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BIOSTRATIGRAPHY OF THE PIERRE SHALE IN NORTH PARK, COLORADO, AND CORRELATION WITH SECTIONS IN BOULDER, MIDDLE PARK, AND NORTHWEST COLORADO

By

Dawn Hill Madden

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This report has not been edited for conformity
with U.S. Geological Survey editorial standards
or stratigraphic nomenclature.

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[Plate in pocket]

CONVERSION TABLE

To convert from	to	Multiply by
Feet	meters	0.3048
Miles	kilometers	1.609

BIOSTRATIGRAPHY OF THE PIERRE SHALE IN NORTH PARK, COLORADO, AND CORRELATION WITH SECTIONS IN BOULDER, MIDDLE PARK, AND NORTHWEST COLORADO

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ABSTRACT

The Pierre Shale consists of interbedded marine shale and sandstone representing nearly continuous marine sedimentation during Late Cretaceous time. The Pierre Shale and time-equivalent marine units in the western interior United States contain 28 ammonite range zones. The ammonites show such rapid evolution and such wide geographic extent that their range zones are useful for time-stratigraphic correlation of marine rocks.

The Pierre Shale is exposed around the margins of the North Park basin in Colorado where its maximum thickness is about 5,500 feet. The formation overlies the Upper Cretaceous Niobrara Formation and is unconformably overlain by the Paleocene and Eocene Coalmont Formation. The Pierre Shale, which consists of an upper sandy member and a lower shaly member, is primarily marine in origin; however, the sandy member includes minor amounts of coal. Twelve ammonite range zones can be recognized in North Park, including ammonites as old as the early Campanian *Baculites obtusus* and as young as the early Maestrichtian *Baculites eliasi*. Zonal distribution indicates that the contact between members becomes older to the northwest.

Comparison of the biostratigraphy of the Pierre Shale in North Park with that of the Pierre Shale near Boulder, Colorado, and in Middle Park, and of time-equivalent units in northwestern Colorado, indicates the following: (1) the Pierre Shale in North Park correlates to the upper Mancos Shale, Iles

Formation, and the lower Williams Fork Formation in northwestern Colorado; (2) two of the three strandlines, represented by nonmarine deposits in the sandy member, correlate to regionally recognized regressions of the Pierre sea; (3) parts of the North and Middle Park structural basin were eroded 1,900-2,300 feet deeper than the Boulder area during the Laramide orogeny; and (4) northwestern North Park was eroded 2,000 feet deeper than northeastern North Park and the area of the stratigraphic section in Middle Park.

INTRODUCTION

This is a preliminary paper reporting on fossils I collected from the Pierre Shale in North Park (fig. 1) during the summer of 1975 (assisted by M. A. Moorman and A. M. Kramer). The localities of collections are compiled on a map at a scale of 1:62,500 (plate 1), together with all other available collections, to show the distribution of ammonite range zones in the North Park basin. Ammonites were identified by W. A. Cobban, U.S. Geological Survey, Denver, Colo.

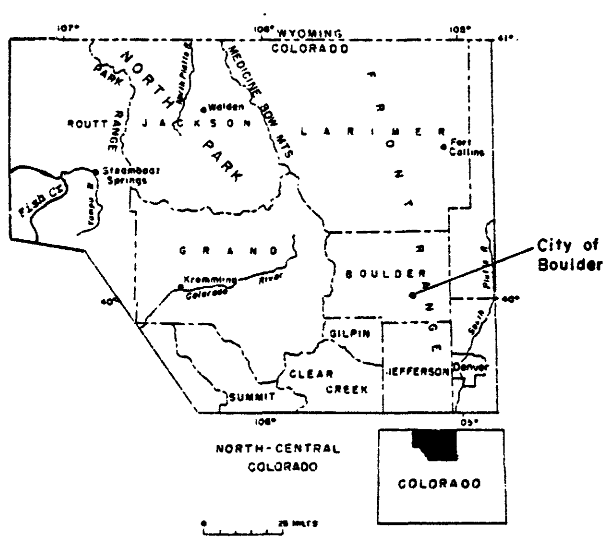

Figure 1.--Location of North Park in north-central Colorado.

PIERRE SHALE IN THE WESTERN INTERIOR OF NORTH AMERICA

The Pierre Shale consists primarily of interbedded marine shale and sandstone, representing nearly continuous marine sedimentation during Late Cretaceous time within the region of the Great Plains and Rocky Mountain States. Thicknesses of the Pierre Shale range from slightly less than 5,000 feet to at least 8,000 feet. The Pierre Shale and time-equivalent rocks contain as many as 28 ammonite range zones, mostly lineage zones based on single lineages of endemic or migrant forms (Gill and Cobban, 1973). The ammonites have limited vertical stratigraphic ranges of a few hundred feet, limited time ranges which average 500,000 years (Gill and Cobban, 1966), but which vary greatly in duration between species (Obradovich and Cobban, 1975), and wide geographic extents (Izett, Cobban, and Gill, 1971). The ammonites are thus beneficial to time-stratigraphic correlation of marine rocks in the Western Interior United States.

The marine section in the western interior region provides the basis for the Cretaceous time scale of Obradovich and Cobban (1975) (fig. 2). This marine section was considered a favorable basis for a time scale because it includes the combination of nearly continuous marine sedimentation, the rapidly evolving ammonite fauna, and nearby volcanic activity producing datable ash beds intercalated with marine sediments. The K-Ar age data from Obradovich and Cobban (1975) have been recalculated for figure 2, using the more recently redetermined isotopic abundances and decay constants of K^{40} (Steiger and Jager, 1977).

The Pierre Shale was deposited in a Late Cretaceous seaway which extended across North America from the Gulf Coast northward to the Arctic Ocean. Although connections are not preserved between the marine rocks in the western interior and those deposited north and south, the outline of the seaway is indicated by the similarity between molluscan faunas of the interior, Gulf Coast, and West Greenland (Tourtelot and Rye, 1969).

Series	Stage	K-Ar ages (m.y.)		Western Interior zone fossils	
Paleocene		65.8	66.3		
			65.5±1.0		
				Triceratops	
			67.1±1.0	*Discoscaphites cheyennensis, Discoscaphites nebrascense*	?
	Maestrichtian			*Discoscaphites roanensis, Hoploscaphites nicolleti*	
		69.0		*Hoploscaphites aff. H. nicolleti, Sphenodiscus (Coahuilites)*	
				Baculites clinolabatus	Gulf Coast migrant and descendant baculites
		70.1	70.2	*Baculites grandis*	
	Maestr/Camp Jeletzky		70.1	*Baculites baculus*	
				Baculites eliasi	Single lineage of endemic baculites
				Baculites jenseni	
	*Maestr/Camp Cobban		70.3	*Baculites reesidei*	
			71.6	*Baculites cuneatus*	
		73.2	73.2	*Baculites compressus*	Gulf Coast migrants
				Didymoceras cheyennense	
		73.7		*Exiteloceras jenneyi*	
	Maestr/Camp Pessagno			*Didymoceras stevensoni*	
Upper Cretaceous		73.9		*Didymoceras nebrascence*	
	Maestr/Camp Olsson			*Baculites scotti*	← *Baculites reduncus*
				Baculites gregoryensis	
				Baculites perplexus (late form)	
				Baculites gilberti	
				Baculites perplexus (early form)	
				Baculites sp. (smooth)	
	Campanian			*Baculites asperiformis*	
				Baculites mclearni	
		79.7 / 79.3		*Baculites obtusus*	
		80.0		*Baculites* sp. (weak flank ribs)	Kp/Kn Boulder, Colo.
				Baculites sp. (smooth)	Kp/Kn Kremmling, Colo.
				Scaphites hippocrepis III	Kp/Kn Red Bird, Wyo.
				Scaphites hippocrepis II	
				Scaphites hippocrepis I	
	Santonian	84.4		*Desmoscaphites bassleri*	

Figure 2.--Late Cretaceous time scale (modified from Obradovich and Cobban, 1975). Underlined K-Ar age figures represent the weighted mean of two or more age determinations. Kp, Pierre Shale; Kn, Niobrara Formation.

*The Campanian-Maestrichtian boundary of Cobban is used in this report.

The Pierre seaway was shallow, 600 feet or less in depth, and it had normal to low salinity, compared to the oceans. The shallowness and low salinity are indicated by paleontologic and geologic evidence found in sections of the Pierre Shale. Pelecypods the size of *Inoceramus* of the Pierre Shale are found today in shallow waters (Gill and Cobban, 1966). Descendants of other extinct fossil species from the Pierre Shale (some within the same genera as the fossils) occur today in shallow coastal waters of normal salinity (W. A. Cobban, oral commun., 1978). Evidence from the Red Bird section of Wyoming (a classic reference locality of the Pierre Shale) indicates a shallow-water environment existed even near the geographic center of the sea where it probably was deepest (Rubey, 1930; Gill and Cobban, 1966). For instance, at Red Bird, Late Cretaceous bryozoans lived on the interior walls of partially mud-filled ammonite living chambers which lay on the sea floor, suggesting that the water was not very deep. Unglauconized fecal pellets also indicate shallow depth. Motion of bottom water at Red Bird is indicated by the broken condition of some fossils and by the indistinct, impure nature of bentonite layers in parts of the section (Gill and Cobban, 1966). Much of the bentonite was deposited in waters less than 200 feet deep (Gill and Cobban, 1966) and the black shales were deposited in waters less than 600 feet deep (Tourtelot and Rye, 1969). Comparison between oxygen isotope composition of baculites from the interior seaway and from the continental margins, including the Atlantic, Pacific, Gulf Coast, and Greenland, indicates dilution of the Pierre sea with large amounts of meteoric water (Tourtelot and Rye, 1969), which, when mixed by currents with the seawater, probably resulted in a lowering of the salinity. However, the salinity was within ranges tolerable by mollusks, because the Pierre faunas are marine in aspect and not qualitatively different from Late Cretaceous faunas of the Gulf and Atlantic Coastal Plains (W. A. Cobban, *in* Tourtelot and Rye, 1969).

The Pierre seaway lay between the rising cordillera to the west and a low-lying stable platform to the east. The narrow, unstable cordilleran highland, separating the interior seaway from Pacific waters, supplied clastic sediment to the sea including nonmarine and shallow-water marine sediments (Iles and Williams Fork Formations of northwestern Colorado) along the western margin. During marine transgressions, these marginal sediments were covered with marine tongues (Mancos and Lewis Shales) of the Pierre Shale. The eastern margin of the sea lay along the stable platform of the eastern United States and Canada, probably along the longitude of eastern Minnesota and Iowa (Gill and Cobban, 1966), and contributed little sediment to the sea, as indicated by the increasing abundance of shallow-water carbonate rocks to the east (Gill and Cobban, 1966; Izett, Gill, and Cobban, 1971).

PIERRE SHALE IN NORTH PARK

Lithology and thickness

The Pierre Shale is exposed along the margins of the North Park topographic basin in northern Colorado (pl. 1 and fig. 1). The Pierre Shale is the youngest Cretaceous formation in North Park, where it conformably overlies the Upper Cretaceous Niobrara Formation and unconformably underlies the Paleocene and Eocene Coalmont Formation.

The Pierre Shale in North Park consists of marine shale, sandstone, and siltstone, and minor, thin sequences of coal, carbonaceous shale, and conglomerate. The formation has been divided into two members: a lower shaly member of dark marine shale, becoming more silty and sandy toward the top, and an upper sandy member of interbedded marine sandstone, siltstone, and shale, and minor nonmarine beds (Kinney and Hail, 1959). The contact between the members is placed in the transitional sequence of interfingering shale, siltstone, and sandstone and is not at the same stratigraphic horizon in all sections (Hail, 1965).

The Pierre Shale has a maximum thickness of 5,500 feet (Kinney and Hail, 1959). The entire formation was removed in some areas (secs. 7 and 18, T. 8 N., R. 81 W., secs. 15 and 22, T. 7 N., R. 82 W., secs. 18-20, T. 6 N., R. 79 W.) before deposition of the Coalmont Formation. Uneroded sections of the shaly member are 1,500-3,000 feet thick. The shaly member is thickest in northwestern North Park and thins eastward and southward. The sandy member is now as much as 3,000 feet thick, but was originally considerably thicker everywhere.

Biostratigraphy

Fossil collections and range zones.--Fossil collections from the Pierre Shale include ammonites, pelecypods, gastropods, and bryozoans. Only ammonites have been used to delineate biozones. The fauna is preserved best in concretions of fine-grained limestone, calcareous and noncalcareous siltstone, and claystone, both in the sandy member and in the upper part of the shaly member. The fossils are well preserved because the concretions formed around them before dissolution of the fossils by seawater and before significant compaction of the sediment could crush or greatly distort the fossils. Surrounding shales generally appear to be barren or contain a poorly preserved fauna.

The ammonite range zones occurring in the Pierre Shale in North Park include, from oldest to youngest, *Baculites obtusus*, *B. asperiformis*, *B.* sp. (smooth), *B. perplexus* (including the early and late forms and *B. gilberti*), *B. gregoryensis*, *B. reduncus*, *B. scotti*, *Didymoceras stevensoni*, *Exiteloceras jenneyi*, *B. compressus* (including *B. cunneatus*), *B. reesidei*, and *B. eliasi*.

The map (pl. 1) shows collections containing index ammonites. The collections, or zonules, are connected by labeled lines. which show approximate and relative locations of range zones and the relations between the geologic and biostratigraphic units.

Zonules and connecting lines do not occur at any particular position within range zones but at various intervals within zones, wherever fossils were found. The labeled lines connecting zonules are therefore not precise time lines.

Two stratigraphic sections through the Pierre Shale in North Park are shown on plate 1. In addition to the ammonite zones shown in these sections, I made collections of *B. reduncus*, *D. stevensoni*, *B. compressus*, *B. reesidei*, and *B. eliasi* elsewhere in the area and are shown on the map (pl. 1), which should be used when comparing the sections in North Park with sections from other areas.

The thicknesses of individual ammonite range zones in North Park do not exceed several feet. Thicknesses of four zones are estimated from the northeastern North Park section (pl. 1) as follows: *B. obtusus*, at least 325 feet; *B. perplexus* (including *B. gilberti*) between 230 feet and 650 feet; *B. gregoryensis*, at least 150 feet.

B. asperiformis was not found in the section in northeastern North Park, where its stratigraphic range is either very thin or absent.

Delineation of geologic structures.--Geologic structures, previously unmapped because of poor exposure of bedrock, can be delineated using the distribution of biozones and aerial-photo mapping. This method is most successful where fossil collections are most numerous as in northeastern North Park. The anomalous distribution of baculites in the northwestern part of T. 8 N., R. 77 W., confirmed the presence of faults previously mapped from aerial photographs.

Age of the contact between members.--The contact between the sandy and shaly members of the Pierre Shale occurs within or below the zone of *B. perplexus* and probably entirely above the zone of *B. asperiformis* in northeastern and southwestern North Park. However, in northwestern North Park, the contact is within the zone of *B. asperiformis* east of Sheep Mountain (pl. 1), and within or below that zone west of Sheep Mountain. The contact between the two members is thus time-transgressive within the North Park basin, becoming older to the northwest.

Nonmarine deposits.--Coal, carbonaceous shale, and conglomerate beds occur within the sandy member of the Pierre Shale on the western and eastern sides of North Park basin. In northwestern North Park, a coaly sequence occurs within or below the zone of *B. asperiformis*, where a subbituminous coal bed 4.5 feet thick was mined (T. 10 N., R. 81 W., SE¼ sec. 31) early in this century (Beekly, 1915; Hail, 1965). Clay-pebble conglomerate occurs locally in the same area (T. 9 N., R. 81 W., NW¼SE¼ sec. 8), within or near the zone of *B. asperiformis*. A Cretaceous shark tooth, apparently not reworked, was found in the clay-pebble conglomerate and indicates deposition in a shallow-water marine location (Hail, 1965, and oral commun., 1978; W. A. Cobban, oral commun., 1978). On the other side of the basin, in northeastern North Park, an outcrop of conglomeratic sandstone lies 5 to 10 feet stratigraphically above siltstone concretions containing *B. asperiformis* (T. 9 N., R. 78 W., NE¼ sec. 34, nearly on the northern section line). This collection locality is near the core of South McCallum anticline. Carbonaceous shale occurs within or just above the zone of *B. perplexus* south of southwestern North Park (T. 4 N., R. 81 W., sec. 35; Hail, 1968), near the faulted anticline. A thin coal bed less than 4 feet thick occurs somewhere within the zones from *D. stevensoni* to *B. compressus*(?) in northeastern North Park (T. 9 N., R. 78 W., SE¼SW¼ sec. 7), near the core of North McCallum anticline.

Regressions of the Pierre sea.--Three regressions of the Pierre sea are represented by the nonmarine and marginal marine lithologies in the North Park sequence. The first regression occurred during the time span represented by the range zone of *B. asperiformis*, at least 78.8 million years (m.y.) ago. During this early regression, the strandline traversed northwest North Park in the area of Sheep Mountain and came close to the area of the South McCallum anticline in northeastern North Park. The strandline did not traverse farther eastward to the eastern flank of the Johnny Moore syncline where _B. asperiformis_ occurs only within the shaly member of the Pierre Shale. The second regression occurred during, or shortly after, the time span represented by the range zone of _B. perplexus_, and before the time of _D. stevensoni_, between 77.7 m.y. and 73.8 m.y. ago. During this time, a shoreline emerged south of southwestern North Park (T. 4 N., R. 81 W.). The third regression occurred sometime during the time span represented by the ranges of _D. stevensoni_ to _B. compressus_(?), approximately 73.8 m.y. to 73.2 m.y. ago. Again, a shoreline appeared in the area of the McCallum anticline in northeastern North Park, but fossil collections are not yet numerous enough to determine the age more closely.

Regional or local regressions(?).--Nonmarine lithologies in the Pierre Shale in North Park occur near the following uplifts: the North and South McCallum anticlines, the Lone Pine anticline (northwestern North Park), and the faulted anticline. Local Cretaceous structural highs could have affected lithologies within the Pierre in North Park by causing emergence of local areas and the deposition of nonmarine and near-shore marine sediments. Such structural features would be more likely to occur in western parts of the shallow Pierre sea, such as North Park, close to the rising, unstable cordilleran highland. If local Cretaceous structural activity did interrupt deposition of the sandy member of the Pierre Shale in North Park, then the stratigraphic thicknesses of the affected biozones should be consistently less in sections closer to the anticlines than in sections farther away from them. This possibility could be tested by measuring sections and comparing zonal thicknesses near and away from these anticlines (if adequate rock exposures and fossil control can be found).

Rate of rock accumulation.--The average rate of rock accumulation for the Pierre Shale in North Park was 404 feet per million years. The rate was calculated by dividing the thickness of the section from northeastern North Park, between collections of E. jenneyi and B. obtusus, by the difference in age between these species. The rate of sedimentation was greater than the rate of rock accumulation because the original mud was at least 2 to 2½ times thicker than the compacted rock (Gill and Cobban, 1966).

CORRELATION OF THE PIERRE SHALE WITH SECTIONS IN BOULDER, MIDDLE PARK, AND NORTHWEST COLORADO

The ammonite range zones within the Pierre Shale serve as approximate time lines, providing the basis for correlation of the Pierre Shale outside of North Park basin. Well-sampled sections of Pierre Shale occur 80 miles to the southeast, near Boulder, Colo. and 40 miles to the south, in Middle Park. A section of time-equivalent units, with a few fossil collections, occurs 40 miles to the southwest along Fish Creek in northwestern Colorado.

Correlation of the sandy and shaly members of the Pierre Shale outside North Park basin requires separate correlation of the two North Park sections because of the time-transgressive nature of the contact between the members. Correlations are illustrated in figure 3, where the top of the northeastern North Park section is extended to the zone of B. eliasi (see map, pl. 1).

Relative rates of rock accumulation.--The relative rates of rock accumulation, were calculated from sections measured in northwestern Colorado (Bass, Eby, and Campbell, 1955; Izett, Cobban, and Gill, 1971), Middle Park (Izett, Cobban and Gill, 1971), northeastern North Park (Kinney and Hail, 1959), and and the area northeast of Boulder (Scott and Cobban, 1965). The rate decreased from east to west. The rate of rock accumulation near Boulder, between and including the zones of B. obtusus and B. clinolobatus, is 680 feet per million years. North Park accumulated 404 feet per million years; Middle

Stage	WESTERN INTERIOR AMMONITE ZONES	FORMATIONS IN NW COLORADO (Bass, Eby, & Campbell, 1955; Izett, Cobban, & Gill, 1977)	PIERRE SHALE IN MIDDLE PARK (Izett, Cobban, & Gill, 1971)	PIERRE SHALE IN NW NORTH PARK (this paper)	PIERRE SHALE IN NE NORTH PARK (this paper)	PIERRE SHALE NE OF BOULDER, COLO. (Scott and Cobban, 1965)
	Sphenodiscus *Coahuilites*	Lance Formation				Upper Transition Member
	Baculites clinolobatus	?				
MAESTRICHTIAN	*Baculites grandis*	Lewis Shale				
	Baculites baculus	?				
	Baculites eliasi		Upper part			
	Baculites jenseni		Gunsight Pass Member			
	Baculites reesidei					Larimer and Rocky Ridge Sandstone Members
~	*Baculites cuneatus* *Baculites compressus*	Williams Fork Formation	Middle part			
	Didymoceras cheyennense	?			Sandy Member	
	Exiteloceras jenneyi					Terry Sandstone
	Didymoceras stevensoni		Carter Sandstone Member			
	Didymoceras nebrascense	Iles Formation	Middle part			
	Baculites scotti		Hygiene Sandstone Member			Hygiene Sandstone Member
	Baculites gregoryensis	?	Middle part			
	Baculites perplexus *Baculites gilberti*		Muddy Buttes and Kremmling Sandstone Members	Sandy Member		
	Baculites asperiformis		Middle part			
	Baculites mclearni		Lower part			
CAMPANIAN	*Baculites obtusus*	Mancos Shale	Sharon Springs Member	Shaly Member	Shaly Member	
	Baculites sp. (weak flank ribs)		Lower part			Lower Transition Member

Figure 3.--Stratigraphic nomenclature of NW Colorado, Middle Park, North Park, and Boulder, Colorado.

Park (between and including the zones of B. sp. (weak flank ribs) and B. eliasi) accumulated 430 feet per million years; and northwestern Colorado, at Fish Creek (between and including the zones of B. mclearni to B. reesidei) accumulated 350 feet per million years.

The westward decrease in rate of rock accumulation does not correspond with the pattern of Late Cretaceous sedimentation rates in Wyoming and Montana where the rates increase westward (shoreward) (Gill and Cobban, 1973), nor does it correspond with modern sedimentation patterns in which the shoreline rates are 30 to 50 times higher than deep oceanic rates of sedimentation (Gill and and Cobban, 1973).

The rate of rock accumulation was determined from several factors: the original rate of sedimentation (which increases near modern shorelines, Gill and Cobban, 1973), the presence of hiatuses and diastems (hiatuses would be more common in nonmarine sections), lithology (more sandstone occurs in nonmarine sections), percent of compaction (compaction affects sandstone thickness less than shale thickness), faulting within the measured sections, and the lack of complete fossil collections throughout the total local range of the species used to determine the rate. The factors considered here to be more important in determining the relative rates in the four areas are the possible presence of hiatuses in the Fish Creek section, more diastems in the North and Middle Park sections than in the Boulder section, and the possibility that unrecognized faults occur in some sections. More sections must be measured to establish relative rates. However, if the relative rates of rock accumulation actually reflect relative rates of sedimentation, then sediment moved more directly to the Boulder area than to the Fish Creek and North and Middle Park areas.

Relative amounts of Laramide erosion.--Biostratigraphic evidence indicates that parts of the North-Middle Park structural basin, including northeastern

North Park (pl. 1) and the area of the Middle Park section, were eroded to the same level during the Laramide orogeny. The thicker section at Boulder retained much of the younger sequence of the Pierre and provides a standard for comparing amounts of erosion. If younger parts of the Pierre (time-equivalent to the Boulder section) were originally present in the North-Middle Park area, then erosion was 1,900-2,300 feet deeper in northeastern North Park than it was in the Boulder area. Regional correlation indicates 3,000 to 4,000 feet of Pierre Shale were removed from Middle Park (Izett, Cobban, and Gill, 1971). Northwestern North Park, near Sheep Mountain, was more deeply eroded by approximately 2,000 feet than the areas of the other two North-Middle Park sections, suggesting greater vertical relief in that part of the basin during the Laramide orogeny.

CORRELATION OF REGIONAL REGRESSIONS

The Pierre Shale in North Park, near Boulder, and in Middle Park and parts of the Mancos Shale and the Mesaverde Group of northwestern Colorado, all include some of the same ammonite range zones, indicating they are, in part, time-equivalent units.

The upper, sandy member of the Pierre Shale in North Park lies geographically between the entirely marine sections of Pierre Shale in eastern Colorado, and to the south in Middle Park, and the largely nonmarine to shallow-water marine sequence of the Mesaverde Group to the west, in northwestern Colorado. The minor nonmarine and very shallow-water marine lithologies in the sandy member are technically easternmost and southernmost tongues of the Mesaverde Group. Geologic mapping of poorly exposed tongues of a separate nonmarine unit in North Park, however, may be impractical unless further work shows, for instance, that most sandstones in the whole upper member are lithologically equivalent to Mesaverde units.

The thin sequences (wedge-edge tongues) of nonmarine rocks penetrating the largely marine North Park sequence mark the positions of ancient strandlines (Zapp and Cobban, 1960). Positions of strandlines that far east of the Late Cretaceous cordilleran highland indicate regressive movements of the Pierre sea. The regressive movements, if regional in scale, should correlate to regressions documented along the western margins of the Pierre sea by previous studies in Colorado and Wyoming (Zapp and Cobban, 1960; Weimer, 1960; Izett, Cobban, and Gill, 1971).

The regression in North Park represented by the strandline of *B. asperiformis* is time equivalent to part of the Mancos Shale to the west, and this strandline is an anomaly in the regional picture. Biostratigraphic evidence indicates that the strandline of *B. perplexus* (or younger) may correlate in time to the RC regression represented by the Iles Formation to the west (Zapp and Cobban, 1960), and more generally, to the R3 regression represented by the Mesaverde Group to the west (Weimer, 1960). Biostratigraphic evidence indicates the third regression in the North Park area may correlate in time to the RD regression represented by the Williams Fork Formation to the west (Zapp and Cobban, 1960) and the late part of the R3 regression of Weimer (1960).

REFERENCES CITED

Bass, N. W., Eby, J. B., and Campbell, M. R., 1955, Geology and mineral fuels of parts of Routt and Moffat Counties, Colorado: U.S. Geological Survey Bulletin 1027-D, p. 143-250.

Beekly, A. L., 1915, Geology and coal resources of North Park, Colorado: U.S. Geological Survey Bulletin 596, 121 p.

Gill, J. R., and Cobban, W. A., 1966, The Red Bird section of the Upper Cretaceous Pierre Shale in Wyoming, *with a section on* A new echinoid from the Cretaceous Pierre Shale of eastern Wyoming, by P. M. Kier: U.S. Geological Survey Professional Paper 383-A, 73 p.

Gill, J. R., and Cobban, W. A., 1973, Stratigraphy and geologic history of the Montana Group and equivalent rocks, Montana, Wyoming, and North and South Dakota: U.S. Geological Survey Professional Paper 776, 37 p.

Hail, W. J., Jr., 1965, Geology of northwestern North Park, Colorado: U.S. Geological Survey Bulletin 1188, 133 p

______1968, Geology of southwestern North Park and vicinity, Colorado: U.S. Geological Survey Bulletin 1257, 119 p.

Izett, G. A., Cobban, W. A., and Gill, J. R., 1971, The Pierre Shale near Kremmling, Colorado, and its correlation to the east and the west: U.S. Geological Survey Professional Paper 684-A, 19 p.

Kinney, D. M., 1970, Preliminary geologic map of the Gould quadrangle, North Park, Jackson County, Colorado: U.S. Geological Survey open-file report, 2 sheets, scale 1:48,000.

______1971, Preliminary geologic map of Kings Canyon quadrangle, North Park, Jackson County, Colorado: U.S. Geological Survey open-file report, 1 sheet, scale 1:48,000.

Kinney, D. M., and Hail, W. J., Jr., 1959, Upper Cretaceous rocks in North Park, Jackson County, Colorado, in Rocky Mountain Association of Geologists Guidebook, Symposium on Cretaceous rocks of Colorado and adjacent areas: p. 105-109.

______1970, Preliminary geologic map of the Hyannis Peak quadrangle, North and Middle Parks, Jackson and Grand Counties, Colorado: U.S. Geological Survey open-file report, 2 sheets, scale 1:48,000.

Kinney, D. M., Hail, W. J., Jr., Steven, T. A., and others, 1970, Preliminary geologic map of the Cowdrey quadrangle, North Park, Jackson County, Colorado: U.S. Geological Survey open-file report, 2 sheets, scale 1:48,000.

Obradovich, J. D., and Cobban, W. A., 1975, A time-scale for the Late Cretaceous of the western interior of North America: Geological Association of Canada, Special Paper No. 13, p. 31-54.

Rubey, W. W., 1930, Lithologic studies of the fine-grained Upper Cretaceous sedimentary rocks of the Black Hills region: U.S. Geological Survey Professional Paper 165-A, p. A1-A54, pls. 1-5.

Scott, G. R., and Cobban, W. A., 1965, Geologic and biostratigraphic map of the Pierre Shale between Jarre Creek and Loveland, Colorado: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-439, scale 1:48,000.

Steiger, R. H., and Jager, E., 1977, Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359-362.

Tourtelot, H. A., and Rye, R. O., 1969, Distribution of oxygen and carbon isotopes in fossils of Late Cretaceous age, western interior region of North America: Geological Society of America Bulletin, v. 80, no. 10, p. 1903-1922.

Weimer, R. J., 1960, Upper Cretaceous stratigraphy, Rocky Mountain area: American Association of Petroleum Geologists Bulletin, v. 44, no. 1, p. 1-20.

Zapp, A. D., and Cobban, W. A., 1960, Some Late Cretaceous strandlines in northwestern Colorado and northeastern Utah, _in_ Short Papers in the Geological Sciences: U.S. Geological Survey Professional Paper 400-B, p. B246-B249.