BLUE PECTOLITE FROM THE DOMINICAN REPUBLIC

By Robert E. Woodruff and Emmanuel Fritsch

Blue pectolite from the Dominican Republic, also known by the trade name Larimar, has recently entered the U.S. market. Large quantities of this attractive ornamental stone have been found in cavities and veins of altered basalt. Most of the gemological properties are consistent with those previously reported for pectolite; the cause of color in this material is believed to be related to the presence of small amounts of Cu^{2+}. The color appears to be stable to light, but does react to irradiation and to the heat of a jeweler's torch. It is easily separated from similar-appearing materials.

ABOUT THE AUTHORS

Dr. Woodruff, a professional entomologist who has studied insect inclusions in amber, is the owner of Woodruff's Gems, Gainesville, Florida. He has been involved in the marketing of pectolite since 1975 and has made numerous trips to the mine. Dr. Fritsch is research scientist at the Gemological Institute of America, Santa Monica, California.

Acknowledgments: The authors thank Ramón Ortíz for his hospitality and contributions to this study. Jake and Marianella Brodzinsky provided housing and technical assistance in the Dominican Republic. Samples and information were also provided by Charles Mark, of Mountain-Mark Trading Ltd. Dr. James Shigley provided helpful suggestions. Waldo Winterburn and Dr. Julie Paque, of Stanford University, did the wavelength-dispersive XRF and microprobe analyses respectively. C. W. Fryer obtained the X-ray diffraction patterns. Skip Franklin prepared many of the samples for spectroscopic studies. Dr. George Rossman, of the California Institute of Technology, helped with the irradiation experiment.

Gems & Gemology, *Vol. 25, No. 4, pp. 216–225*

The Dominican Republic is perhaps best known to gemologists as an important source of amber and conch "pearls." Since 1986, however, it has gained recognition as the source of a relatively new gem material, blue pectolite. Although actively mined since about 1974, blue pectolite has recently benefited from greater availability and broader distribution (Koivula and Misiorowski, 1986a). Previously, gem pectolite occurred only in an unattractive white to gray color and was considered rare because of its scarcity in pieces suitable for cutting (Webster, 1983; Liddicoat, 1976). The new and more plentiful supply of blue, and less commonly green, pectolite has helped it achieve recognition as an excellent lapidary material (figure 1); carvings are now on display in the Smithsonian Institution and the Lizzadro Museum (Lizzadro, 1987).

The first mention of this material in the gemological literature was by Arem (1977). Although he does not list blue under the possible colors of pectolite, he includes a photograph of some Larimar cabochons. More recently, two articles have appeared in the lapidary and consumer literature (Woodruff, 1986, 1987). The present article reviews the deposit where this material is found, its history, location, and geology. Also examined are the gemological properties of pectolite, including chemistry, cause of color, and reaction to treatment.

LOCATION AND ACCESS

The Dominican Republic occupies the eastern portion of the island of Hispaniola (figure 2). The blue pectolite is found approximately 170 km southwest of the capital, Santo Domingo (Ciudad Trujillo), just west of Baoruco, a small village south-southwest of Barahona in the province of the same name. The climate is tropical and the vegetation luxuriant. Waterworn fragments of pectolite were first found in the alluvials of the Río Baoruco and later traced to their in-situ source upstream.

Figure 1. The 26 × 14 mm cabochon of fine blue pectolite in this silver ring is from the Dominican Republic. Behind it is an excellent example of some of the best rough material. Photo by Kris Illenberger; courtesy of Mountain-Mark Trading Ltd.

The actual deposit is located on the road to Filipinas in an area known as Los Checheses (two localities so small that they do not appear on local maps). The entrance to this road is about 3 km north of Baoruco. Dirt roads lead to the mine, but four-wheel drive vehicles are needed to negotiate the last few kilometers of the journey. The area is accessible all year round.

The pectolite is found in various portions of a single volcanic deposit approximately 0.15 km^2 in surface area. The Río Sitio, a small stream that drains into the Río Baoruco, was probably the carrier of those tumbled pieces first found at Baoruco.

HISTORY

In 1974, Norman Rilling, a Peace Corps volunteer, reportedly found some blue stones at Baoruco that were later identified as pectolite (Woodruff, 1986). By 1975, specimens had already appeared in jewelry shops in Santo Domingo. Many unverified stories exist about the find and subsequent developments (Woodruff, 1986), but it is known that Miguel Mendez, a local resident, originally was the sole supplier to the domestic trade. According to Luis Augusto Gonzales Vega, lawyer and owner of property on which a portion of the deposit occurs, he and Mendez formed a corporation to mine and market pectolite. The original documents of this venture give the trade name Travelina, but this was later changed to Larimar, coined by Mendez from his daughter's nickname *Lari* combined with the Spanish word for sea, *mar*. This trade name has been used consistently since 1975, although neither Gonzales Vega nor Mendez is currently involved in the marketing of this material.

All mineral rights in the Dominican Republic belong to the government, and pectolite mining is permitted only by concession from the Minería, the Dominican Bureau of Mines. By 1985, nearly 100 miners were working the deposit. To avoid confusion, overlapping claims, and disputes, the Minería suggested that the miners form a cooperative and sell Larimar only from a small outlet in the town of Baoruco. After the cooperative was formed, Ramón Ortíz of Puerto Plata purchased the eastern part of the deposit and obtained a 10-

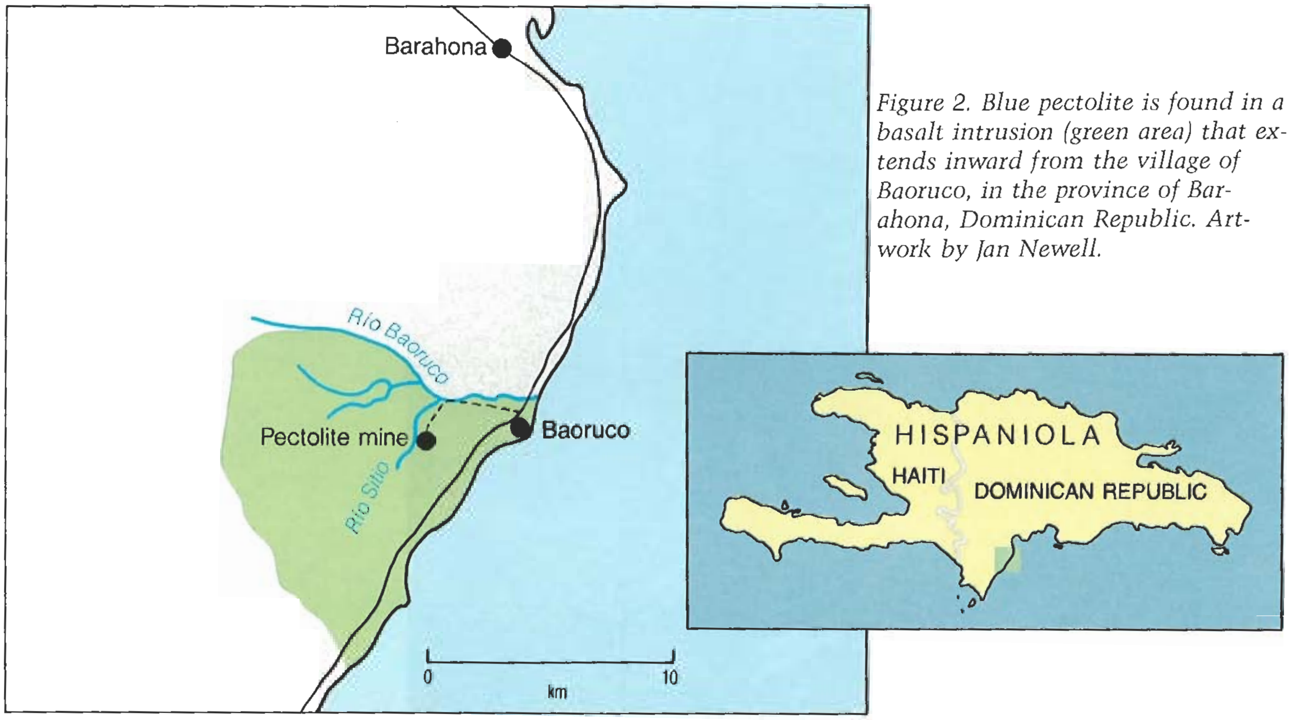


Figure 2. Blue pectolite is found in a basalt intrusion (green area) that extends inward from the village of Baoruco, in the province of Barahona, Dominican Republic. Artwork by Jan Newell.

year mining concession. His miners and those of the cooperative work side-by-side. Currently, as many as 150 miners are involved on an irregular basis. Pectolite may be purchased either at the mine—from the cooperative or from Ortíz—or at the cooperative building in the village of Baoruco.

GEOLOGY AND OCCURRENCE

The commercial quantities of blue pectolite available today are all mined at the primary deposit in the mountains above Baoruco. The few stones collected in the bed of the Río Baoruco, where it was originally discovered, are mostly small, tumbled pieces, although some are of excellent quality.

The Barahona peninsula extends south of a major west-east depression containing Lake Enriquillo (approximately 40 m below sea level). This peninsula is composed of Tertiary limestones (Oligocene to Miocene), with a few enclaves of Upper Cretaceous volcanic rocks described as basalts and andesites (Zoppis de Sena, 1969). The main basalt intrusion, in which the pectolite is

Figure 3. This exceptionally large (about 20 cm) slice of a pectolite vein shows the mineral and color zonation typical of this gem material. Natrolite (light gray) and chalcocite (black) crystallize, for the most part, on the walls of the vein. In this sample, they are followed by red sprays ("plumes") of hematite crystals intergrown with several generations of blue pectolite of different color intensity and transparency. Fibrous colorless pectolite and white calcite fill the center. Photo by Robert Weldon.

found, extends from the coast inward at the latitude of the village of Baoruco (again, see figure 2). The volcanic rocks have been intensely weathered and for the most part are altered to fine-grained serpentine. The only recognizable mineral visible in thin sections of the basalt matrix is clinopyroxene in small twinned crystals.

Indications of copper, especially chalcocite, have been reported in these basalts (Vaughan et al., 1921). Blue pectolite occurs as a hydrothermal mineral in cavities and veins in the altered basalt. This is the typical occurrence for the white to gray material, as already noted for pectolite deposits in Italy, Scotland, and the United States (Webster, 1983). Sprays of elongated natrolite crystals are sometimes present on the walls along which pectolite crystallizes in finely fibrous spherulites (figure 3). No other zeolites have yet been found in this deposit. Colorless calcite is also commonly associated with the blue pectolite in these veins. Rarely, peridot crystals and small amounts of white pumice are found as well.

The blue pectolite does not occur systematically; generally the veins are found under an uppermost layer of altered basalt that contains red hematite. These veins may disappear or enlarge very suddenly (unlike the system of fractures associated with pegmatite veins, for example).

Petrified, carbonized logs are found embedded in the altered basalt. Rarely, some logs even exhibit a filling of blue pectolite in fractures between the rings of the wood (figure 4).

Figure 4. This 17-cm slab of fossilized wood found at the mine shows blue pectolite between the rings.

MINING

Most mining is open pit, with miners using only pick, shovel, and hammer to break the weathered basalt in search of pectolite. Until recently, the pits averaged 1 m across and were no deeper than 10 m. The heavy rainfall common to this area floods the pits periodically, so mining is intermittent. The recent acquisition of a scraper and a pump has resulted in a number of pits that are larger (as much as 10 m in diameter) and deeper (as much as 25 m) than average (figure 5). This acquisition coincided with the development of the western area of the deposit. The fine blue of the gem-quality material found in this newer area contrasts

Figure 5. Although much of the area is marked by small pits dug by hand, the newly developed part of the mine uses more sophisticated equipment and techniques to excavate deeper, larger pits in the weathered basalt that hosts the blue pectolite. Photo by Richard Barrett; courtesy of Mountain-Mark Trading Ltd.

Figure 6. A striking contrast is seen between this fine blue pectolite (15 × 21 mm) found in 1987 and a green cabochon (18 × 25 mm) with considerable matrix and natrolite inclusions found in 1975. The stone on the left is representative of the finest color found to date. Photo by Robert Weldon.

markedly with the poorer quality green stones (figure 6) originally found in the mouth of the Río Baoruco. Many miners work only when they are not picking coffee—which is harvested from November to February—or fishing.

GEMOLOGICAL PROPERTIES

Six samples of Larimar were tested by X-ray powder diffraction to confirm their identity as pectolite, $NaCa_2Si_3O_8(OH)$. While pectolite is decomposed and gelatinized by HCl (Deer et al., 1978), it does not effervesce to the standard 10% solution commonly used in testing (Liddicoat, 1988); if effervescence occurs, it is due to the presence of calcite inclusions.

Visually, blue pectolite displays finely fibrous spheroidal aggregates in polished slabs or cabochons; some pieces show patches of what appears to be chatoyancy. The range of color is similar to that of turquoise (figure 7), although most valued are the few darker specimens that resemble chrysocolla. White calcite veinlets between the spherules are common, and hematite inclusions form fern-like patterns in some pieces that are referred to as "red plume." Homogeneous pieces of rough seldom exceed 10 cm.

Index of Refraction. We measured R.I. on a flat, well-polished surface of each of 12 samples of blue and green pectolite, and determined a range of 1.59–1.63 for this polycrystalline material. This corresponds to that reported for pure pectolite (Deer et al., 1978). Less accurate measurements by the spot method ranged from 1.57 to 1.63, with the variations due to different contents of iron and manganese (Arem, 1977; Schmetzer, 1984).

Specific Gravity. Measurements obtained by the hydrostatic method on five of the sample stones varied from 2.62 for the green material to 2.87 for a fine, homogeneous blue cabochon. A specimen with numerous chalcocite inclusions showed an S.G. of 2.90. These values are consistent with measurements of 2.84–2.90 reported by Deer et al. (1978) and 2.74–2.90 by Schmetzer (1984). Note that the green pectolite with the lowest S.G., 2.62, in our sample group contained numerous natrolite inclusions (S.G. of 2.20–2.25).

Hardness and Toughness. Scratch tests on freshly mined material suggest a Mohs hardness of somewhat over 5 to as much as 6 for finely fibrous, compact material. Although the book value for pectolite is 4½–5 (Roberts et al., 1974; Deer et al., 1978), fibrous types may be expected to have a higher value as well as greater toughness than their monocrystalline counterparts, because each grain boundary forms a barrier to the propagation of microfractures induced by the scratch (Fritsch and Misiorowski, 1987; M. Gardos, pers. comm., 1989). The toughness of blue pectolite is excellent, although pieces less than 2 mm in thickness may tend to flake. Carvers report that they work this material using methods and agents similar to those used to carve jadeite. Like jadeite, pectolite also takes an excellent polish.

Fluorescence. More than 20 specimens of blue and green, rough and cut, pectolite were examined for their reaction to long- and short-wave radiation. The blue pectolite exhibited a moderate, zoned fluorescence to long-wave U.V. A very chalky green usually predominated, with some zones more yellow and others almost blue. Fluorescence was weaker in areas of very deep blue as compared to those with the fibrous whitish material. The green pectolite fluoresced yellow to long-wave U.V.

Fluorescence to short-wave U.V. of both colors of pectolite was much more homogeneous and slightly more intense; the color was a very turbid green. Sinkankas (1964) reported that pectolite fluoresces orange to short-wave U.V.; we presume

Figure 7. The different colors of Larimar are similar to that of turquoise. These reference stones, all about 16 × 11 mm, illustrate the general grading system used for the various qualities of pectolite: good blue (top left) to green (bottom, middle) and "red plume" (middle right). Stones courtesy of Mountain-Mark trading Ltd.; photo by Robert Weldon.

that this is due to the high manganese content of the gray to white varieties then known.

Inclusions. Red dendrites, identified by X-ray diffraction as hematite, create distinctive fern-like patterns in the so-called "red plume" variety; most such dendrites appear in outer portions of the pectolite veins (again, see figure 3). The carver of the elephant in figure 8 took advantage of such patterns to create a drapery effect on the back of the beast. Hematite is abundant in the altered basalt just above the pectolite-bearing veins.

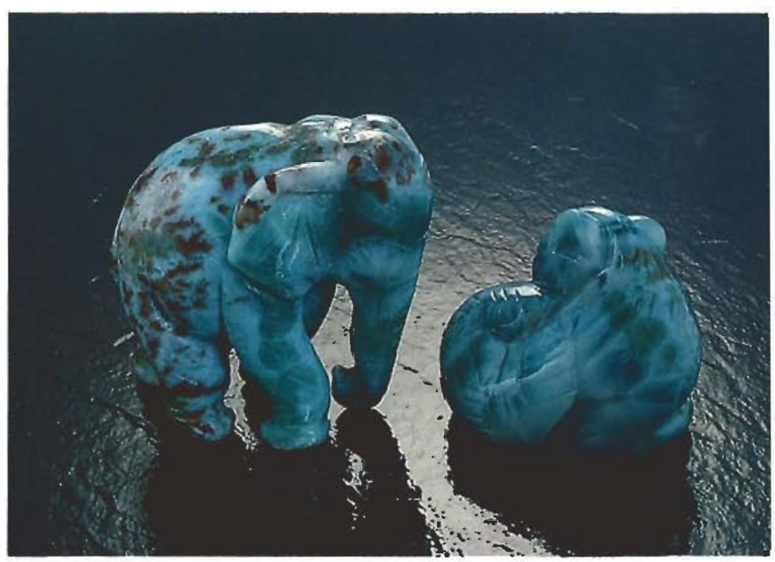
More common are white to gray squarish patches of calcite that may be as large as 2 mm in maximum dimension (figure 9). Calcite also occurs as submicroscopic crystals between the ends of the pectolite fibers. Natrolite, another common inclusion, appears as transparent light gray sprays of elongated square crystals in the pectolite. When a cabochon is cut perpendicular to the main orientation of a natrolite spray, the surface is marked by shallow undercut pits of square or lozenge shape.

Chalcocite forms clusters of microscopic black flakes (again see figure 9) and sometimes adopts euhedral form (figure 10); material that is heavily included with chalcocite is not used for gem purposes. Rarely, native copper may be present, usually fairly close to the wall of the vein.

CHEMISTRY AND CAUSE OF COLOR

The chemical composition of three samples of blue pectolite was determined with an electron microprobe (Joel 733 Superprobe). The results, shown in table 1, are similar to those published previously for pectolite from other localities (Deer et al., 1978). The presence of manganese is not surprising, as it is known to substitute easily for calcium

Figure 8. In these two blue pectolite carvings produced in Thailand, the carver has used the "red plume" layer to mimic a drapery on the elephant's back and the sheen of the fibrous pectolite to suggest the cat's fur. The elephant is approximately 5 cm high × 5 cm along its base. Photo by Robert Weldon.



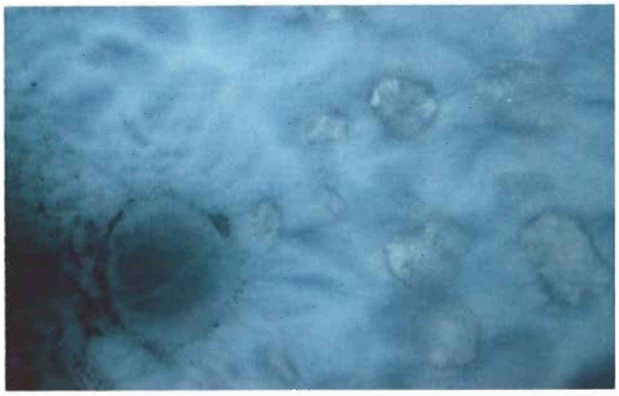


Figure 9. These squarish, slightly fibrous light gray inclusions are calcite crystals. Microscopic flakes of black chalcocite sometimes form "black eyes" (bottom left) in blue pectolite. Photomicrograph by John I. Koivula; magnified 10×.

Figure 10. Rarely, minute euhedral monoclinic crystals of chalcocite are scattered in the blue pectolite. The presence of this copper sulphide strongly suggests that the color is related to traces of Cu. Photomicrograph by John I. Koivula; magnified 2×.

in the crystal structure (in fact, pectolite forms an isostructural series with serandite, the manganese analogue of pectolite; see Deer et al., 1978).

The copper content, too low to be determined accurately with the electron microprobe, was obtained by means of wavelength-dispersive X-ray fluorescence (WDXRF) using a Rigaku spectrometer. Three measurements, in different areas of a single sample of good color, gave a remarkably homogeneous concentration of 46 to 47 ppm copper.

TABLE 1. Chemical composition of light blue and dark blue pectolite from the Dominican Republic.[a]

Oxide	Light blue	Dark blue
MnO	0.06	nd[b]
FeO	nd	nd
SiO_2	53.74	52.36
Al_2O_3	0.07	0.04
CaO	35.50	36.27
MgO	nd	nd
CuO	0.01	0.03
TiO_2	nd	nd
Cr_2O_3	nd	nd
Na_2O	8.10	8.13
P_2O_5	0.11	0.11
K_2O	0.02	0.02
Total	97.61	96.95

[a]*Microprobe analyses performed at the Center for Materials Research, Stanford University, by Dr. Julie Paque. The total composition does not equal 100% because water, a component of pectolite, cannot be measured with an electron microprobe. The range of water concentration measured in pectolite is 2.25% to 4.08% (Deer et al., 1978).*
[b]*nd = not detected.*

Similar features were observed in the optical absorption spectra of all six blue pectolite slices examined using a Pye Unicam 8800 spectrophotometer (figure 11). A strong absorption in the ultraviolet decreases toward the red end of the visible spectrum, except for a very broad, asymmetric absorption band centered at approximately 630 to 650 nm in the red. This creates a transmission "window" in the blue at around 480 nm, from which the blue color of the pectolite is derived.

The spectrum of the rarer green variety (two specimens studied) is similar to that of the blue specimens (again, see figure 11). However, the absorption centered in the ultraviolet expands about 80 nm further into the visible. A weak, very broad band centered at around 470–475 nm is present on its slope. Both features are apparently responsible for shifting the transmission window from 480 to approximately 510 nm, which explains the green color of this material. More detailed chemical and spectroscopic data are necessary to interpret those relatively minor variations.

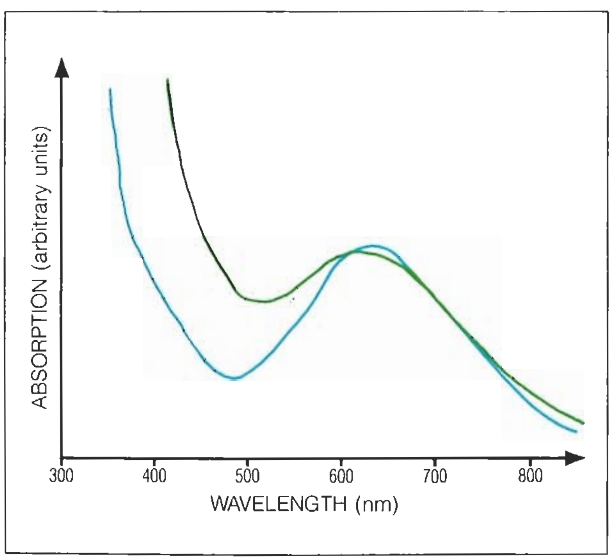
These pectolite spectra are reminiscent of those of turquoise, which might suggest that the two materials have the same coloring agent (Koivula and Misiorowski, 1986b). However, turquoise contains copper as a major constituent, while it is present only as traces in pectolite. The occurrence of copper in silicate minerals is rather unusual, and there is little research available on this coloring mechanism (Gordon Brown, pers. comm., 1986).

We do know that the absorption coefficient of the main copper absorption in the red is 373 to 691 mol^{-1} cm^{-1}, assuming a homogeneous copper concentration of 50 ppm. This contrasts sharply with values of 6 to 40 mol^{-1} cm^{-1} for coloration due to isolated Cu^{2+} ions (Lehmann, 1978; Rossman 1988). This, along with other technical arguments, suggests that the absorption might be due to processes involving multiple atoms, probably within small clusters of Cu^{2+} ions. Even for a small overall concentration, such processes may absorb light efficiently enough to produce the depth of color seen in fine blue pectolite. However, the details of the electronic transitions involved are not known at present.

COLOR STABILITY

To test for color stability, we cut a specimen of blue pectolite into two parts and exposed one to light at the end of a FiberLite for more than 50 hours. No noticeable difference in color was observed when this specimen was compared to the unexposed control.

Figure 11. The optical absorption spectra of blue and green pectolite show an increasing absorption toward the ultraviolet and a broad, asymmetrical band centered at around 645 nm, which is attributed to trace amounts of copper. The position of the resulting transmission window (480 nm for the blue and 510 nm for the green) accounts for the color. Artwork by Jan Newell.



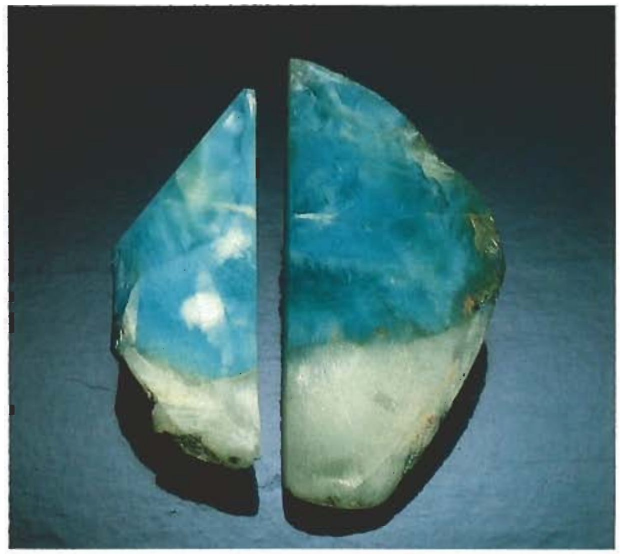


Figure 12. The left part of this pectolite slice was submitted to a jeweler's torch for a few seconds, while the right section remained untouched. The heated section shows a loss of color and transparency that is due in part to the development of small fractures which also reduce the toughness of the specimen. Photo by Robert Weldon.

TREATMENT

We do not know of any effort to commercially enhance blue pectolite. Rumors in the Dominican Republic about dyeing low-quality material with a copper sulphate could not be substantiated, and we have no direct evidence that such a treatment has been performed.

We submitted a slab of blue pectolite to a dose of 16 Mrads using Cs-137 gamma rays. Irradiated in this fashion, the specimen turned mostly violet, although small blue spots remained and the white areas (calcite) turned brown. The violet coloration is thought to be due to the formation of Mn^{3+} by irradiation of Mn^{2+}, which is present in trace amounts in blue pectolite (again, see table 1). For further discussion of Mn^{3+} as a coloring agent, see Fritsch and Rossman (1988).

When exposed to the flame of a jeweler's torch, pectolite tends to get whiter as a result of the propagation of small cracks (see figure 12). Also, some transparency is lost in the process. However, no noticeable change in color or transparency was observed in a thin slab of blue pectolite that was heated in an oven to approximately 300°C for 10 hours.

Figure 13. Blue pectolite is used in virtually any type of jewelry as well as in carvings. Photo by Jeff Lotz.

SEPARATION FROM OTHER MATERIALS

Because of blue pectolite's distinctive appearance, only a few materials are likely to be mistaken for it. "Victoria stone," a devitrified man-made glass, shows a fibrous structure similar to that observed in high-quality pectolite. However, the fibrous aggregates in pectolite are much smaller and more irregular, and none of the colors in which "Victoria stone" is produced actually matches those of Dominican pectolite. Recently, GIA's Technical Development Department noted the similarity of Larimar to "Imori stone," a partially devitrified glass (manufactured in Japan) into which fibrous inclusions are induced to give it an overall fibrous appearance. However, the vividness and homogeneity of "Imori stone's" color, as well as the perfection of its fiber bundles, makes its separation from pectolite relatively easy.

Although the best blue pectolite (figure 6) may resemble chrysocolla-stained chalcedony, fine pectolite has a higher R.I. (1.59–1.63 versus 1.46–1.57) and S.G. (2.87 versus 2.24 or lower).

PRODUCTION AND DISTRIBUTION

Since this deposit of blue pectolite was first discovered, production has been extremely erratic. No exact figures are available, although Ramón Ortíz estimates that 2,500 kg were removed in 1975, and 300–500 kg per week in early 1987. Unfortunately, no records have been kept, so it is difficult to estimate the volume and quality of the material produced between 1975 and 1987. In 1988, Ortíz reports, he had almost no production, and he believes that the cooperative also encountered little material. In mid-December 1989, however, four major veins of good-quality material were found in the western part of the deposit, which is being worked by the cooperative (C. Mark, pers. comm., 1989). There are no firm estimates of future reserves.

The material produced varies greatly in quality. Buying rough is considered a *lotería* (lottery) because the pectolite is difficult to grade without cutting. Ortíz estimates that about 20% is cuttable, but only 5% is truly gem quality. The presence of matrix and fractures further limits the usefulness of the material.

A simple grading system has been developed by one entrepreneur to help communicate with his customers (again, see figure 6). It is based on the relative proportion of blue, white, and green (in order of decreasing value) in a particular piece and the presence or absence of "red plume." Although a large lapidary market has yet to develop because of the limited availability of raw material, several dealers were selling the material at the 1989 Tucson Gem and Mineral Show. Larimar is also one of the few gemstones to be trademarked in the U.S., with the moniker "Gemstone of the Caribbean."

Blue pectolite is used in many types of jewelry, from rings and necklaces to bola ties (figure 13). One style typical of pectolite jewelry manufactured in the Dominican Republic is a silver necklace combining Larimar cabochons with white boar's tusk ivory ("Amber . . .," 1978). A market has also developed with "New Age" initiates, who appreciate blue pectolite in various nonstandard products, such as meditation wands and even as pebbles.

CONCLUSION

Although relatively little has been written on blue pectolite from the Dominican Republic, this new gem material has become a familiar item on the U.S. colored stone market. Production remains, however, unpredictable, and much of what we see on the market today was cut from material found some years ago. An organized effort is needed to understand the geology of the deposit and the distribution of the pectolite veins so that the commercial potential of this material can be better evaluated.

REFERENCES

Amber and Larimar (1978) *The Great Escape*, Vol. 2, No. 16, pp. 6–9.

Arem J. (1977) *Color Encyclopedia of Gemstones*, 1st ed. Van Nostrand Reinhold, New York.

Deer W.A., Howie R.A., Zussman J. (1978) *Rock Forming Minerals. Vol. 2A: Single Chain Silicates*, 2nd ed. Halsted Press and John Wiley & Sons, New York.

Fritsch E., Misiorowski E.B. (1987) The history and gemology of Queen conch "pearls." *Gems & Gemology*, Vol. 23, No. 4, pp. 209–221.

Fritsch E., Rossman G.R. (1988) An update on color in gems. Part 3: Colors caused by band gaps and physical phenomena. *Gems & Gemology*, Vol. 24, No. 2, pp. 81–103.

Koivula J.I., Misiorowski E.B. (1986a) Gem News: Pectolite. *Gems & Gemology*, Vol. 22, No. 2, p. 114.

Koivula J.I., Misiorowski E.B. (1986b) Gem News: Pectolite. *Gems & Gemology*, Vol. 22, No. 3, pp. 187–188.

Lehmann G. (1978) Farben von Mineralien und ihre Ursachen. *Fortschritte der Mineralogie*, Vol. 56, No. 2, pp. 172–252.

Liddicoat R.T. Jr. (1976) Developments and highlights at GIA's lab in Los Angeles. *Gems & Gemology*, Vol. 15, No. 5, p. 138.

Liddicoat R.T. Jr. (1987) *Handbook of Gem Identification*, 12th ed. Gemological Institute of America, Santa Monica, CA.

Lizzadro J. (1987) The interesting story of a new blue gem material called Larimar. *Lizzadro Museum*, Summer–Fall, pp. 13–14.

Roberts W.L., Rapp G.R., Weber J. (1974) *Encyclopedia of Minerals*. Van Nostrand Reinhold, New York.

Rossman G.R. (1988) Optical spectroscopy. In F. C. Hawthorne, Ed., *Reviews in Mineralogy, Vol. 18: Spectroscopic Methods in Mineralogy and Geology*, Mineralogical Society of America, Washington, DC, pp. 207–254.

Schmetzer K. (1984) Pektolith aus der Dominikanischen Republik. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 33, No.1–2, pp. 63–64.

Sinkankas J. (1964) *Mineralogy*. Van Nostrand Reinhold, New York.

Vaughan T.W., Cooke W., Condit D.D., Ross C.P., Woodring W.P., Calkins F.C. (1921) *A Geological Reconnaissance of the Dominican Republic*. Official Publication of the Secretaryship of State of Fomento and Communications, Washington, DC.

Webster R. (1983) *Gems. Their sources, descriptions and identification*, 4th ed. Revised by B. W. Anderson. Butterworths, London.

Woodruff R.E. (1986) Larimar, beautiful, blue and baffling. *Lapidary Journal*, Vol. 39, No. 10, pp. 26–32.

Woodruff R.E. (1987) The new Caribbean gem. *Aboard*, Vol. 11, No. 2, pp. 6–7, 35, 58–59.

Zoppis de Sena R. (1969) *Atlas geológico y mineralógico de la Republica Dominicana*. (No publisher noted.)