by F. R. Clark.]

Puerco formation: Shale, bluish, clayey.

Unconformity.

		Feet.
Ojo Alamo sandstone:		
Sandstone, brown, highly indurated		2
Sandstone, friable, yellow		4
Shale, bluish gray		7
Sandstone, gray, friable; contains coarse siliceous pebbles		25
Sandstone, red-brown, coarse, conglomeratic, hard		3
Sandstone, coarse, yellowish		5
Shale, gray	These beds form a soft unit.	10
Sandstone, gray, friable		20
Shale, gray, sandy		8
Sandstone, gray, friable		11
Sandstone, coarse, usually friable, gray to white		32
Sandstone, coarse, yellow, indurated, conglomeratic		2
		129

Unconformity.

Kirtland shale: Yellowish shale.

FLORA OF THE ANIMAS FORMATION.

By F. H. Knowlton.

INTRODUCTION.

The Animas formation as now restricted by Reeside (see pp. 32–35) comprises certain greenish-gray and tan beds which contain a considerable amount of andesitic material and which, on Animas River, Colo., "lie unconformably upon the purple beds assigned to the McDermott formation and unconformably below the Torrejon formation." It is confined, so far as at present known, to the northern rim of the San Juan Basin, extending from a point about 18 miles southwest of Durango, Colo., eastward to Pagosa Junction, though future study will probably somewhat extend the limits, especially on the east. The beds now named McDermott formation by Reeside (p. 24) have heretofore formed a part of the Animas formation.

As the areal distribution and lithologic and structural features of the Animas formation have been very fully covered by Reeside in the first part of this paper (pp. 32–35), it is only necessary in the present connection to give a very brief historical review to serve as a setting for the discussion of the flora.

Andesitic beds on Animas River below Durango, Colo., which now include the McDermott formation and the Animas formation as restricted were first noted in 1892 by Whitman Cross from collections and field observations made by T. W. Stanton,[1] though they were not then given a name. In 1896 Cross[2] discussed these beds at greater length, calling them the "Animas River beds." He regarded them as "a most direct equivalent of the Denver beds, identical in peculiar lithologic character, * * * and containing fossils, which, so far as known, indicate a similar fauna and flora." The position of the Animas beds, thought by Cross to be "between typical Laramie and Puerco," has not been corroborated by fuller knowledge, as the supposed Laramie is now known to belong to the Montana.

In 1912 and later W. T. Lee[3] made brief mention of the Animas formation, giving a section of the beds on Florida River prepared for him by J. H. Gardner in his mapping of the Ignacio quadrangle, Colo.

The Animas formation ranges in thickness from 100 feet in the Red Mesa quadrangle, southwest of Durango, to 2,670 feet on the divide between Pine and Piedra rivers in secs. 31 and 32, T. 35 N., R. 5 W. It is about 1,100 feet thick at the type section on Animas River, 1,800 feet in the section measured by Gardner on Florida River, and 1,840 feet near Pagosa Junction. As the top shows everywhere an erosion surface, there is no means of knowing to what extent the original thickness has been reduced.

As interpreted by Reeside, the Animas formation rests unconformably on the McDermott formation, which was originally combined with it but which is really very distinct, and is unconformably overlain by the Torrejon formation. It is not known to be in contact at any point with the Puerco formation, but on structural and stratigraphic grounds Reeside is of the opinion that it lies below the Puerco.

As to the age of the Animas formation the present paleobotanic study amply confirms the original assignment by Cross, namely, that it is in close affinity with the Denver, and indicates also that it is closely related to the Raton formation of southeastern Colorado and the Wilcox group of the Gulf region and like them is, in my opinion, undoubtedly Tertiary. Not a single species is known to be common to the Animas formation and the Cretaceous exclusively—in fact, there are only five species that extend into the acknowledged Cretaceous anywhere.

[1] Cross, Whitman, Post-Laramie deposits of Colorado: Am. Jour. Sci., 3d ser., vol. 44, pp. 25–27, 1892.

[2] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, pp. 217–219.

[3] Lee, W. T., Stratigraphy of the coal fields of northern central New Mexico: Geol. Soc. America Bull., vol. 23, pp. 584–587, 1912; U. S. Geol. Survey Prof. Paper 101, pp. 185, 186, 1917.

LOCALITIES.

Fossil plants are not abundant in the Animas formation, and most of those that have been collected, with the exception of those from the vicinity of Pagosa Junction, are fragmentary and more or less poorly preserved. Several small collections that have heretofore been included in the Animas flora came from beds now excluded from the Animas. Thus, two or three collections made in 1898 by Cross and Spencer from Animas River below Durango, Colo., came from the purple andesitic beds now named the McDermott formation by Reeside. These plants are listed and discussed on page 27.

The several lots of Animas plants are as follows:

731.[4] Five miles south of Durango, Colo., above the conglomerate [McDermott formation] that overlies the coal-bearing series; collected by T. W. Stanton, 1891:

Magnolia magnifolia Knowlton?

A single rather fragmentary example. It was first recorded under the name *Magnolia tenuinervis* Lesquereux, but this species was found to be in great confusion, as explained in my paper on the Raton flora,[5] and this specimen has been transferred with some question to *Magnolia magnifolia* Knowlton.

5455. Ignacio quadrangle, Colo., east side of sec. 21, T. 35 N., R. 6 W., 1,650 feet above base of [McDermott formation]; collected by J. H. Gardner, August, 1909:

Juglans berryi Knowlton.
Juglans? innominata Knowlton, n. sp.
Platanus aceroides Göppert.
Sapindus obtusifolius Lesquereux.
Cornus studeri Heer.
Viburnum rotundifolium Lesquereux.

5456. Ignacio quadrangle, Colo.; southeast corner of sec. 15, T. 35 N., R. 6 W., about 200 feet above base of McDermott formation; collected by J. H. Gardner, August, 1909:

Ficus planicostata Lesquereux.

5667. Ignacio quadrangle, Colo.; pebbles near top of Animas formation; collected by J. H. Gardner, August, 1909:

Artocarpus pungens (Lesquereux) Hollick.
Nyssa? racemosa Knowlton.

The *Artocarpus* was first recorded as *A. lessigiana* Lesquereux, but the finding of better-preserved material at Pagosa Junction leads me to the view that it best referred to *A. pungens*.

[4] The numbers thus recorded are the lot numbers of the paleobotanic collections of the U. S. Geological Survey.

[5] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, pp. 311-313, 1917.

6309. Pagosa Junction, Colo., half a mile downstream from the station; collected by W. T. Lee, 1912:

Ficus pseudo-populus Lesquereux.
Juglans sp. cf. J. berryi Knowlton.
Nelumbo lakesii (Lesquereux) Knowlton.
Viburnum antiquum (Newberry) Hollick.

6443. About 1 mile northeast of Pagosa Junction, Colo.; collected by W. T. Lee, 1912:

Sabal? ungeri (Lesquereux) Knowlton.
Ficus pagosensis Knowlton, n. sp.
Ficus sp.
Artocarpus sp.?
Platanus aceroides Göppert.
Platanus raynoldsii Newberry.
Malapoenna sessiliflora (Lesquereux) Knowlton.
Viburnum speciosum Knowlton.

6444. About 1 mile northeast of Pagosa Junction, Colo.; collected by W. T. Lee, 1912:

Sabal? ungeri (Lesquereux) Knowlton.
Ficus neo-planicostata Knowlton.
Platanus, probably P. raynoldsii Newberry.
Oreodaphne pagosensis Knowlton, n. sp.
Magnolia angustifolia Newberry.
Rhamnus cleburni Lesquereux.

7452. Ignacio quadrangle, Colo., 1 mile northwest of Bayfield, in SW. ¼ sec. 3, T. 34 N., R. 7 W.; upper part of Animas formation; collected by J. B. Reeside, jr., 1920:

Platanus sp. cf. P. raynoldsii Newberry.
Platanus aceroides Göppert.

7453. Ignacio quadrangle, Colo., 7 miles northeast of Bayfield, in NE. ¼ sec. 18, T. 35 N., R. 7 W.; collected by J. B. Reeside, jr., October, 1920:

Anemia sp.

7460. Ignacio quadrangle, Colo., 5 miles east of Durango, in NW. ¼ SE. ¼ sec. 30, T. 35 N., R. 8 W.; collected by J. B. Reeside, jr., 1920:

Platanus? sp.

7463. Ignacio quadrangle, Colo., 5 miles east of Durango, in SW. ¼ sec. 30, T. 35 N., R. 8 W., 700 feet above base of Animas formation; collected by J. B. Reeside, jr., 1920:

Platanus raynoldsii Newberry.
Rhamnus goldianus Lesquereux.
Cissus? sp.

7464. Ignacio quadrangle, Colo., 5 miles south of Durango, in SE. ¼ NW. ¼ sec. 13, T. 34 N., R. 10 W., 400 to 500 feet above base of upper Animas beds [Animas restricted]; collected by J. B. Reeside, jr., September, 1920:

Ficus? sp.

7479. Pagosa quadrangle, Colo., on first hill west of road past Talian mine, 5 miles north of Pagosa Junction; collected by Singewald and Reeside, May, 1921:

Juglans berryi Knowlton.
Cyperacites sp.

7480. Pagosa quadrangle, Colo., top of hill west of Talian mine, 5 miles north of Pagosa Junction, about 600 feet above base of Animas formation; collected by Singewald and Reeside, May, 1921:

Sabal? ungeri (Lesquereux) Knowlton.

7481. Pagosa quadrangle, Colo., hill above Talian mine, 5 miles north of Pagosa Junction, loose on slope but probably from about 600 feet above base of Animas formation; collected by Singewald and Reeside, June, 1921:

Anemia grandifolia Knowlton, n. sp.
Sabal? ungeri (Lesquereux) Knowlton.
Ficus pseudo-populus Lesquereux.
Ficus planicostata Lesquereux.
Ficus monodon (Lesquereux) Berry?
Magnolia hilgardiana Lesquereux.
Oreodaphne sp?

7482. Pagosa quadrangle, Colo., hill above Talian mine, 5 miles north of Pagosa Junction, about 600 feet above base of Animas formation; collected by Singewald and Reeside, June, 1921:

Platanus aceroides Göppert.
Aralia reesidei Knowlton, n. sp.

7483. Pagosa quadrangle, Colo., 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction, about 300 feet above base of Animas formation; collected by Singewald and Reeside, June, 1921:

Ficus subtruncata Lesquereux.
Cinnamomum salicoides Knowlton, n. sp.
Zizyphus lanceolatus Knowlton, n. sp.
Aralia lobata Knowlton, n. sp.
Aralia? sp.
Apocynophyllum wilcoxensis Berry.
Phyllites eocenica Knowlton, n. sp.
Phyllites herbacea Knowlton, n. sp.

7484. Pagosa quadrangle, Colo., on road half a mile south of Talian mine, 4½ miles north of Pagosa Junction, about 1,000 feet above base of Animas formation; collected by Singewald and Reeside, June, 1921:

Dryopteris cladophleboides Knowlton.

7485. Same locality as 7484, but about 1,100 feet above base of Animas formation:

Juglans berryi Knowlton.
Castanea intermedia Lesquereux.
Platanus aceroides Göppert.
Platanus aceroides latifolia Knowlton.
Ficus pseudo-populus Lesquereux.
Ficus neo-planicostata Knowlton.
Magnolia angustifolia Newberry.
Magnolia hilgardiana Lesquereux.
Rhamnus cleburni Lesquereux.
Phyllites eocenica Knowlton, n. sp.

7486. Pagosa quadrangle, Colo., five-eighths of a mile south of Talian mine, 4½ miles north of Pagosa Junction, about 1,200 feet above base of Animas formation; collected by Singewald and Reeside, June, 1921:

Crataegus? giganteus Knowlton, n. sp.

7492. Ignacio quadrangle, Colo., 7 miles northeast of Bayfield, in SE. ¼ NE. ¼ sec. 15, T. 35 N., R. 6 W., about 500 feet above base of Animas formation; collected by Singewald and Reeside, June, 1921:

7493. Pagosa quadrangle, Colo., 8 miles northeast of Bayfield, 2,450 feet above base of Animas formation, practically at top; collected by Singewald and Reeside, June, 1921:

7496. Pagosa quadrangle, Colo., half a mile west of Pagosa Junction (same locality as Lee's lot 6309); collected by J. B. Reeside, jr., June, 1921:

Allantodiopsis erosa (Lesquereux) Knowlton and Maxon.
Salix reesidei Knowlton, n. sp.
Juglans schimperi Lesquereux.
Juglans berryi Knowlton.
Fagus crossii Knowlton, n. sp.
Dryophyllum berryana Knowlton, n. sp.
Ficus occidentalis Lesquereux.
Ficus denveriana Cockerell.
Ficus sp.
Ficus sp.
Artocarpus pungens (Lesquereux) Hollick.
Laurus primigenia Unger.
Nectandra lancifolia Berry.
Magnolia angustifolia Newberry.
Magnolia hilgardiana Lesquereux.
Cassia puryearensis Berry.
Rhus coloradensis Knowlton, n. sp.
Zizyphus fibrillosus Lesquereux.
Zizyphus daphnogenoides Knowlton, n. sp.
Carpites sulcatus Knowlton, n. sp.
Phyllites pagosensis Knowlton, n. sp.
Phyllites innominata Knowlton, n. sp.
Phyllites sp.

7497. Pagosa quadrangle, Colo., on Cat Creek about 1 mile north of Pagosa Junction (same locality as Lee's lots 6443 and 6444), upper part of Animas formation; collected by Singewald and Reeside, June, 1921:

Ficus pseudo-populus Lesquereux.

7498. Pagosa quadrangle, Colo., on Cat Creek about 1 mile north of Pagosa Junction, upper part of Animas formation; collected by Singewald and Reeside, June, 1921:

Platanus aceroides Göppert.
Platanus aceroides latifolius Knowlton.

FORMS INCLUDED IN THE FLORA.

As a preliminary to the discussion of the Animas flora a complete list of the forms recognized is given below:

Allantodiopsis erosa (Lesquereux) Knowlton and Maxon.
Dryopteris cladophleboides Knowlton.
Anemia grandifolia Knowlton, n. sp.
Sabal? ungeri (Lesquereux) Knowlton.
Salix reesidei Knowlton, n. sp.
Juglans schimperi Lesquereux.
Juglans berryi Knowlton.
Juglans innominata Knowlton, n. sp.
Fagus crossii Knowlton, n. sp.
Castanea intermedia Lesquereux.
Dryophyllum berryana Knowlton, n. sp.
Ficus planicostata Lesquereux.
Ficus neoplanicostata Knowlton.
Ficus occidentalis (Lesquereux) Lesquereux
Ficus denveriana Cockerell.
Ficus subtruncata Lesquereux.
Ficus monodon (Lesquereux) Berry?

Ficus pseudo-populus Lesquereux.
Ficus pagosensis Knowlton, n. sp.
Ficus sp.
Ficus sp.
Artocarpus pungens (Lesquereux) Hollick.
Platanus raynoldsii Newberry.
Platanus aceroides Göppert.
Platanus aceroides latifolia Knowlton.
Laurus primigenia Unger.
Nectandra lancifolia (Lesquereux) Berry.
Malapoenna sessiliflora (Lesquereux) Knowlton.
Oreodaphne pagosensis Knowlton, n. sp.
Cinnamomum salicoides Knowlton n. sp.
Nelumbo lakesiana (Lesquereux) Knowlton.
Magnolia angustifolia Newberry.
Magnolia hilgardiana Lesquereux.
Magnolia magnifolia Knowlton?
Crataegus? gigantea Knowlton, n. sp.
Cassia puryearensis Berry.
Rhus coloradensis Knowlton, n. sp.
Sapindus obtusifolius Lesquereux.
Rhamnus cleburni Lesquereux.
Rhamnus goldianus Lesquereux.
Zizyphus fibrillosus Lesquereux.
Zizyphus daphnogenoides Knowlton, n. sp.
Zizyphus lanceolatus Knowlton, n. sp.
Aralia lobata Knowlton, n. sp.
Aralia reesidei, Knowlton, n. sp.
Aralia? sp.
Cornus studeri? Heer.
Nyssa? racemosa Knowlton.
Apocynophyllum wilcoxensis Berry.
Viburnum rotundifolium Lesquereux.
Viburnum antiquum (Newberry) Hollick.
Viburnum speciosum Knowlton.
Carpites sulcatus Knowlton, n. sp.
Phyllites eocenica Knowlton, n. sp.
Phyllites pagosensis Knowlton, n. sp.
Phyllites herbacea Knowlton, n. sp.
Phyllites innominata Knowlton, n. sp.
Phyllites sp.

From the above list it appears that the Animas flora comprises 59 forms, of which 19 are regarded as new to science and 4 are not named specifically, leaving 36 previously known species having a distribution outside its limits. The distribution of these 36 species is shown by the following lists:

Species common to the Animas and Denver formations

Allantodiopsis erosa.
Juglans schimperi.
Castanea intermedia.
Ficus occidentalis.
Ficus denveriana.
Ficus subtruncata.
Artocarpus pungens.
Platanus aceroides.
Platanus raynoldsii.
Laurus primigenia.
Nelumbo lakesiana.
Magnolia magnifolia.
Rhamnus cleburni.
Rhamnus goldianus.
Zizyphus fibrillosus.
Zizyphus daphnogenoides.
Cornus studeri.
Nyssa? racemosa.

Species common to the Animas and Raton formations.

Allantodiopsis erosa.
Dryopteris cladophleboides.
Sabal? ungeri.
Juglans schimperi.
Juglans berryi.
Castanea intermedia.
Ficus neoplanicostata.
Ficus occidentalis.
Ficus denveriana.
Ficus pseudo-populus.
Platanus raynoldsii.
Platanus aceroides.
Platanus aceroides latifolia.
Nectandra lancifolia.
Nelumbo lakesiana.
Magnolia angustifolia.
Magnolia hilgardiana.
Magnolia magnifolia.
Rhamnus cleburni.
Zizyphus fibrillosus.
Cornus studeri.
Nyssa? racemosa.
Apocynophyllum wilcoxensis.
Viburnum speciosum.

Species common to the Animas formation and Wilcox group.

Juglans schimperi.
Juglans berryi.
Ficus planicostata.
Ficus neoplanicostata.
Ficus occidentalis.
Ficus denveriana.
Ficus monodon.
Ficus pseudo-populus.
Artocarpus pungens.
Laurus primigenia.
Nectandra lancifolia.
Magnolia angustifolia.
Magnolia hilgardiana.
Cassia puryearensis.
Rhamnus cleburni.
Cornus studeri.
Apocynophyllum wilcoxensis.

Species common to the Animas and Fort Union formations.

Allantodiopsis erosa.
Castanea intermedia.
Platanus raynoldsii.
Platanus aceroides.
Laurus primigenia.
Viburnum antiquum.

A few of the Animas plants have been reported from higher Tertiary horizons. Thus, two species (*Juglans schimperi* and *Sapindus obtusifolius*) have been recorded from the Green River formation; three (*Allantodiopsis erosa, Juglans schimperi,* and *Ficus planicostata*) from the upper part of the Clarno formation; and one (*Laurus primigenia* Unger) from the Hanna formation.

RELATION BETWEEN THE FLORAS OF THE ANIMAS AND PUERCO FORMATIONS.

The flora of the Puerco formation is scanty and on the whole poorly preserved. The first collection was a small one made by Sinclair and Granger and was reported on by me in their paper.[6] The following forms were noted:

Ficus occidentalis Lesquereux.
Artocarpus sp.
Paliurus zizyphoides? Lesquereux.
Platanus sp. cf. P. haydenii Newberry.
Populus sp. cf. P. cuneata Newberry.
Viburnum lakesii? Lesquereux.
Viburnum sp.?

At a point 1 mile northeast of Ojo Alamo, N. Mex., which is at or very near the locality from which Sinclair and Granger collected their material, J. B. Reeside, jr., procured in 1921 a small but interesting collection, in which these forms have been recognized:

Ficus sp., large leaf.
Platanus raynoldsii Newberry.
Platanus marginata (Lesquereux) Heer?
Viburnum melaenum Knowlton and Cockerell.
Viburnum rotundifolium Lesquereux.
Viburnum sp.
Magnolia hilgardiana Lesquereux?
Rhamnus cleburni Lesquereux.
Fragments.

I have not had the opportunity of reviewing the collection made by Sinclair and Granger, but in the light of the recent material, as well as knowledge of the Animas flora, it is possible to make certain emendations in the first list. Thus the *Artocarpus* sp. is in all reasonable probability *Artocarpus pungens*. The sycamore compared with *Platanus haydenii* is now found to be *Platanus raynoldsii*. The leaf identified as *Viburnum lakesii?* is probably only a small leaf of *Viburnum rotundifolium*. Neither *Ficus occidentalis* nor *Populus* cf. *P. cuneata* Newberry appears to be present in the Reeside collection. Combining the two lists we have the following species identified with a fair degree of certainty:

Ficus occidentalis.
Ficus sp.
Artocarpus pungens?
Platanus raynoldsii.
Platanus marginata?
Populus cf. P. cuneata.
Magnolia hilgardiana?
Viburnum melaenum.
Viburnum rotundifolium.
Viburnum sp.
Paliurus zizyphoides?
Rhamnus cleburni.

The leaves identified as *Platanus marginata?* differ in a number of respects from the type material of that species, which came from "post-Laramie beds" at Black Buttes, Wyo., and should probably be described as new. They agree in shape of base and in nervation, but differ in having a pointed instead of nearly truncate apex and in having the marginal teeth small and sharp instead of obtuse or deltoid. The range in size is also much greater than in the type material.

All the positively identified species in the Puerco flora and two of those provisionally identified (*Artocarpus pungens* and *Magnolia hilgardiana*) occur also in the Animas flora, and none of them indicate Cretaceous age. It therefore seems legitimate to conclude that, on the basis of the plants, the Puerco formation is of Tertiary age and in the approximate position of the Denver, Raton, and Wilcox beds.

RELATION BETWEEN THE FLORAS OF THE ANIMAS FORMATION AND THE CRETACEOUS.

Five of the Animas species have been reported more or less definitely from horizons of Cretaceous age. These are

Allantodiopsis erosa.
Sabal? ungeri.
Ficus planicostata.
Ficus denveriana.
Cornus studeri.

The distribution of these species is as follows: A single specimen of *Allantodiopsis erosa* was found in beds supposed to be in the Vermejo formation, at Rockvale, Colo., but the specimen was loose on the surface and may or may not have come from this horizon. *Sabal? ungeri* is probably the most abundant and widely distributed form in the Raton of Colorado and New Mexico, and a single specimen was found in the highest known beds of the Vermejo

[6] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, N. Mex.: Am. Mus. Nat. Hist. Bull., vol. 33, p. 306, 1914.

formation in Ponil Canyon, N. Mex. *Ficus planicostata* has a recorded range from Mesaverde to upper Eocene and hence is of little value as a horizon marker. Its type locality is the "post-Laramie beds" at Black Buttes, Wyo., where it is abundant. *Ficus denveriana* was found first in the Denver beds at Golden, Colo., and later at many points in the Raton and Wilcox beds and at a single locality in the Lance formation of South Dakota, and was identified with question in the Laramie near Colorado Springs, Colo. *Cornus studeri* is essentially a Tertiary species, occurring in the Denver, Raton, and Wilcox beds and questionably in the Mesaverde at Point of Rocks, Wyo.

From the above discussion it appears that the relation between the flora of the Animas formation and any Cretaceous flora is practically negligible. The real relationship of the Animas flora is undoubtedly with those of beds at higher horizons.

RELATION BETWEEN THE FLORAS OF THE ANIMAS FORMATION AND THE BASAL PART OF THE WASATCH FORMATION ("TIFFANY BEDS" OF GRANGER) IN THIS REGION.

The flora of the so-called "Tiffany beds" of Granger is even more scanty than that of the Puerco formation. Two collections are known, one of which came from the base of the beds furnishing the "Tiffany" fauna. The forms recognized are as follows:

- Ficus planicostata Lesquereux.
- Ficus cf. F. denveriana Cockerell.
- Ficus cf. F. schimperi Lesquereux.
- Ficus sp.
- Aralia? sp.
- Celastrinites cf. C. artocarpidioides Lesquereux
- Platanus? sp.

This material is so poorly identified that very little can be said as to the age indicated by it. If all the suggested identifications were authenticated there would be no hesitation in regarding it as approximating in age the Denver and Raton formations, and there is nothing in the collections that in any way militates against this conclusion.

RELATION BETWEEN THE FLORAS OF THE ANIMAS AND McDERMOTT FORMATIONS.

The McDermott formation unconformably underlies the Animas formation. It is composed largely of andesitic material, usually purplish, and has—until recently differentiated by Reeside—been considered a part of the Animas formation. It has yielded plants at a number of localities in southwestern Colorado and northwestern New Mexico. Thus, at a point 1 mile east and a quarter of a mile north from Pina Veta China, N. Mex., Bauer collected the following species (lot 6965):

- Pistia corrugata Lesquereux.
- Ficus leei? Knowlton.
- Ficus? sp., large broken leaf.
- Unrecognized plant suggesting Selaginella.

A second lot (No. 6966) obtained 1 mile east and three-quarters of a mile north from Pina Veta China shows the following species:

- Onoclea neomexicana Knowlton.
- Asplenium neomexicanum Knowlton.
- Palm (genus?).
- Ficus leei Knowlton.
- Myrica? neomexicana Knowlton.
- Leguminosites? neomexicana Knowlton.
- Pterospermites sp.

On Florida River, east of Durango, Colo., J. H. Gardner collected *Ficus planicostata* Lesquereux in beds over 200 feet above the base of the McDermott.

On the west side of Animas River, below Durango, Colo., Cross and Spencer collected the following species:

- Fern, new, genus?
- Sabalites sp.?
- Cyperacites sp.
- Ficus denveriana? Cockerell.
- Ficus eucalyptifolia Knowlton.
- Quercus praeangustiloba Knowlton.
- Grewiopsis sp.
- Cissus coloradensis? Knowlton and Cockerell.
- Rhamnus cf. R. cleburni Lesquereux.

Near the same locality Cross and Spencer procured the following forms:

- Sequoia acuminata? Lesquereux.
- Cyperacites sp.
- Canna? magnifolia Knowlton.
- Laurus socialis Lesquereux.
- Cinnamomum linifolium? Knowlton.

A small collection (lot 7457) was procured by Reeside 4 miles south of Durango, which yielded the following:

- Salpichlaena sp., apparently new.
- Ficus sp.
- Laurus sp.
- Fragments of dicotyledons.

Bringing together the different forms in the above lists gives the following species as representing the flora of the McDermott formation:

Onoclea neomexicana.
Asplenium neomexicanum.
Salpichlaena sp.
Fern, genus?
Sequoia acuminata? Lesquereux.
Cyperacites sp.
Canna? magnifolia Knowlton.
Sabalites sp.?
Palm, genus?
Pistia corrugata.
Myrica? neomexicana.
Quercus praeangustiloba.
Ficus eucalyptifolia.
Ficus denveriana?
Ficus leei.
Ficus planicostata.
Ficus sp.?
Laurus socialis Lesquereux.
Laurus sp.
Cinnamomum linifolium?
Grewiopsis sp.
Cissus coloradensis?
Leguminosites? neomexicana.
Rhamnus cf. R. cleburni.
Pterospermites sp.

The bearing of this flora on the question of age is difficult of satisfactory or conclusive evaluation. At first sight it would seem that the two collections from Pina Veta China, N. Mex., are unmistakably Cretaceous, being recorded[7] as from the Kirtland formation, but it is now disclosed that this is the type locality for four of the six named species, and the beds in which they occur are now placed by Reeside in the McDermott formation instead of the Kirtland. This leaves only two previously known species (*Pistia corrugata* and *Ficus leei*) that occur in unquestioned Cretaceous rocks.

The several lots of plants from the vicinity of Durango, Colo., are also difficult of allocation. Three of the species enumerated (*Canna? magnifolia, Ficus eucalyptifolia,* and *Quercus praeangustiloba*) are known only from the Cretaceous. Another species (*Ficus planicostata*) is known to range from Mesaverde to upper Eocene and is therefore of little value in fixing age. The remaining forms (*Ficus denveriana?, Cinnamomum linifolium?, Rhamnus* cf. *R. cleburni, Laurus socialis,* and *Cissus coloradensis*), although identified with question, seem to indicate Tertiary age. Two explanations are possible to account for this apparent confusion. The material, especially that indicating Tertiary affinity, may not have been correctly identified; or the beds may be so high in the Cretaceous section that the plants foreshadowed a Tertiary facies, but this is, of course, unsubstantiated conjecture. As the matter now rests the plants undoubtedly favor placing the McDermott formation in the Cretaceous, but they are not conclusive.

[7] Knowlton, F. H., Flora of the Fruitland and Kirtland formations: U. S. Geol. Survey Prof. Paper 98, pp. 327-353, 1916.

SUMMARY AND CONCLUSIONS.

1. The known flora of the Animas formation comprises 59 forms, of which 19 are new, 4 are not named specifically, and 36 are previously known species.

2. Of the 36 previously known species, 18 are found in the Denver formation, 25 in the Raton formation, 17 in the Wilcox group, 6 in the Fort Union formation, 3 in the Green River formation, 2 in the upper part of the Clarno formation, and 1 or 2 scattered in other Eocene formations.

3. The flora of the Puerco formation includes 12 forms. As all of these that have been positively identified and two of them that have been provisionally identified occur in the Animas formation, the conclusion is reached that the Puerco formation is of approximately the same age as the Animas.

4. The flora of the McDermott formation includes 25 forms, 10 of which are not named specifically. Of the 15 named species 5 are known only from the McDermott. The ermaining species, although favoring Cretaceous age, are inconclusive.

5. Of the 36 Animas species having an outside distribution only five, and several of these of doubtful authenticity, are found in beds of Cretaceous age. The Cretaceous affinity is therefore regarded as unimportant and practically negligible.

6. On combining the Animas species found in the Denver, Raton, and Wilcox, it appears that 33 species, or over 90 per cent of those having an outside distribution are held in common, and the conclusion is reached that the Animas formation is of the same age—namely, Eocene Tertiary.

SYSTEMATIC DESCRIPTIONS.

Phylum PTERIDOPHYTA.

Class FILICES.

Family POLYPODIACEAE.

Allantodiopsis erosa (Lesquereux) Knowlton and Maxon.

Plate VI, Figure 1.

Allantodiopsis erosa (Lesquereux) Knowlton and Maxon, U. S. Geol. Survey Bull. 696, p. 61, 1919.

Pteris erosa Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 12, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 53, pl. 4, fig. 8, 1878.

Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 244, 1917 [1918].

Pteris subsimplex Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 52, pl. 4, figs. 5–7, 1878.

Osmunda major Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 121, pl. 18, fig. 5, 1883.

Pteris undulata Lesquereux, Mus. Comp. Zool. Bull. vol. 16, p. 43, 1888.

The type locality for *Pteris erosa* Lesquereux is Fisher's Peak, Colo., in the Raton formation. It was found to be most abundant in the Denver formation at Golden, Colo., and from specimens obtained at that locality it was at different times described under the names *Pteris subsimplex*, *Pteris undulata*, and *Osmunda major*. Study of a large series of specimens has shown, however, that they are all slightly variant forms of the same species, which takes the name *Pteris erosa*, the earliest name applied. A fine fruiting specimen was found in beds of the Arapahoe formation near the Douglas coal mine, a few miles west of Sedalia, Colo. It was on the basis of the close relation of this specimen to the living *Allantodia* that the new genus was erected. This genus is described in full in my report on the flora of the Denver formation now awaiting publication.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction; collected by J. B. Reeside, jr., June, 1921 (lot 7496).

Dryopteris cladophleboides Knowlton.

Plate VI, Figure 2.

Dryopteris? cladophleboides Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 284, pl. 54, fig. 1, 1917 [1918].

The collection from Pagosa Junction includes a single fragment that appears to belong to this species. The matrix on which it is preserved is rather coarse grained, with the result that little nervation beyond the midvein is retained. In size, angle of pinnules, and sharp points to the pinnules it is apparently identical with the species named.

Occurrence: Animas formation, Pagosa quadrangle, Colo., on road half a mile south of Talian mine, 4½ miles north of Pagosa Junction; collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7484).

Family SCHIZEACEAE.

Anemia grandifolia Knowlton, n. sp.

Plate V.

The specimen figured is the only one, with the exception of a single fragmentary pinnule, that was found in the collections. This is a nearly perfect frond 29 centimeters long and about 16 centimeters wide between the tips of the lowest pair of pinnae. It is narrowly deltoid in general outline. The rachis is moderately strong and deeply channeled. The pinnae are alternate, at an angle of about 50°, lower ones remote and short stalked, becoming closer and decurrent in the middle and confluent in the apical portion. The pinnae are linear-lanceolate, with a slender acuminate apex, and are deeply cut into numerous lanceolate or narrowly deltoid lobes, the margins of which are entire or with an occasional small sharp tooth; midrib of the lobes (pinnules) arising from the secondary rachis at an angle of about 80°, reduced by forking several times before reaching the margin.

The genus *Anemia* enjoys a wide geographic range in the late Mesozoic and early Cenozoic, but it appears always to be rather rare and moreover is usually fragmentary. A perfectly preserved frond is distinctly exceptional, and the present specimen is one of the few that approach this standard.

Among fossil species there are several that are very similar to the one under discussion. Thus *Anemia eocenica* Berry,[8] from beds of Wilcox age in the Lagrange formation at Puryear, Tenn., is of the same general type but differs in having the lobes of the pinnules with six or eight marginal teeth, commonly in pairs, each being "distinctly serrate, with the points produced and directed upward." The pinnules are said to be at-

[8] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 164, pl. 9, fig. 7; pl. 10, fig. 2; pl. 11, figs. 1, 2, 1916.

tached to the main rachis by their entire bases, though Berry thinks that lower down on the frond they may have had a narrowed base and have free pinnules. In this particular it agrees perfectly with *Anemia grandifolia*.

A fragment of *Anemia* [9] not named specifically, from the Fruitland formation of San Juan County, N. Mex., is also of this type, but it is much larger and has the lobes of the pinnules distinctly toothed.

Anemia occidentalis Knowlton,[10] from the Raton formation, differs in having the pinnules strongly toothed rather than lobed. Some of the more strongly lobed forms of *Anemia subcretacea* (Saporta) Gardner and Ettingshausen,[11] from the Middle Bagshot beds (Lutetian) of Bournemouth, England, are strikingly like *Anemia grandifolia* but differ in having the lobes usually toothed and the midrib of the lobes less distinctly forked.

Occurrence: Animas formation, Pagosa quadrangle, Colo., hill above Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7481).

Phylum SPERMATOPHYTA.

Class ANGIOSPERMAE.

Subclass MONOCOTYLEDONES.

Order ARECALES.

Family ARECACEAE.

Sabal? ungeri (Lesquereux) Knowlton.

Sabal? ungeri (Lesquereux) Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 288, pl. 58, 1918.

Geonomites ungeri Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 118, pl. 11, fig. 2, 1878.

This species is one of the most abundant forms in the Raton formation of the Raton Mesa region of Colorado and New Mexico and is also found at several localities in the Animas beds.

Occurrence: Animas formation, Pagosa quadrangle, Colo., about 1 mile north of Pagosa Junction, collected by W. T. Lee, 1912 (lots 6443, 6444); hill above Talian mine and top of hill west of Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1920 (lots 7480, 7481).

Subclass DICOTYLEDONES.

Series CHORIPETALAE.

Order SALICALES.

Family SALICACEAE.

Salix reesidei Knowlton, n. sp.

Plate VI, Figure 3.

Leaf small, linear-lanceolate, petioled, long acuminate at apex and narrowly wedge-shaped at base; margin entire; nervation very strong for the size of the leaf and deeply impressed, consisting of a thick, straight midrib and some ten or twelve pairs of strong secondaries, which arise at an angle of about 45°, all camptodrome, each arching inside the margin and joining the the one next above; finer nervation not discernible.

This little leaf is the only one observed in the collections. It is 4 centimeters long, including the petiole, and 6 millimeters wide in the middle.

This species is of the type of a number of living species, such as *Salix fluviatilis* Nuttall, *Salix sessilifolia* Nuttall, of the central part of the continent and the Pacific coast region, but both these have a few faint teeth above the middle. It is also similar to *Salix angustifolia* Fries and *Salix incanea* Schrank, of central and northern Europe, but differs in details of nervation. It is apparently different from any fossil species from this country thus far described. It is of the same size as some of the smaller leaves of *Salix plicata* Knowlton,[12] from the Raton formation, but this differs in the secondary nervation.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7496).

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[9] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 98, p. 333, pl. 84, fig. 4, 1916.

[10] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 285, pl. 54, fig. 2, 1917 [1918].

[11] British Eocene flora, Filices, vol. 1, p. 45, pls. 8, 9, 1880.

[12] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, pl. 37, fig. 8, 1917 [1918].

Order JUGLANDALES.

Family JUGLANDACEAE.

Juglans schimperi Lesquereux.

Plate VII, Figure 1.

Juglans schimperi Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 8, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 287, pl. 56, figs. 5–10, 1878.
Hollick, Louisiana Geol. Survey, Special Rept. 5, p. 280, pl. 32, fig. 5; pl. 33, figs. 1, 2; pl. 35, fig. 3, 1899.
Berry, U. S. Geol. Survey Prof. Paper 91, p. 182, pl. 18, figs. 3–5; pl. 19, fig. 4, 1916.
Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 296, pl. 64, fig. 1, 1917 [1918].

This species was described from specimens collected from the Green River formation of Wyoming and has since been detected in the Denver, Clarno, Fort Union, and Raton formations, as well as in several of the formations of the Wilcox group of the Gulf region. Whatever may be thought of the probability of a species enjoying so wide a geologic and geographic range as is thus indicated, the fact remains that it is impossible to draw any satisfactory line between the forms described. They are to all intents and purposes the same thing, as may be noted on comparing the many figures that have been published.

The leaflet here figured is nearly perfect, except that it lacks the base. It was probably about 11 centimeters long and is 4 centimeters wide. It agrees perfectly in shape, size, and essential details of nervation with leaflets as figured by Lesquereux, Hollick, and Berry.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7496).

Juglans berryi Knowlton.

Plate VI, Figures 5, 6.

Juglans berryi Knowlton, in Berry, U. S. Geol. Survey Prof. Paper 91, p. 183, 1916; U. S. Geol. Survey Prof. Paper 101, p. 293, pl. 63, fig. 3; pl. 64, fig. 3; pl. 73, fig. 3, 1917 [1918].

The type of this species was described from material obtained in the Raton formation of southeastern Colorado, and the species was also found by Berry in the Wilcox group in Louisiana and beds of corresponding age in the Lagrange formation of Kentucky. The specimen here figured does not differ from the type specimens. Specimens not figured from the Ignacio quadrangle, Colo., are also identical.

Occurrence: Animas formation, Ignacio quadrangle, Colo., east side of sec. 31, T. 35 N., R. 6 W., New Mexico principal meridian, collected by J. H. Gardner, August, 1909 (lot 5455); Pagosa quadrangle, Colo., 1 mile northeast of Pagosa Junction, collected by W. T. Lee, 1912 (lot 6444); same locality as last, but half a mile downstream from station (lot 6309); west of Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7479); 4½ miles north of Pagosa Junction (lot 7485).

Juglans? innominata Knowlton, n. sp.

Plate VII, Figure 2.

Leaflet very firm in texture, broadly ovate-lanceolate, apex missing but apparently acute, base strongly unequal sided, being abruptly rounded on the upper side and cut away to wedge shape on the lower side; petiole short (about 8 millimeters long), very stout; midrib very thick, straight; secondaries about 10 pairs, subopposite, emerging at an angle of about 45°, slightly curved upward, apparently camptodrome; finer nervation obsolete.

This species is represented by a number of fragmentary specimens and by the nearly perfect one figured. This was probably not less than 10 or 11 centimeters in length and about .5 centimeters in width. The margin inclines to be slightly undulate but is otherwise entire.

This leaflet is about the size and general appearance of the larger of the leaflets of *Juglans leconteana* Lesquereux,[13] but the latter is more nearly entire at the base and has the secondaries more obviously camptodrome.

Occurrence: Animas formation, Ignacio quadrangle, Colo., east side of sec. 31, T. 35 N., R. 6 W. New Mexico principal meridian, collected by J. H. Gardner, August, 1909 (lot 5455).

[13] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 54, figs. 10, 11, 1878.

Order FAGALES.

Family FAGACEAE.

Fagus crossii Knowlton, n. sp.

Plate XIX, Figure 2.

Leaf apparently thin, oblong-ovate, acuminate, broadest about the middle, whence it tapers gradually to the rounded base, margin perfectly entire below, faintly and obscurely toothed above; petiole slender; midrib slender, straight; secondaries about 15 pairs, mainly alternate, at an angle of about 45°, close, parallel, not much curved upward, craspedodrome, ending in the margin or in the upper portion in the faint marginal teeth; nervilles very numerous, percurrent, at right angles to the secondaries.

The specimen is nearly perfect, lacking only a small portion of one side. It is 9 centimeters long and slightly over 4 centimeters broad, and the petiole is preserved for a length of 1 centimeter.

This species is very similar in size, shape, and general appearance to the living *Fagus americana* Sweet, the common beechnut of eastern North America, except that the marginal teeth are far less prominent.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7496).

Castanea intermedia Lesquereux.

Plate VIII, Figure 1.

Castanea intermedia Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 386, 1876; Ann. Rept. for 1874, p. 313, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 164, pl. 31, fig. 7.

Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 297, pl. 68, fig. 2, 1918.

One of the collections from Pagosa Junction, Colo., contains the leaf here figured, which seems indistinguishable from *Castanea intermedia* Lesquereux, especially as described and figured [14] from the specimen found in the Raton formation of southeastern Colorado, although it is slightly longer and proportionately a little narrower. Although this leaf lacks the upper portion, it could hardly have been less than 15 centimeters long and is fully 4.5 centimeters wide. In all the characters except size—that is in the long wedge-shaped entire basal portion, the numerous sharp marginal teeth, the very thick, straight midrib, and the numerous close parallel secondaries which enter the teeth—it agrees with *Castanea intermedia.*

Thus far six species of *Castanea* have been differentiated in American rocks. The other five are the living *Castanea pumila* (Linné) Miller,[15] found in the Pleistocene of Kentucky and West Virginia; *Castanea castaneaefolia* (Unger) Knowlton,[16] from the Mascall formation of Oregon; *Castanea pulchella* Knowlton,[17] from the Miocene of Yellowstone National Park, which Marty is inclined to refer to *Dryophyllum; Castanea claibornensis* Berry,[18] from the Barnwell formation of Georgia; and *Castanea dolicophylla* Cockerell,[19] from the Florissant lake beds (Miocene) of Colorado. Of these five, *Castanea pumila* and *Castanea castaneaefolia* (formerly known as *C. ungeri* Heer) are readily distinguished from the Animas form, the latter especially by its broader shape and low-angled secondaries. The other species, but particularly *Castanea claibornensis* and some of the narrower leaves of *Castanea pulchella,* are distinguished with difficulty from *Castanea intermedia*—in fact, it is doubtful if a mixed collection could be separated.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 4½ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7485).

Dryophyllum berryana Knowlton, n. sp.

Plate VIII, Figure 2.

Leaf of medium size, coriaceous, long elliptical-oblong, apparently abruptly rounded at the base, gradually rounded above to an acuminate apex; margin obscurely toothed; midrib rather slender, straight; secondaries about a dozen pairs, alternate, slender, emerging at an angle of about 60°, slightly curved upward, terminating in the marginal teeth;

[14] Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 297, pl. 68, fig. 2, 1917 [1918].

[15] Knowlton, F. H., Am. Geologist, vol. 18, p. 371, 1896.

[16] Knowlton, F. H., U. S. Geol. Survey Bull. 152, p. 60, 1898.

[17] Knowlton, F. H., U. S. Geol. Survey Mon. 32, pt. 2, p. 702, pl. 86, figs. 6-8; pl. 87, figs. 1-3, 1899.

[18] Berry, E. W., U. S. Geol. Survey, Prof. Paper 84, p. 138, pl. 28, figs. 1, 2, 1914.

[19] Cockerell, T. D. A., Am. Mus. Nat. Hist. Bull., vol. 24, p. 87, 1908.

finer nervation obscure but apparently with the nervilles mostly unbroken.

The specimen figured lacks the basal part but is otherwise nearly perfect. It was apparently about 12 centimeters long and is 4 centimeters wide. It is of the same width for more than half the length of the blade.

This species is undoubtedly most closely related to *Dryophyllum moorii* (Lesquereux) Berry,[20] from the Wilcox group of Mississippi and Texas and beds of Wilcox age in the Lagrange formation of Kentucky—in fact, if a considerable series were available for comparison it seems likely that they would prove to be identical. As it now stands, however, based on a single example, it seems best to consider the Animas leaf distinct. The Wilcox species is relatively broader, is more elliptical-lanceolate, and usually has more pronounced marginal teeth.

Dryophyllum berryana is also very much like certain of the smaller, narrower, less distinctly toothed leaves of *Dryophyllum levalense* Marty,[21] from the "Paléocène" (Montian) of Hainaut, Belgium. Marty has shown a very great range in size in his species, and the larger examples are very unlike the one under consideration. This species is named in honor of Prof. Edward Wilber Berry, of Johns Hopkins University, who has done so much to elucidate the Eocene floras of the Coastal Plain.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7496).

Order URTICALES.

Family MORACEAE.

Ficus planicostata Lesquereux.

Plate IX, Figure 2.

Ficus planicostata Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 393, 1878; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 201, pl. 31, figs. 1–8, 10–12, 1878.

The type locality for this species is Black Buttes, Wyo., in beds believed by me to be of post-Laramie age. Since it was first described it has been identified, though probably not always correctly, in beds that range in age from middle Montana to upper Eocene. It undoubtedly occurs in the Laramie as well as in the Denver of the Denver Basin of Colorado and in the Wilcox of Louisiana.

The example figured agrees in every particular with the larger of the types as figured by Lesquereux.

Occurrence: Animas formation, Ignacio quadrangle, Colo., in the southeast corner of sec. 15, T. 35 N., R. 6 W., collected by J. H. Gardner, August, 1909 (lot 5456); hill above Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7481).

Ficus neoplanicostata Knowlton.

Plate IX, Figure 4.

Ficus neoplanicostata Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 303, pl. 73, fig. 4; pl. 74, figs. 2, 3; pl. 76, fig. 4, 1917 [1918].

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7485); same locality, collected by W. T. Lee, 1912 (lot 6444).

Ficus occidentalis (Lesquereux) Lesquereux.

Plate VIII, Figure 5.

Ficus occidentalis (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 200, pl. 32, fig. 4, 1878.
Berry, U. S. Geol. Survey Prof. Paper 91, pp. 121, 197, pl. 28, fig. 3, 1916.
Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 331, pl. 73, fig. 1, 1917 [1918].

The type locality of this species is in the Denver formation, but it has since been noted in the Raton, Wilcox, and Midway formations. The specimen here figured lacks all of the upper portion, and the lateral main ribs are not quite so much curved upward as those of the type, but otherwise they do not differ essentially.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr. (lot 7496).

[20] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 190, pl. 22, fig. 1; pl. 23, figs. 1–3, 1916.

[21] Marty, Pierre, Mus. hist. nat. Belgique Extrait Mem., vol. 5, p. 15, pl. 5, fig. 4, 1907.

Ficus denveriana Cockerell.

Plate IX, Figure 1.

Ficus denveriana Cockerell, Torreya, vol. 10, p. 224, 1910.
Berry, U. S. Geol. Survey Prof. Paper 91, pp. 11, 198, 1916.
Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 302, pl. 75, figs. 1, 2, 1917 [1918].
Ficus spectabilis Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 379, 1873; U. S. Geol. Survey Terr., Rept. vol. 7 (Tertiary flora), p. 199, pl. 33, figs, 4–6, 1878. [Homonym, Kunth and Bouché, 1847.]

The type locality for this species is in the Denver formation at Golden, Colo., where it is abundant. It was subsequently found in the Raton formation of the Raton Mesa region of southeastern Colorado and northeastern New Mexico, and by Berry in the Wilcox group of Arkansas and Louisiana and in beds of Wilcox age in the Lagrange formation of Kentucky, as well as in beds thought to be of Midway age in Bexar County, Tex. It has also been reported from the Lance formation near Edgemont, S. Dak.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., June, 1921 (lot 7496).

Ficus subtruncata Lesquereux.

Plate VIII, Figure 3.

Ficus subtruncata Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 205, pl. 30, figs. 7–9, 1878.
Ficus auriculata Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 379, 1873; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora, p. 206, pl. 30, figs. 4–6, 1878. [Homonym, Loureiro, 1834.]

The little leaf figured is undoubtedly identical with the leaves from the Denver formation at Golden, Colo., figured by Lesquereux, especially those figured under the name *Ficus auriculata*. It is distinctly auriculate at the base and has the fine nerves given off to supply the lower lobes of the leaf as originally described.

The complete history of this species is given in my "Flora of the Denver formation," not yet published.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 4½ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7483).

Ficus monodon (Lesquereux) Berry?

Plate X, Figure 1.

Ficus monodon (Lesquereux) Berry, U. S. Geol. Survey Prof. Paper 91, p. 201, pl. 32, fig. 2; pl. 33, fig. 2, 1916.
Populus monodon Lesquereux, Am. Philos Soc. Trans., vol. 13, p. 413, pl. 15, figs. 1, 2, 1869.

The collection from the Animas beds contains the single example here figured, which appears to be identical with *Ficus monodon* from the Wilcox group of Mississippi, as figured and described by Berry. It is only a fragment from the apical portion of the leaf, and although it seems to agree well with the figures given by Berry the reference is questioned until further data can be obtained.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lot 7481).

Ficus pseudo-populus Lesquereux.

Plate VII, Figure 4; Plate IX, Figure 3.

Ficus pseudo-populus Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 387, 1875 [1876]; Ann. Rept. for 1874, p. 313, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 204, pl. 34, figs. 1a, 2, 1878.
Berry, U. S. Geol. Survey Prof. Paper 91, p. 230, pl. 37, figs. 3–5, 1916; pl. 113, fig. 3, 1916.
Knowlton, U. S. Geol. Survey Prof, Paper 101, p. 304, pl. 72, figs. 2–4; pl. 73, fig. 2; pl. 112, fig. 3, 1917 [1918].

The type locality for this species is in the Evanston formation at Evanston, Wyo. It was subsequently found to be very abundant in the Raton formation of Colorado and New Mexico and was also found at several localities in the Wilcox group of Louisiana and in corresponding beds in the Lagrange formation of Tennessee. Its presence in the Animas formation is attested by several specimens, two of the best of which are here figured. They are nearly perfect except for the apex. The larger one was probably 10 or 12 centimeters long and is about 6.5 centimeters wide, and the stout petiole is preserved for a length of over 2 centimeters.

Ficus pseudo-populus is essentially palmately three-ribbed from the top of the petiole, but occasionally the basal pair of secondaries on the lateral ribs is enlarged, thus producing a pseudo five-ribbed appearance. The specimen figured, however, is distinctly three-ribbed, with the lateral ribs diverging at an angle of about 20° and passing high up to join the lowest secondaries on the midrib.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile downstream from Pagosa Junction, collected by W. T. Lee, 1912 (lot 6309); 5 miles and 4½ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., June, 1921 (lots 7481, 7485); same as last but higher beds (lot 7497).

Ficus pagosensis Knowlton, n. sp.

Plate XI.

Leaves very large, 22 to 25 centimeters long, 15 to 18 centimeters broad, firm in texture, ovate-elliptical, broadest just below the middle, whence they are narrowed gradually to the nearly truncate base; apex not preserved but apparently rather obtuse; petiole exceedingly thick; midrib moderately strong for so large a leaf; secondaries about five pairs, the lower pairs very strong, arising at the very base of the blade, thus producing a three-ribbed effect, moderately curved upward, reaching well above the middle of the leaf, each with from eight to ten strong camptodrome tertiary branches on the outside, which join in broad loops inside the margin, and sometimes several on the inner side; upper secondaries opposite or nearly so, slightly curved upward near the margin; nervilles numerous, very strong, approximately at right angles to the secondaries.

This fine species is represented by one nearly perfect leaf—the one figured—and by the very well preserved basal portion of another even larger example. Together they are sufficient to give a fair conception of its characters.

Ficus pagosensis is of the type of *Ficus speciosissima* Ward,[22] a well-known Montana species, but differs markedly in being ovate-elliptical instead of nearly circular, and more particularly in the nearly truncate instead of the deeply cordate-auriculate base, often with overlapping lobes. *Ficus leei* Knowlton,[23] another Montana species, also belongs to this group, but it is much smaller, is nearly orbicular, and usually has the cordate-auriculate base as in *F. speciosissima*. There should be no difficulty in recognizing the new species if the basal portion is present.

Occurrence: Animas formation, 1 mile northeast of Pagosa Junction, Colo., collected by W. T. Lee, 1912 (lot 6443).

Ficus sp.

Plate VII, Figure 3.

The specimen here figured is very obscurely preserved in all except outline. It seemingly lacks at least the upper third. It appears to have been long elliptical, with a regularly rounded, almost truncate base. The margin is entire. The midrib is only moderately strong for the size of the blade. The secondaries are very obscure but appear to be alternate, at an angle of 45° or 50°, and not much arched upward. Little trace of finer nervation is discernible. The leaf was probably at least 10 centimeters long and is 6 centimeters wide.

This leaf resembles a number of described species of *Ficus*, but it is so fragmentary and obscure that it can not be identified with certainty. Thus, it is similar in size and shape to *Ficus uncata* Lesquereux,[24] from the Raton formation, but the secondary nervation does not seem to be so regular. It is also like *Ficus duplicata* Knowlton,[25] which also comes from the Raton formation, but this is much larger and has the secondaries at a less acute angle.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., June, 1921 (lot 7496).

Ficus sp.

Plate VI, Figure 7.

The specimen that is the basis of the figure here given is so much broken that ordinarily it would not be taken into account, but it is the only one noted in the collection and shows a number of features not before observed. It was apparently approximately circular in outline, or possibly it was a little broader than long. It is very deeply heart-shaped at the base, with the basal lobes rounded and full. The margin, so far as can be made out, is perfectly entire. It is strongly 5-ribbed from the

[22] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., p. 552, pl. 45, fig. 1, 1886; Bull. 37, p. 39, pl. 21, fig. 3, 1887.

[23] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 261, pl. 39, figs. 1-6; pl. 40, figs. 1, 2, 1917 [1918].

[24] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 35, figs. 1, 2, 1878.

[25] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 302, pl. 74, fig. 1, 1917 [1918].

top of the petiole; the midrib is slightly stronger than the others and has several alternate secondaries in the upper part of the blade. The next pair of ribs arise at an angle of 60° or 70° and are considerably curved upward and bear a number of secondaries on the outside. The lowest pair of ribs are nearly at a right angle with the midrib and are curved upward for a great distance, each with 8 or 10 secondary branches on the lower and outer side, which supply the rounded basal lobes, several of them with tertiary branches. The nervilles are numerous and strong. Reliable measurements can not be given for this leaf, though it could hardly have been less than 12 centimeters long and fully 10 centimeters broad.

This leaf is of the type of *Ficus speciosissima* Ward,[26] from the Mesaverde formation; *Ficus leei* Knowlton,[27] from the Vermejo formation; and *Ficus cockerelli* Knowlton,[28] from the Laramie and later formations, so far as regards size and shape, but it differs essentially in being strongly 5-ribbed instead of 3-ribbed.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., June, 1921 (lot 7496).

Artocarpus pungens (Lesquereux) Hollick.

Plate XII.

Artocarpus pungens (Lesquereux) Hollick, Arkansas Geol. Survey Special Rept. 5, p. 281, pl. 38, figs. 1, 2, 1899.

Berry, U. S. Geol. Survey Prof. Paper 91, p. 195, pl. 25, fig. 1; pl. 27, fig. 1; pl. 29, fig. 1, 1916.

Aralia pungens Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 123, pl. 19, figs. 3, 4, 1883.

The leaves of *Artocarpus* are difficult to identify satisfactorily. They are mostly very large leaves that were either fragmentary when entombed or broken during excavation, and, moreover, they are rare in collections, it being unusual to find more than three or four in a large series of specimens. The present case is no exception, for out of some hundreds of specimens only two have been found—the one here figured, with its counterpart, and a fragment of the upper part of a similar leaf.

This specimen from the Animas beds was clearly a very large leaf, for it is 22 centimeters long and lacks both base and apex. The very thick midrib seems to indicate that there was probably at least one more lobe, and if so, the leaf would have been 30 centimeters long. The apex of the lowest lobe is not preserved, but presumably it was sharp pointed. The upper lobe is small, sharp pointed, and curved upward. The apex of this lobe also is not preserved but was apparently pointed. The nervation is characteristically that of *Artocarpus*, consisting of a strong, straight midrib and three or four strong secondaries, which terminate in the apices of the lateral lobes, each, but especially the lower ones, with several remote, camptodrome secondaries. There is also a strong primary running to the sinus.

This leaf is identical in shape and nervation with one of the types of *Artocarpus pungens*,[29] but it is much larger. Berry in his report on the Wilcox flora figures several leaves under the name *A. pungens*, but they are not so similar to the present specimen as the types above mentioned.

In 1909 J. H. Gardner collected a single fragment of an *Artocarpus* in the Ignacio quadrangle, Colo. This fragment was first thought to belong to *Artocarpus lessigiana* Lesquereux and later to *Artocarpus similis* Knowlton, but in the light of the larger example here referred to *Artocarpus pungens* it seems probable that this fragment also should be referred to this species. As a matter of fact, it is so small a fragment that an attempt to place it definitely is perhaps unwise, although it seems to agree well with this species, so far as can be made out.

Occurrence: Animas formation, Ignacio quadrangle, Colo., top of Animas beds, collected by J. H. Gardner, August, 1909 (lot 5667); Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., June, 1921 (lot 7496).

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[26] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., p. 552, pl. 45, fig. 1, 1886.

[27] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 201, pl. 39, figs. 1-6; pl. 40, figs. 1, 2, 1917 [1918].

[28] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 130, p. 132, pl. 12, fig. 2; pl. 23, figs. 1, 2, 1922.

[29] Lesquereux, Leo. U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), pl. 19, fig. 3, 1883.

Order PLATANALES.

Family PLATANACEAE.

Platanus raynoldsii Newberry.

Platanus raynoldsii Newberry, New York Lyceum Nat. Hist. Annals, vol. 9, p. 69, 1868; U. S. Geol. Survey Mon. 35, p. 109, pl. 35, 1898.
Knowlton, U. S. Geol. Survey, Prof. Paper 101, p. 324, pl. 95, fig. 1, 1917 [1918].

Platanus raynoldsii was described originally from material collected in the Fort Union formation of Montana and has since been found to be one of the most abundant and widely distributed forms in the Lance and Fort Union formations and was also found in the Raton formation of the Raton Mesa region of Colorado and New Mexico.

One of the collections from the Animas formation about 5 miles east of Durango, Colo., contains some large leaves of *Platanus*, which, although fragmentary, show the decurrent base characteristic of this species. No specimens have been figured, as they would not add particularly to knowledge of the species.

Occurrence: Animas formation, Ignacio quadrangle, Colo., 5 miles east of Durango, in the SW. ¼ SE. ¼ sec. 30, T. 35 N., R. 8 W., 700 feet above base of Animas beds, collected by J. B. Reeside, jr., 1920 (lot 7463); Pagosa quadrangle, Colo., 1 mile north of Pagosa Junction, collected by W. T. Lee, 1912 (lot 6443), about 1 mile northeast of Pagosa Junction, collected by W. T. Lee, 1912 (lot 6444); 1 mile northeast of Bayfield, Colo., collected by J. B. Reeside, jr., 1920 (lot 7452).

Platanus aceroides Göppert.

Platanus aceroides Göppert, Deutsch. geol. Gesell. Zeitschr., vol. 5, p. 492, 1852.
Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 184, pl. 25, figs. 4, 5, 1878.

One of the collections of Animas leaves contains a number of fragmentary leaves that appear to belong to this species. They are, for instance, of the same size and nervation as certain leaves figured by Lesquereux under this name, but they are practically without margin, and it is therefore impossible to be certain of their identity. So far as it is possible to compare them, however, they seem to agree with the usual forms of this species.

Occurrence: Animas formation, Ignacio quadrangle, Colo., east side of sec. 31, T. 35 N., R. 6 W. New Mexico principal meridian, collected by J. H. Gardner, August, 1909 (lot 5455); Pagosa quadrangle, Colo., 1 mile northeast of Pagosa Junction, collected by W. T. Lee, 1912 (lot 6443); 1 mile northeast of Bayfield, Colo., collected by J. B. Reeside, jr., 1920 (lot 7452); 5 miles north of Pagosa Junction, Colo., collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7482); same as last but higher in the section (lot 7485); Cat Creek, 1 mile north of Pagosa Junction, Colo., collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7498).

Platanus aceroides latifolia Knowlton.

Plate XIII, Figure 3; Plate XIV, Figure 4.

Platanus aceroides latifolia Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 321, pl. 92; pl. 93, fig. 3; pl. 94, 1917 [1918].
Berry, U. S. Geol. Survey Prof. Paper 91, p.13, 1916.

These collections include a considerable number of sycamore leaves, but most of them are fragmentary. Two of the best-preserved ones have been selected to be figured. The smaller one is about 13 centimeters long and 11 centimeters wide, and the larger one is about 16 centimeters wide, but the length can not be ascertained.

These leaves appear to agree most closely with *Platanus aceroides latifolia* Knowlton, and they are so referred. The larger of the two leaves figured also resembles *Platanus haydenii* Newberry; they differ in the marginal teeth.

Platanus aceroides latifolia was described from specimens found in the Raton formation of the Raton Mesa region of Colorado and New Mexico, where it is abundant. It was also found by Berry in beds supposed to be of Midway age at Earle, Bexar County, Tex.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile south of Talian mine 4½ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7485); Cat Creek, 1 mile north of Pagosa Junction (lot 7498).

Order THYMELEALES.

Family LAURACEAE.

Laurus primigenia Unger.

Laurus primigenia Unger. Lesquereux, U. S. Geol. Survey Terr., Rept., vol. 7 (Tertiary flora), p. 214, pl. 36, figs. 5, 6, 8, 1878.

The leaves identified under this name by Lesquereux and figured in his "Tertiary flora" came from the Evanston formation at Evanston, Wyo. Since then leaves apparently identical with these have been recorded from the Hanna formation at Carbon, Wyo.; the Denver formation at Golden, Colo.; basic brecias of Fort Union age in the Yellowstone National Park; and the Wilcox group of Louisiana.

A number of leaves have been found in the Animas formation that appear to be referable to this species, except that they are a little smaller. One of them has the petiole preserved apparently entire; it is over 1 centimeter in length.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1 mile north of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Nectandra lancifolia (Lesquereux) Berry.

Plate XIII, Figure 1.

Nectandra lancifolia (Lesquereux) Berry, U. S. Geol. Survey Prof. Paper 91, p. 308, pl. 85, fig. 2, 1916.
Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 318, pl. 90, figs. 1, 2, 1917 [1918].
Persea lancifolia Lesquereux, Am. Philos. Soc. Trans., vol. 13, p. 419, pl. 19, Figs. 3, 4, 1869.

Described originally from specimens collected from the Wilcox group, in which it is found at a number of localities in Mississippi, Louisiana, and Texas, and in corresponding beds in the Lagrange formation of Tennessee. It also occurs at several places in the Raton formation of northeastern New Mexico and southeastern Colorado. The specimen here figured is indistinguishable from the one shown in Plate XC, Figure 1, of my Raton Mesa paper (Professional Paper 101).

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1 mile north of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Malapoenna sessiliflora (Lesquereux) Knowlton.

Plate XIV, Figure 3.

Malapoenna sessiliflora (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 142, 1898.
Laurus sessiliflora Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 407, 1874.
Tetranthera sessiliflora (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary Flora), p. 217, pl. 35, fig. 8a [fig. 9], 1878.

Leaves small, subcoriaceous, narrowly obovate-lanceolate, rather obtuse at apex; long, narrowly wedge-shaped at base, length about 6 centimeters, width 2 centimeters; petiole long, slender, nearly 2 centimeters long; secondaries five pairs, slender, much curved upward, camptodrome; nervilles (in the type) numerous, nearly at right angles to the midrib.

The type specimen of this species as at present restricted came from the Evanston formation at Evanston, Wyo., and has been well described and figured by Lesquereux, except that the supposed calyx is shown as attached to the petiole, which is of course impossible. The leaf from the Animas beds agrees perfectly with the type but does not have the nervilles preserved.

Occurrence: Animas formation, about 1 mile northeast of Pagosa Junction, Colo., collected by W. T. Lee, 1912 (lot 6443).

Oreodaphne pagosensis Knowlton, n. sp.

Plate XV, Figure 5.

Leaves evidently of firm texture, ovate-elliptical, apparently moderately acuminate at the apex, abruptly rounded below to a narrowly wedge-shaped, almost decurrent base; length about 16 centimeters, width nearly 6 centimeters; petiole stout; midrib very strong; secondaries not particularly strong, about seven pairs, somewhat irregular, the lowest at acute angles and with several camptodrome tertiary branches on the outer side; other secondaries alternate, at less acute angles, not much curved upward, curving just at the margins; nervilles obscure, apparently at right angles to the secondaries.

This leaf appears to be congeneric with a number of leaves from the Wilcox group described by Berry and to fall within his section of "leaves with well-marked lateral primaries in the lower half of the leaf." In size and shape this species suggests *Oreodaphne obtusifolia* Berry,[30] but it differs in having the base more decurrent and the basal pair of large secondaries less well marked and not ascending for so great a distance; the nervilles are obscure but apparently differ from those in the Wilcox species mentioned. The Pagosa Junction leaf is also of the type of *Oreodaphne salinensis* Berry [31] except that the latter is much smaller and much less wedge-shaped at the base.

Occurrence: Animas formation, about 1 mile northeast of Pagosa Junction, Colo., collected by W. T. Lee, 1912 (lot 6444).

[30] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 301, pl. 83, figs. 2–5, 1916.

[31] Idem, p. 303, pl. 82, fig. 1, 2.

Cinnamomum salicoides Knowlton, n. sp.

Plate XV, Figure 2.

Leaves small, coriaceous, narrowly lanceolate, broadest below the middle, long wedge-shaped and slightly decurrent at base, narrowly acuminate at apex; midrib relatively very strong, lateral ribs arising just above the base, dividing the space between midrib and margin about equally, ascending for one-half or more the length of the leaf and then approaching the margin; secondaries few, high upon the midrib, at an acute angle; all finer nervation obsolete.

This form is represented by a considerable number of leaves, but all of them are broken except the one figured, which lacks only a minute portion of the tip. This is 5.5 centimeters long and about 1 centimeter wide, and has the petiole 5 millimeters long. Other specimens are nearly 2 centimeters wide and must have been 7 centimeters or more in length.

This species somewhat resembles the very narrow forms of *Cinnamomum linifolium* Knowlton,[32] of the Raton formation, but differs in being acuminate instead of rounded at the apex. It is also similar to *Cinnamomum oblongatum* Berry,[33] from the Lagrange formation of Tennessee, but the latter has the ribs near the margin and the secondaries on the midrib at a low angle.

Cinnamomum salicoides is much more closely related to certain of the narrower leaves of the European *C. lanceolatum*—in fact, with the scanty material available it is difficult to see any differences. Staub, in his "Geschichte des Genus *Cinnamomum*," has brought together all the published figures of the genus. On Plate XII of his monograph are a number of figures of *C. lanceolatum* and *C. salicifolium* that are certainly very close to the one under consideration, but they are found mainly in the Oligocene and Miocene, and for the present at least it seems best to regard them as distinct.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7483).

[32] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 319, pl. 88, fig. 6, 1917 [1918].

[33] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, pl. 79, figs. 1, 2, 1916.

Order RANALES.

Family NYMPHAEACEAE.

Nelumbo lakesiana (Lesquereux) Knowlton.

Nelumbo lakesiana (Lesquereux) Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 308, 1917 [1918].

Nelumbium lakesianum Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 403, 1874.

Nelumbium lakesii Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 252, pl. 46, figs. 1, 2, 1878.

A single fragmentary specimen without margin but apparently belonging to this species; it has not been figured.

Occurrence: Animas formation, Pagosa quadrangle, Colo., Pagosa Junction, half a mile downstream from the station, collected by W. T. Lee, 1912 (lot 6309).

Family MAGNOLIACEAE.

Magnolia angustifolia Newberry.

Plate X, Figure 3; Plate XVI, Figure 5.

Magnolia angustifolia Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 513, 1882 [1883].

Berry, U. S. Geol. Survey Prof. Paper 91, p. 214, 1916.

Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 309, pl. 79, fig. 1; pl. 80; pl. 81, fig. 1, 1917 [1918].

Magnolia attenuata Weber. Lesquereux, U. S. Geol. Survey Terr., vol. 7 (Tertiary flora), p. 250, pl. 45, fig. 6, 1878.

This species was named and described but not figured by Newberry in 1883 from specimens found in beds now known as the Raton formation of Fisher's Peak, Colo. In 1878 Lesquereux figured the lower half of a leaf from the same locality under the name *Magnolia attenuata* Weber, a European Miocene species, but the two are quite distinct. It was next figured by Hollick,[34] who identified it as *Magnolia lanceolata* Lesquereux, from the Wilcox of Louisiana. It was found to be very abundant in the Raton formation of the Raton Mesa region of Colorado and New Mexico.

The larger specimen here figured agrees perfectly in size and shape with the Raton leaves but differs slightly in the more evenly spaced secondaries. The smaller example figured is indistinguishable from one found in the Raton formation.[35]

[34] Hollick, Arthur, Arkansas Geol. Survey Special Rept. 5, pl. 40, 1899.

[35] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, pl. 81, fig. 1, 1917 [1918].

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1 mile northeast of Pagosa Junction, collected by W. T. Lee, 1912 (lot 6444); 4¼ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7485); half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Magnolia hilgardiana Lesquereux.

Plate XVI, Figure 4.

Magnolia hilgardiana Lesquereux, in Owen, Second report of a geological reconnaissance of the middle and southern counties of Arkansas, p. 319, pl. 6, fig. 1, 1860; Am. Philos. Soc. Trans., vol. 13, p. 421, pl. 21, fig. 1, 1869.
Hollick, Arkansas Geol. Survey Third Ann. Rept., p. 282, pl. 39, 1899.
Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 310, pl. 79, fig. 2; pl. 85, fig. 1, 1917 [1918].
Quercus lyelli Heer. Lesquereux, Am. Philos. Soc. Trans., vol. 13, p. 415, pl. 17, fig. 3 [not figs. 1, 2], 1869.
Terminalia hilgardiana (Lesquereux) Berry, U. S. Geol. Survey Prof. Paper 91, p. 325, pl. 92, fig. 2, 1916.

The leaf here figured agrees perfectly with the leaf from the Raton formation of southeastern Colorado figured by me under this name in 1918. The type locality of *Magnolia hilgardiana* is somewhat in doubt, though in all reasonable probability it was in the Wilcox of Mississippi, where this species has since been found at a number of localities by Berry. It was identified by Berry in beds supposed to be of Midway age at Earle, Bexar County, Tex. It was also identified [36] in the Miocene of Lassen County, Calif., though this identification may require revision.

Berry [37] has transferred this species to the genus *Terminalia*, but I prefer to retain it under *Magnolia*.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7481); 4¼ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7485); half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

[36] Knowlton, F. H., in Lindgren, Waldemar, U. S. Geol. Survey Prof. Paper 73, pp. 60, 61, 1911.
[37] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 325, 1916.

Magnolia magnifolia Knowlton?

Magnolia magnifolia Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 311, pl. 85, 1917 [1918].
Magnolia tenuinervis Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 249, pl. 44, figs. 5, 6; pl. 45, figs. 1–3 [not pl. 45, figs. 4–6], 1878.

The conclusion that this species is present in the Animas beds is based on a single rather fragmentary specimen. The species was first recorded under the name *Magnolia tenuinervis* Lesquereux and came from the Denver formation at Golden, Colo. It was found, however, that *Magnolia tenuinervis* was a composite species, and the Denver leaves were referred to *M. magnifolia*. The Animas leaf is smaller than the usual leaves of *M. magnifolia*, but it is so poorly preserved that its identity is somewhat uncertain.

Occurrence: Animas formation, 5 miles south of Durango, Colo., above the conglomerate (McDermott formation) that overlies the coal-bearing series, collected by T. W. Stanton, 1891 (lot 731).

Order ROSALES.

Family POMACEAE.

Crataegus? gigantea Knowlton, n. sp.

Plate X, Figure 2.

Leaf of firm texture, broadly deltoid in general outline, slightly wedge shaped at the broad base, pinnately 5-lobed, possibly 7-lobed, the lobes separated by deep rounded sinuses; lower lobes lanceolate, 3 or 4 centimeters long, 1.2 to 2 centimeters broad at base, acuminate at apex; margin remotely toothed, the teeth sharp; petiole short, a little over 1 centimeter long; midrib slender, straight; secondaries apparently three pairs, subopposite, at an angle of 40° or 50°, a little curved upward, ending in the lobes, the lower pair with numerous tertiary branches at various angles, much curved upward and craspedodrome; finer nervation not retained.

This leaf is rather fragmentary, as it lacks all of the apical portion, but the base with its petiole complete and one basal lobe is well shown. It was probably 10 or 12 centimeters long and about 10 centimeters between the tips of the lower lobes.

The proper generic reference for this strongly marked leaf is uncertain. It can hardly be referred to *Acer*, *Aralia*, or *Sterculia*, to each of which it has some points of resemblance, but it is like certain deeply incised leaves of *Crataegus*, such as *Crataegus apiifolia* Michaux or *Crataegus nigra* Kitarbel, but it is twice or more the size of the usual leaves of *Crataegus*. The sinuses separating the lobes in the deeply incised living species are usually sharp or only moderately rounded, whereas in the Animas leaf they are deep and distinctly rounded. It is doubtful if this leaf really belongs to *Crataegus*, but it may remain here until a more definite allocation can be made.

Occurrence: Animas formation, Pagosa quadrangle, Colo., five-eighths of a mile south of Talian mine, 4½ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7486).

Family CAESALPINACEAE.

Cassia puryearensis Berry.

Plate XIV, Figures 1, 2.

Cassia puryearensis Berry, U. S. Geol. Survey Prof. Paper 91, p. 230, pl. 51, figs. 13, 14, 1916.

I am not able to see any essential difference between the leaflet here figured and the figures given by Berry. This leaflet is about 8.3 centimeters long and 2.5 centimeters wide, has a strong-midrib and about eight pairs of camptodrome secondaries which emerge at an angle of about 50°; the finer nervation is obsolete. This agrees perfectly with Berry's description, except that it is slightly more wedge-shaped at base.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Order SAPINDALES.

Family ANACARDIACEAE.

Rhus coloradensis Knowlton, n. sp.

Plate X, Figure 4.

Leaflet small, about 4.5 centimeters long and 2 centimeters wide, elliptical oblong, rounded truncate at base, obtusely acuminate at apex, slightly unequal-sided; margin obscurely and remotely toothed; midrib very strong; secondaries about eight pairs, strong, alternate, emerging at a nearly right angle below but about 40° above, camptodrome, curving just within the border and sending slender branches to the teeth; finer nervation obscure.

This little leaflet appears to be of the type of the living *Rhus copallina* Linné, which ranges over the eastern United States and as far west as Nebraska, Kansas, and eastern Texas, except that in the fossil the teeth are a little more pronounced. There are a number of fossil species that the present one somewhat resembles, such for instance as *Rhus frigida* Knowlton,[38] from the Eocene rocks of Herendeen Bay, Alaska.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Family SAPINDACEAE.

Sapindus obtusifolius Lesquereux?

Plate VIII, Figure 4.

Sapindus obtusifolius Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 419, 1874; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 266, pl. 49, figs. 8–11, 1878.

There is a single specimen in one of the collections of Animas plants that appears to be a medium-sized leaflet of this species, but inasmuch as the nervation is not very well preserved I have questioned the identification. It agrees in size and shape and in nervation as well as this can be made out.

Occurrence: Animas formation, Ignacio quadrangle, Colo., east side of sec. 21, T. 35 N., R. 6 W. New Mexico principal meridian, collected by J. H. Gardner, August, 1909 (lot 5455).

Order RHAMNALES.

Family RHAMNACEAE.

Rhamnus cleburni Lesquereux.

Plate XVII, Figure 4.

Rhamnus cleburni Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 381, 1873; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 280, pl. 53, figs. 1–3, 1878.

Berry, U. S. Geol. Survey Prof. Paper 91, p. 283, 1916.

Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 382, pl. 113, fig. 3, 1917 [1918].

The example figured is nearly perfect, lacking only a small portion of the tip. It is clearly indistinguishable from the type speci-

[38] Knowlton, F. H., U. S. Nat. Mus. Proc., vol. 17, p. 227, pl. 9, fig. 6, 1894.

mens described by Lesquereux, from the Denver formation at Golden, Colo., where the species is abundant. This species was also found at a number of localities in the Raton formation of southeastern Colorado and northern New Mexico and was reported by Berry in the Wilcox group of Mississippi and Louisiana. It was doubtfully identified [39] in the lower part of the Clarno formation of Cherry Creek, Oreg.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 4½ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7485); 1 mile north of Pagosa Junction, collected by W. T. Lee, 1912 (lot 6444).

Rhamnus goldianus Lesquereux.

Rhamnus goldianus Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 381, 1873; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 281, pl. 53, figs. 4–8, 1878.

A single leaf that appears to belong to this species.

Occurrence: Animas formation, Ignacio quadrangle, Colo., 5 miles east of Durango, in SW. ¼ sec. 30, T. 35 N., R. 8 W., 700 feet above base of Animas beds, collected by J. B. Reeside, jr., 1920 (lot 7463).

Zizyphus fibrillosus (Lesquereux) Lesquereux.

Zizyphus fibrillosus (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 276, pl. 52, figs. 1–5 [not fig. 6, which = *Zizyphus daphnogenoides* Knowlton], 1878; Mus. Comp. Zool. Bull., vol. 16, p. 55, 1888.

Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 335, pl. 102, fig. 1, 1917 [1918].

Ceanothus fibrillosus Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 381, 1873.

This species was described originally from material found in the Denver formation at Golden, Colo., and subsequent collecting at this locality has shown it to be one of the most abundant and characteristic species of the formation. It was also found at a number of localities in the Raton formation of the Raton Mesa region of Colorado and New Mexico. The specimen from the Animas formation is absolutely identical with the leaves from Golden. Although it lacks the upper part, the cordate base, strongly inarching ribs, and very strong nervilles are clearly characters of this species.

[39] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 80, 1902.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Zizyphus daphnogenoides Knowlton, n. sp.

Daphnogene anglica? Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 401, 1874; Ann. Rept. for 7876, p. 510, 1878; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 222, pl. 37, fig. 9, 1878.

Zizyphus fibrillosus (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol 7 (Tertiary flora), pl. 52, fig. 6 [not figs. 1–5], 1878.

Leaves of firm texture, ovate-lanceolate, abruptly rounded or very obtusely wedge-shaped at base, long and narrowly acuminate at apex; margin entire, perhaps slightly undulate; petiole very thick, the principal ribs descending into it for some distance below the margin of the blade; nervation peculiar, strong, three-ribbed, the ribs arising well down on the petiole, the middle one slightly strongest, straight, ending in the extreme tip; lateral ribs at a very acute angle, arching outward but slightly, then inward and running nearly or quite to the tip; midrib without secondary branches, lateral ribs with five or six secondary branches on the outside, the lowest nearly basal, all at relatively acute angles, arching and passing high upward, camptodrome; lower secondary with a few short, camptodrome tertiary branches on the outside; nervilles numerous, strong, parallel, unbroken, mainly at right angles to the midrib.

Types: U. S. Nat. Mus. Nos. 317 (identified as *Daphnogene anglica*), 430 (identified as *Zizyphus fibrillosus*), 51066 (with manuscript identification as *Zizyphus raincourtii* var.).

This species is represented by some half a dozen more or less perfect examples from the Denver formation at Golden, Colo., which together afford a pretty complete knowledge of its size and form. They show considerable range in size, the smallest being the specimen described and figured by Lesquereux as *Daphnogene anglica?* Heer ("Tertiary flora," pl. 37, fig. 9), which is 6 centimeters long and only 1.6 centimeter wide, whereas the largest is fully 12 centimeters in length and about 6 centimeters in width. The petiole is preserved for about 1.5 centimeters and is evidently not complete. The outline also differs somewhat, ranging from narrowly ovate-lanceolate to broadly ovate-lanceolate. The base is in no specimen heart-shaped. The apex is long and narrowly acuminate. The primary nervation is strongly marked and is peculiar in that the three ribs arise well down on the petiole and far below the lower margin of the blade. It is really only three-ribbed, but the lowest pair of secondaries sometimes arise so low down as to make it appear five-ribbed.

The solitary leaf identified by Lesquereux as *Daphnogene anglica?* Heer is present in the U. S. National Museum collection (No 317) and has long been a puzzle. Its identification with this European species rested on extremely insecure grounds, as it was never figured, Lesquereux making the identification on the short description alone. It has remained unique in American strata until the present time, but although much smaller and narrower than the typical form of *Zizyphus* appears to be, it is so absolutely similar in everything except size that I have no hesitation in placing them together.

The question of relationship has to be further considered. Lesquereux was evidently in doubt as to the propriety of referring it to *Daphnogene* and stated: "It is therefore probable that, as Saporta supposes, this leaf may represent a *Zizyphus* or a *Ceanothus*," and such seems to me to be the case. The little narrow original specimen has seemingly a relationship to *Zizyphus vulgaris* Linné, the common living form, though the latter differs in having serrate margins and in lacking the strong branching on the outside of the lateral ribs. But in the light of the additional material now referred to this form it appears beyond question to be most closely related to *Zizyphus fibrillosus* Lesquereux—in fact, the line separating them is very uncertain. Unfortunately most of the leaves of *Z. fibrillosus* are so fragmentary that it is difficult to determine the shape of the base; it appears, however, that this is always more or less deeply heart-shaped, whereas in the form under discussion the base is truncate or obtusely wedge-shaped. The apex is also uncertain in many of the examples referred to *Z. fibrillosus*, but in none of them does it appear so long or so narrowly acuminate as in the specimens under consideration. The nervation is certainly very much of the same type in both, and it may be that subsequent discoveries will show that *Z. daphnogenoides* is not a well founded species, though in the light of present understanding it seems a far call from the narrow leaf figured by Lesquereux ("Tertiary flora," pl. 37, fig. 9) to the large, extremely broad leaves of typical *Z. fibrillosus*.

This form is also to be compared with *Zizyphus distortus* Lesquereux, which is really almost too close to warrant separation, and if the type and only examples of *Z. distortus* were better preserved or reinforced by additional material it is possible that all three would be thrown together.

I have also referred to *Zizyphus daphnogenoides* one of the six specimens figured by Lesquereux as *Zizyphus fibrillosus* ("Tertiary flora," pl. 52, fig. 6). This specimen (No. 430, U. S. Nat. Mus.) represents the nearly complete apical portion of a long, narrow leaf that was probably about 7 centimeters long and not much if any over 3 centimeters wide. It must have been narrowed or very obtusely wedge-shaped at the base and is certainly quite unlike the broad truncate or heart-shaped leaves normal for *Z. fibrillosus*.

Among the specimens from the Denver formation acquired by the United States National Museum from the Lacoe collection there is one labeled by Lesquereux as an undescribed variety of *Zizyphus raincourtii* (Saporta) Saporta. This specimen (No. 51066, U. S. Nat. Mus.) is a rather fragmentary basal portion of a small leaf that appears indistinguishable from certain of the leaves now placed in *Z. daphnogenoides*. Saporta's species,[40] which is from the Eocene of Sézanne, is of about the same size as the leaf under consideration but differs in a number of marked particulars. Thus, it is three-ribbed from the top of the petiole, but the lateral ribs do not ascend much above the middle of the blade, and the middle rib has numerous secondary branches in the upper part. The margin of the leaf is denticulate instead of entire. The Lacoe specimen is undoubtedly referable to *Zizyphus daphnogenoides*.

The Lacoe collection also contains another specimen that must be referred to *Zizyphus daphnogenoides*. This specimen (No. 51063, U. S. Nat. Mus.) was labeled by Lesquereux as *Smilax* sp., but it is indistinguishable from the ordinary leaves of *Z. daphnogenoides*,

[40] Saporta, Gaston de, Prodrome d'une flore fossile des travertins anciens de Sézanne: Soc. geol. France Mém., 2d ser., vol. 7, p. 414, text fig. 22, pl. 14, figs. 8-10, 1868.

such, for instance, as that figured by Lesquereux in the "Tertiary flora" (pl. 52, fig. 6) as *Zizyphus fibrillosus*.

The above description and discussion was prepared for the paper on the flora of the Denver formation, but inasmuch as the species has now been found in the Animas formation, the account of which is to be published first, it is necessary to present the facts and the reasons for the action taken. The figures of the Denver specimens will be published in the paper mentioned.

The Animas leaf is a very perfect specimen, lacking only a bit of the extreme tip. It is narrowly ovate-lanceolate, about 6 centimeters long and 2 centimeters wide, and has the complete petiole, 2 centimeters long. As may be seen on comparison, it is identical in all particulars with the Denver leaf identified by Lesquereux as *Daphnogene anglica?* Heer. There can be no question as to their being the same.

Occurrence: Denver formation, Golden, Colo. The leaf figured by Lesquereux as *Daphnogene anglica?* Heer was collected in the seventies by Capt. Ed. Berthoud. The specimen removed from *Zizyphus fibrillosus* was collected about 1872 by Leo Lesquereux. The additional examples were collected by Arthur Lakes on the south face of South Table Mountain, 100 feet below the lava cap.

Animas formation, Pagosa quadrangle, Colo.; half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Zizyphus lanceolatus Knowlton, n. sp.

Plate XV, Figure 3.

Leaf small, coriaceous, slightly elliptical-oblanceolate, broadest above the middle, whence it narrows below to the long wedge-shaped base and more abruptly above to the acuminate apex; petiole short, stout; midrib relatively very strong; lateral veins arising at a very acute angle from the top of the petiole, thin, passing up near the margin to or very near the tip of the blade, each with two or three branches on the outside which unite and form a thin "vein" nearly to the tip of the blade; midrib with several pairs of secondary branches in the upper part, these joining the intramarginal rib or vein; the lower part of the blade has the area between the midrib and the ribs with an irregular mesh of nervilles. This little leaf is 5 centimeters long and 1.4 centimeters wide.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7483).

Order UMBELLALES.

Family ARALIACEAE.

Aralia lobata Knowlton, n. sp.

Plate XVII, Figures 1, 2.

Leaves small or of medium size, coriaceous, three-ribbed from the very base, where the lateral ribs form the margin for some distance; five or seven lobed, the central lobe much longer than the others, narrow, cut into several very large lanceolate lobes; upper lobes similar to the middle lobe but smaller; next pair much reduced, with only one or two of the large lobes; midrib of the central lobe very strong, with several pairs of alternate, strong secondaries; lateral ribs that supply the upper pair of lobes strong, at an angle of about 65°; basal lobe supplied with a midrib which arises from the lateral rib some distance from the base and which in turn, in seven-lobed leaves, gives rise to the midrib of the lobe.

This is a very remarkable species, represented in the collections by the two examples figured and by a number of fragments. Although neither of the figured specimens is perfect, there is enough present to give a fairly complete idea of the form. The better-preserved one, shown in Figure 1, must have been about 12 or 13 centimeters long to the tip of the central lobe and about 8 centimeters wide; it has the petiole 2.5 centimeters long. The other specimen (fig. 2) was slightly longer but is so broken that measurements can hardly be made.

Aralia lobata is strikingly similar in facies to *Aralia dissecta* Lesquereux,[41] from the Miocene lake beds at Florissant, Colo., but the latter is not only very much larger, with the lobes much more segmented, but differs in having all the seven ribs arising at the top of the petiole.

There are also certain species of *Aralia*, as, for instance, *A. wellingtoniana* Lesquereux,[42] from

[41] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 176, pl. 35, 1883.

[42] U. S. Geol. Survey Mon. 17, pl. 22, fig. 3, 1892.

the Dakota sandstone of Kansas, that are of this general facies, but the Dakota form differs essentially in having the lobes merely toothed and in having the lateral ribs arising well above the decurrent base of the blade.

Occurrence: Animas formation, Pagosa quadrangle, Colorado, 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7483.)

Aralia reesidei Knowlton, n. sp.

Plate XVII, Figure 3.

Leaf of medium size, coriaceous, palmately strongly three-ribbed from a point above the decurrent base of the blade; five-lobed, the central lobe largest, broadly lanceolate; upper pair of lobes deltoid, short, acute; basal pair of lobes small, acute; margins of lobes remotely few toothed, the teeth low, sharp; three upper lobes with five or six pairs of strong, irregularly spaced secondaries which terminate in the marginal teeth; midrib of the basal lobes arising from the lateral pair of ribs well above the base, with three or four secondaries on the lower side only; nervilles numerous, strong, mainly percurrent.

This species is represented by the single nearly perfect leaf figured. It is about 12 centimeters long and about 13 centimeters broad between the points of the basal lobes. The petiole is evidently very strong, as appears in the decurrent portion of the blade, where it gives rise to the three ribs.

This species is undoubtedly of the same type as *Aralia coloradensis* Knowlton,[43] from the Raton formation of southeastern Colorado, and is closely related to it—in fact, if a series of the two were available for comparison it might well be found that they are identical, but unfortunately each is at present known from a single specimen. *Aralia coloradensis* is a much larger leaf, being about 20 centimeters long and 16 or 18 centimeters broad between the tips of the lateral lobes.

Occurrence: Animas formation, Pagosa quadrangle, Colo., hill above Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7482).

[43] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 341, pl. 107, fig. 2, 1917 [1918].

Aralia? sp.

Plate VI, Figure 4.

This is probably a small, distorted leaf of *Aralia lobata* and perhaps ought not to be mentioned, but it is so peculiar that it may be worthy of a brief description. It is long wedge shaped at the base, with at least three lobes, a strong irregular central one and two lateral sharp-pointed ones, which differ greatly in size. It has three ribs that arise at the top of the petiole, the lateral ones with a fork or supplementary rib considerably above the base.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7483).

Family CORNACEAE.

Cornus studeri? Heer.

Plate XIII, Figure 2; Plate XV, Figure 1.

Cornus studeri? Heer, Flora tertiaria Helvetiae, vol. 3, p. 27, pl. 105, figs. 18–21, 1859.

Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 244, pl. 42, figs. 4, 5, 1878.

The two specimens figured are referred to *Cornus studeri?* on the ground of their rather close agreement with leaves so identified by Lesquereux, from the Denver formation at Golden, Colo. They are quite different from Heer's figures of leaves from the Aquitanian of Switzerland, as indeed are the Denver leaves figured by Lesquereux, and they are also different from the leaf from the Wilcox group figured by Berry,[44] and from that from the Raton formation of Colorado figured by me.[45] In fact, some seemingly very diverse forms have been referred to Heer's *Cornus studeri*, though always with question, and it is doubtful if all are conspecific or even congeneric. Thus Berry suggests that possibly this leaf should probably be placed in *Ficus*, and this is the conclusion reached by Saporta regarding the European types of the species. I do not think that either the specimens under discussion or those figured by Lesquereux should be referred to *Ficus*, though the forms somewhat

[44] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, pl. 68, fig. 3, 1916.

[45] Knowlton, F. H., U. S. Geol. Survey, Prof. Paper 101, pl. 109, fig. 2, 1917 [1918].

resemble certain leaves placed under *Laurus*, but the strongly inarching upper secondaries are characteristic of *Cornus*.

The smaller of the two figured leaves is about the same size and nervation as *Cornus rhamnifolia* Lesquereux,[46] described from beds near Point of Rocks, Wyo., supposed to be near Green River age, but the secondaries are a little less curved upward. The larger leaf figured is slightly obovate-elliptical, as in some leaves of *Laurus*, but the upper secondaries are those of *Cornus*.

Occurrence: Animas formation, Ignacio quadrangle, Colo., east side of sec. 31, T. 35 N., R. 6 W. New Mexico principal meridian, 1,650 feet above base of beds, collected by J. H. Gardner, August, 1909 (lot 5455).

Nyssa? racemosa Knowlton.

Nyssa? racemosa Knowlton, U. S. Geol. Survey Bull. 152, p. 153, 1898; Prof. Paper 101, p. 343, 1917 [1918].

Sabalites fructifer Lesquereux [part], U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 11, fig. 3*a* [not fig. 3], 1878.

The type locality of this species is Golden, Colo., in the Denver formation, where it was found by Lesquereux in association with *Sabalites? fructifer*, of which it was supposed to be the fruit. It has been found to be not uncommon in the Denver formation and has been identified in the Raton formation near Raton, N. Mex., and in "post-Laramie beds" at Black Buttes, Wyo.

The specimens from the Animas formation are detached fruits that agree perfectly in size and shape with the types. They are not, however, so distinctly striate, though faint transverse striae can be made out. These specimens have not been figured.

The proper generic reference for these fruits is still unsettled. They probably do not belong to *Nyssa*, and if their affinity can not be established they should be designated by a new generic name.

Occurrence: Animas formation, Ignacio quadrangle, Colo., pebbles near top of beds, collected by J. H. Gardner, 1909 (lot 5667).

[46] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 42, fig. 6, 1878.

Order GENTIANALES.

Family APOCYNACEAE.

Apocynophyllum wilcoxensis Berry.

Plate XIV, Figure 5.

Apocynophyllum wilcoxensis Berry, U. S. Geol. Survey Prof. Paper 91, p. 342, pl. 103, figs. 2, 3; pl. 108, fig. 4, 1916.

Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 345, pl. 103, fig. 3; pl. 105, figs. 1, 2; pl. 106, fig. 1, 1917 [1918].

This species was described by Berry from specimens obtained in the Wilcox group of Mississippi and Louisiana and in beds of Wilcox age in the Lagrange formation of Tennessee and was subsequently identified by me in the Raton formation of southeastern Colorado. The leaf here figured, from the Animas beds, agrees perfectly in all except size with the smaller examples from the Raton formation. The Raton leaves are from 16 to 23 centimeters long and 2.5 to 3.75 centimeters wide, whereas the Animas leaf is only 10 centimeters long and 1.5 centimeters wide. The description of the Raton leaves is given as follows:

> Leaves thick and coriaceous in texture, narrowly lanceolate in shape, more or less unequal-sided and slightly falcate, broadest near the middle, thence tapering upward to the long, slender apex and downward to the narrowly wedge-shaped base; midrib very strong, especially below, straight; secondary nervation thin, delicate, more or less uneven, consisting of numerous rather close parallel secondaries which emerge at an angle of about 20° and run nearly straight to the margin, each joining the one next above, thus producing a somewhat irregular intermarginal "stitch."

A comparison of the figures shows them to agree in every essential particular, including the coriaceous substance of the leaf, the narrowly lanceolate, slightly falcate shape, unequal sides, and thin secondary nervation, ending in the intermarginal vein.

The smaller of the leaves of *Apocynophyllum wilcoxensis* from the Raton formation, as well as the one from the Animas beds, are very similar in size, shape, and nervation to the leaf from the Green River formation that Lesquereux[47] described as *Eucalyptus? americanus*, but the Green River leaf differs in having the second-

[47] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 296, pl. 59, fig. 11, 1878

aries at an angle of 40° or 45°. It would seem that they must be at least congeneric, but they are permitted to stand until further specimens are available.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7483).

Order RUBIALES.

Family CAPRIFOLIACEAE.

Viburnum rotundifolium Lesquereux.

Plate XVI, Figure 1.

Viburnum rotundifolium Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 305, 1875; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 225, pl. 38, fig. 10; pl. 61, fig. 22, 1878.

One of the collections from the Animas beds contains a number of leaves that do not seem to differ essentially from the types of *Viburnum rotundifolium*. They are slightly less truncate than the types but are otherwise the same.

Occurrence: Animas formation, Ignacio quadrangle, Colorado, east side of sec. 21, T. 35 N., R. 6 W. New Mexico principal meridian, collected by J. H. Gardner, August, 1909 (lot 5455).

Viburnum antiquum (Newberry) Hollick.

Plate XVIII, Figures 1-3.

Viburnum antiquum (Newberry) Hollick, in Newberry U. S. Geol. Survey Mon. 35, p. 128, pl. 33, figs. 1, 2, 1898.

Tilia antiqua Newberry, New York Lyceum Nat. Hist. Annals, vol. 9, p. 52, 1868.

Viburnum tilïoides Ward, U. S. Geol. Survey Sixth Ann. Rept., p. 556, pl. 61, figs. 1–7; pl. 62, figs. 1–6, 1886; Bull. 37, p. 107, pl. 50, figs. 1–3; pl. 51, figs. 1–8; pl. 52, figs. 1, 2, 1887.

The collection made by W. T. Lee near Pagosa Junction, Colo., contains a number of finely preserved leaves that I am not able to separate satisfactorily from *Viburnum antiquum*, the well-known Fort Union species. The only difference I am able to note is that in these leaves the secondaries are slightly more erect than in the Fort Union types. I have figured three specimens to show the range in size and how closely they compare with those figured by Newberry and Ward.

Occurrence: Animas formation, Pagosa Junction, Colo., half a mile downstream from the station, collected by W. T. Lee, 1912 (lot 6309).

Viburnum speciosum Knowlton.

Plate XVI, Figure 3.

Viburnum speciosum Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 347, p. 111, figs. 1–5, 1917 [1918].

Lee's collection from Pagosa Junction, Colo., contains a number of well-preserved specimens that belong to this species. The one here figured is seen to agree perfectly with Figures 2 and 4 of the types as illustrated in the paper cited.

Occurrence: Animas formation, about 1 mile northeast of Pagosa Junction, Colo., collected by W. T. Lee, 1912 (lot 6443).

PLANTS OF UNCERTAIN OR UNRECOGNIZED SYSTEMATIC POSITION.

Carpites sulcatus Knowlton, n. sp.

Plate XIX, Figures 3, 4.

The collection from Pagosa Junction, Colo., includes two specimens of a rather peculiar fruit of unknown affinity. They are elliptical, about 10 millimeters long and 6 or 7 millimeters broad, with two or three longitudinal ridges separated by shallow furrows. One of the specimens shows a carbonaceous layer about 1 millimeter thick, possibly representing a shell or in any event a firm exocarp. No point of attachment can be distinguished.

The ridged surface suggests a fruit of *Hicoria*, but the size and shape seemingly preclude such affiliation. It will have to remain under *Carpites* until further information is forthcoming.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Phyllites eocenica Knowlton, n. sp.

Plate XVIII, Figure 4.

The specimen shown was a large leaf, probably not less than 15 centimeters long and 8.5 centimeters wide. It is apparently thick and firm in texture and ovate-lanceolate, but it is so fragmentary that the characters can not all be made out. Thus it appears to have been rounded and obtusely wedge-shaped at the base and probably acuminate at the apex, though both are missing. The margin so far as can be made out is perfectly entire. The nervation is very strong, consisting of a very thick, straight midrib and about five pairs of nearly as strong secondaries. The basal pair appear to arise at the base of the blade and might almost be called ribs. They pass upward at an angle of about 75°, with a very slight curve, nearly two-thirds the length of the blade; they have several branches on the outside. The other secondaries are also at an angle of about 75° and arch just inside the margin. The finer nervation is not retained.

This leaf resembles a number of described species, but its fragmentary nature prevents a decision on certain characters. Thus, it suggests some leaves of *Cornus studeri?* Heer, as figured by Lesquereux,[48] but it has fewer secondaries, and the broken apex prevents determining whether they curve inward, as in *Cornus*. It is apparently more of the type of *Ficus planicostata goldiana* Lesquereux,[49] from the Denver formation at Golden, Colo., but it is proportionately narrower and has the secondaries at a slightly more acute angle. The critical character of the origin of the basal pair of secondaries can not be ascertained, as the base of the leaf is lacking.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7483); half a mile south of Talian mine, 4½ miles north of Pagosa Junction, collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7485).

Phyllites pagosensis Knowlton, n. sp.

Plate XVI, Figure 2.

The collection obtained near Pagosa Junction, Colo., contains a single specimen of the form here figured. It is presumably a leaflet, as the base is almost squarely truncate on one side and greatly reduced and wedge-shaped on the other side. It was apparently narrowly lanceolate in general outline, though the apical portion and much of one side is absent. The margin is cut by very large sharp-pointed teeth, some of which are again cut by smaller teeth. The midrib is strong, straight, and provided with numerous evenly spaced parallel secondaries, which emerge at an angle of about 30° and terminate in the large teeth, with a smaller branch entering the secondary teeth. The finer nervation is obscure. No satisfactory measurements can be given beyond the width of one side, which is slightly over 1.5 centimeters. The whole length must have been some 8 or 9 centimeters.

There is so much uncertainty concerning the proper generic reference for this fragment that it seems best to place it, temporarily at least, in the noncommittal *Phyllites*. At first sight it strongly suggests *Myrica*, with its low-angled secondaries and strongly toothed margin, but the double serration excludes it from the majority of species of that genus. Heer[50] has described a doubly serrate species from the Swiss Miocene under the name *Myrica graffii*, but it is very different from the one under consideration.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction, collected by J. B. Reeside, jr., 1921 (lot 7496).

Phyllites herbacea Knowlton, n. sp.

Plate XV, Figure 4.

Leaf small, thin, broadly ovate, slightly unequal sided, truncate at the base, with a wedge-shaped decurrent portion; apex destroyed but apparently rather obtuse; margin coarsely and irregularly toothed; nervation thin, three-ribbed from the very base of the decurrent portion of the blade, the midrib with two or three pairs of very thin secondaries in the upper part, craspedodrome; lateral ribs at an acute angle (about 70°), each with a strong branch that arises some distance above the base, the one on the narrow side of the leaf entering the lowest marginal tooth, that on the broad side with about four secondary branches on the lower side; finer nervation obscure.

The specimen figured is the only one of this kind noted in the collections. It is nearly perfect except for the apical portion, and was apparently about 6.5 centimeters long. It is slightly over 1.5 centimeters wide on the narrow side of the leaf and 2.5 centimeters wide on the broader side.

I have not been able to place this leaf satisfactorily. Its obviously thin texture and irregularly toothed margin suggest a herbaceous plant, such as some species of *Aster*, but the likeness

[48] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 42, fig. 5, 1878.

[49] Idem, pl. 33, figs. 1-3.

[50] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, pl. 150, figs. 19, 20, 1859.

is not sufficient to warrant placing it in this or any other genus that has been recognized. It also suggests perhaps remotely some of the leaves of the European poplar (*Populus alba*), but its thin texture, unequal sides, and three-ribbed, decurrent base apparently exclude it from *Populus*. It seems best to refer it to *Phyllites* and await further light on its affinities.

Occurrence: Animas formation, Pagosa quadrangle, Colo., 1,000 feet south of Talian mine, 5 miles north of Pagosa Junction; collected by Q. D. Singewald and J. B. Reeside, jr., 1921 (lot 7483).

Phyllites innominata Knowlton, n. sp.

Plate XIX, Figure 5.

Leaf large, firm, elliptical-ovate, abruptly rounded to a truncate base (apex wanting); margin perfectly entire; petiole short, moderately strong; nervation pinnate, the midrib strong, straight; secondaries probably about eight pairs, mainly alternate, at an angle of about 40°, little curved upward, the lowest pair arising at the very base of the blade, with three or four tertiary branches on the outside; nervilles strong, mainly at right angles to the secondaries.

This is a large, fine leaf that must have been approximately 15 centimeters long, but the apex is destroyed; it is 8.5 centimeters wide. The petiole, which appears to be completely preserved, is 2.5 centimeters long.

Although this leaf is seemingly so well marked, its affinity is not recognized. It is similar to certain leaves that have been referred to *Ficus*, and on this basis it would perhaps do no great violence to convention to make such an assignment, but that genus is already overburdened, and in the absence of proof it seems best to place the leaf under *Phyllites* until its biologic affinity is recognized.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction; collected by J. B. Reeside, jr., 1921 (lot 7496).

Phyllites sp.

Plate XIX, Figure 1.

The fragment here figured is only the basal portion of a very large leaf that must have been 20 or 25 centimeters long and 10 centimeters or more wide. It appears to have been lanceolate in general outline, though this is, of course, uncertain, and obtusely wedge-shaped at the base. It has a very thick petiole and midrib and very strong alternate secondaries.

Ordinarily it would hardly be worth while to describe and figure so fragmentary a specimen, but it is so much larger than the other leaves in this collection that it seems to merit brief mention. It may be the basal part of a large leaf of *Artocarpus*, and it is also suggestive of certain large-leaved species of *Quercus*, but it is too fragmentary to warrant a decision.

Occurrence: Animas formation, Pagosa quadrangle, Colo., half a mile west of Pagosa Junction; collected by J. B. Reeside, jr., 1921 (lot 7496).

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PLATE V.

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Anemia grandifolia Knowlton, n. sp. Pagosa quadrangle, Colo., Talian mine, about 5 miles north of Pagosa Junction. U. S. Nat. Mus. No. 36631. Reduced one-tenth ---------- 78

FLORA OF THE ANIMAS FORMATION.

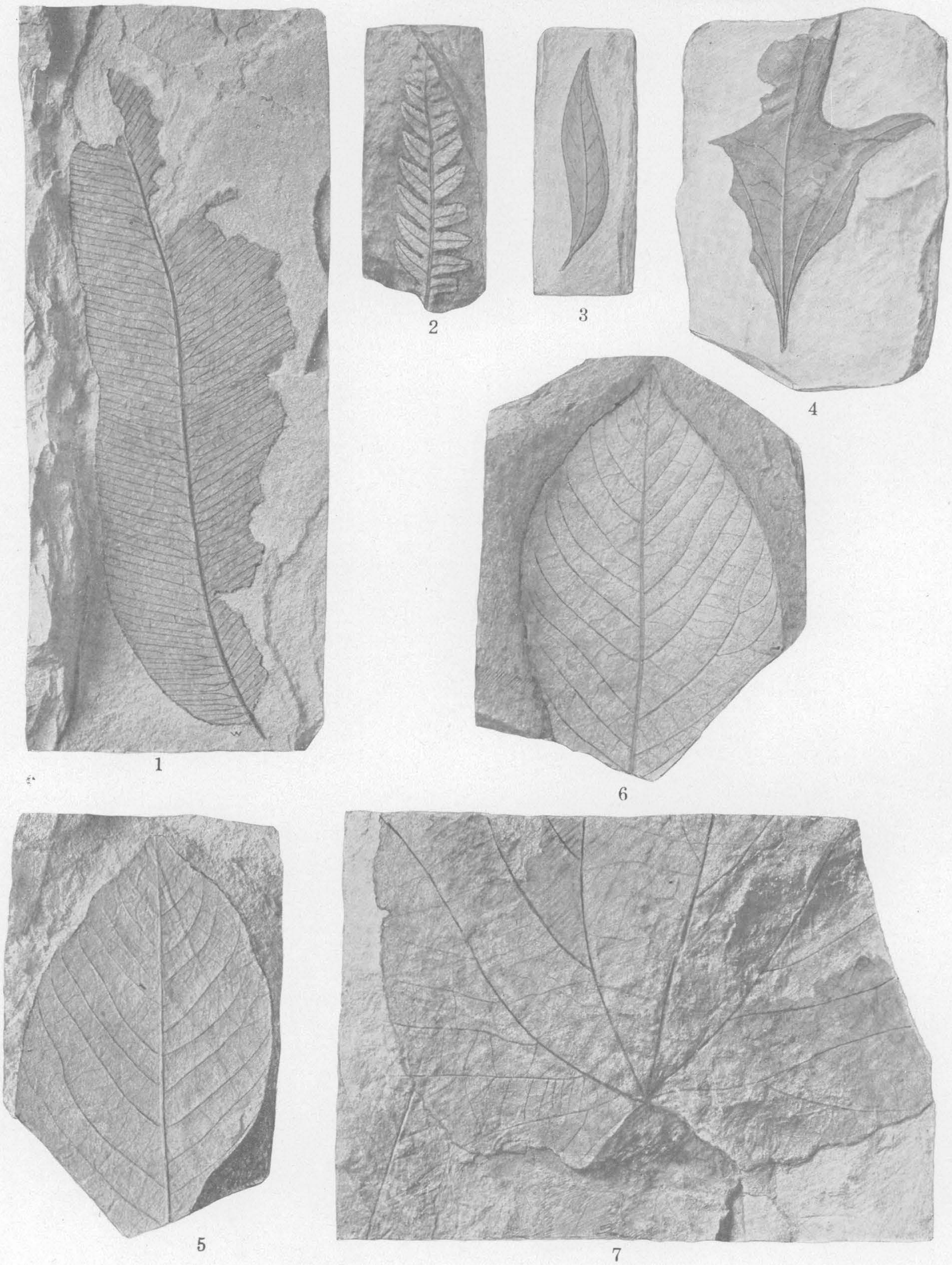

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PLATE VI.

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FIGURE 1. *Allantodiopsis erosa* (Lesquereux) Knowlton and Maxon. Pagosa quadrangle, Colo., $4\frac{1}{2}$ miles north of Pagosa Junction. U. S. Nat. Mus. No. 36632 ---- 78

2. *Dryopteris cladophleboides* Knowlton. Pagosa quadrangle, Colo., $4\frac{1}{4}$ miles north of Pagosa Junction. U. S. Nat. Mus. No. 36633 ---- 78

3. *Salix reesidei* Knowlton, n. sp. Pagosa quadrangle, Colo., half a mile west of Pagosa Junction. U. S. Nat. Mus. No. 36634 ---- 79

4. *Aralia* sp. Pagosa quadrangle, Colo., near Talian mine, 5 miles north of Pagosa Junction. U. S. Nat. Mus. No. 36635 ---- 94

5, 6. *Juglans berryi* Knowlton. Pagosa quadrangle, Colo., near Pagosa Junction. U. S. Nat. Mus. Nos. 36636, 36637 ---- 80

7. *Ficus* sp. Pagosa quadrangle, Colo., half a mile west of Pagosa Junction. U. S. Nat. Mus. No. 36638 ---- 84

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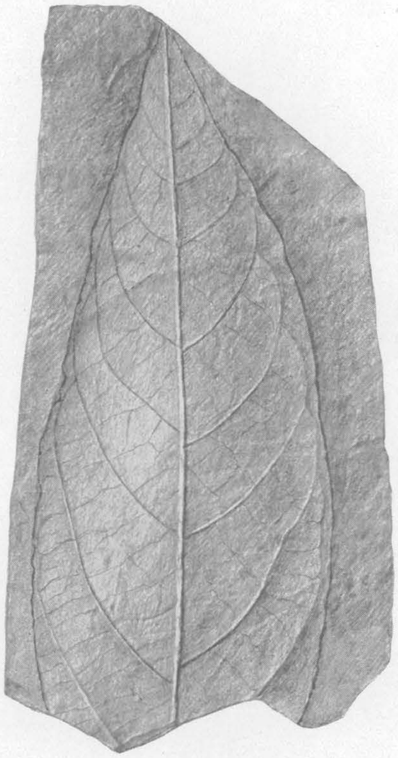

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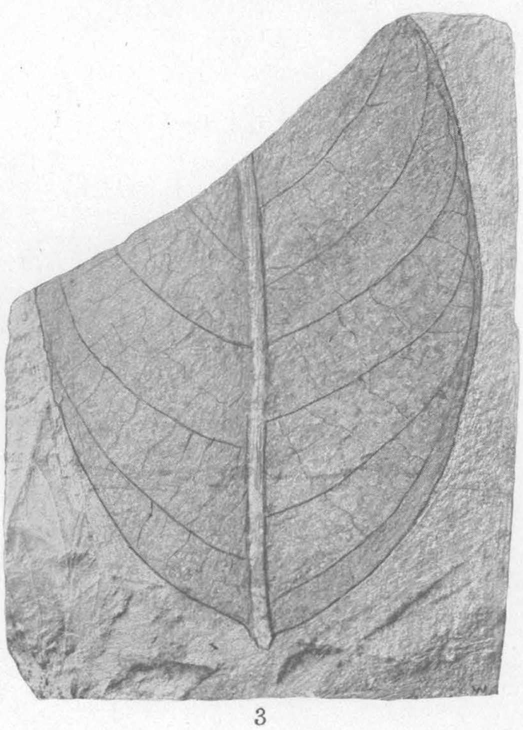

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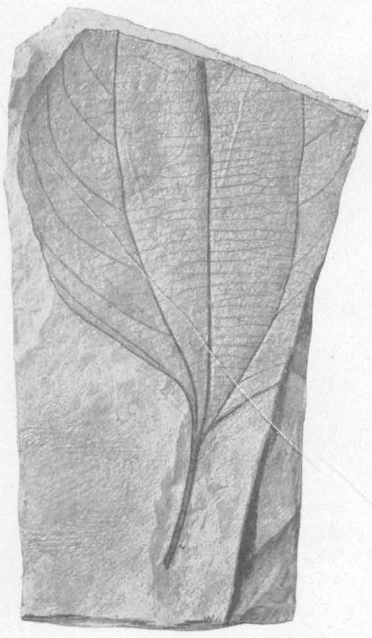

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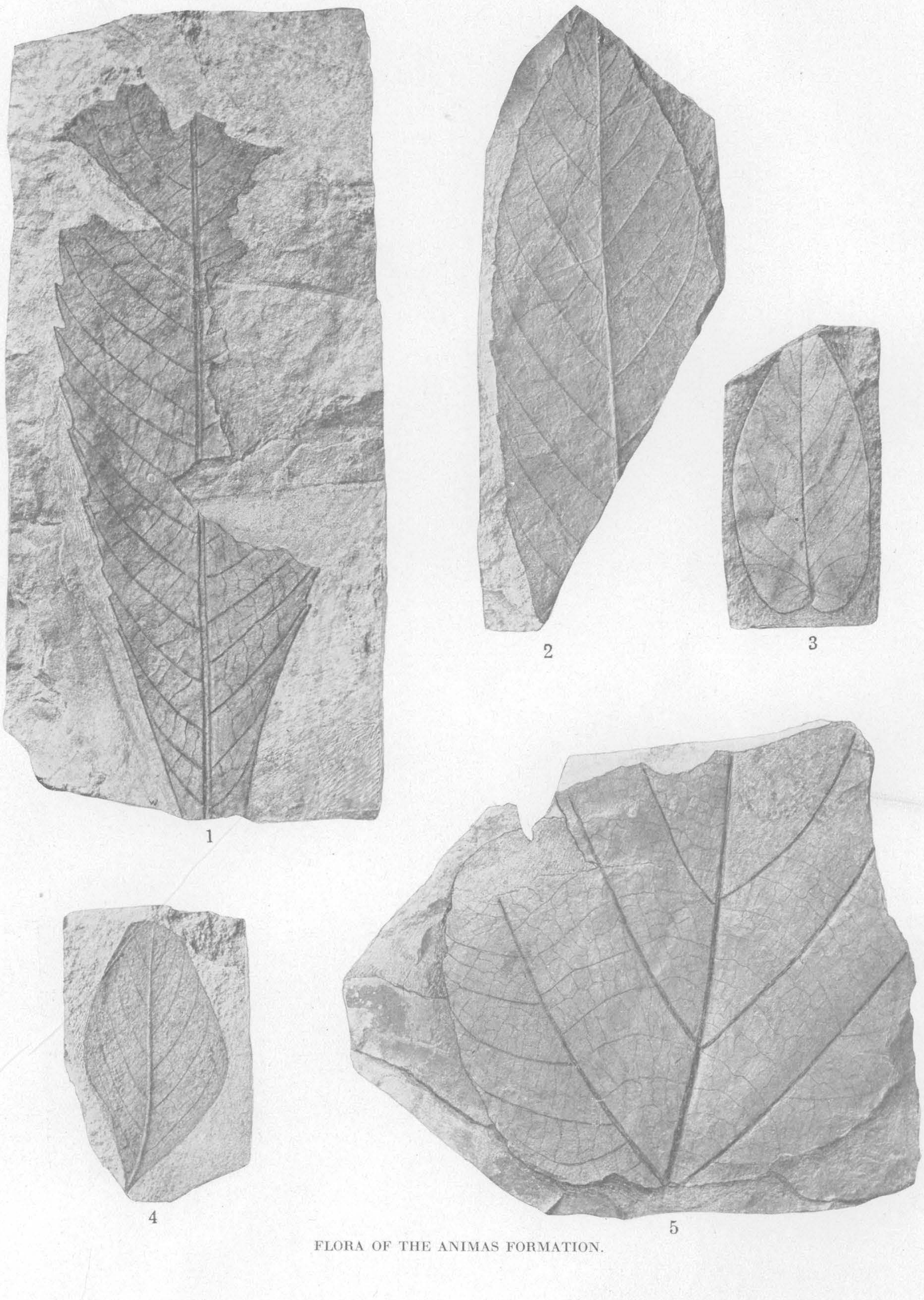

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FIGURE 1. *Castanea intermedia* Leqsuereux. Pagosa quadrangle, Colo., 4½ miles north of Pagosa Junction. U. S. Nat. Mus. No. 36643 81

2. *Dryophyllum berryi* Knowlton, n. sp. Pagosa quadrangle, Colo., half a mile west of Pagosa Junction. U. S. Nat. Mus. No. 36644 81

3. *Ficus subtruncata* Lesquereux. Pagosa quadrangle, Colo., 4½ miles north of Pagosa Junction. U. S. Nat. Mus. No. 36645 83

4. *Sapindus obtusifolius* Lesquereux? Ignacio quadrangle, Colo., sec. 21, T. 35 N., R. 6 W. New Mexico principal meridian. U. S. Nat. Mus. No. 36646 90

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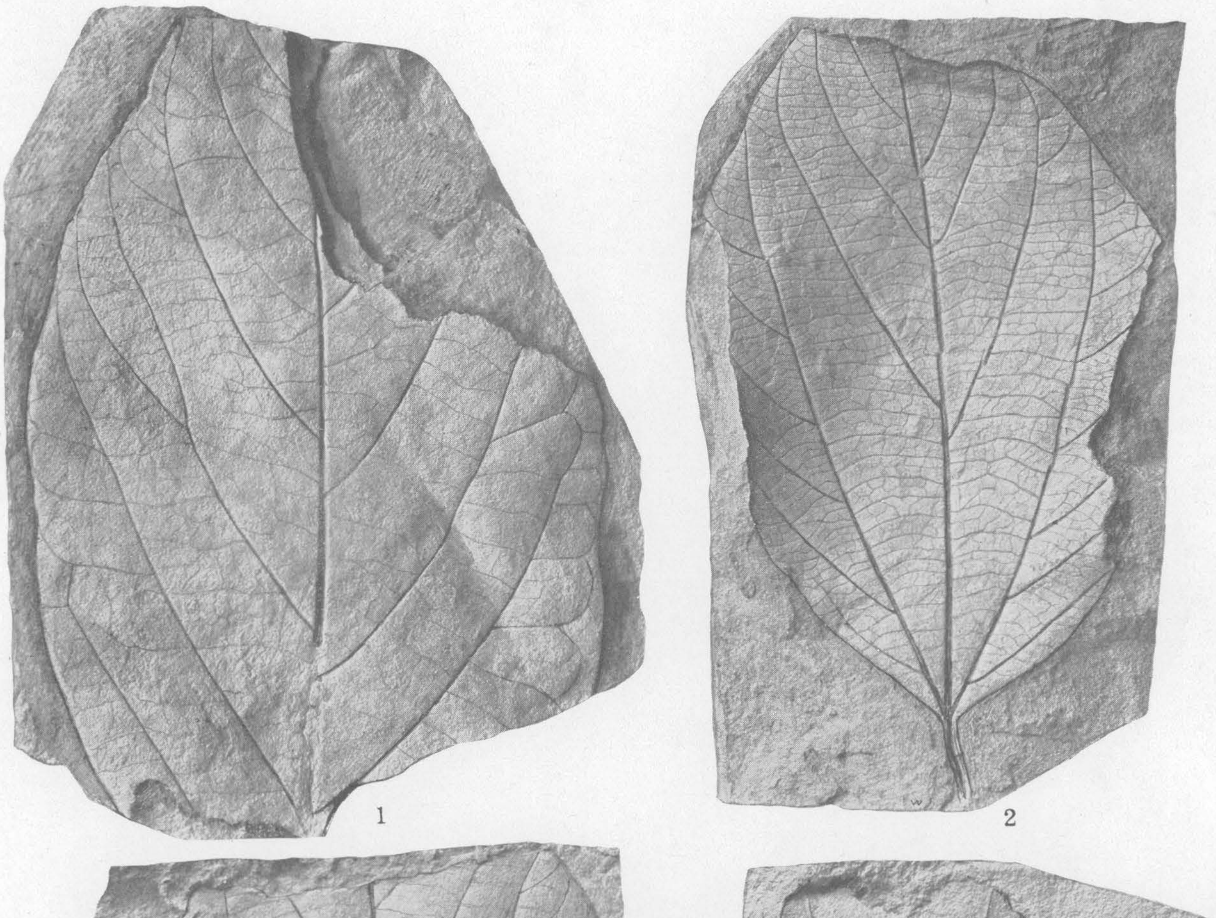
PLATE IX.



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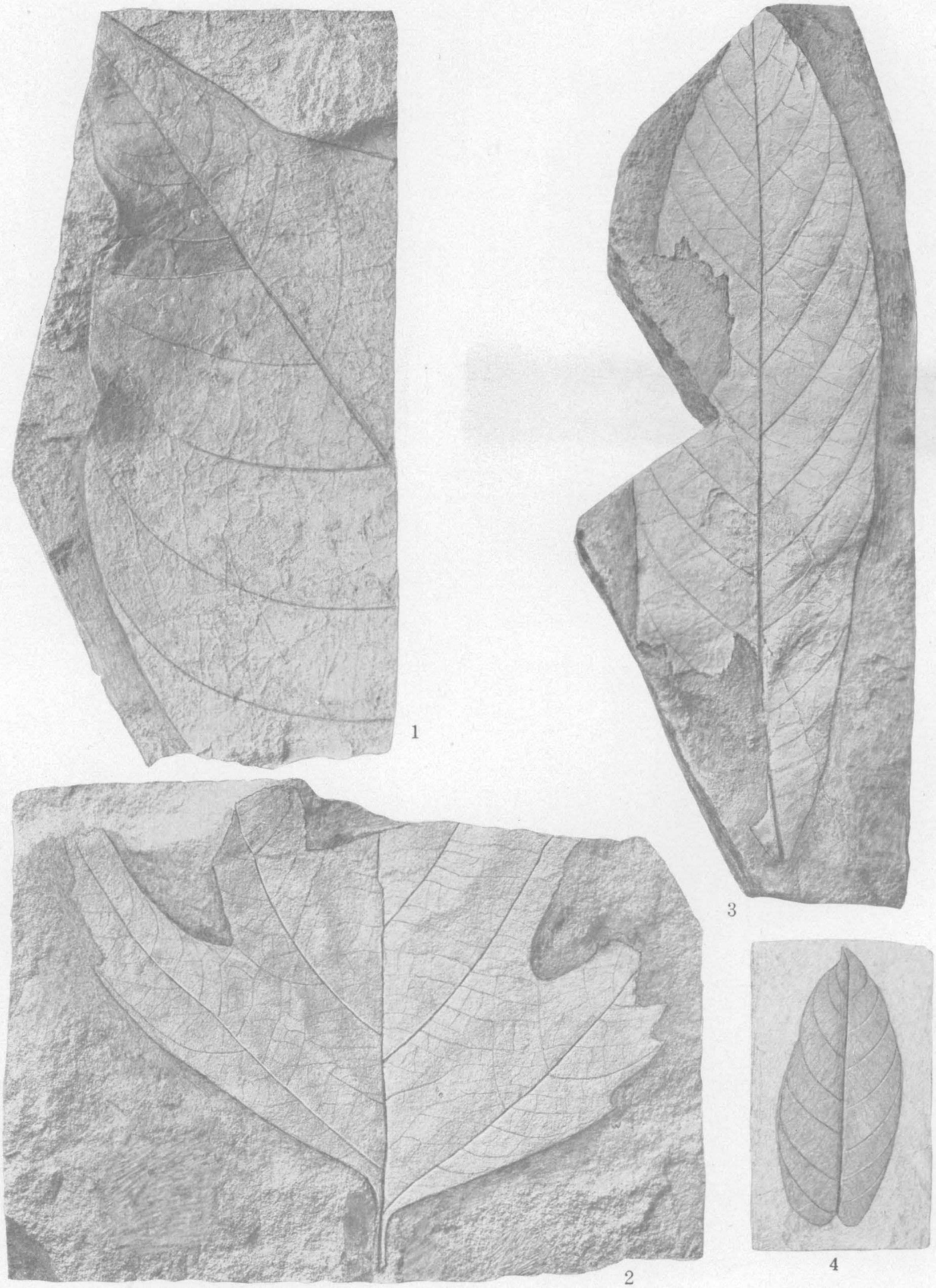

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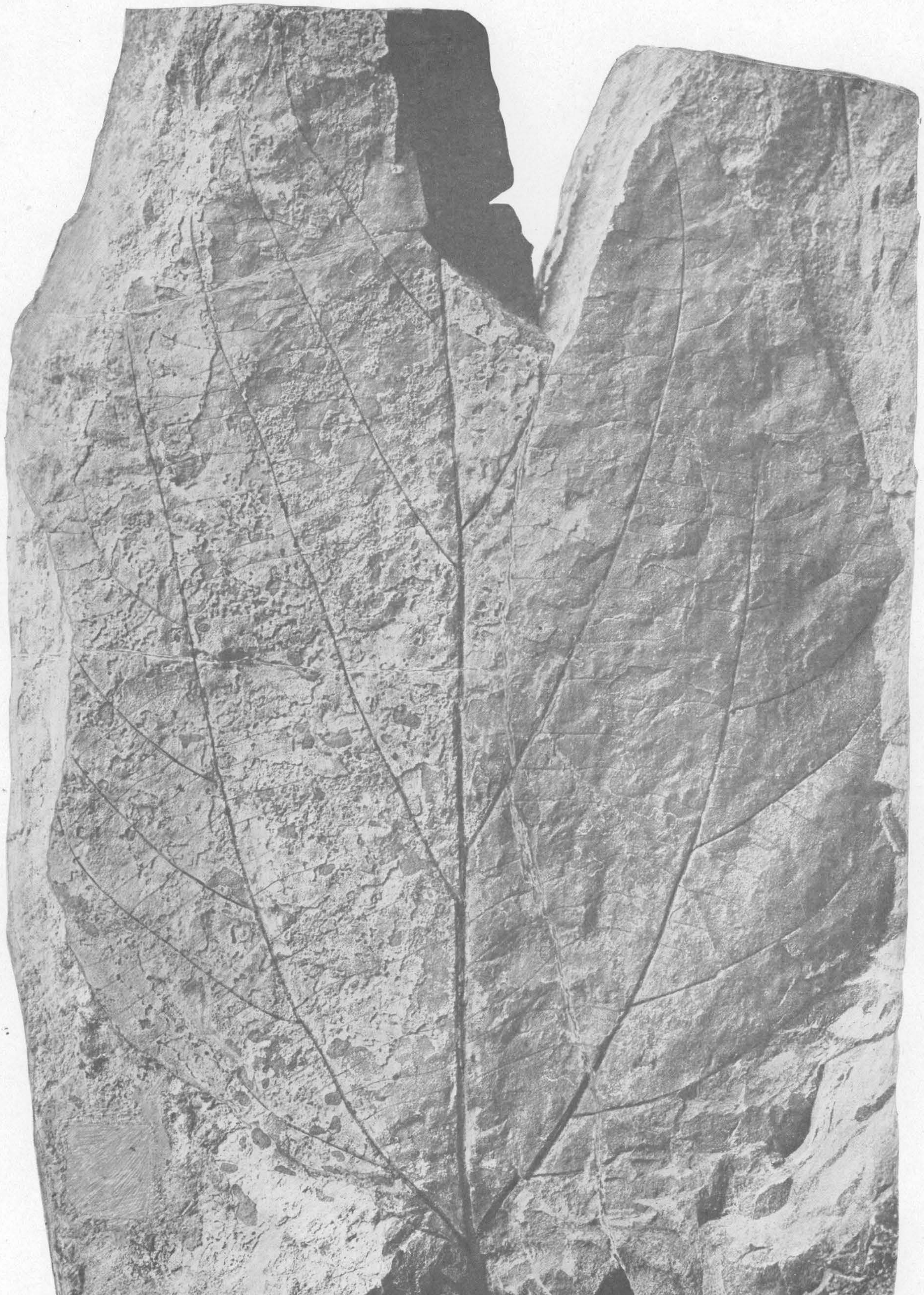
3.	*Magnolia angustifolia* Newberry. Pagosa quadrangle, Colo., $4\frac{1}{2}$ miles north of Pagosa Junction. U. S. Nat. Mus. No. 36654	88
4.	*Rhus coloradensis* Knowlton, n. sp. Pagosa quadrangle, Colo., half a mile west of Pagosa Junction. U. S. Nat. Mus. No. 36655	90

PLATE XI.



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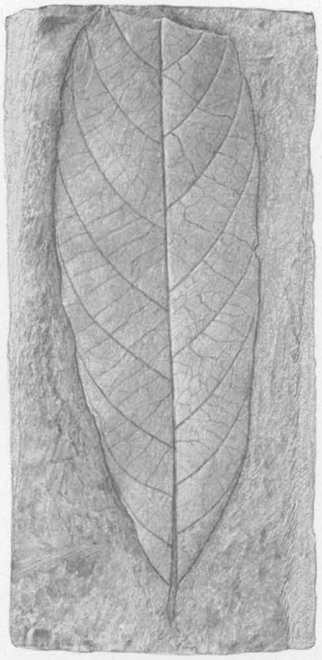
Artocarpus pungens (Lesquereux) Hollick. Pagosa quadrangle, Colo., half a mile west of Pagosa Junction. U. S. Nat. Mus. No. 36657 85

PLATE XIII.



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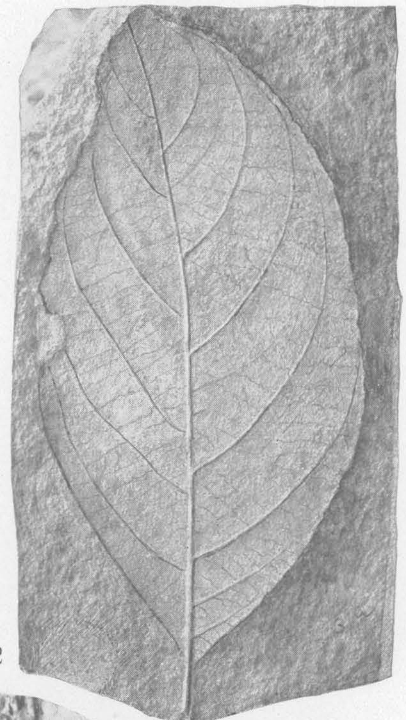

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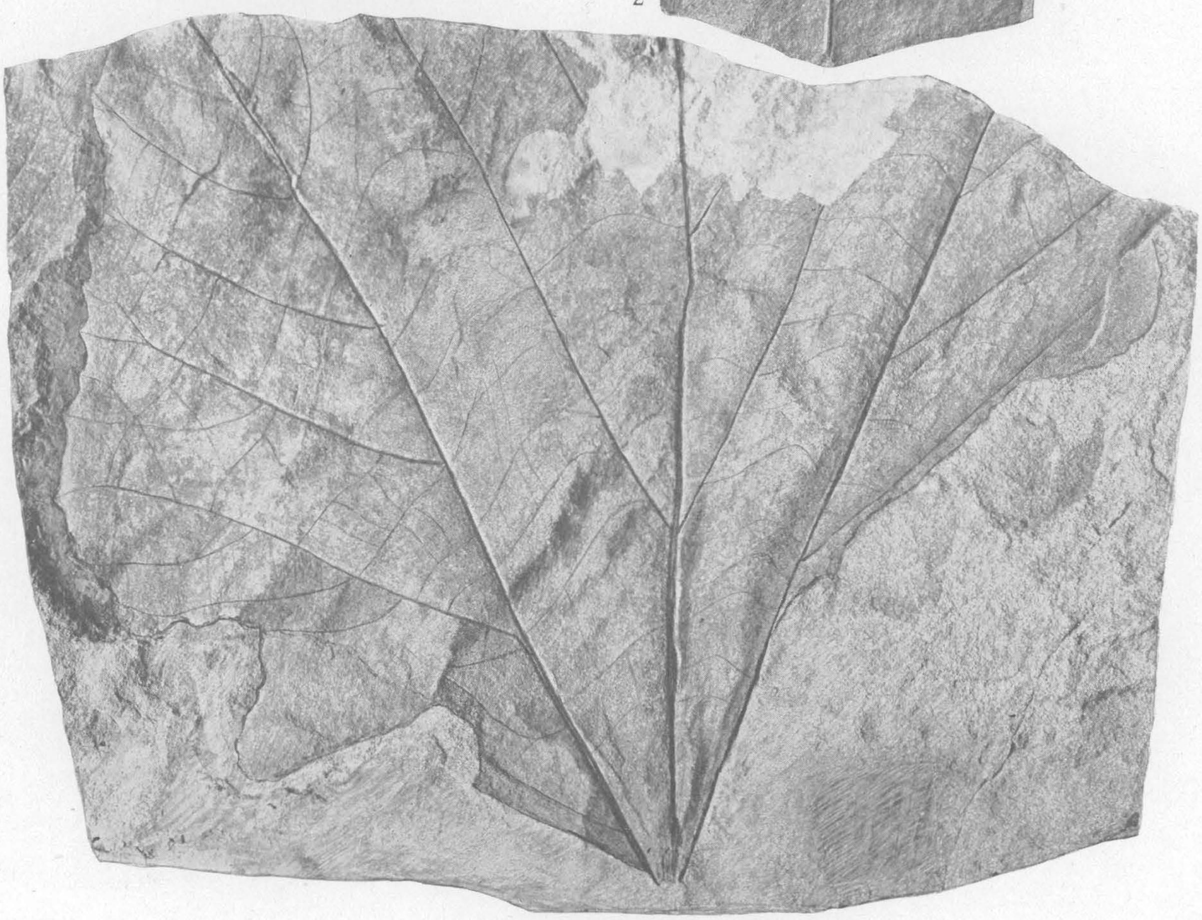

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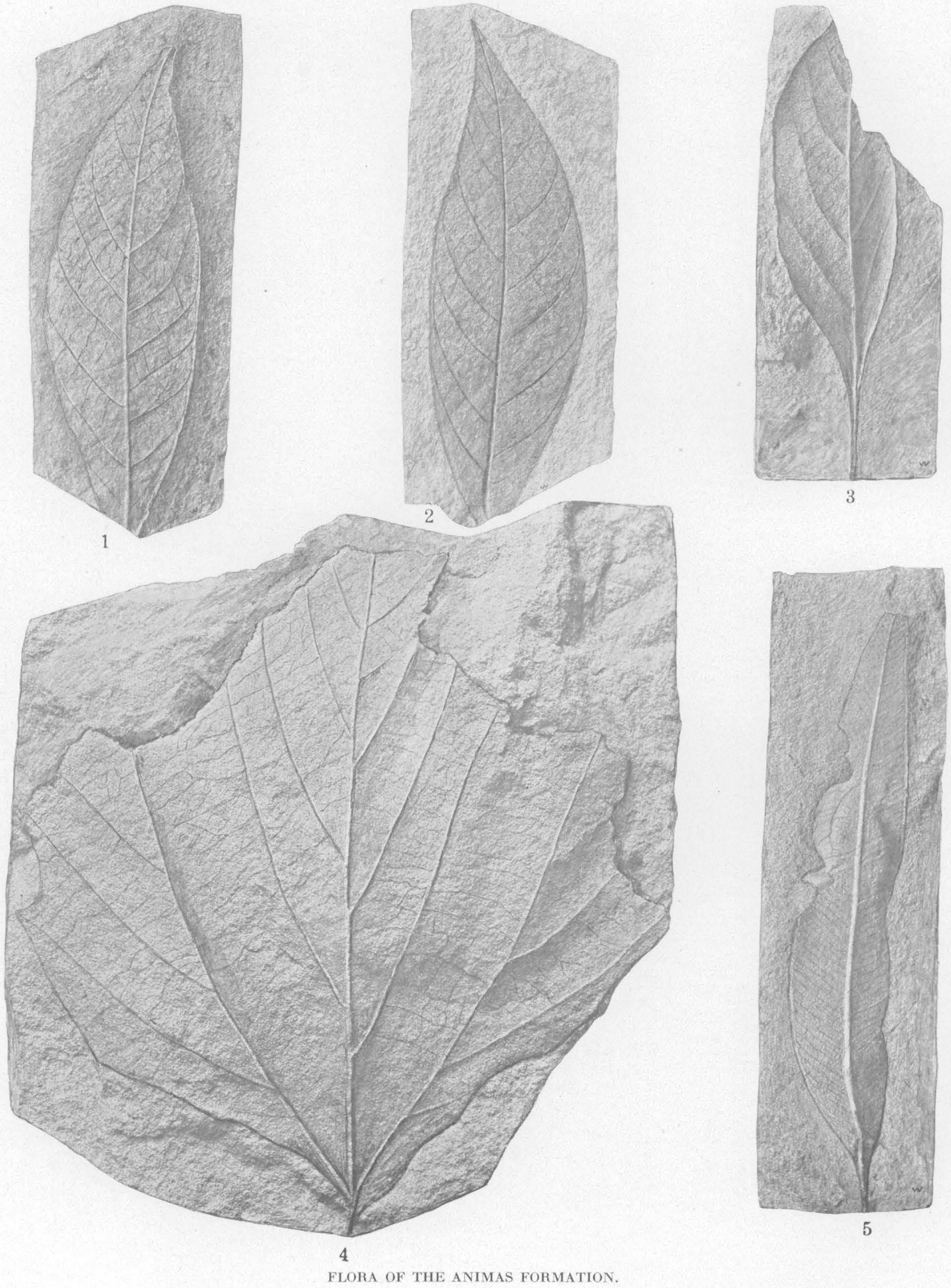

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PLATE XV.

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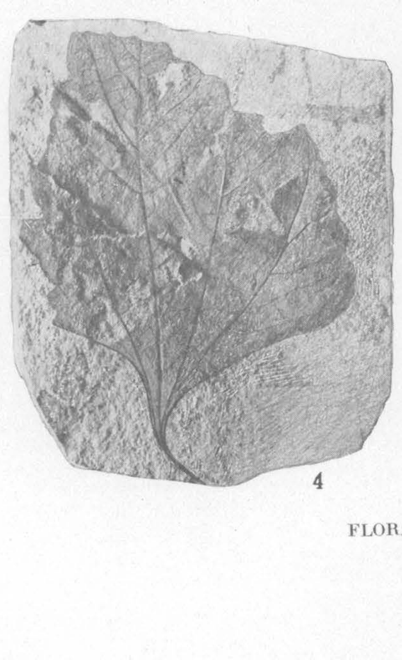

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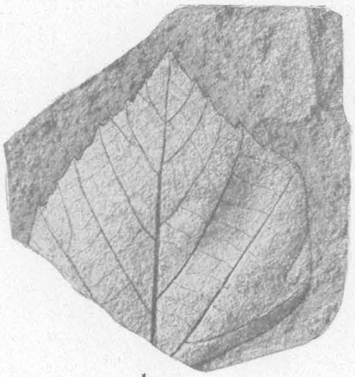

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FLORA OF THE ANIMAS FORMATION.

PLATE XVI.

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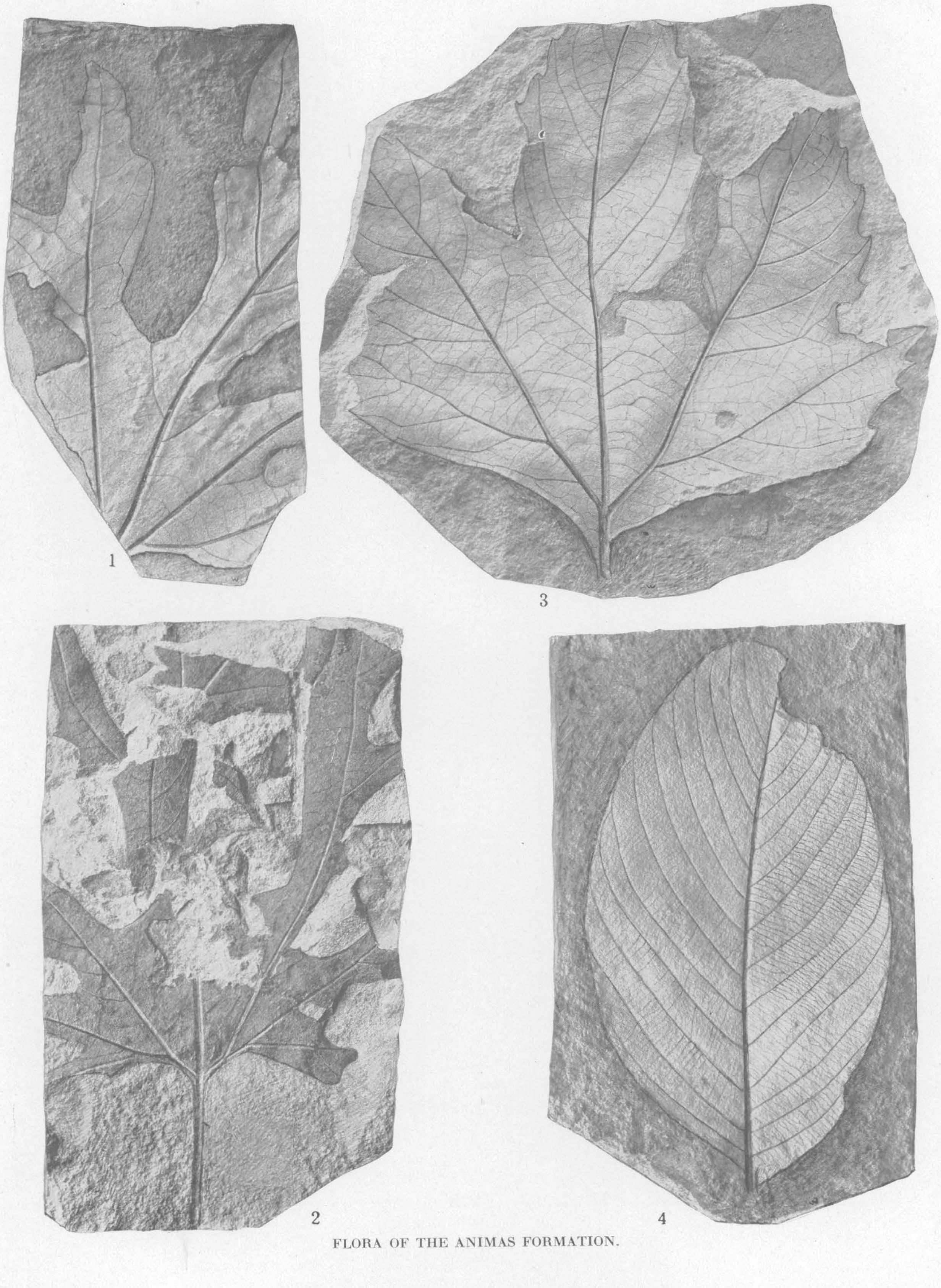

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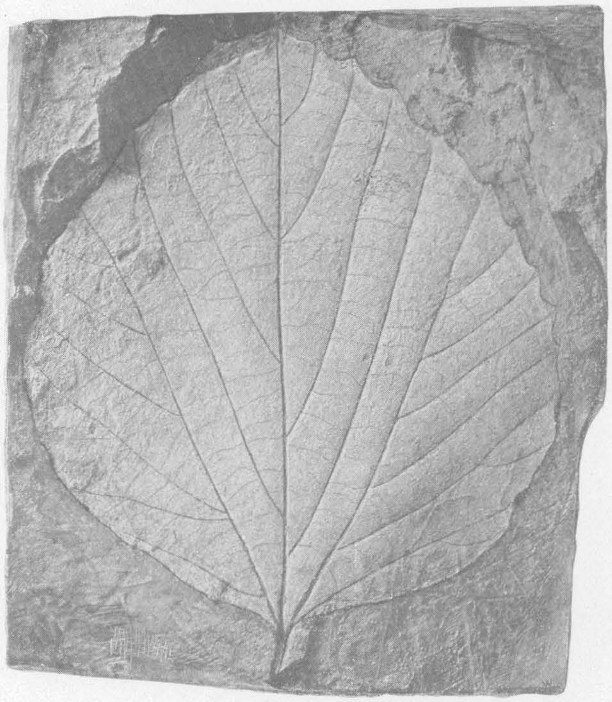

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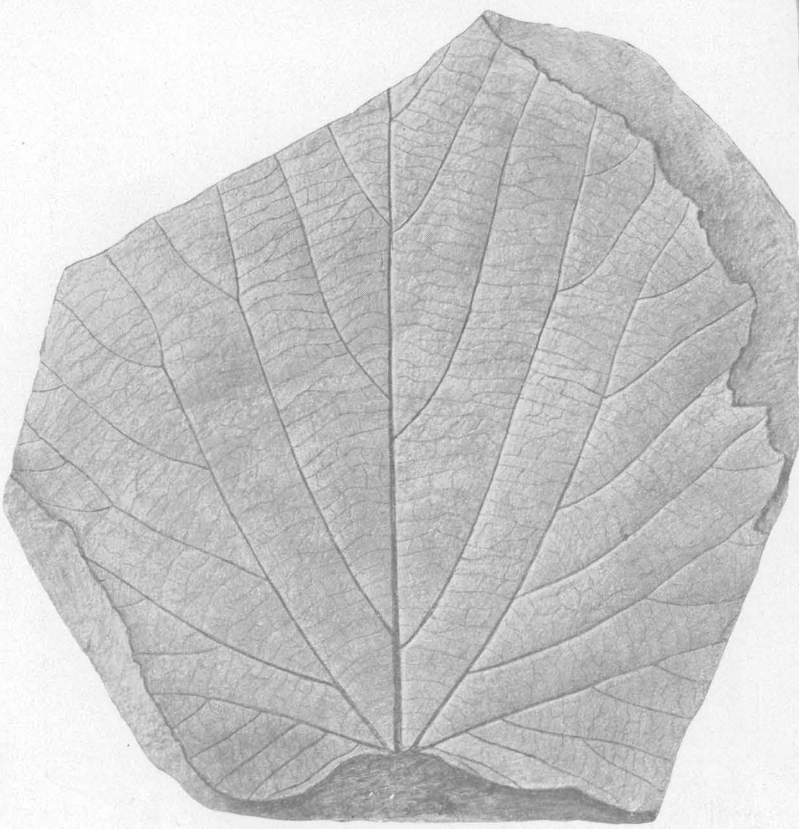

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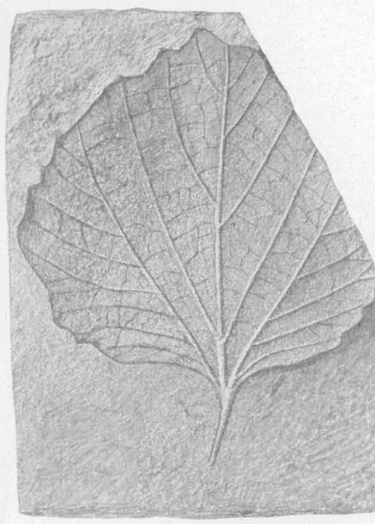

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