Journal & Proceedings of the Royal Society of New South Wales, Vol. 138, p. 77–84, 2005
ISSN 0035-9173/05/020077–8 $4.00/1

An Apparent Diatreme Source for Gem Corundums and Zircons, Gloucester River, New South Wales

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Abstract: A mineral sample from the AuK2 diatreme site, Gloucester River, NSW, was studied by X-ray diffraction. It contains a gem association (ruby, sapphire, zircon, sapphirine) among minerals from xenolithic (almandine-rich garnet, diopside, spinel) and megacryst (phlogopitic mica, hastingsitic amphibole, rutile) suites and from quartzose components within Carboniferous sedimentary beds. The grain characteristics suggest a proximal source or sources. Fission track dating of zircons gave three separate ages, Palaeocene (62 Ma) for moderate uranium content zircons, Eocene (39 Ma) for low U zircons and Pliocene (4 Ma) for high U zircons. This implies either repeated eruptions among Gloucester River diatremes or incomplete thermal resetting of zircons. The AuK2 sample suggests diatremes play a role as gem sources in the Barrington field.

Keywords: Diatreme, ruby, sapphire, zircon, fission track dating, gemstone sources.

INTRODUCTION

At Barrington Tops, rubies, sapphires and zircons from Cenozoic plateau basalts shed into alluvial placer deposits and formed a commercial gemfield (Sutherland and Graham 2003, Roberts et al. 2004). Mining from placers at Gummi Flats, Upper Manning River, began in March 2005 with plans to market the rubies as faceted, but untreated Australian stones (Cluff Resources Pacific NL 2005, P. Kennewell, pers. com. 2005). The Cenozoic basaltic eruptives here are suspected as the sources for the megacrystic gem material within the placers, as evidenced by marked magmatic corrosion or high temperature fusion crusts on many corundums (Sutherland and Coenraads 1995, Sutherland et al. 1998a, Roberts et al. 2004). No direct examples of corundum and/or zircon in basalt, however, are recorded. This paper provides the first description of these gem minerals associated with an explosive eruptive body, namely the AuK2 breccia pipe, a diatreme located within a tributary of Gloucester River, 25 km WSW of Gloucester township, New South Wales.

Material at AuK2 pipe was sampled during diamond exploration, when it and the nearby AuK1 pipe were tested for diamonds between 1967 and 1971 (MacNevin 1977). Sampling of AuK2 by Stockdale Exploration was observed by A.W. Chubb, a Gloucester resident, council road worker, part-time prospector and a longstanding correspondent with the Australian Museum Mineralogy Department. In a letter to the Department dated '5-1-73' he described '. . . a 500 acre area we applied for, covering an area Stockdale (DeBeers) relinquished after finding a pipe of granulite and eclogite which contains microscopic diamonds and very nice pale lemon yellow coloured zircon. The largest of the zircon I saw was about as big as the end of my thumb to the first joint, plus plenty more which would be from five to fifteen carat'. He also marked the precise location of the pipe on a Gloucester 1 inch to 1 mile army map for the Museum. This corresponds with the AuK2 site located on Stockdale report maps at Watsons Creek.

In August 1995, after discussion on the AuK pipes with two of the authors (F.L. Sutherland and G.B. Webb), A.W. Chubb provided the Museum with a taped packet of mineral concentrate from AuK2. It is uncertain whether the sample was taken directly from the exposed pipe or from material around the pipe. Recent detailed examination of this sample (G.B. Webb) revealed the presence of gem corundums and zircons, the significance of which is presented in this paper. The paper is dedicated to Arch Chubb, for his input into the Australian Museum Barrington gemstone research program from 1969 until his death in 1996.

GEOLOGICAL SETTING

The AuK1 (Grid 377700 E, 6451200 N; 360 m asl) and AuK2 (377400 E, 6452200 N; 330 m asl) diatreme pipes lie in adjacent tributary drainages leading into Gloucester River (Dungog 1:100,000 Map Sheet, Zone 56, AGD 1966). The Gloucester River rises some 10 km west of the AuK sites (Figure 1), among remnant basalt cappings and gem-sites on the Late Palaeozoic granodiorite-intruded basement massif exposed on Gloucester Tops at elevations around 1300 m asl (Roberts et al. 1991, Sutherland and Graham 2003). Some confusing differences exist in the drainage nomenclature at the AuK sites, with Watsons Creek and Oaky Creek as designated in the Stockdale exploration reports (MacNevin 1977) being renamed as Oaky Gully and Flaggy Creek respectively in the later Dungog 1:100,000 maps (Roberts et al. 1991).

The pipes intrude dominantly westerly-dipping (approx. 21°–33°) Early Carboniferous metasedimentary beds. The AuK2 site is structurally located near a fault intersection (Figure 1), where Early Carboniferous Conger Formation beds form a wedge against undifferentiated Early Carboniferous beds. Several magnetic anomalies were linked to garnet sources at the AuK sites (Stracke 1971) and with other rock samples suggest multiple diatremes and dykes exist in this area.

The AuK1 and AuK2 pipes both yield megacrysts and xenoliths within their altered ultramafic and basaltic host lithologies (Stracke 1971, Wilkinson, 1974, MacNevin 1977). AuK1 contains serpentinised olivine and brown mica in a chloritic, serpentinitic, calcitic and iron oxide-bearing matrix; heavy mineral concentrates yielded garnets, including pyrope, Cr-bearing diopside, orthopyroxene, clinopyroxene, hornblende and diopside. AuK2 samples yielded phlogopitic mica, orange garnet, hornblende and diopside. High-pressure xenoliths (garnet clinopyroxenites, garnet ± scapolite granulite and rare amphibolite) described by Wilkinson (1974) and Griffin and O'Reilly (1986) mostly came from AuK2, while similar xenoliths described by O'Reilly et al. (1988) and Sutherland and Graham (2003) were largely AuK1 material. These garnet-bearing metamorphic assemblages were fragments from underlying lower crustal to upper mantle lithologies and were mostly nepheline-normative in chemical composition. Their isotopic compositions suggest that they represent original island arc or sea-water altered ocean-ridge basalts that were involved in underplating processes associated with Palaeozoic subduction events. It was further suggested that the amphibole-altered mantle lithologies may generate minor felsic melts that produce magmatic sapphires, which are found on the Barrington plateau (Sutherland et al. 1998b).

Definite ages for the Gloucester River diatremes are not established, although links to Jurassic alkaline melts were postulated on the presence of dark mica in the diatremes and in mica megacryst-bearing alnoite dated at 160 Ma northwest of Gloucester (Sutherland and Graham 2003). Zircon megacrysts in the AuK2 sample, however, provide an opportunity for dating eruptive activity around this site. The AuK2 concentrate is also significant for containing similar corundums (ruby and sapphire) to the Barrington Tops-Gloucester Tops gem corundum suites and so bears on the potential sources for the gem deposits. This AuK2 study provides further detail into the eruptive history of the Barrington volcanic province which extends from at least 60 to 3 Ma (Sutherland and Fanning 2001, Sutherland and Graham 2003, Roberts et al. 2004).

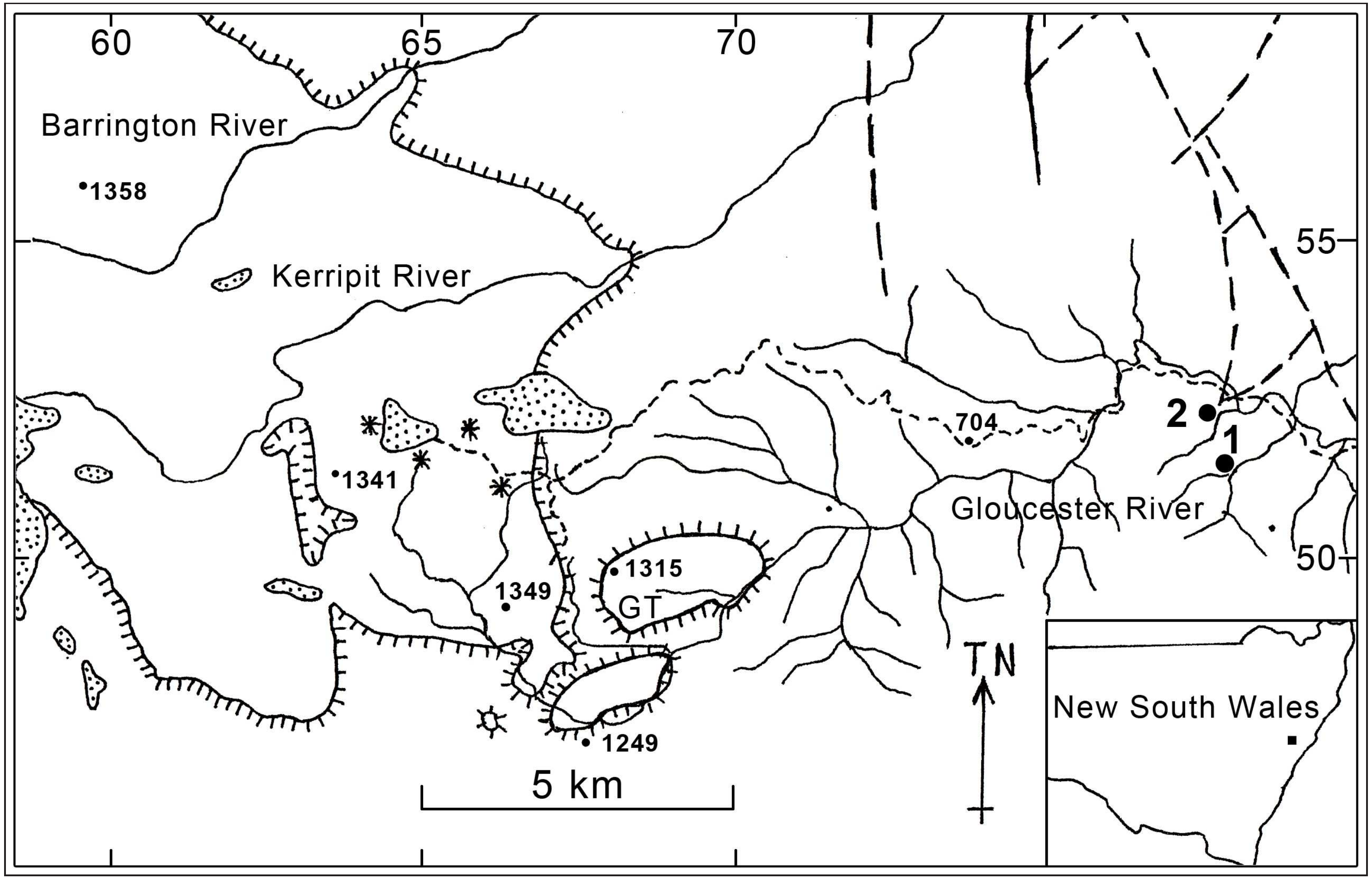

Figure 1. Geological outline map of the Gloucester Tops - Gloucester River area, based on the Dungog 1: 100,000 Sheet mapping (Roberts et al. 1991). Gloucester River (thin drainage lines) is shown along with main drainages for Kerripit River and Barrington River. The Gloucester diatreme sites (solid circles) include AuK1 (1) and AuK2 (2). Geological areas include folded Palaeozoic basement beds (clear areas), contact zones bounding Permian Barrington Tops Granodiorite intrusions (hatchured lines) and Cenozoic basalt cappings (stippled areas). Gloucester Tops gem sites (stars) come from Sutherland and Coenraads (1995). Mapped faults and inferred faults are shown as thick and thick-dashed lines. The Gloucester Tops road from Bucketts Way (short dashed line) follows the Gloucester River before ascending the Gloucester Tops massif. Spot asl elevations in m. The inset (bottom right) shows the map area within New South Wales.

MATERIALS AND METHODS

Mineral grains from the AuK2 concentrate (Australian Museum registration no. D 53724) were examined using a gemmological binocular zoom microscope, ultraviolet light and polariscope and were separated into groups of similar appearance and properties (G.B. Webb). Representative grains from each group were subjected to X-ray diffraction (XRD) analysis. The work mostly utilised a Philips PW 1820 powder diffractometer, mounted on a PW 1825 X-ray generator, operating with CuKα radiation at 40 kV and 30 ma; the patterns were checked against a Traces search and match database (D.M. Colchester). A few minerals were run on similar equipment at the Australian Museum. The mineral groups and identifications are listed in Table 1.

A colour range of zircons chosen from the concentrate was submitted to Geotrack International PL, Melbourne, for fission track analysis. Grains were mounted in Teflon and etched in molten KOH-NaOH (Gleadow et al. 1976). Mounts were sealed in low-uranium mica detectors and placed between uranium standard glass, before insertion into an aluminium can for irradiation. After removal, mounts were etched in hydrofluoric acid and fission tracks were counted using Zeiss® Axioplan microscopes. Fission track ages were calculated after Hurford and Green (1982). The zeta calibration factor was determined (Hurford and Green 1983) and grain ages were calculated using Poissonian statistics (Galbraith 1981, Green 1981). The results, including graphical radial plots, were presented in Geotrack Report #946 (2005) for the Australian Museum (P.F.G̃reen, analyst) and are collated in Table 2.

RESULTS

The mineral grain identifications not only confirmed previously identified megacryst and xenolith species from AuK2 exploration investigations (vermiculite altered from phlogopite 3T?, almandine, hastingsite and diopside), but also identified a range of other minerals. These included corundum (varieties ruby and sapphire) and zircon, typical of Barrington Top plateau gem suites, and sapphirine in independent grains, whereas normally it is found as intergrowths and inclusions in Barrington rubies. The presence of well-developed, and even complete alteration crusts on some ruby and garnet cores suggests there was minimal transport from the source rock.

The zircon fission track results on 20 crystals suggest three age groups of zircons, each with differing U contents (Table 2). The oldest group, with moderate U contents (150–300 ppm) is Palaeocene and at a 62 ± 6 Ma is among the oldest zircons associated with the Barrington shield volcano. An intermediate age group, with low U contents (30–80 ppm) is Eocene and at 39 ± 7 Ma appears to mark a slightly younger eruptive event than found for widespread similar zircons (av. U 72 ppm) on Barrington plateau (44 ± 3 Ma). The youngest Pliocene age group has higher U contents (180–840 ppm) and at 4 ± 1 Ma overlaps a high U group (5 ± 1 Ma) within the Gloucester River catchment on Gloucester Tops (Sutherland and Fanning 2001). The latter zircons, however, are different in colour, crystal shape and transparency and are significantly higher in U ($>$ 1000 ppm) and, have noticeable metamict cracking; such detrital crystals would not survive intact during extended transport down Gloucester River and denote a separate source.

A range of quartzose grains was identified among the in the AuK2 sample. Small, irregular quartz aggregates suggest fragmented quartzitic materials, expected from explosive blasting of metasedimentary beds during diatreme emplacement. Rounded, polished chalcedonic nodules resemble worn transported materials, but could represent originally recycled material in the local sedimentary beds. Angular fragments of crystallised quartz could come from extensive quartz veining within the local beds.

Material	Description	Identification	Abundance
Pale, dark pink, and red grains	Angular to round, flat to equant, up to 1 cm. Some corroded surfaces, fusion crusts, sapphirine (?) intergrowths	Corundum (XRD) ruby (colour)	Common
Grey, yellow and blue grains	Subangular to flattened, up to 0.8 mm, some corroded, some include silk	Corundum (XRD) sapphire (colour)	Common
Purple, mauve and purple-mauve grains	Subangular, up to 0.7 mm	Corundum (XRD) sapphire (colour)	Sparse
White, yellow, orange brown and red grains	Anhedral to subhedral, irregular to prismatic, lustrous, up to 0.6 mm, some corroded or fluorescent in UV light	Zircon (optics) F.T. Analysis	Sporadic
Pink, red grains	Subangular, up to 0.6 mm	Almandine (XRD)	Rare
Green, black grains	Angular, some elongate, up to 0.6 mm	Sapphirine (XRD)	Rare
Brown, black flakes	Flat, cleavage flakes, partly altered	Vermiculite (XRD)	Sporadic
Dark brown crystals	Subangular, elongate, up to 0.5 mm	Hastingsite (XRD)	Sparse
Dark, green grains	Subangular, up to 0.7 mm	Enstatite (XRD)	Sparse
Grey green grains	Irregular, some elongate, up to 0.9 mm	Diopside (XRD)	Sporadic
Black opaque grains	Rounded to irregular, shiny, partly conchoidal, up to 0.5 mm	Spinel (optics)	Sporadic
Black crystal	Tabular, brown coating, up to 0.8 mm	Rutile (XRD)	Rare
Black grains	Shiny, red in part, up to 0.5 mm	Hematite (optics)	Rare
Black grain, red core	Spinel-rich? crust, 3 mm across	Spessartine (XRD)	Rare
Clear to smoky chips	Angular, part conchoidal, up to 0.6 mm	Quartz (optics)	Common
White, grey nodules	Polished, rounded, up to 1 cm	‘Chalcedony’ (optics)	Common
Red, brown grains	Polished, subangular, up to 0.7 mm	‘Jasper’ (optics)	Sporadic
Yellow, grey grains	Rounded, with ragged angular edges, up to 0.5 mm	Quartz (XRD)	Sporadic
Pale green masses	Irregular, rounded to elongate, diffuse surface, up to 0.9 mm	Diopside-augite alteration (XRD)	Sparse

Table 1. Mineral groups, separated from AuK2 concentrate sample (D53274). Common (>20 % grains), sporadic (10–20 %), sparse (5–10 %), rare (<5 %).

Grns	Ns(av)	Ni(av)	Na(av)	ρ_s(av)$\times 10^6$	ρ_i(av)$\times 10^6$	Uppm(av)	FT Age$\pm 1\sigma$(av)
Palaeocene (moderate U) group							
4	310	251	100	4.922	3.922	163–283 (187)	61.7 ± 5.6
Eocene (low U) group							
7	58	71	100	0.917	1.128	31–77 (53)	39.3 ± 7.3
Pliocene (high U) group							
9	58	651	100	0.927	10.350	183–824 (484)	4.2 ± 0.6

Table 2. Zircon fission track (FT) results, AuK2 site. ρ_D (Track density from U standard glass) 1.14 $\times 10^6$ cm^{-2}. N$_D$ (Total tracks counted for determining ρ_D) 1787. Ages calculated using a zeta 87.7 ± 0.8 for U3 glass. Grns, No. of grains. Ns, No. of spontaneous tracks in Na grid squares. Ni, No. of induced tracks in Na grid squares. Na, No. of grid squares counted in each grain. ρ_s Spontaneous track density. ρ_i Induced track density. Analyst: P.F. Green.

DISCUSSION

The AuK2 mineral sample provides a fuller picture of diatreme mineralogy and emplacement ages in the southeastern Barrington volcanic field. The presence of ruby, sapphire and zircon supports the prospect that diatreme and pyroclastic sources are important vehicles for the provision of these gem materials.

The corundum suites in the AuK2 sample include both metamorphic and magmatic types and mark the most eastern gem site located in the Barrington field. The spread in zircon ages, with three separate groups, is a complicating feature. It implies multiple proximal zircon sources here, as the zircon groups differ to those from the headwaters at Gloucester Tops. Alternatively, some zircon groups were not thermally reset in eruptions. Derivation of gem suites from the Gloucester Tops high country is also unlikely given a comment recorded by Arch Chubb that only ‘pulverised sapphires of various colours in the surface wash’ were found in the adjacent Kerripit River, 10 km downstream from its incision into Gloucester Tops.

The zircon dating from AuK2 material supplements the previous comprehensive zircon and basalt dating on Barrington Tops plateau (Sutherland and Fanning 2001, Sutherland and Graham 2003, Roberts et al. 2004) and reinforces evidence of repeated, extended volcanic activity in this field. The youngest phase of activity (3–5 Ma) is now identified in four well-separated sites across the whole field (East Tomalla Creek, Gummi Flats, Gloucester Tops, Gloucester River). A southerly decreasing age-trend in young (<12 Ma) zircon ± corundum-bearing volcanic sites was proposed from studies extending from Childers-Proston in Queensland to Uralla-Barrington in New South Wales (Sutherland 1993). Based on this well-established young Barrington event at 4 ± 1 Ma and Australian plate motion rates (7 cm/yr) since then, the present potential eruptive source would now underlie the Wollongong-Southern Highlands region below the southern Sydney Basin.

ACKNOWLEDGEMENTS

Drs L.M. Barron, B.J. Barron and I.T. Graham provided discussion on AuK sites and read the script. Sue Folwell, Australian Museum, assisted with script preparation. The Australian Museum funded the zircon fission track dating, while the School of Science, Food and Horticulture, University of Western Sydney, and The Australian Museum (R.E. Pogson) provided facilities for the mineral X-ray investigation.

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(Manuscript received 16.09.2005, accepted 4.11.2005)