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Lexicon of bedrock stratigraphic names of North Dakota

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LEXICON OF BEDROCK STRATIGRAPHIC NAMES OF NORTH DAKOTA

by
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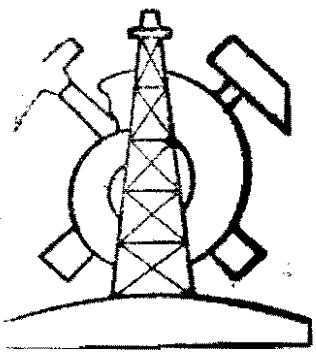

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This thesis submitted by Joanna Van Ornum Groenewold in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

This lexicon of bedrock stratigraphic names of North Dakota consists of a general definition of each unit as well as the history of stratigraphic nomenclature. An attempt was made to include all units for North Dakota whether formally or informally named, or currently being used in the state. The general definition includes name(s) of the unit, age, area of extent, lithology, relationships to other units, characteristic fossils, economic significance, depositional environment, type section (if one has been proposed), and other remarks that might be significant. The history of stratigraphic nomenclature includes a chronological listing of the first definition of the unit and any changes that occurred subsequent to the introduction of the unit. The lexicon includes approximately 350 terms. Of these, 1% is in the Cambrian System, 6% are in the Ordovician, 1% is in the Silurian, 10% are in the Devonian, 12% are in the Mississippian, 3% are in the Pennsylvanian, 3% are in the Permian, 1% is in the Triassic, 7% are in the Jurassic, 24% are in the Cretaceous, and 32% are in the Tertiary System.

INTRODUCTION

Purpose

In the past two decades, the geology of North Dakota has been receiving much attention. The economic potential of the Williston basin has motivated this attention, as well as the academic interest by North Dakota's universities, the North Dakota Geological Survey, and the United States Geological Survey. Therefore, a need has developed for a lexicon of the bedrock stratigraphic units of the state. This lexicon provides an organized list of well-known units and their definition and evolution, as well as less well-known terms and local terms in an attempt to make this lexicon of use to as many people as possible. The academic geologist, economic geologist, and any person interested in stratigraphy should find this lexicon of use.

Quaternary units are not included in this lexicon because, only recently, have stratigraphic studies been extended to include this part of the column. Consequently, these units are in a state of confusion because their relationships are not clearly understood.

Methods

An incomplete preliminary list of stratigraphic units was determined by examining publications, primarily of the North Dakota Geological Survey, that contained sections on stratigraphy. The Lexicon of Geologic Names of the United States (Wilmarth, 1938, and Keroher, 1966, 1970) and Changes in Stratigraphic Nomenclature of the U. S.

Geological Survey (Cohee, Bates, and Wright, 1970a, 1970b; and Cohee and Wright, 1972, 1974, 1975a, 1975b, 1976; and Sohl and Wright, 1977) were consulted for the history of stratigraphic nomenclature of each unit. A Guide to the Stratigraphy of South Dakota (Agnew and Tychsen, 1965), and Catalog of Stratigraphic Names for Montana (Balster, 1971) were reviewed for further references for the history of stratigraphic nomenclature and also for any additional stratigraphic terms for North Dakota. The Annotated Bibliography of the Geology of North Dakota, 1806-1959 (Scott, 1972), Bibliography and Index of Geology (Geological Society of America, 1971, 1972, 1973, 1974, 1975, 1976, 1977), and Bibliography of North American Geology (U. S. Geological Survey, 1918-1973) were used to determine additional entries for the history of stratigraphic nomenclature. The bibliography of each of these publications was also examined for references that may have been missed. University of North Dakota theses and dissertations were reviewed for unpublished information that may be pertinent. Personnel of the North Dakota Geological Survey also provided local drillers' terms that had not been noted in the literature.

The literature determined from the above sources was read for the general definition and history of stratigraphic nomenclature. The general definition includes, where applicable, all names of the stratigraphic unit, age, areal extent, lithology, thickness, relationships to other units, characteristic fossils, type section, and other more subjective items such as economic potential, depositional environment, and suck other remarks that may be pertinent. All parts of the definition were derived exclusively from the literature with no personal interpretations entered.

Nearly all bedrock units occur essentially throughout the Williston basin but a neighboring state or province may not use the same name for the same unit; lithologies also change from one area to another possibly resulting in a multiplicity of names for a single unit. Cross-references are included to alleviate possible confusion. The thickness of a unit refers to the maximum thickness in North Dakota. The thickness at the type section was also given if it significantly differed from the thickness in the state. Relationships of a unit to other units refers to whether the contacts of overlying and underlying units are conformable or unconformable. Lateral equivalents are also given if known. Characteristic fossils are listed for units where they are known. Only the economic significance as given in the literature was included in the general definition. If no economic significance is indicated, the unit may still be valuable as a natural resource but its value has not been discussed in publication. Depositional environment, too, is indicated only if it has been discussed in print. The type section is listed if one has been formally proposed according to the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1972). Otherwise, the informal type area has been included under the remarks section. The remarks section includes "see also" listings, and other information that might be pertinent but did not fit under other headings. The section on history of stratigraphic nomenclature follows the usual procedure of annotating the first naming or mention of a unit and any subsequent changes in that original definition, resulting in a chronological list of the usage and definition of the unit. This history is the bulk of the

research of this thesis and involved many hours of searching and reading to determine the significance of a specific publication. Decisions to include a reference or information were generally self-evident, but not always. The recording of change to a particular unit includes literature of 1978 resulting in a current history of stratigraphic nomenclature.

GEOLOGY OF NORTH DAKOTA

Pre-Quaternary Geologic History of North Dakota

The Williston basin is an intracratonic basin that includes 51,600 square miles in North Dakota, or approximately the western two-thirds of the state, as well as areas adjacent to North Dakota (Figure 1). Up to 15,000 feet of sedimentary strata, representing every geologic period, occur in this basin.

Carlson and Anderson (1966, p. 1833) summarized the history of the Williston basin as follows:

> The Upper Cambrian to Lower Ordovician Epochs are represented by the Deadwood Formation, which is a stable shelf deposit extending eastward from the Cordilleran geosyncline. The Williston structural basin began to be filled in Middle Ordovician time with a relatively thin clastic sequence (Winnipeg Group) followed by predominantly carbonate deposition (Red River, Stony Mountain, and Stonewall Formations). Carbonate deposition continued through Early and Middle Silurian time (Interlake Formation) followed by a period of erosion marked by a major unconformity.
>
> During the Middle and Upper Devonian Epochs the Williston basin was a part of the larger western Canada basin of deposition which was characterized by predominantly carbonate deposition with a thick evaporite in the lower part (Duperow, Nisku, Three Forks). Deposition was continuous or nearly continuous into the Mississippian, but the center of the Madison depositional basin was nearly coincident with the present Williston basin. Mississippian deposits began with predominantly carbonate deposition, evaporites increasing in the upper part. The evaporites are mostly halite in the central basin area and anhydrite toward the flanks of the basin. Predominantly clastic deposition (Big Snowy Group) followed the evaporites; another unconformity is at the top of the Big Snowy.
>
> The Pennsylvanian and Permian Periods are represented by clastics with minor carbonates (Minnekahta Formation) and some evaporites. This was a time of slight subsidence,

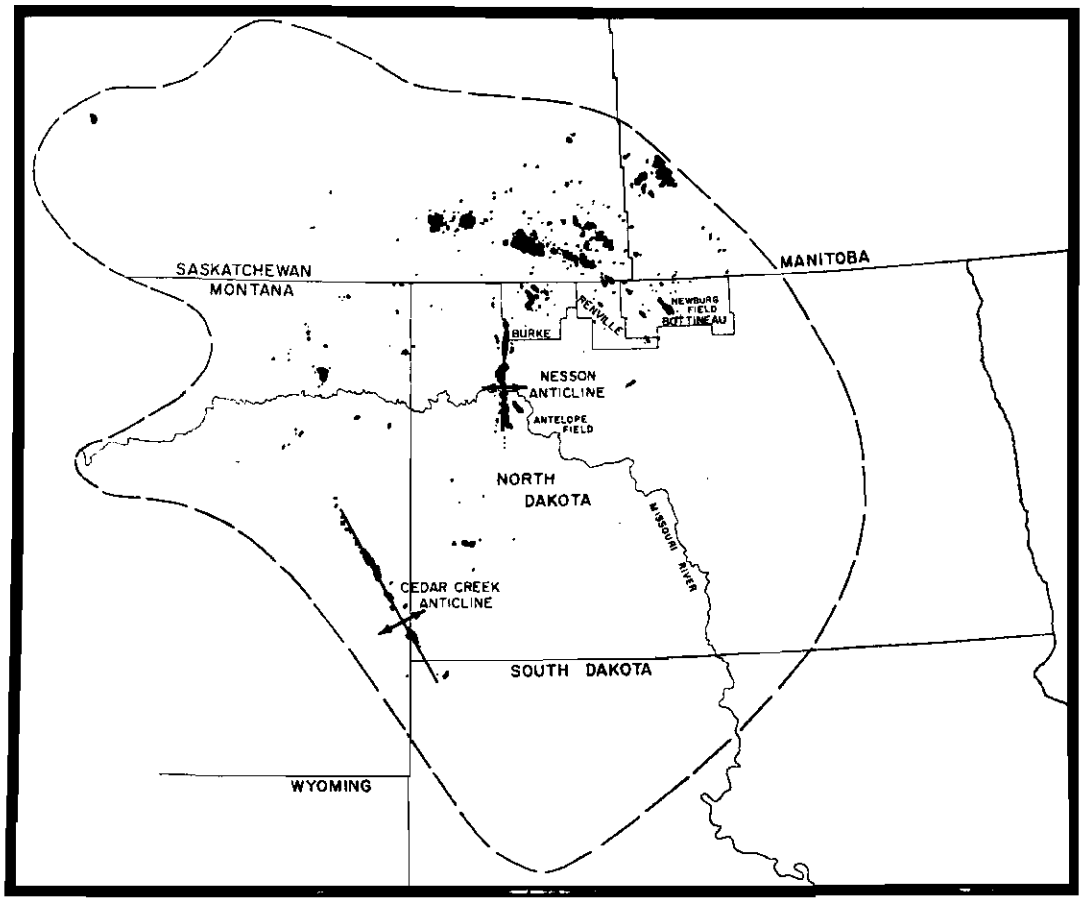

Fig. 1. Williston basin showing two of its major structural features and major oil fields (from Carlson and Anderson, 1966, p. 1834).

with the Williston basin area a part of a larger depositional area extending south and west. Similar conditions continued through the Triassic with deposition of fine-grained clastics and some evaporites, which are overlain by some nonmarine red beds and another unconformity.

Peterson (1972), McGookey et al. (1972), and Robinson (1972) describe Jurassic, Cretaceous, and Tertiary sedimentation for the Rocky Mountains as well as the interior of the United States. Jurassic strata are predominantly fine-grained clastics and wind-blown volcanics derived from the Rocky Mountains and the units are the result of four marine transgressive-regressive cycles. North Dakota has stratigraphic evidence of the second, third, and fourth marine cycles (Piper-Nesson, Rierdon, and Swift Formations) and continental beds of latest Jurassic time (Morrison).

In Cretaceous time, sedimentation in North Dakota was still predominantly of fine-grained clastics from the Rocky Mountain region, and the area was partly or completely covered by epicontinental seas of the Western Interior Seaway. Early Cretaceous time included the Skull Creek marine invasion (Lakota, Fuson, Fall River, Skull Creek, Newcastle, Dynneson, Mowry, and Dakota Formations). Four major transgressive and regressive cycles began in the Early Cretaceous and continued through much of the Tertiary time. These cycles are Greenhorn (includes Belle Fourche, Greenhorn, and part of Carlile Formations), Niobrara (Carlile, Niobrara, and Eagle Formations), Claggett (Pierre Formation) and Bearpaw (top of Pierre and Fox Hills Formations). Tertiary deposits include Ludlow, Cannonball, Slope, Bullion Creek, Sentinel Butte, Golden Valley, and White River Formations and were deposited on a stable alluvial plain. During the Cretaceous and Tertiary time, volcanic activity of the Rocky Mountains is evidenced in North Dakota by bentonite beds.

Naming of Geologic Columns in North Dakota

Meek and Hayden published the first geologic column for the Nebraska Territory in 1862 (Figure 2), determined from their previous reconnaissance work of the area during the 1850s. Several of the fossils collected along the Missouri River by Meek are from the area that is now North Dakota. The emphasis of this column is on Cretaceous rocks as these crop out conspicuously in the Great Plains.

The first geologic column of North Dakota was introduced in 1906 by Leonard under the auspices of the North Dakota Geological Survey (Figure 3). The economic interest at this time was the clay of the Cretaceous-Tertiary sequence in North Dakota. A fairly simple scheme of stratigraphic nomenclature was sufficient because stratigraphic work was only beginning; subsurface work had not yet begun.

Laird and Towse (1949) produced a column of units that exhibits growth of stratigraphic knowledge to that time (Plate 1). Shortly afterward, the discovery of oil in the Williston basin resulted in an "explosion" of subsurface stratigraphic information, and the economics of the situation has allowed research to continue rapidly to the present.

The North Dakota Geological Society published a geologic column in 1954, during the early part of the oil boom (Figure 4). In 1966, Carlson and Anderson presented a refinement of that column (Figure 5).

In the early 1970s, coal became an economic factor. Consequently the upper part of the stratigraphic column began to receive renewed attention. Partly because of this research, the North Dakota

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General Section of the Cretaceous Rocks of Nebraska.

Divisions and Subdivisions.			Localities.	Estim. thickness.	
Upper Series.	Fox Hills beds. Formation No. 5.	Gray, ferruginous and yellowish sandstone and arenaceous clays, containing *Belemnitella bulbosa*, *Nautilus Dekayi*, *Ammonites placenta*, *A. lobatus*, *Scaphites Conradi*, *S. Nicolletti*, *Baculites grandis*, *Busycon Bairdi*, *Fusus Culbertsoni*, *F. Newberryi*, *Aporrhais Americana*, *Pseudobuccinum Nebrascensis*, *Mactra Warrenana*, *Cardium subquadratum*, and a great number of other molluscous fossils, together with bones of *Mosasaurus Missouriensis*, &c.	Fox Hills, near Moreau River,—near Long Lake above Fort Pierre. Along base Big Horn Mountains, and on North and South Platte Rivers.	500 feet.	Eq. Upper or White Chalk and Maestricht beds. (Senonien, D'Orbigny.)
	Fort Pierre Group. Formation No. 4.	Dark gray and bluish plastic clays, containing near the upper part, *Nautilus Dekayi*, *Ammonites placenta*, *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, *Dentalium gracile*, *Crassatella Evansi*, *Cucullaea Nebrascensis*, *Inoceramus Sagensis*, *I. Nebrascensis*, *I. Vanuxemi*, Bones of *Mosasaurus Missouriensis*, &c., &c., &c.	Sage Creek, Cheyenne River and on White River above the Mauvaises Terres.	700 feet.	
		Middle zone nearly barren of fossils.	Fort Pierre and out to Bad Lands,—down the Missouri on the high country to Great Bend.		
		Lower fossiliferous zone, containing *Ammonites complexus*, *Baculites ovatus*, *B. compressus*, *Helicoceras Mortoni*, *H. tortum*, *H. umbilicatum*, *H. cochleatum*, *Ptychoceras Mortoni*, *Fusus vinculum*, *Anisomyon borealis*, *Amauropsis paludinaeformis*, *Inoceramus sublaevis*, *I. tenuilineatus*, bones of *Mosasaurus Missouriensis*, &c.	Great Bend of the Missouri, below Fort Pierre.		
		Dark bed of very fine unctuous clay, containing much carbonaceous matter, with veins and seams of gypsum, masses sulphuret iron and numerous small scales fishes. Local; filling depressions in the bed below.	Near Bijou Hill, on the Missouri.		
Lower Series.	Niobrara Division. Formation No. 3.	Lead gray calcareous marl, weathering to a yellowish or whitish chalky appearance above. Containing large scales and other remains of fishes, and numerous species of *Ostrea congesta* attached to fragments of *Inoceramus*. Passing down into light, yellowish and whitish limestone, containing great numbers of *Inoceramus problematicus*, *I. pseudo-mytiloides*, *I. aviculoides* and *Ostrea congesta*, fish scales, &c.	Bluffs along the Missouri below the Great Bend, to the vicinity of Big Sioux River; also below there on the tops of the hills.	200 feet.	Eq. Lower or Gray Chalk (and Upper G. Sand) of British Geologists (Turonien and Cenomanien? of D'Orbigny.)
	Fort Benton Group. Formation No. 2.	Dark gray laminated clays, sometimes alternating near the upper part with seams and layers of soft gray and light-colored limestone. *Inoceramus problematicus*, *I. tenuirostratus*, *I. latus*? *I. fragilis*, *Ostrea congesta*, *Venilia Mortoni*, *Pholadomya papyracea*, *Ammonites Mullani*, *A. percarinatus*, *A. vespertinus** *Scaphites Warreni*, *S. larvaeformis*, *S. ventricosus*, *S. vermiformis*, *Nautilus elegans*? &c.	Extensively developed near Fort Benton on the Upper Missouri; also along the latter, from ten miles above James River to Big Sioux River, and along the eastern slope of the Rocky Mountains, as well as at the Black Hills.	800 feet.	
	Dakota Group. Formation No. 1.	Yellowish, reddish and occasionally white sandstone, with at places, alternations of various colored clays and beds and seams of impure lignite. Also silicified wood, and great numbers of leaves of the higher types of dicotyledonous trees; with casts of *Pharella*? *Dakotensis*, *Arkansas Siouxensis*, and *Cyprina arenarea*.	Hills back of the town of Dakota; also extensively developed in the surrounding country in Dakota County below the mouth of Big Sioux River,—thence extending southward into Northeastern Kansas and beyond.	400 feet.	

* This is *A. Texanus* of Roemer. It is on the authority of Mr. Gabb that it is here regarded as identical with *A. vespertinus* of Morton. We should never have suspected this from Dr. Morton's figure, but Mr. Gabb assures us that after a careful comparison of Dr Morton's specimen, he can see no difference.

1861.]

Fig. 2. Geologic column of Cretaceous rocks of Nebraska Territory (from Meek and Hayden, 1862, p. 419).

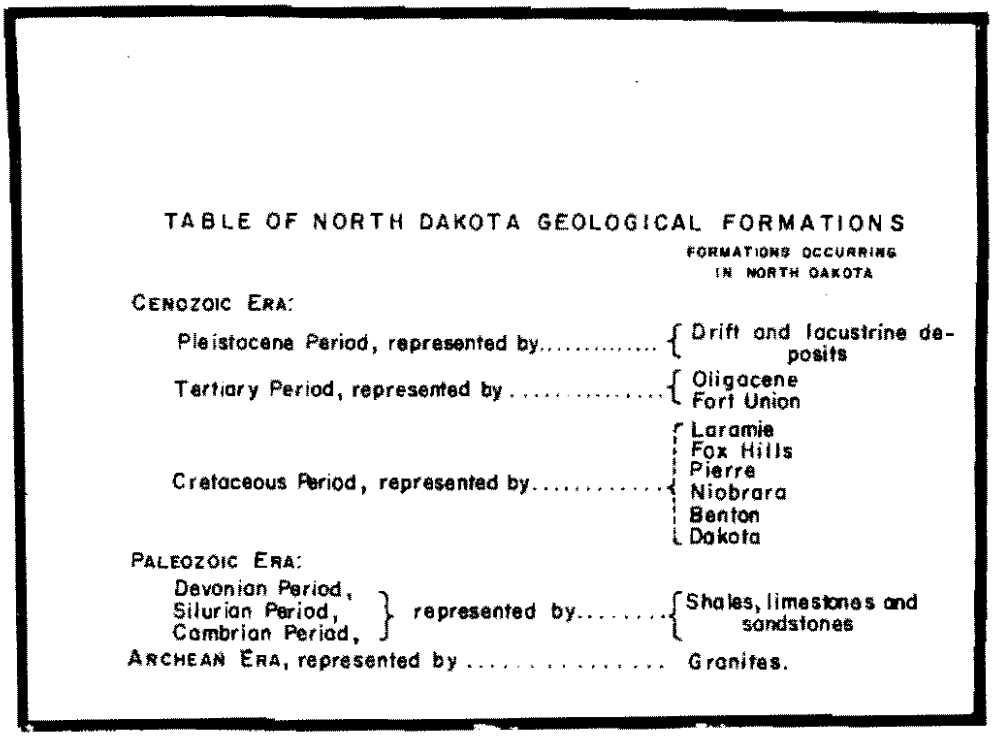

TABLE OF NORTH DAKOTA GEOLOGICAL FORMATIONS

	FORMATIONS OCCURRING IN NORTH DAKOTA
CENOZOIC ERA:	
Pleistocene Period, represented by.....	Drift and lacustrine deposits
Tertiary Period, represented by.....	Oligocene Fort Union
Cretaceous Period, represented by.....	Laramie Fox Hills Pierre Niobrara Benton Dakota
PALEOZOIC ERA:	
Devonian Period, Silurian Period, Cambrian Period, represented by.....	Shales, limestones and sandstones
ARCHEAN ERA, represented by	Granites.

Fig. 3. First geologic column of North Dakota (from Leonard, 1906, p. 66).

AGE	GROUP	FORMATION
QUATERNARY		White River
TERTIARY		Golden Valley
		Fort Union
CRETACEOUS		Hell Creek
		Fox Hills
		Pierre
		Niobrara
		Carlisle
		Greenhorn
		Belle Fourche
		Mowry
		Newcastle
		Skull Creek
		Dakota
		Fuson
		Lakota
JURASSIC		Morrison
		Swift
		Rierdon
		Piper
TRIASSIC		Spearfish
PERMIAN		Minnekahta
		Opeche
PENNSYLVANIAN		Minnelusa
MISSISSIPPIAN		"Amsden"
	Big Snowy Group	Heath
		Otter
		Kibbey
	Madison Group	Charles
		Mission Canyon
		Lodgepole
		Bakken
DEVONIAN		Three Forks
	Saskatchewan Group	"Nisku"
		"Duperow"
	Beaverhill Lake Group	Souris River
		Dawson Bay
	Elk Point Group	Prairie Evaporites
		Winnipegosis
		Ashern
SILURIAN	Interlake Group	Interlake Group
ORDOVICIAN		Stony Mountain
		Red River
		Winnipeg
		Unnamed
CAMBRIAN		Deadwood

Fig. 4. North Dakota stratigraphy in 1954 (from North Dakota Geological Society, 1954, Stratigraphy of the Williston basin, flyleaf).

SEQUENCE	SYSTEM	GROUP OR FORMATION		DOMINANT LITHOLOGY
TEJAS	TERTIARY	GLACIAL DEPOSITS		Glacial Drift
		WHITE RIVER		Clay, Sand and Limestone
		GOLDEN VALLEY		Clay, Sand and Silt
		FORT UNION GROUP	TONGUE RIVER	Shale, Sandstone and Lignite
			CANNONBALL	Marine Sandstone and Shale
			LUDLOW	Sandstone, Shale and Lignite
ZUNI	CRETACEOUS	HELL CREEK		Sandstone, Shale and Lignite
		MONTANA GROUP	FOX HILLS	Marine Sandstone
			PIERRE	Shale
		COLORADO GROUP	NIOBRARA	Shale, Calcareous
			CARLILE	Shale
			GREENHORN	Shale, Calcareous
			BELLE FOURCHE	Shale
		DAKOTA GROUP	MOWRY	Shale
			NEWCASTLE	Sandstone
			SKULL CREEK	Shale
			FALL RIVER	Sandstone and Shale
			LAKOTA	Sandstone and Shale
	JURASSIC	MORRISON		Shale, Clay
		SUNDANCE		Shale, green and brown and Sandstone
		PIPER		Limestone, Anhydrite, Salt and red Shale
ABSAROKA	TRIASSIC	SPEARFISH		Siltstone, Salt and Sandstone
	PERMIAN	MINNEKAHTA		Limestone
		OPECHE		Shale, Siltstone and Salt
	PENNSYLVANIAN	MINNELUSA		Sandstone and Dolomite
		AMSDEN		Interbedded Dolomite Limestone, Shale and Sandstone
KASKASKIA	MISSISSIPPIAN	BIG SNOWY GROUP	HEATH	Shale
			OTTER	Sandstone and
			KIBBEY	Limestone
		MADISON		Interbedded Limestone and Evaporites
				Limestone
		BAKKEN		Siltstone and Shale
	DEVONIAN	THREE FORKS		Shale, Siltstone and Dolomite
		BIRDBEAR		Limestone
		DUPEROW		Interbedded Dolomite and Limestone
		SOURIS RIVER		Interbedded Dolomite and Limestone
		DAWSON BAY		Dolomite and Limestone
		PRAIRIE		Halite
		WINNIPEGOSIS		Limestone and Dolomite
TIPPECANOE	SILURIAN	INTERLAKE		Dolomite
		STONEWALL		Dolomite and Limestone
	ORDOVICIAN	STONY MOUNTAIN FM.	GUNTON MEMBER	Limestone and Dolomite
			STOUGHTON MEMBER	Argillaceous Limestone
		RED RIVER		Limestone and Dolomite
		WINNIPEG GROUP	ROUGH LOCK	Calcareous Shale & Siltstone
			ICEBOX	Shale
			BLACK ISLAND	Sandstone
SAUK	CAMBRIAN	DEADWOOD		Limestone, Shale and Sandstone

Fig. 5. North Dakota stratigraphic column in 1966 (from Carlson and Anderson, 1966, p. 1844).

Geological Survey incorporated many changes in a recent geologic column of North Dakota (Plate 2).

A specific geologic column in the western part of the state will differ significantly from a column in eastern North Dakota. Figure 6 illustrates the basin structure that causes truncation and pinching out of units from west to east.

Stratigraphic Nomenclature

Principles of Stratigraphic Nomenclature

The Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1972) contains the recommendations for uniform usage of stratigraphic classification and terminology in North America. The Code defines four categories of stratigraphic units (Article 2): Rock-stratigraphic, soil-stratigraphic, biostratigraphic, and time-stratigraphic. It also describes time units. I have considered primarily rock-stratigraphic units with occasional references to biostratigraphic and time-stratigraphic units.

A rock-stratigraphic unit is a rock stratum defined by lithologic characteristics. A subdivision of a rock-stratigraphic unit cannot have the same name as the rock-stratigraphic unit, as that would result in confusion. Mechanical log "kicks" are used to delineate certain units in North Dakota but these "kicks" are not used to define a unit.

The formation is the basic rock-stratigraphic unit, and must be lithologically homogeneous and mappable either on the surface or traceable in the subsurface. A member is a subdivision of a formation and may contain recognizable beds. A group consists of two or

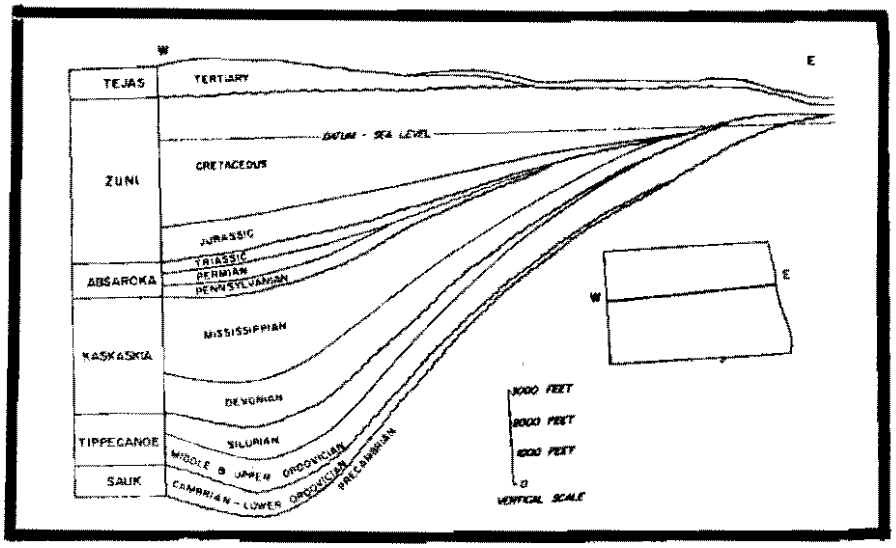

Fig. 6. West-east cross-section showing pinching out and truncation of strata in the Williston basin (from Carlson and Anderson, 1966, p. 1834).

formations that may be divisible in one area and undifferentiated in another area, as can a formation and its members.

Rock-stratigraphic units are formal if the names are proposed in publication in accordance with Article 13 of the Code. Certain names of units antedate the rules and are given formal status because of the historical use of the terms. Informal units are those that have not been formally proposed. The rule of priority generally applies when deciding upon a valid name for a rock-stratigraphic unit.

Explanation of Ranking for North Dakota Units

Each unit name in the following section was given a ranking so that one not familiar with the stratigraphy of North Dakota would be able to understand the relative importance of each name. If the name is capitalized, the stratigraphic unit has been formally proposed and is an accepted name by the North Dakota Geological Survey (e.g., MADISON GROUP). If the name is in upper and lower case and underlined, the stratigraphic unit has been formally proposed but is not used by the North Dakota Geological Survey (e.g., Charles Formation). If the name is in upper and lower case but not underlined, the stratigraphic unit has been informally introduced but is being used in the state by the North Dakota Geological Survey (e.g., Poplar interval). The lowest ranking involves upper and lower case in quotation marks and indicates that a unit has been informally introduced and is no longer used in the state (e.g., "Muddy sandstone").

Each unit entered in the lexicon, arranged alphabetically, contains two sections. The first section contains these subheadings: age, area of extent, lithology, thickness, relationships to other units, characteristic fossils, economic significance, depositional environment, type section (if applicable), and remarks. The second section is a history of stratigraphic nomenclature. There are a few units that have only a history of stratigraphic nomenclature as a complete definition was not available.

Alamo Bluff bed (of GOLDEN VALLEY FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Survey, Open-file Rep. p. 252): Lower member of Golden Valley Formation is capped by thin, impure lignite or carbonaceous shale, which locally thickens to coal bed 2-6 feet thick, named Alamo Bluff bed. Named for ruins of adobe house called Alamo on northeast corner of sec. 28, T. 143 N., R. 90 W.

See also Bear Den Member.

ALASKA BENCH FORMATION (of BIG SNOWY GROUP), Limestone Member (of AMSDEN FORMATION)

Age: Pennsylvanian.

Area of extent: Southern Montana, southwestern North Dakota. Probably represented in Wyoming by dolomite and limestone in basal Amsden.

Lithology: Excessively well indurated, gray, fossiliferous limestone that weathers red. Outcrops of hog backs and sloping benches.

Thickness: 100-150 feet in type area. Up to 68 feet in North Dakota.

Relationships to other units: Overlies Tyler Formation and underlies Ellis Group in type area.

Characteristic fossils: Brachiopods, corals, rare fusilinids, including Millerella inflecta, Paramillerella pinguis, P. circuli, P. ampla, and P. advena. Chonetes pseudoliratus, Linoproductus nodosus, Pugnoides quinqueplecis, and Composita subquadrata are restricted to and characteristic of strata of Amsden Group.

Depositional environment: Shallow seas influenced by mild oscillatory tectonism.

Remarks: Type locality on Alaska Bench, east of Big Snowy Range, Fergus County, Montana.

See also Amsden Formation, Big Snowy Group.

History of stratigraphic nomenclature:

Freeman, O. W., 1922 (Eng. Min J.-Press, v. 113, no. 19, p. 826-827): Alaska Bench limestone is well indurated, gray, fossiliferous limestone that weathers red; forms series of hogbacks and sloping benches around Big Snowy Mountains. Well exposed on top of Alaska Bench, east of Big Snowy Mountains where thickness is 100-150 feet. Underlain by 300 feet of white to red sandstones, interbedded with varicolored shale named Tyler sandstone. Overlain by 100 feet of nonfossiliferous black shale usually classified as part of Quadrent but may, in part, belong to Ellis formation. In generalized section, 100 feet of black shale above Alaska Bench limestone are all included in Quadrent Formation.

Mundt, P. A., 1956 (Am. Assoc. Pet. Geol., Bull. 40, no. 8, p. 1925-1929): Limestone is light to dark brown and gray, with dull purplish red mottlings. Where exposed, commonly weathers to pink, red, and gray; weathered Alaska Bench limestone superficially resembles unweathered carbonate rocks of Amsden formation. Underlies Amsden formation, overlies and is gradational with Tyler Formation.

Hadley, H. D., and Lewis, P. J., 1956 (Billings Geol. Sock, Gdbk., 7th Ann. Field Conf., p. 142-143): Overlies Cameron Creek and underlies Devils Pocket Formation (both new).

Gardner, L. S., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 2, p. 332, 334, 338-339, and 347): Alaska Bench limestone includes massive limestone sequence recognized by O. W. Freeman (1922) and is similar and closely related to overlying beds of limestone and dolomite that are missing from type area but are exposed on south flank of Big Snowy Mountains. Only known complete surface sections are in vicinity of Stonehouse Ranch on south slope of Big Snowy Mountains and at Durfee Creek.

Willis, R. P., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 8, p. 1942, 1963): Reallocated to member status in Amsden Formation (restricted). Underlies unnamed dolomite member; overlies Cameron Creek member of Tyler Formation.

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Alaska Bench Formation of North Dakota includes limestone interbedded with red and gray shale. Is distributed fairly uniformly throughout southwestern North Dakota; is absent from northern part of Nesson Anticline because of erosional truncation or facies change to shale so that strata is similar to underlying Tyler Formation. Thickness is 0-68 feet.

Almont sandstone (of TONGUE RIVER MEMBER of FORT UNION FORMATION)

Hennen, R. V., 1943 (Am. Assoc. Pet. Geol., Bull. 27, no. 12, p. 1573, 1580): Almont sandstone lies 35 feet above base of Tongue River Member. Section measured along south margin of T. 138 N., R. 86 and 87 W.; sandstone forms high cliffs just above drainage, 1 mile south of Almont Railway Station, Morton County, North Dakota.

"Amaranth formation"

Laird, W. M., and Towse, D. F., 1949 (N. D. Geol. Surv., Rep. Invest. 2, pl. II): Amaranth Formation is 75 feet of calcareous red shale at top of Devonian.

Term used in Manitoba for equivalent of Spearfish Formation.

Amidon member (of CHADRON FORMATION)

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. 43-45): Amidon Member is lowest occurrence of clay in Chadron Formation; lies unconformably above Interior Formation and lies uncomformably beneath Chalky Buttes Member. Consists of clay and silty claystone. Type section is south-facing exposure near head of deep, unnamed gully at NENE sec. 15, T. 134 N., R. 101 W., Slope County about 4¼ miles southwest of Amidon and about 18 miles north of Bowman, Bowman County, North Dakota.

Amsden Formation, Group

Age: Pennsylvanian (also Mississippian locally).

Area of extent: Wyoming (excluding southern part), southern and eastern Montana, Black Hills of South Dakota, and southwestern North Dakota.

Lithology: Red shale, with limestone; cherty and sandy limestone in type area.

Thickness: 150-350 feet in type area; 400 feet in Powder River Basin of Wyoming. Up to 380 feet in North Dakota.

Relationships to other units: Uncomformably overlies Madison Limestone or locally unconformable over Big Snowy Group; unconformably overlain by Broom Creek Formation.

Characteristic fossils: Chonetes pseudoliratus, Linoproductus nodosus, Pugnoides quinqueplecis, and Composita subquadrata.

Economic significance: Oil productive in central Montana.

Depositional environment: Marine. Shallow oscillatory sea, local intermittent restriction. Minor tectonic movements caused thin interbeds of differing lithologies, lenticular beds, local diastems, and increased evaporite deposition.

Remarks: Type locality along Amsden Branch of Tongue River, west of Dayton, Wyoming.

See also Medora lithozone, Dickinson lithozone, and Bismarck lithozone.

History of stratigraphic nomenclature:

Darton, N. H., 1904 (Geol. Soc. Am., Bull. 15, p. 394-401): Amsden Formation consists of red shale, white limestone, and cherty and sandy limestone. Underlies Tensleep sandstone and overlies, without apparent unconformity, Little Horn limestone. [Now replaced by Madison limestone.] Named for Amsden Branch of Tongue River, west of Dayton, Wyoming. Total thickness, 150-350 feet.

Branson, E. B., and Gregor, D. K., 1918 (Geol. Soc. Am., Bull. 29, no. 2, p. 309-326): Amsden of Wind River Mountains is Mississippian.

Scott, H. W., 1935 (J. Geol., V. 43, no. 8, pt. 2, p. 1017, 1020-1023): In type locality, Amsden consists of all beds between top of Madison Limestone and base of Tensleep formation. Originally considered Pennsylvanian; Wind River area Amsden is Mississippian. In south central Montana, Amsden rests on erosional surface developed on Madison limestone. Between Three Forks and Townsend, Big Snowy Group (1200 feet of fossiliferous sandstone, shale and limestone) separates Madison and Amsden formations. In central Montana, Amsden underlies Ellis formation (Late Jurassic). Section measured on southeast side of Quadrent Mountain (type section of Quadrent) shows Amsden formation (beds 1-7) 109 feet thick; underlies Quadrent Formation (beds 8-21); overlies Madison Limestone.

Branson, C. C., 1936 (Geol. Soc. Am., Proc. 1935, p. 391): Lower part of Amsden Formation is Mississippian; is designated Sacajawea Formation, with type section at Bull Lake Creek. Upper part of Amsden is Pennsylvanian; is not separable stratigraphically or faunally from rest of Tensleep.

Berry, G. W., 1943 (Geol. Soc. Am., Bull. 54, no. 1, p. 18-19, 21): Amsden in Three Forks area, overlies Madison formation and underlies Quadrent. Lower part, probably equivalent to Sacajawea, contains upper Mississippian fauna, beds in upper 100 feet contain Pennsylvanian fossils.

Perry, E. S., and Sloss, L. L., 1943 (Am. Assoc. Pet. Geol., Bull. 27, no. 10, p. 1293-1295): Between redefined Tensleep (Quadrent) and Sacajawea (lower beds of Ste. Genevieve fauna) are unnamed beds with Chesteran fauna traceable throughout central Montana and much of Williston Basin, overlapping truncated edges of Big Snowy strata, and transgressing over peninsula area with no Big Snowy or Sacajawea sediments along Montana-Wyoming border. Term Amsden should be retained in these strata of Montana and Williston or new term coined.

Sloss, L. L., 1946 (in Gardner, L. S., and others, Mont. Bur. Mines and Geol., Mem. 24, 100 p.): Mississippian-Pennsylvanian boundary is within carbonate sequence of Amsden in Montana. Amsden of northern Wyoming is younger than Amsden of central Montana.

Sloss, L. L., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 69): Amsden of Williston Basin probably represented by Minnelusa formation as suggested on cross section.

Scott, W. F., and Wilson, P. C., 1953 (Geol. Soc. Am., Bull. 64, no. 12, pt. 2, p. 1554 abs.): Sacajawea restricted vertically to include only red-bed sequence at base of Amsden and extended laterally wherever red beds are recognizable. Amsden retained for limestones and dolomites between Sacajawea (restricted) and Tensleep or its equivalents.

Shaw, A. B., and Bell, W. G., 1955 (Am. Assoc. Pet. Geol., Bull. 39, no. 3, p. 333-337): Fossils from lower part of Amsden formation at Cherry Creek, Wind River Mountains, place Mississippian-Pennsylvanian boundary between 48 and 63 feet above Madison limestone. Lower faunas Chesterian in age; upper faunas Atokan (?). Term of Sacajawea formation rejected for Mississippian beds at Cherry Creek. Presence of two sandstones in Amsden, both have been called "Darwin sandstone." Amsden at Cherry Creek contains beds not found in northern Wind River Mountains causing dual usage of term Amsden. Restudy of type area should show either both Mississippian and Pennsylvanian faunas (Cherry Creek like typical Amsden)or Sacajawea fauna (restricted Amsden like typical Amsden).

Mundt, P. A., 1956 (Am. Assoc. Pet. Geol., Bull. 40, no. 8, p. 1918-1919, 1928-1929): Amsden formation of central Montana divided into three lithologic units (descending): 1) upper dolomite, 2) brownish limestone, and 3) lower sequence of red shale and sandstone beds. Dolomite unit is lithologically, stratigraphically, and paleontologically equivalent to carbonate of Amsden at type locality. Amsden dolomite overlaps underlying brown limestone and red shale beds and Big Snowy Group toward south. Unconformably(?) underlying Amsden dolomite of Atokan age is brown ostracodal limestone, probably of Chesterian age but may be all or part early Pennsylvanian; named Alaska Bench formation. Total thickness 33 feet; top of section eroded.

Freeman, V. L., Ruppel, E. T., and Klepper, M. R., 1958 (U. S. Geol. Surv., Bull. 1042-N, p. 498-499, 550): In Townsend Valley, Broadwater and Jefferson Counties, Montana, Amsden Formation probably separated from Mission Canyon limestone by erosional unconformity, includes rocks of Mississippian and Pennsylvanian age. Consists of red calcareous siltstone with middle unit of gray carbonate, grades into Quadrent Formation. Thickness 259 feet in Limestone Hills.

Gardner, L. S., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 2, p. 344-346): Big Snowy Group revised to include (ascending) Kibby

sandstone, Otter, Heath, Cameron Creek, and Devils Pocket Formations. Parts of Big Snowy Group (revised) have been correlated with Amsden formation of northern Wyoming and southern Montana. These two sequences represent same general interval of time (end of Madison to beginning of Tensleep) but occupy distinct basins separated by divide. Amsden rocks thin from south and Big Snowy thins from north toward divide. Scott (1935) used term Amsden for rocks (Cameron Creek Formation and Alaska Bench Limestone) overlying Heath. Few dependable correlative data found between Big Snowy rocks of central Montana and Amsden rocks 50 miles away in southern Montana. Mundt (1956) shifted name to different rocks of Atokan age. Suggested to give these rocks separate formational names and discontinue term Amsden in central Montana.

Willis, R. P., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 8, p. 1942-1966): Sacajawea applies to persistent red shale unit (including Darwin sand) formerly called lower Amsden. Term Amsden restricted to overlying cherty carbonate sequence; restricted usage in central Montana for carbonate sequence underlain by Tyler or older rocks. Unit overlain by Tensleep, Minnelusa formation of Williston Basin, or Ellis Group. Maximum thickness 400 feet in southern end of Judith Basin. Divisible into two units (ascending): 1) Alaska Bench limestone member and 2) unnamed dolomite member. Pennsylvanian (Morrowan-Atokan). Names Tyler-Heath (below) and Amsden (restricted) extended eastward from Montana into Williston Basin of North Dakota.

Todd, T. W., 1959 (Dissert. Abs., v. 20, no. 6, p. 2230-2231): Sacajawea Formation, Amsden Formation, and Tensleep Sandstone product of marine transgressive-regressive cycle on Wyoming cratonic shelf during Pennsylvanian as one phase in development of eastern Cordilleron geosyncline. Term Montchauve Group is suggested for these formations.

Peterson, D. O., 1960 (Dissert. Abs., v. 20, no. 7, p. 2757): Study of Pennsylvanian stratigraphy in northern Utah, western Wyoming, northwestern Colorado, and southeastern Idaho suggests that terms Quadrent and Casper be abandoned and Tensleep-Amsden-Sacajawea terminology extended to include strata formerly referred to by these names and Sacajawea be accepted as formational name applicable to red clastic sequence between Madison limestone, or equivalent, and Amsden carbonates.

Sandberg, C. A., 1962 (U. S. Geol. Surv., TEI-809, p. 68): Recognized term Amsden in North Dakota, but not South Dakota, where it is apparently included in lower part of Minnelusa.

Wilson, P. C., 1962 (Pennsylvanian System in the United States: Am. Assoc. Geol., Sym., p. 138): Mississippian-Pennsylvanian boundary within Amsden-Tensleep sequence.

Maughan, E. K., and Roberts, A. E., 1967 (U. S. Geol. Surv., Prof. Pap. 554-B, p. 1-27): Amsden raised to group status with following formations (descending): Devils Pocket, Alaska Bench, and Tyler. Amsden assigned to Pennsylvanian.

Nieschmidt, C. L., 1953 (U. S. Geol. Surv., Oil and Gas. Inv., Chart 50, 1 sheet): Amsden divided into 3 members. Lower member of grayish-red and brown shales interbedded with siltstones, limestones, and sandstones. Sandstone forms base of member locally. Middle member of finely crystalline limestone; upper member finely to coarsely crystalline locally cherty dolomite.

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Amsden Formation ranges in thickness from 0-380 feet in North Dakota; marked thinning occurs on western flank of Nesson Anticline. Amsden is unconformably(?) underlain by Alaska Bench Formation and unconformably overlain by Broom Creek Formation. Divided into three lithozones on basis of prominent marker units (ascending): Medora, Dickinson, and Bismarck Lithozones.

Arikaree formation

Stone, W. J., 1973 (Stratigraphy and sedimentary history of middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. xvii-xviii): Arikaree Formation term rejected for strata overlying White River Formation in North Dakota because deposits are lithologically distinct from type Arikaree in Nebraska and Arikaree of badlands of South Dakota. Killdeer Formation proposed for 25-200 feet of green concretionary, calcareous sandstone, siltstone, silty claystone, and dolostone.

See also Killdeer Formation.

Ashern Formation

Age: Middle Devonian

Area of extent: Central part of Williston basin.

Lithology: Brick-red to gray-orange and green-gray, dolomitic shale. Is locally silty.

Thickness: Up to 125 feet.

Relationships to other units: Unconformably overlain by Elm Point or Winnipegosis Formation; unconformably overlies Silurian rocks.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Residual, soil, and possibly erosional channel fill deposits.

Remarks: Type locality near Ashern, Manitoba. Ashern has been misapplied to many erosional and residual deposits within Devonian and Late Silurian. Where basal Middle Devonian red beds occur, they are generally erratic and discontinuous. Sandberg, C. A., and Hammond, C. R., (1958) included Ashern in Winnipegosis Formation.

History of stratigraphic nomenclature:

Baille, A. D., 1950 (Manit. Dep. Mines Nat. Resour., Mines Br. Pub. 49-2, p. 9-12): Ashern is 5-125 feet of red to pink to orange, dolomite and dolomitic, red to green shales, often silty and sandy. May be brecciated at base and appears to fill holes in "karst-like" topography of underlying Silurian. May represent "fossil laterite" or soil profile developed on Silurian strata in interval between Silurian and Devonian deposition. Equivalent to "3rd red" of Saskatchewan.

Harris, S. H., and Mallin, J. W., 1957 (Williston Basin Oil Rev., v. 6, no. 5, p. 15-16): In Williston Basin, Ashern is up to 50 feet of fine red to pink clastics and carbonates. Fossils north of Winnipeg are Middle Devonian. Represents initial stage of deposition of pre-Devonian karst topography of low relief; transgresses time boundaries.

North Dakota Geological Society, 1961 (Stratigraphy of the Williston Basin Devonian System: Conrad, Bismarck, p. 809): Ashern overlain by Winnipegosis Formation over most of Williston Basin. Similar basal red shales were deposited by Dawson Bay, Souris River, and Duperow seas of later Devonian time and locally rest unconformably on "true" Ashern, but are nearly impossible to differentiate. Society recommended that "Ashern" be mapped "together with the basal red shales of . . . whatever the identifiable Devonian formation onlapping the truncated Silurian of older beds may be" (p. 9).

Ashville Formation

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 993-1010): Ashville Formation of Cenomanian age is found on Pembina escarpment, Manitoba and North Dakota.

This usage not followed by later authors.

Assiniboine Member

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 993-1010): Assiniboine Member of Favel Formation (Late Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota.

This usage not followed by later authors.

BACON CREEK MEMBER (of HELL CREEK FORMATION)

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 33): Bacon Creek Member is vari-colored bentonites, bentonitic shales, and lignitic shales. Type section is west of Bacon Creek in SE¼ sec. 23, T. 133 N., R. 106 W., Slope County, North Dakota. Overlies Marmarth Member; underlies Huff Member. Outcrops in Little Missouri valley around Marmarth and south into Bowman County. Top of unit is bentonite bed which indicates time horizon. Fossil remains (Triceratops, rare invertebrates) and nature of sediments indicate nonmarine origin.

Baker's Ferry bed

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 109): Baker's Ferry bed is lowest coal seam of Rough Creek area. Considered to be of Fort Union Formation.

Bakken formation, "shale"

Age: Late Devonian and Early Mississippian.

Area of extent: Subsurface in Saskatchewan, Manitoba, North Dakota and Montana.

Lithology: Two black organic shales separated by fine-grained calcareous or dolomitic sandstone and siltstone.

Thickness: Up to 105 feet.

Relationships to other units: Locally unconformable under Lodgepole; unconformable above pre-Mississippian formations.

Characteristic fossils: Rare conodonts.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Names from Amerada 1 Bakken oil test between interval of 9,615 and 9,720 feet in SWNW sec. 12, T. 157 N., R. 95 W., Williams Co., North Dakota. May be partially equivalent to lower beds of Lodgepole Formation.

History of stratigraphic nomenclature:
Nordquist, J. W., 1953 (Billings Geol. Soc. Gdbk., 4th Ann. Field Conf., p. 72-74): Consists of two, black, fissile shales separated by

light-gray to gray brown, fine-grained calcareous sandstone interbedded with minor amounts of gray brown cryptocrystalline limestone. Occurs at depths of 9,615 to 9,720 feet in Amerada 1 Bakken oil test in SWNW sec. 12, T. 157 N., R. 95W., Williams Co., North Dakota. Overlies Three Forks Formation. May be equivalent to lower beds of Lodgepole Formation.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Petrol. Geol., Bull. 42, p. 2328): Bakken is present in central part of Williston basin and parts of Montana. Where Bakken not deposited, lowermost Mississippian beds are correlated with Englewood limestone of South Dakota.

Sandberg, C. A., 1962 (U.S. Geol. Surv., Rep. TEI-809, p. 55) Relationships of Bakken and Englewood described in detail.

Kume, Jack, 1963 (N. D. Geol. Surv., Bull. 39, p. 38): Bakken ranges in thickness from 42 feet in Pembina County to erosional edge in northern Butte and Meade Counties, Montana. Overlain by Englewood in Butte County.

"Banded beds"

See BULLHEAD LITHOFACIES, Member of Fox Hills Formation.

Bar-H lignite (of LUDLOW FORMATION)

King, J. W., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 85): Bar-H lignite is 135 feet below top of Ludlow Formation; named from Bar-H Ranch, Harding County, South Dakota.

BEAR DEN MEMBER (of GOLDEN VALLEY FORMATION)

Hickey, L. J., 1977 (Geol. Soc. Am., Mem. 150, 181 p.): Bear Den is lower member of Golden Valley Formation; is 5-65 feet of light gray or brightly-colored kaolinitic strata. Is conformable on Fort Union Formation and underlies Camels Butte Member (new). In weathered outcrop, member develops three color zonations (ascending): basal gray zone, middle orange zone, and somber colored-calcareous zone. Thin bed of lignite (Alamo Bluff lignite) or its lateral equivalent, silified silt or freshwater limestone (Taylor bed) mark upper boundary. Is Late Paleocene in age based on megaflora of 41 species mostly of lowland forest community. Is fluvial in origin. Is equivalent to Hebron Member of Golden Valley Formation.

Beaver Creek coal group

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 102-105): Beaver Creek group of coals occurs in northwestern corn of Billings County. Lies above Medora group beds and uppermost bed is 100 feet below Sentinel Butte group. Contains beds N-P.

"Beaverhill Lake equivalent"

See Souris River Formation.

Towse, D., 1953 (N. D. Geol. Surv., Rep. Invest. 12, 1 sheet): Beaverhill Lake equivalent is shaly and anhydritic limestone and dolomite unit above Manitoban Formation and below "Woodbend equivalent."

BEAVERHILL LAKE GROUP, Formation

Age: Late Devonian.

Area of extent: Alberta and Saskatchewan, and North Dakota.

Lithology: Series of cyclic fragmental and argillaceous limestone beds in central Alberta, partly dolomitized near outer limits in Saskatchewan.

Thickness: 722 feet in type well. Fairly uniform in thickness over basin area.

Relationships to other units: Overlies Elk Point Formation. Overlain conformably by Cooking Lake Member of Woodbend Formation. Is equivalent to lower part of Duperow and Souris River Formations.

Characteristic fossils: Brachiopods and other fragmental fossil debris, possibly charophytes.

Economic significance: Oil productive from reef developments in Alberta.

Depositional environments: Marine, favoring reef growth.

Type section: 4325-5047 feet in Anglo-Canadia #2 Beaverhill Lake, Lsd. 11, sec. 11, T. 50, R. 17, W. 4 M., Alberta, Canada.

Remarks: Named after Beaverhill Lake, 7 miles north of well site.

History of stratigraphic nomenclature:

Stanton, M. S., 1953 (Billings Geol. Soc., Gdbk., 4th Ann. Field Conf., p. 61): Beaverhill Lake Group includes dominantly normal marine carbonates with intermittent evaporites overlying Elk Point Group and extending upward into prominent gamma-ray "kick" marking top of widespread argillaceous carbonate zone. Thickness is 300-750 feet in Saskatchewan. Divided into two formations (ascending), Dawson Bay and Souris River. "The term 'Beaverhill Lake' is here used in quotation marks since this gamma-ray marker . . . occurs some 70-150 feet below the stratigraphic point frequently considered equivalent to the top of the Beaverhill Lake Formation in Alberta. For this reason it would be preferable to introduce a new group name" (p. 61).

Layer, D. B., et al. 1950 (Am. Assoc. Pet. Geol., Bull. 34, no. 9, p. 1823-1825): Beaverhill Lake Formation named from Anglo-Canada #2 Beaverhill Lake oil well in southeastern Alberta.

Laird, W. M., 1953 (Interstate Oil Compact, Quart. Bull., v. 12, no. 2, p. 74): Beaverhill Lake Group consists of Dawson Bay and Souris River Formations in Williston basin.

Baille, A. D., 1955 (Am. Assoc. Pet. Geol., Bull. 39, no. 5, p. 579): Beaverhill Lake Formation is equivalent to nearly all of Manitoba Group.

Walker, C. T., 1956 (N. D. Geol. Soc., 1st Internat. Williston Basin Sym., p. 131): Beaverhill Lake Formation equivalent to upper part of Souris River Formation.

"Bed Q"

See LINTON MEMBER OF FOX HILLS FORMATION.

BELFIELD MEMBER (of SPEARFISH FORMATION)

Dow, W. G., 1967 (N. D. Geol. Surv., Bull. 52, p. 6-8): Belfield Member (formerly restricted Spearfish) is up to 232 feet thick in northwestern Dunn County; consists of fissile, gray shale interbedded with reddish-orange siltstone and mudstone; few anhydrite and dolomite beds present. Conformably overlies Minnekahta Limestone where Minnekahta present but does not extend beyond limits of Minnekahta; conformably underlies Pine Salt or Saude Members of Spearfish. Type interval is at 7228-7431 feet in Amerada R. E. Newton No. 1 well, NWSW sec. 31, T. 140 N., R. 99 W., Stark County, North Dakota.

BELLE FOURCHE SHALE

Age: Late Cretaceous.

Area of extent: Black Hills area, eastern and central Montana, western North Dakota, and South Dakota.

Lithology: Gray to black shale, ironstone concretions, numerous bentonite beds.

Thickness: Up to 600 feet.

Relationships to other units: Conformably underlies Greenhorn Limestone and overlies Mowry Shale. Equivalent to top of Graneros Shale of Kansas and shale zone below Second White Specks Zone of southern Alberta.

Characteristic fossils: Inoceramus, Exogyra, Mantelliceras.

Economic significance: None.

Depositional environment: Extensive seas influenced by mild tectonism and windblown volcanic ash (bentonite).

Remarks: Type locality at Belle Fourche Creek in neighborhood of Wind Creek, Crook County, Wyoming.

History of stratigraphic nomenclature:
Collier, A. J., 1920 (U. S. Geol. Surv., Press Bull. 9065): Belle Fourche Shale, of Late Cretaceous age, underlies Greenhorn Limestone and overlies Mowry Shale.

Collier, A. J., 1922 (U. S. Geol. Surv., Bull. 736, p. 83): Belle Fourche Shale Member is top member of Graneros Shale. Consists of greater than 560 feet of dark-gray shale that varies in hardness but is softer than underlying Mowry. Contains calcareous concretions near top, ironstone concretions in lower part, and thick bentonite bed near base.

Moore, R. C., 1949 (Geol. Soc. Am., Mem. 39, fig. 18): Calcareous shale and thin limestones of Greenhorn facies occur lower in stratigraphic column and at expense of dark, noncalcareous shale of Belle Fourche facies southeasterly toward Black Hills. Contact between Belle Fourche and Greenhorn is at base of lowest limestone (Bull Creek Limestone).

Cobban, W. A., 1951 (Am. Assoc. Pet. Geol., Bull. 35, no. 10, p. 2197): Formations in Black Hills equivalent to Colorado Shale are Fall River Sandstone, Skull Creek Shale, Newcastle Sandstone, Mowry Shale, Belle Fourche Shale, Greenhorn Formation, Carlile Shale, and

Niobrara Formation. Belle Fourche Shale of northern Black Hills consists of 565 feet of dark bluish shale with many beds of bentonite and ferruginous concretions. In central Montana Belle Fourche is represented by 240-315 feet of similar beds in middle of Colorado Shale. Is Cenomanian in age.

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, pl. 1): Boundary between Lower Cretaceous and Upper Cretaceous at base of Belle Fourche Shale. Bull Creek Limestone equivalent to Orman Lake which is term that should be used.

Knechtel, M. M., and Patterson, S. H., 1962 (U. S. Geol. Surv., Bull. 1082-M, p. 914-919): Belle Fourche in northern part of Black Hills divided into: upper member--6-32 feet of soft, dark-gray shale with calcareous concretions and bentonite beds, base of unit rests on Bentonite Bed F, lateral facies changes cause Belle Fourche-Greenhorn contact to occur lower in section; lower member--consists of three units, upper part is soft dark-gray shale with many bentonite beds and calcareous concretions and cone-in-cone concretions near top and is 200 feet thick near Belle Fourche but thickens to west as Greenhorn contact rises in section, middle part is sandy shale with thin lenses of soft, gray sandstone and thick layers of dark-gray, soft, fissile shale, bentonite beds common, probably equivalent to Frontier sands farther west, lower part is dark shale that is harder and less fissile than overlying units; abundant, oblate, spheroidal, corrugated or pitted concretions of siderite; is 30-45 feet thick, includes Bentonite beds D and E, rests on Clay Spur Bentonite Bed of Mowry.

Benton Shale

Age: Cretaceous

Introduced as Fort Benton shale by F. B. Meek and F. V. Hayden in 1862 (Acad. Nat. Sci., Philadelphia, Proc., v. 13, p. 419-421). Term "Fort" was deleted. Term "Benton" now obsolete as equivalents (Carlile, Greenhorn, Belle Fourche, and Mowry) are presently used.

Leonard, A. G., 1906 (N. D. Geol. Surv., 4th Bienn. Rep., p. 67): Benton is oldest member of Colorado Formation exposed in North Dakota. Shales used for manufacture of brick. Is not likely that these beds belong to Pierre Formation.

Laird, W. M., and Towse, D. F., 1949 (N. D. Geol. Surv., Rep. Invest. 2, 2 sheets): Graneros and Carlile Shales are subdivisions of Benton Shale. Graneros divided into Skull Creek, Newcastle, Mowry, and Belle Fourche.

Berg bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 39): Berg bed is lignite bed of local extent in Square Butte area.

Beulah bed (of SENTINEL BUTTE FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 127): Beulah bed is coal bed in vicinity of Beulah; is 190 feet below Beulah-Zap bed.

See also Hagel Bed.

Beulah-Zap bed (of SENTINEL BUTTE FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 125): Beulah-Zap bed is perhaps most important and extensive lignite bed of North Dakota. Crops out along Knife River and Spring Creek. Named for towns of Beulah and Zap.

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 43): Beulah-Zap bed crops out along Otter Creek and Brady Creek. Consists of two beds about 15 feet apart and coals are about 5 feet thick each.

BIGHORN GROUP

Ross, R. J., Jr., 1957 (U. S. Geol. Surv., Bull. 1021-M, p. 446-448): Term Bighorn Group used to include (ascending) Red River and Stony Mountain Formations in subsurface. Overlies Winnipeg Formation. Ordovician fossils present.

Darton, N. H., 1904 (Geol. Soc. Am., Bull. 15, p. 394-401): Bighorn limestone consists of 250-300 feet of hard, massive limestone on east side of Bighorn Mountains. Top member is thinly-bedded, impure limestone with Late Ordovician Richmond fauna. Middle member somewhat massive and is locally fine-grained, light-colored limestone containing corals. Lower member is hard, massive, impure, light-gray or faint buff limestone with network of silica veinlets that weather to honeycomb appearance; fossils are Middle Ordovician (Trenton) in age. Underlies Madison Limestone; overlies Deadwood Formation.

BIG SNOWY GROUP

Age: Mississippian-Pennsylvanian.

Area of extent: Central Montana, western North Dakota, and northwestern South Dakota.

Lithology: Variegated shale with intercalated limestones and sandstones.

Thickness: Up to 100 feet.

Relationships to other units: Overlies Madison Group (Charles Limestone) in North Dakota; underlies Amsden Formation.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Named from Big Snowy Mountains, Montana. Standard section is composite of Stonehouse Ranch and State Road No. 25 section.

See also Heath, Kibbey, and Otter Formations.

History of stratigraphic nomenclature:

Scott, H. W., 1935 (Geol. Soc. Am., Proc. 1934, p. 367): Big Snowy Group consists of Kibbey, Otter, and Heath Formations. Is variegated with intercalated limestones and sandstones. Overlies Madison.

Scott, H. W., 1935 (J. Geol., v. 43, p. 1011-1032): Big Snowy Group is new name for lower part of beds previously assigned to Quadrant Formation in central Montana. "True" Quadrant is absent in central Montana where rocks are all Mississippian--older than Quadrant Formation of Quadrant Mountain. Yellowstone National Park which is early Pennsylvanian and westward extension of Tensleep Sandstone--also older than Mississippian Amsden that underlies Quadrant of Quadrant Mountain as well as Quadrant of southern Montana and overlies Big Snowy Group in central Montana. Group has maximum thickness of 1200 feet and rests on Madison limestone. Divided into three conformable formations (descending): Heath (new), Otter, and Kibbey.

Seager, O. A., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 5, p. 863): In subsurface in Cedar Creek anticline, southeastern Montana. Big Snowy includes (ascending): Charles (new), Kibbey, Otter, and Heath; underlies Amsden; overlies Madison.

Perry, E. S., and Sloss, L. L., 1943 (Am. Assoc. Pet. Geol., Bull. 27, p. 1287-1304): Big Snowy Group of northern Great Plains described only lower formation (Charles) present in North and South Dakota. Kibbey and Otter pinch out within the Dakotas and Heath is present only in Montana and North Dakota.

Sloss, L. L., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 65, 67-68): Excluded from Big Snowy Group is Charles formation which is assigned to Madison Group. As restricted includes (ascending): Kibbey, Otter, and Heath formations.

Gardner, L. S., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 2, p. 329-349): Big Snowy Group expanded and redefined to include (ascending): Kibbey Sandstone, Otter Formation, Heath Formation. Cameron Creek Formation, Alaska Bench Limestone, and Devils Pocket Formation. Upper three units were previously Scott's (1935) Amsden. Underlies Triassic (?) or Permian (?) and Pennsylvanian undifferentiated, or locally, Ellis Group; overlies Madison Group. Thickness 1509 feet at standard section. Mississippian and Pennsylvanian.

BIRDBEAR FORMATION (of JEFFERSON GROUP)

Age: Late Devonian.

Area of extent: Montana, North Dakota, South Dakota, Manitoba, and Saskatchewan.

Lithology: Gray to brown fossiliferous limestone and micro- to finely-crystalline dolomite with anhydrite at top locally.

Thickness: Up to 125 feet.

Relationships to other units: Conformably and locally disconformably overlies Duperow Formation. Probably equivalent to upper Delia Formation in southern Alberta.

Characteristic fossils: Amphipora.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Type locality between 10,310 and 10,400 feet in Mobil No. 1 Birdbear, sec. 22, T. 149 N., R. 91 W., Dunn County, North Dakota. Commonly referred to as "Nisku" but H. R. Belyea, (1955, Can. Geol. Surv., Pap. 55-3, p. 29), indicated no depositional relationship between Nisku Formation of Alberta and Birdbear Formation of Williston Basin.

History of stratigraphic nomenclature:
Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2292, 2302-2303, and 2318-2322): Birdbear Formation proposed for widespread belts of light-colored finely crystalline dolomite and limestone that overlie Duperow and underlie Three Forks in Williston basin and central Montana. Thickness to 125 feet. Replaces term Nisku formation now restricted to type area

in central Alberta. Type locality given. Birdbear and underlying Duperow constitute Jefferson Group.

North Dakota Geological Society, 1961 (Stratigraphy of the Williston Basin Devonian System. Conrad, Bismarck, p. 27-29): Birdbear is conformable with underlying Duperow formation and overlying Three Forks Formation in Williston basin of North Dakota. Probably equivalent in part to Delia formation which underlies Nisku formation in central Alberta. Thickness 70-140 feet; over much of Williston Basin thickness is constant at 90-100 feet. Oil productive.

Dallas, D. D., and Lalin, Dale E., 1962 (Billings Geol. Soc., 13th Ann. Field Conf., p. 101-105): Commercial production in Charleson Field, McKenzie County, North Dakota. Birdbear has well developed sucrosic dolomite section with good porosity and considerable oil staining at this interval at Nesson anticline of northwestern North Dakota.

"Bismarck lithozone"

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Bismarck lithozone is upper unit of Amsden Formation, possibly unconformably overlies Dickinson lithozone and unconformably underlies Broom Creek Formation. Consists of interbedded sandstones and arenaceous dolomite. Is 0-145 feet thick. Bismarck lithozone represents a migrating littoral environment and implies decrease in restriction of environment of deposition. Equivalent to Meek Group and possibly part of Hayden Group in South Dakota.

See also Amsden Formation.

"Blackhorse shales"

Keyes, C. R., 1922 (Pan-Am. Geol., v. 37, p. 63-64): Blackhorse shales are 500 feet thick, underlie Ludlow lignites and overlie Fox Hills Sandstones. Is basal shale of Lance Formation in North and South Dakota. Named from Blackhorse Butte of South Dakota.

BLACK ISLAND MEMBER (of WINNIPEG FORMATION)

Age: Ordovician.

Area of extent: North Dakota, Saskatchewan, north-central South Dakota, and Manitoba.

Lithology: Well-rounded, usually frosted, very fine- to medium-grained, very friable, quartzose sandstone.

Thickness: Up to 170 feet.

Relationships to other units: Lies unconformably on Deadwood Formation except in northwestern North Dakota where it is conformable; in northeastern North Dakota it lies nonconformably on Precambrian rocks; underlies Ice Box Member.

Characteristic fossils: None listed for this unit.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Named from Black Island, Lake Winnipeg, Manitoba.

History of stratigraphic nomenclature:
Genik, G. J., 1951 (M. S. Thesis, Univ. Manit.): Black Island Member proposed for basal sandstone of Winnipeg Formation.

Genik, G. J., 1954 (Albert. Soc. Pet. Geol., J., v. 2, no. 5, p. 1): Black Island term applied to basal sandstone unit of Winnipeg Formation in surface and subsurface of Manitoba and subsurface of Williston Basin.

Carlson, C. G., 1960 (N. D. Geol. Surv., Bull. 35, p. 55-57): Black Island term used for lower sandstone of Winnipeg Formation in Williston Basin. Black Island consists of mottled light-gray, very fine- to medium-grained, round to subangular, poorly sorted silty to argillaceous sandstone, cemented with silica or pyrite.

Fuller, J. G. C. M., 1961 (Am. Assoc. Pet. Geol. Bull. 45, no. 10, p. 1341): Black Island of Carlson (1960) in North Dakota not the same as Black Island in Manitoba (Genik, 1954). Replaced name with Burgen Sandstone from mid-continent area. (This usage not followed by North Dakota Geological Survey.)

Boissevain Formation

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am. Bull. 63, no. 10, p. 993-1010): Boissevain Formation of Maestrichtian age is found on Pembina escarpment, Manitoba and North Dakota.

This usage not followed by later authors.

"Bottineau interval"

Heck, T., 1978 (Mont. Geol. Soc., Williston Basin Sym., 24th Ann. Field Conf., p. 196-197): Bottineau interval divided into four subintervals (ascending): 1) Scallion subinterval, normal marine conditions; 2) lower and upper Virden subinterval, gradual marine regression of cyclical nature with variable clastic influx; 3) lower and upper Whitewater Lake subinterval, gradual marine regression of cyclical nature with variable clastic influx; and 4) Flossie Lake subinterval; gradual marine regression. Kinderhookian in age and is interval of Madison Formation.

BOWES MEMBER (of PIPER FORMATION)

Age: Middle Jurassic.

Area of extent: Montana and North Dakota.

Lithology: Red to varicolored shale facies grading westward into sandstone and sandy oolitic limestone.

Thickness: Up to 52 feet.

Relationships to other units: Conformably overlies Firemoon Limestone Member, southward overlaps Firemoon Member and uncomformably overlies Madison Limestone. Underlies Rierdon Formation.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Marine.

Type section: Interval from 3,360-3,417 feet in Northern Ordnance no. 1 Guertzgen well, SWNWNE sec. 2, T. 31 N., R. 19 E., Blaine County, Montana.

History of stratigraphic nomenclature:
Nordquist, J. W., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 97, and 102-103): Bowes Member displays varying lithologies, represented in Williston Basin by red to varicolored shale facies that grades westward into sandstone and sandy oolitic limestone on east flank of Sweetgrass Arch. In type section, consists of (ascending): 18 feet of light-brown, finely crystalline to fragmental limestone, very sandy to argillaceous in part with few thin stringers of light-gray calcareous sandstone; 7 feet of light-gray, fine- to coarse-grained, very calcareous sandstone; 20 feet of light-gray, oolitic to sandy limestone with thin beds of calcareous sandstone; and 12 feet of light-brown, fine-grained calcareous sandtone grading

downward into light-gray, sandy and partly oolitic, limestone. Becomes increasingly sandy and somewhat variable in thickness west of type well; eastward becomes interbedded with shale and eventually grades into varicolored shale with uniform thickness. Conformably overlies Firemoon Limestone Member (new) in Williston basin and most of north-central Montana; southward overlaps Firemoon Member and unconformably overlies Madison Limestone. Underlies Rierdon Formation.

Boyne Member (of Vermillion River Formation)

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 993-1010): Boyne Member of Vermillion River Formation (Late Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota.

This usage not followed by later authors.

Brazda bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 38): Brazda Bed is lignite bed of local extent in Square Butte area.

BREIEN MEMBER (of HELL CREEK FORMATION)

Laird, W. M., and Mitchell, R. H., 1942 (N. D. Geol. Surv. Bull. 14, p. 14-15): Thin, fossiliferous, marine member interfingering with lower part of nonmarine Hell Creek; named Breien Member of Hell Creek Formation. Occurs 20 feet above base of Hell Creek; consists of two gray sand beds separated by gray bentonite. Upper sand is greenish and contains marine fossils. Breien is 31 feet thick in Morton County, North Dakota, and has been reported farther south, west of Fort Yates, North Dakota. Type locality near village of Breien, T. 134 N., R. 82 W., Morton County, North Dakota.

BROOM CREEK GROUP, Formation

Age: Permian (Wolfcampian).

Area of extent: Eastern Wyoming, northeastern Colorado, southwestern South Dakota, and North Dakota.

Lithology: Interbedded limestones and sandstones.

Thickness: Up to 250 feet.

Relationships to other units: Overlies Wendover Group or Bismarck or Dickinson lithozones of Amsden Formation; underlies Cassa Group or unconformably underlies Opeche Shale.

Characteristic fossils: Fusulinids.

Economic significance: Oil productive.

Depositional environment: Marine; migrating beach or offshore bar system.

Remarks: Type locality in Broom Creek valley, sec. 10, T. 28 N., R. 66 W., Platte County, Wyo.

History of stratigraphic nomenclature:

Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13, p. 2, 5, 18-19, 37, and 45): Broom Creek Group consists of interbedded limestones and sandstones. Comprises interval between top of Wendover Group (new) and base of Cassa Group (new). Age is uncertain but is Pennsylvanian or Permian. Thickness of 14-75 feet.

Condra, G. E., and Reed, E. C., 1943 (Nebr. Geol. Surv., Bull. 14A, p. 37-38): Broom Creek Group stratigraphically expanded to include few higher beds than included in original definition, placing top on unconformity in overlying Cassa Group. Thickness is 85-101 feet. Is Permian in age.

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym., 1st Internat., Bismarck, N. D., p. 150-164): Broom Creek comprises lower part of Division I of Hartville "Formation" (Condra, G. E., and Reed, E. C., Nebr. Geol. Surv., Pap. no. 9, 46 p.). Consists of two distinct facies divided by structural high along North Dakota-South Dakota border. Southern facies is anhydritic dolomite (up to 350 feet thick); northern facies is sandstone with lesser amounts of dolomite (up to 100 feet thick). Erosional unconformity separates Broom Creek Group from overlying Cassa Group.

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Broom Creek Formation in North Dakota is of interbedded sandstones and dolomites. Subsurface reference section is from 7391-7630 feet in Cardinal Petroleum No. 16-5 N.P.R.R. SESE sec. 5, T. 139 N., R. 98 W., Stark County, North Dakota.

Brule Formation, member

Hayden, F. V., 1857. Phila. Acad. Nat. Sci., Proc., v. 9, p. 151-158): Brule Formation had originally been termed Turtle and Oreodon beds

by Hayden, F. V., 1867 (Rep. of F. V. Hayden, U. S. Geol. Surv. Terr., 1st Ann. Rep.)

Darton, N. H., 1899 (U. S. Geol. Surv., 19th Ann. Rep. pt. 4, p. 736): Brule clay separated from underlying Chadron Formation (equivalent to Titanotherium beds) for use in South Dakota.

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. xvi): Two new members proposed for Brule Formation in North Dakota (ascending): Dickinson Member and Schefield Member. Dickinson Member includes Fitterer Bed (new) consisting of sandstone.

Buckmann bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 44): Buckmann Bed is lignite found on Buckmann Farm in sec. 34, T. 143 N., R. 87 W. Is 65-75 feet above Beulah-Zap Bed and is exposed in Otter Creek area.

BULLHEAD LITHOFACIES, Member (of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: South Dakota and North Dakota.

Lithology: Thinly interbedded sand, silt, and clay.

Thickness: Up to 135 feet thick.

Relationships to other units: Lateral facies with Colgate lithofacies.

Characteristic fossils: Plant remains and shell fragments.

Depositional environment: Marine delta-front or lagoon.

Principal reference section: NE-facing bluff of badland rim, center of west line, W½ sec. 33, T. 14 N., R. 19 E., U. S. Geol. Surv. Redelm NE quad., Ziebach County, S. D.

Remarks: See Iron Lightning Member. Bullhead Member named for Indian Village in north-central South Dakota.

History of stratigraphic nomenclature:
Searight, W. V., 1931 (S. D. Geol. Surv., Rep. Invest. 10, p. 1-35): Upper Fox Hills divided into two members: lower banded shale and sandstone and upper sandstone.

Morgan, R. E., and Petsch, B. C., 1945 (S. D. Geol. Surv., Rep. Invest. 49, p. 17): Thin series of banded beds occur stratigraphically higher than Timber Lake Member and stratigraphically lower than butte-capping sandstone.

Stevenson, R. E., 1956 (S. D. Geol. Surv., Geol. quad., Bullhead 1:62, 500): Scattered outcrops occur on uplands and high valley-sides in southern half of quadrangle. Consists of alternating thin (1-14 inches) beds of light gray, medium- to fine-grained, locally cross-laminated, subgraywacke sand, and thin, fissile, clay limonitic concretions throughout member and along some bedding planes. Vari-gradational contact with overlying and underlying members. Lower 25 feet characterized by fauna of Timber Lake Member; Ostrea glabra occurs in few scattered layers in upper part. Total thickness 135 feet.

Waage, K. M., 1961 (Wyo. Geol. Assoc., 16th Ann. Field Conf., p. 237): Bullhead Member is 15-75 feet of banded, gray clay-shale and light-gray siltstone or fine-grained sandstone. Colgate and upper part of banded beds are lateral facies. Lenses of Colgate-like sand occur in lowest part and top of Bullhead in north-central South Dakota.

Feldman, R. M., 1967 (Ph.D. Dissert., Univ. N. D., 366 p.): Bullhead Member in North Dakota, of interbedded sandstone and shale. Represents brackish-water deposition.

Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist. Bull. 27, p. 119-122): Bullhead lithofacies consists of thinly interbedded sand, silt, and clay with abundant plant fragments and some marine fauna. Local zones of contorted bedding associated with intercalated lenses of sand of Colgate lithofacies are evidence of delta-front sediments. Principal reference section selected to show fossiliferous phase.

Erickson, J. M., 1971 (Ph.D. Dissert., Univ. N. D., p. 26): Bullhead lithofacies in south-central North Dakota; consists of interbedded, poorly consolidated sandstone or siltstone. May represent lagoonal deposit behind barrier bar or baymouth bar.

Bullion Butte bed (of SENTINEL BUTTE FORMATION)

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, p. 50): Bullion Butte Lignite of Sentinel Butte Shale is 16 feet thick and occurs only in Bullion Butte. Occurs above HT Butte lignite.

BULLION CREEK FORMATION (of FORT UNION GROUP)

Clayton, L., et al. 1977 (N. D. Geol. Surv., Rep. Invest. 59, p. 10-12): Bullion Creek Formation consists of alternating beds of clay, silt,

sand, and lignite. Named from Bullion Creek; type section is SW¼ sec. 27, SE¼ sec. 28, NE¼ sec. 33, and SW¼ sec. 34, T. 137 N., R. 103 W., Golden Valley County, North Dakota. Conformably overlain by Sentinel Butte Formation; unconformably underlain by Slope Formation (new). Is 50-200 metres thick and occurs in western North Dakota, northwestern South Dakota, and westward to Cedar Creek anticline of Montana; is equivalent to part of Ravenscrag Formation of Saskatchewan. Is Paleocene in age and is of fluvial-plain origin including overbank, flood basin, and point-bar sediments. Consists of strata considered to be equivalent to entire Tongue River Formation or lower, middle, or upper part of Tongue River Formation.

Burgen Sandstone

See Black Island Member (of Winnipeg Formation)

Fuller, J. G. C. M., 1961 (Am. Assoc. Pet. Geol., Bull. 45, no. 8, p. 1341): Replaced term "Black Island Formation" of North Dakota, South Dakota, and Montana with Burgen Sandstone. (Usage not followed by North Dakota Geological Survey.)

Burlington bed (of BULLION CREEK FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 147): Coal bed mined in Des Lacs and Mouse River valleys is Burlington Bed.

Byer bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Survey., Bull. 1076, p. 46): Byer Bed lies 65 feet above Otter Creek Bed and consists of lignite.

"Cambro-Ordovician"

Term used for all pre-Winnipeg Formation sedimentary rocks.

CAMELS BUTTE MEMBER (of GOLDEN VALLEY FORMATION)

Hickey, L. J., 1977 (Geol. Soc. Am., Mem. 150, 181 p.): Camels Butte is upper member of Golden Valley Formation; consists of up to 150

feet of yellow to tan illitic to montmorillonitic strata. Unconformably underlies White River Group and may contain up to 75 feet of weathering or leaching zone; overlies Bears Den Member (new). Is early Wasatchian in age, based on megaflora of 37 species, including Salvinia. Is fluvial in origin. Is equivalent to Dickinson Member of Golden Valley Formation.

CANNONBALL FORMATION (of FORT UNION GROUP)

Age: Paleocene.

Area of extent: North Dakota, South Dakota, Manitoba, and Saskatchewan.

Lithology: Poorly consolidated, very fine- to fine-grained, light to medium brownish yellow-weathering sandstone and light gray-weathering, sandy mudstone.

Thickness: Up to 385 feet.

Relationships to other units: Overlain by Tongue River Formation; overlain and underlain by Ludlow Formation in places.

Characteristic fossils: Foraminiferids, molluscs, and crustacean burrow Ophiomorpha.

Economic significance: Uranium potential.

Depositional environment: Marine complex of environments, including tidal flat, lagoon, beach, and shelf.

Remarks: Type area is along Cannonball River in T. 132 and 133 N., R. 87 W. and R. 88 W., Grant County, North Dakota.

History of stratigraphic nomenclature:
Lloyd, E. R., 1914 (U. S. Geol. Surv., Bull. 541, p. 248-249): Cannonball Marine Member comprises upper 250-300 feet of Lance Formation. Consists of 144.5 feet of (descending): 1) calcareous sandstone, 6 inches; 2) gray, partly consolidated sandstone containing numerous layers cemented with iron, 10.5 feet; 3) yellow consolidated sandstone, 5 feet; 4) hard, red sandstone, 6 inches; 5) dark-gray shale with "cannonball" concretions, 25 feet; 6) very dark-gray shale, very sandy, with layer of marine shells 20 feet from base and with "cannonball" concretions, 103 feet; base concealed. Marine invertebrates belong to modified Fox Hills fauna.

Lloyd, E. R., and Hares, C. J., 1915 (J. Geol., v. 23, p. 523-547): In large area west of Missouri River in North and South Dakota, Lance Formation consists of lower nonmarine part containing flora similar to Fort Union and upper marine member containing fauna resembling Fox Hills. Upper part, because of peculiar fauna, has been mapped

separately and named Cannonball Marine Member of Lance Formation. Farther west, nonmarine beds with lignite and occupying similar stratigraphic position have been named Ludlow Lignitic Member of Lance Formation. Cannonball Member mapped from Mandan to 4 miles west of Haley, North Dakota, distance of 130 miles. Presence of Ostrea glabra near Yule County, North Dakota, shows sea extended some distance farther than its sediments mapped. Cannonball Member becomes thinner to west; oyster beds near Yule may represent western limit of Cannonball sea which probably advanced into western North and South Dakota from east or northeast. Is contemporaneous with Ludlow Lignitic Member and overlies 400-525 feet of somber-colored shale, yellow sandstone, and thin lignite beds composing lower, nonmarine member of Lance. Consists of dark, sandy shale or shaly sandstone with lesser amounts of dark-yellow and gray sandstone and thin limestone; strata is lenticular and can be followed only for short distances. Sections show Cannonball Member overlying or grading laterally into Ludlow. "Cannonball" concretions are formed by cementation of sandy shale by deposition of calcium carbonate. No definite boundary could be determined between nonmarine and marine beds of Lance.

Dorf, E., 1940 (Geol. Sec. Am., Bull. 51, p. 213-236): Paleobotanical evidence supports known vertebrate evidence in placing boundary between true Lance and Fort Union at base of nondinosaur-bearing Tullock, Ludlow, or Bear Formations or their equivalents (at top of Triceratops-bearing Hell Creek or Lance Formations as originally defined).

Laird, W. M., and Mitchell, R. H., 1942 (N. D. Geol. Surv., Bull. 14, p. 18-20): Cannonball of Fort Union Group comprises upper 250-300 feet of old Lance Formation. Is typically exposed along Cannonball River. To west, intergrades with underlying Ludlow Formation and southern Morton County, underlies and is gradational with Ludlow. Conformably underlies Tongue River Formation.

Fox, S. K., Jr., and Ross, R. J., Jr., 1942 (J. Paleo., v. 16, no. 5, p. 660-673): Analyses of foraminifera from Cannonball beds of North Dakota indicates Midway (Paleocene) age.

Seager, O. A. et al., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 8, p. 1414-1415, 1417): Fort Union in North Dakota is represented by three members: Tongue River, Cannonball, and Ludlow. Cannonball and Ludlow are interfingering contemporaneous sediments of early Paleocene age.

CARLILE SHALE (of COLORADO GROUP)

Age: Late Cretaceous.

Area of extent: Eastern Montana, Colorado, Wyoming, North Dakota, South Dakota, Kansas, and Nebraska.

Lithology: Dark gray, partly silty to sandy to bentonitic shale in subsurface. Often lighter color in outcrop and with calcareous concretions, bentonite, and some iron-stained concretions.

Thickness: Up to 650 feet.

Relationships to other units: Distinct lithologic and faunal break with underlying calcareous Greenhorn, probably is unconformity. Probably conformable with overlying Niobrara.

Characteristic fossils: Scaphites and other cephalopods.

Economic significance: None.

Depositional environment: Widespread, shallow marine with repeated minor oscillations.

Remarks: Named for outcrops around Carlile Spring and Carlile Station, 21 miles west of Pueblo, Colorado. See also Niobrara Formation.

History of stratigraphic nomenclature:

Gilbert, G. K., 1896 (U. S. Geol. Surv., 17th Ann. Rep., pt. 2, p. 565): Carlile Shale is medium-gray shale with thin, purplish limestone or thicker, yellow sandstone at top. Is top formation of Benton Group.

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 1, p. 348): Niobrara and Benton are not now considered groups but are included in Colorado Group. Referred to as Niobrara Limestone and Benton Shale where not subdivided.

Cobban, W. A., 1951 (Am. Assoc. Pet. Geol., Bull. 35, no. 10, p. 2187-2190): Carlile of northern Black Hills consists of basal unnamed dark-gray shale, 75-155 feet thick; middle, gray, sandy member (Turner), 185-260 feet thick; and upper dark-gray shale (Sage Breaks), 195-305 feet thick.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 77): Carlile is 370-440 feet thick in western South Dakota; underlies almost entirely North Dakota and South Dakota, and is much thinner on eastern side of Williston basin. Lower half of formation consists of dark-gray, fissile shale and very finely interbedded shale and glauconitic siltstone with thin sandstones and large limestone concretions. In upper half of formation, three definite but thin sandstones are present.

Knechtel, M. M., and Patterson, S. H., 1962 (U. S. Geol. Surv., Bull. 1082-M, p. 920-925): Carlile in northern Black Hills consists of three members (descending: Sage Breaks Shale Member--195-300 feet of dark-gray noncalcareous shale with many limestone concretions; Turner Sandy Member--210-260 feet of dark shale with many limestone concretions and lenses of light-gray sandstone and sandy shale; and Pool Creek Shale Member--upper unit of 81 feet of black-gray shale that contain in lower part, two bentonite layers, and in upper 37

feet many clay-ironstone concretions; and lower unit of 13 feet of dark-gray soft papery shale, with limestone concretions at top.

Carrington shale facies

Age: Mississippian

Area of extent: Subsurface in North Dakota.

Lithology: Noncalcareous shale.

Thickness: Up to 90 feet.

Relationships to other units: Unconformably overlies Bakken Shale; conformably underlies Bottineau interval.

Type section: Interval of 2,362 to 2,425 feet mechanical log depth in Pure Oil Company J. M. Carr 1 well, sec. 15, T. 146 N., R. 66 W., Foster County, North Dakota (Ballard, 1963, p. 19). Named for Carrington, North Dakota.

Remarks: See also Madison Formation.

History of stratigraphic nomenclature:
Ballard, F. V., 1963 (N. D. Geol. Surv., Bull. 40, p. 19-24): Carrington shale facies proposed to be part of Bottineau interval instead of equivalent to Three Forks Formation.

Cassa Group

Age: Permian.

Area of extent: Eastern Wyoming, northeastern Colorado, southwestern South Dakota, and North Dakota (?).

Lithology: Red, pink, orange-red, blocky, lumpy, calcareous shale with salt casts and salt anhydrite and gypsum inclusions with siltstone.

Thickness: Up to 300 feet.

Relationships with other units: Underlies Phosphoria Group; overlies Broom Creek Group.

Depositional environment: Intermittently restricted marine.

Remarks: Type locality is Buckshot Canyon (also called Ragan Canyon), T. 29 N., R. 67 W., 3 miles northeast of Cassa, Platte County, Wyo.

History of stratigraphic nomenclature:

Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13A, p. 2, 5, 19, and 45): Cassa Group is upper 180 feet of Division I of Hartville "Formation" (Condra, G. E., and Reed, E. C., 1935, Nebr. Geol. Surv., Pap. no. 9, 46 p.). Thickness is 175-328 feet. Underlies Phosphoria Group; overlies Broom Creek Group (new). Consists of Owl Canyon Formation (new) below, Lyons Sandstone above.

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym., 1st Internat., Bismarck N. D., p. 150-164): No Cassa Group deposits along eastern flank of Permo-Pennsylvanian basin of South Dakota or in North Dakota. In restricted basin in west-central North Dakota, Cassa(?) sediments are 400 feet thick. Consists of red to pink, soft, lumpy, clayey, locally silty and sandy, shale that may be calcareous or dolomitic with anhydrite inclusions and salt beds (up to 100 feet thick).

CHADRON FORMATION (of WHITE RIVER GROUP)

Darton, N. H., 1899 (U. S. Geol. Surv., 19th Ann. Rep., pt. 4, p. 736): Chadron Formation is thin sheet of light-greenish sandy clay, underlying Brule clay. Forms basal member of White River Group; rests unconformably on Pierre Shale. Formerly called "Titanotherium beds."

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. xvi): Three new members proposed for Chadron Formation in North Dakota (ascending): Amidon, Chalky Buttes, and South Heart Members.

Chalky Buttes member (of CHADRON FORMATION)

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. 48-54): Chalky Buttes Member proposed for middle of Chadron Formation. Consists of "dazzling white," gravel-bearing sandstone unconformably overlying Amidon Member and underlying South Heart Member. Type section is south-facing exposure near head of deep, unnamed gully at NENE sec. 15, T. 134 N., R. 101 W., Slope County, about 4¼ miles southwest of Amidon.

Charles Formation (of MADISON GROUP)

Age: Late Mississippian (Meramacian)

Area of extent: Montana; subsurface in North Dakota, South Dakota, and Saskatchewan.

Lithology: Anhydrite and limestone; salt in eastern Williston Basin.

Thickness: Up to 800 feet.

Relationships to other units: Conformably overlies Mission Canyon; unconformably underlies Kibbey. Charles Formation exhibits facies relationships with Mission Canyon Limestone in Williston basin.

Characteristic fossils: Algae and ostracodes.

Economic significance: Oil productive, possible salt production.

Depositional environment: Intermittently barred marine basin.

Type section: Interval of 3200 and 3800 feet in Argo-California 4 Charles oil test in sec. 21, T. 15 N., R. 30 E., Garfield County, Montana (Andrichuk, 1955, p. 2176). Named from Charles lease.

History of stratigraphic nomenclature:

Seager, O. A., 1942 (Am. Assoc. Pet. Geol., v. 26, no. 5, p. 861-864): Charles includes shale, salt, anhydrite, and earthy limestone beds (810 feet). Represents post-Madison, pre-Kibbey sedimentation and placed in Big Snowy Group.

Sloss, L. L., 1952 (Billings Geol. Soc., 3rd Ann. Field Conf., p. 66-67): Charles assigned to Madison Group and overlies Mission Canyon Limestone. Charles is recognizable in many outcrops of Montana.

Andrichuk, J. M., 1955 (Am. Assoc. Pet. Geol., Bull. 39, No. 11, p. 2170-2210): Charles equivalent mapped as upper unit of Madison Group, plus upper (second) evaporite zone of middle unit. Recognized north of Black Hills, reaching greater than 300 feet at South Dakota-North Dakota border. Type section suggested in sec. 21, T. 15 N., R. 30 E., Garfield County, Montana.

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Inv. 28, 2 sheets): Mississippian Charles Formation contains seven salt beds. In descending order, "A" through "F" Mississippian Salts and seventh salt named "X" Salt. In north-central North Dakota, seventh salt is two separate salts (descending): "X" Salt and "XY" Salt. "A" through "F" Salts are located in deepest part of Williston Basin (western one-third of North Dakota and eastern Montana) and are equivalent to Poplar beds. "D" and "F" Salts extend into Canada and are 60 feet and 90 feet respectively. "X" Salt equivalent to Frobisher--Alida beds. "A" Salt is 150 feet thick.

Gardner, L. S., 1959 (Am. Assoc. Pet. Geol., Bull. 43, No. 2, p. 330-332): Charles Formation transitional laterally in subsurface into upper beds of Mission Canyon Limestone (middle unit of Madison Group).

Smith, M. H., 1960 (Am. Assoc. Pet. Geol., Bull. 44, No. 6, p. 959): Changes in nomenclature of Mississippian Madison Group reported by Committee of Mississippian Madison Group of North Dakota Geological Society. Five marker determined intervals and two subintervals defined by log deflection.

Carlson, C. G., and Anderson, S. B., 1970 (N. D. Geol. Surv., Misc. Ser. 28, p. 1842): Charles facies shown to include all of Poplar interval where present and parts of Ratcliffe interval, Midale subinterval, and Frobisher-Alida interval where present.

Sando, W. J., and Dutro, J. T., Jr., 1974 (U. S. Geol. Surv., Prof. Pap. 842, 22 p.): Geographically and stratigraphically restricted to subsurface Williston basin of central and eastern Montana and western part of Dakotas; name was formerly extended to surface rocks in part of central and western Montana and included beds considered to be part of underlying Mission Canyon Limestone.

"Charles salt," "lower" or "last"

Age: Mississippian

Area of extent: Subsurface in Saskatchewan and North Dakota.

Remarks: Informally named in Charles Formation. See also "Ratcliffe beds" and Madison Formation. See also Charles Salt.

History of stratigraphic nomenclature:
North Dakota Geological Society, 1959 (Nesson Anticline of North Dakota: Bismarck, Conrad Pub. Co., p. 9): Base of "last Charles salt" in Stratigraphic section.

"Charles salts" ("A," "B," "C," "D," "E," "F," "X," and "XY")

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Inv. 28, 2 sheets): Mississippian Charles Formation contains seven salt beds. In descending order, "A" through "F" Mississippian salts and seventh salt named "X" Salt. In north central North Dakota, seventh salt is two separate salts (descending): "X" Salt and "XY" Salt. "A" through "F" Salts are in deepest part of Williston Basin (western one-third of North Dakota and eastern Montana) and are equivalent to Poplar beds. "D" and "F" Salts extend into Canada and are 60 and 90 feet thick. "X" Salt equivalent to Frobisher--Alida beds. "A" Salt is 150 feet thick.

See Charles Formation of Madison Group and Charles Salt, lower or last.

C Lignite bed (of LUDLOW FORMATION)

King, J. W., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 85): C lignite bed is 50 feet below top of Ludlow Formation.

CLOVERLY GROUP

Age: Lower Cretaceous.

Area of extent: Central, eastern, and northern Wyoming, North Dakota, and central-southern Montana.

Lithology: Varicolored claystone with basal, coarse-grained, massive sandstone.

Thickness: Up to 125 feet.

Relationships to other units: Conformably to disconformably overlain by lower Dakota or Fall River Sandstone; disconformably overlies Morrison. Equivalent to Fuson Shale of Black Hills and Kootenai of Montana and Alberta.

Characteristic fossils: Gastropods and plant fossils.

Economic significance: Oil productive in Montana.

Depositional environment: Fluvial, alluvial.

Remarks: Named for exposures near Cloverly post office on east side of Big Horn basin, Wyoming.

History of stratigraphic nomenclature:
Darton, N. H., 1904 (Geol. Soc. Am., Bull. 15, p. 394-401): Cloverly Group is varicolored claystone of red-purple-green and gray with basal, coarse-grained, massive sandstone in Bighorn Mountain area.

North Dakota Geological Society, 1954 (Stratigraphy of the Williston Basin: Conrad Pub., Bismarck): Cloverly Group consists of Lakota, Fuson, and Dakota Formations in Williston basin of North Dakota.

Coalbank coal bed (of BULLION CREEK FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 91): Coalbank Coal Bed is exposed along Coalbank Creek and is mappable for a distance of 10 miles along valley of Cannonball River and 15 miles along Coalbank Creek.

Coal Creek bed (of BULLION CREEK FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 256): Coal Creek Bed is named for exposures along Coal Creek. Consists of lignite 35-40 feet below Stanton Bed; may be equivalent to Hazen B bed.

COLGATE LITHOFACIES, Member (of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: Central-eastern Montana, southwestern North Dakota.

Lithology: White to yellowish (weathered), fine- to medium-grained sandstone.

Thickness: Up to 110 feet.

Relationships to other units: Conformable with overlying Lance or conformable and unconformable with overlying Hell Creek; locally unconformable on underlying sandstone and shale of Fox Hills.

Characteristic fossils: Plant remains.

Depositional environment: Brackish to shoreline marine.

Remarks: Type locality is near Colgate Station on Northern Pacific Railway, Dawson County, Montana. See also Iron Lightning Member.

History of stratigraphic nomenclature:

Calvert, W. R., 1912 (U. S. Geol. Surv., Bull. 471, p. 189-198): Basal Colgate sandstone member of Lance formation is 185 feet of white and yellowish sandstone. Exposed on both sides of Cedar Creek Anticline, Dawson County, Montana. Near Iron Bluff (NE part of T. 14 N., R. 55 E.), consists of descending): 1) 35 feet of massive white sandstone, 2) 75 feet of brown sandstone forming summit of Iron Bluff, with fossil leaves at base, and 3) 75 feet of shale and sandstone with fossil leaves in upper 20 feet. Overlies Pierre Shale; underlies, with local unconformity, 500 feet of somber-colored clay and lenticular sandstone with few lignite beds of Lance Formation. Appearance of transition between Colgate and Pierre, suggesting that Colgate occupies same stratigraphic position of Fox Hills but fossil leaves indicate late age, placing it in Lance Formation.

Thom, W. T., Jr., and Dobbin, C. E., 1924 (Geol. Soc. Am., Bull. 35, p. 484-497): Colgate sandstone member redefined as upper white sandstone of Fox Hills, typically developed between Colgate Station and Glendive, Montana and exposed along Cedar Creek Anticline and elsewhere in eastern Montana. Colgate is 35 feet of white sandstone

and forms top of lower 75 feet of sandstone of Iron Bluff; ferruginous matter leached from Lance masked usual white color. Halymenites major casts and fossil leaves in exposure along Cedar Creek Anticline. Colgate is gradational, into underlying marine strata on Little Beaver Creek, south of Baker, Montana; is strikingly developed along Missouri River between Hell Creek and Musselshell River. Fluvatile basal sandstone of Lance in central Montana is probably equivalent to Colgate sandstone and upper white sandstone of Fox Hills but has not been traced.

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, 110 p.): 17-40 feet of Colgate sandstone Member at top of Fox Hills Sandstone in Marmarth lignite field, North Dakota.

Waage, K. M., 1961 (Wyo. Geol. Assoc., 16th Ann. Field Conf., p. 237): Facies relationships between Bullhead and Colgate are source of mapping confusion, as lenses of Colgate-like sand occur in lower Bullhead, as well as at top, in north-central South Dakota. Colgate and upper part of banded beds are lateral facies.

Feldman, R. M., 1967 (Ph.D. Dissert., Univ. N. D., 366 p.): In North Dakota, Colgate is light greywacke sandstone. Members were deposited penecontemporaneously with Timber Lake sediment that represents normal marine deposition; Bullhead represents brackish deposition, and Colgate represents strandline deposition.

Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist., Bull. 27, p. 122-124): Upper part of Iron Lightning Member is clayey, grayish-white sand with brackish-water fauna named Colgate lithofacies (reduced from member rank). Lateral transition to Bullhead lithofacies.

Erickson, J. M., 1971 (Ph.D. Dissert., Univ. N. D., p. 26): Colgate lithofacies recognized in south-central North Dakota.

COLORADO GROUP, Shale, Formation

Age: Early and Late Cretaceous.

Area of extent: Montana, North Dakota, South Dakota, Wyoming, Colorado, Nebraska, Kansas, Iowa, and New Mexico.

Lithology: Dark gray to gray-black shale. Some siltstone and sandstone and limy beds locally.

Thickness: Up to 2200 feet.

Relationships to other units: Disconformably overlies Kootenai or Cloverly Formations and is disconformable to conformable with overlying Telegraph Creek.

Characteristic fossils: Inoceramus, Scaphites.

Economic significance: None.

Depositional environment: Relatively stable marine over wide area with local fluctuations; sporadic, but much wind-blown ash.

Remarks: Type locality along eastern base of Front Range, Colorado.

History of stratigraphic nomenclature:
Hayden, F. V., 1876 (U. S. Geol. and Geo. Surv. Terr., 8th Ann. Rep., p. 45): Nos. 2, 3, and 4 of Cretaceous (Fort Union, Niobrara, and Fort Pierre divisions) may be regarded as one group, under name of Colorado Group as adopted by Clarence King, 1876 (U. S. Geol. Expl. 40th Paral., Atlas, map 1). Underlain by Dakota Group and overlain by Fox Hills Group. Exposed along eastern base of front of Colorado range.

White, C. A., 1878 (U. S. Geol. and Geog. Surv. Terr., 10th Ann. Rep., p. 21-22, 30): Colorado Group includes equivalents of No. 2 (Fort Benton) and 3 (Niobrara) of Meek and Hayden's original section, leaving No. 4 (Fort Pierre Group) to be included with strata of Fox Hills Group.

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, pl. 1): Base of Colorado Group is contact between Mowry and Belle Fourche Shale.

Coteau bed (of BULLION CREEK FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 148): Coteau Bed is thick bed of coal in extreme southeast corner of Ward County. Named for Missouri Coteau.

Crow Creek Member (of PIERRE SHALE)

Age: Late Cretaceous.

Area of extent: South Dakota.

Lithology: Basal sand; marl.

Thickness: Up to 15 feet.

Relationships to other units: Overlies Gregory Member; underlies Oacoma zone.

Characteristic fossils: Gümbelina-Globigerina microfauna.

Depositional environment: Marine.

Remarks: Type locality at and south of the mouth of Crow Creek, southwestern Buffalo County, South Dakota. See also Pierre Shale, Gregory Member, and Sully Member.

History of stratigraphic nomenclature:

Gries, J. P., and Rothrock, E. P., 1941 (S. D. Geol. Surv., Rept. Invest. 38, p. 5, 14-17): Basal sand and chalk beds of Sully Member previously correlated with Gregory chalk of Rosebud Bridge section. Sully marl actually correlates with upper marl (Gregory chalk). Therefore, Gregory name cannot also apply to lower calcareous zone. Crow Creek zone proposed for sand and marl at base of Sully Member.

Crandell, D. R., 1950 (Am. Assoc. Pet. Geol., Bull. 34, no. 12, p. 2345): Crow Creek, Verendrye, and DeGrey named as members. Sully usage abandoned. Type locality designated.

Stevenson, R. E., 1951 (Geol. Soc. Am., Bull. 62, p. 1542): Crow Creek marl facies of Sully Member shows greatest variation in Charles Mix and Gregory Counties, South Dakota. Crow Creek of marl and chalk with quartz grains, separated locally by Gregory clay into two marls. Base is sandy marl. Gümbelina-Globigerina microfauna.

Crandell, D. R., 1952 (Am. Assoc. Pet. Geol., Bull. 36, p. 1754-1765): Crow Creek Member of Pierre Shale is basal 10-15 inch sandstone with overlying 7-10 feet of marl. Crow Creek of marine origin because of presence of Foraminifera.

Agnew, A. F., and Tychson, P. C., 1965 (S. D. Geol. Surv., Bull. 14, p. 64): Authors' note of recent unpublished stratigraphic work by L. G. Schultz of United States Geological Survey (summer, 1963) indicates upper marl zone (in Oacoma facies of DeGrey Member) in Gregory County and east, has erroneously been called Crow Creek in past. True Crow Creek is lower marl, lies below Oacoma facies, and rests on very thin Gregory Member overlying Sharon Springs. Crow Creek recognized by presence of quartz sand zone at base.

CROWGHOST MEMBER (of HELL CREEK FORMATION)

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 33-34): Crowghost Member consists of lignitic, bentonitic sediments, mostly shales, with few sandstones, siderite nodules weathered to limonite common. Overlies Colgate or Bullhead Member of Fox Hills Formation, underlies Breien Member. Named from Crowghost Cemetery; type section is center sec. 33, T. 134 N., R. 82 W., Sioux County, North Dakota. Can interfinger with Bullhead Member of Fox Hills and probably also interfingers with Breien Member. Ranges from 6 feet thick in central Emmons County to 31 feet thick at type section in Sioux County.

DAKOTA GROUP, Sandstone, Formation

Age: Lower Cretaceous.

Area of extent: Montana, North Dakota, South Dakota, Wyoming, Nebraska, Kansas, Colorado, Northwestern Oklahoma, and northeastern New Mexico.

Lithology: Gray to white, fine-grained sandstone, partly micaeous and with euhedral grains. Interbedded with gray siltstone and dark gray, partly carbonaceous shale. At type locality formation is "peanut brittle" conglomerate.

Thickness: Up to 100 feet in central Williston Basin.

Relationships to other units: Disconformable, at least in part, with underlying continental beds of Kootenai (Fuson) or Lakota. Conformable with overlying black shale of Skull Creek of Wyoming or Black leaf in northwestern Montana. Equivalent to Fall River Sandstone of Black Hills area and Flood Member of Blackleaf Formation in Sweetgrass arch area of Montana.

Characteristic fossils: Plant fossils, pelecypods in marine facies.

Economic significance: Oil productive.

Depositional environment: Near shoreline deposit, partly continental, partly marine. Broad shallow seas where slight oscillations brought wide changes in deposition.

Remarks: Type locality near town of Dakota, Dakota County, Nebraska. Other reference sections given by G. E. Condra and E. C. Reed, 1943 (Neb. Geol. Surv., Bull. 14) and W. T. Lee, 1923 (U. S. Geol. Surv., Bull. 751-A).

History of stratigraphic nomenclature:

Meek, F. B., and Hayden, F. V., 1861 (Acad. Nat. Sci., Philadelphia, Proc., v. 13, p. 419-420): Dakota Group (Formation No. 1 of Cretaceous) consists of yellowish, reddish, and occasionally white sandstone, locally with alternations of varicolored clays and lignite beds. Thickness is 400 feet. Occurs in hills near town of Dakota, and is extensively developed in Dakota County (Nebraska) below mouth of Big Sioux River, and extends into Kansas. Underlies Fort Benton Group, of which it may probably be only of member status.

Newton, H., and Jenney, W. P., 1880 (U. S. Geog. and Geol. Surv., Rocky Mountain Region, p. 151-180): Dakota Group includes equivalents of Lakota, Fuson, and Fall River. Forms capping rock on foothills. Coaly plant fossils present. Is Early Cretaceous in age.

Jenney, W. P., 1899, 1901 (U. S. Geol. Surv., 19th Ann. Rep. pt. 2-3, p. 568-593): Dakota usage restricted to upper sandstone of former Dakota Group in northern Black Hills.

Russell, W. L., 1927 (Am. J. Sci., 5th ser., v. 14, p. 402): Dakota Sandstone of Black Hills region is older than true Dakota as is Fall River Formation. Overlies Fuson Formation and underlies Graneros Shale.

Rubey, W. W., 1931 (U. S. Geol. Surv., Prof. Pap. 165-A, p. 5): Fall River Sandstone is Dakota Sandstone of previous reports in Black Hills region. Is top formation of Inyan Kara Group, of Early Cretaceous age. Conformably underlies Graneros Shale and overlies Fuson. Is continental deposit except upper 20 feet, which contains marine fossils.

Ballard, N., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 10, p. 1562): Strata of Dakota Group crop out as hogbacks surrounding Black Hills and are present throughout Dakotas in subsurface. Dakota Group consists of upper unnamed sandstone member, middle or Fuson Shale Member, and lower or Lakota Sandstone Member. Maximum thickness is 725 feet.

Gries, J. P., 1954 (Am. Assoc. Pet. Geol., v. 38, no. 1, p. 446-449): Term "Dakota" used for thick sandstone sequence in central South Dakota, where called "true Dakota," and where it overlies Skull Creek Shale, "true Dakota" is age-equivalent of Newcastle-Mowry interval and what is called Dakota in Williston basin to north is actually Fall River Sandstone.

Waage, K. M., 1955 (U. S. Geol. Surv., Prof. Pap. 274-B, p. 15-49): Dakota Group applied to pre-Benton sandstone and shale sequence in northern Front Range of Colorado can be correlated with strata including Lakota (below) and Newcastle (above). Dakota Group is strictly a rock term and age should be irrelevant to usage.

Sandberg, C. A., 1962 (U. S. Geol. Surv., TEI-809, p. 94-95): Dakota Group of Williston basin includes only what Inyan Kara Group comprises in Black Hills--Lakota and Fall River.

"Dakota silt"

Informal term applied in subsurface to uppermost, silty part of Fall River Formation. Wulf, G. R., 1962 (Am. Assoc. Pet. Geol., Bull. 46, no. 8, p. 1370) noted that "Dakota silt" should be abandoned because Dakota had been used in different sense previously.

DAWSON BAY FORMATION (of BEAVERHILL LAKE GROUP)

Age: Middle Devonian.

Area of extent: Williston basin.

Lithology: Brown to dark brown, fossiliferous limestone grading downward to gray-brown, argillaceous limestone. Entire section may be partly or completely dolomitized; dolomitization becomes more complete outward from center of Williston basin. At base is gray and red, dolomitic shale bed known as "second red bed."

Thickness: Up to 200 feet in north-central North Dakota.

Relationships to other units: Conformably overlies Elk Point Group; conformably underlies Souris River Formation. Disconformably underlies strata in areas on outer margin of basin.

Characteristic fossils: Rare chitiozoans, brachiopods, ostracods, and stromatoporoids.

Economic significance: Oil productive in Montana.

Depositional environment: Open marine.

Remarks: Type locality near Dawson Bay at north end of Lake Winnipegosis.

History of stratigraphic nomenclature:

Baille, A. D., 1953 (Am. Assoc. Pet. Geol., Bull. 37, no. 2, p. 444-452): Dawson Bay Formation is lowest sequence of strata of Manitoba Group. Lower boundary is at base of "second red" and green argillaceous zone that overlies Elk Point Group. Upper boundary marked by top of widespread reefoid and stromatoporoid zone. Thickness is 100-200 feet. In outcrop overlies Winnipegosis Formation; underlies unnamed strata of Beaverhill Lake Group.

Laird, W. M., 1953 (Interstate Oil Compact Quart. Bull., v. 12, no. 2, p. 74): Underlies Souris River Formation (new). Included in Beaverhill Lake Group.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2302-2309): Baille (1953) placed Dawson Bay Formation and overlying unnamed beds approximately equivalent to Souris River Formation, to Manitoba Group. This grouping not recommended for Williston basin of United States because Dawson Bay and Souris River Formations are readily separable. Dawson Bay Formation is less than 1 foot to 185 feet; thickest along international boundary and in north-central North Dakota. Underlies approximately same area as Elk Point Group in Williston basin and northeastern Montana but extends slightly beyond limit of Winnipegosis Formation. Overlies Prairie Formation of Elk Point Group; underlies Souris River Formation. Does not outcrop in United States.

DEADWOOD FORMATION

Age: Late Cambrian to Early Ordovician.

Area of extent: North Dakota, South Dakota, northeast Wyoming, southeast Montana.

Lithology: Sandstone, shale, and carbonates.

Thickness: Up to 1000 feet.

Relationships to other units: Overlain by Winnipeg Formation; unconformably overlies Precambrian crystalline rocks and conformably (?) underlies Aladdin Sandstone. Roughlock Siltstone, uppermost part of original Deadwood underlies Late Ordovician Whitewood Dolomite unconformably. Deadwood (restricted) is equivalent to Cambrian part of Zartman Member of Emerson Formation of central Montana.

Characteristic fossils: Faunizones of Late Cambrian, Crepicephalus, Aphelaspis, Elvinia, Conaspis, and Ptychaspis-Prosaukis faunizones are known. Distacodid conodonts are present.

Economic significance: None.

Depositional environment: Shallow marine.

Remarks: Type locality is Whitewood Canyon at Deadwood, South Dakota.

History of stratigraphic nomenclature:

Darton, N. H., 1901 (U. S. Geol. Surv., 21st ann. Rep., pt. 4, p. 505): Deadwood Formation consists of red-brown quartzite and sandstone, locally conglomeritic and partly massive. Upper part is thinner-bedded softer sandstone, interbedded with shale in places. Basal member is usually hard, massive, reddish-brown quartzite; portions of basal beds are conglomeritic. Rests unconformably on Precambrian granites and schists and underlies Englewood Limestone (Mississippian).

McCoy, M. R., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 45-47): Changed Scolithus Sandstone to Aladdin Sandstone and took it out of Deadwood Formation. Thickness of revised Deadwood is 350 feet.

Carlson, C. G., 1960 (N. D. Geol. Surv., Bull. 35, p. 49-50): Deadwood Formation of North Dakota includes all pre-Winnipeg sedimentary rocks. Consists of sandstone, shale, and carbonates of Late Cambrian to Early Ordovician age. McCoy's (1952) correlation of Aladdin with lower sand member of Winnipeg is erroneous.

Sandberg, C. A., 1962 (U. S. Geol. Surv., TEI-809, p. 23-27): Deadwood consists of basal, grayish-red, conglomeritic, quartzitic,

sandstone and remainder is interbedded greenish-gray and gray shale, gray limestone and limestone-pebble conglomerate, and light-gray, grayish-red, and brownish-red sandstone and siltstone, which grades eastward into mainly sandstone. Is Late Cambrian in age.

DEGREY MEMBER (of PIERRE SHALE)

Age: Late Cretaceous

Area of extent: Central South Dakota, North Dakota.

Lithology: Shale, clay, and bentonite.

Thickness: Up to 160 feet.

Relationships to other units: Overlies Crow Creek Member; underlies Verendrye Member.

Type section: Cutbank of Missouri River, 2 miles south of DeGrey in western edge of NW¼ sec. 8, T. 109 N., R. 75 W., Hughes County, South Dakota. Named after DeGrey Post Office.

History of stratigraphic nomenclature:

Crandell, D. R., 1950 (Am. Assoc. Pet. Geol., Bull. 34, p. 2341-2346): No representative type section of Agency-Oacoma zone: DeGrey Member proposed for unit. Verendrye and Crow Creek raised to member rank. Sully no longer used. DeGrey is 82 feet of shale, clay, and bentonite. Top placed on horizon between "gumbo-forming" shale of overlying Verendrye Member and "step-forming" shale of DeGrey Member. Base of member is between noncalcareous shale of DeGrey Member and calcareous beds of underlying Crow Creek Member.

Wilson, E. E., 1958 (Master's Thesis, Univ. N. D., 134 p.): Pierre Shale along northern Sheyenne River and in Stutsman County may be equivalent to Verendrye and DeGrey Members of South Dakota.

Robinson, C. S., Mapel, W. J., and Cobban, W. J., 1959 (Am. Assoc. Pet. Geol., Bull. 43, p. 101-123): Monument Hill Bentonitic Member fossils found in DeGrey Member of Pierre of central South Dakota.

Gill, J. R., and Cobban, W. A., 1965 (U. S. Geol. Surv., Prof. Pap. 392A, 20 p.). DeGrey Member exposed along Sheyenne River Valley in North Dakota and along South Branch of Park River.

Des Lacs bed (of BULLION CREEK FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 146): Des Lacs Bed is only coal bed mined in Ward County. Is 4-6 feet thick.

"Devils pocket formation"

See Amsden Formation.

"Devonian 'A'"

See "Nisku" Formation.

"Devonian 'B'"

See Duperow Formation and "Woodbend equivalent."

"Devonian 'C'"

See Souris River Formation and "Beaverhill Lake equivalent."

"Devonian'F'"

See Elm Point Formation.

"Dickinson lithozone"

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Dickinson lithozone is middle unit of Amsden Formation. Lithologic markers delineating unit are anhydrite or anhydritic dolomite at top and bottom; is 0-140 feet thick. Contacts appear to be conformable with overlying and underlying strata, but presence of extensive anhydrite marker units appear to reflect evaporative conditions over wide areas and possible concentration of sulfates associated with hiatus. Overlies Medora lithozone; underlies Bismarck lithozone, Broom Creek, Opeche, Spearfish, or Piper Formations. Equivalent to much of Hayden Group in Hartville area.

See also Amsden Formation.

DICKINSON MEMBER

Hickey, L. J., 1966 (The paleobotany and stratigraphy of the Golden Valley Formation in western North Dakota: Ph.D. Dissert.,

Princeton, 265 p.): Dickinson Member is upper member of Golden Valley Formation; consists of soft, kaolinitic clays, silts, sands and lignite. Yellow color predominates and is result of oxidation of iron; flakes of mica are in silts and sand; and lignites up to 6 feet thick although none extend laterally more than few miles. Lies above Alamo Bluff lignite. Is unconformably overlain by White River Formation; is unconformably and conformably underlain by Hebron Member of Golden Valley Formation. Type area is south and west of town of Dickinson in Stark County, sec. 20, T. 139 N., R. 96 W., and secs. 29 and 32, T. 139 N., R. 97 W., and secs. 14, 21-23, T. 138 N., R. 98 W. Dickinson Member has best developed channel and interchannel facies of Golden Valley Formation.

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. 63-66): Dickinson Member is lowest member of Brule Formation. Consists of 60-130 feet of clay, cross-bedded sandstone, and pitted-weathering, silty claystone. Conformably lies above South Heart Member of Chadron Formation; conformably underlies Schefield Member of Brule Formation or younger deposits. Contains 5-9 feet of fossiliferous, cross-bedded sandstone named Fitterer Bed. Type section is small butte about ¼ mile northeast of Fitterer Ranch house in NWSE sec. 7, T. 137 N., R. 97 W., Stark County, North Dakota.

See also Camels Butte Member.

D lignite bed (of LUDLOW FORMATION)

King, J. W., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 85): D lignite bed is 10 feet below top of Ludlow Formation.

Dunham salt

Age: Jurassic.

Area of extent: North Dakota, northeastern Montana.

Lithology: Anhydrite and mudstone.

Thickness: Up to 100 feet.

Relationships to other units: Conformably overlies Saude Formation.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Evaporitic.

Remarks: See also Saude Formation, Pine Salt, Spearfish Formation, and Triassic "A" salt.

History of stratigraphic nomenclature:
Zeiglar, D. L., 1955 (N. D. Geol. Soc., South Dakota Black Hills Field Conf., Gdbk., p. 53): Dunham Salt consists of evaporites overlying Saude Formation conformably. 0-100 feet thick. Slight erosion of upper part of Saude occurs locally.

Dow, W. G., 1964 (3rd Williston Basin Sym., Conrad, Bismarck, N. D., p. 127-131): Dunham salt, formerly of Spearfish Formation, is considered to be facies of lower evaporite unit of Piper Formation and is Jurassic in age.

Dunn Center bed (of SENTINEL BUTTE FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 83): Dunn Center Bed is one of thickest coal beds in Dunn County. Named for town of Dunn Center.

DUPEROW FORMATION

Age: Late Devonian.

Area of extent: East of Rocky Mountains in Montana, north-central Wyoming, and Williston basin portion of Saskatchewan, North Dakota, and South Dakota.

Lithology: Brown limestone, commonly dolomitized to sucrosic porous. Thin gray shale and green-gray dolomite layers are common.

Thickness: Up to 600 feet.

Relationships to other units: Rests conformably on Souris River Formation and unconformably on Silurian or older beds. Nisku or Birdbear Formation conformably overlies persistent shale bed of uppermost Duperow. Equivalent to Woodbend Group of Alberta and all but upper part of Jefferson Formation of western Montana.

Characteristic fossils: Algae, brachiopods, and corals. Amphipora locally common.

Economic significance: Oil productive along Nesson anticline in North Dakota.

Depositional environment: Marine.

Type section: Hunt No. 1 Olsen, sec. 18, T. 163 N., R. 77 W., Bottineau County, North Dakota. Standard subsurface section is at depth of 10,400 to 10,743 in Mobil #1 Birdbear oil test in sec. 22, T. 149 N., R. 91 W., Dunn County, North Dakota (Owen, J. R., 1952, Oil in Canada, v. 5, no. 1, p. 54).

History of stratigraphic nomenclature:

Powley, D., 1951 (M. S. Thesis, Univ. Sask.): Duperow defined from Tidewater No. 1 Duperow Crown Well in southwest Saskatchewan. Is equivalent to all but lower part of Beaverhill Lake Formation and is not mappable over much of Williston basin.

Stanton, M. S., 1953 (Billings Geol. Soc., Gdbk., 4th Ann. Field Conf., p. 62): Duperow is thick series of carbonates, normal marine to fossil-fragmental limestone, dolomitized limestone, and dolomite, with anhydrite and minor shale; argillaceous phases are common and minor silty carbonates present. Limestone is characteristically light-gray to gray-brown, microcrystalline to fine-crystalline, and dense. Duperow Formation includes strata above well-defined gamma-ray "kick" marking upper limit of Souris River Formation to top of gamma-ray marker at base of "Nesker" (Nisku) Formation. Thickness is 50-500 feet.

Towse, D., 1953 (N. Geol. Surv., Rep. Invest. 12, 1 sheet): Devonian "B" of earlier North Dakota Geological Survey reports is equivalent to Duperow Formation or "Woodbend equivalent" of this report.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2315-2318): Through misunderstanding of Powley's (1951, unpub.) definition, Duperow was considered to be equivalent to Woodbend Formation of Late Devonian age which overlies Beaverhill Lake Formation of Alberta. In 1953, Williston Basin Nomenclature Committee of American Association of Petroleum Geologists abandoned usage of Duperow Formation according to Powley and applied name to overlying lithologic unit. Consists of medium- to brownish-gray, dense to microcrystalline limestone, brownish gray, finely crystalline dolomite, and white to brownish-gray anhydrite, interbedded with thinner beds of greenish-gray dolomitic shale, very fine-grained siltstone, and sandy argillaceous dolomite. Maximum thickness is 600 feet in north-central and northeastern Montana. Standard subsurface section designated. Overlies Souris River Formation; underlies Birdbear Formation (new); is in Jefferson Group. Contains Late Devonian fossils.

"Dynneson sand" (of MOWRY SHALE)

Wulf, G. R., 1962 (Am. Assoc. Pet. Geol., Bull. 46, no. 8, p. 1396-1402): Mowry Shale of Williston basin divided into two units separated by bentonite bed. Lower unit (Dynneson unit) is shale with two prominent sandstone lithofacies, Dynneson (of Williston basin) and Bow

Island (of northwest Montana). Dynneson unit marked by unconformity at top of Skull Creek. Where Dynneson sand absent, unit is called "lower Mowry." Dynneson Sandstone Member is blanket-type sandstone with shoe-string sandstone bodies at top. Grains are light-gray and fine in size.

EAGLE SANDSTONE (of MONTANA GROUP)

Age: Late Cretaceous.

Area of extent: Montana, Wyoming, and North Dakota.

Lithology: White, fine- to medium-grained sandstone, individual cliff-forming beds up to 50 feet thick in outcrop, and gray sandy shale and some interbedded lignite seams.

Thickness: Up to 300 feet.

Relationships to other units: Probably conformable with underlying Telegraph Creek; disconformably overlain by Claggett Shale.

Characteristic fossils: Scaphites hippocrepis, pelecypods, plant fossils.

Economic significance: Produces gas; can also be important aquifer.

Depositional environme nt: Neritic to lagoonal to brackish.

Remarks: Type locality is along Missouri River near confluence with Eagle Creek, 40 miles east of Fort Benton.

History of stratigraphic nomenclature:
Weed, W. H., 1899 (U. S. Geol. Surv., Folio 55): Eagle Sandstone consists of sandstone, shale with interbedded lignite and coal seams.

Laird, W. M., and Towse, D. F., 1949 (N. D. Geol. Surv., Rep. Invest. 2, 2 sheets): Eagle Sand shown to produce gas at several localities in North Dakota.

East Tioga clay bed

See Golden Valley Formation.

E lignite bed (of Tongue River Formation)

King, J. W., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf.,

p. 85): E lignite bed is 60 feet above Tongue River Formation basal contact. Tongue River is 600 feet thick in section.

ELK BUTTE MEMBER (of PIERRE SHALE)

Age: Late Cretaceous

Area of extent: South Dakota, Wyoming, and North Dakota.

Lithology: Gray shale; weathers to thin flat polygonal chips with submetallic luster.

Thickness: Up to 310 feet.

Relationships to other units: Grades into overlying Fox Hills Sandstone; underlain by Mobridge Member of Pierre Shale.

Type section: Along U. S. Highway 12, between 1 -5 miles west of Wakpala, Corson County, South Dakota. Type location is actually on Rattlesnake Butte (Agnew and Tychsen, 1965). See also Pierre Shale.

History of stratigraphic nomenclature:
Searight, W. V., 1937 (S. D. Geol. Surv., Rept. Invest. 27, p. 50-55): Elk Butte Member is 60-310 feet of fine-textured, medium-gray shale that weathers to fine, thin, flat, polygonal chips with submetallic luster. Gradational contact with overlying Fox Hills Sandstone; basal beds are noncalcareous shale that overlie buff, calcareous shale of Mobridge Member.

Fisher, S. P., 1952 (N. D. Geol. Surv., Bull. 26, p. 8-10): Most of Pierre Shale in Emmons County is Elk Butte Member.

Wilson, E. E., 1958 (Master's Thesis, Univ. N. D., 134 p.): Emmons County has equivalent strata of Elk Butte Member.

ELK POINT GROUP, Formation

Age: Middle Devonian.

Area of extent: Alberta Basin and central part of Williston basin.

Lithology: Red shale, anhydritic dolomite, thin argillaceous limestone, and varying amounts of salt.

Thickness: 1557 feet at type locality, thinning to 1520 feet to west and southwest. To east in Williston basin, Elk Point Group reaches 750 feet.

Relationships to other units: Conformably underlies Dawson Bay Formation of Late Devonian or Waterways Formation of Alberta. Unconformably overlies Silurian, Ordovician, Cambrian, or Precambrian rocks. May be equivalent to Ghost River Formation of Alberta Rocky Mountain area.

Characteristic fossils: Algae, stromatoporoids, Amphipora.

Economic significance: Potash deposits in Saskatchewan.

Depositional environment: Oxidizing environment and reworking indicated for basal red beds followed by normal marine carbonate and restricted marine evaporite deposition.

Remarks: Type locality at Elk Point area of east-central Alberta. See also Ashern, Elm Point, Winnipegosis, and Prairie Formations.

History of stratigraphic nomenclature:

McGehee, J. R., 1949 (Am. Assoc. Pet. Geol., Bull. 33, no. 4, p. 603, 606-611): Elk Point Formation underlies thick section of Late Devonian strata and overlies Ordovician, Cambrian, or Precambrian rocks. Consists of two conspicuous red shales, anhydritic dolomites, and thin, slightly ofssiliferous, argillaceous, silty limestones, and one to three shale members. Maximum thickness is 1550 feet. Formation is probably Silurian in age but upper part of formation is Middle Devonian.

_____. 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 64): Recent wells in southern Saskatchewan, southwestern Manitoba, eastern Montana, and North Dakota show sequence of strata believed to be equivalent to Elk Point Formation of Alberta Plains. Dominant lithology is evaporite; underlies thick section of Late Devonian and late Middle Devonian carbonate rocks. Similarity in lithology and position indicates Elk Point age for evaporite portion of deposits.

Belyea, H. R., 1952 (Can. Geol. Surv., Pap. 52-27, p. 7-12): Rank-raised to group but subdivisions not named.

Baille, A. D., 1953 (Am. Assoc. Pet. Geol., Bull. 37, no. 2, pp. 444-452): Term "Elk Point Group" applied to basal major Devonian unit in Williston basin. Group approximately equivalent to Elk Point Formation in Alberta. In Williston basin, Elk Point Group includes (ascending) Ashern, Elm Point, and Winnipegosis Formations of outcrop area and subsurface equivalents and also Middle Devonian salt and anhydrite section named Prairie Evaporite (new). Upper limit is top of evaporite section or top of Winnipegosis Formation where evaporite not present; underlies Manitoba Group. Is Middle Devonian in age.

Williston Basin Correlation Committee, unpublished, February 18, 1953. Elk Point Group consists of marine carbonates and evaporite beds. Of four groups of strata of Devonian age, Elk Point Group exhibits

greatest degree of shelf and basin differentiation. Divided into three formations (ascending): Ashern, Winnipegosis, and Prairie. Maximum thickness is 800 feet near Saskatoon.

Baille, A. D., 1955 (Am. Assoc. Pet. Geol., Bull. 39, no. 5, p. 590): Middle Devonian evaporitic section of Williston basin is part of sequence divided into several lithologic units of formation rank, is proposed to designate strata that include such formations as Elk Point Group. Formations included are (ascending): Ashern Formation, Elk Point Limestone, Winnipegosis Formation, and Prairie Evaporite.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2302-2307): In United States portion of Williston basin and adjacent areas, Elk Point Group consists of Winnipegosis Formation and overlying Prairie Formation. Underlies Dawson Bay.

ELLIS GROUP

Age: Middle and Late Jurassic.

Area of extent: Montana, North Dakota and Alberta.

Lithology: Fossiliferous, dense, dark-gray, shaly limestone interbedded with calcareous, medium-gray shale overlain by light-gray, thick-bedded fine- to coarse-oolitic limestone and maroon and olive-green, mottled, silty, shale, overlain by thin- to thick-bedded, fine-grained, pebbly, calcareous, glauconitic, fossiliferous, sandstone and interbedded fossiliferous limestone.

Thickness: Varies widely; 289 feet at type locality.

Relationships to other units: Unconformably overlies Triassic to Mississippian strata and conformably underlies Late Jurassic Morrison Formation. Equivalent to Sundance and Gypsum Springs Formations of Wyoming and South Dakota; to Vanguard, Shaunavon, Gravelbourg, and Watrous Formations of Saskatchewan; to part of Fernie Group of Canadian Rockies; to Stump Sandstone, Preuss Sandstone, and Twin Creek Limestone of southeastern Idaho.

Characteristic fossils: Ostrea strigilecula, Eumicrotis curta, Cardioceras (?) sp., Gryphaea nebrascensis, Camptonectes sp., Pentacrinus sp., Pholadomya sp., Arctica (?) sp., Kepplerites sp., and others.

Depositional environment: Shallow marine.

Type section: North side of highway, in Rocky Canyon about 3.7 miles southeast of site of Fort Ellis, or 7 miles southeast of Bozeman Court House, sec. 19, T. 2 S., R. 7 E., Gallatin County, Montana.

History of stratigraphic nomenclature:

Peale, A. C., 1893 (U. S. Geol. Surv., Bull. 110, map): Ellis Formation overlies Quadrant Formation and underlies Cretaceous strata in vicinity of Three Forks, Montana.

Iddings, J. P., and Weed, W. H., 1894 (U. S. Geol. Surv., Folio No. 1, Livingston): Ellis limestone consists of sandy limestone underlain by Myacites beds (impure fossiliferous limestones or soft, earthy, dark-gray calcareous rocks, with sandstones at base). Thickness 400 feet. At Cinnabar Mountain, Myacites beds rest upon massive cross-bedded, ripple-marked sandstone, underlain by bright-red sandstone that may be equivalent to Red-bed sandstones of more southern localities. Underlies Dakota Formation and overlies Quadrant quartzite.

Peale, A. C., 1896 (U. S. Geol. Surv., Folio No. 24, Three Forks): Basal part of Ellis Formation (Juratriassic) consists of 40-60 feet of nonfossiliferous quartzitic sandstone which may be Juratriassic or possibly Carboniferous. Above basal quartzite is argillaceous limestone, many beds crowded with Jurassic fossils. Middle and upper parts of formation are more arenaceous and devoid of fossils. Total thickness 300-500 feet. Overlies Quadrant Formation and underlies Dakota Formation.

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 1, p. 676): Commonly accepted definition of Ellis Formation applies to Late Jurassic marine strata and excludes any older beds that may inadvertently have been included in earlier mapping.

Cobban, W. A., Imlay, R. W., and Reeside, J. B., Jr., 1945 (Am. Assoc. Pet. Geol., Bull. 29, no. 4, p. 451-453): Thickness 297 feet at type section. Underlies Morrison Formation; overlies Tensleep(?).

Cobban, W. A., 1945 (Am. Assoc. Pet. Geol., Bull. 29, no. 9, p. 1262-1303): Rank raised to group and subdivided into (ascending): Sawtooth, Rierdon, and Swift Formations (all new). Name restricted to marine Jurassic beds. In Sweetgrass Arch area, north-central Montana, unconformably overlies marine Mississippian beds and underlies Upper Jurassic continental deposits (Morrison) or Lower Cretaceous continental deposits (Kootenai). Middle and Upper Jurassic (Bathonian-Argovian).

Imlay, R. W., Gardner, L. S., Rogers, C. P., Jr., and Hadley, H. D., 1948 (U. S. Geol. Surv., Oil and Gas Inv. Prelim. Chart 32, 1 sheet): Group, in south-central Montana, comprises (ascending) Piper (new), Rierdon, and Swift Formations.

Vine, J. D., and Hail, W. J., Jr., 1950 (U. S. Geol. Surv., Oil and Gas Inv. Prelim. Map 108): Group, in Hobson area of central Montana, consists of (ascending): Piper, Rierdon, and Swift Formations. Entire group is less than 100 feet thick; Swift is only formation represented. Overlies Amsden Formation; underlies Morrison Formation.

Peterson, J. A., 1957 (Am. Assoc. Pet. Geol., Bull. 41, no. 3, p. 413, 417): Although five Sundance subdivisions and names of Black Hills are useful there, in Williston and Powder River basins more continuous sedimentation makes nomenclature of Ellis Group more useful. Redwater abandoned for Swift Formation; Lak, Hulett, Stockage Beaver, and Canyon Springs retained as local members of Rierdon Formation. Sundance includes Rierdon and Swift Formations.

ELM POINT FORMATION

Age: Middle Devonian.

Area of extent: Southern Manitoba, Saskatchewan, and North Dakota.

Lithology: Yellow-gray, thin-bedded dolomitic limestone.

Thickness: Up to 100 feet.

Relationships to other units: Unconformably overlies Ashern Formation and conformably underlies originally defined Winnipegosis.

Characteristic fossils: Atrypa arctica.

Economic significance: None.

Depositional environment: Open marine.

Remarks: Type locality is cliffs near Elm Point on eastern shore of Lake Manitoba. Equivalent strata are probably present in most of Williston Basin, but are very difficult to distinguish from Winnipegosis Formation.

History of stratigraphic nomenclature:
Kindle, E. M., 1914 (Can. Geol. Surv., Summ. Rep. 1912, p. 251): Elm Point Formation is beds that crop out in cliffs near Elm Point on eastern shores of Lake Manitoba.

Baille, A. D., 1950 (Manit. Dep. Mines Nat. Resour., Mines Br. Pub. 49-2, 72 p.): Elm Point Formation is 50 feet of yellowish-gray, finely granular, thin-bedded limestone with yellowish brown, dolomitic mottles. Most common fossil is Atrypa arctica. Basal part of formation contains iron sulphide nodules and greenish-gray, dolomitic shales with dark, reddish-brown mottling. Elm Point conformable with overlying Winnipegosis but difficult to differentiate. Winnipegosis redefined to include Elm Point.

Towse, D., 1953 (N. D. Geol. Surv., Rep. Invest. 12, 1 sheet): Devonian "F" of earlier North Dakota Geological Survey Reports is equivalent to Elm Point Formation. Consists of dark-colored, finely-crystalline, shaly mixture of limestone and dolomite lying below Winnipegosis and above Ashern.

Enning Facies

See White Owl Member of Fox Hills Formation.

Fairman bed

Smith, C. D., 1908 (U. S. Geol. Surv., Bull. 381, p. 24): Fairman Bed is coal seam mined at Satterlund Mine.

See also Satterlund-Kugler Bed.

FAIRBANK FORMATION, Tongue (of FOUNTAIN FORMATION)

Age: Pennsylvanian.

Area of extent: Eastern Wyoming, southwestern South Dakota, and north- and west-central North Dakota.

Lithology: Red sandstone or quartzite.

Thickness: 30-100 feet.

Relationships with other units: Underlies Reclamation Group; overlies Pahasapa Limestone; basal tongue of Fountain Formation.

Characteristic fossils: None.

Economic significance: Oil productive.

Depositional environment: Reworked laterite deposits.

Remarks: Type locality is North Platte River, bluffs immediately north and northwest of site of abandoned village known as Fairbank, sec. 27, T. 27 N., R. 66 W., Platte County, Wyo.

History of stratigraphic nomenclature:
Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13A, p. 2-3, 32, 35, and 44): Fairbank Formation, or lower tongue of Fountain Formation, consists of 30-100 feet of red sandstone or quartzite, locally calcareous. Underlies Reclamation Group (new); overlies Pahasapa Limestone. Comprises Division VI of Hartville "Formation" (Condra, G. E., and Reed, E. C., 1935, Nebr. Geol. Surv., Pap. no. 9, p. 11).

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym. Internat., Bismarck, N. D., p. 150-164): Fairbank Formation is basal

Pennsylvanian deposit consisting of sand or sand and red shale. Thickness is 10-20 feet over most of North and South Dakota but reaches 100 feet locally. In Morton County, North Dakota, sands reach thickness of 80 feet and thin, becoming slightly silty and shaly to west, north, and east.

Fairpoint Member (of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: South Dakota.

Lithology: Lower shale, silt and sand sequence, middle sandstone, upper coal facies.

Thickness: Up to 280 feet.

Relationships with other units: Overlies Pierre Shale; locally unconformable with overlying White Owl Creek Member.

Characteristic fossils: Corbicula.

Depositional environment: Deltaic.

Type section: Along east-west road north of Fairpoint between NENWNE sec. 13, T. 9 N., R. 10 E., and NWNWNE sec. 16, T. 9 N., R. 11 E., Meade County, S. D.

Remarks: See Stoneville Member.

History of stratigraphic nomenclature:
Pettyjohn, W. A., 1967 (Am. Assoc. Pet. Geol., Bull. 51, pt. 7, p. 1361-1364): Fairpoint Member consists of (descending): 1) 140 feet of coal facies (Stoneville coal facies), 2) 128-162 feet of compact, uncemented silt and fine- to medium-grained dirty sand, and 3) 20-60 feet of interbedded shale, silt, sand, and sandstone. Channel is at contact between lower banded beds and middle sandstone; channel usually contains 1 foot coquina layer with Corbicula. Type section given.

FALL RIVER SANDSTONE (of DAKOTA GROUP)

Age: Early Cretaceous.

Area of extent: Wyoming, western South Dakota, southwestern North Dakota, and southeastern Montana.

Lithology: White, gray to iron-stained and brown, fine- to medium-grained sandstone with interbeds of dark gray, sometimes carbonaceous shale.

Thickness: Up to 160 feet.

Relationships to other units: Conformable(?) with underlying Fuson or Kootenai Formation; disconformable with marine Skull Creek.

Characteristic fossils: Pelecypods and plant remains.

Economic significance: None.

Depositional environment: Continental environment of deposition with exception of upper 20 feet which contains marine fossils; possibly wide spread shallow embayments containing essentially fresh water.

Remarks: Type locality is Evans Quarry on Fall River, below Hot Springs, South Dakota. See also Dakota Group.

History of stratigraphic nomenclature:

Russell, W. L., 1927 (Am. J. Sci., 5th ser., v. 14, p. 402): Dakota Sandstone of Black Hills region is older than true Dakota and is named Fall River Formation. Overlies Fuson Formation; underlies Graneros Shale.

Russell, W. L., 1928 (Econ. Geol., v. 23, no. 2, p. 136-137): Dakota Sandstone of Black Hills is renamed Fall River Formation as fossil plants indicate older age than typical Dakota Sandstone of eastern Nebraska. Consists of 75 feet of sandstones and interbedded shales underlying Graneros Shale and overlying Fuson Shale. Type locality is at Even's Quarry on Fall River, below Hot Springs, Fall River County, South Dakota.

Rubey, W. W., 1931 (U. S. Geol. Surv., Prof. Pap. 165-A, p. 5): Fall River Sandstone is top formation of Inyan Kara Group of Early Cretaceous age. Consists of continental deposits except for upper 20 feet, which contain marine fossils.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 75): Fall River and Dakota(?) are continuous blanket of sand but lack of subsurface data makes Dakota-Fall River relationship uncertain. Well at Kadoka, South Dakota, suggests that artesian sand there and to west is part of sand wedge coming in from east of about same age as siliceous Mowry Shale farther west. Beneath this sand, Newcastle Sandstone and 180 feet of shale occur beneath Fall River-Fuson-Lakota sequence. Is postulated that true Dakota of Missouri River is Mowry in age and black shale and perhaps Fall River-Fuson-Lakota sequence have wedged out to east. Thickness of Fall River is 54-196 feet.

Waage, K. M., 1958 (Wyo. Geol. Assoc., Gdbk., 13th Ann. Field Conf., p. 71-76): Fall River Sandstone (of Inyan Kara Group) overlies Fuson-Lakota sequence and underlies Skull Creek Sandstone.

Davis, R. E., and Izett, G. A., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 11, p. 2745-2756): Fall River Formation in northern Black Hills consists of 120-140 feet of well-bedded siltstone, silty claystone, and very fine- to fine-grained sandstone, subdivided into three and locally four units. Underlies Skull Creek Shale; overlies sequence of lensing and interfingering continental deposits of claystone, siltstone, and sandstone that seem genetically related to underlying Morrison Formation. Sequence has been referred to as Lakota and Fuson Formations undifferentiated, or Lakota Formation. Separated from underlying rocks by nearly planar surface of transgressive disconformity.

Waage, K. M., 1959 (U. S. Geol. Surv., Bull. 1081-B, p. 26-33): Fall River Formation is redefined so that basal contact conforms to transgressive disconformity and formation becomes upper part of twofold division of Inyan Kara Group here redefined. Type locality redefined to exposures in bluffs in Fall River in area of falls and Evan's quarries that lie on opposite sides of river just above falls. All exposures are in N½ sec. 33, T. 7 S., R. 6 E., Hot Springs quadrangle, Fall River County, South Dakota. Thickness at type locality is 158 feet where it overlies Lakota and underlies Skull Creek. Thickness range is 110-160 feet. Upper conformable contact is abrupt change from sandstone to gray, sandy shale to black shale typical of Skull Creek.

Pettyjohn, W. A., 1960 (S. D. Acad. Sci., Proc., v. 38, p. 34-38): Dakota Group includes Lakota, Fuson, Fall River, Skull Creek, and Newcastle Formations.

Gries, J. P., 1962 (Wyo. Geol. Assoc., Gdbk., 17th Ann. Field Conf., p. 167): Fall River should be recognized eastward from Black Hills as far as overlying marine Skull Creek can be recognized.

Favel Formation

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 993-1010): Favel Formation (Late Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota. Overlies Ashville Formation; underlies Keld Member of Vermillion River Formation.

FIREMOON LIMESTONE MEMBER (of PIPER FORMATION)

Age: Middle Jurassic (Upper Bajocian).

Area of extent: Montana and western North Dakota.

Lithology: Buff to brown, dense to earthy limestone; locally becomes sandy and oolitic.

Thickness: Up to 70 feet.

Relationships to other units: Overlaps Tampico Shale Member and unconformably overlies Madison Limestone. Occasionally in contact with Amsden Formation on Big Snowy Platform. Correlative with middle limestone member of Piper. Transitional with Tampico Shale Member and overlying Bowes Member.

Characteristic fossils: Paleontologic study not completed.

Economic significance: None.

Depositional environment: Marine.

Type section: Interval from 4,618-4,687 feet in Murphy Corp. no. 1 Firemoon well, Center SESE sec. 12, T. 30 N., R. 41 E., Valley County, Montana.

History of stratigraphic nomenclature:
Nordquist, J. W., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 97, and 101-102): Firemoon Limestone Member consists of 69 feet of buff to brown, dense to earthy limestone in type section. Locally becomes sandy and oolitic. On east flank of Sweetgrass Arch, member is dolomitic and cherty. In south-central Montana, unit is thinly-bedded with varicolored claystone and locally gypsum. Pebbly, oolitic and coquinoid limestones are common. Is uniform in thickness. In outcrop, member appears transitional with underlying Tampico Shale Member (new) and overlying Bowes Member (new). In subsurface of northern Montana boundaries are generally sharp. West and south of Bearpaw Mountains, overlaps Tampico Member and uncomformably rests on Madison Limestone. Occasionally in contact with Amsden Formation on Big Snowy platform. Unit correlative with middle limestone member of Piper.

"'First red' bed"

Age: Late Devonian.

See Souris River Formation.

First white specks zone

See Niobrara Formation.

Fitterer bed, sandstone

Skinner, M. F., 1951 (in Bump, J. D., Ed., Soc. Vertebrate Paleont. Gdbk., 5th Ann. Field Conf., Western South Dakota, Aug. Sept., 1951, p. 54): Fitterer channel is 5-9 feet of fossiliferous, cross-bedded sandstone named for exposures on Fitterer Ranch in Stark County, North Dakota.

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Zenozoic (Oligocene and Miocene) deposits in North Dakota. Ph.D. dissert., Univ. N. D., p. 67-69): Fitterer Bed is 5-9 feet of fossiliferous cross-bedded sandstone contained within Dickinson Member of Brule Formation in western Stark County. Lower contact unconformable; upper contact conformable. Is Middle Oligocene (Orellan) in age.

"Flossie lake subinterval" (of Bottineau interval)

Heck, T., 1978 (Mont. Geol. Soc., Williston Basin Sym., 24th Ann. Field Conf., p. 197-198): Flossie Lake subinterval is cyclical in nature like Virden and Whitewater Lake subintervals but cycle does not include oolites. Oolites thought to be absent because of progradation of oolites by marine regression. Is Kinderhookian in age.

FORT PIERRE GROUP

See Pierre Shale.

FORT RICE MEMBER (of HELL CREEK FORMATION)

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 36-37): Fort Rice Member consists of lignitic and bentonitic shales, thin sandstones and siderite nodules that weather to limonite and may be concentrated in zones. Overlies Breien Member and underlies Huff Member. Named from site of previous Army fort 25 miles south of Bismarck; type section is 1 mile north of Huff, in N½ sec. 1, T. 136 N., R. 80 W., Morton County, North Dakota. Fort Rice Member is recognizable only where underlain by Breien Member (Missouri River Valley and tributaries. Dentalium, Discoscaphites, Ostrea, and Corbicula indicate marine, fresh- and brackish-water conditions, probably estuaries.

FORT UNION GROUP, FORMATION

Age: Paleocene.

Area of extent: North Dakota, Montana, Wyoming, northwestern South Dakota, and Colorado.

Lithology: Somber clays and sands; with coal and lignite beds.

Thickness: Up to 2000 feet.

Relationships to other units: Overlies Hell Creek Formation; underlies Golden Valley Formation.

Characteristic fossils: Plant fossils.

Economic significance: Lignite. Possible uranium potential.

Depositional environment: Seaward part of delta.

Remarks: Named for Fort Union, near mouth of Yellowstone River, later lumber from Fort Union used to build Fort Buford downstream, Williams County.

History of stratigraphic nomenclature:

Meek, F. B., and Hayden, F. V., 1862 (Acad. Nat. Sci., Philadelphia, Proc., v. 13, p. 433): Fort Union or Great Lignite Group consists of clay and sand, with round, ferruginous concretions, numerous beds, seams, and local deposits of lignite, and great numbers of dicotyledonous leaves and stems of many genera. Thickness is 200 plus feet. Overlies Fox Hills beds (Cretaceous) and underlies Wind River deposits. Occupies area around Fort Union and north into British possessions and south to Fort Clark. Seen under White River Group on North Platte River above Fort Laramie, and on west side of Wind River Mountains. Is probably Eocene in age.

Meek, F. B., 1876 (U. S. Geol. and Geog. Surv. Terr., Mon. 9, p. lix): Fort Union Group at Fort Union, consists of (descending): 1) 20-30 feet of ferruginous marl, with arenaceous concretions, upper part may contain concretionary sandstone ledges several feet thick; 2) 20 feet of drab, indurated, arenaceous clay; 3) 1 foot of impure lignite, with numerous selenite crystals; 4) 50-70 feet of gray and drab, indurated clay, with locally numerous leaf impressions; 5) 1.5 feet of impure lignite with much silicified wood; 6) 30 feet of gray, indurated sand with clay, numerous fossil beds and many fragments of entire stumps of trees (silicified); 7) 0.33 feet of impure lignite; and 8) 2 feet of yellowish-gray, indurated clay.

Hayden, F. V., 1878 (U. S. Geol. Surv. Terr., Mon. 7, pt. 2, p. iv): "Lignitic Group" included Laramie and Fort Union. Fort Union probably identical with whole, or at least part, of Wasatch Group.

Weed, W. H., 1893 (U. S. Geol. Surv., Bull. 105, 68 p.): Fort Union of Livingston, Montana, divided into (descending): 1) Fort Union Formation (Eocene), 4000-8000 feet of massive, cross-bedded sandstone with gray, silty shales and local lenses of impure limestone. Rests unconformably on Livingston Beds, 7000 feet of assorted and water-worn volcanic material, somber-colored sandstone, shales and grits, which rest unconformably on 1000 feet of massive, light-colored, coal-bearing sandstone and intercalated shales with leaf remains and invertebrates corresponding to Cretaceous Laramie Formation.

Stone, R. W., and Calvert, W. R., 1910 (Econ. Geol., v. 5, p. 551-557, 652-669, 741-764): In Crazy Mountain region, Montana, strata consist of following formations (descending): 1) Fort Union Formation, 4000 feet of massive sandstones and shales, with Lebo Andesitic Member at base; 2) Lance Formation ("Ceratops beds"), 1000-2400 feet of light-gray sandstone and variegated shale; 3) Lennep Sandstone, 250-400 feet of sandstone with intercalated shales that may correspond to Fox Hills Sandstone; 4) Bearpaw Shale; 5) Judith River Formation; 6) Claggett Formation; 7) Eagle Sandstone; 8) Colorado Shale; and 9) Kootenai Formation. Lebo Anesitic Member is 450-2200 feet thick and contains Fort Union (Eocene) fossils.

Dorf, E., 1940 (Geol. Soc. Am., Bull. 51, p. 213-236): Paleobotanical evidence supports known vertebrate evidence in placing boundary between true Lance and "Fort Union" at base of nondinosaur-bearing Tullock, Ludlow, or Bear Formations or their equivalents, at top of Triceratops-bearing Hell Creek or Lance Formations. Table of proposed revision shows Fort Union Group comprises Tullock Formation (equivalent to Ludlow Formation and Cannonball Marine Member) in lower part and several formations (not discussed) in upper part. Overlies Lance Formation (equivalent to Hell Creek Formation). Is Paleocene in age.

Laird, W. M., and Mitchell, R. H., 1942 (N. D. Geol. Surv., Bull. 14, p. 16-23): Fort Union Group of southern Morton County consists of Ludlow, Cannonball, and Tongue River Formations. Overlies Hell Creek Formation. Is Paleocene in age.

Benson, W. E., and Laird, W. M., 1947 (Geol. Soc. Am., Bull. 58, no. 12, pt. 2, p. 1166-1167): Fort Union Formation of North Dakota underlies Golden Valley Formation (new).

May, P. R., 1954 (U. S. Geol. Surv., Bull. 995-G, p. 267-268): Fort Union Group of Wibaux area, Montana and North Dakota, consists of Ludlow, Tongue River, and Sentinel Butte Members. Conformably overlies Late Cretaceous Hell Creek Formation.

Clayton, L. et al., 1977 (N. D. Geol. Surv., Rep. Invest. 59, p. 7-12): Two formations added to Fort Union Group of North Dakota. Slope Formation consists of strata considered to be upper part of Ludlow Formation or part of Tongue River Formation. Bullion Creek Formation consists of strata considered to be equivalent to either

entire Tongue River Formation or lower, middle or upper part of Tongue River Formation.

FOX HILLS FORMATION, Sandstone, "group"

Age: Late Cretaceous.

Area of extent: Eastern Montana, North Dakota, South Dakota, Wyoming and eastern Colorado.

Lithology: Gray to white, fine- to medium-grained, non-calcareous sandstone and clays. Weathers to yellow or brown.

Thickness: Up to 500 feet.

Relationships to other units: Conformable with underlying Pierre. Conformable and unconformable with overlying Hell Creek.

Characteristic fossils: Pelecypods, gastrods, cephalopods, Ophiomorpha, and plant remains.

Economic significance: Possible uranium potential, building stone.

Depositional environments: Marine; shoreline of regressive sea or barrier bar or island-deltaic environments.

Remarks: Type area on Fox Ridge, northwestern Armstrong and southwestern Dewey Counties, South Dakota. See also Linton Member, Colgate lithofacies, Bullhead lithofacies, Trail City Member, Timber Lake Member, Iron Lightning Member, Fairpoint Member, White Owl Creek Member and Stoneville Member.

History of stratigraphic nomenclature:

Meek, F. B., and Hayden, F. V., 1862 (Acad. Nat. Sci. Phila., Proc., v. 13, p. 419, 427): Fox Hills beds (Formation No. 5 of Cretaceous) are 500 feet of gray, ferruginous and yellow sandstone and arenaceous clays. Outcrops at Fox Hills near Moreau River, along base of Bighorn Mountains, and on North and South Platte Rivers. Fox Hills is top formation of Upper Cretaceous in Nebraska (including Wyoming, Montana, and Dakotas). Underlies Tertiary Fort Union or Great Lignite Group; overlies Fort Pierre group (Pierre Shale of present usage).

White, C. A., 1878 (U. S. Geol. Geog. Surv. Terr., 10th Ann. Rep., p. 21, 22, 30): Fort Pierre group (Pierre Shale) transferred from Colorado group to overlying Fox Hills group.

White, C. A., 1879 (U. S. Geol. Geog. Surv. Terr., 11th Ann. Rep., p. 186-187): Fox Hills group, consolidation of Fort Pierre group (Cretaceous No. 4) and Fox Hills group (Cretaceous No. 5), proposed

for Colorado and adjacent territories, but because lithologic and paleontological characteristics cannot delineate separation, Fox Hills will continue to be used in restricted sense according to original authors in Upper Missouri River region.

Eldridge, G. H., 1888 (Colo. Sci. Soc., Proc., v. 3, pt. 1, p. 93 footnote): Montana Group, with approval of C. A. White, introduced to replace Fox Hills broad definition. Original restricted definition of Fox Hills will continue to be used.

Todd, J. E., 1896 (U. S. Geol. Surv., Bull. 144, 71 p.): Fox Hills sandstone in Kidder, Burleigh, and Emmons Counties, North Dakota.

Babcock, E. J., 1901 (N. D. Geol. Surv., 1st Bienn. Rep., p. 23): Fox Hills found adjacent to Missouri River, in Turtle Mountains, and west of Rugby, North Dakota.

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 234): Fox Hills represents last advance of Cretaceous sea into North Dakota. Erosional surface at top of Fox Hills along Little Beaver Creek.

Stanton, T. W., 1910 (Am. J. Sci., 4th ser., v. 30, p. 172-188): Top of Fox Hills contains marine and, in places, brackish fauna (oysters, Anomia and Corbicula). Beds indicate transition between marine unit below and fresh-water unit above. Change in character and thickness of Fox Hills from Colorado to North Dakota may be function of distance from source and variation in topographic expression of source.

Calvert, W. R., 1912 (U. S. Geol. Surv., Bull. 471, p. 187-201): Colgate sandstone member of Lance Formation occupies same stratigraphic position as Fox Hills Formation, but plant fossils indicate Tertiary age. As no other sandstone is present in Bowman County, Fox Hills must not be in Bowman County.

Knowlton, F. H., 1916 (U. S. Geol. Surv., Prof. Pap. 98, p. 87): Flora indicates distinct Upper Cretaceous age and warm, temperate climate.

Thom, W. T., Jr., and Dobbin, C. E., 1924 (Geol. Soc. Am., Bull. 35, no. 3, p. 484-495): Fox Hills includes Colgate Member defined as white upper sandstone, formerly placed as basal member of Lance Formation.

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, 110 p.): 17-40 feet of Colgate Sandstone Member at top of Fox Hills Sandstone at Marmarth lignite field, North Dakota.

Dobbin, C. E., and Reeside, J. B., Jr., 1929 (U. S. Geol. Surv., Prof. Pap. 158, p. 9-25): No evidence of unconformity between Fox Hills and overlying Lance Formation. Discordant bedding relationships represent minor, erosional scour features or cross-bedding or

small, local fault structures. Similarity of fauna of Cannonball marine member of Lance Formation and Fox Hills further indicates no major break in deposition.

Rocky Mtn. Assoc. Pet. Geol., by its committee, composed of T. S. Lovering, H. A. Aurand, C. S. Lavington, and J. H. Wilson, 1932 (Am. Assoc. Pet. Geol., Bull. 16, no. 7, p. 702-703): Base of Fox Hills formation considered as horizon below which section is predominantly gray, marine, clay shales and sandy shales of Pierre age, and above which section changes abruptly to buff or brown sandstone and sandy shale. Top of Fox Hills is horizon above which is predominantly fresh- and brackish-water deposits accompanied by coals and lignitic shales, and below which is predominantly marine.

Searight, W. V., 1934 (S. D. Geol. Surv., Rep. Invest. 22, p. 4-15): In South Dakota, Fox Hills sandstone is 435-465 feet of sediment between uppermost transition beds of Pierre and gumbo clays and gumbo sands of lower Hell Creek member of Lance. In Meade County, Fox Hills divided into four members (descending): 1) sandstone member with thin, interbedded shale, 2) Stoneville Coal Member, 3) sandstone member with thin beds of shale, and 4) basal member of alternating beds of shale and sandstone.

Morgan, R. E., and Petsch, B. C., 1945 (S. D. Geol. Surv., Rep. Invest. 49, p. 11-18): Fox Hills formation of Dewey and Corson Counties, South Dakota contains two identifiable units of almost pure sandstone and two other units that are less sandy. Sandstone members are (descending): 90 feet of Timber Lake and 50-90 feet of Trail City. Total thickness of section is 120-250 feet. Overlies Pierre; underlies Hell Creek formation.

Gries, J. P., 1952 (Billings Geol. Soc., 3rd Ann. Field Conf., p. 78): Fox Hills cannot be same age everywhere as retreating Cretaceous sea deposited formation.

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, p. 1026): Fox Hills is Late Maestrichtian in age.

Fischer, S. P., 1952 (N. D. Geol. Surv., Bull. 26, p. 10-17): Fox Hills is most extensive of formations cropping out in Emmons County, North Dakota. Trail City and Timber Lake Members pinch out eastward and disappear between southwestern corner and center of county. Upper 160-230 feet is gray to brown sands with thin, gray shales; capped by sandstone bed.

Stevenson, R. E., 1957 (S. D. Geol. Surv., Geol. quad. McIntosh): Formation includes (descending): 1) 15 feet of Colgate Member, 2) Bullhead Member (new), 3) 20-25 feet of Timber Lake Member, and 4) 65 feet of Trail City Member.

Robinson, C. S., Mapel, W. J., and Cobban, W. A., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 1, p. 101-123): Along west and north flanks of Black Hills, typical Fox Hills lithology appears stratigraphically lower; upper four Baculites zones of Pierre in central South Dakota are in Fox Hills in Black Hills.

Waage, K. M., 1961 (Wyo. Geol. Assoc., 16th Ann. Field Conf., p. 229-240): Four members defined (descending): 1) Colgate; fine- to medium-grained sandstone; 2 Bullhead, banded gray clay shale and light-gray siltstone or fine-grained sandstone; 3) Timber Lake, fine- to medium-grained greenish-gray sand; and 4) Trail City, light-gray to brownish-gray clayey silt and silty to sandy clay. Members vary in stratigraphic detail over large area but remain uniform in Corson, Dewey, and Ziebach Counties, South Dakota. Each member is lateral facies of members above and below.

Pettyjohn, W. A., 1967 (Am. Assoc. Pet. Geol., v. 51, no. 7, p. 1361-1367): Deltaic sediments in Meade County placed in Fox Hills Formation. Strata dominantly of continental origin; contain coal seams. Two members named (descending): 1) White Owl Creek, 195 feet of lower cross-bedded sand and sandstone and upper, purple clay-shale; and 2) Fairpoint Member, 20-60 feet of lower shale, silt and sand sequence, 128-162 feet of middle sandstone, and 140 feet of upper coal facies. Stoneville coal facies, upper unit of Fairpoint Member, formerly Stoneville Coal Member. Fairpoint Member is equivalent to part of Colgate and Bullhead Members farther east. White Owl Creek should correlate in time with Hell Creek in type area of marine Fox Hills or with Colgate Member near Creighton, South Dakota. Purple clay-shale named Enning facies of White Owl Creek Member is result of weathering in late Eocene.

Feldman, R. M., 1967 (Ph.D. Dissert., Univ. N. D., 366 p.): In North Dakota, Trail City Member cannot be recognized. Timber Lake Member is unconsolidated medium- to fine-grained sandstone becoming cross-bedded near top. Bullhead Member is interbedded sandstone and shale. Colgate is light greywacke sandstone. Members were deposited penecontemporaneously with Timber Lake sediment. Bullhead deposition represents brackish conditions; Colgate represents strandline deposition, and Timber Lake deposition represents normal marine deposition.

Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist., Bull. 27, 175 p.): Fox Hills is 300-350 feet of sandy, fossiliferous, marine, and brackish-water strata divisible into two distinctive parts; gradational into marine Pierre below and nonmarine Hell Creek above; equivalent to lower part of nonmarine Lance Formation in eastern Wyoming. Lower part is Trail City Member, basal clayey silt, grading upward and laterally into Timber Lake Member, wedge-like sand body that pinches out westward. Trail City Member contains Little Eagle lithofacies, biogenically-assemblage zones in lower part in eastern two-thirds of type area; westward is Irish Creek lithofacies, thinly-bedded silt and shale with concretions.

Upper part is Iron Lightning Member (new) of (ascending) thinly-bedded sand, silt and shale with few marine fauna named Bullhead lithofacies and clayey, grayish-white sand with brackish-water fauna named Colgate lithofacies. Bullhead and Colgate formerly classed as members but cannot be consistently separated in type area. Sharp contact between upper and lower parts of Fox Hills is product of different depositional regimes.

Erickson, J. M., 1971 (Ph.D. Dissert., Univ. N. D., 247 p.): In south-central North Dakota, four members of Fox Hills recognized (descending): 1) unnamed member, very fine- to fine-grained siliceous sandstone; 2) Iron Lightning, interbedded, poorly consolidated sandstone or siltstone (Bullhead lithofacies and medium-grained, poorly consolidated, sandstone (Colgate lithofacies); 3) Timber Lake, fine- to medium-grained, poorly consolidated sandstone; and 4) Trail City, poorly consolidated sandy shale and siltstone. Trail City and Timber Lake Member represent lower to upper shoreface of barrier bar environment; Iron Lightning Member and unnamed member deposited within deltaic complex. Bullhead lithofacies may represent lagoonal facies behind barrier bar or baymouth bar.

Gill, R. J., and Cobban, W. A., 1973 (U. S. Geol. Surv., Prof. Pap. 776, Fig. 19): Sheridan delta is name given to deltaic complex affecting sedimentation in Rocky Mountain region during Late Cretaceous time; includes Fox Hills Formation.

Klett, M. C., and Erickson, J. M., 1976 (N. D. Acad. Sci., Proc. 28, pt. w, p. 3-21): Linton Member named; previously placed in Colgate lithofacies (or member). Consists of 0.64-22.4 feet of light olive gray to grayish brown, fine-grained, subangular, moderately to poorly sorted, indurated, siliceous sandstone with volcanic shards; interpreted as channel sand deposit. Is probably Meek and Hayden's Bed Q, resistant sandstone that caps Fox Ridge. Type section in N½ sec. 8 and 9, T. 132 N., R. 76 W., 1 mile east of Linton, North Dakota.

Fox Hills group (broad sense).

See 1878, 1879, and 1888 entries under Fox Hills Formation, sandstone, group.

"Fritz sandstone"

Ziebarth, H. C., 1962 (Univ. N. D., M. S. Thesis, p. 30-31): Fritz sandstone is blanket-type sandstone that covers most of western North Dakota in subsurface. Is oil productive in Ricky Ridge oil field and is very similar to Fryburg sandstone higher in section.

"Frobisher evaporite," "anhydrite"

Age: Mississippian.

Area of extent: Subsurface in Saskatchewan and North Dakota.

Remarks: Informally named for Frobisher Oilfield, southeastern Saskatchewan. See also Rival subinterval and Madison Group.

History of stratigraphic nomenclature:
Fuller, J. G. C. M., 1956 (Sask. Dep. Miner. Resour., Rep. 19, p. 34): "Frobisher evaporite" is bedded primary anhydrite and caps oil pools in Saskatchewan and North Dakota.

Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol. Surv., Rep. Invest., No. 36, p. 4): "Frobisher evaporite" part of Rival subinterval at top of Frobisher-Alida interval; overlies "Frobisher-Alida beds" and equivalent to Rival subinterval if present.

Frobisher-Alida interval, "beds"

Age: Mississippian.

Area of extent: Subsurface in Saskatchewan and North Dakota.

Economic significance: Oil productive.

Remarks: Informally named for Frobisher and Alida Oilfields, southeastern Saskatchewan. See also Rival subinterval and Madison Formation.

History of stratigraphic nomenclature:
Porter, J. W. (Chm.), 1956 (Sask. Geol. Soc., Report of the Mississippian Names and Correlation Committee, p. 1-4): "Frobisher-Alida beds" bounded above by "Midale beds" or "Frobisher anhydrite" and bounded below by "Tilston beds." Boundaries of "beds" well-defined horizons of silty or evaporitic beds. Boundary between Charles Formation and Mission Canyon Limestone may be at top of "Frobisher-Alida beds."

Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol. Surv., Rept. Invest., No. 36, p. 5): Frobisher-Alida interval includes Rival subinterval at top and "Frobisher-Alida beds" where applicable. Bottom boundary difficult to determine as wells generally do not penetrate to base of "Frobisher-Alida beds."

Fryburg coal bed (of BULLION CREEK FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 140): Of two coal beds 50-60 feet apart in western Stark County, lower one has burned out extensively in vicinity of Fryburg and is named Fryburg Coal Bed.

See also Heart River bed.

"Fryburg sandstone"

Ziebarth, H. C., 1962 (Univ. N. D., M. S. Thesis, p. 31-32): Fryburg sandstone is blanket sand over most of western North Dakota in subsurface. Thickness is 15-25 feet. Lack of fine material at some intervals indicates winnowing. Oil productive at Scoria-Fryburg oil field.

FUSON FORMATION, Shale (of DAKOTA GROUP)

Age: Early Cretaceous.

Area of extent: Black Hills area, north-central Wyoming, North Dakota and southeastern Montana.

Lithology: Varicolored plastic claystone (bentonitic) and massive to lenticular sandstone.

Thickness: Up to 300 feet.

Relationships to other units: Conformably overlain by Fall River Sandstone and conformably overlies Lakota Sandstone.

Characteristic fossils: Gastropods, some plant remains.

Economic significance: None.

Depositional environment: Nonmarine basins periodically flooded with sand from adjacent highlands. Bentonite beds suggest deposition of volcanic ash under marine conditions.

Remarks: Type locality is Fuson Creek Canyon, east side of Black Hills near Buffalo Gap, Wyoming.

History of stratigraphic nomenclature:
Darton, N. H., 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 4, p. 530): Fuson Formation is very fine-grained sandstone and massive shale and clay of varying colors. Thickness is 30-100 feet. Underlies Dakota

Sandstone and overlies Minnewaste Limestone. Included in Dakota Sandstone of previous reports.

Rubey, W. W., 1930 (U. S. Geol. Surv., Prof. Pap. 165-A, 54 p.): Fuson Formation is middle formation of Inyan Kara Group.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 75): Fuson should not be considered as separate formation but shaly closing phase of Lakota deposition. Similar pind, gray and buff clays may be traced in subsurface east of Missouri River. There is tendency to lump Lakota-Fuson-Fall River divisions of Dakota(?) into Dakota or Cloverly Group.

Waage, K., 1959 (U. S. Geol. Surv., Bull. 1081-B, p. 33): Fuson term should be dropped from usage because of its close facies relationship with Lakota Formation and its miscorrelations elsewhere. Where local Minnewaste Limestone is present, Fuson term may be helpful but needs new type section because base of Fuson not present at Darton's (1901) type section.

Gammon Ferruginous Member (of PIERRE SHALE)

Age: Late Cretaceous

Area of extent: Northeastern Wyoming, southeastern Montana, Black Hills of South Dakota, and North Dakota.

Lithology: Dark gray mudstone and shale with red-weathering concretions and thin beds of siderite. May contain sandstone (Groat) in upper part.

Thickness: Up to 1000 feet.

Relationships to other units: Disconformable on Niobrara in Colorado; disconformably overlain by Mitten Black Shale Member of Pierre Shale.

Characteristic fossils: Scaphites hippocrepis, Baculites, Inoceramus, fish remains.

Depositional environment: Stable, offshore marine.

Remarks: Named for exposures along Gammon Creek, T. 57 N., R. 67 W. and R. 68 W., Crook County, Wyoming. Equivalent to Claggett and Eagle Formstions of central Montana and Claggett, Eagle (Shannon), and Telegraph Creek Formations of central-southern Montana and western part of Powder River Basin. See also Pierre Shale.

History of stratigraphic nomenclature:
Rubey, W. W., 1930 (U. S. Geol. Surv., Prof. Pap. 165-A, p. 4): Gammon Ferruginous Member, basal member of Pierre Shale in northeastern

Wyoming and southeastern Montana, consists of 800-1000 feet of light-gray mudstone and shale with concretions and thin beds of siderite. Includes Groat Sandstone, 150 feet, near top, and Pedro bentonite bed at base. Overlies Niobrara; commonly forms bare buttes. Possible unconformity at or near base.

Cobban, W. A., 1952 (Billings Geol. Soc., 3rd Ann. Field Conf., p. 87): Gammon Member, lower half of Pierre Formation, thins eastward across north flank of Black Hills. In common corner of Montana, Wyoming, and South Dakota; 800 feet of Gammon Member divided into three units. Upper unit is 150 feet of gray mudstone with numerous ferriginous and calcareous concretions; middle unit is 50 feet of Groat Sandstone; lower unit is 600 feet of gray mudstone, slightly calcareous in basal 150 feet, with numerous red-weathering ferruginous concretions and thin, shaly ferruginous layers.

Robinson, C. W., Mapel, W. J., and Cobban, W. J., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 1, p. 101-123): Gammon Ferruginous Member along west and north flanks of Black Hills, consists of (descending): 1) upper unit, dark-gray mudstone and shale with dark-gray, iron-cemented, septarian concretions, 2) Groat Sandstone Bed, 75-100 feet, light-gray glauconitic iron-stained sandstone, and 3) lower unit, same as upper except concretions are not septarian. Groat fossils are same as those in Telegraph Creek Shale and Eagle Sandstone of Montana, and same as in Shannon Sandstone of Powder River Basin, Wyoming.

Tourtelot, H. A., 1962 (U. S. Geol. Surv., Prof. Pap. 390, p. 8): Gammon not present south of Newcastle, Wyoming. From Newcastle, Wyoming, southward, overlying Mitten becomes Sharon Springs of southern part of Black Hills.

Gill, J. R., and Cobban, W. A., 1973 (U. S. Geol. Surv., Prof. Pap. 776, p. 16-19): Assigned as formation of Montana Group (newly restricted) only in central Montana; no longer assigned as member or formation to any named group elsewhere. Remains in good usage as Gammon Ferruginous Member of Pierre Shale or Cody Shale in southeastern Montana and northeastern Wyoming.

Garner Creek bed (of BULLION CREEK FORMATION)

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, p. 50): Garner Creek Bed lies about 180 feet above Harmon Bed and consists of lignite.

Garrison Creek bed (of SENTINEL BUTTE)

Andrews, D. A., 1939 (U. S. Geol. Surv., Bull. 906B, p. 72): Garrison Creek Bed, named from exposures along Garrison Creek, crops out along Missouri River, and in Minot area of North Dakota.

GOLDEN VALLEY FORMATION

Age: Eocene.

Area of extent: Southwestern North Dakota and northwestern South Dakota (?).

Lithology: Lower member is white to light purplish-gray kaolinitic clay with variable amounts of silt and sand; clay bed near middle of lower member stained yellow to orange by iron oxide. Upper member is light-gray to yellow and brown, micaceous silt and sand with few lenses of gray clay and lignite.

Thickness: 5-175 feet, may reach 300 feet.

Relationships to other units: Conformably overlies Sentinel Butte Formation; conformably overlain by White River Formation or is youngest bedrock formation exposed in North Dakota.

Characteristic fossils: Salvinia preauriculata and other plant remains.

Economic significance: Possible clay potential.

Remarks: Named from exposures in secs. 2 and 5, T. 143 N., R. 90 W., and secs. 32 and 33, T. 144 N., R. 90 W. near town of Golden Valley, Mercer County, North Dakota.

History of stratigraphic nomenclature:

Benson, W. E., and Laird, W. M., 1947 (Geol. Soc. Am., Bull. 58, p. 1166-1167): Golden Valley Formation consists of series of fine-grained, micaceous sands with minor amounts of light-colored clays and shale (upper unit), which rest on hard, white to dark-gray clay and locally lignite (lower unit). Near middle of lower unit is reddish-yellow mottled "marker bed." Beds were formerly known as "unnamed formation" of Wasatch Group. Overlies Paleocene Sentinel Butte Shale Member of Fort Union Formation; unconformably overlain by Oligocene White River Group.

Benson, W. E., 1949 (Geol. Soc. Am., Bull. 60, p. 1873-1874): Upper member of Golden Valley Formation is fine- to coarse-grained, micaceous, sands and silts with small clay lenses; lower member is purplish-gray, carbonaceous shales interbedded with white, sandy, bentonitic clays commonly stained bright yellow-orange. Golden Valley Formation is conformable with underlying Tongue River Formation and unconformable with overlying White River Group. In places, pre-Oligocene erosion removed entire Golden Valley Formation before White River sediments were deposited.

Great Northern Railway Company Mineral Research and Development Department, 1958 (Great Northern Railway Co. Min. Res. and Devel. Dept.,

Rep. 5, p. 5-23): In Mountrail County, Golden Valley includes White Earth, South Ross, and East Tioga clay beds.

Hickey, L. J., 1977 (Geol. Soc. Am., Mem. 150, 181 p.): Golden Valley Formation consists of up to 180 feet of claystone, mudstone, siltstone, micaceous sandstone, and lignite deposited under fluvial conditions during Late Paleocene and early Eocene in Williston basin. Divided into (ascending): 5-65 feet of light gray or brightly colored kaolinitic strata named Bear Den Member, and up to 150 feet of yellow to tan illitic to montmorillonitic strata named Camels Butte Member. Bear Den is Paleocene in age; Camels Butte is Wasatchian, based on megaflora.

Graneros Shale (of COLORADO GROUP)

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, p. 1011-1044): Graneros Formation considered to be in Ward County, North Dakota.

Laird, W. M., and Towse, D. F., 1953 (rev.) (N. D. Geol. Surv., Rept. Invest. 2, 2 sheets): Graneros Shale is subdivision of Benton. Benton divided into two subdivisions: Graneros and Carlile. Graneros divided into Skull Creek, Newcastle, Mowry, and Belle Fourche Formations.

This usage not followed by North Dakota Geological Survey although the United States Geological Survey sometimes uses term Graneros Shale.

Great Bend coal group

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 80-90): Great Bend coal group occurs along Little Missouri River from Yule to Garner Creek, Beds G-i lie in lower 150 feet of middle division of Fort Union.

See also Harmon Lignite bed.

GREAT LIGNITE GROUP

See Fort Union Formation, Group

GREENHORN FORMATION (of COLORADO SHALE)

Age: Late Cretaceous.

Area of extent: Eastern Montana, North Dakota, South Dakota, eastern Wyoming, Nebraska, and Kansas.

Lithology: Gray to light gray calcareous shale (mudstone) and shaly marl. Contains thin beds of limy "sandstone" partly composed of fossil debris. Shale often contains white to pink, calcareous specks (Second Speck Zone).

Thickness: Up to 300 feet.

Relationships to other units: Apparently conformable with underlying Belle Fourche and slightly disconformable with overlying Carlile. Equivalent to part of Frontier Sandstone of western Wyoming and Mosby Sandstone of central Montana.

Characteristic fossils: Inoceramus labiatus, Dunveganoceras, Globigerina, fish remains.

Economic significance: None.

Depositional environment: Widespread, stable marine.

Remarks: Type locality on Greenhorn Creek near Pueblo, Colorado. Second speck zone used extensively by subsurface petroleum geologists. Top of Greenhorn usually indicated as readily identifiable "kick" on electric logs.

History of stratigraphic nomenclature:

Gilbert, G. K., 1896 (U. S. Geo. Surv., 17th Ann. Rep., pt. 2, p. 564): Greenhorn Limestone consists of limestone beds, 3-12 inches thick, separated by somewhat thicker shale beds. Total thickness is 25-40 feet. Middle formation of Benton Group in Arkansas Valley region, Colorado.

Cobban, W. A., 1951 (Am. Assoc. Pet. Geol., Bull. 35, no. 10, p. 2183): Greenhorn on north flank of Black Hills may be divided into four lithologic units (descending): 1) 60 feet of bluish- to whitish-weathering marl with limestone lenses and concretions; 2) 22 feet of dark bluish-gray, noncalcareous, very fissile shale with numerous, soft, yellow, limonitic nodules; 3) 33-80 feet of calcareous shale and impure calcareous marl with calcareous, ferruginous concretions and buff-weathering, thin, shaly limestone beds; and 4) 125-250 feet of light gray, calcareous mudstone with interbedded marl, shaly limestone, and black-gray, noncalcareous shale. Base may be marked by 1 foot of buff, shaly limestone called Orman Lake Limestone. Greenhorn is Cenomanian and Turonian in age.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 76): Greenhorn consists of 35-65 feet of thin limestones with thick partings of calcareous shale. Contains Inoceramus labiatus. Often referred to in subsurface of Williston basin as "Second white specks zone."

Knechtel, M. M., and Patterson, S. H., 1962 (U. S. Geol. Surv., Bull. 1082-M, p. 918-920): Facies relationships of Greenhorn and underlying Belle Fourche causes contact to migrate down-section 45-60 feet from position above Bentonite bed G from west to east across northern Black Hills. Thinned upper member of Belle Fourche is replaced by thickened lower part of Greenhorn.

Gregory Marl

See Gregory Member and Crow Creek Member of Pierre Shale.

Gregory Member (of PIERRE SHALE)

Age: Late Cretaceous

Area of extent: South Dakota.

Lithology: Marl and dark, bentonitic, bituminous shale.

Thickness: 12-145 feet.

Relationships to other units: Underlies Agency shale zone; overlies Niobrara.

Type section: In Gregory County, South Dakota, at south end of Rosebud Bridge, south of Wheeler. See also Pierre Shale and Crow Creek Member.

History of stratigraphic nomenclature:
Searight, W. V., 1937 (S. D. Geol. Surv., Rept. Invest. 27, p. 10-20): Gregory of Pierre Shale is divided into two lithologically and faunally distinct parts. Upper Gregory is chalk, argillaceous chalk, or marl. Lower Gregory is dark, bentonitic bituminous shale with fish scales. Basal member of Pierre includes all beds from top of Niobrara to Oacoma beds south of Great Bend of Missouri River, and northward from this locality, all beds below Agency shale zone, which lies between Gregory Member and Sully Member.

Moxon, A. L., Olson, O. E., Searight, W. V., and Sandals, K. M., 1938 (Am. J. Botany, v. 25, p. 795-796): Upper Gregory referred to as Gregory Marl and Gregory is subdivision of Sully Member, not Pierre Formation. Lower Gregory changes to Sharon Springs Member of Pierre Formation.

Gries, J. P., and Rothrock, E. P., 1941 (S. D. Geol. Surv., Rept. Invest. 38, p. 5): Beds comprising upper unit of Searight's (1937) Sharon Springs Member lie above marl; thus, original

Gregory Member of Searight contained two marls. Upper part of Sharon Springs changed to Gregory Member and Crow Creek Marl and sand is name for Searight's upper Gregory marl and thin sandstone directly beneath it.

Gill, J. R., and Cobban, W. A., 1965 (U. S. Geol. Surv., Prof. Pap. 392A, 20 p.): In eastern North Dakota Gregory Member is light-colored calcareous rocks best exposed in valley of Sheyenne River at Valley City and southward. Overlies Pembina Member, underlies DeGrey Member.

Rice, O. C., 1977 (U. S. Geol. Surv., Misc. Invest. Map OC-70, 1 sheet): Gregory Member is in eastern North Dakota on correlation chart.

GUNTON MEMBER (of STONY MOUNTAIN FORMATION)

Age: Late Ordovician.

Area of extent: Manitoba, Saskatchewan, North Dakota, northern South Dakota, and eastern Montana.

Lithology: Gray and buff to tan, finely crystalline dolomite and dolomitic, fossiliferous limestone. In central part of basin may contain thin anhydrite beds. Around basin margins and on Cedar Creek anticline, formation becomes sandy and silty.

Thickness: Up to 70 feet.

Relationships to other units: Is upper member of Stony Mountain Formation. Conformably overlain by Interlake Group.

Characteristic fossils: None listed.

Economic significance: Produces hydrocarbons along Cedar Creek anticline.

Depositional environment: Margins of slowly subsiding, cratonic marine basin.

Remarks: Type locality is Stony Mountain area, Manitoba. See also Stony Mountain Formation.

History of stratigraphic nomenclature:
Okulitch, V. J., 1943 (Roy. Soc. Can., Trans., 3rd ser., v. 37, sec. 4, p. 60, and 62-63): Gunton beds consist of thick-bedded, dense, hard, massive dolomite, commonly buff with occasional red or maroon bands. Thickness is 15-19 feet. Overlies Penitentiary Member (new) and underlies Birse Member (new).

Baille, A. D., 1952 (Manit. Dep. Mines Nat. Res., Mines Br., Pub. 51-G, p. 34-35): Gunton Member and Birse Member combined as the upper member of Stony Mountain Formation in Manitoba.

Stearn, C. W., 1956 (Can. Geol. Surv., Mem. 281, 162 p.): Gunton of Ordovician age because Ordovician fossils found in overlying Stonewall.

Saskatchewan Geological Society, 1958 (Rep. of the Lower Palaeozoic Names and Correlations Committee: Regina, Sask., Sask. Geol. Soc., p. 8): In subsurface, Gunton beds comprise fossiliferous, fragmental, dolomitized limestone and dolomite with maximum thickness of 60 feet, overlain by 1-5 feet of anhydrite and 1-5 feet of arenaceous dolomitic shale. Overlies Stoughton beds (new). In outcrop Gunton beds are equivalent to Gunton Member.

Carlson, C. G., and Eastwood, W. P., 1962 (N. D. Geol. Surv., Bull. 38, p. 6 and 7): Gunton is lower member of Stony Mountain Formation found in subsurface of North Dakota; overlies Stoughton Member, underlies Stonewall Formation.

GYPSUM SPRING FORMATION, MEMBER

Age: Middle Jurassic.

Area of extent: Northern and central Wyoming, Montana, South Dakota, and North Dakota.

Lithology: Limestone, gypsum, and red shale, with algal limestone and sandstone.

Thickness: Up to 250 feet.

Relationships to other units: Unconformably overlies Chugwater Formation or Spearfish; locally rests conformably on Early Jurassic Nugget Sandstone in Wyoming. Unconformably underlies Sundance Formation.

Characteristic Fossils: Defonticeras, Stematoceras, and many other molluscs.

Economic significance: Gypsum beds.

Depositional environment: Restricted--evaporitic and open, shallow marine.

Remarks: Type locality is on east side of Red Creek, sec. 6, T. 6 N., R. 3 W., 18 miles southeast of Dubois, Fremont County, Wyoming. Equivalent and coextensive with Piper Formation of Montana.

History of stratigraphic nomenclature:

Love, J. D., 1939 (Geol. Soc. Am., Spec. Pap. 20, p. 42-43, 45-46): Gypsum Spring Member of Chugwater Formation consists of white, cliff-forming gypsum (lower half) and variegated shale, sandstone, and limestone. Thickness is 182 feet where exposed on Red Creek, 250 feet in Maverick Springs oil field. Unconformably overlain by Sundance Formation and underlain by Popo Agie Member of Chugwater. Triassic(?).

Branson, E. B., and Branson, C. C., 1941 (Am. Assoc. Pet. Geol., Bull. 25, no. 1, p. 124, 126, and 136): Rank raised to uppermost formation of Chugwater Group.

Love, J. D. et al., 1945 (U. S. Geol. Surv., Oil and Gas Inv., Prelim. Chart 14): Gypsum Spring classed as formation and member of Chugwater. Consists of basal, red, blocky, sandy, siltstone overlain by 50-125 feet of massive, white gypsum on surface and white anhydrite in subsurface. Gypsum overlain by sequence of thin gypsum beds, red shale, gray dolomites, and limestone. Maximum thickness is 250 feet in northwest part of Wind River Basin. Unconformable above Nugget Sandstone. Overlain by Lower Sundance. Contains Middle Jurassic fossils.

Imlay, R. W., 1947 (Am. Assoc. Pet. Geol., Bull. 31, no. 2, p. 231, 236-247): Sequence of gypsiferous beds underlying Sundance Formation in part of Black Hills region, previously considered part of Spearfish Formation, are correlative with Gypsum Spring Formation of central Wyoming. Lowest marine Jurassic beds included in Gypsum Spring comprise two laterally intergrading facies. One facies consists of gypsum, generally interbedded with soft, maroon, siltstone and shale, and is locally 15 feet thick; occurs on western side of Black Hills from Elk Mountain to Sundance and on northeastern side from 10 miles south of Sturgis to Spearfish. Second facies consists of interbedded gray shale, limestone, and dolomite and is 21 feet thick; occurs at northwestern end of Black Hills. Gypsum Springs Formation represents first widespread invasion and withdrawal of marine water during Jurassic in Western Interior region. Middle Jurassic, representing Late Bajocian and Bathonian ages. Underlies Stockade Beaver Shale Member or Canyon Springs Sandstone Members of Sundance Formation. Overlies Nugget(?); locally overlies Spearfish Formation.

_____ et al., 1948 (U. S. Geol. Surv., Oil and Gas Inv., Prelim. Chart 32): Basal part of Piper Formation (new) locally includes equivalents of type Gypsum Spring of Central Wyoming.

_____, 1952 (Geol. Soc. Am., Bull. 63, no. 9, p. 967-968): Gypsum Spring Formation represents basal deposits of transgressive sea; may not be same age throughout, and may represent more time at one locality than at another. Gypsum Spring in Big Horn Basin of Wyoming is correlative with Piper Formation of eastern Montana and includes more than type Gypsum Spring. Gypsum Spring of type area in central Wyoming represents only early Middle Jurassic and is correlative with

lower member of Gypsum Spring. Gypsum Spring usage in Montana arose because of mapping ease and term Gypsum Spring was assumed to include all beds of Middle Jurassic older than type Sundance. Piper now used for Gypsum Spring in Montana.

Mapel, W. J., and Bergendahl, M. H., 1956 (Am. Assoc. Pet. Geol., Bull. 40, no. 1, p. 84-93): Gypsum and redbed sequence known as Gypsum Spring Formation in Elk Mountain-Sundance region and Sturgis-Spearfish region is also near Hulett, Wyoming, where it is from 0-125 feet thick. It is absent along southern and eastern sides of Black Hills. Lithologic character and stratigraphic position suggest representation of eastward extension of Gypsum Spring Formation of central and northern Wyoming, and lower and middle Piper Formation (Middle Jurassic) of south-central Montana.

Storey, T. P., 1958 (Albta. Soc. Pet. Geol., J., v. 6, no. 4, p. 90-104): Late and Middle Jurassic of Williston basin comprises nine stratigraphic units or regional intervals and two regional unconformities. Faunal, environmental, and tectonic evidence groups units into four major depositional sequences or stage-like intervals; Gypsum Spring (or Piper), Sawtooth, Rierdon, and Swift Formations. Miscorrelation of type sections of formations is result of variations in stratigraphic succession caused by sub-Swift and sub-Rierdon unconformities that correspond, respectively, to Early Callovian and late Callovian-Early Oxfordian marine transgressions. Lower Swift (Stockade Beaver-Hulett of lower Sundance) is older than type Swift and younger than type Rierdon Formations; Sawtooth is discrete stratigraphic unit younger than Piper or Gypsum Spring.

Hagel Bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 40): Hagel Bed, named for Hagel Mine, is thickest coal bed in area. Is found along Square Butte Creek and tributaries in Oliver County. Is 25-50 feet above Yeagher Bed; may be equivalent to Otter Creek Bed.

Carlson, C. G., 1973 (N. D. Geol. Surv., Bull. 56, pt. 1, p. 2): Hagel Bed is 275 feet above base of Tongue River and is being mined near Center and Stanton.

Hagel Bed is believed to be equivalent to Beulah bed by the North Dakota Geological Survey.

Hancock bed (of BULLION CREEK FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 258): Hancock bed is lignite named for Hancock Mine. Is about 15 feet below Stanton bed. May be equivalent to Wolf Creek bed of Smith, C. D., 1908 (U. S. Geol. Surv., Bull. 381, p. 19, 20).

Hanks bed

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 157): Hanks bed is burned coal bed in vicinity of Hanks, North Dakota.

Harmon lignite bed (of FORT UNION GROUP)

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 80-90): Near base of Fort Union Formation is group of thick lignite beds called Great Bend group. Harmon bed is top bed of Great Bend lignite group, or bed II of Great Bend Group. About three-quarters of mile north of Harmon Ranch in sec. 5, T. 138 N., R. 102 W., thickest coal seam is 11 feet.

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, p. 49): Estimate based on mapped outcrop of Harmon bed or zone indicates it underlies 5500 square miles and it may be workable over larger area in adjacent fields.

King, J. W., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 85): Harmon Lignite is 420 feet below top of Tongue River which is 600 feet thick. Named from Harmon Ranch, North Dakota.

Hayden Group

Age: Pennsylvanian (DesMoinesian).

Area of extent: Eastern Wyoming, southwestern South Dakota and North Dakota.

Lithology: Dark-gray to black sandstone, shale and dolomite.

Thickness: Up to 120 feet.

Relationships with other units: Underlies Meek Group; overlies Roundtop Group.

Characteristic fossils: Mesolobus.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Type locality is Hayden Cliff, sec. 22, T. 27 N., R. 66 W., Platte County, Wyo.

History of stratigraphic nomenclature:
Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13A, p. 2, 3, 22 and 45): Hayden Group consists of dark-gray to black sandstone, shale, and dolomite with red sandstone. Comprises Division III of Hartville "Formation" (Condra, G. E., and Reed, E. C., 1935, Nebr. Geol. Surv., Pap. no. 9, 46 p.). Thickness is 120 feet. Underlies Meek Group (new); overlies Roundtop Group (new).

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym., 1st Internat., Bismarck, N. D., p. 150-164): Hayden Group is transitional with underlying Roundtop and is difficult to distinguish. Lower part of section contains several shale or argillaceous zones that do not show up well in samples but exhibit high radioactivity on gamma ray logs. Gamma ray radioactive zone is at contact with overlying Broom Creek Group over most of North Dakota, but does not occur along western flank of Williston basin, in western North and South Dakota and eastern Montana. Hayden probably consists of basal sandy zone and radioactive sequence in North Dakota but contacts not chosen.

Haymarsh Creek bed (of BULLION CREEK FORMATION)

Barclay, C. S. V., 1974 (U. S. Geol. Surv., Coal Invest., Map C-67, 13 p., 2 pl.): Haymarsh Creek bed is local lignite unit in Dengate Quadrangle, North Dakota. Is probably equivalent to HT Butte lignite of western North Dakota.

See also H T Butte lignite.

Haynes bed (of BULLION CREEK FORMATION)

Lloyd, E. R., 1914 (U. S. Geol. Surv., Bull. 541G, p. 252): Haynes bed is lowest important lignite in Cannonball River Field except in vicinity of Cannonball River. Reaches thickness of 6 feet.

Hazen A bed (of SENTINEL BUTTE FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 255): Hazen A bed is lowest coal bed that crops out near town of Hazen. Is 4-5 feet thick; occurs 155-160 feet below Beulah-Zap Bed.

Hazen B bed (of SENTINEL BUTTE FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 245): Hazen B bed, named for exposures near Hazen, outcrops along

Knife River valley to town of Beulah. Hazen B Bed is about 110-115 feet below Beulah-Zap Bed.

H bed (of BULLION CREEK FORMATION)

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, p. 48): Near base of Fort Union Formation is group of thick lignite beds called Great Bend Group. Bed H is lowest bed of group and lies about 60 feet above Lance Formation.

See also Great Bend Group.

Heart River bed (of SENTINEL BUTTE FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 140): Of two coal beds 50-60 feet apart in western Stark County, upper bed is named Heart River Coal bed.

See also Fryburg Coal bed.

HEATH FORMATION of BIG SNOWY GROUP

Age: Mississippian (Late Chesterian).

Area of extent: Montana, possibly western North Dakota.

Lithology: Black fissile, petroliferous shale and minor sandstone.

Thickness: Up to 150 feet.

Relationships to other units: Unconformably underlies Tyler or Amsden Formation and conformably overlies Otter Formation.

Characteristic fossils: Spirifers, corals.

Depositional environment: Restricted marine.

Remarks: Type locality is north flank of Big Snowy Mountains, sec. 6, T. 12 N., R. 20 E., near Heath, Montana. Thin chips of petroliferous Heath shale give off enough volatile material when heated to support flame. Locally, hollow brachiopod shells contain free brown oil. See also Big Snowy Group.

History of stratigraphic nomenclature:
Scott, H. W., 1935 (Geol. Soc. Am., Proc., 1934, p. 367): Big Snowy Group includes Kibbey, Otter, and Heath Formations. Consists of

variegated shale with intercalated limestones and sandstones. Overlies Madison limestone.

Scott, H. W., 1935 (J. Geol., v. 43, p. 1016-1032): Heath formation consists of primarily black petroliferous shales with sandstone, forming upper formation of Big Snowy Group. Thickness may reach 500 feet. In most sections, three sandstone beds occur in upper half. On southeastern flank of Big Snowy Mountains, sandstone beds have been grouped as Van Dusen sand, which should be considered as member at top of Heath Formation. On northeastern flank of Big Snowy Mountains, sandstone beds occupying same stratigraphic zone are Tyler sand which should be considered as member at top of Heath. Heath conformably underlies Amsden and conformably overlies Otter. Fossils are closely related to fauna of Brazer limestone of Idaho and Moorefield formation of Arkansas and are not older than Warsaw nor younger than Upper Chester.

Anderson, S. B., 1954 (N. D. Geol. Surv., Rep. Invest. 16, 2 sheets): Heath Formation is sequence of sandstones and black shales confined to subsurface of western North Dakota. Maximum thickness is 130 feet in North Dakota. Oil productive. Excellent marker on radioactivity logs.

Mundt, P. A., 1956 (Billings Geol. Soc., Gdbk., 7th Ann. Field Conf., p. 46-47): Upper limit of Heath Formation (Scott, 1935), is not acceptable since upper part includes prolific oil sands (Tyler sandstone), and unit is separated from lower nonsandy part of Heath by angular unconformity. Heath should be restricted to beds below the unconformity, and beds above, formerly included in Heath, should be separate unit (Tyler).

Willis, R. P., 1959 (Am. Assoc. Pet. Geol., Bull. 43, p. 1940-1966): Tyler-Heath interval extends eastward from central Montana into Williston basin of North Dakota. Tyler-Heath is overlain by Amsden (restricted), and is early Pennsylvanian (Morrowan-Atokan). Heath considered uppermost unit of Big Snowy Group.

Foster, F. W., 1961 (World Oil, v. 152, p. 89-93): Representation of Heath Formation (restricted) is in form of erosional remnants and particles of Heath Shale in basal Tyler conglomerate. Alaska Bench Formation overlies "Heath."

Ziebarth, H. C., 1962 (Univ. N. D., M. S. Thesis, 146 p.). Heath Formation in subsurface of southwestern North Dakota consists of five laterally traceable lithologic units (three shaly sequences separated by two locally petroliferous sandstone units). Unconformity, evidenced by conglomeratic horizon, separates lower two from upper three units. Fauna includes nonmarine ostracodes and nonmarine pelecypods and syncarid crustaceans that occur in units intertonguing with units containing marine brachiopods and pelecypods. Fossils above unconformity indicate Pennsylvanian age and fossils

below indicate Mississippian age. Heath Formation above unconformity is correlative with Tyler Formation in Montana. Overlies Otter and underlies Amsden; is oil productive.

Hecla beds, facies (of RED RIVER FORMATION)

Decker, C. E., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 1, p. 123-125): Middle Ordovician graptolites found in transition zone in South Dakota.

Baille, A. D., 1952 (Manit. Dep. Mines Min. Resour., Mines Br. Pub. 51-6, p. 15): Dog Head Member given to beds at base of Red River Formation in Williston basin.

Carlson, C. G., 1960 (N. D. Geol. Surv., Bull. 35, p. 61): Transition zone placed in upper part of Roughlock Member of Winnipeg Formation.

Fuller, J. G. C. M., 1961 (Am. Assoc. Pet. Geol., Bull. 45, no. 8, p. 1345-1348): Hecla beds are 10-40 feet thick and are in Red River Formation. Named from Hecla Island near Grindstone Point on west shore of Lake Winnipeg. Hecla beds (transition zone) are typically calcareous, variably sandy and argillaceous, and sporadically glauconitic.

Sandberg, C. E., 1962 (U. S. Geol. Surv., TEI-809, p. 28): Hecla beds are part of underlying Winnipeg Formation.

Hebron member (of GOLDEN VALLEY FORMATION)

Hickey, L. J., 1966 (The paleobotany and stratigraphy of the Golden Valley Formation in western North Dakota: Ph.D. Dissert., Princeton, 265 p.): Hebron Member of Golden Valley Formation consists of 5-65 feet of hard, kaolinitic clay or silstone, generally light or brightly colored. Conformably and unconformably overlain by Dickinson Member; conformably underlain by Fort Union Formation. Type locality is in secs. 1-6, 8, 9, and 11, T. 140 N., R. 90 W., north of Hebron, North Dakota.

See also Bear Den Member.

HELL CREEK FORMATION

Age: Late Cretaceous.

Area of extent: Montana, North Dakota, South Dakota, northern Wyoming, Saskatchewan, and Manitoba.

Lithology: Alternating beds of sandstone and shale, with lignite.

Thickness: Up to 400 feet.

Relationships to other units: Conformable, locally unconformable on underlying Fox Hills Sandstone; conformable with overlying Fort Union Formation. Probably equivalent to lower(?) part of Lance Formation.

Characteristic fossils: Triceratops, plant fossils, occasional pelecypods, and small mammal remains.

Economic significance: None.

Depositional environment: Subaerial marine top-set beds of giant delta.

Remarks: Named from exposure on Hell Creek, Garfield County, Montana. Hell Creek crops out in Burleigh, Emmons, and Sioux Counties in North Dakota. Also are outcrops in southwestern part of state. See also Crowghost, Breten, Fort Rice, Huff, Pretty Butte, Little Beaver Creek, Marmarth, and Bacon Creek Members.

History of stratigraphic nomenclature;

Brown, B., 1907 (Am. Mus. Nat. Hist., Bull. 23, art. 33, p. 329-835): Hell Creek Beds are 560 feet of fossil-bearing, fresh-water deposits of alternating sandstone and clay in western half of Dawson County, Montana. Most constant member of series is massive basal sandstone up to 160 feet thick. Hell Creek beds are probably continuous with dinosaur-bearing beds of Little Missouri, Grand and Moreau Rivers. Is Late Cretaceous in age. Is separated from overlying Fort Union Formation by 100 feet of lignite beds named Fort Union (?). Unconformably overlies Fox Hills Formation. Is lithologically similar to Ceratops beds of Converse County, Wyoming.

Thom, W. T., Jr., and Dobbin, C. E., 1924 (Geol. Soc. Am., Bull. 35, p. 484-499): Hell Creek Member of Lance Formation defined as "Hell Creek Beds" plus "lignite beds" Brown (1907) between Fox Hills Sandstone below and Tullock Member of Lance above. In southwestern North Dakota is overlain by either Ludlow Lignitic Member of Lance Formation or equivalent Cannonball Marine Member of Lance; overlies Fox Hills Sandstone. Consists of somber badlands clays, probably accumulated in topset swamps of large delta, and fluvatile sandstones; sandstones being more numerous and conspicuous toward southwest. Remains of small mammals found in sandstones; dinosaurs (including Triceratops) are numerous below "A" Lignite, which marks base of Brown's (1907) "lignite beds," but have not been found above that horizon. Hell Creek and overlying strata are much more calcareous than Brown member of Fox Hills and older strata. In Cedar Creek anticline, North Dakota and Montana, Hell Creek Member overlies Colgate Sandstone Member of Fox Hills.

Simpson, G. G., 1937 (U. S. Nat. Musc., Bull. 169, p. 15-20): Fort Union of Crazy Mountain field, Montana; consists of beds up to and including true dinosaur-bearing Lance and Hell Creek and their equivalents belong to Cretaceous and that overlying beds without dinosaurs (except by redeposition) and with mammals of Tertiary type (including carnivores, condylarths, and others) from Puerco and its equivalents upward, are to be placed in Tertiary. Hell Creek Formation underlies Bear Formation (new).

Collier, A. J., and Knechtel, M. M., 1939 (U. S. Geol. Surv., Bull. 905, p. 10-11): In McCone County, Montana, Hell Creek beds mapped as member of Lance Formation, overlie Colgate Sandstone Member of Fox Hills Formation and underlie Tullock Member of Lance. Since present report was written (footnote, p. 10), Hell Creek and Tullock Members have been raised to rank of formation. Hell Creek is considered to be Cretaceous, and Tullock to be Cretaceous or Eocene. Lance is assigned to Eocene(?).

Dorf, E., 1940 (Geol. Soc. Am., Bull. 51, p. 213-236): Study of floras of type Lance and Fort Union Formations show that Lance Formation (equivalent to Hell Creek Formation) is placed in Late Cretaceous; Tullock Formation (equivalent to Ludlow Formation and Cannonball Marine Member) is placed at base of Paleocene Fort Union Group.

Laird, W. M., and Mitchell, R. H., 1942 (N. D. Geol. Surv., Bull. 14, p. 9-15): Hell Creek Formation described in Morton County where it reaches 250 feet in complete exposures. Includes Breien Member (new). Overlies Fox Hills Formation; underlies Ludlow Formation of Fort Union Group.

Seager, O. A. et al., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 8, p. 1415-1418): Hell Creek is youngest Cretaceous Formation of North Dakota. Consists of gray bentonitic sands and shales with lenticular beds of lavender-brown, lignitic shale and rusty-brown to purplish-black, ferruginous concretions. Thickness varies from 575 feet near Marmarth to less than 100 feet in Souris River area. Underlies Cannonball Member-Ludlow Member of Fort Union.

Colton, R. B., and Bateman, A. F., Jr., 1956 (U. S. Geol. Surv., Misc. Geol. Invest., Map I-225): Hell Creek Formation returned to original definition of Brown (1907) and "lignitic beds" included within Fort Union Formation.

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 30-39): Hell Creek Formation divided into 8 members in North Dakota (ascending): Crowghost Member (new), Breien Member, Fort Rice Member (new), Huff Member (new), and Pretty Butte Member in central North Dakota and ascending Little Beaver Creek Member (new), Marmarth Member, and Pretty Butte Member in southwestern North Dakota. Unnamed ninth member may be present in Montana.

"Hell Creek lignite" (of HELL CREEK FORMATION)

King, J. W., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 85): Illustrated Hell Creek lignite as being 10 feet below top of Hell Creek Formation.

Herman bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 44): Herman bed is lignite found on Herman farm in sec. 28, T. 143 N., R. 87 W. Is 25-30 feet above Buckmann bed and crops out along Otter Creek.

HT Butte lignite (of BULLION CREEK FORMATION)

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, p. 50): HT Butte lignite is basal bed of Sentinel Butte Shale; averages 9 feet in thickness but can reach 16 feet thick. Has been largely eroded or burned out and now only occurs as remnants. Equivalent to bed F of Sentinel Butte Lignite Group of Leonard, A. G., and Smith, C. D., 1909 (U. S. Geol. Surv., Bull. 341, p. 30) and Bed R of Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 90-102) and may correspond to Roland Coal of northern Wyoming.

HUFF MEMBER (of HELL CREEK FORMATION)

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 37-38): Huff Member consists of thick sandstone bodies separated vertically and laterally by bentonites and bentonitic shales. Overlies Fort Rice Member; underlies Pretty Butte Member. Named from Huff, North Dakota; type section is 1 mile southwest of Huff, SW¼ sec. 8, T. 136 N., R. 79 W., Morton County, North Dakota. Is very extensive member of Hell Creek Formation. Fossils are marine, brackish-water, and fresh water forms. Huff Member is considered to be channel deposits of large rivers.

ICE BOX SHALE MEMBER (of WINNIPEG FORMATION)

Age: Middle(?) Ordovician.

Area of extent: Northern Black Hills, possibly present in subsurface of Montana and North Dakota.

Lithology: Soft, silty, green-gray to olive shale.

Thickness: Up to 145 feet.

Relationships to other units: Overlies Aladdin Sandstone and underlies Roughlock Siltstone in northern Black Hills area. This unit formerly included in Whitewood Dolomite. Equivalent to part of Winnipeg Formation of Williston Basin.

Characteristic fossils: Scolecodonts, conodonts, fish remains, pelecypods, gastropods, and linguloid brachiopods.

Economic significance: None.

Depositional environment: Marine shelf.

Type section: Secs. 14 and 23, T. 5 N., R. 3 E., Butte County, South Dakota.

Remarks: Named from Ice Box Gulch. See also Winnipeg Formation.

History of stratigraphic nomenclature:
McCoy, M. R., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 45-46): Ice Box Shale Member is 30-40 feet of silty, fissile, greenish-gray to olive shale; soft, noncalcareous, occasionally platy to splintery, with black phosphate nodules several millimeters in diameters in upper part. Overlies Aladdin Sandstone (new) and underlies Roughlock Siltstone (new). Type section given.

Carlson, C. G., 1960 (N. D. Geol. Surv., Bull. 35, p. 58-59): Ice Box Member of Winnipeg Formation consists of 90-145 feet of greenish gray to dark greenish gray, splintery to fissile, waxy, non-calcareous shale. Locally, in eastern North Dakota, shale may be pale brown or grayish red. Gradational contact with underlying Black Island and overlying Roughlock Members.

Interior Member (of PIERRE SHALE)

Age: Late Cretaceous

Area of extent: Southwestern South Dakota and northwestern Nebraska.

Lithology: Thin-bedded, sandy shale.

Thickness: Up to 45 feet.

Relationships to other units: Unconformably underlies Chadron Formation; overlies Pierre.

Remarks: Type locality is a few miles west of Interior, Jackson County, South Dakota.

History of stratigraphic nomenclature:

Ward, F., 1922 (S. D. Geol. Nat. Hist. Surv., Bull. 11, p. 18-20): Top 35 feet of Pierre in southeastern Pennington County and southwestern Jackson County is Interior phase. Thin beds of yellow-brown shale become darker brown and darker purple in upper part. Fossils are those of Pierre; field studies place it as Fox Hills. Grades into underlying "typical" Pierre. Unconformably underlies Chadron Formation (Oligocene).

Toepelman, W. C., 1922 (S. D. Geol. Nat. Hist. Surv., Bull. 11, p. 64): Interior may be slightly sandy phase of Pierre formed by weathering and leaching. Nebraska Geological Survey calls these beds Rusty Member of Pierre.

Wanless, H. R., 1923 (Am. Philos. Soc., Proc., v. 62, p. 194): Interior is 0-45 feet of lavender and blue clays weathering to rusty-brown. Contains calcareous nodules with cone-in-cone structure and concentrically banded pink or red nodules. Rests on Pierre with irregular surface.

Ward, F., 1926 (Am. J. Sci., 5th Ser., v. 11, p. 350-352): Type locality is few miles west of Interior, Jackson County, South Dakota. Is 30 feet thick at type locality, 45 feet thick 21 miles north of type locality. Interior is part of Fox Hills Formation.

Moxon, A. L., Olson, O. E., and Searight, W. V., 1939 (S. D. Agr. Exp. Sta., Tech. Bull. 2, p. 20): Mobridge Member replaced by Interior as Interior has precedence.

Gries, J. P., and Rothrock, E. P., 1941 (S. D. Geol. Surv., Rept. Invest. 38, p. 9-30): Since incomplete equivalence of all Interior beds to Mobridge beds, Mobridge retained. Interior usage dropped.

Dunham, P. J., 1961 (Geology of Uranium in Chadron area, Nebraska-South Dakota, U. S. Geol. Surv., Open-File Rep., p. 55-98): Weathered zone formed on rocks of Pierre Shale down to Niobrara and Carlile studied. Weathered zone is Eocene in age; has been called Interior Formation.

Interior formation

Pettyjohn, W. A., 1966 (U. S. Geol. Surv., Prof. Pap. 550-C, p. 61-65): Eocene paleosol, which has been termed Interior Phase of Pierre, Interior formation, or Interior period of weathering is exposed at several widely separated localities in western North Dakota.

INTERLAKE FORMATION, GROUP

Age: Silurian.

Area of extent: Manitoba, Saskatchewan, North Dakota, northwestern South Dakota, and eastern Montana.

Lithology: Fine-grained, pale dolomite and dolomitized, fragmental limestone with beds of sandy, silty, or clayey dolomite. Three thin beds of anhydrite occur in central basin area.

Thickness: Up to 1100 feet.

Relationships to other units: Overlies Stony Mountain Formation and underlies Ashern Formation in eastern Montana. Difference of opinion exists among workers as to top and base of Interlake Group in subsurface of Williston basin.

Characteristic fossils: Leperditia hisingeri, Virgiana decussata, Fletcheria guelphensis, Palaeofavosites sp., Brachyprion sp., "Amplexus" severnensis.

Economic significance: Oil productive.

Depositional environment: Shallow-water marine.

Remarks: Type locality is Interlake area of Manitoba. See also Stonewall Formation.

History of stratigraphic nomenclature:

Baille, A. D., 1951 (Manit. Dep. Mines Nat. Resour., Div. Mines Pub. 50-1, p. 6): Interlake Group consists of cream to white, earthy to lithographic limestone and dolomite with local zones of reefy porosity and permeability. Contains pyrite and thin, irregular laminae of green shale, and scattered sand grains. Interlake Group is divided into five formations (referred to by letters), but only basal formation (Stonewall) named. Thickness is 200-800 feet. Top and base of unit is under discussion.

Stearn, C. W., 1953 (Geol. Soc. Am., Bull., v. 64, p. 1477-1478): Stonewall fauna is late Ordovician. As rest of Interlake is Middle Silurian, Stonewall should be removed from Interlake. Interlake divided into six formations.

Porter, J. W., and Fuller, J. G. C. M., 1958 (N. D. Geol. Soc., 2nd Internat. Williston Basin Sym.: Conrad, Bismarck, p. 33-39): Interlake Group divided into lower, middle, and upper beds.

Andrichuk, J. M., 1959 (Am. Assoc., Pet. Geol., Bull. 43, no. 10, p. 2381): Stonewall Formation retained in Interlake Group, as most recognizable unconformity occurs at base of Stonewall.

Fuller, J. G. C. M., 1961 (Am. Assoc. Pet. Geol., Bull. 45, no. 8, p. 1350-1351): Interlake is succession of pale-colored dolomite, anhydrite, and calcareous sandstone. Interlake divided into three unnamed units.

Carlson, C. G., and Eastwood, W. P., 1962 (N. D. Geol. Surv., Bull. 38, p. 10): Interlake Formation of Silurian age is divided into three intervals (upper, middle, and lower) on basis of fine-grained clastic marker horizons that mark interruptions in predominantly carbonate deposits. Stonewall Formation is separate distinct formation of possible Ordovician age, and is not included with Interlake Formation.

Irish Creek Lithofacies (of TIMBER LAKE MEMBER of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: South Dakota and North Dakota.

Lithology: Clay and silt with some fine-grained sand.

Thickness: Up to 150 feet.

Relationships to other units: Overlies Pierre Shale and underlies Iron Lightning Member of Fox Hills.

Characteristic fossils: Rare molluscs.

Depositional environment: Marine.

Type section: South-facing cutbank and bluff north of Moreau River about 0.8 miles southwest of its confluence with Irish (formerly Worthless) Creek, in the center, sec. 32, T. 15 N., R. 21 E., U. S. Geol. Surv. Dupree NE quad., Ziebach County, S. D.

Remarks: See Timber Lake Member.

History of stratigraphic nomenclature:
Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist., Bull. 27, p. 60-73): West of study area, Irish Creek lithofacies is thinly-bedded silt and shale with mostly barren concretions. Upper part of Irish Creek occurs along northwestern part of Grand River and tributaries, west side of Moreau River Valley, and on south and east end of Cheyenne-Moreau Divide in South Dakota.

IRON LIGHTNING MEMBER (of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: South Dakota and North Dakota.

Lithology: Thinly-bedded sand, silt and shale with bodies of clayey, grayish-white sand.

Thickness: Up to 170 feet.

Relationships to other units: Conformable with underlying Timber Lake or Trail City Member; conformable and unconformable with overlying Hell Creek.

Characteristic fossils: Molluscs, fish, reptiles, birds, mammals, and plants.

Depositional environment: Marine delta.

Type section: Pieced from partial sections in W½, sec. 33, T. 14 N., R. 19 E., U. S. Geol. Surv. Redelm NE quad., Ziebach County, S. Dk.

Remarks: See also Bullhead and Colgate lithofacies.

History of stratigraphic nomenclature:
Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist., Bull. 27, p. 116-138): Iron Lightning Member is upper Fox Hills and consists of thinly-bedded sand, silt, and shale with sparse marine fauna (Bullhead lithofacies and bodies of clayey grayish-white sand with brackish-water fauna (Colgate lithofacies). Iron Lightning rests on planed surfaces at several levels on lower Fox Hills, rising steplike eastward. Conformable with Hell Creek Formation in South Dakota. Sediments are of deltaic front advancing from west. Some fluctuations in sea levels are indicated.

Erickson, J. M., 1971 (Ph.D. Dissert., Univ. N. D., p. 25): Iron Lightning Member found in south-central North Dakota; consists of interbedded, poorly consolidated sandstone or siltstone (Bullhead lithofacies) and medium-grained, poorly consolidated sandstone (Colgate lithofacies). Iron Lightning deposited in marine deltaic sequence; Bullhead lithofacies may be lagoonal deposit behind barrier or baymouth bar.

JEFFERSON GROUP, Formation

Age: Middle Devonian.

Area of extent: Montana, western Wyoming, Idaho, Utah, North Dakota, and South Dakota.

Lithology: Cyclic sequence of carbonates and evaporites with minor amounts of siltstone and shale.

Thickness: Maximum of 640 feet in North Dakota.

Relationships to other units: Overlies Souris River Formation; underlies Three Forks Formation.

Characteristic fossils: Corals, stromatoporoids, and bryozoans.

Economic significance: Oil productive.

Depositional environment: Alternating restricted and open marine.

Remarks: Named after Jefferson River, Montana.

History of stratigraphic nomenclature:

Peale, A. C., 1893 (U. S. Geol. Surv., Bull. 110, p. 27-28): Jefferson Formation consists of 640 feet of brown and black crystalline limestone; underlies Three Forks Shale and conformably overlies Gallatin Formation. Is well-exposed on bluffs on both sides of Missouri River just below junction of Three Forks of Missouri River, and on both sides of Jefferson a few miles above mouth, in Three Forks quadrangle, southwestern Montana. Probably can be correlated with part of Beaver Hill Lake Formation of Saskatchewan and Manitoba Formation of North Dakota and Manitoba.

Sloss, L. L., and Laird, W. M., 1946 (U. S. Geol. Surv., Oil and Gas Invest., PC 25): Jefferson Formation divided into upper dolomite member and lower limestone member. Basal limestone member transitional with underlying shales.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2315): Jefferson Group divided in Duperow (below) and Birdbear (above) Formations. Definition of Jefferson Group is original definition of Peale (1893) as redefinition by Sloss and Laird (1946) includes bottom part of Three Forks Formation.

JUDITH RIVER FORMATION (of MONTANA GROUP)

Laird, W. M., and Towse, D. F., 1949 (N. D. Geol. Surv., Rep. Invest. 2, 2 sheets): Judith River Formation shown to produce gas at several locations in North Dakota.

Jura-Triassic red beds

Age: Late(?) Permian and Early(?) Jurassic.

Area of extent: Montana, North Dakota, and Saskatchewan.

Lithology: Reddish brown, silty and non-silty dolomitic shales with sand; with salt in western North Dakota and eastern Montana.

Thickness: Up to 625 feet.

Relationships to other units: Unconformably rests on limestones and redbeds of Paleozoic age. Boundary difficult to determine where redbeds are in contact with Big Snowy Group or Minnekahta and Opeche Formations of Montana and North Dakota because of lithologic similarities. Conformably underlies Jurassic nonclastics.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Marine, and eolian sand.

Remarks: No type section, locality, or area. Jurassic-Triassic contact probably within this unit. See also Spearfish Formation, Pine Salt, Saude Formation, and Dunham Salt.

History of stratigraphic nomenclature:
Francis, D. R., 1956 (Sask. Dep. Min. Res., Rep. 18, p. 18-22): Jura-Triassic Red Beds consist of reddish-brown silty and non-silty dolomitic shales. One or more unconformities may exist within unit. Lower boundary difficult to determine where redbeds in contact with Big Snowy Group or Minnekahta and Opeche Formations in Montana and North Dakota, but readily apparent where redbeds rest on Paleozoic carbonates. Upper boundary placed at lowest occurrence of massive nonclastics in Jurassic; overlying beds are evaporites in eastern half of Williston basin and carbonates over western half.

_____, 1957 (Am. Assoc. Pet. Geol., Bull. 41, no. 3, p. 376): Jura-Triassic Red Beds underlie Gypsum Spring or Sundance Formations in Williston Basin. Consist of red silty shales grading into argillaceous siltstone near base and becoming progressively less silty upward. Lower part or all Jura-Triassic Red Beds is considered to be equivalent to Spearfish Formation of Black Hills.

Keld Member (of Favel Formation)

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 993-1010): Keld Member of Favel Formation (Late Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota. Overlies Ashville Formation; underlies Assiniboine Member of Favel Formation. This usage not followed by later writers.

KIBBEY FORMATION, Sandstone (of BIG SNOWY GROUP)

Age: Chesterian to Late Meramecian.

Area of extent: Montana, western North Dakota, northwestern South Dakota.

Lithology: White to red sandstone, red shale, and thin gypsum beds. Characteristically has medial unit called Kibbey Limestone.

Thickness: Up to 200 feet.

Relationships to other units: Conformably underlies Otter Formation; disconformably overlies Charles Formation. Lowest unit of Big Snowy Group.

Characteristic fossils: None.

Economic significance: Oil productive.

Depositional environment: Marine shelf, under oxidizing conditions.

Remarks: Type locality near Kibbey Post Office, Fort Benton region, central Montana. See also Big Snowy Group.

History of stratigraphic nomenclature:

Weed, W. H., 1899 (U. S. Geol. Surv., Geol. Atlas, Folio 55): Kibbey Sandstone constitutes lowest beds of Quadrant Formation.

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 1, p. 1091): U. S. Geological Survey adopted Kibbey Sandstone Member of Quadrant Formation in 1907.

Scott, H. W., 1935 (J. Geol., v. 43, p. 1011-1032): Big Snowy Group is new name for lower part of beds formerly assigned to Quadrant Formation. Divided into three conformable formations (descending): 1) Heath (new), 2) Otter, and 3) Kibbey formation. Kibbey is red to grayish-yellow sand and red shale, with occasional gypsum or anhydrite. Few limestones. Thickness 50-300 feet.

Seager, O. A., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 5, p. 863): In subsurface of Cedar Creek anticline, southeastern Montana, Kibbey Formation overlies Charles Formation (new).

Anderson, S. B., 1954 (N. D. Geol. Surv., Rep. Invest. 16, 2 sheets): Kibbey Formation in North Dakota is sequence of shales, sandstone, and limestone in subsurface of western North Dakota and eastern Montana. Overlies Charles in deeper part of Williston basin; underlies Otter and Heath where not eroded. Kibbey is reddish or occasionally light gray, medium- to fine-grained, rounded sandstone with limestone or occasional dolomite below sandstone and variegated shale at base. Total thickness 225 feet. Resistivity curve "kick" selected as top of Kibbey.

Lauden, L. R., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 210): Kibbey, Heath, Otter and Amsden are believed to represent shore facies of various parts of early Pennsylvanian seas.

Gardner, L. S., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 2, p. 333-334, 341-342, 346-347): Kibbey Formation is 220 feet thick in composite section of revised Big Snowy Group. Underlies Otter Formation; unconformably overlies Mission Canyon Limestone of Madison Group.

Anderson, S. B., 1974 (N. D. Geol. Surv., Misc. Map 17, 1 sheet): Kibbey Formation of North Dakota divided into three mappable units (descending): sandstone, limestone, and silt.

Anderson, S. B., 1977 (Personal communication, October 4, 1977): Although Kibbey sand produces in Montana along Weldon fault, Kibbey lime produces in Redwing Creek Field in North Dakota.

Killdeer formation

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. xviii): Killdeer Formation proposed for strata overlying White River Group in North Dakota and below unconsolidated deposits whose source and age are unknown (formerly considered Arikaree Formation). Consists of 25-200 feet of green-colored, concretionary, calcareous sandstone, siltstone, silty claystone, and dolostone. Fossil evidence (Paleocastor sp., Hypertragulus minor, and Amphicaenopus(?)) suggests Arikareean (early Miocene) age.

Kinderhook Formation

Laird, W. M., and Towse, D. F., 1949 (N. D. Geol. Surv., Rept. Invest. 2, 2 sheets): Kinderhook term used in stratigraphic column of North Dakota. Is equivalent of Englewood.

Term used in Montana. Is age term representing Englewood Formation.

KLINE MEMBER (of NESSON FORMATION)

Age: Jurassic.

Area of extent: Subsurface in North Dakota, Montana, and Manitoba.

Lithology: Light-gray to white, earthy dolomite and fine-grained sandstone; calcareous shale with white gypsum; and dark-brown, finely crystalline limestone; light-gray to buff, fine- to medium- crystalline limestone.

Thickness: Up to 150 feet.

Relationships with other units: Overlies Picard Member; underlies Piper Formation. Uppermost member of formation.

Characteristic fossils: None listed.

Economic significance: None.

Depositional environment: Marine.

Type section: Interval of 4,386-4,533 feet in Price Drilling Co. No. 1, Kline well, Center SESESE sec. 16, T. 157 N., R. 85 W., Ward County, North Dakota.

History of stratigraphic nomenclature:
Nordquist, J. W., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 104, and 105-106): Kline Member is uppermost member of Nesson Formation (new); overlies Picard Member (new); underlies Piper Formation. At type section, consists of (descending): 34 feet of light-gray to white earthy dolomite and fine-grained sandstone; 13 feet of gray-green to purple calcareous shale containing white gypsum; 37 feet of light- to dark-brown finely crystalline limestone, oolitic in part, and becoming shaly toward base; 63 feet of light-gray to buff, fine- to medium-crystalline limestone, earthy, gypsiferous and fossiliferous in part. Pinches out by nondeposition short distance east of Big Snowy uplift and wedges out in like manner on west flank of Bowdoin dome. On west margin of Williston basin, unconformably overlies either Mississippian, Pennsylvanian, or Triassic beds.

Knoop bed (of BULLION CREEK FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 257): Knoop bed is named for exposures on Knoop Ranch on west side of Missouri River in secs. 8, 9, 16, and 17, T. 145 N., R. 85 W. Consists of two beds of coal separated by 3-4 feet of clay. Is about 80-120 feet below Stanton bed. May be lateral equivalent of Wolf Creek bed.

Kruckenberg bed (of SENTINEL BUTTE FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 260): Kruckenberg bed is coal bed named for Kruckenberg Farm where it is exposed. Is 50 feet above Garrison Creek bed.

Kuether bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 40): Keuther bed is 35-45 feet above Hagel bed and is named for Keuther Mine. Is found in Oliver County, North Dakota.

Lakeside clay bed

See Golden Valley Formation.

LAKOTA FORMATION, SANDSTONE (of DAKOTA GROUP)

Age: Early Cretaceous.

Area of extent: Montana, Alberta, Saskatchewan, North Dakota, and South Dakota.

Lithology: Irregular to massive, often cross-bedded, cherty, fine- to coarse-grained sandstone.

Thickness: 50-100 feet.

Relationships to other units: Unconformably overlies Morrison, filling in channels and depressions in upper Morrison Shale, conformably on Morrison on edges of basin; conformably overlain by Fuson or Kootenai.

Characteristic fossils: Plant fossils.

Economic significance: Oil productive in Montana and Wyoming.

Depositional environment: Widespread, but sporadic, flood-plain and channel deposit.

Remarks: Type locality is Lakota Peak, summit on Hogback Range, 4 miles northwest of Hermosa, South Dakota. Named from tribal division of Sioux Indians. Standard reference section in valley of Fall River in center W½ NW sec. 33, NENE sec. 32 and adjacent part sec. 29, T. 7 S., R. 6 E., Fall River County. Hot Springs quadrangle, South Dakota.

History of stratigraphic nomenclature:
Darton, N. H., 1899 (Geol. Soc. Am., Bull. 10, p. 387): Lakota sandstone is coarse, buff sandstone with fire clay and local coal. Overlies Beulah Shale (Morrison Formation) in Black Hills, South Dakota. Is Early Cretaceous or Jurassic.

Darton, N. H., 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 4, p. 526): Lakota Formation consists of massive, buff, coarse, cross-bedded sandstone with shale and local coal beds. Uppermost member is dull yellow sandstone. Thickness is 200-300 feet. Contains local unconformities and if not Jurassic, it represents earliest deposit of Cretaceous. Underlies Minnewaste Limestone and unconformably overlies Jurassic Beulah Shales. Included in Dakota Sandstone of earlier reports and name is derived from tribal division of Sioux Indians.

Darton, N. H., and O'Hara, C. C., 1909 (U. S. Geol. Surv., Belle Fourche folio, no. 164, p. 4): Type locality of Lakota sandstone is Lakota Peak, 4 miles northwest of Hermosa, South Dakota.

Rubey, W. W., 1931 (U. S. Geol. Surv., Prof. Pap. 165-A, 54 p.): Lakota Sandstone included in Inyan Kara Group.

Condra, G. E., and Reed, E. C., 1943 (Neb. Geol. Surv., Bull. 14, p. 15): Lakota shown on columnar section as basal formation of Dakota Group. Underlies Fuson shale.

Waage, K., 1959 (U. S. Geol. Surv., Bull. 1081-B, p. 26-33): Inyan Kara Group redefined to show change in environment of deposition from continental (Lakota) to marginal marine (Fall River). Upper one-third of Inyan Kara is well-bedded, fine-grained, brown-weathering sandstone with intercalated gray to black shale and siltstone; lower two-thirds is more variable with varicolored and variegated claystone and siltstone, and massive, locally poorly-sorted sandstone, carbonaceous shale and coal, and shale and limestone. Two units are separated by transgressive disconformity. Lakota comprises Minnewaste Limestone Member and Fuson Shale Member. Name Lakota should not be used outside Black Hills region; type locality at Lakota Peak should not be considered adequate for reference or comparison--standard reference section designated. Base of Lakota is arbitrary, indefinite, and inconsistent, generally drawn at base of first appreciable sandstone bed above Sundance Formation.

Pettyjohn, W. A., 1960 (S. D. Acad. Sci., Proc., v. 38, p. 34-38): Dakota controversy discussed. Suggested term Dakota Group be used to include Lakota, Fuson, Fall River, Skull Creek, and Newcastle Formations.

Gries, J. P., 1962 (Wyo. Geol. Assoc., Gdbk., 17th Ann. Field Conf., p. 163): Lakota should be recognized eastward from Black Hills as far as overlying marine Fall River and Skull Creek Formations can be identified.

Lance Formation

Age: Late Cretaceous.

Area of extent: Northern Rocky Mountains, North Dakota and South Dakota.

Lithology: Sandstone, siltstone and shale, several coal and lignite beds.

Thickness: Up to 1000 feet.

Relationships to other units: Disconformable to conformable on Fox Hills Formation; unconformably overlain by Fort Union beds.

Characteristic fossils: Plant fossils, dinosaurs.

Depositional environment: Unstable nearshore marine to brackish to mostly fresh-water continental deposits.

Remarks: Type locality and exposures on Lance Creek, Niobrara County, Wyoming.

History of stratigraphic nomenclature:
Hatcher, J. B., 1903 (Am. Geol., v. 31, p. 369-375): Lance Creek (Ceratops) beds--name Ceratops beds cannot be used for Wyoming deposits. Conformably overlies Fox Hills; underlies Fort Union.

Stanton, T. W., 1910 (Am. J. Sci., 4th ser., v. 30, p. 172-188): Name Lance Formation has been adopted by U. S. Geological Survey for "Ceratops beds" of eastern Wyoming and adjacent areas. It is abbreviated form of "Lance Creek Beds." Lance Formation is considered to be transition from marine Cretaceous Fox Hills Sandstone into Lance Formation; sedimentation continuous from one to the other and probably on through overlying Fort Union.

Lloyd, E. R., and Hares, C. J., 1915 (J. Geol., v. 23, p. 523-547): In region west of Missouri River in North Dakota and South Dakota, Lance Formation consists of two distinct parts: lower nonmarine part that contains fauna resembling that of Fox Hills Sandstone and upper part, because of peculiar fauna, has been mapped separately and named Cannonball Marine Member of Lance Formation. Farther west, non-marine beds bearing lignite and occupying similar stratigraphic position have been named Ludlow Lignitic Member of Lance.

"Lance Creek beds"

See Lance Formation.

Laramie Formation, Group

Mapped by King, Hayden, and other early workers; covered large areas

in Rocky Mountains. Now it is restricted to Denver basin.

See also Fort Union Formation, Group.

Lebo shale member

Stone, R. W., and Calvert, W. R., 1910 (Econ. Geol., v. 5, no. 8, p. 746): Lebo Andesitic Member of Fort Union consist of 450-2200 feet of dark-colored beds of volcanic material lying between Lance Formation and sandstone of Fort Union Formation.

Thom, W. T., Jr., and Dobbin, C. E., 1924 (Geol. Soc. Am., Bull. 35, no. 3, p. 492): Ludlow Member of Lance is equivalent to Lebo Member of Fort Union of Montana plus Tullock Member of Lance and "lignitic beds" which are part of Hell Creek Member of Lance lying above "A" lignite zone.

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, 65 p.): Lebo Member is tongue of shale near top of Ludlow in southwestern North Dakota.

LINTON MEMBER (of FOX HILLS FORMATION)

Age: Late Cretaceous (Maestrichtian).

Area of extent: Emmons and Sioux Counties, North Dakota, and eastern Corson County, South Dakota.

Lithology: Fine-grained, moderately to poorly sorted, indurated, siliceous sandstone with volcanic shards.

Thickness: Up to 22 feet.

Relationships to other units: Underlies Hell Creek.

Characteristic fossils: Plant remains (Equisetum) and Ophiomorpha.

Depositional environment: Marine, large shoals in an estugrine tidal river or deltaic distributary.

Type section: N½ secs. 8 and 9, T. 132 N., R. 76 W., 1 mile east of Linton, North Dakota.

Remarks: Probably equivalent of "Bed Q" of Meek, R. B., and Hayden, F. V., 1857 (Philadelphia Acad. Nat. Sci., Proc. 9, p. 117-148).

History of stratigraphic nomenclature:
Meek, R. B., and Hayden, F. V., 1857 (Acad. Nat. Sci., Phila., Proc.,

v. 9, p. 117-148): "Bed Q" is gray, indurated to slightly-friable sandstone and is basal unit of "Great Lignite Group." Total thickness 30 feet.

Klett, M. C., and Erickson, J. M., 1976 (N. D. Acad. Sci., Proc. 28, pt. 2, p. 3-21): Linton Member named; strata previously placed in Colgate lithofacies (or member). Consists 0.6-22.4 feet of light-olive-gray to grayish brown, fine-grained, subangular, moderately to poorly sorted, indurated, siliceous sandstone with volcanic shards. interpreted as channel sand, deposited in and along major, wide, shallow, southward-flowing estuarine tidal river. Is probably Hayden's Bed Q, resistant sandstone that caps Fox Ridge and other buttes in Missouri Valley north of Grand River in South Dakota. Type section given.

LITTLE BEAVER CREEK MEMBER (of HELL CREEK FORMATION)

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 30-31): Little Beaver Creek is lowest member of Hell Creek Formation in Little Missouri valley. Consists of lignitic sandstones and shales. Named after Little Beaver Creek; type section is SW¼ sec. 7, T. 132 N., R. 106 W., Bowman County, North Dakota. Conformably and unconformably overlies Fox Hills Formation; underlies Marmarth Member. Member is largely continental (cones of Sequoia dakotensis found) but probably has marine beds near base.

Little Eagle Lithofacies (of TIMBER LAKE MEMBER of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: South Dakota and North Dakota.

Lithology: Clayey silt and clayey sand.

Thickness: Up to 100 feet.

Relationships to other units: Overlies Trail City Member of Pierre Shale; underlies Iron Lightning Member of Fox Hills.

Charactersitic fossils: Ammonites and other molluscs.

Depositional environment: Marine.

Type section: Southwest-facing bluffs along narrow end of southeast-trending spur in SW¼ sec. 26, T. 20 N., R. 26 E., U. S. Geol. Surv., Little Eagle NW quad., Corson County, S. Dak.

Remarks: See Timber Lake Member.

History of stratigraphic nomenclature:
Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist., Bull. 27, p. 60-73): Little Eagle lithofacies is clayey silt with several richly fossiliferous concretion layers on south side of Moreau River Valley, on Cheyenne-Moreau Divide and Grand River Valley. Bedding in lower half of sediment is obliterated due to burrowing organisms. Principal assemblage zones are (ascending): 1) Lower nicolleti, 2) Limopsis-Gervilla, and 3) Protocardia-Oxytoma. Two lower assemblage zones extend to Linton, North Dakota. Upper concretionary layers of Little Eagle lithofacies contain few fossils. Little Eagle lithofacies assemblage zones formed off down-current end of Timber Lake sand body.

Lodgepole Limestone (of MADISON GROUP)

Age: Early Mississippian (Kinderhookian).

Area of extent: Montana, Wyoming, South Dakota; subsurface in North Dakota and Saskatchewan.

Lithology: Thinly-bedded argillaceous limestone with chert beds.

Thickness: Up to 1,000 feet.

Relationships to other units: Unconformable on Bakken Shale; conformably underlies Mission Canyon Limestone.

Characteristic fossils: Spirifers, crinoids, bryozoans, and corals.

Economic significance: Oil productive.

Depositional environment: Marine.

Type section: Bed of tributary of Lodgepole Creek in Little Chief Canyon in NENW sec. 30, T. 26 N., R. 25 E., Blaine County, Mont., and extends across SE¼ sec. 19 into SWNW sec. 20 (Sando, W. J., and Dutro, J. T., Jr., 1974), p. 17. Named for Lodgepole Canyon, Little Rocky Mountains, Montana.

History of stratigraphic nomenclature:
Collier, A. J., and Cathcart, S. H., 1922 (U. S. Geol. Surv., Bull. 736F, p. 171-178): Madison ranked as group when subdivided into two formations in Little Rocky Mountains of Montana. Formations named (descending) Mission Canyon Limestone (500 feet of thickly-bedded limestone) and Lodgepole Limestone (800 feet of thinly-bedded limestone) from exposures in Mission and Lodgepole Canyons. Lodgepole Limestone overlies Jefferson Formation in this area.

Sloss, L. L., and Hamblin, R. H., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 3, p. 305-335): Lodgepole Limestone divided into two

members (descending): Woodhurst Member and Paine Member. Fossils listed. Lodgepole Limestone overlies Three Forks Formation.

Smith, M. H., 1960 (Am. Assoc. Pet. Geol., Bull. 44, no. 6, p. 959): Changes in nomenclature of Mississippian Madison Group reported by Committee of the Mississippian Madison Group of North Dakota Geological Society. Five marker determined intervals and two subintervals defined by log deflection.

Ballard, F. V., 1963 (N. D. Geol. Surv., Bull. 40, p. 18-26): Bottineau interval equivalent to Lodgepole Limestone.

Sando, W. J., and Dutro, J. T., Jr., 1974 (U. S. Geol. Surv., Prof. Pap. 842, p. 17): Type section for Lodgepole Limestone described at NENW sec. 30, T. 26 N., R. 25 E., and SE¼ sec. 19 into SWNW sec. 20, Blaine County, Mont.

Sando, W. J., and Dutro, J. R., Jr., 1974 (U. S. Geol. Surv., Prof. Pap. 842, p. 17-21): Lowermost member, Little Chief Canyon, abandoned. Paine Shale Member and Woodhurst Limestone Member changed to Paine Member and Woodhurst Member, respectively.

LUDLOW FORMATION, Lignitic Member (of FORT UNION FORMATION)

Age: Late Cretaceous or Paleocene.

Area of extent: Northeastern Montana, western North Dakota, South Dakota.

Lithology: Unconsolidated, white to buff, calcareous sandstone and gray shale, with much lignite.

Thickness: Up to 350 feet.

Relationships to other units: Conformably overlies Hell Creek; is gradational with and replaces Cannonball Formation westward.

Characteristic fossils: Plant fossils.

Economic significance: None.

Depositional environment: Marine, brackish to littoral to freshwater swamps.

Remarks: Named from exposures in vicinity of Ludlow, Harding County, South Dakota.

History of stratigraphic nomenclature:
Lloyd, E. R., and Hares, C. J., 1915 (J. Geol., v. 23, p. 523-547): Ludlow Lignitic Member of Lance Formation occupies large area in

Harding County, South Dakota, and has been mapped northward into Bowman and Billings Counties, North Dakota, and eastward into Perkins, South Dakota, where it merges with Cannonball Marine Member. In vicinity of Ludlow, South Dakota, consists of 350 feet of loosely consolidated buff and cream-colored, calcareous sandstone and shale with interbedded lignite. Contains most of the lignite of South Dakota and presence of this lignite is criterion for considering it as distinct member of Lance Formation. In South Dakota, its lithologic character is like Fort Union Formation but different than lower part of Lance Formation, and fossil flora is identical with that of Fort Union or lower part of Lance. In North Dakota, flora is same as in South Dakota, but lithology resembles lower part of Lance except for presence of numerous lignite beds. All of Triceratops collected in Little Missouri Area came from below T Cross lignite bed (in lower part of Ludlow) and oysters came from above it.

Dorf, E., 1940 (Geol. Soc. Am., Bull. 51, p. 213-236): Paleobotanical evidence supports known vertebrate evidence in placing boundary between true Lance and Fort Union at base of nondinosaur-bearing Tullock, Ludlow, or Bear Formations or their equivalents, which is at top of Triceratops-bearing Hell Creek or Lance Formations as originally defined. Marine invertebrates of Cannonball Formation, which interfingers with Ludlow, do not contradict this position.

Brown, R. W., 1952 (Billings Geol. Surv., Gdbk., 3rd Ann. Field Conf., p. 91): Fort Union in eastern Montana is divided into (ascending): Tullock Sandstone, Lebo Shale, Tongue River Sandstone, and Sentinel Butte Shale. East of Miles City, Montana, two lower members merge in facies so that they are combined as Ludlow in North and South Dakota.

Laird, W. M., and Mitchell, R. H., 1942 (N. D. Geol. Surv., Bull. 14, p. 16-18): Ludlow of southern Morton County is 17-49 feet thick, overlies Hell Creek Formation; underlies and is in gradational contact with Cannonball Formation which it replaces westward. Is of Fort Union Group, and is Paleocene in age.

Brant, R. A., 1953 (U. S. Geol. Surv., Circ. 226, p. 1, 11-12): Ludlow is basal member of Fort Union Formation in North Dakota. Is equivalent to Tullock Member and Lebo Shale Member in lignite fields of southeastern Montana. Underlies Tongue River Member. In Marmarth lignite field, consists of 250 feet of alternating shale, sandstone, and lignite beds. Thins to east and interfingers with Cannonball Formation. Overlies Hell Creek Formation. Is Paleocene in age.

Denson, N. M. et al., 1955 (U. S. Geol. Surv., Map C-33): Ludlow, Cannonball, and Tongue River, all members of Fort Union Formation, considered to be Paleocene in age.

"Lyleton formation"

Age: Late Devonian.

Area of extent: North-central North Dakota and eastern margin of Williston basin.

Lithology: Red, dolomitic shale and siltstone.

Thickness: 65-90 feet at type locality.

Relationships to other units: Equivalent to all or part of Qu'Appelle and Three Forks Formation. Regarded as facies of Three Forks.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Shallow marine.

Remarks: Type locality at Souris Valley Oil Company No. 1 Gordon White well near Lyleton in southwestern Manitoba. Term "Lyleton" should perhaps be discarded because it was not formally proposed or adequately defined, and because of confusion in correlation.

History of stratigraphic nomenclature:
Allan, J. D., and Kerr, L. B., 1950 (The Precambrian, v. 23, no. 10, p. 8-10): Lyleton Shale is name given to 90 feet of red shale marking top of Devonian.

Towse, D., 1953 (N. D. Geol. Surv., Rep. Invest. 12, 1 sheet): Lyleton Formation consists of reddish-brown, fine to medium crystalline, shaly dolomite and dolomitic limestone. Underlies Mississippian Englewood; overlies "Nisku equivalent." Lyleton equivalent to Three Forks Formation.

MADISON FORMATION, GROUP, or Limestone

Age: Early and Late Mississippian.

Area of extent: Montana, Idaho, Wyoming, and Utah. Sursurface in North Dakota.

Lithology: Clean to argillaceous limestone, evaporite facies in Charles Formation of Williston basin.

Thickness: Up to 2,000 feet.

Relationships to other units: Unconformable on Bakken Shale, disconformably underlies Kibbey Formation in Williston basin of North Dakota.

Characteristic fossils: Crinoid debris, spirifers, bryozoans, and corals.

Economic significance: Oil productive.

Depositional environment: Marine, stable to unstable shelf, periodically restricted.

Type section: North side of Gallatin River, north of Logan in SESW sec. 25, T. 2 N., R. 2 E., Gallatin Co., Mont. (Sando, W. J., and Dutro, J. T., Jr., 1974, p. 4): Named for Madison Range, central part of Three Forks quadrangle, Mont.

History of stratigraphic nomenclature:
Original Reference: Peale, A. C., 1893 (U. S. Geol. Surv. Bull. 110, p. 32): Madison limestones consist of (descending): 575 feet of massive, jaspery limestone; 350 feet of light bluish gray, massive limestone; and 325 feet of dark, compact, laminated limestone. Overlain by Quadrant Formation and underlain by Three Forks Shale. Fossils listed.

Collier, A. J., and Cathcart, S. H., 1922 (U. S. Geol. Surv., Bull. 736F, p. 171-178): Madison ranked as group where subdivided into two formations in Little Rocky Mountains of Montana. Formations named (descending) Mission Canyon Limestone (500 feet of thickly-bedded limestone) and Lodgepole Limestone (800 feet of thinly-bedded limestone) because of exposure in Mission and Lodgepole Canyons.

Sloss, L. L., and Hamblin, R. H., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 3, p. 305-335): Lodgepole Limestone divided into two members (descending): Woodhurst Member and Paine Member. Fossils listed. Madison Group overlies Three Forks Formation and underlies Kibbey Sandstone, Ellis Formation, or Amsden Formation.

Sloss, L. L., 1952 (Billings Geol. Soc., 3rd Ann. Field Conf., p. 65-69): Charles Formation, previously included in Big Snowy Group, added to Madison Group of Williston basin. Descending order for section: Charles Formation (thick succession of limestone, dolomite, and evaporite); Mission Canyon Limestone (massive, fine-grained limestone with dolomite toward top of formation); and Lodgepole Limestone (massive limestone with crinoidal fragments); beds of dark limestone, cherty limestone, and thin shale beds; and black shale marks bottom of section).

Andrichuk, J. M., 1955 (Am. Assoc. Pet. Geol., Bull. 39, no. 11, p. 2170-2210): Madison Group of three units, boundaries redefined on interpretation of depositional environments of entire Mississippian carbonate sequence in Wyoming and southern Montana. Upper unit approximately upper three-fourths of Charles Formation, middle unit of remainder of Charles and most of Mission Canyon Limestone, and lower unit of remainder of Mission Canyon and entire Lodgepole Limestone. Type section for Charles Formation suggested.

Porter, J. W., 1955 (Alberta Soc. Pet. Geol., J. 3, no. 8, p. 126-130): Charles, Mission Canyon, and Lodgepole Formations interfinger and exhibit facies relationships in subsurface of Williston basin of Manitoba and Saskatchewan. Facies interpreted to be time transgressive as changes in lithology lateral and vertical.

Fuller, J. G. C. M., 1956 (Sask. Dep. Miner. Resour., Rep. 19, p. 1-72): Basal Bakken Formation placed in Madison Group. Lodgepole and Mission Canyon Limestones combined into Madison Limestone. This usage not followed by later writers.

Porter, J. W. (Chm.), 1956 (Sask. Geol. Soc., Report of the Mississippian Names and Correlations Committee, p. 1-4): "Beds" were chosen for subdivisions of limestone sequence of Madison Limestone because no adequate correlation exists between rocks of northeastern Williston basin and Mission Canyon or Lodgepole Limestone of Montana. "Beds" may include several contrasting lithologies and have lateral and vertical facies changes. "Beds" named Poplar, Ratcliffe, Midale, Frobisher-Alida, Tilston, and Souris Valley from oilfields of southeastern Saskatchewan.

Anderson, S. B., 1958 (N. D. Geol. Surv., Rep. Invest. no. 31, p. 1-9): Madison Formation of grading belts of lithology that cross time lines in subsurface of North Dakota. Charles magnafacies proposed for evaporitic facies and Mission Canyon magnafacies proposed for massive marine facies of Williston basin to eliminate confusion caused by time connation of original definition of formations within Madison Group. Lodgepole Limestone used for sequence below "Tilston beds" and above Englewood (Bakken) Formation.

Smith, M. H., 1960 (Am. Assoc. Pet. Geol., Bull. 44, no. 6, p. 959-960): Changes in nomenclature of Mississippian Madison group reported by Committee of the Mississippian Madison Group of North Dakota Geological Society. Five marker-determined intervals and two subintervals defined by log deflection.

Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol. Surv., Rep. Invest. no. 36, p. 1-25): Mississippian Madison Group Committee of North Dakota Geological Society proposed following units (descending): Poplar, Ratcliffe, and Frobisher-Alida intervals; Middle subinterval substituted for "Midale evaporite) and upper two-thirds of "Midale beds" in Ratcliffe interval; Rival subinterval substituted for "Frobisher evaporite" and lower one-third of "Midale beds" in Frobisher-Alida interval; and Poplar interval substituted for "Souris Valley beds." Interval and subinterval boundaries defined by prominent deflection on gamma ray and spontaneous potential logs; these markers define intervals of laterally varying lithology and assumed to be para-time-rock units (nearly time parallel.).

Ballard, F. V., 1963 (N. D. Geol. Surv., Bull. 40, p. 18-26): Bottineau interval equivalent to Lodgepole Limestone. Tilston interval

conformably overlies Bottineau interval and conformably underlies Frobisher-Alida interval. Poplar interval, Midale subinterval, Ratcliffe interval, Rival subinterval, and Ratcliffe interval follow usage by earlier authors and followed by North Dakota Geological Survey presently. Carrington shale facies proposed as part of Bottineau interval instead of equivalent to Three Forks Formation.

Sando, W. J., and Dutro, J. T., Jr., 1974 (U. S. Geol. Surv., Prof. Pap. 842, p. 1-22): Descriptions of precisely located type section for Madison Group, Lodgepole Limestone, Mission Canyon Limestone, and Paine Member and Woodhurst Member of Lodgepole Limestone.

MANITOBA GROUP (also Manitoban Formation)

Tyrrell, J. B., 1892 (Can. Geol. Surv., Ann. Rep. pt. E, p. 1890-1891): Manitoban Formation is of shales and limestones that overlie Winnipegosan Formation.

Baille, A. D., 1953 (Manit. Dep. Mines, Pub. 52-5, p. 25-26): Manitoba Group proposed for carbonate and argillaceous strata overlying Elk Point Group in Williston basin. Manitoba Group has same areal extent as Elk Point Group. Thickness is generally less than 300 feet. Consists of repetitive sequences of carbonates with thin, shaly beds. Sequences consist of shale and argillaceous limestone that grade upward to light-colored, bedded limestone overlain by fragmental and reefoid zone; evaporites commonly mark upper member of sequence. Basal sequence of group exposed in outcrop area is named Dawson Bay.

Towse, D., 1953 (N. D. Geol. Surv., Rep. Invest. 12, 1 sheet): In North Dakota, Manitoban Formation consists of light olive to yellowish gray, fine- to medium-grained sugary dolomite and limestone. Makes distinctive gamma ray "kick." Is Middle Devonian in age.

See Dawson Bay and Souris River Formations.

MARMARTH MEMBER (of HELL CREEK FORMATION)

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 30-31): Marmarth Member consists of two thick sandstone bodies separated by thin sequence of bentonites, bentonitic shales and lignitic shales. Named for town of Marmarth, North Dakota and type section is just west of Marmarth in SW¼ sec. 26, T. 133 N., R. 106 W., Slope County, North Dakota. Overlies Little Beaver Creek Member; underlies Bacon Creek Member. Sandstones appear to have been deposited in large river although no aquatic animal fossils found.

Medora coal group

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 96-102): Medora group of coal beds crops out along valley of Little Missouri River from Bullion Butte to northern boundary of Billings County. Beds J-M make up this group of coals.

"Medora lithozone"

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Medora lithozone is basal zone of Amsden Formation; includes 0-200 feet of strata between top of Alaska Bench Formation and base of anhydritic marker unit (base of Dickinson lithozone). Consists of two lithologic facies (ascending): 1) Grayish pink and pale red to pale yellowish brown, microcrystalline to occasionally medium and coarse crystalline dolomite interbedded with red calcareous shale; and 2) pale yellowish brown to pale red, microcrystalline, generally nonporous dolomite. Basal contact may represent unconformity; upper contact apparently conformable. Where overlying units of Amsden are absent, Medora lithozone unconformably overlain by Broom Creek, Opeche, Spearfish or Piper. Lithologic relationships suggest carbonate bank accumulations along with progressive restriction of environment. Medora lithozone equivalent to all of Roundtop Group in South Dakota and entire Amsden in central Montana.

See also Amsden Formation.

Meek Group

Age: Pennsylvanian.

Area of extent: Eastern Wyoming, southwestern South Dakota, and North Dakota.

Lithology: Limestones and silty limestones with sandstone.

Thickness: Up to 130 feet.

Relationships with other units: Underlies Wendover Group; overlies Hayden Group.

Characteristic fossils: Fusulinids.

Economic significance: None.

Depositional environment: Marine.

Remarks: Type locality is Meek Cliff, sec. 22, T. 27 N., R. 66 W., Platte County, Wyo.

History of stratigraphic nomenclature:
Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13A, p. 2, 22, and 28): Meek Group consists of limestones and silty limestones with sandstone. Comprises lower 130 feet of Division II of Hartville "Formation" (Condra, G. E., and Reed, E. C., 1935, Nebr. Geol. Surv., Pap. no. 9, 46 p.). Thickness is 119-130 feet. Underlies Wendover Group (new); overlies Hayden Group (new).

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym., 1st Internat., Bismarck, N. D., 46 p.): Wendover-Meek Group is poorly represented in North Dakota. All beds from base of overlying Brook Creek to below radioactive markers are missing in broad areas of southeastern and eastern Montana, southwestern North Dakota, and northwestern South Dakota. Over rest of basin in North Dakota, Broom Creek rests directly on radioactive zones or is separated by few feet. Sandstone or sandy dolomite are most common lithologies of Wendover-Meek Group.

Meyer bed (of BULLION CREEK FORMATION)

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, p. 50): Meyer bed is thin and of poor quality. Crops out in lower part of Bullion Butte.

"Midale beds"

Age: Mississippian.

Area of extent: Subsurface in Saskatchewan and North Dakota.

Economic significance: Oil productive.

Remarks: Informally named for Midale Oilfield, southeastern Saskatchewan. See also Rival subinterval, Midale subinterval, Frobisher-Alida interval, Ratcliffe interval, and Madison Group.

History of stratigraphic nomenclature:
Fuller, J. G. C. M., 1956 (Sask. Dep. Miner. Resour., Rep. 19, p. 34-35): "Midale beds" of 80 feet of uniformly dolomitized, oolitic limestone and argillaceous dolomite, bounded below by "Frobisher-Alida beds" and above by "Midale evaporite." "Midale beds" most prolific of Mississippian oil-producing rocks in southeastern Saskatchewan.

Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol. Surv., Rep. Invest. no. 36, p. 15): Basal Midale subinterval of Ratcliffe interval of approximately two-thirds of "Midale beds"; remainder of "Midale beds" in Rival subinterval at top of Frobisher-Alida interval. Carbonate zone in Midale subinterval is oil-producing in North Dakota.

Midale subinterval, "evaporite," "anhydrite"

Age: Mississippian.

Area of extent: Subsurface in Saskatchewan and North Dakota.

Remarks: Informally named for Midale Oilfield, southeastern Saskatchewan. See also Ratcliffe interval and Madison Formation.

History of stratigraphic nomenclature:
Fuller, J. G. C. M., 1956 (Sask. Dep. Miner. Resour., Rep. 19, p. 35): "Midale evaporite" is anhydrite capping oil pools in several southeastern Saskatchewan oil fields.

Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol. Surv., Rep. Invest., no. 36, p. 15): Midale subinterval of Ratcliffe interval includes approximately two-thirds of "Midale beds," entire "Midale anhydrite" or basal one fourth of "Ratcliffe beds" if "Midale anhydrite" does not occur.

MINNEKAHTA LIMESTONE

Age: Permian.

Area of extent: Northeastern Wyoming, southeastern Montana, western South Dakota, and western North Dakota.

Lithology: Gray, thinly-bedded limestone.

Thickness: Up to 50 feet.

Relationships to other units: Equivalent to Sybille tongue of Phosphoria and eastward tongue of Park River facies.

Characteristic fossils: Few molluscs, ostracods, and stromatolites.

Economic significance: None.

Depositional environment: Marine, possibly tidal flat.

Remarks: Type locality near hot springs, Black Hills, South Dakota. Is prominent carbonate tongue over sandstone in eastern Wyoming to Black Hills area.

History of stratigraphic nomenclature:
Darton, N. H., 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 4, p. 514): Minnekahta Limestone is thinly-bedded gray limestone, 30-50 feet thick; underlies Spearfish Formation and overlies Opeche Formation in Black Hills. Referred to as "Purple limestone" in previous reports. Type locality is region near Hot Springs, South Dakota, originally known as "Minnekahta" by Indians.

Laird, W. M., and Towse, D. F., 1953 (N. D. Geol. Surv., Rept. Invest. 2, sheet 1): Permian System of North Dakota includes Minnekahta Formation, 40 feet of pink to purple dolomite and limestone; underlain by Opeche Formation.

Burk, C. A., and Thomas, H. D., 1956 (Wyo. Geol. Surv., Rep. Invest. 6, 11 p.): Goose Egg Formation of eastern Wyoming is sequence of interbedded red shales and silstones, thin limestones gypsum and limestone breccias. Overlies Minnelusa and equivalents (Tensleep, Casper, and Hartville); underlies Spearfish and equivalent (Chugwater). Minnekahta is limestone with farthest easterly extent, is underlain by Opeche Shale; less extensive limestones are overlying Forelle and Ervay, all of Phosphoria Group.

Goldsmith, J. W., 1959 (U. S. Geol. Surv., Misc. Inv., Map I-300, p. 4): Minnekahta is Permian (possibly Leonardian) in age.

MINNELUSA FORMATION, Sandstone

Age: Pennsylvanian.

Area of extent: Eastern and southeastern Montana, western North Dakota, western South Dakota, and eastern Wyoming.

Lithology: Sandstones and carbonates interbedded with shale, sandstone, and anhydrite.

Thickness: 500 feet in North Dakota; 600 feet in type area.

Relationships to other units: Unconformably overlies Madison Group; conformably underlies Opeche Formation (Permian).

Characteristic fossils: Fusilinids, ostracods, and brachiopods (Mesolobus mesolobus), and Chaetetes milliporaceous.

Economic significance: Oil productive.

Depositional environment: Intermittently restricted shallow sea and nearshore environment.

Type section: Sundance Canyon, SW¼ sec. 10, T. 52 N., R. 61 W., Crook Co., Wyo.

Remarks: See also Amsden Formation and Tyler Formation.

Winchell, N. H., 1895 (in Ludlow, W., U. S. Eng. Dep., U. S. Army, Black Hills of Dakota, p. 38 and 65): Minne-lusa Sandstone or upper sandstone consists of nearly white, crystalline, subsaccharoidal sandstone, coarsely granular when weathered and hard. Locally iron-stained. Thickness 75 feet in Black Hills. Underlies Upper Limestone and overlies Lower Limestone. Is Indian name of valley where exposed.

Jagger, T. A., 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 3, p. 178-181): In northern Black Hills Minnelusa limestones and sandstones consist of (descending): 1) Minnelusa saccharoidal sandstone, 200 feet, 2) Minnelusa "alternate" series, 300 feet; and 3) Minnelusa white sandstone, 100 feet. Separated from overlying Minnekahta limestone by 90 feet of red sandstone. Overlies 200-700 feet of gray limestone equivalent to Madison Limestone.

Darton, N. H., 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 4, p. 510): Minnelusa Formation consists of buff and red calcareous sandstones with thin limestones. 400-450 feet thick. Term Minnelusa used to designate all sandstones and limestones in Black Hills lying between Pahasapa Limestone below and red sandstones and shales of Opeche Formation above. Minnelusa is Dakota Indian name for Rapid Creek.

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 2, p. 1382): Minnelusa Formation probably includes Permian strata at top and Mississippian strata at base.

Gries, J. P., and Tullis, E. L., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 34): Lithologic correlation of upper Minnelusa beds with those in western Nebraska--Hartville, Wyoming area suggests uppermost Minnelusa in Black Hills may be Early Permian in age. No fossil evidence.

Reed, E. C., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 46): Pennsylvanian-Permian boundary placed in eastern Wyoming and southwestern South Dakota in Hartville and Minnelusa Formations at top of Wendover Group and 150 feet below top of Minnelusa Formation in Black Hills.

Bates, R. L., 1955 (Am. Assoc. Pet. Geol., Bull. 39, p. 1991-1995): Term Minnelusa sandstone is misnomer as type area contains 58% sandstone and subsurface sections contain lower proportion. Brecciated upper Minnelusa in southern Black Hills is correlative lithologically with upper evaporite zone of subsurface Minnelusa. Black Hills Minnelusa represents leached, thinner counterpart of more completely developed formation toward southwest (Hartville). Upper evaporite zone of subsurface Minnelusa appears contemporaneous with Upper Hartville (Wolfcampian(?). No paleotologic evidence to refute or support this correlation.

McCauley, V. T., 1956 (Williston Basin Sym., 1st Internat., Bismarck, N. D., p. 150-164): Permian-Pennsylvanian strata correlated with Hartville Formation of Hartville Formation of Wyoming and Minnelusa of Black Hills. Minnelusa is divided into (ascending): 1) Fairbank Formation, basal sandstone and shale; 2) Reclamation group, limestone and dolomite sequence, 3) Hayden group, dolomite and sandstone, and 4) Wendover-Meek group, sands and shales. Unconformity truncates Hayden and Wendover-Meek groups, separating strata from overlying dolomites, anhydrites, and sandstones of Broom Creek Group. In North Dakota, salt and silty shale section previously assigned to Opeche is thought to be time equivalent of Cassa. Unconformity separates Broom Creek and Cassa groups in North Dakota. Fairbank, Reclamation, Roundtop, Hayden, and Wendover-Meek groups are Pennsylvanian and Broom Creek and Cassa groups are Permian.

Brady, F. H., 1958 (Wyo. Geol. Assoc., Bdbk., 13th Ann. Field Conf., p. 45-47): In Sundance-Beulah area, Wyoming, 383 feet of upper Minnelusa exposed in deep canyons. In exposure, 166 feet is local strata not exposed in rest of area. Minnelusa underlies Opeche and is 257 feet thick at newly named type section; Sundance Canyon, SW¼ sec. 10, T. 52 N., R. 61 W., Crook County, Wyoming. Late Pennsylvanian to early Permian.

Jennings, T. V., 1959 (J. Paleo., v. 33, no. 6, p. 986-1000): "Red marker bed" separates Pennsylvanian from Permian part of Minnelusa. Pennsylvanian part of Minnelusa correlated with Missourian-Virgilian, Desmoinesian, and Atokan stages based on fossil fusulinid evidence.

Sandberg, C. A., 1962 (U. S. Geol. Surv., TEI-809, p. 68): Amsden Formation included in lower part of Minnelusa in South Dakota.

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Minnelusa Group includes strata above unconformity on Madison and Big Snowy Groups and below Opeche Formation. Contains Tyler, Alaska Bench, Amsden, and Broom Creek Formations.

Minter bed

Andrews, D. A., 1939 (U. S. Geol. Surv., Bull. 906B, p. 73): Minter coal bed, named from Minter Mine, crops out along Douglas Creek near Minot, N. D.

Mission Canyon Limestone (of MADISON GROUP)

Age: Mississippian (Upper Kinderhookian to Osagian)

Area of extent: Montana, Wyoming, South Dakota; subsurface in North Dakota and Saskatchewan.

Lithology: Massive argillaceous limestone.

Thickness: Up to 325 feet.

Relationships to other units: Conformable on Lodgepole; conformably underlies Charles. Charles Formation exhibits facies relationships with Mission Canyon Limestone in Williston basin.

Characteristic fossils: Crinoid debris, bryozoans, and few brachiopods.

Economic significance: Oil productive.

Depositional environment: Marine.

Type section: Roadcut on east side of U. S. Highway 89, 1.8 highway miles north of road intersection at Monarch and about 100 yards north of sign marking boundary of national forest, SWNE sec. 27, T. 16 N., R. 7 E., Cascade County, Mont., and continues northward across SE¼ sec. 22 into NE¼ sec. 22 (Sando, W. J., and Dutro, J. T., Jr., 1974, p. 9). Named for Mission Canyon, Little Rocky Mountains, Montana.

History of stratigraphic nomenclature:

Collier, A. J., and Cathcart, S. H., 1922 (U. S. Geol. Surv., Bull. 736F, p. 173): Madison ranked as group where subdivided into two formations in Little Rocky Mountains of Montana. Formations named (descending) Mission Canyon Limestone (500 feet of thickly bedded limestone) and Lodgepole Limestone (800 feet of thinly bedded limestone) because of exposure in Mission and Lodgepole Canyons. Mission Canyon Limestone is not as fossiliferous as Lodgepole Limestone.

Sloss, L. L., and Hamblin, R. H., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 3, p. 315): Mission Canyon Limestone lithologically and faunally identical with Castle limestone whose usage has been discarded. Proposed that Mission Canyon be applied throughout Montana and northern Wyoming. Overlies Woodhurst Member of Lodgepole Limestone; underlies Amsden Formation, Ellis Formation, or Kibbey Sandstone.

Porter, J. W., 1955 (Alberta Soc. Pet. Geol., J. 3, no. 8, p. 126-136): Charles, Mission Canyon, and Lodgepole Formations interfinger and exhibit facies relationships in subsurface of Williston basin of Manitoba and Saskatchewan. Facies interpreted to be time transgressive as changes in lithology were lateral and vertical.

Anderson, S. B., 1958 (N. D. Geol. Surv., Rep. Invest. no. 31, p. 1-9): Madison Formation grading belts of lithology cross time lines in subsurface of North Dakota. Charles magnafacies proposed for evaporitic facies and Mission Canyon magnafacies proposed for massive marine facies of Williston basin to eliminate confusion caused by time connation of original definition of formations within Madison Group.

Smith, M. H., 1960 (Am. Assoc. Pet. Geol., Bull. 44, no. 6, p. 959): Changes of nomenclature of Mississippian Madison Group reported by Committee of the Mississippian Madison Group of North Dakota Geological Society. Five marker determined intervals and two subintervals defined by log deflection.

Carlson, C. G., and Anderson, S. B., 1970 (N. D. Geol. Surv., Misc. Ser., no. 28, p. 1842): Mission Canyon facies shown to include all of Tilston interval and parts of Frobisher-Alida interval, Midale subinterval, and Ratcliffe interval.

Sando, W. J., and Dutro, J. T., Jr., 1974 (U. S. Geol. Surv., Prof. Pap. 842, p. 9): Type section for Mission Canyon Limestone described at roadcut on east side of U. S. Highway 89, 1.8 highway miles north of road intersection at Monarch and about 100 yards north of a sign marking boundary of national forest, SWNE sec. 27, T. 16 N., R. 7 E., Cascade County, Mont. and continues northward across SE¼ sec. 22 into NE¼ sec. 22.

MOBRIDGE MEMBER (of PIERRE SHALE)

Age: Late Cretaceous

Area of extent: South Dakota, North Dakota, and Wyoming.

Lithology: Gray shale and chalk beds; weathers buff.

Thickness: Up to 230 feet.

Relationships to other units: Overlies Virgin Creek Member of Pierre Shale; underlies Elk Butte Member of Pierre Shale.

Remarks: Typical exposure above west end of old highway bridge across Missouri River at Mobridge, Walworth County, South Dakota. Named from Mobridge, South Dakota. See also Pierre Shale.

History of stratigraphic nomenclature;
Searight, W. V., 1937 (S. D. Geol. Surv., Rep. Invest. 27, p. 44-49): Thinly laminated, calcareous, medium bluish-gray to dark-gray shale, marl and chalk. Weathers to light or brownish buff; ligher shades of buff generally predominate in upper and lower parts of section. Beds uniform; total thickness 90-230 feet. Overlies gumbo-forming shale of Virgin Creek Member and underlies noncalcareous shale of Elk Butte Member.

Moxon, A. L., Olson, O. E., and Searight, W. V., 1939 (S. D. Agr. Exp. Sta. Tech. Bull. 2, p. 20, 25): Replaced by Interior Member, which has precedence.

Gries, J. P., and Rothrock, E. P., 1941 (S. D. Geol. Surv., Rep. Invest. 38, p. 34-35): Since incomplete equivalence of all Interior beds to Mobridge beds exists, Mobridge retained as originally defined.

Fisher, S. P., 1952 (N. D. Geol. Surv., Bull. 26, p. 8-10): Mobridge Member may be present in Emmons County, North Dakota.

Wilson, E. E., 1958 (Master's Thesis, Univ. N. D., 134 p.): Strata of Bowman County, although similar to Emmons County strata, are older and may be equivalent to Mobridge Member.

MONTANA GROUP

Age: Late Cretaceous.

Area of extent: Montana, Wyoming, Colorado, North Dakota, South Dakota, Kansas, New Mexico and Utah.

Lithology: Dark gray to brownish-gray, partly bentonitic shale, silty and sandy in local areas.

Thickness: 1800-2700 feet.

Relationships to other units: Contact gradational with underlying Niobrara Formation; disconformably and conformably underlies Hell Creek Formation.

Characteristic fossils: Baculites, other cephalopods, and Inoceramus.

Depositional environment: Nearshore, flood-plain and swamp, littoral and offshore marine; some nonmarine sediments deposited in piedmont, inland flood-plain, channel and lake environments.

Remarks: Named from exposures along Upper Missouri River, north-central Montana.

History of stratigraphic nomenclature:
Eldridge, G. H., 1888 (Colo. Sci. Soc., Proc., v. 3, pt. 1, p. 93 footnote): With approval of C. A. White, Montana Group introduced to replace Fox Hills Group; includes Fox Hills Sandstone and Pierre Shale.

_____, 1889 (Am. J. Sci., 3rd ser., v. 38, p. 313-321): Original subdivisions of Fox Hills Sandstone and Pierre Shale are recognized in Dakotas, eastern Montana, eastern Wyoming, and eastern Colorado. Group divided into (descending) Bearpaw Shale, Judith River Formation, Claggett Shale and Eagle Sandstone in southern Montana; divided into Horsethief Sandstone, Bearpaw Shale, Two Medicine Formation, and Eagle Sandstone in northwestern Montana; divided into Lewis Shale, Mesaverde Formation, and Steele Shale

in central and southern Wyoming. Group is overlain by Laramie Formation (Upper Cretaceous) in eastern Colorado; overlain by Medicine Bow Formation (Upper Cretaceous) in central southern Wyoming; and by Lance Formation (Upper Cretaceous elsewhere in Wyoming and Montana).

Rothrock, E. P., 1934 (S. D. Geol. Surv., Rep. Invest. 20, fig. opposite p. 18): Terms Colorado Group and Montana Group used for bedrock below glacial drift and above Precambrian granite in Grant County, South Dakota.

Richards, P. W., 1955 (U. S. Geol. Surv., Bull. 1026, p. 50-63): Group in Bighorn-Canyon-Hardin area, Montana and Wyoming, comprises (ascending) upper part of Cody Shale (with Telegraph Creek Shale equivalent to Eagle Sandstone and Claggett Shale Members), Parkman Sandstone, and Bearpaw Shale. Overlies Colorado Group; underlies Hell Creek Formation.

Laird, W. M., and Towse, D. F., 1958 (rev.) (N. D. Geol. Surv., Rept. Invest. 2, 2 sheets): Stratigraphy of North Dakota includes Montana stage consisting of Fox Hills and Pierre Formations.

Gill, J. R., Cobban, W. A., and Schultz, L. G., 1972 (Mont. Geol. Soc., 21st Ann. Field Conf., p. 91-97): Rocks of type Montana Group are cyclic Upper Cretaceous transgressive and regressive deposits. Marine shale of Colorado, Claggett, and Bearpaw represent periods of transgression and local westward expansion of sea; Telegraph Creek-Eagle, Parkman-Judith River, and Fox Hills-Hell Creek Formations record episodes of regression and eastward movements of strand.

Gill, J. R., and Cobban, W. A., 1973 (U. S. Geol. Surv., Prof. Pap. 776, 37 p.): Rocks of type Montana Group in Montana and equivalent rocks in adjacent states consist of eastward-pointing wedges of shallow-water marine and nonmarine strata that enclose westward-pointing wedges of fine-grained marine strata. Beds of bentonite occur in transgressive part of Claggett and Bearpaw Shales. Strandline movement more rapid during transgressions. Final phase of Fox Hills regression produced Sheridan delta. Twenty-nine ammonite zones characterize marine strata of Montana Group; suggested that Hell Creek Formation be included in Montana Group.

Geographically restricted to central and eastern Montana.

Montana series

Proposed by G. H. Ashley, 1923 (Eng. Min. J.--Press, v. 115, no. 25, p. 1106-1108) to include Montana Group and overlying Laramie Formation.

MORDEN MEMBER (of Vermillion River Formation)

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 1011-1043): Morden Member of Vermillion River Formation (Late Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota. Overlies Assiniboine Member of Favel Formation; underlies Bogne Member of Vermillion River Formation.

Wosick, F. D., 1977 (Univ. of N. D., M. S. Thesis, 152 p.): Morden Member of Vermillion River Formation crops out in eastern Cavalier County, North Dakota. Canadian Morden Member used instead of Carlile Formation because of lithologic similarity and proximity to Morden type area. Is dark gray to black, noncalcareous, organic-rich shale. Is 225 feet thick, thins toward outer edge of Williston basin.

MORRISON FORMATION

Age: Late Jurassic.

Area of extent: Widespread, southern and northern Rocky Mountains and adjacent plains.

Lithology: Green, drab, or gray, marl containing, in lower two-thirds, numerous lenticular bodies of limestone. Sandstone unit near base. Upper one-third with many sandstone beds.

Thickness: 0-400 feet.

Relationships to other units: Conformably overlies marine Jurassic beds. Underlies Cretaceous beds conformably in North Dakota, unconformably elsewhere.

Characteristic fossils: Dinosaurs, fossil wood, "gastroliths," rare molluscs and microfossils.

Economic significance: Oil productive.

Depositional environment: Fluvial, lacustrine and brackish.

Remarks: Type locality near Morrison, Jefferson County, Colorado.

History of stratigraphic nomenclature:
Cross, W., 1894 (U. S. Geol. Surv., Folio 7, 8 p., 5 maps): Morrison Formation described.

Eldridge, G. H., 1896 (U. S. Geol. Surv., Mon. 27, p. 51-62): Morrison Formation is throughout Denver region and along east base of Rocky Mountains; of fresh-water marls 200 feet thick. Overlain by Dakota

sandstone, underlain by brown and pink sandstone of Triassic. Marls are green, drab or gray and have lenticular, drab-colored limestone in lower two-thirds. At 20 feet above base occurs persistent band of alternating limestone and sandstone or all sandstone, 10-15 feet thick. Clays of lower two-thirds contain reptilian remains and are called Atlantosaurus clays from dominant form. Upper one-third of Morrison is succession of sandstones and marls. Saurian sandstone occurs just above Atlantosaurus clays; 5-35 feet thick; and is 10-125 feet below Dakota Sandstone. Morrison is unconformable with underlying Wyoming Formation.

Darton, N. H., 1904 (Geol. Soc. Am., Bull. 15, no. 8, p. 388): Thickness of Morrison is up to 150 feet in Black Hills region. Absent to southeast where unconformity shows erosion on surface of Unkpapa sandstone. Unconformably underlies Lakota sandstone. Formation has been known as Atlantosaurus beds and Beulah shale.

Fisher, C. A., 1909 (U. S. Geol. Surv., Bull. 356, p. 28-30): Morrison Formation occurs along northern base of Little Belt Mountains. In previous investigations, Morrison Formation had not been recognized and beds comprising it had been grouped with Kootenai and included in Cascade Formation. Dinosaur bones of Jurassic age were found at several localities; at one exposure, sec. 3, T. 16 N., R. 2 E., about 30 feet below bone-bearing bed, was green shale with fresh-water fauna younger than fauna of Ellis Formation. These rocks, here provisionally regarded as constituting Morrison Formation, consist of sandstone and bright-colored sandy shale with scattered layers (many lenticular) of impure limestone. Conformably lies on Ellis and overlain conformably by Kootenai. Thickness 60-120 feet. Future investigation may prove that rocks here tentatively regarded as Morrison constitute, basal member of Kootenai.

Calvert, W. R., 1909 (U. S. Geol. Surv., Bull. 390, p. 22-24): Morrison of Lewston coal field consists of shale, sandstones, and argillaceous fresh-water limestones. Thickness 125 feet. Overlies Ellis Formation; underlies Kootenai with no suggestion of unconformity at either boundary. Top of Morrison is believed to be marked by persistent sandstone member, 10-15 feet thick, containing bone fragments. Above this member, beds are distinctly arenaceous and are mapped as Kootenai on basis of lithology and occurrence of Lower Cretaceous plants just above base.

Lee, W. T., 1920 (Am. J. Sci., 4th ser., v. 291, p. 183-188): Type section of Morrison redefined. Strata originally assigned to Morrison include those equivalent to Sundance Formation and those that contain fossil plants of Upper Cretaceous type. Section at Morrison comprised 10 units (numbered in descending order 1-10). Units 1-5 are Dakota group (265 feet thick); units 6-7 are Morrison Formation (160 feet thick); and units 8-10 are Sundance Formation (17 feet thick). Units 1-3 regarded as two sandstones of Dakota and shale is "Dakota fire clay." Unit 4 is part of Morrison as originally

defined, yet contains fossil plants described as belonging to "Dakota flora" (100 feet thick). Unit 5 (10 feet thick) is conglomeratic sandstone--Saurian conglomerate--containing dinosaur bones and pebbles of quartz and jasper; is sharply separated from underlying shale.

Lee, W. T., 1927 (U. S. Geol. Surv., Prof. Pap. 149, p. 17): At Morrison, Colorado, type locality of Morrison Formation, rocks were once assigned to this formation that do not belong; at base is 17 feet or more of orange sandstone now known to be unconformable with overlying Morrison and underlying Lykins, and at top is nearly 200 feet of beds younger than Morrison. Thicknesses given in this paper should replace thicknesses previously published (1920). Cretaceous (?).

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 2, p. 1424): In western South Dakota, Wyoming, and eastern Colorado, Morrison Formation is underlain by marine Sundance Formation of Late Jurassic age. U. S. Geological Survey classifies Morrison as Upper Jurassic although for many years it was considered Lower Cretaceous (?).

Waldschmidt, W. A., and LeRoy, L. W., 1944 (Geol. Soc. Am., Bull. 55, no. 9, p. 1097-1114): Revised type section proposed. Subdivided into six lithologic units. Basal sandstone unit is of 7 feet of buff, massive, locally crossbedded, coarse- to medium-grained, calcareous sandstone, conglomeratic in lower part; north from type locality unit thickens to 30 feet. Gray and red shale unit, represents lower 55 feet of Morrison. Gray clay and limestone unit of interbedded gray clay and gray lithographic fresh-water limestones, is 49.75 feet thick. Gray shale and sandstone unit is 51.5 feet thick. Red shale unit is 36.75 feet thick and most highly colored interval in formation. Sandstone and shale unit is 76.5 feet thick; variegated sandy shales, maroon most prevalent, constitutes about 30% interval. Formation, as herein described, is mappable unit between Dakota sandstone as originally defined by Eldridge (1896) and strata assigned to probable Sundance by Lee (1920) which have, in part, been assigned to Ralston Formation (new). Age is Jurassic. As herein defined, Morrison lies with apparent disconformity below conglomeratic phase of Dakota as defined by Eldrige (1896) and Lee (1927), and overlies disconformably red, sandy shales assigned to Lykins Formation. At some localities, basal sandstone of Morrison is in juxtaposition with strata that have been correlated with Sundance (Jurassic) and that have been included in Ralston Formation.

Cobban, W. A., Imlay, R. W., and Reeside, J. B., Jr., 1945 (Am. Assoc. Pet. Geol., Bull. 29, no. 4, p. 451-453): Morrison Formation overlies Ellis Formation at type section of Ellis. Morrison is 100 feet thick.

Cobban, W. A., 1945 (Am. Assoc. Pet. Geol., Bull. 29, no. 9, p. 1269-1270, 1290): In Sweetgrass Arch, Montana, Ellis is raised to group rank to include (ascending): Sawtooth, Rierdon, and Swift Formations. Overlying Ellis Group are continental beds of Late Jurassic and Early Cretaceous age. Thickness is 348-1,300 feet. Beds are divisible into three major rock units. Consists of fine-grained clay shale and mudstone, dense gray limestone, and fine- to very fine-grained gray and brown sandstones, dominant color is greenish-gray. Unit is up to 310 feet thick and rests conformably on Swift Formation. Along Little Belt Mountains and west to Craig, top of unit is either coal bed or black carbonaceous clay and mudstone. Charophyte oögonia and ostracods from lower part of unit show definite Morrison (Jurassic) affinities. Unit described above is assigned to Morrison Formation and two overlying units to Kootenai. West of Kevin-Sunburst dome, Kootenai rests unconformably on Morrison, Swift, and Rierdon Formations.

Brown, R. W., 1946 (Am. Assoc. Pet. Geol., Bull. 30, no. 2, p. 238-248): If Morrison enlarged to include 75 feet, more or less, of basal beds referred to as Kootenai (all greenish shales and coal, with associated dark shale, up to Cobban's (1945) unconformity), then small florule of ferns, cycads, and conifers added to total flora. Enlarged Morrison is most likely equivalent in whole or in large part to Kootenay of Canada; and Kootenai of United States corresponds in large part with lower Blairmore of Canada.

Yen, Teng-Chein, and Reeside, J. B., Jr., 1952 (U. S. Geol. Surv., Prof. Pap. 233-B, p. 22-25): Summary of stratigraphy of formation and systematic description of molluscan fauna of Morrison Formation.

Peterson, J. A., 1954 (Am. Assoc. Pet. Geol., Bull. 38, no. 4, p. 464): Morrison is Kimmeridgian (Late Jurassic) in age.

Waage, K. M., 1955 (U. S. Geol. Surv., Prof. Pap. 274-B, p. 15, 23-26): Both new and old type sections of Morrison have indefinite upper contacts. Beds between disconformity that marks top of Lytle and greenish-gray claystones of undoubted Morrison are lenticular and variable in thickness and lithology. Conglomeratic lenses are locally common at two horizons. Upper horizon has thicker and more persistent conglomeratic lenses; unconformity at base of upper horizon is taken as Morrison-Lytle contact. This contact is believed to correspond to Morrison-Dakota of Eldridge (1896). Throughout most of northern foothills local conglomeratic lenses at base of Lytle crop out near enough to one another so that position of Morrison-Lytle contact can be interpolated between them. Where it is not possible to recognize contact over large area, Lytle should be mapped with Morrison as undifferentiated unit.

Francis, D. R., 1957 (Am. Assoc. Pet. Geol., Bull. 41, no. 3, p. 393): Morrison of Williston basin is complex series of shales and sandstones with abrupt facies changes. In North Dakota, Morrison is light- and dark-gray shale interbedded with light-gray fine-grained sandstone.

Waage, K. M., 1959 (U. S. Geol. Surv., Bull. 1081-B, p. 38-40, 50-52): In Black Hills region, Morrison underlies Lakota Formation. Thickness is 21.5-111 feet. Position of Morrison-Lakota contact is problem, because of lack of persistent well-defined lithic change. Beds called Morrison in Black Hills may be equivalent to only part of sequence of beds of type Morrison. In area of type Morrison, conglomeratic lenses occur at two horizons, suggesting hiatuses; one is at base of Lytle Formation, other is at base of upper third of Morrison. Top of Lytle is marked by transgressive disconformity that also marks top of Lakota. Matching breaks in Front Range and Black Hills sequences leads to matching Lytle with upper Lakota and upper third of Morrison with lower Dakota.

Sandberg, C. A., 1962 (U. S. Geol. Surv., TEI-809, p. 90-91): In parts of Williston basin, sandstone in upper part of Morrison is indistinguishable from sandstone at base of overlying Dakota Group of Early Cretaceous age.

MOWRY SHALE (of COLORADO GROUP)

Age: Early Cretaceous.

Area of extent: Montana, North Dakota, South Dakota, and Wyoming.

Lithology: Surface exposures consist of light gray to silver-gray, platy to blocky shale and thin-bedded gray siltstone or very fine gray sandstone laminae or beds; bentonite is common to abundant. In subsurface formation is dark gray-brown to black, hard, blocky shale with thin laminae and interbeds of gray-white silicious siltstone and very-fine-grained, often micaceous to glauconitic sandstone.

Thickness: Up to 250 feet.

Relationships to other units: Conformable with overlying dark gray Belle Fourche Shale. Probably disconformable with underlying Newcastle. Equivalent to Aspen Shale of Colorado and Bootlegger Member of Blackleaf Formation of Sweetgrass arch area, Montana.

Characteristic fossils: Fish remains, shark teeth.

Economic significance: May contain beds of commercial bentonite.

Depositional environment: Widespread marine, with mild, oscillatory tectonism. Some volcanic activity causing deposition of windblown material (bentonite).

Remarks: Type locality along Mowry Creek, northwest of Buffalo, Johnson County, Wyoming. Easily recognized in outcrop and has consistent electric-log characteristics. Usually drills harder than shale above.

History of stratigraphic nomenclature:

Darton, N. H., 1904 (Geol. Soc. Am., Bull. 15, p. 394-401): Mowrie beds consist of hard, light-gray shale and thin-bedded sandstone that weathers to light-gray and forms ridges. Contains large number of fish scales and occasional fish teeth and bones.

Rubey, W. W., 1931 (U. S. Geol. Surv., Prof. Pap. 165-A, p. 4): Nefsy Shale Member of Graneros Shale now included in base of Mowry Shale into which it grades; Nefsy usage has been abandoned.

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 2, p. 1575): Mowry has been approved spelling of this name since 1906.

Reeside, J. B., Jr., 1944 (U. S. Geol. Surv., Oil and Gas Invest., Prelim. Map 10): Mowry Shale overlies Newcastle Sandstone; underlies Bell Fourche Shale. Is Late Cretaceous in age.

Cobban, W. A., and Reeside, J. B., Jr., 1951 (Am. Assoc. Pet. Geol., Bull. 35, no. 8, p. 1892-1893): Uncrushed ammonites collected from Mowry Shale belong to Early Cretaceous genera Gastroplites and Neogastroplites.

Cobban, W. A., 1951 (Am. Assoc. Pet. Geol. Bull. 35, no. 10, p. 2179-2181): Formations equivalent to Colorado Shale are Fall River Sandstone, Skull Creek Shale, Newcastle Sandstone, Mowry Shale, Belle Fourche Shale, Greenhorn Formation, Carlile Shale, and Niobrara Formation. Mowry, in northern Black Hills, consists of 235 feet of light gray weathering, siliceous shale with abundant marine fish scales, and interbedded with creamy white layers of bentonite (Clay Spur Bentonite at top). In central Montana, beds are less siliceous and more sandy. Farther west, rocks of Mowry age thicken and become more sandy; lower part passes into nonmarine sediments with tuff, bentonite, and bentonitic mudstone. Mowry considered formation in Black Hills and member of Colorado Shale in central Montana. Is Early Cretaceous in age.

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, pl. 1): Boundary between Early and Late Cretaceous placed at top of Mowry Shale. Mowry considered Aptian in age.

Gries, J. P., 1954 (Am. Assoc. Pet. Geol., Bull. 38, no. 4, p. 446-449): Term Dakota Group applied to thick sandstone sequence in central South Dakota where cabled "true Dakota" and overlies Skull Creek Shale. "True Dakota" is age equivalent of Newcastle-Mowry interval, and what is called Dakota in Williston basin to north is actually Fall River Sandstone.

Gries, J. P., 1962 (Wyo. Geol. Assoc., Gdbk., 17th Ann. Field Conf., p. 170): East of Black Hills, Mowry Shale interval only irregularly silicified and much of it resembles underlying Skull Creek Shale. Mowry merges with Dakota of central South Dakota.

Wulf, G. R., 1962 (Am. Assoc. Pet. Geol., Bull. 46, no. 8, p. 1396-1402): Mowry Shale in Williston basin subdivided into two units, separated by marker bentonite bed. Dynneson (lower) unit is shale with two promient sandstone lithofacies named Dynneson (of Williston basin) and Bow Island (of northwest Montana). Base of Dynneson unit is marked by disconformity at top of Skull Creek. Where Dynneson is absent, unit called "lower Mowry." Dynneson Sandstone Member is blanket-type sandstone with shoestring sandstone bodies on top. Grains are light gray and fine.

"Muddy sandstone"

Age: Early Cretaceous.

Area of extent: Eastern and southern Montana, North Dakota, South Dakota, and eastern Wyoming.

Lithology: Gray to white, fine- to medium-grained sandstone with interbedded dark gray shale. May be two or more sandstone beds. Shale often carbonaceous to coaly. Often represented by very silty shale with no true sandstone present.

Thickness: Up to 130 feet.

Relationships to other units: Disconformably overlies Skull Creek; probably disconformable with overlying Mowry.

Characteristic fossils: Occasional plant fossils and pelecypods.

Economic significance: Oil productive.

Depositional environment: Marine beach- and bar-deposits with intermittent nonmarine, but nearshore, swampy conditions.

Remarks: Subsurface term originally used in Big Horn Basin oil fields by drillers because sand mixed with interbedded shale to form "muddy" mixture using cable tools. Is same as Newcastle Sandstone. See also Newcastle Sandstone.

NESSON FORMATION

Age: Jurassic.

Area of extent: North Dakota, Montana, and Manitoba.

Lithology: Sequence of carbonates and evaporites.

Thickness: Up to 260 feet.

Relationships with other units: Underlies Tampico Shale Member of Piper Formation; unconformably overlies Spearfish Formation.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Restricted marine.

Type section: Interval of 5,730-5,990 feet in Amerada No. 1 Clarence Iverson well, Center SWSW sec. 6, T. 155 N., R. 95 W., Williams County, North Dakota.

Remarks: Named for Nesson anticline. See also Poe Evaporite, Picard Shale, and Kline Member.

History of stratigraphic nomenclature:
Nordquist, J. W., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 104-106): Nesson Formation proposed for sequence of carbonates and evaporites with Tampico Shale Member (new) of Piper Formation in Williston basin area; unconformably overlies Triassic(?) Spearfish Formation. Thickness is 260 feet. Includes (ascending): Poe Evaporite, Picard Shale, and Kline Members. Formation pinches out by nondeposition on west side of Bowdoin Dome; wedges out northeast of Big Snowy Platform and has no equivalent in Pipe type section on north flank of Big Snowy Mountains.

NEWCASTLE SANDSTONE, FORMATION (of DAKOTA GROUP)

Age: Early Cretaceous.

Area of extent: Southeastern Montana, North Dakota, South Dakota, and eastern Wyoming.

Lithology: White, yellowish to reddish (when weathered) sandstone on outcrop. Usually gray to white, fine- to medium-grained, often silty sandstone in subsurface. May be two or more sandstone beds separated by black, often carbonaceous shale. Occasional thin coal beds. Can be represented as silty shale zone in subsurface.

Thickness: Up to 140 feet.

Relationships to other units: Presumably lies disconformably on Skull creek Shale. Possible disconformity with overlying Mowry. Equivalent to Bow Island of Alberta, Viking of Saskatchewan, and Vaughn Bentonitic Member of Blackleaf Formation of Sweetgrass arch area.

Characteristic fossils: Occasional plant fossils and pelecypods.

Economic significance: Oil productive.

Depositional environment: Marine beach- and bar-deposits with intermittent nonmarine, but nearshore, swampy conditions.

Type section: NWNW sec. 28, T. 45 N., R. 61 W., exposed on northwest side of cut on Highway 85, 0.4 miles northeast of junction with U. S. Highway 16, 1 mile east of Newcastle, Weston County, Wyoming.

Remarks: Also called Muddy Sandstone.

History of stratigraphic nomenclature:

Hancock, E. T., 1920 (U. S. Geol. Surv., Bull. 716, p. 39, 42, 96): Newcastle Sandstone Member of Graneros Shale consists of reddish to light-yellow sandstone associated with black carbonaceous shale. Named for exposures at Newcastle, Wyoming.

Reeside, J. B., Jr., 1944 (U. S. Geol. Surv., Oil and Gas Invest., Prelim. Map no. 10): Rank raised to formation and Newcastle is basal Late Cretaceous sand of Black Hills. Underlies Mowry; overlies Skull Creek.

Crowley, A. J., 1951 (Am. Assoc. Pet. Geol., Bull. 35, no. 1, p. 83-107): Suggested that Black Hills were uplifted during closing stage of Early Cretaceous time, and that Precambrian core supplied sand for Newcastle. Newcastle is interpreted to be closing phase of Early Cretaceous deposition and overlying Mowry is introductory phase of Upper Cretaceous.

Cobban, W. A., 1951 (Am. Assoc. Pet. Geol., Bull. 35, no. 10, p. 2196-2197): Formations in Black Hills that are equivalent to Colorado Shale are Fall River Sandstone, Skull Creek Shale, Newcastle Sandstone, Mowry Shale, Belle Fourche Shale, Greenhorn Formation, Carlile Shale, and Niobrara Formation. Newcastle of northern Black Hills consists of 40 feet of lenticular sandstone, dark-gray shale, bentonite, and lignite. In central and northwestern Montana, equivalent rocks, 300-430 feet thick, are largely gray-weathering sandy shale, with thin layers of bentonite.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 76): Crowley's 1951 hypothesis not tenable as faunal collections near Rapid City contain Early and Late Cretaceous species.

Grace, R. M., 1952 (Wyo. Geol. Surv., Bull. 44, p. 5): Newcastle Formation has shale and siltstone facies with distribution of equal magnitude to that of sandstone facies. Newcastle Formation is preferred usage. Two phases of formation are indicated--carbonaceous one on west and northwest flanks of Black Hills and noncarbonaceous one on east flank.

Gries, J. P., 1954 (Am. Assoc. Pet. Geol., Bull. 38, no. 4, p. 446-449): Dakota not used in Black Hills but applied to thick sequence in central South Dakota where it is called "true Dakota" and overlies Skull Creek Shale. "True Dakota" is age equivalent of Newcastle-Mowry

interval, and what is called Dakota in Williston basin to north is actually Fall River Sandstone.

Skolnick, H., 1958 (Am. Assoc. Pet. Geol., v. 42, no. 4, p. 787-815): Newcastle is member of Skull Creek Formation and is Early Cretaceous. Faunal and mineralogical evidence indicates that physically and spatially Skull Creek Shale, Newcastle Sandstone, and lower Mowry Shale are sufficiently related to be considered one unit. Type section given.

Gries, J. P., 1962 (Wyo. Geol. Assoc., Gdbk., 17th Ann. Field Conf., p. 170): Newcastle described as series of bars along constantly changing shoreline, rather than deposits due to uplift of Black Hills.

Pettyjohn, W. A., 1960 (S. D. Acad. Sci., Proc., v. 38, p. 34-38): Suggested term Dakota Group be used to include Lakota, Fuson, Fall River, Skull Creek, and Newcastle Formations.

Wulf, G. R., 1962 (Am. Assoc. Pet. Geol., Bull. 46, no. 8, p. 1378): Described new unit Dynneson Sand in northwestern South Dakota and adjoining parts of Wyoming, Montana, and North Dakota which has been called Newcastle in previous reports of Williston basin. Newcastle considered to be lenticular sand member at top of Skull Creek Shale. Newcastle is channel sandstone, and Newcastle delta extended westward from western South Dakota into northeastern Wyoming and southeastern Montana.

NIOBRARA FORMATION (of COLORADO GROUP)

Age: Late Cretaceous.

Area of extent: Montana, eastern Wyoming, North Dakota, South Dakota, Nebraska, southern Minnesota, Kansas, northeastern New Mexico and eastern Colorado.

Lithology: Gray to dark gray, marly shale, weathers whitish.

Thickness: Up to 700 feet.

Relationships to other units: Conformably underlain by Greenhorn Formation; conformably overlain by Pierre Shale. Upper part is "First White Speck Zone."

Characteristic fossils: Inoceramus deformis, Scaphites, Ostrea congesta and other cephalopods.

Economic significance: None.

Depositional environment: Widespread, shallow, stable, marine environment.

Remarks: Named from exposures near mouth of Niobrara River, Knox County, Nebraska. "First White Speck Zone" is commonly used marker bed of subsurface geologists. Calcareous white specks are rhabdoliths and coccoliths.

History of stratigraphic nomenclature:

Meek, F. B., and Hayden, F. V., 1862 (Acad. Nat. Sci., Philadelphia, Proc., v. 13, p. 419, 422): Niobrara division (Formation No. 3 of Cretaceous) consists of upper part of lead-gray calcareous marl, weathering to yellowish or whitish chalky appearance; lower part is light-yellowish and whitish limestone. Total thickness is 200 feet and occurs in bluffs along Missouri River below Great Bend to vicinity of Big Sioux River. Overlies Fort Benton Group (now Benton Shale) and underlies Fort Pierre Group (now Pierre Shale).

Leonard, A. G., 1906 (N. D. Geol. Surv., 4th Bienn. Rep., p. 67-71): Niobrara is upper member of Colorado Formation in North Dakota. Is exposed along Little Pembina and Sheyenne Rivers. Contains more calcareous clays than Benton.

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 2, p. 1500: Niobrara is upper formation of Colorado Group. In places, deposits are chiefly or wholly shale and are called Niobrara Shale.

Cobban, W. A., 1951 (Am. Assoc. Pet. Geol., Bull. 35, no. 10, p. 2170, 2187, 2192-2198): Formations in Black Hills that are equivalent to Colorado Shale of central and northwestern Montana are (ascending): Fall River Sandstone, Skull Creek Shale, Newcastle Sandstone, Mowry Shale, Belle Fourche Shale, Greenhorn Formation, Carlile Shale, and Niobrara Formation. In northern Black Hills, Niobrara consists of gray chalk marl that weathers creamy, pale yellow or orange; thin layers of bentonite abundant, dark gray noncalcareous shale partings present near base and top of formation. Sage Breaks Shale reallocated to member of Carlile Shale.

"'Nisku' formation," equivalent (see BIRDBEAR FORMATION)

Towse, D. F., 1953 (N. D. Geol. Surv., Rep. Invest. 12, 1 sheet): "Nisku equivalent" is Devonian "A" (previous usage of North Dakota Geological Survey).

ODANAH MEMBER, "series" (of PIERRE SHALE)

Age: Late Cretaceous.

Area of extent: Manitoba and North Dakota.

Lithology: Light gray, hard, clay shale.

Thickness: Up to 100 feet.

Relationships to other units: Overlies Millwood "Series" of Manitoba; overlies DeGrey Member of North Dakota; underlies Fox Hills Formation.

Characteristic fossils: Only Inoceramus and radiolarians reported from North Dakota.

Depositional environment: Marine.

Remarks: Named from locality near Minnedosa, Manitoba, 85 miles north of International Boundary.

History of stratigraphic nomenclature:

Tyrrell, J. B., 1893 (Can. Geol. Surv., New Ser., v. 5, pt. 1, pp. 83E-85E, 199E, 212E-215E): Odanah series of Pierre Shale is light gray, hard, fissile shale occurring on upper portion of Riding Mountain in Manitoba and southward to International Boundary. Very few fossils.

MacLean, A., 1916 (Can. Geol. Surv., Summ. Rep. 1915, p. 131-133): Odanah is hard, light-colored shale above soft Millwood beds in Pembina Mountain area.

Williams, M. Y., 1932 (J. Geol., v. 40, no. 6, p. 561): Odanah of Manitoba is correlated with Bearpaw of Montana, Wyoming, and Alberta.

Wickenden, R. T. D., 1945 (Can. Geol. Surv., Mem. 239, p. 48): Odanah is poorly defined hard facies of Riding Mountain Formation.

Tovell, W. M., 1948 (Manit. Dept. Mines Nat. Resour., Mines Br., Prelim. Rep. 47-7, p. 6): Odanah treated as distinct member of Riding Mountain Formation.

Gill, J. R., and Cobban, W. A., 1965 (U. S. Geol. Surv., Prof. Pap. 392-A, p. A15-A16, A18): Odanah Member of Pierre Shale is hard, siliceous shale that overlies DeGrey Member. Thickness of Odanah in Pembina Mountains is unknown. Lower 65 feet crops out along North Dakota Highway 5 near Tongue River. 200 feet crops out in Pembina Mountains of Manitoba. Outcrops of Odanah are scarce in rest of North Dakota and with little thickness. Part of Odanah grades southwest to Virgin Creek Member of Pierre Shale in South Dakota.

Bluemle, J. P., 1973 (N. D. Geol. Surv., Bull. 57, pt. 1, p. 12): Odanah Member crops out in Walsh and Nelson Counties, North Dakota; is hard, siliceous, gray shale with reddish-brown and purple stains on joint faces and concretions. Appears to be jointed along north-south zone that may be result of glacial movement or loading.

Arndt, B. M., 1975 (N. D. Geol. Surv., Bull. 62, pt. 1, p. 7): Odanah Member in Cavalier and Pembina Counties, North Dakota; weathers into distinct plates or flakes.

OPECHE FORMATION, Salt, Shale

Age: Permian.

Area of extent: Western South Dakota, Wyoming, and northwestern Nebraska.

Lithology: Red, friable, sandstone and sandy shale.

Thickness: Up to 280 feet.

Relationships to other units: Underlies Minnekahta Limestone; overlies Minnelusa Formation.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Marine.

Remarks: Type locality on Battle Creek; Opeche is Indian name for Battle Creek.

History of stratigraphic nomenclature:

Darton, N. H., 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 4, p. 513): Red, soft, sandstone and sandy shale; deep-purple shale at top, basal beds usually red sandstone, 4-15 inches thick. Underlies Minnekahta Limestone and overlies Minnelusa Formation. Typically developed on Battle Creek; Indian name of which is Opeche.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 72): In southern Black Hills, between typical Minnelusa and typical Opeche beds is up to 120 feet of "transitional beds" of fine, brick-red sandstone in outcrop and orange or mottled red and orange sandstone in subsurface. These beds included with Cassa Group of Minnelusa or in Opeche Formation. No fossils in Opeche but usually considered to be Permian.

Laird, W. M., and Towse, D. F., 1953 (N. D. Geol. Surv., Rep. Invest. 2, sheet 1): Permian System in North Dakota includes Opeche, 88 feet of red shale and anhydrite, overlain by Minnekahta Formation.

Burk, C. A., and Thomas, H. D., 1956 (Wyo. Geol. Surv., Rept. Invest. 6, 11 p.): Goose Egg Formation of eastern Wyoming is sequence of interbedded red to ocher shale and silstone, thin limestone, gypsum, and limestone breccia. Rests on Minnelusa and equivalents (Tensleep, Casper, and Hartville); underlies Spearfish and equivalents (Chugwater). Minnekahta is limestone with farthest east extent, underlain by Opeche Shale; less extensive are overlying Forelle and Ervay Limestones, all in Phosphoria Group.

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Invest. 28, 2 sheets): Opeche Formation, reddish sandstone, siltstone, and red shale sequence in North Dakota, contains Permian "A" Salt. Opeche overlain conformably by Permian Minnekahta and unconformably overlies Pennsylvanian Minnelusa. Permian "B" Salt occurs below "A" Salt but not extensive.

Otter Creek bed (of SENTINEL BUTTE)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 45): Otter Creek bed is named for Otter Creek; lies 135-145 feet above Beulah-Zap bed. Consists of two coals about 15 feet apart.

OTTER FORMATION (of BIG SNOWY GROUP)

Age: Late Mississippian (Chesterian).

Area of extent: Central and eastern Montana and western North Dakota.

Lithology: Green, gray-green, gray, and rarely red shale interbedded with tan limestone and dolomite.

Thickness: Up to 170 feet.

Relationships to other units: Conformably overlies Kibbey Formation and is conformably overlain by Heath Formation. Heath-Otter contact usually gradational. Is middle unit of Big Snowy Group.

Characteristic fossils: Algae and ostracods.

Depositional environment: Open and semi-restricted marine.

Remarks: Type locality is Otter Creek, Fort Benton quadrangle, Montana. "Apple-green" shale of Otter is unique color and easily recognizable. Many areas of covered Otter may be recognized by green soil that retains its color even after extensive weathering. See also Big Snowy Group.

History of stratigraphic nomenclature:
Weed, W. H., 1892 (Geol. Soc. Am., Bull. 3, p. 307): Detailed section at Belt Creek, Montana consists of following succession in lower part: 1) conglomerate and sandstone with Jurassic fossils, 215 feet; 2) white limestone, red earthy patches, Paleozoic facies, 90 feet; 3) Otter Creek shale, alternating gray, purple, green, and black shales and earthy limestones yielding carboniferous fossils, 212 feet; 4) black chert, 8 feet; 5) limestone and shale, 80 feet; and 6) gypsum, 3 feet.

Weed, W. H., 1899 (U. S. Geol. Surv., Geol. Atlas, Folio No. 55): In Fort Benton quadrangle, lowest beds of Quadrant Formation are gypsiferous Kibbey sandstone, overlain by Otter shale. Otter is upper member of Quadrant Formation, 303 feet of dark-gray or purple basal shales, becoming bright coppery-green higher up, and interbedded with limestone (1 or 2 feet thick, oolitic, with lower carboniferous fossils). Otter assigned to Carboniferous. Otter shale overlain by Ellis Formation.

Wilmarth, M. G., 1938 (U. S. Geol. Surv., Bull. 896, pt. 2, p. 1575): United States Geological Survey adopted Otter Shale Member of Quadrant Formation in 1907.

Scott, H. W., 1935 (Geol. Soc., Am., Proc., 1934, p. 367): Big Snowy Group consists of Kibbey, Otter, and Heath Formation. Otter is variegated shale with intercalated limestones and sandstones. Overlies Madison limestone.

Perry, E. S., 1937 (Mont. Bur. Mines and Geol., Mem. 3, p. 16): In type locality, Big Snowy Group comprises (ascending): Kibbey, Otter, and Heath Formations. Otter is 600 feet of gray to vivid green shale with anhydrite and gypsum, and thin beds of limestone and sandstone.

Anderson, S. B., 1954 (N. D. Geol. Surv., Rep. Invest. 16, 2 sheets): Otter Formation present over western half of North Dakota in subsurface. Consists mainly of variegated shales and little limestone.

Laudon, L. R., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 210): Kibbey, Heath, Otter and Amsden believed to represent shore facies of early Pennsylvanian seas.

Gardner, L. S., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 2, p. 333-334, 340-341, 346-347): Thickness 374 feet in composite standard section for revised Big Snowy Group.

PEMBINA MEMBER (of Vermillion River Formation)

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 1011-1043): Pembina Member of Vermillion River Formation (Late Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota. Conformably underlies Riding Mountain Formation, unconformably overlies Boyne Member of Vermillion River Formation.

Gill, J. R., and Cobban, W. A., 1965 (U. S. Geol. Surv., Prof. Pap. 392A, p. 6-7): Pembina Member of Pierre Shale found in Pembina Mountain area of North Dakota is 0 feet of dark noncalcareous shale resting on Boyne Member of Vermillion River Formation or Niobrara Formation of North Dakota.

Permian "A" salt

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Invest. 28, 2 sheets): Permian "A" salt is sequence of salt in Opeche Formation. Section difficult to pick because of associated impurities. Occupies most of Williston basin, but lateral extent not as far as Mississippian salt. Greatest thickness is 181 feet.

See also Opeche Formation.

Permian "B" salt

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Invest. 28, 2 sheets): Permian "B" salt lies below Permian "A" salt but is not extensive.

See also Opeche Formation.

PICARD SHALE MEMBER (of NESSON FORMATION)

Age: Jurassic.

Area of extent: Subsurface in Montana, North Dakota, and Manitoba.

Lithology: Dark-red shale with thin interbeds of white earthy gypsum.

Thickness: 40 feet in type section; thins toward margins of basin.

Relationships with other units: Conformably overlies Poe Evaporite Member and underlies Kline Member.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Marine.

Type section: Interval of 6,610-6,650 feet in Deep Rock Oil Corp. No. 1 Picard well, Center NWNE sec. 6, T. 29 N., R. 52 E., Roosevelt County, Montana.

History of stratigraphic nomenclature:
Nordquist, J. W., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 104-105): Picard Shale Member is shale unit that conformably overlies Poe Evaporite Member (new) and underlies Kline Member (new). In type section, consists of 40 feet of dark-red shale that is slightly

silty in part and contains masses or thin interbeds of white, earthy gypsum in lower half of unit. Thins toward margins of Williston basin.

PIERRE SHALE

Age: Late Cretaceous.

Area of extent: North Dakota, South Dakota, eastern Montana, eastern Wyoming, eastern Colorado, Nebraska, and western Minnesota.

Lithology: Dark gray silty to sandy shale with bentonite beds and scattered concretions.

Thickness: Up to 2,700 feet.

Relationships to other units: Possibly unconformable with underlying Niobrara Shale and overlying Fox Hills sandstone.

Characteristic fossils: Numerous species of Baculites, Scaphites, and other cephalopods, Inoceramus, and foraminiferans.

Depositional environment: Offshore marine with nearshore silty zones. Volcanic debris blown in from far west source.

Type section: Exposure at Fort Pierre in either Stanley or Hughes County, South Dakota. Exact location of Fort Pierre not known.

Remarks: Equivalent to total section of Bearpaw, Judith River, Claggett, and Eagle Formations of central and northern Montana and to Lewis, Mesaverde and Steele Formations of western Powder River basin. Can be readily divided in subsurface by use of electric logs.

History of stratigraphic nomenclature:

Meek, F. B., and Hayden, F. V., 1862 (Acad. Nat. Sci. Phila., Proc., v. 13, p. 419, 424): Named Fort Pierre Group (Formation No. 4 of Cretaceous). Thickness 700 feet in Nebraska [then included Wyoming, Montana, and Dakotas]. Underlies Fox Hills beds and overlies Niobrara. Fort Pierre Group consists of (descending): 1) dark-gray and blue fossiliferous plastic clays exposed on Sage Creek, Cheyenne River, and White River; 2) middle zone, barren of fossils exposed at Fort Pierre and in Badlands and down Missouri River or high country to Great Bend of Missouri River, 3) lower fossiliferous zone exposed at Great Bend of Missouri, and 4) dark bed of very fine clay containing much carbonaceous matter with veins and seams of gypsum, masses of sulphuret of iron, and fish scales exposed near Bijou Hills on Missouri River.

White, C. A., 1878 (U. S. Geol. Geog. Surv. Terr., 10th Ann. Rept., p. 21, 22, 30): Fort Pierre Group (Pierre Shale of present usage) transferred from Colorado Group to overlying Fox Hills Group.

Darton, N. H., 1896 (U. S. Geol. Surv., Ann. Rept. 17, p. 609-694): Previous descriptions repeated but name shortened to Pierre. Pierre is extended to Yankton and under Turkey Ridge of South Dakota.

Leonard, A. G., 1908 (N. D. Geol. Surv., Bienn. Rep. 5, p. 42): Pierre found in northwestern Bowman County, North Dakota, and into eastern Montana on an anticlinal fold. Pierre Shale is bluish gray shale, jointed, weathers to small flaky fragments with iron oxide staining. Numerous concretions of impure lime carbonate, and marine fossil shells occur in the formation.

Barry, J. G., and Melsted, V. J., 1908 (N. D. Geol. Surv., Bienn. Rep. 5, p. 171-184): Described as conformably overlying the Niobrara shale with actual contact perhaps at base of series of black and yellow bands that are uniform over large distance. Pierre reaches a thickness of 1000 feet in central part of North Dakota and thins toward eastern edge due to erosion. Pierre is gray to black shale with clay ironstone in lower 40-50 feet.

Calvert, W. R., 1910 (U. S. Geol. Surv., Bull. 471, p. 193): Maximum of 300 feet of Pierre Shale exposed in eastern Montana due to Cedar Creek anticline.

Rubey, W. W., 1931 (U. S. Geol. Surv., Prof. Pap. 165-A, p. 3-4): Pierre shale of Black Hills, South Dakota, includes (descending) 150-200 feet of unnamed, dark-gray fissile shale and mudstone, 150 feet of Monument Hill bentonitic member, 500-800 feet of unnamed mudstone shale, 150-200 feet of Mitten black shale member, and 800-1000 feet of Gammon ferruginous member with Groat sandstone bed (150 feet in northern part). Overlies Niobrara Formation; underlies Fox Hills Sandstone.

Searight, W. V., 1937 (S. D. Geol. Surv., Rep. Invest. 27, p. 5-63): Along Missouri River of South Dakota, Pierre includes (descending): 1) Elk Butte, of fine, medium gray shale; 2) Mobridge, of buff, calcareous shale, marl and chalk beds; 3) Virgin Creek, of light to medium gray hard shale with thin bentonite beds and concretions; 4) Sully, of clay and shale with concretions of clay ironstone (Verendrye shale zone), bentonite clays and shales with manganiferous iron concretions (Oacoma zone), and hard gray, siliceous shale (Agency shale zone); and 5) Gregory Member, of dark bentonite bearing, bituminous shale with chalk beds at top. Total thickness 361-1204 feet. Overlies Niobrara Formation; underlies Fox Hills Formation.

Moxon, A. L., Olson, O. E., Searight, W. V., and Sandals, K. M., 1938 (Am. J. Botany, v. 25, p. 795-796): Lower Gregory changed to Sharon Springs Member. Mobridge replaced by Interior, as Interior has precedence.

Moxon, A. L., Olson, O. E., and Searight, W. V., 1939 (S. D. Agr. Exp. Sta. Tech. Bull. 2, p. 20): Sharon Springs is considered to be all beds above Niobrara and below Gregory marl (Crow Creek Member). Sharon Springs is divided into upper and lower unit.

Gries, J. P., and Rothrock, E. P., 1941 (S. D. Geol. Surv., Rep. Invest. 38, p. 9-30): Pierre redefined in South Dakota as follows (descending): 1) Elk Butte, of dark, gray shales, 2) Mobridge, of chalk, chalky shale, and sandy shale, 3) Virgin Creek, of upper zone of gray shale, lower zone of gray shale with bentonite beds, 4) Sully, 5) Gregory, of upper thick shale zone and lower chalk beds, and 6) Sharon Springs Members, of upper shale zone and lower fish scale zone in dark gray shale. Sully Member further subdivided (descending): 1) Verendrye zone, of light to medium dark shale, with iron-manganese carbonate concretions, 2) Oacoma zone, of upper beds contain abundant iron-manganese concretions and numerous bentonites, lower beds contain fewer concretions, 3) Agency zone, of hard, light gray, siliceous shale, and 4) Crow Creek zone, of marl or impure chalk over basal sandstone.

Gries, J. P., 1942 (S. D. Geol. Surv., Rep. Invest. 43, p. 5-29): Same usage followed as above with following exceptions: 1) Oacoma zone and Agency zone of Sully Member combined to Agency-Oacoma zone, 2) Gregory Member not divided into shale zone and marl, and 3) Sharon Springs Member not divided into upper and lower zones.

Kline, V. H., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 3, p. 353-355): Pierre underlies drift in most of eastern half of North Dakota except Red River valley; crops out along Missouri River in south-central North Dakota, Little Missouri River in southwestern corner, James River, Sheyenne River, and Pembina Mountains. Pierre is gray shale, weathers to thin, hard flakes. Fullers earth, limestone, and sandy shale beds are local. Calcareous shale outcrop at Valley City may be equivalent to upper Gregory Member of South Dakota. Total thickness 930-2390 feet.

Crandell, D. R., 1950 (Am. Assoc. Pet. Geol., Bull. 34, no. 12, p. 2337-2346): DeGrey Member proposed for Agency-Oacoma zone. All zones of Sully Member raised to member status, Sully no longer used. Pierre Shale of central South Dakota includes (descending): Elk Butte, Mobridge, Virgin Creek, Verendrye, DeGrey, Crow Creek, Gregory, and Sharon Springs Members.

Fisher, S. P., 1952 (N. D. Geol. Surv., Bull. 26, p. 8-10): Pierre is oldest formation exposed in Emmons County. Most of Pierre is Elk Butte Member; Mobridge Member may be present. Total thickness 135 feet; underlies Fox Hills Formation.

Wilson, E. E., 1958 (Master's Thesis, Univ. N. D., 134 p.): Lowest unit of Pierre Shale of Cavalier County, North Dakota, probably equivalent to Sharon Springs Member of South Dakota and Pembina Member of Vermillion River Formation of Manitoba and Saskatchewan. Stratigraphically higher unit may be equivalent to southern Sheyenne River section. Highest unit may be equivalent to "Odanah" beds of Manitoba. Pierre of northern Sheyenne River and Stutsman County may be equivalent to Verendrye and DeGrey Members of South Dakota. Emmons County has equivalent of Elk Butte Member; Bowman County

strata, similar to Emmons County strata, are older and may be equivalent to Mobridge Member.

Robinson, C. S., Mapel, W. J., and Cobban, W. J., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 1, p. 101-123): On northern and western flanks of Black Hills, marine Pierre Shale consists of dark gray shale with sandy shale and bentonite. Total thickness 2,000-2,700 feet. Pierre divided into members based on lithologic differences in shale and sandy and bentonitic beds. These are (descending): Kara and Monument Hill bentonitic members, an unnamed upper part of half or more of Pierre Formation, Mitten Black Shale Member, and Gammon Ferruginous Member including Groat Sandstone bed. Overlies Niobrara Formation and underlies Fox Hills Sandstone. Pierre-Fox Hills contact becomes older northward from Newcastle, Wyoming to Carter County, Montana.

Tourtelot, H. A., Schultz, L. G., and Gill, J. C., 1960 (U. S. Geol. Surv., Prof. Pap. 400-B, p. 447-448): Sharon Springs and Mitten Black Shale Members of Pierre and Claggett Shale are contemporaunits of organic-rich black shale and beds of non-swelling bentonite. Silty and sandy beds overlying Mitten along west side of Black Hills are 400-600 feet thick; equivalent to Judith River and Mesaverde Formations of Montana and Wyoming.

Gill, J. R., and Cobban, W. A., 1962 (U. S. Geol. Surv., Prof. Pap. 450-B, p. 21-24): 200-725 feet of gray, marine, silty shale, named Red Bird Silty Member and is lowest of two unnamed shales above Mitten Member and below Monument Hill in eastern Montana and Wyoming, and western South Dakota. Traceable into Gregory and Crow Creek Members of Pierre Shale in central South Dakota, westward into Parkman Sandstone of Mesaverde in Powder River basin, and northwestward into Judith River Formation of eastern Montana.

Gill, J. R., and Cobban, W. A., 1965 (U. S. Geol. Surv., Prof. Pap. 392A, 20 p.): Five units related by lithology and fossil content to equivalent units in type Pierre Shale of central South Dakota and units in Vermillion River and Riding Mountain Formations of Manitoba. They are (ascending): Pembina, Gregory, DeGrey, Odanah, and the fifth (youngest) is unnamed.

Gill, J. R., and Cobban, W. A., 1973 (U. S. Geol. Surv., Prof. Pap. 776, p. 16-19): Assigned to Montana Group (newly restricted) only in southeastern Montana; no longer assigned to any named group elsewhere.

Pine member, salt

Age: Permian-Triassic.

Area of extent: North Dakota and eastern Montana.

Lithology: Halite with anhydrite and reddish-brown mudstone.

Thickness: Up to 300 feet.

Relationships to other units: Conformably underlies Saude; unconformably overlies Spearfish.

Characteristic fossils: None.

Economic significance: Possible salt production.

Depositional environment: Nonmarine evaporitic.

Remarks: See also Spearfish Formation, Saude Formation, and Triassic "B" Salt.

History of stratigraphic nomenclature:
Zeiglar, D. L., 1955 (N. D. Geol. Soc., South Dakota Black Hills Field Conf., Gdbk., p. 51): Pine Salt is anhydrite and reddish-brown mudstone. Nonmarine evaporitic environment of deposition probable. Conformably underlies Saude Formation; erosional unconformity between Pine Salt and Spearfish Formation.

Dow, W. G., 1964 (3rd Williston Basin Sym., Conrad Pub. Co., Bismarck, p. 127-131): Pine Salt considered to be member of Spearfish Formation. Grades laterally into anhydrites and shales of lower Spearfish and is considered to be Permian.

PIPER FORMATION

Age: Middle Jurassic.

Area of extent: East of 111° meridian in Montana, and eastward into North Dakota.

Lithology: Generally includes lower red bed and gypsum member, middle member of gray shale, limestone and dolomite, and upper red bed and gypsum member.

Thickness: Up to 400 feet.

Relationships to other units: Conformably underlies Rierdon Formation; unconformably overlies Triassic to Mississippian strata in Montana. May conformably overlie Nesson Formation in Williston basin and nearby area in subsurface. Piper is later equivalent of Sawtooth of western Montana and Gypsum Springs Formation of Wyoming.

Characteristic fossils: Chondroceras (Defonticeras), numerous pelecypods; locally Astrocoenia hyatti (coral).

Economic significance: Oil productive, gypsum.

Depositional environment: Restricted evaporitic to open marine.

Remarks: Type locality about 1 mile southwest of Piper, Montana, on northern margin of Big Snowy Mountains. See also Ellis Group, Tampico Shale, Firemoon Limestone, and Bowes Member.

History of stratigraphic nomenclature:

Imlay, R. W., Gardner, L. S., Rogers, C. P., Jr., and Hadley, H. D., 1948 (U. S. Geol. Surv., Oil and Gas Inv. Prelim. Chart 32, 1 sheet): Piper includes all Middle Jurassic red beds, gypsum, and associated normal marine beds underlying Rierdon Formation in eastern Montana east of Sweetgrass-Big Belt line of uplift. Basal part locally includes equivalents of type Gypsum Spring Formation of central Wyoming; upper part includes beds that have been placed in lower part of lower Sundance in Wind River basin and central Wyoming. In Montana, consists of lower red bed and gypsum member, middle member of gray shale, limestone, and dolomite, and upper red-bed gypsum member. Members grade into each other vertically, and, to some extent, red beds grade laterally into middle marine member; upper member grades laterally into yellowish, calcareous, marine siltstone and sandstone. At type section, consists of (ascending) about 12 feet of massive white gypsum, 6 feet of brittle, chocolate-gray limestone, 57 feet of maroon and green siltstone and shale, 5 feet of gray, silty limestone, 9 feet of gray papery to chunky shale, and 4 feet of yellowish-gray, sandy limestone. Thickness 0-300 feet and varies considerably within short distances. Grades laterally into Sawtooth Formation.

Imlay, R. W., 1952 (Geol. Soc. Am., Bull. 63, no. 9, p. 967-968): Piper includes all Middle Jurassic beds underlying Rierdon Formation in eastern Montana east of Sweetgrass-Big-Belt line of uplift. First identified as Gypsum Spring Formation; later fieldwork showed that Gypsum Spring of type area in central Wyoming represents only basal Middle Jurassic; correlates with lower member of Gypsum Spring in Montana and part of Big Horn Basin of Wyoming. Because beds equivalent to type Gypsum Spring in Montana are not mappable, name Piper is used for beds formerly called Gypsum Spring. Middle member of Piper has ammonites such as Defonticeras and Teloceras, which are of middle or late Bajocian age; upper red-bed member grades laterally in western Montana into yellowish siltstone, sandstone, and limestone that contains Arctocephalites and Procerites and is considered Late Bathonian.

_____, 1954 (Billings Geol. Soc., Gdbk., 5th Ann. Field Conf., p. 56): Piper Formation is conformably overlain by Rierdon Formation in most areas, but in south-central Montana contact may be disconformable.

Nordquist, J. W., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 99-104): Piper subdivided to include (ascending): Tampico Shale, Firemoon Limestone, and Bowes Members (all new). Units are recognizable in subsurface and surface sections. In subsurface of Williston basin overlies Kline Member of Nesson Formation (both new).

Storey, T. P., 1958 (Alberta Geol. Soc. Pet. Geol., J. 6, no. 4, p. 90-104): In Jurassic of Williston basin and adjacent areas, faunal, environmental and tectonic evidence groups units into four major depositional sequences or stagelike intervals which Imlay (1948) referred to as Gypsum Spring (or Piper), Sawtooth, Rierdon, and Swift Formations. Miscorrelation of type sections of these formations are result of variations in stratigraphic succession caused by sub-Swift and sub-Rierdon unconformities that correspond respectively to Arkell's (1956, Jurassic geology of the world: New York, Hafner Publishing Co.) Early Callovian, and Latest Callovian to Early Oxfordian marine transfessions. Recognition of regional extent and significance of these unconformities suggests these are the following stratigraphic variations: 1) Lower Swift (Stockade Beaver-Hulett of Lower Sundance) is older than type Swift and younger than type Rierdon; and 2) Sawtooth is discrete stratigraphic unit younger than Piper or Gypsum Spring.

Dow, W. G., 1964 (3rd Williston Basin Sym., p. 127-131): Dunham salt, formerly of Spearfish Formation, is considered to be facies of lower evaporite unit of Piper Formation and is Jurassic in age.

Witkind, I. J., 1971 (U. S. Geol. Surv., Geol. Quad. Map, GQ-898): Name change to Piper Limestone in central Montana.

POE EVAPORITE MEMBER (of NESSON FORMATION)

Age: Jurassic.

Area of extent: Subsurface in North Dakota, Montana, and Manitoba.

Lithology: Salt, gypsum and ahydrite; small amounts of dolomite; limestone at top of unit.

Thickness: 118 feet at type well, thins to east.

Relationships with other units: Underlies Picard Shale Member; unconformably overlies Spearfish Formation. Basal member of Nesson Formation.

Characteristic significance: None.

Environmental significance: None.

Depositional environment: Restricted marine.

Type section: Interval of 6,947-7,065 feet in Phillips-Skelly-Gulf No. 1 Hoehn (Poe Unit) well, Center NESE sec. 13, T. 152 N., R. 102 W., McKenzie County, North Dakota.

History of stratigraphic nomenclature:
Nordquist, J. W., 1955 (Billings Geol. Soc., Gdbk., 6th Ann. Field Conf., p. 64-105): Poe Evaporite Member is basal unit of Nesson Formation (new). Underlies Picard Shale Member (new); unconformably overlies Triassic(?) Spearfish Formation. In type section, consists of 65 feet of basal bed of massive salt, overlain by 53 feet of white to pink gypsum and anhydrite and dark-red shale with few thin interbeds of gray to red, dense dolomite; thin bed of buff to brown, very finely crystalline to earthy limestone present at top. Thins eastward from type well and appears to merge in Bowdoin dome area with younger members of formation. Unit exhibits abrupt facies changes on east flank of Williston basin where member overlaps Spearfish Formation and Madison limestone and rests on pre-Mississippian rocks.

Poplar interval, "beds"

Age: Mississippian.

Area of extent: Montana and subsurface in Saskatchewan and North Dakota.

Economic significance: Oil productive.

Remarks: Informally named for Poplar Oilfield, Montana. See also Madison Group.

History of stratigraphic nomenclature:
Porter, J. W., (Chm.), 1956 (Sask. Geol. Soc., Rept. of the Miss. Names and Correlation Comm., p. 1-4): "Poplar beds" bounded below by "Ratcliffe beds" and above by Kibbey Limestone or Big Snowy Group.

Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol. Surv., Rep. Invest. no. 36, p. 1-25): Poplar interval bounded below by Ratcliffe interval and above by Spearfish Formation.

PRAIRIE EVAPORITE, FORMATION (of ELK POINT GROUP)

Age: Middle Devonian.

Area of extent: Northeastern Montana, northwestern North Dakota, and Saskatchewan.

Lithology: Salt; locally with anhydrite and dolomite near base. Red shale layers become more common near margins; minor amounts of potash salts.

Thickness: Up to 700 feet.

Relationships to other units: Conformably overlies Winnipegosis Formation and conformably underlies Dawson Bay Formation. Upper formation of Elk Point Group.

Characteristic fossils: None.

Economic significance: Potash deposits mined in Saskatchewan.

Depositional environment: Marine saline basin.

Type section: Depths of 4,350 and 4,990 feet in Imperial Oil Co., No. 1 Davidson, Land surface datum 16, sec. 8, T. 27 N., R. 1 W., 3rd Meridian, Saskatchewan.

History of stratigraphic nomenclature:
Baillie, A. D., 1953 (Am. Assoc. Pet. Geol., Bull. 37, no. 2, p. 444-446): Prairie Evaporite Formation proposed for salt and anhydrite beds of upper unit of Elk Point Group throughout most of Elk Point basin. Beds are 50-600 feet thick. Overlies Winnipegosis Formation; underlies Dawson Bay Formation of Manitoba Group.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2306-2307): Prairie Formation underlies deepest part of Williston basin in northwestern North Dakota and northeastern Montana. Thickness 0-500 feet. In center of basin Prairie divided into two members: Lower member is anhydrite and dolomite interbedded with shale and thin beds of halite; upper member is halite and is termed Salt Member.

PRETTY BUTTE MEMBER (of HELL CREEK FORMATION)

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, p. 38-39): Pretty Butte Member consists of bentonites and bentonitic shales with sandstone; siderite nodules are common. Named from Pretty Butte, butte in Slope County, North Dakota; type section is 12 miles north of Marmarth on southeast-facing slope on northeast end of butte on west side of "West Marmarth Road" in SWNE sec. 26, T. 134 N., R. 106 W., Slope County, North Dakota. Interfingers with Huff Member below; top of member coincides with top of Hell Creek Formation. Member found everywhere in western and central North Dakota. Fauna and sediments suggest coastal plain with swampy conditions, small meandering streams, and covered at times by volcanic ash.

"Purple limestone"

Refers to Minnekahta Limestone in reports prior to 1901.

See Minnekahta Limestone.

Qu'Appelle Group

Includes Lyleton Formation and upper unit. Different applications of Qu'Appelle Group have been made because stratigraphic position of Lyleton Formation not clearly designated. Group generally regarded as approximately equivalent to Three Forks Formation.

Ratcliffe interval, "beds"

Age: Mississippian.

Area of extent: Subsurface in Saskatchewan and North Dakota.

Remarks: Informally named for Ratcliffe Oilfield, southeastern Saskatchewan. See also "Poplar beds," "Midale beds," "Midale anhydrite," Midale subinterval, and Madison Group.

History of stratigraphic nomenclature:
Fuller, J. G. C. M., 1956 (Sask. Dep. Miner. Resour., Rep. 19, p. 36): "Ratcliffe beds" of 75 feet of Upper Madison limestone of southeastern Saskatchewan contain anhydrite, dolomite, and mudstone, bounded below by "Midale beds." Oil productive where capped by "Charles lower salt" in Ratcliffe Oilfield.

Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol. Surv., Rep. Invest., no. 36, p. 12): Base of Ratcliffe interval at lower boundary of Midale subinterval and top at prominent gamma-ray marker overlying lowest Madison salt bed. Ratcliffe interval includes (descending) bottom one-third of "Poplar beds," "Ratcliffe beds," "Midale anhydrite," and top two-thirds of "Midale beds" where applicable.

Reclamation Group

Age: Pennsylvanian (Desmoinesian).

Area of extent: Eastern Wyoming, southwestern South Dakota, and North Dakota.

Lithology: Red, gray, and green limestones and shales.

Thickness: Up to 87 feet.

Relationships to other units: Underlies Roundtop Group; overlies Fairbank Formation.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Marine.

Remarks: Type locality is Reclamation Hill, sec. 27, T. 27 N., R. 66 W., Platte County, Wyo.

History of stratigraphic nomenclature:
Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13A, p. 2-3, 28, and 32): Reclamation Group consists of red, gray, and green limestones and shales. Comprises Division V of Hartville "Formation" (Condra, G. E., and Reed, E. C., Nebr. Geol. Surv., Pap. no. 9, 46 p.): Thickness is 72-87 feet. Underlies Roundtop Group (new); overlies Fairbank Formation (new).

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym., 1st Internat., Bismarck, N. D., p. 150-164): Reclamation Group is light-colored, argillaceous limestone interbedded with thin, red and green shales. On electric logs, Reclamation is resistant unit overlying shales and porous sands of Fairbank and underlying more argillaceous Roundtop Group. Transition zone is frequently developed at top; contact between Reclamation and Roundtop is difficult to pick.

Red Butte bed

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 42): Red Butte bed is named for Red Butte. Lignite underlies Knife River, Square Butte Creek and Sweet Briar Creek.

RED RIVER FORMATION (of BIGHORN GROUP)

Age: Middle Ordovician.

Area of extent: Manitoba, Saskatchewan, North Dakota, northern South Dakota, and eastern Montana.

Lithology: Sandstone and shale; minor amounts of anhydrite in central part of basin.

Thickness: Up to 600 feet.

Relationships to other units: Overlies Winnipeg Formation and underlies Stony Mountain Formation. Equivalent to part of Bighorn Dolomite found in Bighorn Mountains, Wyoming.

Characteristic fossils: Climacograptus typicalis crassimarginalis and Diplograptus amplexicaulis, crinoids, brachiopods, and ostracods.

Economic significance: One of main hydrocarbon reservoirs of Williston basin.

Depositional environment: Marine; cratonic basin and shelf areas marginal to basin.

Remarks: Type area at quarries along shore of Lake Winnipeg, Manitoba.

History of stratigraphic nomenclature:

Foerste, A. F., 1929 (Denison Univ., Bull., J. Sci. Lab., v. 29, no. 2, p. 35, 37): Red River Formation is thick-bedded, crystalline to fragmental limestones and dolomites, very uniform and widespread near Lake Winnipeg. Some shale in basal unit and often sandy to cherty in middle unit. In outcrop, is divided into three units (descending): Selkirk, limestone; Cat Head, dolomite and chert; and Dog Head, dolomitic limestone. In subsurface, formation has distinctive three-fold aspect known as Units A, B, and C. Red River equivalents to Whitewood of Black Hills and Bighorn Dolomite of Montana. Thickness is 250-1100 feet.

Kline, V. H., 1942 (Am. Assoc. Pet. Geol., v. 26, no. 3, p. 345): Red River Formation extended into subsurface of North Dakota.

Ross, R. J., Jr., 1957 (U. S. Geol. Surv., Bull. 1021-M, p. 446-448): Red River Formation is basal unit of Bighorn Formation; overlies Winnipeg Formation; underlies Stony Mountain Formation. Members not differentiated. Is Late Ordovician in age.

Fuller, J. G. C. M., 1961 (Am. Assoc. Pet. Geol., Bull. 45, no. 8, p. 1343-1349): Red River divided into two general lithologic units: lower, marine, fossiliferous limestone, variably dolomitized; and upper evaporitic, thinly-bedded, carbonate sequence. "Transition" beds at base (called Hecla beds) are part of Red River Formation. Top of Red River marks end of Middle Ordovician time.

Sandberg, C. A., 1961 (U. S. Geol. Surv., TEI-809, p. 28): "Transition zone beds" are placed in underlying Winnipeg Formation.

Reservation bed

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 81, 104): Reservation bed is lowest coal bed of this area and appears along southern boundary of Fort Berthold Indian Reservation.

Riding Mountain Formation

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 1011-1043): Riding Mountain Formation (Late Cretaceous)

is found on Pembina escarpment, Manitoba and North Dakota. Underlies Boissevain Formation; overlies Pembina Member of Vermillion River Formation. Includes Odanah facies.

This usage not followed by later writers.

RIERDON FORMATION (of ELLIS GROUP)

Age: Late Jurassic.

Area of extent: Montana, western North Dakota, and western South Dakota.

Lithology: Alternating, gray, limy shale and limestone in type area.

Thickness: Up to 180 feet in surface of Williston basin; up to 300 feet in subsurface.

Relationships to other units: Disconformably underlies Swift; conformably overlies Sawtooth Formation (Piper Formation), except in areas where it overlaps onto older formations.

Characteristic fossils: Cadoceras muelleri, Kepplerites tychonis, Gryphaea nebrascensis, Arctocephalites, Pachyteuthis, and other molluscs.

Depositional environment: Shallow open marine.

Remarks: Type locality is Rierdon Gulch, sec. 23, T. 24 N., R. 9 W., Teton County, Montana, about 25 miles west of Choteau, Montana. See also Ellis Group.

History of stratigraphic nomenclature:

Cobban, W. A., 1945 (Am. Assoc. Pet. Geol., Bull. 29, no. 9, p. 1277-1281): Rierdon is group of alternating, gray, limy shales and limestones overlying Sawtooth Formation (new). At type locality, consists of (ascending) 20.5 feet of medium-gray limy shale containing few, dense, gray, modular limestones; 33.5 feet of dark-medium-gray, fissile, calcareous to almost noncalcareous shale containing thin beds of gray, dense, nodular limestone; 43.5 feet of medium-gray, shale containing few, thin beds of limestone in lower part; and 39 feet of alternating 4- to 6-inch limestone layers and thicker beds of medium gray, limy shale. At type locality, lower part of formation is of Late Bathonian age and rest is Early Callovian. Basal beds are younger on flanks of South arch than along Rocky Mountain front.

Imlay, R. W., Gardner, L. S., Rogers, C. P., Jr., and Hadley, H. D., 1948 (U. S. Geol. Surv., Oil and Gas Inv. Prelim. Chart 32, 1 sheet): In south-central Montana, overlies Piper Formation (new).

Peterson, J. A., 1954 (Am. Assoc. Pet. Geol., Bull. 38, no. 4, p. 466, 475-477, 482): Swift-Rierdon nomenclature of Ellis Group in Montana is applied in eastern Wyoming to formations of Sundance Group. Names are applicable to marine Upper Jurrassic throughout most of Wyoming and western South Dakota, but term Sundance should be retained because of historical use. Section of Rierdon, measured northeast of Newcastle, Wyoming, is 212 feet thick; includes (ascending) Stockade Beaver Shale, Hulett Sandstone, and Lak Member. Overlies Gypsum Springs Formation; underlies Swift Formation. In places in the Black Hills formation includes fourth member, Canyon Springs, at base.

_____, 1957 (Am. Assoc. Pet. Geol., Bull. 41, no. 3, p. 413, 417): Although five Sundance subdivisions and names of Black Hills are useful there, in Williston and Powder River basins more continuous sedimentation makes nomenclature of Ellis Group more useful. Redwater abandoned in favor of Swift; Lak, Hulett, Stockade Beaver, and Canyon Springs retained as local members of Rierdon. Sundance includes Rierdon and Swift. Rierdon seas deposited three main lithologic units in Williston basin (ascending): Rierdon "A" is calcareous and gives good electric log "kick"; Rierdon "B" is shale; and Rierdon "C" is sandstone. Thickness 350 feet in central part of Williston basin.

Storey, T. P., 1958 (Alberta Soc. Pet. Geol., J. 6, no. 4, p. 90-104): On basis of regional extent and significance of sub-Swift and sub-Rierdon unconformities of Williston basin and adjacent areas, Swift is divided into Lower, Middle and Upper units. Lower Swift in Williston basin is equivalent to Stockade Beaver and Hulett Members of Sundance and unconformably overlies Rierdon, which has been considered equivalent to Stockade Beaver and Hulett. Rierdon corresponds essentially to type Rierdon of Sweetgrass arch where it occurs with notable unconformity, both below Middle and Upper Swift and above Sawtooth and older Gypsum Spring beds. Lower Swift of Williston basin is absent over Sweetgrass arch and over most of western Montana, where it is overlapped by Swift Formation of Cobban (1945).

Rival subinterval

Age: Mississippian.

Area of extent: Subsurface in Saskatchewan and North Dakota.

Remarks: Informally named for Rival Oilfield, Burke County, North Dakota. See also "Midale beds," Frobisher-Alida interval, and Madison Formation.

History of stratigraphic nomenclature:
Anderson, S. B., Hansen, D. E., and Eastwood, W. D., 1960 (N. D. Geol.

Surv., Rep. Invest., no. 36, p. 5): Rival subinterval is top of Frobisher-Alida interval and equivalent to lower part of "Midale beds" or "Frobisher evaporite."

ROUGHLOCK MEMBER, Siltstone (of WINNIPEG FORMATION)

Age: Middle Ordovician.

Area of extent: Western South Dakota, North Dakota.

Lithology: Very light gray, very fine-grained, calcareous sandstone and siltstone; grades laterally into greenish gray, calcareous shale.

Relationships to other units: Conformably overlies Ice Box Formation; underlies Red River Formation.

Characteristic fossils: Conodonts.

Depositional environment: Marine.

Remarks: Type locality is 2.4 miles north of Maurice in Spearfish Canyon, Lawrence County, South Dakota. Agnew and Tychsen (1965) indicate 6.5(?) miles southwest(?) of Maurice. Named from Roughlock Falls, South Dakota.

History of stratigraphic nomenclature:

McCoy, M. R., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 44-46): Roughlock Siltstone consists of 25-30 feet of pale gray-green to cream siltstone. Conformably underlies Whitewood dolomite; conformably overlies Ice Box Formation (new). Unit disappears by nondeposition 10 miles south of Deadwood, South Dakota.

Carlson, C. G., 1960 (N. D. Geol. Surv., Bull. 35, p. 59-61): Roughlock accepted as upper member of Winnipeg in Williston basin. Consists of 0-90 feet of very light gray, very fine-grained, calcareous sandstone and siltstone in south-central North Dakota. Siltstone grades laterally into greenish gray, calcareous, silty shale and greenish gray, calcareous shale to north and northeast. Roughlock becomes difficult to trace in northern part of state. Interval referred to as "Winnipeg transition zone" is included in Roughlock member. Is probably Trentonian in age.

Roundtop Group

Age: Pennsylvanian (Desmoinesian).

Area of extent: Wyoming, southwestern South Dakota, and North Dakota.

Lithology: Shale, mudstone, and thin limestone.

Thickness: Up to 149 feet.

Relationships to other units: Underlies Hayden Group; overlies Reclamation Group.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Type locality is Roundtop Mountain, sec. 22, T. 27 N., R. 66 W., Platte County, Wyo.

History of stratigraphic nomenclature:
Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13A, p. 2-3, 33-34, and 44): Roundtop Group consists mostly of shale, mudstone, and red, green, and gray thin limestone. Comprises Division IV of Hartville "Formation" (Condra, G. E., and Reed, E. C., 1935, Nebr. Geol. Surv., Pap. no. 9, 46 p.). Thickness is 149 feet. Underlies Hayden Group (new): overlies Reclamation Group (new).

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym., 1st Internat., Bismarck, N. D., p. 150-164): Roundtop Group consists of red, green, and brown, waxy to subwaxy, shales, interbedded with very thin beds of dolomite. Dolomitic content increases toward top of group.

"Sanish sandstone"

Age: Late Devonian.

Area of extent: In and around Antelope Field in northeastern McKenzie County, North Dakota.

Lithology: Brown, dolomitic, slightly argillaceous, silty, friable sandstone.

Thickness: Up to 15 feet.

Relationships to other units: Uppermost unit of Three Forks Formation; overlain by Bakken Formation.

Characteristic fossils: None.

Economic significance: Oil productive.

Depositional environment: Shallow marine.

Remarks: Local term; not formally introduced in literature.

SASKATCHEWAN GROUP

Age: Late Devonian.

Area of extent: Subsurface in Saskatchewan, Manitoba, Montana, North Dakota and South Dakota.

Lithology: Dolomite, anhydrite, limestone, and shale.

Thickness: Up to 750 feet.

Relationships to other units: Overlies Souris River Formation of Beaverhill Lake Group or overlies Manitoba Group; underlies Qu'Appelle Group. Divided into two units (ascending): Duperow and Nisku (Birdbear) Formations.

Characteristic fossils: None.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Named after Saskatchewan, Canada. See also Duperow and Birdbear Formations.

History of stratigraphic nomenclature:

Baille, A. D., 1953 (Manit. Dep. Mines Nat. Resour., Mines Br. Pub. 52-5, p. 30-32): Saskatchewan Group consists of a thick series of strata directly overlying Souris River Formation of Beaverhill Lake Group and underlying carbonate-clastic-evaporite units of Qu'Appelle Group. Predominant lithologies are dolomite, anhydrite, limestone, and shale. Divided into two units (ascending): Duperow and Nisku (Birdbear).

_____, 1955 (Am. Assoc. Pet. Geol., Bull. 39, no. 5, p. 603): Persistent argillaceous bed occurs less than 150 feet below top of Saskatchewan Group. Bed is 10-30 feet thick, and consists of red and green dolomitic shale, slightly silty in places and argillaceous limestone; is easily recognized by lithologic or mechanical logs and is perhaps most reliable marker bed of group.

Agnew, A. F., and Tychsen, P. C., 1965 (S. D. Geol. Surv., Bull. 14, p. 163): Saskatchewan Group represents same interval as Jefferson Group of South Dakota.

Satterlund-Kugler bed

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol., Surv., Bull. 4, p. 119): Satterlund-Kugler bed is lignite bed mined about

5 miles west of Washburn. Bed is 8-11 feet thick and is named for mines of area.

See also Fairman bed.

Saude member, formation

Age: Triassic(?)

Area of extent: North Dakota and western Montana.

Lithology: Reddish-orange siltstone and very fine-grained sandstone with medium- to coarse-grained sandstone interbeds.

Thickness: Up to 350 feet.

Relationships to other units: Conformably overlies Pine Salt and conformably underlies Dunham Salt or disconformably underlies Piper or Gypsum Spring Formation. Equivalent to Watrous "red-beds" of Canada.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Littoral to restricted marine.

Remarks: See also Dunham Salt, Pine Salt, and Spearfish Formation.

History of stratigraphic nomenclature:

Zieglar, D. L., 1955 (N. D. Geol. Soc., South Dakota Black Hills Field Conf., Gdbk., p. 52): Saude is reddish-orange siltstone and fine-grained sandstone with medium- to coarse-grained sandstone interbeds. Anhydrite present as inclusions in finer-grained matrix; nearly spherical, frosted quartz grains are common. Saude conformably overlies Pine Salt and conformably underlies Dunham Salt. Where Pine Salt absent, Saude rests unconformably on Permian(?) to Devonian rocks.

Dow, W. G., 1964 (3rd Williston Basin Sym., Conrad Pub. Co., Bismarck, p. 127-131): Saude Formation considered to be member of Spearfish Formation; is stratigraphically equivalent to lower two units of Watrous Formation of Saskatchewan, and upper evaporite unit of Watrous is correlative with lower member of Piper Formation; therefore, Triassic-Jurassic time boundary may lie within upper part of Saude in northern North Dakota. Majority of Saude in North Dakota is Triassic.

Scallion subinterval

Heck, T., 1978 (Mont. Geol. Soc., Williston Basin Sym., 24th Ann. Field Conf., p. 196-197): Scallion subinterval is equivalent to lower Bottineau interval and consists of sediments of normal marine circulation. Five major facies developed: 1) dark gray to black, irregularly laminated, crinoidal, mudstone-wackestone (central basin), 2) medium to light gray, argillaceous, crinoid, brachiopod, wackestone to packstone (basin slope), 3) light colored, cherty, skeletal wackestone to packstone (open shelf), 4) crinoidal mudstone (at or near shelf break) and 5) gray shale (restricted environment shoreward). Is Kinderhookian in age.

Schaffner bed (of GOLDEN VALLEY FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 253): Schaffner bed named for exposures near Schaffner Creek is coal occurring about 30 feet above Alamo Bluff bed. Is in upper member of Golden Valley Formation.

Schefield member (of BRULE FORMATION)

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. 73): Schefield Member is 25-77 feet of silty claystone and clay that forms vertical cliff-forming strata of uppermost part of Brule Formation in North Dakota. Lies above Dickinson Member of Brule and below Killdeer Formation. Contains calcareous concretions. Age is late Orellan through Whitneyan.

Schoolhouse bed

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 251): Schoolhouse bed named for exposure in small mine near rural school in southern part of sec. 27, T. 142 N., R. 89 W.; is 45-100 feet above Beulah-Zap bed.

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 43): Schoolhouse bed is 30-45 feet above Beulah-Zap bed in Square Butte area.

"'Second red' bed"

Age: Middle Devonian.

See Dawson Bay Formation.

Second white specks zone

See Greenhorn Formation.

Sentinel Butte coal group

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 90-96): Sentinel Butte coal group is highest coal group in region and three of the beds are in Sentinel Butte Formation. Contains beds Q-U. Beds Q-S occur at Bullion Butte.

See also HT Butte lignite.

Sentinel Butte coal group

See Sentinel Butte Formation.

SENTINEL BUTTE FORMATION

Age: Late Paleocene.

Area of extent: North Dakota, Montana, and Wyoming.

Lithology: Dark-colored somber shales and interbedded lignites and coal beds; few local lenticular sandstones and yellowish, silty beds, some of which are baked from burning lignite, forming red clinker beds.

Thickness: Up to 660 feet.

Relationships to other units: Conformably overlies Tongue River Member of Fort Union Formation; conformably underlies Golden Valley Formation and is sometimes unconformably overlain by White River Formation in part of western North Dakota.

Characteristic fossils: Fresh-water molluscs, and plant remains including petrified wood.

Economic significance: Possible uranium potential, lignite.

Depositional environment: Alluvial plain.

Type section: Sentinel Butte; top of butte is in west-central sec. 8, T. 139 N., R. 104 W., Golden Valley County, North Dakota.

History of stratigraphic nomenclature:

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 105-113): Sentinel Butte Coal group of southwestern North Dakota is in upper part of Fort Union Formation and includes coals Q, R, S, T, and V. Underlying Beaver Creek coal group included coals N, O, and P.

Thom, W. T., Jr., and Dobbin, C. E., 1924 (Geol. Soc. Am., Bull. 35, p. 484, 495-497): Sentinel Butte Shale Member of Fort Union(?) Formation is typically developed at Sentinel Butte (Billings County, North Dakota). Consists of dark clay shales resembling Hell Creek Member of Lance Formation and Lebo Shale Member of Fort Union Formation. Overlies Tongue River Member of Fort Union Formation and underlies Ulm coal group of Wasatch Formation. Is essentially equivalent to intermediate coal group of northern Wyoming and also Roland Coal bed.

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, 110 p.): Sentinel Butte Member of Fort Union(?) Formation is 325 feet thick in Marmarth field of southwestern, North Dakota. Consists of dark, somber, sandy shale, gray sandstone, and lignite interbedded. Overlies Tongue River and unconformably underlies White River(?) Formation. Bullion Creek lignite bed lies near top of HT Lignite bed at base.

Benson, W. E., and Laird, W. M., 1947 (Geol. Soc. Am., Bull. 58, no. 12, pt. 2, p. 1166-1167): Golden Valley Formation (new) overlies Sentinel Butte Shale Member of Fort Union Formation now considered to be of Paleocene age.

Brown, R. W., 1948 (Am. Assoc. Pet. Geol., Bull. 32, no. 7, p. 1265-1274): Sentinel Butte Shale is, as originally described and assigned, dark sequence of strata in upper part of Fort Union Formation (Paleocene).

Beroni, E. P., and Bauer, H. L., Jr., 1952 (U. S. Atomic Energy Commis., TEI Rep. 124, p. 14-16): In Golden Valley County, North Dakota, Sentinel Butte contains 15 feet of uraniferous lignite bed named Boullion Butte bed. In southwestern North Dakota, member is 300-500 feet thick and is conformable with both underlying Tongue River Member and overlying rocks tentatively identified as Golden Valley (?) Formation.

Fisher, S. P., 1953 (N. D. Geol. Surv., Rep. Invest. 11, 2 pl.): Sentinel Butte considered facies of Tongue River in central McKenzie County.

May, P. R., 1954 (U. S. Geol. Surv., Bull. 995-G, p. 267-268): About 200 feet of Sentinel Butte Shale, uppermost member of Fort Union, is exposed at top of Blue Mountain in northern Wibaux area, Montana and North Dakota. Composed of gray and brown sandstone and shale and thin lignite beds. Overlies Tongue River Member. Is Paleocene in age.

Hanson, B. M., 1955 (N. D. Geol. Surv., Rep. Invest. 18, 1 pl.): Sentinel Butte reallocated to member of Tongue River Formation. In Elkhorn ranch area of Billings and Golden Valley Counties, only lower 250 feet present. Contact of Sentinel Butte and underlying part of Tongue River Formation is locally picked at base of most persistent and prominent clinker bed or on basis of characteristic lithologies--Tongue River light-tan to gray sand and clay and Sentinel Butte of brown sand and clay.

SKULL CREEK SHALE (of DAKOTA GROUP)

Age: Early Cretaceous.

Area of extent: Southeastern Montana, southwestern North Dakota, western South Dakota, and northeastern Wyoming.

Lithology: Dark gray-black to black, fissile, flaky to splintery shale. Often silty at top of section.

Thickness: Up to 300 feet.

Relationships to other units: Disconformably underlain by Fall River Sandstone. Presumably disconformable with overlying Newcastle (Muddy) Sandstone. Equivalent to part of Thermopolis Shale of Big Horn basin, Wyoming and south-central Montana.

Characteristic fossils: Inoceramus bellevuensis.

Economic significance: None.

Depositional environment: Widespread, shallow, stable marine.

Remarks: Type locality along Skull Creek, southeast of Osage, Weston County, Wyoming.

History of stratigraphic nomenclature:
Collier, A. J., 1922 (U. S. Geol. Surv., Bull. 736, p. 79): Skull Creek Shale is basal member of Graneros Shale in Osage oil field, Weston County, Wyoming. Is dark bluish-gray shale, about 200 feet thick with few calcareous concretions and some siliceous shale near base. Contains few fossils. Is called Thermopolis Shale by drillers but represents only basal part of true Thermopolis Shale. Is well-exposed along Skull Creek southeast of Osage; lies between Dakota Sandstone below and Newcastle Sandstone above.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 76): Contact with underlying Fall River is usually sharp, but top is difficult to locate where lower sands of Newcastle Formation are not well developed. Microfossils indicate early Cretaceous age. Is equivalent to lower part of Thermopolis Shale of Wyoming.

Gries, J. P., 1954 (Am. Assoc. Pet. Geol., Bull. 38, no. 4, p. 446-449): Dakota not used in Black Hills but applied to thick sandstone sequence in central South Dakota where it was termed "true Dakota" and where it overlies Skull Creek Shale. "True Dakota" is age equivalent of Newcastle-Mowry interval, and what is called Dakota in Williston basin to north is actually Fall River Sandstone.

Pettyjohn, J. A., 1960 (S. D. Acad. Sci., Proc., v. 38, p. 34-38): Dakota Group to be used to include Lakota, Fuson, Fall River, Skull Creek and Newcastle Formations.

SLOPE FORMATION (of FORT UNION GROUP)

Clayton, L. et al., 1977 (N. D. Geol. Surv., Rept. Invest. 59, p. 7-9): Slope Formation consists of alternative beds of clay, silt, sand, and lignite. Named for Slope County, North Dakota, and type section is south-facing exposure in NW¼ sec. 15 and SW⅛ sec. 10, R. 105 N., R. 135 W., Slope County, North Dakota. Overlies Cannonball Formation in central North Dakota and Ludlow Formation in western North Dakota; is unconformably overlain by Bullion Creek Formation (new). Is 20-90 metres thick. Is Paleocene in age and consists of strata considered by others to be upper part of Ludlow Formation or part of Tongue River Formation.

SOURIS RIVER FORMATION

Age: Late Devonian.

Area of extent: Williston basin.

Lithology: Interbedded dolomite, limestone and minor anhydrite. Gray, green and red shale and argillaceous dolomite, often referred to as "First red bed," make up base; this unit locally silty and sandy and is 30 feet thick or more.

Thickness: Up to 40 feet in northeastern Montana and northwestern North Dakota.

Relationships to other units: Conformably underlies Duperow Formation and conformably overlies Dawson Bay Formation, except near basin margins where disconformable on Dawson Bay or older formations. Upper part of Souris River is correlative to Maywood Formation in western Montana. Souris River is equivalent to part of Beaverhill Lake Formation in Alberta and Saskatchewan and possibly to unnamed upper part of Manitoba Group.

Characteristic fossils: Algae, ostracods.

Economic significance: Oil productive.

Depositional environment: Marine.

Remarks: Proposed standard subsurface section is interval 10,743-11,052 feet in Mobil #1 Birdbear oil test, SESW sec. 22, T. 149 N., R. 91 W., Dunn County, N. D.

Type section: 5912-6160 foot interval in California Co. No. 1 Blanche Thompson, sec. 31, T. 160 N., R. 81 W., Bottineau County, North Dakota.

History of stratigraphic nomenclature:

Laird, W. M., 1953 (Interstate Oil Compact, Quart. Bull., v. 12, no. 2, p. 74): Beaverhill Lake Group has been divided into two formations (ascending) Dawson Bay and Souris River. Souris River Formation is new term for part of Devonian known only in subsurface of north-central North Dakota and adjacent parts of Saskatchewan and Manitoba. Overlies Dawson Bay; underlies Duperow Formation.

Towse, D., 1953 (N. D. Geol. Surv., Rep. Invest. 12, 1 sheet): Devonian "C" of earlier North Dakota Geological Survey reports is equivalent to Souris River Formation or "Beaverhill Lake equivalent" of this report.

North Dakota Geological Society, 1954 (Stratigraphy of the Williston Basin: Conrad Pub., Bismarck, p. 14): Base of Souris River Formation is persistent shale or argillaceous dolomite marker (first red bed). Lithology of rest of shale is dull-gray to buff, argillaceous dolomite with interbedded, greenish-gray, dolomitic shale.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, p. 2310-2311): Report of Williston Basin Correlation Committee not published; Souris River Formation not formerly proposed or adequately described. Proposed standard subsurface section be interval 10,743-11,052 feet in Mobil #1 Birdbear oil test, SESW sec. 22, T. 149 N., R. 91 W., Dunn County, North Dakota (adopted by North Dakota Geological Society, 1961, Stratigraphy of Williston Basin Devonian System: Conrad Pub., Bismarck, p. 21). Consists of thin, interbedded gray, greenish-gray, and brownish-gray, argillaceous dolomite, argillaceous limestone, shale, siltstone, and anhydrite. Is Late Devonian in age.

South Heart member (of CHADRON FORMATION)

Stone, W. J., 1973 (Stratigraphy and sedimentary history of Middle Cenozoic (Oligocene and Miocene) deposits in North Dakota: Ph.D. dissert., Univ. N. D., p. 55-58): South Heart member is uppermost member of Chadron Formation; conformably overlies Chalky Buttes Member and conformably underlies Brule Formation. Consists of

South Ross clay bed

See Golden Valley Formation

Spear bed (of SENTINEL BUTTE FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 252): Spear bed occurs about 60 feet below Beulah-Zap bed. Named for exposures at Spear Ranch in northeast corner of sec. 12, T. 143 N., R. 89 W.

SPEARFISH FORMATION

Age: Permian-Triassic(?).

Area of extent: Western South Dakota, western North Dakota, eastern Montana, eastern Wyoming, and northwestern Nebraska.

Lithology: Red shale, siltstone, and sandstone with interbedded salt and gypsum, and minor carbonate.

Thickness: 350-500 feet at type locality; up to 1,000 feet in North Dakota.

Relationships to other units: Overlain by Piper Formation; underlain by Minnekahta Limestone (Permian) but onlaps rocks as old as Mississippian in Montana and North Dakota.

Characteristic fossils: None.

Economic significance: Oil productive.

Depositional environment: Littoral marine to restricted marine.

Remarks: Type locality in Black Hills; named for Spearfish, Lawrence County, South Dakota. See also Pine Salt and Saude Formation.

History of stratigraphic nomenclature:
Darton, N. H., 1899 (Geol. Soc. Am., Bull. 10, p. 387): Triassic Spearfish Formation (red beds) unconformably underlies Sundance Formation in Black Hills.

Darton,N. H., 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 4, p. 516): Spearfish Formation consists of red, sandy clay or shale with gypsum beds up to 30 feet thick. Thickness is 350-500 feet at type locality in Black Hills. Overlies Minnekahta limestone and unconformably underlies Sundance Formation.

Imlay, R. W., 1947 (Am. Assoc. Pet. Geol., Bull. 31, no. 2, p. 235, 237-240): Spearfish Formation extended into Black Hills area; unconformably underlies Gypsum Spring Formation. Gypsiferous facies of Gypsum Spring was included by Darton at top of Spearfish, contains marine Jurassic fossils and interfingers laterally with dolomite and limestone containing marine fossils.

Gries, J. P., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 73): Spearfish red beds extend eastward to Missouri River to subsurface where they pinch out. East of Black Hills, Spearfish is 350 feet thick, thickens to north and west; 1,000 feet thick in North Dakota. Stratigraphic correlation with Wyoming strata indicates Spearfish is Permo-Triassic in age but no fossils recovered.

Reed, E. C., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 46): Lower Spearfish in Black Hills is equivalent to middle and upper Phosphoria, and is Permian, not Triassic in age. No concrete evidence to divide Spearfish into Triassic and Permian.

Zieglar, D. L., 1955 (N. D. Geol. Soc., South Dakota Black Hills Field Conf., Gdbk., p. 53, 54): "Red-bed" sequence between top of Minnekahta and base of Piper is divided into (ascending): 1) Triassic Spearfish (Spearfish by this usage limited to western one-third of state), 2) Pine Salt, 3) Jurassic Saude, and 4) Dunham Salt.

Mapel, W. J., and Bergendahl, M. H., 1956 (Am. Assoc. Pet. Geol., Bull. 40, no. 1, p. 88, 90-93): In Black Hills, Gypsum Spring rests with sharp undulating contact on sequence of red claystone, siltstone, and sandstone assigned to Spearfish Formation. Is 30-50 feet thick. Age is Triassic.

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Invest. 28, 2 sheets): Spearfish Formation of North Dakota contains two salts (descending): 1) Triassic "A" Salt, up to 142 feet thick, and 2) Triassic "B" Salt, up to 199 feet thick. Spearfish "A" salt thins over Nesson anticline.

Dow, W. G., 1964 (3rd Williston Basin Sym., Conrad Pub., Bismarck, p. 127-131): Spearfish Formation of Williston basin divided into three members (ascending): 1) lower shale unit, 2) Pine Salt Member, and 3) Saude Member. Lower shale unit is Permian in age; Pine Salt grades laterally into anhydrites and shales of lower Spearfish and is considered to be Permian in age. Saude Member is stratigraphically equivalent to lower two units of Watrous Formation of Saskatchewan, and upper evaporite unit of Watrous is correlative with lower member of Piper Formation; therefore, Triassic-Jurassic time boundary may be within upper part of Saude in northern North Dakota. Majority of Saude is primarily Triassic in age. Spearfish overlain by Piper Formation (Jurassic).

Dow, W. G., 1967 (N. D. Geol. Surv., Bull. 52, p. 6-8): Restricted Spearfish of Zieglar (1955) named Belfield Member. Consists of fissile gray shale interbedded with reddish orange siltstone and

mudstone, few anhydrite and dolomite beds present. Conformably overlies Minnekahta but does not extend beyond the limits of Minnekahta; conformably underlies Pine Salt or Saude Members of Spearfish.

Spring Valley-Richter lignite zone (of SENTINEL BUTTE FORMATION)

Barclay, C. S. V., 1974 (U. S. Geol. Surv., Coal Invest., Map C-67, 13 p., 2 pl.): Zone of locally thick and persistent lignite beds in Glen Ullin and Dengate Quadrangles named Spring Valley-Richter lignite zone. Named from Spring Valley and Richter Mines. Spring Valley and Richter beds are at least partly equivalent.

Stanton bed (of SENTINEL BUTTE FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 256): Stanton bed is named for exposures of coal 4-6 miles south of Stanton. May be equivalent to Garrison Creek bed of Andrews, 1939 (U. S. Geol. Surv., Bull. 906B, p. 43-84).

Star bed (of SENTINEL BUTTE FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 255): Star bed is poorly exposed bed 25-40 feet above Hazen B bed and 75-95 feet below Beulah-Zap bed. Named for Dakota Star Mine where it is 10 feet thick. Equivalent to Stanton bed.

STONEWALL FORMATION, LIMESTONE

Age: Silurian and Ordovician.

Area of extent: Manitoba, North Dakota, South Dakota, and Montana.

Lithology: Anhydrite at base, overlain by finely crystalline limestone, overlain by anhydrite and finely crystalline, dolomitic limestone.

Thickness: Up to 50 feet.

Relationships to other units: Conformably overlies Stony Mountain Formation; underlies Ashern Shale.

Characteristic fossils: Kochoceras and Antiplectoceras. None found in North Dakota.

Economic significance: None.

Depositional environment: Marine; occasionally restricted.

Remarks: Named for quarry near Stonewall, Manitoba.

History of stratigraphic nomenclature:
Kindle, E. M., 1914 (Can. Geol. Surv., Summ. Rep. 1912, p. 247-261): Stonewall formation includes all beds of Silurian age exposed in Manitoba.

Baille, A. D., 1951 (Man. Dept. Mines Nat. Res., Mines Br., Pub. 50-1), p. 6): Replaced originally defined Stonewall Formation with term "Interlake Group"; Stonewall restricted to lowest formation of group. Stonewall overlain by series of units, B. C, D, and E (ascending), for which naming is deferred until units can be established in subsurface. Consists of arenaceous shale and dolostone above, and yellowish-gray, finely crystalline dolostone with salt crystals below. Thickness is 40-50 feet. Overlies Stony Mountain Formation; underlies Ashern Shale. Fauna assigned to Silurian, although several Late Ordovician fossils present.

Stearn, C. W., 1953 (Geol. Soc. Am., Bull. 64, p. 1477-1478): Stonewall fauna is Late Ordovician in age and should be removed from Interlake Group.

Andrichuk, J. M., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 10, p. 2381): Stonewall retained as basal unit of Interlake Group as significant lithologic break occurs at base of Stonewall. Usage, therefore, returned to Baille's (1951) definition.

Carlson, C. G., and Eastwood, W. P., 1962 (N. D. Geol. Surv., Bull. 38, p. 8-10): Stonewall in North Dakota consists of basal anhydrite overlain by finely-crystalline dolomitic limestone. Toward margins of basin, anhydrites pinch out and entire section becomes dolomitic. No fossils noted in Stonewall from cuttings in North Dakota. Ordovician-Silurian boundary tentatively placed with Stonewall Formation in North Dakota.

STONY MOUNTAIN FORMATION (of BIG HORN GROUP)

Age: Late Ordovician.

Area of extent: Manitoba, Saskatchewan, North Dakota, eastern Montana, and northern South Dakota.

Lithology: Upper part is gray to buff to tan, finely crystalline dolomite and dolomitic, fossiliferous limestone; thin anhydrite beds may be present in central part of basin (Gunton Member) and lower part is medium-dark gray, fossiliferous limestone interbedded with dark gray calcareous, fossiliferous shale (Stoughton Member).

Thickness: Up to 200 feet.

Relationships to other units: Conformably overlies Red River Formation and is conformably overlain by Interlake Group except around margins of Williston basin.

Characteristic fossils: Brachiopods, bryozoans, crinoids, and graptolites (Nematograptus gracilis, Diplograptus amplexicaulis, and Climacograptus typicalis crassimarginalis).

Economic significance: Gunton Member produces oil along Cedar Creek anticline.

Depositional environment: Marine cratonic basin and on shelf areas marginal to basin.

Remarks: Type area is Stony Mountain area, Manitoba.

History of stratigraphic nomenclature:

Dowling, D. B., 1901 (Can. Geol. Surv., Ann. Rep., new ser., v. 11, p. 46F-53F): Stony Mountain Formation divided into three members at outcrop (descending): 1) Gunton dolomite, shale, and sand; 2) Penitentiary dolomite; and 3) Stony Mountain Shale. In subsurface, Stony Mountain is shale or shaley limestone with dark-brown to black fossil fragments. Exact age of Gunton not established; may represent transition from Ordovician to Silurian. Fauna from wells in eastern Montana is similar to that of Maquoketa Formation of Iowa. Thickness is 25-200 feet.

Miller, A. K., 1930 (Am. J. Sci., 5th ser., v. 20, p. 211): Stony Mountain Formation of Manitoba equivalent to upper part of Bighorn Dolomite of Richmond age.

Kline, V. H., 1942 (Am. Assoc. Pet. Geol., Bull. 26, no. 3, p. 339, 360-361): Stony Mountain Formation extended into subsurface of North Dakota.

Okulitch, V. J., 1943 (Roy. Soc. Can., Trans., 3rd ser., v. 37, sec. 4, p. 59-74): Stony Mountain Formation divided into four members (ascending): Stony Mountain Shale, Penitentiary, Gunton, and Birse.

Baille, A. D., 1952 (Man. Dep. Mines Min. Res., Pub. 51-6, p. 8): Stony Mountain Formation consists of calcareous shales, argillaceous dolostones, and dolostones. Divided into three members (ascending): Stony Mountain Shale, Penitentiary, and Gunton. Gunton Member includes Birse Member of V. J. Okulitch (1943).

Ross, R. J., Jr., 1957 (U. S. Geol. Surv., Bull. 1021-M, p. 447): In Williston basin, Stony Mountain Formation consists of two units: 1) lower shale, commonly called Stony Mountain Shale by oil geologists; and 2) upper dolomite. Upper unit includes Penitentiary

(below) and Gunton Member of A. D. Baille (1952) and restricted Stonewall Formation of C. W. Stearn (1953, Geol. Soc. Am., Bull. 64, p. 1477-1478). Overlies Red River Formation.

Sinclair, G. W., and Leith, E. I., 1958 (J. Paleon., v. 32, p. 243-244): Gunn Member proposed for lower member (formerly Stony Mountain Shale) of Stony Mountain Formation to abide by Stratigraphic Code (Art. 16, d), which states same name should not be applied to whole unit and part of same unit.

Porter, J. W., and Fuller, J. G. C. M., 1959 (Am. Assoc. Pet. Geol., Bull. 43, p. 131): Stony Mountain Formation divided into two units in subsurface (ascending): lower or Stony Mountain Shale Member and upper or Gunton Member. Lower member equivalent to Sinclair and Leith's (1958) Gunn and Penitentiary Members of outcrop section. Gunton Member equivalent to Gunton Member of outcrop section.

Saskatchewan Geological Society, 1958 (Rep. of the Lower Paleozoic Names and Correlations Committee: Sask. Geol. Soc., Regina, Sask.): Stony Mountain Formation divided into two units ascending); Stoughton beds (for lower or Stony Mountain Shale Member) and Gunton Member (upper).

Fuller, J. G. C. M., 1961 (Am. Assoc. Pet. Geol., Bull. 45, p. 1334-1365): Stony Mountain Formation of Williston basin consists of lower shale member, 75 feet of dark-gray to brown shelly, argillaceous limestone with few interbedded calcareous shale beds; and upper dolomitic fossiliferous, fragmental limestone (Gunton beds). Is overlain by Stonewall Limestone.

Carlson, C. G., and Eastwood, W. P., 1962 (N. D. Geol. Surv., Bull. 38, p. 5-8): Stoughton Member consists of medium dark-gray fossiliferous limestone interbedded with dark-gray, calcareous, fossiliferous shale; Gunton Member consists of brownish-gray to yellowish-brown, finely crystalline, limy dolomite and dolomitic, fossiliferous limestone with anhydrite bed in northwestern North Dakota. Stony Mountain Formation is 115-180 feet thick.

STOUGHTON MEMBER, BEDS (of STONY MOUNTAIN FORMATION)

Age: Late Ordovician.

Area of extent: Manitoba, Saskatchewan, and northern North Dakota.

Lithology: In central part of Williston basin consists of gray, calcareous, fossiliferous shale interbedded with gray, fossiliferous limestone. In eastern and southern North Dakota, limestone is more argillaceous and shale varies between green-gray and purple.

Thickness: Up to 110 feet.

Relationship to other units: Conformably underlies Gunton Member and overlies Red River Formation. Equivalent to Stony Mountain Shale Member.

Characteristic fossils: Brachiopods, bryozoans, and crinoids.

Economic significance: Oil productive.

Depositional environment: Marine cratonic basin and shelf.

Remarks: Standard reference section is interval of 7,768-7,816 feet in Imperial Canadian Superior Stoughton No. 3-27, Lsd. 3, sec. 27, T. 8, R. 8 W., 2nd mer. Saskatchewan. Type locality is Stony Mountain area, Manitoba. See also Stony Mountain Formation.

History of stratigraphic nomenclature:
Saskatchewan Geological Society, 1958 (Rep. of the Lower Paleozoic Names and Correlations Committee: Regina, Sask., Sask. Geol. Soc., p. 8): Two facies included in Stoughton beds are: 1) dark-gray calcareous shale and highly fossiliferous shale and limestone sequence confined to southwestern Manitoba, southeastern Saskatchewan, and northern North Dakota; and 2) laterally equivalent dolomite or dolomitic limestone elsewhere. Beyond depositional edge of argillaceous beds (Stony Mountain Shale) Gunton and Stoughton sequences merge into sequence of carbonate (undifferentiated Stony Mountain beds); Stoughton beds reach maximum thickness (100 feet) in eastern North Dakota. Equivalent to Stony Mountain Shale Member as defined by Porter and Fuller (1958, Am. Assoc. Pet. Geol., Bull. 43, no. 1, p. 124-189) in near-outcrop Manitoba subsurface.

Carlson, C. G., and Eastwood, W. P., 1962 (N. D. Geol. Surv., Bull. 38, p. 3 and 7): Stoughton Member is basal unit of Stony Mountain Formation. Underlies Gunton Member.

SUNDANCE GROUP, Formation

Age: Late Jurassic.

Area of extent: Western South Dakota, central Montana, North Dakota, Wyoming, northwestern Nebraska, and central Colorado.

Lithology: Green shale and red, thinly-bedded sandstones.

Thickness: Up to 600 feet.

Relationships to other units: Conformably and unconformably overlies Gypsum Spring Formation and conformably underlies Morrison Formation. Equivalent to Swift and Rierdon Formations of Montana.

Characteristic fossils: None listed for North Dakota.

Economic significance: None.

Depositional environment: Marine.

Remarks: Type area southeast [southwest] of Belle Fourche Quadrangle, South Dakota, north of Sundance, Wyoming. Named from Sundance, Wyoming, 15 miles west of South Dakota boundary. Standard reference section is 1 mile north-northeast of center of Spearfish, sec. 3, T. 6 N., R. 2 E., Lawrence County, South Dakota. See also Swift and Rierdon Formations.

History of stratigraphic nomenclature:

Darton, N. H., 1899 (Geol. Soc. Am., Bull. 10, p. 387-393): Sundance Formation consists of green shale and thinly-bedded sandstones, 60-400 feet thick. Underlies Unkpapa Sandstone; unconformably overlies Spearfish Formation in Black Hills. Contains marine Jurassic fossils.

_____, 1901 (U. S. Geol. Surv., 21st Ann. Rep., pt. 4, p. 520): Sundance Formation consists of dark drab to green shale alternating with red or buff sandstones. Is 25 feet of massive red sandstone at base.

_____, and O'Harra, C. C., 1909 (U. S. Geol. Surv., Folio No. 164, p. 3): Type locality of Sundance is above Sundance, Wyoming, not southeast of Belle Fourche Quadrangle.

Imlay, R. W., 1947 (Am. Assoc. Pet. Geol., Bull. 31, no. 2, p. 227-273): Members of Sundance Formation in Black Hills area are (ascending): 1) Canyon Springs Sandstone Member, 2) Stockade Beaver Shale Member, 3) Hulett Sandstone Member, 4) Lak Member and 5) Redwater Shale Member. Thickness is 200-500 feet. Overlies Gypsum Spring; underlies Morrison Formation. Type section named by Darton considered to be inadequate. Standard reference section (1 mile north-northeast of center of Spearfish, sec. 3, T. 6 N., 2 E., Lawrence County, South Dakota) is 327 feet thick and includes all members except Canyon Springs. Is Callovian and Oxfordian in age.

Peterson, J. A., 1954 (Am. Assoc. Pet. Geol., Bull. 38, no. 4, p. 464-500): Sundance ranked as group comprising two formation, which are correlated with Swift and Rierdon Formations of Montana. Because of historical use, term Sundance retained, and, despite correlation with upper units of Ellis Group, Sundance Group here applies to marine Late Jurassic rocks of Black Hills, northern Colorado, subsurface of northwestern Nebraska, and Wyoming. Sundance Group may be expanded to include Gypsum Spring Formation; if so, Sundance Group would include Middle Jurassic Bajocian age as well as Callovian to Oxfordian (Late Jurasssic).

_____, 1957 (Am. Assoc. Pet. Geol., Bull. 41, no. 3, p. 413): Although five divisions of Sundance are useful in Black Hills, in Williston and Powder River basins more continuous sedimentation makes nomenclature

of Ellis Group more useful. Term Redwater abandoned for Siwft Formation; Lak, Hulett, Stockade Beaver, and Canyon Springs retained as local members of Rierdon Formation. Sundance includes Rierdon and Swift Formations.

Storey, T. P., 1958 (Albta. Soc. Pet. Geol., J., v. 6, no. 4, p. 90-104): On basis of regional extent and significance of sub-Swift and sub-Rierdon unconformities of Williston basin and adjacent area, Swift is divided into lower, middle and upper units. Lower Swift is considered to be lithologically similar to and regionally conformable with Middle and Upper Swift, which corresponds to type Swift of western Montana. Lower Swift of Williston basin and equivalent Stockade Beaver and Hulett Members of Lower Sundance in Black Hills lie unconformably on Rierdon, and are younger than Rierdon and older than Swift. Lak and Redwater Members are equivalent to type Swift of western Montana.

Agnew, A. F., and Tychson, P. C., 1965 (S. D. Geol. Surv., Bull. 14, p. 178): South Dakota Geological Survey uses Sundance Group in Black Hills for Jurassic members (except Gypsum Spring), including Canyon Springs at base and Redwater at top. In central South Dakota Sundance Formation used. In Williston basin, Piper (equivalent to Gypsum Spring), Rierdon, and Swift (equivalent to Redwater) used as formations of Sundance Group. Ellis Group not used.

Love, J. D., and Keefer, W. R., 1975 (U. S. Geol. Surv., Prof. Pap. 729-D, p. 17-21): Sundance considered to be Middle to Late Jurassic in age.

Swan River Formation

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 1011-1043): Swan River Formation (Early Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota. Overlain by Ashville Formation.

This usage not followed by later writers.

SWIFT FORMATION (of ELLIS GROUP)

Age: Late Jurassic.

Area of extent: Montana, western North Dakota, western South Dakota, and eastern Wyoming.

Lithology: Dark-gray, non-calcareous shale overlain by fine-grained, glauconitic sandstone.

Thickness: Up to 300 feet.

Relationships to other units: Unconformably overlies Rierdon and locally older formations; conformably underlies Morrison Formation.

Characteristic fossils: Quenstedticeras, Pavloviceras, Cardioceras, and other molluscs.

Economic significance: Oil productive.

Depositional environment: Shallow, open marine.

Remarks: Type locality on north shore of Swift Reservoir on Birch Creek NE¼ sec. 27, T. 28 N., R. 10 W., Ponderosa County, Montana, about 15 miles west of Dupuyer, Montana. See also Ellis Group.

History of stratigraphic nomenclature:

Cobban, W. A., 1945 (Am. Assoc. Pet. Geol., Bull. 29, no. 9, p. 1264, 1281-1286, and 1288-1289): At type locality, two members consists of (ascending): 1) dark-gray, non-calcareous shale; 54.5 feet, and 2) flaggy, ripple-marked sandstone with abundant black-gray, shale partings; 80 feet. Lithology at type locality persists along mountain front from south boundary of Glacier National Park southeast to Sun River. From Sun River southeast along mountain front, formation becomes increasingly sandy. On South Arch, formation consists of fine-grained, flaggy sandstone with pebble horizon at base. In Little Belt Mountains, formation is massive, fine-grained sandstone containing prominent basal conglomerate. Thickness 135 feet at type locality; underlies Morrison formation; overlies Rierdon Formation (new). In areas where Rierdon is absent, unconformably overlies Sawtooth Formation.

Peterson, J. A., 1954 (Am. Assoc. Pet. Geol., Bull. 38, no. 4, p. 480-486, 491-504): Swift-Rierdon nomenclature of Ellis Group in Montana is applied in eastern Wyoming and western South Dakota to formational units of Sundance Group. Names are applicable to marine Upper Jurassic throughout most of Wyoming and western South Dakota, but term Sundance should be retained because of historical use. Thicknesses in outcrop of Swift vary from 63 feet in Laramie County to 289 in Johnson County. Overlies Rierdon Formation; underlies Morrison Formation.

_____, 1957 (Am. Assoc. Pet. Geol., Bull. 41, no. 3, p. 413, 417): Although five Sundance subdivisions are useful in Black Hills, in Williston and Powder River basins more continuous sedimentation makes nomenclature of Ellis Group more useful. Redwater abandoned in favor of Swift; Lak, Hulett, Stockade Beaver and Canyon Springs retained as local members of Rierdon Formation. Sundance includes Rierdon and Swift. At type locality Swift consists of two units:

55 feet of lower dark-gray shale and 80 feet of upper glauconite sandstone. In Williston basin these two units are present but lower shale is thicker (up to 400 feet). Lower shale becomes sandier east of basin's center.

Storey, T. P., 1958 (Alberta Soc. Pet. Geol., J. 6, no. 4, p. 90-104): On basis of regional extent and significance of sub-Swift and sub-Rierdon unconformities in Williston basin and adjacent areas, Swift is divided into Lower, Middle, and Upper units. Lower Swift is lithologically similar to and regionally conformable with Middle and Upper Swift that corresponds to type Swift Formation of western Montana. Lower Swift of Williston basin and equivalent Stockade Beaver and Hulett members of Lower Sundance in Black Hills are considered to lie unconformably on Rierdon and, therefore, are younger than Rierdon and older than Swift of Cobban. Lak and Redwater Members of Sundance are considered equivalent to type Swift Formation.

TAMPICO SHALE MEMBER (of PIPER FORMATION)

Age: Middle Jurassic.

Area of extent: North Dakota, Montana, and Saskatchewan.

Lithology: Gray-green calcareous shale, may be interbedded with red shale and smaller amounts of limestone, gypsum, and sandstone.

Thickness: Up to 86 feet.

Relationships to other units: Unconformably overlies Nesson Formation, Madison Limeston on upper Mississippian through Triassic Strata. Lithologically correlative with upper unnamed member of Gravelbourg Formation; equivalent in time to lower part of Sawtooth at its type section.

Characteristic fossils: None.

Economic significance: None.

Depositional environment: Shallow marine with local restricted embayments.

Type section: Interval of 3,858-3,944 feet in Gulf Oil Corp. No. 1 Cornwell, Center SWNE sec. 14, T. 30 N., R. 38 E., Valley County, Montana.

History of stratigraphic nomenclature:
Nordquist, J. W., 1955 (Billings Geol. Soc., 6th Ann. Field Conf., p. 101): Tampico Shale Member is lower red bed and gypsum member of Piper Formation. Consists of 86 feet of gray-green calcareous shale; may be interbedded with red shale and less limestone, gypsum

and sandstone. Sandstones well-developed in Saskatchewan; red shales more prevalent in central and southern Montana. Maintains uniform thickness. Underlies Firemoon Limestone Member (new); overlies Nesson Formation (new).

Tavis Creek bed (of BULLION CREEK FORMATION)

Barclay, C. W. V., 1974 (U. S. Geol. Surv., Coal Invest., Map C-67, p. 3): Tavis Creek lignite bed is 5-11 feet thick; occurs 20-40 feet below top of Tongue River.

T-Cross lignite (of LUDLOW FORMATION)

Hares, C. J., 1928 (U. S. Geol. Surv., Bull. 775, p. 47): T-Cross bed is extensive and principal lignite bed in Ludlow "Lignitic" Member of Lance, corresponding to Giannonaitti Bed of northwest South Dakota. Has been traced from T. 20 N., R. 8 E., South Dakota, to vicinity of Yule and westward to Montana; ranges from 3-8 feet thick. At T-Cross Mine, sec. 20, T. 133 N., R. 104 W., bed is 24 feet thick. Is "lowest persistent lignite" of eastern Montana.

King, J. W., 1955 (N. D. Geol. Soc., Gdbk., Black Hills Field Conf., p. 85): T-Cross lignite is 185 feet below top of Ludlow Formation.

Agnew, A. F., and Tychsen, P. C., 1965 (S. D. Geol. Surv., Bull. 14, p. 180): T-Cross lignite is equivalent to upper coal of Shadehill lignite facies.

"Third red"

See Ashern Formation.

Tilston interval, "beds"

Age: Mississippian.

Area of extent: Subsurface in Manitoba, Saskatchewan, and North Dakota.

Economic significance: Oil productive.

Remarks: Informally named for Tilston Oilfield, Manitoba. See also Mission Canyon Limestone and Madison Formation.

History of stratigraphic nomenclature:
Fuller, J. G. C. M., 1956 (Sask. Dept. Miner. Resour., Rep. 19, p. 34): "Tilston beds" are bounded below by "Souris Valley beds" and above by "Frobisher-Alida beds" equivalent to part of Mission Canyon Limestone. "Tilston beds" are oil productive where capped by anhydrite in eastern portion of Saskatchewan.

Ballard, F. V., 1963 (N. D. Geol. Surv., Bull. 40, p. 18-26): Tilston interval overlies Bottineau interval and underlies Frobisher-Alida interval.

THREE FORKS FORMATION, SHALE

Age: Late Devonian.

Area of extent: Williston basin, north and south-central Montana, Idaho, Utah, Wyoming, and possibly southern Alberta.

Lithology: In type section, formation consists of gray-brown and gray-green shaly dolomite overlain by gray-green shale and gray-brown limestone; overlain by buff calcareous sandstone.

Thickness: Up to 240 feet.

Relationships to other units: Conformably underlies Bakken or Lodgepole Formation, except where pre-Mississippian erosion cuts into formation. Conformably overlies Birdbear Formation. Equivalent to upper part of Potlatch Formation in northwestern Montana. Probably equivalent to Big Valley and Stettler Formations of Alberta.

Characteristic fossils: Rare brachiopods.

Economic significance: Oil production from sandatone ("Sanish sand") at Antelope Field in McKenzie County, North Dakota.

Depositional environment: Normal to restricted shallow marine.

Remarks: Type "locality" is north side of Gallatin River at Logan, Montana. Named for exposures at junction of Three Forks of Missouri River, near Three Forks, Montana. Standard subsurface section. Williston basin in Montana east of 111° meridian in interval between depths of 10,076 and 10,310 feet in Mobil Producing Co. Birdbear Well 1, center SENW sec. 22, T. 149 N., R. 91 W., Dunn County, North Dakota. In some areas, strata becomes so calcareous that it is called Three Forks Limestone.

History of stratigraphic nomenclature:
Peale, A. C., 1893 (U. S. Geol. Surv., Bull. 110, p. 29): Three Forks Shale consists of (descending): 1) yellow, laminated sandstone, 25 feet; 2) dark, bluish-drab or black, argillaceous limestones,

45 feet; 3) highly fossiliferous green, purple, and black, argillaceous and calcareous shale, 70 feet; 4) grayish-brown, compact, limestone, 15-20 feet; and 5) reddish and brownish-yellow, calcareous and argillaceous shales, 65 feet. Rests on Jefferson, Limestone and underlies Madison Limestone.

Berry, G. W., 1943 (Geol. Soc. Am., Bull. 54, no. 1, p. 14-16): Named Peale's unit no. 1 and Sappington Sandstone; considered to be Early Mississippian.

Sloss, L. L., and Laird, W. M., 1946 (U. S. Geol. Surv., Oil and Gas Invest., PC-25): Redefined lower contact of Peale's Three Forks to exclude units 4 and 5, which were placed in underlying Jefferson Limestone.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2323): Suggested that lower contact of Three Forks as originally defined be re-established. In Williston basin, Three Forks Formation is interbedded greenish-gray, grayish orange, and grayish-red, dolomitic siltstone and shale. Standard subsurface section designated. Overlies Birdbear Formation (new): underlies Bakken Formation.

TIMBER LAKE MEMBER (of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: South Dakota and North Dakota.

Lithology: Lower part usually greenish-yellow, medium-grained, soft or uncemented quartz sand; upper part is thinly banded fine-grained, orange to brown, well-cemented limonitic claystone.

Thickness: Up to 200 feet.

Relationships to other units: Overlies Trail City Member; underlies Iron Lightning Member.

Characteristic fossils: Cucullaea and Sphenodiscus.

Depositional environment: Marine, lower to upper shoreface of barrier bar environment.

Principal reference section: NE½ SW¼ sec. 27, T. 15 N., R. 23 E., U. S. Geol. Surv., Lantry NE quad., Dewey County, S. D.

History of stratigraphic nomenclature:
Morgan, R. E., and Petsch, B. C., 1945 (S. D. Geol. Surv., Rep. Invest. 49, p. 15-17): Timber Lake Sandstone Member crops out in most of

Dewey and Corson Counties, South Dakota. In fresh exposures, lower part is greenish-yellow medium-grained, soft or uncemented quartz sand. Upper part contains thin bands of fine-grained, orange to brown, well-cemented, limonitic claystone. Limonitic claystone occurs most abundantly at base of series of lens-like masses formed by concretionary cementation of sand.

Stevenson, R. E., 1956 (S. D. Geol. Surv., Geol. Quad., Bullhead, 1:62, 500): Name shortened to Timber Lake Member.

Waage, K. M., 1961 (Wyo. Geol. Assoc., 16th Ann. Field Conf., p. 236): In north-central South Dakota, Timber Lake and underlying Trail City Members are lateral facies. Timber Lake overlain conformably by Bullhead.

Feldman, R. M., 1967 (Ph.D. Dissert., Univ. N. D., 366 p.): Timber Lake Member is unconsolidated medium- to fine-grained sandstone becoming cross-bedded near top. Timber Lake represents normal marine deposition.

Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist., Bull. 27, 175 p.): Timber Lake Member is sand lithofacies of Lower Fox Hills. Numerous, shallow, undrained depressions are topographic evidence of member. Timber Lake is not continuous; in western part of type area, member disappears by facies change; northeast from study area, member encroaches on underlying Trail City Member. Contains Little Eagle lithofacies, biogenically-mixed clayey-silt with several fossiliferous concretionary layers forming assemblage zones in lower part of eastern two-thirds of type area; westward is Irish Creek lithofacies, thinly-bedded silt and shale with concretions.

Erickson, J. M., 1971 (Ph.D. Dissert., Univ. N. D., p. 25): Timber Lake Member present in south-central North Dakota; consists of fine- to medium-grained, poorly consolidated sandstone. May represent "spit-barrier bar" environment of deposition.

TRAIL CITY MEMBER (of FOX HILLS FORMATION)

Age: Late Cretaceous.

Area of extent: South Dakota and North Dakota.

Lithology: Light-grey-weathering clayey silt.

Thickness: Up to 145 feet.

Relationships to other units: Overlies Pierre Shale, underlies Timber Lake Member in eastern part of Fox Hills type area and underlies Iron Lightning Member in western part of Fox Hills type area.

Characteristic fossils: Molluscs.

Depositional environment: Marine, barrier bar environment.

Principal reference section: East of S. D. Highway 63, in E½ SW¼ sec. 32, T. 15 N., R. 24 E., U. S. Geol. Surv., Parade NW quad., Dewey County, S. D.

Remarks: See also Little Eagle and Irish Creek lithofacies.

History of stratigraphic nomenclature:

Morgan, R. E., and Petsch, B. C., 1945 (S. D. Geol. Surv., Rep. Invest. 49, p. 13-14): Trail City Member is lowest member of Fox Hills Formation, extending from Trail City on east end of Grand-Moreau Divide southwest to St. Patrick's Butte, just west of S. D. Highway 65. Consists of brown or buff sandy shale, becoming more sandy toward top. Contains 3-5, locally persistent zones of fossiliferous concretions that have cores of dense limestone and may have sandy jackets that fall off when weathered.

Waage, K. M., 1961 (Wyo. Geol. Assoc., 16th Ann. Field Conf., p. 236): Trail City and Timber Lake Member are lateral facies.

Feldman, R. M., 1967 (Ph.D. Dissert., Univ. N. D., 366 p.): Trail City Member cannot be recognized in North Dakota.

Waage, K. M., 1968 (Yale Univ., Peabody Mus. Nat. Hist., Bull. 27, 175 p.): In eastern two-thirds of type area, Trail City Member is biogenically-mixed clayey silt with several richly fossiliferous concretion layers forming assemblage zones in lower part (Little Eagle lithofacies). Westward in type area, Trail City grades to thinly-bedded silt and shale with mostly barren concretions (Irish Creek lithofacies. Trail City grades into Timber Lake Member.

J. M. Erickson, 1971 (Ph.D. Dissert., Univ. N. D., p. 26): Trail City Member found in Logan, Emmons, and Sioux Counties, North Dakota. Lithofacies of Trail City Member not recognizable in south-central North Dakota as unit is thin.

TONGUE RIVER MEMBER (of FORT UNION FORMATION) (also FORMATION OF FORT UNION GROUP)

Age: Paleocene.

Area of extent: North Dakota, Montana, and Wyoming.

Lithology: Yellowish to light-colored tan, massive lenses of sandstone and alternating beds of lignite and shale.

Thickness: 600-980 feet.

Relationships to other units: Conformably overlies Hell Creek in southwestern North Dakota and Montana; conformably underlies Sentinel Butte Shale in southwestern North Dakota and parts of Montana and Wyoming.

Characteristic fossils: Fresh-water molluscs, plant remains, and petrified trees.

Economic significance: Possible uranium potential, lignite.

Depositional environment: Alluvial plain.

Remarks: Named from Tongue River, Wyoming.

History of stratigraphic nomenclature:

Taff, J. A., 1909 (U. S. Geol. Surv., Bull. 341, p. 129-130): Coal-bearing rocks of Sheridan coal field, Wyoming, are divided into three coal groups (descending): 1) Ulm coal group, 2) intermediate coal group equivalent to at least part of Sentinel Butte Shale Member, exclusive of Roland coal, and 3) Tongue River coal group. Top bed of Tongue River coal group is Roland coal; Tongue River includes also Smith, Dietz, Monarch, Carney, and Masters coals. Is exposed along Tongue River.

Thom, W. T., Jr., and Dobbin, C. E., 1924 (Geol. Soc. Am., Bull. 35, p. 484-499): Tongue River Member of Fort Union Formation consists of yellow or light-colored strata containing massive sandstones and numerous thick coal beds. Top of member is placed beneath Bed K of Sidney field, Bed F of Sentinel Butte field, and Roland coal of Sheridan field. Base is place beneath light-colored, coal-bearing rocks that characteristically form clinker-capped escarpment rising above lowlands or badlands developed from Lebo Shale, with which it intertongues at contact. Fort Union Formation should be restricted to Lebo Andesitic (or Shale) Member and Tongue River Member although overlying Sentinel Butte Shale is considered Fort Union by U. S. Geological Survey. Tongue River Member well-exposed on Tongue River between Carneyville, Wyoming, and Brandenburg, Montana; and along Yellowstone River between Burns, Montana, and Buford (Fort Union), North Dakota; and in Missouri Valley above Fort Clark, North Dakota.

Laird, W. M., and Mitchell, R. H., 1942 (N. D. Geol. Surv., Bull. 14, p. 21-23): In southern Morton County, North Dakota, Tongue River Formation of Fort Union Group is 180 feet thick. Overlies Cannonball Formation. Is Paleocene in age.

Hennen, R. V., 1943 (Am. Assoc. Pet. Geol., Bull. 27, no. 12, p. 1573, 1580): In Morton County, Almont Sandstone (new) lies about 35 feet above base of Tongue River Member of Fort Union.

Benson, W. C., 1949 (Geol. Soc. Am., Bull. 60, no. 12, pt. 2, p. 1873): Tongue River Member of Fort Union Formation conformably underlies Golden Valley Formation.

Fisher, S. P., 1953 (N. D. Geol. Surv., Rept. Invest. 11, 2 pl.): Tongue River Formation includes all strata above Ludlow-Cannonball Formation and below Golden Valley beds. Includes Sentinel Butte Shale Facies in upper part. Thickness is 745-1010 feet.

May, P. R., 1954 (U. S. Geol. Surv., Bull. 995-G, p. 268): Tongue River Member of Wibaux area, Montana and North Dakota is composed of light-yellow, tan and gray sandstones and shales; thin lenses of limestones; and numerous beds of lignite. Thickness of 1200 feet in Sidney lignite area and 600 feet in Marmarth field. Overlies Ludlow Member; underlies Butte Member.

Hanson, B. M., 1955 (N. D. Geol. Surv., Rep. Invest. 18, 1 pl.): Upper 350 feet of Tongue River Formation well-exposed in bluffs bordering Little Missouri River along Elkhorn ranch area. Lower 750 feet exposed between mapped area and Marmarth, 36 miles to south. Total thickness of Tongue River, including Sentinel Butte Member is 1600 feet.

Triassic "A" salt

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Invest. 28, 2 sheets): Triassic "A" salt is up to 199 feet thick in Spearfish Formation of North Dakota, thins over Nesson anticline. Equivalent to Dunham Salt.

See also Spearfish Formation and Dunham Salt.

Triassic "B" salt

Anderson, S. B., and Hansen, D. E., 1957 (N. D. Geol. Surv., Rep. Invest. 28, 2 sheets): Triassic "B" salt is in Spearfish Formation of North Dakota. Appears to show salt solution with resulting collapse of overlying formations in Slope County and may create traps for accumulation of oil. Equivalent of Pine Salt.

See also Spearfish Formation and Pine Salt.

Tullock formation, Member

Thom, W. T., Jr., and Dobbin, C. E., 1924 (Geol. Soc. Am., Bull. 35, no. 3, p. 484-495): In Montana, Fox Hills Formation is overlain by (ascending): Hell Creek and Tullock Members of Lance.

Frye, C. I., 1969 (N. D. Geol. Surv., Bull. 54, 65 p.): Tullock formation extended from Montana into southwestern North Dakota.

Includes beds below T Cross of C. J. Hares, 1928 (U. S. Geol. Surv., Bull. 775, p. 47) and above lowest persistent coal of R. W. Brown, 1962 (U. S. Geol. Surv., Prof. Pap. 375, 119 p.).

Twin Buttes bed (of SENTINEL BUTTE FORMATION)

Benson, W. E. B., 1952 (U. S. Geol. Surv., Open-file Rep., p. 252): Twin Buttes bed is named for exposures near pair of small conical buttes in sec. 28, T. 134 N., R. 92 W. Is 130-150 feet above Beulah-Zap bed.

"Tyler-Heath interval"

Willis, R. P., 1959 (Am. Assoc. Pet. Geol., Bull. 43, no. 8, p. 1956): Tyler-Heath interval in North Dakota overlies Otter Formation and underlies Amsden Formation (according to North Dakota Geological Survey).

TYLER FORMATION, Sandstone Member (of BIG SNOWY GROUP)

Age: Pennsylvanian.

Area of extent: Southern Montana, western North Dakota.

Lithology: Gray and varicolored shale with local sandstone lenses. Thin conglomerate occurs locally at base.

Thickness: 300 feet in type area. Up to 270 feet in North Dakota.

Relationships to other units: Underlies Alaska Bench Limestone; overlies Otter Formation.

Characteristic fossils: Cypridopsis fabuline, spores, and fragments of sharks' teeth.

Economic significance: Sandstone of Tyler is oil productive.

Depositional environment: Littoral to open marine, possibly subaerial in part.

Type section: 5 miles west of Tyler School (also site of old Tyler Post Office), at southeast end of Middle Bench in S½ sec. 5, T. 12 N., R. 21 E., Fergus County, Montana.

History of stratigraphic nomenclature:
Freeman, O. W., 1922 (Eng. Min. J.-Press, v. 113, no. 19, p. 827):

Tyler sandstone is white to red sandstone interbedded with varicolored sandy shale. Thickness 300 feet. Overlain by Alaska Bench Limestone (text) or 100 feet of gray shale (generalized section).

Scott, H. W., 1935 (J. Geol., v. 43, p. 1028-1029): Tyler sands of Freeman (1922) occur at same stratigraphic zone as Van Dusen sand on southeast flank of Big Snowy Mountains. Sands are not a lithologic, paleontologic, or mappable unit over broad areas but should be considered member of Heath Formation.

Hadley, H. D., Lewis, P. J., and Larsen, R. B., 1952 (Billings Geol. Soc., Gdbk., 3rd Ann. Field Conf., p. 142): Tyler is member of Heath Formation. Thickness is 5 to 100 feet. Mississippian.

Mundt, P. A., 1956 (Am. Assoc. Pet. Geol., Bull. 40, no. 8, p. 1920-1925): Tyler defined as formation to include black, gray and reddish shales within which sandstone bodies (formerly Tyler Sandstone) occur; also includes marine limestone tongue locally present near top. Thickness where typically exposed is 382 feet. Underlies Alaska Bench Formation; unconformably overlies Heath Formation. Unit has been referred to as Amsden, Heath, Heath-Amsden transition zone, and nonmarine Heath. Mississippian. Uncertainty exists as to exact position of Freeman's type locality. Type section restated.

Harris, S. H., 1958 (N. D. Geol. Soc., 2nd Williston Basin Sym.: Bismarck, p. 42): Lower Amsden carbonate marker bed traced through western North Dakota. "Lower Amsden operational unit" is developed on post-Heath erosion scour zone. As black fossiliferous shale and calcareous sandstone may indicate Tyler, brown limestone Amsden marker might be Alaska Bench Formation.

Willis, R. P., 1959 (A, Assoc. Pet. Geol., Bull. 43, no. 8, p. 1948-1962): Tyler Formation in Montana area is limited to central Montana trough, and overlaps locally underlying Heath Formation. Isopach pattern shows abrupt thinning toward north along Cat Creek trend. Formation divided into two members: lower, predominantly dark, slightly calcareous shale, and upper, predominantly red and maroon calcareous shale with marine fauna. Term Cameron Creek used for upper member. "A" zone denotes both sand facies and limestone equivalent (Bear Gulch member or tongue); at base of "A" zone Tyler becomes marine and trend changes from east-west to southwest-northeast. Pennsylvanian (Morrowan).

Gardner, L. S., 1959 (Am. Assoc. Pet. Geol. Bull. 43, no. 2, p. 335-337): Tyler Formation not used in revision of Big Snowy Group because sands are neither lithologically or paleotologically similar and not mappable over broad areas. Name is also twice preoccupied. Type section given by Mundt (1956) is of Heath and Cameron Creek Formations made anomalous by local appearance of 150 feet of gray to white sandstone interbedded with black shale (Heath) and overlain by red shale of Cameron Creek. No regional unconformity found within Big Snowy sequence. Erosional

unconformity at base of Mundt's Tyler is believe to be result of widely spaced local channel cuts, each of which can be traced for few hundred yards or few miles.

Foster, F. W., 1961 (World Oil, v. 152, p. 89-93): Tyler divided into 2 units (ascending): 1) lower unit is black to dark gray carbonaceous shale with fresh-water ostracode, and other fauna, plant remains, and coal; and 2) upper unit is red, yellow, green and black shale with thinly-bedded limestone. Sand lenses occur in lower unit in North Dakota. Tyler is absent in southwestern North Dakota but thickens to 150 feet in west-central North Dakota; is usually dull red shale often called lower Amsden. Intraformational unconformity or diastem separates lower unit from upper unit but authot not ready to apply Cameron Creek or Sacajawea to these units. Tyler developed on relatively flat shelf in North Dakota; basin influenced development in South Dakota. Heath represented by basal detritus in Tyler, which unconformably rests on Otter. Pennsylvanian.

Ziebarth, H. C., 1962 (Ph.D. Dissert., Univ. N. D., 414 p.): Tyler Formation in North Dakota is medium to dark-gray shale and limestone with local sandstone lenses; ranges in thickness from 0-270 feet. Thickening toward periphery of unit may be result of disappearance of identifiable marker beds or facies changes within Alaska Bench and basal Amsden units similar to lithology of Tyler. Hiatus marks top of Tyler.

"Van Dusen sand"

Scott, H. W., 1935 (J. Geol., v. 43, p. 1028): Van Dusen sand is name used by oil geologists for oil sand in Devils Basin field. Named from discovery well. Should be considered member of Heath Formation. Consists of thin, calcite-cemented sandstone approximately 500 feet below Quadrant or Tensleep Formation.

Vermillion River Formation

Cobban, W. A., and Reeside, J. B., Jr., 1952 (Geol. Soc. Am., Bull. 63, no. 10, p. 1011-1013): Vermillion River Formation (Late Cretaceous) is found on Pembina escarpment, Manitoba and North Dakota. Overlies Favel Formation; underlies Riding Mountain Formation.

This usage not followed by later writers.

VERENDRYE MEMBER, Shale Zone (of PIERRE SHALE)

Age: Late Cretaceous.

Area of extent: South Dakota, North Dakota.

Lithology: Gray shale with concretions.

Thickness: Up to 200 feet.

Relationships to other units: Underlies Virgin Creek Member; overlies Oacoma zone.

Remarks: Type locality presumably under Verendrye Monument at Fort Pierre, Stanley County, South Dakota. See also Pierre Shale; Sully Member.

History of stratigraphic nomenclature:
Searight, W. V., 1937 (S. D. Geol. Surv., Rep. Invest. 27, p. 25-26, 34): Verendrye zone of light- to medium-gray banded shale. Concretions light-gray to olive-green where fresh, weathers dark-brown. Underlies Virgin Creek and overlies manganiferous Oacoma beds. Total thickness 10-200 feet.

Crandell, D. R., 1950 (Am. Assoc. Pet. Geol., Bull. 34, p. 2345): Verendrye and Crow Creek raised to member rank and DeGrey Member (Agency-Oacoma unit) named. Sully no longer used.

Wilson, E. E., 1958 (Master's Thesis, Univ. N. D., 134 p.): Pierre Shale of northern Sheyenne River and Stutsman County of North Dakota may be equivalent to Verendrye and DeGrey Members of South Dakota.

"Virden subinterval"

Heck, T., 1978 (Mont. Geol. Soc., Williston Basin Sym., 24th Ann. Field Conf., p. 197): Virden subinterval is sequence reflecting gradual marine regression coupled with prograding into basin. Three facies developed: 1) medium to dark gray, argillaceous, pelletal, skeletal, muddy grainstone (shallow open shelf), 2) oolite grainstone (as shoals or near shelf break), and 3) light-colored, argillaceous, cherty, pelletal, skeletal wackestone to packstone interbedded with oxidized skeletal mudstone to wackestone (shoreward of oolite shoals). Lower unit is more argillaceous than upper unit, which is relatively clastic-free. Is cyclical, grading from basal oolite shoal and skeletal grainstones interbedded with argillaceous limestone and shale, grading upwards to interbedded pelletal limestone and skeletal grainstone. Is Kinderhookian in age.

Virgin Creek Member (of PIERRE SHALE)

Age: Late Cretaceous.

Area of extent: South Dakota, North Dakota.

Lithology: Gray shale with bentonite beds. Small fossiliferous concretions and bed of large limestone concretions.

Thickness: Up to 224 feet.

Relationships to other units: Overlies Verendrye Member; underlies Mobridge Member.

Type section: Valley wall of Virgin Creek, about 1½ miles south of Promise, Dewey County, South Dakota. See also Pierre Shale.

History of stratigraphic nomenclature:
Searight, W. V., 1937 (S. D. Geol. Surv., Rep. Invest. 27, p. 35-43): Virgin Creek divided into two zones (descending): Upper zone contains small fossiliferous concretions in lower part and bed of large limestone concretions; lower zone is light- to medium-gray shale with thin bentonite beds. Basal part of lower unit weathers to gray gumbo, tinged rusty-brown in places. Overlies Sully Member; underlies calcareous beds of Mobridge Member. Top of zone of limestone concretions contains Sage Creek fauna farther west.

Crandell, D. R., 1950 (Am. Assoc. Pet. Geol., Bull. 34, no. 12, p. 2340): Overlies Verendrye Member; underlies Mobridge Member.

VIRGIN CREEK MEMBER (of PIERRE SHALE)

Searight, W. V., 1937 (S. D. Geol. Surv., Rep. Invest. 27, p. 35-43): Virgin Creek is divisible on basis of lithology into two zones. Lower is relatively resistant light- to medium-gray shale that contains numerous thin but conspicuous bentonite beds. Upper part, especially at base, breaks down to lead-gray gumbo and may be rusty brown. Upper Virgin Creek may contain characteristic small fossiliferous concretions in lower part, and bed containing large limestone concretions. Virgin Creek includes all beds between Sully Member and highly calcareous beds of Mobridge Member.

Rice, O. C., 1977 (U. S. Geol. Surv., Misc. Invest., Map OC-70, 1 sheet): Virgin Creek Member is in eastern North Dakota on correlation chart.

Wendover Group

Age: Pennsylvanian.

Area of extent: Eastern Wyoming, northeastern Colorado, southwestern Dakota, and North Dakota(?).

Lithology: Limestones interbedded with sandstones, mudstones, and shales.

Thickness: Up to 104 feet.

Relationships with other units: Underlies Broom Creek beds; overlies Meek Group. Called Wendover-Meek Group in North Dakota.

Characteristic fossils: Fusulinids.

Economic significance: None.

Depositional environment: Marine.

Remarks: Type area is in Platte River Valley in vicinity of Wendover, Platte County, Wyo.

History of stratigraphic nomenclature:

Condra, G. E., Reed, E. C., and Scherer, O. J., 1940 (Nebr. Geol. Surv., Bull. 13A, p. 2-3, 5, 22, 23-24, 28, 30, and 45): Wendover Group consists of limestones interbedded with sandstones, mudstones, and shales. At base is sandstone that probably marks unconformity. Comprises upper part of Division II of Hartville "Formation (Condra, G. E., and Reed, E. C., 1935, Nebr. Geol. Surv., Pap. no. 9, 46 p.): Thickness is 104 feet. Underlies Broom Creek beds (new); overlies Meek Group (new).

McCauley, V. T., 1956 (N. D. Geol. Soc., Williston Basin Sym., 1st Internat., Bismarck, N. D., p. 150-164): Wendover-Meek Group is poorly represented in North Dakota. All beds from base of overlying Broom Creek to below radioactive markers are missing in broad areas of southeastern and eastern Montana, southwestern North Dakota and northwestern South Dakota. Broom Creek rests directly on radioactive zones or is separated by few feet. Sandstone or sandy dolomites are most common lithologies of Wendover-Meek Group.

"Wendover-Meek group"

See Wendover Group or Meek Group.

White earth, clay bed

See Golden Valley Formation.

WHITE RIVER GROUP, Formation

Age: Oligocene.

Area of extent: North Dakota, South Dakota, Wyoming, eastern Montana, Nebraska, and northeastern Colorado.

Lithology: White, hard calcareous limestone, and white, calcareous shale, and sandstone.

Thickness: Up to 200 feet.

Relationships to other units: Unconformably overlies upper Fort Union in most of southwestern North Dakota; unconformably overlies Golden Valley in Killdeer Mountains of Dunn County, North Dakota. Is youngest bedrock formation exposed in North Dakota.

Characteristic fossils: Fish, mammalian and chelonian remains, and Titanotherium and Oreodon.

Economic significance: None.

Depositional environment: Fresh-water, lacustrine.

Remarks: Named for exposures along White River in southwestern North Dakota.

History of stratigraphic nomenclature:

Meek, F. B., and Hayden, F. V., 1857 (Acad. Nat. Sci., Philadelphia, Proc., v. 9, p. 119, 133): White River (Miocene) deposits in places crown summits of hills on east side of Missouri River near mouth of White River. Titanotherium bed of White River basin is oldest member. No evidence that any Tertiary deposits known in Nebraska are older than Miocene.

Meek, F. B., and Hayden, F. V., 1862 (Acad. Nat. Sci., Philadelphia, Proc., v. 13, p. 433-434): White and light-drab clay with sandstone beds and local layers of limestone. Is 1000 feet thick. Fossils contain no brackish-water or marine forms. Occurs in Bad Lands of White River, on Niobrara, and across area to Platte River. Overlies Fort Union Group on North Platte River above Fort Laramie; underlies Loup Fork beds (Pliocene).

Meek, F. B., 1876 (U. S. Geol. and Geog. Surv. Terr., Mon. 9, p. lxi-lxiv): Contains great numbers of mammalian and chelonian remains with very fine state of preservation. No marine or brackish water remains found so must be fresh-water lacustrine deposit. White River spreads extensively south of Black Hills into Nebraska, Colorado, and Kansas. Unconformably overlies Fort Union Group; underlies Pliocene lake deposit on Loup River and other areas of Nebraska.

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 64-71): Beds of White River Formation confined to White Butte or Chalk Butte of southern Billings County and Sentinel Butte. Conformably overlies Fort Union Formation. Is Oligocene in age.

"Whitewater Lake subinterval"

Heck, T., 1978 (Mont. Geol. Soc., Williston Basin Sym., 24th Ann. Field Conf., p. 197): Whitewater Lake subinterval is sequence reflecting gradual marine regression coupled with prograding into basin. Three facies developed: 1) medium to dark gray, argillaceous, pelletal, skeletal, muddy grainstone (shallow open shelf), 2) oolite grainstone (as shoals or near shelf break), and 3) light-colored, argillaceous, cherty, pelletal, skeletal, wackestone to packstone interbedded with oxidized skeletal mudstone to wackestone (shoreward of oolite shoals). Lower unit is more argillaceous than upper unit which is relatively clastic-free. Is cyclical in nature, grading from basal oolite shoal and skeletal grainstones, interbedded with argillaceous limestone and shale, grading upwards to interbedded pelletal limestone and skeletal grainstone. Is Kinderhookian in age.

Wilton bed (of BULLION CREEK FORMATION)

Leonard, A. G., Dove, L. P., and Eaton, H. N., 1925 (N. D. Geol. Surv., Bull. 4, p. 119): Wilton bed is most important lignite bed of district. Named for town of Wilton.

WINNIPEG FORMATION (of BIGHORN GROUP)

Age: Early(?) and Middle Ordovician.

Area of extent: Manitoba, Saskatchewan, North Dakota, South Dakota, and eastern Montana.

Lithology: Varicolored, non-calcareous shale and white to buff, poorly consolidated, medium- to coarse-grained, quartz sandstone. Basal sandstone present over wide areas in Williston basin; pyrite and phosphatic nodules present; thin limestone beds occur locally.

Thickness: Up to 357 feet.

Relationships to other units: Lies unconformably on Deadwood Formation except in northwestern North Dakota where it may be conformable on Deadwood and in northeastern North Dakota where it lies nonconformably on Precambrian rocks.

Characteristic fossils: None.

Depositional environment: Transgressive sea moving into slowly subsiding cratonic basin.

Remarks: Type section exposed on shores and islands in southern part of Lake Winnipeg, Manitoba. See also Black Island, Ice Box, and Roughlock Members.

History of stratigraphic nomenclature:

Dowling, D. B., 1896 (Ottawa Field Nat. Club, Trans. 1895-1896, v. 11, p. 67-68): Winnipeg Formation is basal sandstone unit and overlies green shale sequence. Sand locally present in upper green shale; formation may contain pyrite and phosphate nodules; thin limestone beds occur locally. Thickness is 60-800 feet.

McCauley, G., and Leith, E. I., 1951 (Geol. Soc. Am., Bull. 62, p. 1461-1462): Winnipeg Formation assigned to Late Ordovician Richmondian age.

Baille, A. D., 1952 (Manit. Dep. Mines Nat. Resour., Pub. 51-6, p. 41): Winnipeg considered to be Trentonian(?) in age.

Erickson, H. D., 1954 (S. D. Geol. Surv., Rep. Invest. 74, p. 43): Winnipeg Formation divided into two lithologic units (descending) in South Dakota: Winnipeg Shale, light gray to green, mobtled bentonitic shale and siltstone with few sandy horizons; and Winnipeg Sandstone, well-sorted, medium-textured, clear quartz sand, few fossils present. Unit has been called Black River and St. Peter in previous reports of South Dakota Geological Survey.

McCauley, G., 1955 (Albert. Soc. Pet. Geol., J., v. 3, no. 4, p. 49-52): Winnipeg Formation is shale and sandstone section that underlies Red River Formation and overlies Precambrian basement complex in Manitoba. In Saskatchewan and Dakotas, formation is underlain by Cambrian sediments. No type outcrop section can be established because upper and lower contacts are not exposed at any one place. Suggestions given for two type wells.

Ross, R. J., Jr., 1957 (U. S. Geol. Surv., Bull. 1021-M, p. 448-449): In subsurface of Williston basin, Winnipeg Formation overlies Deadwood Formation and underlies Red River Formation of Bighorn Group.

Carlson, C. G., 1960 (N. D. Geol. Surv., Bull. 35, p. 44-74): Winnipeg Formation consists of sandstone, shale, and siltstone. Lies unconformably on Deadwood Formation except in northwestern North Dakota where it may be conformable on Deadwood and in northeastern North Dakota where it lies nonconformably on Precambrian rocks; overlain conformably by Red River Formation. Is divided into three members (ascending): Black Island, Ice Box, and Roughlock. Thickness is 0-357 feet. Age is Middle Ordovician, Black Riveran and Trentonian, based on conodonts.

Fuller, J. G. C. M., 1961 (Am. Assoc. Pet. Geol., Bull. 45, no. 8, p. 1341): Black Island Member of Carlson (1960) not same as originally defined and thus replaced by Burgen Sandstone (p. 1339). (This usage not followed by North Dakota Geological Survey.)

"Winnipeg transition zone"

Carlson, C. G., 1960 (N. D. Geol. Surv., Bull. 35, p. 61): In northwestern North Dakota, near limit of recognition of Roughlock Member, interval referred to as "Winnipeg transition zone" by some petroleum geologists; is included in Roughlock Formation.

WINNIPEGOSIS (WINNEPEGOSAN) FORMATION (of ELK POINT GROUP)

Age: Middle Devonian.

Agea of extent: Williston basin.

Lithology: Tan-gray, porous, fine-grained dolomite in outcrop. In subsurface is tan, gray-tan to brown, and gray-brown microcrystalline to fine-granular dolomite. Tan-gray to dark gray-brown, argillaceous limestone and dolomitic limestone, locally shaly where Elk Point equivalent present.

Thickness: 0-175 feet; up to 400 feet in reefs in east-central Saskatchewan.

Relationships to other units: Middle formation of Elk Point Group. Conformably overlies Elm Point Formation in outcrop; in subsurface, formations are difficult to differentiate. Winnipegosis includes Elk Point. Conformably overlain by Prairie Formation.

Characteristic fossils: Stromatoporoids, Amphipora corals.

Economic significance: Oil productive in Montana.

Depositional environment: Shallow-water marine.

Remarks: Type area at exposures along Lake Winnipegosis in Manitoba.

History of stratigraphic nomenclature:
Tyrrell, J. B., 1893 (Can. Geol. Surv., new ser., v. 5, pt. 1, p. 144E-199E): Winnipegosan Formation of Manitoba is Devonian in age.

Wallace, R. C., 1915 (Can. Geol. Surv., Summ. Rept. 1914, p. 77): Winnipegosan beds are exposed at Graves Point, Lake Winnipegosis. Winnipegosis and Winnipegosan spellings used in report.

Baille, A. D., 1953 (Am. Assoc. Pet. Geol., Bull. 37, no. 2, p. 444-447): Formation originally called Winnipegosan by Tyrrell (1893) but, because adjectival suffix has time connotation, term "Winnipegosis" used to conform with usage recommended by Geological Survey of Canada and American Commission on Stratigraphic Nomenclature.

In outcrop, overlies Elm Point Formation; underlies Dawson Bay Formation (new). Redefined in subsurface to include Elm Point Limestone. Is member of Elk Point Group.

Check, R., 1956 (N. D. Geol. Soc., 1st Internat. Williston Basin Sym., p. 140): Winnipegosis extends from eastern Alberta to Manitoba and south to its depositional edge in North Dakota and Montana.

Sandberg, C. A., and Hammond, C. R., 1958 (Am. Assoc. Pet. Geol., Bull. 42, no. 10, p. 2299, 2303-2306): In Williston basin, Winnipegosis is redefined to include strata previously assigned to Ashern Formation of Baille (1951, Manit. Dep. Mines Nat. Resour., Mines Br. Pub. 49-2). In United States, Winnipegosis restricted to Williston basin and northeastern Montana. Is less than 1 to 300 feet thick. Lower formation of Elk Point Group; underlies Prairie Formation. In Birdbear well, Dunn County, North Dakota, Winnipegosis lies at 11,438-11,698 feet and rests unconformably on Silurian rocks. Is Middle Devonian.

Wolf Creek coal bed (of BULLION CREEK FORMATION)

Smith, C. D., 1908 (U. S. Geol. Surv., Bull. 381, p. 19, 20): Wolf Creek coal bed is lignite bed of Washburn Lignite Field. Named for Wolf Creek.

Andrews, D. A., 1939 (U. S. Geol. Surv., Bull. 906B, p. 70): Wolf Creek coal bed crops out on east side of Missouri River in Minot area of North Dakota. Named from Wolf Creek. Is about 80 feet above base of Fort Union Formation.

"Woodbend equivalent"

See Duperow Formation.

Towse, D., 1953 (N. D. Geol. Surv., Rep. Invest. 12, 1 sheet): Consists of thick medium to dark brown dolomite above "Beaverhill Lake equivalent."

Yeagher bed (of SENTINEL BUTTE FORMATION)

Johnson, W. D., Jr., and Kunkel, R. P., 1959 (U. S. Geol. Surv., Bull. 1076, p. 39): Yeagher bed is coal named for Yeagher Mine. Crops out along Square Butte Creek and is 30 feet above Berg bed, when both found together. Is composed of two beds of lignite separated by 8 feet of sandy shale. Lower bed is 6 feet thick; upper bed is 5 feet thick.

"Yule coal group"

Leonard, A. G., 1908 (N. D. Geol. Surv., 5th Bienn. Rep., p. 77-80): Coal beds found in vicinity of Yule and farther south on Bacon and Coyote Creeks named Yule coal group. Beds A-F occur in lower member of Fort Union Formation.

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GEOLOGIC FORMATIONS OF NORTH DAKOTA

CENOZOIC	Olig			White River formation 50-200' clays, shales, limestone, sandstone
	Eo,		WASATCH STAGE	Golden Valley formation 100-200' light-colored clay, ash, sandstone
	Pa.		FORT UNION STAGE	Tongue River formation 300' light-colored and dark-colored shale and sandstone and lignite
				Cannonball-Ludlow formation 0-300' marine sands, clays lignite, shale and sandstone
MESOZOIC	CRETACEOUS	UPPER		Hell Creek formation 100-575' grey bentonitic sandstone and shale, lignitic shale and concretions
			MONTANA STAGE	Fox Hills 180-320' brown to grey sandstone with ironstone concretions
				Pierre formation 930-2390' grey shales and ironstone concretions
			COLORADO STAGE	Niobrara formation 200-250'grey shale and "cement rock"
				Benton formation 500-1000' dark grey shale
				Dakota formation 15-90' micaceous white sandstone with pyrite, gypsum and lignite
		LOWER		Fuson formation 50-150'grey shale, sandy shale and sandstone
				Lakota formation 78-150' white sandstone with little shale
	Jura.			Morrison formation 20-260' grey and green shale and shaly sandstone
				Sundance formation 440-682' glauconitic sandstone, green shale, sandstone and shaly limestone with gypsum
	Tria.			Spearfish formation 225-970' red sandstone and red shale, brown sandstone, red shale and red evaporites
PALEOZOIC	PERMIAN			Minnekahta formation 40' purple dolomite and limestone. Not extensively developed in the state
				Opeche formation 88' red shale and anhydrite. Not extensively developed in the state
	Pa.			Minnelusa formation 0-200' white and reddish sandstone. Not extensively developed in the state
	MISSISSIPPIAN	TENNESSEAN	MEREMAC-CHESTER	Amsden formation 79-250' orange, red, purple dolomite limestone shale
			BIG SNOWY GROUP	Heath formation 145' black carbonaceous shale, grey to green shale, dolomite
				Otter formation 105' varicolored shale and anhydrite
				Kibbey formation 115-300' varicolored shale and fine grey sandstone near base
				Charles formation 550-810' brown buff dolomite limestone, gray and white anhydrite, varicolored shale
		WAVERLYN	OSAGE	Mission Canyon formation 124-530' granular and oolitic buff limestone
				Lodgepole formation 633-880' grey to buff granular to finely crystalline limestone
			KINDERHOOK	Englewood formation 30-110' carbonaceous shale, limestone, grey shale and siltstone
	DEVONIAN			Amaranth formation 75' calcareous red shale
				Manitoban formation 180' granular buff limestone, dolomite and anhydrite
				Winnipegosan formation 216' granular and dense grey to brown limestone and dolomite
	Silurian system poorly developed if found in the state			
	ORDOVICIAN			Big Horn formation 618' dense to granular buff to white dolomitic limestone and varicolored shale
				Upper Whitewood formation 831' grey to tan dense to granular dolomitic and sandy limestone
				Lower Whitewood (Winnipeg) formation 521' green shale, conglomeratic sandstone, sandy limestone, grey sandstone
	Cambrian 219' green shale, and dolomite, glauconitic sandstone			
	Pre-Cambrian granite and amphibolite			

FROM: LAIRD AND TOWSE, 1949

PLATE I

J.V. GROENEWOLD

NORTH DAKOTA STRATIGRAPHIC COLUMN

AGE (MILLIONS OF YEARS BEFORE PRESENT)	ERA	PERIOD / EPOCH	SEQUENCE	ROCK UNIT: GROUP	ROCK UNIT: FORMATION	ROCK UNIT: MEMBER OR OTHER UNIT	LITHOGRAPHIC COLUMN (Relative resistance of exposed units shown)	MAXIMUM THICKNESS feet (metres)	LITHOLOGY, DEPOSITIONAL ENVIROMENTS, AND OTHER CHARACTERISTICS
0.01	CENOZOIC	QUATERNARY / HOLOCENE	TEJAS		OAHE	RIVERDALE PICK CITY AGGIE BROWN MALLARD ISLAND		50(15)	Clay, sand, silt, and gravel; dispersed organic material; river, windblown, lake, and slough sediment; found throughout the state; the four recognized members (see Rock Unit column) are differentiated in the field by color differences and include the complete range in grain sizes found in materials overlying the Coleharbor Formation.
		QUATERNARY / PLEISTOCENE		COLEHARBOR	NAMED FORMATIONS: WEST CENTRAL / EAST / RED RIVER VALLEY; SNOWSCHOOL, HORSE SHOE VALLEY, MEDICINE HILL, FALCONER, DAHLEN, GARDAR, VANG; DOWNER, SHERACK, POPLAR RIVER, BRENNA, HUOT, WYLIE, RED RIVER FALLS, ST HILLAIRE, MARCOUX (Numerous other named and unnamed Sedimentologic units and formations)			1000(300)	Pebbly, sandy, silty clay (till); pebbles of limestone, dolomite, granite, gneiss, and basalt; associated bedded clay, silt, sand, and gravel; glacial, river, lake, and windblown sediment; found throughout the glaciated part of the state. Several subdivisions of the Coleharbor have been recognized and formally-named. In the Red River Valley they include: the Downer (beach sand of glacial Lake Agassiz), Sherack, Brenna and Wylie (all offshore lake sediment), Poplar River (river sediment), Huot, Falconer, Red Lake Falls, St. Hillare, and Marcoux (all glacial sediment). West of the Red River Valley in eastern North Dakota, the Dahlen, Gardar, and Van (all glacial sediment) have been described. In west-central North Dakota, the Snow School, Horseshoe Valley, and Medicine Hill (all glacial sediment) have been described.
2					CHARGING EAGLE			300(90)	Gravel, sand and sandstone, silicified wood, concretion; locally derived river sediment; mainly pebbles and cobbles; terrace, fan, and pediment deposits of Quaternary age. Clay, silt, sand, and gravel; western-derived pebbles and cobbles; valley fills of Paleocene to middle Quaternary age.
		TERTIARY / PLIOCENE			ARIKAREE			400(120)	Sandstone and limestone, tuffaceous, light gray, greenish or white, corss bedded; river and lake sediment; found mainly on butte tops; Oligocene, Miocene, and Pliocene age.
		MIOCENE							
		OLIGOCENE		WHITE RIVER	BRULE			150(45)	Siltstone and clay, pinkish; offshore lake sediment and some river and shoreline sand; forms steep slopes on hills and buttes in the southwestern part of the state.
					CHADRON			100(30)	Sand with quartzite and porphyry pebbles, light colored; overlain by clay, dark colored; river and lake sediment; forms rounded slopes on hills and buttes in the southwestern part of the state.
54		EOCENE			GOLDEN VALLEY	CAMELS BUTTE		215(65)	Camels Butte Member: upper part is shale and siltstone, gray, montmorillonitic, minor lignite; river and lake sediment; lower part is sandstone, yellowish, micaceous, cross bedded; river sediment.
						BEAR DEN			Bear Den Member: kaolinitic clay, lignite, and chert; white to yellow with shades of lavender; weathering zone. The Golden Valley Formation is found mainly over upland areas in the western part of the state.
		PALEOCENE		FORT UNION	SENTINEL BUTTE (TONGUE RIVER)			650(200)	Silt and clay, brownish gray, varying amounts of sand, lignite, natural brick, limestone and sandstone: river, lake, and swamp sediment; forms steep, rilled slopes; found throughout western North Dakota; forms badlands topography.
					BULLION CREEK (TONGUE RIVER)			650(200)	Silt and clay, yellowish brown, varying amounts of sand, lignite, natural brick, limestone, and sandstone; gently rounded slopes; most of the rock and sediment included in the Bullion Creek Formation is equivalent to rock and sediment that were previously referred to the Tongue River Formation; found throughout western North Dakota; forms badlands topography.
					SLOPE (TONGUE RIVER)	RHAME BED		650(200)	Silt, sand, and clay, grayish to yellowish brown; some sandstone and minor lignite; river, lake, and swamp sediment and some marine sediment; Rhame silcrete bed (weathered zone) at top; has been called Ludlow and Lebo Formations; found along southern flank of Williston basin in southwest North Dakota; Paleocene.
					CANNONBALL				Sand and mudstone, brownish yellow and light gray, with lenticular and concretionary sandstone: marine shoreline and offshore sediment; found in approximately the same area as the Slope Formation.
68					LUDLOW	T-CROSS BED			Silt, sand, and clay, grayish brown and thin bedded; some sandstone and minor lignite; river, lake, and swamp sediment; T-Cross lignite bed at top; equivalent to beds formerly known as Tullock.
					HELL CREEK			500(150)	Sand, somber shades of light gray to brownish gray, and cross bedded sandstone with lignitic shale and dark purple, manganese-oxide-stained concretions; river sediment and some estuarine sediment; forms rilled slopes except clayey member at the top forms smooth, rounded slopes; forms badlands topography.
		CRETACEOUS	ZUNI			COLGATE			
				MONTANA	FOX HILLS	BULLHEAD TIMBER LAKE		400(120)	Silt and shale, sandy shale, sandstone, and siltstone, shades of buff to yellowish brown; interbedded with lignitic shale laminae; some beds fossiliferous; intermittent sandstone at top is grayish brown to white, fine, siliceous; silt and shale gradational downward with shale of the Pierre Formation: largely marine coastal sediment; forms gentle, rounded slopes.
					PIERRE	TRAIL CITY ELK BUTTE MOBRIDGE VIRGIN CREEK ODANAH DEGREY JUDITH RIVER SAND / GREGORY PEMBINA EAGLE SAND / GAMMON		2300(700)	Shale. Pierre Formation consists of marine offshore sediments that can be subdivided into the following member in North Dakota (top to bottom): Elk Butte Member: medium gray, flaky, noncalcareous shale; Mobridge Member: calcareous shale and marlstone; Virgin Creek Member: dark-gray, soft, flaky, noncalcareous shale; Odanah Member: hard, siliceous, noncalcareous, medium light gray shale, reddish-brown stained joint faces, light yellowish bentonite bed near the base, forms steep slopes in exposures in the Pembina Hills; DeGrey Member: olive to dark gray, noncalcareous, flaky shale, ironstone concretions; Gregory Member: dark-gray to yellowish, soft, thinly bedded, slightly calcareous to marly, pyritic shale and claystone, smooth, loose surface that tends to slump; Judith River Sandstone (locally in the west, subsurface only): fine-grained silty sand. Pembina (Sharon Springs or Mitten Black Shale) Member: grayish brown to brownish black, soft, noncalcareous shale, yellowish streaks of jarosite and gypsum-encrusted phosphate nodules, highly organic in the middle portion with abundant fish scales, light-colored, waxy beds of montmorillonitic clay at the base. Gammon Ferruginous Member: gray mudstone with calcareous and ferruginous concretions; Eagle Sandstone (locally in the southwest, subsurface only): fine-grained sandstone. Odanah, Degrey, Gregory, and Pembina Members are widely exposed in parts of northeast North Dakota; lower members (undifferentiated) are exposed along the Cedar Creek anticline in southwest North Dakota.
				COLORADO	NIOBRARA			200(60)	Shale, medium light gray to medium gray, calcareous with white, limy inclusions (referred to by drillers as "First White Specks"); marly zone near the middle. Upper part is tan to yellowish or golden in weathered exposures; lower part weathers to grayish hues; steep slopes.
					CARLILE			410(125)	Shale, medium dark gray to black, noncalcareous, soft; large ellipsoidal concretions containing abundant gypsum (selenite); zone of fine, secondary gypsum crystals at the top. Rounded slopes in exposures.
					GREEN HORN			150(45)	Shale, dark gray, calcareous; soft; thin-bedded shaly limestone; good electric and radioactivity log marker; referred to by drillers as "Second White Specks."
					BELLE FOURCHE			350(105)	Shale, medium to dark gray, soft, micaceous, lumpy to massive, spongy; includes beds of light bluish gray bentonitic clay; silt and sand facies near base in parts of eastern North Dakota.
				DAKOTA	MOWRY			180(55)	Shale, medium to dark gray, soft, flaky, spongy; traces of light blue gray bentonitic clay; top is marked by radioactive zone.
					NEWCASTLE			150(45)	Sandstone, light gray, fine to medium grained angular quartz grains, some calcareous cement, silty; shale, medium to dark gray, soft, lumpy, fissile, micaceous; known also as "Muddy." Probably type "Dakota."
					SKULL CREEK			140(40)	Shale, medium to dark gray, micaceous, soft, flaky to lumpy; sandstone, fine grained, friable, calcareous, light gray, clauconitic, especially in east; traces of pyrite and white bentonitic clay.
135					INYAN KARA			500(150)	Upper part is mainly marine sandstone, light gray, fine to coarse, quartzose; and shale, gray silty, and lumpy. Lower part is mainly nonmarine sandstone, medium to coarse, angular to subrounded, quartzose; occasional lenses of gray, bentonitic shale commonly contain manganese-siderite spherulites (pellets).
					MORRISON			260(80)	Shale and siltstone, light gray green to varicolored, soft, pyritic; small amounts of thin, interbedded calcareous sandstone and sandy limestone.
		JURASSIC		ELLIS	SWIFT			400(120)	Shale, dark gray to greenish, fissile, waxy, silty, calcareous; local limestone and glauconitic sandstone.
					RIERDON			100(30)	Shale, varicolored shades of gray, green, and red, calcareous; some limestone. Characteristic log marker at the top is known as the "Rierdon Shoulder."
					PIPER	BOWES MBR. FIREMOON MBR. TAMPICO MBR. KLINE MBR. PICARD MBR. POE MBR.		625(190)	Limestone, white to buff, brown, or gray, dense, finely crystalline, colomitic, oolitic, fossiliferous; shale, red, gray-green, and purple, silty; gypsum and anhydrite. Recognized members include the Poe Member at the base (mainly shale and anhydrite; Dunham Salt is a facies of the Poe), the Picard Member (shale), the Kline Member (limestone), the Tampico Shale, the Firemoon Limestone (also known as "Piper Limestone"), and the Bowes Member (shale) at the top.
190		TRIASSIC	ABSAROKA		SPEARFISH	SAUDE MBR.		750(225)	Siltstone, moderate to light brown and reddish brown; sandstone, fine-grained, frosted, rounded grains, slightly calcareous; halite, massive, clear large crystals with anhydrite, white, silty; interbeds of shale, gray, fissile, and mudstone, reddish orange; traces of pyrite and colomite. Recognized members include the Belfield, Pine Salt, and Saude Members.
225						PINE SALT			
						BELFIELD MBR.			
		PERMIAN			MINNEKAHTA			40(12)	Limestone, creamy, pink and purple mottled, chalky to sublithographic, clayey, anhydritic locally.
					OPECHE			510(155)	Shale, orange-red, slightly dolomitic, locally silty, straks of anhydrite and gypsum; halite locally.
				MINNELUSA	BROOM CREEK			275(85)	Sandstone at base, pinkish gray to pale reddish brown, fine to medium grained, subangular to well rounded, shaly, locally dolomitic; overlain by interbedded shale, reddish and greenish, and dolomite, pinkish gray to grayish red, microcrystalline, locally anhydritic; cherty at unconformity top.
280					AMSDEN			450(135)	Dolomite, pinkish gray to pale yellowish brown, microcrystalline to coarse crystalline, dense, sand; interbedded shale, dark reddish brown, silty, blocky fissility; and anhydrite, white to grayish brown, fine crystalline, colomitic; sandstone near top, gray to pale red, fine grained, calcareous. Alaska Bench Member at base is limestone, pinkish gray to pale yellowish brown, micritic, shaly.
		PENNSYLVANIAN				ALASKA BENCH			
					TYLER			200(60)	Shale and limestone, medium to dark gray to red and varicolored, carbonaceous near base; local sandstone lenses.
320				BIG SNOWY	OTTER			200(60)	Shale, greenish and reddish gray, variegated near basin edge, carbonaceous; minor limestone, gray to green, marly, fossiliferous, oolitic, thin bedded.
					KIBBEY			250(75)	Sandstone, reddish to light gray, fine to medium grained, rounded; limestone, white to brown, dense, dolomitic; shale, reddish to variegated, silty, interbedded gypsum. Limestone ("Kibbey lime") is excellent log marker.
		MISSISSIPPIAN	KASKASKIA		MADISON: CHARLES FACIES (FORMATION)	POPLAR INTERVAL		600(185)	Evaporites; interbedded anhydrite, halite, dolomite, mudstone, and shale; iron staining common; Poplar interval contains most of the halite of the Madison Formation.
					MADISON: MISSION CANYON FACIES	RATCLIFFE INT. MIDDLE RIVAL		250(75)	Limestone, pale yellow brown, dolomitic, oolitic; alternating with dolomitic limestone, anhydritic, and shale beds; Midale subinterval at base is dolomitic limestone; Ratcliffe interval includes lower Madison salt in the central Williston basin ("last salt").
						FROBISHER-ALIDA INTERVAL		585(180)	Limestone, yellow brown to pink, fine, fragmental, oolitic and pseudo-oolitic; intertonguing lenses of anhydrite and shaly dolomitic limestone; increasingly evaporitic eastward; Rival subinterval at top is anhydrite and dolomitic limestone. Includes the "X salt," the lowest Mississippian salt.
						TILSTON INT.		230(70)	Limestone, pale yellowish brown to pink, dolomitic, fine-grained to coarsely crystalline, oolitic and crinoidal, cherty; anhydritic; minor gray shale.
					MADISON: LODGEPOLE FACIES (BOTTINEAU INTERVAL)	FLOSSIE LAKE WHITEWATER LAKE VIRDEN SCALLION CARRINGTON MBR.		630(190)	Limestone, dark gray to brown to pale orange or pinkish, argillaceous to cherty to dolomitic, gragmental, finely crystalline to granular, dense, vuggy to fine intergranular.
					BAKKEN				Shale, dark gray to red with green mottling, no calcareous, clayey. Present on eastern flank of basin only.
345					THREE FORKS			110(35)	Shale, black, noncalcareous, carbonaceous, fissile, pyritic; gray, argillaceous dolomite in middle part; pebble conglomerate at base near basin margin.
				JEFFERSON	BIRDBEAR			240(75)	Siltstone and shale, grayish shades of red, green, and orange, interbedded and interlaminated, dolomitic, anhydritic; sandstone ("Sanish Sand") locally at top, silty to fine grained.
					DUPEROW			125(40)	Limestone and some dolomite, light gray to medium brownish gray, thick bedded, finely crystalline, porous, fossiliferous; anhydrite, brownish to medium gray. Called Nisku Formation by some.
		DEVONIAN		MANITOBA	SOURIS RIVER			460(140)	Limestone, light brownish gray, crystalline to granular, dense; dolomite, grayish brown, microcrystalline to sucrosic, anhydritic, porous and permeable; interbedded shale, siltstone, sand, and cyclical evaporites.
					DAWSON BAY	UPPER LOWER		300(90)	Dolomite and limestone, light to dark gray and brownish gray, crystalline to dense, anhydritic, clayey or silty in part, interbeds of silt, shale, and evaporites. "First Red" at base.
				ELK POINT	PRAIRIE			185(55)	Limestone, gray to brown, dense, fossiliferous, clayey, silty and sandy near the eastern limit; dolomite, brown, microcrystalline to microgranular, anhydritic, porous. "Second Red" at base.
					WINNIPEGOSIS			500(150)	Evaporites: potassium and sodium salts interbedded with thin anhydrite beds; locally absent due to salt solution; multiple sequence salt solution has resulted in development of complex structural features over stratigraphically limited intervals. Three major potash beds recognized are the Montrail Member, Belle Plaine Member, and Esterhazy Member.
					ASHERN			400(120)	Upper part: dolomite, reddish brown, shaly, anhydritic, crystalline, dense; has marked thickness variations due to the development of reef and inter-reef facies. Lower part: limestone and dolomite, dark gray to brown, dense, clayey to shaly.
395								75(25)	Shale, shades of red, white, and green, thin bedded, dolomitic; locally breciated; locally anhydritic; "Third Red."
		SILURIAN			INTERLAKE	UPPER MIDDLE LOWER		1100(335)	Upper part: dolomite and limestone, light brownish gray to light gray, finely crystalline, fragmental and microgranular, vuggy porosity; silty and sandy near the base. Middle part: dolomite, light yellowish gray to pale orange, microgranular and lithographic, fine to medium crystalline, cherty. Lower part: dolomite, light-brownish gray to brownish gray, finely crystalline; thin anhydrite interbedding in central basin area.
440			TIPPECANOE	BIG HORN	STONEWALL			120(35)	Dolomite and limestone, light brownish gray, finely crystalline; thin anhydrite interbedding in central basin area.
					STONY MOUNTAIN	GUNTON STOUGHTON		200(60)	Gunton Member: dolomite, brownish gray to yellowish brown, finely crystalline, limy; limestone, dolomitic and fossiliferous; thin anhydrite in central basin area: sandy zones near the top. Stoughton Member: limestone and shale, dark gray, interbedded, fossiliferous, pyritic.
					RED RIVER			700(215)	Upper part: limestone and dolomite, mottled yellowish to brownish gray, fragmental, argillaceous, anhydritic. Lower part: limestone, mottled gray to pale brown, dolomitic, finely fossiliferous and fragmental, finely crystalline. The porosity zones indicated range from less than 10 feet thick ("A") to as much as 70 feet thick ("D").
				WINNIPEG	ROUGHLOCK			90(30)	Siltstone, and sandstone, light gray, fine grained, calcareous; gradational into shale, greenish gray, silty, calcareous.
					ICEBOX			145(45)	Shale, greenish gray, splintery to fissile, saxy, noncalcareous; black phosphate nodules; some sand lenses.
					BLACK ISLAND			170(50)	Sandstone, mottled light gray with clay, fine to medium grained, poorly sorted, well rounded, frosted, friable, quartzose; some pyrite.
500			SAUK		DEADWOOD			1000(300	Limestone, sandstone, and shale. Limestone, light gray, fine to medium crystalline, dolomitic, sandy, glauconitic; sandstone, slightly calcareous, quartzose, medium to coarse, well rounded, poorly cemented, frosted, glauconitic and dolomitic in east; shale, grayish red to greenish and medium gray, calcareous.
		CAMBRIAM							
570		PRECAMBRIAN		CHURCHILL PROVINCE / SUPERIOR PROVINCE				UNKNOWN	Eastern North Dakota (Superior Province): greenschist and amphibolite facies, intermediate-mafic schists; banded iron formation; stratched pebble conglomerate; metabasalt; serpentinite; felsic tuff; mylonite; intermediate-felsic plutonic rocks; migmatite; layered gneiss. Western North Dakota (Churchill Province): greenschist and amphibolite facies schists; intermediate-felsic plutonic rocks; diabase; amphibolite-granulite facies gneiss.
4700									

The units, Lodgepole, Mission Canyon, and Charles (recognized as members or formations in some places), are facies which cut across the log markers.

The terms "Bottineau," "Tilston," "Frobisher-Alida," "Ratcliffe," and "Poplar" refer to intervals between markers on geophysical logs. The Bottineau, Tilston, and Frobiser-Alida intervals have not been traced into the central part of the Williston basin.

"Madison Undifferentiated" (term used in the central part of the Williston basin where geophysical log markers used for correlation on the east side of the basin are absent): limestone, brownish gray to pale yellowish brown and light to medium gray, fine fragmental, sucrosic to sublithographic, dense, oolitic in part; some dolomite.

PLATE 2

J.V. GROENEWOLD