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# Trace Elements in Muscovite As a Guide to Gem Tourmaline Bearing Pegmatites in Nepal

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## ABSTRACT

The pegmatites of Hyakule, and to a lesser extent, of Phakuwa area, Sankhuwa Sabha district, Eastern Nepal, have been a source for gem quality tourmaline since about 60 years. Only 4 pegmatite bodies, 2 each in Hyakule and Phakuwa, out of about 40 dikes altogether, yielded this precious stones despite at least 5 larger openings and probably some smaller ones in other dikes.

The Phakuwa and Hyakule area occupies the eastern limb of the Arun anticline and consists of high grade metamorphic rocks of possibly Precambrian age belonging to the basal part of the Higher Himalayan crystalline. These rocks thrust southward along the Main Central Thrust over the rocks of the Nawakot complex belonging to the Lesser Himalaya.

The metamorphic sequence, about 2500 m thick, consists mainly of gneisses, garnet-kyanite and garnet-staurolite mica schist, quartzites and marbles with intercalated minor calc-silicate rocks. Pegmatites occur in the mica schist and interbedded calc-silicate schist sequence (approximately 1000 m thick) as scattered lenses or possibly dikes of a few m in thickness, which cut discordantly through the host rocks. Internal zoning has developed generally into an upper blocky feldspar zone, a central quartz core with tourmaline and beryl (partly as aquamarine) and a lower fine grained, garnet bearing muscovite-quartz-feldspar zone. Schorl is quite frequent as is biotite, the latter is often more abundant than muscovite. Uraninite and Ta-Nb minerals (tantalite, wodginite, pyrochlore) as well as cassiterite have been found in heavy mineral concentrates of a few investigated pegmatite samples.

The current paper deals with several questions: what is the type of these pegmatites in terms of a classification? Do all pegmatites belong to the same generation and/or stage of evolution? Why are gem quality tourmalines known only from a few dikes? Is there an exploration method to distinguish between barren and gem tourmaline pegmatites in these areas? Could this method possibly be applied to other pegmatite areas in Nepal?

We used trace and some major element characteristics of 24 coarse grained muscovite samples from 19 pegmatite dikes in Phakuwa and Hyakule and from localities nearby to answer these questions. Additional 4 muscovite samples from gem tourmaline bearing and barren pegmatites in the Ilam district have been included for comparison. The trace element characteristics, some main elements and some element ratios of coarse grained muscovites in Hyakule and Phakuwa distinguish clearly between a group of gem producing and *barren* pegmatites. The most powerful distinguishing geochemical features are the concentration ranges of Rb, Ba, MnO and MgO and the element ratios K/Rb and Li/Mg. Less useful are the concentrations of Cs, Sn and Ta because of a somewhat irregular behaviour. Surprisingly, Li is rather low in all samples and does not discriminate very distinctly between the two pegmatite groups. The results of this study can probably be used as a rapid exploration tool in sorting out barren pegmatites from pegmatites with a potential for gem quality tourmaline.

## INTRODUCTION

For the last 60 years, Nepal was intermittently a minor producer of gem tourmaline of a fine quality. According to Bassett (1985, 1987), at least 1300 kg were extracted from the principal producing locality at Hyakule, Sankhuwa Sabha district, Eastern Nepal. Additional though minor amounts of tourmaline were produced from pegmatites at the village of Phakuwa closeby. Today, mining has nearly ceased because of geological diffi-

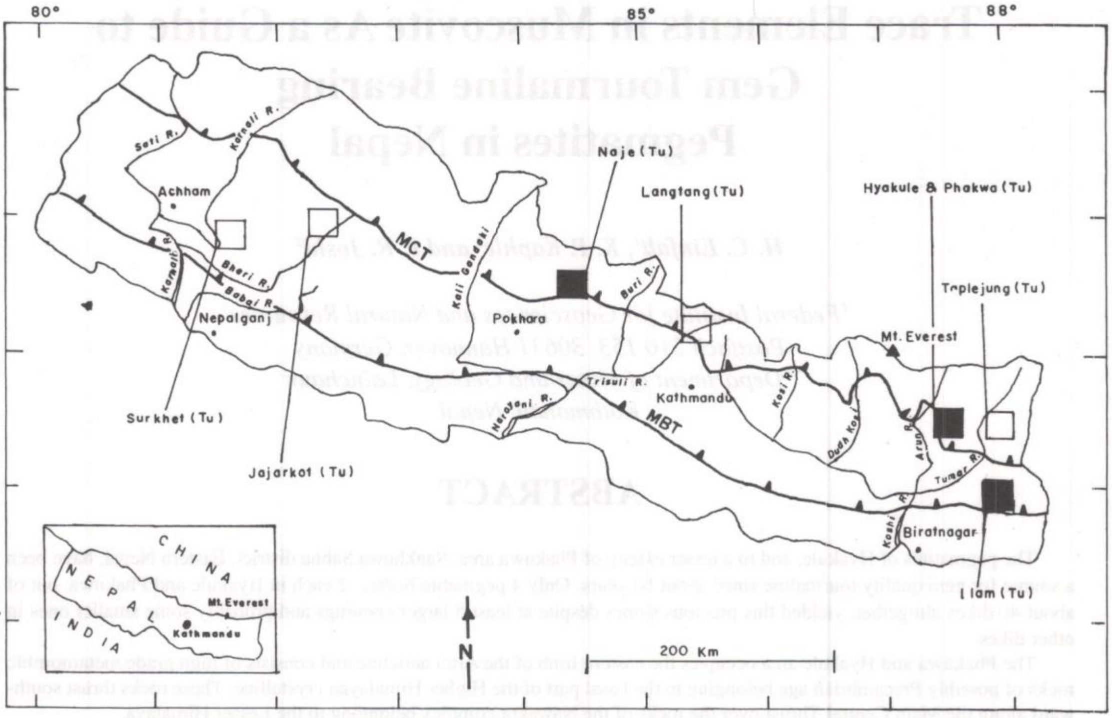


**Fig. 1 Localities known for gem tourmaline bearing pegmatites in Nepal (modified from Niedermayr et al. 1993, and United Nations 1993). Sampled localities are shown with solid squares.**

culties at the site, a lack of proper understanding of the lease holders in mining methods and unwillingness to invest money into the development of the property.

A few other places are also known in Nepal to produce gem tourmaline since about 10 years (Fig. 1 and Table 1), though there is no constant production

The investigation of the Phakuwa-Hyakule pegmatites aims at answering several questions:

- what is the type of pegmatites in terms of a classification?
- do all pegmatites belong to the same generation?
- why are gem quality tourmalines known only from a few pegmatites?
- is there a rapid exploration method to distinguish between gem tourmaline pegmatites and barren ones in this area?
- is this method possibly applicable to other pegmatite areas in Nepal?

Concerning the last question, a few samples from other pegmatite fields in Nepal (Ilam district and Naje/Manang district) are included in this study.

Joshi (1985, 1986) developed criteria to distinguish between barren and gem tourmaline pegmatites in the Phakuwa-Hyakule area, based mainly on a careful investigation of mineralogical composition and internal zonation. However, this method has the disadvantage of being time consuming and requiring good exposures in the field. Instead, a geochemical method was applied using the trace element pattern of coarse grained muscovites in search for mineralised pegmatites (Gordiyenko 1971, Trueman and Cerny 1982, Moller and Morteani 1987).

## GEM TOURMALINES OF NEPAL

The tourmalines from Hyakule and Phakuwa have been described comprehensively by Bassett (1985, 1987). In Hyakule, gem tourmaline crystals

**Table 1 Occurrences of coloured tourmalines in Nepal**

| Province | District | Locality | Host rock | colour | as gem | others | type | Reference |
|---|---|---|---|---|---|---|---|---|
| Western | Jajarkot | North of Surkhet | unknown | green | probably | unknown | unknown | BASSETT, 1987 |
| Western | Jajarkot | North of Surkhet | seric. sch. (dolom.marb.) | yellow-brown, orange | doubtful (fract.) | unknown | dravite | ARYAL, pers. comm. BASSETT, 1985 |
| Western | Manang | Naje | pegmatites | yellow-green | yes | unknown | elbaite | UNITED NATIONS, 1993 |
| Central | Langtang valley | unknown | unknown | pink | probably | unknown | unknown | BASSETT, 1987 |
| Eastern | Taplejung | N of Taplejung, Ikhabu pegmatite | pegmatite | unknown | yes | unknown | unknown | BASSETT, 1987 |
| Eastern | Taplejung | near Phabung, north Mewa Khola | unknown | yellow-brown | doubtful (fract.) | unknown | dravite | BASSETT, 1987 |
| Eastern | north. Bhojpur | unknown | unknown | unknown | unknown | unknown | unknown | unconfirmed |
| Eastern | Sankhuwa Sabha | Mayum vill. near Chainpur, Chokte pegmatite(s) | pegmatites | blue ?? | yes | unknown | | BASSETT, 1985 |
| Eastern | Sankhuwa Sabha | Ranidunga Danda, Thurbu pegmatite | pegmatite | unknown | yes | unknown | unknown | BASSETT, 1987 |
| Eastern | Sankhuwa Sabha | Mangsima east of Num | pegmatite(s) | unknown | yes | unknown | unknown | BASSETT, 1987 |
| Eastern | Sankhuwa Sabha | Phakuwa | pegmatites | multi (no blue) | yes | aquam. | elbaite | BASSETT, 1985 |
| Eastern | Sankhuwa Sabha | Hyakule | pegmatites | multi (no blue) | yes | aquam. | elbaite | BASSETT, 1985 |
| Eastern | Ilam | various places | pegmatites | olive-green | yes | unknown | elbaite | TAMRAKAR, pers.comm. |

up to 15 cm or more in length was produced. The crystals are frequently zoned with bands of brown, yellow and olive green followed by pink and rose to colourless outward. The most common colour is rose or pink, yellow crystals of good quality are comparatively rare. Melon coloured tourmalines (pink with a green shell) also occur. No blue tourmalines are known from this locality (and from Nepal in general). Very small pink coloured crystals were found in the massive part of the pegmatite. Joshi (1985) reported polychrome tourmaline from the massive part of the pegmatite interlocked with quartz and feldspars, unsuitable for facetting.

In Phakuwa, gem tourmaline was of dark brown, amber and green colour, including a rare emerald green. Single crystals were only of a few cm in size, occurring in small pockets in the intermediate and the core zone (Joshi 1985).

The tourmalines from Naje are greenish yellow to olive-green. They occur in the massive quartz core, often together with dark blackish green schorl. It is not known whether a pocket zone developed in these pegmatites. On a cm scale, cavities with protruding platelets of albite and radiating, mm-thin yellow tourmaline needles were observed in one of the pegmatites. This zone developed by alkali metasomatic reactions, replacing coarse grained microcline with albite and forming small cavities by dissolution.

No data are available for the gem tourmalines from the Ilam district except that crystals are zoned with various shades of green colour (Tamrakar *pers. comm.*).

Until recently, little was known about the chemical composition of tourmalines from Nepal. Bassett (1985) was probably the first to analyse a yellow tourmaline from Hyakule, revealing a high MnO content of 5.77%, a fairly high Li and a low Fe concentration as the main characteristics (Table 2). Qualitative microprobe analyses on a zoned tourmaline indicated low Mn contents in the light yellow outer zone, a high Mn content for the medium dark brown to very dark brown shell and the highest concentration for the medium yellow core (Bassett, unpubl. manuscript). The yellow to brownish colour of tourmalines (including samples from Hyakule) was related by Rossman and Mattson (1986) to a Mn - Ti intervalence charge transfer. Recently, further analytical data from Hyakule and Naje (Niedermayr et al. 1993) confirmed the high MnO content in the yellowish green gem tourmalines (from Hyakule and Naje), whereas pink tourmalines (from Hyakule) have low MnO values (Table 2).

A black (at the thin edges slightly dark greenish black translucent tourmaline), and a yellowish green tourmaline of gem quality save for the abundant fractures and inclusions, both from Naje, were partially analysed. The data demonstrate a drastic decline in Fe content and a strong increase in Mn and Al from the early precipitated schorl to the late crystallised gem type tourmaline of elbaite composition (Table 2).

## SAMPLE PROVENANCE, PREPARATION AND CHEMICAL ANALYSIS

Altogether 29 muscovite samples were collected from 25 pegmatites at the three investigated areas (Phakuwa-Hyakule:20; Ilam: 4; Naje: 1). In addition, one lepidolite sample from the main pegmatite at Hyakule and 2 tourmaline fragments (schorl and elbaite) from one of the Naje pegmatites were taken for chemical analysis.

Samples were hand picked by selecting coarse grained, clean muscovite books (a few cm, rarely only 1 cm in size) from outcrops, hand specimen and in a few cases from mine waste. No further cleaning was done except for a visual screening of fragments with the aid of a hand lens (10x) for adhering or intergrown silicates and iron stained flakes. This procedure aims at a rapid, time saving preparation for use in exploration. It is assumed, that only the Fe content (total Fe as $Fe_2O_3$) is not reliable, since small iron oxide particle may still have been present in some samples.

Grinding was done either in an agate or in a steel mortar. For the latter procedure, contamination by Cr in one sample batch was evident.

The chemistry of the muscovites, the lepidolite and the two tourmalines was determined in a routine

**Table 2 Chemistry of tourmalines from pegmatites in Nepal; sources: BAS - Bassett (unpubl. manuscript), contains 1.17 % $Li_20$, 10.30% $B_2O_3$, 3.50% $H_2O$; NBH - Niedermayer et al. (1993), MgO for all samples at or below detection limit of 0.02%, NBH 12 with 0.51 % $Li_2O$; RM - Rossman and Mattson (1986), ZnO: 0.03%, < detection limit, 0.33%, resp.; F: 1.5%, 1.6%, 1.2%, resp; EKJ: this publ., MgO < detection limit and 0.13 %, resp; br - brown, brgr - brownish green, bryel - brownish yellow, dbr -dark brown, gryel - greenish yellow, lbr - light brown, olgr - olive green, plgr - pale green, yel - yellow, yelbr - yellowish brown. Total Fe as FeO.**

| Sample | Colour | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO | MnO | CaO | $Na_2O$ | $K_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **Hyakule** | | | | | |
| **BAS** | yel | 37.30 | 0.45 | 36.80 | 1.26 | 5.77 | 0.75 | 2.50 | n.d. |
| **NBH** | 1 bryel | n.d. | 0.16 | n.d. | 0.06 | 5.40 | 0.64 | 2.05 | 0.04 |
| | 2 yelbr | n.d. | 0.31 | n.d. | 0.14 | 4.70 | 0.93 | 2.62 | 0.05 |
| | 3 brgr | n.d. | 0.24 | n.d. | 0.36 | 6.10 | 0.83 | 1.96 | 0.04 |
| | 4 dbr | n.d. | 0.64 | n.d. | 2.75 | 4.80 | 0.75 | 2.14 | 0.03 |
| | 5 br | n.d. | 0.25 | n.d. | 0.62 | 5.90 | 0.88 | 2.11 | 0.04 |
| | 6 olgr | n.d. | 0.48 | n.d. | 0.35 | 6.10 | 1.06 | 2.05 | 0.03 |
| | 7 brgr | n.d. | 0.19 | n.d. | 0.11 | 4.00 | 0.88 | 2.02 | 0.04 |
| | 8 pink | n.d. | 0.03 | n.d. | <0.02 | 0.43 | 1.58 | 1.86 | 0.02 |
| | 9 pink | n.d. | 0.06 | n.d. | 0.02 | 0.45 | 1.85 | 1.28 | 0.03 |
| | 10 pink | n.d. | 1.04 | n.d. | 1.04 | 2.48 | 0.97 | 2.58 | 0.02 |
| **RM** | 1 yel | 35.1 | 0.46 | 39.0 | 0.13 | 5.74 | 1.22 | n.d. | n.d. |
| | 2 lbr | 35.8 | 0.26 | 38.2 | 1.48 | 5.10 | 0.81 | n.d. | n.d. |
| | 3 dbr | 35.4 | 0.78 | 37.3 | 4.79 | 3.58 | 0.78 | n.d. | n.d. |
| | | | | **Naje** | | | | | |
| **NBH** | 11 olgr | n.d. | 0.35 | n.d. | 3.90 | 0.28 | 1.09 | 2.13 | 0.03 |
| | 12 plgr | n.d. | 0.12 | n.d. | 0.03 | 3.40 | 1.00 | 1.94 | 0.03 |
| | 13 yelgr | n.d. | 0.18 | n.d. | 0.09 | 6.40 | 0.68 | 2.21 | 0.09 |
| | 14 yelgr | n.d. | 0.17 | n.d. | 0.05 | 9.20 | 0.65 | 2.94 | 0.09 |
| | 15 yel | n.d. | 0.12 | n.d. | 0.03 | 4.90 | 0.70 | 2.17 | 0.05 |
| | 16 yel | n.d. | 0.10 | n.d. | 0.15 | 3.10 | 1.36 | 1.86 | 0.07 |
| **EKJ** | 1 gryel | 34.06 | 0.14 | 37.08 | 0.51 | 4.83 | 0.80 | 2.36 | 0.03 |
| | 2 black | 32.50 | 0.97 | 29.73 | 17.78 | 0.39 | 0.13 | 2.29 | 0.08 |

procedure by XRF (Philips 1604) for main and 26 trace elements using Li-tetraborate glass beads, except for Li, which was analysed by AAS. Analytical work for the mica samples was done at the laboratories of the Federal Institute for Geosciences and Natural Resources, Hannover, Germany and tourmalines from Naje were analysed at the Mineralogical Institute, University of Karlsruhe, Germany.

# PHAKUWA-HYAKULE PEGMATITES

## *GEOLOGY*

The Phakuwa-Hyakule area has been investigated by Meier (1989) and Andrews (1985). The area is situated at the base of the Higher Himalayan crystalline of almandine amphibolite facies. The area lies in the MCT Zone (between the MCT1 and MCT2, Arita 1983).

Three main lithological units, supposedly of Precambrian age, exist in the Sabha Khola area (Andrews 1985) as shown in Fig. 2.

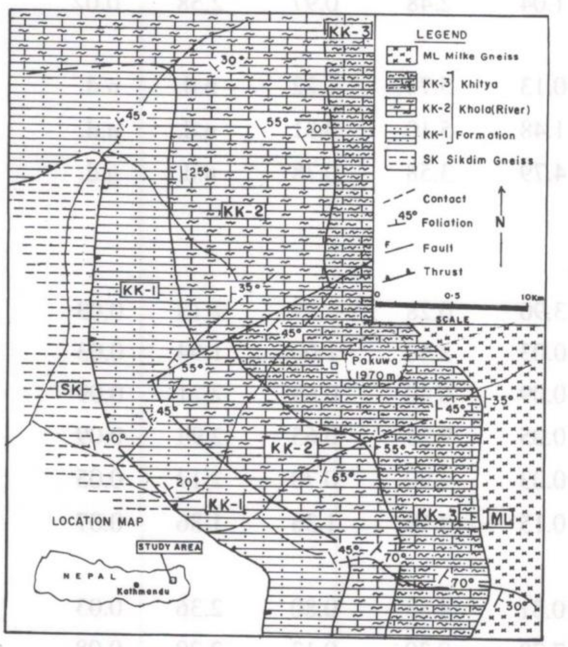


**Fig. 2 Geological map of the Phakuwa-Hyakule area (from United Nations 1993)**

- the basal unit of the Sikdim gneiss, a banded, sugary-textured biotite gneiss with interbeds of biotite-muscovite schists, of about 2500 m thickness, separated by a thrust from the following formations;

- the Kithya Khola Formation, a sequence of schists, quartzites and metamorphosed, partially siliceous limestones, divided into three units according to the dominant lithology (Fig. 3): a lower quartzite dominated part (KK 1 of Fig. 3), followed by beds of quartzites, metamorphic dolomites and schists (KK 2), and an upper section of marble (KK 3) with interbeds of kyanite biotite schist, altogether about 900 m in thickness;

- the Milke gneiss on top of this sequence, a banded, medium grained biotite gneiss of amphibolite facies with kyanite and sillimanite, and occasionally interbeds of hornblende gneiss, and small bodies of intrusive tourmaline granite and associated pegmatites, with a total thickness of at least 3500 m.

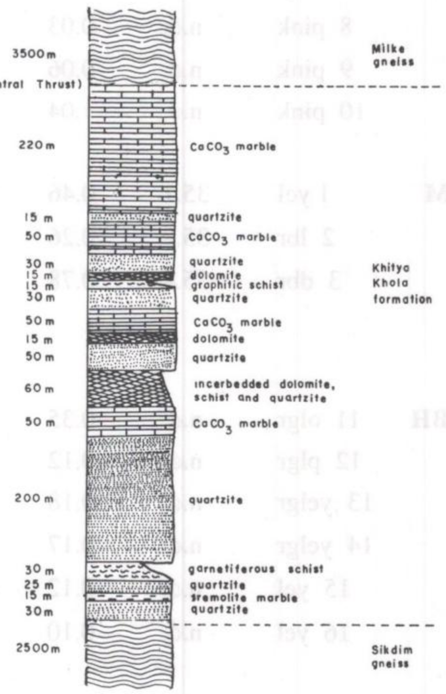


**Fig. 3 Stratigraphic column through the Kithya Khola Formation as the host rock of the pegmatites from the Phakuwa-Hyakule area (from Andrews 1985)**

The pegmatites of Phakuwa and Hyakule are hosted in the upper part of the Kithya Khola Formation. At Phakuwa, most of the pegmatites occur in mica schists below a slightly Pb-Zn mineralised band of calc-silicate gneiss and siliceous marbles. Similarly, the two main pegmatites of Hyakule occur in mica schists, separated by a calc-silicate gneiss layer (Khatri and Shrestha 1969)

## PEGMATITES

The area has been investigated by Joshi (1985, 1986) with special emphasis on the pegmatites. More than 20 pegmatites are known from the Phakuwa pegmatite field, of which three have been mined for gem tourmaline and aquamarine. Mining was attempted at least on 3 other pegmatites, but nothing is known about the results.

Host rock is a coarse grained muscovite-biotite mica schist of high pressure almandine amphibolite facies, containing sporadically garnet and porphyroblasts of kyanite in blades up to 3 cm in size; staurolite and sillimanite were also reported (Joshi 1985). Locally, it develops into a mica-bearing, quartz-rich feldspathic schist. The mica schists contain small bands of calc-silicate rocks with calcite, wollastonite, tremolite/actinolite, phlogopite and diopside. The general strike is 150° with a moderate dip to NE. Ptygmatic folding was observed.

At Hyakule, host rock lithology is dominated by calc-silicate schists and micaceous quartzites with a similar attitude as at Phakuwa. Only about 6 to 8 pegmatites are known from this locality. Two of them have been mined for gem tourmaline (one of them is currently inaccessible because of mine waste) and one for aquamarine.

Barren as well as aquamarine / gem tourmaline bearing pegmatites are also known from the wider surroundings of the Phakuwa-Hyakule area (the pegmatites at Sinkole, Gaire Tal, Thurpu and Pokhari, and other places).

Pegmatites occur as single bodies or as swarms, often in en echelon pattern or as parallel veins or lenses of a few 1 m in thickness and tens of meters in exposed length. Contacts to the host rock are sharp and discordant, though some of the pegmatites follow the strike of the host rock with a steeper dip angle.

Internal zonation is known from the gem producing pegmatites. It consists of a 5 cm to 20 cm wide fine grained border zone of quartz, feldspars, muscovite, biotite and black tourmaline, followed by a blocky zone of white microcline (at Hyakule also containing amazonite), white to greyish quartz (often in graphic intergrowths), abundant schorl and beryl, and a minor amount of biotite and muscovite. The core zone is discontinuous, forming lenses of quartz (sometimes slightly rose coloured or as smoky quartz) together with coarse, fragmented feldspar, beryl and schorl. Towards the footwall, a fine grained, aplitic zone was observed, containing albite, fine grained muscovite, schorl and light red garnets, probably spessartine; Bassett (1987) mentions additional grossularite (variety hessonite). Both the blocky zone and the core zone at Phakuwa developed cavities up to 30 cm in diameter, from which the small gem tourmalines were mined.

At Hyakule, the cavity zone contains additionally a minor amount of small flakes of lepidolite (see Table 3 for chemical composition). Hambergite and danburite were described by Bassett (1985, 1987) from this locality.

Besides the common occurrence of schorl and beryl, the characteristic aspect of the pegmatites of this area is their simple textural and mineralogical composition (apart from the gem tourmaline, and the various rare minerals in the main pegmatite of Hyakule), noticeably the small amount of white mica, which made sampling difficult or impossible at some localities, the occurrence of coarse grained plates of biotite (especially near the hanging wall, and in some pegmatites dominant with respect to muscovite) and the apparent lack of intensive microcline replacement by albite (though Shmakin 1981, mentions alkaline replacement at Hyakule as well developed), of sugary grained replacement bodies of albite and of a complex internal zonation.

There are also distinctly different types of pegmatite bodies among the Phakuwa pegmatites which lack internal zonation, has simple mineralogical composition with coarse grained feldspars, quartz, biotite and a small amount of magnetite and forms highly irregular discordant contacts with the host rock.

## MUSCOVITE CHEMISTRY

The chemistry of the muscovites shows major differences among the samples (Table 3). The main changes in Mn and Mg content seems to be significant. There is a considerable range in concentration of incompatible, lithophile trace elements, suggesting a wider spread of pegmatite melt composition from undifferentiated to at least moderately differentiated character.

The trace elements Rb, Cs, and Li in muscovite (Fig. 4) have been used by Gordiyenko (1971, cited in Trueman and Cerny 1982) to distinguish between barren pegmatites of a muscovite bearing province (here referred to as barren muscovite type), and pegmatites of rare element provinces (here referred to as rare element type) ranging from unmineralised to highly mineralized pegmatites (with respect to minerals of Ba, Nb, Ta, Sn, Li and Cs).

The Rb concentrations in the Phakuwa and Hyakule muscovites cover a wide range from barren muscovite type to moderately mineralised rare-element pegmatites, whereas the few samples from pegmatites at nearby localities (Gairetal and Pokhari) are very low in Rb and restricting these pegmatites to the barren muscovite type. Similarly, Cs data indicate barren muscovite type pegmatites to strongly mineralised rare-element pegmatites in Phakuwa and Hyakule, again restricting the pegmatites from Gairetal and Pokhari to the barren muscovite type.

In the Li diagram, however, all pegmatites from the three groups plot into the barren muscovite type, though the samples from Hyakule and Phakuwa are distinctly higher, barely reaching the range of barren rare-element pegmatites. This obviously reflects the generally low Li content of the investigated pegmatites and probably characterises the pegmatite field of the larger area around Phakuwa and Hyakule as Li-poor. Li enrichment occurred only during the last stage (pocket formation) of pegmatite crystallisation in the gem tourmaline pegmatites, forming

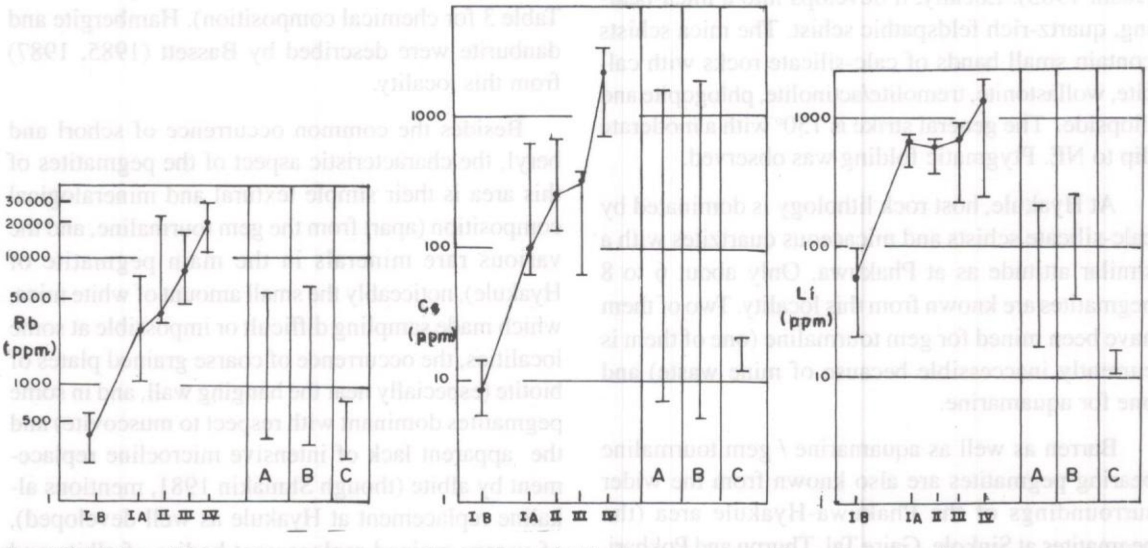


**Fig. 4 Li, Rb and Cs contents of muscovites typical of: IB - barren pegmatites of the mica-bearing provinces; IA - barren pegmatites of the rare element provinces; II - muscovite-feldspar pegmatites with Be, Nb, Ta; III - spodumene pegmatites with Li, Be, Ta (Nb, Sn); IV - spodumene and lepidolite pegmatites with Li, Cs, Ta, Be (Nb, Sn). Dots - most probable assessment of the mean; vertical lines - range of arithmetic means with 95% confidence level. From Gordiyenko (1971), modified by Trueman and Cerny (1982). Muscovites from pegmatites of: A-Phakuwa (barren and gem tourmaline bearing); B- Hyakule (barren and gem tourmaline bearing); C- other localities around Phakuwa and Hyakule (without gem tourmaline).**

**Table 3** Selected main elements, trace elements and element ratios in musovites from pegmatites, Phakuwa-Hyakule area and surroundings, Eastern Nepal. Abbreviations: A: Aquamarine; T: gem quality tourmaline; ?: uncertain occurrence. Pegmatites of uncertain position: smalll veins, parallel and close to gem pegmatites, probably without gems. Average: arithmetic mean without pegmatites of uncertain position; K/Cs values calculated by setting ratios above 10000 to 5000; sample PH 7 omitted because of strong deviation.

| Sample | Locality | Vein | Gems | Li ppm | Rb ppm | Cs ppm | Ba ppm | Sn ppm | Ta ppm | Nb ppm | Ta+Nb ppm | MgO % | MnO % | K/Rb | K/Cs | Mg/Li | Ta/Nb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pegmatites mined for gem tourmaline/aquamarine | | | | | | | | | | | | | | | | | |
| PH 4 | Phakuwa | no. 11 | T,A | 245 | 3391 | 543 | 19 | 988 | 87 | 132 | 219 | 0,02 | 0,15 | 23,9 | 149 | 0,49 | 0,66 |
| PH 5 | Phakuwa | no. 11 | T,A | 255 | 3529 | 407 | 23 | 975 | 91 | 125 | 216 | 0,02 | 0,134 | 22,9 | 198 | 0,47 | 0,73 |
| PH 7 | Phakuwa | no. 10 | T,A | 200 | 1379 | 51 | 34 | 231 | 16 | 153 | 169 | 0,08 | 0,132 | 59,9 | 1620 | 2,41 | 0,1 |
| PH 8 | Phakuwa | no. 10 | T,A | 45 | 2302 | 342 | 28 | 502 | 28 | 39 | 67 | 0,03 | 0,342 | 36,5 | 246 | 4,02 | 0,72 |
| PJ 1018 | Phakuwa | no. 8 | T?A | 135 | 5265 | 1310 | 20 | 536 | 122 | 135 | 257 | 0,04 | 0,14 | 17,6 | 58,9 | 1,79 | 0,53 |
| PH 16 | Hyakule | no. 2 | T?A | 288 | 3414 | 160 | 19 | 864 | 53 | 155 | 208 | 0,03 | 0,269 | 23,9 | 509 | 0,65 | 0,34 |
| PH 17 | Hyakule | no. 2 | T?A | 290 | 3137 | 126 | 20 | 932 | 55 | 177 | 232 | 0,07 | 0,23 | 26 | 641 | 1,46 | 0,31 |
| PJ 1032 | Hyakule | no. 3 | T,A | n.d. | 5320 | 1886 | 35 | 554 | 139 | 138 | 277 | 0,03 | 0,142 | 13,3 | 38,9 | --- | 1 |
| Pegmatites with aquamarine only | | | | | | | | | | | | | | | | | |
| JP 51 | Pokhari | no numb. | A | 15 | 477 | 12 | 481 | 8 | 12 | 30 | 42 | 1,05 | 0,021 | 172 | 4330 | 422 | 0,4 |
| JP 52 | Pokhari | no numb. | A | 20 | 701 | 21 | 125 | 21 | 20 | 43 | 63 | 0,47 | 0,034 | 117 | 3980 | 142 | 0,47 |
| Barren pegmatites | | | | | | | | | | | | | | | | | |
| PH 12 | Phakuwa | no numb. | barren | 40 | 664 | 32 | 865 | 64 | 57 | 92 | 149 | 1,33 | 0,029 | 125 | 2600 | 201 | 0,62 |
| PH 15 | Phakuwa | no numb. | barren | 20 | 389 | 7 | 803 | 197 | 10 | 39 | 49 | 1,34 | 0,016 | 214 | 11880 | 404 | 0,25 |
| JP 1 | Phakuwa | no numb. | barren | 75 | 1035 | 23 | 30 | 500 | 18 | 142 | 160 | 0,70 | 0,038 | 81 | 3650 | 56 | 0,13 |
| JP 2 | Phakuwa | no numb. | barren | 72 | 792 | 23 | 75 | 211 | 19 | 131 | 150 | 0,76 | 0,032 | 102 | 3520 | 64 | 0,15 |
| PJ 1020 | Phakuwa | no. 9 | barren | n.d. | 442 | 40 | 505 | 159 | 22 | 69 | 91 | 1,56 | 0,02 | 179 | 1980 | --- | 0,32 |
| PJ 1025 | Phakuwa | no. 14 | barren | 120 | 499 | 15 | 1224 | 91 | 17 | 75 | 92 | 1,81 | 0,022 | 159 | 5300 | 91 | 0,23 |
| PJ 1026 | Phakuwa | no. 15 | barren | 37 | 417 | 15 | 999 | 25 | <10 | 54 | <64 | 1,47 | 0,024 | 189 | 5260 | 240 | >0,19 |
| JP 13 | Gairetal | no numb. | barren | 10 | 402 | 13 | 909 | 71 | 14 | 51 | 65 | 0,82 | 0,032 | 200 | 6180 | 495 | 0,27 |
| JP 29 | Hyakule | no numb. | barren | 51 | 391 | 7 | 1483 | 163 | 10 | 61 | 71 | 1,57 | 0,024 | 201 | 11600 | 186 | 0,16 |
| JP 30 | Hyakule | no numb. | barren | 115 | 372 | 5 | 1491 | 180 | 14 | 52 | 66 | 1,59 | 0,025 | 215 | 16000 | 83 | 0,27 |
| Pegmatites with uncertain position | | | | | | | | | | | | | | | | | |
| PH 3 | Phakuwa | no. 11a | T?,A? | 175 | 771 | 24 | 126 | 223 | 15 | 110 | 125 | 0,77 | 0,027 | 105 | 3380 | 28 | 0,14 |
| PH 9 | Phakuwa | no. 10a | T?,A? | 100 | 467 | 8 | 161 | 49 | 10 | 40 | 50 | 1,31 | 0,022 | 182 | 10600 | 60 | 0,25 |
| PH 10 | Phakuwa | no. 10a | T?,A? | 135 | 480 | 31 | 724 | 59 | 10 | 34 | 44 | 1,23 | 0,048 | 175 | 2700 | 55 | 0,29 |
| PH 13 | Phakuwa | no. 8a | A? | 60 | 895 | 19 | 49 | 489 | 26 | 134 | 160 | 0,77 | 0,037 | 111 | 4360 | 77 | 0,21 |
| Lepidolite from gem tourmaline pegmatite | | | | | | | | | | | | | | | | | |
| JP 6A | Hyakule | no. 3 | T,A | 27000 | 8536 | 3603 | 13 | 84 | 76 | 47 | 123 | 0,02 | 0,074 | 10 | 23,6 | -- | 0,38 |
| | | | | Li | Rb | Cs | Ba | Sn | Ta | Nb | Ta+Nb | MgO | MnO | K/Rb | K/Cs | Mg/Li | Ta/Nb |
| Average gem tourm. pegmatites | | | | 208 | 3295 | 603 | 25 | 698 | 60 | 132 | 206 | 0,04 | 0,192 | 28 | 263 | 1,64 | 0,55 |
| average barren pegmatites | | | | 94 | 548 | 18 | 1124 | 141 | <19 | 70 | <89 | 1,21 | 0,032 | 163 | 4300 | 180 | 0,31 |

elbaites of moderate Li content (Table 2, analysis BAS), and additionally a small amount of lepidolite (Table 3, sample JP 6A) in the gem tourmaline pegmatite of Hyakule.

Since these diagrams indicate the presence of different types of pegmatites being present in the Phakuwa-Hyakule area, trace elements, minor elements and element ratios were plotted (Fig. 5 to 9) for further subdivisions of the pegmatites.

The MnO - MgO diagram, the K/Rb versus Cs diagram and the K/Rb versus Mg/Li diagram clearly distinguish between two groups of pegmatites: one containing barren pegmatites, with high MgO contents and high K/Rb- and Mg/Li-ratios and with low Cs and MnO concentrations in their muscovites; the other containing a group of 5 pegmatites (2 from Hyakule, 3 from Phakuwa) with the opposite characteristics. These pegmatites have been mined, two of them successfully for gem tourmaline (plus aquamarine), the other 3 for gram and the Ta - Sn diagram. The Ba - Rb diagram shows a group of high Ba - low Rb pegmatites indicative of little evolved pegmatites, grading into pegmatites of lower Ba and slightly increased Rb values, and a second group of the highly evolved pegmatites with Rb contents above 2000 ppm and Ba contents below 30 ppm (the gem tourmaline/aquamarine pegmatites). In the Ta - Sn diagram, a general trend is visible, with low but scattered Ta values and even more irregular, low to high Sn values in the muscovites of the barren pegmatites, whereas the highly evolved pegmatites have fairly high Ta and Sn concentrations in their muscovites (between 50 and 140 ppm , and 500 to 1000 ppm, resp.).

The dashed lines in the latter diagram indicate the expected first appearance of Ta-minerals (above about 20 ppm Ta) and the pegmatites with a possible potential for economic mineralisations at about 75 ppm Ta (cited in Trueman and Cerny 1982; and Möller and Morteany 1987). Actually, two samples from one of the highly evolved pegmatites from Phakuwa and from the gem tourmaline pegmatite of Hyakule contained cassiterite, wodginite, pyrochlore and tantalite (besides uraninite and zircon) in their heavy mineral concentrates (Joshi, 1985; XRD determination, analysed by F. Lothe, CRPG, Nancy, France), though the mineralisation seems to be of low grade.

Other, but less useful indicators are the sum of Ta and Nb, which is generally higher for the evolved rare-element pegmatites, and the Ta/Nb ratio. The geochemical characteristics for the muscovites of the two pegmatite groups are summarised as arithmetic averages in Table 3, and as observed ranges in Table 4.

# NAJE PEGMATITES

## *GEOLOGY*

Two larger pegmatite bodies up to several meters in thickness and a couple of smaller pegmatites are exposed at Naje village in Manang district (see also United Nations, 1993). The area belongs to the Higher Himalayan Crystalline lying to the north of the Main Central Thrust.

The host rock is a massive, medium to coarse grained garnet bearing calc-silicate gneiss with a well developed metamorphic foliation in cm dimension. Locally, quartz aggregates form lensoid to vein like intercalations, in exceptional cases up to several m long and several dm wide, but usually of dm dimensions. The calc-silicate gneiss consists dominantly of microcline, quartz, diopside, scapolite of meijonite composition and large porphyroblasts of staurolite. Minor minerals are epidote, titanite, a light brown biotite, a bluish green amphibole and calcite as fillings of interstices. Garnet was observed macroscopically. A retrograde reaction is indicated by small patches of greenish hornblende replacing pyroxene.

The contact between pegmatites and host rock are slightly curved to straight lined, sharp and discordant to the metamorphic foliation, cutting through at high angles with a steep dip to the south. Upper and lower contacts are approximately parallel to each other with some pinching and swelling.

## *PEGMATITE*

Most pegmatite bodies are characterized by up to 30 cm large microclines, partly bluish green coloured amazonite, abundant quartz-schorl intergrowths, and the presence of cm large flakes of dark brown to black biotite. Muscovite is absent or

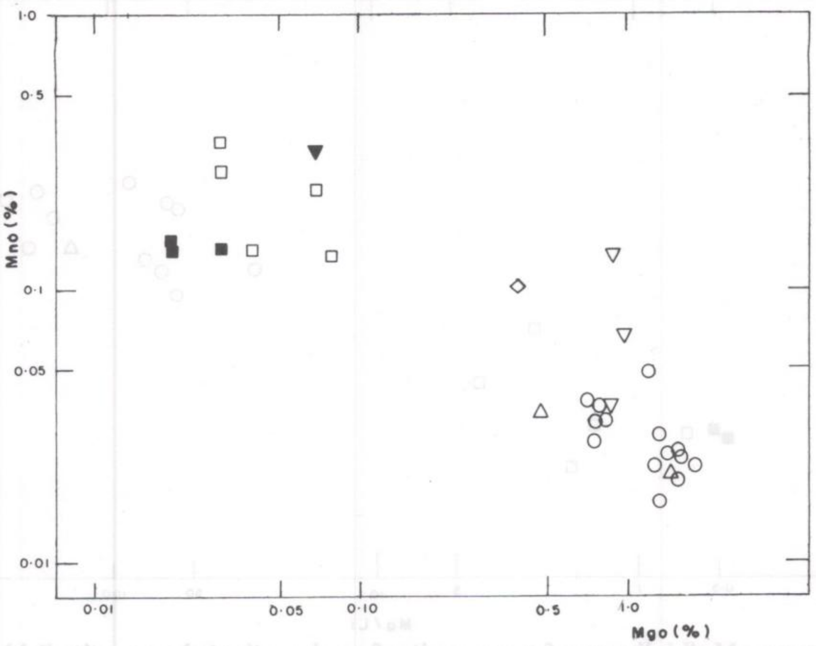


**Fig. 5 MnO - MgO diagram for muscovites from Phakuwa-Hyakule pegmatites (circles and squares), from Naje pegmatite (rhombus) and Ilam district pegmatites (inverted triangles). Solid symbols: gem tourmaline bearing; open symbols: pegmatites without gem tourmaline. Triangles: aquamarine pegmatites from Pokhari near Hyakule; circles: barren pegmatites from Phakuwa-Hyakule; open squares: evolved pegmatites (with beryl/aquamarine) from Phakuwa-Hyakule.**

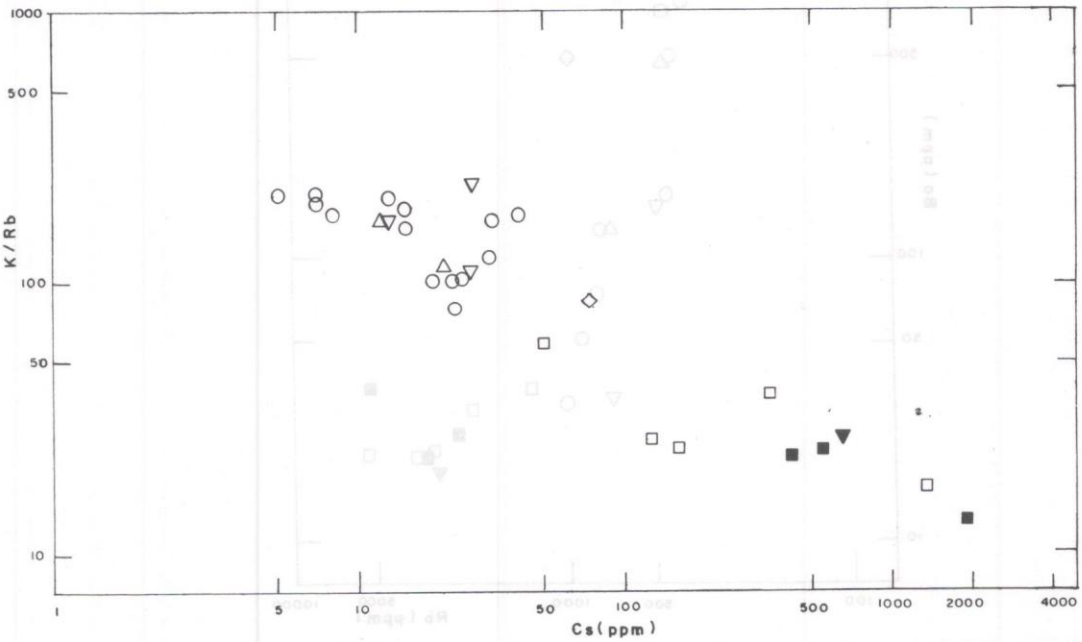


**Fig. 6 K/Rb versus Cs diagram for muscovites from investigated pegmatite fields; symbols as in Fig. 5.**

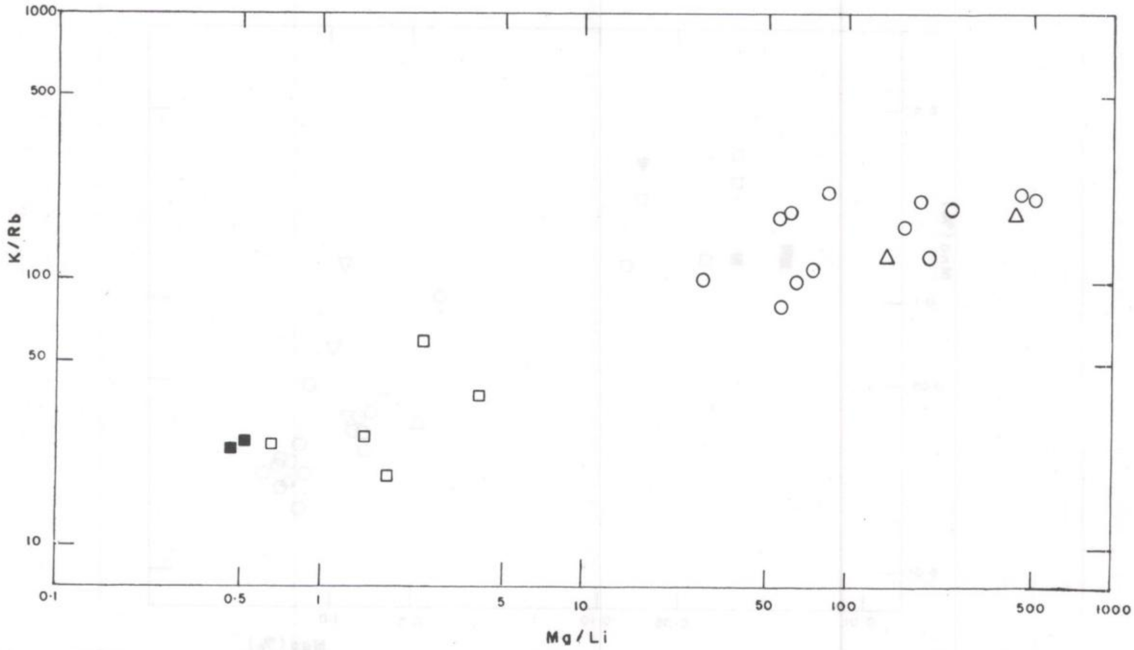


**Fig. 7 K/Rb versus Mg/Li diagram for muscovites from investigated pegmatite fields; symbols as in Fig. 5. No Li data for the tourmaline pegmatite of Hyakule available.**

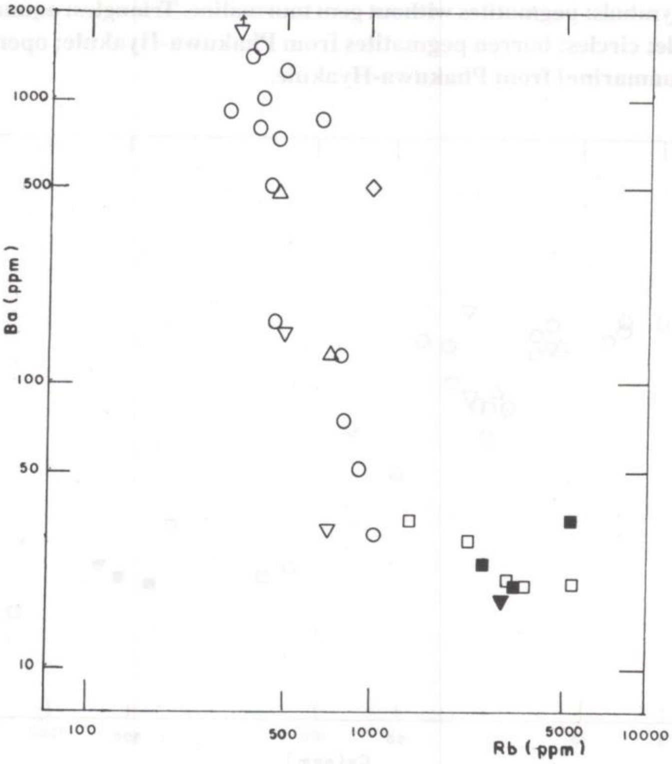


**Fig. 8 Ba - Rb diagram for muscovites of investigated pegmatite fields; symbols as in Fig. 5.**

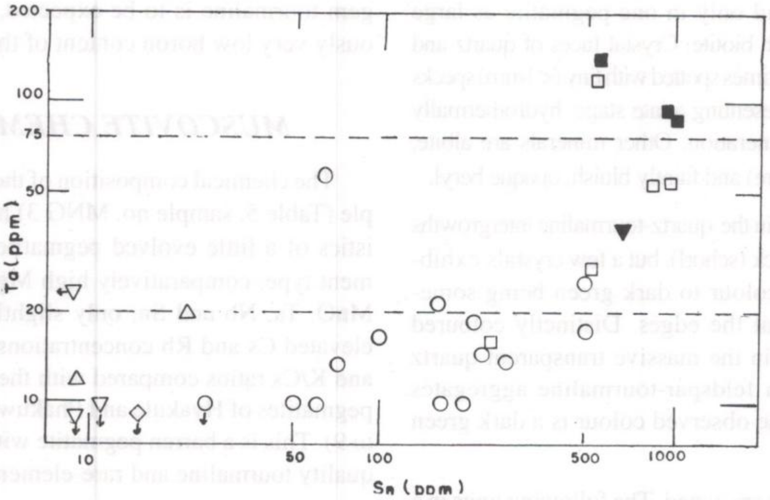


**Fig. 9 Ta - Sn diagram for muscovites from investigated pegmatite fields. Dashed line at 20 ppm Ta: approximatly first occurrence of Ta-minerals (cited in Trueman and Cerny 1982); dashed line at 75 ppm Ta: boundary of potentially economic Ta-pegmatites (as cited in Môller and Morteani 1987); symbols as in Fig. 5.**

**Table 4 Geochemical parameters of muscovites from pegmatites of the Phakuwa - Hyakule area, Sankhuwa Sabha district, Eastern Nepal**

| | | | |
|---|---|---|---|
| Li : | 45 - 300 ppm | < 180 ppm | unreliable |
| Rb : | > 1300 - 5300 ppm | < 1100 ppm | good |
| Cs | 51 - 1880 ppm | < 50 ppm | moderate |
| Ba : | < 50 ppm | 30 - 1500 ppm | good |
| Ta : | 16 - 140 ppm | < 10 - 57 ppm | unreliable |
| Sn : | > 230 - 1000 ppm | 8 - 500 ppm | unreliable |
| MgO : | < 0.1 % | > 0.4 % | very good |
| MnO : | > 0.1 - 0.35 % | < 0.05 % | very good |
| K/Rb : | < 60 | > 80 | good |
| K/Cs : | 39 - 1620 | 1980 - 16000 | moderate |
| Mg/Li: | < 5 | > 30 | very good |

rare and was found only in one pegmatite as large flakes together with biotite. Crystal faces of quartz and microcline are sometimes spotted with tiny (< 1mm) specks of white mica, representing a late stage, hydrothermally developed mica generation. Other minerals are albite, brownish garnet (rare) and faintly bluish, opaque beryl.

The tourmaline in the quartz-tourmaline intergrowths is nearly almost black (schorl), but a few crystals exhibited a change in colour to dark green being somewhat translucent at the edges. Distinctly coloured tourmaline occur in the massive transparent quartz and sometimes in feldspar-tourmaline aggregates besides schorl. The observed colour is a dark green to yellowgreen.

The pegmatites are zoned. The following units in a partly exposed pegmatite were observed:

- the outer zone at the contact to the host rock, a few cm in width, being composed of feldspar and quartz with minor amounts of tourmaline (schorl) and biotite;

- a zone of blocky microcline, at the rim intergrown with quartz. Some schorl is present, mostly in quartz-tourmaline intergrowths, but no biotite;

- the quartz core, a few dm in width consisting of transparent quartz, coloured tourmaline and beryl;

- a zone of feldspar (albite and potassium feldspar, considerably reduced in crystal size as compared to the blocky zone) and tourmaline (schorl mostly) with a minor amount of quartz. This zone is in parts vuggy (cavities of a few mm in diameter), consisting of platelets of albite and abundant mm to cm long needles of greenish-yellow, transparent tourmaline protruding into the cavities. The zone underwent Na-metasomatism at least locally, since albite replaces larger microcline crystals. The footwall zone is not exposed.

Because of the near absence of muscovites in the Naje pegmatites, only one pegmatite was sampled with coarse books of mica of several cm in size. However, this pegmatite differs from the other pegmatites not only in having abundant coarse muscovite in addition to (a minor amount) of biotite, but in lacking the otherwise abundant tourmaline (schorl). Only in the quartz core, tiny needles of schorl were observed. This already indicates that no gem tourmaline is to be expected, given the obviously very low boron content of this pegmatite.

### *MUSCOVITE CHEMISTRY*

The chemical composition of the muscovite sample (Table 5, sample no. MNG 3) has the characteristics of a little evolved pegmatite of the rare-element type: comparatively high MgO, high Ba, low MnO, Ta, Nb and Sn, only slightly to moderately elevated Cs and Rb concentrations, and high K/Rb and K/Cs ratios compared with the gem tourmaline pegmatites of Hyakule and Phakuwa (see also Fig. 5 to 9). This is a barren pegmatite with respect to gem quality tourmaline and rare-element minerals.

## ILAM PEGMATITES

Tourmalines are also mined in the Ilam district, Eastern Nepal. Nothing has been published about the pegmatites and the general geology of this area yet. According to Tamrakar (pers. comm.), tourmalines have olive-green colour. The pegmatites are found in the high grade metamorphic rocks: gneisses, garnet-kyanite schists and calc-silicate rocks, belonging to the Higher Himalayan crystalline.

### *MUSCOVITE CHEMISTRY*

Muscovites from 4 different localities were analysed (Table 5). Only one (IL 1) has a geochemical pattern suggestive of an advanced pegmatite of the rare-element pegmatite group (Fig. 5 to 9), which is very similar in trace element characteristics to the gem bearing pegmatites from Hyakule and Phakuwa (high MnO, Cs, and Sn, fairly high Rb, low MgO, Ba and Sr and fairly low K/Rb and K/Cs ratios), whereas the other three sampleş have the pattern of barren pegmatites. It is therefore expected from these data, that only the IL 1 sample pegmatite is gem tourmaline bearing. Other differences of this sample to the supposedly barren pegmatites are high values of Sn (657 ppm) and Ga (274 ppm), and elevated concentrations of La, Sc and U in sample IL 1.

However, besides sample IL 1 with reported yellow-green gem quality tourmaline, Tamrakar (pers. comm.)

found also multihued green tourmaline in another pegmatite (IL 4), which according to the muscovite chemistry should be a completely barren pegmatite! Either the method can not be applied in this area, or, and we believe it to be the most plausible explanation, the muscovite sample has been wrongly assigned to this pegmatite. It is doubtful, whether the 3 pegmatites (IL 2 - 4) belong to the rare element pegmatite group at all since their trace element pattern is just between the barren muscovite pegmatite type and the barren type of rare-element pegmatites.

# DISCUSSION AND CONCLUSIONS

## *TYPES OF PEGMATITES*

Two pegmatite types can be distinguished in the Phakuwa-Hyakule area on textural and mineralogical grounds, representing two different generations of pegmatites. The first type is an unzoned biotite-feldspar-quartz pegmatites, without muscovite, garnet and beryl (mainly in the Phakuwa area), with irregular shape and contacts, reminding of off-shoots of granitic apophyses. The second type is usually a zoned muscovite-biotite(-beryl-tourmaline-garnet) bearing pegmatites.

The latter types are split according to their muscovite chemistry into:

- a group of pegmatites with very low contents of Rb, Cs, Ta, Sn and MnO, and high values of K/Rb, K/Cs, Mg/Li, Ba and MgO indicative of barren muscovite type pegmatites without special development. It consists of the pegmatites of Gairetal, Pokhari, and some pegmatites of the Phakuwa-Hyakule area with the most "primitive" trace element pattern;

- a group of pegmatites (2 in Hyakule, 3 in Phakuwa) with geochemical characteristics of differentiated rare-element pegmatites ( high Rb, Cs, MnO, Ta and Sn, and low Mg/Li, K/Rb, K/Cs and Ba) of moderate mineralisation.

Intermediate between these two extreme groups are pegmatites, which belong to the barren rare-element pegmatite type according to their chemistry, but are not clearly distinguished in the diagrams from the barren muscovite type as a separate group; only the Ba - Rb diagram (Fig. 8) hints at such a separation. This group includes another 3 veins at Phakuwa with traces of mining attempts, obviously without success as no gems are recorded from these places and the workings are small. The geochemical signature of their muscovites confirms their barren character.

Both the undifferentiated (barren) and the differentiated type of rare-element pegmatites belong most likely to the same genetic event, expressing different degrees of specialization. As it is not uncommon for rare-element pegmatites in a vein swarm to change, often with a zoned pattern, their geochemical signature from place to place, with a few pegmatites in a higher evolved stage.

Rare element pegmatites are known from the Hindukush Ranges in Pakistan, and especially from Afghanistan, where they were extensively investigated by Rossovskiy (1981) and Rossovskiy et al. (1976, 1977). The Nepal rare-element pegmatites are unusual in their mineralogical composition, as they contain abundant biotite and often only very small amounts of muscovite. Additionally, Li contents are low, and complex zonation and extensive replacement bodies are missing. They occur in a high pressure metamorphic zone, which is also unusual for rare-element pegmatites, whereas the gem pegmatites of Afghanistan occur at lower pressure environments of epidote-amphibolite facies (Rossovskiy, 1981).

## *GENETIC ASPECTS*

Little is known about the genesis of the rare-element pegmatites of the Phakuwa-Hyakule area. According to Bassett (1987), they are probably related to local heating to melting temperatures in connection with the overthrusting along the MCT and collection of ion-rich fluids during this process, since no granite is known in the surrounding area to which they could be genetically linked.

It is however very unlikely, that a simple local partial melting can result in such highly specialised pegmatites as the ones under discussion. The high trace element concentrations of Rb, Cs, Ta and Sn, and the low Ba and Mg contents probably require a differentiation process in a larger volume of granitic melt from which the pegmatites evolved.

From field observations it is evident, that the pegmatites formed not in place but are intrusive:

- no migmatites are known in the Kithya Khola Formation thus indicating that temperatures were not high enough for anatexis;

- contacts of the pegmatites against the host rock are sharp, straight lined and, though partially channelled by the schistosity of the host rock, are often discordant;

- chilled margins and contact metamorphic reactions were mentioned by Andrews (1985) pointing to a higher temperature in the melt than in the host rock; similarly, metasedimentary xenoliths in the pegmatite also have reaction rims.

A genetic relationship of the pegmatite formation with the process of overthrusting along the MCT is likely, if granitic melts were produced along the thrust plane according to the model developed for the Manaslu granite by Le Fort (1981) and for the Higher Himalayan granites in general by LE FORT et al. (1987), if these melts were able to develop at least partially into rare element enriched residual melts squeezed into the surrounding high grade metamorphic rocks as pegmatites.

Since rare-element pegmatites occur up to a few km laterally or vertically away from the parent granite, with the higher developed ones often the furthest away, a possible parent granite is not required in an area close to the pegmatites. The Naje pegmatites for instance are located about 10 km south from the nearest known outcrop of the Manaslu granite (from which tourmaline (schorl) rich pegmatites are known especially along its southern border (Vidal et al. 1982), not too far to be a derivative of this granite in view of the possibility of some closer, but not outcropping occurrence of this granite. The fact, that some of the rare-elements are already enriched in the Manaslu granite (Vidal et al. 1982) with Rb up to 1300 ppm and Cs up to 100 ppm, The Naje pegmatites may have a close genetic relation with the Manaslu Granite.

## GEM TOURMALINE PEGMATITES

All the five investigated, highly evolved pegmatites of the Phakuwa-Hyakule area have been mined. However, only one of them from Hyakule and one (perhaps 2) from Phakuwa yielded gem tourmaline (together with some aquamarine), the others contained only beryl/aquamarine, despite the fact of being equally well evolved in geochemical terms.

This difference is explained by the formation of tourmaline bearing cavities (though we suspect some gem tourmaline production from the massive quartz core also), which occur in the gem tourmaline pegmatites but are not recorded from the other pegmatites. According to London (1987), a massive crystallisation of tourmaline depletes the melt rapidly of an alkali borate fluxing component, which raises the solidus temperature and exsolves large amounts of an aqueous fluid, forming pockets under favourable conditions. The abundance of tourmaline (schorl) in the gem tourmaline pegmatites of Phakuwa-Hyakule (with lesser amounts in the other pegmatites) might be taken as a positive indication for this process to have happened.

Additionally, it was noted in the field, that the gem tourmaline pegmatites are poor in muscovite compared to the non-gem tourmaline pegmatites. The same observation was made in the Naje area.

The following process is assumed: The crystallisation of a pegmatite melt starts at the walls and moves inward, Fe-Mg-rich minerals are among the first to crystallise in the wall zone, as observed by abundant biotite and some black tourmaline (schorl) in this zone. This depletes the melt in Fe and Mg. As crystallisation proceeds with coarse microcline and quartz-tourmaline intergrowths contemporarily, it is assumed that the chemical system was in such a state, that despite the presence of sufficient potassium, no or little muscovite precipitated. The prevalent crystallisation of microcline instead of muscovite enriches the residual melt in Al, and the surplus amount of Al together with remaining Fe is taken up by the simultaneously crystallising tourmaline (schorl with high Fe content; see Table 2 , sample EKJ 2). As the colour of tourmaline at this stage changes to a dark brown green to green (as observed in Naje pegmatites) this indicates a depletion of Fe and the formation of a more Al rich (elbaitic) tourmaline. Simultaneously, the Mn content in the melt increases, when

**Table 5 Chemical characteristics of muscovites from pegmatites, Ilam district, Eastern Nepal; and Naje, Manang district, Western Nepal. Sample IL 1 was taken from a gem tourmaline bearing pegmatite. The other samples would be regarded as barren, though IL 4 allegedly belongs to another gem tourmaline pegmatite.**

| Sample no. | Rb | Cs | Ba | MnO | MgO | Sr | Ta | Nb | Sn | K/Rb | K/Cs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **Ilam** | | | | | |
| IL 1 | 3011 | 637 | 17 | 0.336 | 0.06 | < 5 | 38 | 125 | 657 | 26 | 125 |
| IL 2 | 503 | 13 | 150 | 0.037 | 0.85 | 9 | <10 | 80 | 11 | 165 | 6392 |
| IL 3 | 710 | 27 | 31 | 0.135 | 0.88 | < 5 | 26 | 71 | <3 | 112 | 2998 |
| IL 4 | 355 | 17 | 1668 | 0.067 | 0.98 | 18 | <10 | 49 | 10 | 228 | 4757 |
| | | | | | | **Naje** | | | | | |
| MNG 3 | 1015 | 72 | 493 | 0.010 | 0.40 | 11 | <10 | 31 | 15 | 85 | 1194 |

biotite as the dominant Mn collector ceases to crystallise, resulting in an increasing amount of Mn in the tourmalines (and garnets, if present). The final product is a Mn-rich elbaite.

## *MUSCOVITE GEOCHEMISTRY AS AN EXPLORATION METHOD*

The results from the muscovites of the Phakuwa-Hyakule pegmatites demonstrate, that the muscovite chemistry can be successfully applied in this pegmatite field, in distinguishing between barren pegmatites (with respect to gem tourmaline) and evolved pegmatites with a potential for gem tourmaline, though the individual pegmatites is not necessarily gem tourmaline bearing. Since pegmatites from Ilam and Naje have similar geochemical signature in their muscovites, the method can probably be applied in other pegmatite fields of Nepal. The separating quality of the elements and element ratios used here was estimated by the degree of separation in the diagrams (Table 4 ), and is best in case of MnO, MgO and Mg/Li, good in case of Rb, Ba and K/Rb, and unreliable (if used solely) in case of Ta, Sn and Li.

To get reliable information, it is advisable as a common practice to collect several samples of coarse grained muscovite from the same pegmatite to account for irregular deviations in muscovite chemistry and to compensate for sampling errors in selecting different muscovite generations in different pegmatites (see also Trueman and Cerny 1982; Möller and Morteani 1987).

However, in case of pegmatites with small amounts of muscovite like the ones in Phakuwa-Hyakule and Naje, the sampling procedure can be time consuming or even unsuccessful.

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