A NEW GEM BERYL LOCALITY: LUUMÄKI, FINLAND

By Seppo I. Lahti and Kari A. Kinnunen

Strongly etched prismatic crystals of yellow, green, and pale blue gem beryl have been quarried from a pegmatite dike in Luumäki, Finland. To date, the pegmatite has yielded about 15 kg of gem beryl, minor amounts of facet-grade topaz, and many varieties of quartz. The gem beryls from Luumäki are similar in gemological properties and chemical composition to other pegmatitic beryls, such as those from Brazil and the Ukraine. Large primary fluid inclusions surrounded by micro-fracture halos may be diagnostic of the new locality.

In 1982, mineral enthusiast Kauko Sairanen noticed a quartz outcrop near a small road in Luumäki, a commune in southeast Finland. Of particular interest were elongated pockets that were lined with quartz crystals and contained a pale yellow transparent mineral that was later identified as beryl. Subsequent geologic mapping showed that the outcrop represented the core of a small pegmatite dike, which had intruded a coarse-grained rapakivi granite (i.e., a granite that contains large potassium feldspar crystals surrounded by a plagioclase shell).

Mr. Sairanen and some friends took out a mining claim in 1986 and formed a company to work the pegmatite. At first the outcrop seemed promising, and several gem-quality crystals—some quite large—were recovered; many have since been faceted (figure 1). However, the small-scale mining conducted to date indicates that the gem beryl occurs sporadically, so the claim owners have continued their work only intermittently.

Luumäki is about 180 km northeast of Finland's capital, Helsinki, and less than 40 km from the Russian border (figure 2). Public access to the quarry is possible with permission from the owners. For this study, we visited the site and collected specimens several times during the last five years. We also studied the gemological properties of several gem beryl crystals and cut stones provided by the mining company.

ABOUT THE AUTHORS

Dr. Lahti is state geologist in the Petrology Department, and Dr. Kinnunen is special research scientist in the Economic Geology Department, at the Geological Survey of Finland, Espoo, Finland.

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GEOLOGY AND OCCURRENCE

Although numerous complex pegmatites occur in the Precambrian rocks of southern Finland, gem minerals have been found only occasionally. In addition to several quartz varieties, small amounts of topaz, kunzite, morganite, yellow beryl, and colored tourmalines have been recovered in the course of feldspar mining (Haapala, 1966; Erämetsä et al., 1973; Lahti, 1981; Lahti and Saikkonen, 1986).

The Luumäki pegmatite is situated in the northern corner of the large Wiborg rapakivi granite complex, which consists of several granite as well as minor anorthosite (some of which contains the local

Figure 1. This pendant features three faceted Luumäki beryls connected by natural gold nuggets from northern Finland. The largest stone weighs about 8.6 ct and is 17.71 mm long. Pendant designed by Aarne Alhonen; photo by Jari Väätäinen.

labradorite often called spectrolite) intrusions. The Wiborg complex covers an area about 100 × 180 km that extends from southeastern Finland to nearby Karelia, Russia. The different rapakivi granites in the region vary between 1,650 and 1,700 million years (My) old (Vaasjoki, 1977); the pegmatites might be somewhat younger. The Svecokarelian granitoids, schists, metavolcanics, and gneisses into which the rapakivi granites were intruded are 1,800–1,900 My.

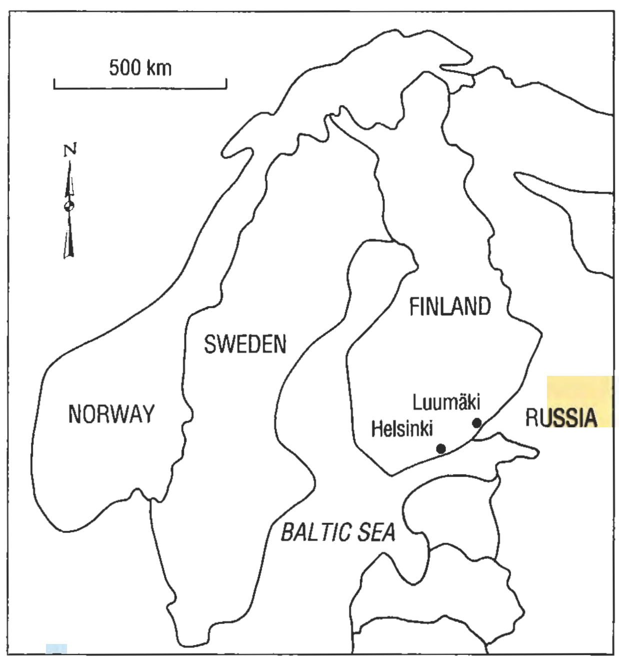
Geologic mapping by one of the authors (SIL) revealed that the pegmatite is a poorly exposed dike about 20 m wide in granite (figure 3). A massive quartz core, about 10 m wide, makes up the central part of the dike. It is surrounded by three feldspar-mica-quartz pegmatite zones referred to here as intermediate, wall, and border. The grain size of the pegmatite increases gradually from the narrow, fine-grained border zone nearest the host granite to the quartz core. The transitions between the zones are also gradual.

The main minerals in the pegmatite, in addition to quartz, are reddish brown microcline, albite, quartz, biotite, and, locally, muscovite. The mineralogy of both the border and wall zones is simple, but the intermediate zone contains a number of rare minerals (table 1). Very large crystals of common beryl, topaz (not of gem quality), and monazite-(Ce) are characteristic in the intermediate zone in particular.

Pockets are abundant in the central parts—the core and intermediate zones—of the dike; they range in diameter from several centimeters to several tenths of a meter. The pockets may contain crystals of quartz, albite, microcline, orthoclase, and gem beryl; locally, bertrandite, goethite, and fluorite are common. The bottom of a pocket is usually covered by a layer of red-brown clay minerals and crystal fragments loosened from the walls.

Two generations of beryl can be distinguished in

Figure 2. The commune of Luumäki, where the gem beryl pegmatite was found, is located about 40 km (25 miles) from Finland's border with Russia.



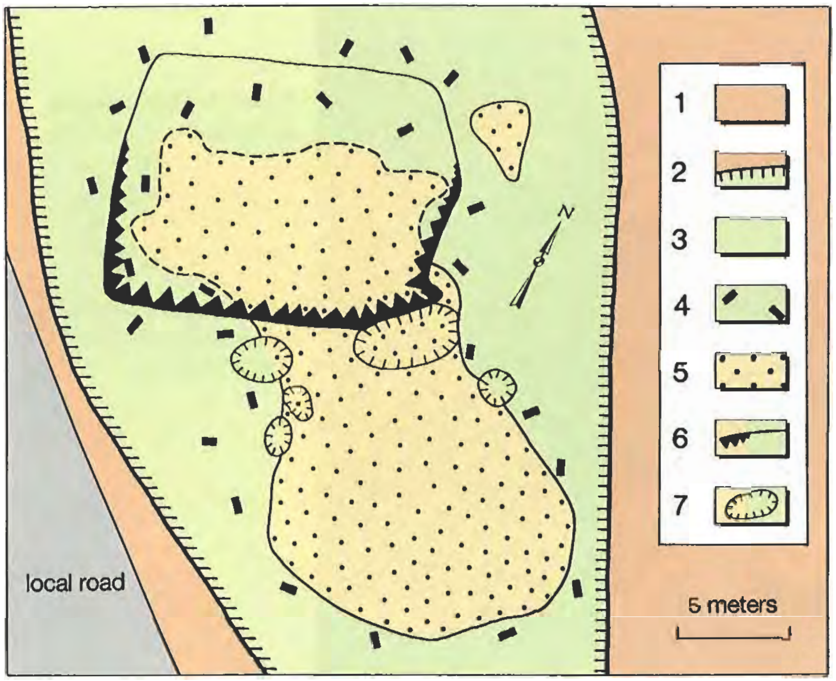


Figure 3. Geologic map of the Luumäki gem beryl pegmatite. The colors represent: (1) rapakivi granite, country rock; (2) fine-grained border zone of the pegmatite dike; (3) wall zone of the pegmatite; (4) very coarse intermediate zone of the pegmatite; (5) quartz core; (6) gem beryl quarry; and (7) larger cavities or crystal pockets observed on the surface, partly abraded and polished during glacial time. Gem beryl has been found in the pockets within the quarry, whereas crystals of common beryl sporadically occur in the intermediate zone around the quartz core. The road on the left joins the village of Jurvala (by the main road no. 6 at Luumäki) to the village of Tuukainen.

the pegmatite: The older is opaque, common beryl (not gem quality), and the younger is transparent, gem beryl. The common beryl is yellow, often strongly altered by hydrothermal solutions, and usually stained and impregnated brown by iron compounds. The crystals of common beryl, which usually range from 5 to 15 cm (up to 30 cm) in diameter, have well-developed first-order prism faces and, occasionally, basal pinacoids (Pitkänen, 1991).

Common beryl occurs in the intermediate zone of the pegmatite, while gem beryl is found only in pockets, either associated with common beryl or embedded in the microcrystalline reddish quartz (jasper) that locally fills the pockets and fractures (figure 4).

The gem beryl crystals usually range in weight from a few grams to several tens of grams. The largest and most attractive crystals found to date are "Mrs. Ellie" and "Mr. Jock," which weigh 450 and 950 grams, respectively. Both are high gem-quality green beryl (figure 5). "Mrs. Ellie" is now in the collection of Finland's Central Museum of Natural History, housed in the Department of Geology and Mineralogy, University of Helsinki.

MINING AND PRODUCTION

The Luumäki pegmatite is mined by a small Finnish company, Suomen Jalokivikaivos Oy, intermittently during the summer months from May to September. The three owners have contracted with a local construction firm for help with heavier mining chores. After blasting with forcite (a slow-detonating type of dynamite), the owners collect the gem material by hand. They use hammers and chisels to empty the pockets and then screen the clay-rich material in water to reveal any gem beryl (figure 6). Currently the pit is 20 m long, 10 m wide, and 5 m deep.

Of the 15 kg of gem beryl found thus far, approximately 40% is facet grade. The gem beryl usually ranges from pale yellow to greenish yellow to yellowish green; rarely, the material is a bright "golden" yellow (figure 7). Approximately 10%–15% of the total would be considered aquamarine, with various shades of blue. Although the mine owners maintain that they have not traded in treated beryl, experiments by the authors have shown that blue aquamarine can also be produced by heating pale green or yellow green beryl from this locality (see Ehrnrooth and Tuovinen, 1989).

TABLE 1. Minerals identified in the intermediate zone of the Luumäki beryl pegmatite.

Silicates		Oxides and others
K-feldspar:	Margarite	Quartz
- Microcline	Illite	Monazite-(Ce)
- Orthoclase	Kaolinite	Goethite
Albite	Smectite	Hematite
Biotite	Vermiculite	Columbite
Muscovite		Microlite-Pyrochlore
Chlorite		Euxenite
Beryl		Fluorite
Topaz		Calcite
Bertrandite		Gypsum

Figure 4. A 5-cm-long cigar-shaped crystal of yellowish green beryl is shown here in the massive reddish brown microcrystalline quartz (jasper) in which it was found at Luumäki. Photo by Jari Väätäinen.

Facet-quality pieces of blue, pale pink, or colorless topaz (0.5–8 ct), as well as smoky, rock crystal, brownish green (praseolite-like), and red (ferruginous, resembling fire opal) quartz have also been found. In addition, much of the quartz recovered can be used for cabochons or tumbling material.

MATERIALS AND METHODS

The Test Sample. The study included about 2 kg of gem beryl rough: numerous crystals or fragments of various sizes and colors—some self-collected and others obtained from the mining company—and 20 faceted stones of various colors that were provided by the mining company. Physical, gemological, and chemical properties were determined on seven (about 1–4 cm) rough pieces of yellow and pale green beryl and on 15 faceted green, yellow, and pale blue stones (1–41.7 ct).

The beryl crystals studied were typical of the locality: prismatic, usually cylindrical or cigar shaped; some were strongly etched and quite irregular in form (again, see figures 4, 5, and 7). The round or oval brilliant-cut, step-cut, and antique-cut stones were fashioned in Finland (by K. Sairanen, M. Lång, and S. I. Lahti) and abroad.

Methods. Gemological properties were determined for the seven rough and 15 faceted beryls, following the routine procedures described in Liddicoat (1989) and Read (1991). Refractive indices were measured with a Rayner refractometer with a sodium light source, and optical absorption spectra were investigated with both a prism and a diffraction-grating spectroscope. Specific gravity was measured in a sodium polytungstate-water solution.

A Philips X-ray diffractometer and Debye-Scherrer camera were used in the X-ray powder diffraction analyses of the beryl samples and in the identification of associated minerals, with reference to the JCPDS (International Center for Diffraction Data) files. Unit-cell dimensions were computed from the indexed X-ray powder diffraction patterns using the computer program of Appleman and Evans (1973). The chemical composition of the gem beryl specimens was determined—using a combination of microprobe analysis, atomic absorption spectroscopy (AAS), and inductively coupled plasma–atomic emission spectroscopy (ICP-AES)—at the Chemical Laboratory of the Geological Survey of Finland.

Solid inclusions were identified by means of polarized microscopy. Gemologically characteristic inclusions were determined from the seven natural-color yellow and pale green beryl crystals and one heat-treated yellow beryl specimen, following the methods outlined by Gübelin and Koivula (1986). The 20 faceted stones were also examined with the microscope; however, most of these were clean, without any inclusions. Fluid inclusions in one rough yellow beryl sample were studied with microscope heating and freezing stages using doubly polished thick sections, (Roedder, 1984; essentially the same techniques and

Figure 5. These three crystals are typical of the high-quality green beryl recovered from the Luumäki pegmatite. The large crystal at the rear, known as "Mrs. Ellie," is 14 cm long and weighs 450 grams. Photo by Jari Väätäinen.

Figure 6. The beryl crystals at Luumäki are usually found embedded in a reddish-brown clay. Here, the miners wash clay removed from pockets in the pegmatite to reveal any beryl crystals present. Photo by Matti Lång.

Figure 7. Most gem beryl crystals from the Luumäki pegmatite range from yellow to greenish yellow and yellowish green. The largest crystal, in the front, is 7.2 cm wide and weighs 110 grams. Note the "golden" yellow crystal in the upper left. Photo by Kari A. Kinnunen.

equipment as described in Spencer et al., 1992). The photomicrography employed new illumination methods and instruments designed by Kinnunen (1991a, b).

PHYSICAL APPEARANCE AND GEMOLOGICAL PROPERTIES

The strongly etched crystals showed prism faces that were striated and/or full of individual rectangular pits, complex groups of pits, or strings of pits along the c-axis (figure 8). The surfaces along the basal pinacoids were full of hexagonal etch pits. The pits varied greatly in area and depth; some had stepped walls.

Figure 8. The surface texture on the prism face of this Luumäki yellow beryl crystal is typical of the material found at this locality. Prolonged natural etching has produced the stepped, mosaic-like surface features, with etch pits and hillocks. Photomicrograph by Kari A. Kinnunen; transmitted Rheinberg illumination (blue/yellow dual-circular filter to enhance the three-dimensional effect) and shadowing; magnified 8×.

The gem beryls examined ranged in color from pale yellow to "golden" yellow, pale yellow-green to pale green, and pale blue (see, e.g., figure 9). The gemological properties, as described in table 2, appear to be consistent with gem beryls in these color varieties from other localities (Liddicoat, 1989; Sinkankas, 1989). Note that the specific gravity is slightly higher than that given for pure $Be_3Al_2Si_6O_{18}$ (2.62–2.66), but corresponds well to the values given for aquamarine and other pale beryls (2.628–2.730) with a low alkali content (see, e.g., Sinkankas, 1989, p. 191).

INTERNAL CHARACTERISTICS

The mineral inclusions identified in the Luumäki beryls—small albite crystals, mica, quartz, beryl (observable only with crossed polarizers), and clay and a hematite-like material filling fractures and growth tubes—are known to occur in beryls from other localities (see, e.g., Gübelin and Koivula, 1986; Sinkankas, 1989). However, certain other internal features appear to be distinctive of this occurrence. Growth tubes and corrosion tubes were common near the basal planes of the crystals examined (figure 10). They were observed to run parallel to the c-axis and usually to widen as they approached the surface of the crystal, similar to the "trumpet-like" inclusions described in the pegmatitic beryls from the Ukraine (Bartoshinskiy et al., 1969; Sinkankas, 1989, p. 245). In cut stones, however, the terminations may be thin. These inclusions are similar to the growth tubes in aquamarines known as "rain" (see Gübelin and Koivula, 1986). In Luumäki beryls, however, the inclusions appeared wider than is typical for "rain," main-

Figure 9. Luumäki gem beryls in a wide range of colors have been faceted. The large oval stone at the top weighs 41.7 ct and is 27 mm wide. All of these stones are of natural color. Photo by Jari Väätäinen.

TABLE 2. Gemological properties of gem beryl from a pegmatite in Luumäki, Finland.[a]

Color	Transparent "golden" yellow, pale yellow, pale yellow-green, pale green, medium green or—rarely—natural (pale blue) aquamarine
Refractive indices	
Pale green and golden yellow	ϵ = 1.566-1.568, ω = 1.574-1.575
Aquamarine (natural blue)	ϵ = 1.564, ω = 1.572
Luminescence	Inert to both long- and short-wave U.V. radiation
Specific gravity	2.685–2.688
Optical absorption spectrum	No specific lines or bands
Dichroism	Green: bluish green/pale yellow green; in heat-treated aquamarine, pale blue-green/blue
Polariscope	Slight anisotropism in the direction of the c-axis
Chelsea filter reaction	Pale green
Internal characteristics	Mineral inclusions—albite, mica, beryl, quartz (all identified with polarized microscopy), clay and hematite-like material in some fractures and growth tubes; large primary fluid inclusions almost always surrounded by micro-fracture halos formed by natural decrepitation may be diagnostic of this locality
Thermal reaction	Strong decrepitation of fluid inclusions at 400°–460°C

[a] *Properties listed were obtained from seven pieces of rough—six yellow and one pale green—and 15 faceted stones. With the exception of dichroism, the gemological properties of the heat-treated material were not tested. See text for methods used.*

ly because of the etching phenomena; some are more properly classified as corrosion tubes.

Primary fluid inclusions (three-phase type) were found in negative crystals along former growth zones, in irregular cavities, and in tube-like channels along the c-axis of the gem beryl. Pseudosecondary and secondary fluid inclusions were found in partially healed fracture planes with a random orientation, commonly as "veils" showing fingerprint-like healing patterns.

Study of the primary and secondary fluid inclusions with microscope heating and freezing stages revealed the following characteristics for the Luumäki beryls: phase composition at room temperature—water 52%–76%, vapor 24%–48%, daughter minerals 2%–3% (one isotropic, two anisotropic, and one nonmagnetic opaque); homogenization temperature—370°–390°C; salinity—7.3%–7.5% NaCl equivalent; density—0.7; pressure estimate—0.2 to1.0 kbar (see Kinnunen et al., 1987); and pressure-corrected crystallization temperature—400° to 490°C. These char-

Figure 10. Growth tubes parallel to the c-axis were found to be characteristic of Luumäki beryl. Small syngenetic mineral inclusions (albite) can be seen here in the ends of the needles. Photomicrograph by Kari A. Kinnunen; transmitted crossed polarized light, magnified 20×.

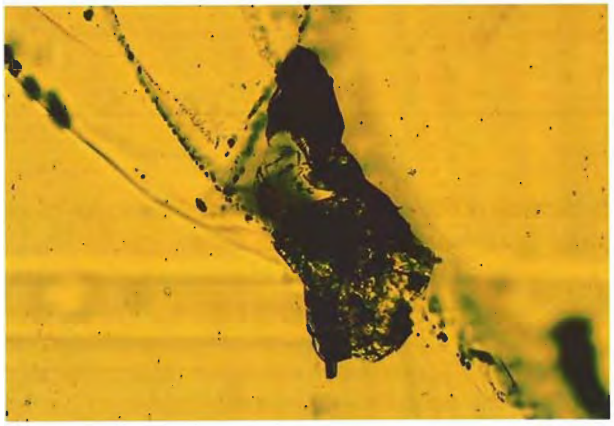


Figure 11. Large, naturally decrepitated fluid inclusions, like those shown here, appear to be diagnostic of Luumäki gem beryls The small cracks incorporate submicroscopic fluid inclusions as a result of healing during recrystallization. Photomicrograph by Kari A. Kinnunen; darkfield illumination, magnified 32×.

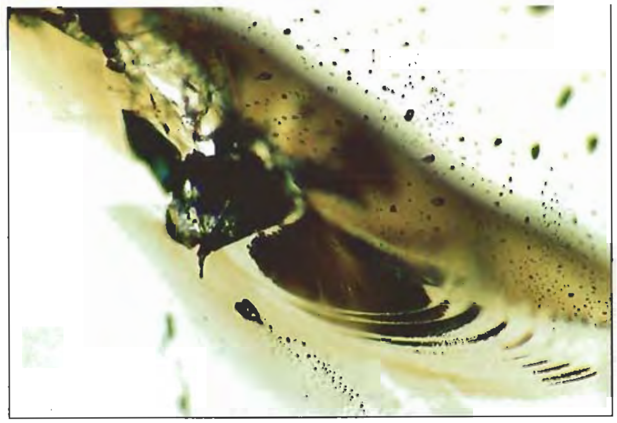


Figure 12. In this heat-treated yellow beryl from Luumäki, the once fluid-containing cavities are now empty. They appear dark because of total reflection of transmitted light. Note, too, the different appearance of the micro-fractures that surround the inclusion. Photomicrograph by Kari A. Kinnunen; magnified 32×.

acteristics are typical of late aqueous fluids from pegmatitic environments (cf. Roedder, 1984).

Many of the large fluid inclusions seen in the Luumäki gem beryls were surrounded by networks of micro-fractures (figure 11), small cracks that formed during natural decrepitation. These micro-fractures healed in recrystallization, at which time small secondary fluid inclusions were trapped. A few of the cut stones also showed these inclusions, which have not been reported in beryls from other localities. When the inclusions were examined with a stereomicroscope and pinpoint lighting, they closely resembled the flower-like discs, or "sun-spangle" inclusions, found in treated amber (see Gübelin and Koivula, 1986). Note that the fractures formed during the heat treatment of beryl are different (air filled) and show no healing textures (figure 12).

CHEMICAL COMPOSITION

The chemical composition of the Luumäki gem beryls (table 3) closely resembles that of certain Ukrainian and Brazilian gem beryls (see, e.g., Bartoshinskiy et al., 1969; Correia-Neves et al., 1984). Both the green and "golden" yellow varieties were found to be poor in alkali and earth alkali metals compared to pegmatite beryl in general (Černý, 1975), but they contained minor concentrations of iron and water. Beryls found in crystal pockets in pegmatites and granites are typically low in alkalis (Černý, 1975).

Unit-cell data for the "golden" yellow beryl are as follows: the space group P6/mcc, a = 9.203 (1) Å and c = 9.192 (2) Å, vol. = 672.68 Å^3, c:a = 0.999. The values agree with those calculated from the chemical data. The lengths of both crystallographic axes are close to those of pure $Be_3Al_2Si_6O_{18}$, or of Brazilian and Ukrainian beryls that contain minor amounts of water in addition to the major elements (see, e.g., Bakakin et al., 1970; Sinkankas, 1989; Correia-Neves et al., 1984). The unit-cell dimensions of the various color varieties did not differ markedly from one another.

HEAT TREATMENT

According to Nassau (1988), the yellow color of beryl is caused by ferric iron (Fe^{3+}) that substitutes for alu-

TABLE 3. Chemical composition of Luumäki gem beryl.[a]

	Yellow		Green	
	Range	Average	Range	Average
Oxide[a] (wt. %)				
SiO_2	64.32–66.09	65.08	64.16–65.44	64.87
Al_2O_3	16.55–17.44	16.86	16.50–17.30	16.86
BeO	13.71		13.32	
Fe_2O_3	0.33–0.48	0.41	0.47–0.68	0.56
Na_2O	0.02–0.06	0.04	0.03–0.08	0.06
Li_2O	0.01		n.d.	
MgO	0.00–0.07	0.02	0.00–0.18	0.05
CaO	0.00–0.02	0.01	0.00–0.04	0.02
H_2O_+	1.02		n.d.	
Trace element (ppm)				
Co		293		438
Cs		278		122
Zn		69		91
Sc		49		29
Cr		18		23
Ni		16		13
V		19		11

[a] SiO_2, Al_2O_3, Fe_2O_3 (= total iron), Na_2O, MgO, and CaO were analyzed by microprobe techniques from a thin section of each crystal; the average is based on nine determinations. BeO, Li_2O, and Cs were assayed from a dissolved beryl sample with atomic absorption spectroscopy (AAS). The other trace elements were determined from the dissolved beryl with inductively coupled plasma-atomic emission spectrometry (ICP–AES): H_2O_+ was determined with a Leco RMC–100 rapid moisture determinator. All of the determinations are from the same two specimens. n.d. = not determined.

minum in the structure of the mineral. In green beryl, iron occurs partly in the channel position and partly replaces aluminum. Heat treatment fades the yellow color and changes green varieties to blue.

Heating experiments with Luumäki beryl gave similar results. The "golden" yellow beryl faded to nearly colorless if the stones were kept two to five hours in an oven at temperatures between 400° and 500° C. Green beryl became blue when heated under the same conditions. The specific hue and saturation of the heat-treated blue color varied from one sample to the next, in direct relationship to the intensity and shade of the original green material (see Ehrnrooth and Tuovinen, 1989).

CONCLUSION

The Luumäki pegmatite shows features typical of miarolitic pegmatites (i.e., those with crystal-lined cavities; Černý, 1991), which are important sources of gem minerals. To date, however, mining has produced relatively little gem-quality beryl. Because only a small portion of the dike is visible on the surface, though, the economic significance of the occurrence is impossible to estimate without further study, further exposure of the pegmatite, and/or core drilling.

The complex rapakivi granite–anorthosite intrusions seem to have potential as sources of gem minerals in Finland. In addition to the known spectrolite deposits, the authors have found minor pockets of gem minerals. The mineralogic and geologic similarities between the Luumäki pegmatite and the productive Ukrainian gem beryl and topaz pegmatites, which occur in a rapakivi-type granite of the same age (Bartoshinskiy, 1969; Sinkankas, 1989; Koshil et al., 1991), also favor this conclusion. In addition, pegmatites usually occur in groups or clusters (i.e., pegmatite districts), so it is likely that there may be more gem-bearing pegmatites in this region of Finland.

REFERENCES

Appleman D.E., Evans H.T. (1973) Job 9214: Indexing and least-squares refinement of powder diffraction data. In *U.S. Geological Survey, Computer Contribution 20*, U.S. National Technical Information Service, Document PB2-16188, 62 pp.

Bakakin V.V., Rylov G.M., Belov N.V. (1970) X-ray diffraction data for identification of beryl isomorphs. *Geochemistry International*, Vol. 7, No. 6, pp. 924–933.

Bartoshinskiy Z.V., Matkovskiy O.I., Srebrodolskiy B.I. (1969) Aktsessornyy berill iz kamernykh pegmatitov Ukrainy (Accessory beryl from the chamber pegmatites of the Ukraine). *Mineralogitcheskiy Sbornik*, Vol. 23, pp. 382–397.

Černý P. (1975) Alkali variations in pegmatitic beryl and their petrogenetic implications. *Neues Jahrbuch für Mineralogie, Abhandlungen*, Vol. 123, No. 1, pp. 198–212.

Černý P. (1991) Rare element granitic pegmatites. Part 1: Anatomy and internal evolution of pegmatite deposits. *Geoscience Canada*, Vol. 18, No. 2, pp. 49–67.

Correia-Neves J.M., Monteiro R.L.B.B., Dutra C.V. (1984) Composição química de berilos pegmatíticos do Brasil e seu significado petrológico e metalogenético (Chemical composition of pegmatitic beryls in Brazil and their petrological significance). *Revista Brasileira de Geociencas*, Vol. 14, No. 3, pp. 137–146.

Ehrnrooth E.-K., Tuovinen P. (1989) Luumäen beryllien lämpökäsittely (Heat treatment of the Luumäki beryls). *Gemmologian Työsaralta* (publication of the Gemmological Society of Finland), No. 18, pp. 4–19.

Erämetsä O., Nieminen K., Niinistö L. (1973) Two transparent beryl varieties from the Kaatiala pegmatite, Finland. *Bulletin of the Geological Society of Finland*, Vol. 45, Part 2, pp. 125–130.

Gübelin E.J., Koivula J.I. (1986) *Photoatlas of Inclusions in Gemstones*. ABC Edition, Zürich, 532 pp.

Haapala I. (1966) On the granitic pegmatites of the Peräseinäjoki-Alavus area, South Pohjanmaa, Finland. *Bulletin de la Commission Géologique de la Finlande*, Vol. 224, 98 pp.

Kinnunen K.A. (1991a) Three-dimensional microscope image using anaglyphic filters: A new aid to fluid inclusion petrography. *American Mineralogist*, Vol. 76, pp. 657–658.

Kinnunen K.A. (1991b) Parempia valokuvia stereomikroskoopilla (High-quality photomicrographs with the stereomicroscope). *Geologi* (publication of the Geological Society of Finland), Vol. 43, No. 6, pp. 113–114.

Kinnunen K.A., Lindqvist K., Lahtinen R. (1987) Fluid history from crystal cavities in rapakivi, Pyterlahti, southeastern Finland. *Bulletin of the Geological Society of Finland*, Vol. 59, Part 1, pp. 35–44.

Koshil I.M., Vasilishin I.S., Pavlishin V.I., Panchenko V.I. (1991) Wolodarsk-Wolynskii Geologischer Aufbau und Mineralogie der Pegmatite in Wolynien, Ukraine (Geology of Wolodarsk-Wolynski; and the mineralogy of the pegmatites in Wolhynia, Ukraine). *Lapis*, Vol. 10, No. 10, pp. 27–40.

Lahti S.I. (1981) On the granitic pegmatites of the Eräjärvi area in Orivesi, southern Finland. *Geological Survey of Finland Bulletin*, Vol. 314, 82 pp. (monograph).

Lahti S.I., Saikkonen R. (1986) Kunzite from the Haapaluoma pegmatite quarry, western Finland. *Bulletin of the Geological Society of Finland*, Vol. 58, No. 2, pp. 47–52.

Liddicoat R.T. Jr. (1989) *Handbook of Gem Identification*, 12th ed. Gemological Institute of America, Santa Monica, CA.

Nassau K. (1988) *Gemstone Enhancement*. Butterworths, London.

Pitkänen R. (1991) Luumäen jalokivipegmatiitti (The Luumäki gem beryl pegmatite). *Kivi* (publication of the Finnish Gem Hobbyists' Society), Vol. 9, No. 1, pp. 27–29.

Read P.G. (1991) *Gemmology*. Butterworth-Heinemann, Oxford.

Roedder E. (1984) Fluid inclusions. In P.H. Ribbe, Ed., *Reviews in Mineralogy*, Vol. 12, Mineralogical Society of America, Washington, DC, 644 pp.

Sinkankas J. (1989) *Emerald and Other Beryls*. Geoscience Press, Prescott, AZ.

Spencer R.J., Levinson A.A., Koivula J.I. (1992) Opal from Querétaro, Mexico: Fluid inclusion study. *Gems & Gemology*, Vol. 28, No. 1, pp. 28–34.

Vaasjoki M. (1977) Rapakivi granites and other postorogenic rocks in Finland: Their age and the lead isotopic composition of certain associated galena mineralizations. *Geological Survey of Finland Bulletin*, Vol. 294, 64 pp. (monograph).