Petr Černý: The classification and tectonic setting of pegmatites

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Introduction

In modern times, few individuals have seen and studied as many pegmatites of different types as did Petr Černý[1]. His emigration from the Czech Republic in 1968, at the end of its Soviet occupation, to Canada opened up opportunities for field travel throughout the world. His relocation to the University of Manitoba in Winnipeg gave him access to explore for pegmatites in remote parts of Canada's central and western provinces, but he is best known for his many publications on the mineralogy of the Tanco pegmatite at Bernic Lake. Černý was a mineralogist first and foremost, and his approach to the chemical characterization and classification of minerals carried over into an effort to characterize and classify pegmatites as a whole. His system for classification appeared in the first of two review articles,

- Černý, P. (1991a) Rare-element granitic pegmatites, Part I: Anatomy and internal evolution of pegmatite deposits. *Geoscience Canada*, (Ore Deposit Models series) ,**18**, 49-67, and
- Černý, P. (1991b) Rare-element granitic pegmatites, Part II: Regional to global relationships and petrogenesis. *Geoscience Canada* (Ore Deposit Models series) **18**, 68-81.

The classification scheme was later revised by Černý and Ercit (2005),

- Černý, P. and Ercit, T.S. (2005) The classification of granitic pegmatites revisited. *Canadian Mineralogist*, **43**, 2005-2026.

The relations of the compositions of pegmatites and the tectonic setting of their source granites were discussed in

- Černý, P. (1991c) Fertile granites of Precambrian rare-element pegmatite fields: is geochemistry controlled by tectonic setting or source lithologies? *Precambrian Research*, **51**, 429-468.

and later debated between Černý and Ercit (2005) and

- Martin. R.F. and De Vito, C. (2005) The patterns of enrichment in felsic pegmatites ultimately depend on tectonic setting. *Canadian Mineralogist*, **43**, 2027-2048.

Background on the Classification of Pegmatites

Pegmatites are defined by textural attributes rather than by composition. Exceptionally coarse crystal size is a hallmark of many pegmatites, though it is just one of several textures that, individually or in combination, may suffice to designate a rock body as a pegmatite. Granitic bulk compositions are by far the most common, so much so that the unmodified word "pegmatite" refers to those of granitic composition in most published works. Pegmatites, however, are derived from and reflect the compositions of other plutonic bodies that include mafic and alkaline rocks and carbonatites.

Jahns (1955) provided the most complete review of the interpretive models for the origins of pegmatites, and some of those models proposed a classification that was founded in composition. Landes (1933) created the first scheme of classification for pegmatites that was widely used in the United States. In his classification, he distinguished chemically simple pegmatites, which he regarded as igneous because of their similarity to common plutonic rocks, from complex ones containing a significant abundance of rare minerals, which he attributed to hydrothermal replacement of pre-existing "simple" pegmatite. Landes (1933) also employed the modifiers acid (granitic), intermediate (dioritic), and basic (gabbroic) to denote the principal igneous compositions. For example, a complex spodumene acid pegmatite was one of mostly granitic composition but containing spodumene.

Fersman (1931) did not classify pegmatites categorically, but he put them in an overall scheme of their temperature of formation in relation to granites ("epimagmatic") and hydrothermal veins:

- epimagmatic (800°-700°C)
- pegmatitic (700°-600°C)
- pegmatoid (600°-500°C)
- hypercritical (500°-400°C)
- high hydrothermal (400°-300°C)
- middle hydrothermal (300°-200°C)
- low hydrothermal (200°-100°C)

Much later, a classification proposed by A.I. Ginsburg (1984) recognized four "formations" that were an amalgamation of temperature, pressure (depth), texture, and composition as defining characteristics (Figure 1). Early in his professional development, Petr Černý was strongly influenced by Soviet concepts of pegmatite formation, and particularly by Ginsburg's (1984) classification, which Černý (1991a; Černý and Ercit 2005) incorporated into his own work.

Černy's Classification of Pegmatites

Černý (1991a) added classifying terms for the groupings of pegmatites that went beyond the informal usage in Cameron et al. (1949)(see essays #1-4 of this series). Černý (1991a) defined a ***pegmatite group*** as an association of pegmatite bodies that can be reasonably be construed to be related to one another through a common and contemporaneous derivation from the same parental granite. A ***pegmatite field*** was an association of one or more groups of pegmatites, related or not to a common time and source, that lay within the same tectonic domain (e.g., the Appalachian orogen, or sub-terranes within the orogen). A ***pegmatite district*** applied to a concentration of pegmatites as a mining resource without regard for origin.

The hierarchy of classification that Černý adopted from Ginsburg (1984) and that was presented by Černý (1991a; Černý and Ercit 2005) started with four pegmatite classes, to which Černý and Ercit (2005) added a fifth. Within most of the pegmatite classes, there were subdivisions by type and subtype of pegmatite based on a manifestation of rare-element mineralogy.

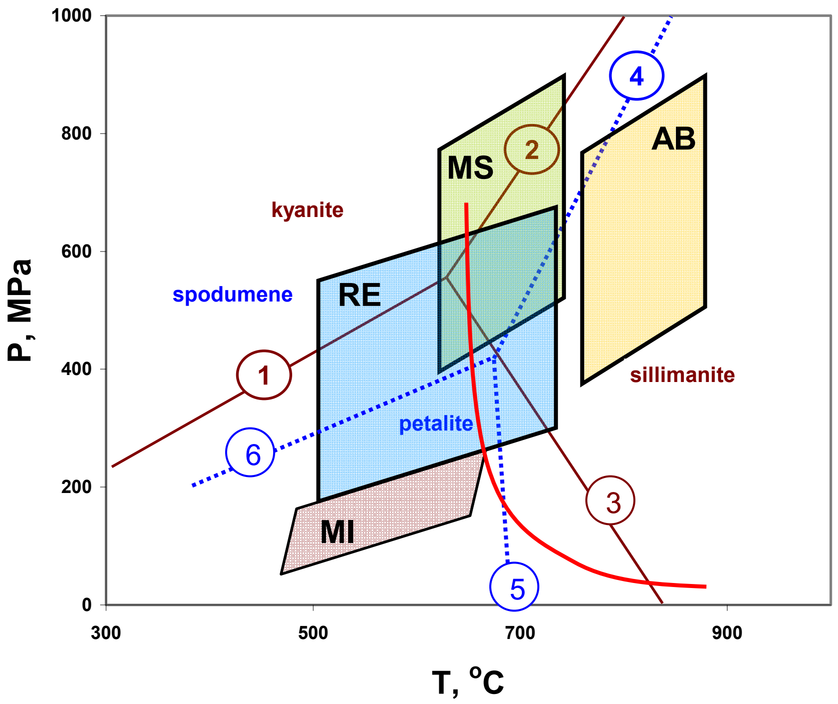

Figure 1. Pressure-temperature fields of the pegmatite classes: abyssal (AB), muscovite (MS), rare-element (RE), and miarolitic (MI), in relation to kyanite-andalusite (1), kyanite-sillimanite (2), andalusite-sillimanite (3), spodumene-β-spodumene (4), petalite-β-spodumene (5), spodumene-petalite (6), and the hydrous granite solidus (red). Modified from London (2008) and sources therein.

The abyssal class

Abyssal pegmatites were originally defined in terms of the high metamorphic grade of their host rocks. Černý (1991a) referred to them as "*segregations of anatectic leucosome*" with no relationship to granites. Later, Černý and Ercit (2005) included "*pegmatites of intermediate depth*" and "*extending to upper-amphibolite conditions*". As described, however, the abyssal pegmatites can possess most of the complex textural features, including graphic granite and aplitic units that are found in pegmatites emplaced at shallower levels. They are defined more by their amphibolite- to granulite-facies hosts than by their mineralogy or texture.

The muscovite class

Černý (1991a) characterized the muscovite class of pegmatites as unrelated to granites, yet he cited pegmatites of the southern Appalachian Mountains as classic examples, and those pegmatites are clearly sourced back to peraluminous granites (see Chapter 5 of London, 2008). In redefining the muscovite class, Černý and Ercit (2005) described them as

> *"largely conformable to, and in part deformed with, host rocks of high-pressure amphibolite facies characterized by the kyanite – sillimanite progression of the classic Barrovian metamorphic facies-series… The pegmatites are generated by partial melting…"* (p. 2009),

a description that is basically indistinguishable from that of the pegmatites of the abyssal class

(Černý and Ercit 2005).

The muscovite – rare-element class

Černý and Ercit (2005) added this new class, the *muscovite – rare-element class*. The principal difference between the muscovite class and the muscovite – rare-element class is that the former are mostly conformable with their host rocks and were thought to be generated locally by anatexis of their hosts, whereas the latter are intrusive bodies that form part of a continuum from granite to rare-element pegmatite. Pegmatites of the *muscovite – rare-element class* are commonly traceable to granitic sources, and evolve to compositions that are capable of producing rare-element minerals. The granite-pegmatite system of Spruce Pine, North Carolina, that was mentioned above would belong to this class (also see Chapter 5 of London, 2008).

The rare-element class

The *rare-element class* of pegmatites corresponds to the complex types of Landes (1933), though without the connotation of an origin for the unusual mineral assemblages by hydrothermal replacement. This class is the most diverse in its assemblages that contain normally rare minerals, which accentuates the various trace-element signatures of their source regions. Černý' (1991a) described them as occurring within or near a source granitic pluton. In the context of pressure and temperature, the rare-element class of pegmatites was part of a continuum with increasing distance, and decreasing pressure and temperature of their host rocks, from the muscovite – rare-element class.

The miarolitic class

The *miarolitic class* of pegmatites was distinguished by the presence of open- or clay-filled and crystal-filled cavities called miaroles. The term "miarole" originates from Italian *miglio*, "millet", apparently in reference to the widespread distribution of minute vugs that resemble grains of millet in the granites near Baveno, Italy. These pegmatites occur as numerous small segregations within shallowly emplaced granitic plutons. The cavities are open (free of clay or loose crystals) as found with crystals attached to the walls of the cavities. A wholly different type of miarolitic pegmatite forms intrusive pegmatites, from concentrically zoned vertical bodies to shallowly dipping layered dikes like those in the classic localities of San Diego County, California. Miarolitic cavities are notable but rarely constitute more than ~ 5% of the pegmatite volume. In the layered dikes, the cavities tend to be concentrated along the central plane of the pegmatite dike. Pockets are crystal-lined but also commonly clay-filled with isolated and unattached crystals suspended in the clay (London, 2013). Miarolitic pegmatites (Chapter 8 of London, 2008) are the principal pegmatitic sources of gem materials and fine mineral specimens.

In Ginsburg's (1984) classification, miarolitic pegmatites were assumed to reflect shallow levels of emplacement because of their conspicuous cavities. These cavities were thought to have been filled with aqueous or carbonic vapor that exsolved from the silicate melt and was trapped as bubbles within the crystallizing pegmatite. Low-pressure environments favor the exsolution of dissolved gases and the creation of large cavities frozen into the pegmatite because the solubility of volatiles in melt decreases with decreasing pressure (e.g., Burnham, 1979) and the volume that the vapor occupies increases with decreasing pressure (e.g., Burnham *et al.* 1969).

I introduced a conflict with this class of pegmatites as the shallow (100-200 MPa) equivalents of the Ginsburg's rare-element class. Spodumene plus quartz is a common primary assemblage in the miarolitic pegmatites that carry the LCT signature. Initially, when the stability field of that assemblage was plotted against the solidus of the hydrous granite system (Figure 1), their region of intersection appeared to be at the same high pressures of the Ginsburg's non-miarolitic rare-element class. That conundrum vanished as my research began to reveal a much lower temperature of crystallization of thin pegmatite dikes at temperatures of ~ 400°-450°C. At those low temperatures, the stability of spodumene plus quartz extends to 200-250 MPa, still higher than Ginsburg's miarolitic class, but lower than the typical non-miarolitic spodumene pegmatites.

Types and Subtypes of Rare-Element Pegmatites

One of Černý's (1991a) contributions was a subdivision of the rare-element pegmatites based on some predominant feature of their composition as reflected by a normally rare mineral that was not part of the simple granite system (plagioclase-K-feldspar-quartz±muscovite-biotite). The proposed types were ***Rare-Earth***, ***Beryl***, ***Complex***, ***Albite-Spodumene***, and ***Albite*** (Table 3 of his article). The Complex type included most of the typical lithium-rich pegmatites as subtypes (***Spodumene***, ***Petalite***, ***Lepidolite***, and ***Amblygonite***). Like the search for new minerals, the search for new subtypes continued, and Černý and Ercit (2005) added several to the rare-earth and complex types and numerous subtypes to the miarolitic class. Despite all the variety, Černý (1991a, Černý and Ercit, 2005) acknowledged that the lithium-rich pegmatites were by far the most common expression of the rare-element class.

Pegmatite Families

Another of Černý's (1991a) contributions, which was more lasting and influential, was a recognition that the predominant types of rare-element pegmatites can be associated with granites whose sources can be ascertained (Table 4 of his article). Černý (1991a) separated the rare-element pegmatites (and, by implication, the muscovite-rare element and the miarolitic classes that are part of the same pegmatite continuum) into two families – the LCT family (for lithium-cesium-tantalum as diagnostic elements) and NYF family (for niobium-yttrium-fluorine as diagnostic elements). The separation by families was based on composition, but Černý (1991a) observed that the pegmatites of the two families could be associated with granites of two sources: the LCT pegmatites with granites of peraluminous character that are derived from the melting of predominantly marine sediments in the waning stages of continental collisions, and the NYF pegmatites with granites of metaluminous to alkaline character that are sourced in the deep continental crust or from mafic igneous rocks that underplate the crust in regions of extension and rifting of continental crust. A third family, of "Mixed" character, has drawn little attention, but it is actually an important recognition that the separation of source materials is not perfect in any likely source region. Marine sediments are mostly deep-water shales, but they may contain admixtures of igneous rocks, arkosic sandstones, and carbonates that are deposited in fore-arc marine basins, and which may be swept out to the open marine environment as deep-water turbidites. The granites that spawn the NYF family carry chemical and isotopic signatures of crustal and mantle sources, but also mixed signatures of both reservoirs.

Much of the remainder of Černý (1991a) was a review of the spatial distributions of pegmatites in relation to their parental granite, the internal zonation of pegmatites, and an evaluation of the current and competing models for the internal evolution of pegmatites at that time. The geologic aspects of that presentation existed elsewhere, and Černý's assessment of models is now largely dated if not entirely obsolete. It can be said, however, that he was significantly influenced by my own work at the time.

A curious aspect of all of these classification methods is that none of them was based on the textures of the rocks, which are in fact the defining features of pegmatite. It could be said with truth that throughout the study of pegmatites, their textures have rarely been documented or compared in ways that might distinguish them. It can also be said that the same textures span the full range of pegmatite compositions, from those of granitic compositions to the most fractionated bodies with exotic mineralogy. But texture is what makes them all pegmatites regardless of their compositions. Another oddity of the classification schemes is that they do not explicitly include the 98-99% of pegmatites whose compositions are simple granites, and which are intrusive, generally not concordant with their host rocks, and undeformed. These might be included in Černý's muscovite-rare element class, but it is not clear that he meant to put them there. We discussed this omission in the preparation of Černý et al. (2012). Černý's response was that in his system of classification based on rare-element chemistry, there is nothing diagnostic or rare about the compositions of the ordinary pegmatites. He remarked to the effect "what was I to do?"

The Lithologic Affiliations of the Pegmatite Families

Whereas Černý (1991a) addressed the internal evolution of individual pegmatite bodies, Černý (1991b) considered the processes responsible for producing pegmatites in the first place. He evaluated two models – one in which pegmatites arise directly *in situ* by local partial melting of their host rocks, which he termed the anatectic model, and the other by which pegmatites represent the late-stage residual melts of much larger granitic plutons, which he termed the igneous model (in reality, all igneous melts begin with anatexis). Černý (1991b) cited numerous objections to the anatectic model, which he expounded on later in Černý et al. (2005).

Černý (1991b; Goad and Černý, 1981) also associated the LCT family of pegmatites with the S-type granites (Chappell and White, 1992), and the NYF pegmatites with the A-type granites (Eby, 1990). Both granite types were ascribed to specific tectonic environments: the S-types with melting of accreted marine sediments in the waning stages of continental collisions, and the A-types with extensional rift environments within continental cratons. Černý (1991b) accepted the prevailing views of the time regarding the tectonic setting for the origins of the two granite types with little discussion. His primary goal was to show that the pegmatites inherit the geochemical attributes of their sources, and amplify those elemental signatures through continued chemical fractionation of the remaining melts.

Černý (1991c), however, reviewed the relations of age and tectonic settings for twenty paired Precambrian granite-pegmatite groups in different global regions. The ages of the granites varied widely in relation to the timing of the most closely associated tectonic event, but in regard to the affiliation of pegmatite families with specific tectonic environments, he said this:

"*There is some tendency toward syn- to late-orogenic origin of LCT's as opposed to post- to anorogenic timing of NYF's, but the correlation is poor compared to the previously accepted* *stereotype. Similarly, both metaluminous and peraluminous fertile granites are about equally spread among syn-, late- and anorogenic environments.*" (p. 429)

Černý and Ercit (2005) elaborated on this point, tying the affiliation of the pegmatite families to the chemical attributes of their source granites, irrespective of the tectonic environment of their origin:

"*The final introductory note concerns the fundamental change in the family concept which took place in the early nineties, was not explicitly pointed out, and occasionally escaped attention. Originally, the NYF and LCT families and their precursors were correlated with anorogenic and orogenic settings, respectively (Černý 1982b, 1989), following the model of Martin & Piwinskii (1972, 1974). However, significant and widespread exceptions were identified from this correlation that prevented it from being used as the principal classification yardstick, and the emphasis was shifted to the NYF and LCT geochemical signatures grounded in the source lithologies (see Černý 1991a for details). This shift does not mean that the tectonic affiliation of the NYF and LCT families with the respective anorogenic- and orogenic-related granites was discarded. These relationships are well documented and valid in a great number of cases, but not as universal as implied in the past and in the more recent arguments by Martin (1989, 1999) and Martin & De Vito (2004).*" (p. 2017)

The Tectonic Affiliations of the Pegmatite Families

Martin and DeVito (2005) reiterated their contention that the elemental signatures of pegmatites are strongly correlated with two tectonic environments: one of subduction, the other of crustal extension:

"*The bulk of the pegmatite bodies encountered are not obviously of anatectic origin, but are derived by fractionation of pluton-size batches of felsic magma. We consider LCT (Li–Cs–Ta-enriched) pegmatites to be members of orogenic (calc-alkaline suites) formed in a subduction setting; in contrast, NYF (Nb–Y–F-enriched) pegmatites, are affiliated with anorogenic suites, formed in an extensional setting, and really not fundamentally different in petrogenetic lineage from suites in silica-undersaturated systems, including carbonatites.*" (p. 2027)

I served as a reviewer of both manuscripts for the publisher. To Černý and Ercit (2005), I said that their almost complete separation of the lithologic signatures – of the LCT family with the S-type granites and the NYF family with the A-type granites – from the tectonic environments of these granites was like "not seeing the forest for the trees." By that I meant that they were so concerned with the exceptions that they failed to see the extent to which there is concordance of lithology and tectonic environment. Černý's studies were mostly in Precambrian terranes where the tectonic regimes may have been less well known, more poorly correlated with the modern equivalents, or simply different because of the thermoelastic properties of the Precambrian crust. However, throughout the Paleozoic, the association of the LCT family of pegmatites with peraluminous granites that are derived from the anatexis of mostly marine sediments in the waning stages of continental collision is undeniable. In the Paleozoic, the association of the NYF pegmatites as segregations within the thin, shallow bodies of A-type granites that arise in continental rift zones is also well demonstrated. I urged Černý to return to his original (Černý, 1991a,b) view of associating the pegmatite families with their chemically similar granites and the environments in which those granites arise. In my opinion, it seemed not only correct in most cases, but it forged a link between pegmatites, granites, and their tectonic environments that had been mostly severed since the publication of Jahns and Burnham (1969).

To Martin and DeVito (2005), I concurred with their suggestion to drop the mongrel classification of Ginsburg (1984). It is not the terms of that classification that are objectionable, but the concept of separation into classes with their inferred pressure-temperature regimes of crystallization. Martin and Devito (2005) devoted considerable discussion to outliers in the pegmatite suite, particularly those of the NYF family with which the authors made parallels to the alkaline igneous rocks of direct mantle origin. It struck me as a digression from their principal point – that the two main pegmatite families correlate with the granites of two distinct tectonic regimes, one associated with subduction, but more accurately with thickening of a sedimentary wedge in a convergent tectonic setting, and the other with an environment of extension and associated rifting within continental interiors. Those conclusions got no argument from me.

The Abysmal Abyssal Class

Černý and Ercit (2005) carried the concept of "abyssal pegmatites" forward, though Černý (1991b, Černý et al., 2005) argued against an origin of pegmatites as the products *in situ* of small volumes of anatectic melts (e.g., see Stewart, 1978, and essay #11 of this series). Martin and DeVito (2005) equated the abyssal pegmatites with small volumes of anatectic melts. At the time I reviewed these articles, I asked Černý if he had any photographs of abyssal pegmatites that I could use in my monograph on pegmatites. He said he didn't have any. I asked him if he had ever seen an abyssal pegmatite. He said he wasn't sure. My sentiments exactly. I have seen coarse-grained leucosomes in migmatites, but there is little else to distinguish them as pegmatites. In general, leucosomes are at least partially cumulate rocks if they have an igneous source, or they are feldspathic blastomylonites that result from tectonic-hydrothermal processes and are not, by my definition, pegmatites. Ercit (2005) cited textures of graphic granite, layered aplites, and zonation pegmatites that he attributed to the abyssal class. Those textures, however, are the result of crystallization at a highly undercooled state of the melt. Melts that remain at the site of anatexis and cool at the rate of uplift of their hosts should not produce such textures because the melts are always in thermal equilibrium with their host rocks.

The Mixed Family of Pegmatites

The one tectonic environment where the two granite magma types might arise in close association – which was not mentioned by Černý and Ercit (2005) or by Martin and Devito (2005) – is in the back-arc basins behind subduction-related volcanic arcs that extend into continental margins. The evolved rhyolites of the Macusani-Morococalla volcanic provinces, Peru and Bolivia, lie in the back-arc region of the Andean subduction zone. They possess the chemical signature of the S-type granites and the LCT family of pegmatites, and their sources were clearly indicative of previously unmelted crustal sedimentary rocks rich in lithium, cesium, phosphorus, and tin (Pichavant et al., 1988). The granite-pegmatite system of the Central Iberian Massif, Spain, is archetypal of the LCT pegmatite – S-type granite signature, but these igneous rocks are not associated with a continental collision. Rather, they lie in the back-arc region of a westward-dipping subduction zone that existed to the east of the Iberian Peninsula (Díaz-Alvarado et al., 2016). The back-arc region of subduction zones is one of extension, uplift, and high heat flow caused by the upwelling of mantle or of basalts from below. Cenozoic rhyolites of the Snake River Plain, western U.S., have initial strontium isotopic compositions that indicate mantle sources for some, crustal sources for others, with mixing between end members (Christiansen and McCurry, 2008). The location and its tectonic environment of crustal extension with rifting follow the trace of the former subduction zone along the western continental margin.

To observe the original extensional environment that gives rise to such mixed sources of igneous signatures, the lower Connecticut River Valley, where I cut my teeth in geology, is a useful example. The valley, now an aulocogen (a failed arm of a triple junction among continental rift zones) along the eastern seaboard that began to open in the late Jurassic period, contains a thick sequence of arkosic hematite-cemented sandstones, black shales, and basalts. Upon melting, the black shales would generate peraluminous S-type granitic melts leading to pegmatites with the LCT signature, the arkoses would produce metaluminous granitic melts similar to those of the A-type granites that are sourced from deep continental crust, and the basalts would produce a more calcic, plagioclase-rich liquid closer to tonalitic composition with a mantle-sourced signature, adding the elements that are distinctive of the NYF pegmatite family.

Pegmatite Classification

Classification based on common attributes, and traits that distinguish an individual or an assemblage of objects from another, have been part of science since the 19th century. A hierarchical classification has been especially useful in the biological kingdoms, where divisions are based on physically observable features. It has been less successful in its application to the mineral kingdom, where members of a mineral group, the apatite group for example, that are related by a common crystal structure and the same general chemical formula, can cut across the mineral classes, which are at a higher level of organization and which are distinguished from one another by the distinctive anion group of each class. In the biological realm, the classification is strictly vertical with no crossing or mixed classes of entities. Mineral species are, or used to be, defined by a specific end-member formula with no variability of its composition. Such an end-member species need not exist in Nature, a situation that would not be possible in the biological classification.

In the case of granitic pegmatites, it is reasonable to identify those pegmatites that share some common attributes, and to examine their associations with granites that might be (but are likely not) exposed, and in relation to the regional tectonic fabrics and deformation structures imposed on their host rocks as an indication of their tectonic environment. One pitfall of that effort lies in the timing of granite-pegmatite systems in relation to the deformation and metamorphism of their host lithologies. In essay #11 of this series, I made the case that the conditions in which pegmatites are emplaced into their hosts long postdates the metamorphism and deformation that is associated with those host rocks. The principal evidence behind this statement lies in the interpretation of pegmatite rock textures, which are indicative of thermal quenching against much cooler host rocks, in the thermal numerical models of cooling of thin dikes in rocks at the geothermal gradient at their depth of emplacement, and in the temperatures of crystallization that are recorded by their primary feldspar pairs. The melting event that leads to the generation of granite-pegmatite systems need not have any temporal relationship to the tectonic event of metamorphism and deformation in the host metamorphic rocks. The granites and pegmatites are essentially undeformed and unmetamorphosed, which is the strongest and most obvious indication that they are not formed in association with the tectonic-metamorphic event of their hosts. This is why pegmatites of the abyssal class, if these possess the common textures of other granitic pegmatites, cannot have been the result of anatexis and crystallization *in situ* of their host rocks.

Černý's (1991a, Černý and Ercit, 2005) classification of pegmatites remains the prevalent scheme in use today. The assignment of individual pegmatite bodies to one of Černý's pegmatite families is widely employed, though Černý (Černý et al., 2012) never intended the terms to be used in reference to any single pegmatite as they commonly are (there is no LCT pegmatite, but there are pegmatites with a chemical affinity to the LCT family). Recently, Dill (2016) introduced a new scheme for the classification of pegmatites that contains over 100 categories, and Müller et al. (2018) have similarly proposed a classification that includes composition, mineralogy, temperature, and new and rather vague references to environments of formation (e.g., the "*superstitial phase of the pneumatolytic stage*", their Figure 2). Whether any of these far more complex schemes of classification takes hold depends on the general health of the study of pegmatites and the numbers of individuals who seek to classify them.

In my book *Pegmatites* (2008), I took a pessimistic view of the classification of pegmatites as it has been presented over the history of the field. My objections started with Landes (1933) classification of pegmatites as "simple" granitic pegmatites and "complex" granitic pegmatites that contained normally rare assemblages of minerals. The reference to "simple" was in composition only, but the granitic pegmatites that lack rare minerals commonly possess all of the textural complexities of the "complex" ones. I proposed that the term "common" was a better modifier for the granitic pegmatites that constitute > 98% of them all, and which are all but left out of the various schemes of classification, including Černý's (1991a). One could add "zoned" and "unzoned" as another useful modifier. Those who study and explore for pegmatites in the field would readily recognize "zoned common granitic pegmatites", with or without the "granitic" adjective, with no further explanation needed. The nomenclature of igneous rocks has always been an amalgamation of terms with references to textures, properties, and place names (e.g., jacupurangite!). In *Pegmatites* (2008), I suggested that metamorphic petrologists got nomenclature right. The metamorphic rock names are descriptive and readily recognizable in the field (schist, gneiss, etc.). Rock names commonly carry just one or two mineralogical modifiers that are also readily visible in the rock, such as garnet-staurolite muscovite schist. If a nomenclature for pegmatites is even necessary, it could be similarly simple: to anyone who has seen one, a "zoned spodumene granitic pegmatite", even without the "granite" modifier, conjures up a visual image as it has appeared in line drawings and photos of many publications.

I became more pessimistic as the quest for new subtypes of pegmatites went on. It seemed like another case of missing the forest for the trees. The common zoned and unzoned granitic pegmatites were omitted entirely, and the emphasis on rare-element minerals that generally constitute a tiny fraction of any pegmatite body seemed misleading. Considering the heterogeneous nature of source materials for all of the pegmatite types, there should be an endless variation among some trace elements that give rise to a multitude of rare-mineral assemblages. So what? Černý recognized that among the multitude of subtypes that began to appear (Černý and Ericit, 2005), only a few were really common enough to be considered important.

In *Pegmatites* (2008), I took the position that Černý's (1991a,b) recognition of pegmatite families served a useful purpose because it linked pegmatites to granites, granites to their sources, and their sources to the tectonic environment of their origins. Through the first half of the 20th century, the study of pegmatites was motivated mostly by their economic potential, by their engaging textures, and by their exotic mineralogy. Dick Jahns, however, pursued the study of pegmatites in their relation to the granite system, with which they have long been associated by those who study pegmatites[2]. I remarked above that the study of pegmatites and the study of granites have had little to no association ever since Jahns and Burnham (1969) was published. This is particularly true of granite petrologists, for most of whom pegmatites are so trivial as to be unrelated to the study of granites. I once engaged in a conversation with one of my graduate faculty members who was famous for his study of the mass balance of elements transported out of granites into their surrounding host rocks by hydrothermal solutions. The granites of his field area had spawned many thousands of pegmatites, and I asked him why he had not factored the pegmatites into his mass balance calculations? He said nothing in reply, but his look conveyed a sense of irrelevance, annoyance, or stupidity on my part, and after a brief awkward moment I left his office. At the beginning of my research career, a program director at the National Science Foundation told me that NSF would never fund me to study pegmatites because no one cared about them. These personal accounts underscore the extent to which pegmatites have been left out of the study of granites, which remains as a robust area of research in petrology. So, my hat's off over my heart to Petr Černý, who always saw the merits of relating pegmatites to their source granites, and vice versa, and forced everyone to recognize those links.

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Footnotes

[1] Richard V. "Dick" Gaines, who worked for Kawecki Berylco Company, later Cabot Mineral Resources, was another of those few individual who traveled so widely in the search for pegmatite deposits that a colleague remarked to me that Dick was known and welcomed in every small remote town and village in Brazil, Mexico, Africa, Europe, Russia, Australia, southern Asia, and throughout North America wherever pegmatites were known to occur.

[2] In recent years, a spate of articles has purported to describe rare-element pegmatites that are the products of direct anatexis without chemical fractionation by crystallization. Černý et al. (2005) cited ten fact-based arguments to dismiss this concept, and London (2018) added more fact-based evidence against the model. At the temperatures of anatexis, the concentrations of rare elements necessary to crystallize rare-element minerals is orders of magnitude higher than any likely source rock can provide.