GEOLOGY OF ACID AND ALKALIC MINOR BODIES ASSOCIATED WITH GRANITIC AND ALKALIC COMPLEXES OF MALAKAND DIVISION, PAKISTAN

[1]MOHAMMAD ASHRAF AND [2]HAMID DAWOOD

[1]179-B, PCSIR EHS-1, Canal Road, Lahore-54590 Pakistan
[2]Pakistan Museum of Natural History, Islamabad-Pakistan

Email ID: drmohammadashrafs@yahoo.com

Abstract*: The pegmatites of the granitic complexes of Malakand, Swat and Dir areas and those of alkaline complex of Bunair have been envisaged to be explored for petrology and economic geology. The pegmatites and similar rocks associated like aplites, albitites etc together are termed as acid minor bodies if formed from S-type granites and are called alkalic minor bodies if derived from alkaline granites/syenites and nephline synites. 163 samples were collected and studied for classification keeping in mind the points: The types of acid minor bodies/alkalic minor bodies, how they are distributed and localized? What is their size, shape, form, external structure and relationship with enclosing rocks and their internal structure? The unzoned pegmatites/aplites are classified on the basis of their critical minerals present throughout the bodies such as microcline, albite and quartz. As a result we got albite-(microcline) pegmatites/aplites when microcline is about 3-4%. With increase in microcline the rock type becomes albite-microcline pegmatite/aplite or vice versa and when microcline is dominant the rocks are microcline pegmatite /aplites. Whereas in zoned pegmatites/aplites each zone is established on the criteria mentioned above. In zoned pegmatites the zones are divided on the basis of dominant minerals. In the present studies three zones are found and are well marked: Wall zone, where minerals are of mixed nature, e.g., albite, microcline, quartz, tourmaline, muscovite/biotite, etc., intermediate zone, dominantly of microcline with minor albite, quartz, muscovite, etc., and core, which is usually quartz rich , and may have upto 98-99% quartz. These zones are symmetrical when first two zones are repeated on both sides of the core.When there is no repetition of wall and intermediate zones on both sides of the core it is asymmetrically zoned. Some albitites have been reported for the first time from Malakand granite gneiss and Lahor granitic complex, other than Mansehta granitic complex, which contain albite more than 80-90%. Similarly, the alkalic minor bodies are classified associated with Ambela-Koga alkaline complex. But here critical minerals are nepheline, sodalite, albite and microcline. So on the basis of these minerals we have nepheline-albite pegmatites, nephline-microcline pegmatites, sodalite-nepheline-albite pegmatites, sodalite-nepheline-albite-microcline pegmatites. The zoned pegmatites are classified as symmetrical and asymmetrical. It is interesting to note that we have three types of albitites associated with Koga nephline syenite they are: Nepheline-microcline albitite, sodalite-nepheline albitite, and microcline albitite. With the help of gechemical studies these classifications will be refined and can help understand the places of enrichment of trace/rare minerals in the next phase.*

Key words: Pegmatites, granitic complexes, alkaline complex, Malakand, Swat, Dir and Bonair, Pakistan

INTRODUCTION

Acidic pegmatites commonly occur in association with granitic rocks. They host a number of economic non-metallic and metallic minerals. The non-metallic minerals are usually potash-feldpar, plagioclase, quartz, muscovite and beryl while metallic minerals are columbite, tantalite, microlite and uraninite. Among the non-metallic minerals, quartz and feldspar are extensively used in ceramic and glass industries. No detailed work on the acidic pegmatites of Swat and Malakand was carried out so far. Fairly detailed work on classification, petrogenesis and geochemistry of the acid minor bodies of Mansehra area has been accomplished by Ashraf (1990 amd 1974). Our previous research on general geology in Swat, Malakand and Hazara shows that there is potential for occurrences of all type of pegmatites. Thus, the petrological, economic, geological and geochemical studies of the pegmatites of these areas are essential for the future expanding demand of raw materials for glass and ceramic industries. Fieldwork was carried out in the Swat and Malakand areas, for the location and selection of pegmatite bodies.

About 100 samples were collected from Malakand, Ilam-Choga and Ambela-Koga representative pegmatites and aplites bodies associated with their respective granites. A lot of 53 samples were collected from representative pegmatites/aplites associated with Lahor granite/gneiss and Yakhtangi-Alpurai granite gneiss. The study on the petrology and economic geology of pegmatites of granitic complexes of Malakand, Swat and Besham areas was envisaged. The rest magmatic

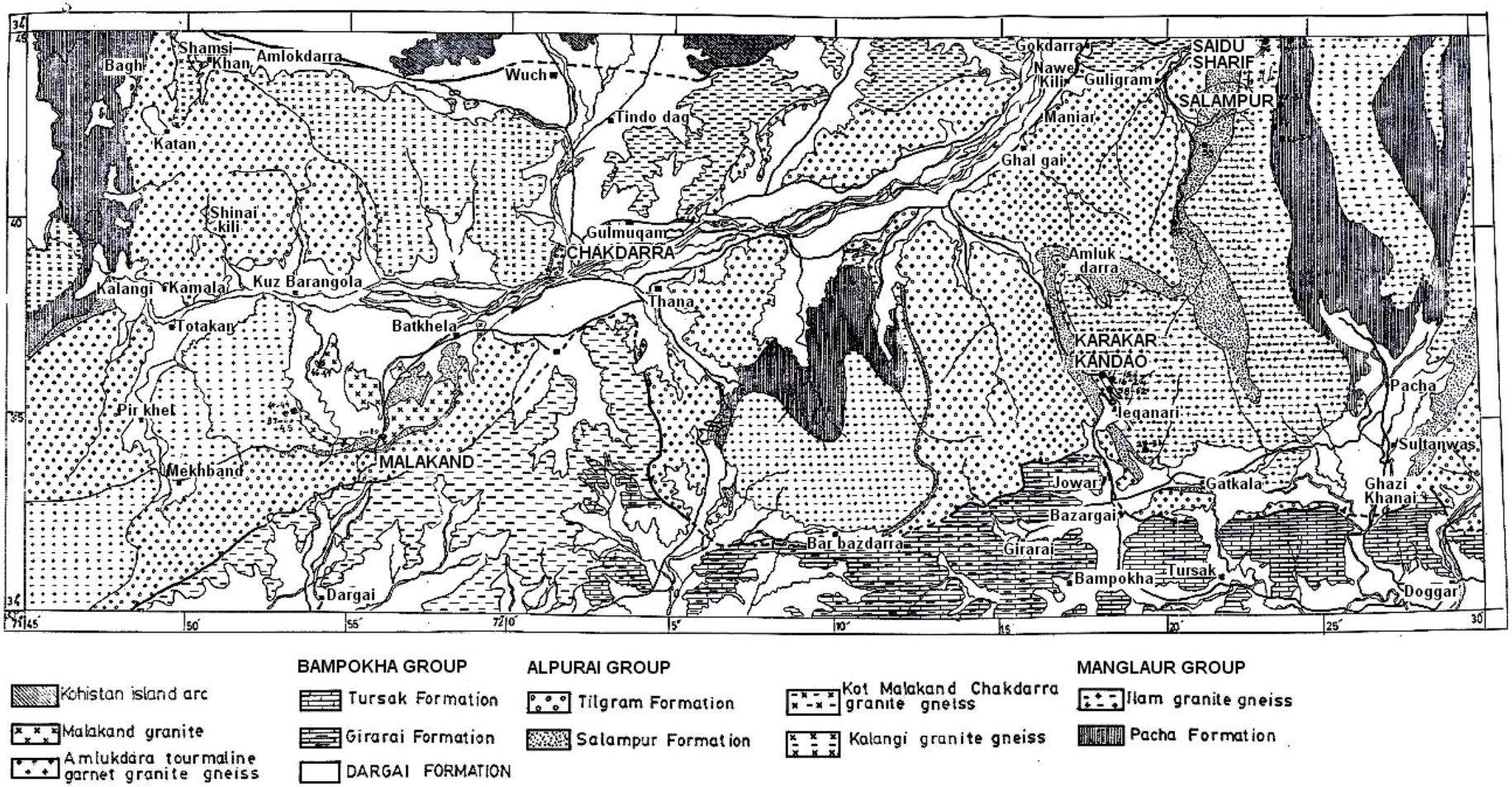

Fig. 1 Showing Geological Map of West of the Besham Syntaxes, Northwestern Himalayas, Pakistan (After Chaudhary, et al., 1994)

solutions crystallization is responsible for the development of acid minor bodies. These acid minor bodies are called as pegmatites (simple/complex, zoned and un-zoned), aplites, albitites, composite aplite/pegmatite bodies and quartz bodies. The present work gives a detailed account of the acid minor bodies. For this purpose following major granites bodies were investigated.

i) Malakand granite/gneiss

ii) Ilam granitic gneiss (Swat)

iii) Alpurai-Yakhtangi granite gneiss

iv) Lahor granite/gneiss (Beham)

v) Ambela-Koga alkaline complex (Bunair)

This study is, therefore, planned to find/discover potential potash feldspar deposits from pegmatites of the areas mentioned above. And also to know their nature, type, internal structure, extent of mineralization and structural levels. Field work of the project areas was carried out mainly by making traverses along the road cuts, nalas and peaks across the granitic bodies to locate and study the pegmatites/aplites.

Samples were collected of the various lithologies of the pegmatite bodies. Geological data like dip/strike was also collected to know attitude with the enclosing rocks, using Brunton type compass. Petrographic microscope was used to study large thin sections. Thin sections were made of the large crystal and medium grained intergrowth to know any intergrowth, alteration and deleterious nature of the minerals.

GENERAL GEOLOGY

Our main purpose is the study of pegmatites of the granitic complexes of Malakand, Swat and Besham and the pegmatites of the alkaline rocks of Ambela-Koga. The pegmatites and pegmatite type rocks like aplites, and albitites are included and designated as acid minor bodies and alkalic minor bodies according to their associations. Therefore, our knowledge of the associated/ host rocks is ubiquitous so that we can know the limits of each type of association. That is, for example what is Malakand granite and what are Malakand granite gneisses and in which type of metasediments are pegmatites emplaced and crystallized, otherwise a mixed and jumbled situation is usually created. In this section the geology of granites and associated rocks is, therefore, presented based on the work of previous authors and modified where found necessary.

Geology of Malakand

There are two distinct plutons (named as Malakand granite and Malakand granite gneiss) of granites in Malakand Agency.

Malakand Granite is well exposed near Malakand (Fig. 1). It is about 8x5km roughly oval shaped body. The Malakand granite is compact, non-foliated to poorly foliated and leucocratic. It is predominantly fine to medyium grained and non porphyritic. Sheared zones are developed at places mostly due to local faulting where the granite in these zones is foliated. Xenoliths of country rocks are commonly present and are usually confined to the marginal zones. The xenoliths are strongly baked, granitized or hornfelsed. The contact of the Malakand granite with the Malakand granite gneiss and metasediments is irregular and sharp. Apophyses of granite are often seen in the granite gneiss. Garnet is extensively developed at the contact.

Abundance of pegmatitic and aplitic veins is the dominant feature of the Malakand granite Chaudhry, *et al.* (1976). The pegmatites range in size from a few cms to about 5 m in thickness and about 0.5 to 15 m in length. Patchy, irregular and replacement pegmatites are also present.

The zoned pegmatites have essentially two zones, the intermediate zone and the core. Their mineralogy is similar to that of (1), (2) and (3) but the core contains more quartz. The composite aplites and pegmatites are commonly present in the Malakand granite and the associated schistose rocks having composition of type (1) and (2). Malakand granite has been assigned Carboniferous age (Smith, *et al.*, 1994). Maluski and Matte (1984) have assigned $^{40}Ar/^{39}Ar$ age of 23 ± 2 Ma to the Malakand granite, however, similar age (23 Ma) has been determined for the Malakand granite using zircon fission track data by Zeitler, *et al.* (1982).

Malakand Granite Gneiss has been described in detail by Hussain, *et al.*, 1992, Hamidullah, *et al.*, 1986, and Chaudhry, *et al.*, 1976 and 1974. Malakand granite gneiss is medium to coarse grained, foliated rock mass and is the northeastern extension of Kot granite gneiss and named as Kot-Malakand granite gneiss (Hussain, *et al.*, 1992). Quartz, feldspar, biotite and muscovite are the main constituents. The accessories include garnet, chlorite and amphibole. The siliceous contents are abundant and due to this, locally, the rock appears to be siliceous. In Kot-Malakand granite gneiss metamorphic screens are commonly present. Metamorphic screens are baked and granitized. Quartz and pegmatite veins are common in Kot-Malakand granite gneiss especially

along its contact with metasediments towards its southwestern part near village Barh and Kot. Blue beryl and fluorite are found in quartz veins/lenses and pegmatites in this granite gneiss. Hamidullah, *et al.* (1986) classified granite gneiss rocks as follows:

1. Siliceous gneiss
2. Silica rich granite gneiss
3. Normal granite gneiss

The lower contact of the granite gneiss in Kot area is not exposed. The upper contact with overlying metasediments is sharp every where and appears to be faulted which is evident by the angular relationship of the foliation of overlying rocks and truncation of garnet mica schist to the east of Kot. Hussain, *et al.*, 1992 classified the pegmatites of Kot-Malakand gneiss, on the basis of their mineralogical composition, as quartz-feldspar pegmatites, quartz-feldspar-mica pegmatites and quartz-feldspar-fluorite-beryl pegmatites.

Geology of Swat Area

The geology of Swat area, west of the Besham syntaxis (Fig. 1) is comprised of a basement overlain unconformably by a cover sequence. The basement is known as the Manglaur Group (Kazmi, *et al.,* 1984) which comprises lower migmatites, pelite-psammites, quartzites and pelite schists with subordinate calc-pelite gneisses, marbles, graphitic schists and amphibolites (the Pacha Formation). The intrusions are of Ilam Granite Gneiss forming a massive granite and tourmaline granite of Hussain, *et al.,* 1992 and Chaudhry, *et al.,* 1992, a porphyritic variety of Butt and Shah, 1985, rapakivi type biotite and sphene granite of Humayun, 1985). The cover sequence, named as Alpurai Group is composed of a lower pelite schist and micaceous quartzite sequences with amphibolites (Salampur Formation) and an upper calc-pelite gneiss-marble units (Tilgram Formation). These rocks unconformably overlie the rocks of Manglaur Group. Graphitic schists of Dargai Formation overlie the calc-pelites of Tilgram Formation.

The porphyroblastic Ilam granite gneiss has generally been considered to be late Precambrian to Cambrian in age on the basis of its correlation with the Mansehra granite (Jan, *et al.,* 1981). Rb-Sr whole rock geochronological study of two sets of granite gneisses from Swat area was undertaken by Ahmed, *et al.* (1997). Ilam granite gneiss from Karora area, Swat gave isochron age of 260±52 Ma. While the granites of Mora Kandao, Parunai and Manglaur area yielded age of 285±8 Ma i.e., Lower Permian/Upper Carboniferous. These studies indicate that contrary to the previously held views, none of the granites are Precambrian or Cambrian in age. Preliminary U-Pb-Zircon dating of the Swat granite gneiss from Jahanabad area, Swat yielded an Early Permian magmatic emplacement age (276±40) Anczkiewicz, *et al.,* 1997) which is roughly the same plutonic age as the Malakand granite (Smith, *et al.,* 1994). However, U-Pb-Zircon dating of the Koga granite gneiss west of Alpurai yielded 468±5 Ma age (Anczkiewicz, *et al.,* 1998), which indicate that the granite gneisses in Swat consist of different intrusions, which range in age from Lower to Upper Palaeozoic.

Geology of Besham Area

The stratigraphy of Besham area has been discussed by Chaudhry, *et al.* (1994a and 1994b), Ashraf, *et al.* (1994), Treloar, *et al*. (1989a and 1989b), Baig and Lawrence (1987), Fletcher, *et al.* (1986), Butt (1983), Chaudhry, *et al.* (1983), Ashraf, *et al.* (1980). Baig (1990) considered the Besham block as a separate entity demarcated on the east by the Thakot Fault and to the west by the Puran-Chakesar Fault. According to Treloar, *et al.* (1989a, 1989b and 1989c), Ashraf, *et al*. (1980) and Baig, *et al.* (1980) the Pre-Cambrian Besham quartzo-feldspathic gneisses are unconformably overlain by a cover sequence, which now may occurs as faulted and folded inliers. Geological map of Besham area is presented as Fig. 2.

Baig (1987) and Fletcher, *et al.* (1986) assigned the name to the rocks of the Indo-Pak plate associated with Lahor basement granite gneiss complex as Besham Group. Besham Group consists of para-autochothonous psammitic, pelitic, carbonaceous, carbonates, granite gneiss, migmatites and small to large acid pegmatites and pegmatoids rocks (Butt, 1983 and Ashraf, *et al.,* 1980). La Fortune, *et al*. (1992) divided the rocks of Besham area into following groups. From oldest to youngest these are:

i. The metasediments and heterogeneous gneisses of the Besham Group.

ii. Mafic dikes intruding into Besham Group and that were subsequently metamorphosed to amphibolites. These tholeiitic dikes have island arc geochemical affinity. These amphibolites may correlate with mafic dikes of Nanga Parbat-Haramosh massif.

iii. Cogenetic small granitic intrusions and associated pegmatites, the Shang granite, the Dubair granodiorite and the Shorgara pegmatites.

iv. The rocks of Karora Group, which comprise conglomeratic, calcareous and carbonaceous sedimentary rocks. This group lies unconformably upon the above-mentioned three units/groups.

v. A relatively undeformed leucogranite that intrudes both the Karora Group and the Besham Group.

The granitic rocks and associated pegmatites of the Besham area are described as the Lahor granite gneiss is a complex body composed of foliated and gneissic fine to medium grained components, abundant pegmatites and pegmatoids and granitised and pegmatised screens. Gneissic albite rich granite, aplite and albitite are minor phases. Ungranitized screens are also present. The granite is fine-grained near its contacts with country rocks (metasediments and metamorphic screens). However, it is generally medium grained. Lahor granite is intruded in metasediments of pelitic psammitic, calcareous and graphitic nature. Besides numerous small sized screens, big screens are present around Besham and Lahor and along Indus River at many places. Apophyses are usually present in the bigger screens and are generally fine grained. Albite, microcline and quartz are essential minerals and biotite, muscovite, magnetite, sphene, garnet etc. are common accessories. Rarely, they may exhibit a graphic structure. Generally the feldspar minerals are dominant and sometimes make about 2/3 of the total constituents. At palaces silicification has taken place resulting in the formation of quartz rich rock. Hydrothermal alteration of granite is a common phenomenon. Dolerite dykes, pegmatites and quartz veins have intruded in this granite. The Lahor granite as a whole has thinner pegmatites ranging from 0.5 to 1m thick lenticular and lensoidal bodies. They have mostly sharp contact with granite. The pegmatites are more abundant in the screens/migmatized zones than in the granite. Pegmatites range from a few milimeter to about 20m in width and upto a maximum of 160m in length. The pegmatites are generally composed of white and gray microcline, albite, quartz, biotite, amphibole, tourmaline and pyrite (Ashraf, *et al.*, 1980). Shang Granite Gneiss is closely associated with migmatites as well as granitic rocks. These gneisses are well foliated and often banded. The darker bands are rich in biotite, magnetite and biotite whereas lighter coloured bands are rich in microcline, sodic plagioclase and quartz. Garnet, sphene, limonite magnetite and rarely andalusite may be present.

Geology of Koga Alkaline Complex

Alkaline rocks occur in the Bunair area near Ambela-Koga and surrounding localities (Fig. 3). The Ambela granitic complex consists of alkali granite and syenite occurring as composite mass. The whole mass is oval shaped body with outer margin or ring as alkali granite called Ambela granite with inward ring or core consisting of Babaji syenite. The Babaji syenite is in turn intruded by feldspathoidal syenites as fine to medium grained and pegmatitic nepheline syenite dykes/mass, with relicts of well preserved Babaji syenite outcrops (Ashraf, *et al.*, 1987, Chaudhry, *et al.*, 1981, Kempe and Jan, 1970, Siddiqui, *et al.*, 1968, and Siddiqui, 1965). The entire area of the Ambela granitic complex is about 900 sq km as a result of later work by Rafiq and Jan, 1989, Rafiq, 1987, Mian, 1987 and Chaudhry, *et al.*, 1981. Out of this area nearly 70% area consists of granite and alkali granites, which is considered as the product of the first magmatic episode. Following the granites sequentially quartz syenites, syenites, feldspathoidal syenites, ijolites and carbonatites are found.

According to Ashraf, *et al.* (1987) Koga feldspathoidal syenites (hereafter called nepheline syenite complex) are closely associated with the Ambela granite and nordmarkite (Babaji Syenite) complex and lies in its middle. The nepheline syenite occurs as massive bodies and as dykes of various textures intruded in the nordmarkite. These rocks are generally light gray with black specks of mafic minerals. They prevails heterogeneity both as regards texture and composition. These rocks have been classified (Ashraf, *et al.*, 1987) on the basis of texture and mineral composition. Texturally they occur as fine-grained nepheline syenites, medium-grained nepheline syenites and coarse-grained nepheline syenite. Compositionally the feldspathoidal rocks as pulaskite, normal nepheline syenite, sodalite nepheline syenite, litchfieldite, foyaite, nepheline pegmatites with associated rock types as fenites, carbonatites, and lamprophyres. Mineralogically all types of rocks consists of nepheline, microcline, albite, sodalite, cancrinite, aegirine, arfvedsonite, biotite, muscovite, calcite, apatite, zircon, sphene, ilmenite, garnet, haematite, magnetite, pyrite and epidote (Ashraf, *et al.*, 1987).

No one has given the detailed account of pegmatites of alkaline complex. A brief classification of the alkaline pegmatites given by Chaudhry, *et al.* (1981) is the base for our present study. Baloch, *et al.* (1994) have further studied the geology of Koga feldpathoidal syenite complex describing four more varieties of nepheline syenite and eleven types of pegmatites.

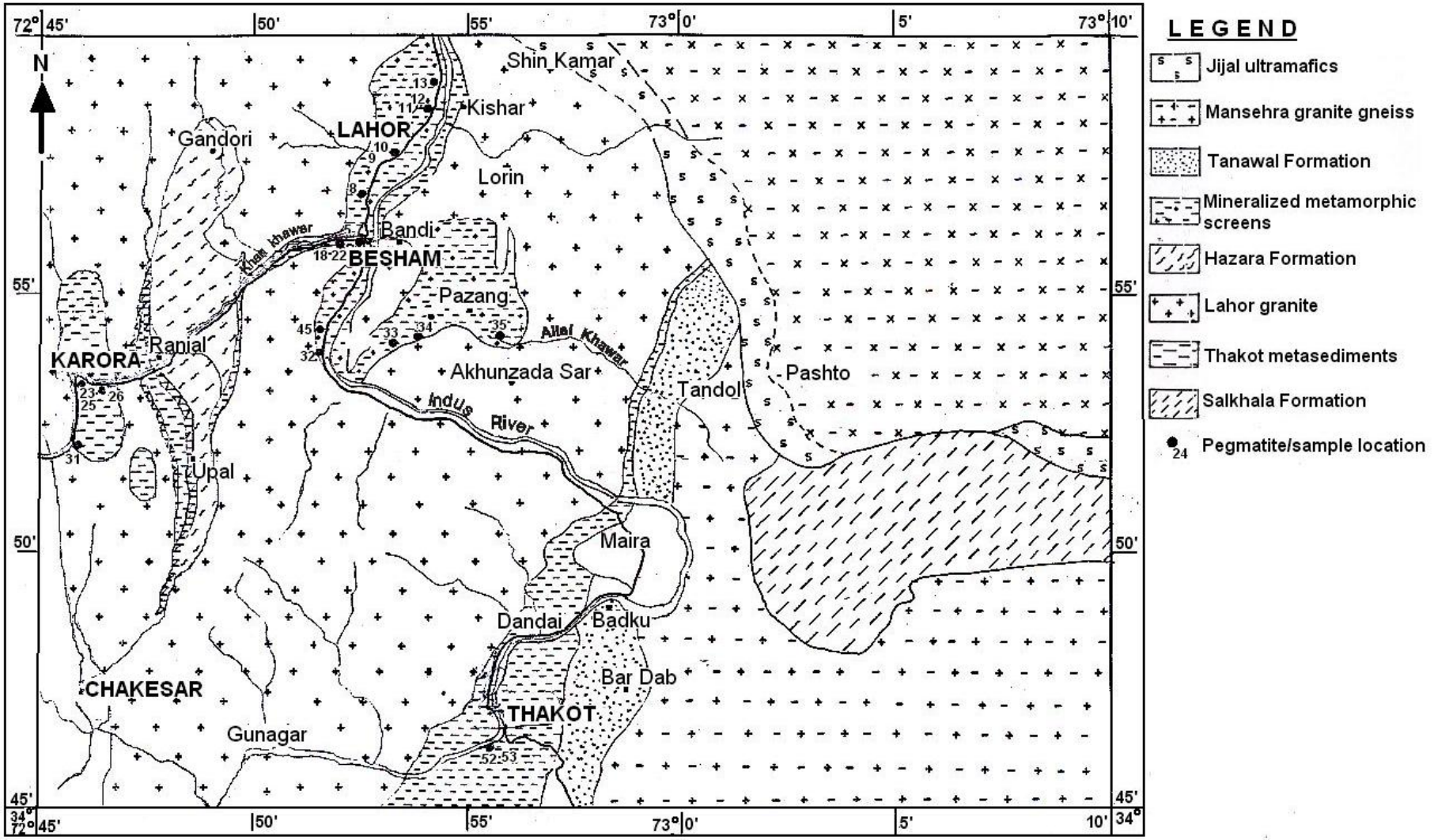

Fig. 2 Showing Geological Map of the Besham-Allai Area, Northwestern Himalayas, Pakistan (After Ashraf, et al., 1980)

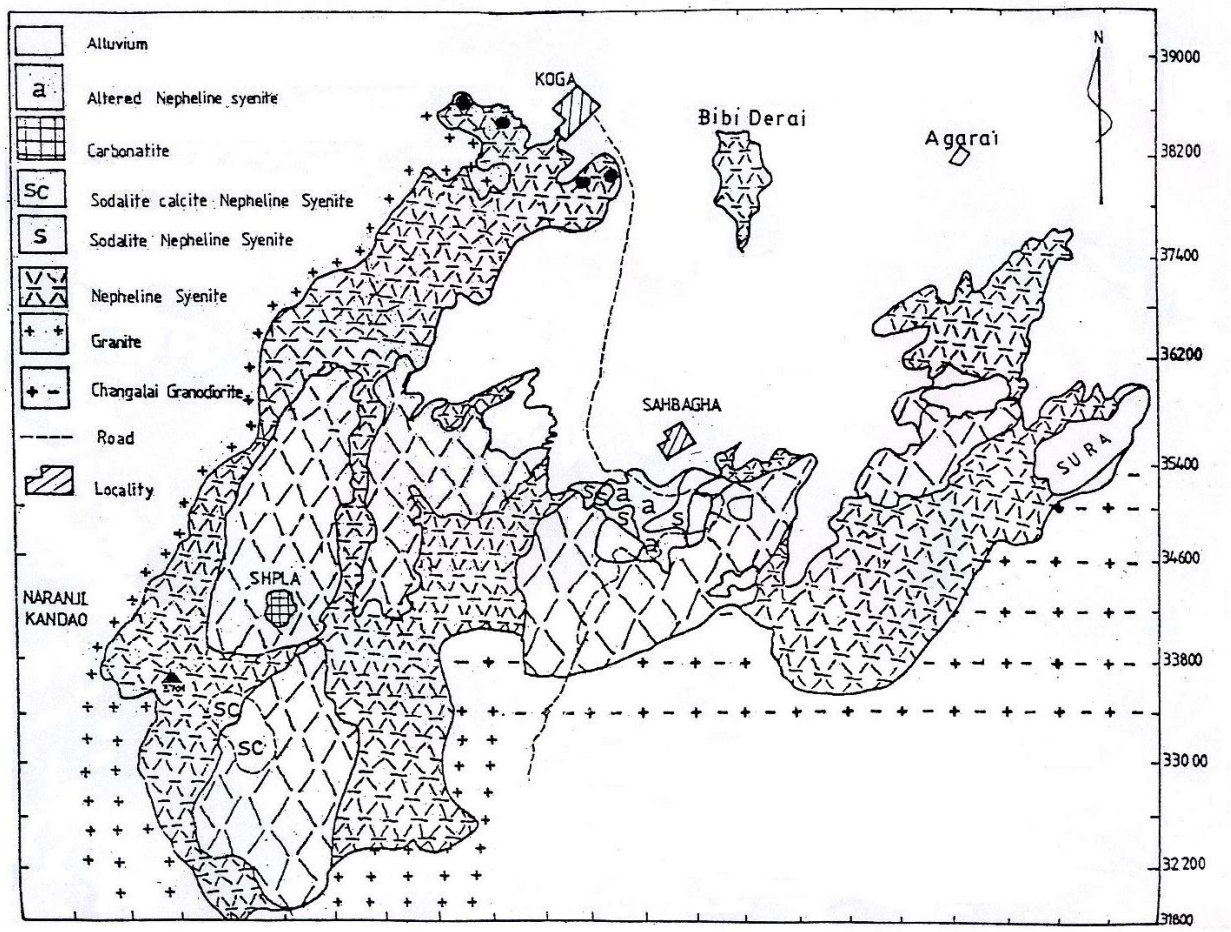

Fig. 3 Showing Geological Map of Koga Area, Southern Swat Valley, Northwestern Himalayas, Pakistan (After Ashraf, et al. 1987)

Chaudhry, *et al.,* 1984 classified the Koga alkaline complex as following types: Sheared and weathered to massive and compact alkalic minor bodies. The albitites are present in the nepheline syenite at a number of places. Only a few pegmatites are zoned where as a rest are un-zoned.

Geology of the Pegmatite/ Aplite Bodies

The pegmatites are coarse-grained equivalent rocks of aplites. These are also known as acid minor bodies if associated with granites of any type (S-type or I-type) and those minor bodies which are associated with alkalic rocks, are called alkalic minor bodies. These minor bodies are invariably formed from rest magmatic solutions (Clemens 2003, Chaudhry, *et al.,* 1981 and Ashraf, 1974). These minor bodies are classified and differentiated on the basis of mineral composition, form, size and relationship with the enclosing rocks, internal and external structures. In the light of the above facts the minor bodies are described and discussed under the following headings.

i. Types of the acid minor bodies/alkalic minor bodies

ii. Distribution and localization

iii. Size, shape, form, external structure and relationship with the enclosing rocks

iv. Internal structure

Types of Acid Minor Bodies/Alkalic Minor Bodies

The acid minor bodies are invariably associated with the S-type granites of Malakand granite/gneiss, Ilam granite gneiss, Alpurai-Yakhtangi granite gnesis and Lahor granite/gneiss. The types of acid minor bodies were determined/differentiated on the basis of

field investigations and microscopic study of the representative rocks. Relative grain sizes of the pegmatites and their zones were determined in the field. The rocks which have grain size less than 1 to 2mm are classified as fine-grained rocks or aplites, those with grain size 2 and 5mm are identified as medium-grained and those which are coarser than 5mm are termed as coarse grained or pegmatitic rocks.

As the granites of different areas were derived from different host metasediments after partial melting so the pegmatite types were differently crystallized in time and space. This has become evident from the field and microscopic study. Ashraf (1974) presented the Mansehra type acid minor bodies as albitite, albite (microcline) aplite/pegmatite, albite- microcline aplite/pegmatite, microcline-albite aplite/pegmatite which occur as simple and complex pegmatite, albitized bodies. Therefore, acid minor and alkalic minor bodies are classified according to association with the various granite/alkalic rocks. This classification is preliminary and tentative for the scope of this paper and it will be refined and defined properly after detailed information obtained from further fieldwork and laboratory investigations.

Table 1 Showing Acid Minor Bodies Associated with Malakand Granite and Granite Gneiss

Acid Minor Bodies Associated with Malakand Granite

A. Simple pegmatite (within granites)

i. Albite-microcline pegmatite (Albite-microcline-quartz-muscovite) MD-01-1/59 and 2/59
ii. Microcline-albite pegmatite (Microcline-albite-quartz-muscovite-biotite) MD-01-6/59

B. Aplites (Within metasedimentary screens)

i. Albite aplites (Albite-quartz-muscovite-biotite) MD-01-8/59 and 10/59
ii. Albite-(Microcline) aplite (Albite-(Microcline minor)-quartz) MD-01-9/59

Acid Minor Bodies Associated with Malaknad Granite Gneiss

A. Simple pegmatites

i. Microcline-pegmatite (Microcline-albite-quartz) DI-37/59
ii. Albite-microcline pegmatite (Albite-microcline-quartz-muscovite) DI-40/59

B. Zoned pegmatites

i. Intermediate zone (Microcline-albite-quartz) DI-44/59
ii. Core zone (Microcline-albite-quartz) DI-42/59

C. Simple aplites

i. Albite-microcline aplite (Quartz-albite-microcline-muscovite) DI-38/59

D. **Albitite**

i. Albite-(minor microcline) albitite DI-47/59

Note: Numbers, such as, DI-38/59 above and in all the tables below represents field/lab. numbers. Petrographic composition of ubiquitous minerals of a rock samples are presented in the parenthesis.

Table 2 Showing Acid Minor Bodies Associated with Ilam Granite Gneiss

A. Simple pegmatites

i. Albite-microcline pegmatite (Albite-microcline-quartz-muscovite) DM-34/59

B. Simple aplites

i. Microcline-albite-quartz aplite (Microcline-quartz-albite-muscovite) DM-35/59

ii. Quartz-albite-microcline aplite (Quartz-albite-microcline-muscovite-biotite-tourmaline) SR-33/59

iii. Microcline-albite aplite (Microcline-albite-quartz-muscovite) JL-51/59

C-1. Zoned pegmatites (symmetrical)

i. Wall zone hanging (Albite-microcline-quartz-muscovite-biotite) KO-11/59
Intermediate zone hanging (Microcline-albite-quartz-muscovite) KO-12/59
Core (Quartz) KO-13/59
Intermediate zone footwall (Microcline-perthitic-albite-quartz-muscovite) KO-14/59

ii. Wall zone (Albite-microcline-quartz) KR-17/59
Intermediate zone hanging (Microcline perthitic-albite-kaolinite) KR-16/59
Core (Quartz) KR-15/59
Intermediate zone footwall (Microcline perthitic-albite-kaolinite) KR-18/59

C-2. Zoned pegmatite (asymmetrical)

i. Border wall zone (Microcline-albite) MR-32/59
Core (Quartz) MR-32/59
Wall. zone-1 (Microcline-albite-quartz-kaolinite) CI-26/59
Wall zone-2 (Microcline-albite-quartz-muscovite-kaolinite) CI-27/59
Wall zone-3 (Microcline-albite-muscovite-kaolinite) CI-28/59
Intermediate outer zone (MicrocIine-aIbite-muscovite-kaoIinite) CI-29/59
Intermediate inner zone (Microcline-albite-perthitic-biotite) CI-25/59

ii. Intermediate zone (Microcline-albite-quartz-muscovite-) JL-50/59
Core (MicrocIine-quartz-pIagiocIase) JL-49/59
Intermediate zone (Microcline-quartz-albite-muscovite) MR-56/59
Core (Quartz-albite-microcline) MR-57/59

C-3. Zoned aplite (asymmetrical)

i. Border wall zone footwall (Microcline-albite-quartz-muscovite/biotite) KR-22/59
Wall zone (Albite-microcline-quartz) KR-23/59
Intermediate zone hanging (Microcline-albite) KR-24/59

ii. Wall zone (Albite-muscovite) KR-20/59
Intermediate outer (Albite antiperthitic-microcline-muscovite-quartz- kaolinite) KR-19/59
Intermediate inner (Microcline-albite-muscovite) KR-21/59

Table 3 Acid Minor Bodies Associated with Alpurai (Swat) Granite Gneiss

A. Simple pegmatites
Albite microcline pegmatite (Albite-microcline-quartz-muscovite) AI-02-30/59
B. Simple aplite
Albite-microcline aplite (Albite-microcline-quartz-muscovite/sericite-kaolinite) AI-02-29/59

Table 4 Acid Minor Bodies Associated with Lahor Granite Gneiss

A. Simple pegmatite

i. Albite-microcline pegmatite (Albite-microcline-quartz-kaolinite) KA-02-24/59 and BM-02-50/59

ii. Microcline-albite pegmatite (Microcline–albite–quartz) CR-02-25/59, CR-02-2759, BM-02-34/59,BM-02-35/59 and TT-02-5259

iii. Muscovite-quartz-microcline pegmatite (Muscovite-quartz-microcline-albite) TT-02-53/59

iv. Albite-microcline-quartz pegmatite (Albite-microcline-quartz-tourmaline) BM-02-45/59

B. Aplites

i. Albite-(microcline) aplite (Albite-quartz-microcline) BM-02-5/59, BM-02-9/59 and BM-02-15/59

ii. Microcline-albite aplite (Microcline-quartz-albite) DR-02-16/59

C. Zoned aplite bodies

i. Border zone (Albite-quartz-muscovite) BM-02-18/59

ii. Intermediate zone (Albite-microcline-quartz-muscovite) BM-02-19/59

iii. Core (Microcline-albite-quartz-muscovite) BM-02-20/59

D. Albitites

(Albite-quartz-microcline) BM-02-11/59

E. Composite aplite/pegmatite bodies

i. Microcline-albite aplite (Microcline-albite-quartz-biotite) BM-02-48/59 and BM-02-49/59

ii. Albite-microcline pegmatite (Albite-microcline-quartz) BM-02-50/59

Table 5 Alkalic Minor Bodies Associated Wwth Ambela Granite

A. Simple pegmatites

i. Microcline-quartz pegmatite (Microcline-quartz-albite) JO-83/59

B. Simple aplites

i. Albite-microcline aplite (Albite-microcline-quartz-muscovite-biotite) AO-77/59.

C. Quartz porphyries

i. Quartz-microcline-albite-porphyry (Microcline-albite-quartz-biotite) AO-81/59.

ii. Quartz-microcline porphyry (Albite-microcline-quartz) AO-80

Table 6 Alkalic Minor Bodies Associated with Babaji Syenite

A.	**Simple pegmatites**
	i. Microcline-albite-pegmatite (Microcline-albite-quartz) BO-70/59 and 71/59.
	ii. Microcline quartz-pegmatite (Microcline-quartz-albite-biotite) BO-75/59
B.	**Composite pegmatite-aplite**
	i. Fine-grained aplite (Albite-microcline-quartz-biotite-epidote) BO-72/59
	ii. Medium-grained aplite (Microcline- albite-quartz-biotite-epidote) BO-73/59
	iii. Pegmatitic aplite (Microcline-albite-quartz) BO-74/59

Table 7 Alkalic Minor Bodies Associated with Koga Nepheline Syenite

A.	**Nepheline syenite pegmatites**
	i. Nepheline-albite pegmatite (Nepheline-albite-microcline-aegirine) AI-85/59 and KA-67/59
	ii. Nepheline-microcline-albite pegmatite (Microcline-albite-nepheline-arfvedsonite) KA-65/59, KA-66/59 and BI-96/59
	iii. Nepheline-microcline pegmatite (Microcline-albite-nepheline-arfvedsonite-biotite) KA-68/59
B.	**Sodalite-nepheline pegmatite**
	i. Sodalite-nepheline-microcline-albite pegmatite (Albite-microcline-nepheline-sodalite-arfvedsonite) KA-69/59
	ii Sodalite-nepheline-albite-microcline pegmatite (Albite-microcline-nepheline-sodalite-arfredsonite-aeqirine-biotite) AI-88/59
C.	**Zoned pegmatite**
	i. Northern intermediate zone (Microcline-albite-nepheline- muscovite/ biotite) AI-89/59 Core (Microcline-albite-nepheline) AI-90/59 Southern intermediate zone (Albite-microcline-nepheline-biotite) AI-91/59
	ii. Border zone (Albite-microcline-nepheline-carbonate) BI-98/59 Intermediate zone (Albite-microcline-nepheline-biotite) BI-99/59
D.	**Albitites**
	i. Nepheline-albitite (Albite-microcline-nepheline) AI-86 and AI-87/59
	ii. Sodalite-nepheline-albitite (Albite-nepheline-sodalite-microcline-carcrinite) AI-95/59
	iii. Microcline albitite (Albite-microcline) AI-93/59

Distribution and Localization

Pegmatite/aplite, etc., minor bodies of eight types of plutons were studied. They were tried to be explored and investigated in the light of work carried out on pegmatites, etc., by Ashraf (1994 and 1976), Heinrich (1963). They recognized three distinct zones for the formation and development of pegmatites etc. Generally these three distinct zones are called as (i) Interior (ii) Marginal and (iii) Exterior zones. In the areas under investigation only Mansehra area has been found to match Heinrich (1963) zonation whereas in the other six areas mineral assemblages so far found are of simple nature, i.e. absence of rare minerals, although some uranitite type minerals have been reported by Butt (1995) in some pegmatites of Ilam granite. In the Ilam granite we have found huge size of crystals of microcline 0.8 x l.10m and 0.75 x 1.30m two dimensionally whose third dimension is studded inside or is not exposed. However, most of the pegmatites associated with nepheline syenite and fenites are complex with critical minerals like sodalite, nepheline, cancrinite etc. In the following pluton wise distribution and localization of minor acid and minor alkalic bodies are discussed.

Malakand Granite: Simple pegmatites occur in Malakand granite as swarms of pegmatites and as composite bodies with aplite as cross cutting thin bodies. They are un-zoned, partially zoned and fully zoned. Such pegmatites occur throughout the granite body which is about 5km x l0km in dimension. They are mostly distributed as albite-microcline pegmatites and microcline albite pegmatites (Table 1).

Simple aplites are mostly fine to medium grained bodies occurring in a big screen along the Malakand-Swat road below Malakand Rest House. These bodies of aplites crosscut the screen metasediments lithology, moreover they are mostly thicker than those bodies in Malakand granite. Compositionally they are albite-aplite while few occur as albite-(microcline) aplites, i.e., with minor patassic phase.

Malakand Granite Gneiss: In Malakand granite gneiss which is spread over a large area has simple pegmatites unzoned and zoned, simple aplite and albitite (Table1). The simple un-zoned pegmatites are (microcline-albite-quartz, DI-37/59) microcline rich and albite rich pegmatites (albite-microcline-quartz-muscovite, DI-40/59) in Dherai area. The zoned pegmatites have two zones: intermediate zone and core. The intermediate zone is slightly richer in albite and quartz (DI-44/59) as compared to core, which is highly rich in microcline (DI-42/59).

A simple aplite in Jalalkot locality is a small outcrop of quartz-albite-microcline-muscovite body. Albitite body has been found for the first time in the Malakand granite gneiss. It is mostly albite rich with minor microcline. It is distributed and localized in the interior zone as albite-(microcline) body.

Ilam Granite Gneiss: In the S-type granites studied so far, Ilam granite gneiss is the only pluton which has a variety of acid minor bodies as un-zoned simple pegmatites / aplites, zoned pegmatites symmetrical and asymmetrical and zoned aplites asymmetrical (Table 2) occurring in the interior and marginal zones of Ashraf (1976) and Heinrich (1963). Butt (1985), however, has reported complex uraninite hearing pegmatites in the marginal and exterior zones.

Lahor Granite Gneiss: The Lahor granite gneiss rocks have four types of acid minor bodies Table 4:

A. Simple unzoned pegmatite

   (i) Albite-microcline pegmatite (KA-02-24/59 and BM-02-50/59)

   (ii) Microcline-albite pegmatite (CR-02-25/59, CR-02-27/59, BM-02-34/59, BM-02-35/59 and TT-02-52/59)

   (iii) Muscovite-quartz-microcline pegmatite (TT-02-02-53/59)

   (iv) Albite-microcline-quartz pegmatite (BM-02-45/59)

B. Simple aplites are of following types:

   (i) Albite-(microcline) aplite (BM-02-5/59, BM-02-9/59 and BM-02-15/59)

   (ii) Microcline-albite aplite (DR-02-16/59)

C. Zoned aplite bodies are, also, found with well marked border zone (BM-02-18/59), intermediate zone (BM-02-19/59) and a core (BM-02-20/59).

D. Albitite body is also, discovered associated with the Lahor granite for the first time. It is albite rich (minor quartz with microcline) BM-02-11/59, occurring near Besham along KKH.

E. Composite bodies of aplite/pegmatites have been found near Kot Syedan and Yadgar areas east of Besham and south of Besham in the interior zone of Lahor granitic complex. They are of the following types:

   i. Microcline-albite aplite (BM-02-48/59 and BM-02-49/59)

   ii. Albite-microcline pegmatite (BM-02-50/59)

Alpurai (Swat) Granite Gneiss: The granite gneiss in Aplurai area appears to be dry granite as it has very thin aplite / pegmatite bodies as they could not be found in many parts of the granitic gneiss body during reconnaissance visit from Yakhtangi to Alpurai. So far in this granitic body two types of acid minor bodies were found in the interior zone of granite near Alpurai. The pegmatite is albite-microcline type (AI-02-30/59) and aplite is also of albite-microcline type. The latter is somewhat sericitized and kaolinized (AI-02-29) Table 3.

Ambela Granite: In the Ambela granite mostly simple aplites and quartz porphyries (Table 5) are distributed extensively as large thick bodies whereas simple pegmatites occur as microcline rich thin bodies but not very frequent (JO-83/59). These are found in the interior zone.

Babaji Syenite: Babaji syenite has mostly simple pegmatites. They occur in the area between Pir Baba Kandao and Ambela Kandao in Bunair district. They occur mostly as microcline-albite pegmatite (BO-70/59 and 71/59) and microcline-quartz pegmatites (BO-75/59). One interesting composite body was found near Ambela spring as pegmatite-aplite (BO-74/59), medium-grained aplite (BO-73/59) and fine-grained aplite (BO-72/59) as given in Table 6.

Koga Nepheline Syenite: In Koga nepheline syenite six complex alkalic types of pegmatites and albitites have been found. The latter is a new discovery, which was not reported by earlier workers. These albitites are:

i. Nepheline albitite (AI-86/59, 87/59)
ii. Sodalite-nepheline albitite (AI-95/59)
iii. Microcline albitite (AI-93/59) occurring in Agarai area of the Koga nepheline syenite complex.

These albitite bodies occur in the interior zone of the complex. The pegmatites group of alkalic rocks has the following types:

A. Nepheline Syenite Pegmatites: These are sub-divided into three types as under (Table 7):

i. Nepheline albite pegmatite (AI-85/59 and KA-67/59)
ii. Nepheline-microcline-albite pegmatite (KA-65/59, 66/59 and BI-96/59)
iii. Nepheline-microcline pegmatite (KA-68/59).

These three types found so far occur near Koga, Agarai and Bibi Dherai in the interior zone of the complex.

B. Sodalite-Nepheline Pegmatites: These are subdivided into two classes as given below:

i. Sodalite-nepheline-microcline-albite pegmatite (KA-69/59)
ii. Sodalite-nepheline-albite-microcline pegmatites (AI-88/59) occurring also in Agarai and Koga

Two beautifully zoned pegmatites have been found with well-developed intermediate and core zones. They occur in Agarai and Bibi Dherai. They also occur in the interior zone of the alkaline complex.

Size, Shape, Form, External Structure and Relationship with the Enclosing Rocks

The acid minor bodies and alkalic minor bodies associated with granites of Malakand, Ilam, Alpurai (Swat), and Lahor, are very thin to as thick as 50m, as tabular, lensoid, lenticular branching, pinch and swell, patches, pods, ptygmatic etc.bodies. These bodies usually have sharp contacts but may have irregular and diffused boundaries. Similarly, the alkalic minor bodies associated with alkaline complex of Koga, Babaji and Ambela are mostly 5-10cm to 17m thick in Koga nepheline syenite. Those in Babaji Syenite are 2cm to 16m thick and alkalic aplites in Ambela granite are about 5 to 12m thick and its pegmatites are quite thin 0.5 to 1m thick. The longer dimension of these alkalic rocks are also variable but with maximum length of 70m. These bodies are mostly tabular, lenticular, lenticular branching type.

Malakand Granite: The older phase of pegmatite are cross cut by a younger phase of aplitic pegmatites and depict a picture of swarm like occurrence. In some cases there are composite phases of aplite and pegmatite which may occur as earlier phase of pegmatite from wall inward and core of aplite/aplitic pegmatite. In one case near Malakand Rest House a pegmatitic bodies which are medium to coarse grained have subradial to fan like attitude of biotite flakes and flake like aggregates. They fill almost entire body of the pegmatite.

There is a big screen lying below Malakand Rest House, which has aplite bodies developed as swarms of lensoid, lenticular branching type aplites and triangular pods. The aplites are 0.2 to 0.6m thick bodies.

The Malakand Granite Gneiss has numerous pegmatite and aplite bodies near Dherai and Jalalkot. In Jalalkot area there are composite aplite/pegmatite bodies. The pegmatites are zoned to partially zoned bodies. The later occur at coordinates 34^{o} 35’36”/71^{o} 51’10” to 34^{o}35’41”/ 71^{o} 53’ 05” discontinuously for about 300m with a variable thickness of 2 to 15m. This pegmatite has gradational contact with granite gneiss giving an aplitic appearance. Just near Jalalkot village swarms of pegmatite/aplites are found in a bed and walls of stream (to the west of village). They are tabular, ptygmatic, stringer and pod like. They are 3cm to 15-20cm thick and extend for 3 to 5m. The thickest pegmatite is about 20m thick and extend for 100 to 120m. Smaller size zoned/unzoned pegmatites are also not uncommon.

The Ilam Granite Gneiss has variety of pegmatites regarding their size, shape from and relationship with enclosing rocks. The pegmatites occurring in southern part of the Ilam granite gneiss are mostly zoned and at almost two places mining operation is on which has exposed the pegmatites fully regarding size shape, external structure etc. There are three pegmatites along the Karakar-Pirbaba Road. Two zoned pegmatites to the north of the road and the biggest one is to the south of the road. Both the northern pegmatites are lenticular with well-developed zones having fully to partially developed core of quartz and microcline rich intermediate zones on both sides. Thickness of first pegmatite (towards Karakar) is 2.5m in middle and length is about 10m. The 2^{nd} well exposed pegmatite is 2.7m (in middle) and extends for 50m in length, i.e.,

thinning out on both sides. This pegmatite contains 0.38 x 0.2m size euhedral crystal of microcline. The southern pegmatite is about 5m thick and extends for about 150m as composite pegmatite bodies. At least three/four pegmatite bodies are juxtaposed together and appear to be continuous as one body but internal structure and mineralogical study show it to be composite bodies.

Similarly an aplite body of white colour occurs at a distance of 300/400m to the east of this large body is 12m thick with a lengthwise exposure of 20m. It is zoned mineralogically as an asymmetrical body similarly another one of interest is just north of village Charai at coordinates 34°34'17"/72° 19' 29". In this body there is a bigger body of 3/4m thick and 70m in length as a lensoid asymmetrically zoned body of pegmatite. It has generally a sharp contact with enclosing hanging wall rock whereas foot wall side is not exposed. Just south east of this main body of pegmatite are smaller bodies of aplites and pegmatites and with a classic example of development of pegmatites (two phases) and aplite (one phase) as composite bodies.

The northern side of Ilam complex was studied in the area south of Mingora near Marghzar, Islampura, Dangram, Jambil, Puronai, etc. In Marghzar area small pod like zoned pegmatites are found in schist near the contact of granite. Peculiar thing of this pegmatite is the development of nearly 90% quartz core and thin microcline border zone (0.5 to 2cm thick). The Islampura pegmatites/aplites occur in calc schists and granite pegmatites as pods and aplites as lenticular bodies without zones. Length of one such aplite body is 50/60m and 12m. In Dangram area apart from some unimportant aplite/pegmatites is an interesting body of zoned pegmatite whose contact with gneiss is sharp with discontinuous zones of tourmaline lenses and pods. It is compositely occurring with a quartz body, which appears to be later and truncating the pegmatite body. The pegmatite is 0.5m thick and about 20m in length whereas quartz body extends for 50m parallel to pegmatite. In Jambil area at coordinates 34° 42'39"/72° 27'19" is an occurrence of bodies of pegmatite and aplitic pegmatites (composite to separate) deformed forming boudinage, pod and ptygmatic structures. Size wise they are small. Another composite aplite/pegmatite is also seen near Dangram.

The Lahor Granitic Complex consists of major albite granite with minor microcline granite gneiss dykes (Dubair granite). The major pegmatitic development is in the giant screen along Indus River, Khan Khawar, Chakeser road and Allai Khawar areas. The Lahor granite as a whole has thinner pegmatites ranging from 0.5 to 1m thick lenticular and lensoidal bodies. They mostly have sharp contact with granite. Some thinner aplitic/pegmatitic bodies are associated with Dubair granite dykes. The larger and thicker bodies of pegmatite (in Lahor granite) are about 5 to 150m thick and extend for 50 to 400m as tabular bodies, which can terminate as lens like shape and also can branch out. Sometimes those within Lahor granite are composite pegmatite/aplite bodies.

The Alpurai (Swat) Granite Gneiss has insignificant occurrences of aplite and pegmatites. They are very thin aplites and aplitic pegmatites. The aplites are found as 2 to 6cm thick and extend for 1.5m. A pegmatite body occurs as pod 20x45cm across. Their contact is sharp with the granite gneiss.

The Ambela Alkaline Complex includes Ambela granite, Babaji syenites and Koga nepheline syenites. Their minor bodies are 5-10cm to 17m thick in Koga nepheline syenite complex. They are mostly tabular, lensoid and lenticular and stringer like bodies with sharp contact in case of well zoned bodies and gradational in some cases of unzoned and thinner bodies. In the Babaji syenite the bodies are usually thinner, 2-10cm with the exception of one thicker body, 16m. The thinner bodies are usually zoned and sheet like, lenticular and lensoidal. The thicker bodies are lenticular and have sharp contact. The Ambela granite has the thickest bodies mostly of aplitic nature, which are usually 5 to 12m thick, and with a maximum length of 70m as mostly tabular bodies. The pegmatite bodies are 0.5 to 1m thick and are lensoidal and lenticular. The latter are developed only scantly where the former are very frequent in the granite body.

Internal Structure

The internal structure of the acid minor bodies and alkalic minor bodies was studied. Most of these bodies are apparently either unzoned or zoned. The zonation is either textural or mineralogical. In the unzoned bodies textural variation if carefully studied show a border zone of finer grained stuff and mineralogically different in some cases. Mineralogical variation (zonation) is well marked in the pegmatites of Malakand granite and gneiss, Ilam granite gneiss, Ambela alkaline complex, and Lahor granitic complex. However the Lahor granite complex pegmatites show apparently mineralogical zonation and even textural zonation.

PETROGRAPHY

General: The studies carried out so far shows that these pegmatites/aplites have no match with Mansehra type complex bodies where there are rare

minerals crystallization like beryl, columbite, smarskite, Rb-rich K-feldspar, Li-muscovite, cleavelandite, etc.

Megascopic: Petrography of pegmatites is very difficult and cannot be representatively presented as compared to aplites. Therefore, their texture and structure have to be field and microscope oriented i.e. size/shape has to be carefully observed and averaged out subsequently. In most cases samples of pegmatites were taken of the coarsest part separately, i.e., from say microcline intermediate zone as 1, 2 or 3 samples to know the variation in a zone and where impurities present were taken separately to know the intergrowths, texture and minerals present.

In most of the pegmatites associated with Ilam granite gneiss, the coarsest microcline crystals were mostly euhedral to subhedral as compared to microcline crystal of other associations. In Ilam granite gneiss pegmatites, huge sized microcline crystals are found which are not present even in Mansehra pegmatites. The coarsest euhedral crystals in a pegmatite body at Karakar, which is also being mined commercially, are about 0.75x1.30m and 0.8x1.10m in size occurring separately. In most cases the pegmatites are un-deformed in Ilam granite gneiss, Malakand granite and Ambela granitic complex. They are, however, mildly deformed in Malakand granite gneiss and Alpurai-Yakhtangi granite gneiss out crops. The pegmatites in Lahor granitic complexes are slightly to strongly deformed possibly because of Thakot and Chakesar faults.

The aplites in almost all the cases are typical aplites in Malakand granite and gneiss, Ilam granite gneiss, Lahor granitic complex, and Ambela granitic complex with sugary texture and grain size 1 to 2mm. However, aplitic pegmatites or pegmatitic aplites are not uncommon where grain size goes upto 5-6mm.

The albitites found in all the complexes are typically medium grained with subhedral to anhedral grains and sugary texture 1 to 3mm and rich in albite along with minor other minerals. This identification became possible and confirmed by microscopic study.

Another very conspicuous feature was observed in many pegmatites of all types of granites except alkaline granite, syenite etc. is the occurrence of graphic growth to sub-graphic intergrowth of microcline and quartz on microscopic to field scale. These observations initially show that most of the pegmatites in Malakand granite gneiss, Ilam granite gneiss, Lahor granitic complex are of higher temperature type with a few of moderate to lower temperature types. Thus the scarcity of rare minerals association is obvious. These are preliminary observations and the lower temperature types have to be studied leading to pneumatolytic/hydrothermal activities.

Microscopic: For petrographic study of the pegmatites (acid/alkalic minor bodies) we envisaged to study about 150 samples. But in order to understand the pegmatites and pegmatite like bodies we collected 163 samples and out of these 83 samples were studied microscopically which are not sufficient to understand fully such large plutons of granites, alkaline granites and nephline syenites. However, for the present study 6 samples from Malakand granite, 6 samples from Malakand granite gneiss, 30 samples from Ilam granite gneiss, 12 samples from Koga nepheline syenite, 3 samples from Ambela granite, 19 samples from Lahor granitic complex, and 2 samples from Alpurai-Yakhtangi granite gneiss and 5 samples from Mansehra granitic complex were studied petrograpically.

Malakand Granite: Six samples were studied from Malakand granite and associated metasediments. Three are pegmatites and three are aplites. The pegmatites as observed under microscope have subhedral to anhedral grains of 12 to 1mm but those with grain size less than 1 down to 0.2mm anhedra to subhedra are also common. Myrmekitic texture is also developed replacing microcline. The coarser grains are mostly microcline and albite. Quartz occurs as pods and veinlets. Other minor minerals are muscovite, epidote, zoisite, etc.

The aplite occurring in a big screen in Malakand granite are mostly 2mm to 0.5mm but 0.05 to 0.3mm are also encountered in the three aplites studied so far. The grains are anhedral to subhedral. Myrmekitic texture is well developed at most places. The absence of microcline in MD-01-8/59 and MD-01-10/59 shows that myrmekite has replaced totally microcline whereas some 8% microcline is still left in the sample MD-01-9/59. Overall texture is sugary but mild foliation is developed in MD-01-8/59. On the basis of dominant albite and quartz presence the rocks are of albite-quartz-muscovite aplite nature with minor minerals like biotite, epidote, garnet, kaolinite, zircon, sphene, etc.

Malakand Granite Gneiss: Two pegmatites of Jalalkot area and two samples of a pegmatite of Dheri associated with Malakand granite gneiss were studied. The Jalalkot pegmatites are unzoned with subhedral to anhedral grains of microcline and albite. The grains are 10 to 5mm in size generally with fine interstitial grains of 2 to 0.5mm. Quartz occur in sample DI-38/59 as very fine to fine grained individual grains to aggregates, with muscovite

flakes. Other minerals in both the samples are kaolinite, biotite, etc.

The zoned pegmatites of Dheri have two zones. The microcline zone is very rich in microcline (82%) with perthitic albite. The perthitic lamellae are usually very fine needle like. The sub graphic texture is developed with quartz laths in the single microcline crystal. Minor alteration is of sericite and kaolinite. The wall zone of the pegmatite is also fairly rich in microcline (65%) but has very well developed graphic to sub graphic growth with microcline, which is also traversed by thin albite/quartz veinlets. Quartz is 15%, muscovite 3% and kaolinite is 2% in the wall zone.

The microcline albitite associated with this granite has subhedra ranging in size from 2.5mm to 0.5mm. They show sugary texture with microcline (8%) developed in the interstices of albite grains (88%). It is slightly altering to sericite/muscovite (1.5%) and kaolinite (1.5). Quartz is very minor in amount (0.5%).

Ilam Granite Gneiss: Four zoned pegmatites were studied occurring in the Ilam granite gneiss towards Bunair on the southern margin of the granitic body. These pegmatites have coarse-grained crystals of microcline and albite whereas quartz core consists of aggregates. The coarse aggregates were studied under the microscope to know types of impurities i.e. association of other minerals. Even in some cases single crystals were cut to study different other phases as in KO-12/59, KR-16/59, KR-18/59. They have microcline 75% (with perthitic albite), 80%, and 85% respectively in the three samples. In other zones of these zoned pegmatites microcline and albite decrease considerably with minerals like quartz, biotite, muscovite/sericite, kaolinite, ore minerals, rutile etc. However, anomalously high amount of tourmaline is found in a footwall zone of pegmatite sample KR-17/59. It is also interesting to see antiperthitic albite in sample KR-19/59.

In the Ilam granite gneiss on Mingora side i.e. northern side most of the pegmatites are in metasediments. Five pegmatite samples were studied, three from unzoned pegmatites and two from zoned pegmatites. These three unzoned samples from Jambil area are coarse to medium grained. Grain size upto 20mm are seen (JL-50/59) showing sub-graphic intergrowth of microcline with quartz. The grain size commonly is down to 0.5mm. Major minerals are microcline, albite and quartz, with minor muscovite, tourmaline, biotite, epidote, zoisite, kaolinite, etc.

One zoned pegmatite found near Manglaur consists of two zones, the intermediate zone (MR-56/59) and the core (MR-57/59). The intermediate zone is mostly rich in perthitic microcline and crystals are usually traversed by quartz veinlets of ~0.2mm width. The quartz also occurs as intergrown lamellae showing graphic to sub graphic textures. The feldspar also alters to sericite on minor scale (~0.2%). Muscovite occurs as flakes (MR-56/59). The core dominantly consists of quartz (85%) as fine to medium grained aggregates of anhedra with inter-granular space filled by microcline 4%, albite 8%, and muscovite 3%.

One asymmetrically zoned aplite was studied occurring along Karakar Road. Texturally the aplite is sugary medium grained, but mineralogically quite variable. The footwall side mineralogy is microcline 40%, albite 35%, and quartz 15% with minor muscovite and biotite (KR-22/59). The core consists of microcline 25%, albite 30%, and quartz 30% with minor minerals like muscovite, biotite, epidote, kaolinite and garnet (KR-23/59). The hanging wall is quite rich in microcline 75%, with albite 15% and little quartz 3% (KR-24/59). Other minerals include muscovite, biotite, epidote and sphene.

Lahor Granitic Complex: Nineteen samples were studied from Lahor granitic complex. They are mostly albite - (microcline) aplites (albite 33-66%, microcline 3-15%), albite aplites (microcline 23-48%, albite 10-20%), albite-(microcline) aplitic pegmatite (albite 33%, microcline 15%), microcline-albite pegmatites (microcline 43-60%, albite 10-27%), composite aplites / pegmatites and albitites (albite 82%) bodies. The aplite or composite aplite and albitite are fine to medium grained generally with subhedral to anhedral shape. The aplitic pegmatite or the composite pegmatites are mostly medium to coarse grained. Muscovite-albite aplitic pegmatite (TT-02-53/59) was found to be highly sheared.

Alpurai-Yakhtangi Granite Gneiss: Two samples were studied from Alpurai-Yakhtangi area, which are albite-microcline aplite (albite 49%, microcline 16%) and albite-microcline pegmatite (albite 30%, microcline 20%).

Koga Feldspathoidal Syenite: Eight samples of unzoned nepheline syenite pegmatites were studied under the microscope. One sample is from Bibi Dheri, two from Agarai and five from Koga area. The Bibi Dheri sample (BI-96/59) is medium (1 – 2mm) to coarse (3.5mm) grained subhedra. Albite shows chessboard type texture. Mineralogically this rock consists of microcline 66%, albite 25%, and nepheline 3%. Minor minerals are biotite, arfvedsonite, sphene, and ore minerals. The samples from Koga area are nepheline-microcline-albite

pegmatites except KA-69/59, which is sodalite-nepheline-microcline-albite pegmatite.

The two Agarai samples (AI-85/59 and AI-88/59) are mostly coarse grained (5 – 7.5mm). Sample No. AI-88/59 shows flow foliation, whereas sample no. AI-85/59 shows very typical development of cleavelandite (albite) at the expense of microcline. Normal albite is also present. In both rocks microcline is 30% & 15%, albite 40% & 78%, nepheline 10% & 1% and sodalite is 2% and nil respectively. Minor minerals include biotite, muscovite, aegirine, epidote, zircon, apatite and garnet, etc.

Two zoned pegmatites were studied, one from Agarai (AI-89, 90 and 91/59) and one from Koga (KA-98 and 99/59). As already mentioned in megascopic studies they are very coarse grained, so they were best interpreted in field.

Albitite in Koga feldspathoidal syenite complex are reported for the first time, and are found to be of three types i.e. without nepheline (AI-93/59), with nepheline (AI-86/59) and with sodalite and nepheline (AI-95/59) as critical minerals. Texturally AI-93/59 is medium to fine grained (1.5mm to ~0.1mm, AI-86/59 is coarse grained to fine grained (3.5mm to about 0.1mm), subhedral to anhedral with chessboard texture shown by albite grains due to replacement of microcline as islands in one or two cases were observed. AI-95/59 is a fine-grained albitite as it has dominantly 0.5 to 0.1mm grains with coarser grains upto 1.0mm. Microcline replacement is shown by albite. Albite in all the four samples is 81-86%, which makes the rock albitite. Minor minerals are microcline 3 to 10%, nepheline 3%, sodalite 3%, cancrinite 3%, carbonate 2%, sphene 1.5%, zircon 0.5%, arvedsonite 1%, agerine 1%, etc.

Babaji Syenite: Five samples of microcline-albite pegmatites were studied petrographically, which are coarse to medium grained with some fine grains (0.2 to 0.6mm) in the interstices. Most of the grains are subhedral to anhedral. Sample BO-74/59 shows graphic to subgraphic intergrowth of microcline with quartz. Samples BO-72/59 and BO-73/59 are albite-microcline aplite and microcline-albite aplite respectively. The former is very fine grained while later is medium grained.

Ambela Granite: Two samples of quartz porphyry and one sample of microcline pegmatite were studied under polarizing microscope. The porphyry sample shows microporphyritic texture due to the presence of coarser minerals of quartz, microcline and albite generally 2 to 2.5mm in size in a groundmass of microcline, quartz, albite, biotite, muscovite, arfvedsonite, epidote, zoisite, etc.

DISCUSSION

The four S-type granitic complexes and one I-type alkaline complex were studied and investigated for acid minor and alkalic minor bodies respectively. A detailed classification of the minor bodies is given above based on texture, mineral distribution and zonation which distinguish them from the host granites as minor intrusions. Many geologists are of the view that granitic pegmatites are derived from the large granitic plutons. Thus the pegmatites represent late residual fraction of silicic melts i.e., rest magmatic solutions moving out of a crustal laden mush to form small pools within the granitic pluton (Ashraf, 1994 and 1992) or travelled in the surrounding rocks. In these pods segregation of alkalies can occur in significant degree if a pegmatite magma becomes saturated with volatile constituents (Jahns and Burnham, 1963). The rest magmatic solutions produce pegmatites, aplites and albitites witin short distances, in Malakand, Swat and Lahor granitic complexes. This is contrary to what has been observed in case of acid minor bodies of Mansehra granitic complex where albitites and albite-quartz rich bodies occur in deeper part of the batholiths and upstairs occur as zoned pegmatites (London, 2006 and Ashraf, 1994).

Many authors (London, 1996, Jahns, 1982 and Ashraf, 1974) suggested that the pegmatites generally are not vapour saturated upon emplacement but become so with crytalliztion. Thus from saturation in a single crystalline phase to multiple crystalline assemblages occur with decreasing temperature. The granitic pegmatites so derived from multiphase mineral assemblages at the on set of crystallization forming border zones to singly saturated units at the end developing microcline zones and quartz cores.This is evident for most of the zoned pegmatites of Ilam granitic complex pegmatite forming model advocated by London (1996) belong to low rates of crystal nucleation from a fluxed boundary layer which is generated from flux viscous granitic melt. The field and petrographic informations gathered so far by us do no show any rare mineralization like beryl, columbite, tantalite, lithium mica etc. in the four granitic complexes. However, Butt (1985) has reported blue beryl and uranium mineralization in the top reaches of Ilam granite.

The albitites/albitized acid minor bodies associated with Malakand granite gneiss and Lahor granite gneiss have dominant phase of albite with minor microcline and quartz. These albitites are

without rare complex minerals, like, columbite, tantalite, cassiterite, etc.

In these four complexes the zoned pegmatites are being mined for potash feldspar and albitite for their ultimate use in glass and ceramic industries. In our views the product should be upgraded by washing, high intensity magnetic separation, etc. to produce high quality ceramic and glass products.

The alkaline complexes in some part of the world are very interesting for their rare minerals in the host rock and the pegmatites (Chakhouradian and Mitchell, 2002). One of such complex pegmatites, also, occurs in Pakistan in Ambela-Koga alkaline complex. The Koga nephline syenite (alkaline) complex is itself coarse, medium and fine grained entity. The former two are prone to magnetic separation to produce very low iron products. This complex has also sizeable pegmatites and albitites bodies which can also be used after beneficiation in glass and ceramic industries.

CONCLUSIONS

1. All the granites studied so far have numerous pegmatites which vary from stringer to large size bodies, except in granite gneiss exposed in Alpurai-Yakhtangi area which has very thin stringer like couple of bodies of smaller extent.
2. After a reconnaissance visit to Mansehra granitic complex it is found that Na-Feldspar bodies (albitites) are numerous and are being mined whereas K-feldspar (Microcline) bearing deposites are depleting.
3. Mining operations for the extraction of K-feldspar from a pegmatite body in Ilam granite gneiss in Karakar area, Swat are already in progress. Besides, some small-scale mining is also being carried out at a few places in Jalalkot-Dheri area, from pegmatites of Malakand granite gneiss. In both these areas the K-feldspar being mined is of graphic to sub-graphic texture. Therefore the ceramic/glass industries are not getting pure K-feldspar. However, the Karakar Mine can yield better quality K-feldspar as it has larger crystal of K-feldspar.
4. There are large size feldspathic bodies in Besham area associated with Lahor granitic complex. From these bodies iron free albite and microcline can be obtained after beneficiation.
5. Koga pegmatitic nepheline syenite has a better scope for its use in ceramic and glass industry after beneficiation.

AKNOWLEGEMENTS

We are thankful to Prof. Emeritus Dr. M. Nawaz Chaudhry for reveiwing our paper. We are thankful to Dr. S. Shahid Hussain, Director of Natural History Museum, Islamabad, for providing field facilities. Financial support provided by Pakistan Science Foundation is gratefully acknowleged to accomplish this work.

REFERENCES

Ahmed, A., Mateen, A., Rogers, G., Chaudhry, M.N., and But, K.A. (1997), "Rb-Sr Geochronology of the Lower Swat Granitic Gneisses, NW Himalayas, Pakistan", Abstract Volume, 3rd Pakistan Geological Congress, Peshawar p 6 Pakistan

Ashraf, M. (1974), "Geochemistry and Petrogenesis of Acid Minor Bodies of Mansehra and Batgram Area, Hazara District", Ph.D. Dissertation, University of the Punjab, Lahore 232p Pakistan

Ashraf, M. (1974), "Geology and Petrology of Acid Minor Bodies from Mansehra and Batgram Area, Hazara District", *Geological Bulletin of the Punjab University*, **11** pp 81-88 Pakistan

Ashraf, M., and Chaudhry, M.N. (1976), "Geology and Classification of Acid Minor Bodies of Mansehra and Batgram Area, Hazara Division, Pakistan", *Geological Bulletin of the Punjab University*, **12** pp 1-16 Pakistan

Ashraf, M., Chaudhry, M.N. (1978), "A Discovery of Carbonatite from Malakand", *Geological Bulletin of the Punjab University*, **14** pp 89-90 Pakistan

Ashraf, M., Chaudhry, M.N., Hussain, S.S. (1980), "General Geology and Economic Significance of the Lahor Granite and Rocks of Southern Ophiolite Belt in Allai Kohistan Area", *Geological Bulletin of Peshawar University*, **13** pp 207-213 Pakistan

Ashraf, M., Chaudhry, M.N. and Hussain, S.S. (1987), "Mineralization Associated with the Alkaline Rocks and Carbonatites in NWFP, Pakistan", *Kashmir Journal of Geology*, **5** pp 51-64 Pakistan

Ashraf, M., Chaudhry. M.N. and Hussain, S.S. (1994), "Geology of the Lead-Zinc-Molybdenum, Copper and Iron Skarns of the Besham Area, Kohistan, NWFP, Pakistan", *Kashmir Journal of Geology*, **11-12** pp 1-27 Azad Jammun & Kashmir

Anczkiewicz, R., Oberli, F., Burg, J.P., Meier, M., Dawood, H. and Hussain, S.S. (1998), "Magmatism South of the Indus Suture, Lower Swat, Pakistan", *Geological Bulletin of Peshawar University,* **31** pp 7-9 Pakistan

Anczkiewicz, R., Burg, J.P., Meier, M., Oberli, F., Vance, D., Dawood, H., Hussain, S.S., Ghazanfar, M. and Chaudhry, M.N. (1997), "Tectonometamorphic Evolution of the Indus Suture Viewed by Structural and Isotopic Data, Lower Swat, NW Himalaya, Pakistan:", In: 12th HKT Workshop International Procceedings, Rome, pp 3-4 Italy

Baig, M.S. and Lawrence, R.D. (1987), "Precambrian to Early Paleozoic Orogenesis in the Himalayas", *Kashmir Journal of Geology,* **5** pp 1-22 Azad Jammun & Kashmir

Baig, M.S. (1990), "Structure and Geochronology of Pre-Himalayan and Himalayan Orogenic Events in the Northwest Himalayas, Pakistan, with Special Reference to the Besham Area, Ph.D. Dissertation (un-published), Oregon State University, Corvallis, Oregon 397p USA

Baloch, I.H., Dunham, A.C. and Ghazanfar, M. (1994), "Geology of the Koga Feldspathoidal Syenite Complex, NW Pakistan", *Pakistan Journal of Geology*, **2-3** pp l-8 Pakistan

Butt, K.A. (1983), "Petrology and Geochemical Evolution of Lahor Pegmatoid/Granite Complex, Northern Pakistan and Genesis of Associated Pb-Zn-Mo-U Mineralization", In: Granites of Himalayas, Karakoram and Hindukush (Ed. Shams, F.A.), Institute of Geology, University of the Punjab, Lahore pp 309-326 Pakistan

Butt, K.A. and Shah, Z. (1985), "Discovery of Blue Beryl from Ilam Granite and its Implications on the Genesis of Emerald Mineralization in Swat District", *Geological Bulletin of Peshawar University*, **18** pp. 75-81 Pakistan

Chakhmouradian, A.R. and Mitchell, R.H. (2002), "The Mineralogy of Ba-and Zr-Rich Alkaline Pegmatites from Gordon Buute, Crazy Mountains (Montana, USA): Comparision between Potassic and Sodic Agpaitic Pegmatites", *Contributions to Mineralogy and Petrology,* **142** pp 93-114 Netherlands

Chaudhry, M.N., Jafferi, S.A. and Saleemi, B.A. (1974), "Geology and Petrology of the Malakand Granite and its Environs, *Geological Bulletin of the Punjab University,* **10** pp 43-58 Pakistan

Chaudhry, M.N., Ashraf, M., Hussain, S.S. and Iqbal. M. (1976), "Geology and Petrology of Malakand and a Part of Dir (Toposheet 38 N/14)", *Geological Bulletin of the Punjab University*, **12** pp 17-39 Pakistan

Chaudhry, M.N., Ashraf, M. and Hussain, S.S. (1981), "Petrology of Koga Nepheline Syenites and Pegmatites of Swat District", *Geological Bulletin of the Punjab University,* **16** pp 83-97 Pakistan

Chaudhry, M.N., Ashraf, M. and Hussain, S.S. (1983), "Lead-Zinc Mineralization of Lower Kohistan District, Hazara Division, NWFP, Pakistan" *Kashmir Journal of Geology*, **1(**1) pp 31-37 Azad Jammun & Kashmir

Chaudhry, M.N., Ghazanfar, M., Ashraf, M. and Hussain, S.S. (1984), "Geology of the Shewa-Dir-Yasin Area and its Plate Tectonic Interpretation", *Kashmir Journal of Geology*, **2**(1) pp 53-63 Azad Jammun & Kashmir

Chaudhry, M.N., Hussain, S.S. and Dawood, H. (1992), "The Lithostratigraphic Framework of the North-West Himalayas, South of the Main Mantle Thrust along Mingora-Daggar Section, Swat, Pakistan", *Pakistan Journal of Geology,* **1** pp 29-40 Pakistan

Chaudhry, M.N., Ghazanfar, M., Ramsay, J.G., Spencer, D.A., and Qayyum, M. (1994a), "Northwest Himalayas-A Tectonic Subdivision", In: Geology in South Asia (Ed. Ahmed I.R. and Sheikh, A.M.), Proceedings of First South Asia Geological Congress, Islamabad pp 175-184 Pakistan

Chaudhry, M.N., Hussain, S.S and Dawood, H. (1994b), "Position of the Main Central Thrust and Subdivision of Himalayas in Swat, Pakistan", Proceedings of First South Asia Geological Congress, Islamabad pp. 208-211 Pakistan

Clemens, J.D. (2003), "S-Type Granitic Magma-Petrogenetic Issues Models and Evidence", *Earth-Science Reviews*, **61**(1-2) pp 1-18 Netherlands

Fletcher, C.J.N., Leake, R.C. and Haslam, H.W. (1986), "Tectonic Setting, Mineralogy and Chemistry of a Metamorphosed Stratiform Base Metal Deposit within the Himalayas of Pakistan", *Journal of Geological Society of London*, **143** pp. 521-536 UK

Hamidullah, H., Jabeen, N., Bilqees, R. and Jamil, K. (1986), "Geology and Petrology of the Malakand Granite Gneiss and Metasedimentary Complex", *Geological Bulletin of Peshawar University*, **19** pp 61-76 Pakistan

Humayun, M. (1985), "Tectonic Significance of Mylonites from Mingora, Swat", *Geological Bulltin of Peshawar University*, **18** pp 137-146 Pakistan

Hussain, S.S., Chaudhry, M.N. and Dawood, H. (1992), "Mineralization and Petrogenetic Study of Rocks along the Indus Suture Zone", 1st Annual Report: Research Project C-PMNH/Earth (38) 186p Pakistan

Jahns, R.H. (1982), "Internal Evolution of Pegmatite Bodies", In: Granitic Pegmatites in Science and Industry (Ed. Cernay, P.), Mineralogical Association of Canada, Short Course Handbook, **8** pp 293-327 Canada

Kempe, D.R.C. and Jan, M.Q. (1970), "An Alkaline Igneous Province in the NWFP, Pakistan", *Geological Magazine*, **107** pp 395-398 UK

Kazmi, A.H., Lawrence, R.D., Dawood, H., Snee, L.W. and Hussain, S.S. (1984), "Geology of the Indus Suture Zone in the Mingora-Shangla area of Swat", *Geological Bulletin of Peshawar University*, **17** pp 127-144 Pakistan

La Fortune, J.R., Snee, L.W. and Baig, M.S. (1992), "Geology and Geochemistry of Indian Plate Rocks South of Indus Suture Zone, Besham Area, NW Himalayas, Pakistan", *Kashmir Journal of Geology*, **10** pp 27-52 Azad Jammun & Kashmir

London, D. (1996), "Granitic Pegmatites", Trans Royal Society of Edinburg, *Earth Science*, **87** pp 305-319 UK

Mian, I. (1987), "The Mineralogy and Geochemistry of the Carbonatite, Syenites and Fenites of North-West Frontier Province, Pakistan", PhD Dissertation (un-published) Leicester University, UK

Rafiq, M. and Jan, M.Q. (1989), "Geochemistry and Petrogenesis of the Ambela Granitic Complex, NW Pakistan", *Geological Bulletin of Peshawar University*, **22** pp 159-179 Pakistan

Siddiqui, S.F.A. (1965), "Alkaline Rocks of Swat Chamla", *Geological Bulletin of the Punjab University*, **5** p 52 Pakistan

Siddiqui, S.F.A., Chaudhry, M. N. and Shakoor, A. (1968), "Geology and Petrology of the Feldspathoidal Syenites and the Associated Rocks of the Koga Area, Chamla Valley, Swat, West Pakistan", *Geological Bulletin of the Punjab University*, **7** pp 1-33 Pakistan

Treloar, P.J., Coward, M.P., Williams, M.P. and Khan, M.A. (1989), "Basement-Cover Imbrication South of the Main Mantle Thrust, North Pakistan", *Geological Society of America, Special Paper 222* pp 137-152 USA

Treloar, P.J., Rex, D.C., Guise, P.G., Coward, M.P. and Luff, I.W. (1989), "K-Ar and Ar-Ar Geochronology of the Himalayan Collision in NW Pakistan: Constraints on the Timing of Suturing, Deformation, Metamorphism and Uplift", *Tectonics*, **8** pp 881-909 USA

Vince, K.J. and Treloar, P.J. (1996), "Miocene, North Verging Displacement along the Main Mantle Thrust, NW Himalayas, Pakistan", *Journal of the Geological Society of London*, **153** pp 677-680 UK

Zeitler, P.K., Tahirkheli, R.A.K., Naeser, C.W. and Johnson, N.M. (1982), "Unroofing History of a Suture Zone in the Himalayas of Pakistan by Means of Fission Track Annealing Ages", *Earth and Planetary Science Letters*, **57** p 227-240 Netherlands