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Field features and petrography used as indicators for the classification of Shigar valley pegmatites, Gilgit-Baltistan region of Pakistan

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Abstract

On the basis of field features and petrography, Shigar valley pegmatites are classified broadly into Group-I and Group-II pegmatites. The Group-I pegmatites are further divided into muscovite-schorl-beryl-garnet pegmatites and muscovite-schorl pegmatites. The muscovite-schorl-beryl-garnet pegmatites are more productive for gemstones. The Group-II pegmatites are classified as biotite ± garnet ± muscovite pegmatites and muscovite-biotite ± garnet pegmatites. The complete absence of biotite and the higher percentage of muscovite in the gemstone bearing class of pegmatites can be used as indicators for gemstone exploration.

Keywords: Petrography; Classification; Pegmatites; Gemstones

1. Introduction

Shigar valley is about 32 km north east of Skardu, the district headquarter of Baltistan in Gigit-Baltistan region of Pakistan and an access for entry to the K-2, the second highest peak of the world after Mount Everest (Fig. 1). This valley is not only known for the gemstone occurrences but also record regional tectonics as Northern suture which welds Asian continent with Kohistan-Ladakh island arc passes through this valley. There are gemstone-bearing and gemstone-barren pegmatites in the valley which need to be delineated on the basis of field observations and petrographic studies. This study is an attempt to distinguish different types of pegmatites in the valley and to discuss their origin for final conclusions.

2. Field features and petrography

Based on field features, Shigar valley pegmatites are classified into two groups. Hereafter referred as the Group-I pegmatites which are gemstone-bearing and the Group-II pegmatites, gemstone-barren. The Group–I pegmatites are further divided into muscovite-schorl-beryl-garnet pegmatites and muscovite-schorl pegmatites.

2.1. Group-I pegmatites

The muscovite-schorl-beryl-garnet pegmatites are very coarse-grained and zoned. These are intruded in Dassu orthogneiss with sharp contact. The coarseness is from margin to core indicating the direction and sequence of crystallization and symmetrical zoning (Plate 1). Zoned pegmatites are typified by fine-grained aplitic border zone, the intermediate zone and the central quartz zone. Gemstones are generally found in the intermediate zone. There are some other pegmatites where inner zone is absent. It is generally noted that aplites are present at the border zones and occasionally may also occur in the cores of pegmatites (Laurs et al., 1998). The Shigar valley pegmatites are either without aplites or if present occupy the margins.

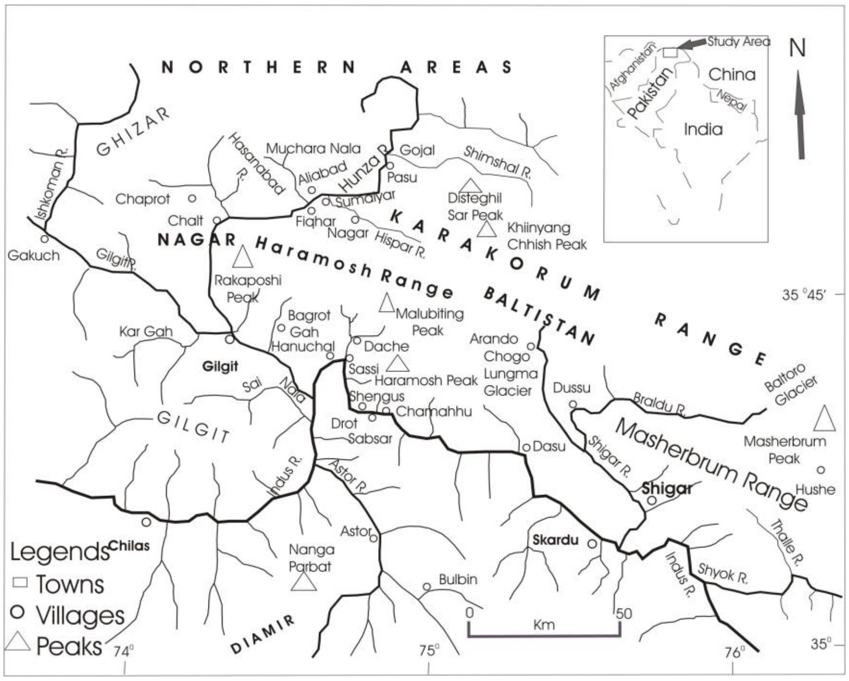

Fig. 1. Location map of the Shigar valley, northern areas of Pakistan.

Petrography shows inequigranular as well as equigranular textures. The muscovite-schorl-beryl-garnet pegmatites contain (in volume percent) plagioclase 18 to 60, orthoclase 9 to 34 and quartz 25 to 35 as essential minerals whereas muscovite 3 to 24, tourmaline traces to 15, garnet traces to 3, epidote traces to 1, apatite traces to 2, zircon and opaque in traces are present as accessories (Table 1). Some orthoclase grains from the pegmatites of Kashmol and Goyungo areas are microperthites. K-feldspar and plagioclase show alteration into muscovite, epidote, sericite, and kaolinite. The alteration generally occurred along margins or micro-fractures of the grains. Unaltered plagioclase grains are also common and exhibit well-developed albite twinning. The crystals of plagioclase are generally tabular to bladed and most of the grains are subhedral whereas the orthoclase grains are mostly anhedral. In some plagioclase, bending is well noticed, which indicates that these pegmatites have gone through regional stresses as is evident from the pegmatites of Dassu area (Plate 2).

In addition, overgrowths and cross cutting relationships within the plagioclase are also common in the pegmatites exposed at Kashmol and Goyungo. Minute tabular grains of plagioclase are also present as inclusions within the orthoclase, indicating their earlier crystallization. On the basis of anorthite contents, the main plagioclase identified is albite. It is typically associated with certain gemstones and is the characteristic feldspar of gem-bearing pegmatites (Laurs et al., 1998; London, 1986; Nabelek et al., 1992). Quartz occurs as discrete anhedral grains as well as interstitial mass. Tiny quartz inclusions are also present within feldspars, garnet and muscovite. Pressure shadows or undulose extinction is common in quartz that shows deformation.

The intergrowths and overgrowths are the common features of the muscovite itself but some muscovites are also intergrown either with plagioclase or orthoclase. Muscovite also occurs as sericite along the margins and fractures of orthoclase. The samples collected from the Dassu, Yuno, Nyit and Goyungo pegmatites are relatively enriched in tourmalines. Euhedral to subhedral tourmaline (schorl) crystals along with fractured crystals of garnet are well noticed in some of the thin sections (Plate 3). Some of the pegmatites also contain zoned tourmalines. Garnet is present as small inclusions within plagioclase in the pegmatites of Kashmol area. Subhedral apatite and titanite are also present in traces. In sample number 32 collected from Goyungo area, the apatite up to 2 vol. % has been noticed. Euhedral crystals of zircon in traces are also found in few thin sections. The opaque phases are present as disseminated grains.

Plate 1. Photograph showing a symmetrical zoned gem-bearing pegmatite at Dassu. The internal zoning is complex and is without the central quartz zone. The border zone at the top and bottom is fine-grained and aplitic. The intermediate zone is rich in schorl

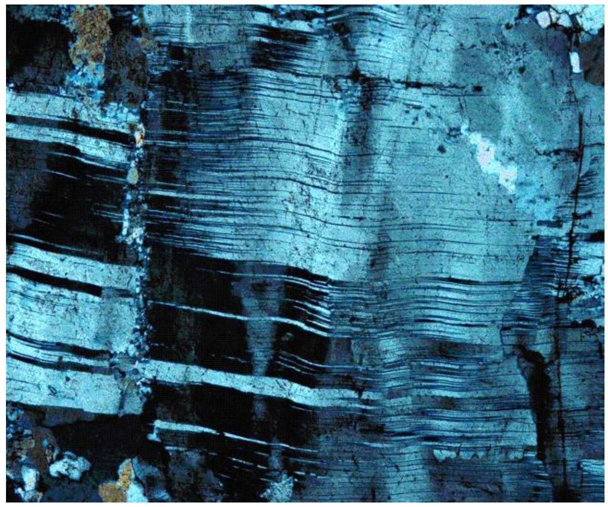

Plate 2. Photomicrograph showing displacement and kinking in the plagioclase. A micro quartz vein is visible at left side. (Mag: 4× / 0.1)

Table 1. Modal composition (visual estimation) of the gem-bearing pegmatites from different localities of the Shigar valley.

a. Muscovite-schorl-beryl-garnet pegmatites													b. Muscovite-schorl pegmatite				
Section #	**DAS-19**	**DAS- 23**	**NYT-28**	**NYT-29**	**GOY-32**	**GOY-33**	**GOY-43**	**GON-47**	**YUN-62**	**YUN-63**	**KSH-66**	**KSH-68**	**NYT-54**	**KSH-74**	**SIL-81**	**ALCH-97**	**HAS-98**
Alkali feldspar	34	9	20	30	20	18	30	30	16	15	9	16	36	16	10	15	28
Plagioclase	18	60	25	25	25	50	36	23	40	35	45	40	30	44	55	55	32
Quartz	28	25	33	27	30	26	25	28	35	25	25	27	25	28	30	26	30
Biotite	tr	–	–	–	–	–	–	–	–	tr	–	–	tr	–	–	1	–
Muscovite	20	4	22	3	20	3	3	15	8	24	18	15	8	12	5	3	10
Garnet	tr	–	–	tr	tr	tr	–	tr	tr	1	3	1	–	–	–	–	–
Tourmaline	tr	2	–	15	3	3	6	3	–	–	–	1	–	tr	–	–	tr
Apatite	–	tr	–	–	2	tr	–	1	tr	tr	tr	tr	tr	–	tr	tr	tr
Epidote	tr	tr	tr	-	–	–	-	-	1	tr	tr	tr	tr	tr	–	tr	–
Sphene	–	–	–	–	tr	tr	–	–	–	–	–	–	tr	–	–	–	–
Zircon	–	–	–	–	–	–	–	tr	–	–	tr	–	tr	–	–	–	–
Opaque	tr	–	–	–	–	–	–	–	–	tr	–	–	1	tr	tr	tr	–
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Key:-DAS=Dassu;NYT=Nyit;GOY=Goyungo;KSH=Kashmol;GON=Gone;YUN=Yuno;SIL=Sildi;ALCH=Alchuri; AS=Hashupa

The muscovite-schorl pegmatites which are the second sub-class of Group-I pegmatites, are coarse to medium-grained and light-gray to white and yellowish brown on fresh and weathered surfaces respectively. Feldspars, quartz, muscovite, tourmaline (schorl) and garnet are prominent minerals. Muscovite also occurs as 3-4 cm cleavable sheets.

Sample number 54 was taken from pegmatites at Gone village (Fig. 1), which are extensively mined for aquamarine, topaz, and quartz etc. These pegmatites are only exposed from Goyungo along the Braldu River up to Sildi villages. It is important to mention here that even the pegmatites are not exposed from Alchuri to proper Shigar but their samples were also seen as transported material in nearby streams.

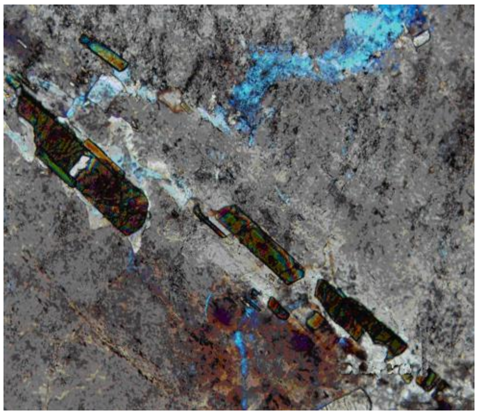

Plate 3. Photomicrograph showing euhedral tourmaline crystals aligned in one direction and are included in orthoclase (cross light, Mag: 4× / 0.1).

Petrography indicates their coarse-grained texture. Main minerals constituting the pegmatites include (in volume percent) orthoclase 10 to 36, plagioclase 30 to 55 and quartz 25 to 30. Amongst the accessory minerals, muscovite is the main constituent amounting up to 20 vol. % (Table 1). Other minor constituents such as biotite, tourmaline, apatite, epidote, titanite and zircon are either absent or present in trace amounts. Opaque phase is present from trace to about 1 vol. %. Orthoclase and plagioclase are usually fresh occasionally altered to sericite and epidote. K-feldspar occurs as orthoclase and perthite. Plagioclase crystals are commonly tabular, lath-like and mostly subhedral to euhedral. Inclusions of muscovite and quartz within orthoclase and plagioclase are also seen in few thin sections. In section number 97, the overgrowth and cross-cutting relationships within plagioclase are also noticed. Some plagioclase grains also show micrographic texture. The majority of quartz crystals are anhedral to subhedral, however, in some cases fresh-looking euhedral quartz are also noticed in the pegmatites near Sildi village. Quartz grains in majority of the samples are strained and undulose whereas plagioclase grains exhibit kinking in some samples. This indicates that the pegmatites were subjected to regional stress.

Among the accessory minerals, muscovite is most dominant phase and its large flakes are well cleaved and showing intergrowths and overgrowths too. In a few muscovite flakes the biotite and quartz are noticed as inclusions. The opaque minerals are present in traces. Iron-leaching is observed along the micro-fractures near the opaque phases. Garnet and tourmaline noticed in hand specimens, are almost absent except a few subhedral-anhedral tourmaline in the pegmatites exposed in Kashmol area. Besides, euhedral apatite, zircon and titanite are also present in trace amounts.

2.2. Group-II pegmatites

The gemstone-barren pegmatites, which are the second class of pegmatites are further divided into biotite ± garnet ± muscovite pegmatites and muscovite-biotite ± garnet pegmatites.

Biotite ± garnet ± muscovite pegmatites are medium to coarse-grained. These are greenish white grayish yellow on fresh and weathered surfaces. Orthoclase, plagioclase, quartz and biotite are diagnostic in hand specimens. Biotite is present in significant amount whereas tourmaline and muscovite are absent. However, muscovite was noticed in traces in a sample collected from a pegmatite exposed at Mungo village. Such kinds of pegmatites are also exposed at Haiderabad and Goyungo villages of the Shigar valley area (Fig. 1).

In thin sections, these pegmatites contain (in volume percent) orthoclase 36 to 45, plagioclase 16 to 23 and quartz 30 to 35 as essential minerals whereas biotite, garnet, muscovite, apatite, epidote, titanite, tremolite-actinolite and opaque minerals occur as accessories. These pegmatites are distinguished from other pegmatites of the area in having no gemstones but with abundant orthoclase (Table 2). In the accessory minerals biotite is present up to 10 vol. % whereas other minor minerals amount in traces, except garnet, which in one sample (MUN- 3) reaches up to 1 vol. %.

Orthoclase and plagioclase exhibit partial to complete alteration. Orthoclase is altered along margins and fractures to sericite, kaolinite and muscovite. The plagioclase grains normally exhibits saussuritization either along the margins or cleavages. Small tabular crystals of plagioclase are also present as inclusion in the orthoclase representing an earlier crystallization of plagioclase. Anorthite contents of these plagioclases are in the range of oligoclase (An_{15-30}). Kink bending in plagioclase is also observed. K-feldspar occurs as orthoclase and perthites. Quartz grains are mostly subhedral to anhedral and occur as individual grains or interstitial mass. In certain cases both the orthoclase and quartz grains show undulose extinction. In addition, quartz is also present as inclusions in feldspars and in deformed garnets. The garnets are mostly euhedral-subhedral but certain crystals are highly fractured. In addition, iron leaching may also be seen.

The second sub-class of the Group-II pegmatites includes muscovite-biotite ± garnet pegmatites. Feldspars quartz, muscovite and biotite are also prominent in hand specimens. Garnet occurs as disseminated grains. Sample number 38 and 41 were taken from the more felsic pegmatites, exposed along upstream of Braldu River after the village of Goyungo.

Petrographic studies show that these pegmatites are medium to coarse-grained and inequigranular. Major mineral constituents are (in volume percent) orthoclase 25 to 42, plagioclase 15 to 40 and quartz 26 to 35 whereas main accessories are biotite 2 to 6 and muscovite 2 to 8. Garnet, titanite, epidote, apatite, zircon and opaque occur in traces.

Table 2. Modal composition (visual estimate) of gem-barren pegmatites from different localities of the Shigar valley.

a. Biotite ± garnet ± muscovite pegmatites				**b. Muscovite-biotite ± garnet pegmatites**					
Section #	**MUN-3**	**MUN-6**	**GON-48**	**MUN-1**	**MUN-5**	**MUN-7**	**DAS-21**	**GOY-38**	**GOY-41**
Alkali feldspar	40	45	36	26	25	30	42	38	40
Plagioclase	18	16	23	40	35	37	18	15	21
Quartz	30	35	33	27	35	26	33	32	34
Biotite	10	3	8	5	2	4	3	6	2
Muscovite	−	tr	−	2	3	3	4	8	3
Garnet	−	1	tr	−	−	−	−	tr	tr
Tourmaline	−	−	−	−	−	−	−	−	−
Apatite	1		tr	−	−	tr	−	1	tr
Epidote	−	tr	tr	−	−	−	tr	tr	
Sphene	1	tr	−	−	−	−	−	tr	tr
Tremolite/actinolite	tr	−	−	tr	−	−	−		−
Opaque	tr	−	tr	tr	−	−	tr	tr	tr
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Key:-MUN = Mungo; GON = Gone; DAS = Dassu; GOY = Goyungo

Orthoclase and plagioclase are generally subhedral to anhedral and hypidiomorphic. Likely, plagioclase is oligoclase with (An_{10-22}). The alteration products of both of the feldspar are sericite, kaolinite, muscovite, and epidote. Microperthitic texture is observed in some thin sections of these pegmatites. In addition, vermiculite texture is also noticed in one thin section. Quartz is mostly subhedral to anhedral, interstitial and exhibit undulose extinction. In addition, quartz is also seen as inclusions within the feldspar. Some euhedral crystals of apatite and titanite are also noticed in some samples. A few crystals of garnet are present as inclusion in orthoclase, indicating that garnet is crystallized prior to the feldspar.

3. Discussion

To classify the pegmatites into different types or sub-types, the earlier and pioneer contributions are from Fersman (1930), Cameron et al. (1949), Jahns (1953, 1955) and Brotzen (1959). Cameron et al. (1949) did detailed work on the zoning and paragenesis of individual pegmatites belonging to the same genetic type. The genetic classification and types such as the border zone, pegmatoid zone, core-margin zone, alkali replacements as proposed by Brotzen (1959) are still used in case of zoned pegmatites.

In the modern classification schemes of pegmatites, the most important contributions are of Stewart (1963; 1978), Jahns and Burnham (1969), Ginsburg et al. (1979), London and Burt (1982), Jahns (1982), Ćerný (1982a,b), Ćerný (1991a,b) and Baker (1998). In all these classifications, the most common parameters and criteria that are used for the classification of pegmatites are: the presence or absence of gemstones and various metals, parental magma, mode of occurrence, internal structure or zoning, presence or absence of accessory minerals, the distance from the parental plutonic body etc. Moreover, the constituent minerals or mineral assemblages are also used as basic criteria along with other parameters.

The present study has clearly identified the constituent mineral phases of the pegmatites of the Shigar valley and as a result different sub-types of pegmatites have been proposed. The field and microscopic studies indicate that the muscovite-schorl-beryl-garnet pegmatites sub-class of Group-I pegmatites, generally contain biotite none to traces but beryl, garnet, schorl, and muscovite are present as main accessory minerals. Majority of the pegmatites in the Shigar valley belong to this sub-class of pegmatites and can be considered to contain gemstones. Present studies further show that the pegmatites of the Shigar valley are mostly miarolitic. In thin sections, rare-earth bearing minerals could not be identified.

Present petrographic studies indicate that the main constituents especially the alkali feldspar and plagioclase feldspar of these pegmatites are partially to highly altered into sericite, muscovite and epidote etc, which may indicate hydrothermal alteration. Moreover, the undulose extinction of quartz, the bending within the plagioclase crystals and intensive fracturing of garnets indicate regional deformation. On the basis of anorthite contents, the gemstone-bearing class of pegmatites is albite enriched whereas oligoclase is found in the gemstone-barren pegmatites.

4. Conclusions

On the basis of present study, the Shigar valley pegmatites are classified broadly into two types, i.e., gemstone-bearing and gemstone-barren pegmatites. Further, depending on the presence or absence or the relative proportion of the accessory minerals, these pegmatites have also been classified into four sub-types which may be related genetically into one common source and the variations in their mineral occurrences may be due to fractional crystallization. It is also concluded here that in the proposed classes of pegmatites of the Shigar valley, the muscovite-schorl-beryl-garnet class of pegmatites is more productive for gemstones. Relatively the complete absence of biotite and the higher percentage of muscovite in the gemstone bearing class of pegmatites may be used as an indicator for further exploration of gemstones in the other areas of this region. The wavy undulation nature of majority of quartz grains and intensive fracturing of garnets indicate an overprint of regional stress.

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