

THE GUJAR KILLI EMERALD DEPOSIT, NORTHWEST FRONTIER PROVINCE, PAKISTAN

By Gary W. Bowersox and Jawaid Anwar

Over the last decade, Pakistan has developed into an important source for many gem materials. A number of localities have been identified for emeralds in particular. This article reports on the emerald deposits in the valley of Gujjar Killi, located in the Northwest Frontier Province. The occurrence, mining, and gemological properties are described. Reserves appear to be good, and increased mining activity suggests strong production for the near future.

ABOUT THE AUTHORS

Mr. Bowersox is president of Gem Industries, Inc., P.O. Box 89646, Honolulu, Hawaii. He has 16 years of experience in Pakistan and Afghanistan. Mr. Anwar is chief geologist for the Gemstone Corporation of Pakistan, Peshawar.

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The lush green valley of Swat, often called the Switzerland of the Middle East, is on the historic "silk route" that carried conquerors and commerce alike between Europe and Asia over the centuries. Gujjar Killi, a side valley of Swat, is only 3 km long and has no roads. Yet it is a gemologist's dream: remote, safe, lush in vegetation, scarce in population, and apparently rich in emeralds.

It was not until 1981 that Sabir Zada, a local landowner, found an emerald crystal while digging into a hillside. Shortly thereafter, an exploration team under the supervision of the Gemstone Corporation of Pakistan (Gemcorp) located the deposit and acquired the mining rights from the government of Northwest Frontier Province.

Since 1981, thousands of carats of gem-quality emeralds have been recovered from this locality. According to Kazmi et al. (in press), Gujjar Killi is the second largest emerald deposit in Pakistan—exceeded only by the Mingora deposits elsewhere in the Swat District, and clearly surpassing the deposits identified at Barang and Khaltaro. Although the crystals tend to be dark, some cut very fine stones (figure 1). The rough usually ranges from 1 to 10 ct, but crystals as large as 197 ct have been recovered. One such large crystal, a 188-ct specimen, is shown in figure 2.

LOCATION AND ACCESS

The Gujjar Killi emerald deposit is located near the small village of Gujjar Killi (lat. 34°49'40"N and long. 72°35'10"E) in the Swat District. It lies at an aerial distance of about 24 km (15 mi.) east-northeast of Mingora and 140 km north-east of Peshawar (figure 3). The mine is at an elevation of 2,057 m (6,750 ft.) above sea level.

The mine is reached by traveling approximately 2 1/2 hours by car on a paved and partially unpaved road from Mingora to the village of Bazar Kot, at the edge of Gujjar Killi Valley, and then walking 3 km (about 45 minutes) to



Figure 1. These three faceted stones (4.49 ct total weight) represent some of the fine emeralds found at the Gujar Killi deposit, Northwest Frontier Province, Pakistan. In general, the emeralds from this locality range from medium to dark bluish green. Photo © Harold & Erica Van Pelt.

the deposit (figure 4). It is normally closed from December through March because of snow.

GEOLOGY

The special geologic conditions required for their formation make high-quality emeralds one of the rarest of all gem materials (Snee and Kazmi, in press). Because beryllium, the major constituent of beryl, is geochemically incompatible with chromium, the primary coloring agent of emerald, a unique set of geologic circumstances is needed to bring these two elements together. In Pakistan, the special situation that produced emerald began with the collision of the Indian and Asian continental plates in Cretaceous and Tertiary time. Not only did this "suturing" of India and Asia ultimately produce the Himalaya Mountains, but it also brought together chromium- and beryllium-bearing rocks that are now exposed across northern Pakistan (Snee and Kazmi, in press).

The Gujar Killi emerald deposit occurs in the Mingora ophiolitic melange of the Indus Suture Melange Group (Kazmi et al., 1986). Rocks in this ophiolitic melange are sandwiched between Saidu graphitic schist in the form of discontinuous lenses, sheets, and blocks that range from 6 m to 300 m long and 3 m to 200 m wide. Talc chlorite schist is the dominant material in the ophiolitic melange, but four subunits are easily differentiated on the basis of mineralogic composition: talc schist, talc carbonate schist, carbonate talc schist, and carbonate. Because the nature and distribution

of these subunits are related to the occurrence of emerald at Gujar Killi (figure 5), they are briefly described below.

Talc Schist. This white and grayish green to whitish green subunit (figure 6) is highly schistose, folded, and well jointed. Two outcrops measuring 20 × 4 m and 30 × 10 m are found in the

Figure 2. Pakistani gem dealer Akbar Khan is seen here holding a 188-ct rough emerald found at Gujar Killi. Such large stones are not uncommon from this locality. Photo © G. Bowersox.

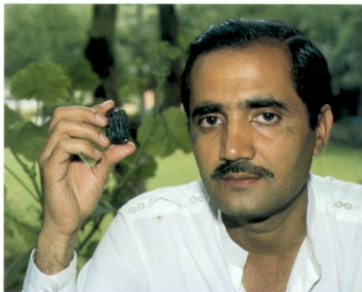




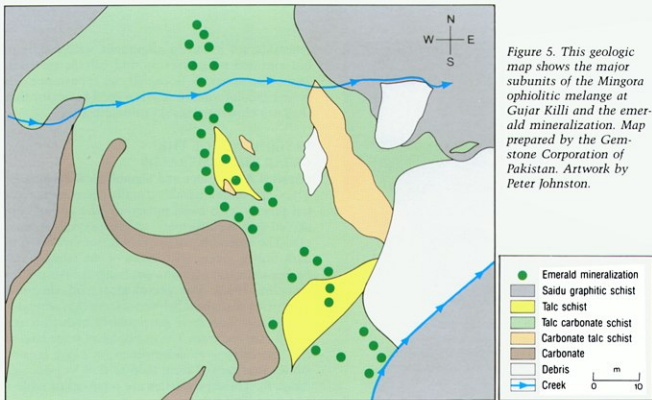
Figure 4. Because Gujjar Killi Valley has no roads, the deposit can only be reached by foot, through lush vegetation. Photo © Gemcorp.



Figure 3. The Gujjar Killi deposit is the second most important source of emeralds—after Mingora—in Pakistan. Artwork by Peter Johnston.

northwestern and southeastern part of the mineralized ophiolitic body in the mine area. The unit is composed almost entirely of talc with accessory amounts of quartz, magnesite, chlorite, muscovite, and fuchsite. The talc occurs as flakes, lenses, and sheaves in the groundmass, as well as veins and veinlets. Veins of milky white quartz, commonly shattered, cross-cut the talc-schist foliation, with fuchsite present at the contacts and within fractures of the quartz veins. Small fragments of chloritic schist and graphitic schist are also found in this unit.

Talc Carbonate Schist. This brownish green to yellowish green subunit occurs in lenses and sheets. It contains the same macroscopically identifiable mineral constituents as the talc schist plus limonite and the carbonates siderite and calcite. Lenticular bodies of flakey talc form the bulk of the rock, while carbonates occur in the groundmass as well as in the veinlets. Quartz veins are common and cut across the foliation. Mica is disseminated throughout. The many limonite patches show the effects of weathering and the leaching of iron-bearing minerals by oxidation. Small xenoliths, 2 to 3 cm in diameter, are also occasionally observed.



Carbonate Talc Schist. This yellowish brown to greenish brown subunit is composed primarily of the carbonates siderite, magnesite, and calcite, with accessory talc, quartz, muscovite, fuchsite, and limonite. Talc occurs along joints and fractures as flakes and sheets. Cross-cutting quartz veins are common. Muscovite is disseminated throughout the unit. The rock is extensively limonitized and looks "rusty." In the northeastern part of the mine area, a 40×10 m block of carbonate talc schist is exposed with talc carbonate schist.

Carbonate. Grayish brown, massive, hard, nonfoliated blocks are common. These range from 3 m to over 60 m in dimension. The carbonates dolomite, siderite, magnesite, and calcite are the principal constituents, with minor quartz, muscovite, fuchsite, chlorite, talc, and limonite. Quartz veins are abundant.

No pegmatites have been observed in or around the mine area to date.

EMERALD OCCURRENCE

Emerald mineralization occurs in a northwest-southeast trending body of the ophiolitic melange that dips 30° to 50° to the northwest. The exposed body measures about $90 \text{ m} \times 80 \text{ m}$, out of which

$40 \text{ m} \times 10 \text{ m}$ was initially proved to be mineralized. The mineralized block is composed primarily of talc schist and talc carbonate schist. Recently, a $4 \text{ m} \times 150 \text{ m}$ mineralized zone was located about 200 m north of the existing zone. It is hoped that further exploration in the area and removal of the soil cover will show that mineralization is continuous between the proven zones, with prospects of locating additional mineraliza-

Figure 6. Talc schist, a major subunit at Gujar Killi, is the source of some of the emerald mineralization. Photo © G. Bowersox.





Figure 7. Emerald mineralization, here indicated by Pakistani gem merchant Azzi Ulla Safi, is most common where limonitized veins intersect in the talc schist or talc carbonate schist. Photo © G. Bowersox.

tion in the southern and northern extensions of the ophiolitic melange.

Emerald mineralization is structurally controlled. A number of northwest-trending faults, with cross-cutting joints and fractures, traverse the mineralized block. Along major faults, fractures, and joints, fault breccia with shattered quartz as well as calcite nodules are commonly observed. The fault, fracture, and joint planes are extensively limonitized. Emerald mineralization is largely confined to these crisscrossing limonitized planes and is most favorable where they intersect (figure 7). According to Snee and Kazmi (in press), the schistose chromium-rich host rocks were derived from "primitive" oceanic rocks that were trapped between the Indian and Asian plates and ultimately included in melange zones that formed when the plates collided. The conditions for emerald mineralization were completed when metamorphism and postmetamorphic faulting produced the pathways in the melange zones that enabled the infiltration of beryllium-bearing solutions from nearby Indian-plate continental rocks.

Emerald is usually found as scattered isolated crystals in the talc-rich sheared joints, fractures, and faults. Only rarely does it occur in pockets, bunches, or aggregates. It is commonly associated with quartz veinlets and rhombohedral calcite nodules (Kazmi et al., in press). Occasionally the

emeralds are found in alignment with foliation, but rimmed structures around calcite are common. The miners believe that the appearance of a greenish coloration in talc is a good indicator that they are close to emerald mineralization.

DESCRIPTION OF THE GUJAR KILLI EMERALDS

Physical Appearance and Gemological Properties.

The Gujar Killi emeralds usually occur as hexagonal prisms with basal pinacoids, the authors observed few well-formed, specimen-quality crystals. The emeralds range in color from medium to dark bluish green, with most of the stones even darker than the Mingora emeralds (illustrated in Gübelin, 1982). The gemological and chemical properties, discussed below, indicate that emeralds from Gujar Killi have particularly high iron and chromium contents. The gemological properties of this material were determined on eight faceted stones that ranged from 0.36 to 0.95 ct (see, e.g., figure 8). These properties are reported in table 1 and described below.

As measured with a Duplex II refractometer, refractive indices for all eight stones were surprisingly consistent, with 1.589 for the extraordinary ray and 1.599 for the ordinary. These values are within the range of refractive indices determined by Dr. Edward Gübelin (in press) for emeralds from this locality. However, the corresponding birefringence of 0.010 is slightly higher, by 0.001, than the maximum birefringence of 0.009 recorded by Dr. Gübelin.

Specific gravity was determined with heavy liquids to be approximately 2.71. By the hydrostatic method it was found to be 2.72.

All stones were inert to both long- and short-wave ultraviolet radiation. This is consistent with emeralds that have a high iron content.

The white-light absorption characteristics of the eight Gujar Killi emeralds were studied by means of a Beck prism spectroscope. The results were consistent across all the stones, with all showing the same chromium-related absorption lines and bands in the same nanometer positions relative to the scale. A strong, close pair of lines at approximately 683 and 680 nm, and another strong pair at 642 and 639 nm, comprised the sharp absorption features, while a relatively strong band between 625 and 585 nm was also present. Individual iron-caused absorption lines were not observed in the blue, but a general absorption extending



Figure 8. These are two of the eight Gujjar Killi emeralds examined to determine gemological properties. Photo by Robert Weldon.

from approximately 430 nm down through the lower limits of the visible region was evident.

When viewed parallel to the optic axis, the color observed in each of the eight emeralds was consistently an intense, very slightly yellowish green; as is the case in the direction of single refraction, no dichroic color shift was observed when a Polaroid analyzer was held over the stones and rotated in a full circle. When viewed perpendicular to the optic axis, the color was also intense,

with two dichroic colors observed: a very slightly yellowish green and a bluish green. Although the color is intense, the pleochroism observed with a Polaroid analyzer could only be described as moderate. With a dichroscope, however, the two dichroic colors were obvious when viewed in any direction other than parallel to the optic axis.

Each of the eight Gujjar Killi emeralds was placed on the tip of a fiber optic illuminator and examined in several directions with a Chelsea color filter. The appearance of the emeralds through the filter can best be described as a very weak to weak red, which once again can be related to the presence of iron. When the stones were examined from different directions, it could be seen that the intensity of the red varied from nonexistent to weak and seemed to be strongest at facet junctions.

Internal Characteristics. All eight faceted stones were carefully examined between the magnification range of 10× to 50× with a standard gemological microscope using a variety of illumination techniques. The inclusions observed, although they do not appear to be locality specific, are nonetheless useful in determining the natural origin of these emeralds.

The only internal feature evident in all eight emeralds was the presence of fluid inclusions (figure 9). For the most part, these took the form of veil-like partially healed fractures composed of

TABLE 1. Gemological properties of emeralds from Gujjar Killi, Pakistan.^a

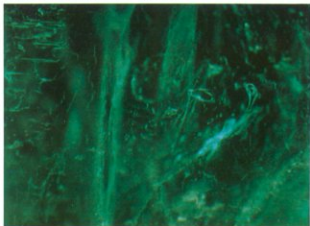
Color	Dark to medium bluish green
Refractive index	
Extraordinary ray	1.589
Ordinary ray	1.599
Birefringence	0.010
Specific gravity ^b	2.71 (2.72 by hydrostatic method)
Reaction to U.V. radiation	Inert to both long- and short-wave
Absorption characteristics	Strong, close pair of lines at approximately 683 and 680 nm; strong pair at 642 and 639 nm; relatively strong band between 625 and 585 nm; general absorption from approximately 430 nm to lower limits of visible region
Dichroism	Moderate: very slightly yellowish green and bluish green
Chelsea color filter reaction	Very weak to weak red
Internal characteristics ^c	Veil-like partially healed fractures composed of numerous minute secondary two-phase fluid inclusions

^aProperties listed were obtained from eight faceted stones ranging from 0.36 to 0.95 ct.

^bDetermined with heavy liquids.

^cOnly those found in all eight emeralds are listed.

Figure 9. Primary and secondary fluid inclusions in this typical pattern were observed in all of the eight Gujjar Killi emeralds examined with the microscope. Photomicrograph by John I. Koivula; magnified 25×.



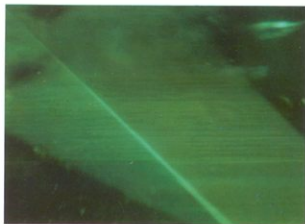


Figure 10. Growth zoning parallels the prism face of this Gujar Killi emerald. Photomicrograph by John I. Koivula; magnified 30 \times .

numerous minute secondary two-phase fluid inclusions. Some slightly larger primary two-phase inclusions were present as well. In one emerald, a thin-film layer of ultra-thin two-phase fluid inclusions was observed in a plane perpendicular to the optic axis. Although no detailed chemical analysis of the fluids could be performed, careful observation revealed no visible fluid immiscibility or fluid carbon dioxide phases in any of these gems.

When shadowing was used, one stone displayed a very subtle form of growth zoning (figure 10) that paralleled the prism faces of the original crystal. In another stone, a hollow tube broke the surface of the crown near the girdle (figure 11). It was partially filled with what appeared to be dirt, polishing compound, or talc.

No mineral inclusions of the type previously described in Pakistani emeralds (Gübelin, 1982 and in press) or in other emeralds found in a schist environment were observed in any of the stones examined.

Chemistry. Hammarstrom (in press) reports the results of 11 microprobe analyses of a sample of Gujar Killi emerald (table 2). Like the emeralds from four other Swat Valley mines that she analyzed, the Gujar Killi specimen was notable for high magnesium, iron, and sodium contents relative to emeralds from other world localities (Hammarstrom, in press, table 6.7), although the Gujar Killi specimen had less iron than the other Pakistani samples (a Mingora specimen, at 0.91 wt.%, was the highest). Hammarstrom also reports that Pakistani emeralds are among the richest in chromium, and the Gujar Killi sample showed the highest value for this oxide among all of the Pakistani samples tested. Many of the emeralds



Figure 11. A foreign substance partially fills this hollow tube in a Gujar Killi emerald. Photomicrograph by John I. Koivula; magnified 20 \times .

display color zoning that appears to correlate directly with variations in chromium content. Otherwise, she found that the Gujar Killi specimen was similar to emeralds from other schist-type deposits.

CUTTING

Most Gujar Killi emerald rough has good crystallization, and the surfaces take a good polish. Some of the large crystals, however, have fine cracks that can hinder cutting. In addition, talc inclusions may give the faceted stone a pitted appearance

TABLE 2. Summary of 11 microprobe analyses of a Gujar Killi emerald (in wt. %).^a

Composition	mean	s.d. ^b
SiO ₂	62.3	1.3
Al ₂ O ₃	13.5	0.4
FeO	0.25	0.02
MgO	2.57	0.05
CaO	0.01	0.01
Na ₂ O	1.88	0.03
K ₂ O	n.d. ^c	
TiO ₂	0.02	0.02
MnO	0.01	0.02
V ₂ O ₅	0.09	0.02
Cr ₂ O ₃	1.65	0.28
F	n.d.	
Cl	n.d.	
BeO (calc) ^d	13.0	
BeO ₂ ^e	11.63	

^aAs reported in Hammarstrom (in press).

^bs.d. = standard deviation.

^cn.d. = not detected.

^dAverage of BeO values calculated for each microprobe analysis assuming an ideal 3 Be cations per 18-oxygen beryl formula unit. This represents the maximum BeO content theoretically possible for the analyses, assuming stoichiometry.

^eBeO values reported by Snee et al. (in press).

[Kazmi et al., in press]. A greater concern is the overcoloration of the crystals caused by the high chromium content. In smaller stones, to avoid a blackish green gem and produce a good yellowish green finished piece, the cutter should window the stone out. Because of the overcoloration, however, this material is excellent for cutting small, 0.10–0.35 ct, stones.

Cutting may also be hindered by the presence of a colorless tube or hexagonal column—usually, in the authors' experience, less than 3 mm in diameter regardless of the size of the stone—parallel to the c-axis near the center of many of the crystals. This is probably due to a lack of chromium. The cutter must experiment with these stones to work around—or with—the zoning for the best result in the finished gem.

MINING AND PRODUCTION

Because the Gujari Killi emerald deposit becomes snowbound in winter, it is operational only about eight to nine months a year. It is largely an open-cast mine worked via benches (figure 12). Some underground mining has been carried out to prove continuation of mineralization at depth, and so far



Figure 12. A series of benches characterize the open-cast workings at the Gujari Killi mine. Photo © G. Bowersox.



about 30 m below the surface has been shown to be potentially productive.

The rocks are generally soft and can be easily removed manually with pneumatic drills (figure 13). Explosives are seldom used except to break up compact and massive blocks of carbonate rock. The open-cast mining is generally safe except for some slope stability problems caused by water seepage.

After the emeralds are removed from the talc, they are washed (figure 14) and then sent for sorting to the operation at the Mingora mine. Local inhabitants supply most of the labor for the Gujari Killi mining operation. They otherwise lead a typical village life supplemented by farming—primarily potatoes and maize—on terraced fields. There is little independent mining; for the most part, activity at the mine is strictly supervised by government security guards.

Figure 13. Miners use pneumatic drills to remove the relatively soft host rock at Gujari Killi. Because of the lack of roads, the compressor was carried to the site part by part and then reassembled at the mine. Photo © G. Bowersox.



Figure 14. Emeralds are washed from the talc at Gujar Killi before they are sent to the Mingora mine for sorting. Photo © G. Bowersox.

The deposit has been worked actively since 1982. The production of rough emerald from the mine since it began operation through the 1987–1988 fiscal year is given in table 3, as reported in official documents of the Gemstone Corporation of Pakistan. The radical increase in production in 1988 resulted because more miners were hired to work a second deposit. Current geologic studies by Gemcorp indicate the existence of many other emerald veins, so it is expected that both the quantity and the quality of emerald will improve during the next few years.

CONCLUSION

The Gujar Killi deposit is the second most important source of emeralds in Pakistan. Like the neighboring Mingora deposits, emeralds occur in

TABLE 3. Production of rough emerald at Gujar Killi from 1981 through August of 1988.^a

Fiscal year	Total production (ct) ^b
1981–82	2,808
1982–83	2,053
1983–84	2,015
1984–85	1,330
1985–86	3,456
1986–87	5,939
1987–88	28,646

^aAs reported by the Gemstone Corporation of Pakistan.

^bApproximately 5%–10% of this material is considered gem quality.

subunits of the Mingora ophiolitic melange, in talc-rich sheared joints, fractures, and faults.

Gemological and chemical testing indicates particularly high contents of iron and chromium. The chromium appears to be responsible for the overcoloration that characterizes much of the Gujar Killi emerald.

Currently, mining is controlled by the Gemstone Corporation of Pakistan, with local inhabitants supplying the labor. It is largely an open-cast operation. At the time of writing, two deposits are being worked and production is good. Reserves appear to be excellent and potentially extensive.

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