Beryl Group Minerals Summary

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General Formula: \( R \ X_3 \ Y_2 \ (T_6O_{18}) \ \bullet \ pH_2O \)

Where:
- \( R = Cs^{1+}, Na^{1+} \) (in the channel site), \( \text{♦} = \) (Vacancy)
- \( X = Be^{2+}, Al^{3+}, Li^{1+}, (Si^{4+}) \)
- \( Y = Al^{3+}, Sc^{3+}, Fe^{3+}, Mg^{2+}, (Cr^{3+}), (V^{3+}), (Fe^{2+}) \)
- \( T = Si^{4+}, Al^{3+} \)

\( \text{♦} \) : Symbol used to indicate vacancy (missing ions from a site).

Ions in ( ) indicate minor substitution.

Where \( p \approx 0.05 - 1.8 \)

### Beryl Group Compositions

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Beryl

Beryl is the most abundant member of the beryl group. It is the aluminum-dominant member of the group and occurs in giant crystals up to many meters in length in some pegmatites. Beryl occurs in several gem varieties that are avidly sought after: blue to green aquamarine, yellow heliodor, grass green emerald, pink morganite, red ‘red beryl’, and colorless goshenite. Beryl is one of the oldest known minerals, though the origin of the term "beryl" is unclear. It may have been derived from the Greek term "beryllios", which was used to refer to blue-green gems in general. The crystal structure consists of flat Si6O18 rings, which are linked to one another by beryllium and aluminum. The Si6O18 are stacked in perfect alignment along the c-axis, creating channels in the crystal structure that run parallel to the c-axis. In most beryl group minerals, some water and cations, particularly alkalis such as sodium, potassium, cesium and rubidium, are contained within the channels.

**Composition:** \( \text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18} \)
**Dana number:** 61.1.1.1

**Crystal System and Structure:**
Beryl is hexagonal; space group P6/mcc, point group 6/m 2/m 2/m; \(a = 9.205-9.274 \, \text{Å}, \quad c = 9.187-9.249 \, \text{Å}\). The structure has the octahedral layer strongly compressed parallel to the c-axis. The Me-O distance in beryl is 1.904 Å.

**Physical Properties:**
Beryl has vitreous luster, a white streak and is not soluble in mineral acids, not very soluble in HF. Beryl has an imperfect cleavage on (0001). Its hardness ranges from 6 to 7; density ranges from 2.63-2.97 g/cm³ (Anthony *et al.*, 1995).

**Color & Luminescence:**
Beryl is most commonly colorless, white, blue to green, yellow, red, or pink (Anthony *et al.*, 1995).

**Optical Properties:**
Beryl is uniaxial negative. \(N_- = 1.567-1.610, \quad N_+ = 1.565-1.599\).

**X-ray Diffraction Lines:**
The following are the eight most intense diffraction lines for beryl (JCPDS # 9-430): 7.98 (90), 4.60 (50), 3.99 (45), 3.254 (95), 3.01 (35), 2.867 (100), 2.523 (30), 2.152 (16), 1.9926 (520), 1.7397 (20).

**Forms and Morphology:**
Crystals are typically prismatic and exhibit the basal pinacoid \{0001\} and the hexagonal prism \{10-10\}, less frequently displayed are several dipyramids.

**Common Beryl Morphologies:** pinacoids, prism; dipyramid 2 -1 -1 2; pinacoids, prism, as well as 1st and 2nd order dipyramids 2 -1 -1 1 and 2 -1 -1 2; thick tabular crystal, pinacoids, prism, dipyramids 2 -1 -1 2

**Alteration and Replacement:**
Alteration products are common; bertrandite, bavenite, as well as many Be-phosphates such as hydroxyherderite are well-known from many locations.

**Occurrence:**
With the exception of the emerald and red beryl varieties, beryl forms primarily in granitic pegmatites. Most ore beryl occurs in massive pegmatite zones, where crystals may reach giant size. Crystals in excess of 20 tons are known. Euhehedral beryl, including goshenite, aquamarine and morganite, can be found adjacent to the core margin of the pegmatite and in miarolitic cavities.

**Locations:**
Important locations for beryl include the Ural Mountains, Russia; near Volhynia in the Ukraine; in the Ligonha district in Mozambique; from many pegmatites in Minas Gerais, Brazil; near Muzo and Chivor, Colombia; near Kunar, Afghanistan; in the Skardu district, Pakistan; in the Wah Wah Mountain, Utah.

**Associated minerals:**
Quartz, potassium feldspar, albite, muscovite, spodumene, tourmaline and many others.
Bazzite

Bazzite is a rare scandium-dominant member of the beryl group. It is named for its discoverer Alessandro E. Bazzi (1892-1929) (Gaines et al., 1997). Bazzite crystals are generally small, typically in the millimeter range, though they sometimes reach a maximum length of several centimeters. Bazzite is morphologically similar to beryl, and in spite of the small crystal size is a highly desirable mineral that is avidly sought by collectors.

**Composition:** \( \text{Be}_3\text{Sc}_2\text{Si}_6\text{O}_{18} \)

**Dana number:** 61.1.1.2

**Crystal System and Structure:**
Bazzite is hexagonal; space group P6/mmc, point group 6/m 2/m 2/m; \( a = 9.521 \, \text{Å}, \ c = 9.165 \, \text{Å}. \) The structure is the same as that of beryl, with the octahedral layer strongly compressed parallel to the \( c \)-axis. The Me-O distance in bazzite is 2.080 Å, which is larger than the 1.904 Å in beryl. Its larger cell edge is caused by the flattening of the octahedral layer (Armbruster et al., 1995).

**Physical Properties:**
Bazzite has vitreous luster, a white streak and is not soluble in mineral acids. Intense blue bazzite is commonly electromagnetic (Gaines et al., 1997). Bazzite has an imperfect cleavage on (0001). Its hardness ranges from 6 to 7; density ranges from 2.77-2.85 g/cm³ (Anthony et al., 1995).

**Color & Luminescence:**
Bazzite is most commonly light to dark blue; however, one find in the Swiss Alps yielded pale yellow bazzite crystals (personal communication, H. P. Mueller, Steinhausen, Switzerland, 1985).

**Optical Properties:**
Bazzite is uniaxial negative. \( \text{N}_\text{a} = 1.623 - 1.628, \ \text{N}_\text{e} = 1.622, \) birefringence \( \sim 0.02 \) (Anthony et al., 1995).

**X-ray Diffraction Lines:**
The following are the eight most intense diffraction lines for bazzite (JCPDS # 19-162): 8.2 (70), 3.29 (100), 2.94 (100), 2.56 (50), 2.28 (50), 1.795 (50), 1.754 (70), 1.646 (80).

**Forms and Morphology:**
Crystals are typically prismatic and exhibit the basal pinacoid \{0001\} and the hexagonal prism \{10-10\} (Anthony et al., 1995).

**Alteration and Replacement:**
No replacement and alteration products have been reported.

**Occurrence:**
Bazzite occurs in Alpine vein type assemblages, in granitic pegmatites (Tørdal, Norway) (Juve & Bergstøl, 1990) and in mioroles in granite (Baveno, Italy) (Gramaccioli et al., 2000).

**Locations:**
Baveno, Italy, in mioroles in granite; from pegmatite sources near Heftetjern, Tørdal, Norway (Juve & Bergstøl, 1990); from La Fibbia, Monte Prosa, and elsewhere in Switzerland; Sugarloaf Mtn., Bethlehem, New Hampshire; from pegmatitic segregations at Mount Antero, Colorado (Anthony et al., 1995).

**Associated minerals**
Quartz, potassium feldspar, albite, muscovite and zeolites for the Baveno location and quartz, albite, chlorite, and others in Alpine veins; the Norwegian pegmatite location includes microcline, quartz, albite, beryl, berthrandite and bavenite.
Stoppaniite

Stoppaniite is an exceedingly rare species in the beryl group, having only been found in one location so far. Stoppaniite is the Fe³⁺ dominant analog of beryl. It was named for Dr. Francesco Saverio Stoppani (born 1947) (Della Ventura et al., 2000)

**Composition:** Fe³⁺³ (Mg, Fe²⁺) Na (Be₆Si₁₂) O₃₆ • 2 H₂O
**Dana number:** 61.1.1.4
**Crystal System:** Stoppaniite is hexagonal; P6/mcc; a = 9.397 Å, c = 9.202 Å
**Physical Properties:** Stoppaniite has vitreous luster. Mohs hardness has not been given but is probably 7 to 8. Stoppaniite has a white streak. The mineral is probably brittle and has a {0001} parting. Density is 2.79 g/cm³ (measured) and 2.85 g/cm³ (calculated) (Della Ventura et al., 2000).
**Color & Luminescence:** Stoppaniite is light blue. Luminescence has not been given, but it is likely nonluminescent.
**Optical Properties:** Stoppaniite is uniaxial negative. N₁ = 1.625, N₂ = 1.619. Pleochroism is weak (colorless to very light blue).
**X-ray Diffraction Lines:** The following are the six most intense diffraction lines for stoppaniite: 8.12 (65), 4.00 (38), 3.278 (100), 2.903 (64), 2.553 (18), 1.752 (18).
**Forms and Morphology:** The crystals are typically prismatic and reach 0.5 mm in maximum dimension.
**Alteration and Replacement:** No alteration or replacement has been noted.
**Occurrence:** Stoppaniite occurs in cavities in volcanic ejecta.
**Locations:** Stoppaniite was found in an explosive breccia of the 'C' pyroclastic flow unit at Capranica, Ronciglione, Vico Lake, Viterbo Province, Latium, Italy.
**Associated minerals** include the typical minerals of the pyroclastic environment.
Pezzottaite

Pezzottaite is a rare cesium-rich member of the beryl group. Crystals are generally small, reaching a maximum dimension of several centimeters. The color, hardness and the chatoyance of some material have quickly made pezzottaite a highly sought gem material (Simmons et al., 2003; Laurs et al., 2003; Hawthorne et al., 2004). Pezzottaite is named for Dr. Federico Pezzotta (b. 1965) of the Museo Civico, Milano, Italy in recognition of his many research contributions on pegmatites and the mineralogy of deposits in both Madagascar and Elba (Hawthorne et al., 2004).

**Composition:** Cs(Be₂Li)Al₂Si₆O₁₈

**Crystal System and Structure:**
Pezzottaite is rhombohedral; space group R3c; z = 18; a = 15.946 Å; b = 15.946 Å; c = 27.803 Å. The basic structure is the same as beryl with cesium filling the channels and lithium substituting for beryllium.

**Physical Properties:**
Pezzottaite has vitreous luster and a Mohs hardness of 8. It is inert to short and longwave ultraviolet radiation. The cleavage on {0001} is imperfect; parting is not observed. It is brittle and shows conchoidal to irregular fractures. Many crystals are penetrated with liquid filled tubular inclusions, which give some stones a pronounced cat's eye effect.

**Color & Luminescence:**
Pezzottaite is typically deep purplish pink and ranges from transparent to translucent. Dichroism is moderately strong: pinkish orange to pink-orange (_ray) and purplish pink to pink-purple (_ray). Non luminescent.

**Optical Properties:**
Pezzottaite is uniaxial negative. N_ = 1.615-1.619; N_ = 1.607-1.610, birefringence 0.008-0.009.

**X-ray Diffraction Lines:**
The following are the eight most intense diffraction lines for pezzottaite: 3.271 (100), 3.027 (41), 3.019 (29), 2.871 (52), 2.229 (12), 2.215 (14), 1.749 (12), 1.632 (14) (Simmons et al., 2003; Laurs et al., 2003; Hawthorne et al., 2004).

**Forms and Morphology:**
The crystals are typically tabular to thick tabular.

**Alteration and Replacement:**
No alteration or replacement has been noted but corrosion on prism faces is fairly common. Corrosion may be followed by an overgrowth of tan-colored pezzottaite with very high cesium content that is filled with numerous fluid inclusions (Laurs et al., 2003; Hawthorne et al., 2004).

**Occurrence:**
Pezzottaite occurs only in cesium-rich pegmatite environments. At the Sakavalana pegmatite near Ambatovita, Madagascar, it appears to have formed after pollucite was corroded and released a flood of cesium into the late stage pegmatite environment (Simmons et al., 2003; Laurs et al., 2003; Hawthorne et al., 2004).

**Locations:**
The type location is the Sakavalana pegmatite near Ambatovita, 140 km southwest of Antsirabe, Madagascar (Laurs et al., 2003). A second location in the Deva mine, Paroon Valley, Kunar, Nuristan, Afghanistan has now been confirmed (Laurs et al., 2003).

**Associated minerals:**
Pezzottaite is found in association with microcline (amazonite), quartz, albite, tourmaline (schorl to elbaite and liddicoatite), spodumene, lithian muscovite, chiavennite, danburite, spessartine, zircon, pyrochlore, cassiterite, hambergite, Mn-hydroxides, and chalcedony (Simmons et al., 2003; Laurs et al., 2003; Hawthorne et al., 2004; Peretti et al., 2004).
Indialite

Indialite is dimorphous with cordierite and is extremely rare. Indialite was named for India, the country in which it was first found (Meagher & Gibbs, 1977).

**Composition:** Mg₂Al₄Si₅O₁₈

**Dana number:** 63.1.1.3

**Crystal System and Structure:**
Indialite is dimorphous with cordierite. Point group is 6/m 2/m 2/m. Space group P6/mcc. The \( a \)-dimension is 9.800 Å and the \( c \)-dimension is 9.345 Å (Meagher & Gibbs, 1977). The structure contains two tetrahedral sites: T1 which is larger (T1 contains 0.72 Al, 0.28 Si) and the smaller T2 site (which contains 0.30 Al and 0.70 Si).

**Physical Properties:**
Indialite has vitreous luster, a Mohs hardness of 7 to 7.5. Cleavage is not observed. Density is 2.512 g/cm³ (measured and calculated).

**Color:**
Indialite is transparent and colorless.

**Optical Properties:**
Indialite is uniaxial negative. \( \beta = 1.537-1.539, \alpha = 1.532-1.535. \)

**X-ray Diffraction Lines:**
The following are the eight most intense diffraction lines for indialite (JCPDS # 13-293): 8.48 (100), 4.89 (30), 4.094 (50), 3.379 (55), 3.138 (65), 3.027 (85), 2.640 (25), 1.688 (30).

**Forms and Morphology:**
Indialite occurs as hexagonal grains and sometimes in spiral aggregates and as crystals with multiple terminations.

**Alteration and Replacement:**
No alteration or replacement has been noted.

**Locations:**
The type location for indialite is in the Bokaro coal seam, southwest of Azaribagh, Bihar, India (Meagher & Gibbs, 1977). A second location for indialite exists near Unazuki in Japan (Anthony et al., 1995).

**Associated Minerals**
Indialite is associated with enstatite, anorthite, corundum, magnetite, glass at the Indian location, and cordierite, sillimanite, andalusite, quartz, and biotite at the Japanese location at Unazuki.