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Reservoir Sandstone Diagenesis of the Barail Sandstones in parts of Upper Assam Shelf

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ABSTRACT

The Barail Group ranges in age from Upper Eocene to Upper Oligocene. It varies widely in thickness from area to area owing to a major unconformity at the top. The lower part of the Barail Group is mainly arenaceous in nature and consists of thick fluvio-deltaic sandstones separated by mudstones, shales and claystones, with hydrocarbons in the upper portions. The sandstones contain both primary and secondary pores. The secondary pores appear to have multiple origins. However, they are basically formed either by partial to complete dissolution of minerals or by microfracturing. The pores are both inter-particle and intra-particle in nature. The dominant clay minerals are kaolinite and illite. Chlorite occurs in clusters in some areas only. Smectite is occasionally observed, but tends to occur mainly as mixed-layer clays such as smectite-illite. Proper treatment of these clay minerals could aid in the prevention of formation damage to a large extent.

Keywords : Reservoir sandstone, Diagenesis, Barail Sandstone, Upper Assam, Shelf

Introduction

A detailed study of the reservoir and associated rocks of the Barail Group in parts of Upper Assam Shelf within Oil India Limited operational area has been carried out in order to unravel their internal characteristics as some of these rocks have a direct bearing on the production behaviour of hydrocarbons.

Scanning Electron Microscopic (SEM) analyses and thin section petrography were carried out in order to study the general mineralogy; clay mineralogy (including the study of migratory clay minerals such as kaolinite, illite and chlorite, and swelling clays such as smectite and mixed-layer, smectite-illite); primary and secondary pore types (including microfractures); pore throat lining and pore bridging material; particle roundness and angularity; and other cementing materials such as calcite, haematite; etc.

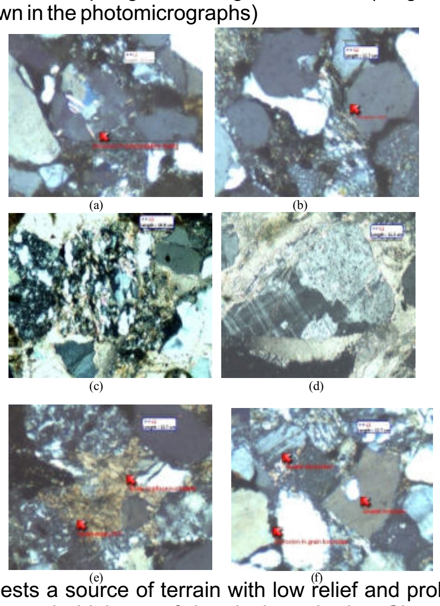
Materials and Methods

For the study, drill-cuttings, sidewall and conventional core samples recovered from various wells in the area were collected and analysed in the laboratory. SEM studies were carried out with the help of the state-of-the-art S-3600N ESEM, ex Hitachi, along with a Thermo Noran EDX for elemental analysis. For the proper emission of secondary electrons and for better resolution, the samples were sputter-coated with gold in a sputter coater. Thin section petrography was carried out with the existing Zeiss Axiolab Trinocular Microscope with Image Analysis software.

Discussion

The sandstones are rich in concentration of quartz varying from 44.3 to 59.7%. It occurs chiefly as monocrystalline quartz although polycrystalline grains are also recorded. The >3 crystal units of polycrystalline quartz is dominant over the 2-3 crystal unit per grain variety (Figure 1a). The grains are sub-angular to sub - rounded and show inclusions in certain samples. Both plagioclase and K-feldspar constitute an average of 1.33 % in the sandstones. In certain cases the sandstones are reported to be devoid of feldspars.

Figure 1. Rock thin section photomicrographs. a, Mineral inclusion in polycrystalline quartz. b, Authigenic development of mica. c, Metamorphic rock fragment d, Dissolution of framework grains by cementing material.. e, Precipitation of argillaceous materials in the pore spaces. f, Corrosion on quartz and feldspar grains along boundaries. (Magnification as shown in the photomicrographs)

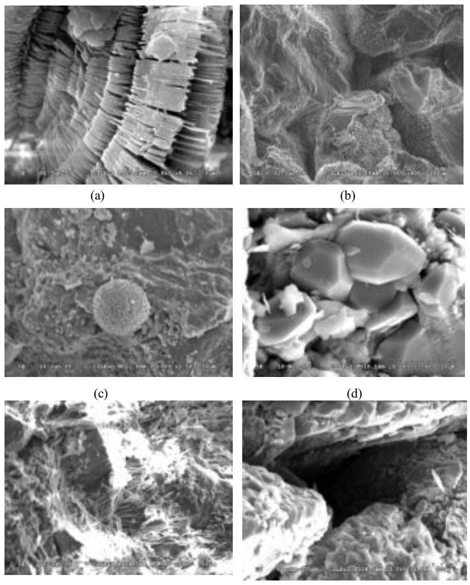


It suggests a source of terrain with low relief and prolonged abrasion and a high rate of chemical weathering. Chert chiefly composed of microcrystalline and chalcedonic quartz, with subordinate mega quartz and minor impurities of clay, silt and pyrite makes up 4 to 8.7% in the sandstones. Mica makes up to 2.4% of the detrital fraction and includes both muscovite and biotite. Development of authigenic mica at the expense of argillaceous matrix is frequently observed in the sandstones (Figure 1b) due to severe effect of diagenesis.

The metamorphic rock fragments (Figure 1c) are dominant over the igneous and sedimentary varieties. They are variable in size and angular to subangular with prominent grain boundaries. The majority of the metamorphic rock fragments are identified as schistose. Average percentage of rock fragments is 5.5%. The proportion of matrix, which constitutes 16 - 30% is mainly siliceous and argillaceous in nature, are higher in concentration than cements in certain samples. Cements are mainly ferruginous, argillaceous and siliceous in nature and comprise 2.3-16% in the sandstone.

The important diagenetic changes observed under thin section study are sandstone compaction, precipitation of different types of cement, alteration and replacement of frame work grains (Figure 1d), corrosion along grain boundary (Figure 1f) and nature of development of grain contacts. Compaction of the sediments started with burial and progressively increased with depth. Under more usual conditions, the point or tangential contacts of sandstones suggest early burial stage of diagenesis that on increased overburden load under deep burial stage come into closer contacts along long and concavo-convex grain boundaries and finally forms sutured contacts. The mechanical compaction of sediments is witnessed by bending of detrital mica flakes and fracturing of quartz grains (Figure 1b). The long and concavo-convex contacts together with the precipitation of secondary chert represent the intermediate stage of diagenesis. The cementation is brought by chemical precipitation of pore solutions. All these cementing materials were precipitated under different pH conditions. The silica cement in the form of quartz overgrowth, precipitation of glauconites between the framework grains, the infiltration of ferruginous cements throughout the sandstones, and the post depositional accumulation of the patches of argillaceous materials within the framework grains (Figure 1f) have a significant influence on the reservoir quality of the sandstone. The metamorphic rock fragments are squeezed to generate dispersed pseudo matrix. Authigenic development of mica at the expense of argillaceous cement and recrystallization of chert to quartz may reduce porosity as well as permeability in the sandstones indicating the Phyllomorphic or late stage of diagenesis. On the contrary, the corrosion, partial dissolution and replacement of the feldspar and mica grains by the cementing material enhance the porosity and permeability in the sandstones. Quartz replacement proceeds along the boundary of the grains. As a result, the replaced parts of the grains are occupied by the replacing fronts. Such replacement processes enhance the reservoir quality.

With the help of SEM, mineralogy, texture and diagenetic sequences can be better elucidated and porosity and permeability can be related to diagenetic features. In the present study the commonly recorded clay minerals are kaolinite and illite. Kaolinte is widely distributed in the sandstones and is recorded as stacking of books pattern (Figure 2a). The kaolinite “books” can disaggregate into individual platelets or entire books can migrate into pore spaces thereby causing reduction in porosity and permeability. The irregular surfaces observed in the feldspar grains may be interpreted as to represent stages of growth of authigenic kaolinite. In most cases the chemical element needed for kaolinite formation, namely silicon and aluminum are thought to derive from the leaching of some pre-existing minerals in the sandstones. K-feldspar and mica constitute the more probable Si and Al sources. Kaolinisation that develops at the expense of extremely deformed and crushed feldspars clearly signifies the post date compaction and belongs to the late diagenetic history. Authigenic growth of kaolinites reduces the permeability/porosity ratio. Moreover, the relative abundance of kaolinite indicates the dominance of fluvial influence in the depositional system. Flaky and fibrous illites found to grow in pore spaces often bridge the pores and offers a high resistance to fluid flow through the sandstone and thereby reduces permeability (Figure 2b). The fibrous illite acts as a fishnet in sandstone pores and creates permeability blocks, which significantly modifies the reservoir property. Guven et. al. (1988) reported the frequent occurrence of authigenic lathed illite in the pores of many sandstone reservoirs from the United States. Illite apparently develops under acidic condition. Presence of framboidal pyrite (Figure 2 c) dolomite and quartz overgrowth (Figure 2d) also reduces the porosity in the sandstones. On the otherhand, partial dissolution of quartz and both K-feldspar and plagioclase feldspar (Figure 2e) enhances the porosity in the reservoir sandstone. Intergranular pores of various shape and sizes are frequently observed (Figure 2f). In most of the cases the quartz grains show intragranular fracturing and this post depositional effect obviously enhances the secondary porosity and permeability to make the sandstones to be highly productive.



Conclusion

The sandstones of the present study are moderate to ill sort with floating type of texture. The progressive diagenetic alteration controls its reservoir quality. Precipitations of cementing materials, authigenesis of secondary minerals like chert, mica, and quartz overgrowth are some of the important diagenetic changes responsible for porosity reduction. Moreover, presence of kaolinites and fibrous nature of illite in the pore throats also play an important role in porosity reduction. Conversely development of intragrnular fractures, corrosion, dissolution and partial replacement of the framework grains by cementing materials contribute towards the development and enhancement of secondary porosity and permeability. So, some of the diagenetic changes within the reservoir make certain horizons to be highly productive while others make to be less productive in spite having good reserves.

ABSTRACT

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