

The Salt Range: Pakistan's unique field museum of geology and paleontology

[Le Salt Range : un musée de géologie et de paléontologie à ciel ouvert au Pakistan]

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Abstract: The Salt Range contains the most important geologic and paleontologic localities in Pakistan, and is one of the outstanding field areas in the entire world. Despite its easy accessibility, it has a wealth of geological and paleontological features. In fact, it represents an open book of geology where various richly fossiliferous stratified rocks are very well exposed due to lack of vegetation. These include the Permian carbonate succession with its outstanding brachiopod fauna, Lower Triassic ammonoid beds (the Mianwali Formation, formerly known as "Ceratite Beds"), and Lower Tertiary marine strata with age diagnostic foraminifera. These rocks also provide an excellent opportunity for appreciation of tectonics in the field. In addition to the easily available roadside geology, some prominent gorges provide fantastic locations to study the sedimentary succession. Older strata are exposed in the eastern Salt Range between the Khewra-Choa Saidan Shah and Fort Kussak including the famous Khewra Gorge. In the west, beyond Kallar Kahar, are younger strata such as in the Nilawahan Gorge at Nurpur, the Nammal Gorge near Mianwali, the Chichali Gorge near Kalabagh, and further west the Lumshiwal Nala at Makerwal. This succession has been rightly called a Field Museum of Geology and Paleontology and can be classified as one of the great paleontological areas of the world, fully worthy of conservation and protection efforts.

Key Words: Pakistan; Salt Range; geology; paleontology; stratigraphy.

Résumé : *Le Salt Range : un musée de géologie et de paléontologie à ciel ouvert au Pakistan.*- Le Salt Range héberge les plus remarquables sites géologiques et paléontologiques du Pakistan, voire même du monde. D'accès facile, sans végétation gênante, ces sites aux thématiques variées sont comme un livre ouvert sur la géologie des roches sédimentaires et leurs fossiles. On y observe une série de carbonates permien et leur remarquable faune de Brachiopodes, un Trias inférieur à Ammonoides (les célèbres "couches à Cératites" de la formation de Mianwali) et un Tertiaire inférieur riche en associations de Foraminifères de référence. La tectonisation de ces couches permet, en prime, d'observer de belles figures de déformation. Précisons que l'observation de ces faits géologiques se fait par de bonnes routes au cœur de gorges très impressionnantes. Les plus anciennes séries sont observables dans la partie orientale du Salt Range entre Khewra-Choa Saidan Shah et Fort Kussak en passant par les gorges de Khewra. A l'ouest, près de Kallar Kahar, les couches les plus récentes s'observent dans les gorges de Nilawahan près de Nurpur, de Nammal près de Mianwali, de Chichali près de Kalabagh. Plus à l'ouest, on visite le Lumshiwal Nala près de Makerwal. Ces sites judicieusement appelés "Musée en plein air de Géologie et Paléontologie" sont reconnus comme l'une des plus importantes zones d'intérêt paléontologique du monde, et méritent tous les efforts possibles de conservation et de développement.

Mots-Clefs : Pakistan ; chaîne du Salt Range ; géologie ; paléontologie ; stratigraphie.

1. Introduction

The Salt Range forms the southern border of the hydrocarbon-bearing Potowar Basin in northern Pakistan, along the northwestern margin of the Indo-Pakistani Plate (Fig. 1). It derives its name from the occurrence of gigantic deposits of rock salt embedded in the Precambrian bright red marls of the Salt Range Formation (formerly known as the "Punjab Saline Series").

Strata in the Salt Range dip northwards into the Potowar Basin where non-marine Tertiary

sediments, collectively known as the Siwaliks, are exposed with a wealth of vertebrate fossils. The southern face of the Salt Range is an escarpment that rises abruptly from the Punjab Plains with a junction marked by the Frontal Thrust. Block faulting is the most characteristic tectonic style within the Salt Range.

The Salt Range is essentially an East-West trending elongated narrow trough bounded on the east by the River Jhelum and on the west by the River Indus. Beyond the River Indus at Kalabagh, it takes a sharp turn to run almost in a North-South direction (Fig. 1). The entire

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mountainous belt has, therefore, previously been differentiated into the Cis-Indus Salt Range and Trans-Indus Salt Range now known

as The Salt Range and Trans-Indus Surghar Range, respectively.

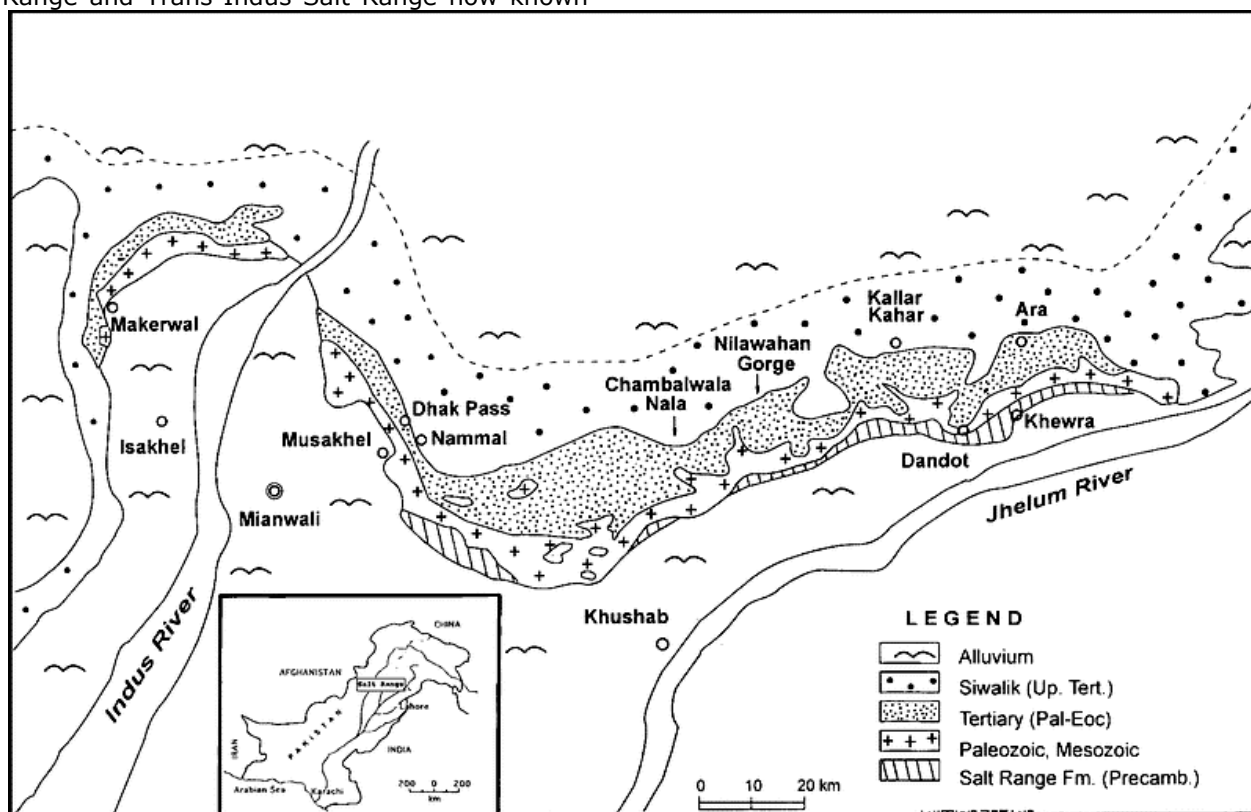


Figure 1: Map of the Salt Range, Pakistan (after E.H. PASCOE, 1919).

The Salt Range is one of the most important geological regions in Pakistan. It is easily accessible and displays a wide variety of geological features and paleontological remains. It has, therefore, been rightly called a field museum of geology and paleontology. It represents an open book of geology with richly fossiliferous stratified rocks that include a Permian carbonate succession with brachiopods, Lower Triassic ammonite bearing beds (the Mianwali Formation, formerly known as "Ceratite Beds") and Lower Tertiary marine strata composed of age diagnostic foraminifera. All the strata are excellently exposed due to lack of vegetation. The quality of the exposure also provides excellent opportunities to appreciate tectonic features in the field. The Salt Range is, therefore, of international scientific and educational value, and is highly worthy of conservation and preservation.

2. Previous work

In the past, the Salt Range has attracted geologists from all over the world to study Cambrian stratigraphy, the Permian-Triassic boundary, and Lower Tertiary foraminiferal biostratigraphy. Of particular note is the pioneering work of E.R. GEE (1935, 1945), who dedicated almost his entire geological career to the study of the Salt Range. His initial work related to solving the controversy regarding the age of the "Saline Series", a burning topic of that time, and he made a great contribution by

producing a geological map (more recently six sheets on a scale 1:50,000 have been published by the Geological Survey of Pakistan excluding the Trans-Indus Surghar Range).

DAVIES and PINFOLD (1937) completed a comprehensive study of Lower Tertiary larger foraminifera of the Salt Range. WAAGEN (1882-1885, 1895) worked on the brachiopods of the Permian of the Salt Range and FATIMI (1973) studied the ceratitids of the Triassic of the Salt Range and Trans-Indus Surghar Range. He also worked on stratigraphic nomenclature on the Salt Range as did SHAH (1977). KUMMEL and TEICHERT (1966, 1970) illustrated Permian brachiopods and described the detailed stratigraphy of the Permian rocks while GRANT (1966) described trilobites. HAQUE (1956) described the smaller foraminifera from the Tertiary formations of the western Nammal Gorge, Salt Range. AFZAL (1997) completed his doctoral thesis on the planktonic foraminifera of the Paleogene and established a planktonic biostratigraphy for the Patala Formation of the Salt Range and Surghar Range (AFZAL & von DANIELS, 1991; AFZAL & BUTT, 2000). SAMEENI (1997) completed his doctoral thesis on the Paleogene biostratigraphy of the Salt Range under UNESCO IGCP-286, headed by Prof. Lukas HOTTINGER of Basel University, Switzerland, and established an alveolinid biostratigraphy for the Eocene succession of the Salt Range (SAMEENI & BUTT, 1996, 2004; SAMEENI & HOTTINGER, 2003). ASHRAF and BHATTI

(1991) worked on the nannofossils of the Patala and Nammal formations of the Khairabad area of the western Salt Range.

3. Geology and Paleontology

PRECAMBRIAN ROCKS

The Precambrian rocks exposed in the Salt Range belong to the Salt Range Formation, which contains the thickest (approximately 5000 feet) seams of rock salt in the world. The Salt Range Formation is widely exposed along the southern edge of the Salt Range from east to west and in the Trans Indus Surghar Range. It is also recognized in the subsurface at Dhullian 200 km north of the Salt Range and at Karampur, approximately 500km south of the Salt Range. The Salt Range Formation is divided into three members:

- 3- Sahwal Marl Member
- 2- Bandarkas Gypsum Member
- 1- Billianwala Salt Member



Figure 2: Salt Range Formation and Khewra Sandstone exposed in the Khewra Gorge.



Figure 3: Diamond-like salt crystals of the Billianwala Member, Salt Range Formation.

All three members are well exposed on both sides of the Khewra Gorge (Fig. 2). The Billianwala Member contains ferruginous marl and thick seams of rock salt (Fig. 3). One of the largest mines in the world is situated in the town of Khewra (Fig. 4) in the eastern Salt Range, where salt is mined by the room and pillar method from 17 floors of the mine. The

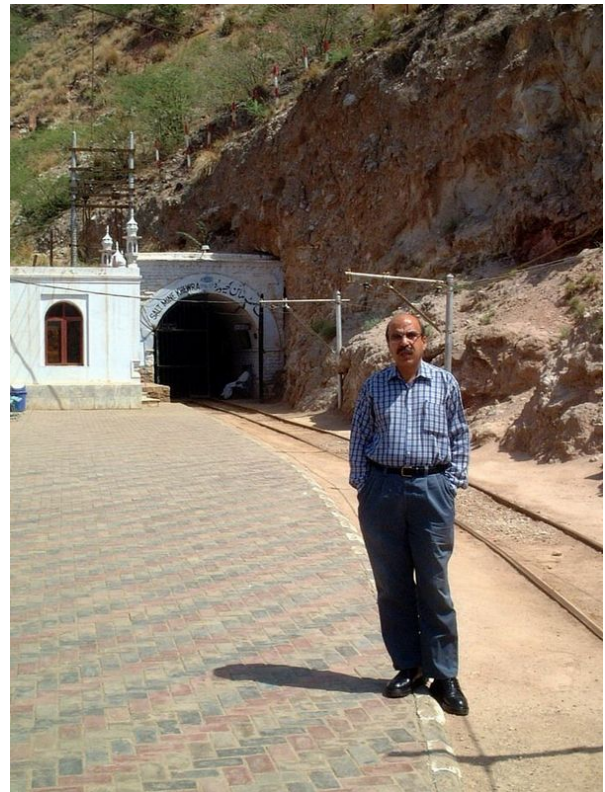


Figure 4: Entrance to the Khewra Salt Mine, one of the largest in the world.



Figure 5: Bandarkas Gypsum member of the Salt Range Formation.



Figure 6: Kewra Gorge.

Bandarkas Gypsum Member contains marl and huge deposits of crystalline and non-crystalline gypsum (Fig. 5). The Sahwal Marl Member contains marl along with 8-10 feet thick seams of rock salt. At the top of this member in the Khewra area, an igneous volcanic body is exposed known as 'Khewrite', which resembles an igneous body that occurs with the Pre-Cambrian Harmuz Salt of Iran. The sharp contact between the Salt Range Formation and the overlying Cambrian Khewra Sandstone (Figs. 2 & 6) can also be observed in the gorge.

PALEOZOIC ROCKS

The Paleozoic rocks exposed in the the Salt Range are of Cambrian and Permian age, with no strata representing the Ordovician to Carboniferous systems. The Cambrian sequence comprises four formations:

- 4- Baghanwala Formation
- 3- Jutana Formation
- 2- Kussak Formation
- 1- Khewra Sandstone



Figure 7: Roadside geology showing the contact between the Baghanwala and Tobra Formations in road cuts.



Figure 8: Contact between Baghanwala Formation (with salt pseudomorphs) and the overlying Permian glacial Tobra Formation.

These Cambrian formations contain (apart from other fossils) a wealth of trace fossils, including trails of trilobites and worm tracks. The Khewra Sandstone shows honeycomb weathering, cross-bedding and interformational folds. The Baghanwala Formation (Figs. 7-8), which contains salt pseudo-



Figure 9: Salt pseudomorphs in the Baghanwala Formation.



Figure 10: The Permian Warchha Sandstone overlying the Dandot Formation exposed along the Khewra-Choa Saidan Shah road.



Figure 11: Permian Amb Formation, Pail Area.

morphs (Fig. 9), is well exposed along the roadside and displays a sharp unconformable upper contact with the overlying Permian glacial deposits.



Figure 12: Fusulinids beds the Amb Formation, Pail Area.



Figure 13: Fusulinids in the Amb Formation, Pail Area.



Figure 14: A view of Nammal Gorge.

The Permian strata of the Salt Range are assigned to two groups, the Nilawan Group and the Zaluch Group. The oldest formation of the Permian, the Tobra Formation of the Nilawan Group, is a non-marine deposit that shows different facies across the region. In the eastern Salt Range, it is tillitic (glacially deposited), grading into a marine sandstone; in the central Salt Range it incorporates lacustrine deposits; in the western Salt Range and Trans Indus ranges it displays a complex facies of

alternating glacial and stream (ice melt water) deposits. The other formations of the group, the Dandot Formation and Warchha Sandstone, are also well exposed along the Khewra-Choa Saidan Shah road with a sharp contact between them (Fig. 10).



Figure 15: Middle *Productus* Limestone in Nammal Gorge.



Figure 16: *Productus* exposed in the limestone in Nammal Gorge.

In the central Salt Range near Pail the Amb Formation, the youngest formation of the Zaluch Group, is very well exposed along the roadside, where it contains numerous fusulinid-bearing beds (Figs. 11-13). Further west in the Nammal Gorge (Fig. 14), the Wargal Formation (formerly known as the Middle *Productus* Limestone) and the Chhidru Formation (formerly known as the Upper *Productus* Limestone) are exposed, and bear abundant specimens of *Productus* and other brachiopods (Figs. 15-16). The Permian rocks have a sharp upper contact with Triassic rocks, marking a paraconformity. The Permian rocks are distinguished by the presence of *Productus*, whereas the Triassic rocks contains *Ceratites*.

MESOZOIC ROCKS

The Triassic Mianwali Formation is very well exposed in the Nammal Gorge as well as in the Dhak Pass, where beautiful *Ceratites* specimens can be found along the roadside (Figs. 17-19). The lower contact of the Mianwali Formation

with the Permian Chhidru Formation is a paraconformity. The Triassic and Jurassic succession contains both marine and non-marine strata. Amongst Cretaceous rocks, the Chichali Formation (formerly known as the "Belemnite Beds") is very well exposed (Fig. 20) in the Chichali Gorge (Trans-Indus Surghar Range) where it bears a wealth of belemnites in the form of a "graveyard"; this formation is also exposed in other parts of the Kohat-Potowar basin.



Figure 17: Road cuts containing abundant *Ceratites* at Dhak Pass.

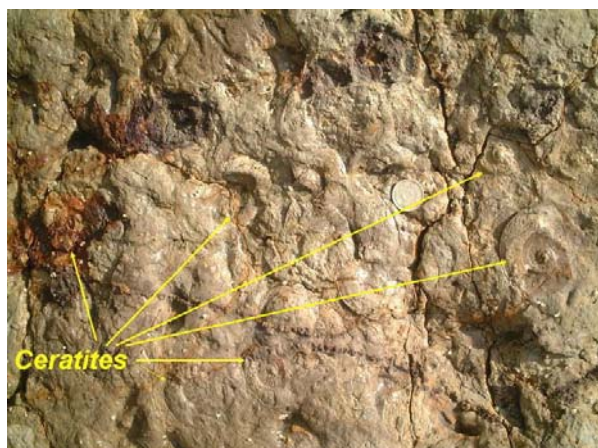


Figure 18: Numerous *Ceratites* exposed on the outcrop.



Figure 19: A well-preserved *Ceratites*.



Figure 20: Abundant Cretaceous belemnites, known as a "belemnite graveyard", in the Chichali Formation in the Surghar Range.

CENOZOIC ROCKS

Paleogene rocks are mostly exposed in the central and western Salt Range (Fig. 21) as well as in the Trans-Indus Surghar Range. These rocks are oil bearing in the adjacent Kohat-Potowar basin, where the Paleocene Lockhart Limestone (Fig. 22) acts as a reservoir rock, the Patala Formation as source rock and the Nammal Formation and Sakesar Limestone as cap rocks. The Lockhart Limestone was deposited in a shallow-shelf, marine carbonate environment inhabited by abundant shallow benthic larger foraminifera (Fig. 23), including guide fossils for the Upper Paleocene such as *Miscellanea miscella* and *Lockhartia haimei*. The Patala Formation, of Upper Paleocene and Lower Eocene age, also contains larger foraminifera. The Lower Eocene Nammal Formation and Sakesar Limestone (Fig. 24) are exposed throughout the Salt Range and Surghar Range, and are rich in age diagnostic larger foraminifera, including *Nummulites*, alveolinids and assiluinids.

The Choegali Formation (formerly known as "Bhadrar Beds"), of Lower Eocene age, is only exposed in the central Salt Range, where it bears age-diagnostic larger foraminifera like *Nummulites* (Fig. 25) and alveolinids.



Figure 21: Paleogene formations exposed in Nammal Gorge.

The non-marine Miocene-Pliocene rocks known as the Lower and Upper Siwaliks (Figs. 26-28) are famous for their vertebrate fauna including mammals (among which is the largest mammal), birds and reptiles.



Figure 22: The Paleogene Lockhart Limestone exposed along a road side near Nammal Gorge.



Figure 23: Nodular foraminiferal limestone beds in the Lockhart Limestone.



Figure 24: Sakesar Limestone.



Figure 25: The Choegali Formation of Eocene age contains numerous *Nummulites*, shown in this image.



Figure 26: The Lower and Upper Siwaliks, non-marine Miocene-Pliocene rocks, occur in the Salt Range.

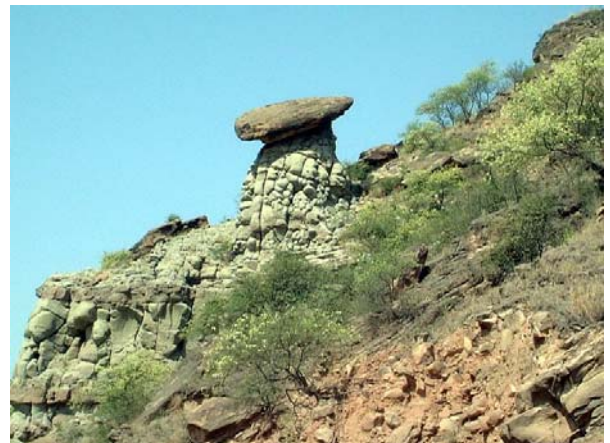


Figure 27: Differential weathering and badlands exposures in the Siwaliks.



Figure 28: Vertebrate fossils are well preserved and abundant at localities in the Siwaliks.

4. Recommendations

The Salt Range contains a number of unique fossil occurrences and many occurrences that are useful in research and education. It should be considered carefully by local paleontologists for the preservation and conservation of these resources. Those sites (of any geographic extent) that are deemed worthy of preservation should be designated a potential PaleoPark and local efforts to preserve them should ensue. This will require significant efforts because of the numerous sites, and the size and paleontological fame of the Salt Range.

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