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CLAY MINERALOGY OF THE QUATERNARY LAKE DEPOSITS OF PESHAWAR BASIN, AT JEHANGIRA, DISTRICT MARDAN, N.W.F.P., PAKISTAN

M. JAVED KHAN and WASEEM AHMAD

NCE and Department of Geology, University of Peshawar.

ABSTRACT

X-ray Diffraction studies of Post-Siwalik Quaternary lacustrine clay deposits exposed near Jehangira suggest the presence of illite, chlorite and montmorillonite. Illite and chlorite show regular and well formed structure suggesting detrital origin. Whereas montmorillonite may have detrital and/or authigenic origin. If authigenic the depositional environments were alkaline and "non-aggressive". Mafic, ultramafic metamorphites of the Kohistan sequence and Main Mantle Thrust (=MMT) melange zone, and the schists of the Indo-Pakistan plate south of MMT are inferred as the ultimate source for these clay deposits.

INTRODUCTION

Post-Siwalik Quaternary sediments of the Peshawar valley have attracted the attention of various geologists (Abbott, 1849; Allen, 1964; Burbank, 1982; Haneef *et al.,* 1986) and consist of alluvial fans, loess, catastrophic flood deposits and lacustrine strata. The lacustrine strata are exposed at various localities. Their outcrops near Jalala (80 km north of Peshawar along Peshawar-Swat highway) and Jehangira (about 3 km north of Jehangira town, along north flank of Kabul River), (Fig. 1), are very conspicuous and eye catching. More than 15 m thick sequence of gray to light gray, horizontal clay beds is exposed. Thickness of individual strata varies from 19 cm to 60 cm. Base of this clay sequence is not exposed and drill holes are not present in this area. The individual strata show good stratification and some plant remains are also present. These clay strata are overlain by sand deposits of modern Indus and Kabul Rivers. It is very likely that the clay beds were deposited in a lake which covered most of the Peshawar valley. The lake itself might have formed due to catastrophic flooding of the Indus River which, as reported by Burbank (1983),

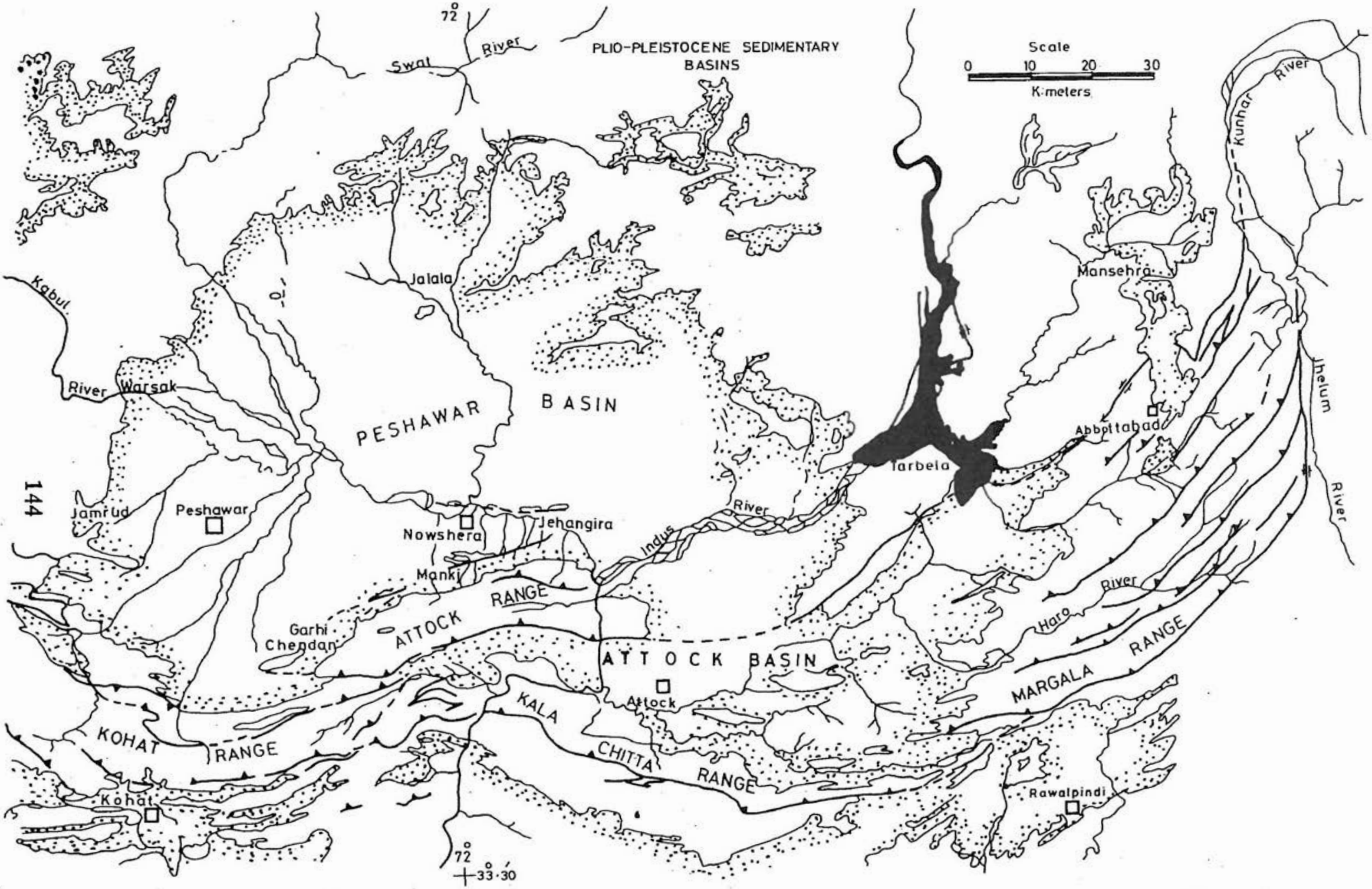

Fig. 1 : A sketch mapo of the Peshawar basin showing the locality of lacustrine clay beds near Jehangira and Jalala (after Burbank, 1983).

are a frequent feature (over geologic time) in Peshawar valley. The extent of a major lake formed by the damming of Indus River is yet to be studied. Present studies are confined to the identification of the clay minerals present in the bedded clay deposits exposed near Jehangira. For this purpose, ten samples form the Jehangira lake deposits were studied. Five samples from the bright red claystone unit of the Chinji Formation (Lower Siwalik Group) from Jalalpur, eastern Salt Range, were studied for comparison of the provenance.

ANALYTICAL TECHNIQUES

Each hand picked, fist-sized sample was crushed in a disk mill for about one minute. A fraction of the pulverized material was separated for the HCl treatment and preparation of unoriented, powder press mounts. The clay fraction from the remaining powder was separated as described below, for analysis by X-ray Diffraction.

Separation of the clay fraction

About 10 gm powder of each sample was dispersed in distilled water. The coarser sand-size particles were removed by letting the powder/water mixture stand for a few minutes and then decanting the suspended material. Further disaggregation was obtained by placing the suspension in a mechanical shaker for 10 minutes. For removing the silt fraction the mixture was centrifuged at 2000 rpm for 30 sec. and the supernate suspended fraction was again decanted and then centrifuged at 3500 rpm for 45 sec. The required clay fraction (10–2 µm) was thus obtained in the form of the settled fraction.

Preparation of oriented mounts

The clay fraction was dispersed in a small amount of distilled water and allowed to settle on the ordinary petrographic glass slides. The oriented mounts thus obtained were air-dried at room temperature and stored in a dessicator as a precaution against the affect of humidity on certain clay minerals.

Ethylene glycolated mounts

Oriented mounts prepared for each sample were glycolated by placing drops of ethylene glycol on the mounts until complete saturation was obtained. These glycolated mounts were then left overnight to dry at room temperature.

HCl treatment

Approximately 10 gm powder of each sample was put in 20 ml of HCl (18%), thoroughly mixed and heated at 80°C (± 1°) for eight hours. The samples were then washed with distilled water. The clay fraction was separated and oriented mounts were prepared from it.

Untreated, unoriented powder press mounts were used for identification of non-clay constituents of the samples. Whereas, oriented mounts, subjected to different treatments were used for determining the nature of the clay minerals. Since quartz was present in all the samples, giving its characteristic [101] and [100] peaks at 3.34 Å and 4.26 Å, it was used as an internal standard for checking the instrumental precision.

Instrumental conditions

The samples were analyzed on the Rigaku X-ray Diffractometer. Cu (K-alpha) radiations generated at a tube voltage of 40Kv and a tube current of 25mA were used for analysis. The angular goniometer scan speed and the chart speed were set at 2°/min. and 20 mm/min., respectively; while the time constant for the ratemeter was set at 2S: Z=3. The X-ray Diffraction patterns of 2θ versus intensity for an angular range of 2–37° 2θ were obtained for the unoriented, untreated oriented, oriented glycolated and oriented HCl-treated mounts. The JCPDS Mineral Powder Diffraction File (1980) was used for interpreting the diffractograms by the Hanawalt method of qualitative analysis.

MINERAL ASSEMBLAGES

The mineral assemblages of the Jehangira lake deposits and the Chinji clay, as identified by X-ray Diffraction, included quartz, albite, illite, chlorite, montmorillonite with some calcite. Non-clay constituents with characteristic reflection beyond 37°2θ were not identified.

Chlorite

In the ordered mounts the chlorite was confirmed by its reflection of 14 Å [001], 7 Å [002], 4.7 Å [003] and 3.5 Å [004] (Figs. 2 and 3). The 14 Å [001] reflection is generally overlapped by the broad [001] reflection of montmorillonite (Weaver, 1958). This overlap in case of samples being studied, was partially resolved on glycolation due to the resulting expansion of montmorillonite. Generally, the mixed layering of chlorite with montmorillonite and vermiculite is indicated by reflections on the high-angle side of the 14 Å spacing, in the normal ordered mounts. Whereas the "swelling chlorites", intermediate between chlorite and montmorillonite or vermiculite have a d–spacing around 28 Å which increases to 32 Å on glycolation (Dunoyer de Segonzac, 1970; Warshaw *et al.,* 1961; Grim, 1958). No such features were observed in the normal ordered mounts, nor changes in the d–spacings were produced on glycolation. This indicates that the chlorite in the studied samples is regular and well formed, and does not contain any mixed layers or expanding structures. The presence of chlorite was further confirmed by the collapse of the 14 Å, 7 Å, 4.7 Å and 3.5 Å peaks after the HCl treatment. As a corollary, the absence of kaolinite was also confirmed.

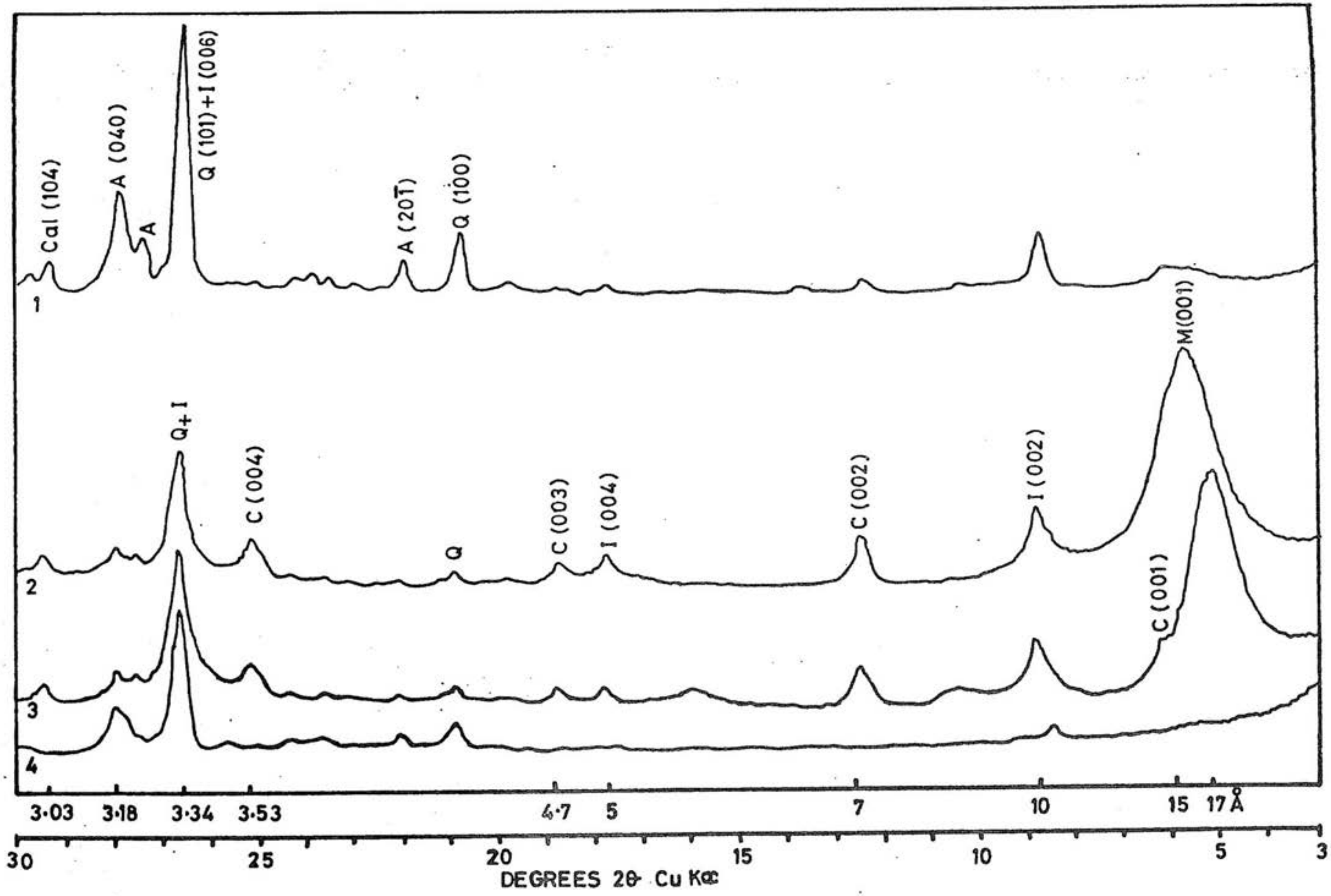

Fig. 2 : Typical X-ray diffractograms of samples from Jehangira lacusturine clay beds. Different scans are: 1 = unoriented, 2 = oriented normal, 3 = glycolated, and 4 = HCl treated. Explanations : A = albite, C = chlorite, Cal = calcite. I = illite, M = montmorillonite, and Q = quartz.

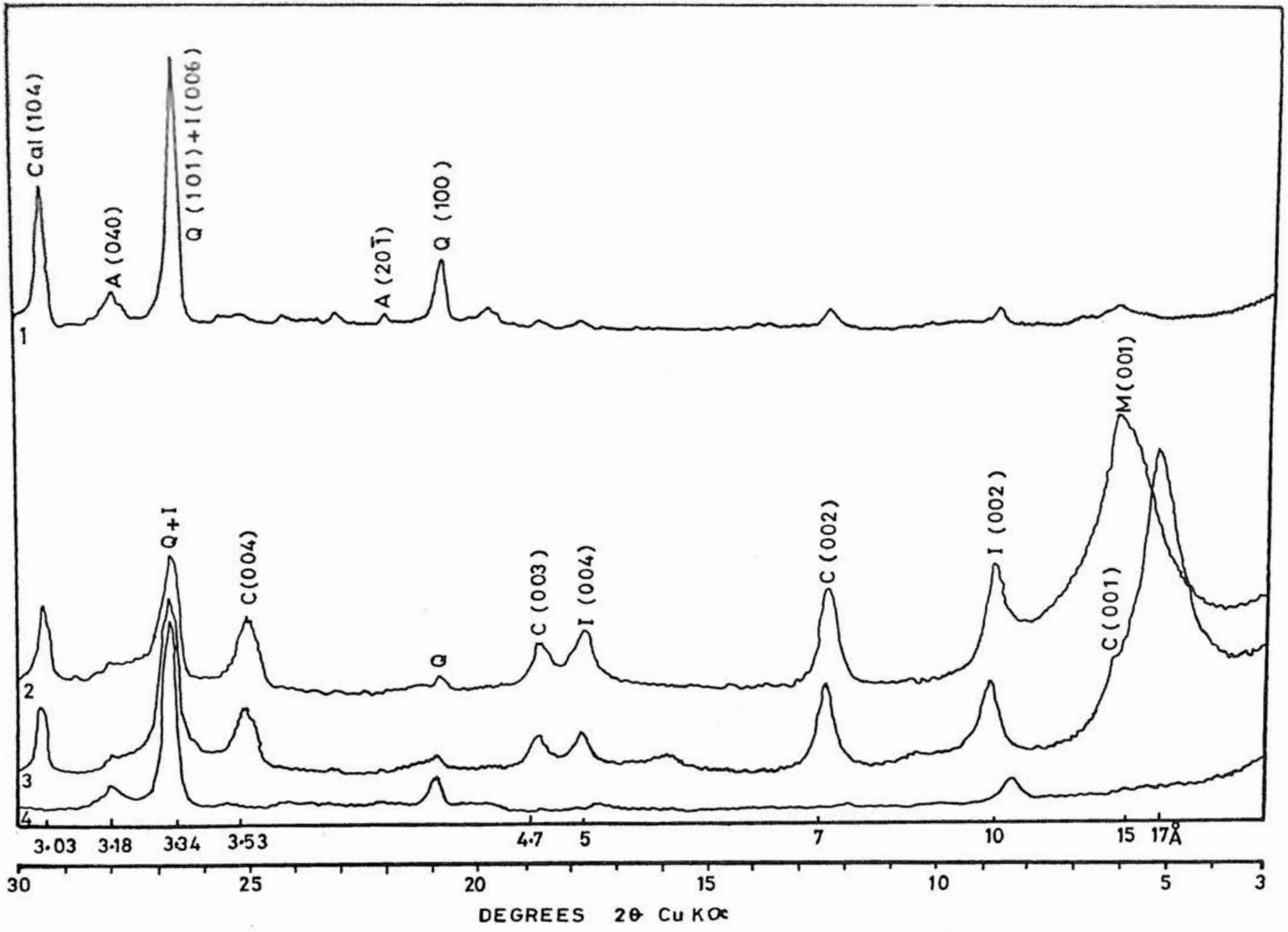

Fig. 3 : Typical X-ray diffractograms of samples from claystone of the Chinji Formation from Jalalpur, eastern Salt Range. Different scans and explanations are same as in Fig. 2.

Montmorillonite

Prominent [001] basal reflections of montmorillonite were obtained at 15 Å in the untreated ordered mounts. From the position of the [001] peak, the type of exchangeable cations contained in the montmorillonite can be estimated (Weaver, 1958). The 15 Å [001] peak of montmorillonite in our samples indicates presence of two layers of water and probably Ca^{++} and/or Mg^{++}. On glycolation the 15 Å peak shifted towards smaller Bragg angles (17 Å), thus further confirming the presence of montmorillonite. Montmorillonite has the property of absorbing ethylene glycol between its silicate layers, forming a smectite-organic complex. According to Bradely (1945), this complex possesses a high degree of regularity and yields sharper [001] reflections. Our results are in concordance with this, as after glycolation the [001] reflection of montmorillonite becomes sharper and more symmetrical (Figs. 2 and 3).

10 A mica

In clays from both the localities the mica was identified as the 2M illite, by its basal reflections of 10.04 Å [002] and 5 Å [004]. Glycolation did not produce any observable effect in these basal spacings (Figs. 2 and 3). This indicates the absence of any mixed-layer structures (Warshaw *et al.*, 1961).

Non-clay minerals

The non-clay constituents of the lacustrine and the Siwalik clays, as determined by X-ray Diffraction, are also quite similar. They include quartz, albite and calcite. Low-quartz was identified by its typical [100] and [101] reflections of 4.26 Å and 3.34 Å, respectively. Low-albite was confirmed by its peaks of 3.18 Å, 4.03 Å and 3.2 Å. The presence of calcite was indicated by its peak at 3.03 Å (Figs. 2 and 3).

DISCUSSION

In the non-marine sedimentary basins chlorites are derived from the weathering profiles by the degradation of ferro-magnesian minerals, and above all, from the erosion of the greenschists which have abundant chlorite. Chlorites may also be formed diagenetically in the "Anchi–" and "Epizones" (close to low grade metamorphism), by the aggradation of less organized sheet minerals such as celedonite and montmorillonite (Dunoyer de Segonzac, 1970; Deer *et al.*, 1976). The 2M form of illite is found in micas of metamorphic zones or in deep diagenetic zones bordering on metamorphism (Kisch, 1970; Dunoyer de Segonzac, 1968, 1970; Weaver, 1958). Thus the 2M illites in recent continental sediments are usually of detrital origin and are common where the cold and dry climate was not favourable to hydrolysis or where erosion was sufficiently rapid to prevent weathering (Dunoyer de Segonzac, 1970; Kisch, 1966, 1968). As for montmorillonite, it occurs in four special environments: in soil profiles, in basic chemical sedimentation, in bentonites (altered volcanic ash) and in hydrothermal veins. In well drained soils illite and chlorite are degraded to montmorillonite which forms and intermediate stage before their total hydrolysis. As for chemical sedimentation of montmorillonite, the environment has to be of alkaline (high pH), and "non-aggressive" type (Grim, 1953; Millot, 1964; Dunoyer de Segonzac, 1970).

The lake deposits of Jehangira and the claystone of the Siwaliks Group do not show any signs of even very low grade metamorphism. Thus, in these deposits the presence of regular well-formed chlorite and the 2M illite, co-existing with the expanding clay (*i.e.,* montmorillonite), can not be attributed to diagenetic neo-formation. Hence, it is inferred that these illites and chlorites are of detrital origin, derived mostly from the abundant mafic, ultramafic metamorphites of the Kohistan arc sequence, the Indus Suture melange group of MMT (greenschists, blueschists, talc-chlorite-dolomite and quartz-mica-chlorite schists) and the schistose rocks of the Indo-Pakistan sequence south of MMT (Kazmi *et al.,* 1984; Jan, 1979).

Since chlorites and illites are the retromorphic products of ferromagnesian minerals, they would form a major portion of the soils at the foothills of the Central and Lesser Himalayas. Further degradation of these illites and chlorites produces montmorillonite which is brought down with the drainage and subsequently deposited in the sedimentary basins further south. This is inferred to be the dominant mode of formation of montmorillonite in both, the lake as well as the studied Siwalik deposits. Nevertheless, the *in situ* formation of some of the montmorillonite in the Jehangira lake deposits can not be ruled out. In such a case, alkaline (high pH) and non-aggressive conditions would be depicted. Presence of some carbonate and the absence of kaolinite in these lake deposits also supports this inference (Grim, 1953; Dunoyer de Segonzac, 1970).

Our present study reveals that there is a similarity between the clay mineral assemblages of the Jehangira lake deposits and the Lower Siwalik Clay of the Chinji Formation. Thus it is inferred that the source of the two deposits was the same, *i.e.,* the mafic, ultramafic metamorphites of the Kohistan sequence and the MMT melange zone, and the schist of the Indo-Pakistan plate sequence south of MMT.

A detailed study of the clay minerals of the various outcrops of Quaternary lacustrine deposits of Peshawar valley is in progress.

CONCLUSIONS

The Jehangira lake deposits were studied for the purpose of identification of clay minerals using X-ray Diffraction. The studies reveal the presence of illite, chlorite and montmorillonite. Samples from the bright red claystone of the Chinji Formation of the Siwalik Group were also analyzed for comparison sake.

Illite and chlorite in both, the Jehangira lake deposits and the claystone of the Chinji Formation are of detrital origin as revealed by their regular and well formed structures. The parent material for these detrital clay minerals, are the abundant mafic, ultramafic metamorphites in northern Pakistan. The similarity of clay mineral assemblages between the Jehangira lake deposits and the Chinji claystone suggests a common provenance.

Montmorillonite in the clays was derived by the degradation of illites and chlorites in the soils near the foothills and in the valleys of the Central and Lesser Himalayas. In the lake deposits of Jehangira some of the montmorillonite could be of authigenic origin indicating alkaline and quiescent environment.

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