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Rutherford began collecting agates as a schoolboy in Scotland in 1858, and his passion culminated in a collecting expedition with his wife that took them from England to New Zealand in 1910–1912. From Bristol they travelled by boat to visit Jamaica and Cuba; then to Florida and up to Quebec, Canada; and then to Vancouver, British Columbia, Canada; and finally to Brisbane in Australia and onward to New Zealand. It was in New Zealand that Rutherford collected a large portion of his agates—in the Clent Hills in Canterbury. He took three-day round trips when the weather permitted, by train and then horseback. He described tonnes of agates weathering out from the lava rocks, dramatically changing every 50 m with a variety of colours, including some of the best picture agates he had found. Others had stalactitic forms within clear chalcedony, plus moss agates, jaspers and common opal. Some agates, although not beautiful, were over 1 m in size. The best specimens were found on the hilltop spurs, and he commented about them being found *in situ* and not waterworn.

Correspondence with the curator at the time (John A. Howe) indicates the arrival at the GM of several crates of agates in early 1917, both for the museum to select specimens and for safekeeping during the war. In mid-1917 Rutherford visited the museum to unpack crates and bring the collection of brooches to be presented if ‘deemed good enough’, and in November he asked if ‘during the raiding season what would you think of putting the brooches down below out of danger as I shall never replace them if they get a bomb’. Later correspondence discussed the best way to set agates as brooches, including backing them with ‘looking glass’ for maximum effect. It is assumed the agates in these brooches all originated from New Zealand. The jewellery was registered by the GM in 1923 under one number and re-registered in 1924 to give individual numbers. In the 1924 catalogue, ‘New Zealand’ was pencilled next to the jewellery entries, perhaps given by word of mouth, but further research would be required to confirm their provenance.

According to Smith and Cole (1996) and Oliver (1977), the Clent Hills area consists of Triassic–Jurassic sedimentary rocks (Torlesse Supergroup) overlain by a Late Cretaceous calc-alkaline volcanic suite (Mount Somers Volcanics). The volcanic rocks show multiple stages of eruptions, and one unit, the Barrosa Andesite, covers much of the Clent Hills. This unit is known for silica-rich amygdules (rounded cavities from gas bubbles in the lava filled by later mineralisation) that include agates, moss agates, chalcedony and opals matching the descriptions given by Rutherford of his collecting. The lava flows were deposited at a low inclination, resulting in the flat-top hills. The agates are thought to have formed not long after the Barrosa Andesite from hot silica-rich fluids associated with this higher-temperature volcanism. The agates are typically horizontally banded, assumed to indicate their orientation during formation, and the *in situ* agates have been used to indicate tilting of the andesite by later geological processes.

The beauty in these agates, combined with an understanding of their journey and the passion of the man who made it happen, makes them a fascinating part of the NHM collection.

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Axinite-(Mg) from Parachinar, Pakistan

Axinite is known from various locations in Pakistan, including the Shigar Valley area of Gilgit-Baltistan (Agheem et al., 2013) and the Taftan Mountains in Baluchistan (Fritz et al., 2007). While on a buying trip to Peshawar, Pakistan in October 2015, gem dealer Dudley Blauwet (Dudley Blauwet Gems, Louisville, Colorado, USA) was offered a 240 g parcel of rough transparent axinite from another locality: the

Parachinar area, in the Federally Administered Tribal Areas within Khyber-Pakhtunkhwa Province of north-western Pakistan. Blauwet selected 27 of the cleaner pieces weighing 100.2 g and had them faceted in July 2016. The cutting yield was rather small, due to the irregular shape and platy habit of the rough. He obtained 100 clean faceted stones that totalled 23.90 carats, with the largest gem weighing 1.36 ct. Compared



Figure 2: These purplish (to more orangey) brown axinites from Parachinar, Pakistan, weigh 0.81–1.36 ct and are strongly pleochroic, even to the unaided eye. Photo by J. C. Zwaan.

to the brown colour of typical axinite, most of these stones showed an overall purplish brown appearance.

Blauwet loaned four faceted axinites for examination: one cushion, two ovals and one trilliant that weighed 0.81–1.36 ct (Figure 2). The stones were purplish brown or orangey brown and displayed strong pleochroism that was visible to the unaided eye. When viewed face-up and slightly tilted, the cushion and the 0.81 ct oval cut showed purplish, orangey and yellowish modifying colours, whereas the trilliant showed purplish and orangey hues and the 1.36 ct oval cut showed orangey and pale yellowish modifying colours. Using a calcite dichroscope, distinct trichroism in orangey brown, purple and light (slightly greenish) yellow was observed in each stone.

RIs ranged from 1.667 to 1.679, yielding birefringence values of 0.011–0.012. Applying the RI measurements as explained by Sturman (2007)— $n_{\alpha} = 1.667\text{--}1.668$, $n_{\beta} = 1.672\text{--}1.673$ and $n_{\gamma} = 1.678\text{--}1.679$, with n_{β} being closer to n_{α} than to n_{γ} —the optic character proved to be biaxial positive. Average hydrostatic SG values were 3.23–3.25. The prism spectroscope revealed only a vague band at approximately 490 nm. The gems were inert to both long- and short-wave UV radiation.

These properties are consistent with axinite, with RIs and SGs between those of the end members axinite-(Mg)—which has RIs of 1.656–1.668, a birefringence of 0.009–0.012 and an SG in the range of 3.17–3.18—and axinite-(Fe)—which has RIs of 1.672–1.685, a birefringence of 0.010 and an SG in the range of 3.28–3.32 (cf. Deer et al., 1986; Dedeyne and Quintens, 2007). Although textbooks generally indicate the optic character of axinite is biaxial negative, the value of the optic axial angle ($2V$) increases with greater Mg content (cf. Deer et al., 1986), and Jobbins et al. (1975) reported an axinite-(Mg) from Tanzania to be biaxial positive, like these specimens from Pakistan.

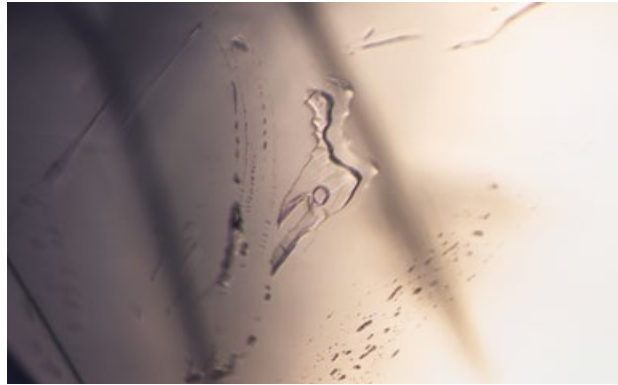


Figure 3: Partially healed fissures containing minute cavities and occasional two-phase inclusions are typical in the axinites from Parachinar. Photomicrograph by J. C. Zwaan; transmitted lighting, image width 1.4 mm.

The samples were eye clean to slightly included and contained partially healed fissures (sometimes with two-phase inclusions; Figure 3) and faint purple straight growth zoning. In addition, hexagonal and slightly rounded doubly refractive inclusions were seen in the trilliant (Figure 4). From their morphology and very low relief, these inclusions were probably apatite; Raman analysis with a Thermo DXR Raman microspectrometer was inconclusive. The principal Raman peak of apatite lies at $\sim 967\text{ cm}^{-1}$, but axinite also has a Raman feature at the same position (see below). Although the Raman spectrum of the analysed inclusion showed relatively more fluorescence (like many apatites), it was not possible to obtain a spectrum that was distinctive from the axinite host to confirm its identity.

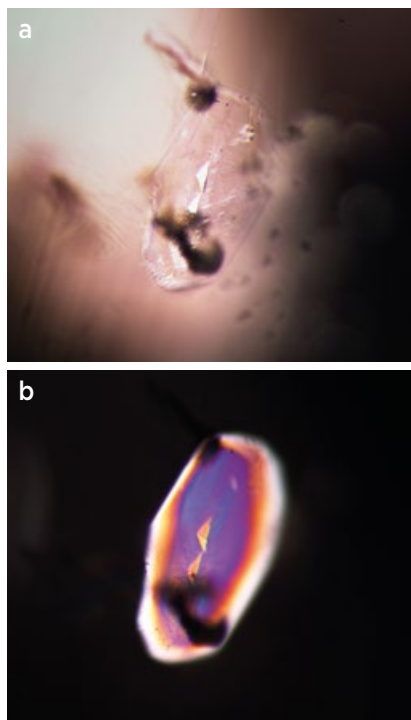
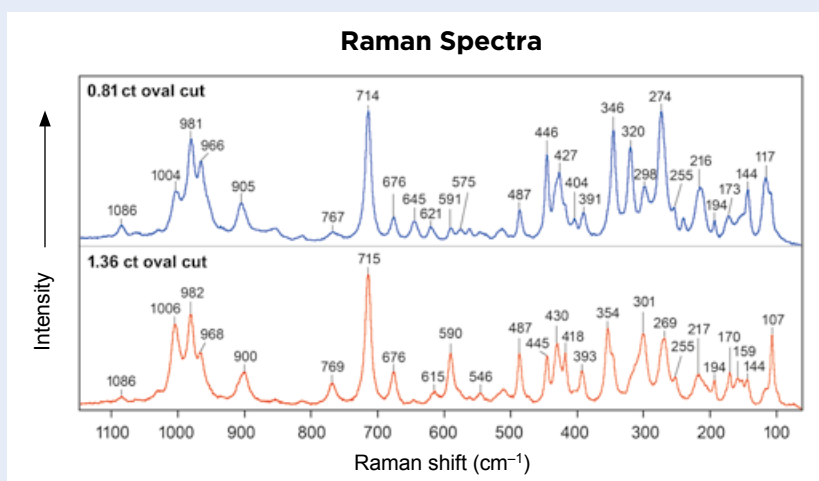


Figure 4: Doubly refractive, slightly rounded inclusions occurring in the trilliant-cut axinite are probably apatite crystals. Photomicrographs by J. C. Zwaan in (a) plane-polarised light and (b) between crossed polarisers; image widths 2.8 mm.

Figure 5: Two representative Raman spectra of the axinites from Parachinar show their variation and complexity; see text for explanation.



Raman spectra of three of the samples showed similar features, while the 0.81 ct oval cut produced a slightly different spectrum (Figure 5). The spectra of all four samples matched those of axinite-(Fe) in the RRUFF database; the three stones with similar spectra also matched axinite-(Mg). Raman spectra of axinites (triclinic borosilicates) are complex; the strong feature at 714 cm⁻¹ is attributed to OBO-bending vibrations, while features in the ranges 1020–950 cm⁻¹ and 690–380 cm⁻¹ are attributed to (SiO₄)²⁻ stretching and bending modes, respectively. Other features are more difficult to interpret; the band at ~902 cm⁻¹ is possibly due to FeOH and MgOH deformation vibrations, while the band at ~768 cm⁻¹ is ascribed to MgOH and other M²⁺OH deformations. Various bands are sometimes present at lower wavenumbers; the features at 320 and ~300 cm⁻¹ are related to FeO stretching vibrations (cf. Frost et al., 2007).

Chemical analyses were obtained by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy with an EDAX Orbis Micro-XRF Analyzer on the tables of the four

stones, using a spot size of 300 μm. Apart from the main elements Si, Al and Ca, the analyses showed 6.1–6.8 wt.% MgO, 3.6–4.0 wt.% FeO and 0.5–0.6 wt.% MnO. This compares well with a summary of electron microprobe data for these stones provided by authors AUF and WBS, with 6.35–6.42 wt.% MgO and 3.68–3.73 wt.% FeO, giving predominantly axinite-(Mg) with a lesser proportion of axinite-(Fe). By contrast, specimens from the other localities in Pakistan mentioned in the first paragraph of this report were identified as axinite-(Fe).

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