Stratigraphy of the Niobrara Formation at Pueblo, Colorado

By GLENN R. SCOTT *and* WILLIAM A. COBBAN

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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A report of an informal subdivision and faunal zonation of the Niobrara Formation

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CONTENTS

ILLUSTRATIONS

[Plates 1-11 follow index]

TABLES

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

STRATIGRAPHY OF THE NIOBRARA FORMATION AT PUEBLO, COLORADO

By Glenn R. Scott and William A. Cobban

ABSTRACT

Eight lithologic units were mapped in the Niobrara Formation of Late Cretaceous age during a study of the engineering geology of the Northwest Pueblo quadrangle. The thin Fort Hays Limestone Member at the base is overlain by seven units in the thick Smoky Hill Shale Member, which, in ascending order, are: shale and limestone, lower shale, lower limestone, middle shale, middle chalk, upper chalky shale, and upper chalk.

The Fort Hays is 40 feet thick. It is composed of thick beds of limestone with almost no shale and contains three characteristic fossil range zones—*Inoceramus* aff. *I. perplexus* Whitfield, *I. erectus* Meek, and *I. deformis* Meek.

The overlying shale and limestone unit is 22 feet thick. It is composed of thick beds of limestone with much shale and contains *Inoceramus deformis.*

The lower shale unit is 56 feet thick. It contains dark-yellowish-brown fissile calcareous shale and platy limestone and contains *Inoceramus involutus* Sowerby and other *Inoceramus* of unknown affinity.

The lower limestone unit consists of a cyclic repetition, 37 feet thick, of light-gray limestone and gray shale beds and contains *Inoceramus involutus* Sowerby, *Inoceramus stantoni* Sokolow, *Phlycticrioceras oregonense* Reeside, *Neocrioceras* n. sp., and *Pseudobaculites* sp.

The middle shale unit contains gray platy silty shale, a thin bed of light-olive-gray sandy shale, a limestone concretion subunit, and, in the upper part, thin beds of shaly limestone. It is 280 feet thick. In the lower few feet it contains *Scaphites depressus* var. *stantoni* Reeside, *S. binneyi* Reeside, *Inoceramus stantoni* Sokolow, *I. undulatoplicatus* Roemer, and *Protexanites shoshonensis* (Meek). The middle part is characterized by *Clioscaphites saxitonianus* (McLearn), *Texanites americanus* (Lasswitz), *Stantonoceras pseudocostatum* Johnson, and *Inoceramus cordiformis* Sowerby. About 50 feet below the top it contains *Clioscaphites vermiformis* (Meek and Hayden). A few feet below the top it contains *Clioscaphites choteauensis* Cobban.

The middle chalk consists of gray hard platy chalk, 28 feet thick, separated by beds of gray hard fissile chalky shale. It contains *Clioscaphites choteauensis* Cobban and *Inoceramus platinus* Logan.

The upper chalky shale unit consists of pale-yellowish-brown fissile chalky shale, 270 feet thick, that contains many beds of bentonite and large concretionary masses of shaly limestone. Fossils in the lower part include. *Inoceramus simpsoni* Meek, *I. patootensis* de Loriol?, and *I. platinus* Logan; fossils in the upper part include *Haresiceras placentiforme* Reeside, *Scaphites* cf. *S. hippocrepis* (DeKay), and *Baculites* cf. *B. haresi* Reeside.

The upper chalk unit consists of olive-black chalk, 8 feet thick, that contains *Inoceramus simpsoni* Meek and large smooth baculites.

The names Timpas Limestone and Apishapa Shale have been abandoned, partly because they do not fit the natural lithologic division of the Niobrara as well as do the names Fort Hays and Smoky Hill and partly because they can not be recognized as widely.

The Niobrara Formation of the Pueblo area is correlated with rocks at Boulder, Colo., in central Utah, in the Wind River Basin, Wyo., and on the Sweetgrass arch, Montana. At Boulder the rocks are nearly identical to those at Pueblo, except that they are less chalky. One different fossil, *Haresiceras natronense* Reeside?, was found at the base of the upper chalk unit at Boulder.

In central Utah the rocks are composed of noncalcareous shale and beds of sandstone. The fossil sequence is the same as at Pueblo but, in addition, *Desmoscaphites bassleri* Reeside is found in rocks equivalent to the lower part of the upper chalky shale at Pueblo.

In the Wind River Basin, correlative rocks are composed of shale, sandy shale, and sandstone. They contain one additional fossil, *Haresiceras montanaense* (Reeside), which is slightly older than *H. placentiforme* and which probably can be found in the middle of the upper chalky shale at Pueblo.

On the Sweetgrass arch correlative rocks are composed of sandstone, calcareous and noncalcareous shale, siltstone, bentonite beds, and limestone concretions. The fossil sequence is the same as at Pueblo except for the additional occurrence of *Desmoscaphites erdmanni* Cobban, *D. bassleri* Reeside, and *Haresiceras mancosense* (Reeside) in beds correlative with the upper chalky shale unit at Pueblo.

INTRODUCTION

This paper presents the results of fieldwork in 1961 on the Niobrara Formation of Late Cretaceous age at Pueblo, Colo. The formation was subdivided and informal names were applied to seven units in the Smoky Hill Shale Member. Excellent exposures of nearly the entire formation made possible the measurement of a detailed stratigraphic section and the collection of hundreds of fossils most of which were previously unknown. Many of the fossils were found to be limited to zones whose boundaries coincide with the contacts of the lithologic subdivisions. Furthermore, many of the fossils are known from time-equivalent rocks in other parts of North America and Europe, and the Niobrara is correlated with these rocks. The contacts of the type Timpas Limestone and type Apishapa Shale were studied in order to decide which nomenclature should be used at Pueblo. As a result of this work, the exact relation of the Timpas Limestone and Apishapa Shale to the Fort Hays Limestone and Smoky Hill Shale Members of the Niobrara Formation was determined.

Fieldwork on the Niobrara Formation was an essential part of an engineering geologic study of Pueblo, Colo. (fig. 1). The Niobrara underlies about one-half of the city and one-third of the two 7½-minute quadrangles that have been mapped. A detailed geologic map showing each unit of different lithology was needed so that the engineering characteristics could be correlated directly with the map units.

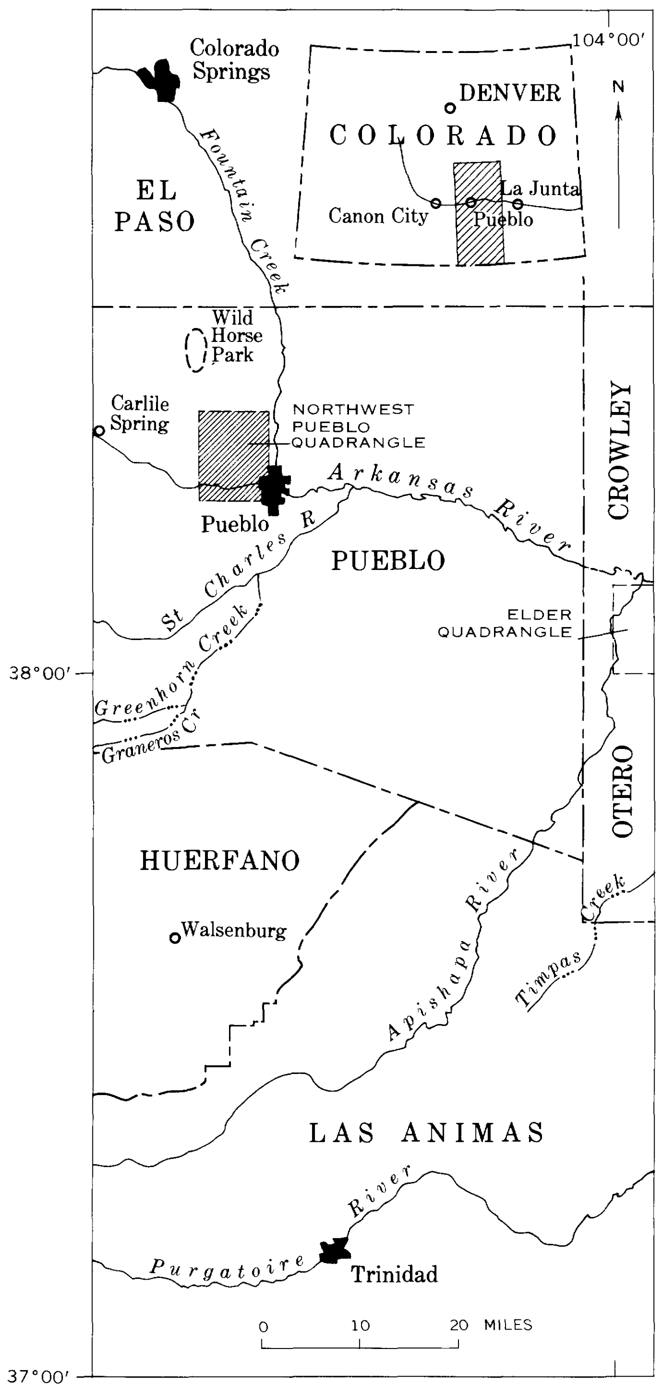

FIGURE 1.—Map showing Northwest Pueblo quadrangle and other places mentioned in text.

The objective of the work was then to measure a complete stratigraphic section, collect fossils wherever available, and establish a set of map units. The fossils were photographed by R. E. Burkholder.

PREVIOUS WORK

Although work on the Niobrara Formation dates back to 1862, the early papers were largely limited to the Niobrara in Kansas. The stratigraphic subdivisions described in these early reports are shown on table 1. Only the geologic reports that provide new information concerning the Pueblo area are reviewed here.

Stanton (1893) reviewed the invertebrate fauna of the Colorado Group of which the Niobrara is the upper part. He identified a small *Inoceramus*, which he referred to as *Inoceramus labiatus* (Schlotheim), at the base of the Fort Hays Limestone Member at Carlile Spring, 15 miles west of Pueblo.

R. T. Hill and G. K. Gilbert (in Gilbert's unpublished field notes, 1893) subdivided the Niobrara at Pueblo in considerable detail (table 1) on the basis of persistent lithologic units, especially scarp-forming limestone beds and valley-forming shale beds. Gilbert gave the scarp rocks informal names that were used by him and his associates in the mapping of most of the quadrangles near Pueblo. He made six collections of fossils from the Niobrara, including the first collection of *Inoceramus undulatoplicatus* Roemer from the western interior of the conterminous United States.

Gilbert later (1896, p. 566–567) subdivided (table 1) the Niobrara Group into a lower unit (Timpas Formation, 175 feet thick) and an upper unit (Apishapa Formation, 500 feet thick) but did not report the detailed subdivision that he and Hill had worked out in their field notes.

Patton (1923) discovered that the lower boundary of the Timpas Limestone is gradational locally with the upper boundary of the Carlile Shale. He also noted the presence of a small *Inoceramus* at the base of the Timpas, which, had been discovered earlier by Stanton (1893). Because it was identified as *Inoceramus labiatus*, Patton apparently assumed that there was a "passing of the lower group [Greenhorn Limestone] up into the higher group [Fort Hays Limestone]."

Patton later (1924, p. 19–22) described the upper part of the Timpas Limestone as consisting of a lower unit of shale and thin limestone beds like those at the base of the formation, a middle unit of shale that weathers into thin papery leaves and scales, and an

Table 1.—*Nomenclature and probable equivalency of outcropping Niobrara strata in eastern Colorado and Kansas*

Mudge (1877)	Williston (1893)	Cragin (1896)	Logan (1898)	G. K. Gilbert (unpublished field notes, 1893)	Gilbert (1896)	Scott and Cobban (this paper)
Niobrara	Niobrara rocks	Niobrara division; Smoky Hill chalk	Pteranodon beds	Middle shale series; Chalky beds	Niobrara group	Niobrara Formation; Smoky Hill Shale Member 700 ft
Niobrara proper	Yellow chalk	Graham jasper horizon near top		Upper scarp rock (Pigback)		Upper chalk
		Norton zone, yellow and chalky	*Hesperornis* beds	Scale shales	Apishapa shale 500 ft	Upper chalky shale
Buff to white chalk and chalky shale 200 ft	Thin-shelled inoceramid 4 ft in diameter, and *Ostrea* 350 ft		*Inoceramus platinus*	Middle scarp rock (Haplo or haploscaphus beds)		Middle chalk
				Intermediate shales *Inoceramus undulatoplicatus*		Middle shale
		?	?			
		Trego zone, bluish and marly	*Rudistes* beds *Haploscapha grandis*	Lower scarp rock (Happy)	Timpas limestone 175 ft	Lower limestone
	Haploscapha			Haploscaphus shale *Haploscapha grandis*		Lower shale
	Rudistes	Bell-rock lenses in base	*Radiolites maximus*	Upper (white band) shale; Lower (black band) shale		Shale and limestone
Fort Hays division (upper part). Yellow chalky limestone 60 ft	Fort Hays beds. Heavy stratified chalk or soft white limestone 80 ft	Osborne limestone	Fort Hays limestone *Inoceramus deformis*	(Hippo or Hippopodium beds)		Fort Hays Limestone Member 40 ft
260 ft	430 ft				675 ft	740 ft

upper unit of limestone layers that are yellow or pinkish yellow. He described the Apishapa as consisting of dark bluish-gray shale at the base, overlain in order by papery-weathering shale, light-colored sandy shale, and—at the top—a dark calcareous shale unit.

Johnson (1930) described an unconformity at the base of the Niobrara in the Pueblo quadrangle at Wild Horse Park. He suggested correctly that the lower limestone beds of the Niobrara are not everywhere of the same age.

Dane, Pierce, and Reeside (1937, p. 220–224), in a reconnaissance of eastern Colorado, studied the Niobrara along the Arkansas River. They chose to map the Hays (Fort Hays) Limestone and Smoky Hill Marl Members of the Niobrara, inasmuch as the upper limestone bed of the Timpas Limestone could not be recognized with assurance or mapped throughout the area. Dane and his associates, apparently included more beds in the upper part of the Fort Hays than are normally considered by others to be part of it as mapped along the Front Range. They stated that *Inoceramus deformis* is limited to the Hays, whereas *I. deformis* actually ranges from 22 to 24 feet above the restricted Fort Hays Limestone Member of the Front Range. They apparently referred all large *Inoceramus* shells in the Smoky Hill to *Inoceramus* (*Haploscapha*) *grandis* Conrad.

LeRoy and Schieltz (1958) studied the foraminiferal fauna above and below the Niobrara-Pierre contact at a locality near Canon City and concluded that the contact may be conformable.

STRATIGRAPHY

The Niobrara Formation at Pueblo contains eight lithologic units, as shown on the generalized bedrock map (fig. 2). Four units of ridge-forming limestone

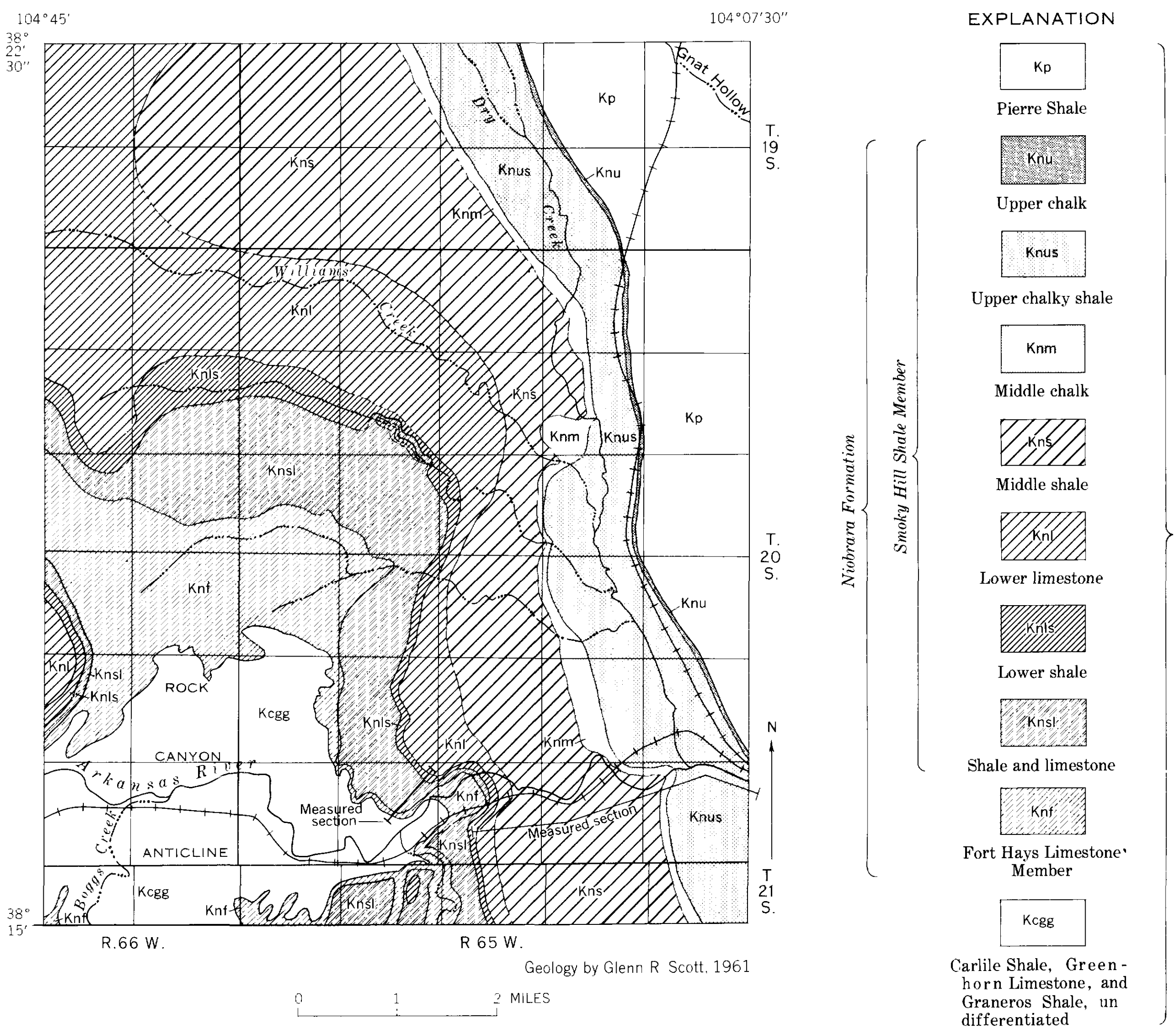

FIGURE 2.—Generalized geologic map of the Northwest Pueblo quadrangle, Colorado, showing outcrop pattern of units in the Niobrara Formation.

and chalk separate four other units of predominantly chalky, calcareous, or sandy shale. Each unit has a distinctive fauna of invertebrate fossils (table 2). These fossils are listed in the stratigraphic sections of each unit; many of them are shown on the accompanying plates. Fossil collections listed without localities are from measured sections; those with localities are from places other than measured sections, but they are placed as accurately as possible in the measured sections.

TABLE 2.—*Subdivisions of the Niobrara Formation at Pueblo, Colo.*

[Thicknesses are from measured sections]

Standard stages		Formation	Member	Unit and thickness	Fossils
Campanian	Lower	Niobrara Formation	Smoky Hill Shale Member, 700 ft	Upper chalk, 8 ft	*Inoceramus simpsoni*, *Baculites* sp. (smooth), *Stramentum haworthi*.
				Upper chalky shale, 264 ft	*Haresiceras placentiforme*, *Scaphites* cf. *S. hippocrepis*, *Baculites* cf. *B. haresi*, *Inoceramus* sp.
Santonian	Upper			Concretionary subunit	*Inoceramus platinus*, *Ostrea congesta*.
					Inoceramus simpsoni, *Inoceramus* cf. *I. patootensis*, *Ostrea* sp., *Baculites* sp. (smooth, small).
	Upper part of middle			Middle chalk, 28 ft	*Inoceramus platinus*, *Clioscaphites choteauensis*, *Baculites* sp. (smooth), *Ostrea congesta*.
				Concretionary subunit	*Inoceramus* sp. (quadrate species), *Inoceramus platinus*, *Ostrea* sp., *Baculites* sp. (smooth), *Clioscaphites choteauensis*. Oyster bed.
	Lower part of middle				*Inoceramus platinus*, *Inoceramus cordiformis*?, *Clioscaphites vermiformis*, *Baculites codyensis*.
				Concretion subunit	*Inoceramus cordiformis*, *Inoceramus platinus*, *Ostrea* sp. (erect), *Anomia subquadrata*, *Lucina* sp., *Inoceramus* cf. *I. undulatoplicatus*, *Clioscaphites saxitonianus*, *Baculites asper*, *Baculites codyensis*, *Texanites americanus*, *Stantonoceras pseudocostatum*, *Placenticeras planum*.
				Middle shale, 283 ft	*Inoceramus platinus*?
				Sandy subunit	Oyster bed.
					Inoceramus undulatoplicatus. *Inoceramus cordiformis*.
	Lower				*Clioscaphites saxitonianus*, *Baculites codyensis*.
Coniacian	Upper				*Inoceramus undulatoplicatus*, *Inoceramus* cf. *I. stantoni*, *Scaphites depressus*, var. *stantoni*, *Scaphites binneyi*, *Protexanites shoshonensis*.
				Lower limestone, 38 ft	*Inoceramus* (*Volviceramus*) *involutus*, *Inoceramus stantoni* (radial ribs), *Pseudobaculites* sp., *Baculites codyensis*, *Baculites asper*. *Neocrioceras* n. sp.
					Inoceramus stantoni (radial ribs), *Phlycticrioceras oregonense*.
	Middle				*Inoceramus stantoni*, *Baculites codyensis*.
				Lower shale, 56 ft	*Inoceramus* (*Volviceramus*) *involutus*, *Ostrea* sp. *Inoceramus stantoni*. *Baculites asper*, *Baculites codyensis*. *Inoceramus* spp. (large and flat, and small and oval).
	Lower			Shale and limestone, 20 ft	*Inoceramus* (*Volviceramus*) *involutus*, *Inoceramus deformis*. *Inoceramus deformis*.
			Fort Hays Limestone Member, 40 ft		*Inoceramus deformis*, *Ostrea congesta*. *Inoceramus erectus*, *Barroisiceras hobsoni*. *Prionocycloceras*?
Turonian	Upper				*Inoceramus* aff. *I. perplexus* Whitfield.

Two members of the Niobrara Formation were mapped at Pueblo, the Fort Hays Limestone Member and the Smoky Hill Shale Member.

FORT HAYS LIMESTONE MEMBER

The Fort Hays Limestone Member (Mudge, 1877, p. 281–290; Williston, 1893, p. 109–110) of late Turonian and early Coniacian age is a ledge-forming unit, 40 feet thick, composed principally of gray hard limestone. It crops out west of Pueblo in a wide gently dipping, northwest-trending belt and forms a cliff that circles the Rock Canyon anticline (fig. 2). Individual beds are distinguishable only in cliffs or quarries (fig. 3); on gentle slopes the limestone weathers to 4-inch residual pieces that hide the bedding. The weathered and dissected ledges of limestone have a dendritic appearance on aerial photographs, and their relief in dissected areas is rough.

The member consists of about 40 layers of gray dense, hard limestone separated by calcareous shale. Layers range in thickness from 1 to 26 inches, but they weather to thinner irregular yellowish-gray layers or flakes. The limestone in the upper part of the member is chalky and not as hard as in the lower part, but it does not slake upon weathering as a soft chalk does. Beds 3 to 4 feet above the base and just above the middle of the

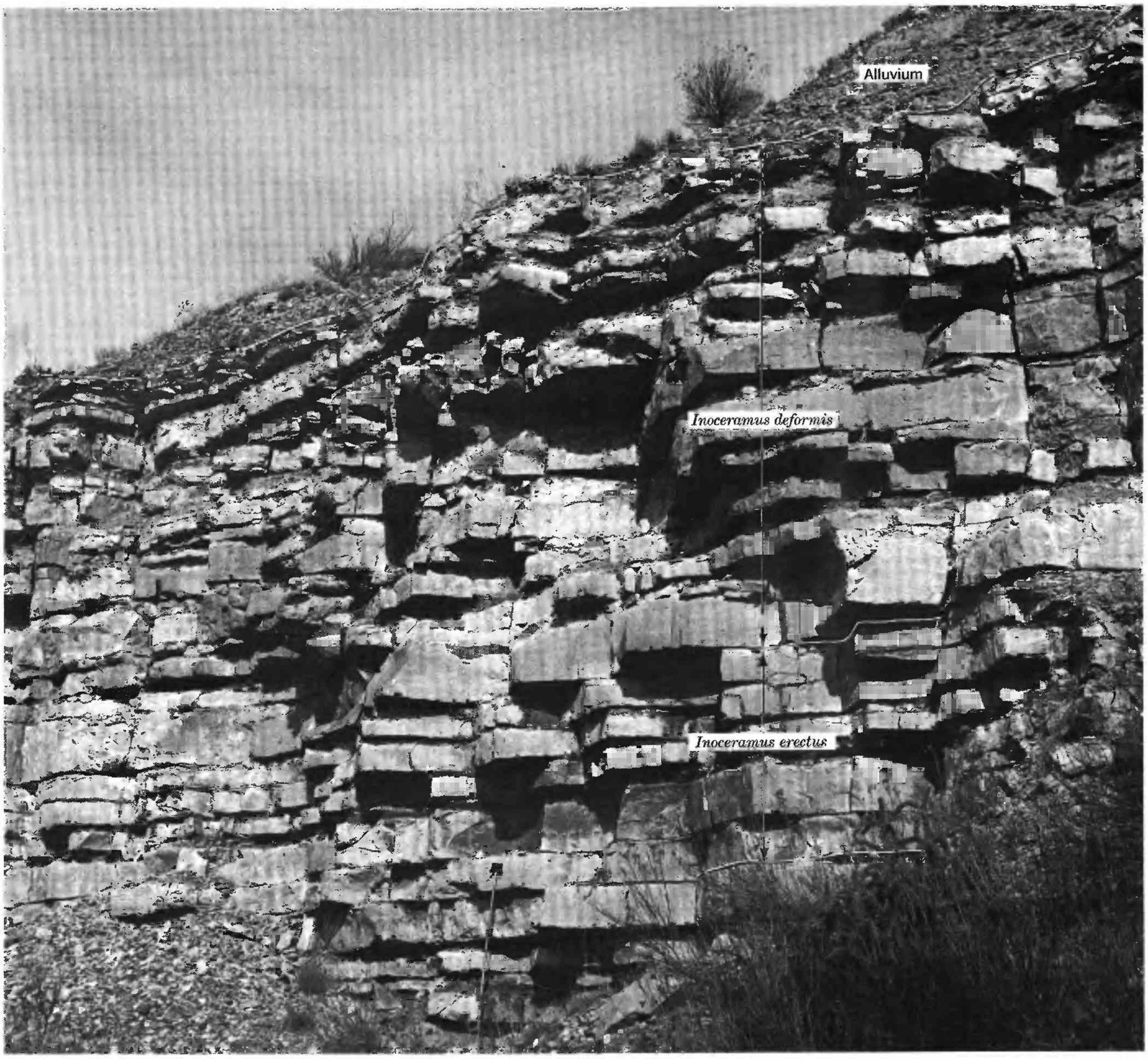

FIGURE 3.—Fort Hays Limestone Member of the Niobrara Formation in a slightly weathered quarry face in the SE¼NE¼ sec. 32, T. 20 S., R. 65 W., Pueblo County, Colo. The uppermost and lowermost parts are not exposed and only two faunal zones are visible. The Jacob staff is 5 feet long.

member contain pseudomorphs of limonite after pyrite; pseudomorphs in the lowest bed are spheres bounded by well-formed crystals. The shale that separates the limestone beds is yellowish gray to dusky yellow, soft, and fissile to platy or blocky. It contains one grayish-yellowish-green bentonite bed 34 feet above the base. The shale beds wash out readily along streams permitting large blocks of limestone to sag.

FOSSILS AND AGE

Fossils from the Fort Hays Limestone Member consist of *Ostrea congesta* Conrad, three species of *Inoceramus*, and very rare fragments of ammonites. Three faunal zones, based on *Inoceramus*, are present.

The lowest 1 foot of the Fort Hays is characterized by a small species of *Inoceramus* (pl. 2, figs. 1–5) that resembles *I. perplexus* Whitfield (1880, p. 392, pl. 8, fig. 3; pl. 10, figs. 4, 5), *I. incertus* Jimbo as emended by Nagao and Matsumoto (1940, p. 10, pl. 3, figs. 1–5; pl. 10, fig. 2), and the forms figured by Fiege (1930, p. 35, pl. 5, figs. 3–11) as *I. costellatus* Woods. A very late Turonian age is assigned to this basal Fort Hays species of *Inoceramus*. *Prionocycloceras*?, a large ammonite, was found 13.5 to 16.5 feet above the base.

Inoceramus erectus Meek (1877, p. 145, pl. 13, figs. 1, 1a; pl. 14, fig. 3) characterizes the Fort Hays Limestone Member 19 to 24 feet above the base (pl. 2, fig. 6 this report). An impression of an ammonite, *Barroisiceras* (*Forresteria*) *hobsoni* Reeside, was found associated with *I. erectus*. (See pl. 2, figs. 7, 8, for Reeside's type.) The presence of *Barroisiceras* establishes that this part of the member is early Coniacian in age (table 2).

Inoceramus deformis Meek (1871, p. 296; 1877, p. 146, pl. 14, figs. 4, 4a) is found in the upper 13 feet of the Fort Hays (fig. 3). The lowest specimen noted was about 4 feet above the highest collection of *I. erectus*. *Inoceramus deformis* is considered early Coniacian in age because in the western interior it lies above *Peroniceras*.

Fort Hays Limestone Member of the Niobrara Formation measured along the north side of the Arkansas River in E½ sec. 32, T. 20 S., R. 65 W.

	Ft	in
73. Limestone	1	0
72. Shale		1
71. Limestone		4
70. Shale		2
69. Limestone, shaly		5
68. Shale		5
67. Limestone, lower 2 in. softer and shaly; contains *Inoceramus deformis* Meek	1	4
66. Shale		5
65. Limestone		7
64. Shale		2
63. Limestone		11
62. Shale; contains ¼-in. bentonite layer 3 in. above base		8
61. Limestone		5
60. Shale		½
59. Limestone; shaly parting in middle		11
58. Shale		2
57. Limestone		5
56. Shale		½
55. Limestone	1	4
54. Shale		2
53. Limestone	1	9
52. Shale		½
51. Limestone, fossiliferous		4
USGS Mesozoic loc. D2988 [1]: *Inoceramus deformis* Meek; *Ostrea congesta* Conrad		
50. Shale		1
49. Limestone		10
USGS Mesozoic loc. D2987: *Inoceramus deformis* Meek		
48. Shale; contains limonitic nodules		6
47. Limestone		8
46. Shale		½
45. Limestone; contains *Inoceramus* sp	2	2
44. Shale		1
43. Limestone		10
USGS Mesozoic loc. D3522: *Inoceramus erectus* Meek		
42. Shale		1
41. Limestone; contains limonite nodules		10
USGS Mesozoic loc. D3521: *Inoceramus erectus* Meek		
40. Shale; contains soft limonite nodules		2
39. Limestone		7
38. Shale; contains limonitic nodules		1
37. Limestone		1
36. Shale		3
35. Limestone	1	4
USGS Mesozoic loc. D2984: *Inoceramus erectus* Meek (pl. 2, fig. 6); *Barroisiceras hobsoni* Reeside		
34. Shale		1
33. Limestone	1	0
USGS Mesozoic loc. D2983: *Inoceramus erectus* Meek		
32. Shale		1
31. Limestone, very light gray, hard; weathers light yellowish gray	1	2
30. Shale		4
29. Limestone, has very smooth upper surface		6
USGS Mesozoic loc. D3924, NE¼ SW¼ sec. 5, T. 21 S., R. 65 W.: *Prionocycloceras*?		
28. Shale		2
27. Limestone		3
26. Shale		3
25. Limestone, contains limonite nodules 1 in. in diameter		9
USGS Mesozoic loc. D3923, NE¼ SW¼ sec. 5, T. 21 S., R. 65 W.: *Prionocycloceras*?		

[1] Fossil collections listed without sec., township, and range location are from the measured section.

Fort Hays Limestone Member of the Niobrara Formation measured along the north side of the Arkansas River in E½ sec. 32, T. 20 S., R. 65 W.—Continued

	Ft	*in*
24. Shale		1
23. Limestone, contains long bifurcated dark-gray worm tubes	1	0
USGS Mesozoic loc. D3922, SE¼ SE¼ sec. 11, T. 21 S., R. 65 W.: *Prionocycloceras*?		
22. Shale		3
21. Limestone, contains long bifurcated dark-gray worm tubes	1	0
20. Shale		2
19. Limestone	1	5
18. Shale		2
17. Limestone, massive, hard, dense	1	6
16. Shale		2
15. Limestone, very light gray, hard, massive; weathers light yellowish gray; contains nodules of limonite after pyrite	1	3
14. Shale, olive-gray; contains iron-stained gypsum nodules		3
13. Limestone; contains nodules of limonite after pyrite. Base of quarry wall	1	0
12. Shale		1
11. Limestone	1	3
USGS Mesozoic loc. D2982: *Inoceramus* sp.		
10. Shale		1
9. Limestone; tends to weather into irregular lenses; contains holes where weathered		10
8. Shale; contains small limonitic nodules		3
7. Limestone, hard, massive; contains tiny clusters of brown limonite crystals after pyrite		7
6. Shale calcareous		2
5. Limestone, very light gray, very finely silty, hard, massive; weathers light yellowish gray; contains a few oysters in lower half		8
USGS Mesozoic loc. D2981: *Ostrea* sp.		
4. Shale, calcareous		4
3. Limestone; contains some bits of oyster and inoceramid shells		8
2. Shale, calcareous; weathers light yellowish gray		4
1. Limestone, very light gray, hard, massive, silty; weathers light yellowish gray; contains small borings filled with tan calcareous silt. Sparsely fossiliferous. On northeast side of Rock Canyon anticline, another 6-in. limestone bed lies below this at the base of the Fort Hays Limestone Member	1	0
USGS Mesozoic loc. D2980: *Inoceramus* aff. *I. perplexus* Whitfield (pl. 2, fig. 5)		
USGS Mesozoic loc. D3467, NE¼NE¼ sec. 26, T. 20 S., R. 66 W.: Rudistid		
USGS Mesozoic loc. D3468, NE¼NW¼ sec. 20, T. 20 S., R. 65 W.: *Inoceramus* aff. *I. perplexus* Whitfield		
Total Fort Hays Limestone Member of Niobrara Formation	39	9

DISCONFORMITY AT THE BASE OF THE FORT HAYS LIMESTONE MEMBER

The best evidence of a disconformity is found in the beds below the Fort Hays Limestone Member, although some evidence of a disconformity is found in the basal beds of the Fort Hays. The basal beds of the Fort Hays, which are as much as 3 feet thick, locally consist of yellowish-gray fine-grained calcarenite or sandy limestone interlaced with worm borings; the filling of the borings is coarser than the matrix. The calcarenite forms rather massive, nearly unstratified deposits that seemingly were dumped into lenticular or rounded depressions on the sea floor. Where the calcarenite is thickest, the underlying beds are thinnest; locally the underlying bed consists only of 4-inch-thick lenses, 3 feet in diameter, although elsewhere in eastern Colorado it seems to be a continuous bed several feet thick. Fossils that elsewhere lie at the base of the Fort Hays lie above the calcarenite; this evidence suggests that a period of erosion or nondeposition preceded deposition of typical Fort Hays Limestone Member.

SMOKY HILL SHALE MEMBER

The Smoky Hill Shale Member (Cragin, 1896, p. 51–52) of Coniacian, Santonian, and early Campanian age is 700 feet thick and consists about equally of chalk and shale and a very small amount of limestone. It crops out in a broad belt that follows the Arkansas River and curves northwestward through Pueblo; a thin layer of the basal part caps the Fort Hays west of Rock Canyon anticline. Several beds in the Smoky Hill at Pueblo form low hogbacks whose relief is gentle because of the softness of most of the beds. The Smoky Hill is divided into seven units, in ascending order, as follows: shale and limestone, lower shale, lower limestone, middle shale, middle chalk, upper chalky shale, and upper chalk.

SHALE AND LIMESTONE UNIT

The shale and limestone unit of early and middle Coniacian age is a 20-foot-thick sequence of typical Fort Hays Limestone and soft calcareous shale that is transitional between the Fort Hays and the typical fissile Smoky Hill Shale. It forms gentle rock-strewn slopes parallel to the Fort Hays outcrop (fig. 2); individual beds are distinguishable only on steep slopes, as in the NE¼ sec. 32, T. 20 S., R. 65 W. (fig. 4).

The unit contains 18 layers of limestone that are very similar lithologically to layers in the Fort Hays. The limestone is gray and massive. It weathers yellowish gray and shaly. Some beds are less indurated and more clayey than those in the Fort Hays. Individual beds range in thickness from 3 to 19 inches and average 6 inches. The shale is gray, calcareous, hard, and blocky. It weathers yellowish gray and soft. Shale layers average 7 inches in thickness. Beds near the base and near the top are gypsiferous. Bentonite beds lie 4 to 5 feet below the top.

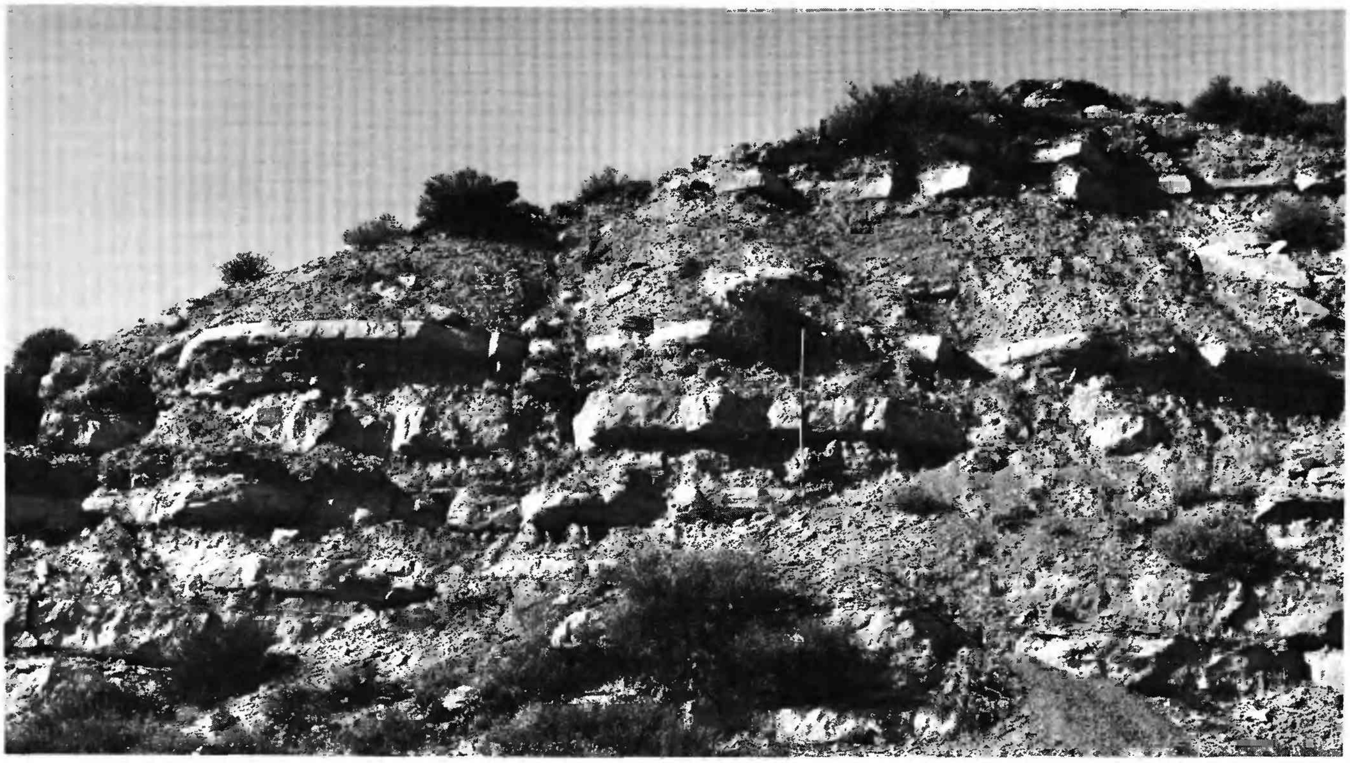

FIGURE 4.—Shale and limestone unit of Smoky Hill Shale Member along north valley wall of Arkansas River in the SE¼NE¼ sec. 32, T. 20 S., R. 65 W., Pueblo County, Colo. Shale predominates over limestone.

FOSSILS AND AGE

The shale and limestone unit contains *Inoceramus deformis* throughout. Specimens are large in the upper part of the unit (pl. 1), and we believe that *I. browni* Cragin (1889, p. 65) was based on these. Cragin's name, however, is herein considered a synonym of *I. deformis*. At Pueblo the top bed of the shale and limestone unit contains the lowest specimens of *Inoceramus* (*Volviceramus*) *involutus* Sowerby. The presence of *Inoceramus deformis* dates most of the unit as early Coniacian in age, but *Inoceramus involutus* suggests a middle Coniacian age for the topmost bed.

Shale and limestone unit measured along north side of the Arkansas River in NE¼ sec. 32, T. 20 S., R. 65 W.

	Ft	in
37. Limestone, gray, shaly		3
USGS Mesozoic loc. D3470, SW¼NW¼SW¼ sec. 4, T. 21 S., R. 65 W.: *Inoceramus deformis* Meek (1 ft in diameter) (pl. 1) USGS Mesozoic loc. D3471, NW¼ sec. 26, T. 18 S., R. 66 W., at Wild Horse Park: *Inoceramus* (*Volviceramus*) *involutus* Sowerby		
36. Shale, gray, soft		3
35. Limestone, gray; shaly in lower part and upper part	1	0
34. Shale, gray, calcareous; contains *Inoceramus deformis* Meek		3
33. Limestone, gray, shaly; contains *Inoceramus deformis* Meek and *Ostrea congesta* Conrad		5

Shale and limestone unit measured along north side of the Arkansas River in NE¼ sec. 32, T. 20 S., R. 65 W.—Continued

	Ft	in
32. Shale, gray, mottled dark-yellowish-orange, soft, gypsiferous		5
31. Limestone, gray, massive; weathers in large plates; contains *Inoceramus*	1	7
30. Shale, gray; contains bentonite at top		4
29. Bentonite, pale-yellowish-orange		½
28. Limestone, gray, shaly		3
27. Shale, hard, gray		4½
26. Limestone, gray; has crossbedded appearance		3
25. Shale, gray		3
24. Limestone, gray; weathers blocky; contains *Inoceramus*		6
23. Shale, gray, calcareous		8
22. Limestone, gray		6
21. Shale, yellowish-gray, hard		1
20. Limestone, gray, shaly		4
19. Shale, gray, blocky, hard, calcareous	1	11
18. Limestone, gray; weathers shaly		3
17. Shale, gray, soft		3
16. Limestone, gray; weathers shaly; contains *Inoceramus deformis* Meek, *Ostrea congesta* Conrad		3
15. Shale, gray, soft		1
14. Limestone, gray, soft, shaly in lower 3 in.; contains *Inoceramus deformis* Meek		8
13. Shale, gray, soft		1½
12. Limestone, gray; weathers very light gray; top 4 in. soft and shaly	1	1
11. Shale, calcareous	1	6
10. Limestone, soft, shaly		6

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Shale and limestone unit measured along north side of the Arkansas River in NE¼ sec. 32 T. 20 S., R. 65 W.—Continued

	Ft	in
9. Shale, calcareous	1	6
8. Limestone, soft, shaly. USGS Mesozoic loc. D3469, NW¼SW¼NE¼ sec. 26, T. 20 S., R. 66 W.; contains *Inoceramus deformis* Meek		3
7. Shale		8
6. Limestone, soft, shaly		5
5. Shale, gypsiferous		5
4. Limestone; in two beds separated by half an inch of shale, contains *Inoceramus deformis* Meek		9
3. Shale	1	1
2. Limestone, soft, shaly, gypsiferous; contains *Inoceramus deformis* Meek		6
1. Shale		9
Total shale and limestone unit	20	5½

LOWER SHALE UNIT

The lower shale unit of middle Coniacian age consists of 56 feet of shale and platy limestone; this is the lowest unit that has a Smoky Hill aspect. The unit forms a shale slope and valley between the underlying hard beds and the overlying lower limestone unit; therefore, it is well exposed only in cliffs or in stream cuts, such as in the SW¼NW¼ sec. 16, T. 20 S., R. 65 W. Several of the limestone layers form minor ledges on steeper slopes.

The unit is composed of pale-, moderate-, or dark-yellowish-brown shale with dark- or light-gray limestone layers. Dark-yellowish-brown earthy shale at the base of the unit contrasts sharply with the underlying gray shale and limestone. The shale layers are fissile to platy and weather to soft crumbly flakes. Limestone layers are more plentiful and more perfectly platy in the upper part of the unit. In a fresh exposure, plates of limestone more than 2 feet square and only a quarter of an inch thick can be broken out from the upper limestone layers. Selenite crystals, fibrous selenite (satin spar), and granular gypsum commonly form lenses in the lower beds and coatings on fossils near the middle of the unit. Many lenses of gypsum are stained dark yellowish orange by limonite. Bentonite beds lie 20 and 25 feet above the base.

FOSSILS AND AGE

The coiled pelecypod *Inoceramus (Volviceramus) involutus* Sowerby (1828, p. 160, pl. 583, figs. 1–3) is found in the lower shale unit and through the overlying lower limestone unit (pl. 3, fig. 4). We regard the following names as synonyms of this species: *I. umbonatus* Meek and Hayden (1858, p. 50), *I. exogyroides* Meek and Hayden (1862, p. 26), *I. concentricus* Logan (1898, p. 490), *Haploscapha grandis* Conrad (1875, p. 23), *H. eccentrica* Conrad (1875, p. 24), *H. niobrarensis* Logan, (1898, p. 493), *Inoceramus pennatus* Logan 1898, p. 488, pl. 118, fig. 2) and possibly *I. undabundus* Meek and Hayden (1862, p. 26).

Two species of *Inoceramus* of unknown affinity are found with *I. (Volviceramus) involutus* in bed 19. One, which has a diameter of at least 12 inches, is thin, flat, and broadly ovate; the other is smaller, thin, flat, and oval. *Inoceramus stantoni* Sokolow first appears in bed 24 of the lower shale, and it persists up through bed 7 of the middle shale unit. We regard the name *Inoceramus kleini* Müller as a synonym of *Inoceramus stantoni*.

Baculites asper Morton and *Baculites codyensis* Reeside first appear in bed 24 of the lower shale and continue upward to bed 20 of the middle shale unit. *Baculites asper* (pl. 3, fig. 5), which has small distantly spaced nodes, predominates in the lower part of this range, whereas *Baculites codyensis* (pl. 7, figs. 3, 4), which has closely spaced ribs, predominates in the upper part.

The presence of *Inoceramus* (*Volviceramus*) *involutus* dates the lower shale as about middle Coniacian (table 2).

Lower shale unit measured along north side of Arkansas River in NE¼ sec. 32 and NW¼ sec. 33, T. 20 S., R. 65 W.

	Ft	in
32. Shale, medium-gray, chalky, shaly; contains limonite-stained streaks of gypsum; yellowish gray where weathered	8	10
31. Shale, yellowish-gray	7	4
30. Limestone, dark-gray, irregular, platy, hard		5
29. Shale, pale-yellowish-brown, soft, fissile	2	0
28. Limestone, dark-gray, hard, irregularly platy		3
27. Shale, pale-yellowish-brown; locally contains fossiliferous limestone in middle	2	7
USGS Mesozoic loc. D3476:		
Inoceramus sp.		
Ostrea sp.		
Baculites asper Morton		
USGS Mesozoic loc. D3921, NE¼NE¼ sec. 23, T. 21 S., R. 66 W.:		
Scaphites sp.		
26. Limestone, light-gray, hard; forms minor ledge	1	0
25. Shale, pale-yellowish-brown, soft; contains limonite-stained gypsum which generally coats shells of *Inoceramus* on which *Ostrea congesta* are attached	3	8
24. Limestone, light-gray, platy		5
USGS Mesozoic loc. D3474:		
Inoceramus (*Volviceramus*) *involutus* Sowerby		
Ostrea sp.		
Baculites asper Morton (pl. 3, fig. 5)		
USGS Mesozoic loc. D3475, SE¼NW¼ sec. 16, T. 20 S., R. 65 W.:		
Inoceramus cf. *I. stantoni* Sokolow		
Baculites codyensis Reeside		
23. Limestone, gray and pale-yellowish-brown, shaly, soft, fissile		10

Lower shale unit measured along north side of Arkansas River in NE¼ sec. 32 and NW¼ sec. 33, T. 20 S., R. 65 W.—Continued

	Ft	*in*
22. Limestone, medium-gray, hard, irregularly platy; contains limonite beds surrounding *Inoceramus* shells at 11–15 in. above base. Lower ledge shows flat joint faces in fresh cut	1	7
21. Shale, gray and dark-yellowish-brown, fissile, soft	2	7
20. Bentonite, pale-yellowish-orange, soft, plastic, well-layered		3
19. Shale, dark-yellowish-brown	3	8
USGS Mesozoic loc. D3473, SE¼NW¼ sec. 16, T. 20 S., R. 65 W.:		
Inoceramus sp. (large, thin shelled)		
I. sp. (small, thin shelled)		
I. (*Volviceramus*) *involutus* Sowerby (pl. 3, fig. 4)		
18. Shale, dark-yellowish-brown	1	8
17. Bentonite, moderate-yellowish-brown		2
16. Shale, pale-yellowish-brown, fissile	1	4
15. Limestone, light-gray; minor ledge former		3
14. Shale, pale-yellowish-brown		9
13. Limonite and gypsum layer, moderate-yellowish-brown, lenticular		3
12. Shale, gray		3
11. Limonite and gypsum layer, moderate yellowish-brown, lenticular		3
10. Limestone, light-gray, platy, hard; minor ledge former		9
9. Shale, pale-yellowish-brown, platy, soft gypsiferous	6	10
8. Limestone, light-gray, platy; contains thin shale partings	1	2
7. Shale, gray and dark-yellowish-orange, gypsiferous; contains *Inoceramus*		9
6. Limestone, dark-gray, platy; contains *Inoceramus* (*Volviceramus*) *involutus* Sowerby	1	1
5. Shale, dark-yellowish-orange; contains fibrous selenite		2
4. Shale and platy limestone, gray; hard in upper part	2	9
USGS Mesozoic loc. D3472, SE¼NW¼SW¼ sec. 4, T. 21 S., R. 65 W.:		
Inoceramus (*Volviceramus*) *involutus* Sowerby		
Ostrea congesta Conrad		
3. Shale, yellowish-brown; layered with fibrous selenite		3
2. Shale, medium-light-gray, platy		2
1. Shale, dark-yellowish-brown; sharp lower boundary; contains light and dark speckles and Foraminifera, fish scales, and fragments of inoceramid shells; has moderate-yellowish-brown layers of selenite crystals	1	9
Total lower shale unit	56	0

LOWER LIMESTONE UNIT

The lower limestone unit of middle and late Coniacian age is 37 feet thick and consists of limestone layers separated by shale. The unit crops out in a broad band of gently dipping limestone that trends northwestward through the west side of Pueblo and encircles Rock Canyon anticline (fig. 5). It forms a cliff along streams and a nearly white low ridge across flat areas, except where it is buried by surficial deposits. Where weathered, individual layers are hidden by yellowish-gray plates or chips of limestone. Farther south in the Raton basin in Colfax County, N. Mex., equivalent rocks are sandy. The unit is recognizable as far east as La Junta, as far north as Boulder and possibly beyond, and at least as far south as beyond Greenhorn Creek.

The lower limestone unit is composed of about 16 distinguishable layers of gray hard slightly chalky platy limestone separated by beds of shale. The lower part of this sequence contains a cyclic repetition (fig. 5) of 6 layers of limestone, 7 to 11 inches thick, separated by 5 beds of shale, 14 to 22 inches thick. In addition, the laminae within some of the shale beds are cyclically banded; one bed contains dark laminae one-sixteenth of an inch thick that alternate with light laminae ½ to ⅝ inch thick. Shale beds in the unit are light olive gray, medium gray, or grayish brown and are calcareous, hard, and fissile to platy. They erode only a little more rapidly than do the limestone layers (fig. 5).

The unit contains two persistent bentonite beds, a persistent limonite bed, and many lenses and nodules of gypsum stained by limonite. Most nodules of gypsum are 2 inches thick and 10 inches in diameter and commonly contain shells of *Inoceramus;* other nodules are 2 inches in diameter and contain septarian veins of gypsum. In addition to the limonite that stains the gypsum nodules, a persistent bed of limonite lies about 3 feet below the top of the unit. A bed of bentonite lies 4 inches below the top and another lies 6 feet below the top.

FOSSILS AND AGE

Inoceramus (*Volviceramus*) *involutus*, which continues up from the underlying units, is larger in the lower limestone unit than in the underlying lower shale unit; also, specimens in beds 11 and 25 of the lower limestone have weak radial folds. Between beds 10 and 29 *Inoceramus stantoni*, which also continues up from the underlying unit, is represented by a second form which has fine radial folds imposed across the concentric folds (pl. 4, figs. 1–3); the form without radial folds continues up into bed 7 of the middle shale. *Neocrioceras* n. sp. was found in bed 20 (pl. 3, figs. 1, 2). *Pseudobaculites* sp. was found in bed 25 with *Inoceramus stantoni*, *Inoceramus* (*Volviceramus*) *involutus*, and *Baculites asper*. The topmost layer contains abundant worm borings. Fish remains were found in the middle of the unit at Williams Creek.

The basal part of the lower limestone unit is probably of middle Coniacian age, but the presence of *Phlycticrioceras oregonense* Reeside (pl. 3, fig. 3) and of radially ribbed *Inoceramus stantoni* in all but the lower 10 feet suggests a late Coniacian age for most of the unit (table 2). This type of *I. stantoni* is asso-

FIGURE 5.—Lower limestone unit of Smoky Hill Shale Member overlying lower shale unit and shale and limestone unit in cliff along north valley wall of Arkansas River in the NW¼ sec. 33, T. 20 S., R. 65 W., Pueblo County, Colo. Cyclic repetition of the limestone beds is well shown.

ciated with *Scaphites depressus* Reeside, *S. binneyi* Reeside, *Phlycticrioceras oregonense* Reeside, *Protexanites shoshonensis* (Meek), *Neocrioceras* n. sp., and *Pseudobaculites* spp. in Utah and Wyoming. *Phlycticrioceras oregonense* is associated with *Baculites codyensis* and *Inoceramus stantoni* in sandy beds in the Niobrara Formation in Raton basin in northeastern New Mexico. *Phlycticrioceras oregonense* is closely related to *P. douvillei* described by Grossouvre (1893, p. 254, pl. 35, fig. 8) from the upper Coniacian of France. The American species differs from the French form by lacking clearly defined constrictions. Constrictions were indicated by Reeside (1927, p. 3, pl. 1, figs. 6, 15) on his retouched photographs, but these are not definite on plaster casts of his types nor on specimens at hand from the western interior.

Lower limestone unit measured along south side of Arkansas River in SE¼NW¼ sec. 33, T. 20 S., R. 65 W.

	Ft	*in*
32. Limestone, light-olive-gray, hard, platy, speckled; locally weathers to shale; contains worm borings		4
31. Bentonite, dark-yellowish-orange		2½
30. Shale, olive-gray		10
29. Limestone, light-olive-gray, hard; weathers to irregular thin-edged plates	1	6
USGS Mesozoic loc. D3483, SW¼NE¼ sec. 16, T. 20 S., R. 65 W.:		
Inoceramus stantoni Sokolow (radial folds)		
I. (*Volviceramus*) *involutus* Sowerby		
28. Limonite, moderate-yellowish-orange		1½
27. Limestone; contains worm borings, *Inoceramus*		4
26. Shale, brown		3

Lower limestone unit measured along south side of Arkansas River in SE¼NW¼ sec. 33, T. 20 S., R. 65 W.—Continued

	Ft	*in*
25. Limestone, dark-gray, hard		3
USGS Mesozoic loc. D3481, SE¼NW¼ sec. 16, T. 20 S., R. 65 W.:		
Inoceramus stantoni Sokolow (radial ribs) (pl. 4, figs. 1, 2)		
I. stantoni Sokolow		
I. (*Volviceramus*) *involutus* Sowerby		
Baculites asper Morton		
Pseudobaculites sp.		
USGS Mesozoic loc. D3484, NE¼NE¼ sec. 32, T. 20 S., R. 65 W.: spiral burrows, 1½-in. diameter, of unknown origin		
USGS Mesozoic loc. D3485, NW¼SE¼ sec. 9, T. 20 S., R. 65 W.:		
Inoceramus stantoni Sokolow		
I. (*Volviceramus*) *involutus* Sowerby		
Baculites sp.		
USGS Mesozoic loc. D3486, SE¼NE¼SW¼ sec. 5, T. 20 S., R. 65 W.: *Inoceramus* (*Volviceramus*) *involutus* Sowerby		
USGS Mesozoic loc. D3487, NW¼SW¼NW¼ sec. 21, T. 20 S., R. 65 W.:		
Inoceramus (*Volviceramus*) *involutus* Sowerby		
I. stantoni Sokolow		
Spiral burrows, same as in D3484		
USGS Mesozoic loc. D3488, NE cor. sec. 8, T. 20 S., R. 65 W.:		
Inoceramus (*Volviceramus*) aff. *I. involutus* Sowerby (radial ribs)		
I. stantoni Sokolow (radial ribs) (pl. 4, fig. 3)		
Bone		
24. Shale, grayish-brown		2½
23. Limestone, shaly; contains *Inoceramus* (*Volviceramus*) *involutus* Sowerby		5
22. Limestone, dark-gray, hard; contains *I.* (*Volviceramus*) *involutus* Sowerby	1	5
21. Bentonite		2
20. Limestone, dark-gray, massive; weathers yellowish gray, shaly, and platy; where weathered, resembles beds 22–30	6	0
USGS Mesozoic loc. D3482, NE¼SE¼NW¼ sec. 16, T. 20 S., R. 65 W.:		
Neocrioceras n. sp., 8 in. below top (pl. 3, figs. 1, 2)		
Inoceramus sp.		
19. Shale, medium-gray		9
18. Limestone, yellowish-gray, shaly	1	3
17. Shale, medium-gray		8
USGS Mesozoic loc. D3480: *Inoceramus* (*Volviceramus*) *involutus* Sowerby		
16. Limestone, light-gray, shaly	1	6
15. Shale, medium-gray; weathers to ½-in. chips; contains limonite-stained gypsum nodules 2 in. in diameter that contain septarian veinlets	1	6
14. Shale, contains thin yellowish-gray and light-gray, fissile to platy limestone layers. Contains *Inoceramus*	3	4
13. Limestone, yellowish-gray, platy; fissile and shaly in upper half; contains limonite-stained pyrite crystals. Contains *Inoceramus*	3	0
12. Shale, light-olive-gray, hard; contains cyclic bedding consisting of alternating layers ½ in. and 1/16 in. in thickness. Contains *Inoceramus* 27 in. in diameter	1	9
11. Limestone, yellowish-gray, slabby, hard		11
USGS Mesozoic loc. D3479:		
Inoceramus (*Volviceramus*) *involutus* Sowerby (excellent example with radial ribs)		
Phlycticrioceras oregonense Reeside (pl. 3, fig. 3)		
10. Shale, light-olive-gray, fissile, hard; contains limonite-stained gypsum lenses	1	10
USGS Mesozoic loc. D3478 (in lower part):		
Inoceramus stantoni Sokolow (radial folds)		
I. (*Volviceramus*) *involutus* Sowerby		
9. Limestone, yellowish-gray, platy		11
8. Shale, light-olive-gray, fissile to platy, hard; lower 6 in. commonly is thin platy limestone; contains *Inoceramus*	1	5
7. Limestone, yellowish-gray, slabby; contains laminated limonite-stained fracture fillings and lenses of gypsum		11
USGS Mesozoic loc. D3477, NW¼ sec. 28, T. 20 S., R. 66 W.: *Inoceramus stantoni* Sokolow		
6. Shale, light-olive-gray, platy to fissile; contains *Inoceramus*	1	8
5. Limestone, yellowish-gray; forms two 5-in. layers where fresh; weathers to irregular plates; contains limonite-stained gypsum lenses		10
4. Shale, light-olive-gray, fissile, hard; contains *Inoceramus*	1	3
3. Limestone, yellowish-gray, slabby; contains *Inoceramus* along bedding in limonite-stained gypsum lenses		8
2. Shale, light-olive-gray, fissile, hard; contains *Inoceramus*	1	2
1. Limestone, yellowish-gray, hard, slabby; contains *Inoceramus* along bedding and in limonite-stained gypsum lenses		7
Total lower limestone unit	37	11½

MIDDLE SHALE UNIT

The middle shale unit of late Coniacian to middle Santonian age is the thickest unit of the Smoky Hill and contains the most variable lithology. It is about 280 feet thick at Pueblo, but thickens toward the south and thins toward the north. It consists principally of calcareous shale and some sandy shale, shaly or platy limestone, and limestone concretions. The unit is nonresistant and forms a broad shale valley that trends northwestward through the west side of Pueblo. Small parts of the unit crop out in stream valleys, but the whole unit does not crop out at any one place, and some parts of the stratigraphic section had to be inferred from poor outcrops.

The middle shale is composed of light-olive-gray, medium-light-gray, pale-yellowish-brown, and yellow-

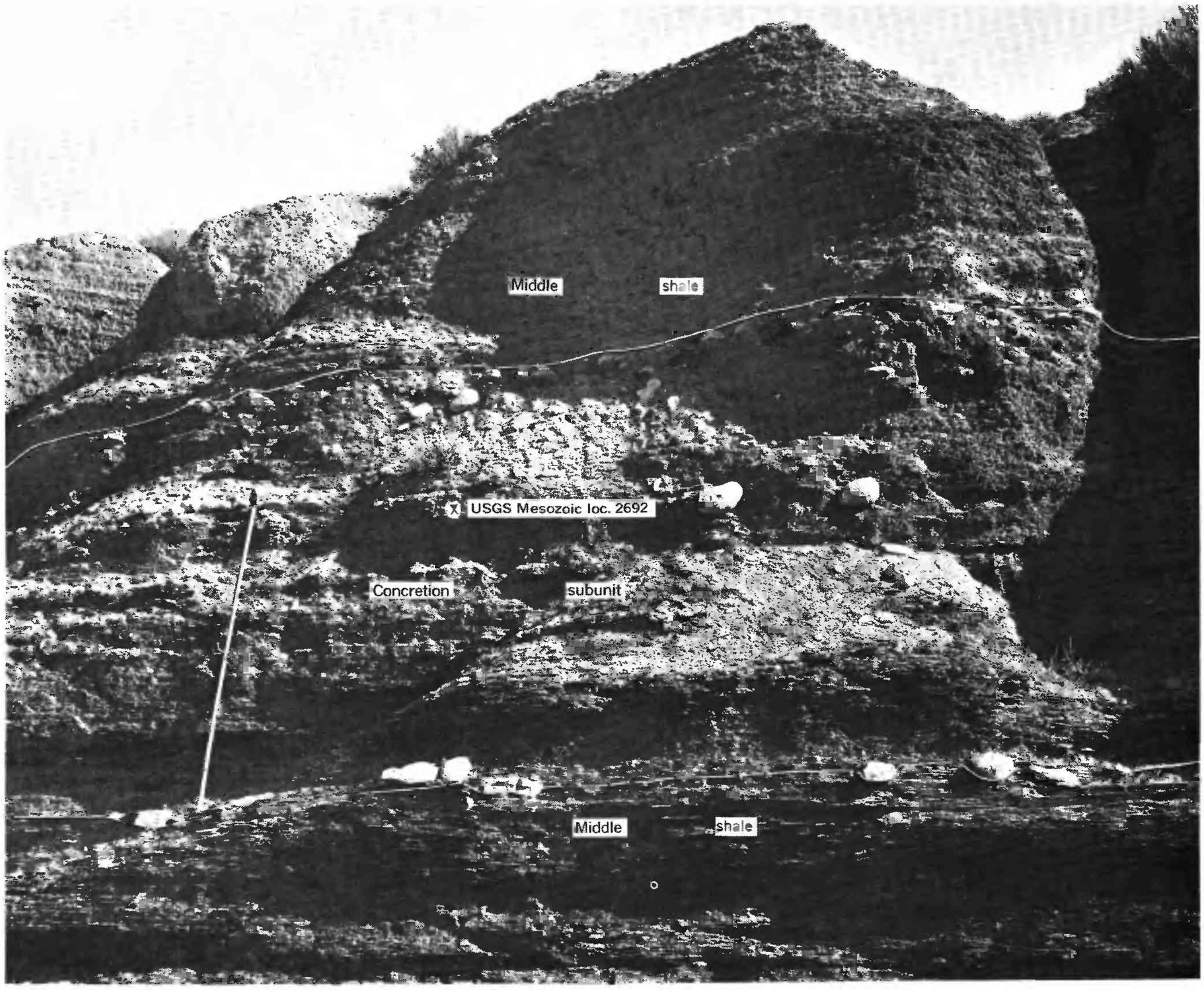

FIGURE 6.—Concretion subunit of middle shale unit of Smoky Hill Shale Member in valley of Dry Creek in the SW¼ sec. 3, T. 20 S., R. 65 W., Pueblo County, Colo. Concretions are more abundant but smaller at top of subunit. The Jacob staff is 5 feet long.

ish-gray shale that is platy, hard, and calcareous. It weathers to pale-yellowish-brown shale that is soft and fissile. In the lower 150 feet the shale contains hard platy layers of silty limestone that are ripped out of stream floors by flash floods and spread across the flood plain in blocks as much as 4 inches thick by 6 feet long. These weather to or can be split into large thin plates. From about 150 to 190 feet above the base are beds of platy light-olive-gray sandy shale—the sandy subunit—that contain thin hard plates covered with the trails of worms and crustaceans. About 30 feet below the top of the middle shale is a concretion subunit that contains several layers of gray limestone concretions (fig. 6). Generally there are four layers of concretions in a shale interval 11 feet thick. The top layer contains extremely hard somewhat flat pyritic concretions 2 to 6 inches long that are ovate or composite and shaped like peanut shells. The second layer contains more rounded concretions, and the lower two layers contain large flat concretions, as much as 14 inches in diameter, some of which formed in the hollows of *Inoceramus* shells. These concretions also contain nodules of pyrite that are altering to limonite; some concretions contain a coating of gypsum.

The upper 30 feet of the unit contains gray hard platy to shaly limestone and calcareous shale that weather dark yellowish brown and yellowish gray. Limonite-stained gypsum nodules or lenses of selenite crystals occur along with beds of limonite and one layer of bentonite. The shale at the top of the unit is a concretionary subunit that contains lenticular concretionary masses, 2 feet in diameter, of gray platy limestone that is more resistant to weathering than the surrounding shale.

FACIES CHANGES OF MIDDLE SHALE

The middle shale varies more in thickness and lithology than any other part of the Smoky Hill as it is traced away from Pueblo. Toward the south it becomes thicker and sandier, and in Raton Basin in northeastern New Mexico contains several hundred feet of sandy beds with calcareous sandstone concretions. Toward the north in the Denver area it consists of only about 60 feet of yellowish-gray chalky fissile shale.

FOSSILS AND AGE

Fossils are common and varied in the middle shale unit. In terms of the range zones suggested by Cobban and Reeside (1952) these fossils range from the upper part of the *Scaphites depressus* zone up into the *Clioscaphites choteauensis* zone.

The lower 25 feet (beds 1–7) contains *Scaphites depressus* var. *stantoni* Reeside (pl. 5, fig. 2), *S. binneyi* Reeside, *Protexanites shoshonensis* (Meek) (pl. 4, fig. 4), *Baculites asper* Morton (pl. 5, fig. 3), *B. codyensis* Reeside (pl. 5, fig. 4), and the lowest occurrence of *Inoceramus undulatoplicatus* Roemer. The scaphites indicate the *Scaphites depressus* Range Zone which is assigned to the upper Coniacian because of the presence of the uncoiled ammonite *Phlycticrioceras* in this zone in Wyoming and Utah and in the upper part of the Coniacian of France. Seitz (1956, p. 3, 4) assigned *Inoceramus undulatoplicatus* to the lower Santonian, but we found that this species overlaps the range zone of *I. cordiformis* and may have a different vertical range than in Europe.

Clioscaphites saxitonianus (McLearn) (pl. 6, figs. 2, 3) first appears 30 feet above the base of the middle shale unit and ranges upward for 220 feet (beds 9–19). The great thickness of this zone compared to the thinness of the other scaphite zones in the Niobrara probably is the result of thickening of the middle shale unit by an incursion of sand and silt from the southwest. The lower part of the range zone of *C. saxitonianus* is probably early Santonian in age because it lies between the top of the range zone of *Scaphites depressus* and the bottom of the range zone of *Inoceramus cordiformis* (table 2).

Inoceramus cordiformis Sowerby (1823, p. 61, pl. 440) (pl. 7, figs. 1, 2) first appears 53 feet above the base of the middle shale unit and ranges up through 150 feet (beds 13–20). Seitz (1956), p. 3, 4) assigned this species to the lower part of the middle Santonian. We regard the following names as synonyms of this species: *I. gilberti* White (1876, p. 113; 1879, p. 285, pl. 3, figs. 1a–c), *I. coulthardi* McLearn (1926, p. 121, pl. 21, figs. 1–4), and *I. pontoni* McLearn (1926, p. 121, pl. 20, figs. 1, 2).

Inoceramus undulatoplicatus Roemer (pl. 5, figs. 1, 5; pl. 6, figs. 1, 4) is common in the lower 110 feet of the middle shale unit (beds 5–13) but may range up to 240 feet above the base. The highest occurring specimen at Pueblo that can be identified with this species is a fragment of a very large individual from bed 19 that differs from the older specimens by being smoother. In Raton Basin, northeastern New Mexico, a similar smooth form occurs with *Clioscaphites vermiformis* (Meek and Hayden).

Inoceramus platinus Logan (1898, p. 491, pl. 116, fig. 2) (pl. 9) first appears about 60 feet below the top of the middle shale unit and ranges up through the unit and into the upper part of the Smoky Hill Member. Some specimens attained diameters of more than 3 feet. The writers regard the following names of Logan (1898) as synonyms of this species: *Inoceramus pennatus* (pl. 120, fig. 2 only), *I. truncatus*, and *I. subtriangulatus*.

The bed of limestone concretions (bed 19, fig. 9) 30 feet below the top of the middle shale unit contains *Inoceramus cordiformis*, *I. platinus*, and *I.* cf. *I. undulatoplicatus*. Ammonites found in these concretions in the Pueblo area are *Baculites asper* (pl. 7, figs. 5, 6), *B. codyensis* (pl. 7, figs. 3, 4), and *Clioscaphites saxitonianus* (pl. 7, figs. 7–9). These concretions contain *Texanites americanus* (Lasswitz) (pl. 7, figs. 13, 14), *Stantonoceras pseudocostatum* Johnson (pl. 8), and *Placenticeras planum* Hyatt at USGS Mes. loc. 14305 near Trinidad about 20 miles south of Pueblo. The presence of *Texanites americanus* and *Inoceramus cordiformis* establishes that these concretions are middle Santonian in age.

Clioscaphites vermiformis (Meek and Hayden) (pl. 7, figs. 10–12) marks a 6-foot zone, 11 feet above the limestone concretions and 20 feet below the top of the middle shale unit. A questionable specimen of *Inoceramus cordiformis* was found with this ammonite. A weakly ribbed form of *Baculites codyensis* is found here also.

Clioscaphites choteauensis Cobban (pl. 10, fig. 6) is found in the upper 6 feet of the middle shale unit. It is associated with smooth baculites (pl. 10, fig. 4), *Inoceramus platinus*, and a quadrate species of *Inoceramus* (pl. 10, figs. 3, 5).

Middle shale unit measured along the Arkansas River in the N½ secs. 33, 34, and 35, T. 20 S., R. 65 W.

	Ft	in
27. Shale, light-olive-gray, soft, fissile; contains 4-in.-thick yellowish-gray nodular oyster bed locally 2 ft above base containing *Inoceramus platinus* Logan and *Ostrea congesta* Conrad; also contains hard gray concretionary limestone masses in middle and 6-in. lenses of iron-stained selenite crystals. About 6 ft below top of unit are olive-gray platy limestone beds that contain fossil mollusks	12	4
USGS Mesozoic loc. D3501, SW¼NE¼SW¼ sec. 10, T. 20 S., R. 65 W.:		
Inoceramus platinus Logan?		
Ostrea sp.		
Baculites sp.		
Clioscaphites choteauensis Cobban		
Inoceramus sp. (quadrate form with fold in shell) (pl. 10, figs. 3, 5)		
USGS Mesozoic loc. D3502, NW¼NW¼ sec. 27, T. 20 S., R. 65 W.: *Inoceramus* sp. (quadrate form with fold in shell).		
26. Limestone, grayish-orange, shaly. Units 20–26 form minor ledge		10
25. Shale, grayish-orange, fissile, soft		5
24. Limonite, dark-yellowish-orange		1
23. Limestone, yellowish-gray, shaly, medium hard		6
22. Bentonite, dark-yellowish-orange and yellowish-gray, soft		1
21. Limestone, yellowish-gray, shaly, medium hard		10
20. Shale, dark-yellowish-brown and yellowish-gray, platy to fissile; contains limonite-stained gypsum nodules; fossil mollusks are present 11 ft above uppermost limestone concretions of bed 19	16	0
USGS Mesozoic loc. D3500, NE¼SW¼ sec. 10, T. 20 S., R. 65 W.:		
Inoceramus platinus Logan		
Inoceramus cordiformis Sowerby?		
Baculites codyensis Reeside (late form, weakly ribbed).		
Clioscaphites vermiformis (Meek and Hayden) (pl. 7, figs. 11, 12).		
19. Shale, dark-yellowish-brown and yellowish-gray; contains gray hard pyritic or gypsiferous concretions in three or four layers at most outcrops; the top layer is hard and pyritic; lower layers are softer and gypsiferous	11	4
USGS Mesozoic loc. D3495:		
Inoceramus platinus Logan		
Baculites codyensis Reeside		
USGS Mesozoic loc. D2692, NE¼SW¼SW¼ sec. 3, T. 20 S., R. 65 W.:		
Inoceramus cf. *I. undulatoplicatus* Roemer		
Inoceramus cordiformis Sowerby		
I. sp.		
I. platinus Logan		
Anomia sp. (concentric folds)		
Baculites codyensis Reeside		

Middle shale unit measured along the Arkansas River in the N½ secs. 33, 34, and 35, T. 20 S., R. 65 W.—Continued

	Ft	in
Clioscaphites saxitonianus (McLearn)		
USGS Mesozoic loc. D3496, NE¼SW¼ sec. 10, T. 20 S., R. 65 W.:		
Inoceramus cordiformis Sowerby		
Anomia subquadrata Stanton		
USGS Mesozoic loc. D3497, NW¼ sec. 25, T. 18 S., R. 66 W.:		
Inoceramus cordiformis Sowerby (pl. 7, figs. 1, 2)		
Anomia subquadrata Stanton		
Ostrea sp. (elongated)		
Lucina sp.		
Baculites codyensis Reeside		
B. asper Morton		
Clioscaphites saxitonianus (McLearn)		
crustacean		
18. Shale, pale-yellowish-brown, platy, soft; silty in upper part; sandy and contains thin lamina of sandstone with worm trails and other markings in the lower 25 ft; contains oyster bed about 8 ft above base	90	0
USGS Mesozoic loc. D3499, SW¼NW¼ sec. 10, T. 20 S., R. 65 W. (from upper silty part):		
Inoceramus platinus Logan?		
Inoceramus undulatoplicatus Roemer?		
Baculites codyensis Reeside		
Clioscaphites saxitonianus (McLearn)		
17. Limestone concretion, yellowish-gray, sandy; lower surface has impression of *Inoceramus undulatoplicatus* Roemer, USGS Mesozoic loc. D3494		2
16. Shale, light-olive-gray, platy; contains sandy layers covered with trails and borings	10	0
15. Bentonite, dark-yellowish-orange, soft		1½
14. Shale, light-olive-gray, platy; contains sandy layers covered with trails and borings	4	0
13. Shale, pale-yellowish-brown, platy, soft. *Inoceramus undulatoplicatus* Roemer, *I. cordiformis* Sowerby, *Ostrea congesta* Conrad, and *Baculites codyensis* Reeside found in float of stream bed 40 ft above bentonite bed 12	63	0
12. Bentonite, dark-yellowish-orange, soft, limonitic		1
11. Shale, dark-gray, platy, hard; weathers pale yellowish brown, platy, soft	35	0
Section reconstructed from several isolated sections at this point. Total reported thickness of middle shale unit may be in error by as much as 50 ft less section than is present at the outcrop owing to possible miscorrelation of bentonite beds in this part of section.		
10. Bentonite, light-gray and dark-yellowish-orange, soft		2
9. Shale, medium-light-gray	7	0
USGS Mesozoic loc. D3491, NE¼SW¼-NW¼ sec. 21, T. 20 S., R. 65 W.:		
Inoceramus undulatoplicatus Roemer		
Pteria sp.		
Ostrea sp.		
Baculites codyensis Reeside		

Middle shale unit measured along the Arkansas River in the N½ secs. 33, 34, and 35, T. 20 S., R. 65 W.—Continued

	Ft	*in*
9. Shale, medium-light-gray—Continued		
USGS Mesozoic loc. D3491—Continued		
Clioscaphites saxitonianus (McLearn) (pl. 6, fig. 2)		
C. saxitonianus var. *keytei* Cobban (pl. 6, fig. 3)		
8. Limonite, dark-yellowish-orange, and yellowish-gray bentonite		1
7. Shale, platy; contains iron-stained gypsum nodules. Best fossils are 4 ft above base	18	6
USGS Mesozoic loc. D3490, NW¼SE¼ sec. 9, T. 20 S., R. 65 W.:		
Inoceramus undulatoplicatus Roemer (pl. 5, figs. 1, 5; pl. 6, figs. 1, 4)		
I. cf. *I. stantoni* Sokolow		
Baculites asper Morton (pl. 5, fig. 3)		
B. codyensis Reeside		
Scaphites binneyi Reeside		
S. depressus Reeside		
fish scales		
USGS Mesozoic loc. D3492, SE¼SW¼ sec. 21, T. 20 S., R. 65 W.:		
Inoceramus sp.		
Baculites codyensis Reeside		
Scaphites binneyi Reeside?		
USGS Mesozoic loc. 1289, NW¼SE¼ sec. 9, T. 20 S., R 65 W.:		
Inoceramus undulatoplicatus Roemer		
Scaphites sp.		
Baculites codyensis Reeside		
Protexanites shoshonensis (Meek) (pl. 4, fig. 4)		
USGS Mesozoic loc. D3493, SE¼NW¼ sec. 16, T. 20 S., R. 65 W.:		
Inoceramus undulatoplicatus Roemer		
Baculites codyensis Reeside (pl. 5, fig. 4)		
Scaphites depressus var. *stantoni* Reeside		
6. Bentonite, dark-yellowish-orange, gypsiferous; mealy clay		½
5. Shale, medium-light-gray, hard, platy; contains *Inoceramus undulatoplicatus* Roemer 2 ft above base	5	0
4. Clay, moderate-yellowish-brown, gypsiferous		¾
3. Bentonite, yellowish-gray, soft		½
2. Clay, moderate-yellowish-brown, gypsiferous		½
1. Shale, light-olive-gray; platy, hard; weathers yellowish gray, fissile, soft; contains iron-stained gypsum nodules	7	0
USGS Mesozoic loc. D3489, NW¼SE¼ sec. 9, T. 20 S., R. 65 W.: *Scaphites depressus* var. *stantoni* Reeside from 4 ft. below top (pl. 5, fig. 2).		
Total middle shale unit	282	8¾

MIDDLE CHALK UNIT

The middle chalk unit of late middle Santonian age is a 28-foot unit of chalk beds separated by thin layers of hard chalky shale. The unit forms a low broad light-colored hogback that parallels Dry Creek for 5 miles north of the Arkansas River (fig. 7). The entire unit is well exposed at many places, especially along a creek in the SW¼ sec. 15, T. 20 S., R. 65 W., and in the S½ sec. 27, T. 20 S., R. 65 W. In the northern and southern parts of the Pueblo area, it is buried by surficial deposits. The unit has been recognized in a low hogback at least as far north as Wyoming, as far south as Graneros Creek, and almost as far east as the Apishapa River, beyond which it was not positively identified.

The middle chalk is composed of five or more distinct layers of gray hard platy to fissile chalk that are separated by shale. The chalk contains small light-colored specks and consists partly of tests of Foraminifera. It weathers to yellowish-gray irregular plates, a few inches in length. The shale is chalky and fissile but is softer than the resistant chalk which forms ledges (fig. 7). A limonite and a bentonite bed lie a little below the middle of the unit. Dark-yellowish-orange iron-stained selenite nodules are common in the upper part of the unit.

Middle chalk unit measured along south side of Arkansas River in NW¼ sec. 35, T. 20 S., R. 65 W.

	Ft	*in*
8. Chalk, very pale orange, platy; forms major ledge	3	9
7. Chalk, moderate-yellowish-orange and yellowish-gray, platy, chalky; contains dark-yellowish-orange selenite nodules. Contains fossils in lower 2 ft in large regular slabs of chalky yellowish-gray limestone	12	0
USGS Mesozoic loc. D2693, NE¼SW¼SW¼ sec. 3, T. 20 S., R. 65 W.:		
Inoceramus platinus Logan		
Ostrea sp.		
Baculites sp. (smooth)		
Clioscaphites choteauensis Cobban		
USGS Mesozoic loc. D3504, NW¼NE¼NW¼ sec. 15, T. 20 S., R. 65 W.:		
Inoceramus platinus Logan—more than 2 ft in diameter (pl. 9)		
Clioscaphites choteauensis Cobban		
Ostrea congesta Conrad		
6. Limonite, dark-yellowish-orange, soft, bentonitic		2
5. Chalk, light-olive-gray; weathers yellowish-gray, platy.		
Contains *Inoceramus platinus* Logan and *Ostrea congesta* Conrad		10
4. Bentonite, dark-yellowish-orange, hard, plastic, gypsiferous		1
3. Chalk, yellowish-gray, platy; forms part of ledge	1	0
2. Shale, light-olive-gray, hard, fissile	7	0
1. Chalk, yellowish-gray, platy; forms minor ledge	3	7
USGS Mesozoic loc. D3503, NE¼NW¼NW¼ sec. 15, T. 20 S., R. 65 W.:		
Inoceramus platinus Logan		
Ostrea congesta Conrad		
Clioscaphites choteauensis Cobban (pl. 10, fig. 6)		
Total middle chalk unit	28	5

FIGURE 7.—Ridge formed by middle chalk unit of Smoky Hill Shale Member along valley of a creek in the SE¼ sec. 16, T. 20 S., R. 65 W., Pueblo County, Colo. Middle bed of middle chalk unit is shown in foreground. Ridge of upper chalk unit lies east of Dry Creek; upper chalky shale unit underlies valley between the two ridges. The Jacob staff is 5 feet long.

FOSSILS AND AGE

The middle chalk contains many specimens of *Inoceramus platinus*. Excellent impressions of specimens 2 feet or more in diameter are found in a platy limestone bed 13 feet below the top of the unit along Williams Creek (pl. 9). *Ostrea congesta* Conrad is abundant. *Clioscaphites choteauensis* (pl. 10, fig. 6) and a smooth baculite are also present. The writers regard the *Clioscaphites choteauensis* Range Zone as late middle Santonian in age inasmuch as it lies above *Inoceramus cordiformis* of early middle Santonian age and below beds containing possible *Inoceramus patootensis* de Loriol of late Santonian age (table 2).

UPPER CHALKY SHALE UNIT

The upper chalky shale unit of late Santonian and early Campanian age is a 264-foot sequence of shale with numerous beds of chalk, limonite, and bentonite. The unit forms a northward-trending belt along which Dry Creek flows through the west side of Pueblo. Most layers of the unit crop out along the south side of the Arkansas River in the N½ sec. 35, T. 20 S., R. 65 W., and at several places along Dry Creek and its small tributaries, but some parts of the unit are not exposed at Pueblo. It underlies a broad alluvium-covered valley between the hogbacks of the middle chalk and the upper chalk. The thickness of the unit is uniform at least as far north as Denver, but its thickness and extent are not as well known to the south or east.

The upper chalky shale unit consists of pale-yellowish-brown, dark-yellowish-orange, olive-gray, and grayish-orange soft fissile chalky shale that contains

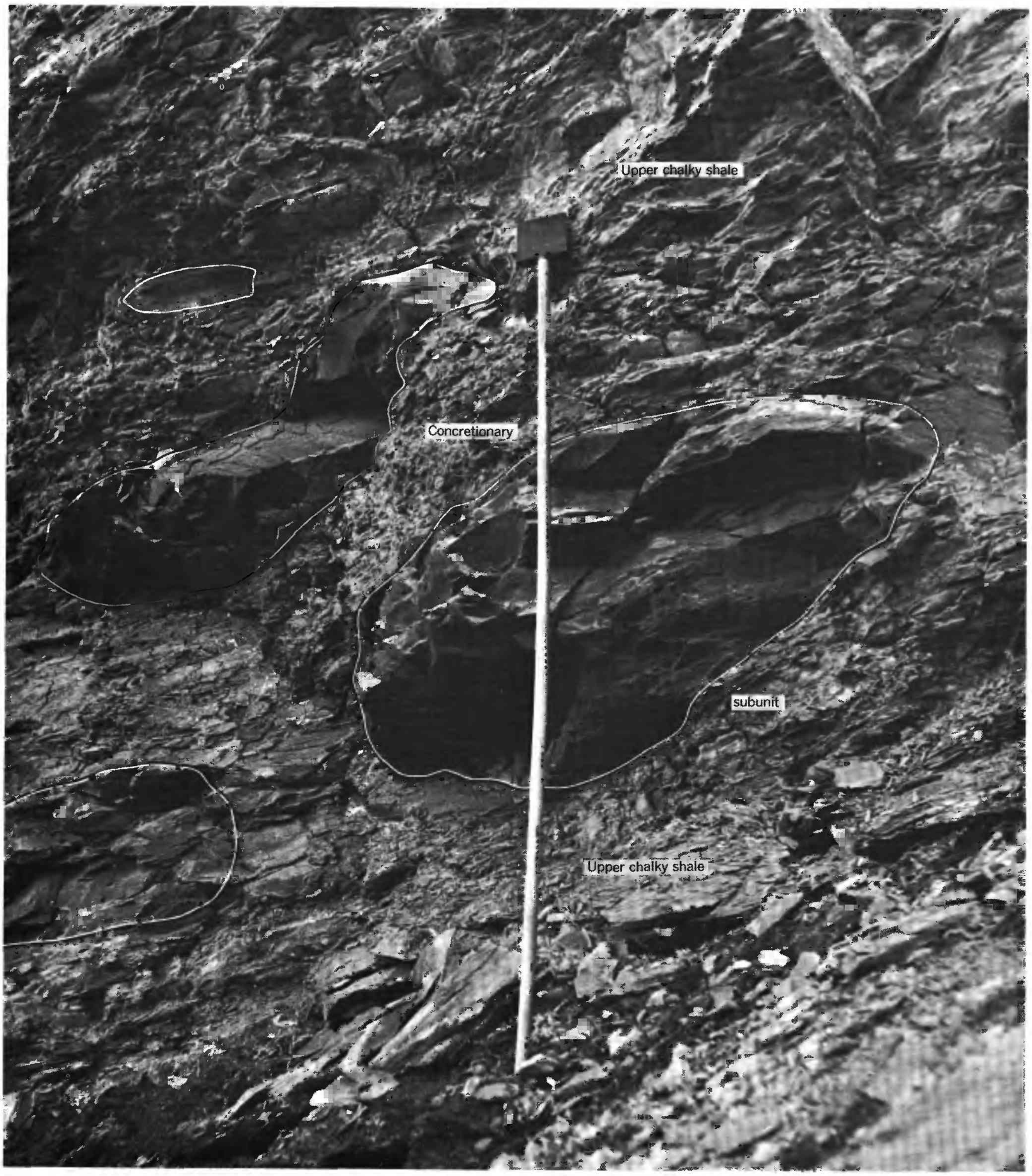

FIGURE 8.—Concretionary subunit of upper chalky shale unit of Smoky Hill Shale Member in valley wall of Arkansas River in the NE¼ sec. 35, T. 20 S., R. 65 W., Pueblo County, Colo. The Jacob staff is 5 feet long.

a concretionary subunit and beds of chalk, limonite, and bentonite. Layers of chalk are most abundant near the base and the top and indicate that the deposition of chalk diminished only slightly between deposition of the middle chalk and the upper chalk. The chalk layers are yellowish gray; they are firm and platy where fresh but soften and wash away readily where weathered. Beds of soft dark-yellowish-orange limonite are abundant in the lower 65 feet. Many of them contain crystalline gypsum or crystals of selenite. Seventeen beds of dark-yellowish-orange granular soft plastic bentonite were observed; most of these lie between 180 and 240 feet above the base of the unit. They serve as excellent marker beds in correlating small local outcrops of the unit.

The concretionary subunit (fig. 8) is about 25 feet thick and consists of layers of olive-gray shale that contain hard dark-gray concretionary speckled limestone lenses and beds of bentonite. The limestone lenses are as much as 3 feet in diameter and 2 feet in thickness and one occurs laterally about every 10 feet. Because they are resistant to erosion, they project from banks of shale and stand as large disks on the floors of arroyos cut into shale.

FOSSILS AND AGE

Only two faunal zones are known from the upper chalky shale. A lower zone, which occurs in bed 10 only 30 feet above the base of the unit, contains *Inoceramus simpsoni* Meek (pl. 10, fig. 1; pl. 11, fig. 5), smooth baculites (pl. 10, fig. 4), and a fragment of an *Inoceramus* that resembles *Inoceramus patootensis* de Loriol (pl. 10, fig. 2). The top of the zone of *Inoceramus platinus* (pl. 11, fig. 1) lies in bed 25. Many specimens of *I. platinus* were collected from the upper part of bed 23; small individuals seem to be somewhat more regularly ribbed than specimens in the middle chalk bed. An upper faunal zone was found in the upper chalky shale 70 feet below the upper chalk along the Apishapa River in the Elder quadrangle 40 miles east of Pueblo but was not found at Pueblo, where its position in the upper chalky shale is unknown. The upper zone contains *Haresiceras placentiforme* Reeside (pl. 11, figs. 3, 4), *Scaphites* cf. *S. hippocrepis* (DeKay), and *Baculites* cf. *B. haresi* Reeside which were found at USGS Mesozoic loc. D3266, NE¼SW¼NW¼ sec. 23, T. 23 S., R. 59 W., Otero County, Colo. Fish scales and bones are more abundant in the upper chalky shale than in any other part of the Niobrara.

The lower part of the unit, which contains possible *Inoceramus patootensis*, is assigned to the late Santonian. An early Campanian age is assigned to the upper part of the unit because of the presence of *Haresiceras placentiforme* Reeside (Cobban and others, 1962, p. B58).

Section measured along south side of Arkansas River in NW¼ SW¼NW¼ sec. 36, T. 20 S., R. 65 W.

	Ft	in
Upper chalk unit:		
1. Chalk, olive-black, blocky; weathers dark yellowish orange; forms a single bed with flat joint faces that is the most resistant bed on the cliff	8	0
USGS Mesozoic loc. D3510: *Inoceramus simpsoni Meek* *Baculites* sp. (smooth) *Stramentum haworthi* Williston		
USGS Mesozoic loc. D3511, NW¼SE¼ NE¼ sec. 15, T. 20 S., R. 65 W.: *Inoceramus simpsoni* Meek		
USGS Mesozoic loc. D3512, SE¼SE¼ sec. 34, T. 20 S., R. 65 W.: *Inoceramus simpsoni* Meek		
Upper chalky shale unit:		
70. Shale; weathers grayish orange, earthy	1	9
69. Chalk, earthy, platy; weathers grayish orange, fissile		7
68. Shale, grayish-orange, earthy	2	4
67. Chalk, yellowish-gray, irregularly platy		9
66. Shale, light-olive-gray, gypsum veinlets	1	2
65. Shale, light-olive-gray, earthy		5
64. Shale, light-olive-gray		8
63. Chalk, yellowish-gray, irregularly platy		3
62. Shale, light-olive-gray, platy		5
61. Chalk, yellowish-gray, platy		7
60. Shale, dark yellowish-brown and yellowish-orange, earthy; seamed with gypsum veinlets	5	10
59. Shale, yellowish-gray; seamed with fibrous gypsum veinlets; shows flat joint faces on fresh exposure	1	0
58. Shale, medium-gray; gypsum veinlets	2	10
57. Shale, medium-gray; seamed with fibrous gypsum veinlets; resistant to weathering		8
56. Shale, medium-gray; weathers dark-yellowish orange; concretionary about 4 ft above base; seamed with gypsum veinlets	6	6
55. Limestone, olive-gray, hard; forms ledge with flat joint faces		7
54. Shale	3	2
53. Limestone, olive-gray, hard; forms ledge with flat joint faces	1	5
52. Shale, olive-black, hard, platy	1	0
51. Bentonite, moderate-yellowish-brown, soft, plastic; swells to 1 in. upon wetting		½
50. Shale, olive-black; weathers light olive gray; like bed 48 except harder	4	0
49. Bentonite, dark-yellowish-orange, stratified, sugary to floury; excellent marker bed along cliff		3½
48. Shale, light-olive-gray speckled; weathers to irregular 1-in. chips	3	0
47. Bentonite, dark-yellowish-orange and yellowish-gray, soft, plastic		2
46. Shale; same as bed 44	20	6
45. Bentonite, dark-yellowish-orange, soft, plastic		1
44. Shale, light-olive-gray, fissile	6	10
43. Bentonite, dark-yellowish-orange, stratified, soft		1

Section measured along south side of Arkansas River in NW¼SW¼NW¼ sec. 36, T. 20 S., R. 65 W.—Continued

	Ft	in
42. Shale, light-olive-gray, fissile to platy; contains a few small concretionary lenses	3	2
41. Shale, same as bed 27. (Top of concretionary shale subunit.)	2	0
40. Bentonite		½
39. Shale; same as bed 27	2	0
38. Bentonite, yellowish-gray, granular, soft		1
37. Shale; same as bed 27	1	8
36. Bentonite, dark-yellowish-orange		1
35. Shale; same as bed 27	3	5
34. Bentonite, dark-yellowish-orange		1
33. Shale, olive-gray; same as bed 27	1	9
32. Bentonite, dark-yellowish-orange, plastic, soft; contains selenite		1
31. Shale, olive-gray; same as bed 27	2	6
30. Bentonite, dark-yellowish-orange, plastic, soft		1
29. Shale, olive-gray, platy, hard; contains hard concretionary lenses of limestone	3	0
28. Bentonite, dark-yellowish-orange, granular, soft		½
27. Shale, olive-gray, platy, hard; contains hard concretionary lenses of dark-gray speckled limestone	3	0
26. Bentonite, dark-yellowish-orange		1
25. Shale, olive-gray, irregularly platy, hard. (Base of concretionary shale subunit.) Contains large concretionary limestone masses	2	6
USGS Mesozoic loc. D3509, SE¼NW¼ sec. 15, T. 20 S., R. 65 W.: *Inoceramus platinus* Logan, (pl. 11, fig. 1)		
24. Bentonite, dark-yellowish-orange, granular, soft		1
23. Shale, dark-yellowish-orange and medium-gray, chalky, fissile; has texture of rotted wood; contains chalk at 74–84 in. and at many other places in overlying exposed part of section. Section is well exposed from 70 to 115 ft, where it consists of chalky shale and chalk weathered light brown and dark yellowish orange and contains fossil mollusks, fish bones, and scales. Also contains some hard dark-gray concretionary nonfossiliferous limestone masses near top as much as 3 ft in diameter and 2 ft thick	115	0
USGS Mesozoic loc. D3506, NW¼NE¼ sec. 22, T. 20 S., R. 65 W.: *Inoceramus platinus* Logan, *Ostrea congesta* Conrad		
USGS Mesozoic loc. D3507, SW¼NW¼ SE¼ sec. 10, T. 20 S., R. 65 W.: *Inoceramus platinus* Logan, *Ostrea congesta* Conrad		
USGS Mesozoic loc. D3508, SW¼ sec. 34, T. 19 S., R. 65 W.: *Inoceramus platinus* Logan		
22. Limonite and gypsum bed		2
21. Shale; same as bed 13	2	2
20. Bentonite, grayish-orange, fissile		2
19. Shale, same as bed 13	6	2

Section measured along south side of Arkansas River in NW¼SW¼NW¼ sec. 36, T. 20 S., R. 65 W.—Continued

	Ft	in
18. Limonite and gypsum bed		2
17. Shale; same as bed 13	3	0
16. Limonite and gypsum bed		1
15. Shale; same as bed 13	3	0
14. Bentonite, limonitic		1½
13. Shale, dark-yellowish-orange and medium-gray, chalky, fissile; has texture of rotted wood	4	4
12. Limonite and bentonite bed, light-brown, soft		1
11. Shale, pale-yellowish-brown, soft, chalky, fissile; lower 6 feet? unexposed; contains several irregular platy speckled chalky limestone beds	14	8
10. Chalk, yellowish-gray, platy		10
USGS Mesozoic loc. D3505, NW¼SE¼ sec. 10, T. 20 S., R. 65 W: *Inoceramus simpsoni* Meek (pl. 10, fig. 1; pl. 11, fig. 5) *Baculites* sp. (smooth) (pl. 10, fig. 4) *Ostrea* sp. *Inoceramus* cf. *I. patootensis* de Loriol (pl. 10, fig. 2)		
9. Shale, pale-yellowish-brown, soft, fissile	2	6
8. Limonite, dark-yellowish-orange		½
7. Shale, pale-yellowish-brown, soft, fissile	4	2
6. Limonite, dark-yellowish-orange, soft; contains selenite crystals		1½
5. Shale, pale-yellowish-brown, soft; contains 8-in.-thick chalky limestone in middle	4	0
4. Limonite, dark-yellowish-orange, soft		3
3. Shale, pale-yellowish-brown, soft; some thin platy limestone beds	11	0
2. Chalk, yellowish-gray, platy; minor ledge former. *Inoceramus*		11
1. Shale, light-olive-gray, fissile	6	0
Total upper chalky shale unit	263	10½

UPPER CHALK UNIT

The upper chalk unit of early Campanian age is an 8-foot-thick bed of massive chalk. The bed forms a narrow sharp hogback that trends northward from the Fourth Street bridge across the Arkansas River just east of the Northwest Pueblo quadrangle along the east side of Dry Creek (fig. 9). The bed is well exposed in cliffs at many places along the hogback, but the best exposure is in the bluff along the Arkansas River in the NW¼SW¼NW¼ sec. 36, T. 20 S., R. 65 W. In the southern part of Pueblo the chalk is buried by surficial deposits. A chalk bed of identical appearance crops out in a hogback as far north as Horse Creek on the east side of the Laramie Range, Wyo. The upper chalk extends eastward beyond the Apishapa River. It was not traced to the south.

The upper chalk is a single massive blocky bed of olive-black chalk that weathers dark yellowish orange. Its description and stratigraphic position are shown in

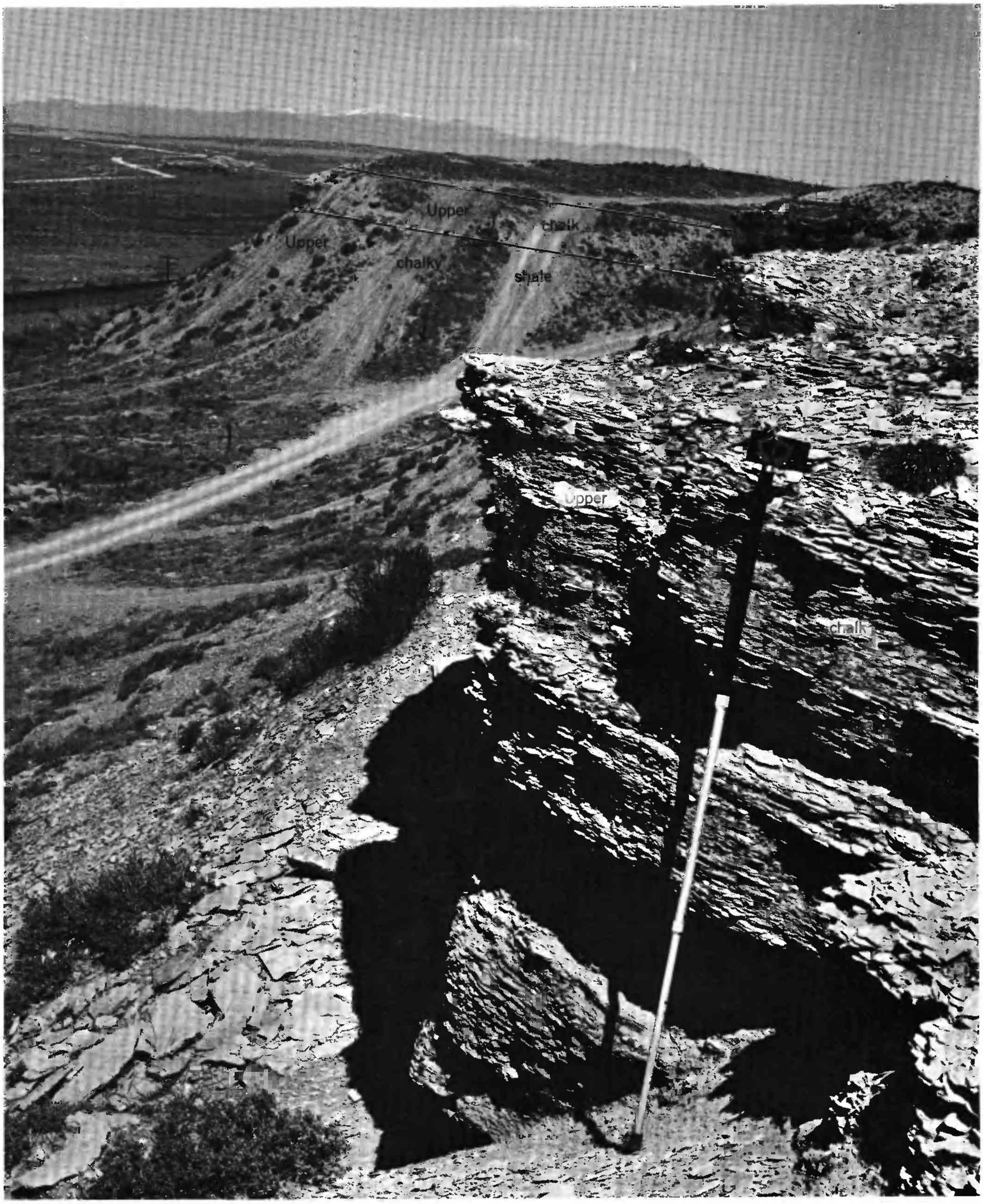

FIGURE 9.—Ridge formed by upper chalk unit of Smoky Hill Shale Member along east side of Dry Creek in the NE¼ sec. 22, T. 20 S., R. 65 W., Pueblo County, Colo. Weathered upper chalk unit is shown in foreground. The Jacob staff is 5 feet long.

a stratigraphic section listed under the upper chalky shale. In a fresh exposure the chalk is difficult to differentiate from underlying and overlying chalky layers. Where weathered, however, the chalky layers below and above are shaly, and only the 8-foot-thick upper chalk bed forms a hogback. The chalk is a weakly cohesive rock composed of small light-colored specks of calcium carbonate, clay, and tests of Foraminifera. The content of calcium carbonate averages about 80 percent; the remainder is clay and silt.

FOSSILS AND AGE

The upper chalk unit at USGS Mesozoic loc. D3510 and D3511 contains three fossil forms that characterize the unit but apparently are not limited to it. They are *Inoceramus simpsoni* Meek, large smooth baculites, and a barnacle, *Stramentum haworthi* Williston (pl. 11, fig. 2), which is attached to the baculites. This chalk unit is probably of early Campanian age.

CALCAREOUS BEDS AT BASE OF PIERRE SHALE

Calcareous shale that contains light-brown speckled chalky layers, moderate-yellowish-orange concretionary limestone, and bentonite beds continues 145 feet above the Smoky Hill Shale Member into the overlying unnamed transition member of the Pierre Shale. These calcareous beds lie above the hogback-forming chalk along the Front Range at least from northern Colorado southward to Walsenburg.

The contact between the calcareous and noncalcareous rocks is not mappable. Therefore, the top of the upper chalk unit, which is mappable, was chosen as the top of the Niobrara Formation. In the subsurface the top of the Niobrara is customarily picked at the break between calcareous and noncalcareous rocks, and we want to emphasize that this boundary is considerably younger and 145 feet higher than the mappable top of the Niobrara at Pueblo. Northward from Pueblo the calcareous rocks decrease in thickness at the base of the Pierre, but they are still nearly 100 feet thick near Denver.

INCORRECT USAGE OF THE NAMES TIMPAS LIMESTONE AND APISHAPA SHALE

The relation of the Fort Hays Limestone and Smoky Hill Shale Members of the Niobrara Formation to the Timpas Limestone and Apishapa Shale is discussed here in order to clear up a misconception, stated or implied repeatedly in the literature, that these formations are exactly equivalent to each other. As a result of the work at Pueblo, we find that the names Timpas and Apishapa are unnecessary and undesirable because they do not properly express the natural division of the rocks. Therefore, we abandon the names Timpas Limestone and Apishapa Shale.

Figure 2 shows that the type Timpas Limestone includes beds from the base of the Niobrara to the top of the lower limestone unit; the Apishapa contains the rest of the Niobrara. The two names were used in the same sense as Gilbert (1896) intended them only in the early folios of the Geologic Atlas of the United States, such as the Nepesta, Apishapa, and Walsenburg folios, which were mapped by geologists who had worked with Gilbert or who knew exactly where he had placed the boundary between the Timpas and Apishapa. Since publication of the last of these folios in 1912, the Timpas has been almost invariably restricted to limestone beds 30 to 40 feet in thickness at the base of the Niobrara, which should correctly be called the Fort Hays Limestone Member. The enlarged Apishapa, as incorrectly applied, contains the upper part of the type Timpas and all the type Apishapa which together really equal the Smoky Hill Shale Member.

In Kansas the type Fort Hays Limestone Member is the lower 55 feet of ledge-forming limestone at the base of the Niobrara. It is overlain by the type Smoky Hill, which contains about 550 feet of chalk and chalky shale.

These two units are recognizable, and the contact between them is readily mappable over nearly all the basin of Niobrara deposition. On the other hand, the contact between the Timpas and Apishapa is mappable only in a small area near Pueblo.

The name Fort Hays has priority because it was proposed 3 years earlier than the name Timpas. The names Smoky Hill and Apishapa were proposed in the same year.

Two sets of names are unnecessary to designate divisions of the Niobrara. If the Pueblo area is considered alone, either set of units could have been subdivided into the eight map units that are used in this report. We prefer, however, to abandon the names Timpas and Apishapa, partly because they have not been used as widely as the Fort Hays and Smoky Hill and partly because Fort Hays and Smoky Hill best fit the mappable units that crop out over most of the basin of Niobrara deposition.

CORRELATION

The Niobrara Formation can be correlated with rocks of varied lithology throughout the western interior of the United States. Four areas (table 3) that are widely separated have been selected to show lithologic variations in rocks equivalent to the Niobrara Formation at Pueblo. At Boulder, Colo., the rocks are calcareous but not as chalky as those at Pueblo. In central Utah, correlative rocks are noncalcareous shale and beds of sandstone. Rocks in the Wind River Basin, Wyo., and on the Sweetgrass arch, Montana, include sandstone,

TABLE 3.—*Correlation of the Niobrara Formation and its equivalents*

Standard stages			Faunal range zones: Scaphites	Faunal range zones: Other fossils		Pueblo	Boulder, Colo.	East-central Utah	Shotgun Butte, Wind River Basin, Wyo.	Sweetgrass arch, Montana
						Niobrara Formation; Smoky Hill Shale Member	Niobrara Formation; Smoky Hill Shale Member		Cody Shale	Marias River Shale (part); Kevin Shale Member
Lower Campanian (part)			*Scaphites hippocrepis*	*Inoceramus simpsoni (part)*	*Haresiceras placentiforme*	Upper chalk	Upper chalk	Mancos Shale (part)	Sandy member	Virgelle Sandstone
Santonian	Upper		*Desmoscaphites bassleri*	?	*Inoceramus patootensis*	Upper chalky shale	Upper shale			Telegraph Creek Formation
			Desmoscaphites erdmanni	*Inoceramus platinus*						Upper ? unit
	Middle	Upper part	*Clioscaphites choteauensis*			Middle chalk	Middle limestone			
		Lower part	*Clioscaphites vermiformis*		*Inoceramus cordiformis*	Middle shale	Middle shale			Middle unit
	Lower		*Clioscaphites saxitonianus*	*Inoceramus undulatoplicatus*						
Coniacian	Upper		*Scaphites depressus*	*Inoceramus (Volviceramus) involutus*	*Inoceramus stantoni*	Lower limestone	Lower limestone		Shaly member	MacGowan Concretionary Bed
	Middle		*Scaphites ventricosus*			Lower shale	Lower shale			Middle unit
	Lower		*Scaphites preventricosus*	*Inoceramus deformis*		Shale and limestone	Shale and limestone			Lower unit
				Inoceramus erectus	*Barroisiceras* and *Prionocycloceras* ?	Fort Hays Limestone Member	Fort Hays Limestone Member		Frontier Formation (part)	
Upper Turonian (part)			*Scaphites corvensis*	*Inoceramus* aff. *I perplexus* Whitfield						

calcareous and noncalcareous shale, siltstone, bentonite beds, and limestone concretions.

BOULDER AREA, COLORADO

The Niobrara Formation, 4 to 6 miles north of Boulder, contains four hogback-forming beds of limestone separated by shale. The Fort Hays Limestone Member is overlain by 23 feet of shale and limestone that contains *Inoceramus deformis*. This is overlain by a light-gray weathering fissile shale that, in turn, is overlain by a hogback-forming platy limestone. This limestone is correlated by its stratigraphic position with the lower limestone at Pueblo. A dark-gray fissile middle shale separates this lower limestone of the Smoky Hill from the middle limestone. About 20 feet below the top of the middle shale, 1 or 2 beds of gray dense hard concretionary limestone crop out that contain *Inoceramus platinus*, *Clioscaphites vermiformis*, and *Baculites codyensis*. The middle limestone contains platy chalky beds in which *Ostrea congesta* is abundant. Overlying the middle limestone is a yellowish-brown soft fissile upper shale. At the top of the Niobrara is a 49-foot hogback-forming bed of olive-gray platy chalk that weathers yellowish orange. *Haresiceras natronense?* Reeside was found in the base of the chalk in the SW¼SE¼ sec. 1, T. 1 N., R. 71 W., Boulder County, Colo. (Cobban and others, 1962, p. B59). The 8-foot-thick upper chalk unit at Pueblo probably correlates with only the upper part of the upper chalk unit at Boulder. Transition beds in the Pierre Shale are calcareous for 44 feet above the upper chalk unit at Boulder.

EAST-CENTRAL UTAH

Most of the Mancos Shale in the Book Cliffs area of east-central Utah is equivalent in age to the Niobrara Formation. Near the town of Green River, Fisher, Erdmann, and Reeside (1960, p. 29, pl. 10) found *Inoceramus involutus* (as *I. exogyroides*), *I. stantoni*, *Baculites asper*, *B. codyensis*, *Phlycticrioceras oregonense*, and *Scaphites depressus* var. *stantoni*, 930 to 1,100 feet above the base of the Mancos Shale. These fossils, which can be assigned to the *Scaphites depressus* Range Zone, indicate a time correlation with the lower limestone unit and the basal part of the middle shale unit at Pueblo. *Clioscaphites vermiformis* was found 1,370 to 1,510 feet above the base of the Mancos Shale near the town of Green River; this evidence indicates a correlation with the part of the middle shale unit above the limestone concretion bed at Pueblo. *Desmoscaphites bassleri* Reeside of late Santonian age was found 1,710 to 1,880 feet above the base of the Mancos Shale near the town of Green River; this evidence indicates a correlation with the lower part of the upper chalky shale unit at Pueblo. *Scaphites hippocrepis* was found 3,250 feet above the base of the Mancos Shale (580 feet below the top); this part of the Mancos is probably equivalent to some part of the uppermost Smoky Hill Member at Pueblo.

Diagnostic fossils of Niobrara age were not found by Fisher, Erdmann, and Reeside (1960, p. 29) near Green River between the Ferron Sandstone Member of the Mancos Shale and the lowest occurrence of *Inoceramus involutus*. About 70 miles west of Green River, however, Reeside (1932, p. 17) recorded *Barroisiceras* with *Inoceramus deformis* in the Mancos Shale 200 feet above the Ferron Sandstone Member. This fossil record indicates a correlation with the upper part of the Fort Hays Limestone Member of Pueblo.

WIND RIVER BASIN, WYO.

Rocks equivalent in age to the Niobrara Formation of Pueblo consist of the uppermost part of the Frontier Formation and the overlying Cody Shale. The Cody Shale is divided into a lower shaly member and an upper sandy member. The sequence is seen best at East Sheep Creek in the Shotgun Butte area on the north side of the Wind River Basin (Keefer and Troyer, 1956), where the uppermost part of the Frontier Formation contains numerous fossils including *Inoceramus deformis*. The *Scaphites depressus* fauna is distributed through 640 feet of beds in the middle of the shaly member of the Cody Shale. It contains *Inoceramus stantoni*, *Scaphites depressus*, *Scaphites binneyi*, *Phlycticrioceras oregonense*, and many other fossils. This zone is several times as thick here as at Pueblo.

The sandy member of the Cody Shale contains *Clioscaphites vermiformis* 340 feet above the base, *Desmoscaphites bassleri* 900 feet above the base, and *Haresiceras montanaense* (Reeside) (as *H. placentiforme*) 1,660 feet above the base. Keefer and Troyer found *Inoceramus patootensis* (as *I. lundbreckensis*) and coarse-ribbed *Scaphites hippocrepis* 2,120 feet above the base (70 feet below the top). This collection probably lies at or near the level of *Haresiceras placentiforme*. The sandy member correlates with all the Santonian and part of the lower Campanian beds at Pueblo.

SWEETGRASS ARCH, MONTANA

Rocks equivalent in age to the Niobrara Formation of Pueblo consist of noncalcareous shale, siltstone, and sandstone on the Sweetgrass arch in northwestern Montana. Here these rocks are divided into the Marias River Shale overlain by the Telegraph Creek Formation, which in turn, is overlain by the Virgelle Sandstone. Most of Coniacian and Santonian time is represented by the Kevin Shale Member of the Marias River Shale and the Telegraph Creek Formation (Cobban and others, 1959, fig. 3 on p. 2792). Fossils from the Kevin and Telegraph Creek have been listed by Cobban (1950, 1951a).

The lower unit of the Kevin Member contains small variants of *Inoceramus deformis* and *I. erectus* which suggest correlation with the middle part of the Fort Hays Limestone of Pueblo. Typical *I. deformis* is present a little higher in the lower unit. The middle unit of the Kevin contains *I. involutus* (listed as *I. umbonatus*) in the lower part, *Scaphites depressus* and *Inoceramus stantoni* (see Cobban, and others, 1958) in the middle part, and the lowest appearance of *Clioscaphites vermiformis* in the upper part. The upper unit of the Kevin Member contains *C. vermiformis* and *Inoceramus cordiformis* (listed as *I.* cf. *I. coulthardi* McLearn and *I. pontoni* McLearn) in the lower part, *Clioscaphites choteauensis* in the middle, and *Desmoscaphites erdmanni* and *Inoceramus patootensis* (as *I. lundbreckensis* McLearn) in the upper part.

Clioscaphites saxitonianus is known from the Sweetgrass arch, but its exact position in the faunal sequence is unknown (Cobban, 1951b, p. 37). In light of the sequence at Pueblo, *C. saxitonianus* probably occurs in the rocks just below those containing *C. vermiformis.*

The Telegraph Creek Formation contains *Inoceramus patootensis* (as *I. lundbreckensis*), *Desmoscaphites bassleri*, and *Haresiceras mancosense* (Reeside) (as *Puzosia mancosensis*). This late Santonian formation correlates with the middle of the upper chalky shale unit of the Smoky Hill Member at Pueblo.

The Virgelle Sandstone, which overlies the Telegraph Creek Formation, has not yielded diagnostic fossils on most of the Sweetgrass arch. It probably is of very early Campanian age on the higher parts of the Sweetgrass arch.

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INDEX

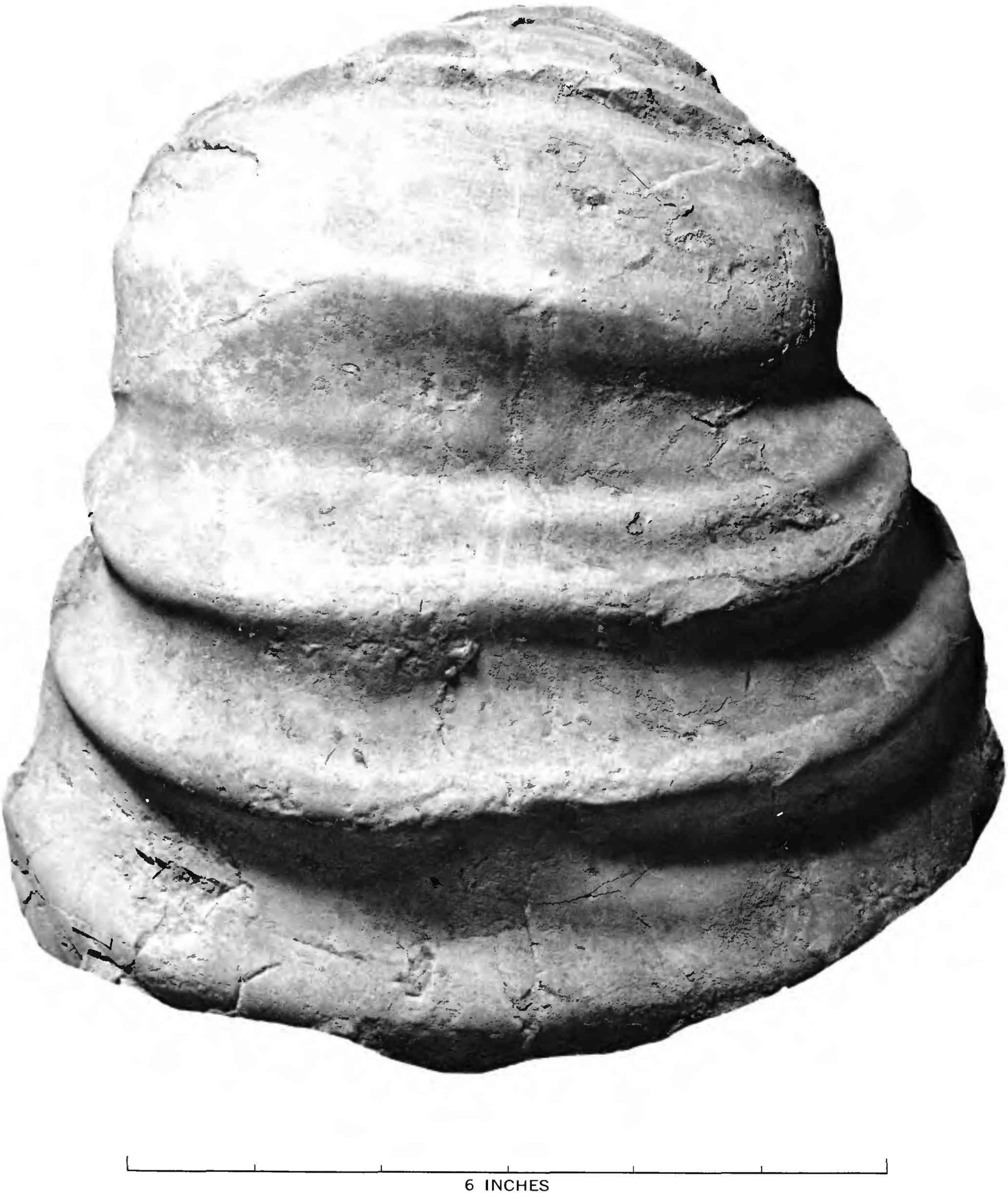
[Italic page numbers indicate major references]

PLATES 1–11

PLATE 1

Inoceramus deformis Meek (p. L9).

View of a very large specimen from the top of the shale and limestone unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3470 in the NW¼SW¼ sec. 4, T. 21 S., R. 65 W. USNM 131488.



INOCERAMUS DEFORMIS MEEK FROM SHALE AND LIMESTONE UNIT OF SMOKY HILL SHALE MEMBER

PLATE 2

[All figures natural size]

FIGURES 1–5. *Inoceramus* aff. *I. perplexus* Whitfield (p. L7).

1–4. Views of four specimens from 2 feet above the base of the Fort Hays Limestone Member at USGS Mesozoic loc. D3514 in the SW¼ sec. 22, T. 18 S., R. 68 W. USNM 131489–131492.

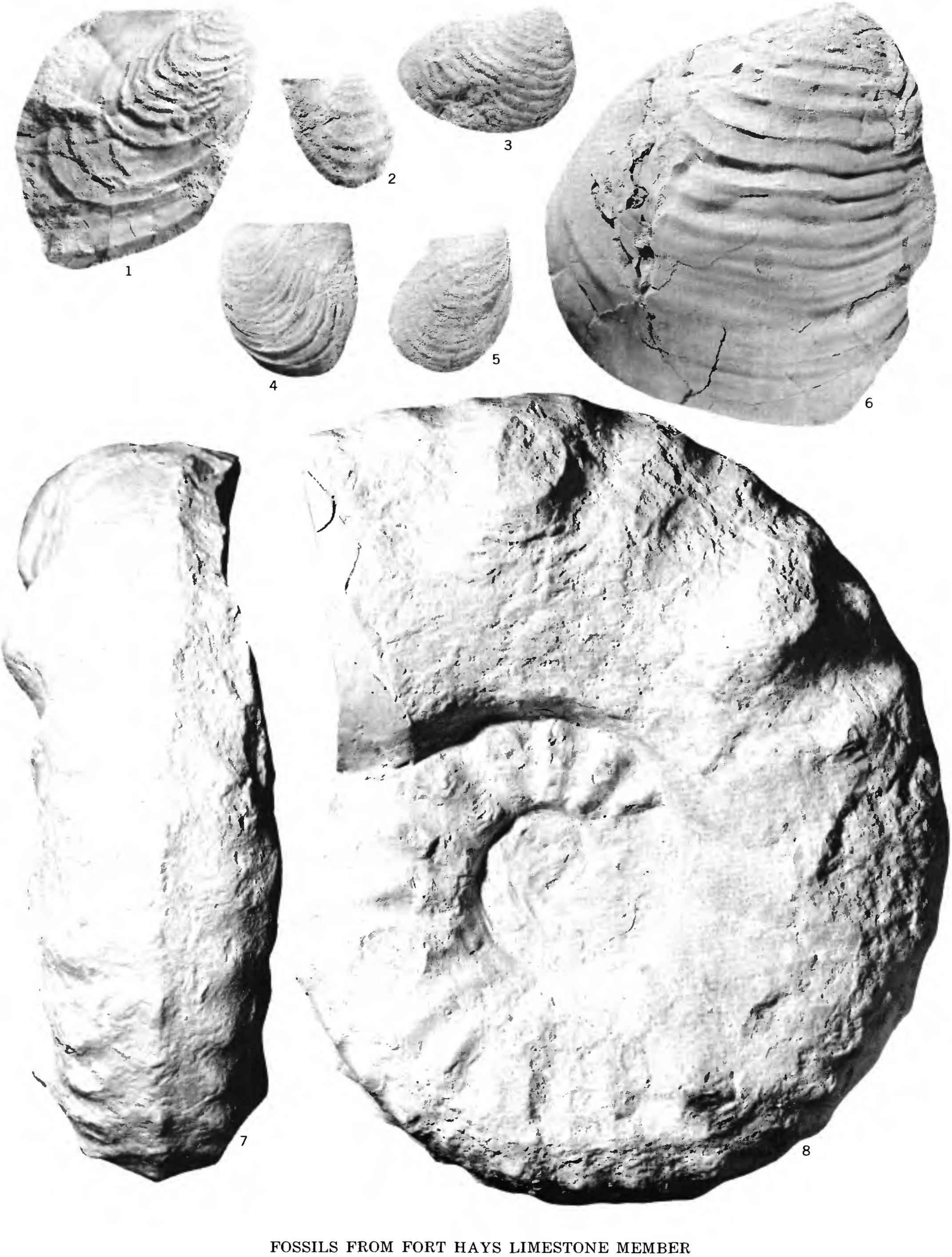
5. View of a specimen from the basal 1 foot of the Fort Hays Limestone Member at USGS Mesozoic loc. D2980 in the SW¼NE¼ sec. 32, T. 20 S., R. 65 W. USNM 131493.

6. *Inoceramus erectus* Meek (p. L7).

View of an average-sized specimen from 20 feet above the base of the Fort Hays Limestone Member at USGS Mesozoic loc. D2984 in the SW¼NE¼ sec. 32, T. 20 S., R. 65 W. USNM 131494.

7, 8. *Barroisiceras* (*Forresteria*) *hobsoni* Reeside (p. L7).

Front and side views of the holotype from the Fort Hays Limestone Member near Carlile Spring, Pueblo County, Colo. USNM 73762. After Reeside.



FOSSILS FROM FORT HAYS LIMESTONE MEMBER

PLATE 3

[All figures natural size]

FIGURES 1, 2. *Neocrioceras* n. sp. (p. L11).

Side views of rubber casts of two impressions from the upper part of the lower limestone unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3482 in the NE¼SE¼NW¼ sec. 16, T. 20 S., R. 65 W. USNM 131495, 131496.

3. *Phlycticrioceras oregonense* Reeside (p. L11).

Side view of a rubber cast of an impression of an adult whorl from the lower part of the lower limestone unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3479 in the SE¼NW¼ sec. 33, T. 20 S., R. 65 W. USNM 131498.

4. *Inoceramus involutus* Sowerby (p. L10).

Right valve of a specimen from the middle of the lower shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3473 in the SE¼NW¼ sec. 16, T. 20 S., R. 65 W. USNM 131499.

5. *Baculites asper* Morton (p. L10).

Side view of a crushed specimen from the middle of the lower shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3474 in the NE¼NE¼ sec. 32, T. 20 S., R. 65 W. USNM 131500.

FOSSILS FROM THE LOWER SHALE AND LOWER LIMESTONE UNITS OF SMOKY HILL SHALE MEMBER

PLATE 4

[All figures natural size]

FIGURES 1–3. *Inoceramus stantoni* Sokolow (p. L11).

1, 2. Views of two specimens from the upper part of the lower limestone unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3481 in the SE¼NW¼ sec. 16, T. 20 S., R. 65 W. USNM 131502, 131503.

3. Both valves of a specimen from near the top of the lower limestone unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3488 in the NE cor. sec. 8, T. 20 S., R. 65 W. USNM 131501.

4. *Protexanites shoshonensis* (Meek) (p. L15).

Side view of part of a whorl from the lower part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. 1289 in the NW¼SE¼ sec. 9, T. 20 S., R. 65 W. USNM 131497.

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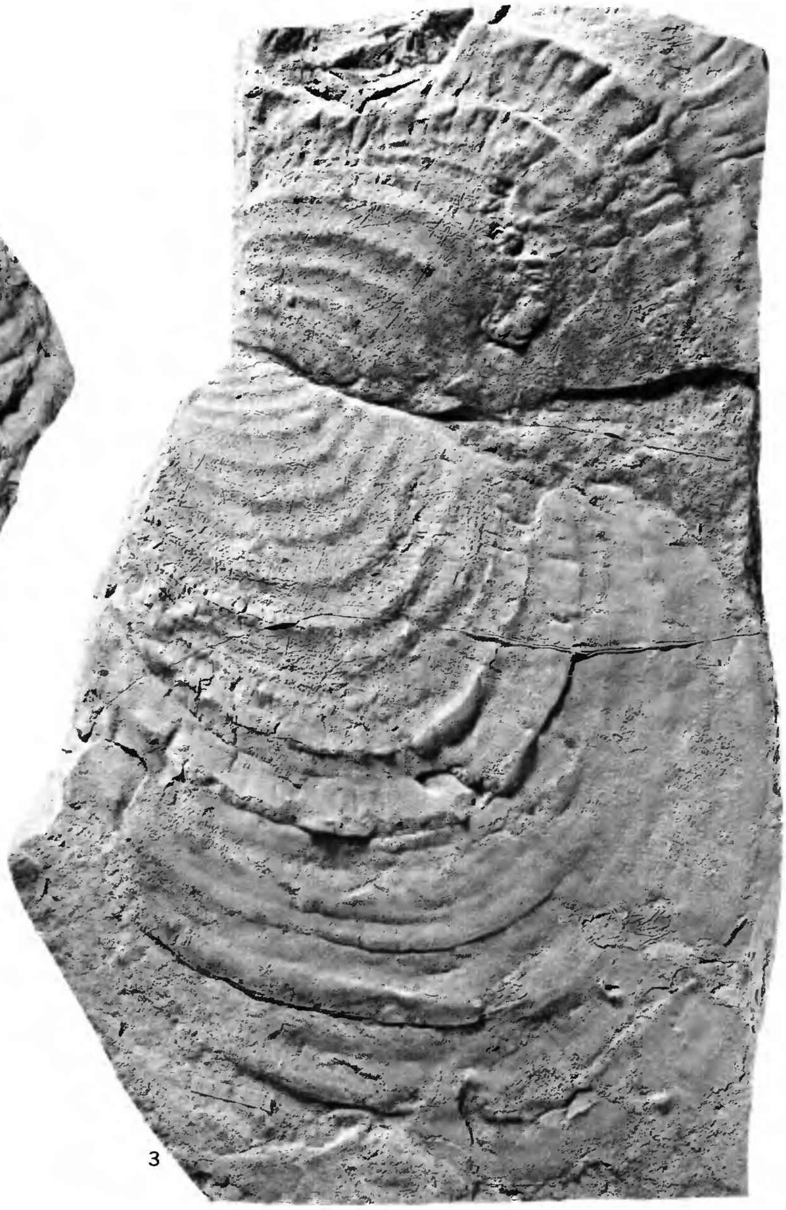

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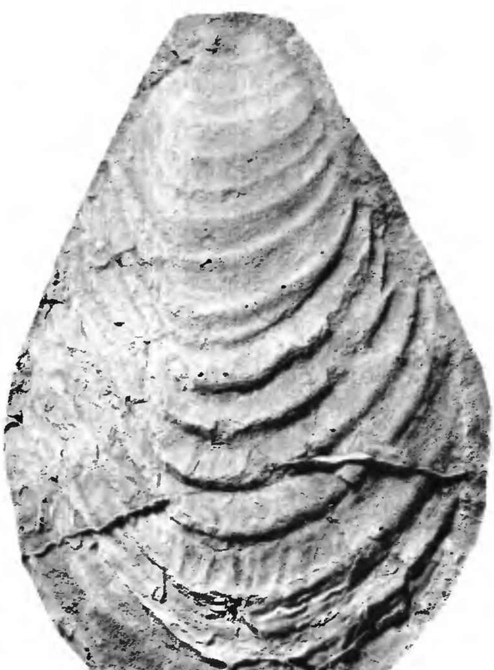

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FOSSILS FROM LOWER LIMESTONE AND MIDDLE SHALE UNITS OF SMOKY HILL SHALE MEMBER

PLATE 5

[All figures natural size]

FIGURES 1, 5. *Inoceramus undulatoplicatus* Roemer (p. L15).
Views of a juvenile and a young adult from the lower part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3490 in the NW¼SE¼ sec. 9, T. 20 S., R. 65 W. USNM 131504, 131505.

2. *Scaphites depressus* Reeside var. *stantoni* Reeside (p. L15).
View of rubber cast of part of a body chamber from the lower part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3489 in the NW¼SE¼ sec. 9, T. 20 S., R. 65 W. USNM 131508.

3. *Baculites asper* Morton (p. L15).
Side view of an incomplete specimen from the lower part of the middle shale unit of the Smoky Hill Shale Member at the same locality as figure 1. USNM 131509.

4. *Baculites codyensis* Reeside (p. L15).
View of a rubber cast of an impression from the lower part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3493 in the SE¼NW¼ sec. 16, T. 20 S., R. 65 W. USNM 131510.

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FOSSILS FROM LOWER PART OF MIDDLE SHALE UNIT OF SMOKY HILL SHALE MEMBER

PLATE 6

[All figures natural size]

FIGURES 1, 4. *Inoceramus undulatoplicatus* Roemer (p. L15).

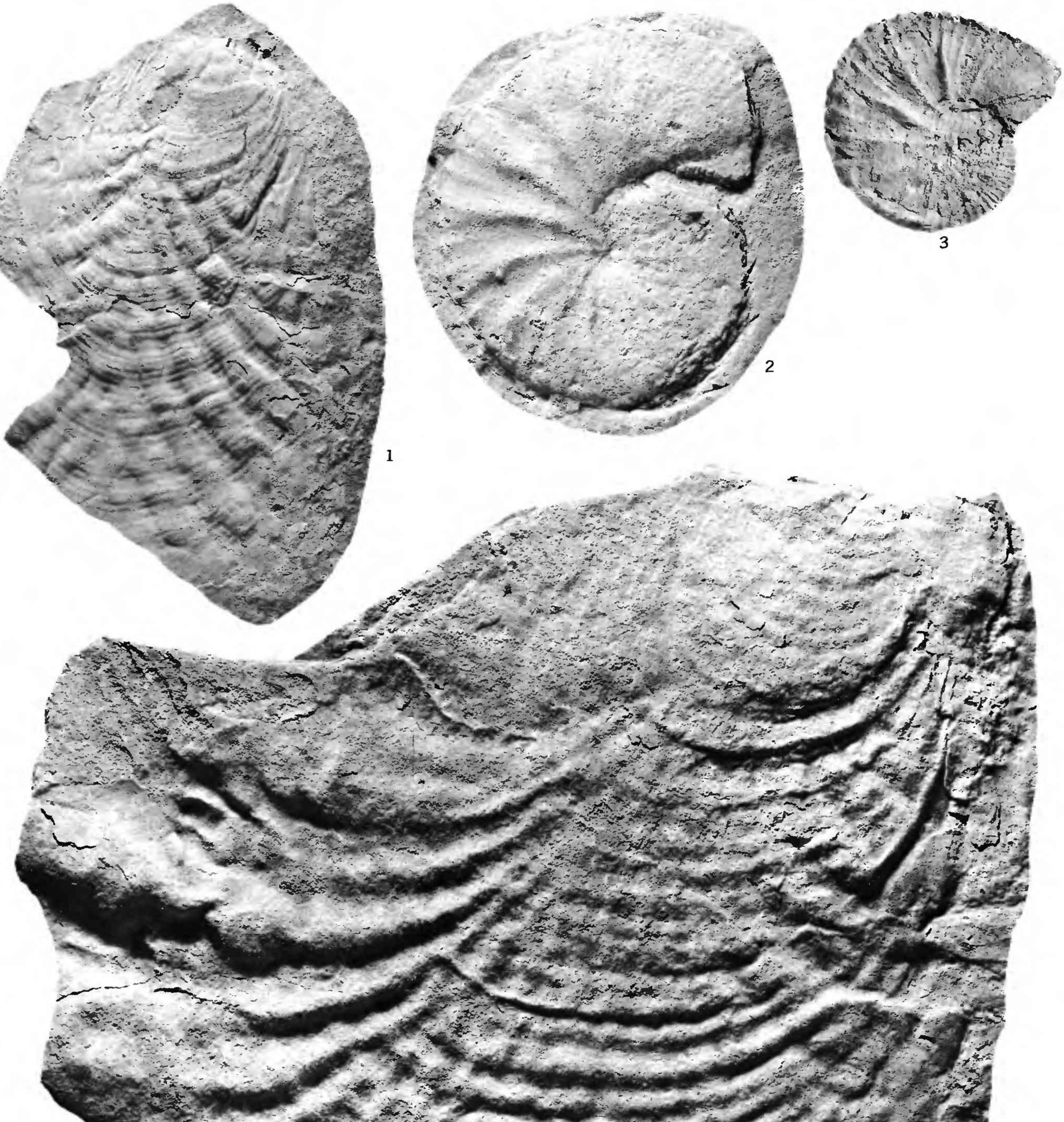
Views of two specimens from the lower part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3490 in the NW¼ SE¼ sec. 9, T. 20 S. R. 65 W. USNM 131506, 131507.

2. *Clioscaphites saxitonianus* (McLearn) (p. L15).

Side view of a crushed specimen from the lower part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3491 in the SW¼NW¼ sec. 21, T. 20 S., R. 65 W. USNM 131511.

3. *Clioscaphites saxitonianus* var. *keytei* Cobban (p. L15).

Side view of a crushed specimen from the same bed and locality as figure 2. USNM 131512.



FOSSILS FROM LOWER PART OF MIDDLE SHALE UNIT OF SMOKY HILL SHALE MEMBER

PLATE 7

[All figures natural size]

FIGURES 1, 2. *Inoceramus cordiformis* Sowerby (p. L15).
Views of a right and a left valve from limestone concretions in the upper part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3497 in the NW¼ sec. 25, T. 18 S., R. 66 W. USNM 131513, 131514.

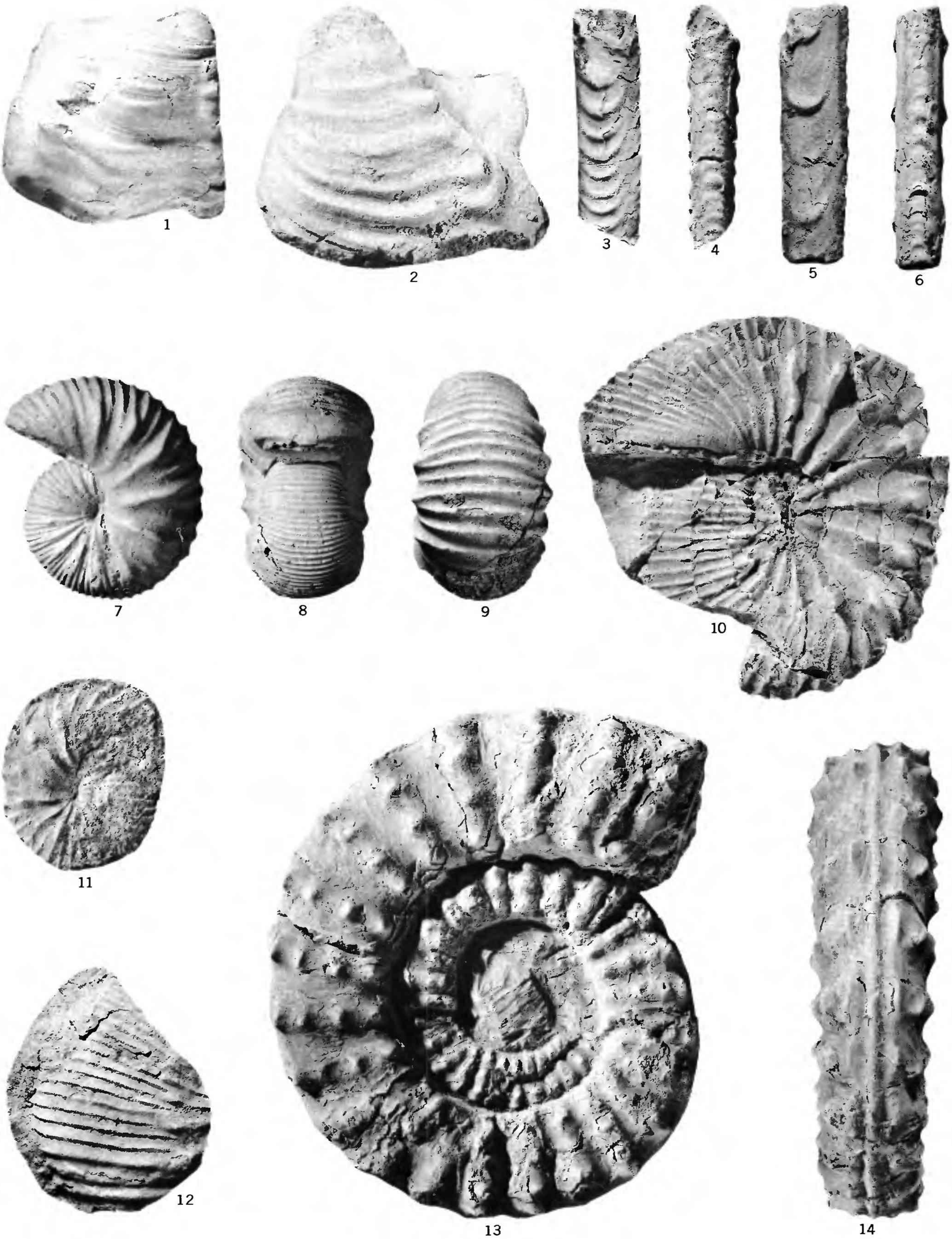
3, 4. *Baculites codyensis* Reeside (p. L15).
Side and ventral views of a specimen from a limestone concretion in the upper part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. 14305 in sec. 1, T. 32 S., R. 62 W., Las Animas County, Colo. USNM 131515.

5, 6. *Baculites asper* Morton (p. L15).
Side and ventral views of a specimen from the same concretions and locality as figure 3. USNM 131516.

7–9. *Clioscaphites saxitonianus* (McLearn) var. *keytei* Cobban (p. L15).
Side, front, and top views of the holotype from the same concretions and locality as figure 3. USNM 106727.

10–12. *Clioscaphites vermiformis* (Meek and Hayden) (p. L15).
10. Side view of a crushed specimen from a limestone bed in the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D1714 north of Boulder in the SW¼NE¼ sec. 7, T. 2 N., R. 70 W., Boulder County, Colo. USNM 131517.
11, 12. Side and rear views of two crushed specimens from the upper part of the middle shale unit at USGS Mesozoic loc. D3500 in the NE¼SW¼ sec. 10, T. 20 S., R. 65 W. USNM 131518, 131519.

13, 14. *Texanites americanus* (Lasswitz) (p. L15).
Side and rear views of a specimen from the same concretions and locality as figure 3. USNM 131520.



FOSSILS FROM UPPER PART OF MIDDLE SHALE UNIT OF SMOKY HILL SHALE MEMBER

PLATE 8

Stantonoceras pseudocostatum Johnson (p. L15).

Side view (× ½) of the septate whorls 406 mm in diameter from a limestone concretion in the upper part of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. 14305 in sec. 1, T. 32 S., R. 62 W., Las Animas County, Colo. USNM 131521.

STANTONOCERAS PSEUDOCOSTATUM JOHNSON FROM UPPER PART OF MIDDLE SHALE UNIT OF SMOKY HILL SHALE MEMBER

PLATE 9

Inoceramus platinus Logan (p. L18).

View of a right valve (× 0.29) 30.5 in. in height from the middle part of the middle chalk unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3504 in the NE¼NW¼ sec. 15, T. 20 S., R. 65 W. USNM 131522.

INOCERAMUS PLATINUS LOGAN FROM MIDDLE CHALK UNIT OF SMOKY HILL SHALE MEMBER

PLATE 10

[All figures natural size]

FIGURE 1. *Inoceramus simpsoni* Meek var. (p. L20).

View of a broad variant that resembles the European *I. balticus* Boehm. From the lower part of the upper chalky shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3505 in the NW¼SE¼ sec. 10, T. 20 S., R. 65 W. USNM 131523.

2. *Inoceramus* cf. *I. patootensis* de Loriol (p. L20).

Small fragment from the same locality as figure 1. USNM 131525.

3, 5. *Inoceramus* sp. (p. L15).

From near the top of the middle shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3501 in the NE¼SW¼ sec. 10, T. 20 S., R. 65 W.

3. Rubber cast of parts of two valves having affinities with *I. cordiformis* Sowerby. USNM 131526.

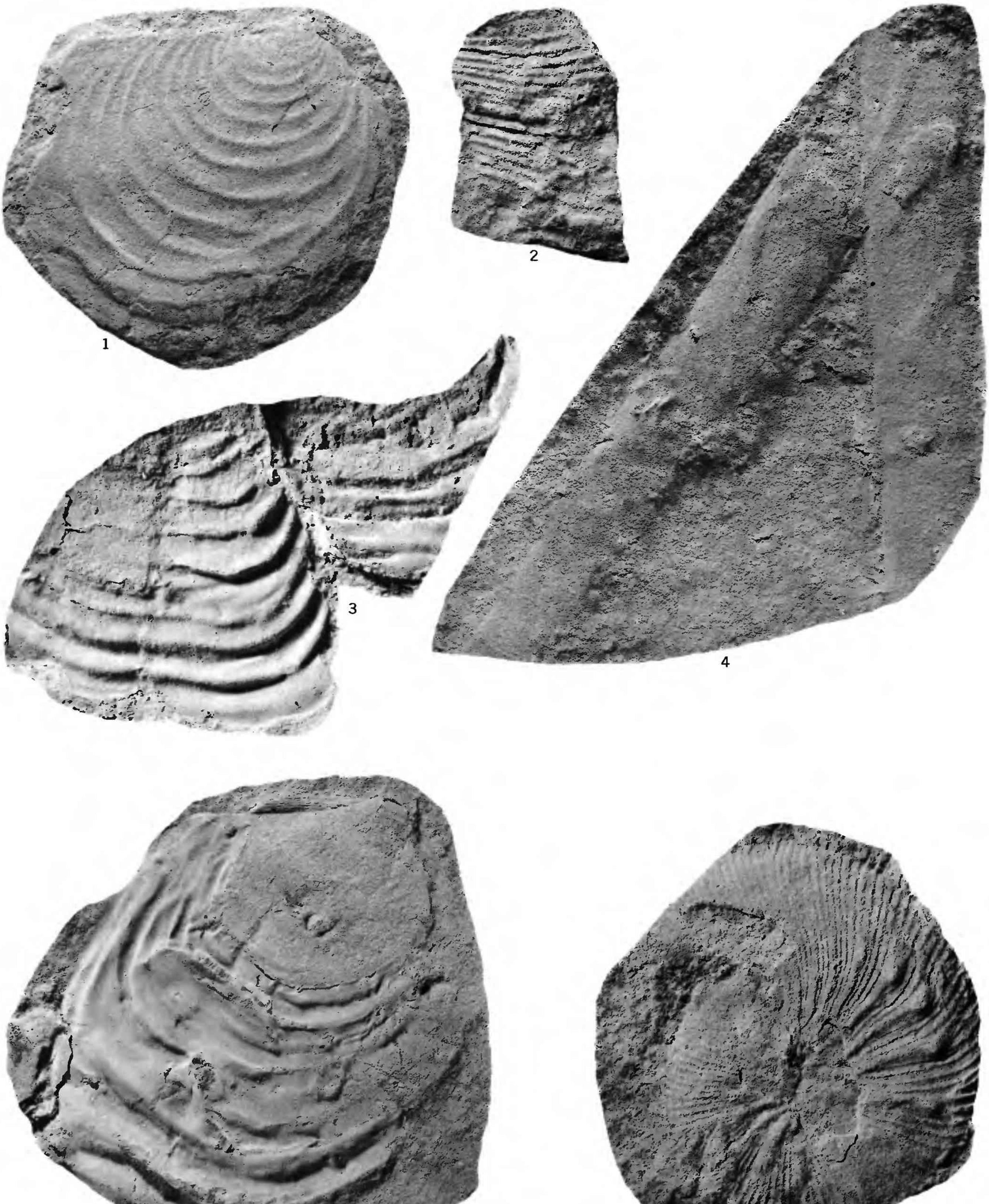
5. View of a crushed specimen having a quadrate form. USNM 131527.

4. *Baculites* sp. (p. L20).

View of a rubber cast of two? specimens typical of the smooth form found in the lower part of the upper chalky shale unit of the Smoky Hill Shale Member at the same locality as figure 1. USNM 131528.

6. *Clioscaphites choteauensis* Cobban (p. L18).

Side view of a crushed adult from near the base of the middle chalk unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3503 in the NW¼NW¼ sec. 15, T. 20 S., R. 65 W. USNM 131529.



FOSSILS FROM MIDDLE SHALE, MIDDLE CHALK, AND UPPER CHALKY-SHALE UNITS OF SMOKY HILL SHALE MEMBER

PLATE 11

[All figures natural size]

FIGURE 1. *Inoceramus platinus* Logan (p. L20).

View of a specimen that has coarse and fine concentric folds. From the upper part of the upper chalky shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3509 in the SE¼NW¼ sec. 15, T. 20 S., R. 65 W. USNM 131533.

2. *Stramentum haworthi* Williston (p. L23).

View of a rubber cast of two specimens attached to the side of a smooth baculite. From the upper chalk unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3513 in the NE¼NW¼ sec. 23, T. 23 S., R. 59 W., Otero County, Colo. USNM 131530.

3, 4. *Haresiceras placentiforme* Reeside (p. L20).

Views of two crushed specimens from the upper chalky shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3266 in the SW¼-NW¼ sec. 23, T. 23 S., R. 59 W., Otero County, Colo. USNM 131531, 131532.

5. *Inoceramus simpsoni* Meek (p. L20).

View of a rubber cast of part of a specimen from the lower part of the upper chalky shale unit of the Smoky Hill Shale Member at USGS Mesozoic loc. D3505 in the NW¼SE¼ sec. 10, T. 20 S., R. 65 W. USNM 131524.

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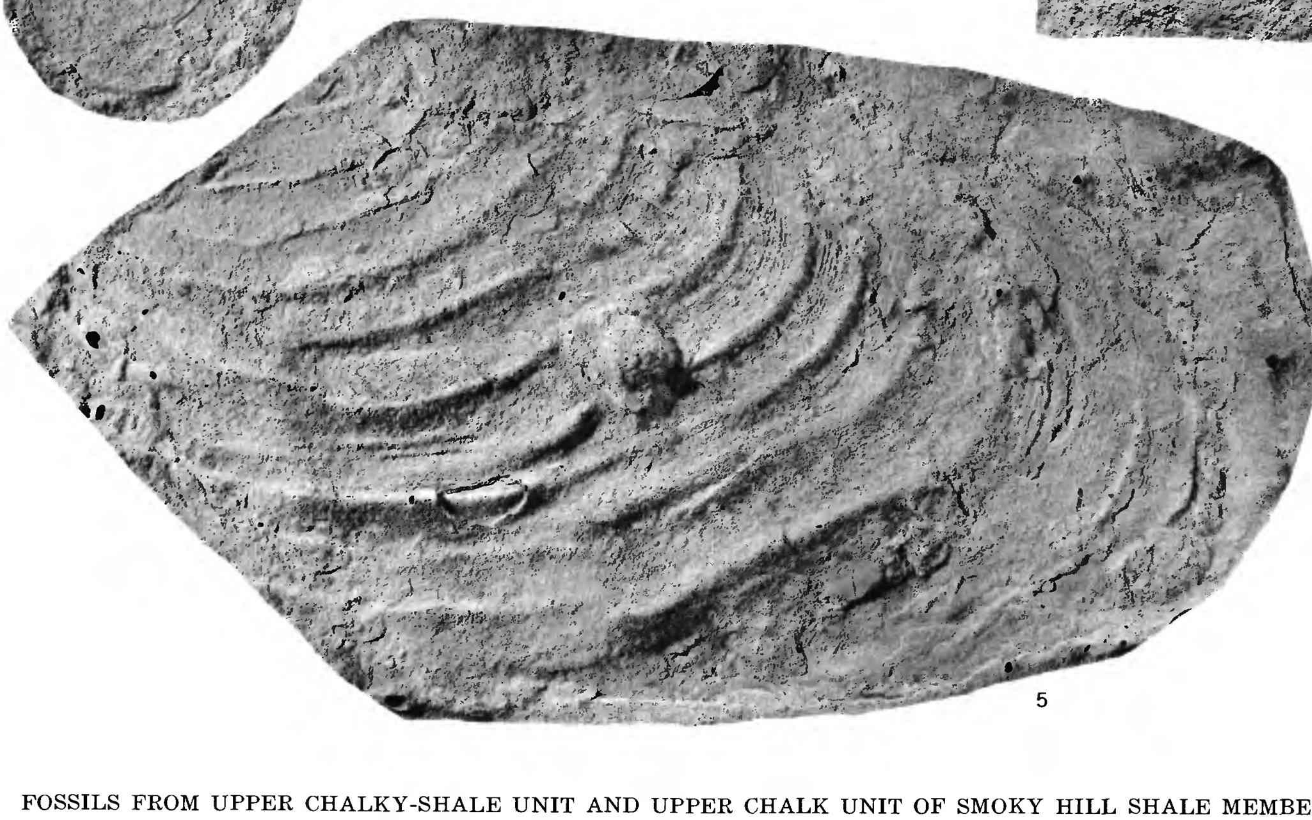

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FOSSILS FROM UPPER CHALKY-SHALE UNIT AND UPPER CHALK UNIT OF SMOKY HILL SHALE MEMBER