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NEPAL GEM TOURMALINES

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ABSTRACT

Gem quality tourmaline crystals from pockets in the pegmatites at Hyakule and Phakuwa in the Sankhuwa Sabha District, Kosi Zone, eastern Nepal, have been mined for over 50 years with a production of at least a ton of gem crystals. Mining continues, despite land-slide problems, in sporadic operations at both mines. Minerals associated with the elbaite tourmalines include quartz, muscovite, biotite, lepidolite, beryl (occasionally of gem aquamarine), both spessartine and hessonite garnets, danburite, hambergite, apatite, and both micro-cline and cleavelandite feldspar. The gem-bearing pegmatites are associated with schist and carbonate rocks in the Khitya Khola formation as defined by E. Andrews in an article in this journal in 1985. The origin of these intrusive pegmatites is still controversial as no body of source granite is exposed in the area. Additional tourmaline-bearing pegmatites are reported in the Sankhuwa Sabha, Taplejung, Jajarkot, and Rasuwa districts. Five distinct mineral species of the tourmaline group occur in Nepal.

INTRODUCTION

About two dozen or more gem pegmatites are now known in Nepal, mostly containing beryl and little or no gem tourmaline. Only three pegmatite areas are confirmed to contain gem-quality tourmaline: Hyakule, Phakuwa and Jajarkot, though the Langtang Valley pegmatites and others in the Sankhuwa Sabha and Taplejung districts may prove productive eventually. Virtually the entire tourmaline production has come from a single pegmatite at Hyakule, with relatively minor contributions from a few pegmatites nearby at Phakuwa. The potential value of Nepal's gemstones could prove to be considerable, and may be an important mineral resource of the country.

TOURMALINES

For more than 250 years, the tourmalines have been among the most famous of mineral species, not only for their wide range of colors and strong polarizing qualities, but in scientific research for their extraordinary pyroelectric and piezoelectric properties. Because of these peculiarities, tourmalines have been the subject of particular scientific scrutiny, and have found uses in a variety of instruments, especially pressure gauges. The great structural complexity of tourmaline was first successfully worked out by Buerger in 1962, who found that the way in which the various clusters of element groups were bonded together created an enantiomorphic spiral configuration around the vertical axis, unique among minerals, which causes the peculiar electrical properties.

The principal tourmaline species according to the dominant elements in their X and Y positions in the standard tourmaline formula:

$X\,Y_3\,Al_6\,(BO_3)_3\,(Si_6O_{18})\,(OH)_4$

are shown in the following chart:

		X: Na	X: Ca
Y_3	Fe	Schorl	(not known)
	Mg	Dravite	Uvite
	Al Li	Elbaite	Liddicoatite

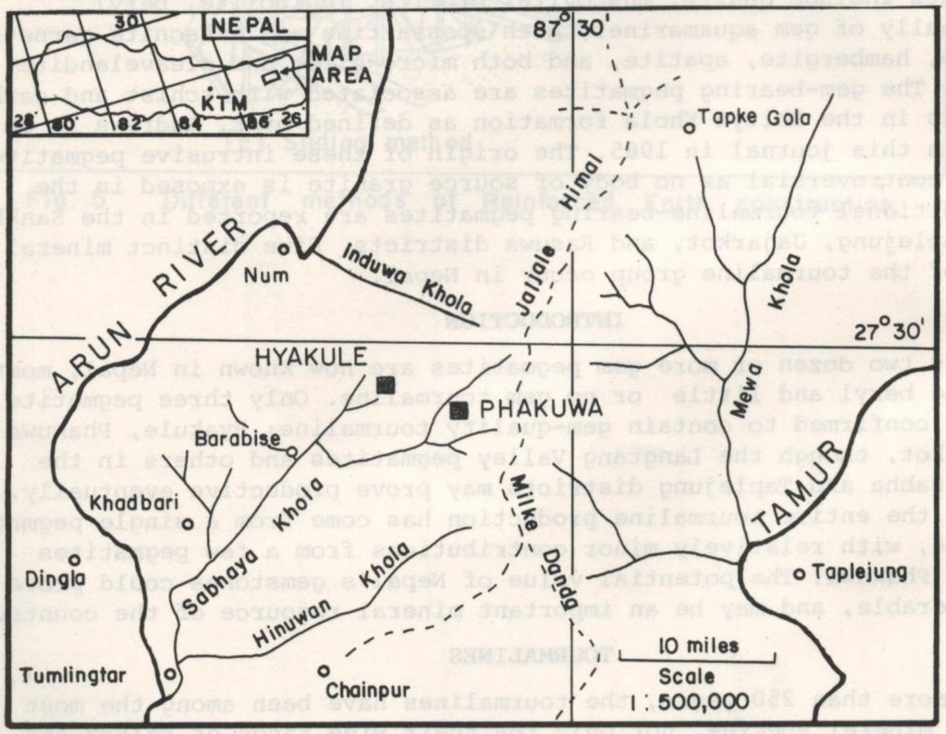

Figure 1. Location of Hyakule and Phakuwa pegmatites

These principal species are all known to occur in Nepal, with liddicoatite not yet completely confirmed. In addition there are three other tourmaline species: chromdravite, ferridravite, and buergerite, none of which are known in Nepal.

By far the most common species is schorl, the black tourmaline that occurs in great abundance most particularly in the high Himalayan granites. Practically all of the gem tourmalines of Nepal are of the multicolored species, elbaite, or the almost identical species, liddicoatite. Dark brown dravite generally occurs in schists and gneisses, and is found in far eastern Nepal in the Taplejung District. Uvite forms in sericite schist (Aryal, R.K., personal communication, 1986) in western Nepal in the Jajarkot District. It is a yellow-brown to amber color, and is seldom, though occasionally, cut as a gem.

HYAKULE and PHAKUWA MINES

The Hyakule and Phakuwa pegmatite dikes are about 5½ km apart at approximately 27° 28' N. latitude and 87° 23' E. longitude, in the Sankhuwa Sabha District, Kosi zone, Eastern Nepal, at an altitude of around 2000 meters. (Figure 1).

At Hyakule, two parallel pegmatites about 62 meters apart strike northwest. The upper, northeastern pegmatite, 150 meters in length, contains no gem tourmaline but has abundant blue beryl, some of which is relatively transparent pale blue aquamarine. Some years ago a tunnel was driven about 30 meters into the length of this pegmatite by the Bureau of Mines to appraise the gem resources, with emphasis on beryl, and a report filed with the Bureau by D.B. Khattri and M.P. Shrestha (1969). The lower, southwestern pegmatite has been intermittently worked for gem tourmaline since its discovery in 1934. Since the pegmatite was last worked intensively many years ago, it has been buried completely by the debris of landslides that occur annually during the heavy monsoon rains of summer (Bassett, 1977) and at present is nowhere exposed in place; therefore its dimensions are not known. It is believed to have a width of approximately 3 meters at its widest bulge and to taper to dikes of 2-meter widths at the extremities of its 90 meter length. The country rock above the upper pegmatite and below the lower pegmatite is a mica schist, while the rock between them is a foliated wavy dolomite, strongly suggesting that the pegmatites were influenced in their emplacement by the boundaries of the dolomite layer.

At the time of the Bureau of Mines investigation (1968-69), the pegmatite was exposed for a length of about 30 meters, and the "width of the pegmatite varies from 1.6m to 2.9m. Tourmaline is found in pockets surrounded by quartz crystals and lithium mica. There is no definite pattern regarding the size and interval of these gem pockets. But it was observed that pockets are present in the portion where there was less concentration of biotite; and near the pockets, the size of quartz and feldspar minerals increased." (Khattri & Shrestha, 1969, p. 4).

At Phakuwa, several pegmatites of various orientations, sizes, and shapes have been opened by crude mining, and, though most of them contain some tourmaline, very little of gem quality has been found. Most of the tourmaline is brown and green in opaque crystals with multiple color bands, but some transparent strongly dichroic yellow-green to emerald-green crystals have been found, and a very few of the distinctive and highly prized grass-green crystals. Work has been suspended at the Phakuwa pegmatites for several years but is due to resume soon.

Boris Shmakin made a study of these two pegmatite fields (1981) and says "the proper classification is schorl-biotite type" in which "alkaline replacement is well developed".

HISTORY AND PRODUCTION

The history of the Hyakule Mine is difficult to reconstruct but the often-conflicting information indicates that in 1934, the year of the great Bihar earthquake of magnitude 8 ½ in the Assam Hills of northeast India, a landslide first exposed the pegmatite, and during the next few years two or three baskets of tourmaline crystals were extracted. During the 1950's and 1960's several successful mining efforts yielded over a ton of tourmaline crystals. In the 1968-69 season, the Bureau of Mines sent a team to investigate the beryl and gem potential, and their report (Khattri & Shrestha, 1969) was discouraging regarding the gem potential. Since then the old dumps have been sporadically reworked but the pegmatite dike has not been uncovered. Finally, in 1980, Nepal Gems Industry Ltd. of Biratnagar acquired the mine claim and hopes to reopen the pegmatite dike for further tourmaline mining.

Over the period of 50 years since the discovery of the Hyakule pegmatite, a fairly well documented yield of at least 1300 Kg of gem tourmaline has been produced, while it is likely that an undocumented 4500Kg has actually been mined. Until the pegmatite is reopened, there is no way to guess how much, if any, remains available.

The nearby Phakuwa mine has produced only a fraction of that from the Hyakule mine. Most of it is of an undesirable opaque brownish green color, but a few very fine crystals of emerald green to vivid grass-green tourmaline have been found there. The new claimant intends to open several new pegmatites in the area.

GEOLOGIC SETTING, ORIGIN AND AGE

In eastern Nepal, small swarms of pegmatite dikes cut discordantly across the foliation and bedding of a metamorphic sequence of marbles, dolomites and schists, with quartzite layers, named the Khitya Khola formation by Andrews (1985), who places it directly below the Main Central Thrust of the Himalayas. This formation extends in a belt that snakes across at least 48 Km of mostly unexplored territory in a pair of north-plunging folds with axes transverse to the general east-west strike of the Himalayan formations. The topography is reversed in these large folds, with the western anticline breached by the Arun River Valley, and the eastern syncline forming the high ridge of the Jaljale Himal. The Hyakule and Phakuwa deposits lie in the northeast-dipping strata of the limb between these folds.

The absence of any known plutonic body from which the pegmatites might have been derived. and their occurrence in the uppermost formation of a series of similar metamorphosed stratigraphic sequences apparently stacked one above the other by imbricate thrusting, suggest that the origin of the pegmatites may not be from residual fluids of a parental granitic pluton, as is thought true for most pegmatites. Their presence just below a major plane of thrusting in the Himalayas suggests the possibility of an origin related to the heat generated by a crustal shortening of at least hundreds of kilometers along that thrust plane as the Indian subcontinent underthrust the Asian continent in a major plate collision that is probably still active.

A more plausible alternative is that under the conditions of intense shearing of the abundant paragneisses in the area, alkali elements and water enabled a lower melting point to cause partial anatexis or localized granitization. Such small, rather diffuse patches of coarse pegmatitic granite with much black tourmaline are seen today in the sheared gneisses. These mobile components may have been squeezed out and up, collecting into large enough quantities to crystallize as pegmatites when they encountered the carbonate rocks just below the Main Central Thrust with which they seem to be associated. The gem pegmatites are clearly intrusive, with thin contact metamorphic borders and xenoliths contained within them, and are not of the diffuse granitization type.

However, the area has not been mapped in sufficient detail to eliminate the possibility that parent granitic plutons exist but have not yet been found, nor can the possibility be ignored that such plutons exist at depth but are nowhere exposed at the surface, despite deep erosion.

In any event, because all enclosing rocks are severely foliated and lineated due to the intense thrust shearing and pressures of burial, whereas the pegmatites are not at all, it is believed that these pegmatites are younger than the adjacent metamorphism, and may well be the youngest pegmatites exposed anywhere in the world. They are probably of late Tertiary age, following most of the mountain-building forces of the Himalayas, but no radiometric dates have yet been obtained specifically on these pegmatites. Many K/Ar dates on metamorphic rocks of eastern Nepal fall in the range of 9 to 20 million years, but "the extremely young ages (3.7 and 5.5 m.y.) determined near the Main Central Thrust are a manifestation of the very late cooling (or the very high temperature gradient) present around this most important feature of the Himalayan Range." (Krummenacher, et al, 1978).

MINERALOGY and GEMOLOGY

Tourmalines are among the most distinctive and fascinating of all the known minerals and rank among the most valuable. The use of the unfortunate term "semi-precious stones" in reference to gems such as tourmaline is strongly discouraged by gemologists and should be abandoned, Due to their rarity and beauty, Nepal tourmalines of fine quality that have been well faceted for maximum brilliance are highly prized by gem connoisseurs and their international recognition has been enhanced by recent publications in international journals (Bassett, 1979, 1985).

Crystal forms

Nepal tourmaline crystals form most commonly in long prisms having a rounded triangular cross section, but some crystals are truly hexagonal, or form as compound trigonal and hexagonal (nine-sided) prisms. Hyakule crystals are most commonly terminated at the positive end by trigonal pyramids or a single pedion face, and sometimes by both, but several simple additional pyramidal faces are sometimes noted at steeper angles on the positive end of the crystals. Generally, imperfect and undecipherable faces, always inclined only slightly from the basal pedion, are typical of the negative ends of doubly terminated Hyakule crystals. All the crystals from Phakuwa are terminated by the pedion, only rarely modified by small pyramidal faces.

Color

Most fine, terminated tourmaline crystals from the Hyakule gem pockets are predominantly pink, with the upper 10 to 20% of their length banded from pink through a colorless or yellow band to a band or pyramidal phantom of bright green, often capped by a thin surface of pink again. The base of the pink crystals is often a dark olive-green, usually not of gem clarity, with a dark brown to amber core. Virtually every color combination has been found with the exception of blue and purple which seem to be colors completely lacking in Hyakule tourmalines. In the solid pegmatite rock, larger opaque tourmalines generally have a color sequence outward from a black or very dark brown core through yellow-brown and yellow-green bands to pink edges. Concentrically color-zoned crystals, called "watermelon" occur commonly in many color combinations; the most distinctive from Hyakule are lemon yellow or brown with a pink rim, or pink with a lemon-yellow or colorless rim. True watermelons with a pink center and green rind are very scarce.

At the Phakuwa mine most material is opaque dark brown, ochre, and yellow-green, though fine crystals of vivid grass-green to strongly dichroic emerald-green have been found.

Pleochroism

Nepal tourmalines are strongly dichroic. Pink crystals, even of only a light to medium pink when viewed through the side of the crystal, appear a rich violet-rose when viewed lengthwise. Much of the Hyakule pink tourmaline has a dichroic yellow component not generally detected without a dichroscope, but in some thick Pink crystals the dichroic yellow completely masks the pink. When a pink crystal has a bright green band, the long-axis colour becomes a deep orange to rose-orange.

The usual green tourmalines of Nepal, as elsewhere, have either total absorption along the c-axis, are dark muddy brown to amber. The least dichroism, except for the achroic tourmaline, is in the lemon-yellow, which may be only faintly greenish perpendicular to the c-axis.

Physical properties

Tourmaline has a hardness of 7 to 7½ and no perceptible cleavage, making it excellent for gemstone use. Specific gravities of Nepal tourmalines range widely from a low of 2.99 for the dusky rose, 3.04 for the typical pink, 3.05 for the lemon-yellow, 3.06 for the green, to as high as 3.14 for the high-manganese deep yellow to amber tourmalines, all readings measured on a gem scale by immersion in water on several unflawed crystals or cut stones of each color.

The indices of refraction (measured on a GIA refractometer) of faceted pink and green elbaites from Hyakule and Phakuwa, are consistently in the range O=1. 640 to 1.645, E = 1. 618 to 1.624, except for the dark yellow and amber manganese-rich tourmalines that run as high as 1.655 and 1.635, respectively.

Fluorescence

As widely reported elsewhere, long-wave (LW) ultra-violet radiation has no visible effect on tourmaline, but under short-wave (SW) ultra-violet, the colorless and pink tourmalines of Nepal react generally with a weak to moderate yellow fluorescence. None of the yellow, amber or green tourmalines react to either SW or LW ultra-violet radiation. These results disagree with those reported by others who list only blue fluorescence for elbaite tourmalines worldwide, whereas all the pink from Hyakule fluoresces yellow.

The uvites from the Jajarkot District fluoresce a strong chalky yellow, while the dravites from Taplejung are inert to any ultraviolet radiation.

Inclusions

Tourmaline is very rarely completely devoid of internal inclusions, particularly in the pink and red varieties, and hence, like emeralds, flawed stones are acceptable in the gem market and retain high value even when moderately included. Flawless tourmaline gems, especially from Nepal, are rare and costly. The usual inclusions in Nepal tourmalines are veils composed of interconnected microscopic cavities of angular and irregular outline filled with liquid and gas, referred to as two-phase liquid inclusions. Also frequent in Nepal tourmalines, especially those of grass-green color from Phakuwa, are many thin thread-like water-filled tubes parallel to the c-axis. When these are closely-spaced enough, it is possible to cut cat's-eye tourmaline cabochons, but these are very rare in Nepal as elsewhere.

Artificial color enhancement

Experiments carried out in an effort to improve the intensity of color in Nepal tourmalines, both by heating and by irradiation, as is done with other gems throughout the world, proved entirely unsatisfactory. Pink tourmaline, especially with fluid inclusions, is extremely heat-sensitive and stones crackle easily. Green tourmalines from Phakuwa suffered the same fate when heated in an attempt to lighten the dark green and drive out the olive color component.

Irradiation experiments with Nepal tourmalines, discussed in a report submitted to the Dept. of Mines & Geology (Bassett, 1978), showed that in crystals of light to medium pink tourmaline that were subjected to gamma radiation from a cobalt-60 source at the French atomic center the shade of pink darkens and becomes yellower. Due to the strong dichroism of tourmaline, the added yellow color causes an unattractive change when viewed perpendicular to the optic axis of the crystal, and creates an odd orange-pink color when viewed parallel to the axis reducing the value of the gems.

Yellow Manganese-rich tourmalines

Distinctive lemon-yellow, chrome-yellow, and amber-colored tourmalines from the Hyakule mine have been analyzed by wet chemical and microprobe methods, yielding results of high manganess content, usually between 3 and 7% MnO (Bassett, 1984), while the pink and green tourmalines are devoid of any manganese. These high-manganese yellow tourmalines have a chemical formula, based on the work of F. Cesbron at the University of Paris, of:

$$(Na, Ca)\ (Al, Mn, Li, Fe, Ti)\ 3Al_6\ (Si_6O_{18})\ (BO_3)_3\ (OH)_4$$

A detailed microprobe study made by W.A. Bassett at Cornell University, New York, U.S.A. (personal communication, 1980) of the concentric color bands surrounding a high-Mn amber and yellow tourmaline from Hyakule yielded results of a manganese content as high as 7% in the shells of strong chrome-yellow color, 5 % in light lemon-yellow, 2½ % in dark amber brown, and zero in pink tourmaline. These microprobe analyses gave the surprising result of calcium greater than sodium in several of the shells, thus indicating that the Hyakule tourmalines are, in part, liddicoatite instead of elbaite.

Although the name tsilaisite has been applied to manganese-rich tourmalines (Kunitz, 1929; Slivko, 1961), there is some question as to whether this is appropriate in as much as aluminum predominates over manganese suggesting that the designation manganese-rich elbaite (or liddicoatite) for these yellow Nepal tourmalines is preferable.

A single 21.50-carat chrome-yellow or chartreuse faceted tourmaline obtained in Nepal, and supposedly from a Nepal crystal, is in the collection of the distinguished Swiss gemologist, Dr. E. Gubelin, who had it analyzed. According to the data he has kindly supplied (personal communication, 1980) about 5% MnO and about 11% MgO without CaO or Li_2O and only about 2% Na_2O could make it a gem manganoan dravite. The author does not know of any other gem tourmaline chemically like it from Nepal even though the color is characteristic of the Mn-rich elbaites of Hyakule that contain no magnesium in their composition (Bassett, 1984).

ASSOCIATED MINERALS

The pegmatite dike minerals consist of the usual quartz, microcline, albite, and muscovite, with an unusual abundance of large thin rectangular plates of biotite mica often ten cm or more in length, many opaque blue beryl crystals, black schorl tourmaline, and garnets, surprisingly of two distinct species: the usually-expected spessartine, and also the hessonite variety of grossular garnet, known locally as gomed, but the garnets are not of gem quality. The beryl is abundant in the pegmatite rock, usually in tapered hexagonal prisms of opaque blue, but occasionally is found in transparent hexagonal prisms of light blue aquamarine, unfortunately filled with closely-spaced lily-pad inclusions in (0001) orientation. Much of the microcline is a light greenish blue color and is known as amazonstone or amazonite.

The zoning of the pegmatite and the positions of other minerals have not been worked out because the author has never been able to see the Hyakule pegmatite in place, but it is presumend that most of the unusual minerals here discussed were formed in gem pockets in the core of the pegmatite midway between the walls, based on observation of loose blocks of pegmatite at Hyakule. The pocket minerals associated with the tourmaline generally in well-formed crystals, include only the following, but it is probable that further species will be identified when fresh pockets are available for inspection:

<u>Quartz</u> - in clear, well-formed crystals as the presumed lining of the gem pockets, sometimes with tourmaline crystals embedded among them;

<u>Cleavelandite</u> - the bladed, untwinned, euhedral variety of albite feldspar at the sodic end of the plagioclase series, forming sheaves of well-formed crystals;

Lepidolite - the pink lithium mica in clusters of crystals in well-formed, often concave, hexagonal plates up to 2.5 cm in diameter, sometimes attached to tourmaline crystals;

Danburite - in finely terminated, transparent, colorless to pale yellow crystals usually 2.5 cm long with almost square cross-sections and pinacoid terminations, that test as niobian by XRF analysis; with one fine crystal measuring about 4 cm in length of a strong medium yellow color.

Hambergite - in 2.5 to 5. cm tabular white or colorless crystals, usually euhedral, opaque and etched, but sometimes in rare instances, transparent.

Apatite - in one small cluster of glass-clear colorless well-formed crystals about 1.5 cm long that seem to be yttrian by XRF analysis. Shmakin (1981) noted grayish blue apatite, sometimes mistaken for Beryl.

Spessartine - brilliantly lustrous, multi-faced bright orange crystals, none of which are facetable, apparently occur in the gem pockets to judge from their very sharp crystal outlines, the largest being on the order of one cm.

Beryl - in two forms, sharp clear aquamarine crystals and deeply etched white goshenite crystals, is found on the mine dumps, but because fresh pockets have not been availabe for study, it is not known whether these occur in the pockets, as suspected, or in the main rock of the pegmatite, as do the abundant opaque blue beryl crystals.

Datolite or Herderite? - a single crystal showed up in a parcal of Hyakule tourmaline as a milky white monoclinic prism with pinacoid termination, having a hardness of 5, specific gravity of 2.98, and unobtainable refractive index, with fragments of tourmaline embedded in its surface. An X-ray analysis identified it as datolite, a very unlikely mineral to occur in a pegmatite, and hence it is thought more likely to be herderite, whose physical properties are almost identical.

Neither topaz nor spodumene, both to be expected, have yet been noted in any of the available material or on the mine dumps. It is likely that these, and such commonly associated pegmatite minerals as petalite, pollucite, and lithium phosphates, will be discovered if access to fresh gem pockets were possible.

OTHER NEPAL TOURMALINE LOCALITIES

In addition to the gem tourmalines of Hyakule and Phakuwa, and a few sparse crystals in nearby pegmatites, pink tourmalines are reported to occur in central Nepal in the Langtang Valley, and green tourmalines are found in the Jajarkot District north of Surkhet in western Nepal, as well as from several other localities in both the Sankhuwa Sabha and Taplejung Districts, and possibly in an unconfirmed report of tourmaline in the northern Bhojpur District. A few crystals of gem-quality tourmaline have come from the Ikhabu pegmatite north of the town of Taplejung, and from three other deposits in the Sankhuwa Sabha District: the Chokte pegmatites near Mayum village east of Chainpur, the Thurbu pegmatite on the Ranidunga Danda, and at least one pegmatite near Mangsima east of Num. These deposits merit further exploration.

From western Nepal, also north of Surkhet in the Jajarkot District, transparent medium yellow-brown to orange uvites in good, but not sharp, doubly terminated crystals from 2.5 to 5 cm in length, occur in sericite schist (Aryal, R.K. personal communication, 1986). Though their amber color is quite unusual, these are generally too fractured to be faceted successfully in sizes larger than one carat. If further mining efforts could uncover larger unfractured transparent crystals of this uvite, yet another tourmaline prospect in Nepal could be commercially viable.

Dravite, in small transparent to opaque, dark yellow-brown, perfectly formed crystals, much fractured and included, occur in some abundance in far eastern Nepal near Phabung in the northern Mewa Khola valley north of Taplejung. They are usually between 6 and 20 mm in length, doubly terminated, and of sharp crystal perfection. They are not likely to prove commercially useful as gemstones.

The author has seen no indicolite (blue tourmaline) among thousands of fragments from Hyakule and Phakuwa, but in 1967 a large 500? - carat crystal of fine indicolite was reported to have been bought from a Hyakule miner and sold in Germany. This, and other indicolites of true medium to dark blue without any green, usually not of faceting quality, have probably come from the Chokte pegmatite about 16 Km southeast of the Hyakule Phakuwa pegmatites according to one of the touraline claim holders (personal communication, 1886).

CONCLUSION

It seems certain that if the Hyakule tourmaline pegmatite were reopened, unusually fine gem tourmaline could be expected. And the proposed resumption of mining in the Phakuwa area by its new claim-holder may yield more of the rare and exquisite grass-green, peridot-colored, and emerald-green tourmaline crystals that have been found in the past. And if further exploration and exploitation of other tourmaline deposits in Nepal could be encouraged, there exists an opportunity for the country of Nepal to be distinguished for its tourmaline production. Even though the supply in Nepal is now very limited, its potential value should not be underestimated, and all efforts should be made to encourage its geologic exploration and mining development for the welfare and prestige of the country, bearing in mind this statement made by Deitrich (1985, p. 348): "Today, tourmaline is the most popular of all colored gem-stones."

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