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Topaz occurrence in Mardan, north-west Pakistan

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SYNOPSIS

COLOURLESS, purple, and pink topaz and transparent quartz crystals have been found in calcite veins (with or without milky quartz) in calcareous rocks near Katlang (34° 24′ N, 72° 6′ E), Mardan district. The veins do not contain any fluorite nor the country rocks any topaz. The topaz and transparent quartz crystals are mostly broken and perfectly euhedral outlines are very rare. Refractive indices, 2V, specific gravity, and the fluorine (determined) and H_2O+ (calculated) contents of two topaz crystals are suggestive of their high 100 OH/(OH+F) ratios (> 25). Rather than being derived, the topaz may have formed *in situ* by hydrothermal/pneumatolytic activity, followed by tectonic movements that fractured the crystals and resulted in their incorporation in later-formed vein calcite.

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TOPAZ OCCURRENCE IN MARDAN, NORTHWEST PAKISTAN

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Fine crystals of topaz have been found 2.5 km to the north of Katlang ($34^{\circ}24'$ N, $72^{\circ}6'$ E), Mardan district, NW Pakistan. The mineral occurs in calcite veins, with or without quartz, in an isolated, subcircular, hilly outcrop measuring 340 x 275 m. The country rocks (recrystallised limestones with subordinate phyllites and autoclastic limestone breccia) belong to the Lower Swat-Buner schistose group of probable Siluro-Devonian age (Martin et al., 1962). The limestones are medium- to fine-grained but a few are aphinitic, and are composed of calcite with a little quartz, mica, ore or carbonaceous dust and, locally, oxidised cubes of pyrite up to one centimetre across.

Veins of calcite and quartz are common but a systematic relationship has not been found between the structure and the topaz-bearing veins. However, that part of the outcrop most worked for gem topaz tends to lie along a comparatively larger anticline in the northern part of the hillock. The calcite veins can be divided into two types: a) usually thin, short, fine-grained and containing pure white calcite, and b) those with white, gray, or brown calcite, usually also containing milky quartz, a minor amount of brown clayey matter and, in places, greenish talc and mica. The presence of the latter two minerals and of quartz are suggestive of a hydrothermal origin. The calcite, locally subtransparent and (?)chemically zoned, reaches up to 25 cm in length. The topaz crystals, usually accompanied by a greater quantity of transparent quartz crystals, occur in veins of the second type, especially in cavities, vugs and vein breccia; the country rocks contain no topaz wholly although a few crystals extend into them from the veins.

Optical and unit cell data for the topaz have been given by Bank (1976) and Petrov et al. (1977 a & b). The present study is concerned with the mineralogy and petrology of the topaz and its host veins.

Mineralogy of the topaz. The Katlang topaz is transparent to subtransparent, colourless, purple or pink, and good crystals are free of impurities. A pink crystal was kept in the summer sun in Peshawar (maximum temperature between 100° & 118°F) and no noticeable change in the colour resulted despite an exposure of 65 days, suggesting that the colour is due to trace elements rather than colour centres. El-Hinnawi and Hofmann (1966) have found considerable cobalt in a pink pycnite, but Petrov et al. (1977 a) consider that the purple colour of the Katlang topaz is due to the present of Cr^{3+}. Most of the crystals of Katlang topaz are less than 2.5 cm in length; the largest crystal, recovered by local people, is said to have measured over 7.5 cm in length, with a deep pink colour. The well-formed crystals have the usual faces of topaz, notably two or three sets of prisms and one or two sets of pyramids, but pinacoids have not been noted. The (110) and (120) prisms are well-developed, often striated, and range from 3:1 to more than 10:1 in length to breadth ratio. A significant feature of the topaz and the associated transparent quartz crystals is their lack of perfectly crystalline outlines; many of them are broken and only two out of 50 topaz crystals were found to be perfectly euhedral.

Correlation between physical properties and OH:F ratio of topaz has been discussed by Deer et al. (1962), Rosenberg (1967), Chaudhry and Howie (1970), and Ribbe and Rosenberg (1971). The substitution of the larger OH for F ion causes an increase in b cell dimension and refractive indices, and a decrease in density and 2V. Rosenberg (1967, 1969) considered also that the composition of topaz may be a sensitive indicator of environmental conditions; topazes with the lowest OH/F ratios are reportedly found in cavities in rhyolites whilst those with higher ratios occur in pegmatites and greisens. Chaudhry and Howie (1970) noted a similar tendency in the Meldon aplite where topazes from strongly metasomatised rocks have higher OH/F ratios than those from pegmatitic veins. Betekhtin (undated) also reports that the replacement of F by OH is higher in topaz of hydrothermal origin.

Table I. Physical and chemical features of the Katlang topaz.

Type of crystal	α	β	γ	$2V_{\gamma}$ (calc.)	Sp. gr.	F %	H_2O^+ % (calculated)
Colourless	1.632	1.633	1.639	45°	3.50	14.54	2.7
Pinkish	1.630	1.632	1.639	45°	3.43	13.92	2.9

Refractive indices, 2V, density, and F, and (calculated) H_2O^+ contents of a colourless and a pink topaz from Katlang are presented in Table I. Whilst the 100 OH/(OH + F) values cannot be accurately determined from these figures because of the differences in the two sets of curves given by Deer et al. (1962) and Chaudhry and Howie (1970), the physical constants are suggestive of high values (> 25) for this ratio. This is also indicated by the F and calculated H_2O^+ contents of the crystals. (Fluorine was determined by the rapid method of Hall and Walsh (1969). H_2O^+ was "estimated" from the fluorine content; a plot of the H_2O^+ against F for the ten analysis given in Deer et al. (1962) and Chaudhry and Howie (1970) strongly suggests linear relationship). From physical properties, Petrov et al. (1977 a) concluded that the Katlang topaz has a high water content (~15% F), and the present work supports this. It is thus probable that the topaz is of hydrothermal/pneumatolytic (metasomatic) origin; Bank (1976) considered it to be pegmatitic.

Paragenesis. The Katlang topaz seems to have a complex origin. Only some of the veins contain topaz and transparent quartz which are broken in most cases. The topaz is broken at one or both ends parallel to {001} but in some cases obliquely to the cleavage. P.G. Embrey (personal communication, 1973) has noted that some of the unbroken ends of the crystals have etched {001} cleavage. In most cases the vein calcite has partially or completely enveloped the topaz. These features would suggest that the topaz and quartz crystals have not grown in place; they may have fallen into the cracks in the limestones in which calcite vein crystals were forming.

This type of origin, however, leaves unexplained the nature and location of the source rocks from which the crystals were derived. The topaz-bearing rocks form an isolated hillock surrounded by alluvium; the nearest outcrops, containing no topaz or silicic rocks, being one km to the northwest. The two known granitic masses in the area, the alkaline rocks to the southeast at Shewa (Kempe, 1973), and the Swat granitic gneisses to the north (Martin et al., 1962) have no topaz and both are about 20 km from the topaz-bearing outcrop. The occurrence of topaz in a limited part of the hillock and its recovery from up to 1.25 metre depth also do not favour a derived origin. In some cases blasting has revealed that the veins, apparently, have no connection with the outer surface or that the connecting passages are too thin and do not dip steeply enough to allow large crystals to sink into them to this depth. Considering the high rate of limestone weathering and erosion in this part of the world, their depth of burial would have been much greater if they had been derived a few hundred thousand years ago. Sinking of crystals along cracks to a few metres depth seems unlikely.

Another possible mode of formation would be that the topaz was formed in situ by hydrothermal/pneumatolytic activity. Embrey (personal communication) considers that topaz occurring in calcareous rocks would always be accompanied by fluorite. The absence of the latter and the broken nature of the topaz and quartz crystals might be explained by the following rather complex origin. Earlier hydrothermal/pneumatolytic activity may have produced topaz, transparent quartz and fluorite, followed by tectonic movements and the production of later solutions which attacked the topaz, fracturing and etching it, and destroyed the fluorite and any feldspar completely by dissolution. Joshi and Taku (1971) have correlated the {001} etch pits in topaz with some of the underlying inclusions. Palache et al. (1960, p.35) consider that CaF_2 is readily soluble in water, especially when the latter is carbonated. Carrel (1973) has found the emerald gems from near Mingora, Swat, to have been fractured and broken by post-formational tectonic forces. It is of significance that a few topaz crystals, moderately to intensely shattered, still lie intact in the calcite veins, while in a few cases the topaz crystals extend from the veins into the host limestone.

It cannot be ascertained whether the mineralising solutions would have been connected with either of the two granitic bodies mentioned above, or with any unexposed rocks at depth. In general, quartz veins become more frequent towards the north and the solutions might be connected (? telethermally) with the Swat granitic gneisses. The occurrence of emerald (considered hydrothermal/pneumatolytic by Carrel, 1973) close to the granitic gneisses at Mingora, and of green chromian tourmaline in calcareous rocks near the contact with serpentinites at Alpurai, Swat, about 6 km from these gneisses (Jan et al., 1972), supports the idea that the mineralising solutions responsible for the development of the Katlang topaz could have been connected with the Swat granitic gneisses.

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