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PETROLOGY OF MIDDLE SIWALIK ROCKS OF KOTLI AREA, AZAD KASHMIR

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ABSTRACT

Sandstones and shales of the Middle Siwalik of the Kotli area have been studied petrographically, chemically and spectrochemically. By comparing the overall compositions of these rocks and those of the rock fragments present in the constituent sandstones, it has been concluded that the Middle Siwalik rocks have been derived from igneous, metamorphic and sedimentary formations lying to the north and northeast of the area, towards the Pir Panjal Range.

INTRODUCTION

This paper describes the Middle Siwalik rocks of Kotli area, Azad Kashmir. Kotli city, the headquarters of Kotli District, is 129 km East of Rawalpindi. The area investigated lies between longitudes 73° 6′ E to 74° 7′ E and latitudes 33° 20′ N to 33° 40′ N and is covered by Survey of Pakistan toposheets 43 G/14, 43 G/15, 43 K/2 and 43 K/3. A geological map of the Poonch area is given in Chaudhry and Ashraf (1980).

The succession of rocks in Kotli and Poonch Districts is given in Table 1. This succession will help understand the role these rocks have played in the formation of the Middle Siwalik rocks of Kotli. The relevant lithological information has been given in the section on "Origin" and has been tied to the provenance of Siwaliks. It has therefore been omitted from the stratigraphic column.

PREVIOUS WORK

This paper is the first petrological study of its kind on the Middle Siwaliks of Kotli. Work of a reconnaissance geological nature was, however, carried out by Meddlicott (1876), Lydekker (1976) and Middlemiss (1896). Wadia (1928) prepared a geological may of the adjoining Poonch area and parts of Punjab on 1″=4 miles, and studied the stratigraphic and mineralogical aspects of the area.

Wadia (1928) divided the Siwaliks of Kashmir into Lower Plandri, Middle Mang and Upper Sand Rock stage. The stratigraphic Committee of Pakistan (1973) has discarded the synonyms Siwalik series of Oldham (1893) and Siwalik system of Holland (1913), and in Potwar has formalised it as the Siwalik Group, divided into:

Soan Formation	Pleistocene
Dokh Pattan Formation	Pliocene
Nagri Formation	Upper Miocene
Chinji Formation	Middle Miocene

This division, however, cannot be strictly applied to Poonch and Kotli Siwaliks which have a different provenance and differ in many ways from Potwar. For instance, the Lower Siwaliks of Poonch resemble Murree closely. In this paper, therefore, the Upper, Middle and Lower Siwalik classification will be retained till the proper stratigraphic study of Siwaliks is carried out.

GEOLOGY OF THE SIWALIKS

The Siwaliks are found in the W and SW part of the area mapped To the west of the faulted limb of the Palana-Devigarh anticline, Siwalik rocks are well-exposed whereas in Kotli and Khuiratta areas they have been weathered into wide alluvial plains. On the basis of lithological characters, the Siwaliks of the area can be identified as Middle Siwaliks, however, the main boundary fault has disturbed the area severely; therefore, outcrops of Upper and Lower Siwaliks are occasionally found. In the following Middle Siwaliks have been described.

The Siwaliks are generally composed of sandstones, clays, shales, mudstones and conglomerates. The sandstones are calcareous as well as argillaceous, medium- to coarse-grained, moderately sorted and composed of rock fragments, quartz, magnetite, hematite/limonite, calcite, dolomite, muscovite/sericite, garnet and carbonaceous matter. They are grey to greenish grey in colour, massive to thickly-bedded, whereas equally proportioned inter-bedded clays are reddish brown to yellowish grey in colour. Generally the sandstones are tough to moderately compacted rocks, forming strike ridges whereas the clays are relatively loose and soft, resulting in strike valleys. Calcite veins and patches are found at places. Cross-bedding is frequent in the sandstones.

Generally the sandstone beds are 6 to 10 m thick and sometimes contain concretions and coarse pebbles. They are predominantly calcareous subfeldspathic lithic arenites. Occasionally micaceous wacke, subfeldspathic lithic wacke and calcareous arenite may occur. The calcareous subfeldspathic lithic arenites have been described in the following. At the end are also described under miscellaneous, one sample each of micaceous wacke, subfeldspathic lithic wacke and calcareous arenite.

Texture and Structure

The sandstones are medium- to coarse-grained moderately sorted, with subrounded to subangular grains. The grains are mostly of quartz, chert, rock fragments and mica. Grains of garnet, epidote, pyribole and tourmaline may also occur. The matrix is composed of very small grains described above, and of clay, sericite, and calcite (which also is a cementing material). The cement is calcareous but at places ferruginous and siliceous.

Mineral Composition

Quartz ($\overline{X}$ =24.63, 1 =4.47, Table – 1) occurs as medium to coarse grains, mostly subangular to subrounded. Some small quartz grains may also occur in the matrix. It often shows strong strain extinction. It may also occur in cherty, phyllitic and quartzitic rock fragments. In them it is generally fine-grained but in the quartzite rock fragments it may be medium-grained. *Chalcedony* ($\overline{X}$ = 1.0, S = 1.20) besides rock fragments it may also occur in the cement as well as in the matrix and shows subradial as well as salt and pepper structure.

TABLE 1. STRATIGRAPHIC SEQUENCE OF KOTLI AND POONCH AREAS

KOTLI	*POONCH*	
Alluvium	Alluvium	Recent to subrecent
Siwalik Group	Siwalik Group	Middle Miocene to Pleistocene
Murree Formation	Murree Formation	Oligocene to L. Miocene
	——Unconformity——	
	Kuldana Formation)	
Margala Hill Limestone	Margala Hill Limestone)	Eocene
Patala Formation	Patala Formation	Paleocene
	——Unconformity——	
(Unconformity marked by Fire clay and Bauxite)		
	Gondwana Group	Permo-Carboniferous
	Panjal Trap	Upper Carboniferous
	Agglomeritic Slates and Tuff	,,
	——Unconformity——	
Abbottabad Group	Abbottabad Group	Cambrian
Dogra Slates	Dogra Slates	Pre-Cambrian

Rock Fragments ($\overline{X}$ = 21.75, S = 4.62) are important constituents of these sandstones. They are mostly medium- to coarse-grained and subangular to subrounded but angular fragments also occur. The fragments are volcanic, metamorphic as well as sedimentary. The volcanic rock fragments are andesitic, basaltic and acidic but some are pyroclastic. The metamorphic rock fragments are of low grade regional metamorphics like phyllites, carbonaceous schists, slates and quartzites. The sedimentary rock fragments are mostly of chert (both colourless and light green to light red), shale, quartzite, limestone and dolomite. Occasionally a few marly and bauxitic rock fragments may also be seen.

K–feldspar ($\overline{X}$ = 3.88, S = 3.36) occurs both as orthoclase and microcline. They are mostly medium-grained and associated with quartz and moderately altered to sericite and clay. K–feldspar also occurs in some volcanic rock fragments.

Albite ($\overline{X}$ = 1.88, S = 1.36) mostly occurs as individual grains as well as in volcanic rock fragments. More basic plagioclase occurs in the andesitic and basaltic rock fragments. Minor alteration to clay, sericite and hydromuscovite is seen after it.

Hematite/Limonite ($\overline{X}$ = 2.28, S = 0.64) are very intimately associated and are brown to yellowish brown in reflected light. They occur as stains, thin streaks and veins in the zone of weathering, as well as in the cement.

Magnetite ($\overline{X}$ = 0.88, S = 0.23) occurs as smal individual grains and aggregates randomly distributed. It is black and opaque and shows metallic silvery lustre.

Calcite/Dolomite ($\overline{X}$ = 23.44, S = 6.98) are often a very important constituent of matrix and cement. They occur mostly as precipitated matter (often moderately well crystallized) but clastic carbonate grains (fine-grained and often micro to cryptocrystalline) are also present.

Muscovite/Sericite ($\overline{X}$ = 3.19, S = 3.05) occur as fine to very fine anhedral grains. Muscovite occurs as small flakes and long laths. Both are mostly in the matrix but muscovite also occurs as coarse flakes. Sericite may be closely associated with clay and as an alteration product of feldspar. *Clay* ($\overline{X}$ = 1.75, S = 1.98) occurs predominantly in the matrix. It is extremely fine-grained and often included in carbonate but also as an alteration product of feldspar.

Chlorite ($\overline{X}$ = 3.50, S = 1.20) may occur either as small individual flakes or as small aggregates, often randomly distributed. It is green, poorly pleochroic and shows anomalous interference colours. *Biotite* ($\overline{X}$ = 0.88, S = 0.83) flakes occur occasionally and show moderate pleochroism, from light brown to yellow brown. They are randomly distributed but often associated with muscovite.

Pyroxene occurs occasionally as fine anhedral to subhedral grains randomly distributed. At places it shows hematite/limonite on the edges. It is also found in some basic rock fragments (where it has survived alteration). *Epidote* ($\overline{X}$ = 1.13,

TABLE 2. PETROGRAPHIC COMPOSITION OF SIWALIK SANDSTONES

Sample Nos.	KDI-77-MHN-4	KDI-77-MHN-5	KA-77-AM-86	KA-77-AM-87	KB-77-AMIK-101	KDI-77-MHN-6	KDI-77-MHN-14	KA-77-AM-88			KA-77-TK-91	KDI-77-MHN-17	KA-77-AM-84
Coordinates	061267	061267	140144	140143	015339	061267	030256	145135			217103	029254	129196
Localities	Dungi	Dungi	Khuiratta	Khuiratta	Khuiratta bridge	Dungi	Dungi	Khuiratta			Kajrala	Dungi	Khuiratta
Rock Type	Sub-feldspathic lithic arenite	Calc. lithic	Sub-feldspathic arenite		Calc. lithic arenite			Calc sub-lithic arenite	$\overline{X}$	S	Micaceous wacke	Sub-feldspathic lithic wacke	Calcareous arenite
Calcite/Dolomite	24.0	20.0	35.0	32.0	15.0	24.5	19.0	18.0	23.44	6.98	—	6.0	40.0
Quartz	27.0	20.0	18.0	26.0	22.0	25.0	32.0	27.0	24.63	4.47	50.0	27.0	21.0
Rock Fragments	17.0	31.0	22.0	22.0	24.0	22.0	20.0	16.0	21.75	4.62	—	10.0	6.0
Chlorite	4.0	4.0	3.0	5.0	5.0	3.0	2.0	2.0	3.50	1.20	—	2.0	3.0
Chalcedony	2.0	2.0	1.0	—	—	—	—	3.0	1.00	1.20	—	2.0	6.0
Haematite/Limonite	3.0	2.0	4.0	3.0	2.0	3.0	3.0	3.0	2.88	0.64	7.0	4.0	5.0
Muscovite/Sericite	3.5	4.0	3.0	2.0	—	2.0	1.0	10.0	3.19	3.05	20.0	4.0	—
Plagioclase/Albite	4.0	2.0	3.0	3.0	—	1.0	1.0	1.0	1.88	1.36	—	1.5	—
K–feldspar	3.0	2.0	3.0	—	—	7.0	2.0	8.0	3.88	3.36	—	3.0	—
Epidote	2.0	2.0	—	2.0	—	1.0	2.0	—	1.13	0.99	—	2.0	—
Biotite	1.0	2.0	1.0	—	—	1.0	2.0	—	0.88	0.83	—	1.0	—
Tourmaline	1.0	—	0.5	1.0	—	0.5	0.5	0.5	0.50	0.38	—	—	1.0
Amphibole	—	2.0	—	—	2.0	—	0.5	—	0.56	0.90	—	1.5	3.0
Magnetite	1.0	1.0	1.0	0.5	0.5	1.0	1.0	1.0	0.88	0.23	—	—	—
Garnet	0.5	1.0	—	—	—	—	0.5	—	0.25	2.38	—	4.0	—
Cherty rock fragments	5.0	3.0	5.0	3.0	22.5	4.0	2.0	4.0	6.06	6.72	—	—	—
Quartzite rock „	2.0	2.0	—	—	3.0	1.0	1.0	2.0	1.38	1.06	23.0	25.5	2.5
Clay	—	—	—	—	4.0	4.0	4.0	2.0	1.75	1.98	—	—	—
Carbonaceous Matter	—	—	1.0	—	—	—	—	—	—	—	—	—	8.0
Pyroxene	—	—	—	—	—	—	—	—	—	—	—	—	—
Sulphide	—	—	—	—	—	—	—	1.0	—	—	—	—	—

Analysis at Engineers Combine Limited, Lahore by M.N. Chaudhry.

S = 0.99) occurs as anhedral to subhedral grains either light green showing anomalous colours (clinozoisite) or colourless showing normal 2nd to 3rd order interference colours. Volcanic rock fragments may also contain epidote grains. It is generally medium-to fine-grained.

Sulphide occurs as black and opaque, tiny anhedral grains which are randomly distributed. In reflected light it shows brown to golden yellow colour. *Tourmaline* ($\overline{X}$ = 0.50, S = 0.38) grains are randomly distributed and show moderate pleochroism from brownish-green to dark greenish-brown. It is mostly fine-grained and schrolite. *Amphibole* ($\overline{X}$ = 0.56, S = 0.90) occurs as fine subhedral grains with moderate pleochroism and at places altered to chlorite. *Garnet* ($\overline{X}$ = 0.25, S = 0.38) is in small subangular to angular, colourless to light pink grains. Mostly fine- to medium-grained, it may occur in matrix and contain tiny quartz inclusions and hematite/limonite staining. *Carbonaceous Matter* occurs as amorphous-looking tiny aggregates. Some carbonaceous matter also occurs in black shale and phyllite rock fragments.

Miscellaneous. One sample (KA–77–TK–91) of micaceous wacke studied is composed of 50% quartz, 23% clay, 20% muscovite/sericite and 7% hematite/limonite. Such bands are very rare in Siwaliks. A sample (KA–77–AM–84) of calcareous arenite contains in addition to silicate, 40% calcite/dolomite and 5% hematite/limonite. One sample (KDI–77–MHN–17) of subfeldspathic lithic wacke studied is composed mainly of quartz (27.0%), clay (25.5% and rock fragments (10.0%). For other constituents Table 1 may be consulted.

PETROGRAPHY OF THE SIWALIK CLAYS

Texture and Structure

The Siwalik clays are unlaminated to poorly laminated and uncompacted. They are fine-grained and mostly microcrystalline to cryptocrystalline.

Mineral Composition

Clay ($\overline{X}$ = 53.78, S = 11.45, Table 2) is the predominant mineral group and is dirty white to dirty grey but stained at places with hematite/limonite. Optical properties show it to be an admixture of illite, smectite and kaolin. *Quartz* ($\overline{X}$ = 15.11, S = 6.43) occurs as tiny angular to subangular grains, randomly distributed.

Calcite/Dolomite ($\overline{X}$ = 12.78, S = 14.96) occur as fine microcrystalline to cryptocrystalline material, mostly associated with sericite and clay. *Hematite/Limonite* ($\overline{X}$ = 4.44, S = 1.51) are intimately associated and occur as distinct grains and amorphous-looking aggregates. They may be found as stains, steaks and

patches. *Chlorite* flakes are found occasionally. They ($\overline{X}$ = 3.83, S = 3.50) are very fine-grained, randomly distributed, and showing slight pleochroism and anomalous interference colours. *Muscovite/Sericite* ($\overline{X}$ = 1.89, S = 2.47) occurs as very fine-grained material intimately associated with clay.

Chalcedony ($\overline{X}$ = 0.33, S = 0.71) is in tiny subangular to irregular aggregates, subradial to lamellar in structure. *Magnetite* ($\overline{X}$ = 0.89, S = 1.05) occurs as fine individual grains showing metallic luster in reflected light. *K–feldspar* (X = 0.56, S = 1.13) is found in small subangular grains mostly associated with quartz. It appears to be authigenic as well as clastic. *Glauconite* occurs in only two samples as tiny grains associated with clay. *Tourmaline* is a rare mineral present as eumorphic to subhedral tiny grains with strong pleochroism. The optical properties show it to be a schorlite. *Carbonaceous Matter* ($\overline{X}$ = 0.67, S = 1.12) may occur occasionally as randomly distributed specks and their aggregates. In reflected light it is dull black to brownish black.

CHEMISTRY

Siwalik Sandstones. One sample of lithic arenites was analysed. It contains 51.78% SiO_2, 16.55% Al_2O_3, 10.55% CaO and 5.43% Fe_2O_3. For the rest of the constituents Table 3 may be consulted. One sample of calcareous subfeldspathic lithic arenite and one sample of micaceous arenite were spectrochemically analysed. They contain 20 ppm Co, 50 ppm Ni, 5 ppm Y, 0.01% Cr and 50 ppm Pb. The calcarous lithic arenite contains 20 ppm Cu, while the micaceous arenite contains 10 ppm Cu. They contain from 0.001 to 0.002% ZrO_2.

Siwalik Shales. One sample of shale (KCK-78-HN-117) was chemically analysed. It contains 48.54% SiO_2, 18.62% Al_2O_3, 7.45% Fe_2O_3, 3.31% MgO and 7.45% CaO. The chemical composition shows it to be a calcareous shale. One sample of shale (KA–77–AM–85) was spectrochemically analysed. It contains 0.002% ZrO_2, 5 ppm Y, 5 ppm Sc, 10 ppm Cu, 20 ppm Co, 50 ppm Ni, 0.01% Cr and 50 ppm Pb.

ORIGIN

In order to understand the provenance of Kotli Siwaliks it is essential to understand the type and nature of rocks, lying to the N and NE in the Districts of Kotli and Poonch towards Pir Panjal Range.

Briefly, the rocks exposed from oldest to youngest are the Precambrian Dogra slates: mainly black and grey slates with carbonaceous horizons and basic volcanics (the Dogra Trap). They are exposed mainly in Poonch. In Kotli a small exposure of slates was discovered in Nail Nala of Kotli (1978, E.C.L.).

TABLE 3. PETROGRAPHIC COMPOSITION OF SIWALIK CLAYS

Sample Nos.	KA-77-AM-85	KCK-78 HN-117	KDI-77-MHN-2	KDI-77-MHN-8	KDI-77-MHN-13	KDI-77-MHN-15	KDI-77-MHN-18	KDI-77-MHN-11	KDI-77-MHN-16		
Coordinates	129196	053217	066266	045275	030256	030256	029254	038275	030256		
Localities	Khuiratta	Chak	Dungi	Dungi	Dungi	Dungi	Dungi	Dungi	Dungi	$\bar{X}$	S
Rock Type	Calc. clays	Calc. shales	Calc. clay	Calc. clay	Marl	Clay	Clay	Calc. clay	Silty clay		
Clay	76.0	63.0	54.0	40.0	42.0	60.0	54.0	44.0	51.0	53.78	11.45
Quartz	15.0	10.0	20.0	20.0	6.0	10.0	10.0	20.0	25.0	15.11	6.43
Calcite/Dolomite	—	15.0	—	18.0	45.0	2.0	3.0	25.0	7.0	12.78	14.96
Haematite/Limonite	6.0	4.0	7.0	4.0	4.0	2.0	5.0	5.0	3.0	4.44	1.51
Chlorite	0.5	6.0	7.0	10.0	2.0	—	—	4.0	5.0	3.83	3.50
Muscovite/Sericite	2.0	—	6.0	5.0	—	—	—	—	4.0	1.89	2.47
Chalcedony	—	—	2.0	—	—	—	—	—	1.0	0.33	0.71
Magnetite	—	—	1.0	3.0	1.0	—	—	2.0	1.0	0.89	1.05
K–feldspar	—	—	2.0	—	—	—	—	—	3.0	0.56	1.13
Glauconite	—	—	—	—	—	5.0	—	—	—	—	—
Tourmaline	0.5	—	—	—	—	—	—	—	—	—	—
Carbonaceous matter	—	2.0	—	—	—	3.0	1.0	—	—	0.67	1.12
Epidote	—	—	1.0	—	—	—	—	—	—	—	—

Analysis at Engineers Combine Limited, Lahore by M.N. Chaudhry.

TABLE 4. CHEMICAL COMPOSITION OF SIWALIK SANDSTONES AND CLAYS

Sample Nos.	KB-77-AMTK-101	KCK-78-HN-117	KA-77-AM-85	KA-77-AM-86	KA-77-TK-91
Coordinates	015339	053217	129196	140144	217103
Localities	Khuiratta bridge	Chak	Khuiratta	Khuiratta	Kajrala
Rock Type	Lithic arenite	Calcareous shales	Shale	Calcareous lithic arenite	Micaceous arenite
SiO_2	51.78	48.54	ZrO_2* 0.002	0.002	0.001
TiO_2	—	—	La —	—	—
Al_2O_3	16.55	18.62	Y 5.0	5.0	5.0
Fe_2O_3	5.43	7.45	Mo —	—	—
MnO	—	—	V 50.0	50.0	50.0
MgO	1.90	3.31	Sc 5.0	—	—
CaO	10.55	7.45	Cu 10.0	20.0	10.0
Na_2O	1.60	0.66	Co 20.0	20.0	20.0
K_2O	1.22	2.32	Ni 50.0	50.0	50.0
P_2O_5	0.17	—	Cr 0.01	0.01	0.01
I/L	10.66	11.67	Pb 50.0	50.0	50.0
Total:	99.86	100.02			

* Oxides and Cr expressed in percentages and elements in p.p.m.
Analyses at: P.C.S.I.R. Laboratories, Lahore.

These are followed by poorly developed Abbottabad Group in Poonch (thin limestone and quartzite beds) and good development of Sirban Formation's thick cherty dolomites and thin quartzites in Kotli. It also contains dispersed and poor Pb–Ni–Co mineralized zones. In Poonch following an unconformity, agglomeritic slates and tuffs of Upper Carboniferous are exposed followed by the Upper Carboniferous Panjal Trap consisting of basalts, andesites, and acidic flows and pyroclasts and ash beds. In Poonch, Panjal Trap is followed by Gondawana Group schists, phyllites and quartzites of Permo-Carboniferous age. This is followed by unconformably overlying Patala Formation of Paleocene which is composed of Khaki, dark grey and black shales with subordinate interbedded limestone which is in turn overlain by Margala Hill Limestone of Eocene age. The unconformity in Kotli is marked by bauxites and fire clays. In Poonch rocks equivalent to Kuldana Formation are also present. Then follow with an unconformity Murree Formation composed of alternating red sandstone and shales. Rarely some marly calcareous beds may also occur. The Murrees are followed by the Siwaliks.

The detailed study the Siwalik sandstones of the Kotli area reveals that it has derived cherty and carbonate rock fragments from the Cambrian dolomite, quartzite fragments and part of quartz from the Cambrian quartzite while the volcanic fragments and green and light red cherty pieces have been derived from the Panjal trap, Dogra traps and agglomeritic slates and tuffs. The other constituents of these sandstones are schists, phyllites and carbonaceous phyllites which are derived from Gondwana and the slate fragments from the Dogra Formation. Some material may also have been derived from the granites to the north. Some shale and calcareous fragments appear to have been derived from Patala Shales and Margala Hill Limestone.

The Siwalik clays are admixtures of clay, quartz and carbonate. Hematite/limonite are ubiquitous accessories. The Siwalik clays are clearly related to the same sources as the Siwalik sandstones. They represent the finer-grained breakdown products of the source rocks mentioned above. A look at the accessories supports this view. These sand rocks are not the equivalents of the rocks described by Krynine (1948, quoted from Williams *et al.*, 1953) as schist arenite from Northern India.

The trace element study shows very low ZrO_2 contents, i.e. 0.001 to 0.002% This shows that the rocks have not derived much material from acid to intermediate plutonics. They show 0.01% Cr_2O_3, 50 ppm Cr, 50 ppm V and 20 ppm Co. This shows significant contributions from basic to intermediate rocks (volcanics of Poonch). The higher values of Pb (50 ppm) can be attributed to the Pb. mineralization in the dolomites. This mineralization also could contribute some Ni and Co. Copper is from 10 to 20 ppm. The source may again be the Poonch volcanics. The trace element study of Poonch volcanics favours this view (Chaudhry *et al.*, 1980).

The petrographic and spectrochemical results show that the Kotli Siwalik rocks have probably been derived from rock formations lying to the N and NE of the area.

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