Diagenesis and Secondary Porosity of the Neogene Sandstones, in the North-Eastern part of Bangladesh: Implications for the Reservoir Characterization of the Bengal Basin

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Summary

Diagenesis refers to all the changes physical, physico-chemical and chemical that take place within the sediments after deposition and burial. The diagenetic history and the generation of secondary porosity of Neogene sandstones are studied over 16 subsurface core samples collected from Fenchugong 2 well, north-eastern part of Bangladesh ranging in depth from 957-4947m. Thin section petrography techniques have been used for this study. Sandstone are mostly medium to very fine grained, moderately to well sorted and texturally mature with average matrix content of 2% of the rock components. Among the various diagenetic factors, principal modification takes place by compaction and cementation. Sporadic, scattered and isolated pore filling late calcite cement strongly reduces reservoir quality. Quartz cementation in the form of quartz overgrowth and chlorite cement has strong a negative influence on reservoir properties. Due to the compaction, plastic deformation of labile grains and pseudo matrix reduce primary intergranular porosity. After the formation of cementation phases, there is a chemical dissolution phase creates secondary porosity. Both primary and secondary porosity are present in the studied sandstones but most of the primary porosity is lost by cementation due to deep burial. Secondary porosity is common after a depth of 2190m. Inhomogeneity of packing, elongate pores, oversized pores of partial dissolution of grains, corroded grains and skeletal grains are noticed in thin section study to identify secondary porosity. Feldspar, lithic grains, calcite cement and dolomite cement are the dissolved materials which enhanced 50-60% of the total porosity of the rock components in studied sandstones and improve reservoir quality. Results of the studied sandstones reveal that Fenchugonj 2 well has good quality of reservoir sandstones. However, this study of diagenesis and secondary porosity has major geological significance as its origin, stability and distribution form important aspects of sandstone diagenesis, production activities as for exploration and reservoir characterization.

Introduction

The Bengal Basin is one of the most widespread sediment reservoirs in the world. The stratigraphic and tectonic framework of the Bengal basin implies that it comprises the lower floodplain and delta plain deposits of India and Bangladesh. The Sylhet trough, a sub basin of the Bengal Basin is thought to have come into existence during the late to post-geosynclinal phase of tectonic evolution of the Bengal Basin (Holtrop and Keizer, 1970). The present study aims at defining the post depositional diagenetic modifications that have taken place in the reservoir sandstones of Fenchugonj gas field and, the influences of these on the reservoir properties. Fenchugonj gas field is located in Sylhet trough and gas reserved in area found in Miocene-Pliocene sandstone of Surma Group, originated in the shallow marine to deltaic depositional condition. Fenchugonj structure is comparatively young reversely faulted anticlines which form the trap of gas pools. Fenchugonj 2 well one of the petroleum exploratory drilled in this structure. It is one of the deepest well and an important hydrocarbon reservoir in the north-eastern part of Bangladesh.

Methodology

In Fenchugonj 2 well, a total of 16 core samples have been collected during drilling. These cores have length in the range of 9-10m. A total of 23 thin sections are made out of the 16 core samples. To facilitate identification of secondary pores in thin section, rock samples are impregnated with color dye (blue). Before processing the samples for thin section, visual study has been carried out with unaided eye for general lithologic description. Detail qualitative and quantitative analysis of the sandstone thin sections are carried out by using petrographic microscope (Nikon, model Eclipse E200) fitted with a digital camera unit. Proportions of various rock components in each slide are estimated by the point counter as well as by using comparison visual chart. Point counts are made with 500 counts per slide "SWIFT" automatic point counter. The components of the studied sandstones are detrital framework grains, matrix, authigenic cements and pores. At the beginning, the textural parameters of rocks especially grain size, grain shape, sorting and grain contacts are studied (Figure 1 and 2) and, quantization estimation of each of the framework grains, cement, matrix and pore spaces are made for each sample composition. Sandstone comprises quartz 43-62%, feldspar 2-9%, lithic grains 3-20% and micas 1-6% of the rock components. The thin section porosity of this sample ranges from 0-22% and, the matrix content ranges from <1-11 % approximately.

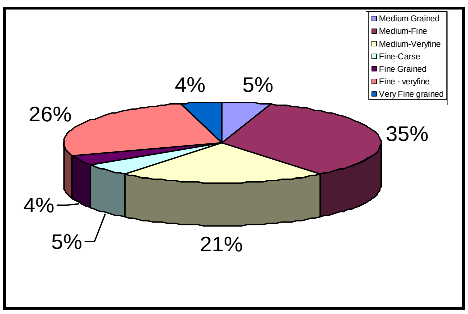

Figure 1. Graphical representation of thin section petrographic data shows grain size of rock components**.**

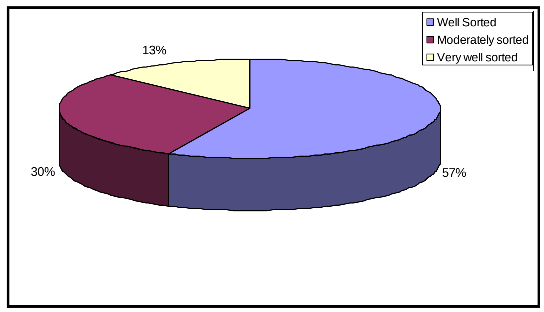

Figure 2. Graphical representation of thin section petrographic data shows grain sorting of rock components**.**

Diagenesis and Secondary Porosity

The diagenesis changes in composition and texture of sediments result in modification of the reservoir properties of sandstones. With respect to the influence on reservoir properties, there are two types of diagenetic processes are found in the studied sandstones which are: i) porosity-permeability reducing processes, compaction, cementation and pressure solution and ii) porosity-permeability enhancing process, dissolution. It is observed that Core 2 at depth 1479m shows poorly to moderately compaction with evidence of predominance of point contact and long contact, little concavo convex and suture contact and no plastic deformation of labile grains. High degree of compaction is found in Core 15 at depth 4721m. The grains are tightly packed with each other with concavo convex and sutured grain contact. Micas are strongly bended. Porosity and permeability are lost significantly due to compaction and, the estimated thin section porosity is 7% of the rock components. Packing rearrangement is found in Core 4 at depth 2190 m. Due to deep burial almost all sandstones show plastic deformation of labial grains but it is more common in sandstones at depth below 2768 m. Core 8 and Core 15 show significant porosity loss occur because of grain squeezing and the percentage of porosity of these sample 10% and 7% of the total rock components. Extensive early poiklitopic cement occurs in Core 8 at depth 3260m, Core 9 at depth 3424m and Core 10 at depth 3615m with 8%, 22% and 9% of the rock components. These types of cementations begin to occur below the depth 2000m and reduce porosity. Late calcites are sporadic, scattered and fill isolated pores. These are minor compared to early calcite cement and commonly found at depth below 3260m. Quartz in the form of quartz overgrowth cement with dust line is found in Core 15 at depth 4721m. Chlorite infilling interstitial pore spaces are found in Core 13 at depth 4248m which constitutes 7% of the rock components of this cement. Kaolinite cement occurs as isolate pore filling cement and very few in situ alteration product of feldspar with <1 to 10% of the rock components. Dolomite is found in Core 9 at depth 3269m which constitutes 3% of the rock components. Siderite cement is found in Core 5 at depth 2457m occurs as up to 10% of the rock components. In the studied sandstones alteration of feldspar and biotite are also found at depth 4248m. Feldspar both potash and plagioclase feldspar and also microcline are altered to kaolinite. Biotites are altered to chlorite and reduce poro-perm properties of the reservoir. Diagenetic processes and their responses are shown in Figure 3.

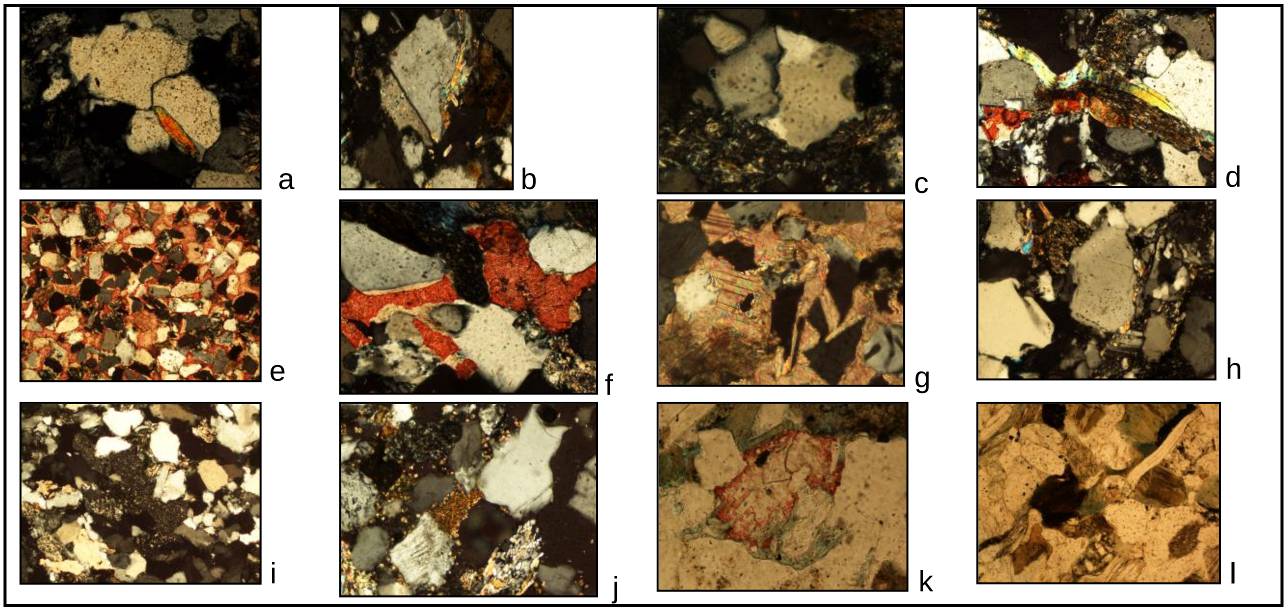

Figure 3. Diagenetic processes and their responses - a) Concavo-convex contact b) long contact c) Sutured contact d) Strong mica bending e) Early poikilotopic calcite cementation f) Isolated pore filling late calcite cementation g) Calcite cement filling pore space h) Quartz overgrowth cement with dust line i) Kaolinite cement j) Siderite cement k) Quartz grain replaced by calcite cement and l) Biotite altered to chlorite.

Porosity generated after deposition and burial of sediment is called secondary porosity. Development of secondary porosity by dissolution of calcite cement, detrital feldspar and some lithic grains are common in the studied sandstones at depth ranges from 2190-3615m. Dissolution of the detrital grains and cement are leaving only an impression of inhomogeneity of packing, elongate pores, oversized pores, corroded grains and skeletal grains. Remarkable generation of secondary porosity has been noticed in Core 4 at depth 2190m although a little bit found in Core 2 at depth 1479 m. It is dominantly found in Core 4 at depth of 2150m, Core 5 at depth 2457m, Core 6 at depth 2768m and Core 10 at depth 3615m. Porosity is exclusively secondary in very deeply buried Core 13, 14, 15 and 16. In some sandstone, it has enhanced 50 to 60% of the total porosity of the rock components. However, the remnant of partially dissolved detrital feldspar known as skeletal grain generally show 60% to 70% of the individual grain dissolved away and creates secondary porosity. These types of features are very common in Core 10, 14 and 15 with deep burial. The criteria for recognition of secondary porosity are shown in Figure 4.

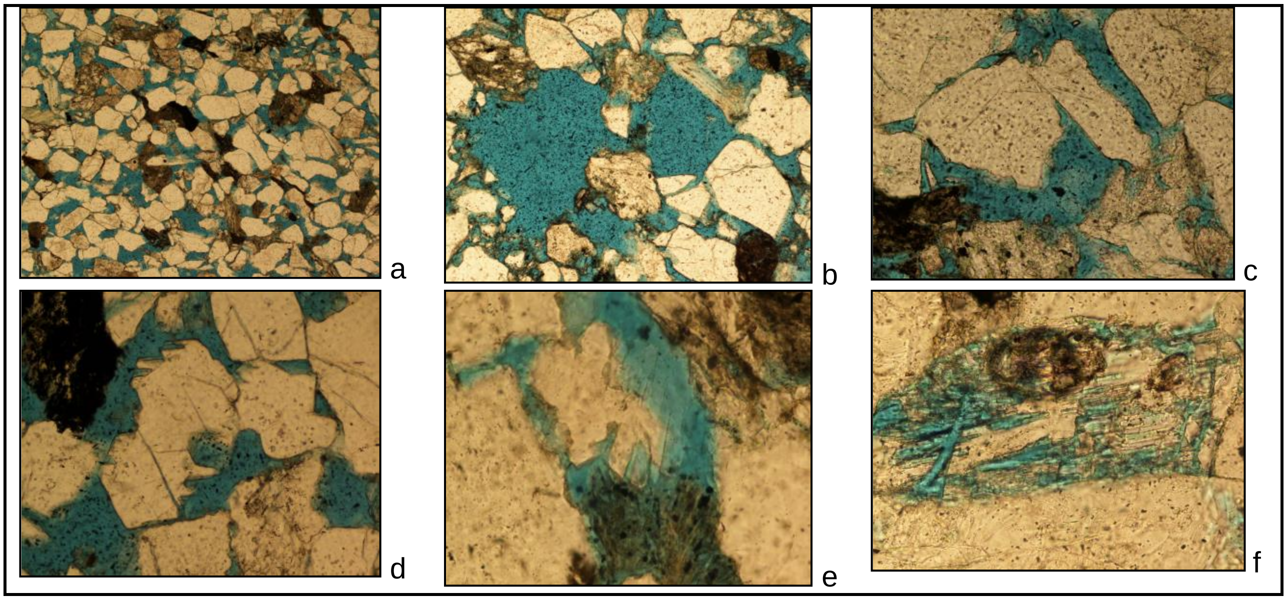

Figure 4. Criteria for recognition of secondary porosity - a) Inhomogeneity of packing b) Over size pore c) Elongate pore d) Corroded grain e) Partially dissolved grain and f) Skeletal grain.

Conclusions

For a rock to act as a reservoir, it requires two essential properties which are porosity and permeability. In thin section study under microscope, porosity estimation show that the percentage of porosity trend gradually decreases with increasing depth of burial by compaction and cementation. As it is found that the estimated thin section porosity of Core 2 at depth 1479m is 20% because of low compaction and absence of cementation. But with increasing depth of burial as well as increasing compaction and cementation porosity gradually decreases. This may be seen from the great extent in Core 4 at depth 2150m and Core 5 at depth 2768m which show porosity of 16% and 10% of the rock components. Furthermore, Core 9 at depth 3424m shows zero porosity due to high cementations and compaction. However, Core 10 at depth 3615m have higher porosity because of higher degree of dissolution and generation of secondary porosity in Core 13 at depth 4248m, Core 14 at depth 4540 m and Core 15 at depth 5721 m. However, the porosity that has been recorded in these sandstones is all secondary dissolution pores. The thin section porosity measured in Core 13, 14 and 15 are 9%, 9% and 12% of the rock components. Also the deepest Core 16 at depth 4947m shows porosity of 6% of the rock components which is mostly secondary. The present study shows diagenesis is actively influencing reservoir after depth 2000m. Moderately effect of diagenesis takes place on depth in between 2000-3500 m. Deeply buried sandstone (in excess of 3500m) are strongly chlorized meaning abundant pore filling, grain coating and replacing chlorite and, it has strong effect of diagenesis. From the above observation, it can be assumed that the Fenchugonj 2 well has good quality of reservoir sandstones with up to 20% porosity and permeability may be up to several millidarey of the rock components. Thus diagenesis of the reservoir sandstones is the most important factor that controls the ultimate nature and performance of reservoir. This study will be definitely helpful for good reservoir characterization of gas bearing Neogene sandstones in the Bengal Basin and successful hydrocarbon exploitation program.

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