Emeralds of the Panjshir Valley, Afghanistan

By Gary Bowersox, Lawrence W. Snee, Eugene E. Foord, and Robert R. Seal II

With the withdrawal of Soviet troops from Afghanistan, villagers in the Panjshir Valley are turning their attention to the emerald riches of the nearby Hindu Kush Mountains. Large, dark green crystals have been found in the hundreds of tunnels and shafts dug there. Teams of miners use explosives and drills to remove the limestone that hosts the emerald-bearing quartz and ankerite veins. The gemological properties of Panjshir emeralds are consistent with those of emeralds from other localities; chemically, they are most similar to emeralds from the Muzo mine in Colombia. "Nodules," previously reported only in tourmaline and morganite, have been found in Panjshir emeralds as well. Approximately $10 million in emeralds were produced in 1990; future prospects are excellent.

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Although "emeralds" have been reported from this region for literally thousands of years, the Panjshir Valley of Afghanistan has produced commercial amounts of emerald only for the last two decades (figure 1). Because of the Soviet occupation of Afghanistan during much of this time, as well as regional political instability, access by Westerners has been limited. In July and August of 1990, however, the senior author visited the Panjshir Valley, collected specimens, and studied the emerald-mining operation.

He found that, although the conflicts in Afghanistan are far from settled, the *Mujahideen* ("freedom fighters") have shifted their energies from the Soviet troops they once battled to the harsh mountains that promise great riches (figure 2). As challenging as the Soviets were, the Hindu Kush Mountains are even more formidable. Commander Ahmed Shah Masood, known as the "Lion of Panjshir" (Follet, 1986), now governs more than 5,000 villagers mining emeralds in the Panjshir Valley (Commander Abdul Mahmood, pers. comm., 1990; O'Donnell, 1990). As first reported in Bowersox (1985), large (more than 190 ct) crystals have been found in the Panjshir Valley, in colors comparable to the finest emeralds of the Muzo mine in Colombia.

This article describes the Panjshir emeralds, their mining, geology, gemology, production, and marketing. The impact of emeralds from Afghanistan on the future gem market could be considerable (Ward, 1990), as the authors feel that the production potential of this area is excellent.

HISTORY

Most authorities believe that the only true emeralds known during ancient Greek and Roman times were from Egypt (Sinkankas, 1981). However, in his first-century A.D. *Natural History,* Pliny mentions "*smaragdus*" from Bactria (Gall, 1959), an area that includes present-day Iran

Figure 1. Only for the last two decades have fine emeralds been mined commercially in the many deposits that dot the Panjshir Valley of Afghanistan. These cut Afghan emeralds range from 1.04 to 12.49 ct. Photo © Harold & Erica Van Pelt.

and Afghanistan (Malte-Brun, 1828). *Smaragdus* is a Latin term that was used in ancient times to refer to emerald and many other green stones. It is questionable, though, whether any of the *smaragdus* from Bactria was emerald.

After Pliny, there is a void in the literature on gems of Afghanistan until approximately 1300 A.D., when the report of Marco Polo's travels of 1265 A.D. first appeared. Marco Polo mentioned silver mines, ruby, and azure (lapis lazuli) from Badakhshan.

Little is known about mining in the Panjshir (also spelled *Panjsher*) area from the time of Marco Polo until the 1900s. During the last 100 years, geologists from Great Britain, France, Germany, Italy, Japan, Canada, and the United States have produced many reports (see, e.g., Hayden, 1916; Argand, 1924; Bordet and Boutière, 1968; and Chmyriov and Mirzad, 1972) on the geology of Afghanistan, but virtually nothing had been written on the emerald deposits prior to 1976. In the early 1970s, emerald was discovered at what is now called the Buzmal mine, east of Dest-e-Rewat village in the Panjshir Valley (Bariand and Poullen, 1978). At about the same time, Soviet geologists began a systematic survey of Afghanistan's gem sources. Although this resulted in a number of publications (Rossovskiy et al., 1976; Abdullah et al., 1977; Rossovskiy, 1981; Chmyriov et al., 1982), the most detailed reports were not released. Following the death in 1973 of President Daoud, political changes hindered geologic work throughout Afghanistan. Nonetheless, in 1977 the names and locations of emerald mines in Panjshir were listed in a report by the United Nations Development Program (Neilson and Gannon, 1977). Agnew

Figure 2. The Hindu Kush Mountains are imposing obstacles to travel into and out of the Panjshir Valley. They are known, however, to carry great mineral wealth, including emeralds. Photo by Gary Bowersox.

(1982) also included a discussion of the Afghan emerald deposits. Information from these reports formed the basis for the senior author's 1985 *Gems & Gemology* article on the Panjshir deposits (Bowersox, 1985).

LOCATION AND ACCESS

The emerald mines are located at elevations between approximately 7,000 and 14,300 ft. (2,135 and 4,270 m) in mountainous terrain on the eastern side of the Panjshir River (figure 3). A dirt road follows the southwest-flowing Panjshir River for 90 mi. (145 km) and provides limited access to the mines. The road begins in the valley's northernmost village of Parian and extends southwestward through the villages of Dest-e-Rewat, Mikeni, and Khenj; Khenj is 70 mi. (113 km) from Kabul. The northernmost emerald deposit is located near the village of Aryu (also spelled *Arew*). The eastern extent of the emerald deposits is defined by the crest of the mountains east of the Panjshir Valley. Currently, the total area of known emerald deposits is approximately 150 sq. mi. (400 km^2) – double the area known in 1985. To the best of the authors' knowledge, Afghanistan has no producing emerald deposits outside the Panjshir Valley.

Because travel from the USSR, China, and Iran to Afghanistan is restricted, the only reasonable option for foreigners to enter the emerald-mining region of Afghanistan is through northern Pakistan. Border crossing, even with the permission of Pakistani authorities (which is not easy to obtain) and the Afghan commanders, is still extremely difficult and dangerous because of the rugged country, tribal rivalries, and the presence of land mines. Then, after crossing the border, one must travel by foot, mule, and horse (figure 4) for 150 mi. (240 km) through fields of land mines and over several mountain passes (some as high as 14,900 ft.) to reach the Panjshir Valley. The senior author needed six days to travel from the Pakistani

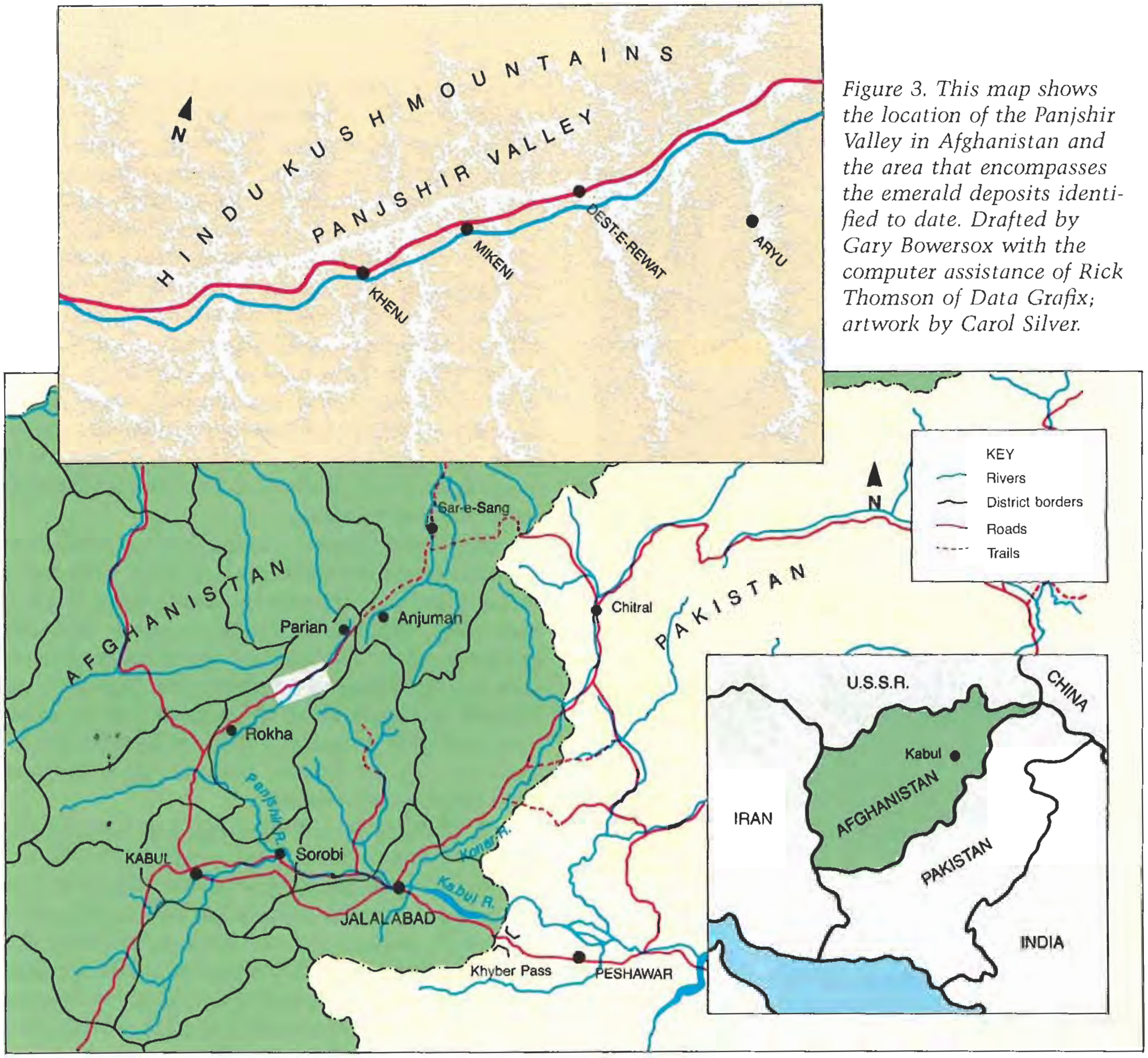


Figure 3. This map shows the location of the Panjshir Valley in Afghanistan and the area that encompasses the emerald deposits identified to date. Drafted by Gary Bowersox with the computer assistance of Rick Thomson of Data Grafix; artwork by Carol Silver.

border near Chitral to Panjshir in the summer of 1990.

The villages of Khenj (figure 5) and Mikeni are comparable to boom towns in the western United States during the gold-rush days of the mid-19th century. Although there are many shops with items such as tools for mining, wood for house construction, and food supplies, including familiar soft drinks such as Sprite and Pepsi, there is no electricity; candles or oil lamps provide light. The only communication with the outside world is via military radio, which is controlled by the local commander, Abdul Mahmood, and is used only for emergency and military purposes.

Because the mines are located at high elevations and the villages are several thousand feet below them, the miners live in tents at the mine sites from Saturday afternoon until Thursday afternoon of each week. During their two days off, they return to their villages to be with their families and to obtain supplies for the following week. Food is meager and mostly consists of rice, *nan* (a wheat bread), beans, and tea.

THE MINES AND MINING TECHNIQUES

The Buzmal mine is the oldest and, because the miners continue to use unsafe methods, the most dangerous mine in Panjshir Valley. This "mine" is actually a collection of literally dozens of pits and tunnels that speckle a mountain 10,000-ft. (ap-

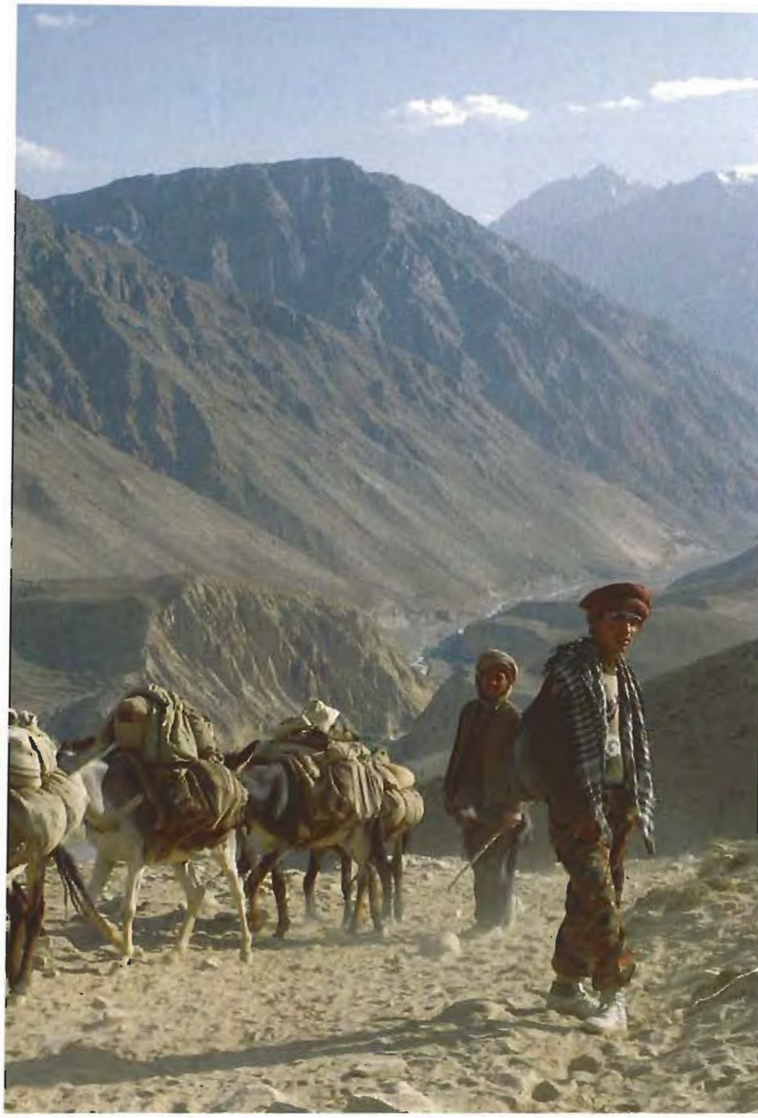


Figure 4. Mule trains are used to carry supplies into the Panjshir Valley from Pakistan. Not only is the path rough and steep in many places as one goes over the mountains, but fields of land mines also pose a constant threat. Photo by Gary Bowersox.

proximately 3,000 m) high. Each group of miners randomly picks a location for tunneling in the technique of "gophering," a term that refers to any small, irregular, unsystematic mine working. Each group tunnels into the limestone with drills and dynamite as far as 30 to 50 yards. The direction may be changed abruptly toward the tunnel of another group that has found emerald. Throughout the Panjshir Valley, the miners do not monitor the amount of explosive used (figure 6) or the timing of the explosions. They tend to use too much explosive, which often destroys the emerald crystals. The senior author experienced considerable uneasiness when, in a matter of minutes, six dynamite blasts from the shaft above shook a tunnel through which he was traveling.

Shafts and tunnels blasted into the limestone are usually approximately 4 ft. (1.2 m) wide and 4 to 5 ft. high, but they may be larger (figure 7). They are oval in shape and lack timber support. With the exception of the Khenj mine, there are no generators or compressors to light the hundreds of tunnels or supply air to the miners. For the most part, passageways are poorly lit by lanterns or oil-burning cans. Miners do not wear hard hats, so head injuries are common.

In addition to the blasting, gas- and diesel-powered hand drills are used, often well inside the tunnels, to work the hard limestone (figure 8). The smoke and carbon monoxide gas have made many miners ill, and caused death for a few. Even the local miners realize that these methods are dangerous; they leave the shafts frequently to breathe fresh air. Because the rocks are riddled with fractures, the potential for cave-ins is also great.

Picks or crowbars may be used on some of the loosened wallrock (figure 9) that does not come completely free with blasting or the drill. All of the broken rock is then carried out of the tunnel by wheelbarrow or simply with a large container. Once in daylight, it is quickly examined, as the miners search for signs of emerald. If no "green" is found, the "waste" rock is simply dumped over the side of the mountain (again, see figure 6). Rocks that do contain emerald are stored by the various members of the team at their campsite until they return to the village.

Figure 5. The village of Khenj bustles with activity these days. Emerald mining is now a primary industry in the region, and shops have sprung up to meet the many needs of mining and the miners. Photo by Gary Bowersox.

During colder months (October through May), snow forces the men either to work mines at lower elevations (where the emeralds found are generally of poorer quality) or sort through the waste rock that was dumped from higher-elevation mines during the normal working season. Plans are being developed for improved processing of the waste material.

There are several mining areas in addition to Buzmal, Khenj, and Mikeni: Sahpetaw, Pghanda, Butak, Abal, Sakhulo, Qalat, Zarakhel, Yakhnaw, Derik, Shoboki, Takatsang, Darun Rewat, Aryu, and Puzughur. They are all similar in both the workings and the character of the terrain; many are at the highest elevations. Work at some, however, is further complicated by the thousands of land mines still left in the area. For example, the mountain top near the Mikeni mine is unworked because it is a known land-mine field.

MINING PARTNERSHIPS

A typical mining team in Panjshir consists of eight miners who do not receive salaries but do share equally the profits from the sale of emeralds they find. Because each team requires blasting and mining equipment, they also normally allot three shares to those who provide mining equipment and three to those who provide blasting materials. Therefore, it is common for the income of a mining team to be divided 14 ways. Mining partners do not have to all be from the same village, but only miners from the local village have a voice at the *buly* of that village. *Buly,* in the Dari language (the most common in Afghanistan), refers to a meeting where the value of the recently mined emeralds is established, the stones are auctioned, and taxes are paid.

Disputes continually arise over mining rights and shaft ownership; they are normally settled by village elders. In difficult cases, the elders may transfer the dispute to Commander Mahmood and appointed judges located in Bazarat, the headquarters of the Jamiat-e-Islami party of Panjshir Province. Because there is no formal registration or bureau of conveyances for record keeping—and there have been diverse land ownership policies over the last 20 years—resolution of the claims is often very complicated.

REGIONAL GEOLOGY

Just as demographically Afghanistan is a collection of tribes and diverse peoples, geologically it is a collection of crustal plates. These plates amalga-

Figure 6. Blasting is common in all of the Panjshir Valley emerald mines. At the Khenj mine shown here, a smoke cloud can be seen toward the top of the diggings, the result of blasting in the mine shaft. Note also the large amount of waste material dumped from the mine. Photo by Gary Bowersox.

Figure 7. This shaft opening in limestone at the Khenj mine is one of the larger ones in the Panjshir Valley. Photo by Gary Bowersox.

Figure 8. Diesel-powered drills are also used to remove the hard wallrock. Because the miners wear virtually no protective gear, injuries from falling or flying rock—as well as illness from the carbon monoxide fumes—are common. Photo by Gary Bowersox.

mated between about 75 and 40 million years ago as fragments of Gondwana (an ancient supercontinent that began to rift apart about 200 million years ago) collided with, and sutured to, ancestral Asia, creating the Himalaya Mountains (Klootwijk et al., 1985; Scotese, 1990). These bits and pieces form a geologic mosaic that is now Afghanistan (De Bon et al., 1987). In fact, a study of the geologic history of Afghanistan provides an excellent example of the theory of plate tectonics (see, e.g., Wilson, 1976).

Panjshir Valley is a major fault zone between two of these crustal plates: the ancestral Asian plate to the northwest and the microcontinental fragment known as Cimmeria to the southeast. Panjshir Valley marks the location of the closure of a major ocean basin known as the Paleotethys.

GEOLOGY OF THE PANJSHIR EMERALD DEPOSITS

The emerald deposits lie southeast of the Panjshir fault zone (again, see figure 3). The geology of this part of the Cimmerian microcontinental fragment is not well known, but the rocks are thought to be an extension of those exposed in the southwestern Pamir Range (DeBon et al., 1987). The rocks of eastern Panjshir include abundant intrusions that were emplaced into a metamorphic basement comprising migmatite, gneiss, schist, marble, and amphibolite of presumed Precambrian age. These older crystalline rocks are overlain by a metasedimentary sequence of schist, quartzite, and marble of probable Paleozoic to Mesozoic age (Kafarskiy et al, 1976). Emeralds have been found only on the eastern side of the valley, even though the western side has been searched extensively. Until the geology of the Panjshir area can be mapped, the detailed nature of this fault zone, and the reason for the absence of emeralds to the west of the valley, will remain unknown.

During his trip to Panjshir, the senior author collected samples of host rock from the three emerald-mining areas of Khenj, Buzmal, and Mikeni. In general, these samples are from a layered metasedimentary sequence of probable Paleozoic age that was metamorphosed to the upper greenschist facies (figure 10). These metamorphic rocks were reportedly intruded by sills and dikes of gabbro, diorite, and quartz porphyry (Kafarskiy et al., 1976). The metasedimentary rocks are hydrothermally altered and are cut by quartz and ankerite (iron carbonate) veins that carry the emeralds (figure 11); pyrite is present in places. Emeralds are also found in silicified shear zones that contain phlogopite, albite, tourmaline, and pyrite

Figure 9. Picks and crowbars are also used in the mine to remove loosened wallrock. Photo by Gary Bowersox.

Figure 10. Emerald mineralization commonly occurs in the quartz and ankerite veins that traverse the sills and dikes intruded into the host limestone. Photo by Gary Bowersox.

Figure 11. The Panjshir emerald crystals are commonly found in quartz (here, from the Buzmal mine). It is not unusual to find literally hundreds of small crystals in a single block. Photo by Gary Bowersox.

as well. Some of the highest-quality material is found in veinlet networks that cut metasomatically altered gabbro and metadolomite.

ORIGIN OF THE PANJSHIR EMERALDS

Emerald, which is generally the result of the substitution of a small amount of chromium for aluminum in the beryl crystal structure (Deer et al., 1986), is the product of unusual geologic conditions. Two of the essential elements contained in emerald, chromium (which produces the color) and beryllium, are geochemically incompatible. Beryllium occurs most commonly in late-stage felsic igneous rocks, such as pegmatites. Chromium is found only in significant abundance in "primitive" rocks such as ultramafic igneous rocks that are characteristic of the ocean floor and mantle; in these rocks, however, beryllium is absent. Thus, special circumstances are necessary to bring chromium and beryllium together to form emerald.

More study of the rocks in the Panjshir Valley is needed before we can confidently draw a conclusion on the origin of the emeralds. However, we speculate that it is highly likely that the Panjshir fault zone is a suture between two crustal plates along which pieces of ultramafic rock, derived from the ocean floor that once existed between the two plates, were trapped. These slivers of ultramafic rock are common along similar structures elsewhere in the world (e.g., the Pakistan emerald deposits), and would be ideal sources of chromium. In addition, the numerous intrusive rocks, including quartz porphyries, of northwest Nuristan would be good sources for the beryllium-bearing hydrothermal fluid, which may have acquired chromium as it passed through chromium-rich rock before it altered the host rock of the emerald-bearing veins. Alternatively, Panjshir emeralds may have been formed during regional metamorphism caused by continental collision in a process similar to that described by Grundmann and Morteani (1989) for "classic schist-host deposits." A detailed discussion of the origin of emeralds, including those of Afghanistan, is presented in Schwarz (1987) and Kazmi and Snee (1989).

PHYSICAL AND CHEMICAL PROPERTIES OF PANJSHIR EMERALDS

Appearance. The emerald crystals from Panjshir vary in quality from mine to mine. As was reported to the senior author in 1985, the miners feel that the best material still comes from the Mikeni and Darkhenj (Valley of Khenj) mines, in the southern end of the mining region.

In general, the crystals are transparent to translucent or opaque. They are commonly color zoned, with very pale interiors and darker green exteriors.

Most of the crystals found to date range from 4 to 5 ct. Crystals over 50 ct continue to be found on a somewhat regular basis (figure 12). Crystals over 100 ct, such as the 190-ct emerald pictured in Bowersox (1985), are considered to be rare.

Morphology. The emeralds occur as euhedral, prismatic crystals with the following crystal forms:

Figure 12. Large emerald crystals are not uncommon in the Panjshir mines. The crystals shown here range up to 132 ct. Photo by Gary Bowersox.

{0001} basal pinacoid and {10$\bar{1}$0} first-order prism (common); {11$\bar{2}$0} second-order prism (rare). First- and second-order dipyramids were not observed on the crystals examined.

Gemological Properties. Examination of nine crystals ranging up to 10 ct revealed conchoidal fracture, vitreous luster, specific gravity of 2.68–2.74 (determined on whole crystals using a Westphal balance), and indistinct (0001) cleavage.

The samples tested proved to be uniaxial negative, in some cases slightly biaxial (2E approaches 6°) because of internal strain. The refractive indices (determined on crushed crystal fragments) of one light green crystal (S.G. = 2.73) were n_e = 1.582 and n_o = 1.588; the R.I.'s of one medium green crystal (S.G. = 2.70) were n_e = 1.574 and n_o = 1.580. These values, measured in index oils in sodium light, were representative of the nine crystals tested. All stones were distinctly dichroic: n_o = pale yellowish green, n_e = pale bluish green.

The crystals did not react to either long- or short-wave U.V. radiation. They appeared light red to reddish orange under the Chelsea color filter.

Inclusions. Polished sections of Panjshir emeralds were examined under a petrographic microscope and found to contain numerous primary, three- and other multiphase inclusions that are characterized by three distinct morphologies and crystallographic orientations. The three morphologies are chemically similar and define growth zones within the emeralds. The first group, tubular inclusions oriented parallel to the c-axis, range up to 1000 μm × 100 μm. The second group, tabular inclusions that formed perpendicular to the c-axis, typically are less than 250 μm in maximum dimension. The final group consists of subhedral, equant inclusions that occur at the intersection of zones defined by the first and second groups. These latter inclusions are typically less than 150 μm in diameter. The multiphase inclusions contain up to eight daughter minerals, an H_2O-dominated brine, and, in some, CO_2 – liquid and gas (figure 13). The most abundant solid displays a cubic habit, suggestive of halite (NaCl). A second isotropic phase of lower refractive index, probably sylvite (KCl), is the next most abundant daughter mineral and forms equant, subhedral grains. Most of these multiphase inclusions also contain up to two additional isotropic daughters and one or two highly birefringent, subhedral to euhedral rhombic phases (carbonates). Noted, too, in some inclusions are minute grains of other unidentified anisotropic solids. The total solids may comprise over 50% of the volume of the multiphase inclusion. Also common are oblique fractures that contain pseudosecondary multiphase inclusions similar to those described above. In addition, several samples contain numerous two-phase (H_2O – liquid and gas) inclusions of secondary or pseudosecondary origins that are oriented along oblique fractures.

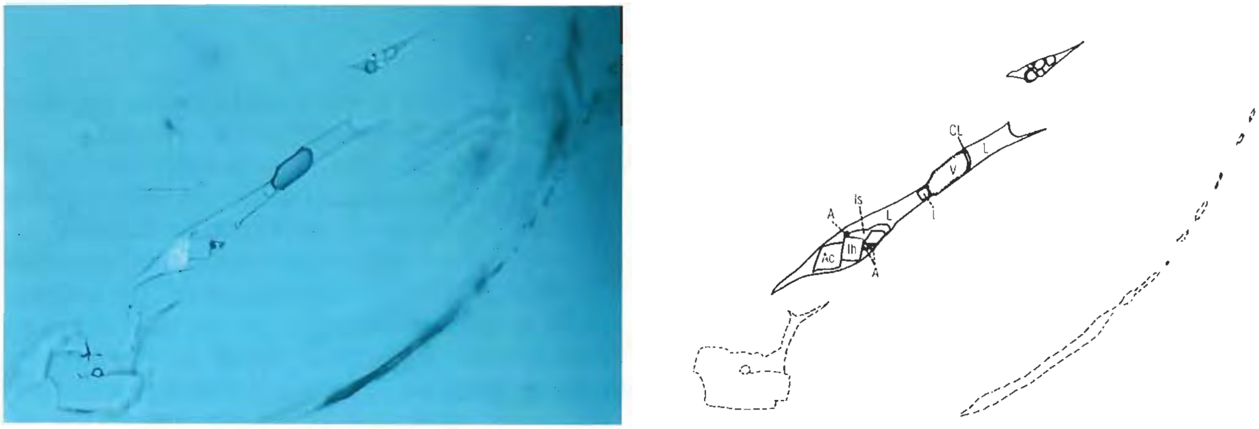


Figure 13. Multiphase fluid inclusions are common in Afghan emeralds. The larger inclusion here contains four isotropic and four anisotropic daughter minerals, brine (L), CO_2–liquid (CL) and vapor (V). The inclined cubic habit of the largest isotropic phase is suggestive of halite (Ih). The lower refractive index isotropic mineral may be sylvite (Is). The identity of the other isotropic daughters (I) is unknown. The large rhombic daughter is probably a carbonate (Ac). The identity of the three smaller anisotropic minerals (A) is unknown. The CO_2 liquid forms a barely visible crescent between the vapor bubble and brine. The smaller inclusion contains two isotropic and two anisotropic daughter minerals in addition to brine and vapor. The length of the large inclusion is 200 μm. Photomicrograph by Robert R. Seal II; magnified 200×.

John Koivula, of GIA Santa Monica, also examined several rough crystals with a gemological microscope. In these crystals, he observed a number of solid inclusions, particularly limonite, beryl, what appeared to be pyrite, rhombohedra of a carbonate (figure 14), and feldspar (J. Koivula, pers. comm., 1991).

In general, the fluid inclusions and associated daughter minerals of Panjshir emeralds distinguish these stones from Pakistani and Colombian emeralds (Snee et al., 1989). The fluid inclusions of Pakistani emeralds are much simpler than those of emeralds from Panjshir, containing only brine and CO_2 vapor (Seal, 1989). In addition, the fluid inclusions in Panjshir emeralds have a greater variety of daughter minerals than fluid inclusions in Colombian emeralds, which typically contain only halite, in addition to brine and CO_2 liquid and vapor (Roedder, 1963).

Chemical Analysis. The chemical composition of emeralds from Panjshir (table 1) falls within the known range for natural emeralds (Snee et al., 1989). However, Afghan emeralds seem to be most similar chemically to Colombian (Muzo) emeralds. In contrast, they can be distinguished chemically from Pakistan emeralds by the higher aluminum and lower magnesium content of the Panjshir stones (Hammarstrom, 1989; Snee et al., 1989).

Surface Etching and 'Nodules' in Panjshir Emeralds. The surface texture of rough Panjshir emeralds ranges from smooth and lustrous to rough and dull (figure 15). The latter results from a natural chemical etching process. In addition, some Panjshir emeralds contain "nodules" (round, marble-shaped bodies) within the larger crystals (figure 16).

Etched surfaces are commonly found on pegmatite gem minerals (e.g., morganite, tourmaline, kunzite, topaz, etc.). Nodules are characteristic of

Figure 14. Rhombohedra of what appeared to be a limonite-stained carbonate were found near the surface of one of the Panjshir emeralds examined. Photomicrograph by John I. Koivula; magnified 5×.

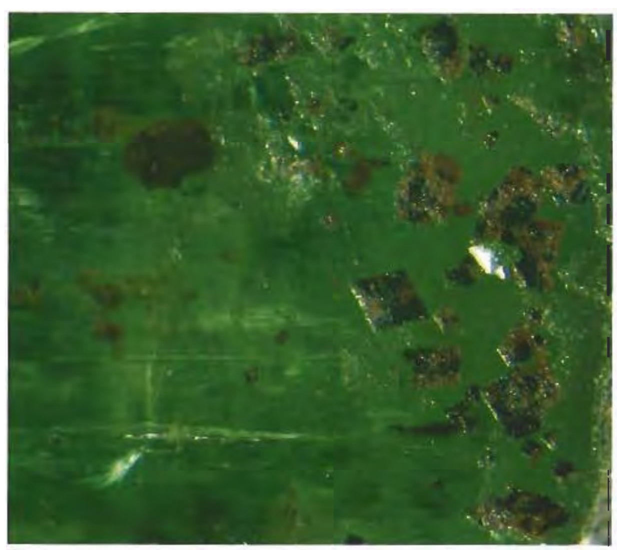


TABLE 1. Four chemical analyses of Afghan emeralds.[a]

Oxide	Analysis 1	2	3	4
TiO_2	na[b]	na	na	0.21
SiO_2	66.0	67.1	65.1	65.5
Al_2O_3	18.2	18.2	17.1	16.4
FeO_T (Total iron as FeO)	0.27	0.27	0.46	0.61
MgO	0.22	0.31	0.75	0.70
CaO	na	na	na	0.07
Na_2O	0.21	0.30	0.70	0.99
V_2O_3	0.08	0.07	0.03	0.10
Cr_2O_3	0.19	0.23	0.10	0.54
BeO[c]	13.8	14.0	13.5	12.04
Total	98.9	100.5	97.7	97.16
Weight loss[d]	na	2.2 %	na	na

[a]Analyses 1, 2, and 3 are microprobe data from Hammarstrom (1989). Analysis 4 is an average of instrumental neutron activation analysis and induction–coupled argon plasma–atomic emission spectrometry data from Snee et al. (1989).
[b]na = not analyzed for.
[c]Theoretical amount of BeO computed for analyses 1, 2, and 3 assuming 3.00 Be cations per formula unit; since Al and Si can substitute in the Be site in the beryl structure, this assumption may not be valid. BeO for analysis 4 was directly determined.
[d]Weight loss was determined by heating one half of the emerald crystal from room temperature to 1400°C in a thermogravimetric analyzer and measuring the weight difference; the other half of the crystal was used for the microprobe analysis.

some gem-quality crystals of tourmaline (elbaite) found in "pockets" in granitic pegmatites (e.g., Sinkankas, 1955) and have been described in zoned aquamarine-morganite crystals (Kampf and Francis, 1989). Like the nodules in these pegmatitic gem materials, the rounded bodies in Panjshir emeralds are typically cleaner than nonnodular emeralds from this locality. In the case of pegmatites, the origins of both the solution (fluid) that caused the etching and the nodules have been extensively studied (e.g., Foord et al., 1986, and references cited therein). The etching of pegmatite minerals may occur because of chemical instability during late-stage pocket evolution. Feldspar, tourmaline, beryl, and other minerals become unstable because of changing fluid conditions, resulting in partial or complete dissolution. The phenomenon of "pocket-rupture" is believed to produce the nodules in pegmatite gem crystals. Compositional differences between growth zones generate differential internal stresses within the gem crystal. The exterior "skin" on the crystal grew after pocket-rupture and is the binding agent that holds the "fractured" crystal together.

Although the conditions of formation for the Panjshir emeralds are undoubtedly substantially different from those of pegmatite pockets, we believe that a somewhat analogous situation caused the etched crystal surfaces and the nodules. Fluid inclusion, chemical, and isotopic evidence on emeralds from other localities (e.g., Muzo, Chivor, Pakistan, Zimbabwe) indicate that emeralds may have formed during two or more distinct periods of crystal growth (Kazmi and Snee, 1989). The fluid from which the initial growth of emerald took place at Panjshir contained less chromium and was of moderate salinity. With continued crystallization, the chromium content of the fluid

Figure 15. Panjshir emerald crystals, like this 43.47-ct crystal from the Khenj mine, are often etched. Photo by Robert Weldon.

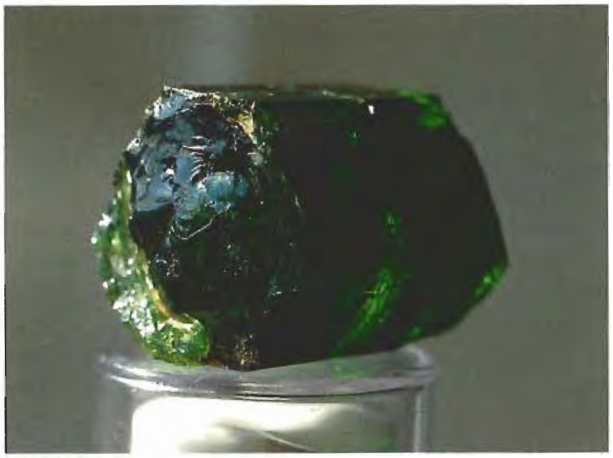


Figure 16. This 36-ct rough emerald from Panjshir contained a large nodule from which several stones, including a particularly fine one at 8.79 ct, were cut. The nodular material is usually much cleaner than the average crystal. Photo by Gary Bowersox.

Figure 17. Panjshir emeralds, like this 1.52 ct stone, are now being set in fine jewelry. Ring courtesy of Jim Saylor Jewelers; photo by Robert Weldon.

increased, as is evidenced by the darker green rims or exterior parts of the emerald crystals. Although not yet observed in Panjshir emeralds, reversals of this zoning pattern (i.e., Cr-richer cores and Cr-poorer rims) are known in emeralds from other localities. A later and distinctly separate fluid from which other minerals (e.g., quartz and/or calcite but not emerald) grew, had a lower salinity and was formed at different temperatures. It is likely that the etching of the emeralds occurred either during the hiatus between the two periods of emerald growth or when the second fluid was introduced.

The origin of the emerald nodules is more difficult to explain. However, we do know that the distinct and sharp compositional zonation with respect to chromium, magnesium, sodium, and iron contents in emerald generates differential stresses within the crystals just as pocket-rupture does in the case of pegmatite minerals. We are not aware of nodules in emeralds from other localities, but they should exist.

MARKETING AND ENHANCEMENT

In general, Panjshir emeralds are mined and marketed in what is basically a free-enterprise system. No government control is exerted except that all emeralds must be brought to one of the three villages nearest the discovery site: Khenj, Mikeni, or Dest-e-Rewat. Each village has a scheduled meeting, or *buly,* of emerald miners and businessmen on Monday and Thursday of each week. During this meeting, chaired by the local commander, the production is evaluated and a tax of 15% of the value is collected. This tax is paid to the Jamiat-e-Islami party to be used for reconstruction of the war-devastated area. After the tax is paid, the emeralds can be retained by the miners or sold via auction to any interested parties in the village. The emeralds are then normally transported to Pakistan for further distribution into the world market, or they may be sold through a newly organized Panjshir emerald syndicate. Afghan emeralds are now being set in jewelry worldwide (figure 17).

A common practice in Pakistan (as elsewhere) is to heat emeralds in one of several oils with a refractive index similar to emerald to reduce the visibility of inclusions. Emeralds that have been treated recently will usually leave oil spots on the parcel paper. Oiling can also be detected with magnification and, in some cases, by a chalky yellowish green fluorescence to long-wave ultraviolet radiation evident in the fractures (see, e.g., Kammerling et al., 1990). Recently, GIA's John Koivula, discovered a dyed crystal in a parcel of Panjshir emeralds purchased by the senior author in Pakistan; this is the first discovery of an Afghan stone treated with dye. Cut stones—usually fashioned in Pakistan or Bangkok—are also available in Pakistan. One must be careful, however, because

Figure 18. This is one of several lots of good-size crystals mined in the Panjshir Valley in 1990. Photo by Gary Bowersox.

several synthetic emeralds have been detected mixed with natural emeralds in sale lots of cut stones.

CUTTING

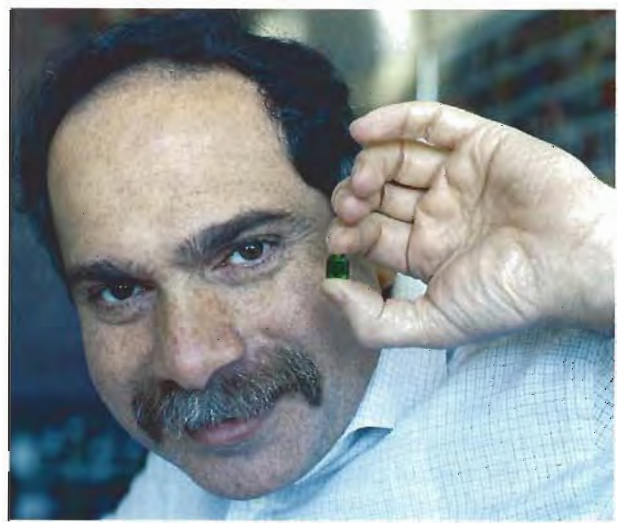
The Panjshir crystals, many of which are large, commonly show complex primary growth and fracture patterns that include outer layers or skins, color variations, complex zoning patterns, and/or etched surfaces. Normally the best color is located near the outer surface of the crystal—a characteristic common to many emeralds. Some parts of the crystals are too dark (overcolored); this is particularly common in emerald crystals from the Khenj mine. In contrast, emerald crystals from the northernmost mining areas (Buzmal, Darun, Darik, and Aryu) tend to be lighter. When faceting lighter-colored emeralds, the cutter must carefully control pavilion angles to limit the amount of light that escapes; this method darkens the color of the cut emerald. In addition, a proper orientation of the table must be maintained to prevent an overemphasis of blue or yellow tones. Panjshir emeralds polish comparably to emeralds from Colombia.

PRODUCTION

No formal records of emerald production for Panjshir exist; however, from tax reports, Commander Masood estimates that approximately US$8 million of rough emerald was produced in 1990 (Tony Davis, pers. comm., 1990). Prior to this report, the senior author had independently derived a figure for 1990 production of $10 to $12 million from discussions with miners and dealers at the 1990 symposium on Afghan gems and minerals held at Chitral, Pakistan, and from sale lots of emeralds seen in Afghanistan and Pakistan (see, e.g., figures 12 and 18). This compares with an estimated production of only $2 million for 1989. With additional miners, improved training and equipment, and development of known mines, production should increase even more dramatically in the future.

Although, as with all gem materials, prices for the Panjshir emeralds vary depending on the quality of the individual stone, an 8.79-ct stone cut from the nodular 36-ct crystal shown in figure 16 was sold by the late Eli Livian in 1987 for US$165,000 ($19,000 per carat; figure 19). The largest fine stone cut to date is approximately 15 ct.

Figure 19. The late Eli Livian is shown here holding an 8.79-ct Panjshir emerald that he sold in 1987 for $165,000. Photo by Gary Bowersox.



SUMMARY

Emerald mining in the Panjshir Valley of Afghanistan is thriving. The best emeralds from Panjshir compete with emeralds from any other source today. Like deposits from some other areas, the Afghan emeralds apparently formed in a continental suture zone. The gemological properties of Panjshir emeralds are consistent with those from other localities. Chemically, Panjshir emeralds are similar to those from Muzo, Colombia. However, this same chemistry, together with their distinctive inclusions, distinguishes them from emeralds from the relatively close Pakistani deposits. The nodules that have been found in some Panjshir emeralds are uncommon in emeralds in general.

Panjshir emeralds are now available worldwide. Some crystals are extremely large, and production of rough in 1990 was valued at approximately $10 million. As postwar conditions improve, production should increase. Future prospects appear to be excellent.

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