PINK TOPAZ FROM PAKISTAN

By Edward Gübelin, Giorgio Graziani, and A. H. Kazmi

In addition to the relatively recent discovery of significant amounts of emerald, aquamarine, and ruby, Pakistan has also begun to produce fine gem-quality pink topaz. In a small hillock of recrystallized limestone north of Katlang, narrow calcite veins encase pink topaz crystals up to 3 cm long accompanied by larger amounts of reddish brown, tan, and colorless topaz crystals. More than 70,000 ct of gem-quality pink topaz has been reported to date. The refractive indices, optic axial angle, unit-cell dimensions, and density of the topaz are influenced by a partial replacement of fluorine by hydroxyl ions. The color is due to trace elements—principally chromium (Cr^{3+}). Treatment experiments revealed that the color of the brown, tan, and colorless topaz from this source may be improved by irradiation and heat.

ABOUT THE AUTHORS

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The occurrence of pink topaz in Pakistan was discovered less than 20 years ago. This attractive material (figure 1) has been reported on several occasions in the gemological literature (Afridi et al., 1973; Bank, 1976a and b; Petrov et al.; 1977a, b, and c; Jan, 1979), but details of the deposit itself have only recently become available. In this article, the authors report on their investigation of the geology and mineralogy of the pink topaz deposit near Katlang, and on the chemistry and the gemologically ascertainable properties of this material. As part of this study, the authors also investigated the other color varieties of topaz found at the deposit and their reaction to treatment.

LOCATION AND ACCESS

The topaz is found in one of two hills that rise abruptly from the fertile agricultural plain of the Mardan District in the neighborhood of a small village. This settlement of farmers and the topaz hillock both bear the same name—Ghundao—and are located about 4 km (2.5 mi.) north of the small town of Katlang (figure 2). The geographic coordinates of the topaz-bearing hill of Ghundao are latitude 34°24′N, longitude 72°06′E, which places it about 63 km (40 mi.) northeast of Peshawar and about 20 km north of the district capital Mardan "as the crow flies" (approximately 50 km southeast of the Swat Valley emerald deposits; see Gübelin, 1982). The hill is easily reached by automobile. The other hill, which contains no topaz deposits, lies about 1 km northwest of the Ghundao hill. The summit of Ghundao, the topaz hill, is approximately 80 m higher than the village, and the two hills are conspicuous features of an otherwise unbroken plain (figure 3).

GEOLOGY AND OCCURRENCE

The Ghundao hill, only about 340 × 275 m at its base, is composed primarily of strata of gray recrystallized limestones tilted to a near-vertical orientation, and intercalated

Figure 1. This fine specimen of pink topaz (7 cm × 3 cm) is from Katlang, in the Mardan District of Pakistan. From the collection of Bill Larson. Photo © Harold & Erica Van Pelt.

with phyllites and autoclastic limestone breccias (figure 4). There are three main lithologic units in the hill:

1. Light gray, thick-bedded, largely autoclastic limestone.
2. Dark gray, medium-bedded, fine-to-medium grained crystalline limestone; the lower part is composed of algal structures. This unit also contains some quartz, mica, and altered pyrite crystals.
3. Thin-bedded limestone and calcareous shale. The gray color of the rock is caused by irregularly dispersed, dust-like bituminous inclusions.

These rocks have been grouped by previous workers (Martin et al., 1962; Afridi et al., 1973; Jan, 1979) with the lower Swat-Buner Schistose Group, and are believed to be of Silurian-Devonian age (Afridi et al., 1973, Jan, 1979). The algal structure in the limestone and the gastropod fossils found in the lower beds of the Ghundao hill support this assessment of age. The Ghundao limestones are probably a northern extension of the Silurian-Devonian rocks of Nowshera formation (which could be about 400 million years old), although they may comprise a different depositional facies.

Structurally, the Ghundao hill comprises a "mini" anticlinorium with the axes of the tight folds trending east-west and plunging eastward (figures 4 and 5). The limbs of the larger folds have themselves been tightly drag-folded and extensively faulted. The gray limestone has been intruded in places by veins of coarse-grained white calcite and quartz. These veins, in which the topaz is found, are of two types:

1. Short, narrow irregular veins (several centimeters wide and less than a meter long) of fine-grained white calcite, which cut randomly across the strike of the fold axes.
2. Much larger veins (as much as 2 m—6 ft.—wide and several meters long) of coarser-grained calcite, which occur along fault planes that run parallel to the fold axes (figure 6). These veins are interspersed by milky-white quartz, green muscovite, and green talc, as well as by minor amounts of a limonitized clay-like material. Topaz mineralization is mainly confined to this latter type of calcite vein. The veins appear to completely penetrate the hill conformably with the gray limestone strata.

The topaz mineralization is structurally controlled (figures 5 and 6) and forms typical saddle-reef type structures in the limonitized clay-like muscovite accumulations of the larger type 2 veins described above. At several places, the limestone has been invaded by stockworks of calcite and quartz veins which also contain beautiful, perfectly euhedral crystals of quartz and topaz, usually completely embedded in the calcite, but occasionally found protruding into cavities or crevices, or lying loose in the breccia debris (figure 7).

Figure 2. This map shows the location of the topaz hill at Ghundao, in the Mardan District of Pakistan, and the geological setting of the surrounding area. Artwork by Cecile Miranda.

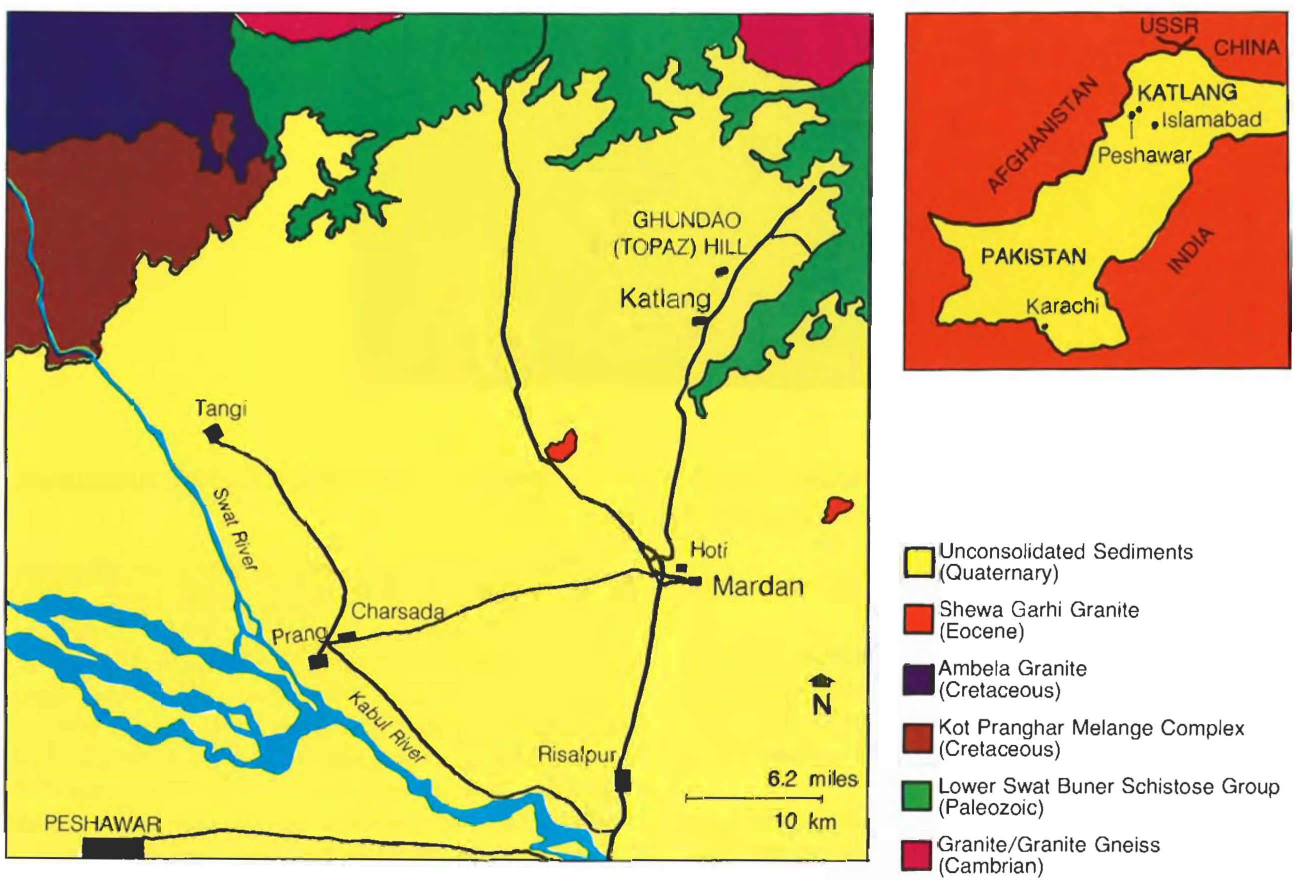


Figure 3. The view from the Ghundao hill across the plain of Katlang toward the southeastern foothills of the Hindu Kush range shows how flat the plain from which the two hillocks rise actually is.

Figure 4. An open cut in the flank of Topaz Hill reveals the vertical stacking of the strata.

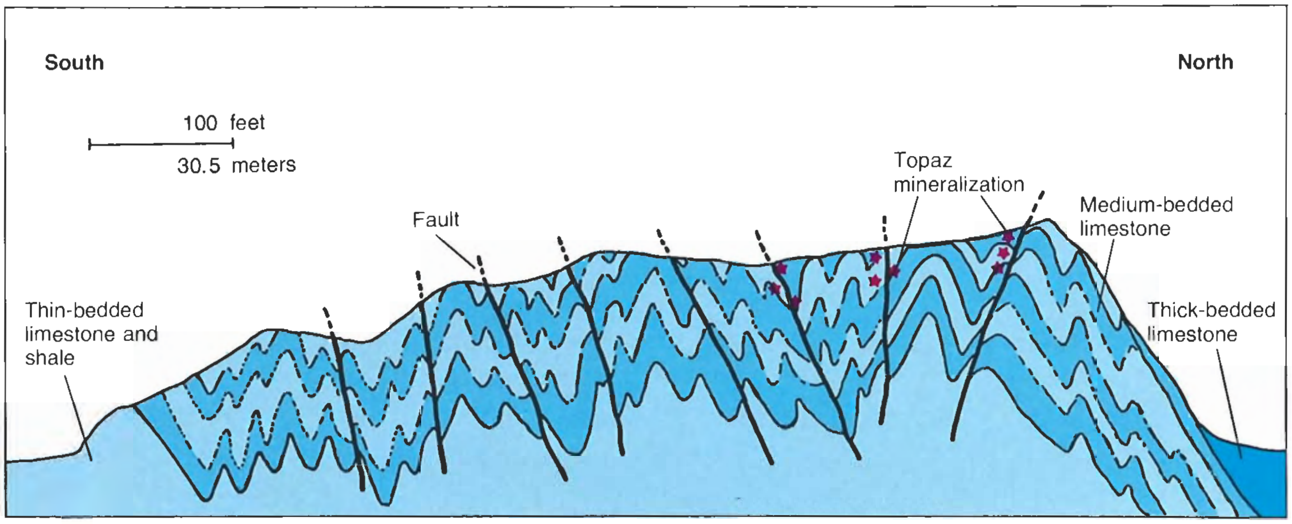


Figure 5. This diagramatic geological section across the Ghundao hill shows the three major lithologic units and the extensive folding and faulting. After A.H. Kazmi. Artwork by Cecile Miranda.

A "pinch and swell" structure is common along the topaz-bearing calcite veins, although some are quite narrow (type 1) and others are much larger and more extensive (type 2). Topaz also occurs in calcite that forms small lenticular tension gashes in limestone at the crests of the folds or drag folds (again, see figure 6).

Jan (1979) concluded that the topaz may have formed by hydrothermal/pneumatolytic activity, followed by tectonic movements which fractured the crystals and resulted in their incorporation into later-formed vein calcite. Although Jan mentions that the mineralizing solutions for the Katlang topaz may have been genetically related to the Swat granite gneisses, the authors believe that the Katlang topaz is late syntectonic, and was formed largely through pneumatolytic processes linked with the final stages of consolidation of the much younger (Eocene) granitic intrusions of Shewa, which are in close proximity to the topaz deposits (again, see figure 2). Some supporting evidence is provided by the fact that trace-element analyses of

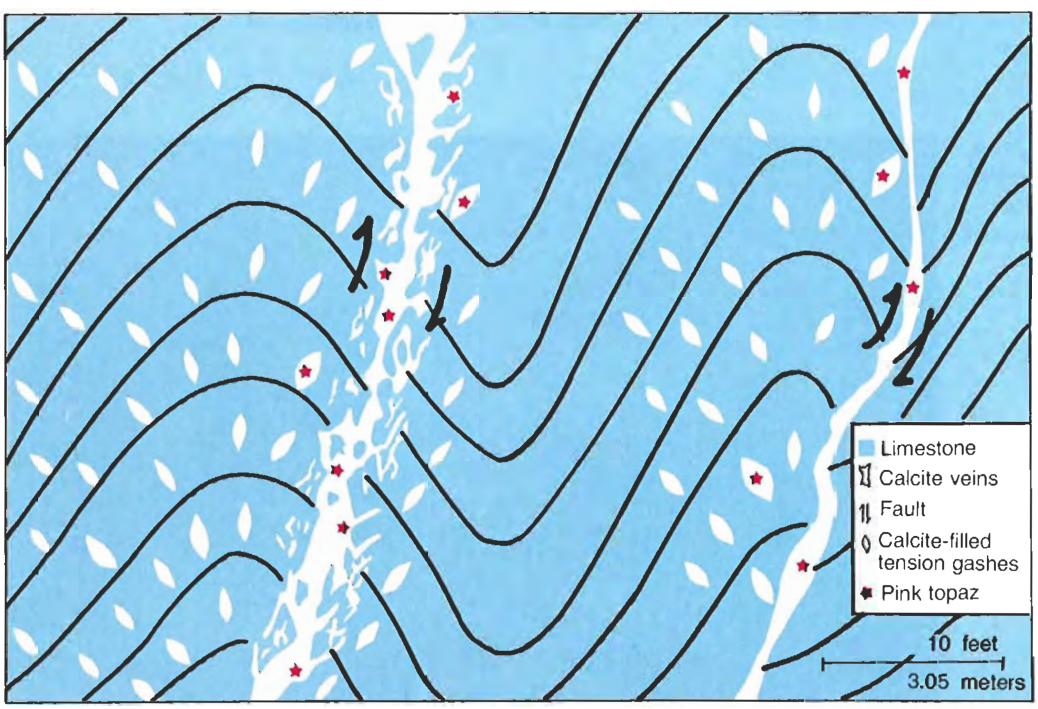


Figure 6. This diagram illustrates the structure and mineralization of the topaz deposit at Ghundao. Note especially the topaz-bearing calcite veins and tension gashes. After A. H. Kazmi. Artwork by Cecile Miranda.

Warsak and Shewa granites (from the Peshawar basin) by Kempe (1983) show up to 10 ppm chromium. This may explain the presence of Cr_2O_3 in the Katlang topaz (see below). Study of these granites by Chaudhry and Shams (1983) has revealed that these rocks developed in an environment that would have been ideal for the formation of the type of mineral deposits that we see today at Katlang.

Figure 7. Although the pink topaz from Ghundao usually occurs embedded in the host calcite, it is also found as fine, well-formed crystals protruding from the host calcite into a vug or as loose crystals.

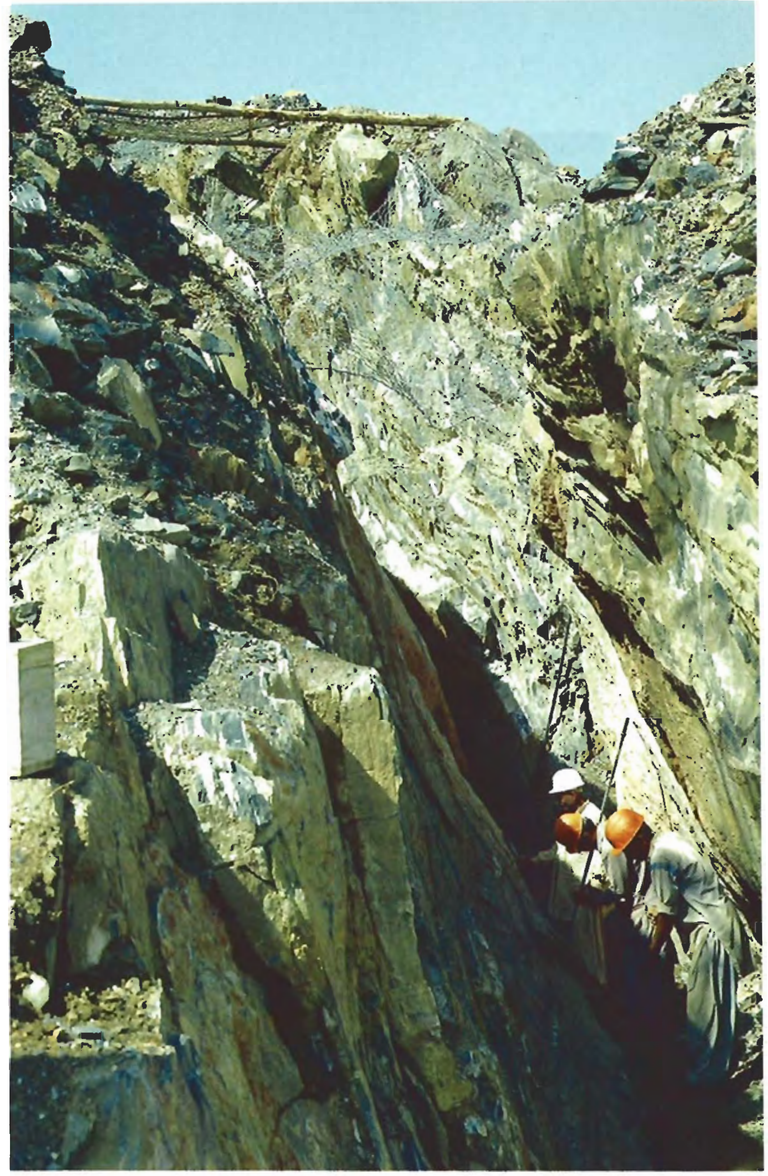


Figure 8. Miners collect the loose rocks at the bottom of one of the large open cuts that has been blasted into the side of the Ghundao hill. One miner uses a pick to remove pieces of calcite from the wall of the cut.

MINING AND PRODUCTION

Topaz was first discovered at Ghundao in the fall of 1972 by local residents who dug the crystals secretly and then brought them to the market in Peshawar. When the government became aware of this illegal digging, the West Pakistan Industrial Development Corporation (WPIDC) was asked to undertake detailed studies of the topaz-bearing hillock. The Mineral Development Cell of the WPIDC in Peshawar first studied the Ghundao hill in January 1973 (Afridi et al., 1973). Prospecting rights were held by the WPIDC and later by its successor, the Pakistan Mineral Development Corporation (PMDC), but no systematic mining was conducted until the deposits were taken over by the Gemstone Corporation of Pakistan (GEMCP) in 1979. Local residents, however, reportedly continued unauthorized mining during this period, until the GEMCP began geologic exploration and systematic mining of the deposits in 1981. This work was carried out under the guidance and supervision of one of the authors, Dr. Kazmi.

Presently, all mining in the area is under the control of the GEMCP. All workings are open cuts consisting of trench-like incisions (figure 8) blasted into the calcite veins that are known to bear topaz. Hand tools as well as pneumatic drills are used to dislodge fragments of calcite that remain attached to the open-cut walls. To minimize damage to the crystals during mining, great care is taken in deciding where to drill, in using low-strength explosive charges, and in controlling

Figure 9. On a heap of blasted pieces of rock, miners break promising pieces in search of topaz crystals.

the blasting. Promising lumps of rock are then carefully broken up with hammers to free the enclosed topaz crystals (figure 9).

By February 1983 (when the senior author visited Ghundao in the company of Dr. Kazmi), three open cuts had been driven deep into the hillside; the largest of these cuts almost reached the summit. At the time, approximately 15 miners were working the deposit. The daily production of topaz was so small that all of it could be carried easily by hand to the small depot in Ghundao Village. Only a very small percentage of the crystals are clean enough to be cut as gems.

The total production of gem-quality pink topaz recorded up to November 1984 is 72,076 ct. Annual production currently ranges between 20,000 and 30,000 ct; collectors' specimens are also available. The largest cut pink topaz from this source recorded to date is 37.76 ct (illustrated in Spengler, 1985, p. 669).

Figure 10. These three crystals represent the main colors—colorless, pink, and brownish—of the topaz found at Ghundao. The sizes of the three crystals are somewhat representative of the proportion in which these colors occur at Ghundao (the largest crystal is approximately 10.25 mm). Like most of the topaz found at this locality, these crystals are highly fractured and broken.

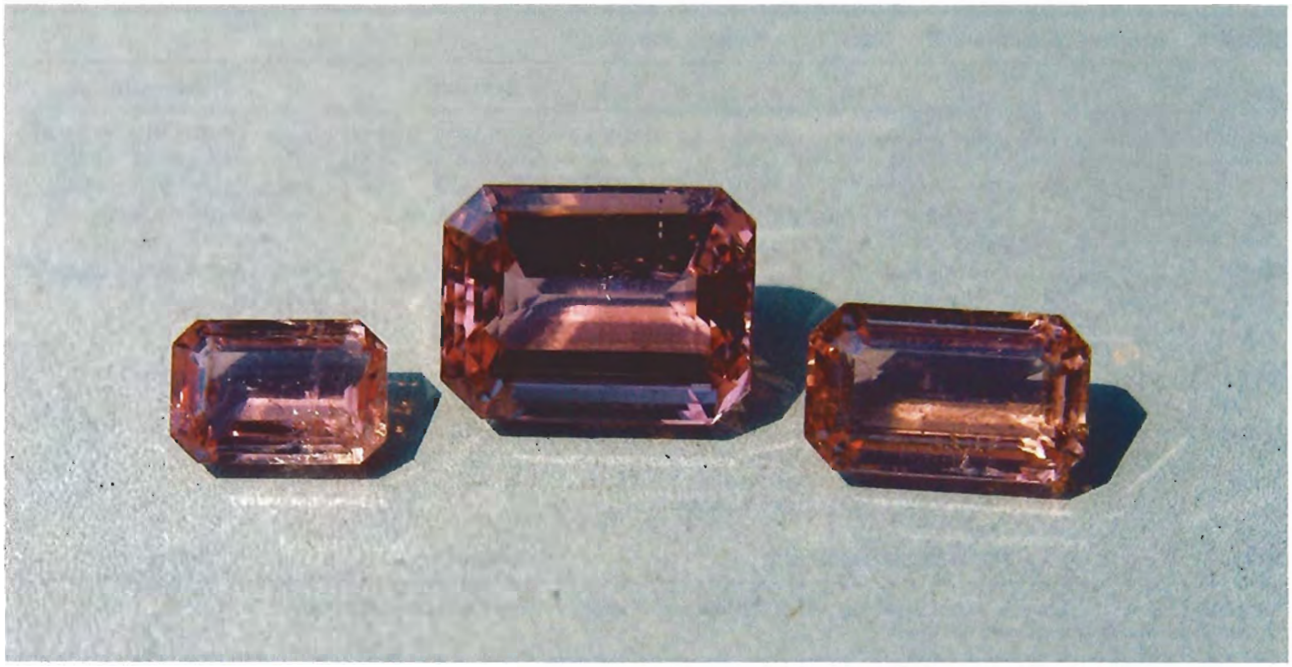


Figure 11. These three faceted pink topazes from Ghundao illustrate the most prized color found at the locality (from left to right: 5.68 ct, 18.41 ct, 9.38 ct).

CRYSTALLOGRAPHY

Well-developed euhedral crystals of topaz are rare at this locality; the majority are broken and highly fractured (see figure 10). Individual crystals seldom attain a length of 3 cm and are usually stubby to tabular in habit; that is, they are flattened along the a-axis due to the pronounced development of the prism {110}. Well-crystallized specimens display the four bipyramids {011}, {012}, {111}, and {112} and two to three prisms of {110}, {120}, and {010}. Both {110} and {120} are nearly always well formed and are commonly striated. The basal pinacoid {001} is rarely present; when it is present, it is usually etched. Most crystals are heavily included.

Unit-cell parameters were obtained from X-ray powder diffraction data, indexed by comparison with the data listed by the JCPDS file No. 12-765 and using a least-squares refinement program (Applemen and Evans, 1973) with reagent grade NaCl as an internal standard. The unit-cell parameters determined are: $\underline{a} = 8.3841 \pm 0.0013$; $\underline{b} = 8.8335 \pm 0.0009$; $\underline{c} = 4.6617 \pm 0.0006$ Å; V = 3.45 ± 0.1 Å^3.

VISUAL APPEARANCE

The topaz crystals found at Ghundao range from colorless through very pale beige to light brown, to very pale to deep pink (again, see figure 10). Only the pink gems find ready buyers in the gem market; unfortunately, these represent a small proportion of the total production. This deposit near Katlang is the only known *in-situ* occurrence of pink topaz. Although some pink crystals were once found in the gravels in the Sanarka River (also called the Kamenko River; see Kornetova, 1950) in the Ural Mountains of the USSR, the *in-situ* deposits yielding them have never been found. All other pink topazes – especially those from Brazil – owe their color to heat treatment.

The pink hue of the Pakistan material is so distinctive that the color-trained eye can distinguish it without much difficulty from the "burned" specimens mentioned above. The prized shade of Katlang pink topaz is faintly violet in tone, and the best examples can be described as cyclamen pink (figure 11). This shade is comparable to color tones 10:2:2 with corresponding values X_c44.4; Y_c34.6; and Z_c37.5 of DIN Color Chart 6164.

The pink topazes from Katlang take an excellent polish and therefore reflect a lively surface brilliance (i.e., luster). They are slippery to the touch, as is usual with faceted topazes.

PHYSICAL PROPERTIES

To establish the physical constants, five faceted gems (2.5–18.4 ct) and seven cleavage fragments were tested using standard gemological instru-

TABLE 1. Gemological properties of topaz from Katlang, Pakistan.[a]

Property	Pink	Colorless	Brownish
Refractive indices	$n\alpha$ = 1.629–1.631 (1.630) $n\beta$ = 1.631–1.634 (1.632) $n\gamma$ = 1.638–1.642 (1.640)	$n\alpha$ = 1.610–1.612 (1.611) $n\beta$ = 1.612–1.615 (1.614) $n\gamma$ = 1.620–1.623 (1.622)	$n\alpha$ = 1.608–1.611 (1.610) $n\beta$ = 1.611–1.614 (1.613) $n\gamma$ = 1.617–1.621 (1.619)
Birefringence	+0.009–0.011 (0.010)	+0.010–0.011 (0.010)	+0.009–0.010 (0.009)
Axial angle	2V = 53°00′	2V = 53°04′	2V = 56°10′
Pleochroism	$n\gamma$ = yellow $n\beta$ = purple (mostly pale) $n\gamma$ = dense mauve to violet	none	Very weak; colorless, yellowish, brownish
Absorption	Extremely weak line at 682 nm (indicates coloration by Cr^{3+})	none	none
Luminescence	Very weak; dark red to long-wave ultraviolet radiation. Distinct to brilliant milky green sheen (amplified in fractures) to short-wave ultraviolet radiation	none	none
Density	3.51–3.53 g/cm³ (3.52)	3.55 g/cm³	3.56 g/cm³

[a]*The extreme values of constants are given, with mean values in parentheses. Twelve pink stones and three each of the colorless and brownish topazes were examined.*

ments (table 1). The data obtained concur very closely with the published statements of Bank (1976a and b), Jan (1979), and Petrov (1977).

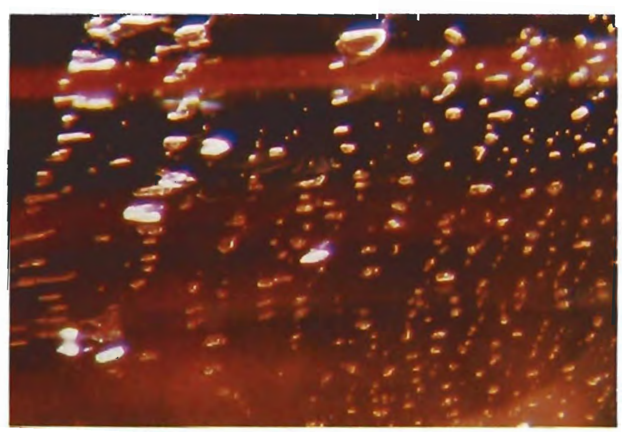
In comparison to the other color varieties found at Ghundao, the pink stones are outstanding not only for their high refractive indices, but also for their somewhat low density, as Bank remarked (1976a and b).

INCLUSIONS

Fissures constitute the bulk of the inclusions in the faceted pink topazes, while mineral inclusions apparently are quite rare. These fissures often appear as cleavage cracks running parallel to the basal plane, either gas or liquid filled or as attractively patterned healing fissures (figure 12). The most interesting patterns are made by various two-phase — liquid and gas — inclusions, in which the liquid phase is dominant. The peculiar shapes of these inclusions did not allow for quantitative analysis, but observations with the microscope indicated that they consist of aqueous solutions of medium to low salinity, since daughter crystals were not observed. When the liquid phase moistens the walls of the fissures in little drops or in elongated tubes in parallel alignment, the regular, planar dispersion makes it easy to recognize the host gem because the pattern is similar to that of innumerable topazes from widely separated

Figure 12. Discrete two-phase inclusions in parallel arrangement are commonly seen in pink topaz from the Ghundao hill, near Katlang, Pakistan. Magnified 50×.

Figure 13. These parallel rows of two-phase inclusions are a diagnostic internal feature of topaz. Magnified 16×.



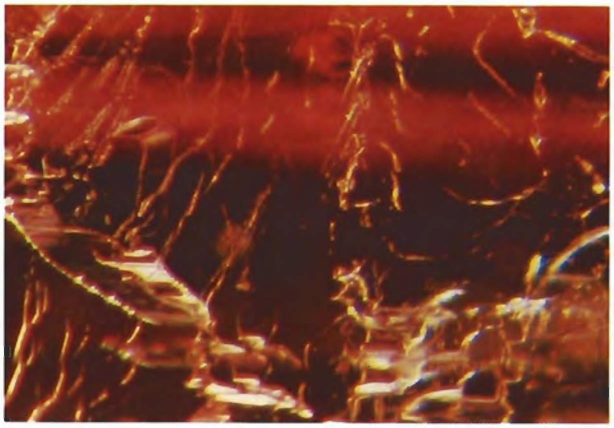


Figure 14. These fine fibers of two-phase inclusions seen in pink topaz from Ghundao are reminiscent of the trichites normally found in tourmaline. Magnified 20×.

Figure 15. These curious swirl marks and growth features observed in Ghundao topaz appear to be connected to cleavage cracks. Such cracks in parallel alignment are an indication that these topazes should be treated with care. Magnified 30×.

sources (figure 13). However, when the liquid inclusions are irregularly dispersed and entwined like tangled threads, they look exactly like the well-known trichites in tourmaline (figure 14). Also noteworthy in this material are random swirls which seem to be connected with the parallel cleavage fissures (figure 15). Cleavages and their accompanying swirl marks also occur in otherwise internally flawless pink topazes.

CHEMISTRY

The composition of topaz is fairly constant except for variation in hydroxyl content. Several microprobe analyses were carried out on each of three different samples, which represented three different shades of cyclamen pink. Wet chemical analyses were subsequently performed, using a specific ion electrode for determining the amount of fluorine (table 2). Particular care was taken to avoid fluorine loss in the process of fusing the sample with alkaline carbonates. Because of problems encountered in performing the thermogravimetric determination of H_2O present in the sample, total H_2O was estimated after heating at a constant temperature of 850°C for 24 hours. The analyzed topazes reveal a low Fe content and minor amounts of Cr, V, and Ca, while Mg and Mn are present in some of the samples but not in others. The analyses also indicate that the pink topaz from this source is poor in fluorine and rich in hydroxyl (considering that topaz may accommodate as much as 30 wt.% F). The systematic variation of unit-cell dimensions with respect to F and OH concentrations (Rosenberg, 1967; Chaudhry and Howie, 1970; Ribbe and Rosenberg, 1971; Bambauer et al., 1971) allow us to estimate a fluorine content of 15.6–16.3±0.5 wt.%.

The correlation between physical properties and the weight percentage of fluorine was studied by Ribbe and Rosenberg (1971), Bambauer et al. (1971), and others. The substitution of the fluorine ion by the larger hydroxyl group leads to an increase in the refractive indices. At the same time, there is a lessening of the optic axial angle $2V\gamma$ and of the density. The behavior of the pink topazes from Katlang is consistent with these observations.

Chemical analyses were not carried out on the colorless or brown Katlang topazes. However, it

TABLE 2. Wet chemical analysis of pink topaz from Pakistan.

Oxide	Wt. %	Numbers of ions on the basis of 24 (O, OH, F)		
SiO_2	32.60	Si	3.988	4.000
TiO_2	—	Al	0.012	
Al_2O_3	56.83	Al	8.183	8.214
Cr_2O_3	0.01	Cr	0.002	
V_2O_5	0.01	V	0.002	
FeO^a	0.08	Fe	0.008	
MnO	—	Mn	—	
MgO	0.07	Mg	0.012	
CaO	0.05	Ca	0.007	
F	15.78	F	6.105	7.411
H_2O^{+b}	1.60	OH	1.306	
H_2O^{-b}	0.30			
	107.33			
O ≡ F	6.64			
Total	100.69			

[a]Total iron as FeO.
[b]Determined by thermogravimetry.

Figure 16. These three sets of stones illustrate the effects of heat treatment and irradiation on the color of topaz from Katlang, Pakistan. The top row = sample 1; the middle row = sample 2; the bottom row = sample 3.

can be deduced from the physical properties (table 1) — i.e., their lower refractive indices and higher specific gravities compared to the pink variety — that they are richer in fluorine. Indeed, the median values for fluorine may be assessed at about 21 ± 1 wt.%.

TREATMENT AND COLOR

The attractive pink color of topaz is caused by trace amounts of the Cr^{3+} ion; other topaz colors are due to color centers (Nassau, 1984). In accord, microprobe analyses of the Katlang pink topazes showed chromium-oxide contents of 0.01 to 0.03 wt.% that correlate with the intensity of color. No color change was observed in specimens that had been exposed to the hot summer sun of Peshawar (38°–48°C) for 65 days (Jan, 1979).

Given the occurrence of other color varieties of topaz from Katlang (light pink, colorless, or brownish tones), in significantly greater quantities, the question arose as to whether these other topazes would lend themselves to color alteration or improvement by heat treatment and/or irradiation. Dr. Kurt Nassau was so kind as to carry out various experiments in color alteration on pink, colorless, and brownish specimens which the senior author had obtained in Pakistan. All irradiation experiments were conducted using 20 Mrad gamma rays from a cobalt-60 source; all heat treatments lasted 15 hours. The results are shown in figure 16.

Sample 1. Reddish brown; lost its orange component after 15 hours heated at 500°C, acquiring a pale pink hue. When it was subsequently irradiated, turned orange-brown; did not change color when heated to 250° or 300°C; heating to 350°C caused a change back to pink (figure 16, top row).

Conclusion: The pink color is due to Cr; it is probably stable at any temperature. The orange-brown color is induced by Cr plus a color center produced by irradiation; it is probably not affected by daylight, but will turn pink if subsequently heated to 350°C for 15 hours.

Sample 2. Very pale tan; turned virtually colorless when heated to 500°C; then turned dark orange-brown and pale tan in zones when subsequently irradiated (figure 16, middle row); subsequent heatings through 80°, 100°, 120°, 140°, up to 250°C caused slow decolorization to colorless.

Conclusion: This material contains color centers that cause intensification of hue upon irradiation, but it subsequently bleaches when heated between 120° and 250°C for 15 hours; while not tested, the irradiated material is almost certain to bleach in daylight.

Sample 3. Colorless; upon irradiation turned dark orange-brown, partly patchy, partly zoned; reverted to colorless when heated for 15 hours to 500°C. Further irradiation and reheating produced the same results, although one cleavage piece showed a slight trace of tan, but another showed a very faint blue (figure 16, bottom row).

Conclusion: Same as for sample 2 above.

The results of these experiments by Dr. K. Nassau are similar to those he reported earlier for topazes (Nassau, 1974, 1975, 1980) exposed to gamma-ray irradiation and subsequent high-temperature heating. Further experiments on the Katlang topazes are planned.

PROSPECTS FOR THE FUTURE

In recent months, the Gemstone Corporation of Pakistan (GEMCP) has extended exploration activities to other hills in the vicinity of Ghundao and has succeeded in locating occurrences of pink topaz in the Shakar Tangi and Rama areas, situated northeast of Ghundao and about 7 km south-southeast of Katlang. At present, detailed exploration of these areas is in progress. There seem to be fair prospects for locating additional deposits.

Pink topaz has never been and is still not an abundant gemstone. Hence, it is welcome news that cuttable pink topaz of natural color is being found at various localities in Pakistan.

Since GEMCP has also been successful in discovering new aquamarine deposits in other parts of Kohistan, the gem world may expect Pakistan to produce more gemstones and additional gemstone varieties, becoming an important supplier to the gem market in the future.

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