From Jeffrey E. Patterson, Ph.D. candidate, University of Calgary, (jeffreyp@pegmatite.com)

Drs. Martin, White, and London present interesting comments regarding some aspects of hollow tourmaline growth in pegmatites. However, they do not address the other primary questions posed by Mr. Rose, to wit, what can he read to further his knowledge base and can his observations be useful for further exploration. The literature is replete with papers dealing with criteria for exploration, including the use of mineralogical trends. Basic models, with assumptions, can be found in Cameron, et al., (1949), Jahns and Burnham, (1969), and Sinkankas, (1988). An easily accessible bibliographical source on tourmalines and their properties is provided by Darrell Henry, at Louisiana State University, (http://www.geol.lsu.edu/henry/Research/tourmaline/bibliography/TurBibliography.htm).

From my current research, I have observed that recent investigation of tourmaline stability and alteration to other minerals is a little studied phenomenon. The changing acidity/alkalinity of the late hydrothermal fluids circulating in pegmatites offers a unique opportunity to examine some of the basic characteristics of pegmatite formation. The work of Thomas, et al., (2003), provides several new insights to this problem. The example presented by Mr. Rose is exceptional in its characteristics, specifically with the apparent pristine nature of the remaining schorl, the terminated quartz on the exterior, and the terminated sphene on the interior. Dr. London's Figures 3, from the Little 3 Mine in Ramona, and 4 and 5, from the Elizabeth R Mine in Pala, serve to provide an additional base for the comment below. The tourmalines in Figures 1 and 2 are worldwide examples of similar phenomena, wherein the early formed tourmaline appears to be unstable with respect to the late formed rind and the interior portion has been hydrothermally leached, altered, or replaced by other minerals.

For the past 9 years I have had the pleasure of being able to conduct basic pegmatite research at the Little 3 Mine. During a ground verification phase to a GPR study, (Patterson, 1996), I observed the phenomena of schorl alteration to a sodium-iron rich, lithian bearing muscovite, (Stern, et al., 1986; Foord, et al., 1989; and Figures 3 to 10). The mine owner, Louis B. Spaulding, Jr., told me that Dr. Richard H. Jahns, a constant visitor to the mine between 1954 and 1982, always said that they were muscovite pseudomorphs after tourmaline. Careful observation has proven this to be true. Apparently, late stage potassium rich hydrothermal fluids circulated upward, from either the lower dyke or the aplite / line-rock unit, and altered the primary schorl to muscovite, (Figure 3).

During the early stages of alteration, the muscovite A-axis followed the schorl C-axis, forming an apparent parallel intergrowth, (Figures 5, 6, 9, and 10). During the late stages of alteration, the tourmaline was almost completely removed, leaving the muscovite to crystallize in jack-straw fashion within the tourmaline shaped cavity left in the host albite, (Figures 4 to 8). Figures 9 and 10 are photomicrographs of thin sections taken from a section of an altered tourmaline removed from the specimen shown in Figure 4. Apparently, the perthitic K-Feldspar in the footwall was also altered at this time, as it shows extensive leaching of albite along the rims of several crystals in the specimen shown in Figure 4. The released elements from this alteration of tourmaline, (Na, Fe, and B_2O_3), and associated Li, K, and H_2O, appear to have been either incorporated into the muscovite or transported along the open pocket-line to form the new mineral boromuscovite, as exemplified by the material in the New Spaulding Pocket, (Stern, et. al., 1986; Foord, et. al, 1989; and Foord, et. al., 1991). This alteration sequence is traceable for several meters updip and along strike in the dyke. Following trends like these elsewhere, on the property, has led to the discovery of other productive pockets, (L.B. Spaulding, Jr., personal communications, 1995-2002).

Alteration of tourmaline to muscovite or lepidolite is well known, as represented by the specimens in Figures 11 to 14 and in London's Figures 4 and 5. Perusal of the images in many of the issues of Mineralogical Record also depicts altered tourmalines, beryls, and other pegmatite minerals. I will leave it to the geochemists to present the appropriate chemical explanation.

In answer to Mr. Rose's question on why some parts of a pegmatite are altered while others are not, I present an alteration sequence of a pegmatite in southern California that deals with the leaching of quartz from Graphic Granite intergrowths in the Garnet Ledge at the Little 3 Mine, (Figures 15 to 19). Here, in a 10 m dip-section of the dyke, all of the quartz was removed, leaving slightly altered perthitic K-feldspar and unaltered schorl, garnet, and apatite. The quartz and related hydrothermal solution appears to have been deposited updip as axinite and large, to 30 cm, quartz crystals enclosing schorl needles, garnet, and axinite. Some of this fluid escaped the confines of the pegmatite and reacted with the host granodiorite, (Patterson, 1997), to form an exocontact of very fine grained green muscovite and schorl-dravite, (Figure 18). In some pockets, cavernous beryl crystals were found, (Figure 19). Elsewhere in this same dyke, and in portions of the Topaz Ledge, similar sections containing quartz leached graphic granite can be observed. Other features of the alteration sequences of the Garnet Ledge are beyond the scope of this comment.

If one considers the permeability of a crystallized pegmatite and the reactivity of the representative minerals, a common theme is observed. Where minerals are altered, they are open to exchange with late stage fluids. These fluids can either be trapped during progressive crystallization or be introduced during later episodes of emplacement. The amount of alteration appears to be a function of the stability of that phase when in direct contact with the hydrothermal solution at that moment. If a mineral is buffered by an impermeable layer or encased in a non-reactive phase, then no alteration will occur. However, if the permeability is high enough for a significant amount of fluid to infiltrate a particular zone, then the possibility exists to encounter a zone of altered material. In the case of the miarolitic pegmatites of San Diego County, if a zone of alteration is encountered, then the optimum gem or specimen grade material is probably minimal, but most probably up-dip a zone of productive material maybe found. An early example of gemmy morganite beryl altering to bavenite was presented by Schaller and Fairchild, (1932). An apparently similar scenario has been the case with the recent finds of pink and green tourmaline at the Cryo-Genie Mine, near Warner Springs, (http://home.earthlink.net/~goke/Cryo-Genie.htm).

I suggest to Mr. Rose that he complete a thorough 3-D geologic map of his pegmatite to look for trends in mineralization and alteration. Some basic geochemistry might also be appropriate to delineate the levels of fractionation. I wish him luck with his endeavors and thank him for this opportunity to express my observations.

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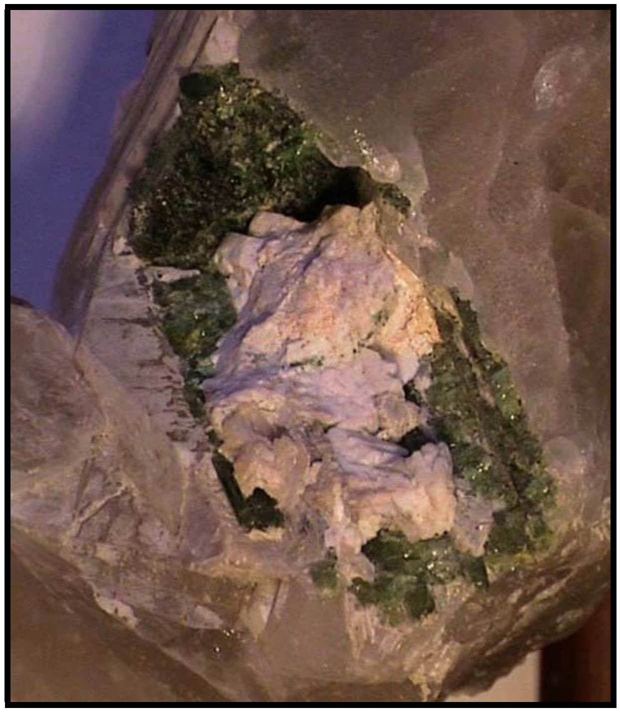
1) 

Figure 1) Green elbaite from Brazil, frozen in quartz. The central portion of the crystal has been altered and replaced by K-feldspar and white mica. The tourmaline crystal is 3 cm dia x 6 cm in length.

2) 

Figure 2) Tourmaline crystal from Malkhan, Russia. The central portion of the crystal has been altered and replaced by K-feldspar. The exterior rind appears pristine. The specimen is 4 x 7 cm.

3)

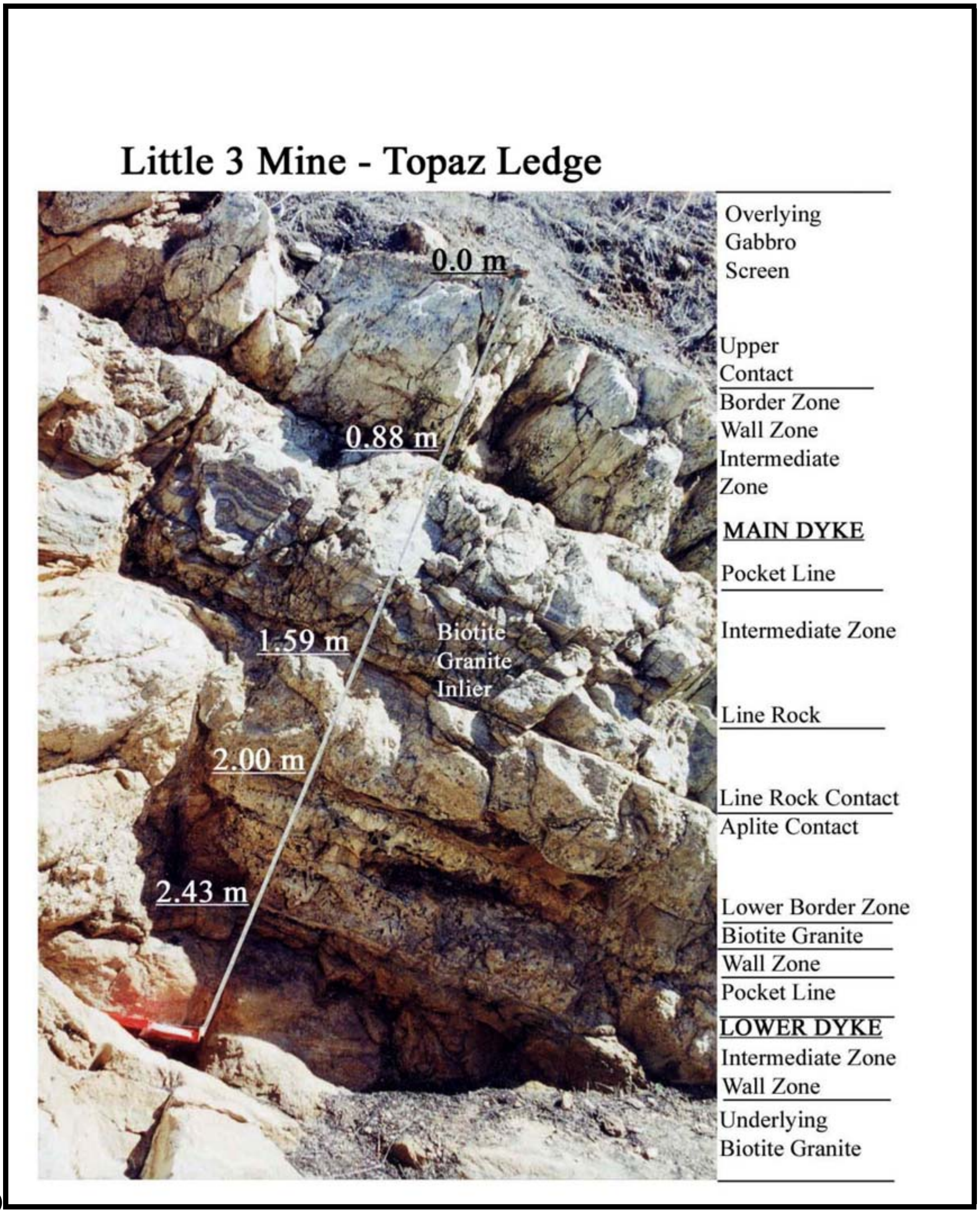
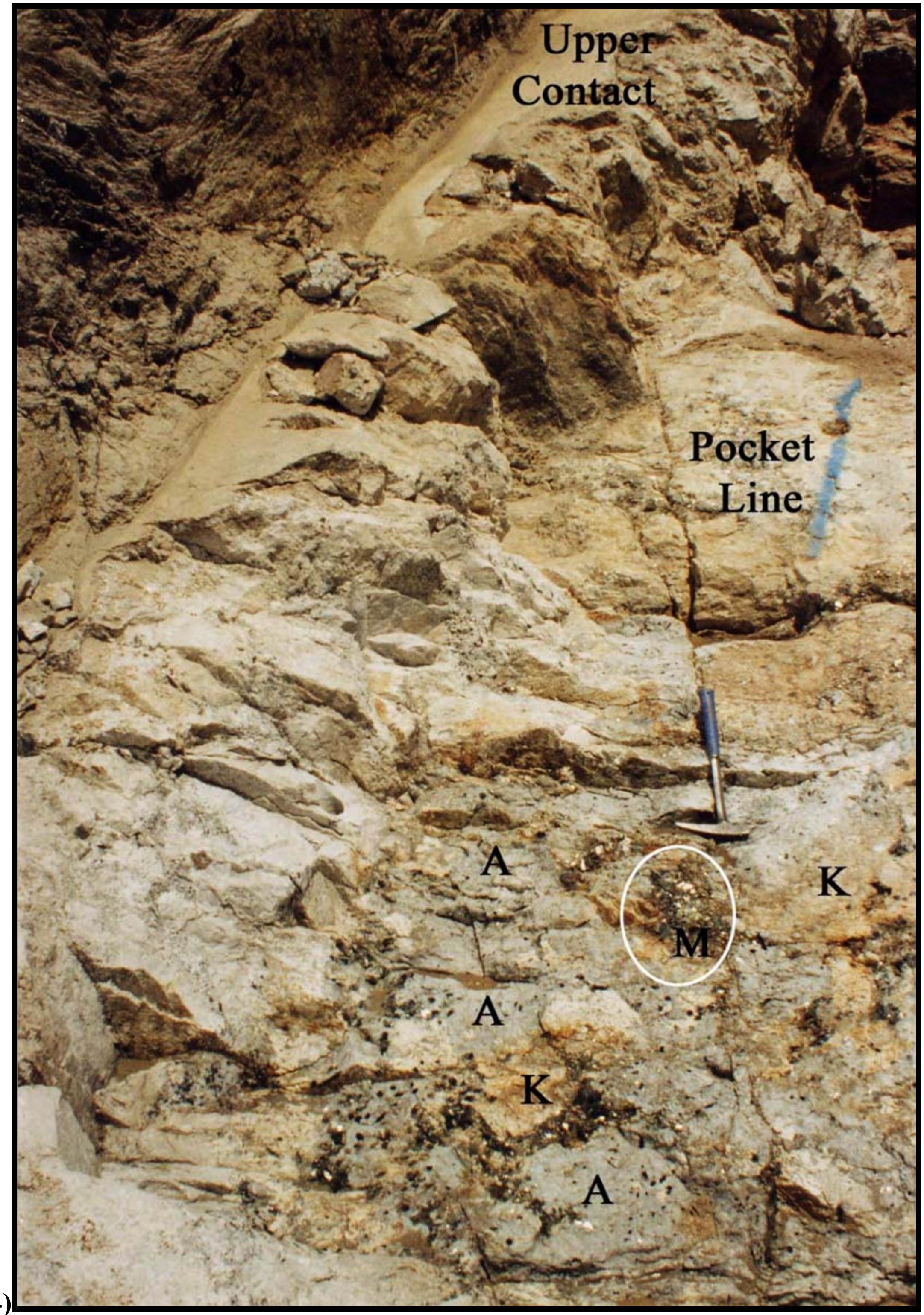
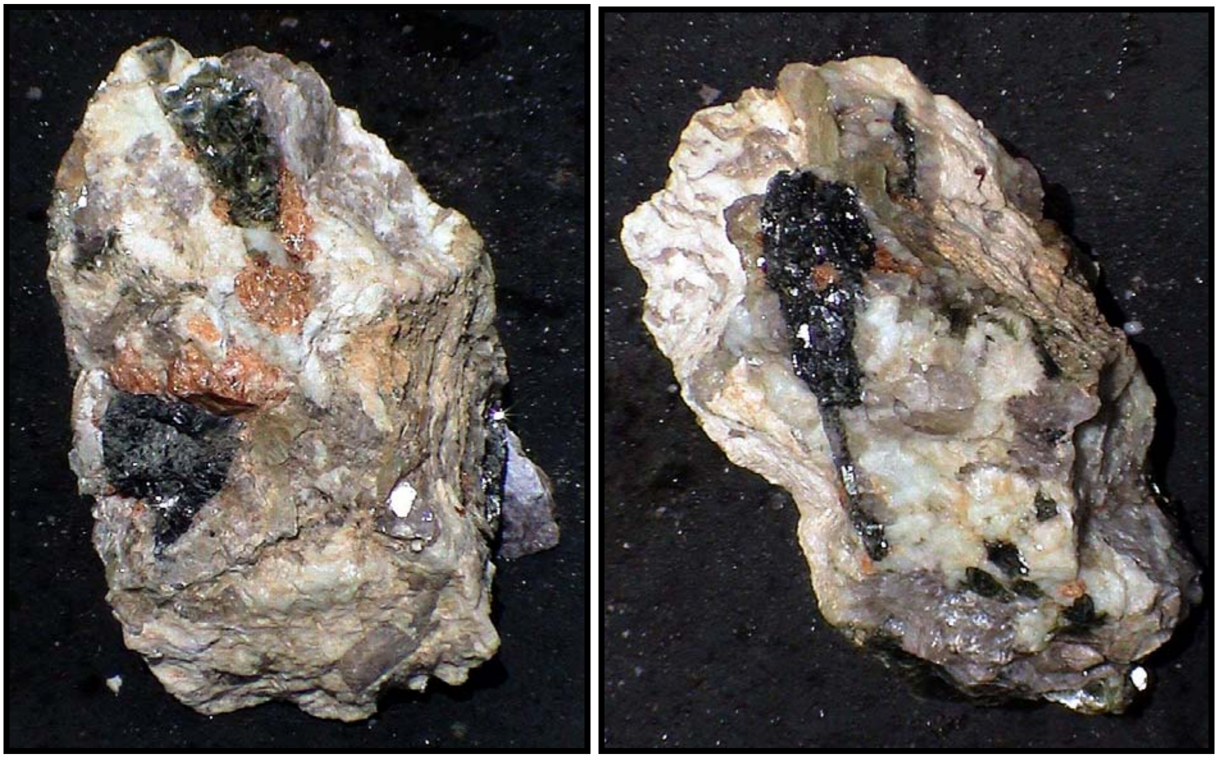


Figure 3) Cross Section of the Topaz Ledge, Little 3 Mine, Ramona, California. The muscovite pseudomorphs after schorl are found in the lower intermediate unit in the Main Dyke. See Stern, et. al., 1986, and Morgan and London, 1999, for chemical composition of the Main topaz bearing dyke. The pockets in the lower dyke appear to contain only schorl and potassium feldspar with an infilling of zeolites.



4)

Figure 4) Exposure of the footwall portion of the "Pocket Line" of the Topaz Ledge, Main Dyke, Little 3 Mine, Ramona, California. Geologic hammer for scale. (A = fine grained albite, K = altered potassium feldspar, slightly perthitic, M with white oval = muscovite nest, Black Spots = schorl with or without muscovite intergrowths)



5A) Front **5B) Back**

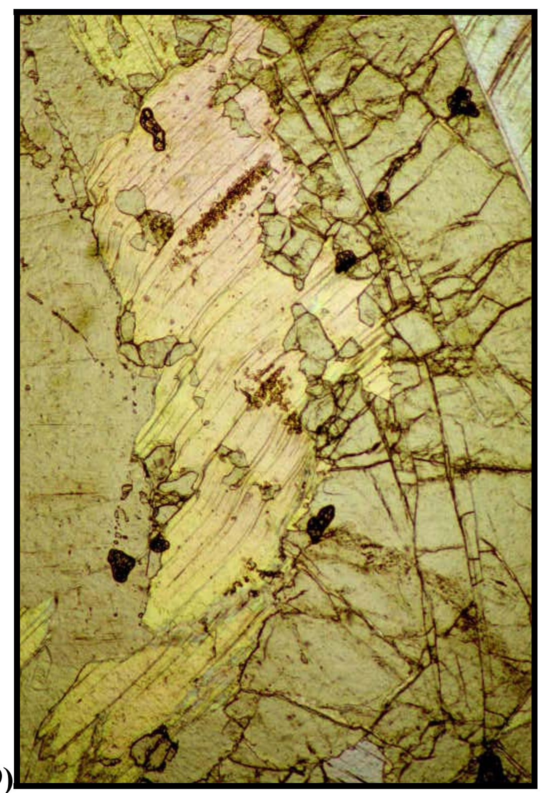
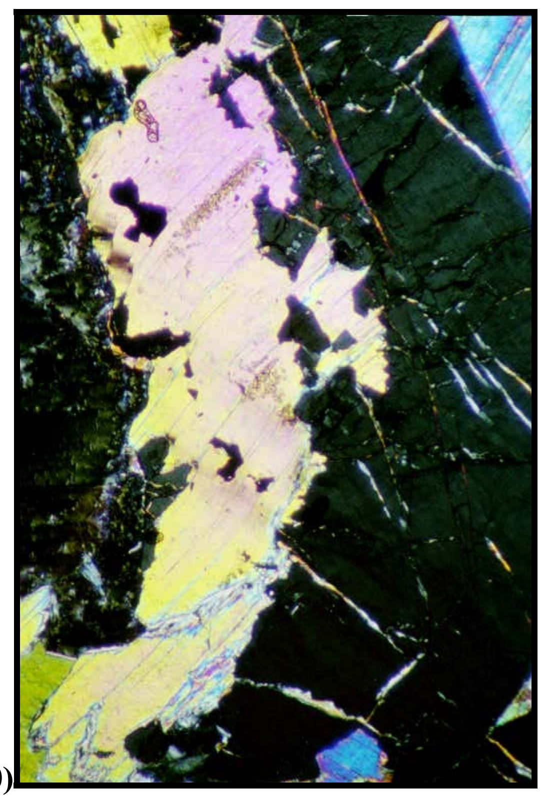
Figure 5 A & B) Specimen from the footwall of the "Pocket Line" from the region of the muscovite nest in Figure 2. Parallel muscovite – schorl alteration on the left side A & B. Complete replacement with jackstraw muscovite flowers on the top of A. Spessartine garnet is abundant in this region of alteration. Perthite on right side of A is altered with plagioclase lamella leached out. Albite in graphic intergrowth with quartz, upper left of B. Specimen is 7 x 15 cm.

6)

Figure 6) Specimen from the footwall of the "Pocket-Line" from the region of the K section below the muscovite nest in Figure 2. The "Pocket-Line" is at the top of the specimen Through-going tourmalines start as small solid flaring crystals at the bottom of the specimen, parallel muscovite-schorl alteration in the middle, and end as muscovite flowers at the top.
Specimen is 12 x 21 cm.

7)  8) 

Figures 7 and 8) Details of muscovite flowers at top of altered schorl and extending into the free space of the pocket line. Fragments of schorl remain in each specimen. The "stalks" of the flowers maintain the tourmaline shape. Each specimen is 1 cm dia x 2 cm high.

9)  10) 

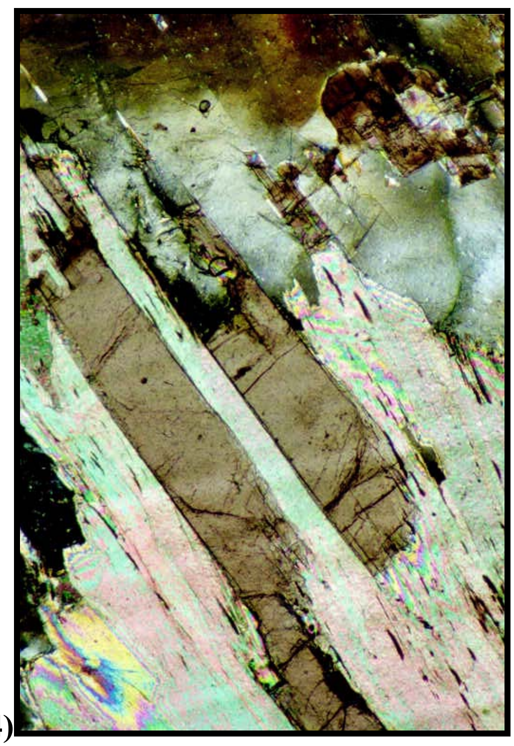
Figures 9 and 10) Photomicrographs of a thin section of a schorl altered to muscovite from the specimen in Figure 6. The crystal is cut oblique to the C-axis. Mineral identification by XRD at the University of Arizona.
9) = PPL, 10) = XPL – Field of View = 2.5 mm

11)

12)

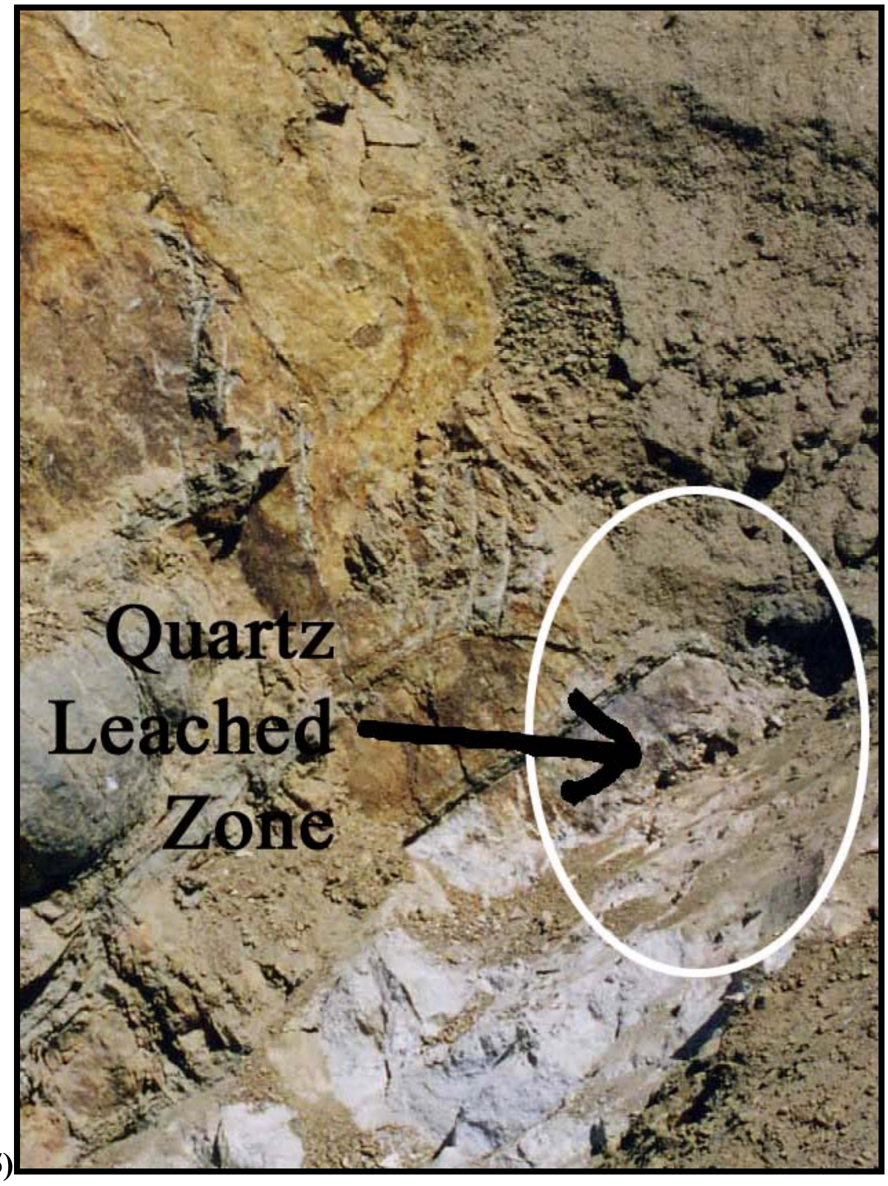
Figure 11) Muscovite pseudomorph after schorl. Unknown pegmatite in Maine. Specimen is 1 cm in dia x 1.8 cm high. Figure 12) Interior portion is a lepidolite pseudomorph after copper bearing elbaite with copper bearing schorl outer rind, Paraiba, Brazil. Specimen is 1.5 x 5 x 7 cm.

13)



14)

Figures 13 and 14) Photomicrographs of a thin section of a copper bearing elbaite altered to lepidolite from the specimen in Figure 12. The crystal is cut parallel to the C-axis. Mineral identification by XRD at the University of Calgary.
13) = XPL, 14) = PPL – Field of View = 2.5 mm



15)

Figure 15) Garnet Ledge, Little 3 Mine, Ramona, California, main cut looking Northwest. The dyke is approximately 2 m thick in this view. Quartz has been leached from the Graphic Granite along the pocket-line.

16) 

Figure 16) Graphic Granite (Perthite) from the Garnet Ledge, Little 3 Mine, with included schorl. All of the quartz has been leached out.
The specimen is 6 x 9 – cm and was taken from the zone shown in Figure 15.

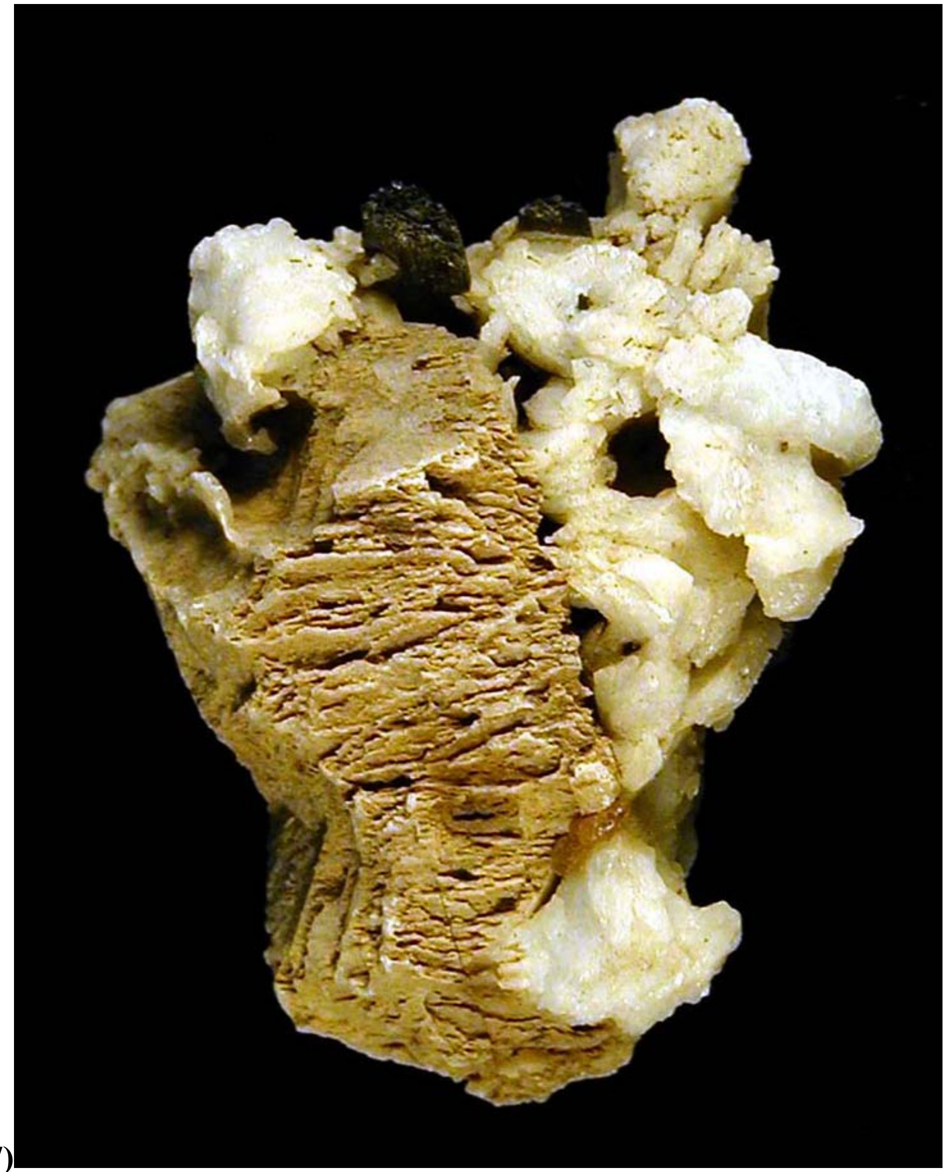
17) 

Figure 17) Graphic Granite (Perthite) with albite, schorl, and garnet from the Garnet Ledge, Little 3 Mine. All of the quartz has been leached out. The specimen is 5 x 7 cm.

18)

Figure 18) Exocontact of very fine grained muscovite and schorl-dravite from the upper contact zone of the Garnet Ledge, Little 3 Mine, Ramona, California, with the overlying host granodiorite.

19)

Figure 19) Cavernous goshenite beryls from the Garnet Ledge, Little 3 Mine. Both crystals show extensive dissolution features on the interior and exterior. It is possible that both beryl and intergrown quartz have been removed.
Specimen on the left is two parallel growth crystals and is 3.2 x 3 cm.
Specimen on the right is coated with Bavenite, by XRD at the University of Arizona, and is 2.6 x 2.5 cm.