STRATIGRAPHY OF THE BAGHANWALA FORMATION, KHEWRA GORGE, KHEWRA, JEHLUM DISTRICT; PUNJAB : PAKISTAN

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ABSTRACT

The Baghanwala Formation consists of variegated shales with thin bedded flaggy sandstone. Stratigraphic studies coupled with the lithology and sedimentary structures revealed that the formation was deposited in a shallow basin under arid and strongly oxidizing environments. Bulk of the sandstone beds are calcareous, with abundant argillaceous material at some stratigraphic levels. Iron oxide pigmentation is dominant.

The Baghanwala Formation on the basis of its conformable contact with the underlying Jutana Dolomite is assigned a Late Early Cambrian-Early Middle Cambrian age.

STRATIGRAPHY

General Features

The Baghanwala Formation conformably overlies the Jutana Dolomite in the Khewra Gorge, Khewra (Fig. 1). It is olive, maroon, and brownish-red in colour and is composed of variegated shales and interbedded with grny and maroon flaggy thin bedded sandstone. The formation shows abrupt variations between sandstone, shale, and siltstone. At places interbeddings of limestone/dolomite are also noticed. Calcareous cementing material and clay minerals are abundantly present. Glauconite and ghost colites/pisolites are noticed on a very limited scale near the very basal part of the formation. The writers suggest that they have been reincorporated from the underlying Jutana Dolomite, as a result of reworking. Micaceous minerals are present throughout, but are abundant in the upper part. Iron leaching is noticed in lower part. The pigmentation appears to be the result of abundant iron oxide, mostly hematite (?), which might have originated during diagenetic

processes or precipitated simultaneously with the Baghanwala Formatior At some stratigraphic levels, pigmentation of iron oxide is so abundant tha nothing except brownish-red pigments or few iron oxide coated quartz grair can be noticed. Oxidation effects are also pronounced and at some place pseudomorphs of biotite are recognized.

Primary sedimentary structures noticed are stratification, cross-beddin ripple marks, worm burrows, and cubic pseudomorphs of halite. Presen of these structures combined with the mineralogical composition indica that during the deposition of the Baghanwala Formation, salinity of tl basin was high which resulted in the crystallization of salt crystals. Howeve the salt crystals were dissolved by the encoraching sea or inflowing fluvi water (?), but their casts were preserved which are now noticed as cub pseudomorphs. No faunal evidence has been reported as yet from this form tion except the worm burrows. On the basis of its conformable contact wi the underlying Jutana Dolomite and unconformable contact with the overlyi Tobra Formation, it has also been assigned a Late Early Cambrian or Ear Middle Cambrian uge.

The formation indicates deposition in a shallow basin under oxidizir and evaporitic environments.

CAMBRIAN SYSTEM

Late Early Cambrian-Early Middle Cambriam

Jehlum Group

BAGHANWALA FORMATION

Definition, Type locality, and Regional Nomenclature

"Salt Pseudomorph Shales" is the first informal name put forward f this formation, by Fleming (1852). Wynne (1878) used the name "Sa Pseudomarph Beds". First formal name based on the geographic name, t type locality of the section, was put forward by Noetling (1894). He ga it the rank of a group and named it as "Baghanwala Group". The nar Baghanwala Group was given on the basis of its best and maximum exposu in a section exposed near the village Baghanwala (Latitude 32° 42′ Longitude 73° 14′ E) located in the eastern Salt Range, Jehlum Distri Punjab; Pakistan. Later Stratigraphic Code Committee of Pakistan forma zed the name as Baghanwala Formation (Published in 1972). The formati

constitutes upper part of the Jehlum Group, as well as the upper most Cambrian suecession of Salt Range. The section exposed in the Khewra Gorge can be used as a reference section.

Distribution

The outcrops of the Baghanwala Formation are prominently exposed in the eastern Salt Range at Pidh, Dandot, Chambel, Makrach, and Jogi Tilla ridges. Exposures of this formation are also present in the eastern side of the Nilawahan Ravine. In the southern part of the Khisor Range, south-east of Saiduwali, there is a thick sequence of the purple sandstone, flaggy dolomite, bituminous shale, greenish-gray shale, and massive white to pink gypsum which seems to be a lateral facies change of the Baghanwala Formation. However, it is not known with certainity that how much of it is Cambrian and how much of it is Post Cambrian (Krishnan, 1968). When traced WNW from Khewra, the Baghanwala Formation is directly unconformably overlain by the Tobra Formation near Sakesar, beyond which this formation is not observed. Subsurface drilling, carried out by AMOCO, has revealed the presence of the Baghanwala Formation at Karampur and Dhariala.

Lithology and Thickness

The Baghanwala Formation is made up of maroon, bright red to purple variegated shales with interbedded thin bedded sandstones of colours which vary from gray, dark gray, brown, red brown to purple. The stratification is prominently preserved throughout. Other primary sedimentary structures observed are ripple marks, pseudomorphs after salt crystals, fossil mud cracks, and worm burrows (organic sedimentary structures). Fucoid markings are reported by many others. The primary sedimentary structures noticed in this formation ate indicative of deposition in shallow water environments. The salinity of water in the basin was too high, and the depth was shallow. Alternating layers of shales were deposited. While the sandstones are indicative of shallow water deposition. The carbonate minerals, calcite/dolomite are also common, rather abundant, in the lower part as compared to the upper part of the formation. The writers suggest that the carbonate were brought by the overflow of marine water (containing dissolved carbonates) into the basin through some part of an inlet in a barrier. Thus the final deposition of the

minerals took place in the basin containing terrigenous quartz grains. The abundance of the carbonate matrix is the result of same process. The other explanation which can be forwarded is that the carbonate flowed into the basin alongwith terrigenous sediments brought in by rivers draining into the basin.

Overall redish to purple colour of formation is suggestive of deposition under strongly oxidizing and arid climate. Oxides of iron are abundant in the upper part as compared to the lower part, and suggest prevalance of more oxidizing environments. Oxides of iron, mostly hematite (?) are the main red pigmenting agents. At some stratigraphic levels in the upper part red pigmentation is also abundant and so profuse that nothing except the brownish-red colour or a few quartz grains can be seen. The writers suggest that some of the iron oxides are the result of direct precipitation as microcrystalline particles, or adsorption of the iron ions on the surface of the clay minerals. However, some of them are of diagenetic origin.

Thin bedded flaggy sandstones are composed of fine to medium quartz grains with some micas and traces of feldspar. The grains are subangular to subrounded and are bounded together by loose calcareous cement. The sandstones also contain clay, and at some stratigraphic levels clay and silt are the dominant constituents of the sandstones. Micaceous contents are not prominent in the upper part as compared to basal part. However, no gradational variation is observed. Muscovite, biotite, and chlorite are the micaceous minerals present. Muscovite occurs in the form of long thin fresh flakes. On the other hand biotite occurs as brown pleochroic flakes, mostly altered to chlorite. In upper layers extensive oxidation has resulted in the complete staining of biotite flakes. In many cases it becomes difficult to identify biotite, and only the pseudomorphs of biotite are noticed. Chlorite occurs as small green pleochroic flakes, and is the alteration product of biotite. It is because of the abundance of calcareous and micaceous minerals that majority of the sandstone samples falls within the category of calcareous sandstones and micaceous sandstones. Mixtures of these two categories are also present. At a distance of about 5 meters and 9 meters from the base there are 25 centimeters and two and half meters thick layers respectively, which are mainly composed of calcite/dolomite and contain very little quartz and mica. These occurrences are suggestive of slight deepening of the basin and discontinuity in the rate of infiux of detrital material from land. However, such conditions never prevailed in the basin for longer periods and the shallow conditions staged a come back soon.

Traces of glauconite and a few ghost structures are noticed in the very basal part of the formation. They are observed at levels containing little calcareous minerals. Since they are absent from the rest of the formation, the writers suggest that such constituents are the result of reworking from the underlying Jutana Dolomite, The glauconite, characteristic of stagnant conditions with slightly reducing environments (which are no where indicated by the Baghanwala Formation), also supports the idea of reworking, as put forward by the writers.

Cubic pseudomorphs after salt crystals are the most important feature of the formation. They are more abundant in the muddy sandstones of the upper part as compared to the lower part. These pseudomorphs are prominently preserved at the bedding planes and their boundaries are shared by both the stratigraphic units. This fact is indicative of salt crystallization at the end of one depositional period its solution by the incoming waters at the start of next depositional period.

The entire formation is thus suggestive of deposition under shallow water environments in strongly oxidizing and evaporitic conditions or arid and desicating conditions The abundance of fossil mud cracks within the Baghanwala Formation also supports this conclusion.

Total thickness of the Baghanwala Formation, measured by the writers, on the eastern side of the Khewra Gorge is about 33 meters. The detailed description of the various lithological units is given as under (from botton to top):

	Meters	Cms.
Micaceous sandstone, olive green and gray, occasionally maroon, fine grained, thinly laminated, interbeddings of calcareous material, occasionally dolomitic, ripple marks common, micaceous sheen developed by concentration of mica along thin layers, fossil mud cracks and annelid burrows common, basal part is soft, middle parr is little bit hard, upper part is more hard, calcareous cement	2	28
Sandstone, olive fine grained, thin bedded with intercalations of shale, small amount of mica present, hard and compact, calcareous cement	1	21

	Meters	Cms.
Sandstone, olive, fine grained, laminated thin bedded, near the top grades into thin bedded siltstone and shale, contains abundant maroon siltstone intercalations, iron leaching common, abundant calcareous cement	0	96
Limestone, Light gray, laminated, thin bedded, contains intercalations of shale near the top, jointed, slightly micaceous, small amounts of clayey minerals also present	2	48
Siltstone-shale, olive, at places maroon, very fine grained, laminated, thick bedded, abundant iron leaching, hard calcareous cementing material is abundant	1	06
Sandstone, olive, with maroon intercalations of sandstone, thin bedded, calcareous cement	0	16
Siltstone, maroon, vesy thinly bedded, a few olive coloured sandstone interealations, cubic pseudomorphs present ...	0	30
Limestone, olive, with maroon intercalations, laminated, thin bedded, slightly micaceous, hard and compact	0	28
Siltstone, maroon, with gray sandstone intercalations, thin bedded, calcareous cement	0	07
Sandston, olive, with thin laminations of maroon siltstone, calcareous and clayey cement	0	07
Siltstone, maroon, with olive sandstone intercalations, thinly laminated, loose, calcareous cement	0	43
Sandstonc at the base and shale at the top, sandstone is gray, while shale is maroon, shale intercalations of less than 2 cms thickness common, intercalations vary in thickness, iron leoching abundant, loosely cemented, clayey cement.	0	83
Sandstone, oiive, with green, thin shaly intercaiations, fine grained laminated, thick bedded, at the base represent apparcnt weathering zones indicated by redepesition of dolomite pebbles, channel sand at one place, cubic pseudomorphs common, iron leaching common, abundantly calareous and clayey	2	97

	Meters	Cms.
Shale, maroon, very fine grained, thinly bedded, abundant iron coating calcareous and clayey cement	0	53
Calcareous sandstone at the base, and shale at the top, gray, very fine grained, thinly bedded, loosely cemented, calcareous and clayey cement	1	14
Sandstone, maroon, very fine grained, very thinly dedded, abundant calcareous and elayey material, iron coating abundant	0	40
Sandstone, brownishred, fine grained, quartz grains subangular, thin bedded, micaceous, abundant iron oxide pigmentation, near the top contains green shaly intercalations, loosely cemeuted, ealcitic and iron oxide (?) cemcnt ...	0	60
Micaceous sandstone, brown, fine grained, thin bedded, intercalations of shale, cubic pseudomorphs abundant, micaceous minerals prominent, abundant iron oxide pigmentation, loosely gemented, calcareous and clayey cement	2	45
Sandstone, brownish-red, fine grained, thin bedded, abundant intercalations of shale, basal part more shaly than the upper part, sandstone is thin bedded at the base, and thick bedded near the top, cubic pseudomorphs abundant, iron oxide pigmentation, loosely ccmented, calcareous and clayey cement	4	15
Scree	6	00
Shale, dark maroon, fine grained, thin bedded, abundant iron oxide pigmentation, calcareous cement	0	23
Sandstone, dark brown, medium to fine grained, thick bedded, massive, contains a few thin shale beds, slightly micaceous, soft, loosely cemented, abundant iron oxide pigmentation, calcareous and clayey cement	0	94

	Meters	Cms.
Sandstone, dark brown, fine grained, quartz grains subangular, laminated, thin bedded, abundant shale intercalations, shale vary from maroon to olive in colour, cross-bedded, ripple marks present near the basal part, abundant iron oxide pigmentation, micaceous sheen, slightly hard, calcareous and clayey cement	4	25
Total thickness in Meters ...	32	69

Relation to Adjacent Formations

The Baghanwala Formation conformably overlies the Jutana Dolomite. The contact is marked by a change of colour from light gray to olive, and at places maroon. The contact is also marked by the increase in thin shaly beds. The difference in the hardness of the underlying and overlying rocks also marks the contact sharp. The underlying Jutana Dolomite forms steep cliffs, whereas the Baghanwala Formation forms gentle slopes and flat surfaces which give rise to small rapids in the course of the stream occupying the gorge. The upper contact of the Baghanwala Formation with the overlying Tobra Formation is unconformable. The Tobra Formation has been assigned an Early Permian age. It is therefore expected that during Ordovician, Silurian, Devonian, and Carboniferous periods the area was definitely uplifted. The marked difference in the dip of the two formations is firmly suggestive of an unconformable contact. The successive truncation of the Jehlum Group and the Salt Range Formation by the Tobra Formation, near Sakesar is the clear indication of an unconformable contact of the Tobra Formation with the underlying Baghanwala Formation.

Age and Correlation

The Baghanwala Formation is unfossiliferous except the burrows of annelids, and fucoid markings of uncertain identification. It is therefore impossible to assign an exact age based on faunal evidence. However, on the basis of conformable contact with the underlying Jutana Dolomite, the same age i. e., the Late Early Cambrian to Early Middle Cambrian, has been assigned to it, and the writers also agree with the assigned age.

The formation marks an end of a megacycle of deposition, in which the Salt Range Formation and the entire Jehlum Group was deposited. The cycle started with an evaporite facies dominated by an arid climate passing through transitional non-marine and marine (Fluvial and beach) environments, then deep marine followed by shallow marine environments. The cycle came to an end with the advent of the evaporite facies of deposition, again dominated by an arip climate. After this cycle, most probably, terristerial conditions of non-deposition prevailed for a long stretch of time. The area recorded heavy and extensive glaciation during Early Permian times, the record of this glaciation is preserved in the form of the Tobra Formation, a thick sequence of boulder bed, dark black pebbly shales, and olive green coarse conglomeratic sandstones.

The Beghanwala Formation is correlated with purple and variegatede shales and interbedded sandstone outcrops exposed at Pidh, Dandot, and on th eastern side of Nilawahan Ravine. Outcrop of approximately similar lithology is also exposed in the southern part of the Khisor Range at Saiduwali. The outcrops and the constituent rocks are considered to be the lateral facies change of the Baghanwala Formation. However, it is not certain as to how much of it is of Cambrian age and how much of post Cambrian age (Krishnan, 1968, p. 212).

CONCLUSION

The Baghanwala Formation conformably overlics the Jutana Dolomite and is composed of variegated shales with flaggy sandstone interbeddings, Dark maroon colour and primary sedimentary features like ripple marks, forsil mud cracks, worm burrows and psedomorphts after sait crystele indicate that the formation was deposited under strongly oxidizing, arid, and shallow water environments. Thin limestone/dolomite interbeddings at certain stratigraphic levels appear to have been deposited under warm, well oxygenated, calm, and shallow marine environments. Majoriry of the sandstone interbeddings are composed of calcareous material with abundant argillaceous material at some stratigraphic levels. Iron oxide pigmentation is abundant and in fact is a most conspieuous feature of the formation.

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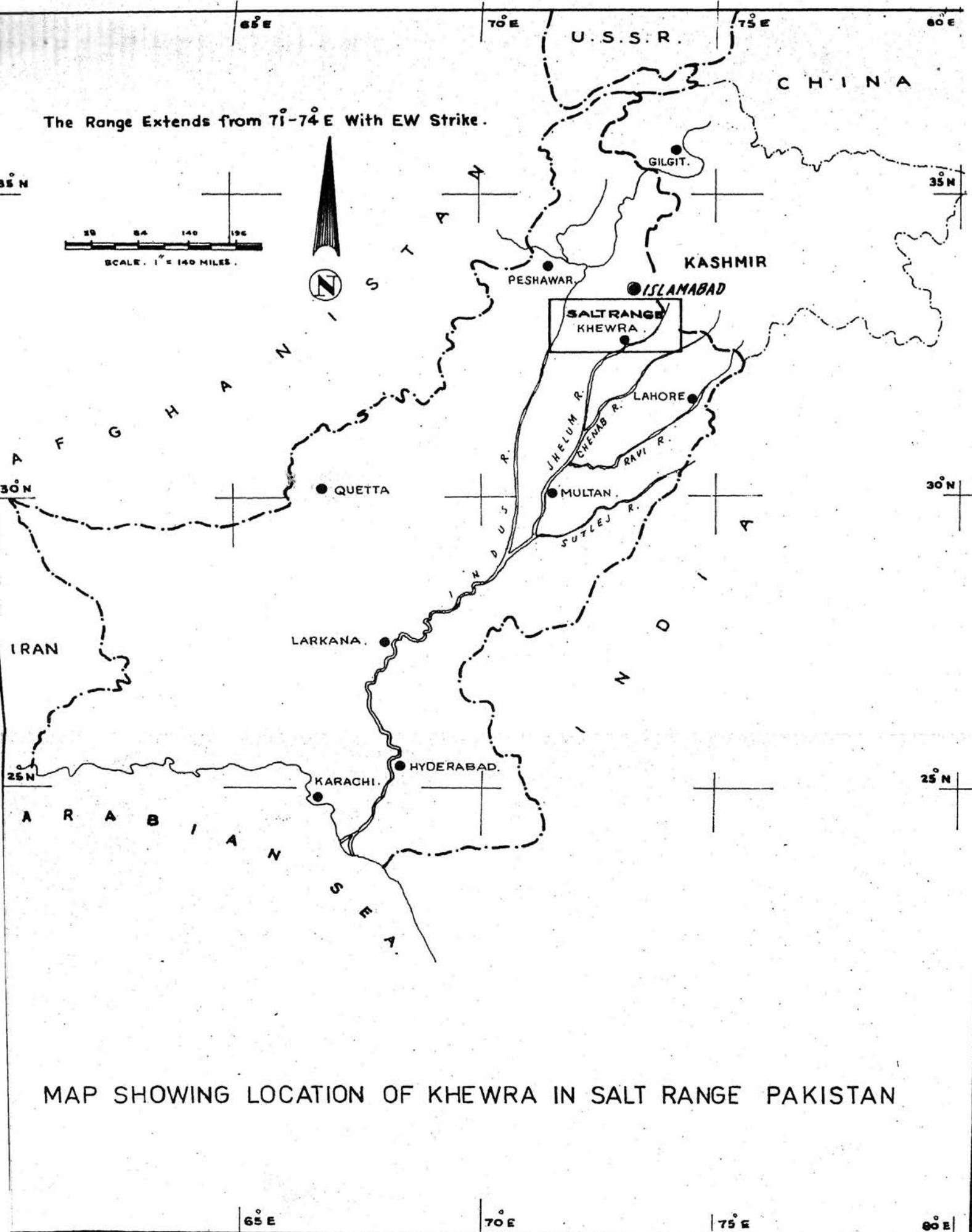

MAP SHOWING LOCATION OF KHEWRA IN SALT RANGE PAKISTAN