Introduction

Todays, there is a vast prospect to explore hydrocarbons from potential carbonate reservoirs throughout the world. Carbonate reservoirs are not only widely distributed in Middle East but their importance being a potential reservoir is enormous as the largest gas reservoir in Pakistan named Sui Main Limestone was explored in Middle Indus Basin in 1952. Similarly, one of the largest oil field namely Ghawar Oil Field of Saudi Arabia was produced from carbonate reservoir in 1951.

However, there are number of reasons behind such a great potential of carbonates to act as a reservoir. The diagenetic evolution of carbonates is a complex process and it is not as simple as diagenesis of siliciclastic rocks. Siliciclastic reservoirs especially sandstone usually possess only homogenous porosity i.e., primary porosity due to their simple diagenetic evolution. While on the other hand, carbonates are accompanied by heterogeneous porosity including primary and secondary porosity.

The porosity of carbonates is enhanced by variety of syndiagenetic and post diagenetic processes and that processes include only pore filling process, neomorphism, compaction, fracturing during tectonic movements etc. Margalla Hill Limestone of Hazara Basin of Pakistan has undergone such a variety of processes and showing huge potential to act as a carbonate reservoir.

Method and Theory

Margalla Hill Limestone of Early Eocene age is a carbonate dominated unit that is widely distributed in the Attock Hazara Fold and Thrust Belt. To evaluate diagenetic properties, depositional model and stratigraphic evolution of the Margalla Hill Limestone, four stratigraphic section including Kuza Gali, Khushi Kot, Lower Barian and Dannaha Sharif of the Southeastern Hazara were measured and sixteen sample from each section were collected to make thin sections for petrographic and microfacies analysis. In the measured sections, formation has an average thickness of 63m.

The Margalla Hill Limestone conformably overlies the Late Paleocene Patala Formation and is conformably overlain by the Early Eocene Chor Gali Formation. The Margalla Hill Limestone predominantly consists of nodular and bedded limestone with subordinate marl and shale. The limestone is commonly grey, light grey to pale grey on weathered surface and dark grey on fresh surface, fossiliferous, nodular, thin to thick bedded and rarely massive in nature. Lithological log of the Margalla Hill Limestone depicting lithological properties, microfacies distribution, faunal dominance and repetition of package of strata is given in Figure 1.

Microfacies analysis and relative abundance of faunal constituents of Margalla Hill Limestone reveals three dominant microfacies namely Milliolid-Lockhartia Mud-Wackstone Microfacies (MF-1), Nummulitic-Assilina Wack-Packstone Microfacies (MF-2) and Larger Benthic Foraminifera Wack-Packstone microfacies (MF-3).

Depositional Model of the Margalla Hill Limestone

Carbonate shelves are common in all geological periods, but were dominant at times when reef-construacting organisms were absent or inhibited. Shelf can be subdivided into inner-, mid-, and outer-shelf environments.

The microfacies analysis of Margalla Hill Limestone represents deposition in carbonate shelf that is further subdivided on the basis of faunal assemblage into Inner Shelf, middle shelf and outer shelf settings (Fig 2).

The Margalla Hill Limestone began to deposit in low energy environment below fair weather wave base that is represented by Mud-Wackstone Microfacies (MF-1) which is chiefly composed of Lockhartia and Milliolid, and pelagic fauna. The assemblage of larger benthic foraminifera, occurrence of pelagic fossils and high ratio of micritic matrix/cement represents deposition in deeper
water setting of middle shelf environments because that is the only place where winnowing of lime mud is minimum.

Figure 1 Lithological Log of the Margalla Hill Limestone (Khushi Kot Section)

The Wack-Packstone Microfacies (MF-2 and MF-3) of the Margalla Hill Limestone is mainly composed of Nummulites, Assilina, other larger benthic foraminifera and lime mud as matrix represents deposition in a shallow water settings that is, towards landward position of basin. That part of Margalla Hill Limestone is influenced by slightly high energy conditions and is found to be deposited in an inner shelf setting.
Diagenesis of the Margalla Hill Limestone

Diagenesis is a sedimentary phenomenon that includes all physical, chemical and biological changes that are taking place after deposition of sediment but before metamorphism.

The diagenesis of the Margalla Hill Limestone includes mechanical and chemical compaction, cementation, neomorphism, replacements etc. All these diagenetic processes resulted in the creation and destruction of porosity.

Mechanical compaction occurs due to overburden which results in fluid expulsion and migration of organic matter. It is prominent in biosparite and sparbiosparite as compared to biomicrite. This process results in the breaking and fracturing of grains by preserving some shelter porosity.

In Margalla Hill Limestone, stylolites and dissolution seams are quite common. These are considered to be formed from pressure solutioning of grain to grain contacts. However, they are laterally filled by residual clays and organic matter. The stylolites can both enhance or reduce porosity.

Neomorphism is frequently observed in mudstone to wackstone facies showing replacement of muddy matrix to sparry calcite.

Sequence Stratigraphy of the Margalla Hill Limestone

Margalla Hill Limestone is a deposit of high stand system tract (HST) forming an aggradational to progradational stacking pattern bounded by maximum flooding surface at the base and basal regressive surface at the top (Fig 3). The maximum flooding surface is marked at the top of the Patala Formation.

The thick bedded Margalla Hill Limestone also suggests the increase in sedimentation, which had overcome the rate of the base level rise showing transgression. Shallowing upward cycles are founded.
in Margalla Hill Limestone that shows outer to inner ramp shallow marine facies. Four thickening upward parasequences are found in Margalla Hill Limestone that represent rapid sea level rise.

**Figure 3** Diagram representing Sequence Stratigraphic Chart of Margalla Hill Limestone on Sea Level Cycle (modified after Wright and Brachette, 1996)

**Conclusions**

The microfacies analysis represents deposition of the Margalla Hill Limestone in an inner to outer carbonate shelf. The diagenetic alterations and generation of secondary porosity such as vuggy porosity, fracture porosity and channel porosity that is verified by petrographic analysis are showing great potential of the Margalla Hill Limestone to act as a reservoir. Thickening upward in Margalla Hill Limestone shows abundance of carbonate constituents and shallowing upward trend indicates deposition during high stand system tract (HST).

**References**


