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Research Paper Petroleum Geology

Reservoir Rock Quality of the Lakadong Member in the Eastern Part of Upper Assam Basin, India

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ABSTRACT

The Lakadong Member (Upper Palaeocene - Lower Eocene) of the Sylhet Formation in Upper Assam is of interest because it contains sandstone reservoirs which are prolific producers of oil and gas. These reservoir sandstone of Lakadong Member is significantly different from the Tipam (Eocene) and Barail (Oligocene) Sandstones and are heterogeneous in character. The thickness of the Lakadong Member in the study area varies from 60 to 150 metres. The individual sandstone beds range in thickness from less than a metre to about 13metres. In spite of having lower thickness the productivity from these clastic reservoirs are very high. Diagenesis has played a major role in controlling reservoir quality of these reservoir sandstones. Especially the development of itergranular and intragranular porosity enhances the permeability within these sandstones. On the other hand, permeability is lost in certain horizons due to development of secondary minerals as well as presence of clay minerals.

Keywords : Reservoir rock, Lakadong Member, Diagenesis, Porosity, Upper Assam

Introduction

The Upper Assam basin is the earliest explored petroliferous basin of India. It represents the northeastern extremity of the Indian subcontinent encompassing an area of about 57000 sq. km. and forms the northeastern part of Assam-Arakan geological province. Tectonically, the Upper Assam Basin represents a structurally wrapped foreland basin between two convergent plate margins and came into existence during Early Cretaceous time. It lies at the junction of Himalayan arc to the north and Burmese arc to the east. The generalized stratigraphy of the Upper Assam Shelf in the study area is given in Table-1. The first oilfield in India, the Digboi Oilfield was discovered in this basin in 1889. Since then extensive exploration activities have been carried out by various companies especially two national companies, Oil and Natural Gas Corporation Limited (ONGCL) and Oil India Limited (OIL) within the Upper Assam basin and has resulted in discovery of a large number of new structures with potential hydrocarbon reserves. A major breakthrough came in 1990, when for the first time commercial oil was discovered in the early Eocene rocks (Lakadong Member) in Upper Assam basin. This Lakadong Member in Upper Assam is of interest because it contains sandstone reservoirs which are prolific producers of oil and gas. The thickness of this member in the area varies from 60 to 150metres. The sandstone beds range in thickness from less than a metre to about 13metres. In spite of having lower thickness the productivity from these classic reservoirs are very high. Diagenesis has played a major role in controlling reservoir quality of these sandstones.

Materials and Methods

Samples of conventional and sidewall cores along with drill-cuttings of Lakadong Sandstones recovered from wells located in different parts of the area have been studied under Olympus Polarizing Microscope Model CX31P with Motic Image Analyser and JOEL JSM-35 CF Scanning Electron Microscope with EDX facility in Research & Development Centre in Oil India Limited, Duliajan. The study of reservoir rocks includes general mineralogy, various types of primary and secondary porosities and the important diagenetic features that control the reservoir quality.

Results & Discussion :

The sandstones of present study are basically quartz arenites to sublitharenite and less commonly of lithic wacke type (Figure 2). The general mineralogy of the sandstones includes mainly subrounded to subangular quartz particles (although angular and rounded particle are present), along with feldspar, glauconite, calcite, clay minerals such as kaolinite, chlorite, illite and minor smectite, and heavy minerals. The role of diagenesis as a porosity modifier is overwhelmingly accepted and its control over the reservoir quality has been evaluated in the present study. The important diagenetic changes observed under thin section study are sandstone compaction, precipitation of different types of cement, dissolution and replacement of frame work grains and nature of development of grain contacts. Compaction of the sediments started with burial and progressively increased load 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. The long and concavo-convex contacts together with the precipitation of secondary chert (figure 3c) represent the intermediate stage of diagenesis. The cementation is brought by chemical precipitation of pore solutions. Precipitation of glauconite between the framework grains (figure 4d), the silica cement in the form of quartz overgrowth (figure 4e) , the infiltration of ferruginous cements throughout the sandstones, and the post depositional accumulation of the patches of argillaceous materials within the framework grains have a significant influence on the reservoir quality of the sandstone. The metamorphic rock fragments are dominating over the igneous and sedimentary variety (figures 3d & 3e) and very few cases these are squeezed to generate dispersed pseudo matrix.

Authigenic development of mica at the expense of argillaceous cement 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 quartz, feldspar and mica grains (figures 3a, 3b & 3f) 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. 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 4 a). 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. The fibrous illite acts as a fishnet in sandstone pores and creates permeability blocks, which significantly modifies the reservoir property. Presence of framboidal pyrite, gypsum (figure 4b) and quartz overgrowth (figure 4e) also reduces the porosity in the sandstones. On the otherhand, partial dissolution of quartz and both K-feldspar and plagioclase feldspar enhances the porosity in the reservoir sandstone. The sandstones are characterized by typical intergranular porosity within the framework grains (figure 4c). In most of the cases the quartz grains show intragranular fracturing (figure 4f) and this post depositional effect obviously enhances the secondary porosity and permeability to make the sandstones to be highly productive.

Conclusion

The Lakadong sandstones (Upper Palaeocene Lower Eocene) of Upper Assam Shelf are basically quartz arenites to sublitharenite and less commonly of lithic wacke type. The sandstones include mainly subrounded to subangular quartz particles (although angular and rounded particle are present), along with feldspar, glauconite, calcite, clay minerals such as kaolinite, chlorite, illite and minor smectite, and heavy minerals. These reservoir sandstones contain generally large secondary pores which are numerous in certain producing horizons. These have developed mainly due to the activity of interstitial solutions. Fracturing and dissolution of quartz, feldspar, rock fragments and the cementing materials are some of the important diagenetic changes that make the reservoir to be highly productive. Moreover, the sorting of the minerals and the presence of micro fractures within the framework grains enhance the porosity and permeability in these sandstones. On the otherhand, development of authigenic minerals as well as the overgrowths and presence of clay minerals in the pore spaces, as revealed from scanning electron microscope studies, affects the reservoir quality.

Figure 1: Location map of the study area

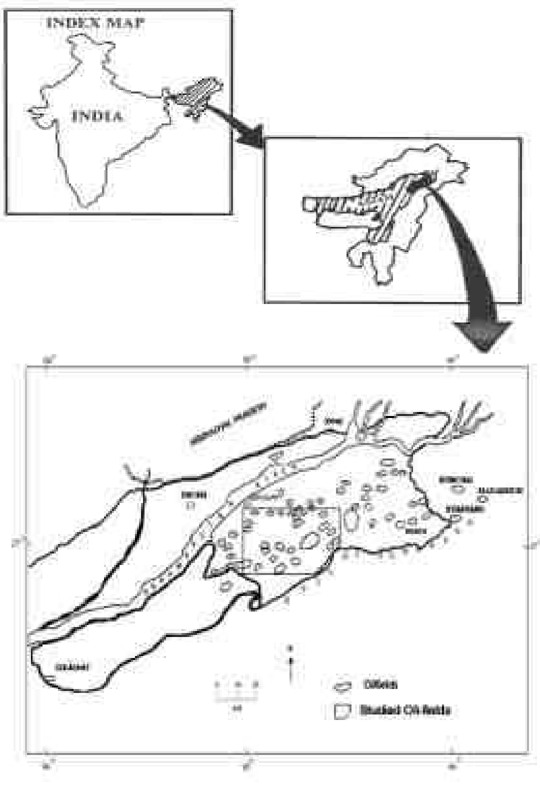

Figure 2 : Classification of the Lakadong Sandstones of the study area (modified after Dott, 1964)

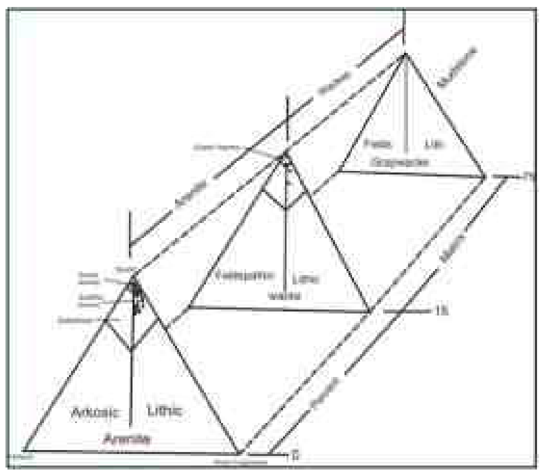

Figure 3. Photomicrographs of Lakadong reservoir sandstones. a, Dissolution of quartz and feldspar grains (100x). b, Dissolution and kink bend of mica flakes (100x). c, Authigenic chert (100x). d, Rock fragment (100x). e, Metamorphic Rock fragment (100x). f, Surface corrosion on microcline grains by cementing material (100x).

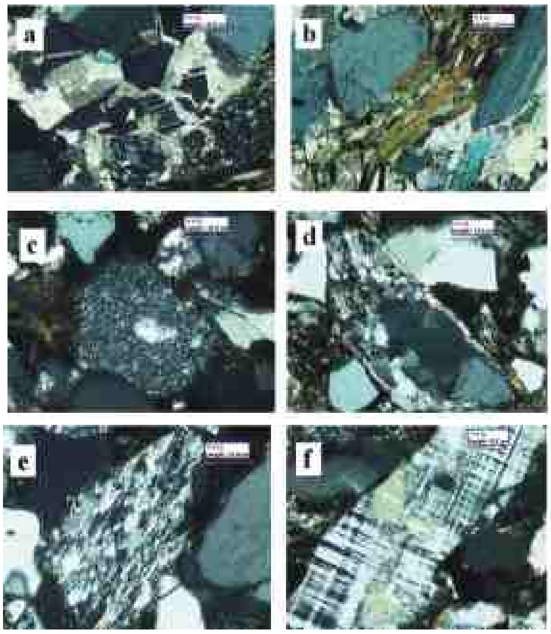

Figure 4. SEM photomicrographs of Lakadong reservoir sandstones. a, Kaolinite books. b, Gypsum crystals. c, Intergranular pore. d, Glauconite developed in pore space. e, Quartz overgrowth. f, Microfracture in framework quartz Magnification as shown in the SEM photomicrographs)

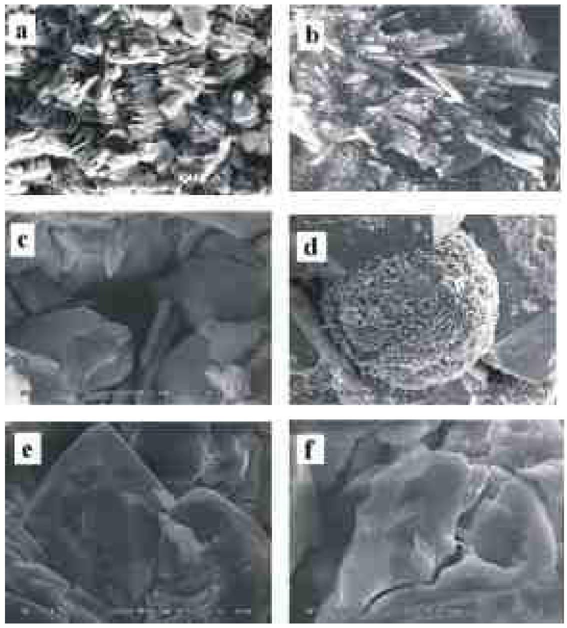

Table 1. Tertiary Succession of Upper Assam Shelf sediments (modified after, Handique *et. al.*,1989)

Epoch	Lithostratigraphic Units Group	 Formation	Thickness (m)	Major Lithological Types
Recent	-	Alluvium		
Pliestocene	Dihing	Dhekiajuli	1300- 2000	Unconsolidated sands with clay and lignitic sands.
----Unconformity----				
Pliocene sands Miocene	Dupitila	Namsang Beds	0-1000	Poorly consolidated sandstone with clay and lignitic
----Unconformity----				
Miocene	Tipam	Girujan Clays	100-2300	Mottled clay with sandstone lenses.
		Tipam Sandstones {Upper	300-500	Essentially arenaceous sequence
		{Middle	100-200	Sand/shale alteration sequence
		{Lower	100-200	Arenaceous sequence
	? Surmas	Not subdivided		Sandstone with shale and grit bands
----Unconformity----				
Oligocene	Barail	Not subdivided	500-1200	{ Upper Part: Mudstone/sale with sandstone beds and coal bands (Argillaceous sequence) { Lower Part: Sandstone with shale bands sequence)
(Arenaceous Eocene sand-	Jaintia	Kopili alterations	280-500	Splintery shale with sandstone and fine-grained stone with coal bands.
		Sylhet Limestone {Prang {Nurpuh {Lakadong	350-450	Splintery shale with sandstone and limestone bands
	Therria		60-170	Sandstone, calcareous sandstone and limestone
----Unconformity----				
Precambrian granitic basement				

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