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THE STUDY OF THE JOINT PATTERNS AND THE OTHER STRUCTURES OF THE MANKI SLATE AND THE ATTOCK SHALE

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ABSTRACT

On the basis of a comparative study of the structures, especially the joint patterns of the Manki Slate and the Attock Shale, the two distinct argillaceous units of the Attock Group, it has been established that there was, most probably, a considerable lapse of time between their deposition. The Manki Slate, as a result of a powerful compression from the north, was later pushed over the Attock Shale along a thrust striking E-W.

INTRODUCTION

The area under investigation starts from the eastern bank of the Indus river near the Attock Fort and runs westwards to Ziarat Kaka Sahib, a village about seven miles from Nowshera. The Survey of Pakistan toposheet No. 43 c/1 covers the whole of the area which, on the map, lies between longitude 72° 0′ to 72° 15′ E and latitude 33°51′ to 33°58′ N. The area is approximately 120 square miles but most of the work was carried out either along the main limestone ridge or along various nalas which cut across the section. Data were, however, also collected from a few suitable isolated sections, other than the nalas, for structural studies of the area.

The purpose of the work was to study the major and minor structural features of the Manki Slate and the Attock Shale. The main emphasis has been laid on the jointing patterns of the two groups of rocks. Various sets of well defined joints are the characteristic features developed on the rock faces. By the study of the attitude of a large number of joints from the Manki Slate and the Attock Shale, an attempt has been made to find out whether or not there is any striking difference between the two.

The directions of the fold axes have also been recorded from the two argillaceous units and used in the structural analysis of the area. The attitudes of the major faults were also mapped and small sedimentary structures of depositional origin were also studied.

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The contact between the Manki Slate and the Attock Shale has been examined and close observation of its structural features was made to ascertain the nature of this contact.

Tahirkheli (1965), (1968a), (1968b) has done considerable work on the Attock group and has differentiated various mapable units on the basis of the nature, lithology, stratigraphy and the fossil contents of these rocks. The argillaceous unit of the Attock Group has been divided into two parts i.e. the Manki Slate of lower Palaeozoic age and the Attock Shale as young as Jurassic. He has also cited evidence of the older group having been thrust over the younger.

As no systematic work has been carried out on the geological structures in the area, it was considered necessary to probe into this aspect also. An attempt is therefore made to ascertain whether the two argillaceous units of the Attock Group which are believed to represent two different eras of the earth's history, display some divergent structural features which could help to differentiate them from each other. Another aspect of this problem is to confirm a tectonic contact between the Manki Slate and the Attock Shale as visualized by Tahirkheli (1968 a and b).

Previous Work.

In the literature available, the first mention of the "Attock Shale" is found in a progress report by Wynne (1873) on the Geology of Parts of the Upper Punjab; Middlemiss (1896) has discussed briefly the Attock Group during his discussion on the Geology of Hazara and the Black Mountains. The geological investigation of the Attock District was conducted by Cotter (1933) and since then, for about thirty years, it seems that no organised work was carried out in the area.

Tahirkheli first published the results of his investigations on the Attock Group in 1965 and has since revolutionised the entire geological conception of these rocks by distinguishing several mappable units and assigning Mesozoic age to the major part of the sequence.

GENERAL DISCUSSION OF THE STRUCTURES WITHIN THE AREA

Dip and Strike.

Towards the western end of the area the general strike of the beds is E-W and their dips are usually very steep. Towards the north west of the area, in Piran Nala, the strike swings from E-W to north east and towards the middle of the section it is south east. The average dip in Piran section is 60° north or north west.

South of this section, near the town of Ziarat Kaka Sahib the strike is E-W and the beds are either vertical or steeply inclined towards the north,

Towards the middle of the area the strike shifts to ENE and the beds dip 65° to 75° towards the north-west. Eastwards the strike again swings to E-W but east of the Indus River it changes to N 65°W. The angle of dip is also reduced gradually from west to east. Near Ziarat Kaka Sahib it is almost vertical while in the Attock Fort section the dip is found to be only 20° north east.

Folds.

Small folds are very common in the area. Their most important feature is the striking similarity in the directions of their axes. All the folds either in the Manki Slate or the Attock Shale have their axes running between E-W and N 60°E. The folds are thus roughly parallel to the strike of the formations. Most of the folds were found to be plunging, either to the east or west.

Faults.

Faults are not easily recognisable in the area because the lithology is uniform for great distances in most parts of the area. Many faults, when picked up, could not be traced for long distances, because the topographic slopes are mostly covered with debris. Even if a fault is traceable it is in most cases difficult to ascertain its nature because most of the beds are nearly vertical. Very few readings of the faults could thus be noted.

In three sections of the Manki Slate a few faults were carefully studied. Most of the faults in this rock group strike N-S to N 15°W. In the Piran section one fault was found to be striking NNE. A reverse fault was recorded from the younger rocks in Khairabad Nala, with a strike of N 65°E.

A regional thrust fault has been postulated on the basis of many field observations. In the area where this fault probably lies, great disturbance, brecciation, mylonitization and other evidence were found to confirm its presence. The Manki Slate towards the north of the Rubbly Limestone are supposed to have been thrusted over their younger counterpart along this fault. The fault has been located south of the main limestone ridge and runs E-W for the whole length of the area.

Joints.

The main emphasis was laid on the study of the joint patterns of the area in order to determine the tectonic style of the region. From all the nine sections of the area sufficient joint data were collected. It has been taken into account that the readings must be recorded from one end of the section to the other. All the readings were then divided into two groups:

(*i*) From the Manki Slate

(*ii*) From the Attock Shale

TABLE I

JOINT DATA FROM MANKI SLATE

Strike	*Dip*	*Nos.*
	Piran Nala	
N10 E	80 NW	6
N 25 W	Vertical	6
N 40 E	-do-	4
N 40 W	-do-	4
N 20 W	-do-	3
N 60 W	-do-	4
N 80 E	-do-	6
N 15 W	85 SW	10
N 40 W	85 SW	3
N 35 W	70 NE	10
N 15 E	75 SE	10
N 17 E	78 SE	20
N 65 E	80 NW	12
N 65 E	80 NW	2
N 50 W	12 NE	2
N 15 W	75 SW	2
N 20 E	80 NW	15
N 15 E	85 NW	13
N 20 W	70 SW	3
N 35 W	25 NW	9
N 55 W	80 SW	5
N 10 W	85 SW	3
N 15 W	Vertical	10
N 17 W	80 SW	13
N 10 E	75 NW	15
	Ziarat Kaka Sahib Section	
N 70 E	35 NW	3
N 80 E	30 NW	2
N 70 E	30 NW	2
E — W	70 NW	3
N 10 W	Vertical	8
N 20 E	55 NW	10
N 15 W	Vertical	12
N 25 W	60 NW	12
N 23 W	62 NW	8

Strike	*Dip*	*Nos.*
	Shah Kalim Khwar	
N 28 E	75 SE	12
N 30 E	85 SW	10
N 20 E	15 SE	6
N 75 W	85 NE	2
N 20 W	70 SW	7
N 15 E	65 SE	8
N 15 E	65 SE	8
N 15 W	85 SE	4
N 10 E	35 SE	5
N 25 W	75 NE	10
N 88 E	75 SE	4
N 5 E	40 SE	4
N 60 E	72 SE	10
N 20 W	80 SW	2
N 25 W	20 NE	12
N 35 W	70 NE	13
	Kund Nala	
N 50 W	70 NE	2
N 60 W	70 NE	3
N 55 W	70 NE	10
N 50 W	76 NE	10
N 75 E	78 NW	10
N 20 E	35 SE	2
N 35 W	76 NE	6
N 20 E	Vertical	9
N 15 W	-do-	5
N 10 W	Horizontal	3
N 10 E	30 SE	13
N 15 E	30 SE	8
N 16 E	35 SE	15
N 20 W	Vertical	3
N 65 E	25 SE	2
N 70 E	30 SE	8

TABLE II

JOINT DATA FROM ATTOCK SHALE

Strike	*Dip*	*Nos.*
Ziarat Kaka Sahib Section		
N 10 E	65 SE	8
N 15 E	72 SE	10
N 65 E	30 SE	2
N 30 W	80 NE	4
N 20 E	70 SE	4
N 25 E	75 SE	3
N 20 W	80 NE	4
N 10 E	85 SE	10
N 25 E	70 SE	2
N 25 W	75 NE	5
N 60 E	30 SE	3
N 65 E	25 SE	9
N 20 W	65 NE	2
N 30 E	30 SE	4
Shah Kalim Khwar		
N 30 E	25 SE	3
N 40 E	30 SE	14
N 50 E	20 SE	19
N 60 E	25 SE	3
E — W	75 NW	2

Strike	*Dip*	*Nos.*
Khairabad Nala		
N 20 E	85 NW	4
N 25 E	63 SE	6
N 55 W	72 SW	9
N 65 W	70 SW	2
N 30 E	65 SE	9
N 10 E	63 SE	13
N 40 W	70 SW	10
N 70 W	75 SW	11
Attock Fort Section		
N 25 W	75 NE	13
N 40 E	65 NE	13
N 80 W	75 NE	16
Section along Railway Line		
N 75 E	55 SE	1
N 60 W	72 SE	2
N 55 W	70 SW	7
N 20 E	Vertical	17
N 55 W	76 NE	3
N — S	25 NW	5
N 50 W	70 NE	9

A total number of 693 joints were studied, out of which 433 were from the Manki Slate and 260 from the Attock Shale. With the help of the data collected from all the sections rose diagrams were prepared for the Manki Slate and the Attock Shale (Fig. 1). Table I gives the joint data from the Manki Slate and Table II from the Attock Shale.

A comparative study of the two patterns of jointing in the area was found to be most interesting; although at places the behaviour of the different sets of joints pose some problems. The overall nature of the jointing is fairly revealing.

Data from four sections in the Manki Slate confirm the presence of three well defined sets. The largest and the most prominent set strikes between N 10° and 20°E. In Shah Kalim Khwar the strike of the same set swings between N 10° and 30°E. Further this set is not only prominent in each locality of the Manki Slate but also has the same trend throughout. In the Attock Shale the major set again has the same trend consistently. From the four sections of the Attock Shale the readings obtained of the strikes of the joints belonging to this set very clearly show this set present in both the rock groups (Fig. 1.) Another set which comes next in order of abundance strikes between N-S and N 60°W. In the Manki Group there is a wide range of fluctuations in the strike directions of the joints of this set. Even within a single section the strikes change freely. In Piran Nala it ranges from N 10°to 40°W; in Kund Nala from N 20° to 50°W and in the section east of Ziarat Kaka Sahib the strike is between N-S and N 10°W. In Shah Kalim Khwar the direction lies between N 20° and 30°W.

Two sections of the Attock Shale i.e. Attock Fort and Ziarat Kaka Sahib, have the same set striking between N 20° and 30°W but, again, in Khairabad Nala, it strikes between N 40° and 70°W.

The authors are convinced that the variations in the trend of this set of joints is due to the many local disturbances. On the basis of the dominant directions of the majority of the joints belonging to this set, the common trend established is between N 40° and 70°W.

The third set, which is probably the most important, is that which strikes between N 60° and 80°E. This set is perfectly developed in all the Manki sections. It is different from the other sets in the sense that a great majority of them exhibit development of quartz veins along their partings and show minor displacement along the other two sets.

Among the Attock Shale in Khairabad Nala, this set is totally absent. In the Attock Fort section there is a set striking N 40°E but it is the first set described earlier.

In the section east of Ziarat Kaka Sahib, however, there is a set striking between N 50° and 60°E. This set is not present anywhere else in the Attock Shale and is thus somewhat confusing. The authors have no explanation for the trend of the joints in this locality. One thing, however, is certain that this set does not have the same characteristics as the joints having the same trend in the Manki Slate i.e. there is neither any quartz development nor any displacement.

Fig. 1. shows that the N 60° to 80°E trending joints are very prominent in the Manki slate and insignificant in the Attock Shale.

CONCLUSIONS

All the field observations and the data collected lead to the conclusion that joints forming the ENE set are probably much older then the remainder and as they are very common in the Manki Slate and uncommon in the Attock Shale, it can be safely inferred that Manki Slate may not only be older than the Attock Shale but that there must be a distinct unconformity between the two formations. The tectonic event responsible for the formation of the ENE joints might have been active before the Attock Shale was deposited.

The general trends of folding in the Manki Slate and the Attock Shale are uniform throughout the area. The most dominant directions of the axes of folding are EW to ENE, i.e. the folding trend is more or less, parallel to the strikes of the formations. It can be assumed that the direction of major pressure which produced the folds had an approximately N-S or NNW-SSE trend. This assumption gathers weight from the presence of a regional thrust fault in the area, striking E-W. The field observations everywhere near the fault are that the Manki Slate and Rubbly Limestone are resting on top of the Attock Shale. The thrust plane should thus be inclined towards the north and a powerful force must have been active from a direction north of the area.

A stress - orientation analysis, though avoided at many places (the reason for not making such an attempt at all localities being that there is usually a range, at places quite significant, in the strikes of the joints in one single set)was carried out with the help of the data collected from Attock Fort section. In this section, over a fairly large area, the joint sets have exceptionally distinct and well marked trends. The direction of the maximum stress as established as a result of this analysis is roughly N-S. This analysis, though not adequate to prove or disprove any geological phenomenon, can be quoted as additional evidence in favour of a general N-S direction of compression which has already been discussed.

The following is a brief account of the field observations which support the presence of a thrust:-

(*i*) In Khairabad Nala, near the elevation points 2292 and 1883, there is a zone of great disturbances. The beds in the vicinity are folded into very close folds. In between two adjacent folds there is a local reverse fault striking parallel to the fold axes. The N-W block of the rock has been pushed up onto the S-E block for a distance of many tens of feet.

Further north the frontal part of a highly broken and thin-bedded limestone is seen resting on the northern slope of a small, low-lying, linear hillock. On the southern slope of this hillock broken fragments of the same limestone are widely scattered. The limestone is recrystallised and the individual laminae are detached from one another. It seems that the limestone has ridden over the northern slope of the hillock. No other rocks exhibiting such a character are found anywhere away from this zone. Slickensiding on the bedding surfaces has also been observed, confirming the sliding of the adjacent beds past each other.

(*ii*) A bed of breccia is found exposed about 100 yards S-E of the elevation point 1883. There are angular fragments of shale and limestone of various sizes embedded in a coarse matrix of a similar nature. The bed is about 20 feet thick and is exposed on the southern side of the nala.

Similar breccia is also found in a section east of Ziarat Kaka Sahib. Only isolated patches of the breccia bed can be seen here because the locality is covered with large amounts of rock fragments that have slid down the slope.

The presence of breccia beds near the main limestone ridge at two widely seperated localities may indicate the presence of a fault in the vicinity.

(*iii*) In Khairabad Nala there is a zone of semi-brittle shale beds, about half a mile wide, and nearly three hundred yards south of the main limestone ridge. Proceeding northwards in this area a gradual decrease in the size of the chips and rods broken from the rocks is observed.

This feature may have developed because the area is located near the thrust zone. The northern part of the shale bed, being nearer the thrust zone, was more severely affected than the southern portion.

(*iv*) Quartz veins are abundant in the vicinity of this area.

(v) In the section east of Ziarat Kaka Sahib a typical reddish-white, thin bedded rock of powdery nature is found. It is highly fissile and consists of a mixture of small fragments of shale and limestone.

At one locality weathering has rendered the material loose and it has spread over the slope at the northern side of the section, resembling powdered lime. This might be the mylonite produced as a result of faulting.

The structural history of the area, in the light of our observations, can be summarised as follows:-

There was a lapse of time between the deposition of the two argillaceous units present in the area. The Manki Slate is considerably older in age than the Attock Shale. After the deposition of the Attock Shale, as a result of some later orogenic event, the older group was thrust over it. The rocks have received a general southward pressure from the north. It is likely that this southward movement may be related to those forces which were responsible for the southward creep of the Himalayas. The great regional thrust which strikes E-W along the main limestone ridge was also produced as a result of powerful compression from the north.

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1. REGIONAL PATTERN OF JOINTING IN THE (A) MANKI SLATE AND (B) ATTOCK SHALE.