Plains CO_2 Reduction (PCOR) Partnership
Practical, Environmentally Sound CO_2 Sequestration

SKULL CREEK 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 (CO_2). This topical report focuses on the general geological characteristics of formations in the Williston Basin 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, hydrodynamic characteristics, and hydrocarbon occurrence. The Skull Creek Formation in the Williston Basin is considered to be an impermeable cap or trap.

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INTRODUCTION

Formation outlines have been prepared as a supplement to the "Overview of Williston Basin Geology As It Relates to CO_2 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, in outline form, 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 outlines will 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 outlines prepared as part of the Phase I activities.

The Plains CO_2 Reduction (PCOR) Partnership believes these outlines are a necessary component in characterizing the sequestration potential of the basin. Although the stratigraphic discussion presented in the "Overview of Williston Basin Geology As It Relates to CO_2 Sequestration" 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. In fact, each lithostratigraphic or geohydrologic unit discussed in that report can be further subdivided into individual formations. Formations may, in turn, be subdivided. Each subdivision may represent a sink, hereafter referred to as a "geological sequestration unit" (GSU), or a confining unit (aquitard). Some of the subdivisions may already be considered part of a large regional GSU or confining unit, while others will be localized and isolated. Many will represent a potential GSU within a regionally defined confining unit or a confining unit within a regionally defined sink.

Presently, the PCOR Partnership refers to carbon dioxide (CO_2) sequestration reservoirs as "sequestration units," based on accepted legal terminology or protocol currently in use in the petroleum industry. Injection of CO_2 will require joint operating agreements that will necessitate the establishment of unitized lands for CO_2 sequestration, whether they are in petroleum reservoirs, coal beds, or subsurface formations or intervals containing brine.

Two main categories of GSUs are recognized in the formation outlines: conventional and unconventional. Conventional GSUs are considered to be nonargillaceous, or "clean," lithologies that have preserved porosity and permeability; unconventional GSUs are those that may be porous but lack permeability or are "dirty." Loss of permeability in a porous reservoir may be due to the presence of organic detritus in the rock matrix. The distinction between conventional and unconventional reservoirs is made for a number of reasons:

- Injection into conventional GSUs may not require significant borehole stimulation because of inherent porosity and permeability; however, injection into unconventional GSUs will require significant stimulation, including fracture stimulation prior to injection, because of the lack of inherent permeability.

- For conventional reservoirs or GSUs, the presence of bounding or confining units will have to be well demonstrated and understood; these units will be the trapping mechanism for injected fluids. Unconventional

GSUs, because of the inherent lack of permeability, may be self-trapping.

- Conventional GSUs may not need expensive stimulation procedures and, therefore, would be less sensitive to economic constraints.

- Unconventional GSUs that have a component of organic-rich matrix materials need to be investigated as to the capacity, if any, to play a role in fixation of CO_2.

A distinction is also made between primary and secondary GSUs. A primary GSU is a regional GSU with lateral continuity and would likely be capable of sequestering a significant amount of CO_2. A primary GSU would be the main target in a regional sequestration unit. A secondary GSU is less continuous and perhaps isolated and capable of sequestering a relatively minor amount of CO_2. For instance, a secondary GSU would not necessarily be a "stand-alone" sequestration target, but it might be utilized for sequestration if a borehole were already in place.

The potential importance of thin or nonregional sinks cannot be overlooked once CO_2 has been captured. The major expenses involved in the postcapture phase of geologic sequestration are transportation and well costs. Smaller sinks that are stratigraphically proximal to a larger sink target represent a means to maximize the economic potential of injection programs by utilizing all available storage encountered in an individual borehole. In order for nonregional sinks to be utilized, detailed characterization and mapping of those units are necessary.

FORMATION NAME

Skull Creek Formation Outline

The stratigraphy and nomenclature of the lower Cretaceous varies greatly throughout the PCOR Partnership region. In this document, 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).

Equivalents to the Skull Creek include the Joli Fou of southern Saskatchewan (Leckie et al., 1994) and the Ashville of southern Manitoba.

FORMATION AGE (LeRud, 1982)

Early Cretaceous
Albian
Dakota Group

GEOLOGICAL SEQUENCE

Zuni

HYDROSTRATIGRAPHY (Figure 1)

Downey (1987): AQ4 Confining Unit
Bachu (1996): Joli Fou Aquitard

GEOGRAPHIC DISTRIBUTION (modified from LeRud [1982])

Manitoba, southeastern Montana, western North Dakota, Saskatchewan, western South Dakota

THICKNESS

In the Williston Basin, the Skull Creek Formation is more than 200 ft thick (Burtner and Warner, 1984) in northwestern South Dakota and southeastern Montana (Figure 2).

CONTACTS

The upper contact with the Newcastle is unconformable (LeFever and McCloskey, 1995; Leckie et al., 1994).

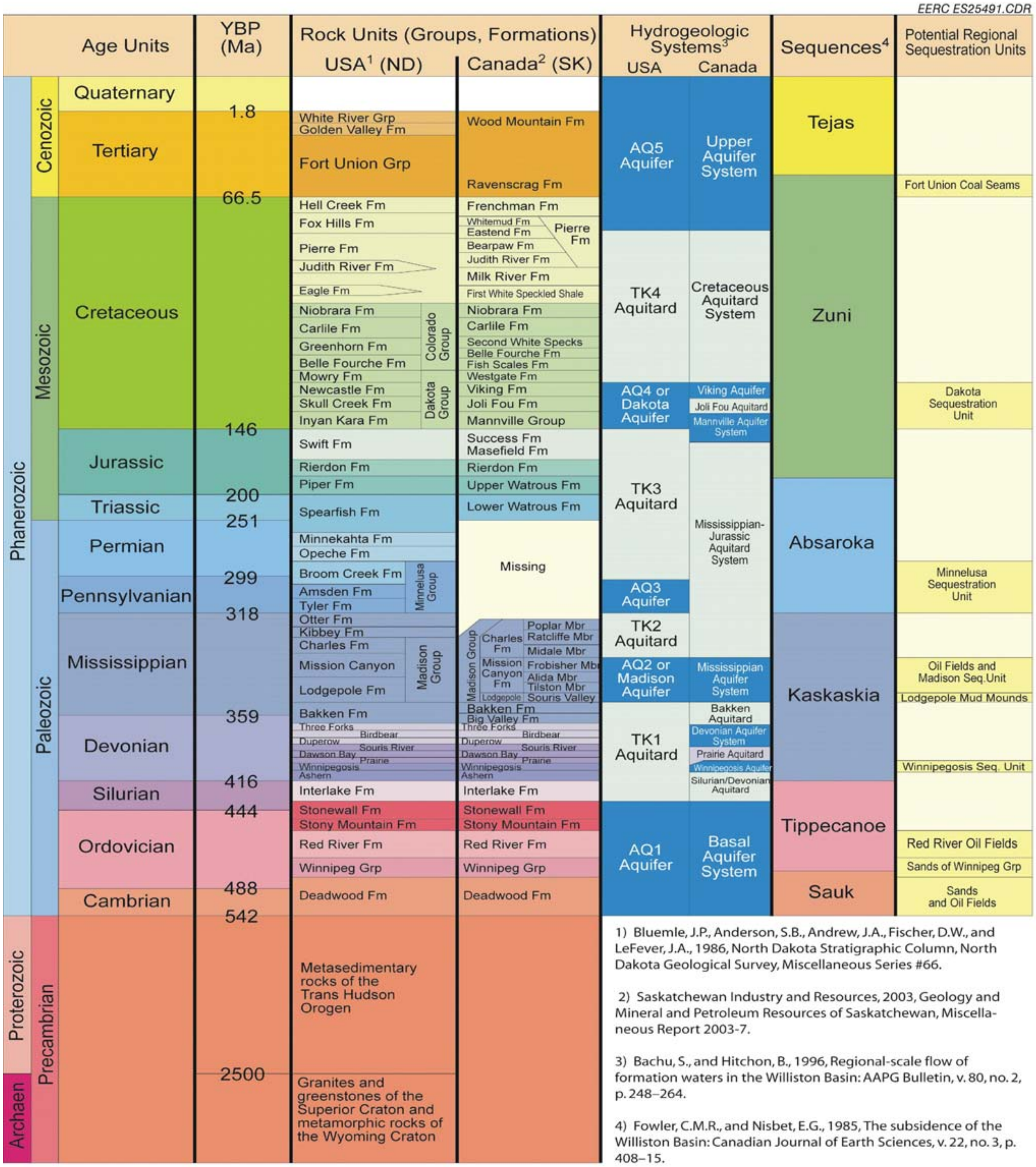
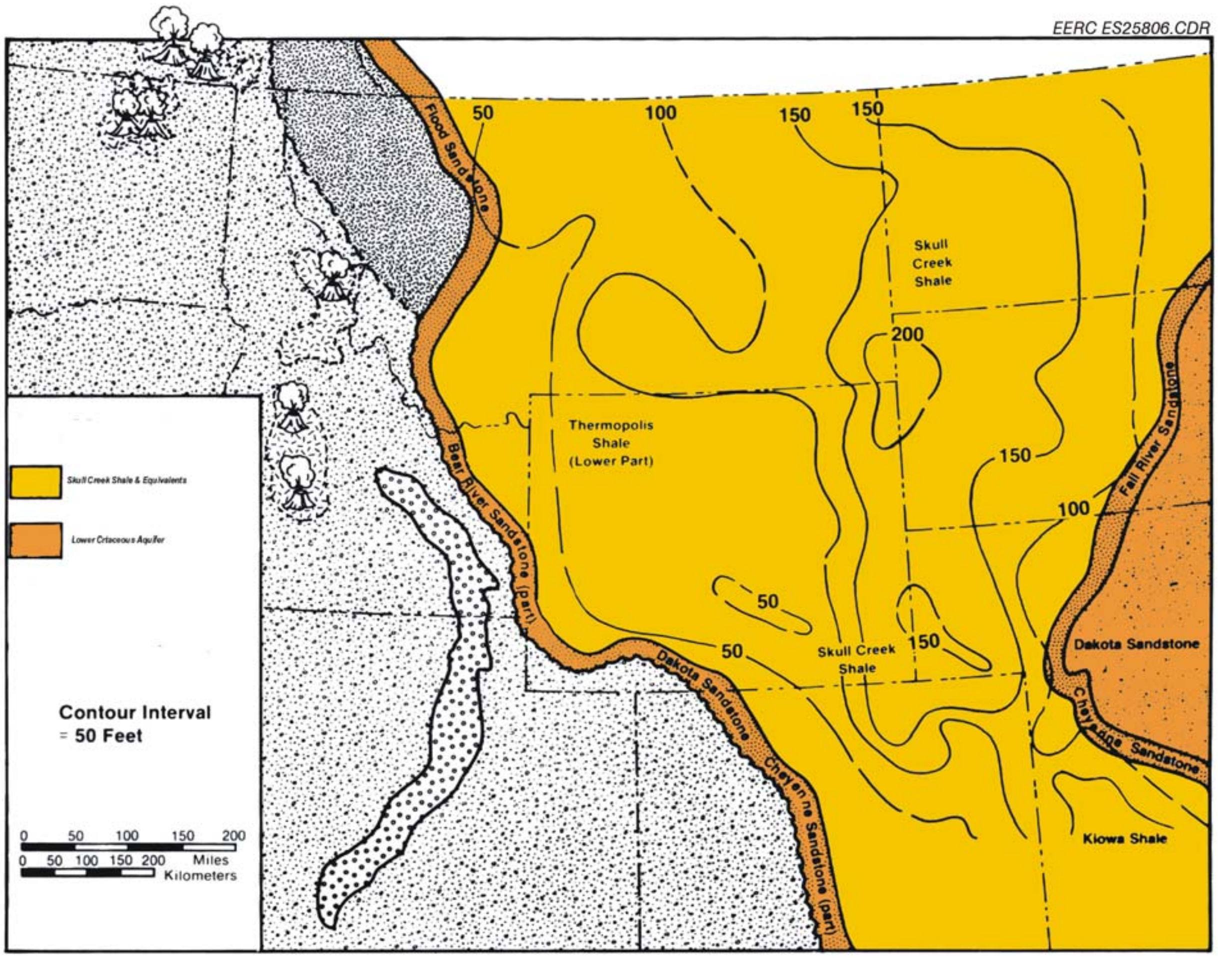


Figure 1. Williston Basin stratigraphic and hydrogeologic column.



Isopach map of the Skull Creek Shale. The base map is modified from the Geologic Atlas of the Rocky Mountain region.

Figure 15 Taken from Burtner & Warner, 1984

Figure 2. Skull Creek isopach.

The lower contact with the Inyan Kara is conformable (LeFever and McCloskey, 1995; Leckie et al., 1994).

LITHOLOGY

Clastic

SUBDIVISIONS

None

LITHOFACIES

The Skull Creek Formation is described as primarily a shale that is medium to dark grey, soft, and micaceous. Bluemle and others, (1986) state that there is a light grey, fine-grained calcareous sandstone lithology present within the shale in the eastern North Dakota portion of the basin.

DEPOSITIONAL ENVIRONMENT

Marine

DEPOSITIONAL MODEL

The shales of the Skull Creek are marine in origin and represent the initial widespread transgression of the Cretaceous sea onto the Western Interior Basin (Caldwell, 1982; LeFever and McCloskey, 1995). LeFever and McCloskey also propose an offshore marine setting for the sandy lithologies present in the formation, noting that “they are not thick or extensive enough to represent shoreline deposits.”

RESERVOIR CHARACTERISTICS

The Skull Creek shale represents a confining layer.

HYDRODYNAMIC CHARACTERISTICS

Case (1984) states that calculations for hydraulic conductivity of the Skull Creek from digital modeling are 1.5×10^{-11} ft/sec by Neuzil (1980) and 8×10^{-11} ft/sec by Milly (1978). Citations for Neuzil and Milly can be found in Case (1984).

Butler (1984) states that the vertical hydraulic conductivity in North Dakota ranges from 8×10^{-8} to 5×10^{-10} ft/sec (2.4×10^{-8} to 1.5×10^{-10} m/sec).

HYDROCARBON PRODUCTION

No production to date.

SINK POTENTIAL

The Skull Creek is not considered to be a good candidate for CO_2 sequestration.

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