

# Geological history of the NW Indian Plate Tethyan passive margin in the Salt Range, Pakistan

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The generally east-west trending Salt Range, located in northern Pakistan, is a part of the foreland zone of the Himalayan Fold and Thrust Belt (HFTB). The 5,000–1,000 m thick Precambrian to Pleistocene sedimentary archives of the Salt Range provide an excellent opportunity for the reconstruction of sedimentation style, palaeoclimatic conditions, and tectonic history of the northwestern margin of the Indian Plate. The Precambrian evaporites of the Salt Range Formation are the oldest rocks in the area and represent the westward extension of the Precambrian evaporitic belt that includes the Hormuz Salt Basin (Iran) and Ara Salt (Arabian Plate). A highly weathered igneous body “Khewrite” occurs in the upper part of the formation and can be correlated with the volcanic record during the Ediacaran-Cambrian transition in the Arabian Plate. The clastic-dominated Lower Cambrian succession in the area is directly overlain by the Permian Tobra Formation and with a gentle angular unconformity. The poorly sorted conglomerates of the Tobra Formation indicate deposition during the Permo-Carboniferous glaciation and the irregular distribution of the Tobra and Dandot formations in the area supports their deposition during the syn-rifting phase of the Neo-Tethys opening. The overlying Upper Permian and Mesozoic strata indicate deposition on the northwestern passive margin of the Indian Plate facing the southern margin of the Neo-Tethys. This represents the drift sequence with multiple phases of passive margin rejuvenation during the Mesozoic. The drift sequence is unconformably overlain by the Paleocene Hangu Formation. Karst bauxites mark this contact and hint at exhumation and exposure in the distal part of the underthrusting plate margin. The Hangu Formation grades upward through the Lockhart Limestone into black shales of the Patala Formation supporting deepening and the possible establishment of a trench setting in the area. The presence of thick evaporites of the Bahadar Khel Salt and Jatta Gypsum in the western part of the area (Kohat Plateau) indicates a restricted lagoonal setting during the closure of the Neo-Tethys during the Eocene. The absence of the Oligocene strata hints at the uplift and

exhumation of the area during the Himalayan Orogeny. The Neogene strata of the area consist of fluvial-continental detritus and represent molasse sedimentation. Thermal history modelling based on Apatite Fission Tract (AFT) data indicates three major cooling (uplift) episodes separated by two burial phases in the area. The first cooling event (ca. 520 Ma) coincides with the emplacement of the Mansehra Granite just north of the area (ca. 516 Ma) and supports exhumation correlative with the Pan-African Orogeny. This was followed by the first burial phase (ca. 500–370 Ma) that supports Late Cambrian–Devonian sedimentation in the area. The second cooling event (ca. 300–280 Ma) coincides with the initial rifting and exhumation associated with the Neo-Tethys opening. Therefore, it appears that the Late Cambrian–Devonian strata were deposited in the Salt Range but were subsequently eroded during the exhumation induced by the Neo-Tethys opening during Permo-Carboniferous. This was followed by Neo-Tethyan passive margin deposition throughout the Mesozoic. An additional cooling episode is observable at around ca. 60 Ma and is supported by the presence of karst bauxites at the base of the Hangu Formation. Provenance analysis of the Paleocene strata suggests that detritus for the Hangu Formation was supplied from the south (Indian Plate). The overlying Patala Formation indicates the onset of sediment supply from the north and hence the uplift of the Himalayan Orogen. The overlying Kuldana Formation supports detritus supply only from the north verifying the Neo-Tethys closure by the end of Eocene. Thus the Paleogene strata represent syn-collisional deposition of the Neo-Tethys in the Salt Range. The second burial event (ca. 20–6 Ma) occurred during the Neogene in response to molasse sedimentation in the foreland of the uplifting Himalayan Orogen that was followed by the final cooling and uplift event (ca. 4 Ma) along the Salt Range Thrust. Thus the stratigraphic successions of the Salt Range provide key information regarding the reconstruction of the northwestern Neo-Tethyan margin of the Indian Plate which can help in the understanding of Neo-Tethyan tectonics in regional and global context.