PETROGRAPHY AND PROVENANCE OF SANDSTONE AND STUDIES OF SHALE OF KULDANA FORMATION, KALAMULA AND KHURSHEEDABAD AREA, KAHUTA, AZAD KASHMIR

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ABSTRACT

Rocks exposed in the study area are Kuldana Formation which is comprised of variegated color shale and sandstone. The model data of Kuldana sandstone exhibit average quartz 35%, feldspars 3%, rock fragments 20% and heavy minerals. The quartz grains are of igneous and metamorphic origin. Mineral quartz, feldspars, and rock fragments in the sandstone suggested an acidic plutonic and metamorphic provenance. Rock fragments are of sedimentary, volcanic and metamorphic rocks. The sedimentary grains include limestone, dolomite, quartzite, sandstone and siltstone. The volcanic rock fragments are of fine grained basalt. The metamorphic rock fragments are of slates and schists.

Heavy minerals include tourmaline, zircon, garnet, epidote, sphenel and apatite. Hematite and calcite are the dominating cementing material with minor chlorite. The sandstone is classified as graywacke. The low modal proportion of quartz and high content of rock fragments indicates low degree of mineralogical maturity of the sandstone. The poor degree of sorting, angular to sub-angular framework constituents and abundance of matrix suggested that sandstone is texturally immature. The sutured quartz grains contacts, alteration of plagioclase to clay minerals and deformed muscovite indicate diagenetic changes in the sandstone at depth under pressure.

The XRD analysis of shale show minerals chlorite thuringite, orthoclase, corrensite mica, illite, albite, smectite, saponite, montmorillonite, goethite, kaolinite, vermiculite, aragonite, calcite, quartz, siderite, muscovite, hematite, pyrite and dolomite. Recalculated value of quartz, clay and carbonates on ternary diagram shows that the clays are argillaceous. Quartz, orthoclase, albite and muscovite in the shale suggest acidic plutonic and metamorphic provenance.

1. Introduction

Himalayas are cretaceous aged mountain belts formed by collision between Eurasian and Indian plate. These mountain belts of Himalayas are subdivided by Gansser (1964). Our study area is bounded by MBT on Western side and PT on East (Fig. 1). These rocks are exposed in the Kalamula and Khursheedabad area (Fig. 2). It is a highly deformed fold and thrust belt. The rock units exposed in this area are mainly comprised of the sandstone and shales of Kuldana Formation which is medium to fine grained sandstone of Cenozoic age.

Regional Tectonic and Geological Settings

The mountain belt of Himalayas is formed due to collision of Eurasian and Indian plates (Kazmi and Jan, 1997). The collision between the two huge continental blocks intensely deformed Phanerozoic sediments. The grade of regional metamorphism, magmatic episodes and intensity of deformation increased towards collisional zone. Himalayas are comprised of igneous, metamorphic, meta-sedimentary and sedimentary rocks. Proterozoic basement rocks are exposed in Besham, Nanga Parbat Haramosh, Upper Kaghan and Neelum Valley in north western margin of the Indian Plate. The basement rocks are regionally metamorphosed and intruded by granite plutons (Kazmi and Jan, 1997). Tectono-stratigraphically the Himalayas are subdivided in to Sub-Himalayas, Lesser Himalayas, Higher Himalayas and Tethyan Himalayas (Gansser, 1964). The Lesser Himalayan region exhibits folding and faulting. The major tectonic features of the area are Hazara Kashmir Syntaxis, Main Boundary Thrust and Panjal Thrust.
Formation as lower part of Murree Formation. The Kuldana Formation was previously recognized and mapped in Muzaffarabad (Khan, 1994) and Kahuta areas (Ashraf and Chaudhry, 1984). The shales of Kuldana Formation show sedimentary cleavage and deformation. The rocks away from MBT are comparatively less deformed and fractured.

Sub-Himalayas
The Sub-Himalayas are the fold and thrust belt of Neogene molasse sediments extending from Western Pakistan to Assam. The term "Siwaliks" is also used for these deposits. The sub Himalayans in northwestern margin of the Indian plate are comprised of rocks of Rawalpindi and Siwalik groups. The Siwaliks are unconformably overlain by alluvial deposits. Himalayan Frontal Thrust (HFT) marks the southern boundary of the Sub-Himalayas while the northern boundary is terminated along Main Boundary Thrust (MBT) (Fig. 2).

Lesser Himalayas
The Lesser Himalayas are comprised of Precambrian to late Paleozoic metasediments intruded by granites, the Cambrian carbonates, Mesozoic and Cenozoic rocks in Hazara and Permian Panjal Volcanics in Kaghan and Kashmir (Greeco, 1989; Bossart et al., 1988). The Lesser Himalayas are very low grade metasedimentary rocks (Heim and Gansser, 1939). The Ordovician to Devonian age rocks are missing. The Lesser Himalayan rocks thrust onto the Sub Himalayas along MBT (Fig. 2).

Higher Himalayas
The Higher Himalayas extends eastward from Indus gorge (near Besham) to Brahmaputra gorge in Assam. In North West Himalayas, the Higher Himalayas are comprised of Nanga Parbat range, upper Kaghan and Neelum Valleys.

The high grade metamorphic rocks of Higher Himalayas have thrusted on to the low grade metasediments of Lesser Himalayas along the Main Central Thrust (MCT; Valdiya, 1980). The ductile deformation, barrovian metamorphic sequence, migmatites and leucogranites have been reported in the area (Pecher, 1989). The northern boundary of Higher Himalayas is marked by South Tibet Detachment (STD) normal fault (Fig. 2).

Tethyan Himalayas
The Tethyan Himalayan zone is comprised of Proterozoic to Eocene siliciclastics as well as carbonate sedimentary rocks (Yin, 2006). Paleozoic to Lower Tertiary marine sedimentary rocks deposited on passive continental margins of the Indian plate are exposed in the Tethyan Himalayas (Liu and Einsele, 1994). Its northern boundary is marked by Indus-Tsangpo Suture Zone (IMSZ) where as its southern boundary is marked by South Tibet Detachment Zone (Yin, 2006).

Tectonic Setting of The Project Area
The Lesser Himalayan region exhibits folding and faulting. The major tectonic features of the area are described as under:

Hazara Kashmir Synthax
Wadia (1931) proposed the term “Northern Himalayan synthax” for an abrupt bend similar to shape of a hairpin between Mirpur, Muzaffarabad and Hazara area. The various workers (Calkins et al., 1975; Bossart et al., 1988; Ghazanfar et al., 1986; Ottiger, 1986) have used the name Hazara Kashmir Synthax (HKS) for this antiformal structure in the area.

The Main Boundary Fault is folded around the syntaxial bend. The Muzaffarabad fault (MF) and Jhelum Fault (JF) extend from the sub-Himalayan zone into the core of Hazara Kashmir Synthax and are terminated in the area against the MBT (Rustam and Mubarak, 1994; Baig and Lawrence, 1987). Precambrian to recent sedimentary, metamorphic and igneous rocks form its geology.

The Main Boundary Thrust (MBT)
The Main Boundary Thrust is located near Nauseri, Lamnian and chalkamia in Muzaffarabad and Khumgila in Kahuta area. In the study area the MBT separates the Panjal Volcanics from the Murree Formation (Fig. 2). Wadia (1928, 1931) recognized the tectonic discontinuity between the steeply plunging Murree beds and Panjal volcanics in Kahuta and Muzaffarabad areas. The tectonic contact, MBT, is clearly exposed in the study area. The rocks along the contact are highly sheared at places.

The Panjal Thrust
The Panjal Thrust runs parallel to MBT on the eastern limb of the syntaxis (Wadia, 1931). In Kahuta area it runs through Kalamula–Kiran area. Along the Panjal Thrust the Dogra Slates were thrust on to the Panjal Formation. The Panjal Thrust extends towards southeast in the area.

Stratigraphy of Kahuta Area
Rocks in the area are from Pre Cambrian to Quaternary and consist of sedimentary, volcanics and metamorphic. The unconformities are marked while some contacts are faulted. The oldest unconformity is between Dogra Slates and Gondwana Group of Carboniferous marked by the presence of conglomerate bed (Fig. 2). Second unconformity is present between Panjal Formation of Permo Carboniferous and Lockhart Limestone of Paleocene age. Chorgali Formation which is marked in other areas is missing here and Patala.

Table 1: Stratigraphic column of Kahuta (Modified after Khan, 1994; Ashraf and Chaudhry, 1980)

<table>
<thead>
<tr>
<th>Formation</th>
<th>Age</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Recent to sub recent</td>
<td>Mainly gravels, boulders, sands but also some clays, glacial and glaciofluvial deposits on higher elevations.</td>
</tr>
<tr>
<td>Murree Formation</td>
<td>Oligocene to Lower</td>
<td>Reddish brown to greyish, fine to coarse grained sandstone and reddish shales.</td>
</tr>
<tr>
<td>Kuldana Formation</td>
<td>Eocene</td>
<td>Red, maroon, purple and green shales with hard sandstone beds.</td>
</tr>
<tr>
<td>Margalla Hill</td>
<td>Lower Eocene</td>
<td>Bituminous black (yellowish grey and fuggy) limestone. Grey, green and khaki shales.</td>
</tr>
<tr>
<td>Limestone</td>
<td>Paleocene</td>
<td>Creamish to dark brown splintery shale and subordinate fine to medium grained nodular limestone.</td>
</tr>
<tr>
<td>Lockhart Limestone</td>
<td>Paleocene</td>
<td>Grey to light grey medium to thick bedded, fossiliferous and nodular limestone.</td>
</tr>
<tr>
<td>Panjal Formation</td>
<td>Permo-Carboniferous</td>
<td>Basal agglomeratic slates and basaltic lava flows.</td>
</tr>
<tr>
<td>Gondwana Group</td>
<td>Carboniferous</td>
<td>Basal quartz conglomerate bed, slates and argillaceous sandstone.</td>
</tr>
<tr>
<td>Dogra Slates</td>
<td>Cambrian</td>
<td>Marble with calcareous schist and кварzite and dolomite.</td>
</tr>
<tr>
<td>Pre-Cambrian</td>
<td>Grey, dark grey to black slates, The Dogra slates also contain volcanics which have been called the “Dogra Trap” (Wadia, 1928). This trap is amygdaloidal as well as free from amygdules.</td>
<td></td>
</tr>
</tbody>
</table>

Formation exhibits a faulded contact with Kuldana Formation (Fig. 2). Another unconformity is marked between Kuldana Formation of Eocene age and Murree Formation of Miocene age in the area. The stratigraphy of the area is described as under:

Dogra Slates
Waggon and Wynne (1972) name the group of metamorphic slate rocks in Hazara area, as Attock Slates. Later on Calkins et al., (1980) named it as Hazara Formation. The Dogra Slates are correlated with Hazara Formation on the basis of age, lithology and stratigraphic position (Wadia, 1928).

Dogra Slates are the oldest rock sequence exposed in Kahuta areas (Fig. 2). The petrography and chemical analysis of Dogra Slates is carried out by (Chaudhry and Ashraf, 1984).The rocks form the steep slopes and escarpments. The Dogra Slates show aremarkable color variation from grey, dark grey to black. The slates are fine grained, thin bedded, argillaceous and the cleavage planes being filled with quartz. The volcanics known as Dogra Trap intruded the Dogra Slates. These volcanic rocks have experienced high grade of metamorphism. The Dogra Slates along with Kailar limestone are thrust over the Paleocene-Eocene Sequence in the area. The rocks of Dogra Trap are basaltic with a high concentration of K2O (Ashraf and Chaudhry, 1980).

Lower contact of Dogra Slates is faulted with Kailar formation and the fault is PT. The age of the Dogra Slates is Precambrian (Wadia, 1928).

Kailar formation
Chaudhry and Ashraf (1980) marks Kailar formation as a stratigraphic equivalent of Abbotabad Formation of Lati (1974). It is exposed from Dhand, Maili to Badori ridge and near Kailar Bridge in Kahuta. Kailar Formation Consist of marble with calcareous schist, dolomite and quartzite ranging from 15 to 50 meters in thickness in the area. Marble...
is brilliantly white to cremish but at some places pinkish patches are found. Foliation is shown at some places which are marked with chlorite and mica. In the study area the lower contact of Kailar Formation is faulted with Kuldana Formation while upper contact is also faulted with Dogra Slates. On the basis of its correlation with Abbottabad Formation tentative age of Cambrian is assigned to these rocks (Chaudhry and Ashraf, 1980).

**Panjal Formation**

Middlemiss (1910) called ‘volcanic belts’ to the volcanic rocks which are present in the apex of Hazara Kashmir Synthaxis. Wadia (1957) named the ‘volcanic belt’ as Panjal volcanic series. But the name Panjal volcanics is given to these rocks by CalKim et al. (1969).

The volcanic succession is formed by basaltic flows, metaconglomerates, pyroclastics, limestone, slates and schists (Khan, 1994). Dykes and laccoliths of mafic composition are also reported by Wadia (1951). The Panjal volcanics are well exposed in Kabul, Helum, Neeulum, and Kaghan areas (Asafsh and Khan, 1993, Khan, 1994). The large volume of the Panjal Volcanics are exposed in the region around Srinagar (Wadia, 1934).

The type locality of formation lies in the "Pir Panjal Range". The Panjal Volcanics are well exposed in the study area (Fig. 2). The agglomerates are comprised of dark grey slates, pyroclastic material embedded in fine grained matrix with meta-conglomerates. At places thin volcanic ash beds are encountered within the agglomerates zone (Khan, 1994). The rocks have been altered and metamorphosed to green schist facies metamorphism. The flows are mainly theliotic basalts. In barat, pyroxene and plagioclase phenocrysts are embedded in fine grained matrix. The lava flows are greenish to dark grey in color. The vesicles are filled with secondary material (Amygdaloidal), (Asafsh and Khan, 1993). In the study area the lower contact of Panjal Formation is faulted with Murree Formation while upper contact is unformable with Lockhart Limestone. Wadia (1928) assigned Carboniferous to Permian age to Panjal volcanics.

**Gondwana Group**

Chaudhry and Ashraf (1980) called it "Gondwana group" and marked at some places between Kalamula and Hillian in Betar valley (Fig. 2). Middlemiss (1876) proposed this name in an un-published portion of his report. On the south side of Pir Panjal, Wadia (1928) marked a great thickness of moderately metamorphosed shale, quartzites and argillaceous sandstone as Gondwana rocks.

The Gondwana rocks are unconformably underlain by Dogra Slates. The unconformity is marked by very coarse boulder conglomerate. This formation is well exposed in Muzaffarabad, and Kotli areas. Ashraf and Khan (1993) marked greenish grey nodular beds as Margalla Hill Limestone in the Kahuta area. However during field investigation the formation was not encountered in the study area. It is marked as early Eocene age.

**Lockhart Limestone**

Davies (1930a) marked Paleocene Limestone in Kohat area and named as Lockhart Limestone. The name is approved by stratigraphic committee of Pakistan. Previous authors marked this unit with different names like as Lockhart Limestone which is approved by stratigraphic committee of Pakistan formally assigned the name of Carboniferous age.

The name Lockhart Limestone is accepted by the stratigraphy of Pakistan to replace its earlier names “Patala shales” of Davis and Pinkold (1937), “Tarkhobi shales” of Eames (1952).

The lithology of formation is shale and marl, with subordinate flaggy limestone and sandstone in the Sutlej range (Shah, 2009). These shales are greenish grey and calcareous while limestone is nodular with light grey color. Sandstone is interbedded in the upper part. Type section of the formation lies in the Patala Nala, Western Sutlej Range. In Dogra area coal seems were reported. In Kohata area shales and limestone shows dark grey color. In Hazara and Kala Chitta area grey argillaceous limestone beds were interbedded with shales and marl and its thickness is 20-182 meters while in Surghar range its thickness is from 30-75 meters (Shah, 2009).

In the study area the dark greyish grey carbonaceous shale and limestone is found. Limestone is interbedded with shale at the base. Due to faulted contact very small patch is marked near Khumgala which formed slope escarpment. In the study area the lower contact of Patala Formation is conformable with Lockhart Limestone while upper contact is faulted with Kuldana Formation. It is assigned as Paleocene age.

**Margalla Hill Limestone**

The stratigraphic committee of Pakistan formally assigned the name “Margalla Hill Limestone” after the work done by Latif (1970). “Nummulitic formation” name was given by Waagen and Wynne (1872). “Hill Limestone” name was proposed by Wynne (1873) and Cotter (1933). “Nummulitic Series” was assigned by Middlemiss (1896). The name is basically derived from Margalla hills in Hazara.

The lithology of formation is represented by thick bedded, nodular, medium grained limestone with interbeds of brownish grey marl and greenish brown shale. The limestone is nodular and medium to thick bedded. Its thickness varies from 80-100 meters. The type section of the formation lies in the Shadara section of the southeastern Hazara. Sections of Margalla Hill Limestone were also marked in Kala Chitta Range, Kohat and Potwar areas. The formation is well exposed in Muzaffarabad, and Kotli areas. Ashraf and Khan (1993) marked greenish grey nodular beds as Margalla Hill Limestone in the Kohata area. However during field investigation the formation was not encountered in the study area. It is marked as early Eocene age.

**Kuldana Formation**

The stratigraphic committee of Pakistan formalized the name “Kuldana Formation” after the work done by Latif (1970). “Kuldana beds” name was assigned by Wynne (1878). The name “Kuldana Series” name was assigned by Middlemiss (1896). Pinkold (1918) called them “variegated shales”. Eames (1952) suggested the name Lower Cherat series. Lithology of the formation consist of mainly shale and marl. Shales are gypsiferous and arenaceous with variegated colors. Beds of sandstone, limestone, conglomerate and dolomite were found occasionally. Type section of the formation is in Kuldana Village near Murree. This formation is well exposed in Hazara, Kala Chitta, Kohat and Potwar area. The formation is also exposed in Jhelum, Neehum, Kaghan and Kotli areas. In Kahuta it is well exposed in Kalar, Khursheedabad and Hajbail area. It consists mostly of bright violet, blue and purple shales. Mostly red shales were found near the base of Kuldana Formation. Sandstone of Kuldana Formation, Kalamula and Khursheedabad Area, Kahuta, Azad Kashmir Earth Science Malaysia (ESMY) 1(1) (2017) 21-31
Kuldana Formation is fine to medium grained. Its thickness is 210 meters in the study area. The lower contact is faulted with Patala Formation at some places and in some places with Lockhart Limestone. While upper contact is also faulted with overlying Kailar Formation. Age assigned to Kuldana Formation is Eocene.

Murrue Formation
The name Murrue Formation is replaced after "Mari group" of Wynne (1874). "Murrue beds" was suggested by Lydekker (1876). "Murrue series" was assigned by Pilgrim (1910). In type section dark red and purple clay and purple grey and greenish grey sandstone with minor in transformation conglomerates are found in the formation. The basal strata of formation also designated as Fatehjang member is composed of calcareous sandstone, conglomerates and foraminifers of Miocene age. Sandstone of upper Murrue is different from lower Murrue as it is medium to coarse grained and grey and brown in color while sandstone in lower Murrue is fine grained and purple. Shales of upper Murrue are purple, reddish, and brownish in color and contains plant fossils. Its maximum thickness is 1830 meters (Wadia, 1928).

Type section of formation lies towards the north of Dholi Maiki in the Attok district. The formation is widely exposed in Salt Range, Kohat-Potwar, Kahuta, Rawalakot, Bagh, Neeium, Jhelum and Kaghan areas. The topographic features of formation in Kahuta area includes ridges, valleys, escarpments and dip slopes. It is composed of alternate beds of sandstone and shale. In Kahuta area it has faulted contact with Panjal Formation and the fault is MBT. The age of the formation is early Miocene.

Quaternary Alluvium
The Quaternary alluvial deposits rests uncomfortably on Neogene molasse sediments. The Quaternary is comprised of conglomerates, sand and clays. The conglomerates are of variable size and shape. The provenance is sedimentary, igneous and metamorphic rocks.

Materials and Methods
The formation selected for research work is Kuldana Formation of Eocene age, exposed in Kalumala and Khursheedabad areas (Figs. 2). The Kuldana Formation comprised of shale and sandstone exposed in the area. It is dominantly composed of shales of variegated color in Kalumala (Fig. 11). The alternating red and green color shales are dominating in the formation. The sandstone beds of greyish green to maroon color, medium bedded, fine to medium grained and well compacted occur in the formation. The Lower contact of Kuldana Formation is faulted with Patala Formation while the upper contact is also faulted with Kailar formation of Ashraf & Chaudhry (1980).

The field work was carried out in the study area to obtain geological data and collection of rock samples by using Topographic sheet and instruments like Brunton compass, hammer Hand lens (10x) and camera. This research study was completed in two phases, field and laboratory work. Field work consists of:

1. Collection of rock samples for petrographic studies
2. Outcrop sections photography
3. Recording of geological data
4. Stratigraphic section measurement of the area

Toposheet no. 43K/1 of the Survey of Pakistan was used to prepare sample location and geological map (Fig 2) of the area. LEICA DM750 polarization microscope with attached LEICA ECG camera was used for thin sections study in the petrology laboratory of the Institute of Geology.

Thirteen sandstone samples of Kuldana Formation were selected for petrographic studies and preparation of thin sections. Section measurement was started from the basal contact of Kuldana Formation to its upper contact with Kailar formation. The thickness of Kuldana Formation is 203 m in the section. The laboratory work included cuttings of the rock samples for the preparation of thin sections. The thin sections were prepared to get maximum textural, mineralogical and diagenetic study. The microscopic study of thin sections was carried out under Polarizing microscope (LEICA DM750P) for identification of constituent minerals, determination of model mineralogical composition, extent of variation in particles size, degree of roundness of the framework grains and classification of sandstone. Photographs of important features were also taken.

Ten samples of Kuldana shales were also taken for X-ray diffraction analysis (XRD). XRD analyses were performed in laboratory to obtain peak graph and identification of shale mineralogy (Figs. 8, 9). The recalculated value of the calcite, quartz, and clay were plotted on the diagram which marked shales as argillaceous (Fig. 5). While giving a number to the sample, the grid reference of the sample was recorded in the field note book and also on the sample, using this data the sample location map of the area was prepared.

Results and Discussion

Petrography of Kuldana Formation
Petrography is the discipline of geology that involves microscopic study of thin sections under microscope in order to determine mineralogy, composition and textures as well as to classify sandstone and deduce sediment transport history, provenance and tectonic setting maturity indices and palaeoclimates. Thin sections of sample were prepared, labelled and studied under petrographic microscope. The photomicrographs were taken. In sandstone the relative abundance of each mineral grain is also shown in Table 2. The detail microscopic study of rocks of Kuldana formation and carbonate were carried out. The study includes the petrography of sandstone of Kuldana Formation.

For the petrological study of Kuldana Formation the samples were taken in areas of varied lithology such as change in color, grain size or contacts. The samples were plotted on the sample location map (Fig 2). Thin sections were prepared for the petrographic studies. The modal mineralogical data of sandstone of Kuldana Formation of Kalumala section is shown in Table 2.

Results and Discussion
The petrological study of sandstone of Kuldana Formation of Kalumala section shows the amount of quartz grains varies from 37-62%. Monocrystalline quartz grains are most common than the polycrystalline quartz. In Kalumala section the contact between quartz grains are planner, point, sutured and concavo-convex. Zircon (Fig. 3c) and apatite inclusions (Fig. 3b) are common in thin section. Amount of feldspar grains in thin section ranges from 5-12%. Plagioclase (Fig. 3e), orthoclase (Fig. 3f) and perthite (Fig. 3g) are commonly identified in maximum thin sections while microcline (Fig. 3h) is rarely found in Kalumala section. Plagioclase is abundant as compared to alkali feldspar. In some thin sections the alteration of feldspar into sercite (Fig 4a), calcite (Fig 4b) and clay is observed.

The average percentage of rock fragments range from 9-28% in abundance. The rock fragments of volcanic rocks (Fig 4c) metamorphic grains including slate, phyllite, schist (Fig 4d) and quartzite (Fig 4f) are present. Sedimentary clasts includes siltstone (Fig 4a), sandstone,
adolomite (Fig. 4a) and limestone (Fig. 4f) in the rocks.

Calcite (Fig. 4b), hematite (Fig. 4g) and clays (Fig. 4b) ct as a cementing material. Cement constitutes 13-32% of bulk volume of the rock. Calcite is the most abundant cement in the sandstone. Hematite also appear as cement in some rock samples while clay and chlorite is also found in considerable amount (Table 4.2).

In Kalamula section the percentage of ac cessory minerals range from 6-12% Hematite, pyrite (Fig. 4h), tourmaline (Fig. 5a), chlorite (Fig. 5b) muscovite (Fig. 5e), zircon (Fig. 3c), epidote (Fig. 3d), apatite (Fig. 3b), and sphene (Figs. 5c, 5d) are comm on accessory minerals in this section.

In order to classify the sandstones of Kuldana Formation, the recalculated values of quartz, feldspar and rock fragments were plotted on equilateral triangle of Blatt and Tracy (1996). According to Blatt and Tracy (1996) arenite have less than 5% clay matrix in its composition and wacke sandstone have more than 5% clay matrix. The sandstones were classified as lithic graywackes (Table. 3). Twelve fragment of lithic graywackes taken from sandstone bed was selected for petrography and all samples have more than 5% matrix.

**Tectonic Provenance of Sandstone**

The source of sandstone constituents is determined by plotting the recalculated values of quartz, feldspar and rock fragments on provenance discrimination diagram of Dickinson et al. (1983). The modal mineralogical data of sandstones fall in the field of recycled orogeny (Fig. 7). In Pakistan previously provenance of Sabathu Formation was describes as recycled orogeny by Najman and Garzanti, (2000). Blatt and Tracy, (1996) suggested that sandstone containing more than 5% matrix in composition and are classified as graywackes. The Kuldana sandstone is classified as Lithic graywacke using the criterion of matrix content (Fig. 6).

The clastic sediments and minerals are useful for determining provenance of sandstone (Dickinson, 1983). The climate and relief of the source region are also important in the supply of detritus (Blatt and Tracey, 1996). The sandstone provenance studies also reveal the ancient tectonic history of the area. The provenance of sandstone of Eocene Kuldana Formation in Kahuta area is determined by using quartz, feldspar, heavy minerals and rock fragments.
Ks-6
The minerals identified in shale sample Ks-6 through diagnostic peaks, position 2 theta, standard d-spacing and values obtained from (Fig. 9b) X-ray diffraction graph are corrensite, rectorite regular interstratified chlorite-montmorillonite, quartz, plagioclase feldspar-albite, illite, smectite montmorillonite, Chlorite thuringite, goethite, pyrite, calcite, muscovite, hematite, and dolomite. The shales are argillaceous that contains 76% clay minerals, 19% quartz and 5% carbonates.

Ks-7
The minerals identified in shale sample Ks-7 through diagnostic peaks, position 2 theta, standard d-spacing and values obtained from (Fig 9c) X-ray diffraction graph are corrensite chlorite thuringite illite.

Ks-8
The minerals identified in shale sample Ks-8 through diagnostic peaks, position 2 theta, standard d-spacing and values obtained from (Fig. 9d) X-ray diffraction graph are corrensite, rectorite regular interstratified chlorite-montmorillonite, quartz, plagioclase feldspar-albite, illite, pyrite, siderite, muscovite, haematite and dolomite. The shale are siliceous that contains 68% quartz, 14% clays and 18% carbonates.

Ks-9
The minerals identified in shale sample Ks-9 through diagnostic peaks, position 2 theta, standard d-spacing and values obtained from (Fig. 9e) X-ray diffraction graph are Chlorite thuringite, Alkali feldspar orthoclase, plagioclase feldspar-albite, smectite saponite, corrensite regular interstratified chlorite-montmorillonite, illite, calcite, aragonite, goethite, quartz, pyrite, siderite, aragonite, rectorite regular interstratified mica-montmorillonite, hematite, quartz and dolomite. The shale are argillaceous that contains, 62% clays, 25% carbonates and 13% quartz.

Ks-10
The minerals identified in shale sample Ks-10 through diagnostic peaks, position 2 theta, standard d-spacing and values obtained from (Fig. 9f) X-ray diffraction graph are Chlorite thuringite, muscovite, corrensite regular interstratified chlorite-montmorillonite, quartz, illite, plagioclase feldspar albite, smectite saponite, goethite, pyrite, siderite, hematite and Dolomite. The shales are argillaceous, that contains 74% clays, 18% quartz and 8% carbonates.

Fig. 9: X-ray diffraction graph of Kuldana Formation shale (KS-5) in kahuta section display major peaks of: Qtz (quartz), Chl-Mnt (Chlorite montmorillonite) and Chl-T (Chlorite Thuringite).

Fig. 8: X-ray diffraction graph of Kuldana Formation shale (KS-1) in kahuta section display major peaks of: Ill (Illite), Chl-Mnt (chlorite montmorillonite) and Chl-T (Chlorite Thuringite).

Diagenesis of Kuldana Formation
The diagenesis is change in loose sand to a sandstone body characterized by specific texture, strength, composition and porosity. Von Gumbel, (1888) use the term diagenesis to include all the post-depositional changes that took place in the sandstone from Kuldana Formation of Middle Eocene age. Diagenesis includes post-depositional physical and chemical processes in which loose sediments are transformed in a hard rock. When un cemented loose sands is deposited, due to lithostatic
pressure, the physical process of compaction starts which reduces the interparticle porosity. Oxidation or reduction indicates the early chemical diagenetic processes. According to Dapples (1979), the initial stage of diagenesis comprises the main lithification phase and involves compaction, compression (deformation), cementation, crystallization and recrystallization.

Sandstone diagenesis is process controlled by sediment source, depositional system and sediments burial environment (Reed et al., 2004). The physical and chemical process affects the detrital sediments including the chemistry of pore water. The fabric of sandstone of Kuldana Formation exhibits a minor change by physical compaction after deposition which reduce pore volume by affecting the arrangement of sand grains. The lithostatic pressure affected the sand grains of the Kuldana Formation. The grains in the sandstone exhibit the planner, concavo-convex and sutured contacts. The burial duration increases the degree of compaction in sandstone. The dissolution between quartz grains of similar solubility and point contacts are changed into sutured contacts in the sandstone (Fig. 1b).

The alteration of minerals is also a major diagenetic change. The monocrystalline quartz grains are replaced by carbonate cement (Fig. 5g). The corroded and etched margins of quartz grains indicated late diagenetic in sandstone. They originated during replacement of quartz by calcite (Fig 5g).

Another diagenetic change is the alteration of feldspar minerals, mica and rock fragments into clay minerals. The alteration is caused by pore and ground water interaction with feldspar which altered feldspar into clay minerals. Chlorite is also a clay mineral which is formed by the alteration of biotite and muscovite. The major alteration of minerals in the sandstone of Kuldana Formation is the alteration of mineral biotite into muscovite which further altered into chlorite (Fig. 5h).

A major diagenetic feature is cementation of a rock. The dominant cement in the sandstone of Kuldana Formation is calcite, hematite and chlorite. Calcite is the common carbonate cementing material in the sandstones of the Kuldana Formation. The carbonate cementing material is derived from dissolution of carbonate rock fragments in the sandstone and ground and surface water containing ions of carbonates. It indicates that the common cement in sandstones is carbonate cement. In alkaline pore solutions, calcite is precipitated (Selley, 1982).

Depositional Environment of Kuldana Formation

A natural geographic entity where sediments are accumulated characterized by physical, biological and chemical conditions is termed as depositional environment.

The Kuldana Formation is dominantly comprised of calcareous shales and clay with fine to medium grained sandstone beds near base. The shale and clay are purple, red, buff, green, greenish grey, crimson, maroon and pale grey to brownish grey. XRD analysis of shale indicate that maroon color is due to presence of goethite and pyrite which indicates reducing environment. Chlorite gives green color to shales and indicates reducing environment. Clay minerals smectite, montmorillonite, chlorite and illite are recognized through XRD analysis of shales. Carbonate minerals siderite, calcite, dolomite and aragonite are present in shales.

The sandstone are of grey to dark grey and maroonish color in the field. Maroonish color in sandstone is due to presence of hematite cementing material.

The Kuldana Formation records the southward progression of a fluvial deltaic system that introduced red shales and sandstones in the basin. It has a continental fluvial origin and was deposited in a basin at the end of a marine regression by rapidly flowing streams (Abbasi and Mceabry, 1991). The sandstone is reddish, maroon, and greenish grey color and shows fluvial and transitional environments in coastal plains (wells and Gingerich, 1987). Reddish maroonish color is due to the presence of hematite while green color indicates chlorite in the sandstone. It is found near the base. The sandstone is grey, thin to medium bedded, cross-bedded, fine to medium grained and often grade into siltstone. These sandstones contain fragments of quartzite, sandstone, dolomite and limestone. The red color of the clays of the formation is result of oxidation. The Kuldana Formation with abundant clays indicates a condition of standing water in the immediate areas and high local environmental diversity with nearness to sea. The purple clays indicate a relatively high water table (Wells, 1983).

Based on the above discussion it is concluded that Middle Eocene age, Kuldana Formation deposited under transitional environment. This indicates the closing of the ocean and strengthening the argument of the southward shift of the paleogeographic setting and the development of the Hazara-Kashmir foreland basin which marks the end of the Paleogene deposition in the area. The Middle Eocene is the time of main Himalayan collision in northern Pakistan and the formation of Hazara-Kashmir foreland basin (Baig, 1991). During Eocene, when regression of sea starts Kuldana Formation was deposited. Water transgress towards the south and under shallow marine to transitional environment Kuldana Formation was deposited. Detritus comes from south eastern side was accumulated in the basin. However, the detritus was also supplied from adjacent uplifted area. In lagoonal or calm water condition shales of Kuldana Formation are deposited. Green color of sandstone and shales (Fig. 11) indicates reducing environment under water condition while reddish maroonish sandstone and shales shows oxidizing conditions. The regular intervals of oxidizing and reducing conditions throughout the formation indicated flushing of water conditions on transitional environment during the middle Eocene.

Discussion

In Paleocene sea water transgression occurred on the western and northwestern margins of the Indian plate (Shah, 2009). However, lower and middle Eocene was a time when most of the northwestern part of Indian plate was submerged under Epicontinental Sea (Shah, 2009). The Kuldana Formation of middle Eocene shows a faulted contact with Patala Formation (Fig. 2).

The Kuldana Formation is dominantly composed of shales. Shales are green and reddish which are interbedded in a regular pattern. XRD
analysis of shales showed that the green color of shales is due to presence of chlorite in the rock samples. It also indicates reducing environment. Reddish maroon color of the shales indicates presence of hematite material in the rock samples. XRD analysis of shales showed that shales are highly argillaceous (Fig. 10).

The sandstone exhibits greenish gray to reddish maroon color. Sandstone is medium bedded and occur near the base of the formation. Sandstone is medium to fine grained, hard and compacted. Petrographic studies showed that sandstone is poorly sorted, mineralogically immature and classified as wackestone.

Conclusion
The conclusion drawn on the basis of field and petrographical studies is as follows:

1. The study area is present in Kahuta area which lies on the Eastern limb of Hazara Kashmir Synaxis in the Lesser Himalayas. Eocene Kuldana Formation is exposed in Kalamula and Khursheedabad area. The lower contact of Kuldana Formation is faulted with Patala Formation. The upper contact of Kuldana Formation is also faulted with Kailar formation.

2. On the basis of mineralogical composition the sandstone of Kuldana Formation is classified as Greywacke. The sandstone is mineralogically immature as it contains low proportion of quartz and very high abundance of rock fragments and matrix. Monocrystalline quartz is more abundant than the polycrystalline quartz while non-undulose quartz is more common than the undulose quartz grains. The angular to sub angular quartz grains indicates short distance of transportation from the source. Plagioclase feldspar albite is found in the sandstone of Kuldana Formation. Alteration of feldspar grains into sericite is commonly recognized.

3. Rock fragments of igneous, sedimentary and volcanics are abundant in the rock. The sedimentary rocks, fragments are of sandstone, siltstone, dolomite and limestone. The metamorphic rock, fragments are of slates and schist are common while clasts of basalt were recognized in volcanic fragments. The igneous rock fragments are of basalt common in the rocks.

4. Cementing material is dominantly of calcite and hematite while in some samples chlorite is also reported as cement. Accessory minerals tourmaline, zircon, garnet, muscovite, epidote, sphene and apatite were found in the sandstone.

5. Presence of calcite cement shows diagenetic changes. Alteration of biotite into muscovite and chlorite mark the early stage of diagenesis. In few samples sutured and convaco convex contacts of grains also indicate diagenetic changes. The modal mineralogical data plotted on provenance discrimination diagram indicate the provenance is recycled orogeny. The low percentage of quartz and abundance of rock fragments and matrix indicates its transitional depositional environment.

6. Shales are argillaceous in Kuldana Formation. Bands of green and red shales are dominant in Kuldana formation. Green color of shales is due to high percentage of chlorite present in them while presence of red color is due to hematite abundance in it.

Acknowledgement
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References

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Table 2: Showing modal analysis of sandstone.

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Table 3: Showing recalculated values of QFL in Kuldana sandstone samples.

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