SAPPHIRES FROM AUSTRALIA

By Terrence Coldham

During the last 20 years, Australia has assumed a major role in the production of blue sapphire. Most of the gem material comes from alluvial deposits in the Anakie (central Queensland) and New England (northern New South Wales) fields. Mining techniques range from hand sieving to highly mechanized operations. The rough is usually sorted at the mine offices and sold directly to Thai buyers in the fields. The iron-rich Australian sapphires are predominantly blue (90%), with some yellow, some green, and a very few parti-colored stones. The rough stones are commonly heat treated in Thailand to remove the silk. While production has been down during the last two years because of depressed prices combined with higher costs, prospects for the future are good.

ABOUT THE AUTHOR

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Unless otherwise noted, photos are by the author.

Few people realize that Australia is one of the major producers of sapphire on the world market today. Yet a fine blue Australian sapphire (figure 1) competes favorably with blue sapphire from noted localities such as Sri Lanka, and virtually all other hues associated with sapphire can be found in the Australian fields (figure 2). In fact, in the author's experience it is probable that 50% by weight of the sapphire sold through Thailand, usually represented as originating in Southeast Asia, were actually mined in Australia.

In spite of the role that Australian sapphire plays in the world gem market, surprisingly little has been written about this indigenous gem. This article seeks both to describe the Australian material and its geologic origins and to introduce the reader to the techniques used to mine the material, to heat treat it prior to distribution, and to market it worldwide.

HISTORY

The two main sources for sapphire in Australia are the New England fields, in northern New South Wales, and the Anakie fields, in central Queensland. Large-scale commercial mining has been successful at these two fields only. Geographically, the two areas are quite different. The Anakie fields are in a semi-arid area of gently undulating low hills, while the New England fields cover an area of tablelands consisting of rich grazing land and fertile river flats that comprise some of the best agricultural country in Australia.

While sapphire was first reported from Inverell (NSW) in 1854, the first sapphire mining started at the Anakie fields almost 40 years later. In 1873, Archibald John Richardson found sapphire near the town of Anakie (Monteagle, 1979), about 50 km to the west of the township of Emerald in central Queensland. Local lore has it that Emerald was so named because green sapphires found in the

Figure 1. Two fine blue sapphires, 1.11 ct and 1.61 ct, respectively, from the New England fields, New South Wales, Australia. Photo © Tino Hammid.

area were originally thought to be emeralds. Sporadic mining operations started in the Anakie fields in the 1890s, and most of the early production went to tsarist Russia via German buyers.

The Anakie area was officially proclaimed a mining field in 1902. Mining consisted of sinking shafts or digging shallow alluvials and then washing the material with sieves. By 1913, two tons of sapphire and other corundum had been removed. Single pieces of gem-quality material as large as 500 ct were reported (Anderson, 1971). Two small villages, Rubyvale and Sapphire, appeared on the fields to service the miners.

The advent of World War I, the collapse of imperial Russia, and the elimination of German buyers brought mining to a virtual standstill. Not until the early 1960s—with the onset of a burgeoning demand for rough sapphire throughout Asia—was systematic mining resumed at Anakie. By 1969, the Anakie fields were being fully exploited through a number of large-scale, fully mechanized operations. Since the beginning of the current decade, however, as the viable areas are exhausted and operating costs continue to mount, there has been a steady decline in production. Many small, semi-mechanized underground operations now run alongside the large, heavily mechanized workings.

The second major mining field is centered around the towns of Inverell and Glen Innes, in northern New South Wales, and is generally referred to as the New England fields. Although sapphire was first found here in 1854, mining did not start until many years later, and even then was only sporadic until 1959. As with the Anakie fields, the Asian buying power in the early 1960s

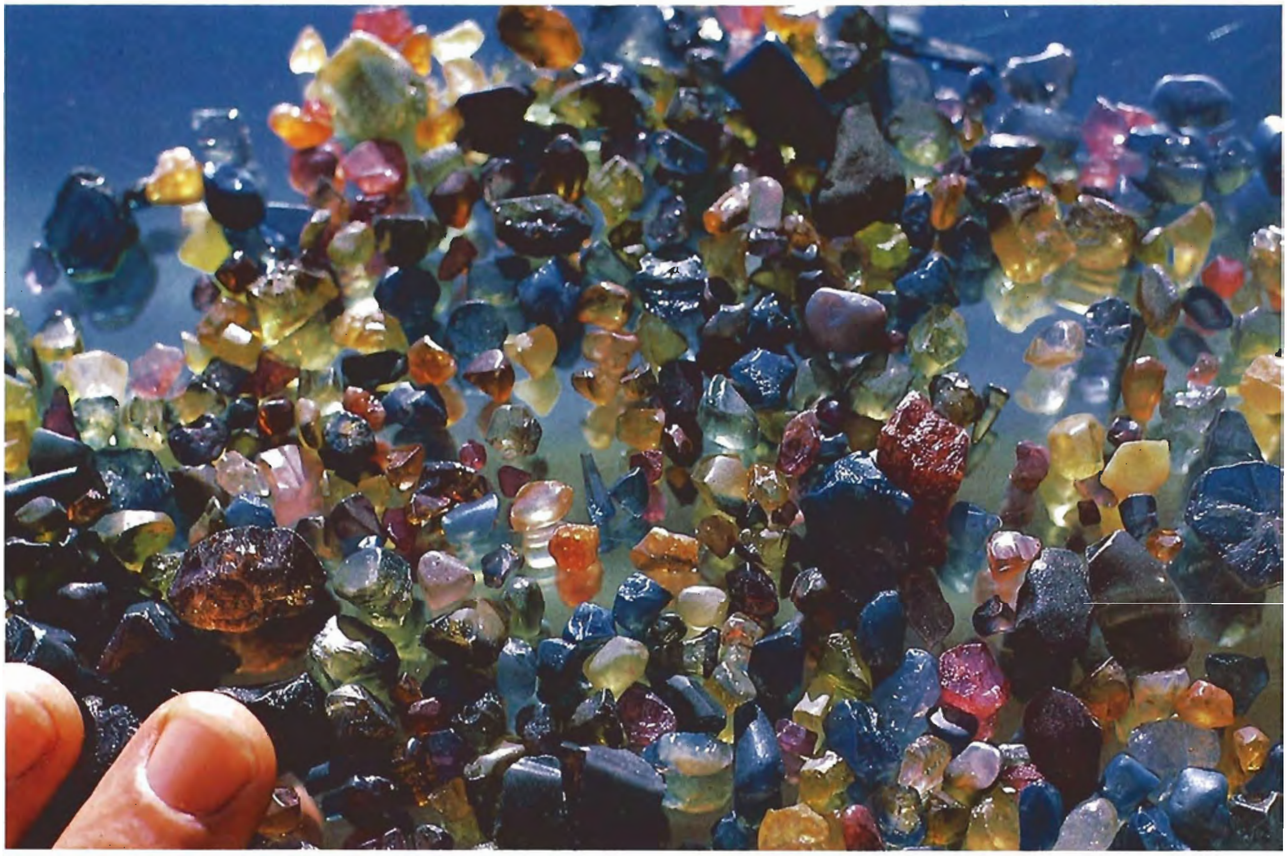

Figure 2. A miner's collection of the different-colored sapphires found at Inverell, in the New England fields, New South Wales.

created favorable conditions for large-scale mechanized mining that has continued to the present time.

Various attempts to mine at other localities in Queensland, New South Wales, and Tasmania have been made, but thus far none has proved viable. It is quite possible that future prospecting will produce new fields.

GEOLOGY

All along the eastern seaboard of the Australian continent are scattered remnant dissected flows and pipes of Cenozoic volcanics (see figure 3). The most common volcanic rock type is alkali basalt, which in many localities contains xenocrysts of such minerals as ilmenite, pleonaste, amphiboles, feldspar, zircon, corundum, and pyrope garnet. In 1902, a geologist with the Queensland Mines Department reported on the new Anakie sapphire fields, and stated that the sapphire found in the surrounding alluvials appeared to have been weathered out of the nearby basalts (Dunstan, 1902). Since then, numerous occurrences of sapphire have been discovered as far north as Cooktown in Queensland and as far south as Tasmania (again, see figure 3). In nearly every case, the sapphires have been found in close proximity to Cenozoic basalts. As mentioned above, however, in only two areas have the deposits proved to be rich enough to allow commercial mining.

In most cases, the sapphire occurs in alluvial gravels, termed "wash" by the miners. The gravels are associated with present-day rivers and creeks in the New England region (Department of Mineral Resources, 1983), and occur as large sheets that cover extensive areas dissected by the present drainage pattern in the Anakie fields.

The sapphire occurs as individual crystals and crystal fragments that in most cases have been locally concentrated, presumably by normal alluvial processes. Other minerals associated with sapphire are found in varying proportions and include (in order of abundance) pleonaste (spinel), zircon, ilmenite, magnetite, olivine, pyroxenes, and amphiboles. Zircon is the only other mineral that commonly occurs in gem quality. These zircons are of "high type" and are either pale yellow or reddish brown, ranging from sand-grain-sized

particles to the occasional clear pieces of several hundred carats. Gemologically they appear to be similar to those found at the Pailin field in Cambodia, as described by Jobbins and Berrangé (1981). The pleonaste is usually much more abundant than the sapphire and zircon; since it has a specific gravity similar to that of sapphire, it is often used as an indicator mineral by the miner. All these minerals have been found at various localities in situ in solid basalt, pleonaste quite commonly and sapphire and zircon very rarely (McNevin, 1972).

At certain localities, such as Lava Plains in northern Queensland (see figure 3), large amounts of sapphire, along with pleonaste, have been found in soil directly overlying the basalts. The surfaces of material from this locality show no evidence of having traveled any distance from their source. However, while pleonaste xenocrysts are plentiful at Lava Plains, no xenocrysts of sapphire have been found in the basalt itself from which the soil apparently derives. Personal observations by the author show that these deposits are very similar in rock type, mode of occurrence, type of stone, and associated minerals to those found at Prae in central Thailand.

Recently, quite rich deposits of sapphire were found seven miles (11 km) east of Inverell in what appears to be pyroclastic (volcanic ash) rocks interbedded with basalt flows. Accessory minerals are zircon and ilmenite (Lishmund and Oakes, 1983).

In all localities, the sapphire occurs as discrete crystals and crystal fragments, often elongated hexagonal pyramids, and occasionally bipyramids. Almost invariably, crystal faces and fracture surfaces alike show evidence of corrosion and etching. Some crystals are so corroded that they appear as long cone shapes without any suggestion of their original hexagonal cross section. For quite a long time it was thought that the material was "water worn," but it is now believed that these surfaces are a result of chemical corrosion (figure 4). These

Figure 3. The distribution of basalts in eastern Australia. Major deposits of sapphire have been found in the Anakie fields (Queensland) and the New England fields (New South Wales). But some sapphire has been recovered from as far north as Cooktown (Queensland) and as far south as Tasmania. Map adapted from an original by the Mineralogy Section of the Australian Museum. Artwork by Lisa Joko.

Figure 4. Two corundum crystals (approximately 5 ct each) from Inverell, in the New England fields. Note that the left side of the piece on the right has been protected and shows the original crystal faces.

features are the same as those reported at Pailin in Cambodia (Jobbins and Berrangé, 1981) and observed by the author in sapphire from Bo-Bloi, Chanthaburi, and Prae in Thailand. They also look very similar to the surface features reported on corundum from Colombia (Keller et al., 1985). Some minor water wearing is observed on the gem material recovered from alluvials, particularly from the Anakie fields.

Although it has been generally considered that the alkali basalt is the source rock for the alluvial sapphire in the area, it is distinctly possible that the pyroclastic rocks associated with the basalts may, in fact, be the source. According to this second hypothesis, the sapphires themselves crystallized originally in an unknown rock in the lower crustal/upper mantle regions and were eventually released into a fluid phase that rose to the surface during a period of volcanism. These fluids eventually consolidated to form the host basalt and pyroclastic rocks. Evidence for either hypothesis is somewhat conflicting and more detailed field work is necessary.

Also of interest is the similarity in rock types between the Australian and Southeast Asian (Jobbins and Berrangé, 1981) sapphire fields. For example, some of the basaltic rocks in Australia near Inverell are very similar to those at Pailin and appear to be closely associated with sapphires. In contrast, the larger tholeiitic basalts of Australia and Pailin are considered to be barren of sapphire.

MINING

The last 20 years (and, more specifically, the last 10 years) have seen the development of sophisticated commercial mining of the alluvial deposits through the use of heavy earth-moving equipment and large throughput processing plants (figure 5). Presently, mining techniques on both fields range from hand sieving, through small one-man operations that use processing plants capable of handling only a few cubic meters of material per hour, to large syndicates and companies that employ up to 30 men on a site and process hundreds of cubic meters per day.

On the New England fields, the mechanized mines dot an area of some 4,000 km^2. Each miner usually works a section of creek or river that is often hundreds of acres in area. First, samples of wash are taken to delineate the richer runs, and then mining proceeds in a systematic manner.

In contrast, on the Anakie fields, most of the mining activity is contained in an area of only a few square kilometers. Because the size of a claim is restricted by the State Mining Law, the miners tend to work almost on top of one another (figure 6), and each miner must accumulate the rights to a number of adjoining claims if he is to have sufficient room to operate. However, Anakie miners are to some extent compensated by the fact that the wash here is usually thicker and richer in sapphire than that in the New England area.

In both areas, the gravel is normally covered by 2–80 ft. (0.5–25 m) of barren overburden consisting of fine grits and brown or black soils. This overburden is removed by either a backhoe or a bulldozer. The sapphire-bearing wash is then excavated and loaded into trucks for transport to the processing plant. Some areas of the Anakie fields are reserved for hand miners who sink shafts up to 100 ft. to reach the gem-bearing alluvials (in much the same manner as their predecessors operated at the turn of the century).

Processing. On arrival at the processing plant, the gravel is tipped into dump boxes where it is washed into a trommel with a high-pressure water jet. Any large pieces of rock are, if necessary, broken up and removed by hand from the dump box. The trommel consists of a revolving screen that usually has two different-sized meshes. The first section has a fine mesh through which sand-sized particles are sieved out. The mesh in the second section is usually about three-quarters to one inch (2–2.5 cm) in size, and anything larger passes out of the trommel into rock bins to be returned to the excavation. The middle-sized fraction—i.e., of

Figure 5. A mechanized processing and recovery plant at Kings Plan, Inverell, in the New England fields.

Figure 6. Note how miners have torn up this area between Rubyvale and Sapphire in the Anakie fields.

Figure 7. Picking out the sapphire from the coarse concentrate at an Inverell (New England fields) mine site.

plus one-sixteenth inch to minus one inch from the second mesh—passes through the trommel down to a pulsator or jig. The trommels may have revolving tynes and high-pressure water jets inside to break up the gravel. In areas with concentrates of clay, the material is often passed through a second trommel or over a vibrating screen to make sure all the sapphire is released.

Because of the scarcity of water on the Anakie fields, many mines there use dry sieving methods. After excavation, the material is laid out to dry and then passed through large, semi-mobile vibrating screens to remove sand and oversized material near the excavation site. The middle-sized product is trucked to the pulsator or jig which is located adjacent to water, usually one of the series of ponds or setting dams through which this very scarce commodity is recirculated.

The pulsator is the main recovery section; the various models range from 18 inches to several feet across. The pulsator is a simple heavy-media unit that pulsates water through a screen divided by a series of riffles. The gravel is fed over the screen, and the "heavier" sapphire and other minerals collect in front of the riffles. The lighter material washes out over the end of the pulsator and is returned to the excavation. Large mines may have banks of several pulsators to process the different sizes. The recovery rate is usually 90%–95%, but it may be less in alluvials with a high clay content.

The mining operations in the New England district are much more rigidly controlled in terms of conservation and restoration than those in Anakie. The waste gravels, sands, and silts are collected in bins and then used to backfill the original excavation. After all the processed gravel has been returned, it is covered by the original overburden and topsoils. All water used in the mining operations is stored in dams and recirculated; only clean water can be returned to the rivers.

At the end of each day, the concentrate in the pulsator is removed. This gravel is composed mainly of highly iron-rich material in addition to the sapphire, pleonaste, zircon, and the like. The sapphires from the coarser fractions are often picked out of the concentrate at the mine site (figure 7). The larger volumes of medium- and fine-sized concentrates are sent to an office to be picked out and sorted.

Sorting and Grading. The first step in recovering

Figure 8. Fine concentrate after removal from the pulsator. Note the abundant black pleonaste.

the sapphire from the medium- to fine-sized concentrate (figure 8) is to dry it and pass it through a magnetic separator. This removes all the iron-rich material, black spinel, and anything else with a reasonably high magnetic attraction; it leaves a concentrate of corundum, zircon, quartz, and other minerals that usually represents 10% of the original concentrate. This material is then washed, dried, and given to the grading staff who select out all the corundum that shows any indication of being cuttable. Usually women are employed to handpick this material as it is passed over mirrors (figure 9). The mirrors reflect light through the rough material so that color and flaws can be observed without the sorter having to hold each stone up to a light.

All blue material found is sorted at the mine's sorting office into what is termed "mine run" parcels; blue sapphire represents approximately 95% by weight and value of the total salable production. A mine run is the total production of all salable blue material produced in a given (arbitrary) time from the one mine.

Often these parcels are quality graded by the miner into firsts, seconds, and thirds and then sieved into various groups. A mine-run parcel varies considerably in quality from one miner to the next, and a standard price per ounce cannot be applied. Variations in a mine-run parcel depend on the type of stone produced in the area mined as well as on the type of grading adopted by the miner. The grading process at this stage is very subjective. Other colors such as greens, yellows, and particolored sapphires are sold separately either in small lots of a few ounces or as individual stones.

A typical Inverell mine-run parcel may have about 10%–20% of the stone over 2 ct in weight, 40%–60% of medium size (0.50 to 2 ct) and 30%–40% of small material (0.20 to 0.50 ct). Material in mine runs from Anakie would be, overall, of a larger particle size (20%–40% are over 2 ct).

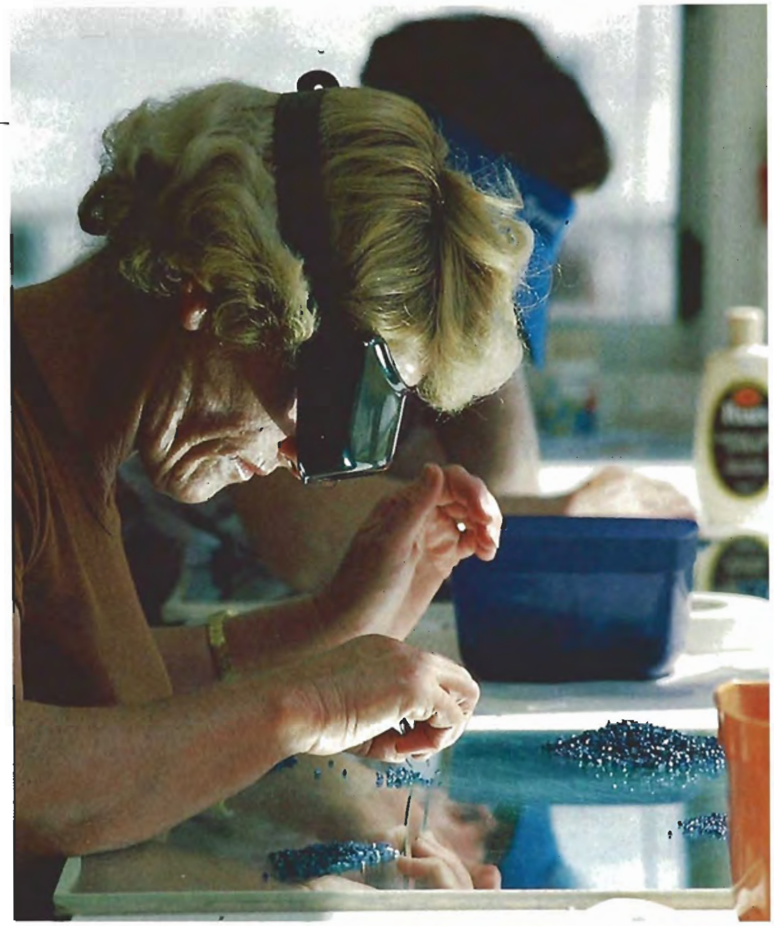

Figure 9. Sorting sapphire on mirrors at an Inverell mine office.

DESCRIPTION

The gemological properties of Australian sapphire, as determined by the author, are given in table 1. As is the case with corundum from Thailand and

TABLE 1. Gemological properties of Australian sapphire.[a]

Color	Refractive index	Birefringence	Specific gravity[b]	Spectra	Reaction to LW/SW ultraviolet radiation
Light blue	1.761–1.769	0.008	4.02	Single band 455–458 nm	Inert
Dark blue	1.763–1.772	0.009	3.99	Strong band 455–460 nm; Narrow band 464–466.6 nm; Single line 478 nm	Inert
Green	1.763–1.772	0.009	4.00	(same as dark blue)	Inert
Yellow	1.765–1.774	0.009	3.97	Broad band 455–465 nm; Single line 478 nm	Inert
Gold	1.763–1.772	0.008	4.01	Same as for yellow, but less distinct	Inert[c]

[a]These properties were taken from a small range of Inverell and Glen Innes stones.
[b]Specific gravity was determined by the hydrostatic method (±0.02).
[c]While almost all Australian sapphire is inert, those showing an orange or pink to mauve color will show some red fluorescence when exposed to long-wave ultraviolet radiation.

Figure 10. A variety of faceted Australian sapphire. Note that the proportion of yellow stones is much greater than is found in overall production. In fact, 90% or more of all Australian sapphire occurs in various shades of blue. Photo by D. Barnes, courtesy of the Department of Mineral Resources, New South Wales.

Cambodia, Australian stones generally have a higher iron content than corundums associated with metamorphic environments (Webster, 1983). This results in a range of colors (figure 10) quite different from those found in Burma, Sri Lanka, and Tanzania. Analyses of sapphire from Frazers Creek, Inverell, show total Fe as over 1% (MacNevin, 1972).

The size of individual pieces ranges from less than 0.05 ct to over 1,000 ct. Stones over one inch in diameter are rarely found these days, as they are removed with other coarse gravel by the trommel. On average most of the cuttable material is under 2 ct in the rough state; clean stones over 10 ct are quite rare.

The vast majority of gem-quality Australian sapphires, perhaps 90% by weight, occurs in various shades of blue (again, see figure 10). These shades range from almost colorless through rich royal blue to some that are so dark as to appear black when cut. The greater proportion occurs as medium to dark material.

The second most common color range covers various tones of greenish blue, and most frequently occurs in a light to medium, very slightly greenish blue.

The two other colors that often occur are yellow and green. The yellows range from light through intense yellow to strong gold (figure 11). Bright orange stones are also encountered, though

Figure 11. A range of fine, natural-color yellow and gold sapphires from the Anakie fields. The large stone in the center weighs 30 ct.

rarely. The greens occur in a great variety of shades, including yellow-green, yellowish green, and brownish green, with tones that range from very pale through almost black. Evenly colored green, yellow, or gold gemstones of over one carat are quite rare, but the author has seen gem-quality rough that weighs over 300 ct.

Occasionally pink, purple, and mauve stones are found, but they are extremely rare. Also seen, but only rarely, are color-change sapphires, some of which show effects similar to those seen in alexandrite, while others change from greenish yellow to orangy pink. The coarser banding of colors such as green, blue, and yellow results in parti-colored stones, some of which are extremely attractive. This coarse banding seems to be much better developed in the Australian material than in that from other localities. One large (2,019.5 ct) piece of gold, green, and blue particolored rough was recently found.

The term *wattle* sapphires has recently come into vogue to describe parti-colored stones that range from yellow with a touch of green to green with a touch of yellow. (*Wattle*, called mimosa in many countries, is Australia's national flower; it has a yellow to gold blossom with green to olive-green foliage.) When this material is cut correctly, the resultant gem can rank as one of the most beautiful of the corundum family (figure 12). Miners often collect them, and both Thai and Australian dealers give them to their wives or sell

Figure 12. An approximately 6-ct parti-colored ("wattle") sapphire from the New England fields. Photo by D. Barnes, courtesy of the Department of Mineral Resources, New South Wales.

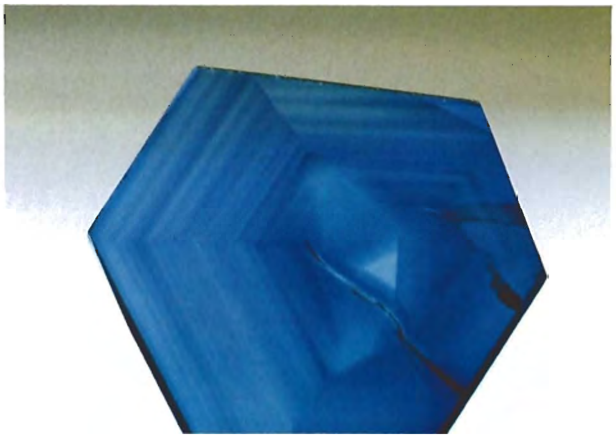

Figure 13. This 1.5-cm thin section of an Australian sapphire crystal, cut at right angles to the c-axis, shows color banding parallel to the crystal faces.

them to friends, so the general retail customer rarely gets a chance to see fine wattle sapphires.

Color banding is a very common feature of Australian sapphire, and even very uniformly colored stones will show fine banding under the microscope; however, patches of color without clear planar boundaries are rare. The banding occurs in two directions (MacNevin, 1972), the first being parallel to the c-axis, which often results in a hexagonally or trigonally banded cross section in which the colors generally are lighter toward the center of the crystal (figure 13). The second type occurs at right angles to the c-axis and generally grades from darker at the base of the crystal to lighter at the top.

In the blue material, darker and lighter shades of blue may alternate randomly with colorless or very pale yellow bands. As mentioned above, coarse to very coarse banding gives rise to particolored sapphire. When the bands are wide enough to give a clear separation between colors such as green and gold or blue and yellow, the effect is quite beautiful; however, alternating fine bands of green and blue cause a rather unpleasant green-blue parti that along with black or heavily included blue material makes up the lower quality end of Australian commercial production.

Star sapphire is also found, the most common of which is black or bronze material very similar to that from Bang Kha Cha in Thailand. Asteriated stones also occur in blue, blue-gray, and occasionally green and gold. Stars may occur in particularly large pieces—one was recorded to weigh approximately 1,900 ct.

Overall differences in color can be noted in the sapphires from the Anakie and the New England fields. The Anakie fields produce darker blue sapphires and more pure green and pure yellow stones than the New England fields, which may be related to the fact that the Anakie material crystallized in a more iron-rich environment. Glen Innes, and particularly Reddistone Creek, in the New England fields is reputed to produce the finest blue stones. Many stones from this area show colorless to pale blue side color* without any hint of green.

HEAT TREATMENT

The color of Australian sapphire is often greatly affected by silk. The blue shades are particularly prone to be silky to varying degrees. Evenly silked stones may be cut as star sapphire, but more commonly the silk mars the beauty of the cut stone by making it appear dull and/or oily green (figure 14). The silk usually appears as very fine, needle-like inclusions oriented parallel to the crystal structure of the host corundum. Sometimes the individual needles cannot be resolved even under very high magnification. The most common type of silk has a whitish appearance and only sometimes produces chatoyancy; it is most likely rutile (Nassau, 1984).

The presence of silk in the blue material results in a gridwork of reflective surfaces throughout all or part of the stone that interferes with the body color and is probably one of the most commercially important features of Australian sapphires. When light enters sapphire, which is doubly refractive, it is split into two waves; in Australian blue sapphire, one ray is pure blue and the other is blue-green. The effect of the silk is to reflect and scatter the two rays as they pass through the stone, such that the blue and blue-green dichroic colors merge into one unattractive oily greenish blue color. This effect can be so complete in very evenly silked stones that the color is the same regardless of the orientation of the stone.

Basically, heat treatment "removes" the silk by forcing it back into solid solution within its

**Usually sapphire is cut with the table at right angles to the c-axis to get the best blue. When the stone is viewed through the side (e.g., through the girdle rather than through the table), a greener color is normally seen, thus the term* side color.

host; a subsequent quick cooling (i.e., in a few hours) traps the silk there. Without heat treatment to clear the stone, the mining of Australian sapphire would not be commercially viable.

The treatment of silk in sapphire appears to have started about 25–30 years ago in Europe, where it was quietly practiced by a few people. At that stage, the demand for Australian sapphire was small, and mechanized mining had just begun.

Twenty years ago it was found that such processes worked very well on Australian sapphire, and Thai dealers—who had become very adept at heat treatment—started visiting Australia to buy. This increase in demand prompted increased production that resulted in the large-scale mechanized mining that continues to the present day.

Most of the Australian blue sapphire is treated in Thailand. The method for treatment of blue Australian sapphire is quite simple, although it differs significantly from the treatment of the Sri Lankan material (which is done for the purpose of darkening color rather than removing silk). The rough Australian stones are first thoroughly washed and any iron stains are removed by acid. The rough stones are then packed in a white glazed porcelain crucible and the lid is sealed with a high-temperature cement.

Some years back, a great variety of chemicals were placed in the crucible with the sapphire, including cobalt salts, fluxes, chloride salts, and the like. While such treatment resulted in stones that appeared to be a bright cobalt blue, it was soon realized that the effect was only superficial, a coating that was removed in faceting. These days, if any chemicals are used at all, they are fluxes such as borax, and the rough stones are simply wet with a mild solution before treatment. The effect of the flux after cooking is to slightly glaze the surface of the stone, which results in brighter-looking rough. It is hard to ascertain if the flux has any internal effect.

After the porcelain crucible has been prepared, it is sealed (with clay) into a slightly larger black assay crucible. Sometimes fine charcoal dust may be placed between the two crucibles, depending on the type of stone (i.e., its origin and general hue), to keep any oxygen from reaching the stone during the burning. While this practice used to be common, most treaters no longer feel it is necessary.

Traditionally, the furnace is a simple coke-fired one (figure 15), around four and a half feet (1.5 m) tall. First a wood fire is built inside the inner chamber of the furnace and then a small amount of coke is added until a glowing base is obtained (figure 16). The whole chamber is then filled with coke and the crucible nestled into a hollow at the top of the pile. A high-temperature brick cap is added to narrow the gas exit to about one-third the diameter of the air inlet. An air blower is used to force air up through the coke.

Figure 14. This single piece of Australian sapphire was cut in half and the piece on the right heat treated. Note that while there is improvement in clarity and color, the change caused by heat treatment is not as dramatic as that commonly seen in white or light-colored Sri Lankan sapphires that are turned blue by heat treatment. Photo © Tino Hammid.

Generally, a burn takes from 45 minutes to one hour before the flame starts to die. As the coke burns from below, the crucible moves down into the hottest part of the furnace. It is very difficult to measure the actual temperature reached, as a pyrometric probe placed in the center of the chamber would be damaged by the movement of the coke and the fluxing action of the slag that results from the burning coke. The author's attempts at such measurements indicate that the hottest temperature is in the area of 1600°–1700°C.

As soon as the blower is turned off, the furnace is sealed at both inlet and outlet and is left to cool for from two to 12 hours or more. Tongs are then used to remove the crucible (figure 17). The operation results in the stones being both heated and cooled in a reducing environment.

Although the body color of the material may be affected, such changes are usually slight and, in most cases, detrimental. The most common prob-

Figure 15. A Thai furnace typical of those used to treat rough Australian sapphire.

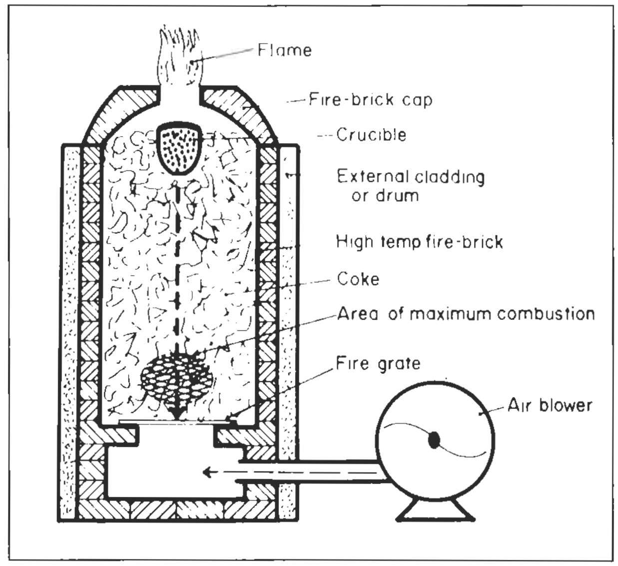

Figure 16. This diagram of the furnace depicted in figure 15 illustrates the process used to heat treat Australian blue sapphire. Artwork by R. Brightman.

Figure 17. The inner crucible has been broken open after treatment of these Australian blue sapphires was completed.

lem is that unsuitable time/temperature parameters may result in a slight to fairly obvious darkening of the stone. Any leakage of air into the crucible in the final stages of the burn or on cooling generally strengthens slightly any green hue that was originally in the stone.

Up until about 10 years ago, a lot of innovations were tried with length of treatment and the like, but over the last decade, the procedure for removal of silk has become more or less standard. The only recent innovation is the use of gas-fired furnaces. Once the process has been mastered and minor adjustments are made for the particular type of stone (e.g., color, density of color, silkiness, and locality of origin—Anakie or New England fields) being treated, the results are quite predictable. Experts at using this type of furnace have many subtle variations in their methods, which results in different people specializing in particular types of stone.

Sapphire other than blue is only occasionally treated, usually to remove silk. The effect on color is usually not great, although occasional strengthening of yellow and gold hues is encountered. Usually the green, yellow-gold, and particolored stones are heated in an electric furnace in crucibles open to the air (an oxidizing environment) inside the chamber.

INCLUSIONS

Very little detailed study has been done on inclusions in Australian sapphire. As most of the rough stone is processed in Thailand, it has been difficult for researchers outside of Australia to acquire material that can be clearly identified as Australian. Microscopic examination of Australian material for this study revealed inclusions similar to those reported for Thai and Cambodian sapphire and may reflect their apparently similar geologic origins.

For example, inclusion of feldspar crystals reported by Gunawardene and Chawla (1984) for blue sapphire from Kanchanaburi, and by Gübelin (1974) for sapphire from Thailand, appear identical to inclusions commonly seen in Australian sapphire (figure 18). Positive identification of feldspar as an inclusion in Australian sapphire was reported by Schubnel (1972). He described colorless transparent crystals between 20–400 microns, sometimes euhedral and sometimes surrounded by circular fractures. These inclusions also sound similar to those shown in figure 18.

Also very common in Australian sapphires are euhedral to subeuhedral bright red to brownish red crystals, sometimes associated with wing-shaped liquid "feathers". They may sometimes have trails of bubbles streaming from them like comet tails (figure 19). The red crystals look similar to those identified as uranium pyrochlore in Pailin sapphire by Gübelin (1974). Such "comet tails" have also been observed coming from other inclusions, particularly from colorless crystals of high relief that may well be zircon.

Unlike the silk in blue star sapphire, asterism in black star material does not appear to be due to rutile but rather to a needle-like precipitate of iron titanium oxide ($FeTiO_2$) with or without lath-like particles of a brown material, possibly hematite (Moon and Phillips, 1984).

Figure 18. This colorless euhedral crystal surrounded by a tension halo and accompanied by a "comet tail" is a common inclusion in Australian blue sapphire. Photo by B. Scheos, Diamond Laboratory Services; magnified 40×.

Different types of inclusions tend to predominate in sapphire from different localities. For example, bright red crystallites (uranium pyrochlore?) commonly occur in stones from the New England fields. The sapphires found at the Anakie fields commonly contain inclusions, as yet unidentified, that are dark brown to opaque euhedral platelets and stubby rods of what appear to be types of mica and horneblende, respectively.

Other internal features commonly encountered are very well-developed polysynthetic twinning and fine "fingerprint" inclusions. The author is at present embarking on a detailed study of Australian sapphires in which electron microanalysis will be used to identify individual inclusions.

DISTRIBUTION TO THE MARKET

The greatest proportion of Australian production is purchased by visiting buyers from Thailand. The price is reached by bargaining between the buyer and the producer, and takes into account previous selling prices, apparent quality of the stone, proportion of large stones, and the overall size of the parcel. The Thais buy anything from individual stones to mine-run parcels. Until two years ago, it was not uncommon to hear of 10 separate buying syndicates on the fields at one time. The galva-

Figure 19. A subeuhedral reddish brown crystal in blue Australian sapphire from Glen Innes. Such inclusions are very common in blue Australian sapphire, either alone or accompanied by small liquid feathers and "comet tails." Photo by B. Scheos, Diamond Laboratory Services; magnified 40×.

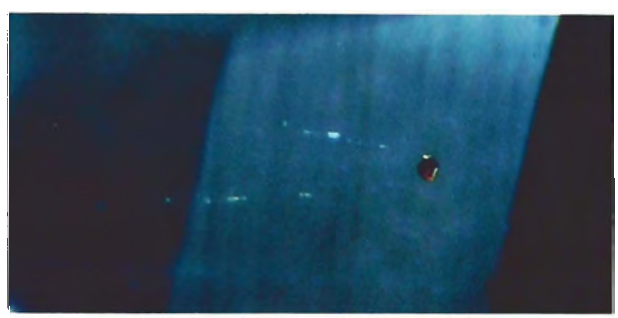

Figure 20. The office of a Thai sapphire buyer on the Anakie fields.

nized iron offices of the Asian buyers at Rubyvale are an accepted part of the scenery (figure 20). Apart from the material purchased by the Thai buyers, a small amount of rough stones are sold to European and Australian cutters.

Thailand, as a result of its own sapphire mines, has long been a center for sapphire processing and marketing. Now, with little production from Thailand's own mines and the virtual cessation of mining in Cambodia, Australian production supplies the raw material to keep a large number of lapidaries and gem merchants going. Until the Thais began processing Sri Lankan sapphire as well a few years ago, it is estimated that some 80% by weight and value of Thailand-cut sapphire exports were of Australian origin. Even with the present drop in production, Australian sapphire could well account for at least 50% of the carat weight of Thailand's total exports of sapphire (pers. comm. with major Thai merchants).

Usually, when the rough parcels arrive in Bangkok, they are split up and sold in smaller lots to the cutting factories. Often, the parcels are of selected rough stone to suit the particular talents of the individual lapidaries. Some lapidaries prefer to work only certain sizes or, because of their particular heat-treatment skills, only one type of stone, e.g., all darker or lighter material.

Since the Thais first began buying Australian sapphire in the late 1960s, the average combined annual production from the New England and the Anakie fields has risen from $1 million (Australian) per year in 1965 to more than $50 million in 1977. While the rise in production has not been steady in recent years (see figure 21), it has not dropped below $25 million since 1971.

DISCUSSION

In almost all cases, Australian miners sell their raw material without the knowledge that would enable them to assess the value of the finished goods (like a farmer selling wheat and not knowing the price of flour). The miners cannot be blamed for this, as they were not, and still are not (to varying degrees), familiar with the changes that can be made in their raw materials by heat treatment.

This situation has allowed the Thais to virtually monopolize the buying of Australian rough, purchasing approximately 95% of the total production. While various Thai buying groups compete against one another, it is interesting to note that, historically, overall prices offered are always only slightly above average production costs. The cut-stone business in Thailand is highly competitive with an ever-continuing "price war" between merchants. Business is generally conducted on a "high turnover, low profit" principle. This has kept prices very low. To reduce their overhead, lapidaries cut the rough stone for maximum weight return and the least labor time required to produce acceptable goods. Unfortunately, visiting cut-stone buyers are prepared to buy such goods, because they in turn need to be competitive in their own local markets with other mechants who buy stock from Bangkok. Therefore, the full potential of a very large amount of excellent gem material is not realized because of poor cutting.

In addition, better-quality Australian sapphire is often not sold as such in Thailand. Quite a considerable amount of the best Australian material is sold mixed into parcels of Sri Lankan, Cambodian, or Thai sapphire. While Thai merchants increasingly refer tó average and better-quality goods as Australian, many of their customers still insist on selling such goods on their home market as Thai or Cambodian in origin when, in fact, they know and ask for Australian goods when buying in Bangkok.

At the lower end of the scale, all poor-quality goods in Thailand are commonly referred to as Australian, whether they are Thai or Australian in origin. This has caused Australian sapphire to gain an ill-deserved reputation as being of poorer quality than Thai sapphire.

In addition to blue sapphire, Australia produces some magnificent gold, yellow, and green sapphires. Because these goods are so rare in relation to the blue production, and because their potential is easily assessed in the rough form, they are usually cut and marketed in Australia. However, all the yellow, green, and parti-colored sapphire rough produced would not represent 1% by weight or value of blue production. As beautiful as they are, they are only of very minor economic importance to the miners.

Almost any jewelry store in the world with a reasonable range of jewelry set with sapphires is bound to have within its doors an Australian sapphire, and perhaps as much as 80% of all the smaller, medium to dark blue stones come from "Down Under."

FUTURE PROSPECTS

The aerial extent of the basalts of eastern Australia is huge (approximately 350,000 km^2) compared with Southeast Asia (90,000 km^2), so the potential

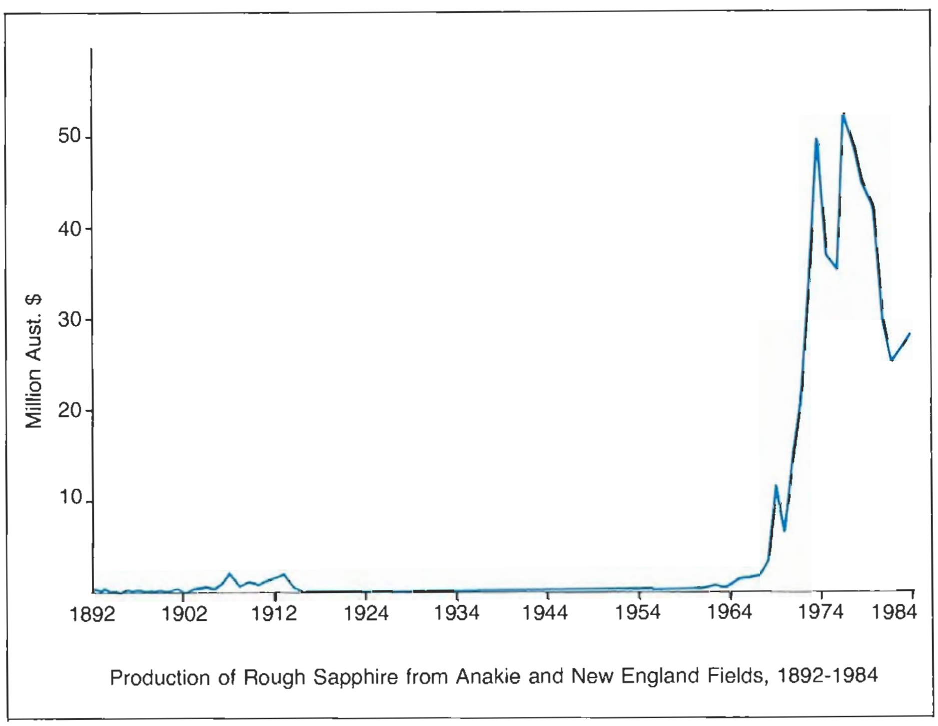

Figure 21. Production of Australian rough sapphire from the Anakie and New England fields, 1892–1984, as compiled by B. C. O'Leary (1985) from the Australian Bureau of Statistics. Note that the production returns on which these figures are based (given in Australian dollars) are only provided by the larger producers. The author suggests that actual production may be twice that indicated. Also, the values do not take into account increases in unit selling prices; today's market value of pre-1924 production would be considerably greater than the graph indicates. The current value of the Australian dollar is approximately US$0.75.

for the discovery of new, economic sapphire fields is good. Considering the similarity of the deposits and the types of gemstones produced in both Australia and Southeast Asia, it is surprising that only very few pieces of ruby have ever been found. Perhaps future prospecting will uncover deposits similar to those of Cambodia and Thailand.

During the last few years, however, there has been a reduction in sapphire mining at both the Anakie and the New England fields. This is due to several factors and, at this stage, it is difficult to determine whether or not it will continue. Specifically, a number of presently known reserves appear to have been mined out. Also, the last few years have seen a rapid rise in fuel, labor, and equipment costs. As there has been no major increase in demand or in prices due to the recent general world recession, many operators—both large and small—have stopped mining. Current production levels from New England are estimated to have dropped approximately 40%, and at Anakie approximately 60%, in the last five years (pers. comm. with miners).

It will be interesting to see what happens when the effects of this reduced production filter down to the marketplace. In order for there to be an increase in mining activity, prices will have to rise considerably, to such an extent that current marginally profitable deposits will become viable propositions.

There is also the possibility that the virtual monopoly that the Thais have over Australian rough purchases may be eroded in the future. As the number of miners is reduced, there is more chance of regulation, either self-imposed or government-enforced, of rough-sapphire marketing techniques. This, combined with an increased worldwide knowledge of heat-treatment methods and a demand for better-quality cutting, could result in larger volume markets for rough stones within Australia and internationally at centers other than Thailand.

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