Perographic and Petrophysical Characteristics of the McCracken Sandstone Member of the Elbert Formation Lisbon Feild, Paradox Basin, Utah

Lisbon Oil Field Term Project

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ABSTRACT

The McCracken Sandstone Member of the Devonian Elbert Formation is located in Lisbon Oil Field, in the Paradox Basin in Southeastern Utah. After conducting 200 point counts on 20 thin sections from well B-614 I found the depositional environment and diagenesis to affect the variability of porosity and permeability within a given lithologic unit. I found the McCracken Sandstone to contain three major lithologic categories; sandy dolomite, dolomitic sandstone and quartz sandstone. A different depositional environment deposited each lithologic category. In turn, the depositional environment and the type of diagenesis that took place are responsible for the variability of porosity and permeability found in the McCracken Sandstone.

INTRODUCTION

The variability of porosity and permeability within a given lithologic unit has long been a puzzling question. There are many suggestions to why this variability occurs, but no one has determined one key factor. Important factors are as follows: Depositional Setting, Diagenesis and Secondary events that occur after lithification and burial. This kind of research intrigues me, and I am determined to discover the key to porosity and permeability variations within a lithologic formation. In order to determine the important contributors and correlations to this variation, I completed a detailed study on a formation of choice, that represents the variability and questions I am looking to answer. I conducted a petrographic analysis of the McCracken Sandstone by point-counting 20 thin sections, analyzing well core data, interpreting the depositional environments and graphically representing all data that correlated. Since the McCracken Sandstone is 8,900 feet underground where my thin sections came from, I visited an outcrop where I measured a detailed stratigraphic section. The measured section and mineralogy of the outcrop are important in determining the depositional setting of the McCracken Sandstone and aid in understanding how diagenesis has affected the maturation process of this formation. After I had concluded the fieldwork, I compiled all of the petrographic information and determined many correlations in Excel.

BACKGROUND

The McCracken Sandstone Member of the Late Devonian Elbert Formation occurs throughout the Paradox Basin of eastern Utah and western Colorado (Fig. 1). The Elbert Formation occurs above the Aneth Shale and below the Ouray limestone. Structurally, Lisbon field is characterized by a northwest-southeast trending anticline truncated on the northeast by the Lisbon-McIntyre Fault (Cole and Moore, 1996)(Fig. 2). At Lisbon field, the McCracken is a major hydrocarbon producer and consists of a 10-35 meter thick sequence of shallow-marine sandstone, mudrock, limestone, and dolomite. Hydrocarbon production comes primarily from littoral to sublittoral sandstone beds in the lower McCracken. This is because in Early Devonian time, a shallow sea transgressed through Nevada into western Utah and eventually covered the Paradox Basin area by the Late Devonian (Spencer, 1900; Baars and Campbell, 1968; Baars, 1972; Campbell, 1981; Stokes, 1986). The Aneth-McCracken vertical profile at Lisbon suggests that the Devonian Transgression was punctuated by three short term, autocyclic transgressive-regressive cycles, which correspond to the lower, middle and upper intervals of the McCracken (Cole and Moore, 1996)(Fig. 4).

Depositional environments that occur in the Lisbon Field included high-energy offshore bars or barrier islands that were flanked to the northeast by lagoons, bays and supratidal flats (Cole and Moore, 1996)(Fig. 3). The McCracken Sandstone contains a significant amount of dolomite (42 %) and siliciclastics (54%). The siliciclastics were probably supplied by longshore transport from distant deltaic centers. There are three major shoaling-upward cycles present that are separated by major transgressive or marine flooding surfaces. These transgressions are regional and probably not eustatic. The three major shoaling-upward cycles are primarily intertidal shoal or subtidal-intertidal deltaic systems. It also turns out that the subtidal-intertidal systems are the major hydrocarbon producers with in the McCracken Sandstone. In addition theses intertidal systems have the largest amounts of quartz and the greatest amount of porosity (Table. 1). Based on sedimentologic characteristics, the McCracken can also be subdivided into 18 depositional episodes, which are designated informally by the letters A-R (Fig. 4).

METHODS

I performed a petrographic analysis on 20 thin sections by conducting 200 point-counts per slide. These 20 representative thin sections were made from core-plug samples collected from the Lisbon B-614 well, at depths ranging from 2711 to 2742 meters. I also did a detailed measured section and sample collection from an outcrop of the McCracken Sandstone on Colebank Pass (Fig. 5). In addition, I have taken the data, entered it electronically into an Excel spreadsheet and evaluated correlations between significant characteristics that affect porosity and permeability variations within the McCracken Sandstone. The depositional setting is another essential factor in understanding porosity and permeability characteristics. I used a very detailed stratigraphic column (Fig. 6) and determined the depth and lithologic facies for my 20 thin sections had. I discovered that there is a major connection between high porosity and lithic sand grains.

RESULTS

The petrographic data show that the framework grains represent 6 to 91 percent of the samples and mainly consist of monocrystaline and polycrystalline quartz, with minor skeletal fragments. Dolomite (7-88 modal percent) and quartz (0-18 modal percent) are the dominant cements. Average grain size ranges from 125 to 1,410 microns, whereas sorting is variable (well to poor) and most framework grains are subrounded to subangular.

Thin-section porosity is highly variable (0-25 modal %). Usually, the coarser grained and better sorted samples have the highest modal porosity values, and correspondingly, the highest measured porosity and permeability values from core plugs. For the sample suite, core-plug porosity values range from 0 to 15 percent, and permeability values range from 0.001 to 63.0 millidarcies.

After careful analysis of the thin section work I found three main lithologic types, sandy dolomite, dolomitic sandstone and quartz sandstone (Fig. 7a, 7b, and 7c). Table 2 shows the three sample suite divisions separated by color. Sandy dolomite is yellow, dolomitic sandstone is orange and quartz sandstone is green. These sample suite divisions were made according to the amount of cement present. If the thin section contained less than 20 percent cement it was classified as quartz sandstone. If the thin section had between 21 and 50 percent cement it was classified as dolomitic sandstone. And if the thin section has greater the 51 percent cement it was classified as a sandy dolomite. Sandy Dolomite had the greatest amount of cement, ranging from 51 to 85.5 percent, and the smallest porosity value of 0 %. In addition the quartz sandstone suit had intermediate porosity values ranging from 3 to 10 percent. The intermediate cement values and high porosity values belong to the dolomitic sandstone, 21 to 45.5 percent and 0 to 15 percent respectively. I attribute some of the larger porosity values in the sandy dolomite suite to secondary porosity that occurred after lithification. I mention this because while performing the point counts on the sandy dolomite and dolomitic sandstone I noticed “skeletal ghosts” or skeletal fragments that were once calcium carbonate limestone, that have been replaced by secondary dolomite.

The environmental setting that best fit the three sample suites are; sandy dolomite – intertidal, dolomitic sandstone - deltaic intertidal, and quartz sandstone – high-energy offshore bars or barrier islands. The intertidal assessment to the sandy dolomite suite is because the quartz sand must of came from a deltaic system far away during a regression period. The calcium carbonate limestone then was deposited during a transgression where the ocean stopped the deltaic deposits from being deposited. Because these minerals were deposited on a transitional zone or beach area the waves had a role in mixing the sand and carbonate together. This is how the sandy dolomite was formed. Some time after the sand and carbonate had been lithified the magnesium then replaced the calcium, forming dolomite. The dolomitic sandstone suit was formed by nearly the same process, only this time there was more sand deposited from distant deltas and less carbonate deposited from shorter transgressive events. As mentioned before the transgressive carbonate was replaced by dolomite after deposition and lithification. This is shown by the “skeletal ghosts” found during point counting. The quartz sandstone is believed to be deposited in off shore bars and barrier island environments. This is because a high-energy system is needed to deposit the sand, but the quartz sand in the thin sections were too well sorted and fine grained to be deltaic or main land beach environments. Thus I conclude the quartz sandstone is being deposited in an off shore barrier island environment with calcite cement forming after deposition.

Finally, I statistical analysis to determine the correlation factor (r^2) between sample characteristics. These correlations were performed in Excel. I compared framework grains to porosity, cement to porosity, tool porosity to thin section porosity and framework grains to cement. I only accepted the correlation as a good correlation if the r^2 value was between .5 and 1. I discovered only three good correlations. They are as follows; framework grains vs. porosity for sandy dolomite with a correlation value of .6932 (Fig. 8a), dolomite cement vs. porosity for dolomitic sandstone with a correlation value of .6739 (Fig. 8b), and dolomite cement vs. porosity for sandy dolomite with a correlation value of .5744 (Fig. 8c). The correlation of framework grains vs. porosity for the sandy dolomite is as follows; the correlation is good because as the framework grains increase so does the porosity value. Likewise the correlation between the dolomite cement and porosity for the dolomitic sandstone is because as the amount of cement decreases the amount of porosity increases. The correlation between dolomite cement and porosity for the sandy dolomite continues as the amount of cement increases the porosity value decreases. I found it somewhat disconcerting that two of the three crossplots displayed a good correlation for porosity in the sandy dolomite suite. At first I found this to be opposite my hypothesis of dolomitic sandstone and quartz sandstone to have better correlation values for porosity than sandy dolomite. However after I examined the cross plots further I found them supportive of my hypothesis after all. Originally I had thought that because the correlation value was good between cement and porosity in the sandy dolomite suite that this meant porosity values were high when the cement was high. However, this is not the case the cross plots actually displays that when the cement value is high in the sandy dolomite suite that the porosity values is in turn low, as expected from the beginning.

DISCUSSION

In addition these intertidal systems have the largest amounts of quartz and the greatest amount of porosity (Table. 1). I discovered that there is a major connection between high porosity, high framework grains and low cement values. However I did find a sandy dolomite thin section to have a porosity value of 8.5 percent while attaining a cement percentage of 85.5 percent. Variability of this sort I attribute to secondary porosity, which was produced by dissolution of carbonate cement and framework grains after deposition. In conclusion there are several contributing factors to why porosity and permeability vary within a given lithologic formation. However, after studying the 20 thinsections and evaluating the depositional settings I am convinced that the amount of cement present in a reservoir rock has the largest effect on porosity. This is because of the correlation values I received for cement vs. porosity in the sandy dolomite and dolomitic sandstone sample suites. Even though I did not receive as many good correlation values from the crossplots as anticipated, the other data collected did show significant relationships between depositional setting, amount of cement (diagenesis) and framework grains and their effects on porosity and permeability within the McCracken Sandstone member of the Elbert Formation. In addition I made large improvements on my understanding of porosity and permeability and what affects their variability.

CONCLUSIONS

After conducting 200 point counts on 20 thin sections, performing a detailed measured section, examining two starigraphic columns and correlating thin section characteristics with crossplots I have determined porosity to be a function of the combination of depositional setting and diagenesis or the amount of cement present within a sample. The type of depositional environment effects what minerals are present, such as quartz sand or dolomite cement, in a lithologic unit and these minerals affect the amount of porosity available. In addition I found diagenesis or the amount of cement present in a lithologic unit to affect porosity values both positively a negatively. In most cases where cement values are high the porosity is affected negatively, meaning porosity is low. However, cement can affect porosity positively when dissolution occurs during diagenesis and secondary porosity is formed as in sample # 63.

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