The Journal of Gemmology

Volume 26 No. 1 January 1998

The Gemmological Association and Gem Testing Laboratory of Great Britain

Gemmological Association
and Gem Testing Laboratory
of Great Britain

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Turquoise from Hubei Province, China

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ABSTRACT: The turquoise deposit in Yunyang district, Hubei Province, China, is characterized by its large scale, complex and variable ore-body types and colour varieties, compared with similar bodies outside China. The copper and phosphorus in the deposit originate mainly from finely dispersed sulphides in layered carbonaceous-siliceous slates, and from colloidal apatites (collophane) that occur in an irregular and patchy distribution pattern. The host rocks favourable for the formation of the turquoise are relatively rich in silica, copper and phosphorus and relatively poor in potassium, calcium and magnesium. The ore occurs mainly in lenticular bodies compressed between the layers. The distinctive mineralization is controlled by lithology, structure and the effects of ground water movement. The colouring mechanism of the turquoise results from a combination of $[Cu(H_2O)_4]^{2+}$, Fe^{3+} and Fe^{2+} ions. The colouring ions and the existing form and content of H_2O limit directly the colour of the turquoise. The turquoise deposit can be considered as having been formed by a process of secondary leaching.

Keywords: turquoise, mineral deposit, secondary leaching

Introduction

Yunyang in Hubei Province, located in the eastern section of the Qinling fold zone at the intersection of Hubei, Henan and Shanxi provinces *(Figure 1)*, is well known not only for its high-quality turquoise but also for its excellent carving techniques and life-like handicrafts *(Figure 2)*.

The exceptionally long mining history of turquoise can be deduced from the 20 turquoise beads unearthed with Qijia cultural relics of late Neolithic Age, located in Yongjing County, Gansu Province, China. This indicates a mining history of about 3200–3800 years (Hao Yongwei *et al.*, 1982). At present, the holes for extraction of the turquoise ore are readily apparent *(Figure 3)*.

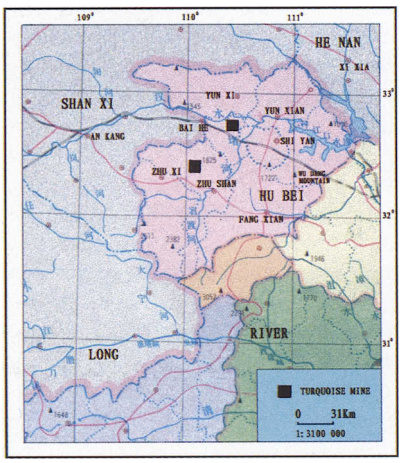

Figure 1: *Location map of the turquoise deposits in Hubei. Bai He is approximately 500 km NW of Wuhan.*

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Figure 2: *Turquoise carving 'A picture of Paradise' (32x48x27 cm). Photo: Yuan Jiaqi.*

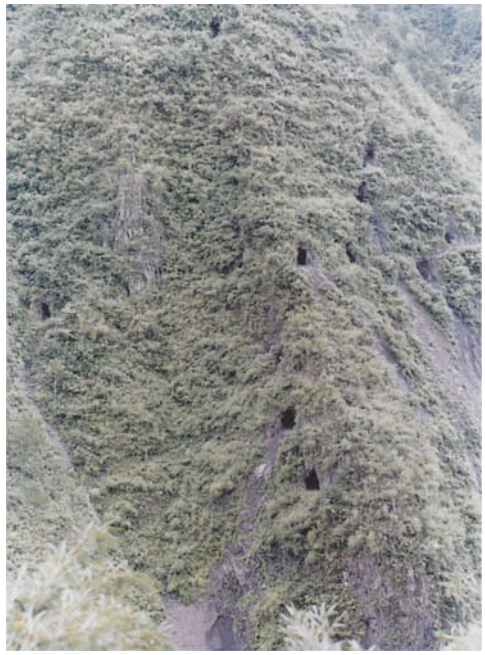


Figure 3: *Ancient caves where turquoise was mined.*

Figure 4: *Turquoise deposits at Yungaisi, Yunxian County, Hubei.*

The complex metallogenic and geological conditions of the turquoise, the various morphologies of the ore body, the wide spatial distribution of the turquoise and its irregular occurrence in this district have attracted little attention from the Government for a long time. In 1980, a team from the Hubei Bureau of Geology and Mineral Resources carried out a reconnaissance geological survey of the turquoise deposit at 1:200,000 scale. In 1982, Zhang Huifen, Jiang Zechun, *et al.*, from the Guiyang Geochemistry Institute under the Academy Sinica made a detailed investigation into the turquoise mineralogy in this district and on the basis of this it was evident that more needed to be done.

For the past several years, the first-named author and his colleagues in the Gemmological Institute of the University of China (Wuhan) have climbed the Qinling

mountains, have investigated several tunnels which were still being actively mined and have explored several abandoned caves in order to trace the origin of the turquoise and to prospect for new occurrences *(Figure 4)*.

Stratigraphical and lithological features

The ore-bearing bed has been identified as the Lower Cambrian Shuigoukou Formation ($\in_1$sg), part of a regionally metamorphosed rock succession (Hao Yongwei *et al.*, 1982). Its lithology is composed mainly of carbonaceous-siliceous slates, carbonaceous clay and siliceous slates, banded thin-layer siliceous slates, carbonaceous mica quartz rocks, calcareous mica quartz-schists and carbonaceous clay marbles. The turquoise occurs mainly in the first three types of rocks. The carbonaceous-siliceous slates (the hosts of the turquoise ore bodies) have been universally silicified and recrystallized into massive slaty quartzite *(Figure 5)*. This rock is grey to black and characterized mainly by an intermediate-to-fine granular structure, and a dense and hard texture. The rock is composed of quartz (80–85%), carbonaceous material (10–15%), sericite (3–5%), and albite (<1%). The carbonaceous siliceous slates from the strongly mineralized segment of this district contain more of the patchy colloidal apatites (collophane). If this rock is sectioned and observed through the microscope, the features, typical of quartz, carbonaceous materials and sericite, can be observed *(Figure 6)*, together with colloidal structures and isotropic areas. Field observations show that the intensity of mineralization, ore body morphology and ore quality of this district are all controlled by the lithology *(Figure 7)*.

Figure 5: *Thin section of carbonaceous-siliceous slate, fine to medium grained, in crossed polars, x60.*

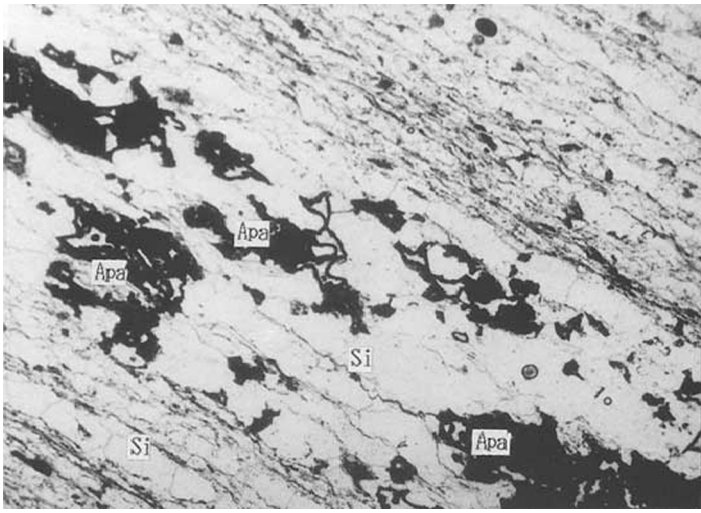


Figure 6: *Collophane (Apa) and quartz (Si) along a bedding plane in carbonaceous-siliceous slate, x60.*

Figure 7: *Mineralized intermediate to thickly bedded carbonaceous-siliceous slates. The marker indicates the mineralization.*

Table I: Chemical compositions of rocks associated with turquoise

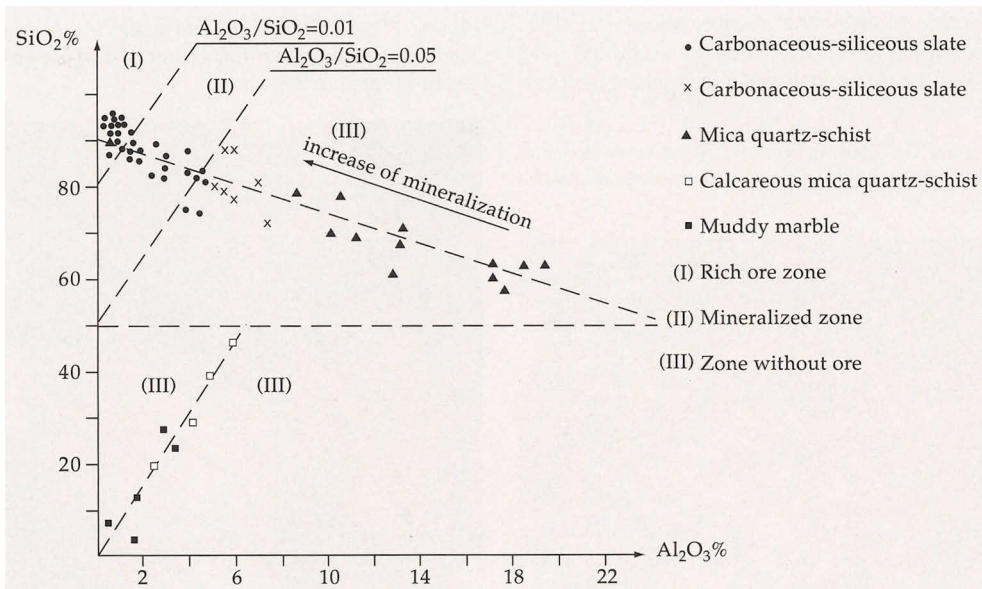
Lithology	Number of analyses	Weight per cent oxide						Parts per million (ppm)							
		SiO_2	Al_2O_3	CaO	MgO	K_2O	P_2O_5	Cu	Pb	Zn	Mo	V	Ag	Ni	Mn
Carbonaceous-siliceous slate	32	90.92	2.26	0.21	0.38	0.51	0.43	747.23	25.41	177.45	196.25	1962.5	4.95	158.75	925
Carbonaceous muddy and siliceous slate	7	84.63	5.28	0.34	0.56	3.44	0.075	28.78	31.14	79.68	176.17	1420.6	7.26	47.41	866.67
Mica quartz schist	12	64.38	13.76	1.95	1.39	4.38	0.194	21.19	27.65	52.06	41.33	125.04	1.09	14.53	815.74
Calcareous mica quartz-schist	4	33.23	4.37	43.31	3.68	2.35	0.026	43.39	13.73	24.54	64.81	92.26	<0.3	13.65	540.16
Muddy marble	5	14.62	2.05	53.87	16.52	0.72	0.128	5.42	11.37	18.92	32.36	85.29	<0.3	9.44	672.01

Note: content of carbon not determined.

Geochemical features of the rocks containing the turquoise ore

The chemical compositions of 60 fresh unmineralized rock samples collected from different sections close to the turquoise deposit reveal that their petrochemical compositions differ greatly from those of the ore-bearing segment *(Table I)*. The contents of silica, copper and phosphorus in the ore-bearing carbonaceous-siliceous slates are much higher than those in the ore-free carbonaceous and siliceous slates and other rocks. Furthermore, the contents of copper and phosphorus are far higher than the regional geochemical background values (Cu: 80 ppm, P: 0.05%).

Figure 8: The relationship between the ratio of Al_2O_3 to SiO_2 in different rock types in the metamorphic rock system and its correlation with zones in the ore deposit (based on the chemical analysis of 60 rock samples).



In order to further understand the state of occurrence of the copper and phosphorus in the ore-bearing rocks, eight samples were chosen from the varieties of rocks in the Shuigoukoy Formation in the Yungaisi profile ($\in_1$sg) and their constituents analyzed in detail. Results show that the copper occurs mainly in sulphides finely dispersed throughout the rock and that it constitutes only a very small percentage of the silicates. Phosphorus occurs mainly in the irregular patchy colloidal apatites (collophane).

Calculations of the ratio Al_2O_3/SiO_2 indicate that silicification is closely associated with the mineralization in this district *(Figure 8)*. That is, with the increase in mineralization, the Al_2O_3/SiO_2 ratio decreases; when the ratio of Al_2O_3/SiO_2 is <0.05%, it is favourable for metallogenesis.

Another marker in terms of the petrochemistry favourable for the formation of turquoise in this district is the relatively high concentration of SiO_2 compared with K_2O, CaO and MgO in the carbonaceous-siliceous slate, that is $(CaO+K_2O+MgO)/SiO_2<0.02\%$.

It is important to note that this district was subject to a series of geological processes including weathering, leaching and migration of metallogenic elements, which resulted in the formation of the turquoise deposit through local concentration and precipitation.

Geological features of the turquoise deposit

The turquoise deposits in Yunyang District occur at the southern edge of the eastern section of the Qinling fold zone and at the western edge of the Wudangshan terrain (Yu Gai Si Mine and La Ba Shan Mine). On the whole, the turquoise deposits follow the same direction as the major regional strikes and tectonic lines (Hao Yongwei *et al.*, 1982; Peng Yuanguo, 1989). In this region, secondary folds and fracture tectonics are well developed, but the tectonic patterns can be very complex. They have, however, created very favourable space conditions for the formation of the turquoise. Gem quality turquoise suitable for use in jewellery often occurs as lenticles and

Figure 9: *Turquoise in a compressed fractured zone between beds of slate.*

nodules in the compressed and fractured zones between the layers of complex fold structures and in tension joints. In this sense, the Yunyang region is distinctively characterized by tectonic control of the ore *(Figures 9 and 10)*.

Most of the fracture zones in the Yunyang District are compressed between the strata of the intermediate- to thick-bedded

Figure 10: *Turquoise filling tension joints in slate.*

Figure 11: *Nodular turquoise in the lenticles compressed between slate beds.*

carbonaceous-siliceous slates. Generally speaking, the more the lenticles have been compressed between the strata, the more nodular the turquoise and the better its gem quality. In addition to turquoise, the lenticles are composed largely of loose clay, carbonaceous materials, limonite, silt, sand and protolithic breccia *(Figure 11)*.

Compared with turquoise deposits outside China (Fayaz and Forghani, 1975; Ivanova, V.P., 1974), the Yunyang turquoise deposits are larger and more complex in both shape and type. The colour varieties and excellent quality are among the best in the world. In Yunyang, also, there are more complex parageneses and a greater variety of associated minerals in the region.

Figure 12: *Nodular turquoise mined from a tunnel.*

Figure 13: *Detail of typical nodular turquoise.*

Figure 14: *Turquoise from a quartz vein.*

The turquoise ore body is lenticular overall, but there are some secondary veins. Locally the accumulation of turquoise is nodular, massive or botryoidal *(Figures 12, 13 and 14)*.

The turquoise deposit is vertically zoned and at Yungaisi, for example *(Figure 15)*, at or near the ground surface 820–840 m above sea level the turquoise deposits are pale in colour, poor in quality, and of small volume and low hardness. But at the approximate ground water surface 720–800 m above sea level there are prolific ore zones with turquoise of the best quality and excellent colours. For instance, about 6000 kg has been mined from just one lenticular ore body, with some individual masses of turquoise as heavy as 100 kg. At depths lower than 700 m

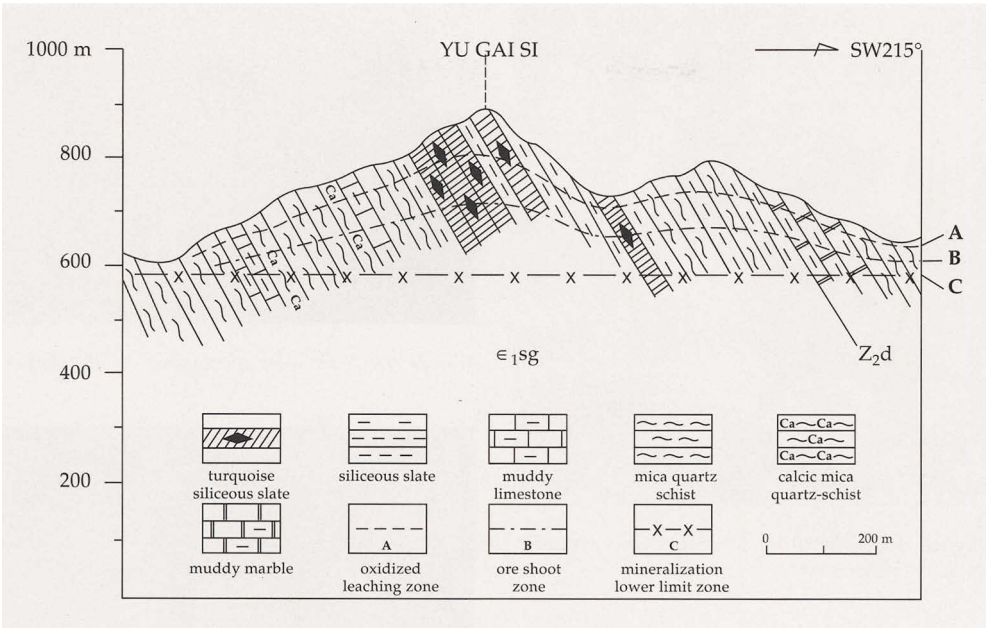


Figure 15: *Schematic diagram of the turquoise range of occurrence.*

above sea level, turquoise rarely occurs. But the quantity of massive allophanite markedly increases. Beneath 680 m above sea level, turquoise is virtually absent (these figures apply to the region whose water table elevation is about 800 m above sea level).

Gemstone and mineral features of the turquoise

Turquoise is a hydrous copper aluminium phosphate with a chemical composition of $CuAl_6(PO_4)_4 \cdot (OH)_8 \cdot 5H_2O$. Although the colour of turquoise is variable, its main chemical constituents Al_2O_3, P_2O_5 and H_2O, are relatively stable *(Table II)*.

Fresh turquoise, massive and opaque, displays a weak lustre described as waxy and a conchoidal fracture. Through the microscope the structure of turquoise can be seen to be cryptocrystalline to microcrystalline, and locally spherulitic *(Figures 16 and 17)*. In places, pisolitic and oolitic structures can be observed *(Figure 18)*. The refractive index of the turquoise ranges from 1.614 to 1.652, its hardness is between 5 and 5.4 and specific gravity lies between 2.56 and 2.78. Brown and black lines and irregular

Table II. *Chemical composition of turquoise from Yunyang, Hubei, China (in weight per cent oxides)*

Sample number	*Colour*	Al_2O_3	P_2O_5	Fe_2O_3	*FeO*	*CuO*	*CaO*	H_2O	*Total*
T-001	Blue	35.92	34.64	1.21	–	8.34	0.04	19.75	99.90
T-006	Pale-blue	36.12	33.40	1.14	–	7.52	0.02	20.64	98.84
T-019	Blue-green	35.57	34.15	2.70	0.03	7.17	–	20.32	99.94
T-022	Green	34.79	35.11	3.07	0.04	6.38	0.02	18.71	98.12
T-025	Yellow-green	34.06	34.89	6.58	0.08	6.23	–	18.73	100.57

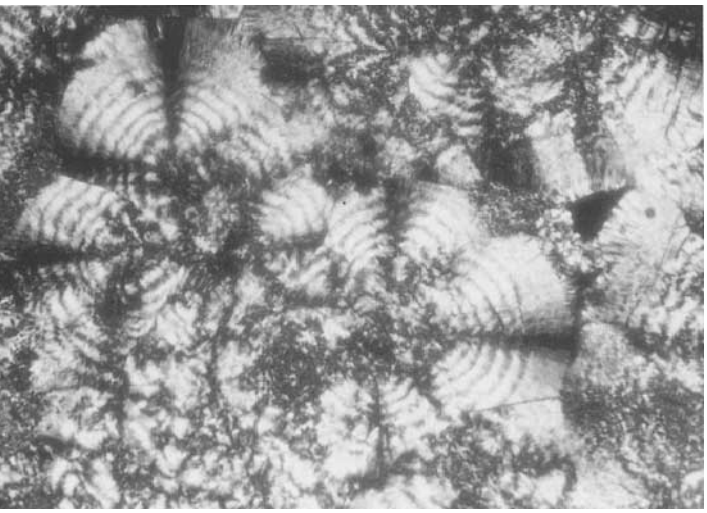


Figure 16: *Spherulitic structure in turquoise, crossed polars, x100.*

white veins in the turquoise are common features *(Figure 19)*; the black lines are attributed to carbonaceous material, and the brown to iron oxides or hydroxides.

Fourier transform infrared spectroscopy (using a Nicolet – 550) can be performed on KBr pressed discs containing the turquoise to determine its infrared absorption spectrum. One spectrum is shown in *Figure 20* where

Figure 17: *Spherulitic structure of turquoise, crossed polars, x100.*

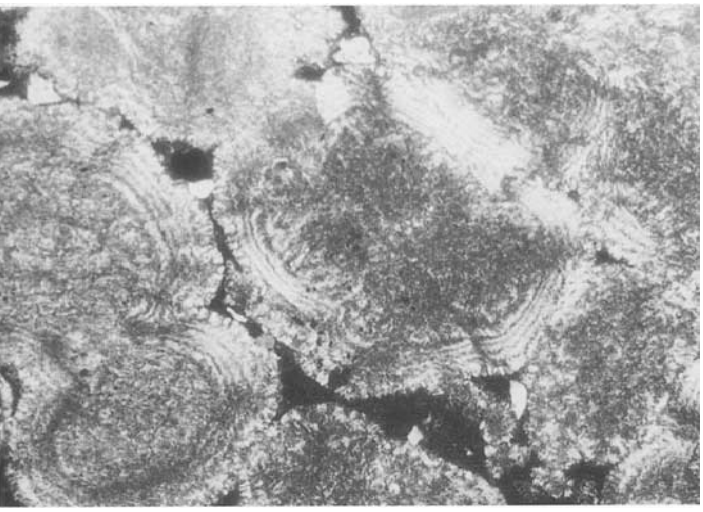


Figure 18: *Turquoise displaying oolitic shapes, x20.*

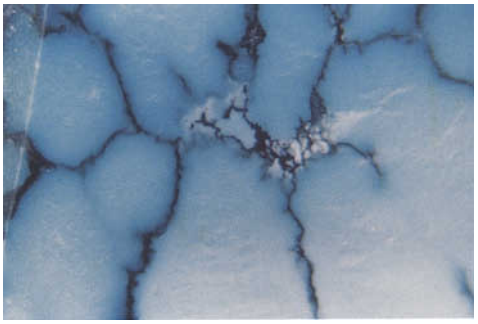


Figure 19: *Irregular brown (iron) and black (carbon) lines with white vein striation crossing turquoise, x10.*

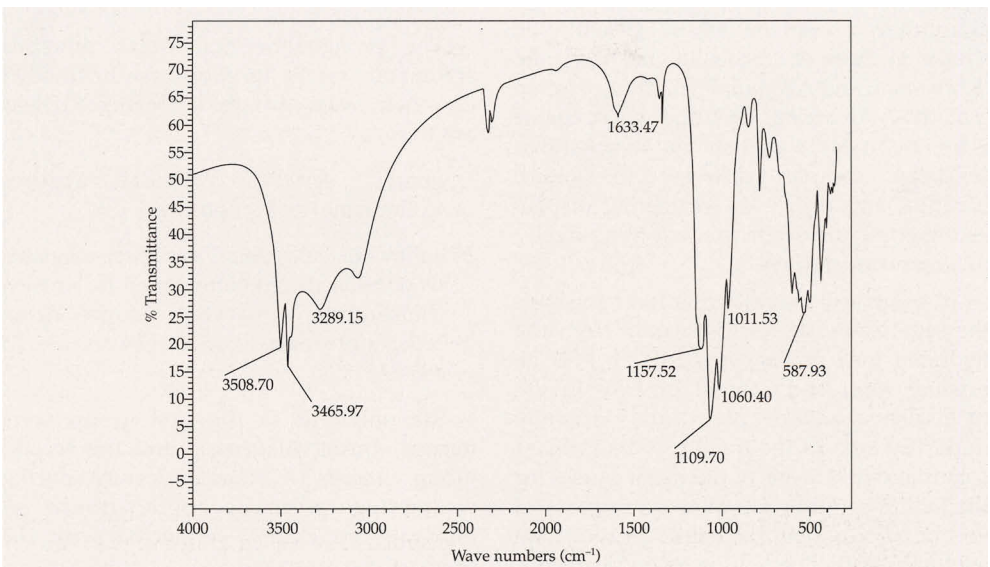
the peaks are interpreted as resulting from the stretching and curving vibrations mainly from OH, H_2O and also from the $[PO_4]$ tetrahedron *(Table III)*.

In the present paper, the differential scanning calorimetry (DTA in DSC mode) technique is employed to determine the behaviour of turquoise powder with increase in temperature, with the turquoise samples and reference samples being subject to the same adjustable temperature conditions. The results are shown in *Figure 21*, in which the values on the ordinate represent Heat Flow (mW). The results show that the water (H_2O) in turquoise is driven off when heating through the temperature range from 350°C to 380°C, and the resulting endothermic effect is caused by the complete breakdown of the crystal lattice of the turquoise. Therefore, it is concluded that the water in turquoise occurs not only as crystalline water but also as

Table III. *Infrared absorption spectra of turquoise (peak positions in cm^{-1})*

Source	*Present paper (blue, 1996)*	*Zhang Huifen (blue, 1982)*	*H. Moenke (1962)*
Vibration type			
Stretching vibration of OH and H_2O	3508.70	3511	3508
	3465.97	3465	3463
	3448.20	3440	3446
	3289.15	3320	3295
	3088.23	3090	3090
Curving vibration of H_2O	1633.47	1625	1650
Stretching vibration of P–O(Υ_3)	1182.40	1184	1195
	1157.52	1160	1175
	1109.70	1105	1115
	1060.40	1050	1063
	1011.53	1010	1016
Stretching vibration of P–O(Υ_1)	902	890	905
Curving vibration of OH	835	837	838
	778	777	790
	723	717	
	698		
Curving of vibration of P–O(Υ_4)	648	645	615
	615	600	615
	588	585	596
	567	540	580
	502	475	480
	478	450	460
Curving vibration of P–O(Υ_2)	446		
	422	425	432
	410	405	411

Figure 20: *Infrared absorption spectrum of turquoise.*



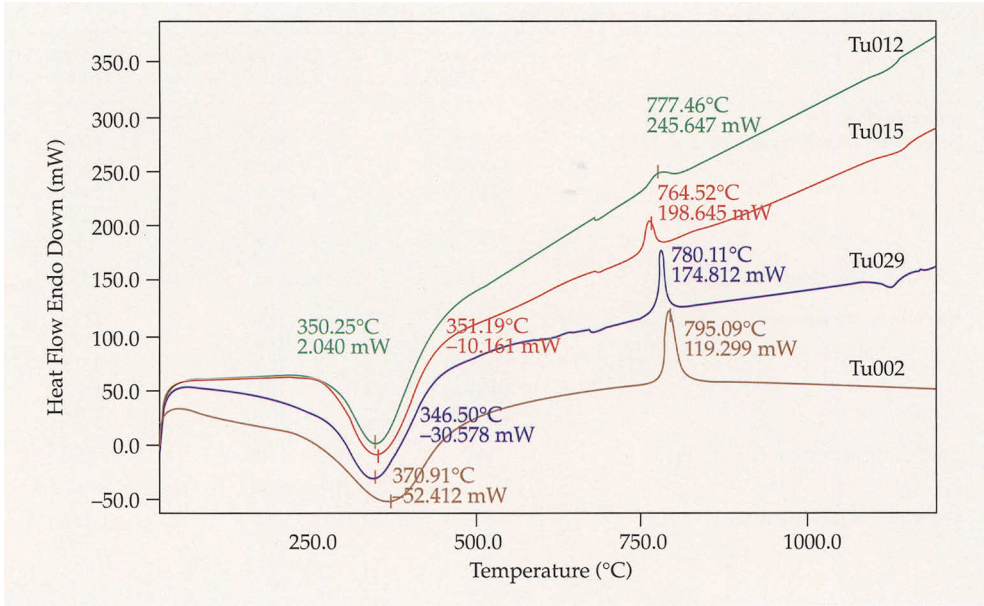


Figure 21: *Differential thermal analysis (DTA) in Differential Scanning Calorimetry (DSC) mode:spectra of turquoises of different colours. (Tu012 grey-yellow; Tu015 yellow-green; Tu029 blue-green; Tu002 blue).*

constitutional water, and the exothermic effect shown in the temperature range from 760°C to 800°C has resulted from recrystallization after expelling the constitutional water from the turquoise, resulting in a new heatphase transformation product. This phase is an aluminium phosphate whose structure is similar to those of cristobalite and tridymite (Khorassani and Abedini, 1976; Zhang Huifen *et al.*, 1982; Anderson, 1962) and whose colour is brown. In addition, it should be noted that turquoise samples differing in colour, hardness and degree of weathering display endothermic and exothermic effects at slightly different temperatures.

In summary, the colouring mechanism of the blue turquoise results mainly from the hydrated ions of copper $[Cu(H_2O)_4]^{2+}$. The existing form and content of H_2O in the turquoise structure plays an extremely important role in the quality of its brilliant colour and also is one of the major causes for the fading of turquoise. With an increase of Fe^{2+} or Fe^{3+} content, the colour of turquoise may vary from blue to blue-green to green.

Because the heat stability of the turquoise from this district is relatively poor, the gem should be well looked after and should be protected from too much exposure to the sun or to high temperatures. In this way the colour of the stone can be maintained.

The paragenetic and other minerals accompanying the turquoise can be divided into two major groups according to their origin:

1. quartz, sericite, colloidal apatites (collophane) and sulphides;
2. halloysite, allophane, variscite, evansite, woodhouseite, goethite, limonite, jarosite, chalcanthite, baryte, cuprocalcite, brochantite and azurite *(Figures 22, 23 and 24).*

The minerals in the first group were formed during diagenesis and the second group consists of minerals formed during weathering processes. Both groups of minerals are closely connected with the origin of the turquoise.

Figure 22: *Evansite, an accompanying mineral of the turquoise.*

Figure 23: *Variscite, associated with the turquoise deposit.*

Summary

The Yunyang turquoise deposit is located at an intermediate latitude where humid and rainy seasons alternate with high temperatures and dry weather. This weather pattern is favourable for the weathering, leaching, migration, concentration and precipitation of metallogenic elements.

Weathering and erosion have affected the ancient land of Wudang for a long period of time, and a great number of metallogenic materials occur in this district. Their abundance in the ore-bearing rocks is tens of times the regional background levels. The copper and phosphorus occur mainly in finely dispersed sulphides in the carbonaceous-siliceous slates, and in the irregular patchy colloidal apatites (collophane).

The intensity of mineralization is controlled by lithology, structure and ground water level. The petrochemical indicators favourable for mineralization are high silica, copper and phosphorus and low CaO, K_2O and MgO; additionally, the ratio Al_2O_3/SiO_2 should be <0.05%, and $(CaO+K_2O+MgO)/SiO_2$<0.02%.

The major ore shoot occurs in lenticular bodies compressed between the main rock strata. This ore-body morphology and the gem quality are both controlled by the scale of the fracture zone compressed between the strata. In space, the direction of the mineral occurrence is the same as that of the overall structural trend of the strata and faults.

The turquoise often occurs in massive nodules or as vein fillings. It contains concentric layered structures resembling specific spherulitic, oolitic or pisolitic bodies; such structures are characteristic of minerals formed by secondary leaching processes (Mitchell *et al.*, 1978). In vertical section, the turquoise deposit is markedly zoned as a result of ground water activity.

After comprehensive analysis of the geological features, the mineral compositions, the paragenetic mineral assemblage and structural features of the turquoise deposit, it is concluded that the turquoise in the Yunyang district was formed by secondary leaching processes.

Figure 24: *Brochantite, associated with the turquoise deposit.*

There are strong indications that the turquoise resources of the Yunyang district have much potential and are of possible significant development in the future.

Acknowledgements

We would like to thank the editors of *The Journal of Gemmology* for their support and help in revising the paper.

References

Anderson, W.R., 1962. Secondary phosphates from Bingham, Utah. *Am. Miner.*, **47**, 1303–9

Fayaz, H., and Forghani, A.H., 1975. The turquoise of Iran. *Rocks and Minerals*, **50**, 526–8

Hao Yongwei, *et al.*, 1982. 1:200,000 Regional geological surveying report in Yunyang, Hubei Province, China, *Hubei Bureau of Geology and Mineral Resources, unpublished*, 2–37

Ivanova, V.P., 1974. Thermoanalysis of rocks and minerals. Nedra Press, Leningrad, 182–223

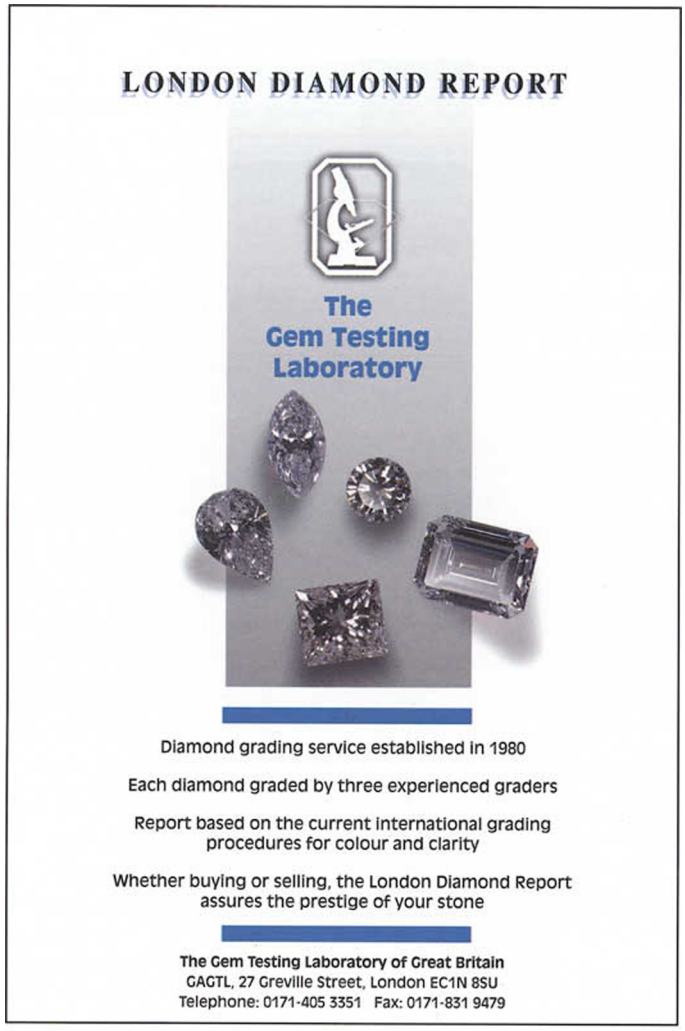
Khorassani, A., and Abedini, M.P., 1976. A new study of turquoise from Iran. *Mineral. Mag.*, **40**, 640–2

Mitchell, R.S., *et al.*, 1978. *Rocks and Minerals*, **53**, 214–8

Moenke, H., 1962. *Mineralspektren I.* Akademie-Verlag, Berlin

Peng Yuanguo, 1989. The origin and prospecting of turquoise. *Information of geological science and technology in Hubei*, **2**, 12–17

Zhang Huifen, Jiang Zechun, *et al.*, 1982. The investigation into turquoise mineralogy. *Journal of Mineralogy, Guiyang, China*, **4**, 254–61



Iridescence in plagioclase feldspars

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ABSTRACT: The play of colours shown by peristerite and some varieties of labradorite are an optical interference phenomenon caused by the occurrence of sets of plagioclase lamellae of two different compositions and thicknesses. It is now becoming clear that these lamellar intergrowths are restricted to and caused by two immiscibility regions in the compositional range of the plagioclase series. These cause distinct differences in the precise structure of the resulting plagioclases and the sharp boundaries of the lamellae.

Introduction

For at least two hundred years, mineralogists and gem lovers have marvelled at and enjoyed the strong iridescence shown by some labradorite, ever since the first specimens of this material were brought back from Paul Island, off the coast of Labrador, Canada, reputedly by Mr Wolfe, a missionary, around 1770 (Dana, 1982). But although numerous explanations have been advanced for this phenomenon, the first detailed scientific investigations were not reported until Lord Rayleigh's paper to the Royal Society in 1923 and that of Bøggild in 1924. Rayleigh (1923) made a detailed study of the optical scattering and calculated that the intergrowth texture giving rise to this scattering was ~6 μm across. Over the next two to three decades further work began to establish the existence of a layered structure, the iridescence in the visible range being an interference phenomenon (reminiscent of that seen in opal) due to the periodicity of the layered lamellar structures.

It was known from chemical analyses that no impurities or inclusions were responsible for this effect and that somehow plagioclase with more than one composition was present.

The advent of electron microscopy enabled the individual lamellae to be seen, e.g. Nissen *et al.* (1967), but it is only now that the crystal physicists, crystallographers and thermodynamicists have been able to provide a plausible scenario based on the plagioclase series as a whole.

It is believed that within the albite-anorthite series[1] there are at least three miscibility gaps due to structural transitions *(Figure 1)*. These were first mooted by Ribbe (1962) and their tentative boundaries outlined by McConnell (1974) and by Smith and Brown (1988), but the paper by Carpenter (1994) proposed an equilibrium phase diagram relating the three miscibility gaps to breaks in the ordering behaviour as a function of composition across the plagioclase series. It is unlikely to be a coincidence that iridescence is seen in the exact compositional ranges of these three gaps. These gaps have become known as the peristerite gap, the Bøggild gap and the Huttenlocher gap (Pe, Bø, Hu in *Figure 1*).

As mentioned above, the iridescence is an interference phenomenon and occurs because the lamellar intergrowths are on the same submicroscopic scale as the

1. For further details of feldspar nomenclature, etc., see, for example, Deer *et al.*, 1992.

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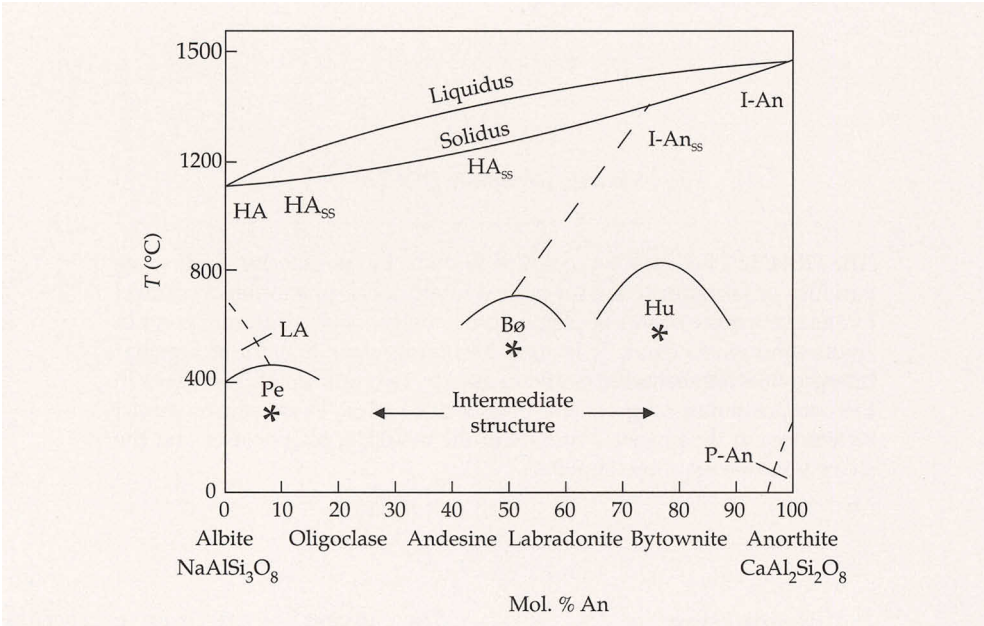


Figure 1: *Schematic illustration of variation in crystal structure across the plagioclase series. HA, high albite; I-An, body-centred anorthite; LA, low albite; P-An, primitive anorthite; ss (subscript) indicates solid solution; Pe, peristerite intergrowth; Bø, Bøggild intergrowth; Hu, Huttenlocher intergrowth (after Deer* et al., *1992). * Regions of 2-feldspar intergrowth.*

Figure 2: *Peristerite: sodic plagioclase showing 'delicate' interference colours.*

wavelength of visible light, i.e. a few hundred nanometres. In the plagioclase series there are two compositional ranges which may show iridescence, those representing a composition of the peristerite gap and the better known labradorescence in the Bøggild gap.

Peristerescence

Peristerescence is restricted to those plagioclases in the albite-oligoclase (An_1–An_{17}) range which show a play of colours (or schiller) reminiscent of those on the neck of a pigeon (Greek peristera). The name was given by Thomson (1843) for a specimen of iridescent albite in a granitic pegmatite from Perth, Ontario. Peristerite has since been described from Froland, Norway, and from many other localities in Ontario and the U.S.A. (Fleet & Ribbe, 1965) and Europe (Nissen *et al.*, 1967). The colours are generally more delicate than for labradorescence, often appearing on a white or buff-coloured plagioclase *(Figure 2)*. From

detailed work with the electron microscope and the electron microprobe, it has been shown that the colours are produced by alternating planar thick and thin lamellae of albite (An_0) and oligoclase (An_{25}), respectively. The sodic component is ordered low-temperature albite while the calcic component appears to be less well ordered oligoclase, the compositional difference being of the order of 20% An. The albite lamellae are always considerably thicker than the oligoclase lamellae, generally by 2:1; most simple lamellar peristerites have periodicities for a + b of 50–300 nm.

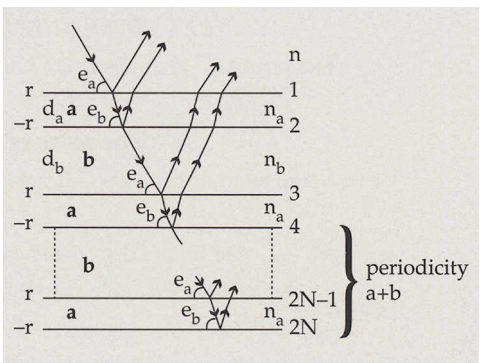
Labradorescence

The second and more familiar type of plagioclase iridescence occurs in the andesine-labradorite (An_{45} – An_{60}) range and is known as *labradorescence*. After being originally found in orthopyroxene-plagioclase gabbro at Paul Island, it is now known to occur in the adjacent Nain gabbroic complex on the mainland of Labrador and in many Precambrian basic/ultrabasic igneous rocks worldwide. As in peristerite, labradorescence is an interference phenomenon due to reflected light waves from a multilayer assemblage of two periodically stacked lamellar structures. The colours displayed are in the blue, red and yellow parts of the spectrum, the overall effect being somewhat darker than for peristerite *(Figure 3)*. Nissen *et al.* (1967) carried out electron microprobe analyses of around 100 specimens and checked the presence of a submicroscopic layered structure by electron microscopy. They found that all the iridescent specimens contained an appreciable amount of the potassium feldspar (orthoclase $KAlSi_3O_8$) molecule (now generally put at ~2.5%) and that the wavelength of the average iridescence (colour) increased with the An content (blue $An_{48.5–52}$, green-yellow $An_{52–55.5}$, orange-red $An_{55–55.8}$). The lamellar periodicities for a + b are ~50–280 nm, but in labradorescence the difference in thicknesses of the two alternating lamellae is rather small, although the more An-rich set increases rapidly in

Figure 3: *Labradorite: intermediate plagioclase showing strong interference colours.*

thickness with increasing An content and the An-poor set decreases slowly. The differences in composition between the two sets of lamellae are ~12–15 mol. per cent An, typically from ~$An_{45–46}$ to $An_{58–60}$. Miúra *et al.* (1975) proposed a model with a schematic arrangement as shown in *Figure 4* for two compositional varieties of plagioclase, termed a and b. More recently, an investigation of Bøggild intergrowth in plagioclase from Ylämma, Finland, using high-resolution transmission electron microscopy demonstrated the occurrence of two phases of composition An_{60} and An_{47} for the thicker and thinner lamellae, respectively

Figure 4: *Schematic representation of a model for lamellar structure in iridescent labradorite (after Miúra* et al., *1975).*



(Hoshi *et al.*, 1996), with a bulk composition of $An_{56.5}$; the matching of the crystal lattices across the exsolution lamellae was noted.

Huttenlocher intergrowth

The third of the miscibility gaps in the plagioclase series is in the calcic labradorite-bytownite range (~An_{67}–An_{90}). The lamellar structure in this region is called the Huttenlocher intergrowth and can be seen by electron microscopy. It is much coarser than intergrowths in the more sodic parts of the plagioclase series and so is unlikely to show any visible iridescence – indeed none has yet been discovered.

References

Bøggild, O.B., 1924. On the labradorization of the feldspars. *K. Danske Vidensk Selsk. Mat.-Fys. Meddel.*, **6**(3), 1-79

Carpenter, M.A., 1994. Subsolidus phase relations of the plagioclase feldspar solid solution. In: Parsons, I. (ed) *Feldspars and their Reactions*, Dordrecht (Kluwer Acad. Publishers), 221–69

Dana, E.S., 1892. *The System of Mineralogy* (6th edition). New York (John Wiley & Sons, Inc), 1xiv, 1134

Deer, W.A., Howie, R.A., and Zussman, J., 1992. *An Introduction to the Rock-Forming Minerals* (2nd edition). London (Longman), xvi, 696

Fleet, S.G., and Ribbe, P.H., 1965. An electron-microscope study of peristerite plagioclases. *Min. Mag.*, **35**, 165–76

Hoshi, T., Tagai, T., and Suzuki, M., 1996. Investigation on Bøggild intergrowth of intermediate plagioclase by high-resolution transmission electron microscopy. *Z. Krist.*, **211**, 879–883

McConnell, J.D.C., 1974. Analysis of the time–temperature–transformation behaviour of the plagioclase feldspars. In: MacKenzie, W.S., and Zussman, J. (eds). *The Feldspars*. Manchester Univ. Press, Manchester, 460–77

Miúra, Y., Tomiska, T., and Kato, T., 1975. Labradorescence and the ideal behavior of thicknesses of alternate lamellae in the Bøggild intergrowth. *Min. J. (Japan)*, 7, 526–41

Nissen, H.-U., Eggman, H., and Laves, F., 1967. Schiller and submicroscopic lamellae of labradorite. A preliminary report. *Schweiz. Min. Petr. Mitt.*, **47**, 289–302

Rayleigh, L., 1923. Studies of iridescent colour and the structure producing it: III. The colours of labradorite feldspar. *Proc.Roy.Soc.London*, **103A**, 34–5

Smith, J.V., and Brown, W.L., 1988. *Feldspar Minerals: 1. Crystals Structures, Physical, Chemical and Microtextural Properties*. Berlin, Heidelberg & New York (Springer-Verlag), xviii, 828

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Notes from the Gem and Pearl Testing Laboratory, Bahrain – 6

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ABSTRACT: Owing to amber's frequent use as prayer beads in the Middle East, we test quite a few pieces each month and these generally include some interesting or unusual examples. In these notes we will describe the surface enhancement, cavity filling, 'construction of and repair to' and chatoyancy observed in five amber prayer beads that were submitted for examination. The notes end with three items on pearls.

Surface-enhanced amber

Surface-enhanced amber is a topic we have discussed on more than one occasion in 'Notes from the Gem and Pearl Testing Laboratory of Bahrain' (Scarratt, 1992; Bubshait and Sturman, 1993). The reason for mentioning it again is that the colour difference between the surface area and the underlying 'body colour' of the 33 round beads, two disc-shaped spacers and one cylindrically-shaped terminating bead (the Arabic name for this bead is 'Shaahed') is exceptional. The row appeared semi-opaque to opaque, dark red to almost black when viewed under an ordinary desk lamp, and black in daylight. However, under a fibre-optic light source a translucent orange/red colour was observed, although it was still difficult to get a clear view of the interior as the light did not penetrate effectively even at full intensity. A saving grace for us was that the 'Shaahed bead' had been broken in two and this allowed the end of the fibre-optic light source to be placed right up against its 'interior surface'. It was evident that the pale yellow interior of this bead was markedly different from the dark orange/red marginal colour. With the customer's permission a small area around the fracture was tested with a thermal probe to see if more of the 'surface colour' could be removed to reveal the true underlying colour. This was carefully done to avoid spoiling the appearance of the bead's surface. Once removed (the material that was removed gave a typical resinous 'amber' odour) the colour difference was more noticeable *(Figure 1)*. Because it was difficult

Figure 1: *The obvious colour difference between the surface and interior of colour-enhanced amber.*

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Figure 2: *The head section of the praying-mantis like insect.*

Figure 3: *Air bubbles trapped within the filler in amber (transmitted light).*

to inspect the interior structure of the beads and find sufficient evidence for a natural or pressed structure, these beads were returned to the customer with only a verbal report. The customer was told that tests were inconclusive and further progress was only possible through removal of the coloured skin – either from a necklace bead or from material of the same type.

Filled amber beads

Although filled stones are often mentioned in gemmological literature, it is usually the more costly gemstones such as diamond, ruby and emerald that are involved. However, two sets of amber prayer beads examined recently, submitted by different customers at different times, revealed interesting fillings.

The first set consisted of beads that contained a number of good insect inclusions in mostly clear amber, including what appeared to be the head section of a praying-mantis-like specimen *(Figure 2)*. Unfortunately this inclusion was awkward to photograph. Most fillings were confined to small surface cavities, but two or three surface reaching fractures running through some beads were also filled. One characteristic of these particular fillings was that numerous air bubbles were found as inclusions within the filler *(Figure 3)*. In reflected light some of these bubbles were evident as 'blow-holes' on the surface (*Figure 4* transmitted and reflected light same feature).

Figure 4: *The same subject as Figure 3 in reflected light. Note the 'blow holes'.*

The second row comprising 33 prayer beads, weighed approximately 650 carats and did not contain insect inclusions. The beads were mostly transparent to translucent, clear to cloudy, yellow or yellow/orange and showed evidence of heat treatment. However, as it is not rare for amber to be heat treated these days, it was not this that interested us but a number of fillings. On the whole the beads were fine and unaffected, but the 'Shaahed' bead (see 'constructed Shaahed' below), two carved cylindrically-shaped spacers and one oval bead were each selectively filled. The material used to fill the 'Shaahed' looked

Figure 5: *Large filled area in one of the oval amber beads.*

Figure 6: *An air bubble trapped in the adhesive used to repair a bead.*

quite different from that used to fill the other three beads. In the 'Shaahed', one end of an unused drill-hole was filled with what appeared to be a transparent, possibly colourless or yellow adhesive, whilst the filler used on the other three beads took on a cloudy, translucent to opaque appearance, that could easily be mistaken for the frequently seen cloudy areas in some types of translucent to opaque amber. The cloudy filler was most apparent in the oval bead, where it had been used to fill a large surface-reaching cavity *(Figure 5)*, originally either a gas bubble or perhaps even the location of a pollen grain.

The fillers in both sets of prayer beads were first detected by optical examination. Secondly, exposure to ultraviolet light revealed a subtle difference in fluorescence that could easily have been overlooked, as the fluorescence of the larger amber beads masked the fluorescence of the filler. Finally, the thermal-probe provided confirmation of the presence of fillers in both sets of beads; each melted and gave wax-like odours. Although we could not identify the fillers, they were significantly different from amber.

Repaired and constructed 'Shaahed' beads

A Shaahed, the Arabic name given to the 'turned' cylindrical bead that commonly terminates a row of prayer beads *(Figure 7)*, is usually fashioned from the same material as the other beads in the row and also from a single piece of such material. There are also gold or silver 'Shaaheds' which are often more durable than amber. In many strings of beads we have examined, the 'Shaahed' has suffered breakage and then been repaired, with varying degrees of skill, using an adhesive. This problem is not surprising given the ratio of thickness to length of the 'Shaahed' and the sometimes rough handling that the prayer beads experience. The repaired area is usually very easy to detect, and commonly contains one or more bubbles in the adhesive *(Figures 6 and 7)*.

Figure 7: *The constructed Shaahed. Note the translucency of the central section, compared to the pieces on either side. This bead was fashioned from three separate pieces of amber that had been bonded together with adhesive.*

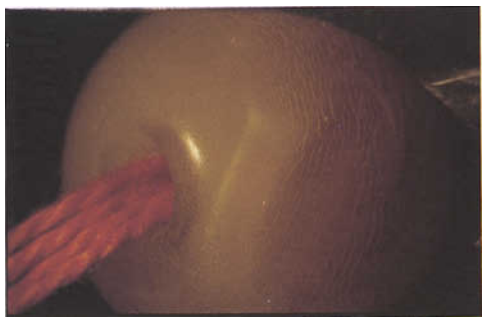

Figure 8: The chatoyant effect noted in one bead from a row of prayer beads.

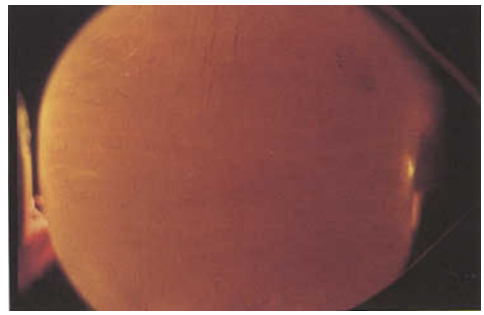

Figure 9: The 'banded' internal structure partly responsible for the chatoyancy seen in Figure 8.

Chatoyancy in amber

If students about to sit their gemmology examination were asked to name any chatoyant gemstone, they would probably suggest the names of the more likely stones such as chrysoberyl, quartz, tiger's-eye, apatite, tourmaline or scapolite. It would be doubtful if anyone would mention amber because it is not in the text books and until very recently we had not seen a convincing example. However, when we were carrying out a routine inspection of the beads in a row of prayer beads, we were surprised to find one bead that appeared to display a chatoyant effect near the drill-hole *(Figure 8)*.

Closer examination revealed that it was a chatoyant effect produced by finely banded streams of minute bubbles *(Figure 9)* combined with a series of 'chatter marks' in the same direction on the surface of the bead. The chatter marks seemed to enhance the rather weak chatoyant effect from the internal bubbles. As with obsidian, this is considered to be an accidental optical effect and not to be considered in the same way as chatoyant varieties of chrysoberyl or tourmaline whose optical effects are structurally controlled.

Figure 10: The 29.22 ct non-nacreous and nacreous, brown and white pearl.

Non-nacreous and nacreous pearl

Most of the pearls that gemmological laboratories around the world examine during their day-to-day routine are nacreous. Although these pearls are commercially more desirable, the majority of gemmologists and jewellers also know that there are certain non-nacreous pearls that are also very desirable, but much harder to find in good quality. These include pearls from various varieties of conch, namely queen conch [Strombus gigas], horse conch [Pleuroploca gigantea] and Melo volutes as well as pearls from other molluscs such as the giant clam (Tridacna gigas) and other lesser-known species. These species always produce non-nacreous pearls, unlike the nacreous pearl-producing species which can produce both kinds (Bubshait and Sturman, 1994, Hurwit, 1989, 1991).

A dark-brown pearl *(Figure 10)*, submitted for examination by Al-Majid Jewellery, showed this interesting phenomenon once again. The undrilled pearl, weighing 29.22 ct, and measuring approximately 18.21–18.34 x 14.51 mm, was found in the Arabian Gulf over forty years ago and has been in the possession of the Al-Majid family ever since. The button-shaped (bouton) pearl appears dark brown over most of its surface, but possesses a white circular area at its base. The whole of the brown area is non-nacreous, whilst the white area is nacreous. Since the pearl was undrilled, an adhesive was used to mount it into a ring for display at an exhibition in Bahrain. One of the Al-Majid brothers tried to recall from what species of oyster the pearl was found and although unsure (he was a young boy at the time), thought that it may have been from 'the same type of oyster that produces the usual (nacreous) pearls', i.e. Pinctada radiata. However, consultation with the Bahrain Centre for Studies & Research and another pearl merchant with a large stock of this type of pearl suggested that the oyster often, but not solely, responsible for producing this type of non-nacreous pearl (usually under 5–6 mm) is Pinctada margaritifera. Exactly which of these two species produced this particular pearl is unclear.

Gemmologically, this pearl was very interesting, because on first impression the white area on the base looked as if it could have been 'fixed' into position with an adhesive to fill a surface cavity. However, no features indicating a cavity of any description could be found with either a microscope or more importantly by using X-radiography. Close examination of the junction between the nacreous and non-nacreous 'junction' also revealed that, although a crack ran all the way around, a very small portion of the non-nacreous area was naturally intergrown with the nacreous area. One possible reason for development of a crack between the nacreous and non-nacreous areas, is that over time the climate together with natural ageing had produced natural shrinkage in one or both substances.

Figure 11: *Orange-red fluorescence displayed by the naturally coloured brown part of the brown and white pearl.*

The reaction of the pearl to ultra-violet light was additionally of great interest. *Figure 11* shows that the pearl fluoresced a strong orangey-red colour over the brown areas and a typical blue-white over the nacreous area at the base. This reaction fits in with those seen in other completely to partially coloured brown, black or grey pearls examined previously including the famous Hope Pearl (Kennedy *et al.*, 1994) and is generally considered to be proof that the colour is natural. The bright blue/white fluorescing areas in the cracks appeared to result from residual adhesive used to fix the pearl in the ring for display, described above. For interest, we contacted a number of natural pearl dealers in Manama (Bahrain's capital) and asked if we could browse through their stocks of brown/black pearls to try and find similar examples for comparison. After browsing through numerous lots of pearls, only a few were found to possess part-nacreous and part-non-nacreous sections, and their features were similar to those described for the large pearl discussed above. The varied fluorescence of three of these pearls can be seen in *Figure 12*.

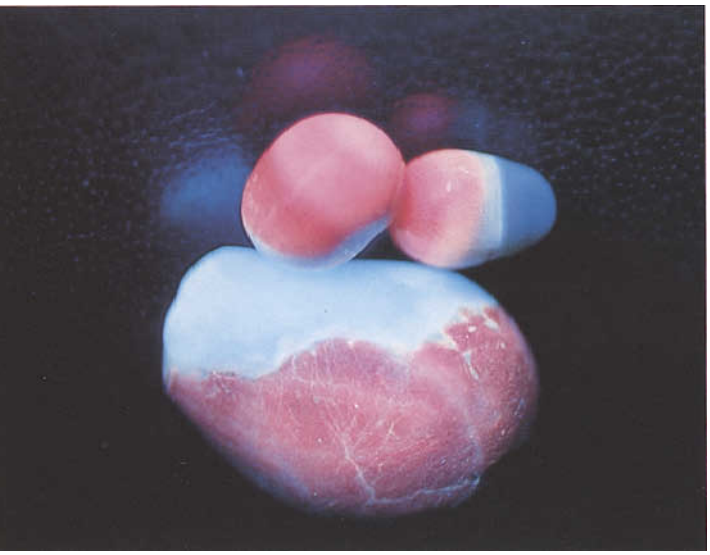

Figure 12: Three brown pearls showing red-orange fluorescence.

Figure 13: Radiograph showing the curious internal structure of the pearl purchased in Hong Kong (the opaque area around the pearl is due to lead).

Update on pearl-producing areas

In discussions with the Bandar Lengeh Fisheries Company (Iran) we have learned that most cultured or non-nucleated cultured pearls produced by Iran come from the islands of Khark (latitude 29°12′N, longitude 50°10′E) and Lavan (26°50′N, 53°15′E) or from along the Bandar Lengeh coasts. The small quantity of cultured and non-nucleated cultured pearls from these sources are usually supplied to the local jewellery trade. The pearl farm at Kish Island, reported by Anderson (Webster, 1983 p. 525) is apparently no longer operational.

In the laboratory, we see fairly large quantities of marine non-nucleated cultured pearls mixed with natural pearls. Up until our discussions with the Bandar Lengeh Fisheries Company, the thought that Iran could be the source of a majority of these was naturally in our minds. However, now our information is that most of the non-nucleated cultured pearls we see appear to originate from Japan as an accidental by-product of the traditional culturing process, i.e. 'keshi' or 'keshi-like' pearls. Large quantities of freshwater pearls from China and possibly Vietnam are also currently available throughout the Middle East and these are generally more prolific than the Japanese keshi pearls.

South Sea pearl

We were recently asked to determine the nature of a South Sea pearl pendant that had been purchased in Hong Kong (it was accompanied by a 'sales certificate'). We explained that the term 'South Sea pearl' usually refers to cultured pearls and the chances of it being natural were low. A radiograph *(Figure 13)* was obtained and proved surprising in that it did not show a shell bead nucleus as expected, but rather a cavity containing an inner 'solid body' that in turn had a small cavity. In normal circumstances, we would ask the customer to unset this particular pearl for further radiography, so that we could build up a three-dimensional image of the internal structure, in order to come to a positive result. Unfortunately, the customer was on a stop-over in Bahrain and had to board a flight the same day, so we had only a short time in which to examine it. Therefore, a

clear idea of the structure could not be determined. However, the internal and external appearance of the pearl suggested it was more likely to be of 'cultured' origin than natural and the price paid for it was consistent with this conclusion. How this pearl formed is unclear. If 'cultured', as expected, was its formation accidental or intentional? If the 'nucleus' was placed within an oyster on purpose to form the larger pearl, the correct nomenclature would be a cultured pearl; if, however, the 'nucleus' and resulting pearl were a result of accidental growth from a piece of mantle placed within an oyster, the term 'non-nucleated cultured pearl' would be more appropriate.'

Acknowledgements

The authors wish to thank Mr K. Scarratt for discussions on areas of the text during the compilation of these notes.

References

Scarratt, K., 1992. Notes from the Laboratory – 16. *J. Gemm.*, **23**, 4, 215–24

Bubshait, A., Sturman, N.P.G., 1993. Notes from the Gem & Pearl Testing Laboratory, Bahrain – 2. *J. Gemm.*, **23**, 7, 398–401

Bubshait, A., Sturman, N.P.G., 1994. Notes from the Gem & Pearl Testing Laboratory, Bahrain – 3, *J. Gemm.*, **24**, 1, 42–4

Hurwit, K., 1989. Gem Trade Lab Notes. *Gems & Gemology*, **25**, 3, 174

Hurwit, K., 1991. Gem Trade Lab Notes. *Gems & Gemology*, **27**, 2, 110–11

Kennedy, S.J., Akamatsu, S., Iwahashi, Y., 1994. The Hope Pearl. *J. Gemm.*, **24**, 4, 235–9

Spinel and garnet star networks: an interesting asterism in gems from Sri Lanka

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ABSTRACT: Four-ray and six-ray star networks are reported in spinel and garnet from Sri Lanka. Details of their arrangement and orientations are discussed.

Keywords: networks, groups, loops, octahedral, rhombic dodecahedron

Introduction

Some Sri Lankan spinels and garnets exhibit star patterns comprising four-ray and six-ray stars combined in spectacular designs which will be described and referred to as *networks*. Complete networks can be seen in eggs cut from these stones *(Figures 1 and 2)*. While spinel can show only one network configuration consisting of four-ray and six-ray stars, garnet may display one consisting only of four-ray stars or another with both four-ray and six-ray stars.

Numerous long or short, slender and parallel crystal inclusions are responsible for the optical star effects and network formations. Several such inclusion groups (which may be simply called *groups*), orient themselves along several directions in the host crystal. In spinel they consist of either rutile (needle-like) *(Figure 3a)*, sillimanite (blade-like) *(Figure 3b)* or diffuse microscopic white granules which look milky and resemble a solution, whereas in garnet there are only rutile needles *(Figure 4)*.

Upon reflection of light from a group, a chatoyant band forms around it, in a plane at 90° to the length of inclusions, and develops an optical loop, in this paper described and referred to as a *loop*. Loops so generated from several groups are oriented in different directions and can intersect to form a web or a network. It is apparent that the star contents (ignoring the star type) of the 3 network configurations are determined by the efficiency of a loop which is defined by:

$$\textit{Loop efficiency} = \frac{\text{Number of stars in the network}}{\text{Number of loops in the network}}$$

Spinel

Four-ray and six-ray network (Figure 1).

A spinel octahedral crystal has six groups which orient parallel to the [110], [1$\bar{1}$0], [101], [10$\bar{1}$], [011] and [01$\bar{1}$] directions (i.e. at 90° to the virtual rhombic dodecahedral crystal faces). They generate six loops which intersect and form a network of eight six-ray stars and six four-ray stars. The former is located at the centre of every (111) face and the latter at every edge point where four crystal faces meet. The loop efficiency = 14/6 (i.e. each loop contributes to form 2^1/$_3$ four-ray and six-ray stars).

Garnet

Four-ray network (Figure 2a).

A rhombic dodecahedral garnet crystal possesses four groups oriented parallel to the

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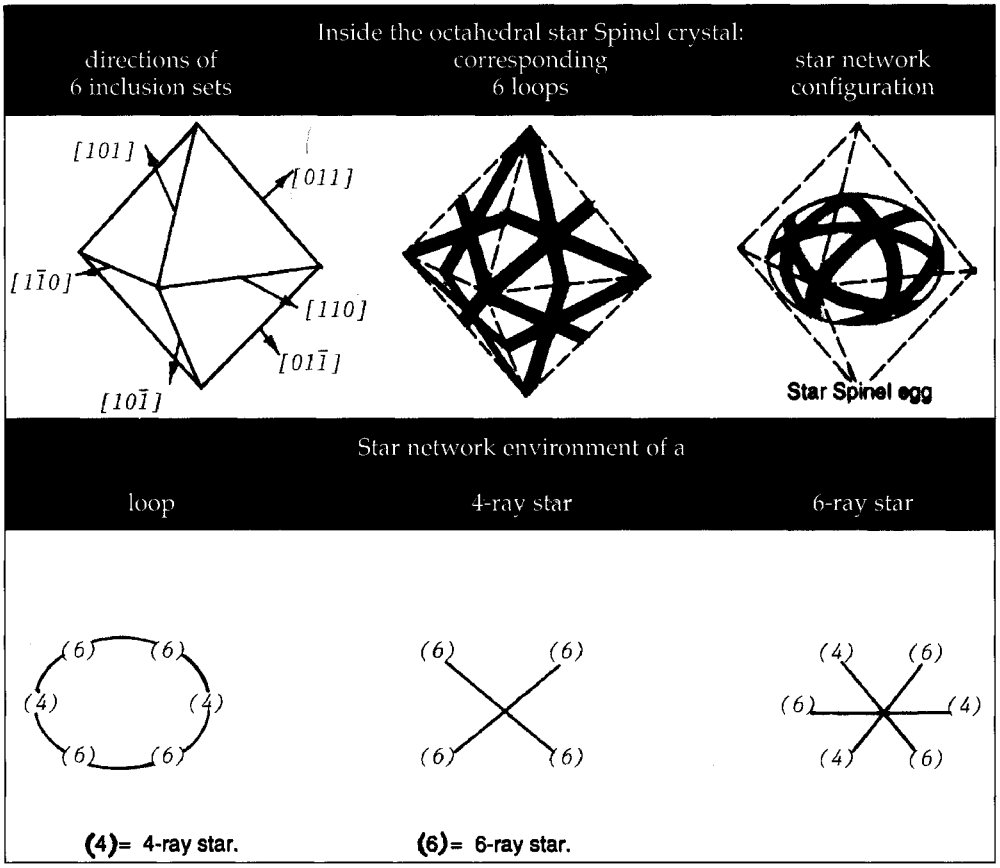


Figure 1: *Details of spinel four-ray and six-ray star network.*

[1$\bar{1}$1], [1$\bar{1}$1], [111] and [11$\bar{1}$] directions (i.e. at 90° to virtual octahedral crystal faces). These develop four loops, which intersect and create a network of twelve four-ray stars, at a rate of a star in the centre of every crystal face. The loop efficiency = 12/4 (=3), and, therefore, this kind of garnet network is more efficient than spinel loops but makes only four-ray stars.

Four-ray and six-ray network (Figure 2b).

A rhombic dodecahedral garnet crystal has 10 groups which fall into two classes of directions. One originates from a virtual octahedral crystal which coincides with the host crystal, with directions [110], [1$\bar{1}$0], [101], [10$\bar{1}$], [011] and [01$\bar{1}$] – as in the example of spinel above, and the other originates from the actual dodecahedral crystal with directions [111], [1$\bar{1}$1], [1$\bar{1}\bar{1}$] and [11$\bar{1}$]. Altogether they are responsible for 10 loops and thus could be labelled as six *octahedral loops* and four *rhombic dodecahedral loops*. Octahedral loops are invariably weak in intensity. Both kinds of loops may combine and create a network with thirty four-ray stars and twenty six-ray stars, making a total of 50 stars. The loop efficiency is 50/10 (=5) and although there are stars weak in intensity, these loops are the most efficient of the three networks discussed.

The correlation between octahedral and rhombic dodecahedral loops can be seen in the diagram given in *Figure 5.*

Box (b): A four-ray star results from an octahedral loop and a rhombic dodecahedral loop. There are 24 stars in total; each located on every corner where two dodecahedral

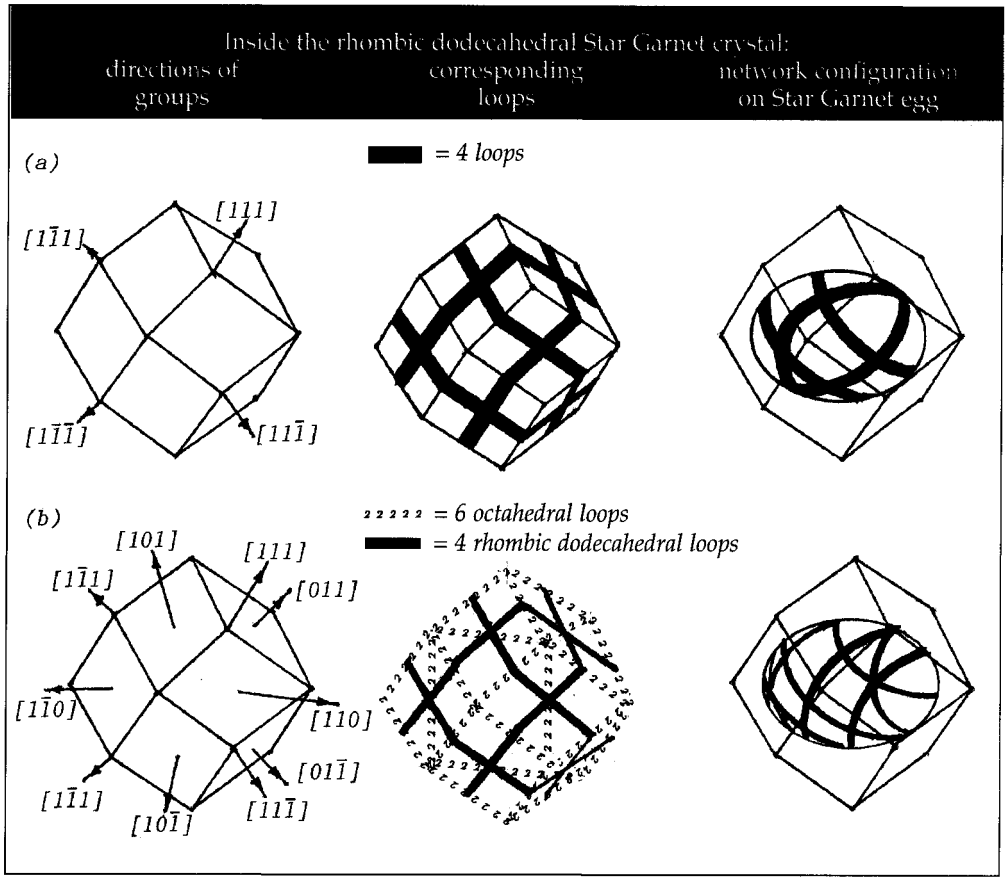


Figure 2: *Details of two garnet star networks.*

Figure 3(a): *Six-ray star isolated from the spinel star network.*

Figure 3(b): *Corresponding 'blade-like' sillimanite inclusion groups.*

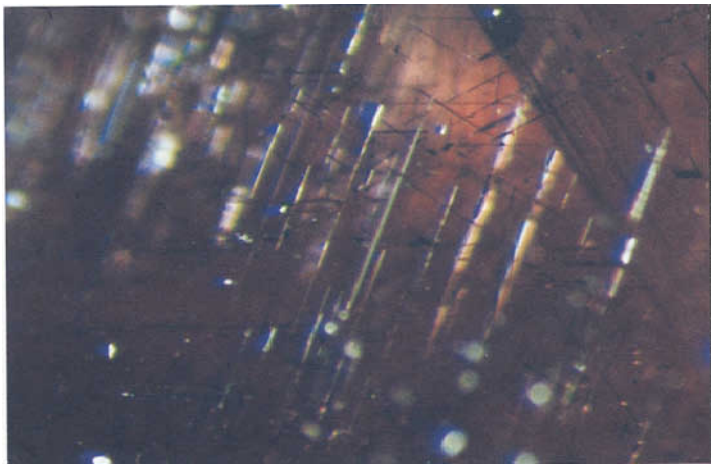
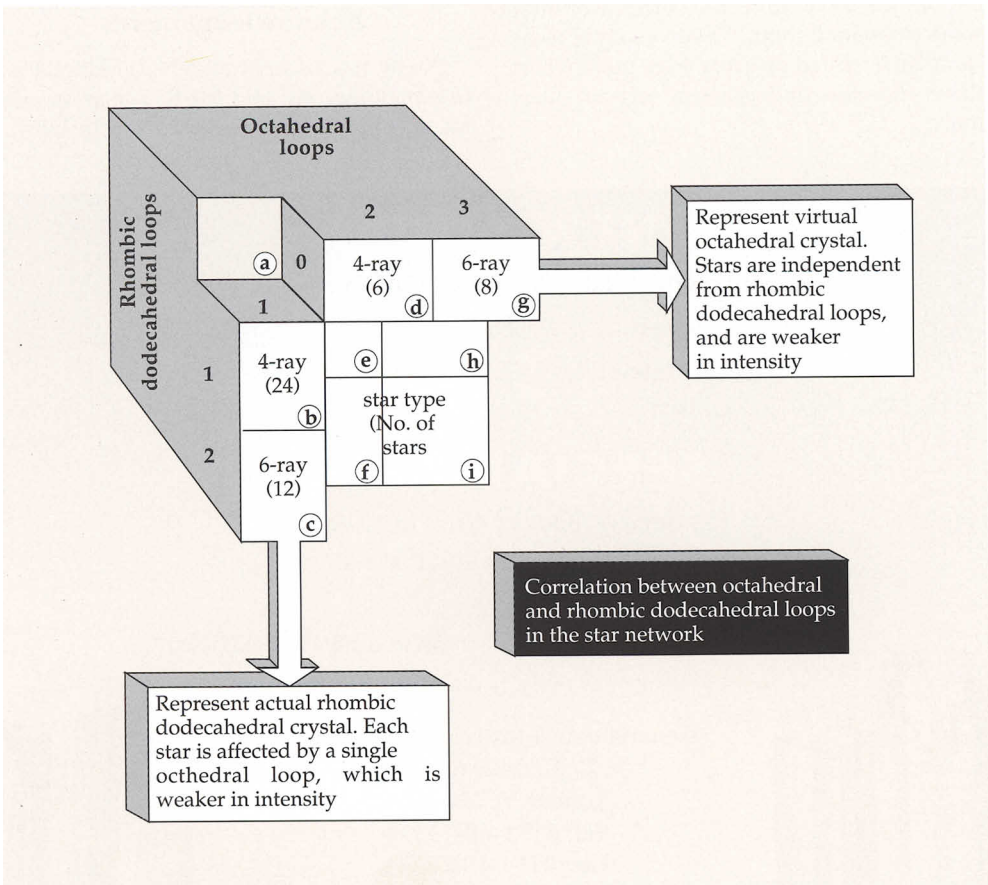


Figure 4(a): *Four-ray star isolated from the garnet four-ray star network.*

Figure 4(b): *Corresponding 'needle-like' rutile inclusion groups.*

Figure 5: *Anatomy of garnet four-ray and six-ray star network.*



crystal faces meet. As the octahedral loop is weaker in intensity compared to the other rhombic dodecahedral loop of the four-ray star, rarely stones have been cut to isolate the stronger loop; the resulting stone may resemble a cat's-eye and thereby be potentially deceptive.

Box (c): A six-ray star results from an octahedral loop and two rhombic dodecahedral loops; again the weaker octahedral loop is immediately noticeable. There are 12 stars in total, each located at the centre of every rhombic dodecahedral crystal face.

Box (d): A four-ray star is formed solely by two weak octahedral loops. There are six stars in total and each is located on every edge point where four rhombic dodecahedral crystal faces meet.

Box (g): A six-ray star is the outcome of three weak octahedral loops. There are eight weak stars, each located on every edge point where three rhombic dodecahedral crystal faces meet.

Boxes (a),(e),(f),(h) and (i): These loop combinations are not valid for the network.

Boxes (b) and (c): Represent an actual rhombic dodecahedral crystal, where each star in the network is affected by a single octahedral loop.

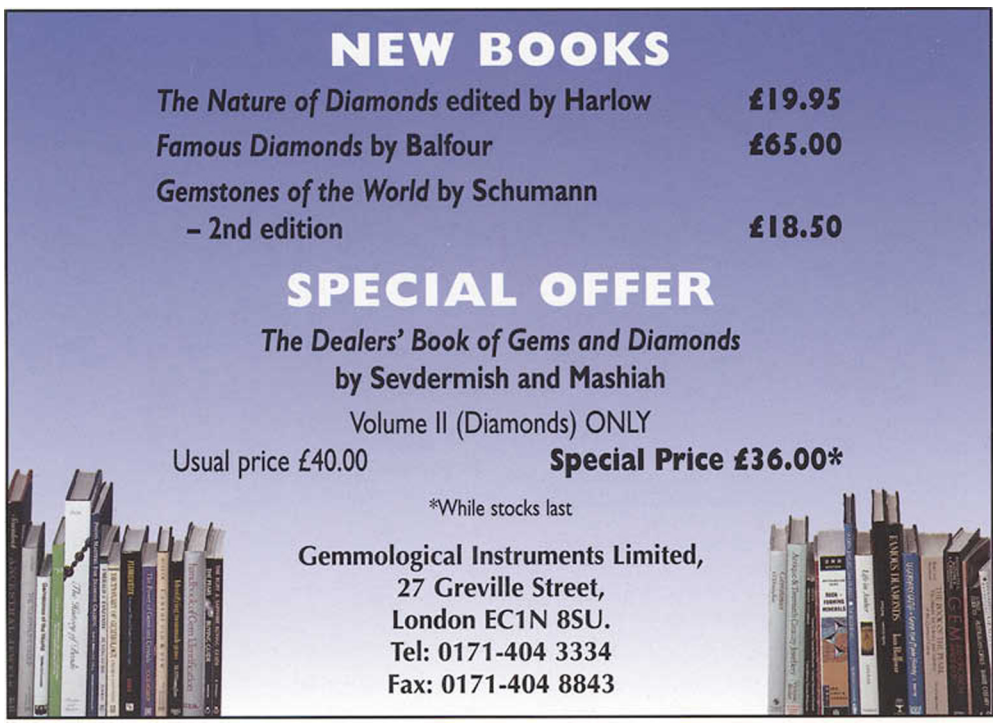
Boxes (d) and (g): Represent an unaffected virtual octahedral crystal.

Conclusion

The directions of the inclusions and their contexts are the most important features in formation of the networks. First, they should be parallel with reference to each other to form a group and, secondly, several such groups orient themselves along specific directions related to the crystallographic orientation of the host stone.

Acknowledgements

Many thanks to Mr T.G.N.R. Malinda for fine photographs, and Mr R. Samaranayake for micro-photograph of garnet inclusions.



Colour in topazes from rhyolite domes of the San Luis Potosi volcanic field, Mexico

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ABSTRACT: In the San Luis Potosi volcanic field (Mexico), both colourless and amber-coloured topazes (up to 4 cm) have crystallized in voids and fractures of the Cerro El Gato lava dome, near the village of Tepetate. They are well crystallized and the largest crystals are cut and marketed. In the neighbouring Cerro El Lobo lava dome, the topazes are very small (less than 5 mm) and slightly yellow tinted. Comparing these different crystals with respect to their growth environments in the field, habits, chemical compositions and EPR characteristics enable an explanation of the crystallization conditions and the amber colour to be given. The zonal distribution of the crystals in the deposits according to their colour can be used as a guide-line for prospecting.

Introduction

Topaz is an aluminium fluorosilicate, $Al_2SiO_4F_{2-x}(OH)_x$, that frequently occurs as accessory minerals in fluorine-rich rhyolites, pegmatites, greisens and hydrothermal veins. Deposits are known and mined in many places in the world (Hoover, 1992), such as in the Volyn region (Ukraine) and along the east side of the Ural Mountains, between Verkhoturye in the north and the Sanarka deposits, 400 km towards the south; along the eastern coast of Australia (Mount Surprise in Queensland is the largest topaz-producing area in Australia), in the western United States rhyolite belt (Thomas Range, Spor Mountain, Wah Wah Mountains in Utah, for example), in the Ouro Preto district and in the Jequitinhonha river basin (Minas Gerais State, Brazil), in Mexico on the eastern side of the Sierra Madre Occidental, from America in the Durango State to the north to Apulco (Hidalgo State) to the south. Clear and transparent crystals exist, but the most economically interesting ones (the gems) are usually yellow, brown, blue, pink or violet.

Most studies on topaz are focused on the crystallographic (Zemann *et al.*, 1979; Parise *et al.*, 1980), physical (Aines and Rossman, 1986; Londos *et al.*, 1992; Petrov, 1977; Ribbe and Gibbs, 1971), optical (Ribbe and Rosenberg, 1971), thermodynamic (Barton, 1982) and chemical (Akizuki *et al.*, 1979; Ribbe, 1982; Hervig *et al.*, 1987) properties with the purpose of identifying the colour origin (transition metals or colour centres)

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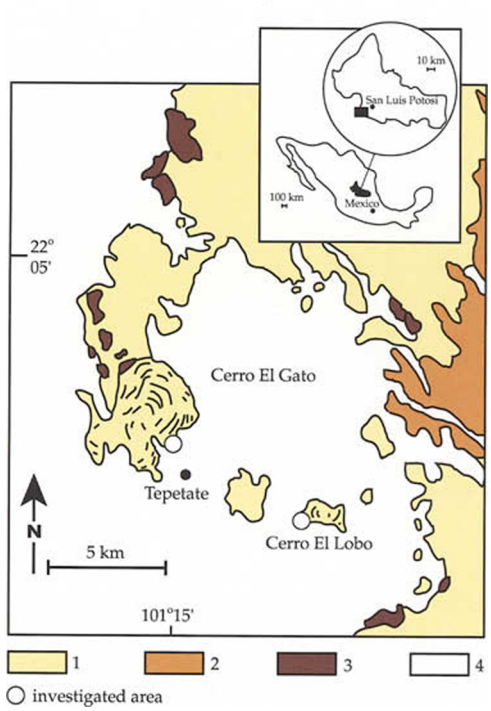


Figure 1: *Geological map and location of the Cerros El Gato and El Lobo (San Luis Potosi State, Mexico) (from Aguillon-Robles, 1994). 1 – San Miguelito rhyolite; 2 – Cantera ignimbrite; 3 – Panalillo rhyolite; 4 – Quaternary.*

and describing the morphological diversity. Topaz presents various crystal habits, well described by Goldschmidt (1913). Other papers deal with the petrogenesis of the topaz-bearing rhyolites (Christiansen *et al.*, 1985), the geological characteristics of the various topaz deposits (Hoover, 1992), origin (Olsen, 1971) and crystallization context (Foord *et al.*, 1988). But none of the papers combine the results of the laboratory analyses with the field studies to determine the growth conditions of the crystals.

It is the aim of this study to investigate the morphological properties (crystal habit and size) and the colour differences of some topazes from the San Luis Potosi volcanic field in Mexico, using both the field observations and the laboratory determinations of crystallography, chemical analyses by Inductively Coupled Plasma–Atomic Emission Spectrometry (ICP-AES) and Mass Spectrometry (ICP-MS), and Electron Paramagnetic Resonance (EPR) (Dewonck, 1996).

Features of Mexican topaz

Topaz-bearing rhyolites are common in Mexico. They correspond to an extensive Tertiary felsic volcanic belt which extends from central Mexico to western United States. In Mexico, the deposits related to rhyolite are located on the eastern side of the Sierra Madre Occidental, from Durango State (America and Cerro de los Renidios) to Hidalgo State (Apulco), but mainly in the central part of the belt in San Luis Potosi and Guanajuato States (Forshag and Fries, 1942; Menzies, 1995; Sinkankas, 1959, 1976). Crystals are usually rather small and a 10 ct gem would be considered large. However, in the Tepetate area (San Luis Potosi State) fine crystals may reach 15 cm in length and the largest flawless cut stone is reported as weighing 25 ct (Sinkankas, 1976). The topazes selected for investigation have been sampled from the Cerros El Gato and El Lobo, which are two rhyolitic domes of the San Luis Potosi volcanic field, near the village of Tepetate, 40 km southwest of San Luis Potosi city *(Figure 1)*. Only the topazes from the Cerro El Gato are worked. They are mainly marketed for mineral exhibition and sale. The largest or the best-crystallized stones are cut (M. Luna, Tepetate, pers. comm.).

Geological environment

The topaz-bearing San Miguelito rhyolite, with an age of 30±1.5 Ma (K–Ar method, Labarthe-Hernandez *et al.*, 1982) and 29.2±0.8 Ma (K–Ar on biotite, Aguillon-Robles *et al.*, 1994) is a silica-rich, meta-to peraluminous lava with a fluor content ranging from 0.1 to 0.35 wt%. Sn minerals (cassiterite) are always present in the lava dome, but are without economic value.

In the Cerro El Gato, the studied topaz-rich zones are located in the south-eastern border of the lava dome *(Figure 1)*, in a more or less anastomosed network of fractures and irregular and elongated voids (some 10

Figure 2a and b: *Topaz-bearing voids in rhyolites from the San Luis Potosi volcanic field. (a) (left) The anastomosed network of fractures and elongated cavities as exposed in the mined trenches of the Cerro El Gato deposits. This is considered as an open system for fluid circulation. Around the cavities the rhyolitic lava is greyish–white due to chemical leaching. (b) (right) The near spherical, closed and isolated cavities (up to 2 cm across) of the Cerro el Lobo lava (the largest cavity shown is 1.5 cm across).*

cm long), parallel to the lava flow *(Figure 2a)*. In the investigated zone, the lava flow is steeply dipping to near vertical, but topaz can also be observed in more or less horizontal lava flows. The colour of the topaz crystals (up to 4 cm) varies according to their location in the deposit. They are yellow to amber-coloured in the central part of the mineralized zone, whereas crystals towards the periphery are colourless, some with red to black inclusions of Fe-minerals. Hematite lamellae are also associated with these colourless topazes. Around the mineralized fractures, the initially grey rhyolite is paler in colour, resulting from chemical leaching. From the field observations, it can be concluded that these topazes have crystallized in an open system, where fluid circulated with possible renewal and chemical element enrichment.

The Cerro El Lobo *(Figure 1)* is a smaller lava dome, characterized by the presence of small (less than 20 mm) spherical-shaped, closed and isolated cavities, disseminated throughout the lava *(Figure 2b)*. As at Cerro El Gato, fluids have separated from the lava during rising and/or cooling, but in contrast to that locality the fluids at Cerro El Lobo did not coalesce and remained in the lava as isolated bubbles. However, very pale yellow topazes occur in these cavities, but do not exceed 5 mm in length. Their growth environment can be considered as a closed system.

Analytical procedures

Crystal habit

The various habits of the topaz crystals with their crystallographic parameters have been determined using a two-circle optical goniometer[1] for the millimetre-sized crystals and a self-collimating telescope for the centimetre-sized ones. The measurements of the angle between the normals to the crystal faces allow indexation of the crystallographically associated forms by their Miller indices. Four morphological groups can be thus distinguished. Using the Miller indices of all the listed pinacoids, prisms and bipyramids, the topaz crystal class (mmm) and their unit-cell parameters (a = 4.6499 Å, b = 8.7968 Å, c = 8.3909 Å) (Rosenberg, 1967), a theoretical crystal model has been drawn for each group *(Figure 3)* using the computer programme SHAPE and compared to the natural crystals.

Chemical characteristics

In order to characterize the factors that control the colour, 56 chemical elements

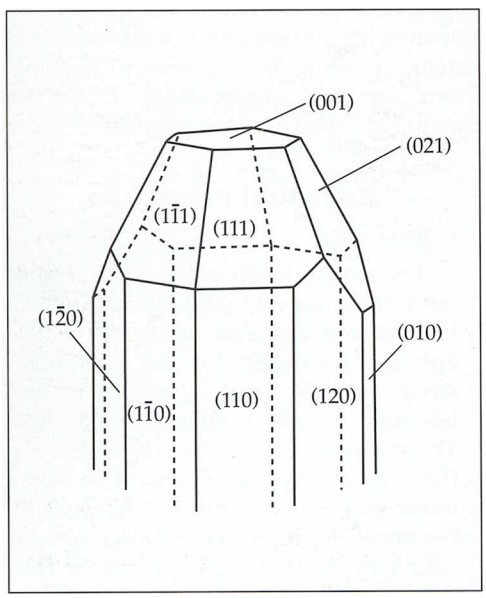
were analyzed in three crystals: an amber-coloured crystal and a colourless one from the Cerro El Gato and a slightly tinted one from the Cerro El Lobo. Eleven elements were analyzed by Inductively Coupled Plasma–Atomic Emission Spectrometry (ICP-AES)[2](Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, P, Sc), 43 by Inductively Coupled Plasma–Mass Spectrometry (ICP-MS)[3] (As, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Ga, Gd, Ge, Hf, Ho, In, La, Lu, Mo, Nb, Nd, Ni, Pb, Pr, Rb, Sb, Sm, Sn, Sr, Ta, Tb, Th, Tm, U, V, W, Y, Yb, Zn, Zr), Li by atomic absorption[4] and F by potentiometry[5]. Only the significant results are given in *Table I.*

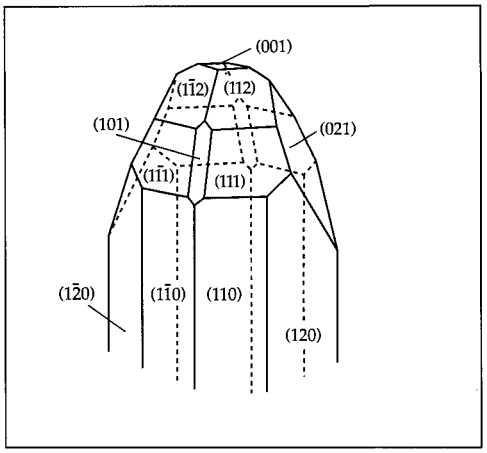
EPR characteristics

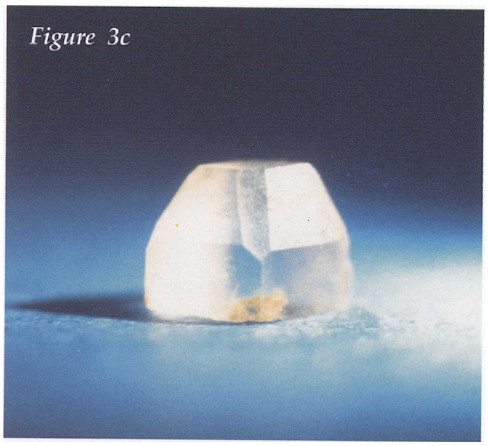
Most minerals owe their colour either to the presence in their structure of transition metal and/or lanthanide elements as major or trace amounts, or to the presence of defects in their lattice (Dusausoy and Weil, 1994) formed by natural irradiation. Colour can be explained in a number of ways and these have been classified into four distinct groups: crystal field, molecular orbital, band theories or physical optic effects (Nassau, 1978). Pure topaz is a colourless mineral. Its colour can be due to the presence of trace amounts of a transition element and/or to hole/electron centres, which are colour centres and can be explained by crystal field theory. Most of these chemical defects are paramagnetic due to the presence of one or several unpaired electrons. Thus they can be identified by their electronic paramagnetic properties. Electron Paramagnetic Resonance (EPR) studies (Weil *et al.*, 1995) will provide data about the irradiation defects related to mineral colour. Although this analytical method is non-destructive if done on a single crystal, most EPR spectra are obtained from powder samples.

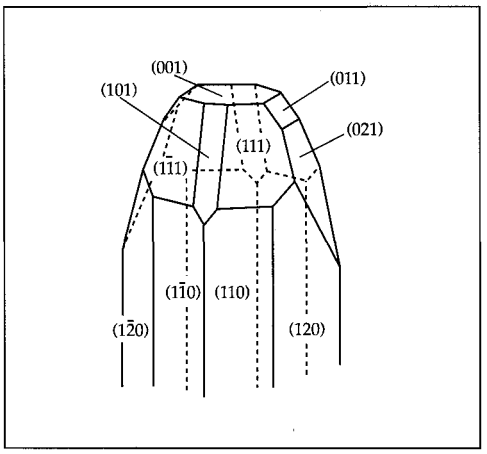
The crystal is placed inside the magnetic field B (Gauss) of the electromagnet which splits electron spin sublevels with an energy difference $g\beta B$ proportional to the value of the magnetic field (β is the Bohr magneton equal to $9.27314.10^{-21}$ erg G^{-1} and g is a non-dimensioned factor characteristic of the paramagnetic defect). For instance, in the case of one unpaired electron, there is a small but essential difference given by the Boltzmann distribution in the electronic spin

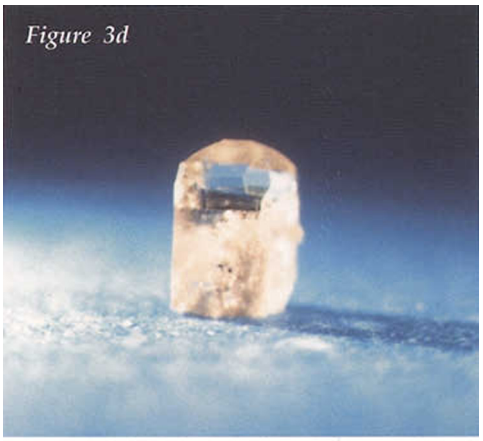
Figure 3a











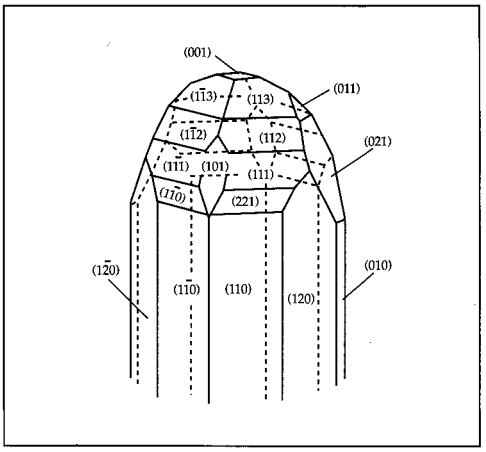


Figure 3: *Natural topaz crystals from the San Luis Potosi volcanic area and the theoretical habits of topaz crystals derived from computer calculations (produced by the computer programme SHAPE). The crystal morphology of the types is defined in Table I. a : type 1 (23 x 9 mm, 11.35 ct). b : type 2 (22 x 11 mm, 12.85 ct). c : type 3 (7 x 10 mm, 3.5 ct). d : type 4 (5.5 x 4 mm, 0.6 ct).*

Table I. *Presence of the various forms in the four types of topaz crystals in the San Luis Potosi rhyolites.*

locality		*Cerro El Gato*		*Cerro El Lobo*
type	*1*	*2*	*3*	*4*
colour	*amber and colourless*	*amber*	*colourless*	*yellow tinted*
size	*cm*	*cm*	*cm*	*mm*
crystal form				
{110}	+	+	+	+
{120}	+	+	+	+
{001}	+	+	+	+
{010}	+			+
{111}	+	+	+	+
{112}		+		+
{113}				+
{221}				+
{021}	+	+	+	+
{011}			+	+
{101}		+	+	+

populations of the ground and excited levels. A second magnetic field B_1 (frequency ν and energy hν, with h the Planck constant equal to $6.62554.10^{-27}$ erg.s) is used to stimulate transitions between adjacent energy levels. If the sample is placed in such a magnetic field B_1, applied perpendicularly to field B, inside a resonance cavity, it comes into resonance (r) when the magnetic field magnitude B or the frequency ν has been adjusted so that $h\nu_r = g\beta B_r$.

In practice, adjusting ν is more difficult than varying B. An EPR spectrometer operates at constant frequency ν produced by a microwave source, i.e. an electron tube (Klystron) yielding a strictly monochromatic emission, but at variable magnetic field B produced by the electromagnet with two different configurations : X-band at ν=9.5 GHz ($9.5\ 10^9$ herz) with B from zero to 8,000 Gauss or Q-band at ν=35 GHz and B from zero to 20,000 Gauss.

In the simplest case, the resulting absorption curve shows a single line and the g factor defines the change in the position of the absorption line in the spectrum depending on the features particular to the state of the paramagnetic electron in the studied defect. But many nuclei of paramagnetic ions or ligands have a magnetic nuclear spin. In this case, if the electronic magnetic spin is in the neighbourhood of a nuclear magnetic spin, an interaction will produce an additonal weak splitting of the electron's spin levels. It will be expressed as new absorption lines in the EPR spectrum called hyperfine structure (HFS) if electronic and nuclear spins belong to the same atom, and called superhyperfine structure (SHFS) if the nuclear spin is located on the ligands surrounding the paramagnetic centre. SHFS is of prime importance in locating the electronic paramagnetic centre in the crystallographic structure. For instance, in topaz, the HSFS of the electron paramagnetic centre Fe^{3+} allows the conclusion that iron is linked to fluoride atoms with a nuclear spin. Thus iron substitutes for an aluminium atom to form an octahedron FeO_4F_2 and occupies a Wyckoff position 8d

of local symmetry point 1 in the space group Pbnm (n°62 International Tables for X-Ray Crystallography).

The EPR study was performed on the crystals that were chemically analysed; either single crystals (2 mm) or powders (60 mg) whose grain-size distribution is in the order of µm, using a Brucker spectrometer[6] operating at X-band between 0 and 4,000 Gauss at 95 K (liquid nitrogen temperature).

1 manufactured by N.V. nederlandsche Instrumenten compagnie, Venlo, Holland
2 JY70 type 2, manufactured by Jobin Yvon
3 model Elan 2000, manufactured by Perkin Elmer
4 model Perkin Elmer 4000
5 manufactured by Tacussel
6 manufactured by Brücker Spectrospin S.A., F-67160 Wissembourg

Results

Crystal habits

In the maximum symmetry of the orthohombic system, Miller indices {h00}, {0k0} and {001} describe pinacoids, {hk0}, {h0l} and {0kl} prisms and {hkl} bi-pyramids. Four morphological groups (types 1 to 4) are thus distinguished *(Figures 3a to 3d; Table I)*. The pinacoid {001} and a strongly developed prismatic system, which always consists of the {110} and {120} prisms, are observed in the four groups. The {010} pinacoid is not always present. The groups mainly differ from each other in the combination of pyramid forms. The crystal habits vary and are represented by 1 to 4 bi-pyramids and 1 to 3 prisms.

The morphology of type-1 topazes *(Figure 3a)* is the simplest and the pyramidal shape consists only of the combination of the {021} prism and the {111} bi-pyramid. The type-2 topaz crystals *(Figure 3b)* differ from those of type 1 by the addition of bi-pyramid {112} and prism {101} on the pyramidal termination. The type 3 habit *(Figure 3c)* is characterized by a combination of {111} bi-pyramid and {021} and {101} prisms. The type 4 morphology *(Figure 3d)* is the most complex with a combination of three prisms, {021}, {011} and {101}, and four bi-pyramids {221}, {111}, {112} and {113}.

The amber-coloured topazes from the Cerro El Gato are characterized by the presence of the type 1 and type 2 habits, whereas the colourless topazes, located in the border zone of the same mineralized structure, are of types 1 and 3. The type 4 morphology was only observed in small topaz crystals from Cerro El Lobo. The most complex habit thus appears to be characteristic of the smallest crystals, those which crystallized in a closed system.

Chemical characteristics

Major element contents have been determined only for two large crystals from the Cerro El Gato *(Table II)*. These topazes (average composition : SiO_2 = 33 wt%, Al_2O_3 = 57 wt%, F = 19 wt%) present a normal composition for topaz associated with rhyolites (Penfield and Minor, 1894). Compositional differences between the amber-coloured and the colourless crystals of the Cerro El Gato are very small.

The 44 trace elements mentioned above have been analyzed in the same crystals from Cerro El Gato and in a yellowish topaz from Cerro El Lobo. Only the significant element contents, i.e. those higher than the ICP-MS limits of detection, are given in *Table II*. For most of these trace elements, as for the major elements, there are no significant differences with respect to the crystal types.

However, some elements seem to be significant in each of the three crystals. The amber-coloured topazes are richer in volatile elements such as As and Sb, than the colourless ones. Conversely, the latter are richer in Li, Nb, Ta, Zr and in metallic elements, such as Cr, Ni and Zn. The small topaz crystals sampled in the vesicles of the

Table II. *Chemical composition of three representative topazes from the San Luis Potosi rhyolites*

Weight %	*Cerro El Gato*		*Cerro El Lobo*
	amber	*colourless*	*yellow tinted*
SiO_2	33.29	33.43	–
Al_2O_3	57.71	58.10	–
Fe_2O_{3t}	0.06	0.04	0.04
P_2O_5	0.06	0.07	–
LOI	1.28	1.30	–
F	18.77	19.10	–
	Cerro El Gato		*Cerro El Lobo*
µg/g	*amber*	*colourless*	*yellow tinted*
As	76.5	4.94	12.0
Ba	0.88	4.18	1.4
Be	tr	tr	1.12
Cr	0.97	3.26	0.89
Cu	1.04	0.94	3.5
Ga	7.68	9.34	13.6
Ge	23.8	21.8	21.2
Li	59	70	–
Nb	4.83	10.09	12.45
Ni	tr	3.39	2.26
Pb	1.01	1.1	1.27
Rb	2.4	1.63	1.13
Sb	0.29	0.03	0.22
Sr	0.18	0.19	tr
Ta	1.74	2.81	2.79
V	tr	0.05	0.47
W	1.97	2.34	0.91
Zn	1.52	2.84	5.96
Zr	1.78	5.32	4.37
numbers of ions on the basis of 24 (O, OH, F)			
Si	3.940}	3.926}	
Al	0.060} 4.00	0.074} 4.00	
Al	7.992}	7.971}	
Fe^{3+}	0.005} 8.00	0.004} 7.98	
P	0.006}	0.007}	
OH	1.011} 8.04	1.019} 8.12	
F	7.026}	7.095}	

Notes: The analytical results of various techniques have been combined in this table.
Total iron values listed as Fe_2O_{3t};
LOI means loss on ignition;
tr means trace;
– means not determined

Cerro El Lobo lava have an intermediate composition for both volatile and metallic elements; they also contain traces of Cu, Pb and Zn.

EPR characteristics

A number of investigations on coloured topaz have been performed in order to characterize the paramagnetic centres as potential causes of colour (Thyer *et al.*, 1967; Holuj and Quick, 1968; Barry and Holuj, 1973). Dickinson and Moore, 1967, connected colour and paramagnetic centres Fe^{3+}, V^{4+}, Cr^{3+} and six different colour centres corresponding to three electron-centres e^- (A, B, C) and to three hole-centres e^+ (X, Y, Z), which disappear with the colour by heating

to 500°C. Petrov (1993) gives a comparison of colour and paramagnetic centres between hydrothermal topazes (pink VO^{2+} and Ti^{3+}; orange Cr^{3+} and Mn^{2+}; yellow Fe^{3+}) and pneumatolytic topazes (colourless Fe^{3+} and AlO_4^{4-}; brown $SiO_4^{3-}/^{27}Al$, $SiO_3^{3-}/^{27}Al$ and PO_4^{4-}; blue PO_3^{2-}).

In all three selected topazes, the Fe^{3+} spectrum consists of sets of SHFS mixed triplets (1400 to 1800 gauss) due to the coupling of the electron spin S of Fe^{3+} (S=5/2) and the nuclear spin I of each atom of ^{19}F (I=1/2, natural abundance 100%). The presence of one fluoride atom in the neighbourhood of Fe^{3+} induces 2I+1 resonance lines, i.e. a triplet in the EPR Fe^{3+} spectrum and the presence of n fluoride atoms induces 2nI+1 lines more or less mixed. The presence of Fe^{3+} in the colourless topaz indicates that this paramagnetic centre does not play any role in the colour of the investigated Mexican topazes. A very weak but broad band at 2500 Gauss can be possibly assigned to two PO_4^{3-} centres at two crystallographically nonequivalent positions.

The EPR-spectrum of the amber-coloured topaz *(Figure 4a)* exhibits several lines that are related to colour-centres (3200 to 3600 gauss). The first well-developed line (g = 2.01) is related to X hole-centre or to two $SiO_4^{3-}/^{27}Al$ centres. The second (g = 1.88) is related to electron-centre A which vanishes with the colour by heating at 500°C. Two weak lines can be assigned to two B centres (g = 1.92 and 1.94). In contrast to that of the amber-coloured topaz the EPR-spectrum of the colourless topaz does not show additional lines that can be assigned to colour centres *(Figure 4b)*.

The slightly yellow tinted topaz *(Figure 4c)* presents, in addition to the Fe^{3+} centre, a broad band at 2850 Gauss observed on both powder and single crystal spectra, most probably due to magnetic micro-inclusions. The X-hole centre at g = 2.01 has produced the only well defined line in this spectrum. Thus the colour of the investigated topazes is clearly related to the presence of colour centres.

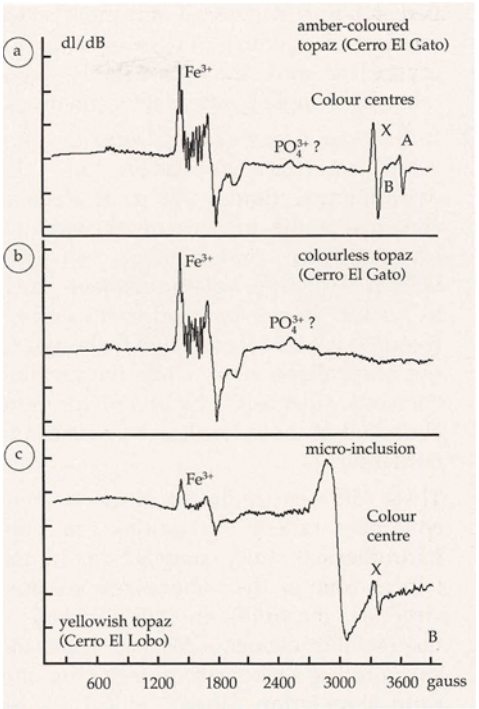


Figure 4: *EPR spectra obtained from powdered samples at T = 95 K, 9.45 Ghz (9.5 10^9 herz) with the magnetic field B ranging from 0 to 4000 gauss. The spectra correspond to the derivative of the intensity as a function of the magnetic field B. (a) amber–coloured topaz; (b) colourless topaz; (c) yellowish topaz*

Discussion and conclusion

1. The small topaz crystals from the Cerro El Lobo present the most complex habits (*Table I*, type 4), whereas the larger crystals from the Cerro El Gato are less complex (types 1, 2 and 3). Several factors can influence the crystallization of a mineral and thus its habit. From field observations it can be concluded that relationships exist between the size of the crystals, their habits and their crystallization environment. The vesicles where the type 4 topazes crystallized are small and considered as closed systems with low fluid abundance and no fluid renewal. Such conditions do not permit the development of large crystals. On the contrary, in an open system with fluid

percolation and renewal and more space (voids and fractures), larger crystals can crystallize and they invariably have relatively simple pyramidal terminations.

2. In the open system of the Cerro El Gato, with a free circulation of the hydrothermal fluids, the trace element contents of the topazes differ with the crystallization environment in the volcanic structure. Volatile elements, such as As and Sb, are enriched in the amber-coloured topazes crystallized in the axis of the mineralized zone, while the metallic elements, such as Cr, Ni or Zn, are more abundant in the colourless crystals of the border zone.

   These differences in the trace element contents reflect variations in the hydrothermal fluid composition. In the border zone of the mineralized volcanic structure, the fluids are still enriched in the metallic elements leached from the surrounding rocks during degassing and fluid circulation. Topaz will thus be enriched in these elements. Moreover, hematite lamellae are also observed in association with topaz in this zone. Consequent upon this, the fluids in the axis of the structure are impoverished in metallic elements but enriched in the most volatile elements, As and Sb.

   Crystallization in a closed system (Cerro El Lobo) results in topazes of intermediate composition with the presence of both metallic and volatile elements. This is due to the lack of opportunity for spatial fluid differentiation as in an open system.

3. Various studies indicate that the colour can be related to the ligand field effects in transition group metal impurities, and that elements such as Fe (Nassau and Prescott, 1975; Grigor'ev 1965), Ni (Deer *et al.*, 1982), Co (Deer *et al.*, 1982), Cr (Nassau and Prescott, 1975; Gübelin and Koivula, 1986) and Ti (Kievlenko, 1982) can be the cause of colour in gemstones. But in the investigated topazes of the San Luis Potosi area, these elements are either not present (Co, Ti), more abundant in the colourless crystals (Cr and Ni) than in amber-coloured ones, or present in all the crystals (Fe). This is in good agreement with the data of Dickinson and Moore (1967), who consider that Fe^{3+} plays no role as colouring agent, in contrast to previous studies (Lemmlein and Melankholin, 1951; Grum-Grzhimaylo, 1953).

4. The EPR studies clearly indicate that the colours of the crystals are caused by colour centres. According to Dickinson and Moore (1967), these colour centres are only stable below 500°C. We therefore may conclude that the colourless topaz crystallized first, in Ni–Cr–Zn-enriched fluids and at a temperature above 500°C, whereas the amber-coloured topaz crystallized most probably later, in volatile-enriched fluids at a lower temperature, below 500°C. The crystallization temperature of the small crystals, sampled in the vesicles of the Cerro El Lobo lava, could be around this temperature, since they contain only one colour centre. The crystallization temperature of the topaz is therefore an important parameter controlling the colour of the topaz in this area.

Acknowledgements

The authors gratefully acknowledge the assistance of Professors Bernard Lasnier and Emmanuel Fritsch (University of Nantes, France) and the anonymous referee for all their comments, and Alfredo Aguillon-Robles for his help in the field.

References

Aguillon-Robles, A., 1994. *Estructura interna de los domos rioliticos del area de Tepetate, S.L.P.* Univ. Auton. De San Luis Potosi, Instituto de Geologia, folleto tecnico, **118**, 58 pp

Aguillon-Robles, A., Aranda-Gomez, J.J., and Solorio-Munguia, J.G., 1994. Geologia y tectonica de un conjunto de domos rioliticos del oligoceno medio en el sur del estado de San Luis Potosi, Mexico. *Revista Mexicana de Ciencias Geologicas*, Univ. Nacion. Auton. Mexico, **11**(1), 29–42

Aines, R.D., and Rossman, G.R., 1986. Relationships between radiation damage and trace water in zircon, quartz, and topaz. *American Mineralogist*, **71**, 1186–93

Akizuki, M., Hampar, M.S., and Zussman, J., 1979. An explanation of anomalous optical properties of topaz. *Mineralogical Magazine*, **43**, 237–41

Barry, W.R., and Holuj, F., 1973. The ESR spectrum of Fe^{3+} in Topaz. III – ENDOR of $^{19}F^{1}$. *Canadian Journal of Physics*, **51**, 95–101

Barton, M.D., 1982. The thermodynamic properties of topaz solid solutions and some petrologic applications. *American Mineralogist*, **67**, 956–74

Christiansen, E.H., Sheridan, M.F., and Burt, D.M., 1985. The geology and geochemistry of cenozoic topaz rhyolites from the Western United States. Geological Society of America, Special Paper, **205**, 82 pp

Deer, W.A., Howie, R.A., and Zussmann, J., 1982. *Orthosilicates*. 2nd edition, vol 1A, Longmans, London

Dewonck, S., 1996. Caractérisation et conditions de croissance des topazes de rhyolite à topazes San Luis Potosi (Mexique). Mém. DEA, Univ. Henri Poincaré-Nancy 1, 51 pp

Dickinson, A.C., and Moore, W.J., 1967. Paramagnetic resonance of metal ions and defect centres in topaz. *Journal of Physical Chemistry*, **71**(2), 231–40

Dusausoy, Y., and Weil, J.A., 1994. Point defects as precursors of electron-hole centres. Systematics and theories of radiation centers in minerals. *Advanced Mineralogy*, Springer Verlag, vol 1, 180–7

Foord, E.E., Jackson, L.L., Taggart, J.E., Crock, J.G., and King, T.V.V., 1988. Environment of crystallization of topaz as determined from crystal chemistry and infrared spectra. Geological Society of America, abstracts with programme

Forshag, W.F., and Fries, C., Jr, 1942. Tin deposits of the Republic of Mexico. *U.S. Geol. Survey Bull.*, **935-C**, 99–176

Goldschmidt, V., 1913. *Atlas der Krystallformen*. Carl Winter, Heidelberg, 1913–1926

Grigor'ev, D.P., 1965. *Ontogeny of minerals*. Daniel Davey, New York

Grum-Grzhimaylo, S.W., 1953. The colour of precious stones. *Zapiski Vsesoyuznogo Mineralogicheskogo Obshchesta*, **87**, Ser. 2, 395–8

Gübelin, E.J., and Koivula, J., 1986. *Photoatlas of inclusions in Gemstones*. ABC, Zurich

Hervig, R., Kortemeier, W.T., and Burt, D.M., 1987. Ion-microprobe analyses of Li and B in topaz from different environments. *American Mineralogist*, **72**(3–4), 392–6

Holuj, F., and Quick, S.M., 1968. The ESR spectrum of Fe^{3+} in Topaz. II – Superhyperfine structure. *Canadian Journal of Physics*, **46**, 1087–99

Hoover, D.B., 1992. *Topaz*. Butterworth – Heinemann, Oxford. 207 pp

Kievlenko, E., 1982. *Geologiya mestorozdeniy dragotsennykh kamney* (The geology of precious stones deposits), Nedra, Moscow

Labarthe-Hernandez, G., Tristan-Gonzalez, M., and Aranda-Gomez, J.J., 1982. Revision estratigrafica del Cenozoico de la parte central del estado de San Luis Potosi. *Folleto técnico*, Univ. Auton. San Luis Potosi, **85**, 208 pp

Lemmlein, G.G., and Melankholin, N.M., 1951. Uber die Farbe zweifarfiger Topaskristalle. *Tr. Inst. Krist. Akad. Nauk. SSSR*, **6**, pp 245–54

Londos, C.A., Vassilikou-Dova, A., Georgiou, G., and Fytros, L., 1992. Infrared studies of natural topaz. *Physica status solidi A. Applied research*, **133**(2), 473–9

Menzies, M.A., 1995. The mineralogy, geology and occurrence of topaz. *Mineralogical Record*, **26**(1), 5–56

Nassau, K., 1978. The origins of color in minerals. *American Mineralogist*, **63**, 219–29

Nassau, K., and Prescott, B.E., 1975. Blue and brown topaz produced by gamma irradiation. *American Mineralogist*, **60**, 705–9

Olsen, D.R., 1971. Origin of topaz deposits near Ouro Preto, Minas Gerais, Brasil. *Economic Geology*, **66**, 627–31

Parise, J.B., Cuff, C., and Moore, F.H., 1980. A neutron diffraction study of topaz: evidence for a lower symmetry. *Mineralogical Magazine*, **43**, 943–4

Penfield, S.L., and Minor, J.C., Jr., 1894. On the chemical composition and related physical properties of topaz. *American Journal of Sciences*, **3**(137), 389–96

Petrov, I., 1977. Farbuntersuchungen an Topas. *Neues Jahrbuch für Mineralogie – Abhandlungen*, **130**(3), 288–302

Petrov, I., 1993. Application of EPR spectroscopy in mineralogy, petrology and geology. *Habilitationsschrift*, Philipps-Universität Marburg, 202 pp

Ribbe, P.H., 1982. Topaz. in P.H. Ribbe (ed.), *Orthosilicates*, 2nd edition, Reviews in Mineralogy, 5, Mineralogical Society of America, 215–30

Ribbe, P.H., and Gibbs, G.V., 1971. The crystal structure of topaz and its relation to physical properties. *American Mineralogist*, **56**, 24–30

Ribbe, P.H., and Rosenberg, P.E., 1971. Optical and X-ray determinative methods for fluorine in topaz. *American Mineralogist*, **56**, 1812–21

Rosenberg, P.E., 1967. Variations in the unit-cell dimensions of topaz and their significance. *American Mineralogist*, **52**, 1890–1895

Sinkankas, J., 1959. *Gemstones of North America*. D. Van Nostrand, New York, **1**, 675 pp

Sinkankas, J., 1976. *Gemstones of North America*. Van Nostrand Reinhold, New York, **2**, 494 pp

Thyer, J.R., Quick, S.M., and Holuj, F., 1967. The ESR spectrum of Fe^{3+} in Topaz. I – Fine structure. *Canadian Journal of Physics*, **45**, 3597–3610

Weil, J.A., Dusausoy, Y., and Votyakov, S.L., 1995. Electron Paramagnetic Resonance. *Advanced Mineralogy*, Vol 2, 40–55

Zemann, J., Zobetz, E., Heger, G., and Vollenkle, H., 1979. Strukturbestimmung eines OH-reichen Topases. *Osterreichische Akademia der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse*, **116**, 145–7

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Gemstones and ornamental stones from Bolivia: a review

Dr Jaroslav Hyršl[1] and Alfred Petrov[2]

1 Kolin, Czech Republic
2 Cochabamba, Bolivia

ABSTRACT: Gem, ornamental and collectors' stones from Bolivia are described. The most economically important are ametrine, amethyst, citrine, sodalite and stromatolite. Ametrine, amethyst and citrine come from the La Gaiba mine in eastern Santa Cruz department. The sodalite deposit of Cerro Sapo in Cochabamba department has been mined probably for almost three thousand years. Gem-quality beryl, cassiterite, phosphophyllite and vivianite are also briefly discussed.

Keywords: Bolivia, gemstones, ametrine, amethyst, sodalite, stromatolite

Introduction

Bolivia, in the centre of South America, is famous mainly for its vast deposits of silver and tin. It has been almost unknown until now as a source of gemstones. Only a few collectors of rare gems have known about the world's best cut cassiterites and phosphophyllites, but the situation has changed with the large production of ametrine in recent years; this has flourished in Bolivia's recent relatively stable political situation. Some relevant features of Bolivian gemstones and ornamental stones, including rare collector stones and several recent finds, are summarized below.

Figure 1: *Map of Bolivia showing main localities mentioned in the text.*

Apatite

Attractive transparent purple apatites were found in the 1940s in Llallagua and were described by Bandy (1944). More recently large apatite crystals have come from a magnetite-hematite vein cutting a dacite laccolith in Potosi department (*Figure 1*). Crystals are up to 10 cm long, yellowish and opaque, and some have a transparent core. According to the X-ray analysis, both the core and crust are probably carbonate-hydroxylapatite. Stones faceted from this material are yellowish-white and

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Figure 2: Cassiterite from Viloco, weights 11.77, 2.31 and 1.09 ct (photo: P. Korbel).

Figure 3: Wood-tin cassiterite from Macha, length of largest cabochon 19 mm (photo: P. Korbel).

contain unusual needle-like inclusions. Their refractive indices are $n_o = 1.642$ and $n_e = 1.637$, specific gravity is 3.11–3.13. They have a pale orange luminescence in short-wave ultraviolet (SWUV).

Beryl

Very large opaque crystals of beryl have been known for a long time from pegmatites near Santa Rosa, San Ignacio de Velasco and San Ramon, east of Santa Cruz. Recently pieces with a transparent bluish core have been found and a few light aquamarines up to about 2 ct have been cut from crystals from the San Ramon area. Reports of alluvial 'aquamarine' crystals from streams draining the batholith north of La Paz city have not been confirmed.

In the eastern Santa Cruz department emerald occurs in veins of quartz and feldspar cutting shales. The crystals are up to 1 cm in length, are light green to a good emerald green, but are opaque and no cuttable material has yet been found.

Cassiterite

Cassiterite is one of the most important Bolivian minerals and the deposits are still a major source of tin. Probably the world's best cassiterite specimens come from the Viloco mine near Araca in La Paz department. Crystals from Viloco are up to 8 cm long and are often partially transparent, usually in a thin layer near the surface. The transparent part is usually yellow to brown but colourless cassiterites are also known *(Figure 2)*. Faceted cassiterites are usually less than 5 ct but there are rare stones up to 25 ct. Faceted cassiterites are extremely beautiful, but their brittleness and relative softness make them unsuitable for setting in rings.

A second type of cassiterite used in jewellery is the opaque colloidal variety called 'wood-tin', known mainly from the Condor-Iquina volcanic plateau of the Potosi department. It has a fine agate-like structure, sometimes with layers of opal or chalcedony and is usually brown, cream or yellow, more rarely black, red or pink. Cabochons cut from this material can be very attractive with a high lustre *(Figure 3)*.

Chalcedony

White to greenish or grey chalcedony with small blebs of native copper (in places oxidized to green malachite) is a very unusual ornamental stone. It was used for beads by pre-Columbian Indians and the source was rediscovered (Ahlfeld and Reyes, 1955) in the Turco Cu-deposit in northern Oruro department.

Another type of chalcedony was found by the authors in the vicinity of Capinota near

Figure 4: *Rough chrome chalcedony from Chiquitania, length of largest piece 5 cm (photo: P. Korbel).*

Cochabamba. Poorly consolidated Cretaceous sand and gypsum marl is cut by a large number of thin veins containing chalcedony which is usually milky but some bluish pieces resembling old chalcedony from Namibia were also found. Thicker veins usually have a centre filled with anhydrite.

Chrome chalcedony

Recently discovered in Bolivia, chrome chalcedony is called 'Chiquitanita' by local jewellers from its occurrence in the Chiquitania region in eastern Santa Cruz department. It occurs as small veins in a silicified laterite overlying Cr- and Ni-bearing ultrabasic intrusives. Some parts are coloured brown by Fe-oxides but the best material is translucent green and facetable *(Figure 4)*.

The refractive index of the chrome chalcedony is 1.530–1.550 with a birefringence up to 0.005 and SG of 2.56–2.57. It is a polycrystalline aggregate, which does not fluoresce in either short- or long-wave ultraviolet, but it is bright red under a Chelsea Colour Filter. The absorption spectrum shows an emerald-like pattern with two broad bands at 416 and 605 nm and a small peak at 684 nm, with a distinct minimum at 510 nm. Similar material was described under the trade name 'Mtorolite' from Mtoroshanga in Zimbabwe (see Phillips and Brown, 1989, and Webster, 1994). Dyed chalcedony (imitating chrysoprase) is brownish-red only under the Chelsea Filter and, when examined with a hand-held spectroscope, displays two absorption lines in the red part of the spectrum.

Some stones show a very fine agate-like structure and others contain a black 'net' of Fe-oxides. Most of the rough material is exported directly to Brazil and at the 1995 Munich mineral show the authors found cut chrome chalcedony described as 'apatite from Brazil', which could well have come originally from this source in Bolivia.

Danburite

Excellent doubly-terminated crystals occur in metamorphosed evaporites in the Alto Chapare region east of Cochabamba (Petrov, 1993). The danburite crystals are usually opaque, due to many dolomite inclusions, but some have been used in their natural shape to create unusual jewellery. Although crystals of up to 5 cm long have been found, their normal length is 1 to 3 cm. Several specimens of bluish danburite with parallel inclusions of a blue-grey amphibole, magnesioriebeckite, have been found and cabochon-cut specimens show a strong cat's-eye effect *(Figure 5)*.

Diamond

Diamonds have been reported from Permian glacial sediments of the Tequeje,

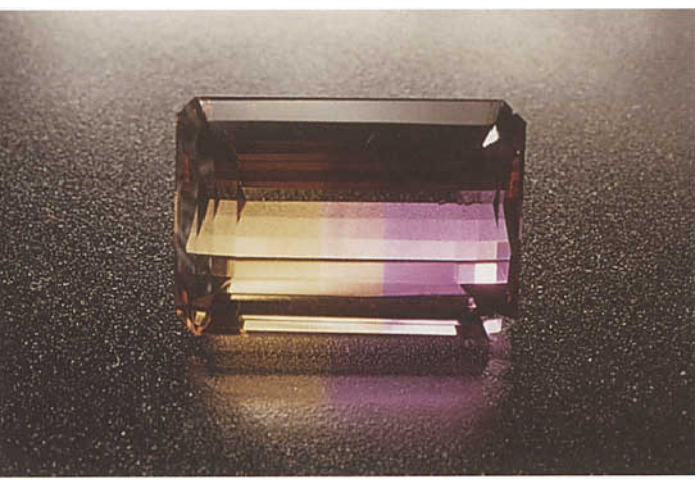
Figure 5: *Cat's-eye danburite from Alto Chapare, cut stone 0.49 ct (photo: P. Korbel).*

Figure 6: Phosphophyllite crystal about 15 cm long on matrix.

Suapi and other rivers in northern La Paz department by Ahlfeld and Reyes (1955) and Oppenheim (1943). They are colourless or pale yellow well-developed crystals generally weighing 0.10–0.35 ct, with some up to 1 ct. Two concessions were worked in the 1920s, but they proved to be uneconomic.

Kimberlites have been reported recently from the Ayopaya province north of Cochabamba, but information about diamonds is lacking.

Figure 7: Tri-colour ametrine from La Gaiba, 81.52 ct (photo: P. Korbel).



Fluorite

The Colquiri and Condeauqui fluorite occurrences north of Oruro have yielded many large pieces of transparent blue-green material.

Garnets

Dark almandines up to about 1 ct have been cut from small pebbles from alluvial deposits in Potosi department, but gem-quality garnets are rare in Bolivia.

Phosphophyllite

By far the world's best crystals of phosphophyllite were found in the 1950s and 1960s in the deepest levels, about 300 m

Figure 8: Ametrine slab with strong Brazil twinning, 39 x 22 mm (photo: P. Korbel).

Figure 9: Tri-colour quartz (purple–yellow–colourless) from La Gaiba, length 30 mm (photo: P. Korbel).

Figure 10: *San Fermin amethyst mine (photo: J. Hyršl).*

Figure 11: *Amethyst specimens from San Fermin (photo: J. Hyršl).*

underground, of the famous silver deposit of Cerro Rico de Potosi (Hyršl and Petrov, 1996). They have a unique blue-green colour, some are partially transparent and the biggest crystals are up to 15 cm long *(Figure 6)*. Only a few hundred crystals were found. Phosphophyllite is extremely difficult to facet due to its perfect cleavage, and of the limited number of faceted stones which do exist very few are over 10 ct (maximum 74 ct, Arem 1987). Consequently, they are in great demand by collectors.

Pyrargyrite

Several large faceted stones were cut from material from the very rich silver deposit at Colquechaca south-east of Oruro.

Quartz

Without doubt, ametrine (bi-colour amethyst-citrine quartz) is currently the most

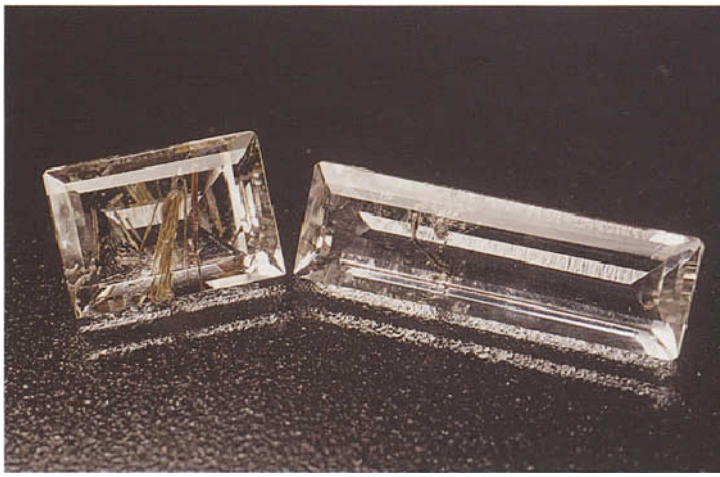


Figure 12: *Quartz with dravite (4.20 ct) and arsenopyrite (5.69 ct) inclusions from Kami (photo: P. Korbel).*

popular Bolivian gemstone (*Figures 7, 8 and 9*). Local jewellers call it 'Bolivianita'. The true locality was unknown for a long time, and some originally thought that it came from Brazil or that it was synthetic. Ametrine occurs at Anahi near La Gaiba in the far east of the Santa Cruz department in hydrothermal quartz veins which cut dolomites and limestones. The Anahi mine was described by Vasconcelos *et al.* (1994) and Collyer *et al.* (1994), but since then more ametrine deposits have been found in the La Gaiba area at the Mina Pobre, although quality and quantity do not match that from the Anahi mine. The mine at La Gaiba is probably also the world's only source of naturally coloured (unheated) citrine at the present time (Vasconcelos *et al.*, 1994).

Amethyst of very good quality is well known from the Anahi mine. Other amethyst occurrences from the La Gaiba area have yielded crystals up to 5 kg suitable for spheres or carving. Ahlfeld and Reyes (1955) described a huge hydrothermal amethyst vein 6 km long and 4 to 6 m wide near the town of Santa Ana in Santa Cruz department, but the amethyst here is of poor quality. Not far from Santa Ana, other vertical amethyst veins occur near the village of San Fermin. One vein is about 1 m wide and is accessed by a 33 m deep shaft

Figure 13: *Sodalite boulder from Cerro Sapo, width 44 cm (photo: J. Hyršl).*

Figure 14: *Sodalite mining camp on Cerro Sapo (photo: J. Hyršl).*

(July 1995, *Figure 10*). The vein has many cavities with crystals and the amethysts are strongly zoned, the tops of crystals being usually covered by milky quartz. Amethyst from the locality is rarely cuttable and is more useful for small carvings or tumbled stones *(Figure 11).*

Quartz with unusual inclusions comes from several Bolivian localities and, when properly cut, can be an interesting material for jewellery. The most interesting inclusions are brown needles of dravite tourmaline and silvery metallic blebs of pyrrhotite, arsenopyrite and marcasite, all from the tungsten deposit of Kami near Cochabamba *(Figure 12).*

Smoky quartz is rare in Bolivia, but a few large clean crystals up to about 50 cm long have come from recent diggings in the pegmatites of the Precambrian shield of Santa Cruz department.

Silicified limestone: An unusual fluorescent rock comes from Pajcha Pata, south of Cochabamba. It is a silicified dolomitic limestone from the Cretaceous Torotoro Formation. White carbonate grains have a net of dark chalcedony veinlets, wider veinlets are bluish and sometimes are filled by quartz microcrystals. Under short-wave UV, the carbonate fluoresces white and the chalcedony is green, while under long-wave UV the carbonate is yellowish and the chalcedony violet. The carbonate shows phosphorescence after exposure to either long- or short-wave UV.

Sapphire

Recently, several opaque to translucent blue sapphires have been found associated with almandine in alluvium in Potosi department. They reach only a few millimetres in size and few have been faceted. One 900 g translucent sapphire was found by Dr F. Ahlfeld in the gold placers of the Yungas de La Paz, but it too was of poor cutting quality.

Sodalite

Beads of blue sodalite have been found during archaeological research from almost all Andean cultural epochs including the oldest Mizque period (900–600 BC). The finds cover a very large area ranging from Ecuador to Argentina. Because a sodalite deposit was not known in the Andes, there were hypotheses about an origin outside South America. However, in 1923, the German geologist F. Ahlfeld found sodalite outcrops on Cerro Sapo (4200 m), Ayopaya province, Cochabamba department (Ahlfeld and Wegener, 1931). Nine old tunnels were found by Ahlfeld, the largest being 90 m long and 5 m high. Their ages range from pre-Incan to the latest period of mining in the eighteenth century by the Jesuits, who believed they were mining lapis lazuli.

The sodalite vein is about 3 km long (the productive part is much smaller) and from 1 to 5 m wide. In detail, the 'vein' is a unique type of carbonatite dyke, consisting mainly of pale green ankerite, white baryte, blue sodalite and

Figure 15: Stromatolite from Potosi; the edge of the cube is 8 cm (photo: J. Hyršl).

minor amounts of analcite, dawsonite, natrolite and sulphides *(Figure 13)*. It cuts both a nepheline syenite body and its surrounding hornfels and slate. The sodalite is an attractive blue and sometimes forms large slabs with a distinct zonal structure. Cabochons over 2 mm thick are opaque. One of the claims on the vein is currently exploited by an Italian company, which has a very well equipped mining camp on the slope of Cerro Sapo *(Figure 14)*. The content of ankerite causes brown patches in the sodalite and hinders outdoor ornamental uses.

More recently, a vein of sodalite up to 3 cm wide and of good quality was found near the town of Independencia. It lies about 20 km south of the Cerro Sapo occurrence and has the same strike.

Tourmaline

Green tourmaline occurs in the pegmatites of the Precambrian shield of eastern Santa Cruz department, but the cut stones are too dark to be attractive.

Vivianite

Good transparent crystals have been known for a long time from the tin deposits of Llallagua and Huanuni, but the best transparent crystals, some more than 20 cm in length, were found in the 1970s in Morococala, east of Oruro. Vivianite has a very distinct blue-green pleochroism. The excellent mica-like cleavage makes faceted stones extremely difficult to cut and therefore rare.

Other minerals and ornamental rocks

Chrysocolla and malachite are known from the vicinities of the Altiplano copper deposits, and there are minor occurrences of colourless topaz and adularescent feldspar in the alluvial 'wood tin' deposits of Macha in the Potosi department. Partially transparent siderite crystals up to 20 cm long have been discovered recently in Potosi.

Also from Potosi is an ornamental stromatolite called 'Pucalita' after its location in the Cretaceous Puca formation. It is an algal rock consisting mostly of calcite, dolomite and quartz with an overall hardness of about 4 and SG of 2.6. The stromatolite is yellow-brown to coffee-brown with distinct dark-brown or black layers and is cut and polished to display its wavy or concentric banding, the latter appearing as 'eyes' in appropriate specimens *(Figure 15)*.

A new red variety of stromatolite has been found in the Oruro department. Its colour is probably caused by hematite and its structure is the same as the yellow variety.

References

Ahlfeld, F., and Reyes, J.M., 1955. Las especies minerales de Bolivia. Bilbao

Ahlfeld, F., and Wegener, R., 1931. Uber die Herkunft der im Bereich altperuanischer Kulturen gefundenen Schmuckstucke aus Sodalith. *Ztschr. Ethnol.* **63**, 288–96

Arem, J.E., 1987. *Color encyclopedia of gemstones*. 2nd Ed. Van Nostrand Reinhold, New York

Bandy, M.C., 1944. *Mineralogy of Llallagua, Bolivia*. Patino Mines & Enterprises Consolidated, La Paz

Collyer, T., Fuzikawa, K., and Schwarz, D., 1994. Das Ametrin-Vorkommen von Anay, Santa Cruz, Bolivien. *Z. Dt. Gemmol. Ges.*, **43**, 117–26

Hyrsl, J., and Petrov, A., 1996. Potosi und Oruro – die bedeutendsten Silbererz-Lagerstatten Boliviens. *Mineralien-Welt*, **7**, 36–49

Oppenheim, V., 1943. Diamonds in the northeastern Bolivian Andes. *Econ. Geol.*, **38**, 658–61

Petrov, A., 1993. Aktuell: Der neue Turmalin aus dem tropischen Regenwald Boliviens. *Extra Lapis*, **6**, 50–3

Phillips, G., and Brown, G., 1989. Mtorolite. *Austral. Gemmologist*, **17**, 205–7

Vasconcelos, P.M., Wenk, H.R., and Rossman, G.R., 1994. The Anahí Ametrine Mine, Bolivia. *Gems & Gemology*, **30**, 4–23

Webster, R., 1994. *Gems: their sources, description and identification*. 5th ed., P.G. Read (ed). Butterworths, London

Rock-forming minerals. [Second edition. Vol. 2B. *Single-chain silicates.*]

W.A. DEER, R.A. HOWIE AND J. ZUSSMAN, 1997. The Geological Society, London. pp x, 764, hardcover. £99.00 [£50 to Geological Society members]. ISBN 1 897799 77 2. Obtainable from the Society at Burlington House, Piccadilly, London W1V OJU [members] or [for members of the public] from Geological Society Publishing House, Unit 7, Brassmill Enterprise Centre, Brassmill Lane, Bath BA1 3JN.

While the progress of the second edition [of *DHZ* or *RFM*] would expect to produce a much larger body of information overall, this volume will probably be found to display a proportionately greater increase over its original form, first published in 1961. Mineralogists and geologists already know that the amphibole group has always posed problems of determination and nomenclature and continues to do so: advances in determinative techniques have, however, succeeded in setting out a base for some kind of permanent structure for the group, into which its individual members may fit more easily than before. At the time of reviewing the International Mineralogical Association is preparing to publish a review of amphibole group nomenclature.

Double-chain silicates are not all amphiboles, however, though the group takes up the bulk of the text. The interesting group of biopyriboles, the name coined in 1911 from pyroxene, amphibole and 'bio' to include the mica group, is surveyed for the first time in a major reference book.

The amphiboles are treated in four sections following a general introduction: Mg–Fe–Mn–Li amphiboles: calcic amphiboles (including tremolite and actinolite, the sections likely to be of most interest to the gemmologist): sodic-calcic amphiboles: sodic amphiboles. Then the biopyriboles are described and followed by the other double-chain silicates deerite and howieite, named after two of the book's authors.

Each section contains its own list of references and species are described structurally and chemically, with notes on experimental work, thermodynamic, optical and magnetic properties. Paragenesis completes the description of each mineral. As in previous volumes of both editions, lists show a number of representative examples, details being referred to the appropriate papers. The text contains well-drawn diagrams and the typeface is easy to read.

Naturally this is a text for reference and not for 'reading through' (although leafing through the text while on the track of one query throws up many other points which need noting for detailed examination later): gemmologists need to approach amphibole nomenclature with some care. Those who are also serious mineral collectors will do well to buy a copy – it is fortunate though of course inevitable that the complete work is being written and published quite slowly so that the sudden expense is not too irksome! While for Geological Society members the cost is very reasonable the list price seems fair, bearing in mind the work done over many years and so painstakingly assembled. M.O'D.

Cartier 1900–1939.

J. RUDOE, 1997. British Museum Press for the Trustees of The British Museum, London. pp 344, illus. in colour, hardcover. £50.00. ISBN 0 7141 0584 8.

The quickest glance into this beautiful book shows that it is an exhibition catalogue. In this case the exhibition is due (at the time of writing) to be held at the Metropolitan Museum of Art, New York, from 2 April to 3 August 1997, and at The British Museum from 3 October 1997 to 1 February 1998. While most of the text forms the catalogue, preliminary chapters describe the history of the firm of Cartier from its foundation by Louis-François Cartier in 1847 at 29 Rue Montorgeuil, Paris, and its division into three parts during the earlier part of the 20th century with separate enterprises in Paris, New York and London. The years from the establishment of the three businesses are described in the second chapter, which is followed by brief reminiscences of celebrated clients and by a review of production processes. Procedures and marks peculiar to each of the three branches are described. The three houses maintain their own archives which are fortunately available for jewellery historians: pages from stock books are reproduced.

The catalogue proper deals first with the gradual emergence of a distinctive style and then with the Russian style which began to appear from about 1906 with the production of hardstone flowers and which later developed into a wide variety of objects rivalling but not too closely resembling those produced by the firm of Fabergé whose London shop had closed in 1917, leading to a move of their clientele to Cartier. Gold and enamel fashion accessories, including cigarette and vanity cases as well as watches, are described in a chapter preceding a treatment of the Egyptian style which flourished from about 1910 to the 1930s: Persian, Indian, Chinese and Japanese styles of jewellery and accessories followed.

The catalogue continues with an account of Cartier's use of colour combinations (black materials with diamonds are especially characteristic), with diamond jewellery between the wars and with a review of design drawings. There is a glossary and a short bibliography.

Items are reproduced with full descriptions which include provenance, measurements, identification of materials, present whereabouts and publication where appropriate. With so attractive a guide we can only await the arrival of the exhibition itself with considerable anticipation. The price is by no means unreasonable for a book produced to so high a standard. M.O'D.

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Proceedings of the Gemmological Association and Gem Testing Laboratory of Great Britain and Notices

OBITUARY

Joseph Azzopardi, FGA (D. 1966), died on 19 September 1997 at his home in Nantwich, Cheshire, aged 72 years. Joe was born in Malta and attended St. Aloysius College until he was drafted into the British Army for the last two years of the Second World War.

On demobilization Joe joined the family business, The Sterling Jewellers (established as D. Azzopardi and Bros. in 1896) in Kingsway, Valletta. By 1971 he had become sole owner of the company and later opened a branch at the Phoenicia Hotel. Apart from retailing, he was closely involved with the design and manufacture of jewellery and with valuations.

By 1984 health problems led Joe to decide to sell the business and retire with his wife to England where his two children had settled.

Joe became an active member of the North West Branch of the GAGTL and served as both Secretary and Treasurer for six years. He was very much admired and respected by Branch members and is sadly missed. He was also a Registered Valuer with the National Association of Goldsmiths.

GIFTS TO THE ASSOCIATION

The Association is most grateful to the following for their gifts for research and teaching purposes:

Professor A. Chikayama, Japan, for a selection of I-pearls – imitation pearls made in Japan.

Luella Woods Dykhuis, Tucson, Arizona, USA, for a copy of the November 1978 issue of the *Lapidary Journal*, *Beautiful Queensland opals* by Lee Cram, eight pieces of quartz and also various packs of stones including emerald, sodalite, tourmaline, labradorite, fluorite and ruby.

Mr John R. Fuhrbach, FGA, Amarillo, Texas, USA, for specimens of cut and rough bytownite from New Mexico, USA, and for 45 items of rough and polished gems - a wide range of material from worldwide sources.

David Hargreaves, The Silurian Co. Ltd, Kingston-upon-Thames, for a rough ruby from Malawi.

High Pressure Diamond Optics, Inc., Tucson, Arizona, USA, for two 'busted' type IIa anvil diamonds.

Dr J. Kanis, Veitsrodt, Germany, for a selection of cut stones from South Africa, Zimbabwe, Zambia and Tanzania, including emerald, tourmaline, topaz, iolite, citrine and tsavorite.

Marcia Lanyon Ltd, London, for 357 various specimens including opal, garnet, ruby, sapphire (including a pinkish sapphire), peridot, topaz and spinel.

Mrs C.M. Ou Yang, Hong Kong, for five examples of B-jade, typical of material currently on the market.

Evelyn Ripley, Stockton, Cleveland, for 41 stones including ruby, spinel, quartz, jet, opal and turquoise.

Prashant R. Suchak of Suchak Mineral Resources Ltd, Arusha, Tanzania, for two tanzanite crystals.

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BEQUEST

We are pleased to announce that the GAGTL has recently benefited from a bequest made by Mrs Jeanne Maude Herbert Towers, daughter of the late Herbert Smith, CBE, MA, D.Sc., who was President of the Gemmological Association from 1942 to 1953.

Mrs Towers passed away on 16 December 1996 and in her will left the Association all her interest in the copyright of the book *Gemstones* written by her father in 1912 as the original set of course notes for the first gemmology course in the world. In addition she left the Association one half of the residuary estate; of which the Assent of copyright in *Gemstones* and a sum of £16 882 has already been received. An unquantified balance will follow at a later date.

At a recent meeting of the Council of Management it was decided to place the money from this bequest into the GAGTL Property Fund which, together with other monies received, will hopefully enable the organisation to acquire a building suitable to house all its activities and provide the standard of service rightfully expected by the membership.

To develop the GAGTL accommodation for teaching, research and gem-testing services is high on the Council's list of priorities and they would encourage members and well-wishers to consider remembering the GAGTL when planning their estates; whether it be in the form of gem materials, books, or a financial donation to either our research or building funds, these are always much appreciated.

MEMBERS' MEETINGS

London

On 24 September at the Gem Tutorial Centre, 27 Greville Street, London EC1N 8SU, Professor Robert A. Howie, President of the GAGTL, gave a talk entitled *Rock-forming Minerals – the writing of a classic.*

On 15 October at the Gem Tutorial Centre, Lynne Bartlett gave an illustrated lecture entitled *From sparks to sparkle – a brief history of the use of marcasite/pyrites.*

On 9 November at the Barbican Centre, London EC2, the GAGTL Annual Conference was held on the theme *Collectors' Gems.* This was followed on 10 November by a trip to the Natural History Museum, South Kensington. A full report of the Conference will be published in the *March issue of Gem and Jewellery News.*

On 3 December at the Gem Tutorial Centre, Professor Andrew Rankin of Kingston University gave a lecture entitled *Fluid inclusions: solutions for mineral genesis and gem identification.*

Midlands Branch

On 31 October at the Discovery Centre, 77 Vyse Street, Birmingham, Brian Jackson of the National Museums of Scotland gave an illustrated talk entitled *The sapphires of Scotland.*

On 16 November a Practical Gemmology Training Day was held.

On 28 November at the Discovery Centre, David Callaghan gave an illustrated talk on Opals.

On 6 December the Branch's 45th Anniversary Dinner was held at Barnt Green.

North West Branch

On 17 September at Church House, Hanover Street, Liverpool 1, Irene Knight gave a talk on jewellery, relating to her visit to Beijing, and Stanley Hill spoke on cloisonnè enamel work.

On 15 October at Church House, Dr Jack Ogden, Chief Executive of the NAG, gave a talk on matters concerning the jewellery trade.

On 19 November the Annual General Meeting of the Branch was held at which Irene Knight was re-elected Chairman, and Deanna Brady and Dr John Franks elected Secretary and Treasurer respectively.

Scottish Branch

On 20 October at the Royal British Hotel, Princes Street, Edinburgh, Brian Dunn gave a talk entitled *Gems – a valuer's heaven or hell?*

On 20 November at the Royal British Hotel Fred Woodward gave a talk entitled *Scottish River Pearls.*

PRESENTATION OF AWARDS

The Presentation of Awards gained in the 1997 examinations was held at Goldsmiths' Hall, Foster Lane, London EC2, on Monday, 10 November. The President, Professor R.A. Howie, presided and welcomed those present.

Professor Howie related a recent problem he had encountered: 'A research student from overseas, now studying in Britain a subject outside the earth sciences, wrote asking me to help a

FORTHCOMING EVENTS

1998

30 January	**Midlands Branch.** Bring and Buy Sale; Practical Gemmology Quiz.
18 February	**London.** Collecting gemstones in Scotland. Brian Jackson.
22 February	**Midlands Branch.** Gem Club – microscopy in all its aspects.
27 February	**Midlands Branch.** Chinese and Japanese pearls. Michael Houghton.
6–8 March	Field trip to Whitby
18 March	**London.** Fired with enthusiasm: the early history of enamel. Dr Jack Ogden.
22 March	**Midlands Branch.** Gem Club – Gemstones. Professor R.A. Howie
27 March	**Midlands Branch.** Dr Jack Ogden.
19 April	**Midlands Branch.** Gem Club – Bragging pieces; collectors' stones
19–25 April	Trip to Idar-Oberstein, Germany
22 April	**London.** Pearls – a fashion opportunity. Christianne Douglas
24 April	**Midlands Branch.** AGM followed by a mosaic of gemmological tessera
26 April	**Midlands Branch.** Diploma pre-examination seminar
3 May	**Midlands Branch.** Preliminary pre-examination seminar
13 May	**London.** The gemstone collections of the GAGTL
17 May	**Midlands Branch.** Gem Club – 'Black pearls' of Guyana, James Gosling, and The opals of Coober Pedy, Gwyn Green
29 June	**London.** Annual General Meeting followed by the Reunion of Members and a Bring and Buy Sale
8 July	**London.** The evolution of Georgian and Victorian jewellery. John Benjamin

For further information on the above events contact:

London:	Mary Burland on 0171 404 3334
Midlands Branch:	Gwyn Green on 0121 445 5359
North West Branch:	Irene Knight on 0151 924 3103
Scottish Branch:	Joanna Thomson on 01721 722936

GAGTL WEB SITE

For up-to-the-minute information on GAGTL events and workshops visit our web site on www.gagtl.ac.uk/gagtl

Dr Roger Harding, Professor Chen Zhonghui, Terry Davidson, Eric Bruton and (seated) Professor Robert Howie at the Presentation of Awards.

colleague in his home country who needed some crystal samples to be reliably identified. His colleague had already tried a National Museum in London and the X-ray Laboratory of a Midlands University but felt unhappy with the results. My name had been recommended as someone of scientific integrity whose opinion he could trust.

Preliminary Trade Prize winner, Simon Millard, receiving his prize from Professor Chen Zhonghui.

'Four specimens eventually arrived and a quick glance showed them to be virtually colourless crystal fragments, some 2 cm across, of calcite, fluorite and quartz (two) – but how to prove it to his satisfaction? Being retired and living in rural Derbyshire, I have no refractometer, spectroscope, X-ray facilities or even microscope – just a loupe and my wits! I have no hardness set as such, but hardness was the answer, and I was soon able to show that the calcite has perfect cleavage and was scratched by known fluorite; the fluorite had a very faint purplish colour, a good cleavage and was scratched by crystals of apatite and quartz and the two quartz pieces were readily scratched by topaz and ruby. I also noted that one quartz displayed growth trigons on one face: very proper for a trigonal mineral, but I wonder whether my overseas enquirer had growth trigons on diamond in his mind? I wrote out my report and have heard no more – but as the address on his notepaper was that of a National Mineral Exploration Programme, I did wonder as to his background!

'In an incident from earlier years, when I was responsible for assessing students for admission to the Geology Department at Kings College, a candidate bounced in and announced that he had a scheme he'd perfected for identifying minerals, did I want to hear it? I told him "No, but have a go at identifying this specimen," and I passed across a translucent octahedral crystal of diamond. "Fluorite," he said. I passed across a Mohs' hardness set and asked him to test it: he soon found that it scratched apatite, feldspar, quartz and topaz – at which point I stopped him, and said "Any comment?" "Hard fluorite!" was his astonishing reply! The moral of these two incidents is that (1) you should put your faith in someone of known integrity and (2) you must trust your results.

'But what is the relevance to tonight's occasion? Simply that you, the award winners, have indeed put your faith in the integrity of the Examiners appointed by the Gemmological Association, which is why you have come from all over the world to sit our examinations. Now put faith in their judgement and go forth with confidence to begin to develop your careers and to profit from your growing experience in the ever-increasing complexities of real gemmology.

'In January and June 1997, 1049 students entered the Preliminary, Diploma and Gem Diamond examinations. A total of 189 students passed the Diploma examination and they came from 21 countries, in all five continents. Here tonight we again have an international gathering

with successful candidates from as far away as Canada, Japan, Myanmar, Sri Lanka and the USA, as well as from Finland, Greece, The Netherlands and Sweden. Eighty-one students passed the Gem Diamond Examination and although this is not quite as widespread as the gemmology exam, there were successful candidates this year from China, Cyprus, Hong Kong and India.'

Professor Howie introduced Professor Chen Zhonghui from the China University of Geosciences in Wuhan who presented the awards. Professor Howie then called on Eric Bruton, immediate past President of the Association, to present the Bruton Medal to Miss Rita Tsang Wai Yi of Hong Kong, the first occasion on which this medal had been awarded.

Professor Chen delivered his address (see below) and a vote of thanks to Professor Chen was proposed by Terry Davidson who expressed the hope that the GAGTL and the China University of Geosciences would continue to work together into the twenty-first century.

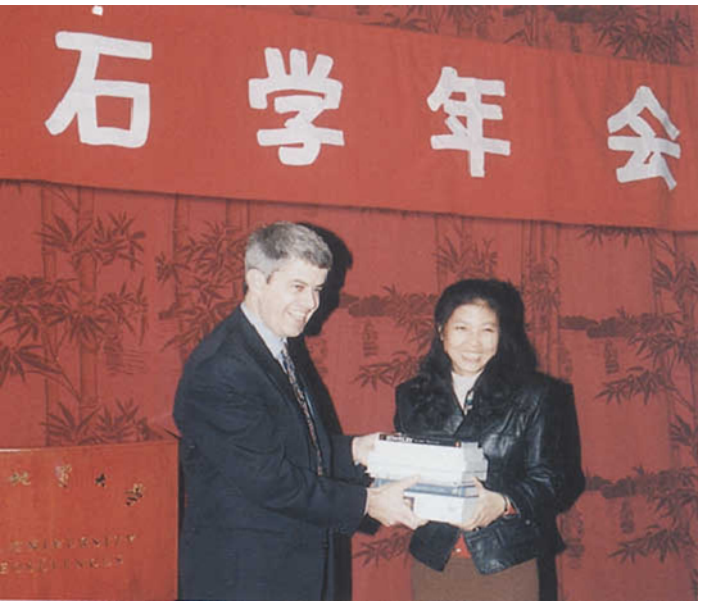
In conclusion, Professor Howie thanked the Goldsmiths' Company for allowing the GAGTL to hold the ceremony at the Hall.

Eric Bruton presenting the Bruton Medal to Rita Tsang.

Address by Professor Chen Zhonghui

'I am very delighted to attend today's Presentation of Awards 1997. First of all, I would like to show my gratitude to the Gemmological Association of Great Britain which has kindly invited my wife, Professor Yan, and myself to pay this visit to your beautiful country. I am also honoured to present the Diplomas to those who have passed successfully the examinations this year. I would like to extend my warmest congratulations to the diligent students who have obtained the treasured Diplomas, especially to those who have obtained prizes this year.

'The Gemmological Institute, China University of Geosciences, started its co-operation with the Gemmological Association of Great Britain in 1988. Today is the tenth year of our friendly co-operation. In the spring of 1988, Alan Jobbins and Dr Jamie Nelson paid their first visit to our University at Wuhan, China. After the friendly negotiation, both parties worked together and eventually made an agreement that a new Allied Teaching Centre under the Gemmological Association of Great Britain be established in our University. This is the first ATC in the Chinese mainland, and also the first ATC in the Chinese language in the world. We will never forget Alan Jobbins, Dr Jamie Nelson and Ken Scarratt who offered us much help in the initial stages of our ATC. They once gave us this metaphor that the British teachers are like a wet towel; they expected our students to wring out this wet towel. Our students did not disappoint these British teachers! The sincere help from these British teachers has laid a solid foundation for the smooth development of our ATC since then. In 1993, a new Gem Diamond Course opened in our University with the help of Eric Emms. This is also the first in the Chinese mainland. Since the establishment of the ATC in our University, 155 students have obtained FGA Diplomas and 64 students have obtained DGA Diplomas, of whom 15 students have won the certificate with distinction, and five students have won prizes. The students in our ATC come from almost all the provinces, autonomous regions and municipalities in China. The graduates with FGA Diplomas have established the first gemmological testing laboratories in many different parts of China. In this sense, they have played an important role in the promotion of the gemmology and jewellery industry in China. The achievements of these graduates from our ATC have also made the FGA and DGA Diplomas by the Gemmological Association of Great Britain known all over China. The experience with the FGA and education in the Gemmological Institute of our University qualifies us to enrol the undergraduate students in gemmology at our University. In addition, the Gemmological Institute has already opened various short-term training programmes in gemmology and the gem diamond course. Around 2000 persons from the gem and jewellery



Stephen Kennedy presenting the Tully Prize to Ms Li Liping.

industry have been trained in these short-term programmes. Because of our persistent efforts and excellent achievements in gemmological education in China, the Gemmological Institute of our University has won the first prize in education at the provincial level, and the second prize in education at the national level in 1997. This has fully showed that what we have done has been positively acknowledged by the relevant authorities and by the public in China.

The first Allied Teaching Centre in the Chinese language in our university resulted in the present ten ATCs in the Chinese language in the Chinese mainland, Hong Kong and Taiwan, and this year also a new ATC in Singapore.

Looking back over the past ten years, we have enjoyed our friendly co-operation with the Gemmological Association of Great Britain. One major purpose of our present visit to your Association is to make a joint research with the Gemmological Association of Great Britain into the enhancement and development of our friendly co-operation with the Association and into the expansion of our field of co-operation. I am confident that more fruits will result from our sincere co-operation. I also sincerely hope that the Gemmological Association of Great Britain will make a greater development in the future.'

PRESENTATION IN WUHAN, CHINA

A presentation of gemmological awards, including those of the GAGTL, was held at the Gemmological Institute, China University of Geosciences, Wuhan, on 22 November 1997, during the Institute's Annual Conference. Stephen Kennedy of the GAGTL gave a lecture entitled 'Pearl Fishing and Pearl Identification' at the Conference and presented the Association's Diplomas and also the Tully Medal which had been awarded to Ms Li Liping of Wuhan.

FEEG EXAMINATION

REMINDER – FEEG application forms are available from Lorne Stather at the Gem Tutorial Centre, GAGTL. All applicants are reminded that they must already hold a gemmological Diploma from either GAGTL or one of the other member organizations. Candidates should note that there are no notes or other course materials available with this exam but that refresher courses could be arranged with sufficient notice.

Exam date – 7 July 1998

Final entry date – 31 May 1998

THE 26TH INTERNATIONAL GEMMOLOGICAL CONFERENCE (IGC)

The conference is biennial and was held in September-October 1997, at the Hunsruck Ferienpark Hambachtal, a conference and leisure centre outside Idar-Oberstein, Germany. It was attended by 44 delegates and 10 observers from 25 countries. The lectures listed below were delivered on 29 September to 2 October and covered a wide range of topics; a collection of abstracts of the talks was provided.

At the IGC business meeting held on 2 October, the place of the next meeting in 1999 was decided and Dr Panjikar of the Gemmological Institute of India, Bombay, will host the 27th IGC. Thanks were expressed to Professor Bank, his colleagues and family for a superbly organized meeting and programme of events.

On 3 October, the final day of the conference was spent on a field trip to the Eifel, north-west of Idar-Oberstein, to search for peridot, sanidine and hauyne in the lavas and tuffs – parts only 13 000 years old (some said they were still warm but that was just the autumn sunshine!).

R.R. Harding

Oral presentations (senior authors only listed)

Balitsky, V.S. The first commercial synthetic ametrine from Russia and its gemmological characteristics

Bosshart, G. Diamond inclusions in corundum

Brown, G. An opal nomenclature

Chikayama, A. The imitation pearl industry in Japan

Dereppe, J.M. Classification of emeralds by neural network analysis

Eliezri, I.Z. The isotopic composition of oxygen in emeralds as an indicator of origin

Forestier, F.H. Bactrian emeralds: myth or reality? Panjshir valley (Afghanistan)

Fritsch, E. The morphology of natural gem diamond: a status report

Fritsch, E. About a blue quartz from Madagascar (given on behalf of B. Lasnier)

Gao Yan. Research on Ti and Cr diffusion treated star sapphires

Gray, M. The benitoite gem mine: historical production and future potential

Graziani, G. The origin assessment of the Roman archaeological emerald

Gübelin, E.J. Gemstones of Switzerland

Hänni, H.A. Maw-sit-sit kosmochlor-jade: a metamorphic rock with a complex composition from Myanmar (Burma)

Harding, R.R. Collectors' stones

Hyrsl, J. Gemstones and ornamental stones of Bolivia

Joshi, V. Comparative study of Indian rubies *vis-à-vis* other rubies

Kane, R.E. Kashmir ruby – a preliminary report on the deposit at Nangimali, Azad Kashmir, Pakistan

Koivula, J.I. Reversible twinning in a unique synthetic material

Levinson, A.A. The Diamond Pipeline into the third millennium: part II. The role of the modern diamond cutting industry of India

Milisenda, C.C. The new Tunduru-Songea gem fields, southern Tanzania

Miyata, T. Relation between surface microtopographs and growth condition of quartz crystals

Ou Yang, C.M. Definition-nomenclature-classification of jade

Panjikar, J. New gem deposits from India

Pienaar, H.S. A fresh look at 'Kauri gum' from North Island, New Zealand

Poirot, J.P. Bezoar

Ponahlo, J. CL emission and photoexcitation spectrometry in gemmology

Saul, J.M. Libyan desert glass

Schmetzer, K. Characterization of Chinese hydrothermal synthetic emerald

Schwarz, D. The chemical properties of gem corundums from south-east Asia

Sevdermish, M. The Diamond Pipeline into the third millenium: part I. The restructured Diamond Pipeline: a multi-channel system and its effects on the retail diamond jewellery industry

Shida, J. Characteristics of cathodoluminescence for yellow diamonds of various types

Siripant, S. A gem colour communication system

Sobolev, N.V. Mineral inclusions in large crystals of Yakutian diamonds

Sunagawa, I. Growth-induced imperfections and inhomogeneities in single crystals

Superchi, M. Sapphire occurrences at Ambondromifehy, Antsiranana Province, North Madagascar

Sutherland, F.L. Remarkable similarities between gem corundum suites from Barrington, Australia, and Pailin, Cambodia, basalt fields

Tay, T.S. Amber identification using micro-Raman spectroscopy

Tillander, H. A critical analysis of rose cuts

Tombs, G.A. Distinction between natural and synthetic or imitation opal

Zoysa, E.G. Colour change garnet from Thelulla-Wellawaya, Sri Lanka

Zwaan, P.C. Cultured pearls from Indonesia

Poster presentations

Balitsky, V.S. High temperature pink quartz and other new synthetic coloured varieties of quartz

Graziani, G. Tomb n.2, Necropolis of Vallerano, Rome, Italy: study about the jewels

Joshi, V. Gemstone deposits of India

Kanis, J. Sandawana emerald mines, Zimbabwe

Shatsky, V. New hydrothermal synthetic sapphires, grown by TAIRUS Co. Ltd in Novosibirsk, Russia

Sutherland, F.L. Gem activities of the Australian Museum

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Contributions are being solicited for this Poster Session. To be considered for this important event (space is limited), please submit a preliminary abstract (no more than 250 words) to one of the Poster Session organizers by 1 October 1998. For further information on the Poster Session, contact Dr James Shigley at 760-603-4019 (Fax: 760-603-4021, E-mail: jshigley@gia.edu) or Ms Dona Dirlam at 760-603-4154 (Fax: 760-603-4256 or e-mail: ddirlam@gia.edu). For information on the Symposium, contact Carol Moffatt at 760-603-4406 (cmoffatt@gia.edu).

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Kuang Yong Hong, Guilin, Guangxi, P.R. China. 1997
Li Dongsheng, Guiling, Guangxi, P.R. China. 1997
Ma Huei Chi, Taipei, Taiwan, Rep. of China. 1997
Ng Wai Ching, Hong Kong. 1997
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Suninmäki, Virpi Kristiina Annika, Helsinki, Finland. 1997
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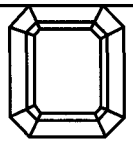
The World  of Gemstones

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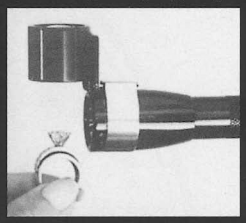

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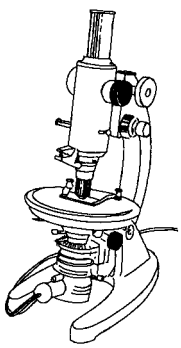

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On matters of style and rendering, please consult *The Oxford dictionary for writers and editors* (Oxford University Press, 1981).

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Books Hughes, R.W., 1990. *Corundum*. Butterworth-Heinemann, London. p. 162

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A picture of Paradise
A turquoise carving photographed by Yuan Jiaqi
(See Turquoise from Hubei Province, China, p. 1)

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ISSN: 1355–4565

Printed by Quadrant Offset Limited, Hertford, England