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Petrographic and Economic Aspects of the Sandstone Unit of the Kamlial Formation, Karaat Hills, South-Eastern Kohat Plateau, NW Pakistan

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ABSTRACT

The Kamlial Formation of middle to late Miocene age is exposed in the hilly area of Karaat, district Karak, Pakistan. It mainly consist of sandstones with intercalations of shales. In order to observe different petrographic features, 16 samples were collected at an average interval of 5 m, from the sandstone unit of the formation. The studied samples mainly consist of quartz, feldspar and rock fragments with an average modal abundance of 45%, 9 % and 15 % respectively and variety of heavy and accessory minerals comprising of muscovite, biotite, garnet, epidote, monazite, tourmaline and zircon. Carbonate is the major cementing material in the studied samples of the Kamlial Formation. By plotting on the triangular diagram majority of the studied samples fall in the field of "feldspathic lithwacke". The high ratio of quartz to feldspar (Q/F=4.8) shows the mineralogical maturity, while, the abundance of matrix suggests that the sandstone is texturally immature even though it comprises of sub-rounded grains and is moderately to well-sorted. Non-undulose to weakly undulose monocrystalline quartz is in a higher proportion in the studied sections whereas the polycrystalline quartz is rare and much less abundant and predominantly consists of two to three sub-grains with straight to only slightly curved sub-grain boundaries. These characteristics of quartz indicates that the source rock is of igneous origin. The friable nature of the sandstone unit makes it a poor building stone but can be used in cement industry and other construction purposes. Kamlial Formation can host potential Uranium deposits because of its environment of deposition.

1. Introduction

Sandstones are sedimentary rocks with grain size of 1/16 to 2mm in size, possessing the reservoir characteristics and mineralogical contents. Sedimentary studies are important in prospect evaluation for mineral reserves due to the huge percentage of the world's economic mineral deposits, in monetary value, come from these rocks. According to Dickson and Suczek [1], the tectonic setup of sedimentary rocks especially sandstone comprises their own rock type which when eroded, produces stones with specific compositional varieties. Hence, knowing the composition and properties of sedimentary rocks are essential in interpreting stratigraphy, tectonic activity of the source area, character of the environment of deposition and the cause of changes in thickness or lithology as well as to correlate beds precisely by mineral work.

Kamlial Formation of middle to late Miocene age [2, 3] is exposed in Karaat hills (Lat. 33˚ 13' 48.74" N, 71˚ 18' 49.68" Long.) with maximum thickness of 107 m (present study), predominantly consisting of sandstone with intercalations of shale at the bottom has been selected for the present study.

The aim of the present study is to present a detailed account of the sandstone from the Kamlial Formation with emphasis on the petrographic characterization and heavy mineral concentration, determination of the extent of textural and mineralogical maturities, provenance studies, categorization of the type and mode of transportation and the economic importance of the sandstone unit.

1.1 Regional Geology

The south-western extension of the Himalayas covers the Kohat Foreland Basin, also regarded as southern foreland fold and thrust belt [4]. The Karaat Hills are located in the Kohat Foreland Basin (Fig. 1) which in turn is a part of the Sub Himalayas, a product of the ongoing collision between the Eurasian and Indian plates in the middle to late Eocene [5-8].

1.2 Stratigraphy of the Area

The present research area comprises of rocks ranging in age from Early Eocene to Late Miocene. The Eocene successions of the area include Bahaderkhel Salt, Jatta Gypsum, Kuldana Formation and Kohat Formation. The Eocene rocks are unconformably overlain by the Kamlial and Nagri formation of Miocene age (Fig. 2).

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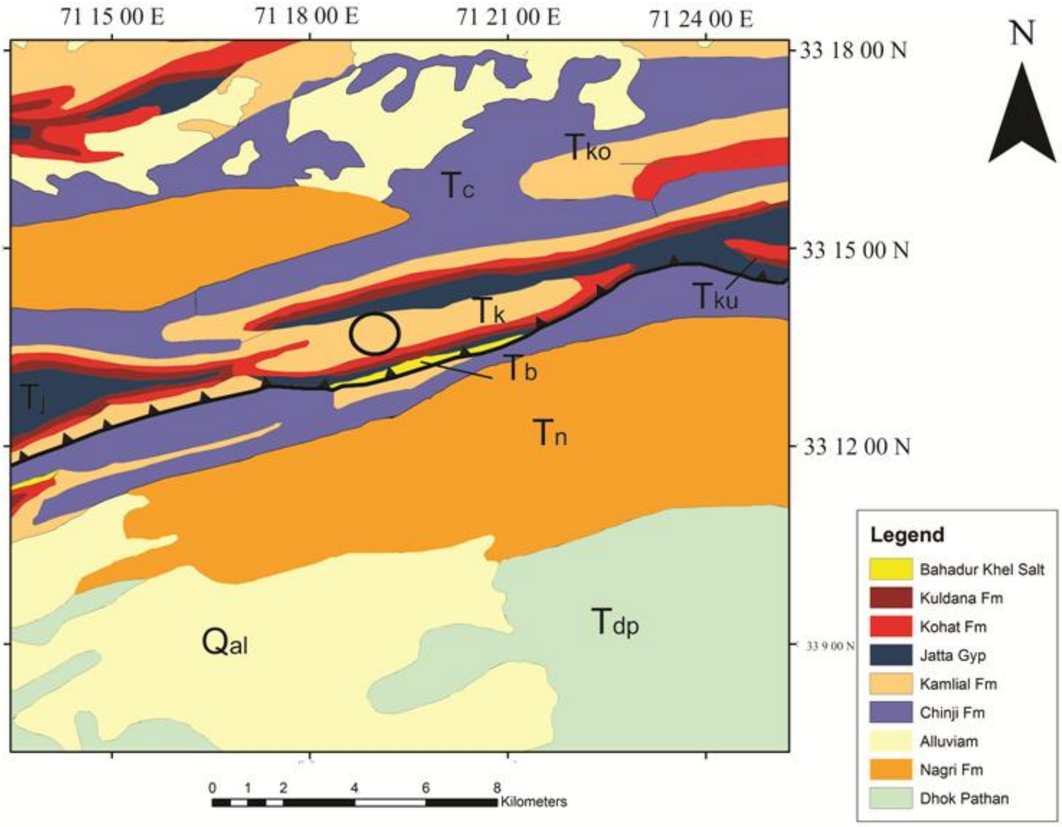

Fig. 1: General geological map of the study area, modified from [3]. Circle showing the study area Tb= Tertiary Bahaderkhel Salt, Tj= Tertiary Jatta Gypsum, Tku= Tertiary Kuldana Formation, Tko=Tertiary Kohat Formation, Tk= Tertiary Kamlial Formation, Tc= Tertiary Chinji Formation, Tn= Tertiary Nagri Formation, Tdp= Tertiary Dhok Pathan Formation, Qal= Quaternary Alluvium

1.2.1 Kamlial formation

As mentioned earlier, the aim of the present research is to determine the petrographic characteristics and economic aspects of the sandstone unit of the Kamlial Formation exposed in the Karaat Hills. The formation mainly comprises of sandstone with, lenses of conglomerate and sub-ordinate siltstone and clay. At Kamlial village the formation is about 575 meters thick but is 107 m thick in the study area. Almost, 90% of the formation consists of thick bedded, medium to coarse grained, cross bedded sandstone and grey to greenish grey in color. The sandstone also contains lenses of conglomerates of soft clay. Siltstone is reddish brown, hard, fine grained, thin bedded and intercalated with clay.

In the study area the formation mainly consists of sandstone with intercalations of shale at the bottom having total thickness of 107 m. Different vertebrate fossils have been found in the formation, on the basis of which middle Miocene age is assigned to the formation [2]. The lower and upper contact is unconformable with the Kohat Formation of Eocene age and Nagri formation of Miocene age respectively.

2. Methodology

For petrographic studies, 16 samples of compact, unweathered/fresh rock units were collected at regular intervals of ~5 m, from the Kamlial Formation. Thin sections of the collected samples were prepared according to the standard procedures. Average modal abundance of each of the sample was determined through visual estimation under the petrographic microscope. The stratigraphic section was measured and lithological units identified on the basis of their distinguishing properties e.g., color, grain size, etc. Other related data i.e., contact relationships, structural features and lithological characteristics were also observed and noted.

3. Results and Discussion

3.1 Framework Constituents

The dominant constituent of the Kamlial sandstone is medium to coarse grained quartz with average modal abundance of 45%. The quartz grains are sub-angular to sub-rounded and occur both as monocrystalline and polycrystalline types with euhedral to sub-hedral shape. The monocrystalline variety is much more abundant than the polycrystalline (Figs. 3A & 3B).

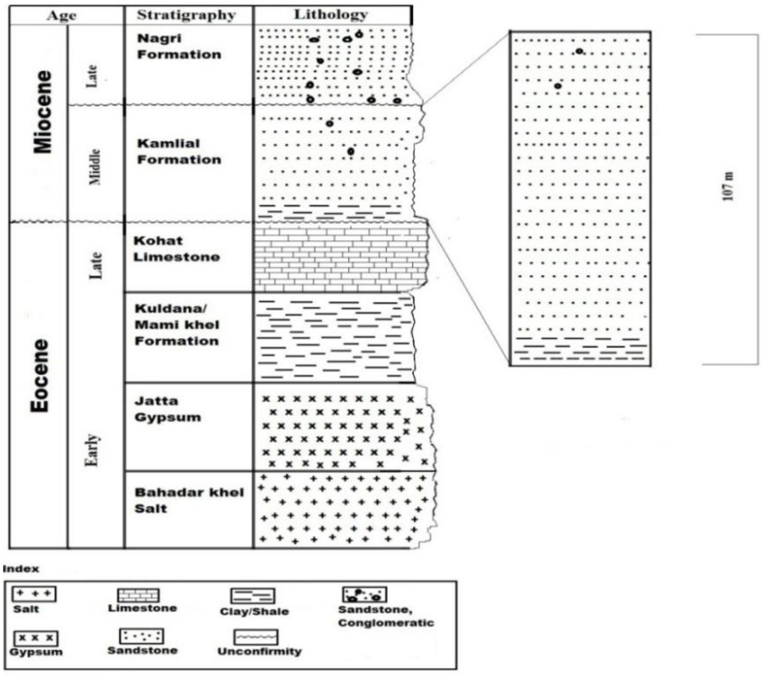

Fig. 2: Generalized stratigraphic column of the study area (Karaat hills), Kohat sub-basin (present study)

Uniform extinction is displayed by the quartz grains, however, some of them, particularly the coarser ones display wavy extinction. Some quartz grains show fractures and these fractures are filled with cement (calcite) or opaque material. Some of the quartz grains display sutured boundaries while others show straight boundaries. Silica overgrowths are present along some quartz grains owing to its origin of secondary processes.

Rock fragments are the second most abundant constituents of the studied samples (15%). The rock fragments occur as small grains with rounded outlines and include igneous, sedimentary and metamorphic rock types (Fig. 3C).

All the studied samples contain appreciable amounts of feldspars with modal abundance of 9%. Most of the feldspar grains are of fine size with only a minor proportion occurring as medium sized grains and have sub-rounded boundaries. Although alkali feldspar is the most abundant type of feldspars, microcline, perthitic alkali feldspar and plagioclase grains are also present in trace amounts (Fig. 3D).

The grains of feldspar show alteration to clay minerals e.g., kaolinite and sericite. These grains are mostly fractured and the fractures are filled with opaque minerals or cement. The alkali feldspar grains show simple twinning and contain inclusions of mica. Plagioclase displays the diagnostic albite polysynthetic twinning. Microcline exhibiting the diagnostic cross hatched twinning is rare and occurs in the form of small grains. The cement and matrix is comprised of carbonate (Figs. 3E & 3F).

3.2 *Accessory and Heavy Minerals Suite*

Accessory and heavy minerals suite of the Kamlial sandstone consists of muscovite, present in almost all the studied sections and shows bending due to deformation and biotite which is highly oxidized and altered. In addition to these, trace amounts of garnet, epidote, monazite, ilmenite, tourmaline and zircon also occur (Figs. 3G, 3H 3I & 3J). The studied samples of sandstone from the Kamlial formation contain some ore minerals; reddish brown to dark brown hematite, being the most common. The overall amount of accessory and heavy minerals in the studied sandstone is 9%.

3.3 *Texture*

The studied samples from the Kamlial Formation are mostly medium grained. The framework constituents are sub-angular to sub-rounded and sub-prismoidal to spherical. The boundaries among the grains of quartz and feldspars are predominantly concavo-convex, while sutured and straight boundaries also occur occasionally. The major cementing material includes carbonate, clay, ferruginous matter and silica as quartz overgrowths. The studied sandstones from Kamlial Formation, based on visual estimation, are moderately to well sorted. The high ratio of quartz to feldspar (Q/F=4.8) shows that the sandstone is mineralogically mature while, the abundance of matrix suggests textural immaturity even though it consists of sub-rounded grains and is moderately to well sorted.

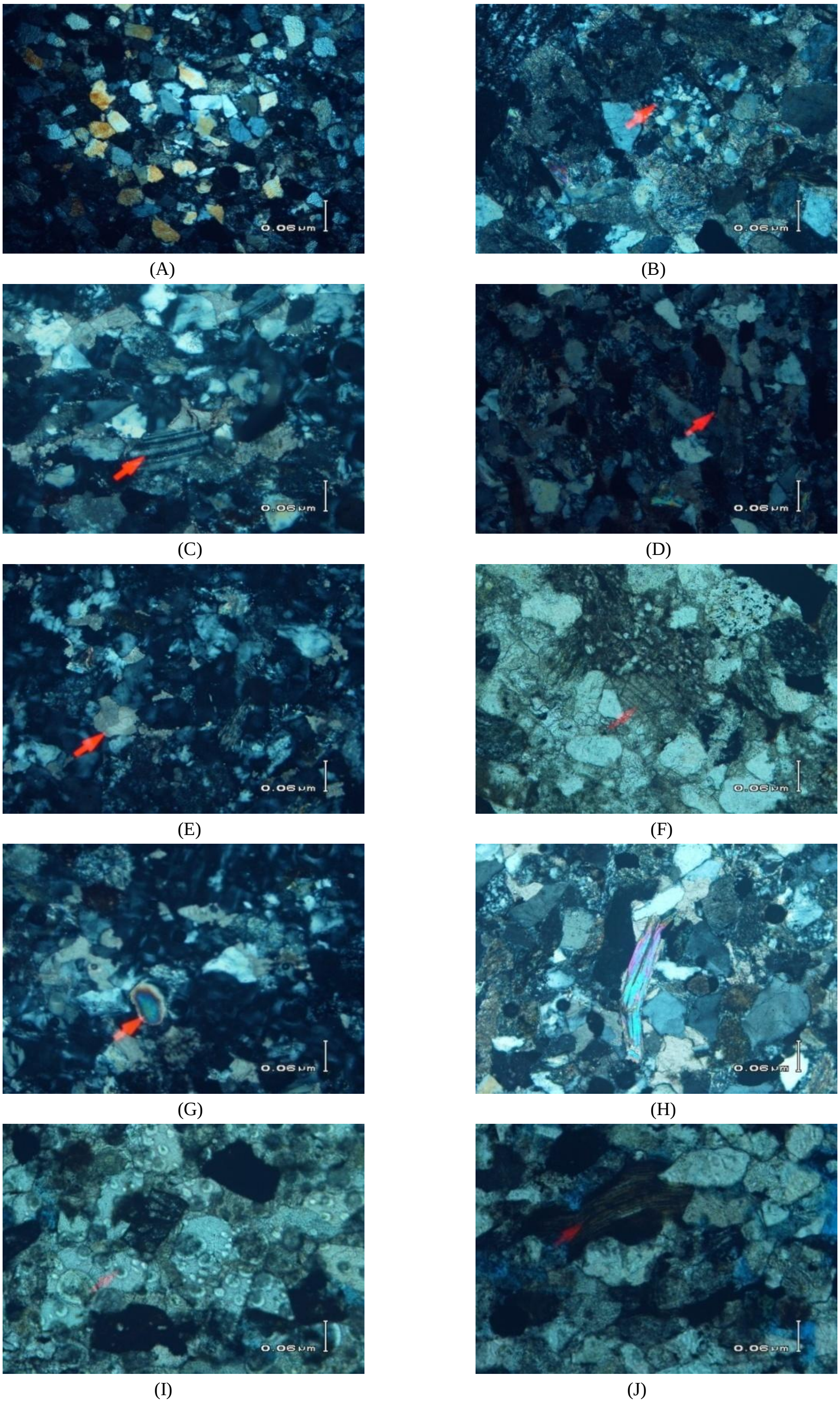

Fig.3: Photomicrographs displaying (A) sub-angular to sub-rounded monocrystalline quartz grains (XPL), (B) polycrystalline quartz grain (XPL), (C) plagioclase grain (XPL), (D) lithic fragments (XPL), (E) calcite crystal and carbonate matrix (XPL), (F) calcite crystal and carbonate matrix (PPL), (G) tourmaline grain (XPL), (H) muscovite flake (XPL), (I) garnet (PPL), (J) Biotite flake (PPL), (XPL=Cross Polarizing Light and PPL=Plane Polarizing Light)

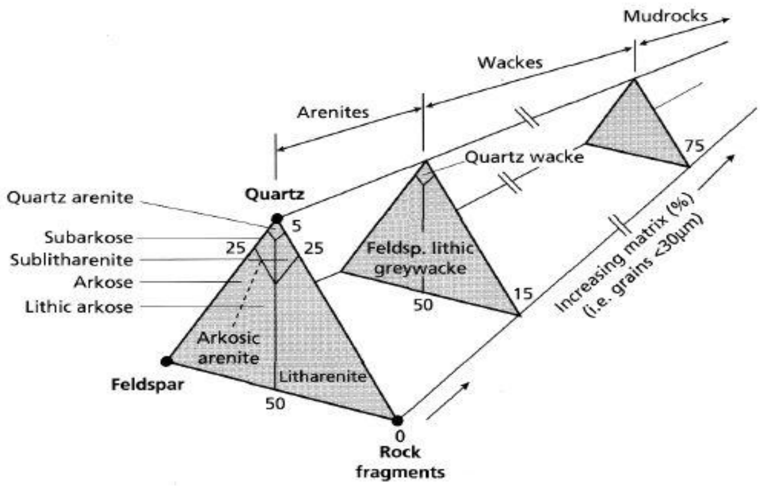

Fig. 4: Sandstone classifications [10]

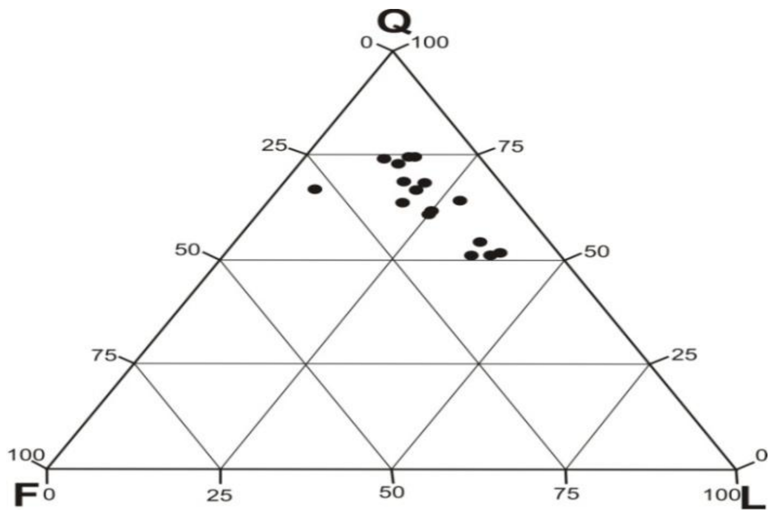

Fig.5: Modal composition of the studied samples plotted on the quartz (Q) – feldspar (F) – lithic (L) triangular diagram of [10]

3.4 Modal composition

For classification of sandstones on the basis of their modal composition, Pettijohn et al. [9] used the three major framework elements, i.e. quartz, feldspar and rock fragments. According to this classification, sandstones having less than 15% matrix with a major amount of either quartz, feldspar or rock fragment are named as quartz arenite, arkosic arenite or lithic arenite respectively. The term sub-arkose and sub-litharenite are used for transitional classes. Those having more than 15% matrix are named as graywacke, arkosic wacke and lithic wacke (Fig.4). By plotting on the triangular diagram of Pettijohn et al. [10; modified from 11], which consists of quartz, feldspar and lithics each on its three end members, almost all the studied samples fall in the field of "feldspathic lithwacke" (Fig. 5).

3.5 Provenance

The provenance of sediment embraces all characteristics of the source area, e.g., source rocks, climate and relief [10]. The various parameters used for sandstone provenance determination are:

1. Quartz: its optical properties, types and percentage.
2. Type and abundance of feldspar and rock fragments.
3. Heavy mineral concentration.

Because of its high mechanical and chemical stability, detrital quartz is the most abundant mineral in all clastic sediments derived from any common parent rock types. In multiply recycled sediments, some quartz may survive several cycles of erosion and represent some remote parent rocks. Quartz has the greatest potential of all detrital minerals for reading provenance of arenites [12]; therefore, it is helpful in interpreting the provenance of sandstones. The greater amount of undulose monocrystalline quartz grains along with the polycrystalline quartz grains with four or more sub-grains indicates the metamorphic source area [12]. Non-undulose and weakly undulose monocrystalline or polycrystalline grains of quartz with only two or three sub-grains are produced by plutonic rocks [12]. However, plutonic source area is also inferred from the polycrystalline grains with more than five sub grains having straight to slightly curved inter-crystalline boundaries [13, 14].

Non-undulose to weakly undulose monocrystalline quartz is in a higher proportion in the studied sections of the Kamlial sandstone whereas the polycrystalline quartz is rare and much less abundant and predominantly consists of two or three sub-grains with straight to only slightly curved sub-grain boundaries.

Feldspars make up-to (9%) of all the studied thin sections. The grains of feldspar present are cloudy and show evidence of dissolution. The plutonic igneous rocks yield orthoclase or microcline and or perthitic alkali feldspar [10]. Therefore, the abundance of alkali feldspar in the present study suggests that the source could be acidic plutonic rock.

Rock fragments present in the studied sections dominantly consists of argillite and chert. However, volcanic lithics and metamorphic lithics are also present in appreciable amounts. The average contents of rock fragments are 15%.

Trace amounts of number of heavy minerals occur in the Kamlial Formation. Association of these heavy minerals has long been used as indices of provenance, indicating specific source rocks [15, 16]. The studied samples include garnet, epidote, monazite, rutile, ilmenite, apatite and chromite. In addition to this monazite, muscovite and zircon are present in the form of inclusions in grains of quartz and feldspars. The assemblage of these heavy minerals indicate acidic igneous as a source rock for the Kamlial Formation.

3.6 Economic Importance

Sands and sandstones produce products that have multiple uses: 1) dimension stone: building stone, rip-rap, flagging; 2) metallurgical silica: silicon metal, ferrosilicon alloys; 3) abrasive; 4) molding and core sands in the foundry industry: blasting sands, engine sands, whetstones; 5) aggregate: in concrete, cements, plasters, bituminous paving mix, terrazo; 6) fillers in paints and bitumens; 7) sand filters; 8) fill sands; 9) glass sand; and 10) silica flour.

The sandstone of Kamlial Formation is friable in nature and this property makes it a poor contender for the building stone. However, most of the above mentioned products can be obtained from sandstones and sands of the Kamlial Formation due to its friable nature.

The Kamlial Formation is a member of thick molasse sequence which makes it a potential for uranium deposits in the area.

4. Conclusions and Comparison

The main conclusions from the present study are compared with those drawn on the basis of similar studies carried out on Kamlial Sandstone from Banda Asar, Bahaderkhel and Chashmai area of southern Kohat plateau [17].

- The sandstone unit of Kamlial Formation mainly constitutes of quartz, rock fragments, and feldspar and trace amount of accessory and heavy minerals. Similar mineralogical composition have been reported by K. Ullah et. al. [17] from Banda Asar syncline, Chashmai anticline and Bahaderkhel anticline.
- The sandstone of Kamlial is matrix (dominantly carbonate) supported with moderately to well sorted, sub-angular to sub-rounded and sub-prismoidal to spherical and medium grain size. Almost similar conclusions are drawn in the study of Kamlial sandstone from Banda Asar syncline, Chashmai anticline and Bahaderkhel anticline [17].
- The quartz feldspar (Q/F=4.8) indicates mineralogical maturity of the studied samples in the present study while abundance of matrix shows textural immaturity. More or less similar results have also been reported for the Kamlial sandstone from Banda Asar syncline, Chashmai anticline and Bahaderkhel anticline [17].
- In the present study the sandstone of Kamlial Formation is mineralogically classified as mostly “feldspathic wacke” while, according to K. Ullah et. al. [17] mineralogically, sandstones of the Kamlial of the Banda Asar syncline, Chashmai anticline and Bahaderkhel anticline belong to both feldspathic and lithic arenites.
- The modal abundance of quartz (pre-dominantly monocrystalline), accessory and heavy minerals suite of the studied samples indicates acidic igneous as a source rock for the Kamlial Formation at Karaat hills. The Kamlial sandstone from Banda Asar syncline, Chashmai anticline and Bahaderkhel anticline shows feldspar-rich igneous and metamorphic source rock [17].
- The sandstone of the studied formation is friable therefore is not suited as dimension stone but at the same time can be used as aggregate and abrasive, fill sands, metallurgical silica, glass sand and sand filters.
- The formation depicts river deposition and marking as the base of molasse sequence in the area providing probable chances for placer gold deposits.

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