



Department of Mines and Mineral Resources

Mineral Building, Fairgrounds

Phoenix, Arizona 85007

(602) 255-3791 Toll Free in Arizona - 1-800-446-4259

BERYL

**A UNIQUE OPPORTUNITY
FOR THE PROSPECTOR AND SMALL MINE OPERATOR**

Circular No. 6

by Ken A. Phillips, Chief Engineer

March, 1986

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BERYL - A UNIQUE OPPORTUNITY FOR THE PROSPECTOR AND SMALL MINE OPERATOR *

Mineral Report No. 5, Revised March, 1986

by Ken A. Phillips, Chief Engineer

WHY CONSIDER BERYL?

Beryl, a specific ore mineral of the metal beryllium, is currently in high demand. The nature of beryl occurrences presents a unique and potentially profitable opportunity for the prospector and small mine operator.

The engineers of the Department of Mines and Mineral Resources are encouraging prospectors and small mine operators to consider beryl. Currently beryl is a more practical prospecting target for the independent prospector than the ever glamorous gold. At more than 55 cents per pound, a ton of beryl ore can be sold for over \$1,100.00. At the current price of gold it would take a grade of almost 3 ounces per ton to make a gold ore of equal value. There is no market for small lots of 3 ounce per ton gold ore. Salable beryl ore can be produced without the need of a mill. In many areas, beryl deposits are mined by family mining operations.

Brush-Wellman, the only free world processor of beryl, has established a small mine beryl ore buying program. Incentive for small mine production includes willingness to purchase shipments of ore as small as 10 tons, fast settlements, and premium prices.

The desire of Brush-Wellman to stimulate domestic production of beryl as opposed to imported ore is exciting. Since January of 1979, the price for beryl ore has risen 300 percent. Valuable beryllium content of beryl ores is reported by assayers as percent of beryllium oxide (BeO). Each 1% BeO is one short ton unit BeO. The value of large (greater than 10 tons) lots of beryllium ores is priced as so many dollars per short ton unit. The current price paid by Brush-Wellman for 10 ton and larger lots of clean, hand-sorted beryl ore is \$147.00 per short ton unit of contained beryllium oxide (BeO) plus additional bonuses for ore grading 11 percent BeO or higher. Brush-Wellman requires the ore grade to be 10 percent BeO or higher.

* As of the date of this reprinting, March 7, 1990, Brush Wellman was not buying beryl at their Delta, Utah facility. Current markets and prices for beryl should be discussed with the Arizona Department of

The continuing demand for beryl ore is felt by many industry experts to be stable. Prices are expected to continue high.

Beryllium, the metal that makes beryl a valuable mineral, is extracted from both beryl and the mineral bertrandite. Beryl deposits are usually mined by small mine operations. In many areas beryl deposits are mined by family mining operations.

WHAT IS BERYLLIUM?

Beryllium is a dark gray metal belonging to the alkaline earth group of elements. Its chemical properties are similar to those of magnesium and aluminum that in some respects it resembles. It has several physical properties that make it valuable in certain industrial applications. It has a low specific gravity (1.84), comparatively high melting point (1287 degrees), and is relatively hard (6 on the Mohs' scale).

High stiffness, low density, and certain other properties make beryllium metal useful for highly specialized applications such as aerospace structures, inertial guidance structures, and optical and nuclear uses.

Beryllium is added to copper to produce alloys that are often used when high hardness, high strength, and the high electrical conductivity of pure (but soft) copper is needed. Applications include electronic springs, connectors, switch contacts, diaphragms, flash welder dies, and injection molds for plastics.

Beryllium oxide is a unique ceramic material that exhibits high thermal conductivity and low electrical conductivity. This rare combination of properties makes it very useful as a carrier for integrated circuits and in the manufacture of

power transistors, microwave radar systems, and other exotic electronic components and systems.

WHAT IS BERYL?

Beryl is one of two commercially mined beryllium minerals. Beryllium does not occur as a native element. Only beryl and bertrandite are presently considered as commercial sources.

Beryl often occurs in pegmatite dikes that may be applicable to small mine production. On the other hand bertrandite is mined from large low grade deposits.

Beryl is a complex silicate of aluminum and beryllium. When pure it has the chemical formula $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$ and contains 14% beryllium oxide (BeO). However, the beryllium can be replaced by other oxides such as calcium, iron, chromium, potassium, sodium, or cesium. The color of beryl varies from white or colorless to green, light blue, amber, and in very rare instances, deep red. It is usually some shade of green or blue. Beryl is about as heavy as quartz, sometimes a little heavier (specific gravity 2.63 to 2.8). Quartz is 2.65. Its outstanding characteristic is its hardness of 5.5 to 8. It is distinctly harder than quartz or tourmaline and practically as hard as topaz. It crystallizes in hexagonal (six sided) prisms ranging in size from mere thread-like pieces to huge crystals many feet in length and weighing several tons. Occasionally it occurs in large columnar or granular masses.

Beryl can be identified by its typical greenish-bluish color, hardness, and crystal shape. In pegmatite occurrences the individual beryl crystal fragments are usually large enough to test their hardness and usually see some portion of their six sided crystal shape. Although light green to light blue is the most common color, colorless, and white beryl has been mined. In such cases, hardness will be a more important factor, as will the

crystal shape. Topaz, apatite, amblygonite, spodumene, quartz, and feldspar may all occur in a pegmatite containing beryl and may be a source of confusion. Beryl is harder than apatite, amblygonite, spodumene, quartz, and feldspar. Topaz is nearly always harder than beryl and topaz has a perfect basal cleavage while beryl does not.

No simple field test for the presence of beryllium exists. However, a test for beryllium is given in Arizona Bureau of Geology and Mineral Technology Bulletin 175, *Field Tests for the Common Mineral Elements*. To perform the test a portion of pulverized rock is fused with sodium carbonate and a sodium hydroxide flux in a platinum wire loop. The fused slag is dissolved in water, a few drops of quinizarin dye solution are added, and the solution is observed under ultraviolet light. The details of preparing the dye solution and performing the test are given in the bulletin that is listed in the bibliography.

WHERE DO YOU FIND BERYL DEPOSITS?

Beryl occurs in some pegmatites. It also occurs in vein deposits and disseminated deposits in tactite and granites. Although any type of beryl deposit could possibly be of economic interest, it is the pegmatite that holds the most promise for a small mining operation.

A pegmatite is an extremely coarse-grained rock. The minerals that make up a pegmatite are usually those found in granite - quartz, feldspar, and mica, but they are of extremely large size. Pegmatites are commonly found as veins or dikes traversing the granular igneous rock or extending out from it into the surrounding country rock.

Although most pegmatites are composed entirely of the minerals found abundantly in granite, those

of interest to the prospector contain additional and rarer minerals, such as beryl. Pegmatites may also contain lithium, columbium, tantalum, bismuth, rare earths, zirconium, uranium, and gems. Such pegmatites are called complex or rare mineral pegmatites. The beryl prospecting venture simply amounts to finding and defining complex pegmatite containing beryl.

Pegmatite dikes and pods are locally abundant in and near Precambrian crystalline rocks exposed in the mountain regions of central and northwestern Arizona. In limited areas pegmatite dikes and pods are located near younger crystalline rocks. In nearly all cases the crystalline rocks are granites and quartz monzonite (similar to granite, but with less potash, feldspar, and more sodium-calcium feldspar). Between 5 and 20 percent of the pegmatites contain beryl.

Beryl bearing pegmatites occur in specific localities in a trend that extends from the northwest corner of the State to the southeast part of the State. This general trend is from 50 to 200 miles wide.

Zoned pegmatite dikes may contain beryl in any zone, from wall to core, however, it is more common in the inner zones. Zones that contain lithium minerals such as amblygonite and spodumene almost always contain beryl.

A brief discussion of a few of the prominent beryl-in-pegmatite occurrences will familiarize the prospector with some of Arizona's occurrences. Regionally, the occurrences are divided into the northwest area, the central area, and the southern area.

The city of Kingman is located in the northwest area. Beryl pegmatites occur in a number of the mountain ranges in this area, including the Virgin Mountains, the Cerbat Mountains, the Haulapai Mountains, and the Aquarius Mountains. Occur-

rences include the Hummingbird, the Jeanene, and the Rare Metals Mines and numerous others that are discussed in "Beryl-Bearing Pegmatites in the Ruby Mountains and Other Areas in Nevada and North Western Arizona", U.S.G.S. Bulletin 1082-D.

The Hummingbird Mine is located in the virgin Mountains in the northwest corner of the State. The nearest communities are St. George, Utah, and Mesquite, Nevada. The pegmatites at the Hummingbird occur in a complex of mica-schist-garnet, quartz-mica-schist and granitic gneiss.

The Jeanene Beryl Deposit is located east of Yucca, Arizona in the Hualapai Mountains. It is discussed in the Department's Jeanene Beryl mine file. The deposit is a zoned pegmatite in granite. The pegmatite is zoned with a quartz core 5' - 10' thick; an intermediate zone of albite feldspar, biotite mica, beryl, and occasionally spodumene 3' to 6' wide. The pegmatite sits atop a diabase dike and is in contact with Precambrian granite above. The overall dimensions of the exposed pegmatite are approximately 125 feet in length and up to 30' wide. Many small 1/4" to 3/4" x 6" to 8" euhedral blue to blue-green beryl crystals occur in the intermediate zone. The beryl comprises up to an estimated 3 percent of the beryl zone.

The Rare Metals mine is located in the Aquarius Mountains east of Wickiup, Arizona. The mine has been a past producer of beryl. The deposit is a zoned pegmatite in granite. The main pegmatite mass is over 600' long and about 40' wide. The beryl occurs in a muscovite rich zone that borders on a conspicuous core of quartz. The deposit also contains several rare earth minerals.

Congress, Arizona is geographically located in about the center of Arizona's pegmatite belt. Notable beryl bearing pegmatites in the central region include those of the White Picacho Mining District and the Weaver Mountains.

The most productive pegmatite deposits in Arizona are those of the White Picacho District southeast of Wickenburg and northeast of Morristown. In this area, complex pegmatites occur as dikes, pods, and irregular bodies in Precambrian metamorphic and igneous rocks throughout an area of about 150 square miles. Beryl has been produced from several mines in the district. The Midnight owl, Outpost Lode, and Homestead Lode have been the most productive.

Beryl is present in almost all the pegmatite zones. It occurs in border zones and wall zones as pale yellowish, greenish, and bluish gray anhedral crystals that are 1/8" to 2 1/2" in maximum dimension, and locally is abundant. Most of the crystals are very irregular in form, and so not show marked elongation. In general they are not readily distinguished from some quartz and feldspar, although they have a characteristic greasy luster that can be recognized by the practiced eye. Much larger crystals with rough faces occur in many of the inner zones, generally as thick prisms 2" to 11" long. These are pale greenish gray to pinkish, and commonly are associated with lithium minerals.

The coarsest beryl in the district occurs in the inner parts of the pegmatite bodies, where it generally is associated with massive quartz. Beryl bearing inner zones contain from 0.08 percent to 1.6 percent of this mineral. However, many other zones appear to be completely barren of beryl.

The largest masses of the beryl are only about a foot in maximum dimension but they can be separated economically from the broken rock by hand methods, especially by persons who have learned to recognize the characteristic pale colors and somewhat greasy luster of the mineral. The much smaller anhedral crystals in the outer zones of several pegmatite bodies probably could not be

recovered economically except by some mechanical means. These crystals represent a potentially important reserve of marketable material, and in some border-zone deposits, like those in the Midnight Owl pegmatite, they constitute 3 - 8 percent of rock masses that amount to 50 tons or more.

The Dixie Queen Mine is located northwest of Yarnell in the Weaver Mountains. The exposed pegmatite body measures approximately 100' wide and 300' long. The major constituents of this pegmatite deposit are (in decreasing order of abundance) potassium and sodium feldspars, quartz, muscovite mica, and beryl. It is estimated that beryl makes up about 1.5 percent of the deposit. The beryl typically occurs in pockets as large crystals where the mineral accounts for about 50 percent of the material. Single beryl crystals up to 14" in diameter and 40" long have been observed by the writer. The beryl ranges in color from a very pale blue through a greenish-yellow to a honey yellow.

Tucson is geographically located in the south central region of the pegmatite trend. Pegmatite deposits containing beryl in this region include the Twilight and Grey Mine in Graham County and the Sharon D. in Pima County. Additionally, a number of non-pegmatite beryl deposits occur in Cochise County.

The Twilight and Grey occurrence is located in south central Graham County. The deposit is a pegmatite in granite. The pegmatite contains scrap and a small amount of sheet mica and scattered beryl crystals. Some good beryl crystals have occasionally been found. The overall beryl content has been estimated at about 3 percent.

The Sharon D. occurrence is one of many in an area located in the northeastern pediment of the Sierrita Mountains west of the community of San

Xavier. The Sierrita Mountains are made up of granitic intrusive complex.

The beryllium bearing or complex pegmatites are small, typically about 30' in length, about 20' wide, and lens-like in shape. These complex pegmatites contain two zones, an inner "core zone" and an other "border zone." A third intermediate zone may be present locally. The core or inner zone consists entirely of massive white, translucent quartz, although a few random crystals of beryl have been reported in the core of the Sharon D.

The beryl in this area is a fine to coarsely crystalline, translucent to transparent, light blue mineral. Some of the crystals could be considered aquamarine. The crystals range in size from microscopic to a foot in length and a couple of inches in diameter. The beryl is restricted to the outer zone of the pegmatite except for a few large crystals that occasionally occur in the gray quartz in the inner zone. No lithium minerals are known in the pegmatites of this area. The area also has many small pegmatite dikes that are simple and contain no beryl.

Details of additional known beryl-bearing pegmatites are given in some of the bibliography references.

What About A Prospecting Method?

Prospecting for beryllium pegmatites shares some characteristics similar to any prospecting effort and has a few special characteristics.

Any prospecting venture should start with a familiarization of where deposits are located. The maps on the following page show some known areas of pegmatites that contain beryl and additional areas suggested for prospecting.

Most pegmatite minerals have a specific gravity similar to common rock forming minerals. Thus, panning gravels in drainages would be of little help in finding a beryl pegmatite. Columbite, tantalite, and bismuth minerals, all of which are heavy, valuable, and occur in pegmatites, can be concentrated by panning.

Most pegmatite dikes are easily visible as outcropping structures. Quartz, the major constituent of the dikes is resistant to weathering and forms prominent outcrops that would be visible from the air and on detailed aerial photographs.

A prospecting routine of finding probable pegmatites by reconnaissance, airplane, and studying aerial photographs, then visiting each site to determine if in reality it is a pegmatite would be a start.

Each pegmatite located should then be prospected for beryl. Such prospecting will require a detailed examination of the deposit. Walk along the entire outcrop, break off and examine many samples. If beryl is not found in the samples by visual examination, save a few samples for the lithium flame test. If lithium is detected it is probable the deposit also contains beryl. Study and prospect in close detail any pegmatite that contains lithium.

One note of special interest, there has always been some sort of market for hand cobbled beryl ore. Therefore, even good beryl prospects will not have much visible and easily identifiable beryl on the surface. The drilling of shallow holes and shooting outcrops may be a help in evaluating the pegmatite's potential.

Mining Beryl From Pegmatites

Pegmatites in which beryl can be identified should be evaluated for possible production. Sampling to determine average ore grade and tonnage of specific rare metals in a pegmatite is probably a waste of time. But some sampling and testing is necessary before trying to start a full time mine. Make sure a marketable ore can be produced. This can be done by hand mining and sorting a few hundred pounds of beryl. Send or bring a sample of the sorted material to the Department. No mine should be started only to find out that even the best hand sorted beryl from the mine will run only 5% BeO because of intergrowths of other minerals in the crystal structure of the beryl.

A small beryl ore mining operation typically consists of drilling and blasting the pegmatite and working the broken rock by hand to sort the beryl and other marketable minerals from the waste. Those pieces containing beryl with other minerals are hand cobbled to remove the waste. Some minerals such as clean quartz, mica, and feldspar should be stockpiled for possible future marketing since it must be handled anyway.

Such operations can be run by as few as two miners who could produce a marketable product with minimum equipment and no mill.

SUGGESTED PROSPECTING AREAS FOR BERYL

