Title: INTEGRATED STRATIGRAPHIC ANALYSIS OF THE UPPER CRETACEOUS SUCCESSION, LOWER INDUS BASIN, PAKISTAN

Research Scholar: Muhammad Rizwan

Abstract

In the Lower Indus Basin, sedimentation in the Upper Cretaceous is characterized by the outer ramp marls of Mughal Kot and shallow marine inner ramp carbonates of Fort Munro formations and preserved the records of Eastern Tethys. This study aims to carry out the detailed stratigraphic analysis of the Upper Cretaceous Succession of Lower Indus Basin based on the sedimentological and paleontological investigations. The micropaleontological and biostratigraphic study is based on the biometric parameters of the genus *Orbitoides* and *Omphalocyclus* in oriented sections from the Fort Munro Formation. Surface of the *Orbitoides* test is smooth, externally discoidal in shape, lenticular, and display a circular outline. Diameter of the tests ranges between 1.3 and 7 mm, but most of the specimens fall in the ranges between 2 and 5 mm. Symmetrically the specimens are biconvex but non-symmetrical specimens also common (concavo-convex to plano-convex), and only few are flat**.** Embryon is trilocular to quadrilocular and their shape varies from spherical to elliptical. The average values of the size of embryon (Li + li) for the eighteen samples ranges between 477 and 516 µm whereas, average E values ranges between 4.2 and 4.7. Based on the average values of E and size of the embryon (Li + li), the whole population of *Orbitoides* has been attributed to the *Orbitoides media* species zone. *Omphalocyclus* tests are discoidal in shape, bilaterally depressed in the center, display a circular outline. Majority of the specimens are asymmetrical, one side is flat or concave due to the central depression. The opposite side is flat to convex with a massive, central hollow in the center. Externally walls of the equatorial chamber are occasionally visible. Diameter of the test ranges between 1.1 and 4.76 mm, with an average between 1.74 and 3.23 mm and embryon is always trilocular. The size of the embryon (Li + li) ranges between 112 and 485 µm, with an average between 153 and 287 µm. The E values ranges between 2 and 3, with an average between 2 and 2.3. Based on the average values of E and size of the embryon (Li + li), the whole population of *Omphalocyclus* has been attributed to the *O. omanensis* species. Upper Campanian age is assigned to the Fort Munro Formation based on the *O. media* and *O. omanensis* species. Detailed biometric study reveals the primitive species of

Orbitoides and *Omphalocyclus* from Eastern Neo-Tethys in the Asian biogeographic province (ASP) during the Late Cretaceous.

Based on the detailed investigation of microfacies, inner to middle and outer ramp depositional environments are suggested for Fort Munro and Mughal Kot formations respectively. Biostratigraphy and variation in the depositional environments based on microfacies are used to establish a sequence stratigraphic framework and shows a transgressive-regressive cycles in the studied succession. The Upper Campanian Mughal Kot and Fort Munro formations shows a deposition in the third order cyclicity. Mughal Kot formation show a transgressive cycle (TST), whereas in the Fort Munro formation a total of twenty-six transgressive-regressive cycles are identified due to local sea-level variation in the time of deposition.

Based on field observations, detailed petrographic investigation of combined Alizarin Red-Potassium Ferricyanide stained thin sections, Scanning Electron Microscopy, X-Rays Diffractometry and geochemical analyses (stable C and O isotopes), a variety of diagenetic phases related to different stages has been observed. The normal paragenetic sequence including the three stages of diagenesis: eogenetic, mesogenetic, and telogenetic in succession is revealed. During the eogenetic stage, the diagenesis occurred in the meteoric and marine environments and is evident from the observed features such as burrowing, micritization, syndepositional syntaxial overgrowth, inversion neomorphism, internal geopetals, and drusy mosaic cement. The mesogenetic stage and the major phase of diagenesis in the studied strata encountered shallow to deep burial diagenetic environments and is characterized by dissolution, mechanical compaction (grains packing and microfractures of sub millimeter scale), fractures of sub centimeter scale, granular mosaic cement, later clear syntaxial overgrowth, blocky calcite cement (BC-3 to BC-5 in paragenetic sequence), chemical compaction and minor dolomitization. The teleogenetic or uplifting stage is evident from the cross-cutting relationship of sub millimeter calcite filled fractures postdating late burial stage diagenetic features. The $\delta^{13}C$ and $\delta^{18}O$ values for whole rock (matrix and grains) is ranging from -3.472 to 2.131 and -3.071 to 0.3, respectively. Whereas the $\delta^{13}C$ and $\delta^{18}O$ values of micro drilled samples from blocky calcite cements of undoubtedly burial stage ranging from -1.58 to 3.05 and -9.97 to -3.68, respectively. The cross-plot of $\delta^{13}C$ versus $\delta^{18}O$ of whole rock samples mostly fall in the category of warm-water skeletons and reveals the marine diagenesis and suggests that the diagenetic fluids were buffered with the surrounding marine carbonates during their flow. The depleted $\delta^{18}O$ values of the micro drilled samples from

veins reflects the precipitation of cements from fluids during deep burial diagenesis with elevated temperature. The studied carbonates display poor reservoir properties (Φ<01% and K<01 md). The detailed petrographic investigation and the observed paragenetic sequence show that the reservoir potential has been occluded by extensive precipitation of various cements in the different diagenetic environments.