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LITHOLOGICAL CLASSIFICATION AND ENVIRONMENT OF DEPOSITION OF THE KHUSSAK FORMATION, KHEWRA GORGE, SALT RANGE; KHEWRA

MOHAMMUD ATTAULLAH KHAN

ABSTRACT

The Khussak Formation (Early Cambrian), exposed in the Khewra gorge, shows rapid variations in lithology from its base towards top. Lithologically, the Khussak Formation can be conveniently divided into three members, (1) Lower Mudstone-Siltstone-Sandstone Member, (2) Middle Shale Member, and (3) Upper Mudstone-Siltstone-Sandstone Member. Interbeddings of dark gray micaceous shale occur at various stratigraphic levels within the Lower and Upper members. Layers with glauconite concentrations, which are traceable over fairly long distances, are fairly persistent in both the Lower and Upper members. The glauconite is conspicuously lacking in the Middle Shale Member.

The Khussak Formation indicates deposition in a restricted marine basin, which became shallow from time to time and recorded low sedimentation. The overwhelmingly dark gray and grayish-green colours of the formation, layers with glauconite concentrations, crawling marks; and rare sun cracks on the surfaces of the interbedded siltstone and sandseone support the above statement. Occurrence of only phosphatic shells of brachiopods, characterized by their dwarfed nature, is an undeniable evidence for the existence of a restricted marine basin in which the Khussak Formation was deposited during the Early Cambrian Period.

INTRODUCTION

The Khussak Formation (formerly Neobolus Beds) of Early Cambrian age is extensively developed in the eastern part of the Eastern Salt Range. The dark gray, grayish-green, and green colours of this formation contrast sharply with the bright maroon and red colours of the underlying Khewra Sandstone. This colour difference makes their recognition very easy. Well exposed sections of the Khussak Formation are seen in the Khewra gorge and in Khussak Hill, the type locality, not far from Khewra. This formation is characterized by remarkable lithological heterogeneity and is composed of micaceous and

glauconitic mudstone, slitstone, and sandstone with subordinate black and dark gray micaceous shale, gray silty dolomite, and very thin layers of dark gray argillaceous limestone. Glauconite occurs in all but shale. Concentration of glauconite occurs in the form of distinct layers both in the Lower and Upper members. A low grade lithification characterizes the Khussak Formation. The oxidation of the pyrite causes the swelling of the argillaceous strata and they disintegrate when touched or walked upon.

During a recent visit to Khewra gorge, the writer measured the Khussak Formation section in order to examine various distinct lithlogical units within the formation. It was observed that a 20 to 30 feet thick bed of dark gray and purplish gray fossiliferous shale, about 172 feet above the base of the formation, separates a Lower Mudstone-Siltstone-Sandstone Member from an Upper Mudstone-Siltstone-Sandstone Member.

This paper describes the major lithological units which can be traced over a fairly long distace and presents the bases for a three-fold lithological division o f the Khussak Formation exposed in the Khewra gorge and vicinity. It also presents a discussion of the environments under which the Khussak Formation was deposited.

STRATIGRAPHY

On the bases of lithology, the Khussak Formation can be divided into three distinct major members (Fig. 1).

(iii) Upper Mudstone-Siltstone-Sandstone Member
(ii) Middle Shale Member
(i) Lower Mudstone-Siltstone-Sandstone Member

(*i*) Lower Mudstone-Siltstone-Sandstone Member.

It is marked by a pebble-bed at base and overlies the Khewra Sandstone without any apparent discordance. The pebble-bed is 18 inches thick and is composed of rounded to subrounded pebbles of milky, gray, and brown quartz, quartzite and chert pebbles. These range in size from 4 mm. to 10 mm. Coarse and medium sand forms the matrix in the pebble-bed. Apparently this coarse bed represents the uppermost part of the underlying Khewra Formation and it grades downward into coarse-grained, cross-bedded red sandstone. The pebble-bed indicates the shallowing of the basin before the Lower Member of the Khussak Formation was deposited. The coarse clastic bed may very well represent a slight disconformity.

The lower part of the Lower Member is composed of thin alternate layers of dark gray bituminous shale, micaceous siltstones, and sandstone which are occasionally dolomitic. Repetition of shale, mudstone, siltstone, and sandstone which is observed through most of the thickness of the Khussak Formation is suggestive of cyclic sedimentation. Three distinct layers of dark maroon coloured hematitic oolites, measuring 6 to 18 inches in thickness, occur in the basal part of the Lower Member. These layers are separated from one another by thinly laminated siltstone and sandstone and dark gray shale. These layers of hematitic oolites either indicate derivation from a well-oxidised terrain or a temporary shallowing of the reducing basin and ensuing oxidising and turbulent environments.

The upper part of the Lower Member is mainly composed of micaceous and glauconitic mudstone, siltstone, sandstone, and subordinate fossiliferous micaceous shale. All the rocks of this part are characterized by the abundance of long and fairly continuous worm burrows. Disarticulated cephala and pygidia of trilobites and small phosphatic shells of brachiopods are also found but are rare. Interbedding of shale, siltstone, and fine-grained sandstone is very common. Primary structures characteristic of a zone of intermittent turbulence are ubiquitous. The Silt and fine sand occur as lenticles, commonly aligned and usually laminated. These superficially resemble the flaser structure of some sheared metamorphic rocks.

The Lower Member's mudstone, siltstone, and sandstone become increasingly glauconitic in the upper part and particularly towards top. Occasionally, glauconite occurs concentrated in 2 to 4 inch thick sandy layers. In these layers glauconite accounts for more than 60 per cent of the constituents. This glauconite may either be insitu as a result of glauconitization or authigenesis or may be a concentrate of authigenic glauconite formed elsewhere and later transported to its present position. In case it represents insitu glauconitization* the layers might indicate slight unconformities.

The total thickness of the Lower Mudstone-Siltstone-Sandstone Member is 172 feet.

(*ii*) Middle Shale Member.

The Lower Member is conformably followed by the Middle Shale Member. This member consists of dark bluish-and purplish-gray bituminous shale, which weather to a light purple gray hue. Unlike the Lower Member, glauconite and mica are lacking in it. Also, no siltstone or sandstone interbeddings occur in

*Thin sections, cut from several samples, do not show a linear or preferred orientation of glauconite grains; thus transport of glauconite from elsewhere is ruled out.

it. It is practically a uniform and homogeneous lithological unit. The Middle Shale Member is fossiliferous and contains inarticulate chitinophosphatic shells of such brachiopods as *Lingula*, *Lingulella*, *Obolus*, *Discinolepis*, and *Neobolus*. All of these are characterized by a smaller size and shells of phosphatic composition both of which are well-adapted to a strongly reducing environment. *Redlichia* and *Ptychoparia* represent trilobites. However, these are never found complete. Usually cephalic parts such as glabella, cranidium, and free cheeks are found as carbon films on the surfaces of freshly broken pieces of shale. The total thickness of the Middle Shale Member is ± 20 feet.

(*iii*) **Upper Mudstone-Siltstone-Sandstone Member.**

The Middle Shale Member is conformably overlain by the Upper Mudstone-Siltstone-Sandstone Member. The basal beds are formed by coarse-grained hard and compact glauconitic sandstone. About 10 feet above the base of the Upper Member, coarse grayish-green glauconitic sandstone gives way to about a 2 feet thick pebbly or concretionary bed which is fairly continuous. The rest of the thickness of the Upper Member is made by interbeddings of dark gray shales, green glauconitic mudstones, siltstones, and sandstones. Dolomitic silty and sandy layers occur near the top of the Member. The Upper Member also cotains layers which are mainly composed of glauconite. These layers are very loosely cemented and crumble on being touched. Micaceous partings in thinly-laminted shales, siltstones, and sandstones are common. The mudstone is also abundantly micaceous. Lenticles of silt and sand aligned and cross-laminated occur in shale and mudstone.

The Upper Member is characterized by worm burrows which are ubiquitous in the entire Khussak Formation. Disarticulated trilobites and phosphatic shells of inarticulate brachiopods also occur.

The lower contact of the Upper Member with the underlying Middle Shale Member is marked by scouring and abrasion, indicating a change in the conditions of sedimentation-from calm to turbulent. Intermittent turbulence seems to be common feature during the deposition of the entire Khussak Formation. The upper contact of this Member with the overlying Jutana Dolomite is marked by a concretionary zone. These concretions have a concentric structure and may represent algal secretions.

The total thickness of the Upper Mudstone-Siltstone-Sandstone is 43 feet.

ENVIRONMENTS OF DEPOSITION

The Khussak Formation indicates deposition in a restricted marine basin, which was perhaps cutoff from the main sea by a topographic barrier or by

sealing off the depositional basin from atmosphere by a density stratification. Such density stratification in marine waters sets in because of marked differences in salinity (Pettijohn, 1957, p. 622).

While measuring the Khussak Formation in the Khewra gorge, the writer observed repetitions of coarse sand, fine silt, mudstone, and black shale. This is suggestive of an oscillatory behaviour of the depositional basin. From time to time sediments were almost lifted above sea level. Very shallow and agitated conditions were set in. Occurrence of three bed of hematitic oolites, measuring six inches to eighteen inches in thickness, supports this conclusion. These beds of oolites would have formed only in an agitated and oxidising environment. However, such environments must have been quickly depleted by the overwhelmingly anerobic conditons and sinking of the depositional interface under toxic waters.

The entire Khussak Formation is characterized by dark gray, black, green, and grayish-green colours. Undoubtedly few black shale layers in the lower part of the formation are decidedly rich in organic matter, nevertheless the overwhelmingly dark gray and black colours are due to abundance of the sulphide of iron. The surfaces of the basal strata of the Lower Member are profusely coated with melanterite or iron sulphate, a white efflorescence, formed by the oxidation of pyrite. Pyriteous shales and dark bituminous shale characteristically develope in reducing or euxenic environments. The fine-grained dolomites and occasional very thin layers of fine-grained argillaceous limestones, which are often associated with such shales, are seen to occur in the Khussak Formation also. The entire lithological association is characteristic of deposition in a restricted and reducing basin.

Glauconite is abundant both in Lower and Upper parts of the formation, however, it does not occur in the Middle Shale Member. It is a characteristic mineral which forms in reducing or euxenic environments of a restricted marine basin. The essential setup, required for its formation, is examplified by the physio-chemical conditions of the basin in which the Khussak Formation was deposited. Abundance of organic material, slow sedimentation, weakly oxidising environments, shallow and warm basin, and abundance of iron-bearing minerals seem to have favoured its large scale formation in the Khussak Formation. It is very likely that concentration of glauconite along certain zones of the formation indicate slight unconformities (submarine surfaces on which accumulation of sediments is very slow may grade laterally to disconformities. A surface like this is indicated by thin layers which are rich in glauconite and organic debris (Compton, 1962, p. 233)). Thin section study does not reveal

any alignment or any noticeable degree of preferred orientation of glauconitic grains. It appears that all of it has formed insitu and represents a vigorous phase of glauconitization favoured by the above mentioned environments. The lacking of glauconite in the underlying Khewra Sandstone and the overlying Jutana Dolomite, deposited in well-oxygenated environments, further supports the existence of euxenic environments during the deposition of the Khussak Formation. The occurrence of only phosphatic shells of brachiopods and absence of any notable carbonate secreting organism, other than trilobites, is an undeniable evidence of the prevalence of euxenic environments during the deposition of the Khussak Formation in Early Cambrian Period.

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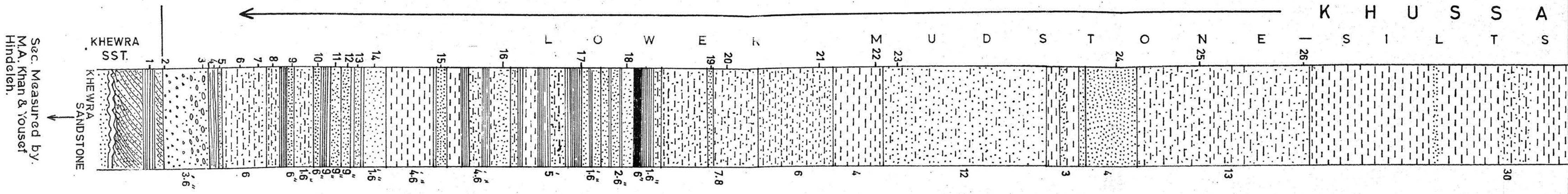
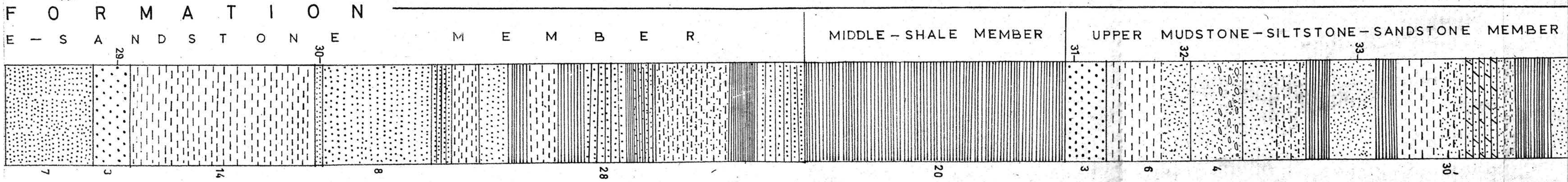


Fig.1:- STRATIGRAPHIC SECTION OF THE KHUSSAK FM. MEARSU



THE EASTERN WALL OF THE KHEWRA GORGE, SALT RANGE. KHEWRA.

DESCRIPTION	*Feet*	*Inches*
Sandstone, conglomeritic towards top, pebbles of white quartz and dark sandstone, loosely cemented, poorly sorted, fair degree of roundness.	3	6
Siltstone, shale and mudstone. Light gray to dark gray, micaceous. Interbedding common.		
Siltstone and sandstone finely laminated.		
Shale, sandy, silty near top. Dark gray siltstone. Light yellow quartzose	6	0
Sandstone, dark, maroon, micaceous, friable	0	6
Siltstone, dark gray, argillaceous, with micaceous shale partings	1	6
Sandstone, gray, fine grained, micaceous	0	6
Micaceous shale, dark gray	0	9
Sandstone, dark maroon, coarse grained, friable ...	0	9
Sandstone, dark gray, medium grained, compact ...	0	9
Shale, dark gray, interbedded sandstone, worm burrows. ...	0	6
Sandstone, argillaceous, light gray, shaly partings, flaser bedding	1	0
Sandstone, dark maroon, coarse friable.		
Shales, siltstone, mudstone, interbedded, dark gray, micaceous, worm burrows	4	6
Sandstone, mudstone, shale, dark gray, micaceous, hard and compact on top.		
Flaser bedding in mudstone and sandstone weathered by exfoliation	4	6
Sandstone, shale, mudstone, and silt. Dark gray, abundant worm burrows. Compact, gray colour sandstone at the top	5	0
Sandstone, gray, micaceous, shaly and muddy partings. ...	1	6
Sandstone. light gray to grayish tan, micaceous, shaly partings, compact, flaser bedding.	2	6
Bituminous shale- black.	0	6
Shales, dark compact, capped by quartzose siltstone of white colour	1	6
Siltstone, gray, micaceous, flaser bedding. Abundant clay and mud.		
Sandstone, gray, coarse grained.		
Siltstone, gray, micaceous, flaser bedding	7	6
Siltstone, gray, very fine grained, abundant, micaceous, finely laminated	6	0
Mudstone, silty, gray, greenish brown, micaceous ...	4	0
Sandstone, silty, whitish gray, micaceous, well laminated ...	12	0
Mudstone, silty, grayish green, glauconitic, intebredded with loose sandstone	3	0
Sandstone, grayish green, glauconitic, well laminated ...	4	0
Mudstone and sandstone, grayish green, glauconitic flaser bedding, characteristic of upper part	13	0
Mudstone, greenish gray, occasionally interbedded with siltstone, coarse sandstone, profusely laminated. Flaser bedding common, worm burrows abundant. fragments of Trilobite exoskeleton and Brachiopod shells common. The entire unit is glauconitic.		
Sandstone, grayish green, coarse grained, well sorted, rounded to subrounded.		
Sandstone, grayish green, quartzose and glauconitic. ...	30	0
Sandstone, light gray and greenish gray, medium to fine grained, quartzose with abundant glauconite, occasionally dolomitic	7	0
Sandstone, grayish green, coarse, hard and compact, glauconitic. Upper part mainly glauconitic	3	0
Mudstone, greenish gray, glauconitic, and micaceous, abundant worm burrows	14	0
Sandstone, greenish gray, quartzose and glauconitic.		
Sandstone, light gray to greenish gray, fine grained, well sorted, angular to subangular, thinly bedded, dolomitic.	8	0
Sandstone, grayish green, fine grained and well laminated, glauconitic.		
Mudstone, micaceous, worm burrows.		
Sandstone, gray, fine grained.		
Shale micaceous.		
Mudstone, greenish gray. abundant worm burrows, glauconitic.		
Shale, gray, dray, silty, micaceous.		
Sandstone, grayish green, fine grained, shale parting common, glauconitic.		
Shales, bluish gray, with micaceous partings, sand and silty occasionally.		
Siltstone, gray green, laminated, with shale partings. glauconitic.		
Shales, gray, greenish gray, silty and sandy, fossiliferous.		
Sandstone, gray to grayish green, fine grained, thin bedded, shale partings, glauconitic	28	0
Shale, bluish gray, well jointed and cleaved, weather into splinters and spheroidal block, worm burrows, fossils of inarticulate Brachiopods and disarticulate exoskeletons of Trilobites, Redlichia and Ptychoparia, Lingula, Lingulilla and Orthis, are common Brachiopods ...	20	0
Sandstone, green and gray, coarse grained, glauconitic. ...	3	0
Mudstone, silty, grayish green, glauconitic.		
Sandstone, grayish green, medium to coarse grained glauconitic.	6	0
Sandstone, gray, greenish green, pebbly towards top, generally coarse grained, medium to massive bedded ...	4	0
Siltstone, gray, laminated, sandy in lower part.		
Shale, dark gray, Bituminous shale.		
Sandstone, gray, hard, compact, fine to medium, angular to subangular, well sorted, dolomitic.		
Shale, dark gray, hard shale.		
Mudstone, gray to greenish gray, micaceous, glauconitic, worm burrows.		
Dolomite, yellowish gray, sandy and silty.		
Shales, yellowish gray, sandy silty.		
Shales, dark gray, bituminous.		
Mudstone, grayish green, silty and sandy at places, glauconitic. Flaser bedding, and laminations in silty and sandy parts. Abundant worm burrows, mainly siltstone in lower part	30	0
Total thickness	238′	2″