San Luis Rey on Display

GEOSCIENCE IN NORTHERN SAN DIEGO COUNTY

SDAG 2013 FIELD TRIP GUIDEBOOK • Brian J. Olson

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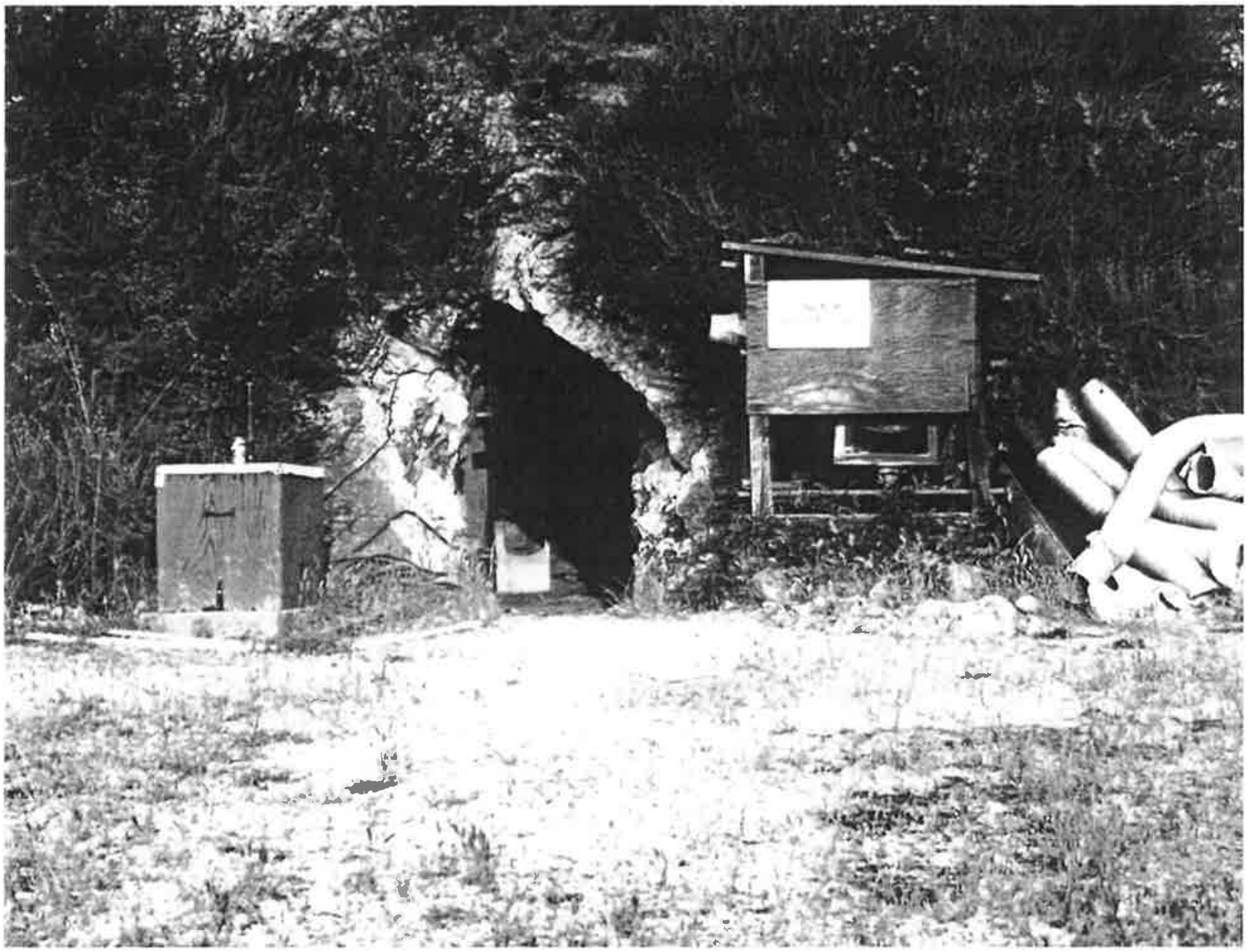

North Adit, Elizabeth R Mine.

Structural Controls and Mineralogical Indicators for the Formation and Distribution of Pockets in the Elizabeth R Mine, Pala, San Diego County, California

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ABSTRACT

The Pala district in northwestern San Diego County produces fine mineral specimen and semi-precious gemstone material. Part of the Peninsular Ranges batholith, the Pala pegmatites have been mined to various degrees since around the beginning of the twentieth century. Tourmaline, beryl, and spodurnene are among the minerals produced. The Elizabeth R mine, located on Chief Mountain in the Ocean View pegmatite, was begun in 1974.

Fine-grained rocks generally occur in the footwall of the dike and may or may not exhibit layers rich in garnet or tourmaline. Graphic granite occurs as masses up to several feet across in all parts of the dike, but primarily in the upper portion near or along the hanging wall. Where no core zone is present, the rest of the dike consists of tourmaline-bearing and muscovite-bearing pegmatite made up of quartz, microcline and albite. Core zones occur in the central or lower portions of the dike and contain the largest crystals in the pegmatite. Primary core zone minerals are quartz, perthite, and spodumene. Pockets or cavities within the core zone contain euhedral crystals of quartz, perthitic microcline, albite, muscovite, tourmaline, beryl, columbite, apatite, and a variety of other phosphate minerals.

The Elizabeth R mine exhibits several controls and indicators for the formation and distribution of significant pockets. Pockets appear where a dike bulges in thickness. These bulges may occur where some weakness, such as a crosscutting fracture set, is encountered in the host rock. The dike may also bulge where the dip changes. These flexures of the dike are referred to as "rolls." In areas where the pegmatite dike does bulge, whether due to either of the structural controls described above or due to other factors, it appears the thicker sections of the dike may facilitate development of a well-developed "core" zone. The core zone is an area of the dike, generally in the central portion, where the largest crystals and the most economically significant mineral assemblages occur.

Certain mineralogic aspects of the pegmatite serve to indicate the presence of pocket-bearing pegmatite. A change in feldspar type, namely an increase in percentage of microcline to albite, occurs in the core zone in and around pockets. Also a change in the chemical composition of large, tapering tourmalines, consisting of a downward enrichment of lithium, is seen near pocket-bearing parts of the dike. Thus changes in mineralogy, either as distinct mineral species or chemical changes within a specific crystal, may indicate the nearby presence of pockets of economically important minerals.

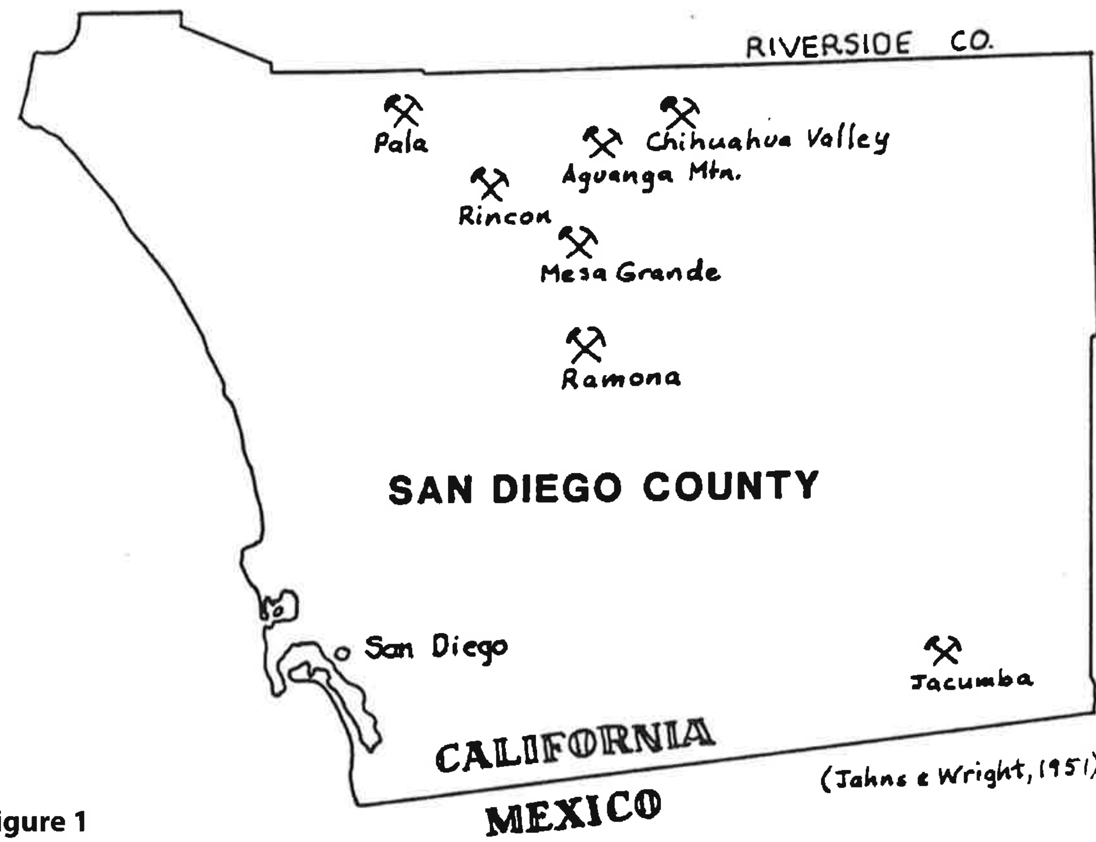


Figure 1

INTRODUCTION

This paper was originally an undergraduate thesis which the author completed in 1986 while working toward his bachelor of science degree in geology at San Diego State University. Although the mine itself has progressed significantly since this study was done, the content of this research and findings of this thesis remain valid.

The pegmatites of Pala, California, are a late-stage part of the Peninsular Ranges Batholith. The Pala district is in northwestern San Diego County about 45 miles north of San Diego (Figure 1). The main part of the district occupies an area of about 5 square miles (Jahns and Wright 1951). Mining began in Pala about the start of the twentieth century and has continued sporadically ever since. Though tourmaline has been the most sought after mineral in the district, several other semi-precious gemstone minerals, including beryl and spodumene, have also been recovered. These various minerals are used both as mineral specimens and as cutting material suitable for faceting into gemstones. Many mines in Pala, including the Stewart, Tourmaline Queen, and White Queen, have been highly acclaimed for their production of high quality material. However, these minerals are not found distributed throughout the pegmatites. Rather they are concentrated in cavities or "pockets" that occur in certain zones in the pegmatite. Because these pocket-bearing zones are not found throughout the dikes, methods have been sought by which to understand the distribution of pockets and predict their occurrence. This report was undertaken in an attempt to determine some of the controls on and indicators for the existence of pockets.

The Elizabeth R mine, known today as the Oceanview mine, is located on the northwest slope of Chief Mountain in the central part of the Pala district (Figure 2). It was chosen as the subject of this report for two main reasons. First is its accessibility to the author and second is the condition of the underground workings. Many mines in Pala and indeed throughout San Diego County are virtually inaccessible to the general public due to the nature of the material being found and the desire of the miners to protect their mines from potential theft. Mines not being worked are generally in poor condition. The Elizabeth R mine is an active mine and had, at the beginning of this study, approximately 575 feet of underground workings. At the completion of this study, this has advanced to about 725 feet. The tunnels are in very good condition and offer good exposures of zonation in the dike.

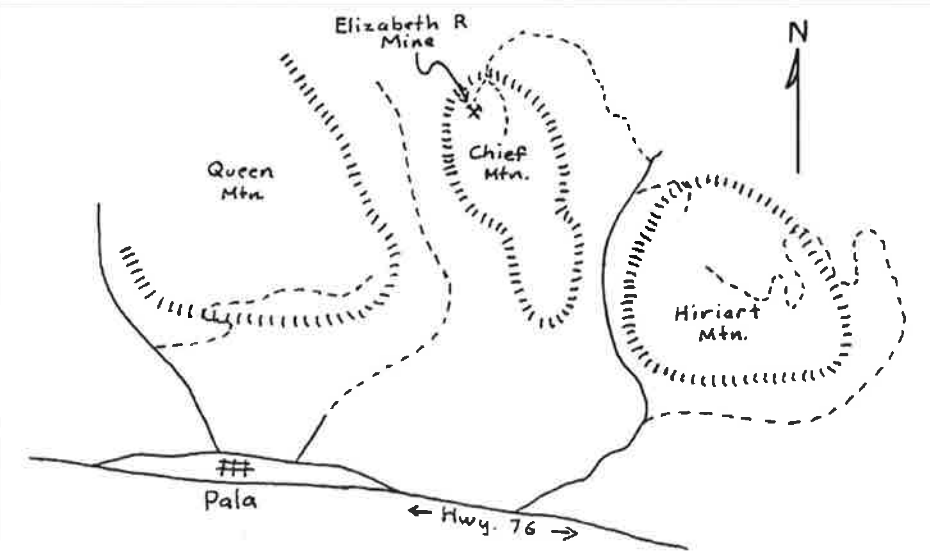


Figure 2

Two aspects of pegmatites, structure and mineralogy, have been investigated in this study as possible guides to the occurrence and distribution of pockets. Structure includes zones where the pegmatite has intruded weak or fractured host rock, and rolls or flexures in the dike. In sections of the pegmatite exhibiting these types of structure the dike tends to be thicker. It is in these thickened areas or bulges that pockets are generally found. Certain characteristics of minerals in the pegmatite can indicate the presence of pockets. Changes in mineralogy, whether a change in species within a given mineral group or a change in chemical composition across a single mineral grain, are seen in and around pocket-bearing parts of the dike.

MINE HISTORY

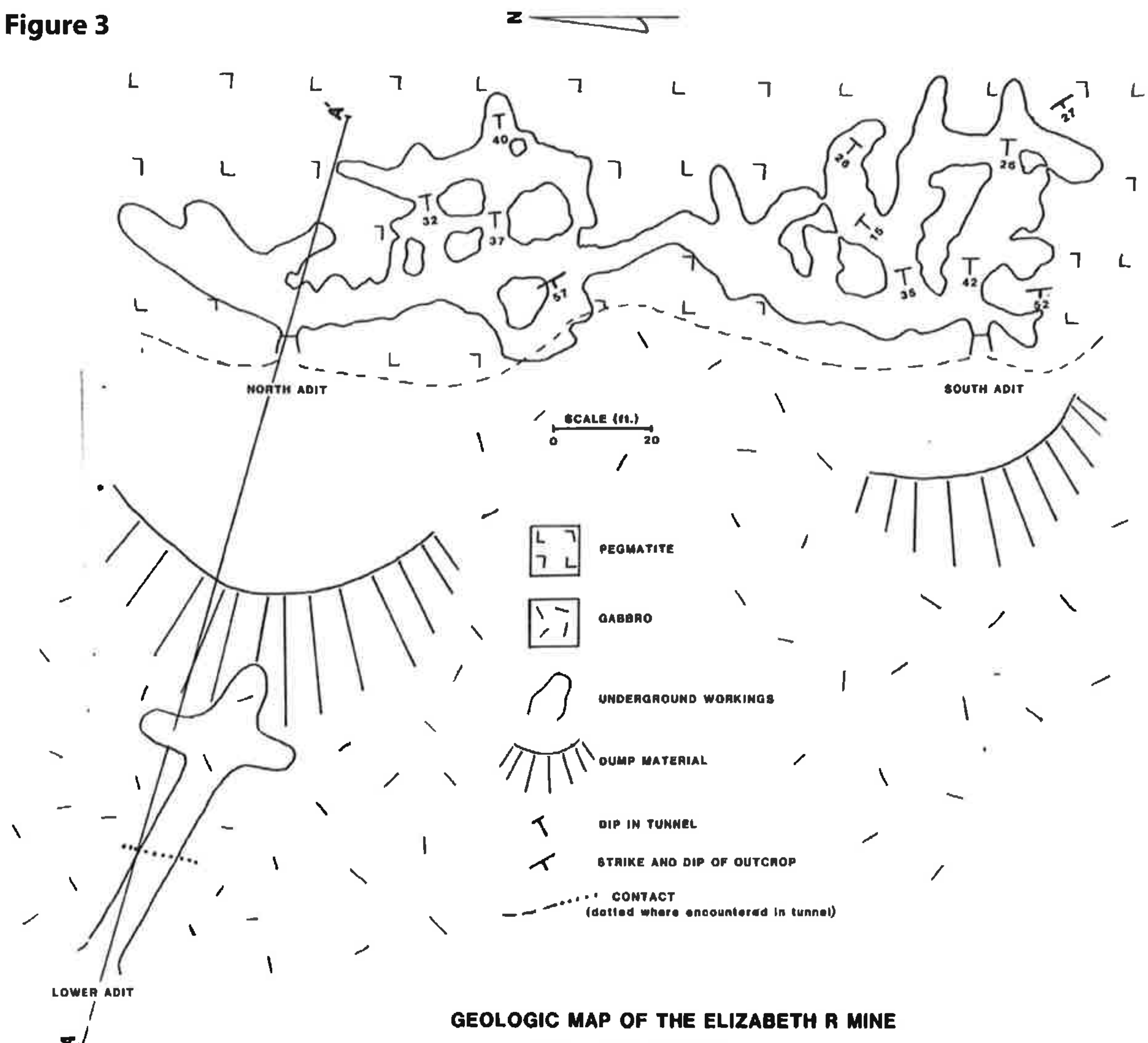
The Elizabeth R mine is in what is referred to as the Ocean View pegmatite (Jahns and Wright 1951). The mine is owned and operated by Jeff Swanger following his purchase in 2000 from Roland Reed of El Cajon, California. The only evidence of work prior to 1974 is an open cut approximately 50 feet north of the north adit. Jahns and Wright (1951) report that early production was mainly quartz and beryl. Roland Reed acquired the property from Joe Zeld and in 1974 made the initial cut in a bulge approximately 50 feet up the hill from the area that now contains the north adit. Upon reaching the core, several small pockets were encountered which contained morganite and colored tourmaline as well as quartz, cleavelandite, and apatite (Reed 1983). What is now the north adit was driven to the core and the main drift advanced south. Several large pockets were found containing quartz crystals in groups up to 150 pounds and 30 inches in diameter (Reed 1983). Upon encountering a concentration of lithium phosphates, Mr. Reed began to stope updip and found a series of pockets containing morganite as well as the already noted minerals.

The main drift was then driven south along the strike of the dike. A second adit was driven to the surface approximately 140 feet south of the north adit and so will henceforth be referred to as the south adit. Because this adit seemed to be on the edge of a very pronounced roll or bulge, Mr. Reed decided to stope updip along the south side of a section of the quartz-spodumene core encountered earlier. Several small pockets containing quartz and feldspar were found. Then, 40 feet updip, a large pocket containing a number of superb beryl specimens, including concentrically zoned and bi-color crystals of morganite and aquamarine, was uncovered.

After several short drifts were made off this stope, a new stope was advanced updip just north of the last stope and angled slightly to the north. One rather significant pocket was found about the time the author began spending time at the mine. This pocket contained a few morganites and a large number of milky to clear quartz crystals and crystal clusters.

Upon completion of a short stope mid-way between the adits in which the dike appeared to "pinch out" about 25 feet above the main drift, a new adit was driven into the hillside to intercept the dike approximately 80 feet below the existing workings. Work also began to advance the main drift north from the north adit. At the time of this study in the mid-1980s, mining was continuing at the north end of the main drift and would soon commence in the lower adit (Figure 3). Further discussion of progress and expansion of the mine since completion of this study can be found at the end of this paper.

Figure 3



GEOLOGIC MAP OF THE ELIZABETH R MINE
PALA, CALIFORNIA

PETROGRAPHY

Fine-Grained Rocks. The fine-grained rock, normally referred to as line rock, usually occurs in the footwall portion of the dike (Figure 4). It is similar in composition to the rest of the pegmatite, being primarily quartz, orthoclase and albite though the average grain size is significantly smaller, being approximately 1 to 2 millimeters. This unit is referred to as line rock because of the layered appearance of some of these rocks. This is due to alternating thin layers that are rich in garnet or tourmaline. One of the best exposures of line rock in the mine is just inside the south adit in the column to the left of the junction of the main drift and the first stope.

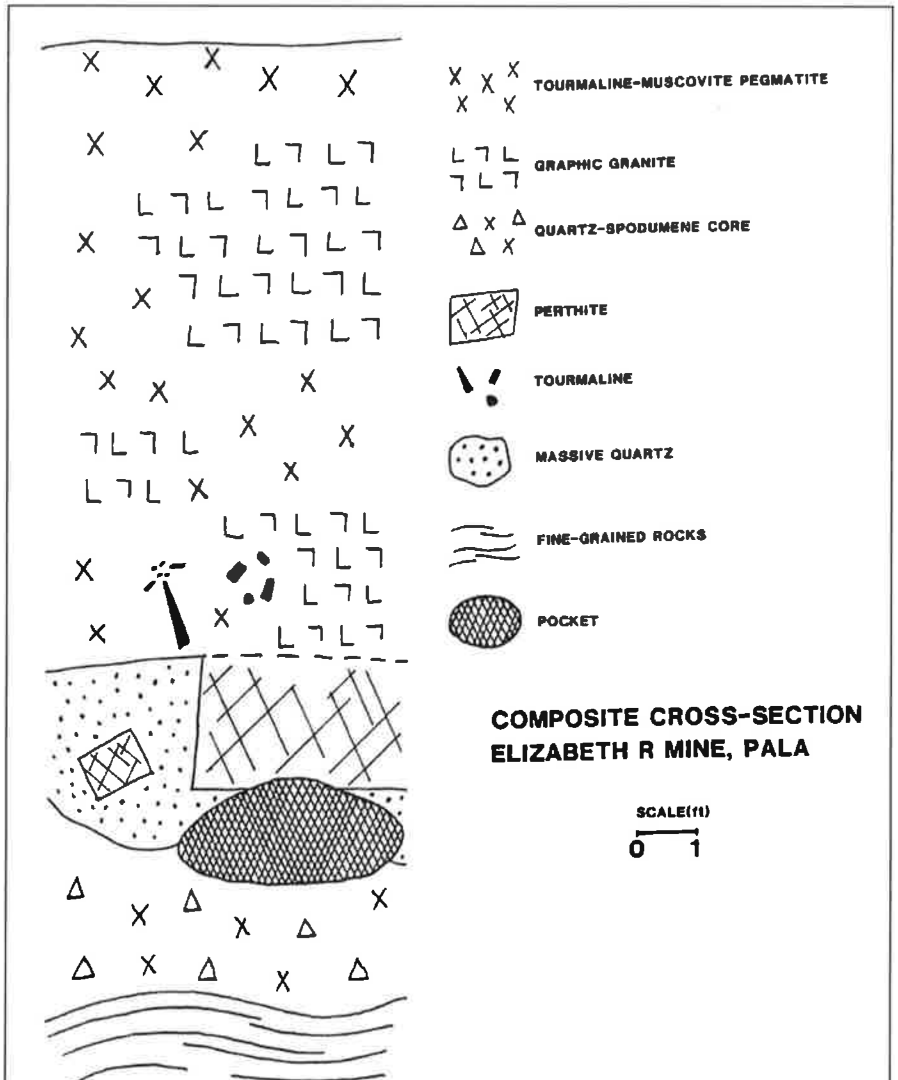


Figure 4

Graphic Granite. One of the more abundant rock types in the mine, the graphic granite forms masses that range from a few inches to several feet and more. It consists of perthitic microcline (Jahns and Wright 1951) containing grains of quartz. The quartz grains occur as elongate rods that vary in cross sectional shape. Some have a triangular or sub-rounded section whereas others have a platy or L-shaped section (Jahns and Wright 1951). The quartz rods range in length from less than an inch to a foot or more and in width from 1$\frac{1}{16}$ inch to as much as 1 inch (Jahns and Wright 1951).

The graphic granite can occur in all parts of the dike but is normally found in the upper part of the dike near or along the hanging wall (Jahns and Wright 1951) (Figure 4). In some parts of the mine the graphic granite comprises a substantial part of the pegmatite. In the southern section of the upper workings, visual inspection of the outcrop and the underground workings gives the impression that the upper one-third to one-half of the dike is composed largely of graphic granite. This is difficult to ascertain as no location in the mine contains a complete section of the dike. However, this abundance of graphic granite would be expected as graphic granite forms the most widespread rock type in the Pala pegmatites (Jahns and Wright 1951). Contacts between the graphic granite and surrounding rock types in the dike are commonly gradational and so not very clear.

One more noticeable association is the gradation of graphic granite into subhedral or euhedral perthite. This is seen in both pocket-bearing and non-pocket-bearing parts of the dike.

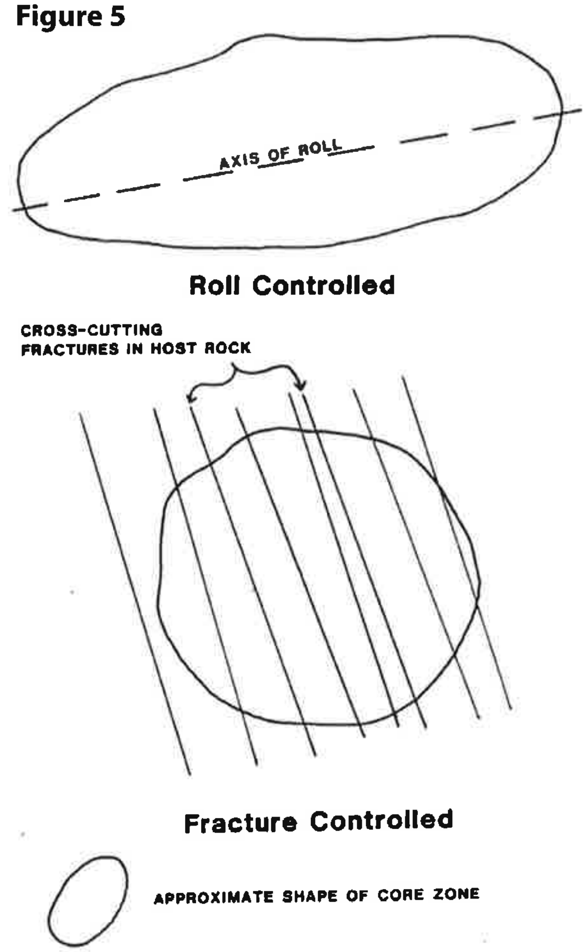
Tourmaline-Muscovite Pegmatite. This rock type occurs alone as a unit and dispersed between and commonly through the blocks of graphic granite. Its primary constituents are intergrown anhedral crystals of quartz, microcline and albite with sporadic muscovite and tourmaline. Muscovite has two modes of occurrance, as individual books and foils ½ inch to 2 inches in diameter and as flakes 1⁄16 inch to approximately ½ inch across disseminated through the rock. The areas or "pods" of disseminated muscovite vary from a few inches to 8 feet across.

Tourmaline occurs as individual euhedral to subhedral crystals ranging from a fraction of an inch to 12 inches or more in length. A pattern is sometimes seen in the orientation of the tourmaline crystals. They are found oriented normal to the hanging wall of the dike in a comb-like structure. In addition, they may form a radial group of crystals radiating out from a finer grained core of tourmaline. Most commonly the tourmaline crystals are randomly distributed through the rock. In the Elizabeth R mine, this rock unit is found in all parts of the dike. In sections without a core zone it commonly makes up a major portion of the dike. The dike in such sections may be composed entirely of graphic granite and tourmaline-muscovite pegmatite with roughly equal distribution of both. In some sections of tunnel, the entire exposed section appears to be tourmaline-muscovite pegmatite. Near the south adit this rock type is observed below the line rock that is normally seen at the bottom of a pegmatite dike.

Core Zone. Jahns and Wright (1951) use the term "giant pegmatite" to describe the core zone. This is a fitting term as it is the core that contains the largest crystals found in the pegmatite dike. Though pockets are found in all parts of the dike, a vast majority of them occur in the core zone. Hence it is the unit of greatest economic importance. The presence or absence of core zone material in an outcrop is one of the best indicators whether a pegmatite has the potential to be productive. The Elizabeth R mine exhibits very well developed core zones that range in thickness from just a few inches to as much as 6 or 7 feet. The core zones are tabular in cross section and taper toward the edges. In plan view (Figure 5) these zones vary in shape depending on the nature of the controls that influence their development. Core zones are found in the thickest parts of the dike and the importance of this observation will be discussed in detail in later sections of this report.

Core zones in the Elizabeth R mine generally occur in the lower portion of the dike (Figure 4), though this is difficult to determine without a

Figure 5



STRUCTURE-DEPENDANT SHAPE OF CORE ZONE

completely exposed section of the dike. The core in the southern part of the upper workings rests directly on the line rock (Figure 6). This relationship is clearly visible just inside the south adit at the junction of the main drift and the first stope. In the northern part of the mine, the core is not nearly as well defined as in the southern part. This may be due to the size of the zone as it appears to be somewhat larger in the north area. Recent work (1986) north of the north adit reveals a large core zone up to 6 feet thick showing an excellent potential for pockets.

The most abundant mineral in the core zone is perthite. It occurs as subhedral to euhedral crystals 1 inch to 6 feet across. As mentioned earlier, these crystals commonly grade upward out of the core zone into graphic granite. The most common color of perthite is white to cream. It sometimes occurs in a gray-brown color. This gray-brown color, coupled with the well defined cleavage of the perthite, gives it a distinctly different appearance from the other minerals common in the core zone. The perthite also occurs as euhedral crystals enclosed in massive quartz. A lattice-like appearance commonly characterizes the perthite. This is because of preferential leaching of either the albite or the microcline from the perthite. The perthite is commonly altered and may be the source of some of the clays found in the pegmatite.

Quartz is another major constituent of the core zone. It occurs as subhedral to anhedral crystals and as massive pods that vary in size up to 5 feet or more in maximum dimension. The intergrowth of euhedral perthite in massive quartz commonly gives a rather striking appearance. Quartz is considered by the miner to be a good indication that pockets may occur in the core although it seems an over-abundance of quartz can indicate the opposite.

Commonly associated with the quartz are lath-like crystals of highly altered spodumene. These range from an inch in maximum dimension to as much as 15 inches by 2 inches. This association can be seen in the column supporting the winze in the northern section of the upper workings and

Figures 6 and 7.

also occurs extensively in the southern section. One stope in the southern section exhibits a pod of phosphate minerals 2 feet across containing an impressive intergrowth of the altered spodumene crystals (Figure 7). Locally a core of unaltered spodumene will be present in the center of the altered spodumene crystal, but these are very small and economically insignificant.

One very interesting rock that occurs in and adjacent the core zone is a type of feldspar referred to by miners as "de-silicified feldspar." This is somewhat a misnomer since feldspar itself is a silicate mineral. The rock gets its name because of the apparent selective leaching of the quartz rods from the feldspar matrix. This gives the rock a vuggy, honeycomb-like appearance. These pods occur adjacent pocket bearing parts of the dike and were probably graphic granite before alteration occurred (Jahns and Wright 1951). Tourmaline is commonly present in these rocks with crystals that average about two centimeters (Simpson 1965).

Pockets. Pockets occur as cavities in the pegmatite as small as ½ inch and as large as 10 feet long by 5 feet wide by 4 feet high. Figure 8 shows quartz crystals in a clay-filled pocket. The minerals lining the pockets become euhedral as they grow into the pocket and pockets larger than a few inches are filled with crystals of various minerals. Clay minerals commonly fill the pockets and give the rock surrounding the pockets a reddish brown color due to the iron staining from the clay. Pockets nearly always occur in the core zone of the dike but all parts of the dike have been observed to contain pockets.

By far the most common mineral found in pockets is quartz. It is normally milky but also occurs as beautiful clear and smoky crystals. These crystals range from a fraction of an inch in length to 18 inches and possibly more.

Perthitic microcline and orthoclase are also common. Orthoclase is white and microcline is white to tan in color. The microcline is commonly altered by the removal of the albite to form the common latticelike appearance. Some of these crystals will also have an overgrowth of unaltered orthoclase. Microcline and orthoclase crystals are normally 1 to 2 inches in maximum dimension although much larger crystals have been noted.

Albite occurs in several forms in the pockets. One form is the fine-grained "sugary" albite that occurs not only in the pockets but throughout the core. Two habits of cleavelandite variety of albite are found in pockets in the Elizabeth R mine. One is the bladed variety found in mines throughout San Diego County. The blades rarely exceed ½ inch in length and form attractive matrices for quartz and beryl crystals. Bladed cleavelandite is very light tan to white, and rarely clear. Another form of this mineral is the blocky crystals that range up to 1 inch across. These are white to light tan and are quite a common constituent of pockets in parts of the pegmatite.

Muscovite occurs in many of the pockets. It is silvery white to green in color and is most commonly associated with bladed cleavelandite and quartz, though it is also found associated with beryl, blocky cleavelandite and tourmaline.

Beryl occurs in roughly half of the major pockets. Most common in the Elizabeth R mine is the peach colored variety called morganite. The blue-green variety, aquamarine, is found in the core of some morganites. It is very rarely found comprising a whole beryl crystal. Beryl crystals range from less than an inch to 6 inches across.

Tourmaline is also found in the Elizabeth R mine, but it is largely limited to a certain area of the mine. This zone of tourmaline pockets is along the south edge of the southern section of the upper workings and forms a line of pockets running roughly parallel to the dip of the dike. The pocket tourmaline crystals are elbaite with a very dark blue color: however crystals larger than 1⁄16 of an inch in diameter appear black. Tourmaline crystals occur in a variety of sizes, the largest being a crystal measuring 7 inches long by 2 inches wide. Another fine tourmaline specimen consists of a tourmaline crystal perched atop a large quartz crystal. The specimen is 10 inches high and the tourmaline is 1½ inches across. Minerals which occur much less frequently in pockets in the Elizabeth R mine include columbite, apatite and a variety of other phosphate minerals.

It should be noted that the ability to efficiently locate pockets is the motivation behind this entire study as it is the pockets that contain virtually all the economic mineral deposits in the pegmatite. One large specimen of beryl crystals on a matrix of quartz and cleavelandite (Figure 9) was valued by Mr. Reed at $20,000 to $30,000 in the mid-1980s. One cannot underestimate the importance of finding pockets in mining a pegmatite. It is with this in mind that this investigation has been made into determining controls and indicators for the existence of pockets.

Figure 8

Figure 9

a.

b.

c.

d.

e.

f.

g.

From left to right, top to bottom:

a. Quartz crystal cluster (approximately 8 inches high)

b. Goethite pseudomorph after pyrite? (Large pseudomorph approximately ¾-inch across)

c. Tourmaline crystal (approximately 1¾ inches high)

d. Spodumene, var. kunzite (lilac colored) with light green "cap" (approximately 2½ inches long)

e. Columbite crystal (approximately 1 inch across) on muscovite and cleavelandite

f. Tourmaline partially replaced by lepidolite. (Crystal is approximately 2½ inches across)

g. Morganite beryl and quartz (specimen approximately 6 inches long)

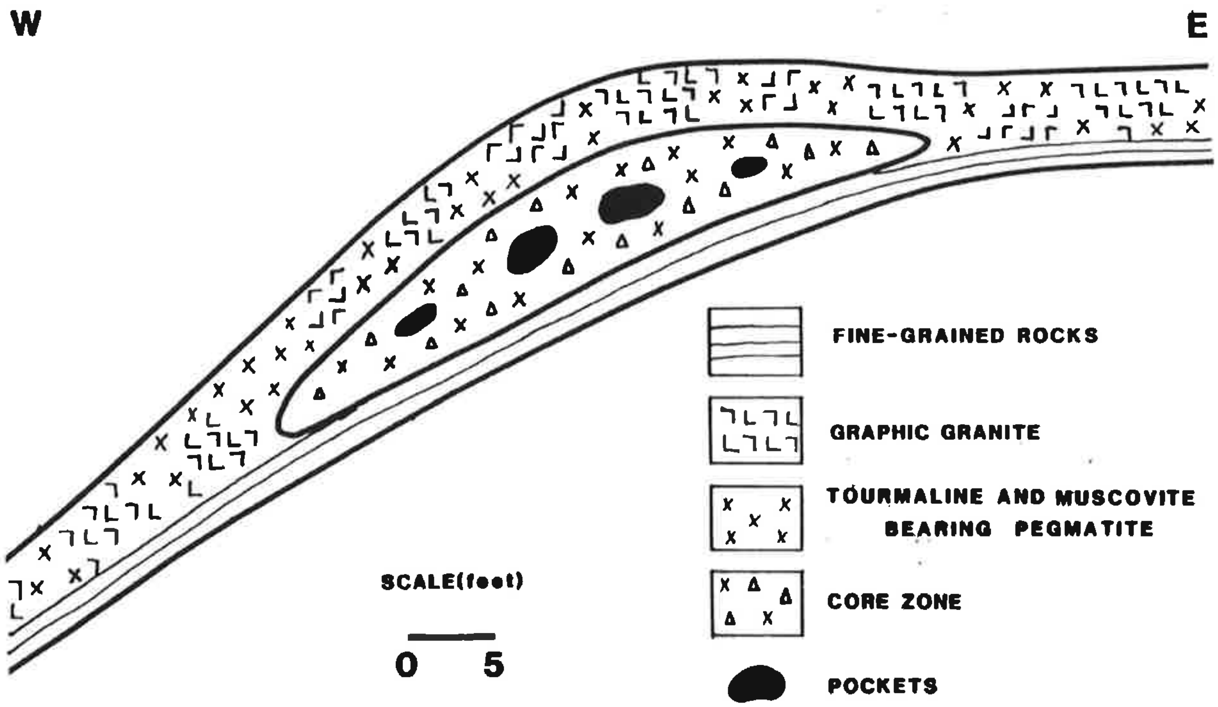


Figure 10 **Roll Controlled Bulging**

STRUCTURAL CONTROL

Two aspects of structure were investigated as possible controlling factors for the formation and distribution of significant pockets. The first, which required little more than visual inspection of the outcrops and underground workings, is that of flexures or "roll" in the pegmatite dike. The second is the major fractures in the pegmatite, presumably an expression of fracture systems in the host gabbro. This feature required more detailed field measurements and correlation with regional features using aerial photographs. The following discussion will explain in more detail the influence of structure on the formation and distribution of pockets and observations that indicate the presence of these structures in the Elizabeth R mine.

Various individuals have stated that rolls in pegmatite dikes are necessary for the formation of pockets. The distribution of pockets along a roll is explained by an analogy that compares the relationship between rolls and pockets to oil being trapped in the apex of an anticline as the oil rises through the higher density host rock. This analogy may seem reasonable in a pegmatite system as one would expect the volatiles to rise. If this were true, pockets would tend to occur along antiformal rolls with synformal rolls being virtually barren of any economic or exotic mineral deposits. Such is not the case and two observations serve to rule out this explanation. First, pockets are commonly distributed along synformal rolls as well as antiformal rolls. Therefore, even if the entire system has been overturned since emplacement, the pockets are still most commonly evenly dispersed between synformal and antiformal rolls. The second observation is that certain pegmatite dikes, such as the Himalaya dike in Mesa Grande, have no noticeable roll structure, dip angles in excess of 40 degrees, and still contain significant distributions of highly mineralized pockets (John Mclean 1986, personal communication). An alternate explanation, which is considered the direct effect of the two structural controls discussed in this paper, is that pockets form where the pegmatite dike is allowed to bulge in thickness and thus develop a well zoned structure including a very-coarse grained core zone. It is in these bulges that the volatile phase is allowed to develop, the coarse core being a reflection of this fact. If the volatile phase develops to a sufficient extent, the volatiles can collect to form large pockets. Therefore, any factor allowing the pegmatite to bulge could contribute to the development of pockets.

It has been noted that where a pegmatite rolls or flexes, it tends to be thicker. This may be due to some inherent weakness in the host rock that allows the dike to bend and at the same time expand as it intrudes (Figure 10). Several observations serve to indicate a roll structure in the Elizabeth R pegmatite dike. The shape of the outcrop, if it is assumed that the face of the outcrop approximates the hanging wall of the dike, indicates a significant roll or thickening in the southern section of the upper workings. Immediately above the mine dump, the outcrop dips 52 to 57 degrees, whereas above this it flattens out to only 27 degrees. The shape of the underground workings, namely the stopes that are driven updip from the main drift, also reflect this roll. The dip of the stopes below the roll dip up to 42 degrees with dip angles as low as 15 degrees above the roll (Figure 3). Again an assumption must be made – that the core zone, which determines the shape and geometry of the tunnel as it is the core that contains the significant pockets, will reflect the overall structure of the dike. A number of pockets have been encountered in the vicinity of this apparent roll, including two pockets that contained several hundred pounds of material each (Figure 11). One of these pockets contained a single specimen of quartz and feldspar (now in the author's back yard) with an estimated weight of 350 pounds and requiring four people to lift!

Another observation is made on the relative attitude of the dike in the upper workings compared to the attitude in the lower adit. Pegmatites tend to vary in dip to form terrace-like features (Jahns and Wright 1951). As was mentioned, the dip of the dike in the lower part of the upper workings is relatively steep, up to 42 degrees. In the lower adit, 140 feet down the hill, the dike dips 27 degrees where the tunnel first encounters the dike. It also contains fractures, interpreted to be cooling fractures, that

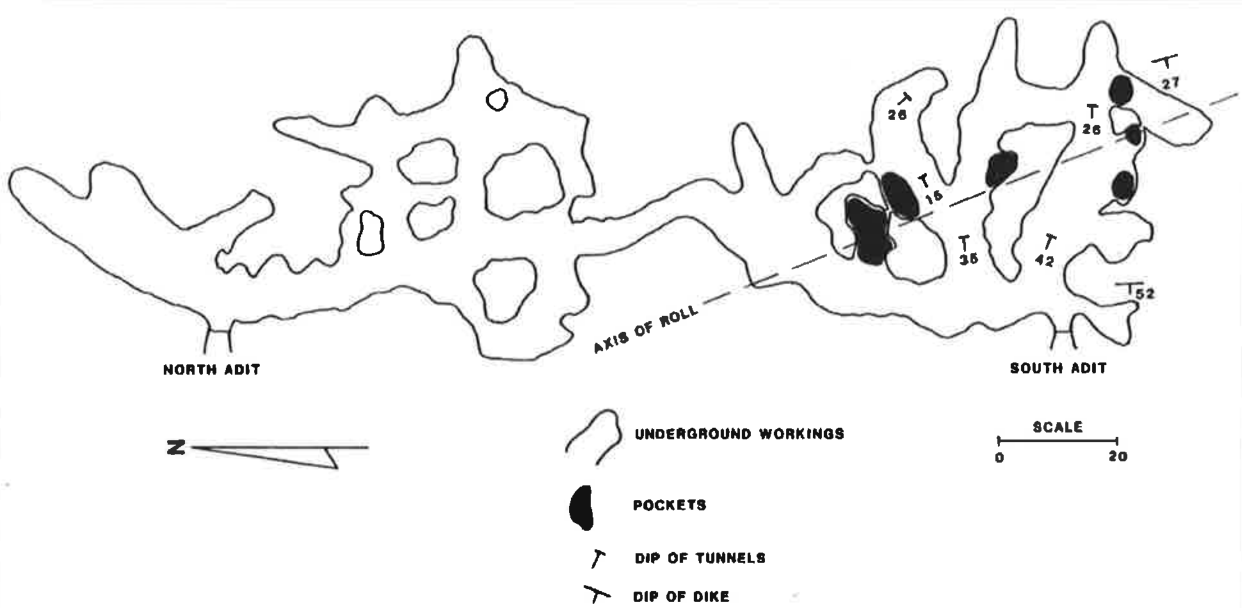
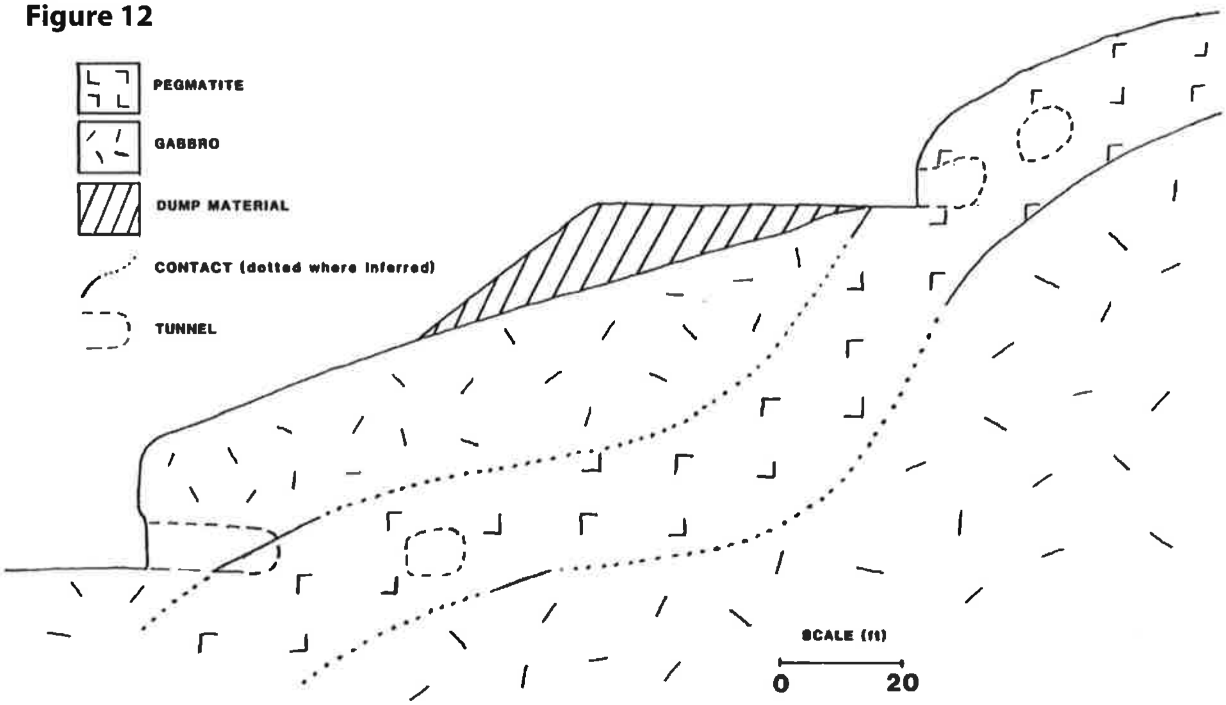


Figure 11 ROLL STRUCTURE-SOUTH SECTION OF UPPER WORKINGS ELIZABETH R MINE, PALA

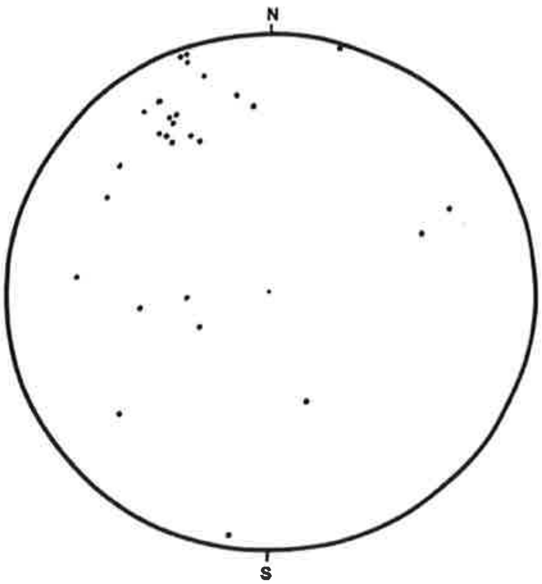
Figure 12



ATTITUDE OF PEGMATITE IN UPPER AND LOWER WORKINGS
ELIZABETH R MINE, PALA

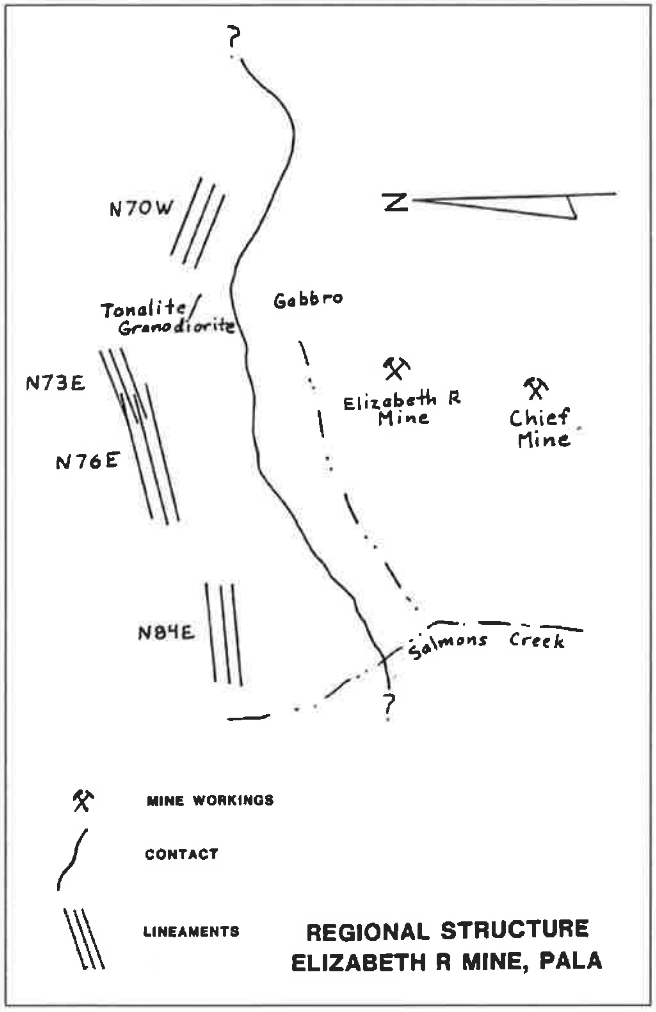
are parallel to the contacts of the dike, and that dip only 18 degrees near the end of the tunnel. Extrapolation of the dike from the lower adit to the upper workings indicates an upwards roll, potentially rather abrupt, between the upper and lower workings (Figure 12). This roll is of particular interest as no exploration has yet reached this section of the dike. The potential for significant pockets to be encountered in this section of the pegmatite warrants some excitement and anticipation on the part of those individuals involved with working the mine.

As was discussed earlier, the dike can bulge where it encounters weak or fractured host rock. Attitude measurements were taken on major measureable fractures throughout the upper workings. Thirty-one measurements were made with 16 measurements (52%) appearing to fit into a sub-parallel set that strikes N60E to N80E and dips 60 to 85 degrees north (Figure 13a). These fractures occur in the northern and southern sections of the upper workings with a zone approximately 50 feet wide in the center nearly void of any major fractures (Figure 13b). There is a contact between the gabbro and another igneous pluton, presumably tonalite or granodiorite, approximately ¼ mile north of the mine. This contact is, at the point closest to the mine, roughly parallel to the fractures observed in the mine workings. The rocks north of the contact show a distinct lineation which is also parallel to the contact and the mine fractures. These lineaments strike N73E to N76E north of the mine (Figure 14). The gabbro, however, shows only very weak lineation at one, and possibly two, locations near the mine. This is attributed to the nature of gabbro as it tends to develop a very deep and very strong weathering profile that would weaken or obliterate any display of lineation. Though it is very weak, the lineation observed in the gabbro also parallels the mine fracture set, the contact, and the lineation in the rocks north of the contact. Therefore the fracture set in the mine appears to have some correlation to the larger scale structural features of the area.



Stereonet Plot of Poles to Measured Fractures
Elizabeth R Mine, Pala
(POLE POINTS IN UPPER HEMISPHERE)

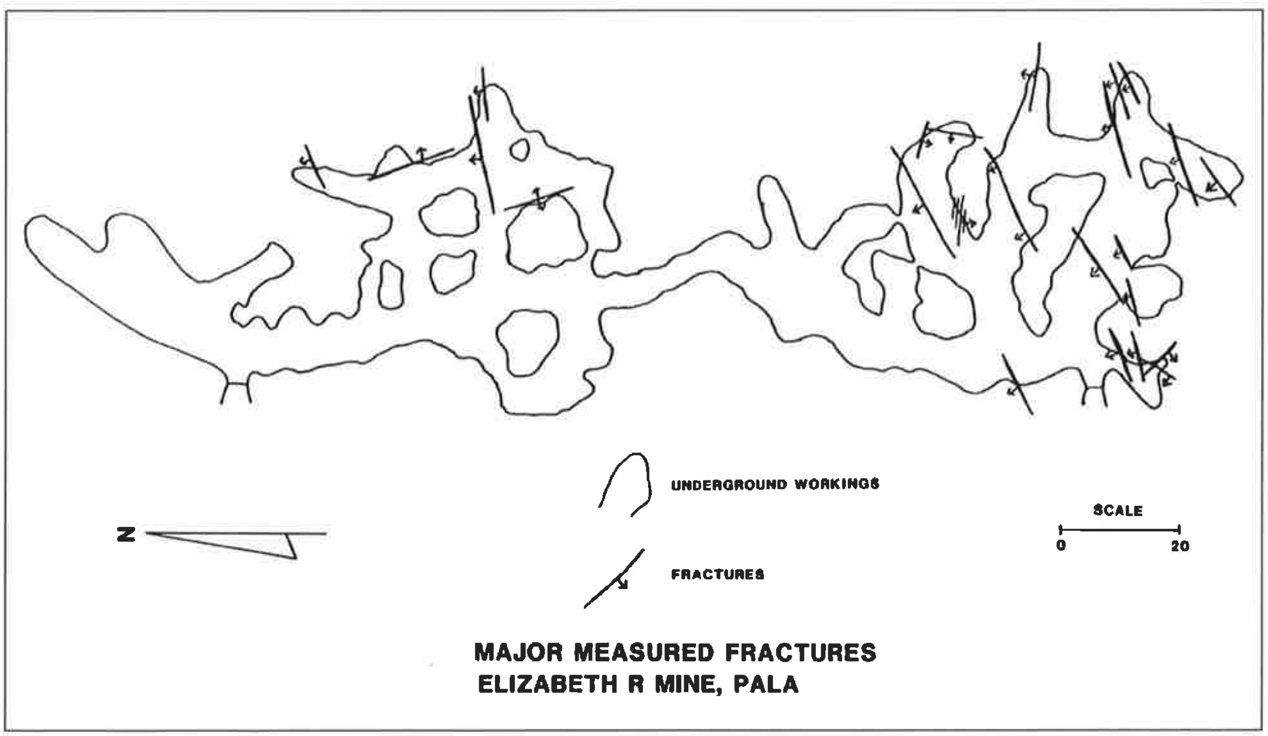
Figure 13a



REGIONAL STRUCTURE
ELIZABETH R MINE, PALA

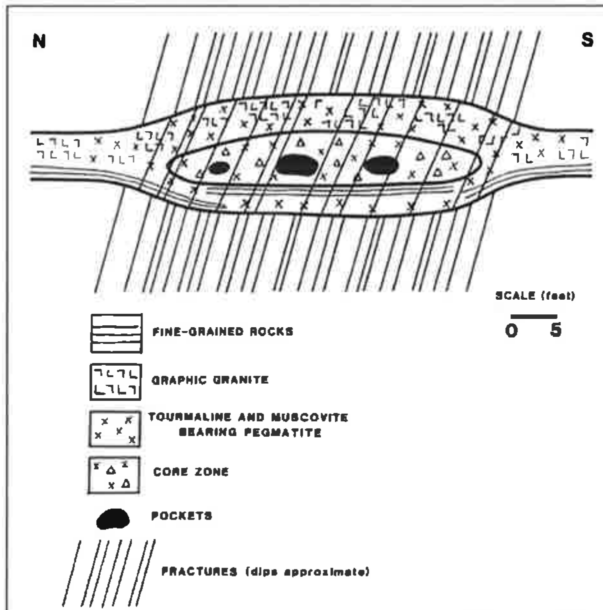
Figure 14

Figure 13b



MAJOR MEASURED FRACTURES
ELIZABETH R MINE, PALA

Joints in the gabbro are not necessarily spaced evenly. They may occur in zones, giving the rock a sheet-like appearance, with areas between free of joints for up to 50 feet (Jahns and Wright 1951). These joint sets or zones would represent a weakness in the rock. If, as the dike intrudes, it encounters such a zone, it might bulge and thus fulfill the criteria for the formation of one or a series of pockets. Though no clear jointing is ascertainable in the host gabbro, the fractures in the northern and southern part of the upper workings may be an expression of pre-existing fracture zones in the gabbro (Figure 15). The unfractured and barren area in the center of the workings would then be in a relatively un-jointed section of the gabbro.



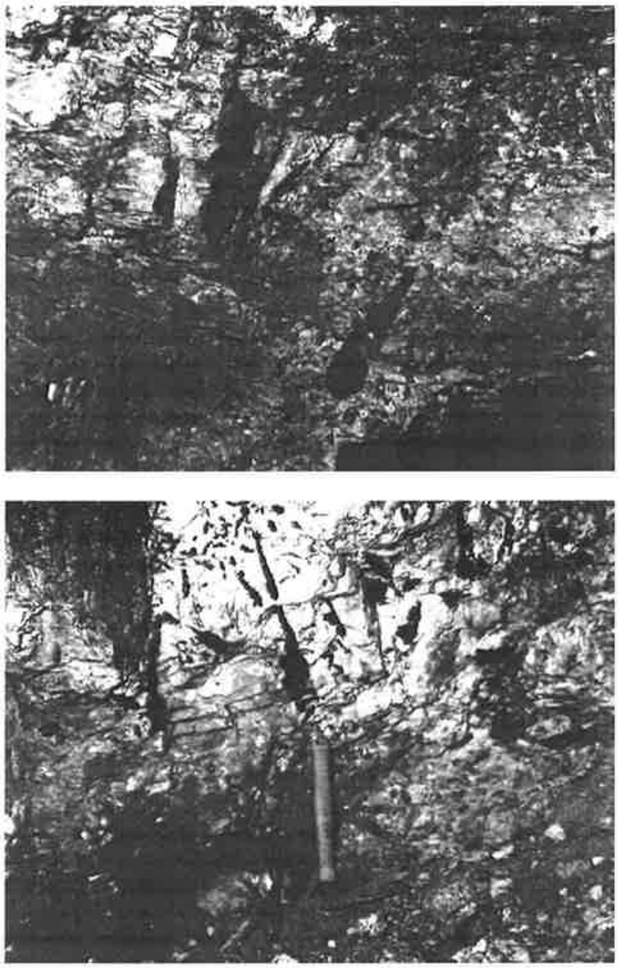
Fracture Controlled Bulging Figure 15

MINERALOGICAL INDICATORS

Two mineralogical investigations were undertaken to determine whether or not any changes in mineral occurrence or chemistry might indicate the presence of potential pocket bearing pegmatite. Samples of feldspar were collected from various positions in and above the core zone and x-ray diffraction used to find what, if any, differences occur. Tourmalines were also tested by x-ray diffraction to determine any difference between the top and bottom ends of large, tapering crystals that occur just above the core zone. The idea was to see how their chemistries might change and, if possible, in what elements they become enriched as they approach pockets or pocket-bearing dike.

Feldspars. Microcline and albite are the two primary feldspars present in the core zone of the pegmatite. In a sample taken above the core zone, microcline is represented by ten major peaks whereas albite is only represented by one major peak. A sample from near the top of the zone has microcline represented by seven peaks and albite by one. A mid-zone run has eleven microcline peaks and two albite peaks. A feldspar sample taken from just below the core zone shows a distribution of nine microcline peaks and eight albite peaks. Converting this to a percentage of major peaks, the albite occupies 9.1% above the core zone, 12.5% in the top of the core zone, 15.4% in the middle core zone and 47.1% below the core zone. This does not necessarily reflect the exact percentage of microcline to albite, but indicates relative amounts of each mineral. The ratio of microcline to albite increases substantially upward through the core zone, indicating a general upward increase in potassium.

Tourmaline. Some larger tourmalines above the core zone in the Elizabeth R mine have been observed to taper upward. Another way of looking at this, obviously, is that they widen as they grow downward. This is thought to be due to increasing volatile content as the dike crystallizes inward allowing the mineral grains to grow larger. Because of this widening of the crystals, it was decided to test the top and bottom of several individual crystals to determine if any chemical difference occurred as the crystal grew downward. Two crystals were tested. One crystal is located above the pocket on the north side of the northernmost stope of the southern part of the upper workings (Figure 16a). The other tourmaline is across from the first one above the core zone where the stope splits (Figure 16b).



Figures 16a and 16b.

The x-ray diffraction run shows the top of the first crystal to be schorl. With the bottom of the crystal four major peaks are schorl and two are elbaite. The same is true with the second crystal, but with two peaks schorl and three elbaite in the bottom. This shows an increase in lithium content as the crystals progress downward.

The occurrence of either of these two mineralogical changes, a change in the type of feldspar or a shift in composition of the tourmaline, might indicate the nearby existence of pocket bearing pegmatite. However, their usefulness is questionable since in the time spent preparing the samples and running the tests one could easily advance workings enough to determine whether core zones or pockets are an imminent discovery.

MINING UPDATE

Since completion of my undergraduate thesis, the Elizabeth R mine has undergone extensive expansion, and even experienced a name change. Mr. Reed continued mining, primarily in the lower workings (beginning with the "lower adit" depicted on Figure 3), adding a south adit to the lower workings, connecting the north and south lower adits in similar fashion to the upper workings, and stoping updip to intercept the upper workings in several locations. He also explored the pegmatite in a downdip direction. Production in the upper workings included quartz crystals, schorl tourmaline, and morganite (sometimes with "aquamarine" cores in the crystals), as well as attractive green, elongate muscovite crystals on or off matrix. With advancement of the tunnels in the lower workings since the completion of this thesis, not only have more pockets of fine morganite and quartz specimens been recovered, but aquamarine beryl crystals have been found and a number of pockets, particularly toward the southern end of the lower workings, have yielded colored tourmaline and kunzite!

Mr. Reed has "semi" retired from mining, although he still makes visits to the workings to view the progress and get a "fix" of the adventure. In 2000, Mr. Reed sold the mine to Mr. Jeff Swanger, who changed the name to the Oceanview mine, after the name given to the pegmatite dike early in the history of mining in Pala. Mr. Swanger has continued mining, adding additional workings even further down-dip below Mr. Reed's lower workings, and continues to recover morganite, colored tourmaline, and very high quality kunzite specimens, as well as fine aquamarine beryl crystals on cleavelandite matrix. He has also built a business providing visitors not only opportunities to see a working pegmatite mine, but to actually "mine" the deposit by screening material brought out of the mine during on-going operations. A visitor typically finds specimens of beautiful pegmatite minerals such as quartz, lepidolite, and the various gem minerals, and if lucky enough, may find a truly high quality tourmaline, beryl, or kunzite that simply got away from the miners. The 2013 SDAG field trip has the privilege of visiting this class operation to screen for the beautiful minerals and see the underground workings of this world class pegmatite mine in the famous Pala mining district.

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I wrote this thesis on a Commodore 64. It took five minutes just to load the word processor (from a 5½ inch floppy disc) before the thesis file (stored on a 5½ inch floppy disc) could be uploaded and written or edited. There was as yet no such thing as a mouse, except of course the small, gray, furry creatures which were abundant at that time.

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