Sequence Stratigraphy of the Inyan Kara Formation, North Dakota

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ABSTRACT

The Inyan Kara Formation of North Dakota is the lowermost unit of the Lower Cretaceous Dakota Group. 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 North Dakota 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) in Williams County was used along with wireline logs from thousands of wells to map the Inyan Kara in the subsurface and develop a working sequence stratigraphic model. Five detailed 1:100,000 scale Inyan Kara sandstone isopach maps (Crosby, Parshall, Stanley, Watford City, and Williston) from the heart of the Bakken in northwestern North Dakota have been published to date, with three more (Grassy Butte, Kenmare, Killdeer) planned for 2017. 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 highstand. 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. 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.