Paleo-Environmental and Stratigraphical Analysis of the Turonian Red Beds, Northern Kirther Range, Pakistan

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During the Cretaceous period in the Tethys Ocean, redox conditions fluctuated between oxic and anoxic conditions, leading to the deposition of Cretaceous oceanic red beds (CORBs) and black/grey shale (oceanic anoxic events), respectively. The former comprises pelagic shales, marls, and fine-grained limestones characterized by a reddish coloration, whereas the latter comprises black shales. In the Kirther Range of the Lower Indus Basin, a unique alternation between red pelagic limestone (RPL) and black shale was observed. Petrographic, mineralogical, geochemical, and stratigraphical analyses were conducted on the red beds to understand their genesis, stratigraphic contexts, and paleo-environments. Petrographic analysis revealed three distinct microfacies within the red pelagic limestone: 1) planktonic foraminiferal wackestone/packestone, 2) planktonic foraminiferal wackestone, and 3) planktonic foraminiferal packestone. The identification of these microfacies indicates that the sedimentary environment is a deep open marine system. Three planktonic foraminiferal biozones have also been identified: Whitinella archeocretacea Partial Range Zone, Helvetoglobotruncana helvetica Total Range Zone, and Marginotruncana sigali Partial Range Zone. The age of the red beds is dated to be early to late Turonian. The RBL, similar to the Goru Formation in the Murree Brewery Section, has been found in several locations across the Tethys Ocean, mainly on the European side. These locations include the Chuangde section in Tibet, China, which represents the Eastern Tethys Ocean; the Vispi Quarry section in Italy; and the Buchberg section in Austria, which represent the Western Tethys. Additionally, the Unas section in Turkey represents the Middle Tethys. Under an optical microscope, red

pigment is observed scattered in the matrix and/or inside the shells of foraminifera. Mineralogical investigations conducted using X-ray diffraction (XRD) confirmed that the red coloration observed in RPL originated from hematite. Three geochemical endmembers classified the Murree Brewery red beds as calcareous (Ca-CORBs) based on the predominant presence of CaO compared to SiO_2 and Al_2O_3. The major elements Al_2O_3, SiO_2, Fe_2O_3T, MgO, K_2O, TiO_2, P_2O_5, and Na_2O were significantly depleted in RPL compared to the average shale composition, with enrichment in MnO attributed to local hydrothermal sources. The geochemical indicators for redox and productivity, including Ni, Co, Cr, Zn, and Cu, showed low values, suggesting that the depositional conditions were oxic and oligotrophic.