

## Abstract

The Inyan Kara Formation of northwestern North Dakota is the lowermost unit of the Lower Cretaceous Dakota Group. The formation does not crop out within the state and limited core is available for study. The formation is the primary subsurface injection zone for produced water where over a million barrels/day is injected. This work examines the subsurface stratigraphy of the Inyan Kara within McKenzie/Williams counties as part of a statewide investigation to identify potential areas for produced water injection. A partial core from the Amerada Petroleum Corporation, Math Iverson #1 (NDIC: #165, API: 33-105-00097-00-00) was used along with wireline logs from numerous wells to develop a working sequence stratigraphic model.

Numerous sedimentary structures and sequence stratigraphic surfaces are observed in both core and on logs. Gamma-ray signatures from well logs are characterized by a distinct, blocky pattern for coarser-grained sandstone deposits, commonly over 100 feet thick. These sandstones then grade upwards into finer-grained units of interbedded sand, silt, and clay. Based on these observations, the Inyan Kara can be subdivided into two units that reflect the overall sea-level rise of the Early Cretaceous. The lower half is interpreted to be a "fluvial" dominated, incised valley-fill complex that can be sub-divided into the following systems tracts: 1) initial incising of the lowermost valley during falling stage; 2) filling of the valley during low-stand and early transgression; 3) initial incursion of the seaway with subsequent flooding and development of estuarine deposits during transgression; and 4) progradational marine deposits of the high stand. This same depositional sequence is repeated in the upper Inyan Kara and into the overlying lower shales of the Skull Creek Formation, with the lower sequence capped by a subaerial unconformity.

The model shows coastline evolution through time and correlation of sequence stratigraphic surfaces basinward/landward from northwestern North Dakota. It can be used to predict the presence and extent of incised-valley-fill sandstone bodies for produced water disposal, as well as distinguishing such bodies from other coarser-grained units that have lesser potential for injection. Initial results indicate that sandstones of the valley-fills are well connected along valley trends (10's of km) and within valleys (km); whereas, coarser deposits of the estuarine, marginal marine, and interfluve facies are not as laterally continuous or well connected.

## Introduction

The Lower Cretaceous Inyan Kara Formation (Dakota Group) is the primary subsurface injection zone for produced water in North Dakota (Fig. 1). In support of produced water disposal operations in industry, the North Dakota Geological Survey (NDGS) is studying the Inyan Kara in detail across the entire State of North Dakota. This poster is based on initial work in northwestern North Dakota (McKenzie and Williams counties) where Inyan Kara cores are present and thousands of well logs are available for study. The focus of this report is on the Math Iverson #1 (Williams Co.) well as it has one of the few quality Inyan Kara cores in the state. Well logs from hundreds of wells were then evaluated across the state to develop a sequence stratigraphic model.

The Inyan Kara Formation consists of sandstones and shales deposited in incised valleys along the coastline of the Cretaceous Western Interior Seaway (Figs. 1, 2, 3, and 4). These valleys were cut by north-northwesterly flowing rivers that drained into the seaway from highlands in southern North Dakota, Minnesota, and Canada. The valleys formed as the Cretaceous seaway withdrew (regressed) from North Dakota twice over a period of approximately 10 million years. The seaway transgressed back into the area forming estuaries, and sands were deposited in the valleys as sea-level rose, again in two transgressive events. Eventually the sea completely flooded all of North Dakota and the overlying marine units were deposited (Figs. 1 and 2).

Inyan Kara sandstones deposited in these valleys are thick, porous (20-30% porosity), and permeable (Darcy level) enough to accept the injected water. The lateral continuity of the units allows for injected water to easily move into the formation, especially along valley trends. Figure 1 shows a typical Class II injection well.





North Dakota stratigraphic column showing the Lower Cretaceous Dakota Group (Murphy et al., 2009).

## Sequence Stratigraphy of the Inyan Kara Formation, Northwestern North Dakota **Extracting the Maximum from Minimal Core and Outcrop Data**

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Paleogeographic map of North Dakota area during Inyan Kara time (c.a., 106 Ma). Modified from Blakey, 2014.





Type log and core for study (Amerada Petroleum Corporation, Math Iverson #1, Williams County, SWNW Sec. 1, T.155N., R.96W.). Js = Jurassic Swift Formation, Kik = Cretaceous Invan Kara Formation, Ksc = Cretaceous Skull Creek Formation

