BLACK ISLAND FORMATION OUTLINE

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EXECUTIVE SUMMARY

The Williston Basin is a relatively large, intracratonic basin with a thick sedimentary cover in excess of 16,000 ft. It is considered by many to be tectonically stable, with only a subtle structural character. The stratigraphy of the area is well studied, especially in those intervals that produce oil.

The basin has significant potential as a geological sink for sequestering carbon dioxide (CO₂). This topical report focuses on the general geological characteristics of the Black Island Formation that are relevant to potential sequestration in petroleum reservoirs and deep saline formations.

This report includes general information and maps on formation stratigraphy, lithology, depositional environment, and hydrodynamic characteristics. The Black Island Formation in the Williston Basin is considered to be a potential sink for long-term sequestration of CO₂.

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The PCOR Partnership represents public agencies, utilities, oil and gas companies, engineering firms, associations and nonprofit organizations, and universities (see PCOR Partnership list below). The Energy & Environmental Research Center (EERC) would like to thank the following partners who have provided funding, data, guidance, and/or experience to support the PCOR Partnership:

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- North American Coal Corporation
- North Dakota Department of Commerce Division of Community Services
- North Dakota Department of Health
- North Dakota Geological Survey
- North Dakota Industrial Commission Department of Mineral Resources, Oil and Gas Division
- North Dakota Industrial Commission Lignite Research, Development and Marketing Program
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- North Dakota Petroleum Council
- North Dakota State University
- Otter Tail Power Company
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INTRODUCTION

Formation outlines have been prepared as a supplement to the "Overview of Williston Basin Geology as It Relates to CO₂ Sequestration" (Fischer et al., 2004). Although the stratigraphic discussion presented in the overview is in a convenient format for discussing the general characteristics of the basin, it does not provide insight into the specific characteristics of every formation. A formation outline summarizes the current knowledge of the basic geology for each formation. If not specifically noted, the formation boundaries and names reflect terminology that is recognized in the North Dakota portion of the Williston Basin. The intended purpose of the formation outline is to provide a convenient basis and source of reference from which to build a knowledge base for more detailed future characterization. The development of sequestration volume estimates and rankings are beyond the scope of the formation outline.

FORMATION NAME

Black Island Formation

Williston Basin stratigraphic nomenclature follows that recognized by the North Dakota Geological Survey as summarized in the North Dakota Stratigraphic Column (Bluemle et al., 1986) and the Williston Basin stratigraphic nomenclature chart (Bluemle et al., 1981) (Figure 1).

FORMATION AGE (LeRud, 1982)

Middle Ordovician Period (Figure 1) Blackriverian Epoch Winnipeg Group

GEOLOGICAL SEQUENCE

Tippecanoe

HYDROSTRATIGRAPHY (Figure 1)

AQ1 Aquifer (Downey et al., 1987)

GEOGRAPHIC DISTRIBUTION (Modified from LeRud, 1982)

Williston Basin; southern Manitoba, eastern Montana, North Dakota, southern Saskatchewan, western South Dakota

THICKNESS

The Black Island Formation reaches a thickness in excess of 260 ft in north-central North Dakota (Figure 2).

CONTACTS

The upper contact is conformable with the Icebox Formation. The lower contact is unconformable with the Deadwood.

LITHOLOGY

Clastic; sandstone, siltstone, and shale

SUBDIVISIONS

Informally divided into a lower and upper member (Figure 3) (Thompson, 1984). In 1995, Ellingson and LeFever proposed to name the lower member, the Hawkeye Valley Member, and the upper member, the Garland Member.

LITHOFACIES (Ellingson and LeFever, 1995)

The lower member (Hawkeye Valley Member) comprises two lithofacies, a basal red-bed lithofacies containing quartz arenites and "clayshales" and an upper green quartz wacke.

The upper member (Garland Member) is further subdivided into two lithofacies, a quartz arenite and green quartz wacke.

									ERC DF31028.CDR	
		2000 2000	YBP	Rock Units (Groups, Formations)		Hydrogeologic		_ 4	Potential	
		Age Units	(Ma)		7/1	Systems ³ USA Canada		Sequences ⁴	Sequestration	
				USA ¹ (ND)	Canada ² (SK)				Targets	
Phanerozoic	Cenozoic	Quaternary				AQ5 Aquifer	Upper Aquifer System	Tejas		
			1.8	White River Grp Golden Valley Fm	Wood Mountain Fm					
		Tertiary		Golden Valley Fm						
				Fort Union Grp						
					Ravenscrag Fm				Coal Seams	
			66.5	Hell Creek Fm	Frenchman Fm			Zuni	oodi oodiiio	
		Cretaceous		Fox Hills Fm	Whitemud Fm \ e.	TK4 Aquitard	r Viking Aquifer Joi Fou Aquitard			
	Mesozoic			Pierre Fm	Bearpaw Fm Fm					
				Judith River Fm	Judith River Fm					
				Eagle Fm	Milk River Fm					
					First White Speckled Shale Niobrara Fm					
				Carlile Fm Creenhorn Fm Co U S	Carlile Fm					
				Greenhorn Fm	Second White Specks Belle Fourche Fm					
				Delle Fourche Fill	Fish Scales Fm Westgate Fm					
				Mowry Fm Newcastle Fm 등 약 약	Viking Fm	AQ4 or			Cool Cooms	
				Newcastle Fm Skull Creek Fm Skull Creek Fm Joseph Golden	Joli Fou Fm	Dakota			Coal Seams Saline Formations	
			146	Inyan Kara Fm	Mannville Group	Aquifer			Calific i Offilations	
		Jurassic		Swift Fm	Success Fm Masefield Fm	3				
				Rierdon Fm	Rierdon Fm	TK3	Mississippian- Jurassic Aquitard System			
			200	Piper Fm	Upper Watrous Fm			Absaroka		
		Triassic		Spearfish Fm	Lower Watrous Fm	Aquitard				
	Paleozoic	Permian	251	Minnekahta Fm						
				Opeche Fm						
			299	Broom Creek Fm 💆 a					Oil Fields	
		Pennsylvanian		Broom Creek Fm Amsden Fm		AQ3			Saline Formations	
			318	Tyler Fm S		Aquifer		Kaskaskia		
		Mississippian		Kibbey Fm	Charles Ratcliffe Mbr Ridale Mbr Mission Frobisher Mbr	TK2				
				Charles Fm Mission Canyon		Aquitard			071 57 111	
				Mission Canyon	Canyon Alida Mbr Fm Triston Mbr	AQ2 or Madison			Oil Fields Saline Formations	
				Lodgepole Fm =	≥ Lodgepole Souris Valley	Aquifer	System		Oil Fields	
			359	Bakken Fm	Bakken Fm Big Valley Fm Three Forks	TK1 Aquitard	Bakken Aquitard Devonian Aquifer System Prairie Aquiclude			
		Devonian		Three Forks Birdbear Duperow	Duperow. Birdbear				Oil Fields	
				Dawson Bay Praine Winipegosis Aubern	Dawson Bay Vinnipegosis				Saline Formations	
				PSOCIALITY	ASSESSED IN COLUMN TO A SECOND		Silurian/Devonian		Saline Formacions	
		Silurian	444	Interlake Fm	Interlake Fm		Aquitard			
		Ordovician	444	Stonewall Fm Stony Mountain Fm	Stonewall Fm Stony Mountain Fm		Basal Aquifer System	Tippecanoe		
				Red River Fm	Red River Fm	AQ1			Oil Fields	
				Winnipeg Grp Roughlock Fm Icebox Fm Black Island Fm	Winnipeg Grp	Aquifer			Oil Fields/Saline Fms	
			488	The same of the sa	255 30 860			Sauk	Oil Fields	
		Cambrian		Deadwood Fm	Deadwood Fm			Sauk	Saline Formations	
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5				Superior Craton, and metamorphic rocks of		 Fowler, C.M.R., and Nisbet, E.G., 1985, The subsidence of the Williston Basin: Canadian Journal of Earth Sciences, v. 				
A				the Wyoming Craton.			, p. 408–415			
				2 200						

Figure 1. Williston Basin stratigraphic and hydrogeologic column.

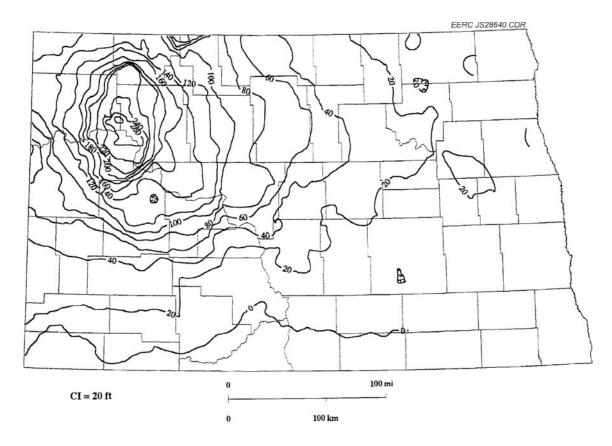


Figure 2. Black Island isopach (Ellingson and LeFever, 1995).

DEPOSITIONAL ENVIRONMENT

Marine to shallow marine

DEPOSITIONAL MODEL

Black Island sediments record the initial transgressive phase of the Tippecanoe Sequence. Tippecanoe sedimentation begins with the Williston Basin connected to the ocean through a southwest trending seaway (Foster, 1972). Sedimentation is recorded by the formations of the Winnipeg Group.

RESERVOIR CHARACTERISTICS (Vinopal and Edington, 1988)

From Vinopal and Edington, 1988.

• Porosity can be in excess of 10%.

• Permeabilities on occasion can approach 100 mD.

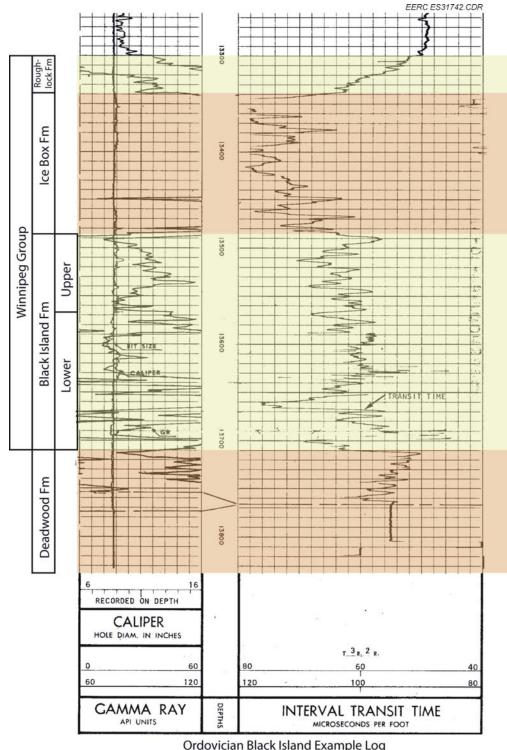
HYDRODYNAMIC CHARACTERISTICS (AQ4) (Downey, 1986)

From Downey, J.S., 1986, Geohydrology of bedrock aquifers in the Northern Great Plains in parts of Montan, North Dakota, South Dakota, and Wyoming, U.S. Geological Survey Professional Paper P 1402-E, p. E1–E87.

If hydrodynamic flow exists, it should be from outcrop positions in the Black Hills, northeast into the basin (Figures 4–6).

HYDROCARBON PRODUCTION

In North Dakota, the Winnipeg Group is productive on the Nesson Anticline and at Richardton and Taylor Fields on the



Ordovician Black Island Example Log Location: C NW 11-155-96 HESS CORPORATION BEAVER LODGE – ORDOVICIAN UNIT No. 4 NDIC File No: 4716 API No: 33-007-00296-00-00

Figure 3. Ordovician Black Island example log.

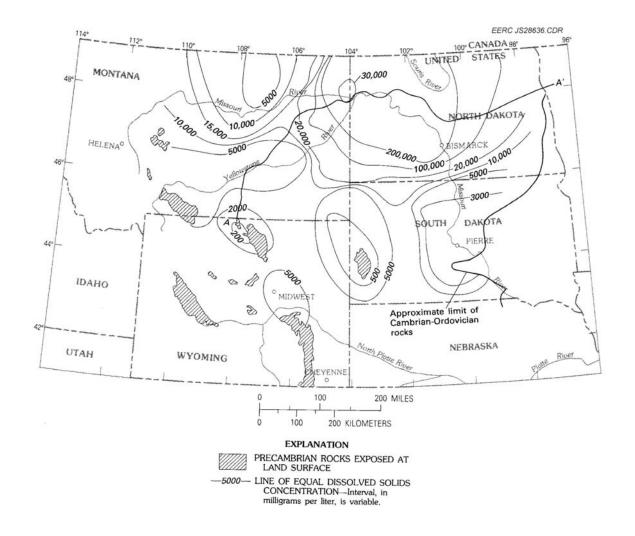


Figure 4. Concentration of dissolved solids in water from the Cambrian–Ordovician Aquifer.

Heart River Anticline in eastern Stark County.

SINK POTENTIAL

The Icebox Formation exhibits both conventional and unconventional sink potential. Where 'clean' quartz arenites are porous and permeable, conventional waste storage could be high.

A series of nearby vertical traps can be demonstrated for the Icebox Formation. Locally, individual clay lithofacies add a

component of trapping. Such clay lithofacies can be identified from well logs.

Regionally, the Icebox Formation of the Winnipeg Group (commonly referred to as the Winnipeg Shale) acts as a trap. The Icebox, primarily a shale, is present throughout most of North Dakota.

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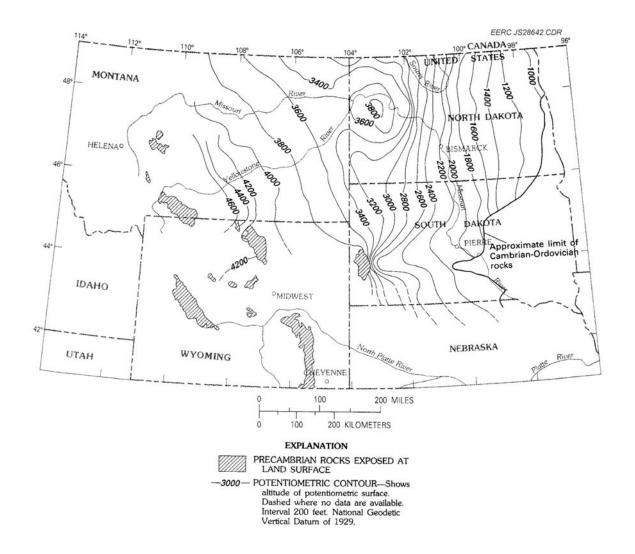


Figure 5. Simulated potentiometric surface of the Cambrian-Ordovician Aquifer.

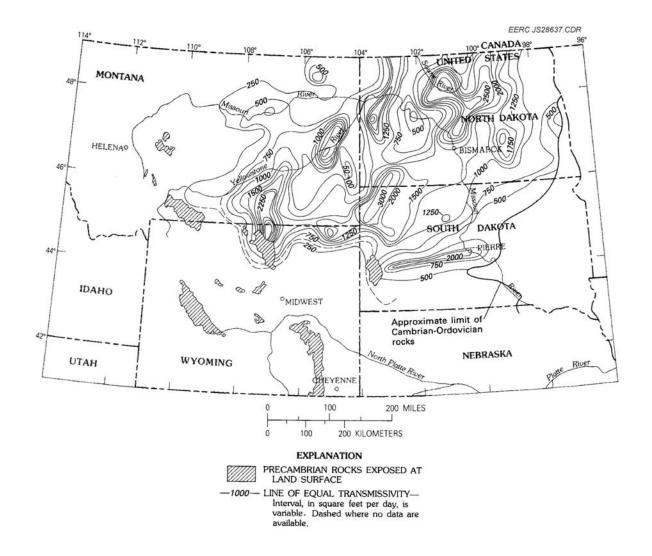


Figure 6. Water temperatures in the Cambrian-Ordovician Aquifer.

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