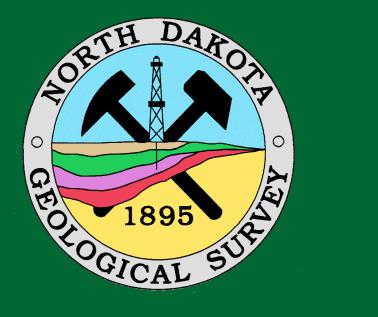
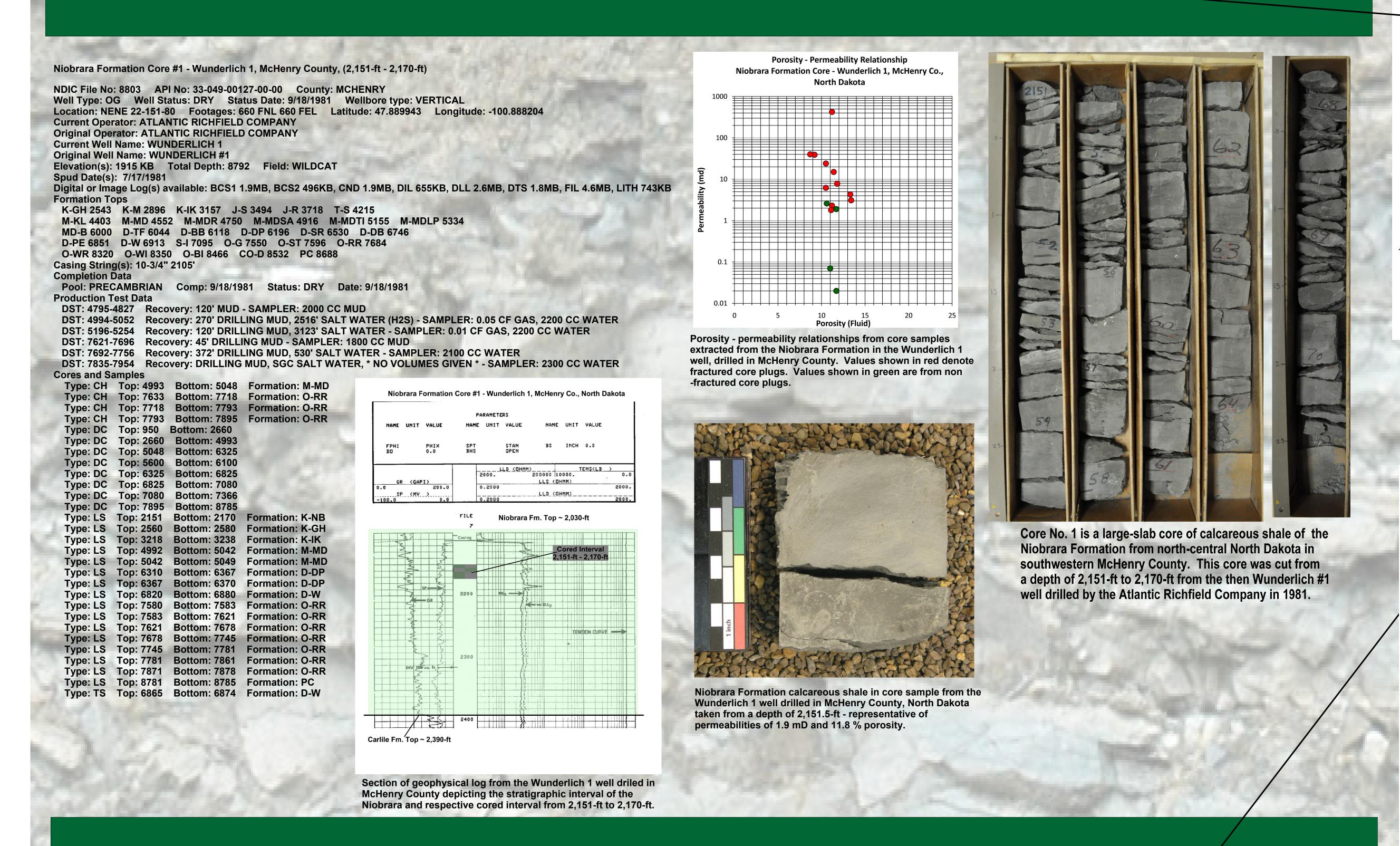


NIOBRARA FORMATION CORES IN NORTH DAKOTA

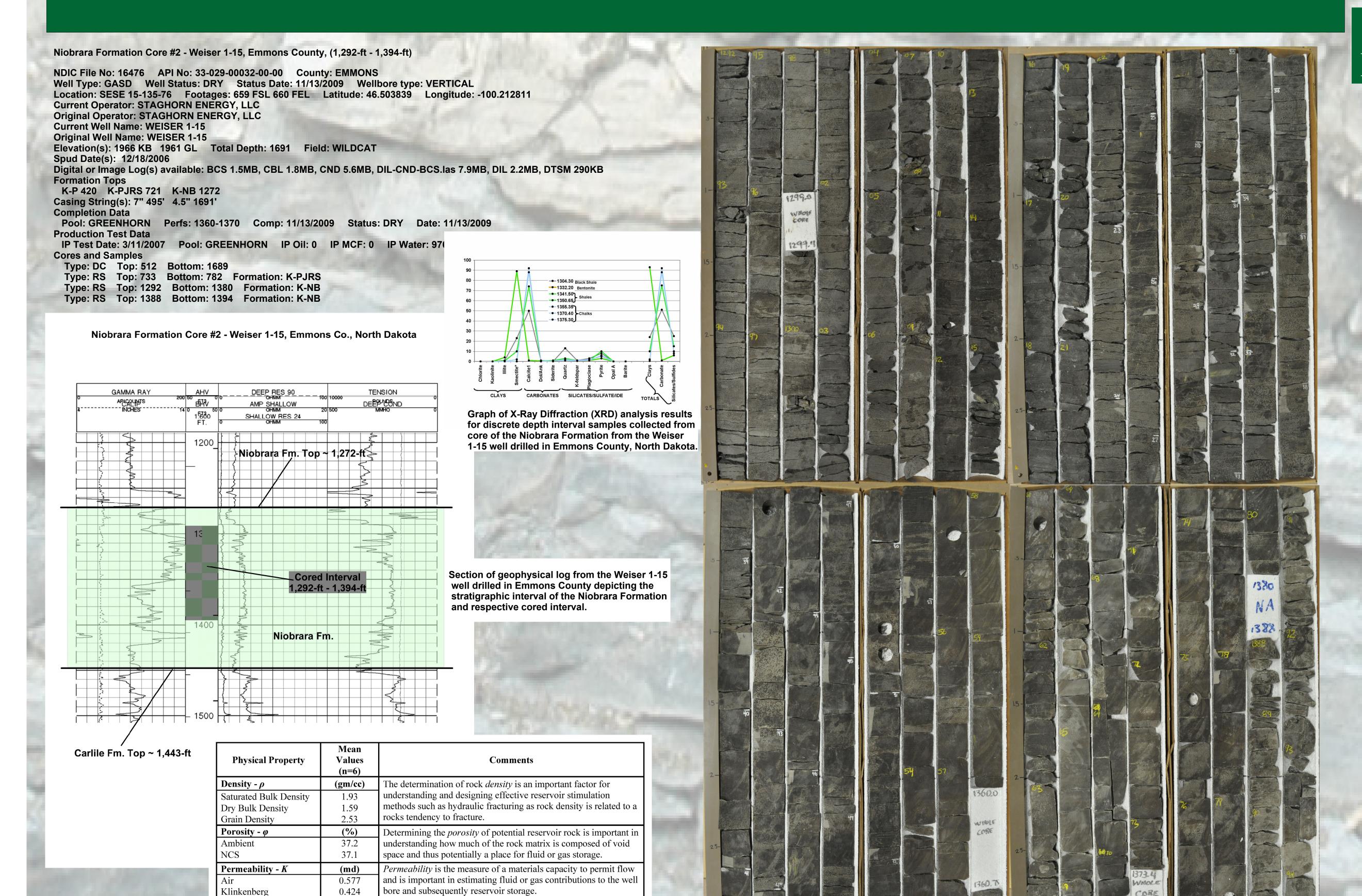
Fred J. Anderson



Niobrara Formation Core No. 1 - Wunderlich 1, McHenry County (2,151-ft to 2,170-ft)



Niobrara Formation Core No. 2 - Weiser 1-15, Emmons County (1,292-ft to 1,394-ft)



Summary of geomechanical rock properties obtained from Niobrara Formation core from the

Core No. 2 is a rocker-slab core of calcareous shale and chalks of the Niobrara Formation from south-central North Dakota in northern Emmons County. This core was cut from a depth of 1,292-ft to 1,394-ft from the Weiser 1-15 well drilled by Staghorn Energy, LLC in 2006.

NIOBRARA FORMATION SUBSURFACE NIOBRARA FORMATION SUBCROP

Figure 1. The extent of the Niobrara Formation in North Dakota (shaded green area) and the location of selected Niobrara cores.

INTRODUCTION

The Niobrara Formation in North Dakota consists dominantly of calcareous shales and chalks, up to 250 feet in thickness, that are dominantly found in the shallow (<5,000 feet) subsurface, to depths of just greater than 4,100 feet in the western part of the state (coincident with the deeper portions of the Williston Basin), shallowing to subcrop depths of 500 feet or less, with occasional exposure at outcrop, in eastern North Dakota (Figure 1). The Niobrara Formation occurs across 87% of the state (61,701 square miles) in the shallow subsurface and subcrops directly beneath the Pleistocene glacial sedimentary cover of the Coleharbor Group, in a narrow north to south trending band, which covers just over 2% of the state (1,629 square miles) in eastern-most North Dakota. The ultra-shallow (<500 feet) Niobrara Formation-Coleharbor group subcrop occurs in (from north to south): Cavalier, Pembina, Walsh, Grand Forks, Steele, Griggs, Barnes, Ransom, LaMoure, Dickey, and Sargent Counties, with limited outcrops, along recent drainages, found in northeastern North Dakota. The Niobrara Formation in North Dakota was deposited in an offshore marine setting during the lower Upper Cretaceous and is conformably overlain by the Upper Cretaceous Pierre Formation across 85% of its occurrence across the state and is underlain by the noncalcareous shale of the Cretaceous Carlile Formation (Figure 2). The Niobrara Formation in North Dakota has been further informally subdivided into an upper chalky member (with an upper or "First White Specks" zone and lower "high-lime zone") and a lower calcareous shale member consisting of a bioturbated calcareous shale member and a laminated, lower "white specks" zone. Calcareous nanoplankton are the dominant micro-paleontological component of the formation along with the occurrence of other macro-invertebrate marine fauna such as bivalves (Inoceramus) and oysters (Pseudoperna congesta) and other traces (e.g., pyritized burrows).

CRETACEOUS STRATIGRAPHIC NOMENCLATURE IN NORTH DAKOTA

5						HELL CREEK	BREIEN COLGATE LINTON BULLHEAD TIMBER LAKE	Wates Ash Wates Wates		330 (101) 400 (122)	Sandstone, siltstone, claystone, mudstone, and thin, discontinuous lignite; somber tones of gray, brown, and purple; moderately-cemented to poorly-cemented, organic-rich, cross-bedded sandstone; bentonitic claystone: tuffaceous beds; limestone, manganese-oxide, and iron-oxide nodules and concretions; dinosaur fossils. Characterized by rapid facies changes; forms rilled to rounded, poorly vegetated slopes and badlands topography. The Brein Member is one of at least two marine/brackish tongues. River, lake, and swamp deposits. Mudstone, siltstone, sandstone; yellowish brown to gray; poorly-cemented to well-cemented sandstone; organic laminae; tuffaceous bed(s); mollusk-rich beds; abundant marine and brackish-water fossils. Generally forms gentle, rounded slopes, but can form flat-topped hills and buttes. The Colgate Member (sandstone) weathers to bright white with steep cliffs and is an important aquifer throughout western North Dakota. The Linton Member is a grayish brown sandstone that caps many of the buttes in central and southwestern Emmons County.
í				ZUNI	MONTANA		TRAIL CITY	Stone			Offshore marine and nearshore deposits.
						PIERRE	ODANAH	Stone		2,300 (701)	Shale; light to dark gray; generally noncalcareous; fissile to blocky. The Pierre and Fox Hills contact is gradational over an interval of approximately 30 feet (9m). The Pierre Formation is subdivided into five members, four of these members (Odanah, DeGrey, Gregory, and Pembina) are exposed in North Dakota. Offshore marine deposits. Odanah Member: shale; light gray; siliceous, noncalcareous; hard, slate-like; iron stained joints; yellow bentonite near base; ferruginous concretions; forms conspicuous cliffs.
							DEGREY		•		DeGrey Member: shale; olive to dark gray; noncalcareous; flaky; abundant ironstone concretions. Contains marine vertebrate fossils. Gregory Member: shale; yellow to dark gray; slightly calcareous to marly; pyritic; soft; thinly bedded. Upper part; pale, yellowish gray
A			Upper				GREGORY				maristone; loose surface, prone to slumping; lower part; shale, containing ironstone concretions. Contains marine invertebrate fossils. Pembina Member: shale; grayish brown to brownish black; noncalcareous; soft; jarosite and selenite-encrusted phosphate nodules; organic-rich in the middle portion; Fuller's earth (bentonite) beds near base of unit. Contains marine vertebrate fossils. Gammon Member: mudstone; gray; calcareous and iron concretions. Originally named the Gammon Ferruginous Member.
		CRETACEOUS					PEMBINA	entonite			The Ardmore Bentonite marks the contact between the Gammon and Pembina Members. Two sandstone/siltstone tongues are present in the subsurface of western North Dakota, the lower is referred to as the <i>Eagle</i> and the upper the <i>Judith River</i> . These may be equivalent to the Eagle Sandstone and the Judith River Formations in Montana. In addition, there are a number of sandstone and siltstone lenses in the Pierre Formation that are often mistakenly referred to as the <i>Eagle</i> or <i>Judith River</i> . The Pierre\Fox Hills contact is the last (highest
		CRET					GAMMON	Gas			stratigraphic) consistent pick that can be made on electric logs with any degree of confidence.
						NIOBRARA				250 (76)	Shale, chalk; light to medium gray, upper exposures weather to yellow; calcareous; zones contain limy inclusions or specks that are referred to as the <i>First White Specks</i> by drillers and are used to differentiate it from the overlying Pierre Formation; very calcareous or marly zone in the lower part of the unit; laminated and bioturbated strata; some pyritized burrows; marine fossils; forms steep slopes. Offshore marine deposits.
-99.6	C				COLORADO	CARLILE				400 (122)	Shale; medium gray to black; noncalcareous; soft; a zone of selenite and large ellipsoidal concretions and septarian nodules near the top; marine fossils; forms rounded slopes. Offshore marine deposits.
	0					GREENHORN				150 (46)	The column changes below this point to indicate these rocks are not exposed at the surface in North Dakota. Shale; dark gray; micaceous; soft; thin-bedded shaly limestone; referred to as the Second White Specks by drillers; the top is a good marker on gamma-ray and resistivity logs. Offshore marine deposits.
	MESOZ					BELLE FOURCHE				350 (107)	Shale; medium to dark gray; micaceous; soft; lumpy to massive; includes beds of bluish gray bentonitic clay; sandstone and siltstone near the base in eastern North Dakota. Offshore marine deposits.
			Lower		DAKOTA	MOWRY				300 (91)	Shale; medium to dark gray; soft; flaky; traces of bluish gray bentonitic claystone; top is marked by a persistent bentonite that has a strong response on a gamma-ray log. Offshore marine deposits.
						NEWCASTLE		Wate		150 (46)	Sandstone; light gray; fine-grained to medium-grained, angular quartz grains; silty; some calcareous cement. Shale; medium to dark gray; micaceous; fissile to blocky; soft. Also referred to as the <i>Muddy</i> . Shallow marine and fluvial deposits.
						SKULL CREEK		Wate		140 (43)	Shale; medium to dark gray; micaceous; soft, flaky to lumpy. Sandstone; light gray; glauconitic, calcareous; fine-grained; friable. Traces of pyrite and white bentonitic claystone. Offshore marine deposits.
						INYAN KARA		Wate		625 (191)	Upper part: Sandstone; light gray; quartzose; fine-grained to coarse-grained. Shale: gray; silty; lumpy. Marine to nonmarine. Lower part: Sandstone; gray; quartzose; medium-grained to coarse-grained; angular to subrounded; occasional lenses of shale; gray; bentonitic; contains manganese and siderite spheres. Equivalent, in part, to the Lakota, Fusion, and Fall River Formations in South Dakota, Wyoming, and Montana. Most oilfield brine injection occurs in this unit. Primarily nonmarine.

Figure 2. Cretaceous stratigraphic nomenclature in North Dakota (modified from Murphy, et.al., 2009) highlighting the Niobrara Formation.

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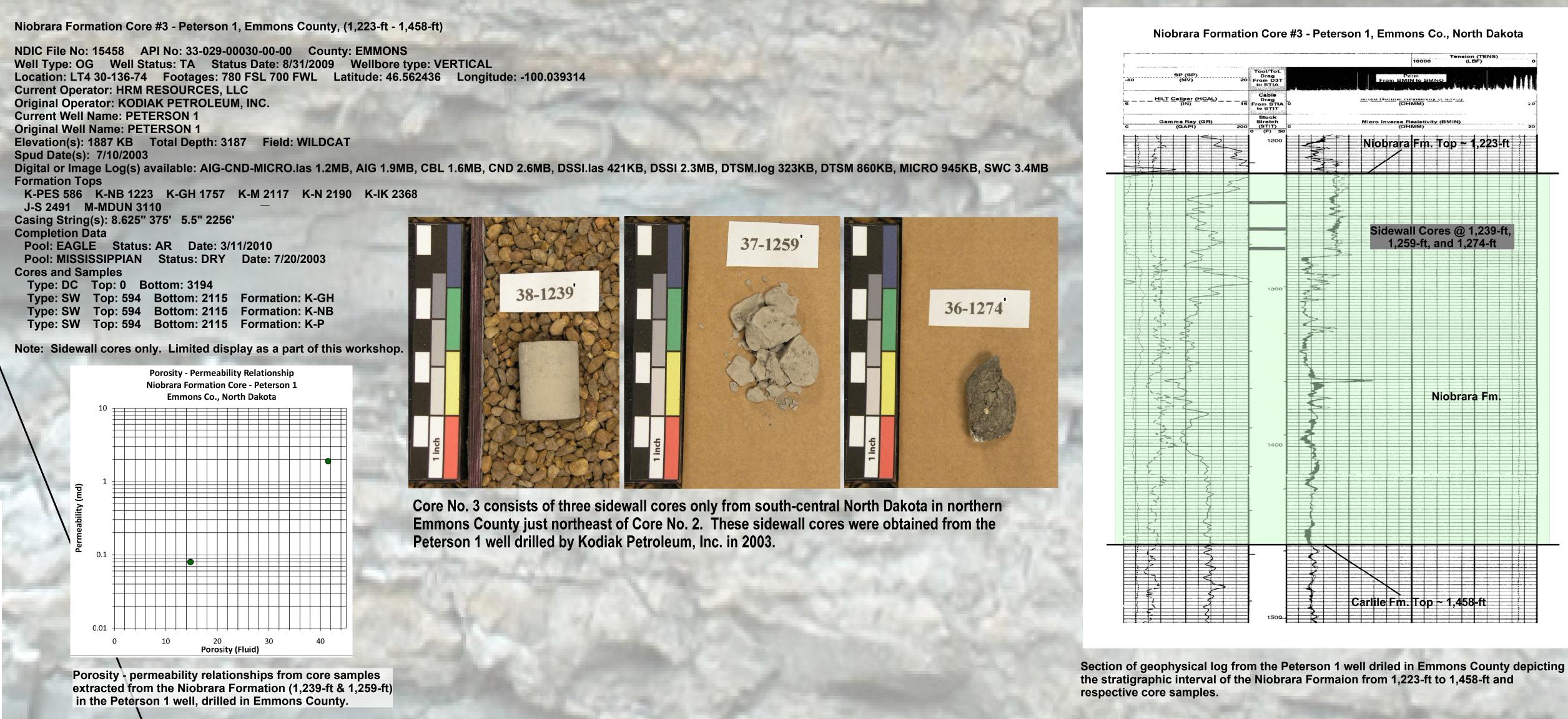
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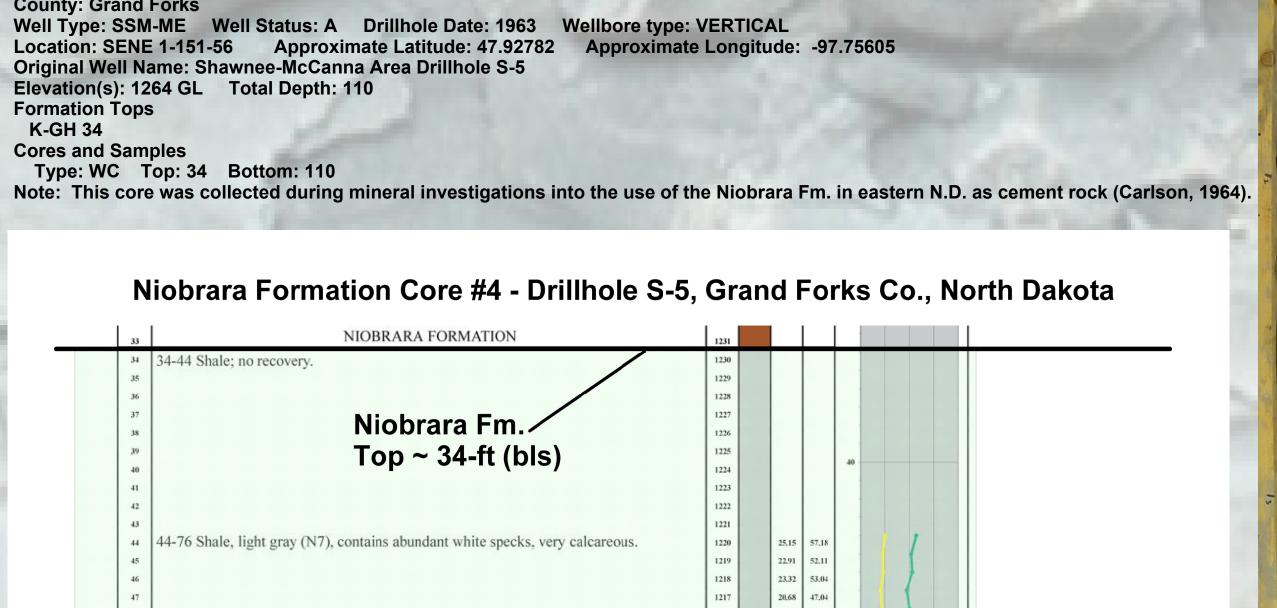
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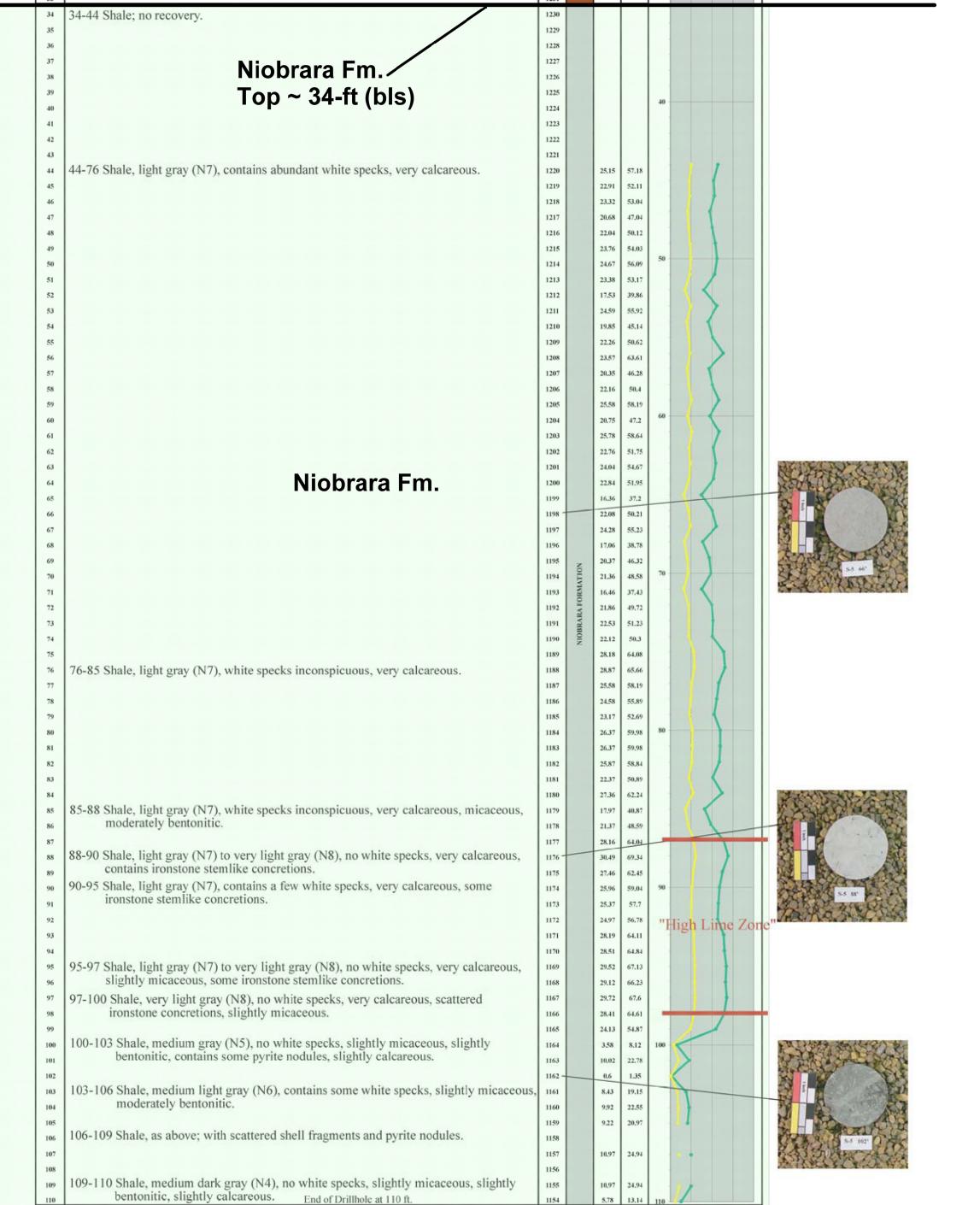
Niobrara Formation Core No. 3 - Peterson 1, Emmons County (1,223-ft to 1,458-ft)



Niobrara Formation Core No. 4 - Drillhole S-5, Grand Forks County (40-ft to 110-ft)



Niobrara Formation Core #4 - Drillhole S-5, Grand Forks County, (40-ft - 110-ft)



Section of lithologic and geochemical log from the S-5 drillhole into the upper Niobrara shale in northeastern North Dakota in Grand Forks County depicting the stratigraphic interval of the Niobrara and respective cored interval from 34-ft to 110-ft.



Core No. 4 is a whole core of the Niobrara Formation from northeastern North Dakota in western Grand Forks County. This core was obtained from a depth of 34-ft to 110-ft and is part of a series of ten drillholes drilled in the Shawnee-McCanna area of western Grand Forks County that were completed during investigation of the Niobrara Formation in northeastern North Dakota for use as Cement Rock.

Top core face view of light-gray (N7) calcareous

shale of the Niobrara Formation from the 66-ft

Grand Forks County, North Dakota, Abundant

white specks (coccoliths) are characteristic of

this "First White Specks" interval.

depth interval from Drillhole S-5 in western