Compositional Features and Rare Metal Mineralization of the Hellroaring Creek Stock, Southeastern British Columbia (NTS 082F/09)

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INTRODUCTION

For a long time, the Hellroaring Creek stock has attracted significant interest due to its association with a large body of granitic pegmatites and substantial beryllium and other rare metal (Nb, Ta, Sn) mineralization. Most efforts, however, were spent on studying the large-crystalline pegmatite outcropping within the Hellroaring Creek stock (MINFILE 082FNE110), and the term "Hellroaring Creek pegmatite" is often equalized to the term "Hellroaring Creek stock". Meantime, this large-crystalline pegmatite composes just a minor fraction of the stock that incorporates much larger volumes of various granitic rocks bearing signatures of the "specialty granites" (Pollard, 1995; Pollard, 1989a, b). This is consistent with many characteristic features of the granites including their distinct rare metal metallogeny and a broad occurrence of the rare metal mineralization in the granites in addition to the much more localized pegmatitic bodies. Other, more evolved pegmatite bodies are located distal to the Hellroaring Creek stock.

Field observations on the pegmatites, granites and their relationships combined with the compositional data allow revealing evolutional trends of the Hellroaring Creek stock granites and pegmatites similar to general trend documented by London (2008). In total, the data on the textural and compositional features of the granites make it possible to compare these with similar "specialty rare metal granites" worldwide (Simandl, 2002). If the "specialty granites" are recognized in British Columbia as a distinct rare metal deposit type, this can further contribute to a better understanding of the rare metal metallogeny of this region.

EXPLORATION HISTORY

According to Smith and Brown (1998), the pegmatite occurrence associated with the Hellroaring Creek stock was originally located by Rice (1941), during a regional study, and a more detailed map was published by Leech (1957). It was regarded as an intrusion of possible economic interest for beryllium and industrial minerals. Then, it was staked as a beryllium prospect and explored by various operators (*i.e.*, Richfield Oil Corp. *etc.*) by stripping, blasting, sampling and mapping; as a result, it was estimated that the northern end of the stock contains no NI 43-101 compliant resource of 500 000 tonnes of the mineralized material grading 0.1% BeO (Wasylyshyn, 1984; MINFILE, 2011). Limited studies by the Geological Survey of Canada have identified the presence of Nb-Ta minerals (Mulligan, 1968). In 1984-85, Lumberton Mines Ltd. further investigated the beryllium potential by drilling seven drillholes totalling 500 m; the beryllium content in the drill core was determined by the beryllium scincillator tool, with just control assaying, and returned low grade values (Wasylyshyn, 1984).

In 1985-87, Lumberton Mines Ltd. performed further exploration of the Hellroaring Creek stock pegmatite, this time focused on the ceramic feldspar. Twenty-one drillholes were drilled totalling 2012.4 m; it was determined, after the subsequent small-scale metallurgical bench testing, that the pegmatite contains a considerable amount of glass and ceramic grade feldspar (Pudifin, 1986).

In 1999-2001, another significant exploration program for beryllium including prospecting and diamond drilling was carried out by Chapleau Resources Ltd. (Anderson, 2001; Soloviev, 2001). The work expanded the area with identified beryllium mineralization; however, the drilling, although it encountered a number of significant intercepts, failed to prove the consistency and continuity of the mineralized sectors that would be sufficient for further development of beryllium resources. Some efforts were spent on investigating the tantalum potential of the Hellroaring Creek stock and the nearby Lightning Creek pegmatite as well as other pegmatite occurrences known in the area. Although no economic concentrations of tantalum were outlined, the work indicated locally elevated to high grade tantalum and niobium as well as tin mineralization associated with the pegmatites and "pegmatoid" (stockscheider) varieties of the granites (Soloviev, 2001). In 2002-05, the Hellroaring Creek pegmatite and other pegmatite bodies known in the area were investigated for their gemstone potential (Brown, 2003; Legun, 2004, 2005).

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DISTRICT GEOLOGY AND METALLOGENY

The Hellroaring Creek stock is situated in southeastern British Columbia, some 20 km southwest of Kimberley and 31 km west-northwest of Cranbrook (Figure 1). The area lies west of the Rocky Mountain Trench within the Purcell Anticlinorium of the Omineca orogenic belt, a Proterozoic pericratonic terrane subjected to tectonic and magmatic activation (of distal subduction-related and/or anorogenic type) occurred mainly in the Mesozoic (Hoy, 1993; Hoy and Van der Heyden, 1988). The area also comprises an older (Precambrian) metasedimentary package and younger (Mesozoic) igneous suites.

The Cranbrook area (Figure 2) is underlain by Mesoproterozoic terrigenous clastic, carbonate, and minor volcanic rocks of the Purcell Supergroup that is believed to have formed in an intracontinental rift system (Hoy, 1993; Hoy *et al.*, 1995; Lydon, 2007). They include the basal Aldridge Formation composed of siliciclastic turbidites 4000 m thick and informally divided into the Lower, Middle, and Upper units. The Lower Aldridge, the base of which is not exposed, comprises about 1500 m of thin to medium-bedded argillite, wacke and quartzitic wacke generally interpreted as distal turbidites. The Sullivan SEDEX orebody occurs at the top of this division (Lydon, 2007). The Middle Aldridge is about 2500 m of grey to rusty, dominantly medium to thick bedded quartzitic wacke turbidites with minor thin-bedded argillites, some of which form finely laminated marker beds (time stratigraphic units correlated over great distances within the Purcell Basin). The Upper Aldridge includes about 300 m of dark argillite and grey siltite. The Aldridge Formation is tectonically (?) overlain by the Creston Formation, consisting of quartzites and grey, green and maroon wackes up to 1800 m thick (Hoy, 1993). In turn, the Creston Formation is overlain by the Kitchener Formation that includes oolitic limestone and dolomitic siltstone (Hoy, 1993). The Purcell Supergroup has been intruded by sills, somewhat discordant sheets and dikes of the 1443 ±10 Ma Moyie Sill suite, most prominent in the lower portions of the Aldridge Formation.

The Hellroaring Creek stock is believed to have been emplaced after the earliest Moyie intrusions (gabbroic sills) and after the first deformation of the Aldridge Formation and, thus, have an age of approximately 1300 Ma (Ryan and Blenkinsop, 1971). However, this age was questioned by Ethier *et al.* (1976) who noted an ambiguous relationship of the stocks to the gabbroic sills as well as general uncertainties of the age correlation between the Moyie intrusions and the Aldridge Formation.

The Purcell Supergroup is intruded also by a number of dikes, stocks and larger plutons of mostly granodiorite, monzonite, and possibly syenite composition that are assigned to the Mesozoic (Hoy and Van der Heyden,

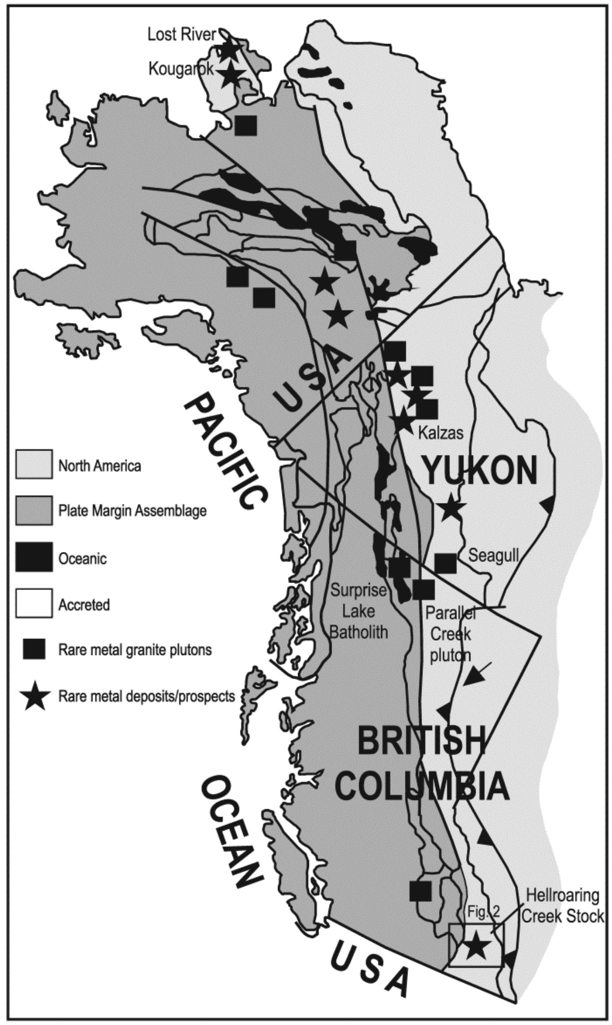


Figure 1. Regional position of the Hellroaring Creek stock and other possible rare metal-bearing granites and pegmatites in the Cordilleran structures. Tectonic assemblage map after Wheeler and McFeely (1991) shows the distribution of North American, plate margin, oceanic and accreted rocks of the Canadian and Alaskan Cordillera, the location of rare metal granite plutons and selected deposits and occurrences.

1988). The larger intrusions, composed essentially of granodiorite, likely correspond to the mid-Cretaceous Bayonne plutonic suite. As defined by Logan (2002), this suite comprises monzogranite, granodiorite, biotite granite, and biotite-muscovite granite. The hornblende-biotite granite is metaluminous to weakly peraluminous; the biotite-muscovite granites, aplites and pegmatites are strongly peraluminous. In the Cranbrook area, the Bayonne suite is represented by the large Reade Lake stock, smaller Kiakho, Grassy Mountain and other stocks as well as by the Angus Creek stock situated south of the Hellroaring Creek stock (Hoy and van der Heyden, 1988). It should be noted that distinguishing the biotite-muscovite rocks of the Bayonne suite from similar in composition granites of the Hellroaring Creek stock and similar (Precambrian?) smaller intrusions nearby is not always fully evident, especially where tourmaline is absent. Abundance of tourmaline as well as common stockscheider textures of marginal varieties, together with

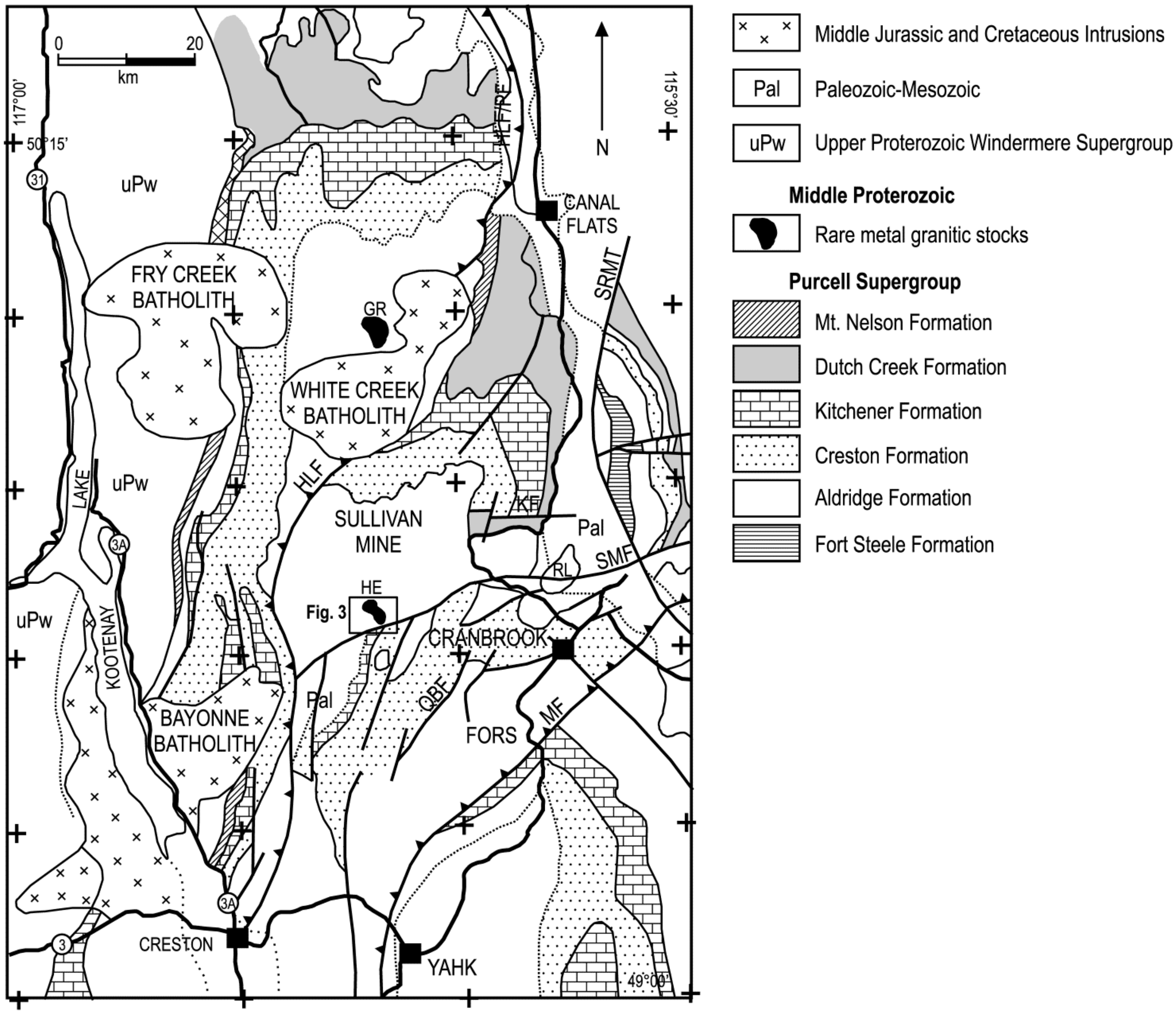


Figure 2. Simplified geology map of southeastern British Columbia (Purcell Anticlinorium) showing location of the Hellroaring Creek stock (modified after Smith and Brown, 1998; Hoy *et al.*, 1995). HE – Hellroaring Creek stock, HLF – Hall Lake fault, KF – Kimberley fault, GR – Greenland Creek stock, MF – Moyie fault, OBF – Old Baldy fault, PF – Purcell fault, SMF – St. Mary fault, SRMT – Southern Rocky Mountain Trench.

enrichment in muscovite, certain geochemical affinity (Li, F, Sn *etc.*) and specific set of accessory minerals, may be helpful in the case of the most evolved varieties.

The Precambrian metallogeny of the area is essentially determined by the lead-zinc deposits and occurrences including the giant Sullivan SEDEX-style deposit and a number of much smaller Pb-Zn occurrences that are hypothesized to correspond with this age and style of mineralization (Hoy *et al.*, 1995). The Precambrian age is currently assigned to the pegmatites including the Hellroaring Creek pegmatite (Ryan and Blenkinsop, 1971) and smaller micaceous, ceramic feldspar and beryllium pegmatites of the Matthew Creek (MINFILE 082FNE088), Greenland Creek (MINFILE 082FNE112) and other occurrences (McFarlane and Pattison, 2000; Brown, 2003), although some other occurrences of similar (beryl *etc.*) mineralization are considered to be Cretaceous, such as those associated with the White Creek batholith and Shaw Creek stock. (Smith and Brown, 1998; Brown, 2003). In general, however, the Mesozoic metallogeny is dominated by intrusive-related gold and associated occurrences (Logan, 2002; Soloviev, 2010).

HELLROARING CREEK STOCK

The Hellroaring Creek stock is a slightly elongated (about 3 by 1 km across) pluton of granitic rocks intruding the Precambrian metaterrigenous rocks and gabbroic "Moyie sills" (Figure 3). The pluton has complex internal structure. Various interpretations of this structure can be suggested. In particular, the structure may be interpreted as a series of bedding-subparallel granitic

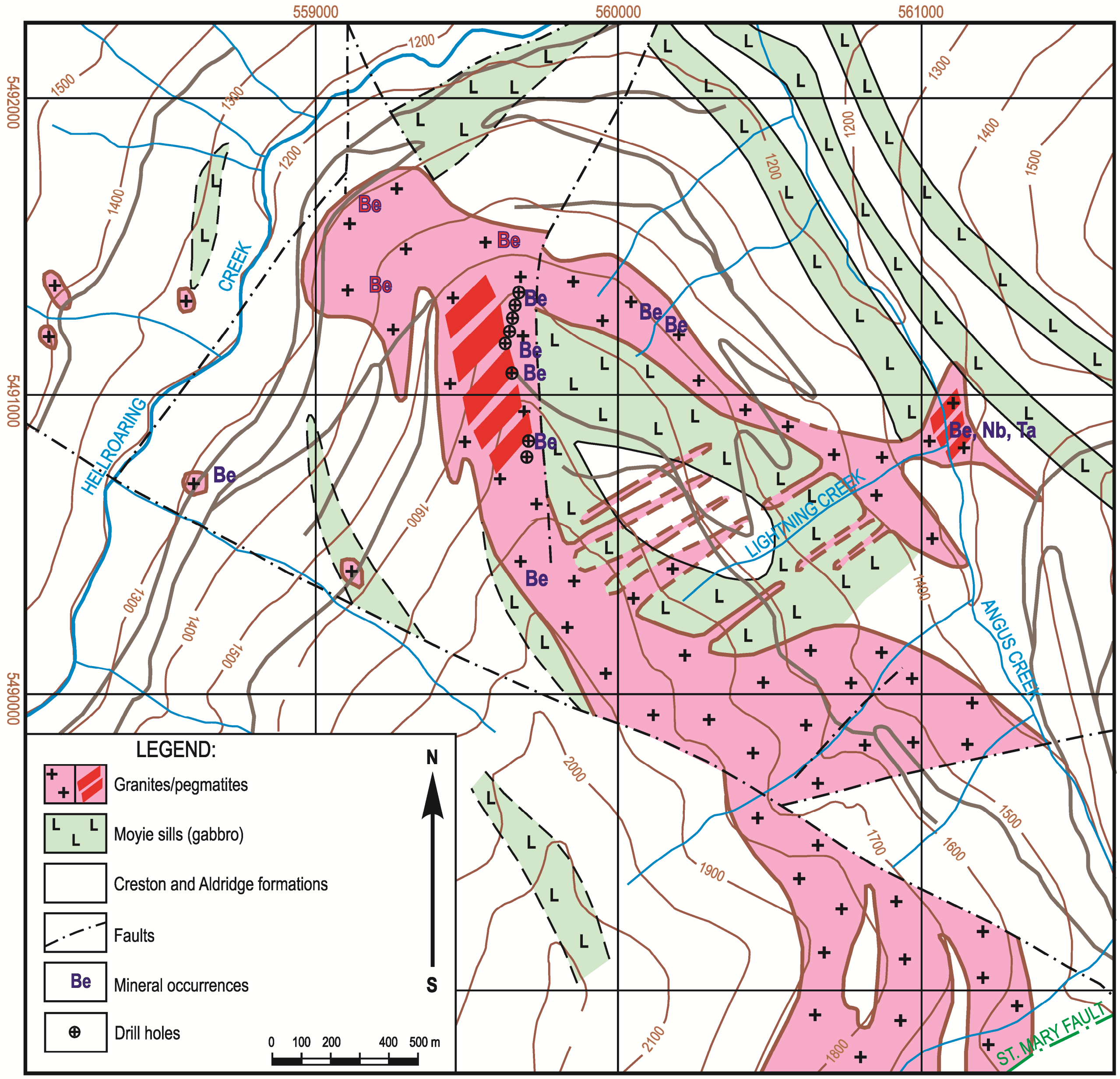


Figure 3. Simplified geological map of the Hellroaring Creek stock showing locations of the pegmatites and identified occurrences of rare metal mineralization (compiled data by David Pighin, personal communication; White, 1987; MacLean and White, 1991; Smith and Brown, 1998; Brown, 2003).

bodies (granitic sills) intruded like "saddle veins" into folded metasedimentary rocks. More plausibly, the stock may be interpreted as a sort of asymmetric ring or semi-ring structure fully or partially surrounding a large block of metasedimentary rocks intruded by the "Moyie sills". Finally, the stock may represent a dome-like intrusive body complicated by roof pendants, and the large block of metasedimentary rocks intruded by the "Moyie sills" may represent one of such roof pendants. Also, several smaller separated intrusive bodies possibly representing various intrusive phases can be suggested within the stock.

In addition, the Hellroaring Creek stock is accompanied by a number of smaller similar intrusions found at some distance (hundreds of metres to a few kilometres) and representing, probably, satellite stocks or cupolas. Pegmatite bodies are also found at a distance from the main pluton contacts, together with relatively small stocks (large dikes?) of aplitic granites.

The contact aureole consists of various altered lithologies including thin bedded lenses of altered pyroxene-garnet skarns with molybdoscheelite and molybdenite, vein-like bodies of quartz-micaceous greisens (?) with beryl, and quartz-sulphide veins with sphalerite, galena, *etc*.

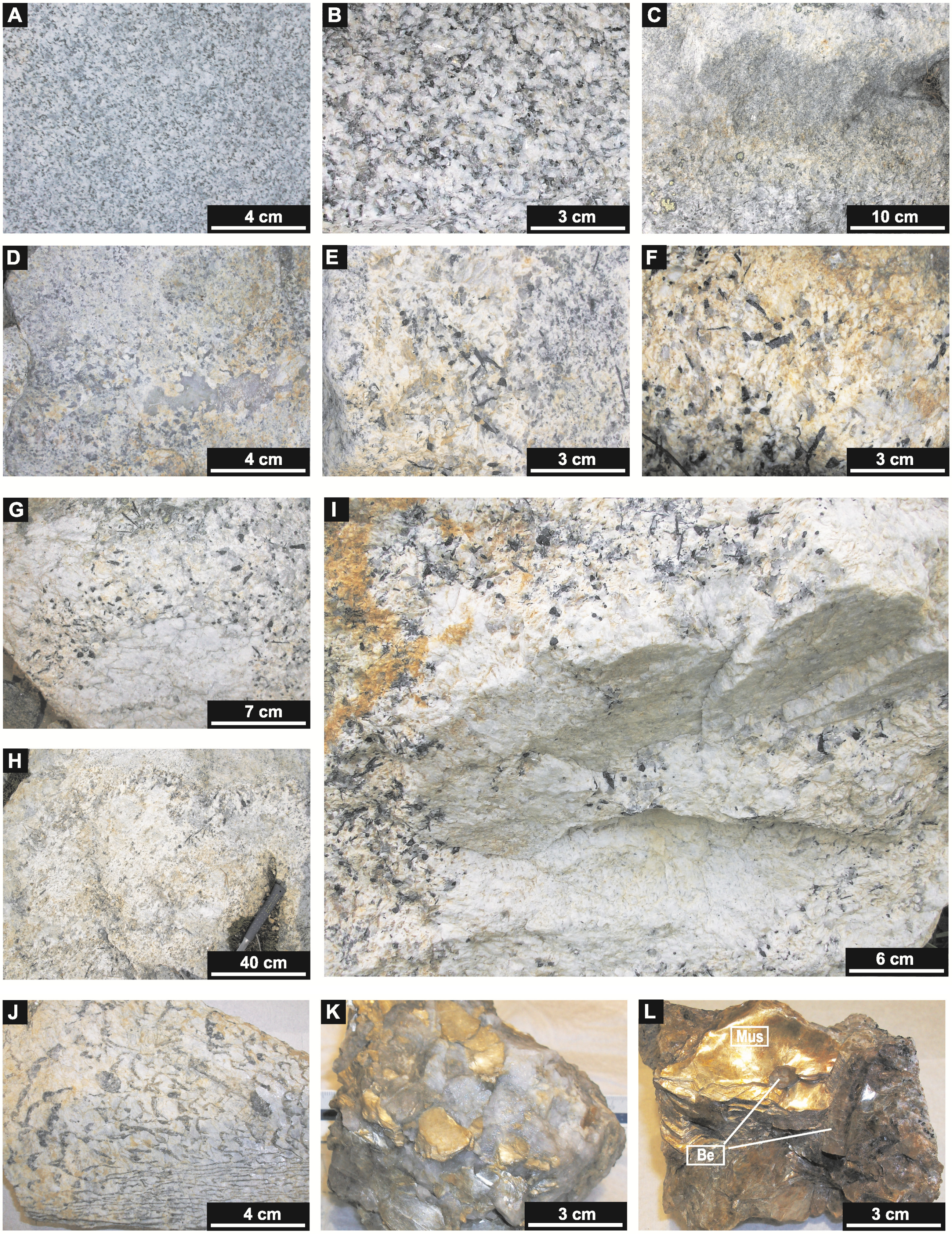
The irregularity of the internal structure of the stock is emphasized by the distribution of various intrusive rocks. In particular, the pegmatites and stockscheider-like varieties of the granites occur mostly in the northern part of the stock; in contrast, more regularly grained to equigranular varieties predominate in its southern part. There are a number of the rock varieties that differ in their abundance, textural appearance, mineral and chemical composition.

INTRUSIVE ROCK TYPES

As noted above, the Hellroaring Creek granite+pegmatite stock incorporates a large number of rock varieties that differ largely in textures and, to a lesser extent, in mineral and chemical composition (Figure 4). Their apparent evolutional sequence may generally be presented as follows:

1. Fine to medium grained equigranular rock typically distinguished as biotite to biotite-muscovite granodiorite. The rock is grey to darker grey, medium grained, seems to be almost equigranular, and is composed of K-feldspar (30-35 vol.%), quartz (20-25 vol.%), plagioclase (30-35 vol.%), and usually strongly altered biotite (5-10 vol.%) replaced by finer grained muscovite. Feldspars are also partially replaced by muscovite and chlorite. This rock is locally observed in variously sized xenoliths found in the other intrusive rocks distinguished in the stock so that it may represent the early intrusion phase.
2. Medium to coarse grained equigranular rock typically distinguished as muscovite to muscovite-tourmaline granite. This rock contains xenoliths of the biotite to biotite-muscovite granodiorite and thus is considered to be a younger phase. The rock is light grey to light pinkish grey and is composed of K-feldspar (25-30 vol.%), quartz (~30 vol.%), plagioclase (25-30 vol.%), with muscovite occupying 5-20 vol.% and black tourmaline occupying 0-20 vol.%. Muscovite and tourmaline typically occur in expense of one another but locally both can be absent.
3. Medium to coarse grained irregularly-textured muscovite-tourmaline to tourmaline-muscovite granite. This granite often contains irregularly-shaped vugs filled with coarse-grained segregations of quartz (±feldspars, ±tourmaline) indicating that the pluton reached fluid saturation and is able to produce pegmatitic and aplitic dikes (*cf.* London, 2008).
4. Coarse grained to large crystalline, equigranular to irregularly-grained “pegmatoid”, or stockscheider-style granitic rock represents further development of this process, *i.e.*, further saturation in water and volatiles, with spreading of the “water-saturated” textures over a greater volume of the granite. The irregularly grained varieties are porphyritic (porphyrocrysts of K-feldspar, black tourmaline and quartz), “pegmatoid” to giant crystalline pegmatitic, banded, and patchy, with short vein-like, small lens-like, *etc.* aggregations of coarser to very coarse grained and even giant crystalline K-feldspar, or K-feldspar+quartz (±tourmaline) patches surrounded by medium grained granitic groundmass. These sectors of textural irregularities vary in size from a few centimetres (observed in hand specimens) to several metres and even tens of metres totally forming a domain-like textural appearance of the rock. These small and large textural domains have both gradual and sharp contacts to more regularly grained medium grained variety of the granite. The relative volume of the “pegmatoid” rocks definitely increases upward, toward the roof of the pluton: at deeper levels, they can be found in small lenses and domains whereas at the higher levels they compose almost whole volume of the pluton. A characteristic feature of the rocks occurred in finer grained and more equigranular variety is the dark gray, smoky and even almost black, morion-like color of quartz. Locally, such quartz occurs in the pegmatoid variety.
5. Coarse and irregularly grained granitic rock containing large potassic feldspar segregations (locally gigantic phenocrysts); these phenocrysts, however, compose a subordinated fraction of the rock and are surrounded by more equigranular tourmaline-muscovite or muscovite-tourmaline granite. This rock gradually evolves into similar rock, in which large potassic feldspar segregations and phenocrysts exhibit internal graphic (with small quartz intergrowths) texture.
6. Coarse crystalline pegmatites occurred within the principal granitic body but likely on its periphery, such as the major well studied ceramic pegmatite occurrence known as the Hellroaring Creek pegmatite. It should be emphasized that even this large pegmatite occurrence, in fact, incorporates a number of smaller pegmatite bodies, or their assemblage, with common mutual boundaries evolving into one another rather than a single large pegmatite body. These pegmatites are composed of predominating potassic feldspar and quartz forming typical blocky, graphic and skeletal textures, with usually subordinated amounts of muscovite and tourmaline.

The pegmatite is closely associated with banded variety of the granite occurred locally that contains thin (few centimetres thick) bands (“layers”) of strongly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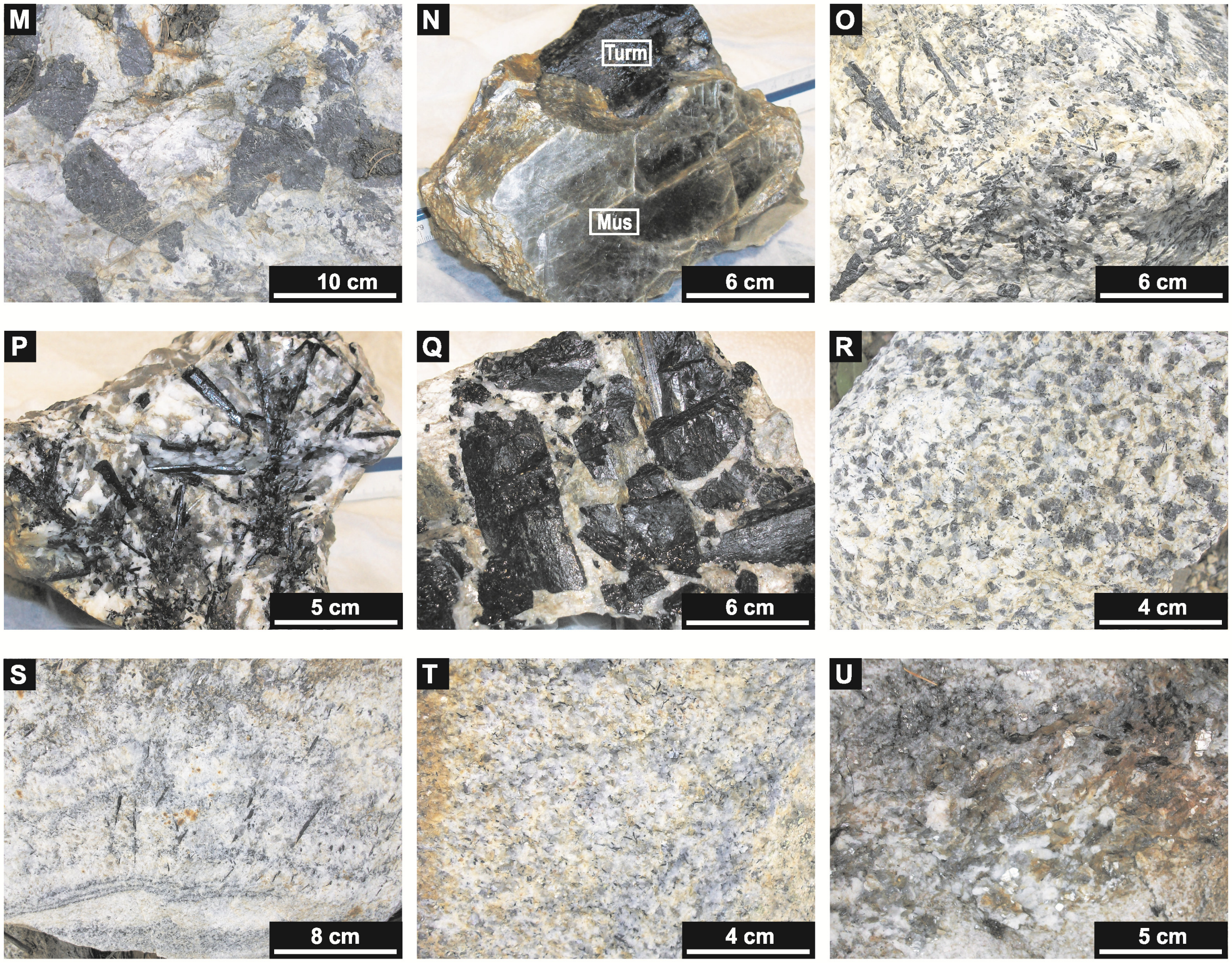

Figure 4. Major types of granites and pegmatites of the Hellroaring Creek stock. A-J – gradual evolution from early granite to granitic pegmatites (granite-pegmatite transition): A – fine-grained biotite (±muscovite) granite of apparently early phase; B – coarse grained equigranular muscovite-tourmaline granite of the later phase (?); C – xenolith of the fine-grained biotite (±muscovite) granite in the coarse grained equigranular muscovite-tourmaline granite evolving into irregularly grained ("pegmatoid", or stockscheider-style) muscovite-tourmaline granite; D – equigranular to irregularly grained muscovite-tourmaline granite with vugs filled in with coarse grained quartz-feldspar aggregate indicative for high degree of magma saturation in water and volatiles; E – further evolution of the granite, with patchy distribution of the pegmatoid (stockscheider-style) domains in more equigranular granitic variety (almost equally abundant); F - pegmatoid (stockscheider-style) granite; G – "pegmatoid" (stockscheider-style) granite incorporating large but still insulated blocky crystals and crystal aggregates of potassic feldspar; H – "spreading" of the stockscheider-style granite with blocky crystals of potassic feldspar over the equigranular muscovite-tourmaline granite, with tourmaline prisms radiating across the contact; the stockscheider-style granite can be called also as "undifferentiated pegmatite" but occurs within the equigranular granite and is not fracture controlled suggesting rather subsolidus state of the host granite at the time of the "pegmatite" crystallization; I – larger domain-like block of potassic feldspar found in the stockscheider-style granite; the potassic feldspar exhibits "initialization" of the internal graphic texture formation; J – fully-developed graphic texture in large granite-hosted pegmatite aggregates (ceramic pegmatites); K-N – some varieties of the pegmatites: K – coarse crystalline quartz-muscovite pegmatite; L – large crystalline essentially muscovite pegmatite with prismatic beryl crystals; M – large (blocky) crystals of black tourmaline; N – large crystalline muscovite-tourmaline pegmatite (Lightning Creek); O-T – minor types of granites and pegmatites: O – tourmaline-albite granite; P – radiating tourmaline aggregates with quartz and feldspars (part of the tourmaline-albite granite); Q – partially brecciated tourmaline crystals ("tourmaline breccia") in fine grained quartz-feldspar matrix; R – tourmaline granite with rounded quartz crystals; S – albite layering in pegmatite, with outward radiating tourmaline crystals; T - fine to medium grained equigranular tourmaline-muscovite granite (the latest phase ?); U – greisen-like patchy and veined muscovite aggregates replacing (?) over granite. Abbreviations on Figures. 4L and 4N: Mus – muscovite, Be – beryl, Tur – tourmaline.

tourmaline-enriched (about 30 vol.%, locally up to 60% and more black tourmaline, both fine, medium and coarse grained) rock alternating with tourmaline-free, usually coarse grained essentially K-feldspar+quartz bands and coarse-grained quartz+white mica bands. There is some regular distribution of various bands: tourmaline-rich and typically finer grained bands occur on a greater distance from the pegmatite, whereas tourmaline-depleted and gradually more and more coarser grained K-feldspar+quartz and further quartz+white mica bands are most proximal to the pegmatite.

7. Finally, coarse crystalline pegmatites occurred outside the principal granitic pluton such as that distinguished as the Lightning Creek pegmatite. The latter is characterized by intense development of fine-grained ("sugary") albite occurred on the periphery of the innermost quartz zone and apparently in the footwall of the pegmatite body as a whole. The pegmatite body is also characterized by the presence of apatite and garnet closely associated with albite, together with beryllium (beryl), tin (cassiterite) and niobium-tantalum (columbite) mineralization. Locally, apatite is quite an abundant accessory mineral and forms thick prismatic crystals and their aggregations; garnet is second in importance forming small (up to 3 by 10 cm) lens-like aggregations.

In addition to the granite and pegmatite varieties described above and representing their major types, the pluton incorporates a number of definitely minor rock varieties likely occurred just in localized sectors ("pockets") with or with no spatial relationships to pegmatites. These minor rock varieties include, in particular, various tourmaline-rich rocks such as tourmaline breccias, with variably sized fragments of tourmaline crystals cemented by fine grained quartz-feldspar matrix, and coarse to medium grained tourmaline granites, with variably oriented long (up to 1 by 10 cm) tourmaline crystals enriching the granites (up to 20-30 vol.%) and locally forming star-like aggregates. Other minor varieties include granites with smoky to morion quartz phenocrysts, fine to medium grained tourmaline-albite granites, leucocratic granites and granite-porphyry, aplites, *etc.*

In particular, the fine to medium grained tourmaline-albite to tourmaline-albite-muscovite granites are relatively more abundant and were observed in drill core, in numerous outcrops, rubblecrops, and float boulders. The rock is light grey due to constant presence of fine grained (thin needles) black tourmaline (5-10 vol.%), is fine to medium grained and usually enough equigranular or with small porphyrocrysts of K-feldspar. Controversial relationships were observed between the tourmaline-albite to tourmaline-albite-muscovite granites and the muscovite-tourmaline granites described above. In particular, these tourmaline-albite to tourmaline-albite-muscovite granites form thin (10-50 cm) apophyses cutting through much coarser grained and pegmatoid varieties of the muscovite-tourmaline granite. Locally, large crystals of tourmaline oriented across the contact form "a crown" around these apophyses emphasizing their later emplacement as a comparison to that of the muscovite-tourmaline granite. However, in other cases, a gradual transition from the coarser grained muscovite-tourmaline granite to the finer grained tourmaline-albite to tourmaline-albite-muscovite granites was observed.

Some of these relationships can be explained, if to assume that the coarser grained muscovite-tourmaline granite represents an apical, fluid-enriched and early crystallized facies, whereas the finer grained tourmaline-albite to tourmaline-albite-muscovite granites represent relatively deeper facies exhibiting gradual transition to the coarser-grained tourmaline-muscovite granite upward but cutting through the already crystallized crust along minor fractures. Also, perhaps, there are several varieties (even intrusion phases?) of the tourmaline-albite to tourmaline-albite-muscovite granites.

Leucocratic granite observed in large outcrops is white, leucocratic, usually tourmaline-free (macroscopically), medium to fine-grained rock composed in equal proportions of quartz, albite, and K-feldspar; there are some, probably, very local sectors of micropegmatoid and slightly coarser grained pegmatoid texture. Accessory pyrite and, probably, other sulphides are very common. Leucocratic granite porphyry observed in float boulders and in the outcrops is pink-coloured rock with numerous rounded quartz porphyrocrysts (about 5 mm across) (totally, up to 25-30 vol.%) surrounded by very fine grained feldspar-quartz groundmass. Accessory pyrite and, perhaps, other sulphides are also very common.

Aplite was observed in numerous but small veinlets cutting the leucocratic granite and, also, in numerous and often large boulders found in float including those occurred nearby the Lightning Creek pegmatite. In addition, gradual transitions of large-crystalline pegmatites to fine grained aplitic rocks are locally observed. This is fine grained, sugary in appearance, equigranular rock composed of albite, quartz, and minor K-feldspar. Similarly to other late leucocratic granitic phases, this rock is enriched in pyrite and, perhaps, other sulphides.

In total, the granitic and pegmatitic rocks found in the Hellroaring Creek stock form a distinct assemblage of compositionally similar and likely genetically related rocks. Their general evolutional pathways can be illustrated on the basis of the recently obtained data on the contents and distribution of the major and trace elements in the rocks.

GEOCHEMICAL FEATURES OF THE GRANITES AND PEGMATITES

The results of chemical assaying of the granitic and pegmatitic rocks are presented in Table 1. These assay results represent the major types of the rocks including medium to coarse grained equigranular muscovite to muscovite-tourmaline granites; coarse grained to pegmatoid granites (stockscheider); pegmatites; albite-tourmaline granites; and albitic (leucocratic and aplitic) granites. The assay results include the contents of the petrogenic and most notable trace elements (including rare metals) as well as boron and fluorine contents.

It can be seen that the stockscheider-style granites are characterized by somewhat elevated, as compared to the equigranular muscovite-tourmaline granites, sodium contents in expense of potassium contents. This is attributed to the elevated contents of sodic (essentially albitic) plagioclase substituting potassic feldspar and is typical for the roof zones of the "specialty granite" plutons evolving toward albite-enriched granites (London, 2008). This evolution is accompanied by some increase in the contents of P, F, B and some trace elements such as Be and Li; however, this trend appears to occur quite sporadically and is better expressed in some more evolved and/or albite-enriched varieties. The granites are characterized by strong europium minimum and nearly symmetric distribution of LREE and HREE that is typical for the rare metal-bearing granites (*cf.* Cuney *et al.*, 1992).

Much greater enrichment in P and F as well as Li, Cs, Be, Nb, Ta and Sn is observed in the pegmatites representing a higher degree of magmatic melt evolution. The pegmatites assayed represent different compositional zones of the respective pegmatite bodies; this explains variations in the Na/K ratios, SiO_2, Al_2O_3, boron and phosphorus contents. The higher P contents are associated with higher K, Ca and Mn values, in expense of Na; the higher Ca values can also be attributed to the high apatite content, whereas the high potassic contents are associated with elevated content of micas (muscovite and likely its Li and Rb varieties). The later is consistent with also elevated values of F, Li, Rb and Cs, although some Rb may be contained also in potassic feldspar. The elevated Mn values are attributed to the abundance of Mn-rich garnet that is observed petrographically. The most apatite-enriched pegmatite contains elevated abundances of REE (especially LREE).

Plotting the assay data on the K/Rb *vs.* Cs diagram suggested by London (2008) for estimation of the evolution degree of rare metal granites and pegmatites shows a common evolutional trend toward less potassic, more cesium-enriched varieties from the Hellroaring Creek granites to micaceous ceramic pegmatites forming the largest pegmatite occurrence found within the Hellroaring Creek stock itself, and then to the pegmatites found at the Lightning Creek occurrence (Figure 5). The latter are characterized by quite a high degree of the evolution that, however, is below the evolutional level of spodumene and lepidolite-bearing pegmatites; this is consistent with the absence of these minerals and generally low Li content in the studied pegmatites. Nevertheless, the trend is indicative of the possible formation of more evolved pegmatites under favored conditions, perhaps at a greater distance from the pluton.

PEGMATITES

The major pegmatite occurrence of the Hellroaring Creek stock was described in a number of publications (Ryan and Blenkinsop, 1971; Smith and Brown, 1998; Brown, 2003; Legun, 2004, 2005) and reports (Wasylyshyn, 1984; Pudifin, 1986; Anderson, 2001; Soloviev, 2001). The pegmatite occurs within the Hellroaring Creek granitic stock and occupies an area of some 500 by 200 m (Figure 1), where the coarse grained to large-crystalline pegmatites are outcropped on the surface. The vertical extent of the pegmatite was not confidently determined by drilling; however, it appears that the pegmatite (*i.e.* the large-crystalline rock) does not extend for more than few tens of metres and then evolves into coarse-grained granite; however, other (smaller and subconcordant?) pegmatite bodies are likely present to a depth of at least some 100 m from the surface. Smaller pegmatite bodies likely occur in other parts of the stock.

Typical zonation of the pegmatites occurs as follows: outer coarse grained to large crystalline tourmaline+potassic feldspar+muscovite+quartz zone – intermediate potassic feldspar+quartz zone (±muscovite) – inner monomineralic quartz zone (±muscovite), or "core". Muscovite forms coarse books that are most common and locally abundant along the boundary of the intermediate and the inner zones locally forming a distinct muscovite zone, locally with vein-like apophyses; however, in some pegmatites muscovite is almost totally absent. Some monomineralic blocks of potassic feldspar are 1-2 m across and 2-3 m in length, and so are the largest quartz lenses representing the innermost pegmatite zones. The pegmatite is locally strongly enriched in black tourmaline that can compose up to 60-80 vol.% of the rock. In such sectors, very large (up to 10 by 20-30 cm) tourmaline crystals are common and are surrounded by much finer grained K-feldspar (±quartz, muscovite) groundmass, which in other sectors can be large crystalline. Beryl is locally present in the pegmatites, typically in the outer to intermediate zones or in the muscovite-rich zones (Figure 6). Ethier and Campbell (1977) determined the tourmaline composition as shorl with characteristically high iron and low calcium content. However, some tourmaline crystals show a distinct color zoning from black to dark olive-green, thus, indicating more evolved (toward shorl-dravite and dravite (?) compositions.

In contrast, the pegmatitic body found in the Lightning (Angus) Creek sector is represented by very coarse grained to large-crystalline (single crystals up to 20-30 cm in size) rock outcropped for several metres of its thickness (?); however, floated fragments of the same rock were observed on the creek walls for the distance of, at least, 100 m above *(i.e.*, these are not the fragments just transported from the outcrop) the creek floor. As a result, a length of the pegmatite body of some 100 m can be easily accepted.

The major minerals composing the pegmatite are K-feldspar, quartz, and very large crystals and books of silver-white to greenish muscovite. Black tourmaline is a common constituent; it also forms large (up to 10 by 30 cm) crystals. Typically, the pegmatite contains about 40 vol.% of K-feldspar, 30% quartz, 20% tourmaline, and 10% muscovite, but locally tourmaline can be absent and muscovite or quartz can predominate over K-feldspar; in

Table 1. Representative analyses of granites and pegmatites from the Hellroaring Creek stock (wt.%, ppm).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Medium to coarse grained equigranular muscovite and muscovite-tourmaline granites							Coarse grained to pegmatoid stockscheider-style granites						
Sample field #	015	017	026	031	033	012	013	016	022	023	025	027	028	032
Northing	559680	559695	559795	560708	560695	560148	560151	559685	559615	559655	559612	559602	559635	560704
Easting	5491234	5491310	5490811	5490012	5490023	5490743	5490739	5491286	5490643	5490699	5490722	5490725	5490712	5490018
SiO_2	75.91	76.67	74.66	75.26	74.44	74.03	76.10	74.88	75.86	72.43	74.59	74.91	75.19	76.20
TiO_2	0.02	0.01	0.01	0.07	0.04	0.02	0.07	0.02	0.02	0.02	0.05	0.01	0.02	0.06
Al_2O_3	14.17	14.07	14.54	14.91	14.64	14.85	13.67	14.81	13.50	15.23	14.79	14.43	14.28	14.27
Fe_2O_3	0.76	1.79	1.05	0.87	0.68	1.27	1.30	0.50	1.61	2.06	3.53	1.21	1.34	2.79
MnO	0.01	0.24	0.02	0.01	0.02	0.01	0.01	0.02	0.09	0.48	0.08	0.03	0.05	0.04
MgO	0.10	0.08	0.10	0.18	0.12	0.19	0.29	0.05	0.10	0.08	0.25	0.08	0.08	0.58
CaO	0.30	0.55	0.66	0.70	0.55	0.61	0.57	0.31	0.50	0.62	0.30	0.51	0.54	0.25
Na_2O	4.36	4.93	4.26	4.23	3.67	5.74	3.63	7.03	5.57	6.96	4.14	5.95	5.96	3.88
K_2O	3.32	1.16	3.30	2.09	5.34	1.19	1.75	1.57	0.50	0.41	0.45	1.42	1.03	0.89
P_2O_5	0.11	0.10	0.14	0.04	0.08	0.06	0.11	0.07	0.09	0.06	0.05	0.07	0.11	0.04
CO_2	0.07	0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05
S tot.	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
LOI	0.90	0.40	0.40	1.40	0.50	1.00	1.60	0.60	0.80	0.60	0.80	0.50	0.60	0.90
Total	99.96	99.96	99.12	99.73	100.09	98.93	98.96	99.84	98.61	98.92	99.02	99.10	99.20	99.87
B	33	682	345	61	239	620	342	66	651	384	1673	467	587	1264
F	100	190	230	310	90	100	240	100	210	170	540	150	170	370
Ba	81	7	<5	18	94	6	102	19	<5	<5	<5	8	7	36
Sr	58	9	6	48	33	24	88	29	10	5.4	5	13	11	22
Co	1.3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	1.0
Ni	5	5	5	5	5	2	6	4	6	2	2	1	6	2
Li	4	10	10	10	4	5	10	4	9	12	29	7	8	7
Rb	118	96	268	119	201	63	95	91	36	20	41	125	84	46
Cs	3	7	7	5	7	2	3	3	2	2	5	9	4	1
Be	3	14	5	5	5	14	3	4	12	10	18	6	12	9
Zr	22	32	45	105	23	57	71	41	32	164	29	19	29	54
Hf	1.1	1.6	2.4	3.8	0.9	2.6	2.4	2.1	1.8	10.7	1.9	1.0	1.8	2.7
Nb	4.5	6.7	4.8	12.6	0.8	4.3	9.4	2.4	2.5	6.1	2.4	2.5	2.6	1.4
Ta	1.3	1.4	1.8	1.6	0.2	0.9	2.3	0.5	0.7	5.1	1.3	1.0	1.3	0.6
Sc	1	1	1	12	1	1	3	1	2	2	1	1	1	3
Sn	6	17	11	14	5	7	7	7	10	5	8	5	5	5
Mo	4	4	3	4	3	4	4	3	4	3	4	3	4	3
W	4	3	2	9	2	10	7	2	3	8	11	8	2	9
Y	5.6	6.9	13.0	55.2	7.3	12.8	15.2	6.2	13.2	17.7	2.7	5.3	5.0	11.7
La	2.0	2.0	4.1	16.9	2.0	6.3	8.6	2.7	5.2	2.2	9.5	2.0	2.1	1.9
Ce	4.4	4.6	9.6	34.8	4.0	15.1	21.0	6.4	11.7	5.4	23.3	4.3	4.9	4.4
Nd	2.0	2.0	4.0	14.7	1.7	6.1	8.9	2.1	4.6	2.3	9.5	1.8	2.0	1.8
Sm	0.7	0.8	1.8	4.8	0.7	2.3	3.0	0.8	1.9	1.0	4.0	0.8	0.8	0.9
Eu	0.11	<0.05	<0.05	0.34	0.17	0.08	0.44	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.12
Gd	0.62	0.64	1.41	5.92	0.83	1.74	2.31	0.70	1.28	0.95	2.24	0.66	0.64	1.07
Tb	0.16	0.19	0.38	1.35	0.20	0.39	0.51	0.16	0.33	0.36	0.30	0.15	0.14	0.28
Yb	0.87	1.17	1.95	6.11	0.92	1.96	1.74	1.29	2.87	3.32	0.25	0.85	0.87	2.21
Lu	0.14	0.17	0.34	0.92	0.14	0.30	0.26	0.21	0.41	0.47	0.03	0.13	0.13	0.34

Table 1. continued.

	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Pegmatites									Fine to coarse grained albite-tourmaline granites				Leucogranites and aplites		
Sample field #	014	018	036	037	038	039	042	043	044	020	021	024	029	009	010	030
Northing	560154	559620	561121	561118	561120	561117	561110	561111	561112	559820	559840	559765	559630	560456	560450	560890
Easting	5490755	5491205	5490920	5490915	5490918	5490922	5490920	5490921	5490922	5490403	5490455	5490615	5490719	5490355	5490359	5489878
SiO_2	75.63	65.18	59.04	74.03	61.69	72.60	73.13	52.20	69.64	75.36	76.80	72.82	76.23	74.70	73.73	76.06
TiO_2	0.06	0.07	0.02	0.03	0.02	0.03	0.05	0.02	0.01	0.01	0.02	0.01	0.04	0.01	<0.01	0.02
Al_2O_3	14.56	20.30	20.49	15.16	18.56	11.48	15.06	9.60	15.72	14.48	14.64	15.76	14.99	14.80	14.19	14.36
Fe_2O_3	1.36	3.00	1.10	1.14	1.78	2.42	1.98	1.19	1.55	1.22	1.25	2.02	2.99	0.53	0.53	0.44
MnO	0.05	0.10	0.39	0.03	0.24	2.17	0.07	1.18	1.09	0.03	0.07	0.06	0.03	0.01	0.01	0.01
MgO	0.19	0.24	0.05	0.05	0.14	0.10	0.12	0.03	0.02	0.12	0.09	0.11	0.44	0.05	0.05	0.07
CaO	0.25	1.52	4.89	0.47	4.18	3.55	0.87	17.90	1.85	0.72	0.68	0.47	0.55	0.25	0.57	0.20
Na_2O	2.31	7.73	4.09	7.46	2.53	0.77	3.74	0.33	5.30	4.72	5.67	6.64	4.13	6.32	6.59	7.60
K_2O	3.12	0.63	4.02	0.40	4.36	2.57	1.94	1.96	1.69	2.86	1.72	0.38	0.84	2.51	1.67	0.49
P_2O_5	0.15	0.87	3.68	0.25	3.10	2.61	0.56	13.02	1.28	0.11	0.08	0.20	0.04	0.12	0.10	0.04
CO_2	<0.05	<0.05	<0.05	0.15	0.08	0.12	0.08	0.19	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08
S tot.	0.08	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01
LOI	1.90	0.70	2.00	0.50	2.40	1.70	0.90	1.10	1.00	0.20	0.40	1.00	0.60	0.60	0.70	0.70
Total	99.59	100.34	99.77	99.51	99.00	99.99	98.32	98.52	99.16	99.82	99.40	99.45	100.48	99.86	98.13	99.87
B	38	2283	91	429	89	63	766	59	44	475	451	680	1344	6	6	9
F	220	1050	4450	550	3950	3050	1450	18950	1750	140	180	310	340	70	<10	<10
Ba	76	22	13	12	140	61	15	19	50	<5	<5	8	7	27	18	13
Sr	51	17	12	12	24	16	14	54	19	8	8	19	11	33	29	34
Co	1.3	1.3	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	0.6	1.0	0.6
Ni	2	2	1	5	6	2	2	5	2	1	5	6	2	4	1	1
Li	5	28	71	19	40	36	39	92	58	7	9	9	10	4	5	3
Rb	187	65	1023	62	834	400	442	551	396	213	132	34	55	107	66	21
Cs	6	27	93	8	144	130	38	246	218	8	10	2	3	3	3	1
Be	9	12	494	78	15	1055	9	4980	2113	8	15	8	4	1	4	3
Zr	17	12	5	5	3	6	8	3	7	45	34	60	39	6	26	8
Hf	1.1	1.2	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	2.0	1.5	3.5	1.7	<0.5	1.2	<0.5
Nb	40.9	5.9	1484.0	14.7	70.0	20.8	38.5	63.9	31.2	8.5	3.3	0.6	2.6	5.6	2.6	2.3
Ta	10.0	10.3	344.0	6.3	44.6	7.8	12.1	30.2	14.1	3.8	1.8	0.3	2.0	1.6	1.1	0.7
Sc	3	1	1	<1	1	1	<1	1	1	2	1	1	6	1	1	<1
Sn	21	25	265	20	225	106	120	144	110	7	7	7	6	6	4	4
Mo	4	3	2	3	2	4	4	3	3	3	3	4	4	3	3	2
W	18	9	26	3	9	6	12	5	9	7	2	2	14	4	8	5
Y	5.8	8.7	11.2	2.7	10.7	13.6	1.9	36.6	5.6	13.3	11.3	5.2	8.3	6.2	12.2	2.2
La	5.3	5.4	14.4	1.4	12.5	10.5	1.8	44.0	6.3	4.6	3.9	3.5	3.2	2.2	3.6	0.7
Ce	10.8	14.6	31.8	3.4	27.2	25.3	4.3	106.6	14.0	10.5	8.4	9.0	7.7	4.0	7.9	1.4
Nd	4.5	7.1	13.6	1.7	10.4	10.2	1.8	47.0	5.7	4.3	3.4	4.0	3.5	1.5	3.4	0.6
Sm	1.6	4.8	7.6	1.1	5.4	5.5	1.1	26.3	3.0	1.6	1.2	1.4	1.3	0.7	1.3	0.3
Eu	0.19	<0.05	0.12	<0.05	0.19	0.22	0.07	0.46	0.06	<0.05	<0.05	<0.05	<0.05	0.12	0.09	0.09
Gd	1.22	4.33	6.33	1.29	3.85	4.44	0.88	19.93	2.12	1.35	1.02	0.97	1.13	0.68	1.16	0.31
Tb	0.23	1.00	1.12	0.23	0.69	0.80	0.15	3.30	0.37	0.34	0.28	0.19	0.24	0.17	0.33	0.07
Yb	0.39	0.30	0.44	0.10	0.85	1.47	0.08	1.88	0.45	2.22	2.16	0.81	1.36	0.72	1.70	0.29
Lu	0.07	0.03	0.06	0.02	0.12	0.22	<0.01	0.24	0.06	0.36	0.34	0.12	0.22	0.11	0.26	0.04

Notes: The assaying was performed in ACME Analytical Laboratories Ltd. by ICP/ES analysis (Mo, Ni, Li, B, F) and by whole rock ICP/MS analysis (major oxides, Ba, Sc, REE and other trace elements). Iron content is presented as sum of Fe_2O_3 and FeO expressed as Fe_2O_3. Samples 009-033 – Hellroaring Creek stock (granites and pegmatites), samples 036-044 – Lightning Creek pegmatite. Samples from pegmatites: 014 – small (1 m thick) zoned body of essentially muscovite (from outer coarse muscovite and muscovite-quartz to inner fine grained muscovite-quartz-feldspar) pegmatite found in metasedimentary rocks near the Hellroaring Creek stock; 018 – giant-crystalline K-feldspar-quartz-tourmaline pegmatite with minor muscovite (2 vol.%); 036 - coarse to giant-crystalline K-feldspar-quartz-muscovite pegmatite from the Hellroaring Creek stock; 037 – fine-grained essentially aplitic pegmatite showing, with rare coarse crystals of potassic feldspar, showing gradual transition to coarse-grained quartz-K-feldspar-muscovite pegmatite; 038 - coarse to fine grained K-feldspar-muscovite-quartz pegmatite (outer zone); 039 - similar to 038 but locally enriched in garnet; 042 - giant-crystalline K-feldspar-quartz-muscovite-black tourmaline pegmatite; 043 - similar to 036 but with large crystals of greenish apatite; 044 - similar to 039 but more muscovite (locally up to 40 vol.%).

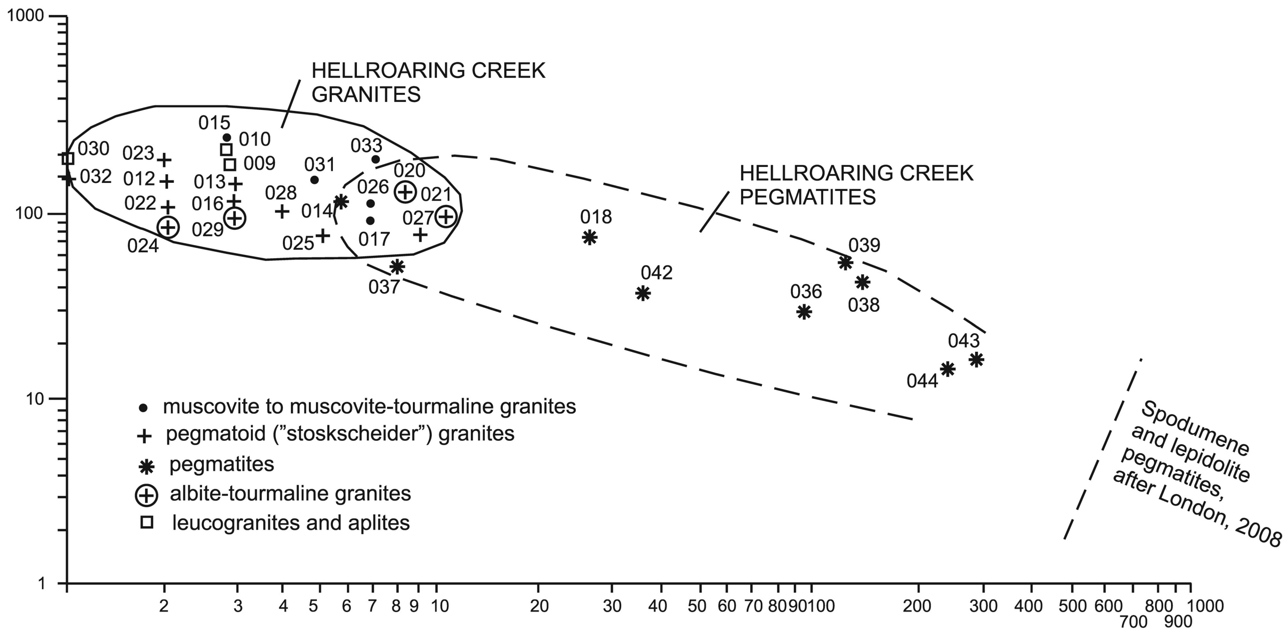

Figure 5. Data on the Hellroaring Creek granites and pegmatites plotted on the K/Rb *vs.* Cs diagram showing gradual evolution of the granites and pegmatites toward more evolved compositions (London, 2008). The sample numbers are sample field numbers listed in Table 1.

Figure 6. Giant beryl crystal from the Hellroaring Creek pegmatite (collection of David Pighin).

other sectors, quartz and tourmaline are the main constituents. Locally, large (several centimetres across) crystals of greenish beryl are present.

Marginal zones of the pegmatite are much finer grained and are composed of medium to fine grained white muscovite, fine grained greenish to light green muscovite, medium-grained quartz and K-feldspar, medium to fine grained black tourmaline found in variable proportions. These zones are locally enriched in fine-grained albite, and contain segregations of small well-shaped apatite and garnet crystals. The same zones contain also prismatic crystals of yellowish green beryl up to 3 by 0.5 cm in size. The pegmatites contain also elevated tin grades (Table 1) that may reflect the presence of fine disseminated cassiterite and/or other Sn-bearing minerals (nigerite, *etc.*).

On the other hand, a gradual transition of the coarse grained quartz-K-feldspar-muscovite pegmatite to fine grained (sugary) essentially albitic aplite (fine grained albite-quartz-K-feldspar groundmass, with scattered small porphyrocrysts of K-feldspar), locally enriched in tourmaline, was observed.

The assay results (Table 1) indicate local enrichment of the pegmatite in tantalum and niobium, with niobium predominating over tantalum and suggesting the possible presence of columbite. Beryl is locally abundant but there is apparently no any correlation between Ta+Nb and Be grades; thus, columbite and beryl may belong to different mineral assemblages of the pegmatite. Low lithium concentrations (Table 1) suggest that lithium resides in muscovite crystal structure rather than spodumene, petalite or lepidolite. High fluorine content could be possibly accounted for fluorine substitution in muscovite and fluorapatite; other minerals containing elevated fluorine (such as triplite, triphylite, *etc.*) can also be present in the pegmatite. All this data shows that the pegmatite belongs to the beryl-columbite-phosphate subtype (*cf.* Cerny, 1993; London, 2008).

Other smaller, metric-scale, pegmatite bodies were observed in the metasedimentary rocks near the periphery of the Hellroaring Creek stock. Some of these bodies include coarse-grained muscovite (muscovite+quartz) outer zone and fine grained muscovite+quartz(+K-feldspar?) inner zone, whereas other bodies are composed of large crystalline (locally in excess of 5-7 cm across) K-feldspar (up to 60 vol.%), quartz (about 25%), black tourmaline (15%), with only minor muscovite (<2%).

ALBITE AND MICA-ENRICHED GRANITES

There are several styles of albite aggregations observed in the granites and pegmatites of the Hellroaring Creek stock and the nearby Lightning Creek pegmatite. They can be arranged as follows:

1. Coarse grained albite crystals and their intergrowths irregularly (spots, segregations, *etc.*) distributed in the granitic rock. Usually, colourless or milky quartz (often in contrast to smoky quartz of the granite) and fine grained, light (silverish, greenish, brownish, yellowish, *etc.*) micas are associated with albite. Tourmaline is also common and is represented often by large long idiomorphic crystals.
2. Medium to fine grained intergranular dissemination of albite partially overprinting K-feldspar and other minerals of granite; this causes an occurrence of irregularities in the texture of granite (occurrence of finer grained "spots" within coarse-grained texture, *etc.*).
3. Fine grained (sugary) albite aggregations forming large "spots" and almost wholly substituting the rock (granite); fine-grained quartz and coarser grained light greenish mica are associated with albite. Fine crystalline tourmaline and fine grained pink garnet are also common.
4. Fine grained (sugary) albite aggregations exhibiting banded, layered distribution, or even alternating albite and quartz bands.

It appears to be reasonable to assume that, although a part of albite (especially larger crystals) are with no doubt primary magmatic in origin forming from magmatic melt in the course of its crystallization, some part of albite may be associated with later possibly metasomatic process ("albitization"), thus replacing the early albite and other primary magmatic minerals of the granites and pegmatites (*cf.* Schwartz, 1992). The albite-rich rocks locally bear elevated content of beryl and possibly Ta-Nb and Sn minerals that is, in some locations, detected by assaying (Table 1).

There are several types of muscovite-bearing granites; the mica occurs both in the form of large books and scales saturating the granites to various degrees and distributed more or less evenly, and in the form of short vein-like aggregations, short stringers and veinlets, or just muscovite-rich patches, in which muscovite occurs together with quartz, tourmaline and locally albite. Similarly to albite, a part of this muscovite can be assigned to the magmatic crystallization, whereas the other part resembles metasomatic formations like quartz-muscovite, quartz-tourmaline-muscovite and other greisens. This is especially suggestive in local sectors, where the granites are anomalously enriched in muscovite (from 10 vol.% to 20-40 vol.%) and quartz, with gradual transition to almost muscovite-free granite, and in exocontact zones, where muscovite to muscovite-quartz formations overprint the host metasedimentary rocks and gabbroic dikes. Correspondingly, the essentially quartz-muscovite greisens contain some black tourmaline (usually <5 vol.%) and albite (about 10-20 vol.%) irregularly distributed in the rock. Less common essentially quartz-tourmaline to quartz-tourmaline-muscovite greisens are composed of quartz (60-80 vol.%) and coarse grained black tourmaline (20-30 vol.%), with minor importance of muscovite (0-20 vol.%). Such muscovite-rich aggregates locally contain fine disseminated to larger-crystalline beryl.

RARE METAL MINERALIZATION

The surface grab samples of the Hellroaring Creek stock granites listed in Table 1 encountered just occasional slightly elevated values of tantalum and niobium (Table 1). A random surface sampling of the Hellroaring Creek stock granites performed in 2000-2001 has identified some number of appreciable rare metal (Be, Ta, *etc.*) values (Table 2). Beryllium mineralization appears to be more widespread in the pegmatites and nearby granites of the Hellroaring Creek stock exposed on the surface, where large beryl crystals attaining 5.5 kg in weight and over 30 cm in length were noted (Figure 6). As noted above, the previous work on the property conducted by Richfield Oil Corporation has indicated the north (actually northwestern) end of the Hellroaring Creek stock contains no NI 43-101 compliant resource of 500 000 tonnes of the mineralized material averaging 0.1% BeO (Wasylyshyn, 1984; Pudifin, 1986).

More often, than in surface grab samples, Ta-Nb mineralization is encountered by systematic sampling of drill core (*i.e.*, on deeper levels of the stock than those exposed on the surface?). In particular, the drilling performed in 2000-2001 by Chapleau Resources Ltd. encountered the areas of preferential concentration of beryllium mineralization in the uppermost part of the granitic stock, in relation with the stockscheider-style granites (Soloviev, 2001). These areas appear to be shaped as discontinuous thin flat-lying lenses extending for few tens of metres along strike and in width. The best intercepts included those in the range of some 450-700 ppm Be over 8-12 m; they are parts of thicker intervals attaining some 270 ppm Be over 23 m. In part, these areas of beryllium concentration are coincident with smaller zones of enrichment in tantalum averaging some 40-50 ppm Ta over 5-8 m (including narrower zones of stronger enrichment up to 120-140 ppm Ta over 1 m). In general, it was demonstrated that these intervals of enrichment and Be and Ta occur preferably in the uppermost 20-30 m (not deeper than 55 m) from the surface, *i.e.*, in the topmost part of the granitic stock.

Assaying of the core from the historical drillholes drilled in 1985-86 by Lumberton Mines Ltd. in the northwestern sector of the Hellroaring Creek stock indicated the presence of elevated tantalum contents at

Table 2. Contents of the rare metals in some surface grab samples of the Hellroaring Creek stock granites (data of Chapleau Resources Ltd.).

NN	Sample Description	Ta, ppm	Nb, ppm	Rb, ppm	Cs, ppm	Sn, ppm	Be, ppm
1463	Medium to coarse grained pegmatoid granite, moderately albitized, quartz+K-feldspar+albite-90%, muscovite-10%, black tourmaline <1%	278.5	715.4	121.3	68.1	32	3329
1467	Same	497.2	1478.5	60.4	26.7	15	920

Table 3. Contents of the rare metals in historical drill core (data of Chapleau Resources Ltd.).

Sample Number	Drillhole Number and Interval	Sample Description	Ta, ppm	Nb, ppm	Rb, ppm	Cs, ppm	Sn, ppm	Be, ppm
1201	86-7, 85.0-86.6 m	Coarse grained, irregularly-grained to stockscheider-style tourmaline-muscovite granite	30.0	35.6	517.7	30.4	31	473
1225	86-7, 108.6-109.6 m	"	39.4	61.7	394.5	33.3	72	53
1226	86-7, 109.6-110.6 m	"	41.7	92.1	459.2	44.3	100	222
1227	86-7, 110.6-111.6 m	"	22.5	59.4	327.0	26.0	66	161
1228	86-7, 111.6-112.6 m	"	31.7	46.0	297.8	25.4	62	70
1231	86-7, 114.6-115.6 m	"	23.3	57.9	439.8	49.6	92	76
1233	86-7, 116.6-117.6 m	"	27.8	104.8	880.1	86.5	171	81
1240	86-7, 123.6-124.6 m	"	20.3	52.4	341.1	15.5	32	179
1241	86-7, 124.6-125.6 m	"	38.3	43.1	579.7	58.2	92	24
4421	86-7, 10.5-11.0 m	"	64.3	74.3	549.3	47.4	81	38
4422	86-7, 11.0-12.0 m	"	219.4	197.9	462.7	45.7	38	734
8803	86-3, 106.0-107.0 m	"	40.6	48.5	93.5	2.9	8	63
8742	86-3, 45.5-46.5 m	"	39.6	141.8	676.0	42.7	60	41
8654	86-1, 83.5-84.5 m	"	22.7	69.3	655.5	42.2	28	522
8605	86-1, 35.8-36.8 m	"	28.9	44.8	826.4	50.1	46	63
1278	86-1, 8.0-9.0 m	"	98.5	284.4	565.0	26.3	32	80
8677	86-2, 14.2-15.2 m	"	20.6	49.0	216.9	15.8	17	138

deeper levels of the stock (Table 3). However, the intervals encountered at the higher (shallower) level of the pluton still bear greater Ta values. The high variability in the Ta/Nb ratios suggests the presence of (besides of columbite-tantalite) other Ta-Nb minerals and/or the presence of various generations of columbite-tantalite with respectively variable Ta-Nb contents. Also, the assay results locally suggest the presence of cassiterite. In general, taking into account the greatly predominating volume of the granites over that of the pegmatites related to the Hellroaring Creek stock, it can be suggested that the predominating amount of the rare metals is associated with the granites rather than with the pegmatites.

The Lightning Creek pegmatite is definitely more evolved (it has higher concentrations of F, Li, Rb, Cs, and Ta) (Table 1) than the pegmatites occurred within the Hellroaring Creek stock and/or closer to its boundaries. This is consistent with the general Cerny (1993), London (2008) model. The Lightning Creek pegmatite contains also beryl and more significant Ta mineralization; according to Mulligan (1968), "...... the pegmatite is a part of a large mass that extends across the ridge from Hellroaring Creek to Angus Creek [Lightning Creek showing – S.S.]. Beryl is also found in Angus Creek [Lightning Creek showing – S.S.] ....most of the beryl was intimately associated with muscovite near the boundaries of quartz segregations. Columbite-tantalite occurs in crystals more than an inch across....minor amounts of tin were reported in composite samples of pegmatite....."

DISCUSSION AND CONCLUSIONS SUMMARY

The data presented suggest that the geological model of the Hellroaring Creek stock should incorporate the features typical for both "specialty rare metal granite" and granitic pegmatite deposits. In particular, the predominating granite bears petrologic and geochemical features of the "specialty rare metal bearing granites" indicating a high degree of evolution (fractionation, *etc.*) of the intrusive rocks, high degree of the magma saturation in volatile components (fluids) and their especial concentration at the topmost levels of the pluton, with the occurrence of the "pegmatoid" (stockscheider-style) "crust" marginal varieties in the endocontact and especially at the upper levels of the pluton. The granite is enriched in albite, especially in marginal varieties, and is characterized by broad although scattered occurrence of disseminated Be, Ta, Nb, Sn mineralization. These features resemble those occurred in granite intrusions representing the respective rare metal granite deposits (*e.g.*, Phuket in Thailand, Beauvoir in France, Abu Dabbab in Egypt, Orlovka and Etyka in Transbaikalia, Russia, Yuichun in China, *etc.*) that typically contain significant tonnages of low-grade rare metal (Ta-Nb, Be, Sn) mineralization (Pollard *et al.*, 1995; Simandl, 2002). At these deposits, the most of Ta-Nb mineralization (tantalite-columbite, Ta-cassiterite, struverite, microlite) is found in the uppermost sectors of the rare metal granite intrusions. Tantalum grades vary from 120 to 300 ppm Ta_2O_5, occasionally higher, and these grades correspond to the ores typically involved in mining. Background grades are as low as 50-80 ppm Ta_2O_5. Vertical extent of tantalum enrichment zones is usually up to 50 m although rarely is as much as 100-150 m and even 200 m (at flat-dipping contacts). Tantalum minerals form very fine dissemination (usually the grains are of 0.1-0.5 mm and up to 1 mm in size). Beryllium mineralization, if present, occurs slightly above the Ta-Nb-enriched zones, in association with micaceous assemblages, part of which may correspond to greisens. Thus the broad occurrence of scattered zones of enrichment of the Hellroaring Creek granites in Be, Ta, Nb, Sn may be suggestive for more voluminous (and perhaps higher-grade) concentrations of the rare metals that may be revealed in the course of further exploration.

Pegmatites are generally uncommon for the rare metal granite deposits but, if occurred, these are located in some (0.5-3 km) distance from the main pluton and change their mineral composition in dependence on the distance from the pluton. Correspondingly, for the pegmatites associated with the Hellroaring Creek stock, a spatial model suggested by Cerny (1993) and London (2008) can be applied. This model would include the muscovite-ceramic pegmatites occurred in the most proximity to the parental ("fertile") pluton (actually, within the plutonic endocontact), and then beryl pegmatite, Li pegmatites and albite-lepidolite and elbaite pegmatites occurred with increasing distance from the granites. The Ta-Nb mineralization occurs in the all types of the pegmatites starting with the beryl pegmatites but attains its maximum in the Li and albite-lepidolite pegmatites; the Ta/Nb ratio in columbite-tantalite increases from the beryl through lithium to albite-lepidolite pegmatites.

A common issue of the preferential occurrence of either rare metal granites or pegmatites is usually resolved by considering their different depth of formation. Specifically, the granite plutons responsible for the formation of rare metal-bearing pegmatites as well as these pegmatites themselves are formed at moderate depths (under the pressure of 2-4 kbar); these plutons have no indications of late- and postmagmatic alteration or mineralization of the granites, thus, indicating a fluid (+metals) concentration in pegmatite-forming residual melt+fluid removed from the granite via relatively large and well-developed fractures only (Cerny, 1993). In contrast, the rare metal granite intrusion, which are intensely late and postmagmatically altered and often accompanied by greisens and related vein systems, in virtually total absence of pegmatites, were formed at relatively shallow levels (under the pressure of 1-2 kbar) that was, probably, the reason for another style of the fluid behavior and release. Correspondingly, the "open" and "closed" magmatic-fluidal systems are distinguished (Pollard *et al.*, 1987; Pollard, 1989 a, b; Suwimonprecha *et al.*, 1995; London, 2008).

Consequently, the Hellroaring Creek stock granite and related pegmatites may represent a genetic link between the typical pegmatite deposits (and associated "fertile" granites) formed at greater depth, and the typical rare metal granite deposits formed at shallower depth. In this regard, the Phuket and other deposits in Thailand show a distinct similarity to the Hellroaring Creek stock granites and pegmatites, as they also incorporate both Sn-Ta-bearing rare metal granites and significant pegmatites (Suwimonprecha *et al.*, 1995). This deposit is also similar to Hellroaring Creek stock by its enrichment in boron, whereas many other rare metal granites are preferentially enriched in fluorine (*cf.* Pollard *et al.*, 1987).

Finally, referring the Hellroaring Creek stock granites to as the "specialty rare metal granites" highlights the potential of recognizing this style of rare metal deposits in the Cordilleran orogenic belt. A brief review of apparently similar granite plutons accompanied by the rare metal (Ta-Nb, Sn, Be, *etc.*) mineralization reveals a distinct belt of deposits and occurrences traceable in the region that may be allocated to this style (Figure 1); this belt may be, at least in part, coincident with the Cordilleran belt of muscovite granites (Miller and Bradfish, 1980). Pell and Hora (1990) were, probably, the first who pointed out the possible presence of the regional-scale belt of the "specialty granites" in North America, and provided Surprise Lake batholith and Parallel Creek intrusion as examples of these in British Columbia. Most notable of the "specialty rare metal granites" and associated deposits/occurrences include Kougarok Sn-Ta and Lost River Sn-Be deposits in Alaska (Puchner, 1986; Hudson and Arth, 1983), Kalzas W-Sn (+Ta?) deposit in Yukon, Seagull, Surprise Lake and Parallel Creek plutons and associated Sn occurrences in Yukon and Northern British Columbia (Liverton, 1999) and a number of smaller and/or less studied occurrences. An apparent feature of these occurrences is the intrusion of relatively small stocks of the rare metal (Ta-Nb, Be) granites after the emplacement of much larger plutons of less evolved stanniferous granites; thus, the larger plutons of Sn-bearing granites may be considered to be initial exploration targets for revealing more localized rare metal mineralization related to supplementary and more evolved rare metal granites. However, most of these occurrences are Mesozoic, whereas the Hellroaring Creek stock is currently assigned to the Proterozoic. This may call for additional radiologic dating of the Hellroaring Creek stock granites and pegmatites; alternatively, this may indicate a broad time span of the rare metal granites and related mineralization, thus, suggesting the potential for their discovery in various Cordilleran terranes.

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