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Evidence of salt-tectonics in the Trans-Indus Salt ranges, NWFP, Pakistan

KHALID PARVEZ DURRANI & IRSHAD AHMED
NCE in Geology, University of Peshawar, Pakistan

The Kohat-Bannu basin is one of the most important zones in an active foreland fold and thrust-belt of Pakistan. It was originated by compressional tectonics at the northern margin of the Indian Plate. This basin is moving southward over a salt layer which acts as a decollement surface between the Precambrian basement rocks and the Eocambrian-Neogene sediments of the Indian Plate. The Trans-Indus ranges (TIR) are the surface expression of the leading edge of a decollement thrust in which the crystalline basement is not involved (see Crawford, 1974; Parvez,1992).

The decollement along the salt in the fold and thrust-belt of Pakistan is formed by the combining processes of sediment load and sliding as a result of north-south compression. Salt behaves like a viscous fluid under stress. When the horizontal compressive stresses exceed the overburden stress of sediment, movement along the salt occurs in the weak zone forming a decollement zone. Some of the salt moves upsection along the thrust faults as a detached salt wedge forming pinch and swell structures. Salt tongues also form in this process.

Several types of structures like piercement, turtle, non-piercement, collapse, and normal faulting are produced in the area of salt-tectonics (Towey, 1988). The non-piercement structures originate because of the horizontal movement of the salt (Bishop, 1988) as noticed in the Trans-Indus Salt Range. The common structures present in the Bannu area are the thrust-faulted anticlinal traps between salt lobes.

The varying morphology of the residual salt structures is the result of variation in sedimentary load, compressive forces and salt thickness (West, 1988). Seismic study shows a series of faults in the area (Parvez,1992). These are, in most cases, branch faults of the major sole thrust running along the evaporite sequence of the Salt Range Formation. Some other faults present in the area are backthrust and normal faults forming delta structure and/or triangle zone. The turtle structures are also present in the vicinity of the anticlinal structures. The presence of evaporites along the sole thrust is confirmed by the presence of salt in the Kalabagh area, Khisor Range, Marwat-1 well and Kundian well drilled south-south-east of the area (Parvez, 1992).

The presence of structures such as withdrawal synclines and radial faults (see Jackson & Talbot, 1986) and the seismic interpretation along the anticlinal structures in the thrusted area suggest the occurrence of salt-tectonics in TIR. The seismic reflectors are of high amplitude and continuity in the structurally undisturbed parts of the area. They give pull-up effect when reach to the anticlinal structures of the Surghar, Marwat, Khisor, and Bhittani ranges. This effect is because of the higher velocity of salt than the neighboring rocks. This pull-up effect on the seismic data from the TIR provides the evidence of the salt-tectonics in the area. The salt might have flowed along the thrust faults and branch faults of the sole thrust, thus forming the fault bend folds.

The most productive oil regions of the world have traps produced by halokinesis, the deep-seated salt movement. The presence of these unconventional potential traps in the study area can be highly promising and therefore a detailed study is suggested, using the new seismic data and techniques.

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Geology and petroleum potential of the Kohat-Bannu Basin, NWFP, Pakistan

KHALID PARVEZ DURRANI
NCE in Geology, University of Peshawar

The Kohat Plateau and Bannu depression, a part of the foreland fold and thrust belt of Pakistan, lies to the south of Himalaya and Karakorum mountains on the Indian Plate. The anticlinal structures of Marwat, Khisor, Surghar, and Bhittani Ranges, "the Trans-Indus Ranges", are the southernmost extension of the fold-and thrust-belt.

Seismic study suggests that the Kohat-Bannu plateau has been overthrusted to the south along a sole thrust fault (Durrani, 1993) which has also been reported earlier (Jaume and Lillie, 1988). Many thrust faults, mostly verging to the south and southeast, cut the sedimentary strata, implying that the Kohat-Potwar plateau was thrust southward and south-eastward as a direct consequence of the crustal shortening that resulted from north-south (post-Paleocene) and northwest-southeast (pre-Eocene) lateral compression.

The Eocambrian Salt Range Formation is a thick evaporite sequence present beneath the foreland fold and thrust-belt which acts as a zone of decollement between the upper sedimentary belt and the lower basement rocks. The basement beneath the foreland fold and thrust-belt is not involved in thrusting (Crawford, 1974; Seeber et al., 1981). A series of anticlines and synclines are developed along with the thrust faults, forming the fault bounded folds of the foreland fold and thrust-belt. The absence of seismic reflections over the curvature of the anticlinal structures may be due to the salt-related thrusting and folding (Durrani, 1993). The anticlines and synclines in the Bannu area are generally gentle and broad structures compared to the overturned, faulted and imbricated structures in Kohat folded zone. Normal faults are present in the sedimentary sequence of Infra-Cambrian to Paleogene rocks. The Bannu basin is downfaulted along normal faults (McDougall & Hussain, 1991). There is evidence of smaller grabens present on the seismic lines and these structures have good potential for petroleum exploration.

Marine and alluvial sedimentary sequence of Infra-Cambrian to Plio-Pleistocene molasse sediments is present in the Bannu depression. Unconformities separate the rocks of different age group present in the area. The complete sedimentary sequence forms a very gentle but large-scale anticline. A series of pinchouts are present in Jurassic to Tertiary rocks. Some carbonate buildups in Permian, Triassic and Jurassic rocks are present and although few in number, they are recommended for future detailed study.

Source rocks are widespread and have been identified throughout the Kohat-Potwar plateau. The best source rocks in the research area are contained in the shale of the Salt Range Formation as well as in the

Patala shale, where it is present. The average geothermal gradient for Kohat-Potwar plateau is 2 °C/100m and the oil window exists at a depth of 2,750-5,200 m (Khan et al., 1986; Raza & Khan, 1986).

A variety of reservoir rocks of carbonate and clastic origin are also present in the area. Most of the hydrocarbons in the region have been found in Paleogene rocks but other rocks of Cambrian, Permian, Jurassic and Cretaceous age also show good reservoir qualities. In area under investigation, rocks of the Hangu, Lockhart and Patala Formations (Paleocene), Lumshiwal Formation (Cretaceous), Datta Formation (Jurassic), Tredian and Mianwali Formations (Triassic), Wargal, Tobra and Warcha Formations (Permian) and Khewra Formation (Cambrian) have the necessary qualities of reservoir rocks.

The hydrocarbon traps have formed as a result of compressional tectonics. These traps are anticlines, structures related to thrust faults, flower structures and/or triangle zone. Stratigraphic traps are also formed by the lateral pinchout of different sedimentary horizons. The Eocene salt in Kohat area can act as a seal. The hydrocarbon potential of the region is promising because of the presence of anticlines, synclines, flower structures, pinchout, unconformities, seals, carbonate buildups, source, reservoir, appropriate geothermal gradient and oil seeps (Parvez, 1992). The area is ripe for further detailed study using modern techniques including seismic reflection interpretation combined with well log control.

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