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NYF-Type Pegmatite

The very first Word to the Wise column dealt with the term *pegmatite* (Rakovan 2003). This was especially fitting because pegmatites are one of the most important rock types or geologic environments for the production of beautiful and interesting mineral specimens. A qualitative assessment of this can be made through a simple review of mineral journals, where one finds that tourmaline, aquamarine (often referred to as t&a), and other pegmatite minerals comprise a large proportion of cover images. Pegmatites were described in a few short paragraphs in that first column, yet the number of papers and books that have been written about them is huge. Although most pegmatites are granitic, there are still many differences among them that have led to classifications of this one rock type based on characteristics such as style of formation, timing of formation relative to their host rocks, depth of formation, magmatic source, internal structure, minor element chemistry, and so forth. One of the most widely used classification schemes is that of Černý (1991). In it, pegmatites are classified by their depth of emplacement (proposed by Buddington 1959; modified by Ginsburg, Timofoyev, and Feldman 1979) and are further divided into subclasses, types and subtypes based on geochemical features, mineral assemblages, and textural attributes that reflect the pressure and temperature conditions present during solidification. The degree to which each of the classes is subdivided is a function of the variability present and our current knowledge. Thus, modifications to Černý (1991) have been suggested as our knowledge of pegmatites has grown (e.g., Wise 1999; Pezzotta 2001; Černý and Ercit 2005). A comprehensive review of all the different classification schemes and pegmatite types is beyond the scope of this column. However, because of its common usage (e.g., Hanson, Simmons, and Falster abstract on the Mojave County pegmatite district, Rochester Mineralogical Symposium abstracts, page 343, this issue), this column focuses on *NYF-type pegmatites* (Černý 1991; Černý and Kjellman 1999; Martin 1999; Wise 1999; Černý and Ercit 2005; Simmons et al. 2003; Simmons 2007).

NYF stands for niobium (Nb), yttrium (Y), and fluorine (F), rare elements that concentrate to the point of becoming minor constituents in the "classic" NYF pegmatites. Originally classified as the NYF family, this term is based on compositional characteristics that are related to the source (provenance) of the original magma and the chemical evolution of the magma as components are removed and others are concentrated as fractional crystallization and differentiation occur. These three elements (NYF) are the most notably enriched; however, other rare elements are also characteristically elevated in their concentration. Yttrium and the lanthanides are rare-earth elements (REE), all of which have similar geochemical behavior; consequently, NYF pegmatites are usually enriched in all of the REE. Elevated concentrations of Sc, Zr, U, and Th are also typical.

The second family of pegmatites proposed by Černý (1991), based on minor element characteristics, is the LCT type that exhibits enrichment in lithium (Li), cesium (Cs), and tantalum (Ta) as well as Rb, Be, Sn, Nb (Ta > Nb), B, P, and F, to varying degrees. An example of an LCT pegmatite is the Oceanview mine, described by Mauthner in this issue (pages 292–297). Many pegmatites fit well into this chemical classification, but as can be expected when trying to pigeon-

***Figure 1*. NYF miarolitic pegmatite pocket, measuring 25 × 36 cm, in Naegi Granite, Tahara, Hirukawa, Gifu Prefecture, Japan. Minerals include smoky quartz and Baveno-twinned microcline. Masutomi Museum specimen.**

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hole the natural world, there are exceptions, including those that have characteristics of both; the result is a third family of pegmatites, the mixed NYF + LCT family.

The depth-related classes in the taxonomy of Černý (1991) include miarolitic, rare-element, muscovite, rare-element muscovite, and abyssal in order of increasing depth (see table). Although these classes are well defined, the use of this nomenclature to describe different depth classes is unfortunate because there are terms that refer to a structural feature (miarolitic pockets), an element group (rare-element), a mineral (muscovite), and a location (abyssal). This can be confusing, especially when one is trying to keep track of other classification terms based on chemistry or other characteristics. Also, miarolitic cavities, for which the miarolitic class is named, are found in most of the other classes. Originally, NYF pegmatites were thought to be restricted to the rare-element class, but pegmatites with an NYF type of signature are now known from all classes (Ercit 2004). Geologically, another confusing aspect is that some of each type can occur in geographically close terrains but have different ages and parent magmas.

Based on geological, chemical, and isotopic data, several possible mechanisms have been proposed by which the parent magmas of NYF pegmatites may form (Černý and Ercit 2005). However, the vast majority of those that have been studied, including the "classic NYF family" formed through magma generation in divergent tectonic settings, known as *anorogenic* (not associated with mountain building) magmas (Wise 1999). In contrast, there is a strong correlation between LCT-family pegmatites and *orogenic* tectonic settings (compressional regimes associated with mountain building). It should be noted that although these correlations exist, there are many exceptions.

Figure 2. **Microcline and smoky quartz from NYF miarolitic pegmatite, Tanakamiyama, Shiga Prefecture, Japan. The specimen, 12 cm across, is the pocket extension of a graphic intergrowth of the two minerals. Kyoto University Museum specimen.**

Classic examples of NYF pegmatites include those of the Pikes Peak Batholith and Mount Antero, Colorado (Henrich 1985; Raines 2001; Lees 2005; Modreski 2005); Moat Mountain and the Conway Granite, New Hampshire (Samuelson, Hollmann, and Holt 1990); Baringer Hill, Texas (Landes

Depth classification of pegmatites (Černý 1991; modified from Simmons et al. 2003).

Class	Family	Typical Minor Elements (mineralization)	Pressure-Temperature Conditions (metamorphic environment)	Relation to Granite	Examples
Miarolitic	NYF	Be, Y, REE, Ti, U, Th, Zr, Nb > Ta, F (poor mineralization, gemstock)	shallow to subvolcanic ~1–2 kb	interior to marginal	Pikes Peak, Colorado; Sawtooth Batholith, Idaho; Korosten Pluton, Ukraine
Rare-Element	LCT	Li, Rb, Cs, Be, Ga, Nb < Ta, Sn, Hf, B, P, F (poor to abundant mineralization, gemstock industrial minerals)	low-pressure, Abukuma amphibolite to upper greeenschist facies (andalusite-sillimanite) ~2–4 kb ~650°–500°C	interior to marginal to exterior	Yellowknife field, NWT; Black Hills, South Dakota; Cat Lake–Winnipeg River field, Manitoba
	NYF	Y, REE, Ti, U, Th, Zr, Nb > Ta, F (poor to abundant mineralization, ceramic minerals)		interior to marginal	Llano Co., Texas; South Platte district, Colorado; Western Keivy, Kola, USSR
Muscovite–Rare Element	—	Be, Y, REE, Ti, U, Th, Nb-Ta, Li	moderate to high pressure, amphibolite facies: ~3–7 kb ~650°–520°C	interior to exterior; locally poorly defined	Spruce Pine and Hickory, North Carolina
Muscovite	—	Li, Be, Y, REE, Ti, U, Th, Nb > Ta (poor to moderate mineralization, micas and ceramic minerals)	high-pressure, Barrovian amphibolite facies (kyanite-sillimanite) ~5–8 kb ~650°–580°C	none; direct melting of lower crustal rocks (anatexis) to marginal and exterior	White Sea region, USSR; Appalachian Province; Rajahstan, India
Abyssal	—	U, Th, Zr, Nb, Ti, Y, REE, Mo (poor to moderate mineralization)	(upper amphibolite to) low- to high-pressure granulite facies ~4–9 kb ~700°–800°C	none; direct melting of lower crustal rocks	Rae-Hearne provinces, Saskatchewan; Aldan and Anabar shields, Siberia; Eastern Baltic Shield

Figure 3. **Topaz on feldspar with smoky quartz from NYF miarolitic pegmatite, Tanakamiyama, Shiga Prefecture, Japan. Estimated topaz crystal length 10 cm. Mitsubishi mineral collection, Ikuno Mineral Museum.**

1932; Francis and Lange 1999); the Sawtooth Batholith, Idaho (Menzies and Boggs 1993); Klein Spitzkoppe and the Erongo Mountains, Namibia (Cairncross 2005; Cairncross and Bahmann 2006); Baveno, Italy (Albertini 1983); Tanakamiyama, Shiga Prefecture (Obayoshi 2002; Nambu 1970); and the Naegi Granite, Gifu Prefecture, Japan (Nambu 1970; Scalisi and Cook 1983).

If this discussion seems a bit confusing, it is in part because our understanding and classification of pegmatites are evolving, and, as stated in Simmons (2007), a trend toward a petrogenetic classification, related to the tectonic regimes and the processes of magma generation, is emerging from current research. For example, Martin and De Vito (2005) attribute these NFY and LCT geochemical "fingerprints" to characteristics of the magma source and to the tectonic setting where the parental magma was generated. However, because the term *NYF-type pegmatite* is commonly employed today, it is useful to understand the general ideas behind it.

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