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Characterization of a reservoir ooid shoal complex and Artificial Neural Networks application in lithofacies prediction: Mississippian St. Louis formation, Lakin fields, western Kansas

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ABSTRACT

Residing in the Hugoton embayment of western Kansas, the Lakin field has produced over 1.8 million bbl of oil from reservoir quality zones within the St. Louis Limestone (Mississippian, Meramecian) oolitic deposits. This study focuses on improving the understanding of the orientation, geometry, and spatial distribution of ooid shoal complexes in Kearny County, Kansas. To this end, the interpretation of petrophysical log data integrated with a facies analysis conducted on 400 ft (122 m) of core from three separate intervals provided the basis, in this study, for understanding the vertical stacking patterns and how facies transitions relate to reservoir quality zones within the ooid shoal complexes. A supervised Artificial Neural Network (ANN) has been trained and validated, based on input-layer of geophysical well-logs and an output-layer of core-lithofacies, for lithofacies prediction where core samples were not available. The porous ooid grainstone is the principal reservoir facies, with an average log-derived porosity measurement of eighteen percent. Ooid shoal complexes are present in St. Louis Zone B and C, with thicknesses reaching up to 10 ft (3 m) and 24 ft (7 m) respectively. These complexes are NW-SE trending and laterally extend up to 16 mi (26 km), with economically viable patches covering up to 8 mile (13 km), and record roughly 2 mile (3 km) in width. The apex of the shoal contains the highest porosity values, with significant porosity reduction towards the shoal margins due to the increased cementation. This study provides information on the characteristics of oolitic deposits for the purpose of understanding controls on reservoir heterogeneity to aid in finding additional hydrocarbon reserves in the St. Louis Limestone in western Kansas.

1. Introduction

Mississippian-aged rocks in western Kansas represent two distinct events; 1) the flooding of a craton by epicontinental shallow seas and deposition of Kinderhookian-Meramecian aged skeletal and oolitic limestone, and 2) a relative sea level fall during the Late Mississippian with associated deposition of interfingered marine and continental sediments (Handford, 1988). During the Early Mississippian, epicontinental seas covered the entirety of Kansas, but the transition into the Late Mississippian records that epicontinental seas inundated only the western and southern portions of the state. During this period, an amalgamation of factors such as global paleoclimate, sea level change, and geochemical factors, along with optimal regional paleogeographic and tectonic conditions, resulted in extensive deposition of marine oolitic limestones across the continent of North America (Qi, et al., 2007; Wilson, 1975; Wilkinson et al., 1985; Handford, 1988; Ettensohn, 1993; Keith and Zuppann, 1993). These oolitic limestones make excellent reservoir facies, resulting in numerous producing fields across the Mid-Continent region.

The study area within Kearny County is in the northwestern portion of the Hugoton embayment, which is a low relief extension of the Anadarko Basin (Fig. 1). A structurally high, subsurface uplift northeast of the Hugoton embayment is referred to as the Central Kansas uplift. This uplift separates the Hugoton embayment from two other significant basins in Central Kansas; the Salina and Sedgwick basins (Goebel, 1968). The total thickness of the Mississippian Limestone ranges between 300 and 500 ft, deepening towards the Anadarko Basin in southwestern Kansas (Goebel, 1968). In western Kansas, the St. Louis Limestone reaches a thickness of 200 ft. (60 km), and is traditionally divided into four informal zones (St. Louis A-D). Only zones B and C will be referred to in this study, as these are the only oolite-bearing zones (Fig. 2).

Within the widespread St. Louis Limestone oolitic deposits, reservoir quality zones are of high interest to oil and gas companies, which

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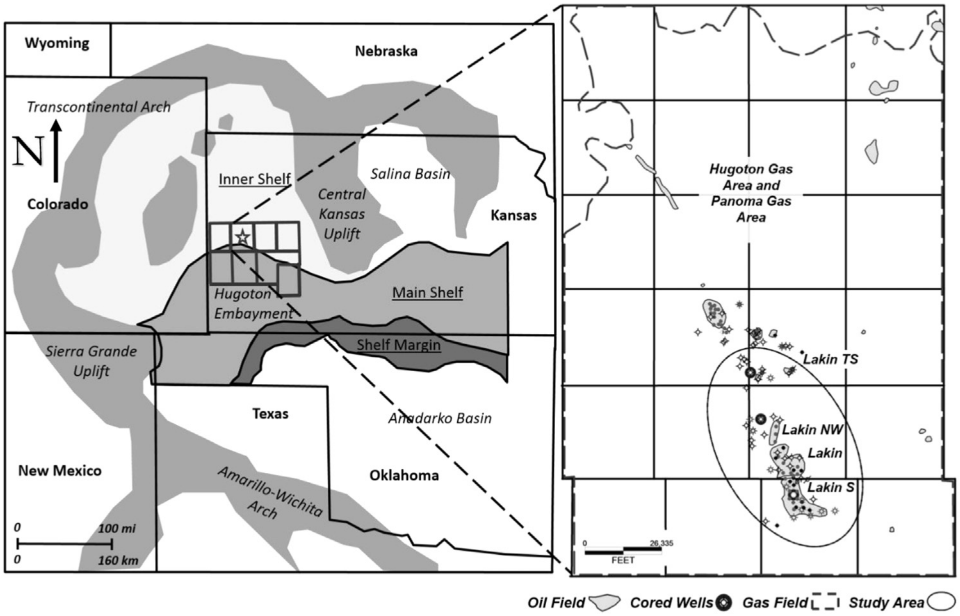

Fig. 1. Mississippian paleogeography of western Kansas (Lane and De Keyser, 1980). The starred square represents Kearny County. Kearny County, enlarged on the right, resides in the Hugoton and Panoma Gas Area which contains numerous oil fields, many of which are oolitic reservoirs. Well symbols same as Fig. 3. Latitude and longitude (NAD27) coordinates of study area; −101.21 to −101.3 and 37.79 to 37.88, respectively.

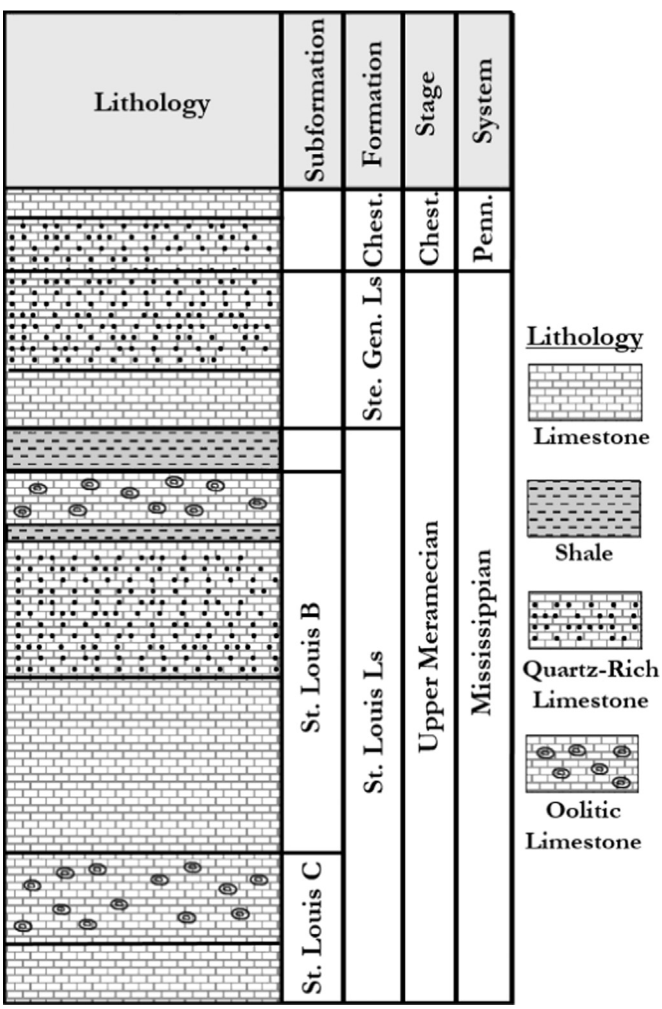

Fig. 2. Upper Paleozoic stratigraphic column, created from study area, illustrating the carbonate dominated Ste. Genevieve/St. Louis Limestone. Quartz-rich and oolitic zones are widespread in Kearny County, Kansas. (modified from Qi. and Carr, 2003).

has resulted in numerous studies over hydrocarbon fields in western Kansas. Residing in Kearny County, Kansas, the Lakin field is producing from reservoir quality zones within the St. Louis Limestone oolitic deposits. Previous to this study, an in-depth study on the internal framework of these producing zones in Kearny County has never been conducted. The purpose of this study is to create an understanding of the orientation, geometry, distribution, and continuity of depositional facies as pertaining to the reservoir and non-reservoir quality zones within the St. Louis oolitic deposits. The objectives of this study include; (1) investigate what the environmental setting was during deposition of Ste. Genevieve/St. Louis (Upper Meramecian) sediments, (2) determine the depositional facies within the parameters of a sequence stratigraphic framework, (3) establish an understanding of the distribution and continuity of the reservoir quality lithofacies, and (4) attempt to train and apply an Artificial Neural Network (ANN) using an input layer of geophysical well-logs and respective core-lithofacies to utilize wire-line logs to predict differentiate lithofacies, specifically reservoir-quality flow units, and to assess whether significant sequence stratigraphic surfaces can be correlated throughout the study area using wire-line log curves.

2. Methods

Three wells in the Kearny County study area were chosen based on satisfying the following conditions: i) availability of extensive core intervals available (> 100 ft.), ii) the available core samples represented the Upper Meramecian intervals, and iii) the core intervals were located within a proximal distance relative to each other to limit variability in the subsurface (Table 1; Fig. 3). Following the guidelines of the AAPG Sample Examination Manual by Swanson (1981), a total of 401 feet of core was described following Dunham (Scholle et al., 1983) to define the lithofacies and their respective depositional environment. In order to augment the initial hand-sample scale evaluation, thirty-six thin sections were prepared for detailed facies analysis. The thin sections were impregnated with blue epoxy, which provided an effective way to identify porosity of each facies. To help differentiate carbonate mineralogy, one half of each thin section was saturated and subsequently stained by alizarin red S and potassium ferricyanid. Generally, in the presence of dolomite or calcite, this