PS Study of Calcite Cement in Submarine Fan Complex in the Lower Cherry Canyon, Delaware Basin, Texas*

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Abstract

Calcite cement is distributed throughout the reservoir quality sandstones in the South Wells Member of the Cherry Canyon Formation in the Ford Geraldine Field area, western Delaware Basin, along the Reeves-Culberson County line, Texas. Irregularly distributed calcite cement occurs in the form of tightly cemented zones with associated reduction in porosity. The volume of calcite cements therefore is probably the dominant control on heterogeneity in porosity and permeability. From four cored wells (~750 ft of core) and thin sections, there are four submarine channel complex intervals of sandstone are identified within the South Wells Member that are separated by thick (~15 to 18 ft) condensed sections of mudstone and associated siltstone.

Within each channel interval, one to six Bouma Sequences were observed that are separated by very thin intervals of siltstone or mudstone. These sands are characterized by irregularly distributed calcite-cemented zones those are contrasted markedly with the surrounding silica and clay-cemented sandstones. Observed calcite cemented zones are divided based on their shape as blocky, spike-like, and elliptical bodies. The most abundant cemented intervals appear as blocky zones that are two to 12 inches thick, whereas spikes have visible terminations in core and are less than one inch thick. Elliptical zones have displacive texture and a maximum diameter of two inches.

Prediction of the distribution of these calcite-cemented, non-reservoir intervals is an important step in reservoir characterization because their distribution influences both the path of fluid flow and reservoir compartmentalization. The calcite-cemented zones appear to be capable of acting as either barriers or baffles to flow within the reservoir. This study documents calcite cement distribution and morphology in the sands in an attempt to predict the lateral extent of these cemented- reservoir intervals by correlating the widely spaced well data in related submarine fan complexes. Evidence of fossils dissolution and the presence of large carbonate rock fragments in the Cherry Canyon suggest that carbonates deposited within the channel sands could be a potential source of calcite cement. The presence of these potential barriers and baffles to fluid flow within highly complex reservoir geometries will affect primary, water-flood, and CO_2 flood recoveries.

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1. Abstract

Calcite cement is found to be distributed throughout the reservoir quality sandstones in the South Wells Member of the Cherry Canyon Formation in the Ford Geraldine area, western Delaware Basin, along the Reeves-Culberson county line, Texas. Irregularly distributed calcite cement occurs in the form of tightly cemented zones with associated reduction in porosity. the volume of calcite cements therefore is probably the dominant control on heterogeneity in porosity and permeability. From four cored wells (~750 ft of core) and thin sections, there are four submarine channel complex intervals of sandstone are identified within the Southwells Member that are separated by thick (~15 to 18ft) condensed sections of mudstones and associated siltstone.

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Prediction of the distribution of these non-reservoir intervals is an important step in reservoir characterization because they influence both fluid pathways and reservoir compartmentalization. These calcite-cemented zones are capable of acting as either barriers or baffles to flow within the reservoir. Their distribution and morphology is documented in an attempt to predict the lateral extent of these cemented-reservoir intervals by correlating widely spaced well data in related submarine fan complexes. Evidence of fossil sdissolution and the presence of large carbonate rock fragments in the Cherry Canyon suggest that carbonated deposited within the channel sands could be a potential source of calcite cement. The presence of these potential barriers and baffles to fluid flow within highly complex reservoir geometries will impact primary, water-flood, and CO2-flood recoveries.

2. Introduction

The Cherry Canyon Formation is one of the three formations that constitute the Delaware Mountain Group of sediments in the Delaware Basin (fig. 2.1) (King, 1942). The sediments of the Cherry Canyon Formations were deposited as a part of a succession of slope and basin fan complex in the Delaware Basin in west Texas and southeastern New Mexico (fig. 3.1). Calcite cementation is a common observation among Cherry Canyon sands from the Ford and Geraldine Ford fields in the Delaware Basin along the Reeves-Culberson county line (Dutton, 2008).

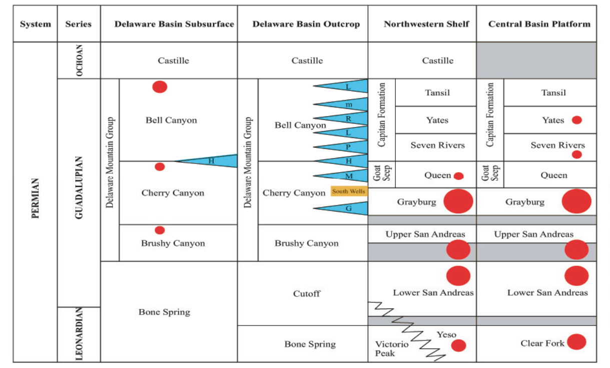

Figure 2.1. Stratigraphic column of the Permian Basin with relative hydrocarbon production from Delware Mountain Group and its time equivalent formations. Blue triangles: carbonate toungues within the Delaware Mountain group. G: Getaway; M: Manzanita; H: Hegler; P: Pinery; R: Rader; m: McCombs and L: Lamar. Golden Rectangle: the South Wells Member. Red Dots represent producing formations with dot volumes indicating relative production from corresponding formations.

Reservoirs in deep-water sandstone of the DMG contained more than 1.8 billion bbl of original oil in place (Holtz, 1995). Until 1998, approximately 350 million bbl of oil was produced from these reservoirs. Statistically, the recovery efficiency of these reservoirs is low; averaging less than 20% since production initiated 80 years ago.

3. Methodology

Multidisciplinary datasets have been used in this study to understand the local as well as the regional spectrum of depositional styles. Cores (750 ft.), thin sections (137) and open-hole logs (17) from different wells have been described in this study (fig. 3.1).

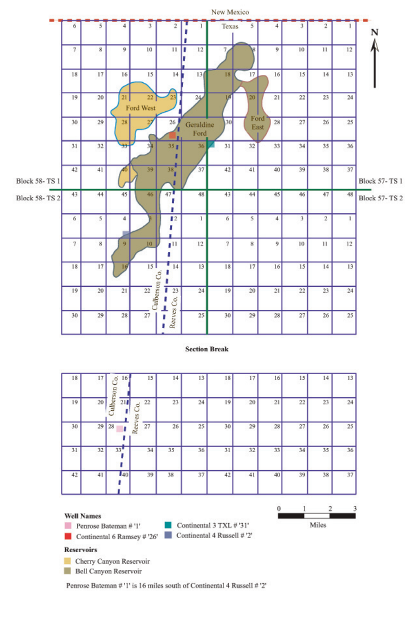

Figure 3.1. Map Showing location of Geraldine Ford, Ford West and Ford East fields (pink circle in the map of right hand side) with reservoir formations of the Delaware Mountain Group in the Delaware Basin. Penrose Bateman # '1' is 12 miles south of the southern margin of the Geraldine Ford field.

4. Observations

4.1. Lithofacies

Three major facies are identified in the Cherry Canyon Formation: fine grained sandstone-coarse siltstone (62%), laminated siltstone (28%) and mudstone (10%) associated with 1-3% carbonate rock fragments.

4.2. Calcite Cementation

Calcite-cemented zones form an average of 6-7% of the total sandstone-siltstone reservoir interval of all the four cores. irregularly distributed calcite cement ranges from 0 - 28% of the total volume Based on shape, three different types of calcite-cemented zones are observed: blocky, spike-like and elliptical (fig. 4.2.1).

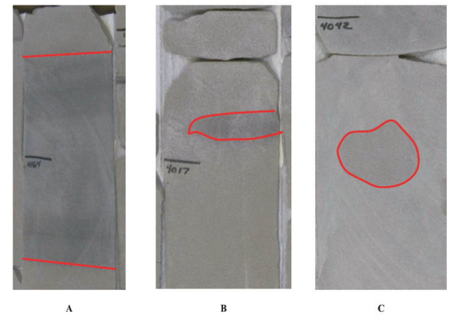

Figure 4.2.1. Core pictures from Continental 3 TXL # '31' showing three types of cemented zones. A: Blocky; B: Spike-like; C: Elliptical.

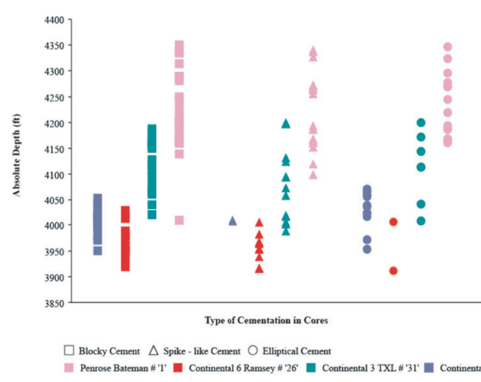

Figure 4.2.2. Distribution of different types of cement on the cores by depth. Cemented zones appear to be randomly distributed regardless of type or depth.

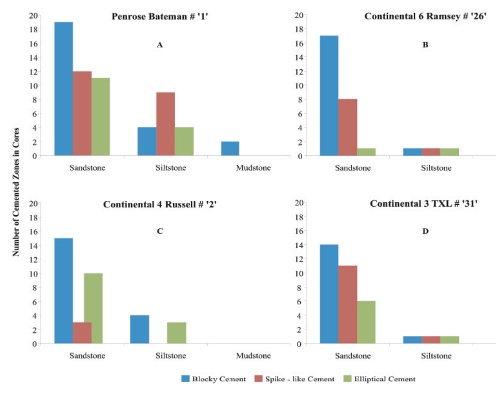

Figure 4.2.3. Distribution of different types of cement on the cores by lithofacies. Blocky cemented zones are seen to be dominant in sandstones.

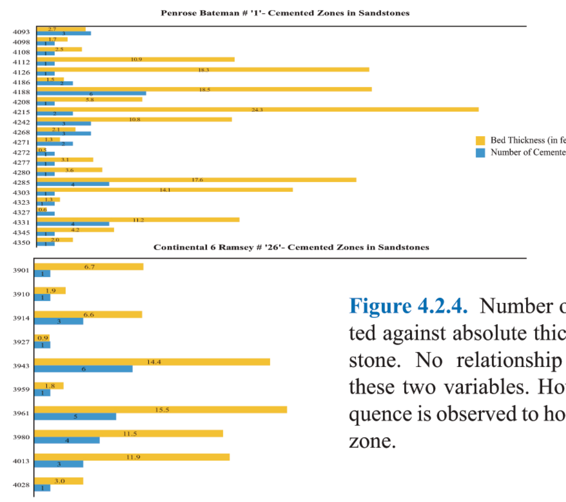

Figure 4.2.4. Number of cemented zones plotted against absolute thickness of the host sandstone. No relationship is observed between these two variables. However each Bouma sequence is observed to host at least one cemented zone.

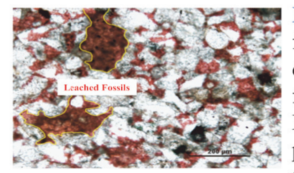

Figure 4.2.5. Photomicrograph showing leached fossil outlines in sandstone. Evidence from fossil dissolution and the presence of carbonate rock fragments coupled with the presence of multiple Bouma sequences suggests that carbonates deposited within the channel sands could be a potential source of calcite cementation.

5. Discussion

5.1. Core Description

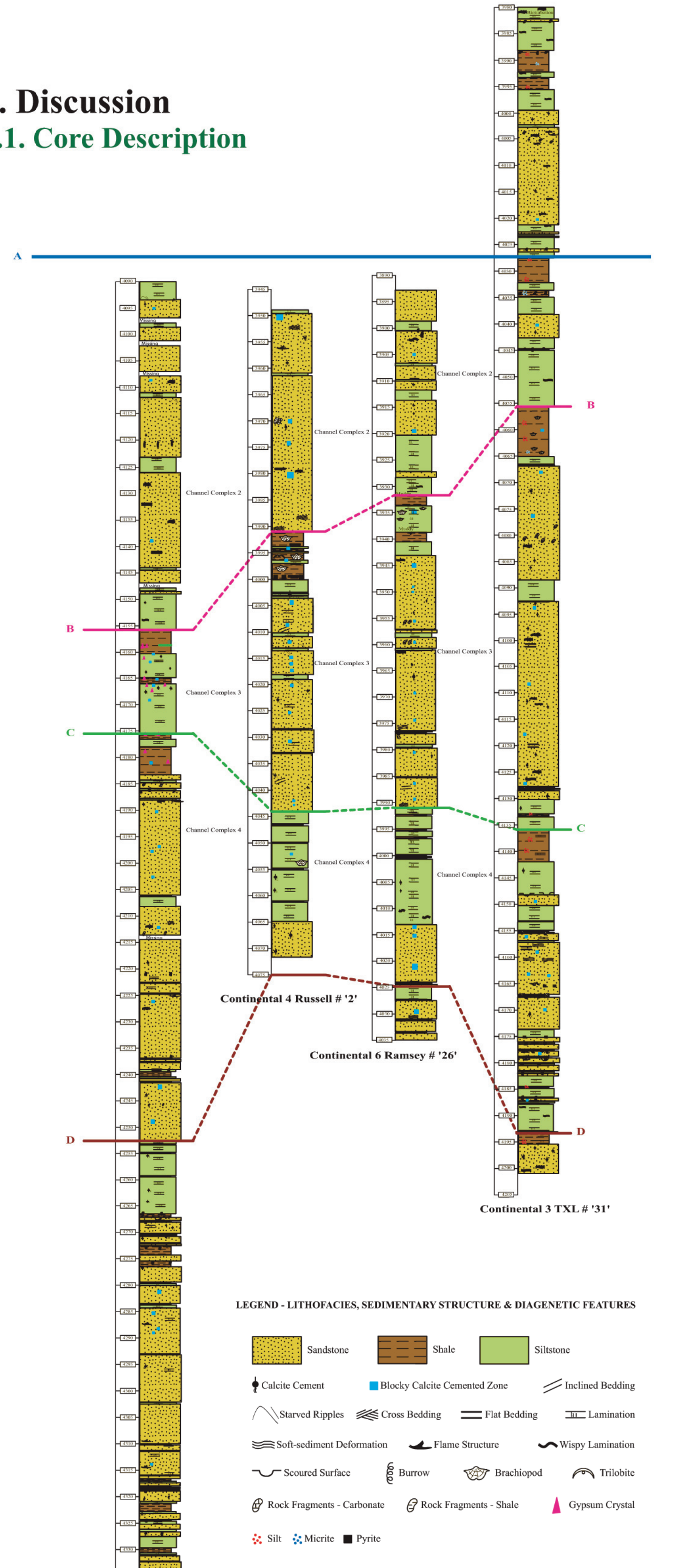

Figure 5.1.1. Core descriptions showing lithofacies and sedimentary structures. A, B, C and D represents widely correlatable condensed section tops.

5.2. Core-Log Correlation

Based on the lithofacies and log signatures, the South Wells Member of the Cherry Canyon Formation has at least four sandstone-rich channel complexes (CC1 to CC4, fig. 5.2.1) which are separated by thick (~15 ft. to 18 ft.) laterally extensive organic rich siltstone & mudstone intervals that are interpreted as abandonment and condensed sections.

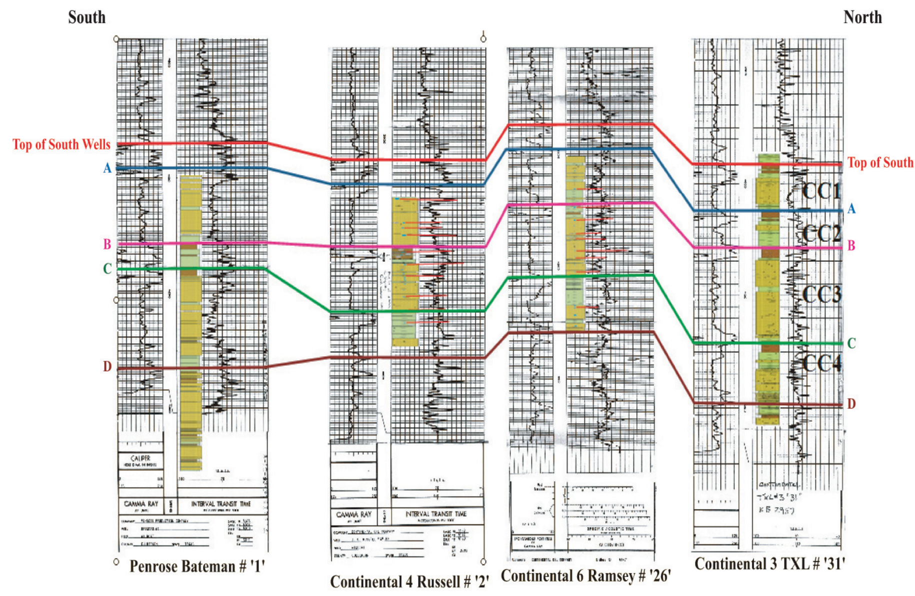

Figure 5.2.1. Structural cross section based on open hole logs. Core descriptions are tied to open hole logs to understand variation of log responses. Thin red lines on logs correlate zones of lower porosity as observed from sonic log to calcite cementation as observed from cores.

5.3. Core Interpretation

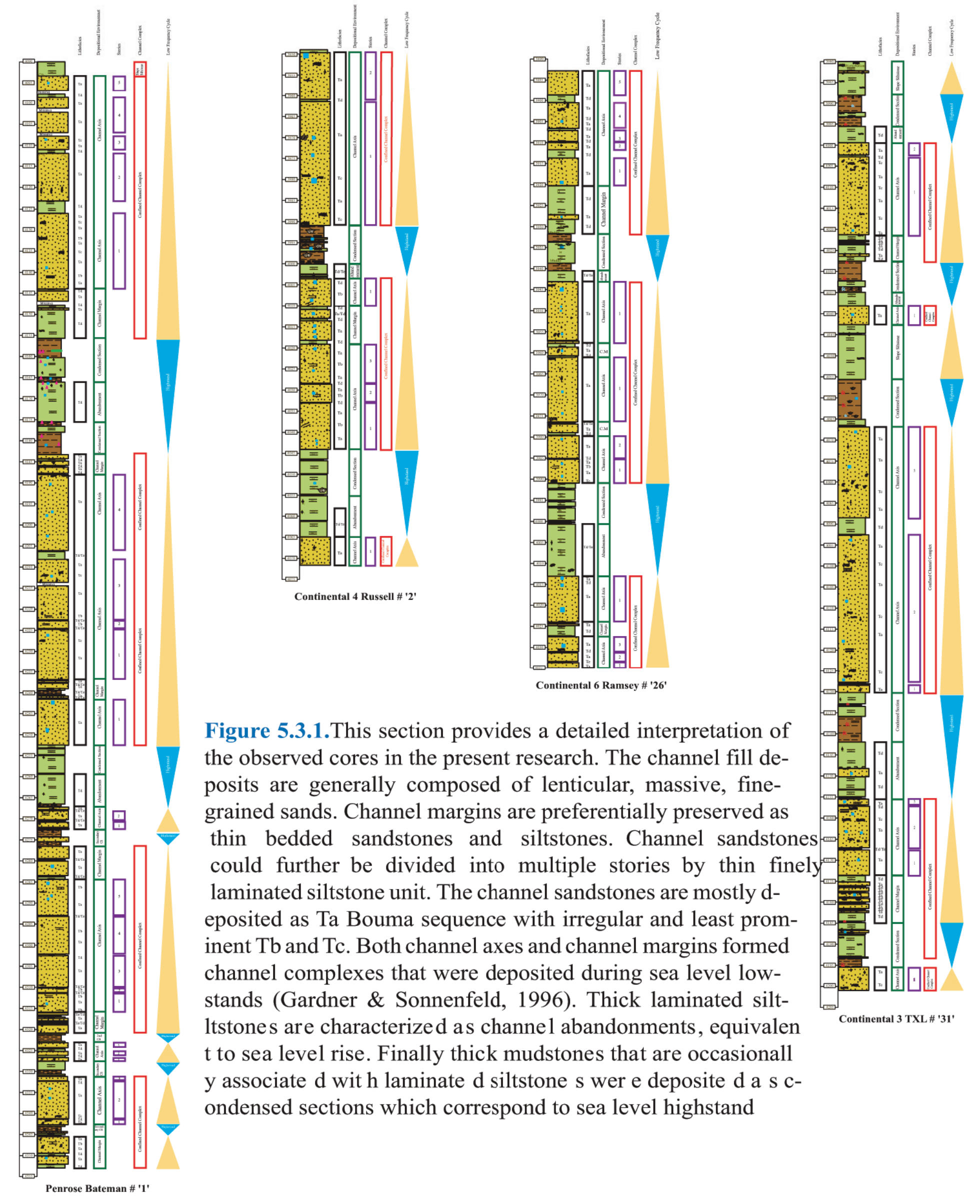

Figure 5.3.1.This section provides a detailed interpretation of the observed cores in the present research. The channel fill deposits are generally composed of lenticular, massive, fine-grained sands. Channel margins are preferentially preserved as thin bedded sandstones and siltstones. Channel sandstones could further be divided into multiple stories by thin finely laminated siltstone unit. The channel sandstones are mostly deposited as Ta Bouma sequence with irregular and least prominent Tb and Tc. Both channel axes and channel margins formed channel complexes that were deposited during sea level lowstands (Gardner & Sonnenfeld, 1996). Thick laminated siltltstones are characterized as channel abandonments, equivalent to sea level rise. Finally thick mudstones that are occasionally associated with laminated siltstones were deposited as condensed sections which correspond to sea level highstand

5.4. Cross Sections

Study of the cross-sections reveals several important attributes of the different channel units (fig. 5.4.1 to 5.4.3). It is observed that the channel-levee complexes are stacked in a compensatory fashion perpendicular to the channel axis. The thick mudstone sections (condensed sections) can be correlated with the "maximum flooding surfaces" on the shelf. The ability of these condensed sections to act as potential vertical permeability barriers, defines their importance in reservoir characterization. The laterally discontinuous channel sand bodie are the potential reservoirs in this system. In these wells, the quality of the reservoirs is directly proportional to sand thickness. Organic rich siltstone and mudstone could together act as horizontal permeability barrier by isolating productive channel sands.

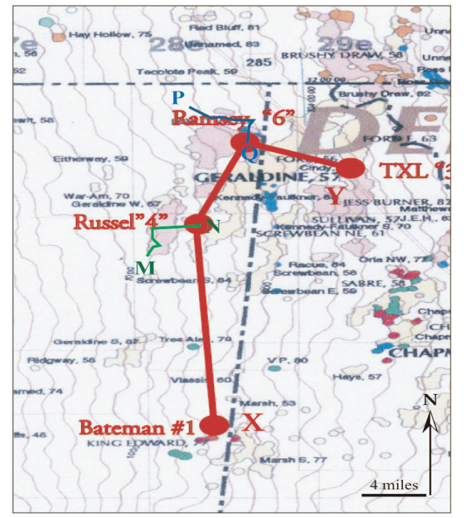

Figure 5.4.1. Map showing cross section lines with respect to core loactions and producing field of the Western Delaware Basin (After Montgomery et. al, 2000). Cross Section on the lines P-Q and M-N are shown in Figure. 5.4.2. Cross Section on the lines X-Y is shown in Figure. 5.4.3.

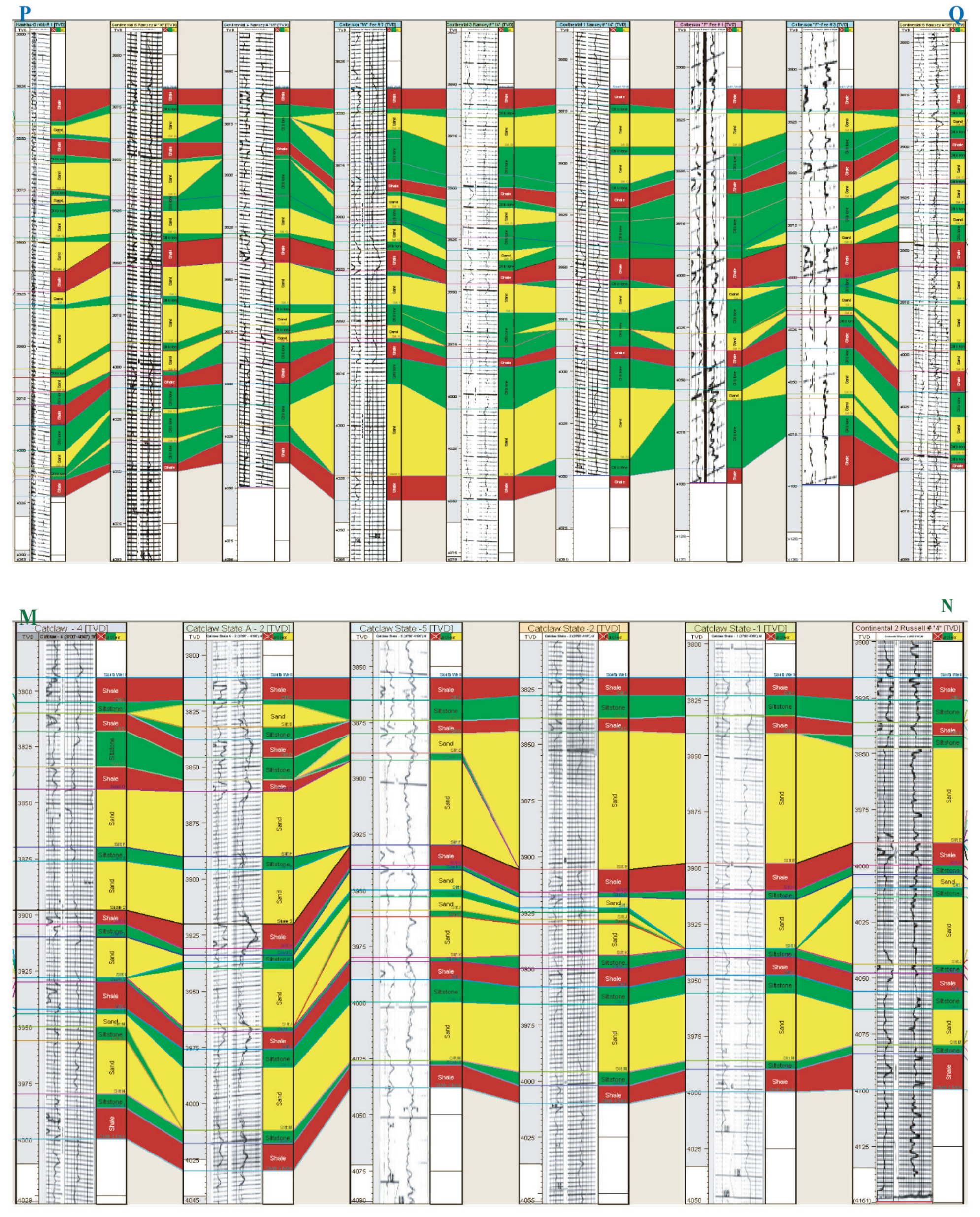

Figure 5.4.2. Stratigraphic cross sections constructed from open hole logs showing stacked channel complexes. Lithofacies legend as in Figure. 5.1.1.

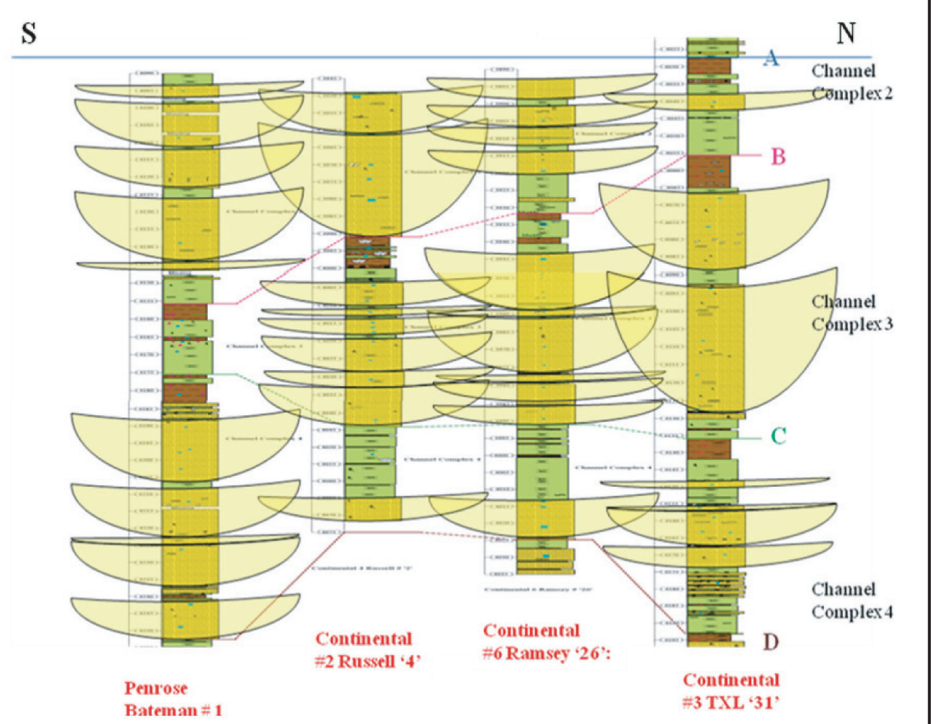

Figure 5.4.3. Channel complexes as interpreted from cores and corresponding logs. Channel Complexes 2, 3; and 4 lie between two condensed section lines A, B, C and D. As can be observed channel compexes can be single to multistoried. Legend as shown in Figure. 5.1.1.

6. Conclusion

Calcite cementation is not a widespread or extensive process however is a complex one but distribution of this cemented zones are least predictable.

Sources of the calcite are internal as evident from leached or broken fossils and carbonate fragments. However possibility of external source/s could not be ruled out.

South Wells Member of the lower Cherry Canyon Formation is composed of at least four channel complexes and each channel complex is bounded by regionally correlatable condensed sections.

Numerous stacked channels are compartmentalized by irregular, non-continuous calcite cemented zones. These are acting as either barriers (blocky cemented zone) or baffles (spike-like and elliptical cemented zones) to flow.

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