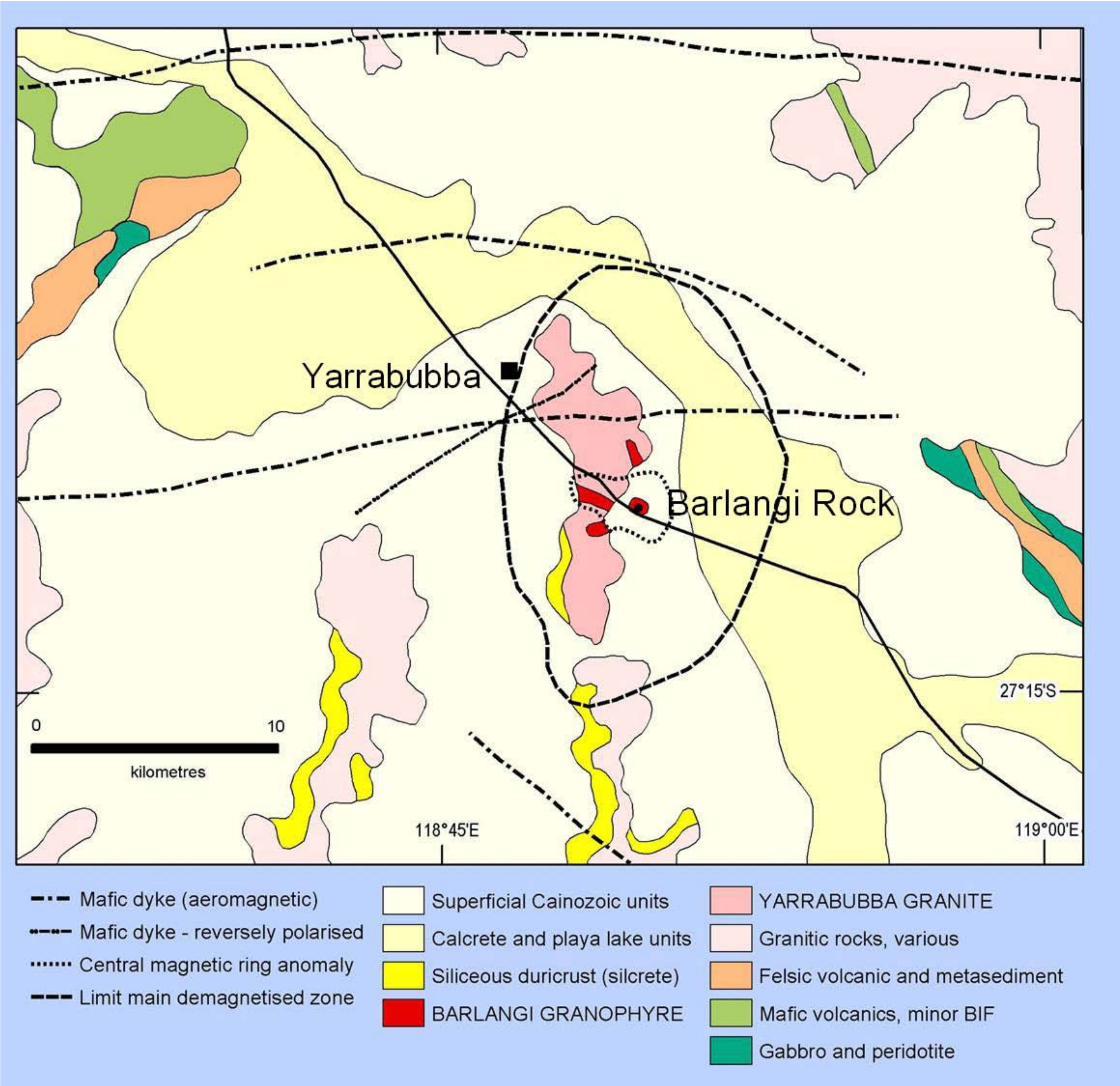


Figure 1: Yarrabubba regional geology.

Yarrabubba Impact Structure

John Bunting

Until recently the only documented impact structures on the Yilgarn Craton were the small Dalgaranga crater, and the Shoemaker Structure (predominantly within the Proterozoic Earaheedy Basin), both of which will be visited on this excursion. The impact record elsewhere indicates that major impact sites should exist on the Yilgarn Craton. The Yarrabubba Impact Structure, first documented by Macdonald et al. (2003) is one such site that gives regional clues to finding others in deeply eroded Archean terranes (Bunting and Macdonald, 2004).

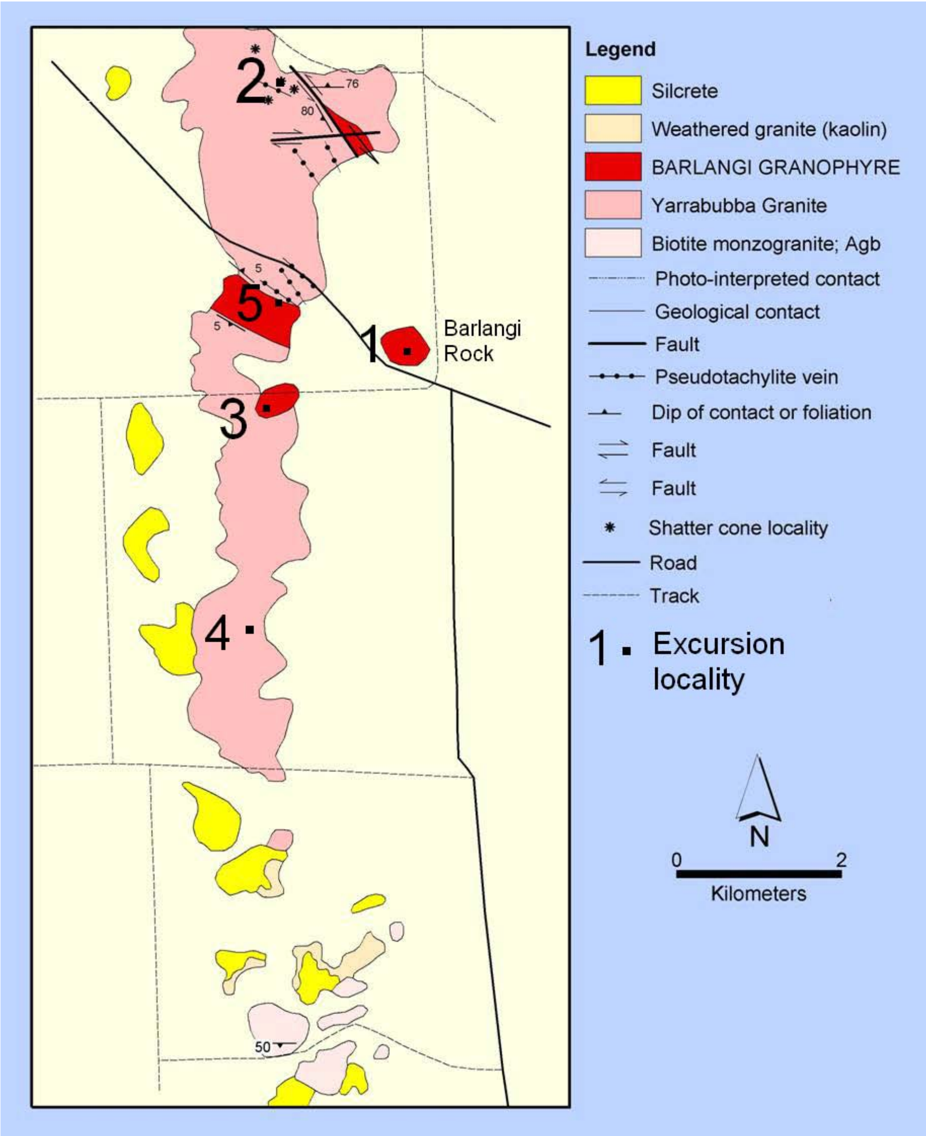


Figure 2: Yarrabubba geology and excursion localities.

The centre of the Yarrabubba Impact Structure (27°11'S 118°50'E) is about 70 km southeast of Meekatharra in the Archean granite-greenstone terrane of the Yilgarn Craton (Figure 1). Unlike most major impact structures Yarrabubba has no obvious circular topographic or geological feature, because it appears to have been eroded to a level well below the crater floor. Outcrop, mainly of granitic rocks, is patchy. Much of the area is covered by superficial alluvium and colluvium, playa lake deposits and valley calcrete. In places deep weathering has kaolinised the granitic rocks and produced a silcrete duricrust. Erosion of the hard silcrete cap and underlying softer kaolinised granite has created spectacular low cliffs ("breakaways") and mesas.

At Yarrabubba, evidence for impact includes shatter cones, planar deformation features (PDFs) in quartz, pseudotachylites and impact breccias, all within the muscovite-bearing Yarrabubba Granite. The centre of the structure is the Barlangi Granophyre, a skeletal-textured felsic rock that is interpreted to have intruded as a multi-lobed sheet of sub-crater impact melt derived from the Yarrabubba Granite (Figure 2).

Discovery of the impact structure relied on recognition by Steve Williams and Will Libby (Geological Survey of Western Australia) of shock metamorphism in a single thin section (Figure 3) of granite collected in 1979 during regional mapping (Libby, 1979; Tingey, 1985). This was not followed up until the study by Macdonald et al. (2003), who recognised the shatter cones, pseudotachylites, minor breccias, circular magnetic feature and the importance of the Barlangi Granophyre.

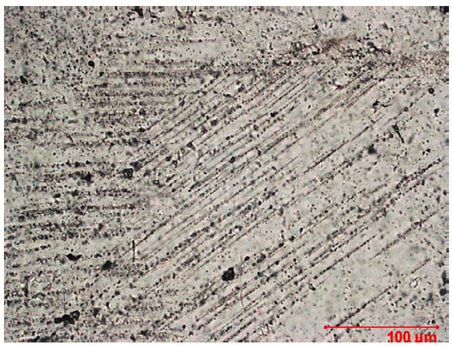


Figure 3: PDFs in quartz, Yarrabubba Granite; GSWA sample 60399 X25 (coll. S Williams, 1979).

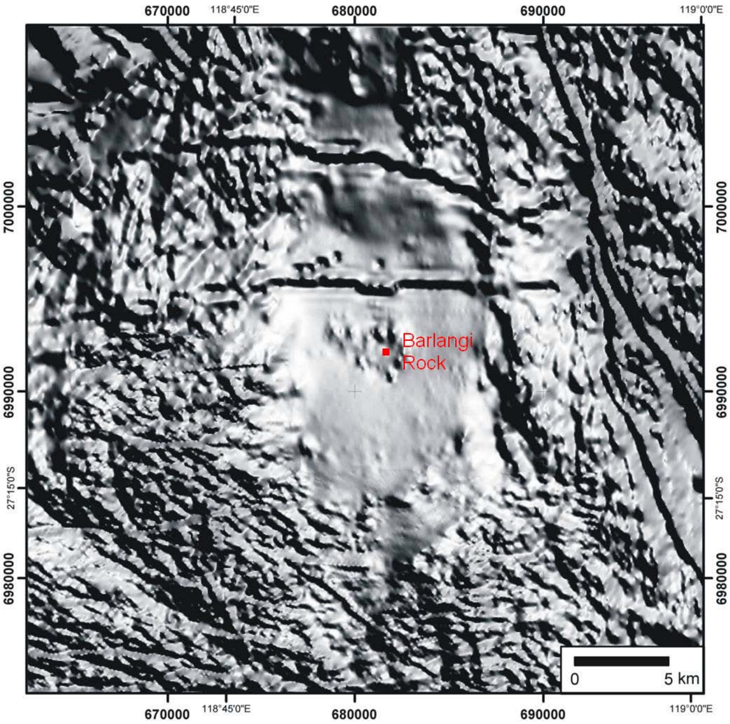


Figure 4: Yarrabubba aeromagnetic TMI image.

The original size of the structure is not known, but some impact effects have been seen in outcrop at least 10 km north (the limit of outcrop) and 9 km south of Barlangi Rock. There is also a 25 x 15 km zone of flat aeromagnetic signature that may represent demagnetisation of the regional granite as a result of the impact (Figure 4). Note the lobate, crudely circular feature in the centre of the demagnetised zone that may have been caused by remagnetisation along the contact of the Barlangi Granophyre with the Yarrabubba Granite.

Three regional features at Yarrabubba are discernable on pre-2002 datasets: (1) the muscovite-bearing Yarrabubba Granite – possibly evidence for alkali metasomatism; (2) the Barlangi Granophyre, distinguished by its unusual skeletal textures; (3) the flat magnetic signature – interpreted as demagnetisation immediately after impact.

The age of the impact is not known with any certainty. Zircons from the Yarrabubba Granite and Barlangi Granophyre give typical Archean ages around 2.6-2.7 Ga (Cassidy et al., 2002; D R Nelson, unpublished data quoted by Pirajno, 2005). The zircons in the Barlangi Granophyre are considered to be xenocrystic, preserved when the granophyre formed by the melting of Yarrabubba Granite during the impact event. Macdonald et al. (2003) concluded on regional grounds that the impact age was probably early Proterozoic. Indirect evidence for an early Proterozoic age is that this northern part of the Yilgarn Craton was probably a peneplaned surface before deposition of the mature sandstones at the base of the Yerrida (>1.9 Ga)and Earaheedy (1.89 Ga, Rasmussen et al., 2012) Groups along the northern margin of the craton. Pirajno (2005) reported an Ar-Ar age of 1134+/-26 from sericitised pseudotachylite, but this could be an alteration age and is therefore a minimum age.

Macdonald et al. (2003) recognised K-metasomatism and reddening of feldspar in the granite. Pirajno (2005) ascribed these, along with veins of bladed calcite and fluorite+biotite/chlorite+prehnite, to hydrothermal alteration associated with the impact.

Excursion localities

Locality 1 is at Barlangi Rock, a prominent rocky hill on the N side of the Meekatharra-Sandstone road at MGA 681770E 6991830N. Park in the trees below the SE side of the hill.

Locality 1: Barlangi Rock

Barlangi Rock is the best of several outcrops of the Barlangi Granophyre. A good route is to climb to the top of the hill, admire the view and the xenoliths, descend the N side, noting the terraces and jointing (Figure 5), then walk east around the base of the hill to the cars.

The granophyre is a pink fine-grained rock, with scattered coarser grains of quartz and feldspar, and xenoliths of coarse-grained granite that range from a few centimetres


Figure 5: Terraces of jointed granophyre at Barlangi Rock.

to 0.4 metres across (best seen a few metres north of the summit cairn). Unlike the surrounding Yarrabubba Granite, the granophyre contains no quartz veins, pegmatite, mafic dykes, or pseudotachylite. Gently southwest-dipping terraces are developed on Barlangi Rock (Figure 5), but not in the surrounding granites. Closely spaced fracturing, best seen on the northern side, could be crude columnar jointing related to cooling, or a later (Proterozoic?) regional fabric.

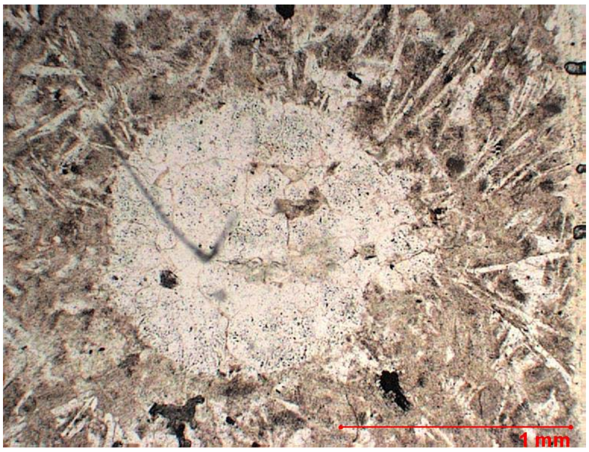


Figure 6: Barlangi Granophyre, Locality 1 – spheroid (xenocryst?) of granulated quartz in groundmass of skeletal-textured quartz and feldspar.

In thin section, the coarser grains in the granophyre appear to be quartz and feldspar xenocrysts. The quartz xenocrysts are rounded, in part resorbed, and consist of a fine mosaic of granulated quartz (Figure 6). Similar granulated textures appear in quartz in the granite xenoliths, in the granite near the granophyre contact, and in the large "pseudotachylite" dykes (see Locality 2b), but not in the regional Yarrabubba Granite. Quartz and clouded feldspar in the Barlangi Granophyre form skeletal textures, indicating rapid quenching (Figure 6). These needles often radiate from quartz xenocrysts, similar to nucleation textures described in the Vredefort (South Africa) impact melt. Shock features (PDFs, shatter cones) have not been observed in the granulated quartz, the granophyre, or the xenoliths.

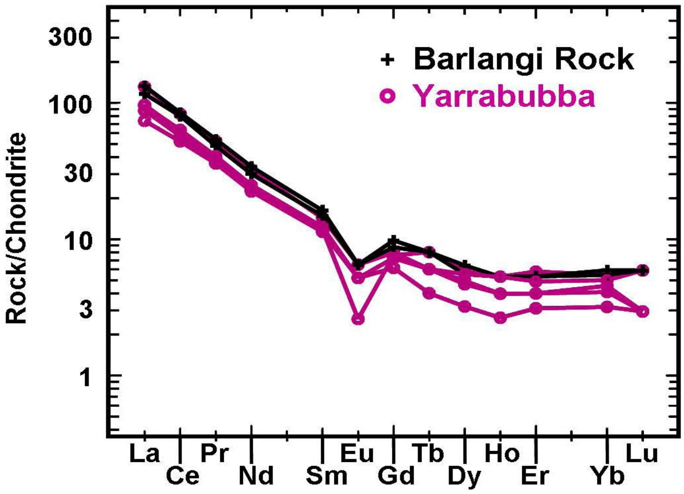


Figure 7: REE plot of five samples of Yarrabubba Granite and two samples of Barlangi Granophyre (data from Cassidy et al., 2002).

The granophyre forms a multi-lobed sheet-like body that is interpreted as an impact-generated melt. Evidence for this includes REE and trace element patterns that are identical to the Yarrabubba Granite and show no evidence for fractionation (Figure 7). Outcrop evidence (see Locality 5), although uncertain, indicates that the contacts of the granophyre are shallow-dipping to horizontal, and the granophyre is overlain and underlain by Yarrabubba Granite. It is possible that the Barlangi Granophyre represents a multi-lobed, sub-crater intrusion of impact-generated melt.

Return to road, turn left, drive 200m and turn left on track. Drive N along W side of fence for 3.7 km to MGA 682045E 6995428N. Turn left on track and drive W for 2.5 km to MGA 680620E 6995563N. Turn left and drive cross-country 250m to Locality 2a at the base of the granite outcrop at MGA 680490E 6995340N.

Figure 8: Shatter cones at Locality 2a.

Locality 2a: Shatter cones and hairline pseudotachylites in Yarrabubba Granite

This is the locality where shatter cones (Figure 8) were first discovered at Yarrabubba in 2002 (Macdonald et al, 2003). The original GSWA thin section, from which PDFs were first described by Will Libby, was from a sample of granite collected by Steve Williams about 1.5 km east of here in 1979.

The Yarrabubba Granite is a pale pink, medium- to coarse-grained monzogranite, consisting of quartz, albitic plagioclase and microcline, with subordinate muscovite and biotite. Here and near Barlangi Rock, quartz grains in the

Yarrabubba Granite display multiple sets of planar deformation features (PDFs) (Figure 3). Plagioclase twin lamellae and cleavages in mica are commonly disrupted or bent. Biotite is commonly altered to a mixture of chlorite and iron oxides, and it also appears that muscovite may have formed from hydrothermal alteration of biotite. Although brecciation in the Yarrabubba Granite is rare, in some outcrops the granite is so highly fractured that it could be classified as monomict breccia.

In general, shatter cones point upwards and have very divergent striation, indicating that the current exposure is far below the original source of the shock wave. Cones range in size from 10cm to, rarely, about 50 cm. Also present, and indeed dominant, are shatter fractures, the diagnostic feature of which is the presence of diverging striated features, known as 'horse-tailing'. Many of the shatter-features at Yarrabubba are best described as shatter surfaces, which are a transitional state between shatter coning and shatter cleavage. Also note sets of curved, discontinuous cleavage.

Figure 9a: Hairline pseudotachylite veins. Note the 10 cm sinistral displacement of a pegmatite vein, top right.

Figure 9b: Detail of left part of Figure 7b, showing "swallowtail" merging of veins.

Also at this locality millimetre-thick black pseudotachylite veins display "cobweb" patterns (Figures 9a and 9b). Note evidence of movement along the veins where pegmatite veins are displaced by a few centimetres. The veins consist of glassy recrystallized granite, which in places, especially in thicker parts where veins join, is a microbreccia (Figure 10). Elsewhere at Yarrabubba (e.g. Locality 5) such black pseudotachylites have been noted up to 20 cm thick.

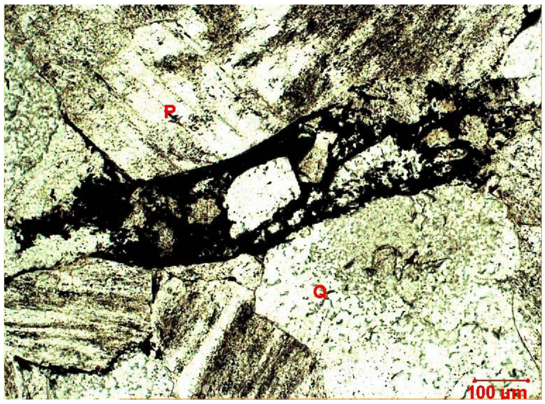


Figure 10 (right): Thin section of microbreccia in pseudotachylite vein (black). P – plagioclase, Q – quartz. Plane-polarised light.

Walk about 230m ESE to Locality 2b at MGA 680684E 6995227N.

Locality 2b: Xenolithic "pseudotachylite" dyke

Within the Yarrabubba structure are numerous dike-like bodies, which range in thickness from a few 10s of centimetres to more than a metre. These bodies are generally of a flinty green aphanitic felsic rock intensely altered (devitrified?) to sericite and quartz, rarely with inclusions of granulated quartz and feldspar. Fault movement is indicated by displacement of pegmatite veins with partially melted pegmatitic clasts strung out within the melt. At Locality 2b the thickest (up to 3m) of these dykes has a central portion containing small (1-2 cm) streaked-out granitic xenoliths with potassium-feldspar

Figure 11: "Pseudotachylite" dyke in Yarrabubba Granite, showing steep south-westerly dip and fracture cleavage.

overgrowths (Figures 11 and 12). Fracture cleavage (partly after flow layering?) and steeply-plunging rodding are also present. In thin section the xenoliths contain resorbed, granulated quartz and hematite-clouded feldspar in a fine-grained quartz-sericite-oxide matrix (Figure 13). Also present in thin section are patches of devitrified glass (Figure 14). These dyke-like bodies are probably fault melts, related to the Barlangi granophyre, injected explosively into the granite.

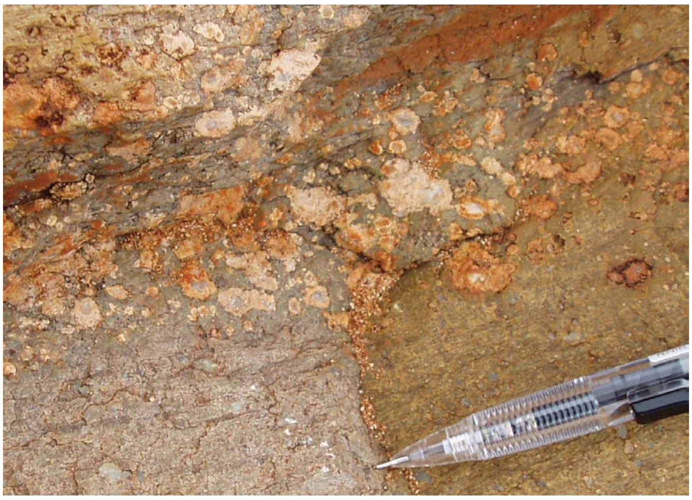
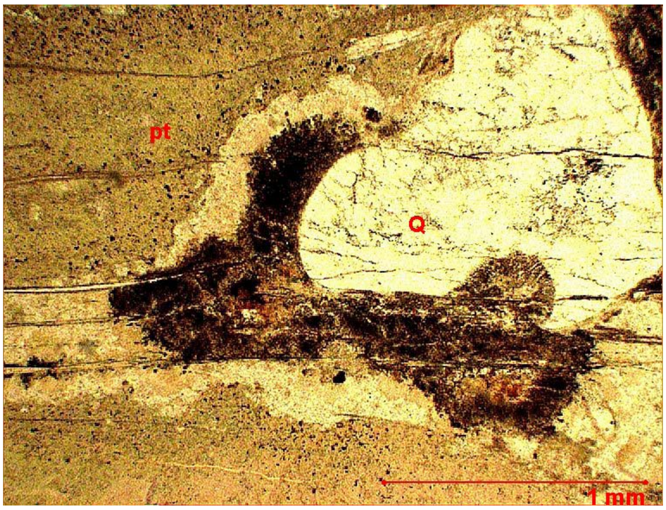


Figure 12: Detail of the central portion of the dyke showing recrystallised rims on resorbed granite-derived quartz and feldspar grains.



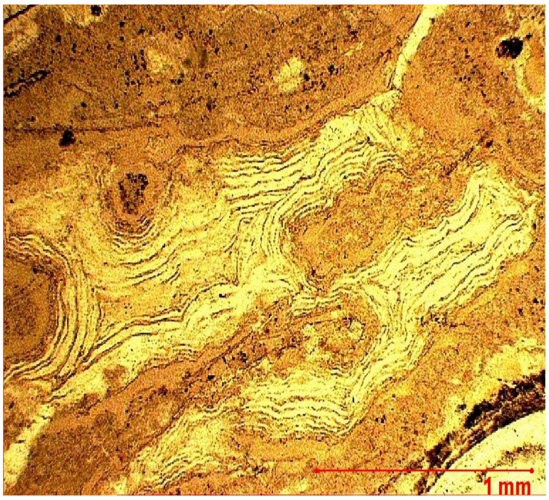


Figure 13 (above): Resorbed and granulated quartz (Q) and iron-stained feldspar (dark) with pink feldspar overgrowth, in "pseudotachylite", with later fractures. Plane-polarised light.

Figure 14 (right): Devitrified glass with flow texture. Plane-polarised light.

Return to the main road. Turn left, cross the grid, and turn right on the track along the east side of the fence. Follow fence around corner at MGA 681994E 6991616N then west for 1.9 km. Walk S 100m to Locality 3a at MGA 680110E 6991480N.

Locality 3a: Quarry locality – Barlangi Granophyre

The Barlangi Granophyre at this locality is very fresh. As at Barlangi Rock (Locality 1) the granophyre contains small granite xenoliths (Figure 15) and resorbed xenocrysts of quartz and feldspar. The low outcrops of granophyre show a faint layering on the weathered surface. The layering has generally steep dips, with the strike varying between NNW and NE. One outcrop shows the layering wrapping around a 10 cm granite xenolith. This is one of the two sampling sites of Barlangi Granophyre described by Cassidy et al (2002). The REE profile is shown in Figure 7.

Outcrops and many of the loose fragments around the outcrops have been reworked, possibly by Aborigines. Please do not disturb or remove this material.

Figure 15: Granite xenoliths in Barlangi granophyre. Scale is 10cm across.

Walk about 200m to the SE side of the clearing, just beyond the last scree of granophyre, to some granite boulders at MGA 680270E 6991380N.

Locality 3b: Quarry locality – Yarrabubba Granite

This is one of the five sample sites of Yarrabubba Granite described by Cassidy et al (2002). At the blast site the fresh coarse-grained monzogranite contains altered alkali feldspar, its brick-red colour caused by Fe-oxide dusting, and pale green-grey sericitised plagioclase. Dark-grey fine-grained pseudotachylite is present as a vein 2-3 cm wide and as several thinner veins and irregular patches. The granite outcrop is very close to the contact with the granophyre. This contact coincides with the lobate, circular magnetic feature at the centre of the large demagnetized zone on the aeromagnetic map (Figure 4).

From the fence N of Locality 3a, drive S through the scrub for 2.8 km to Locality 4 at MGA 679670E 6988810N. Note: Because of time constraints and difficult access it might not be possible to visit Locality 4 on this excursion.

Locality 4: Impact breccia

This is the only locality at Yarrabubba where an impact breccia has been found (illustrating the amount of erosion of the original crater). Outcrop is poor and consists mainly of scattered rubble of slightly weathered Yarrabubba Granite. The impact breccia consists of a few blocks 20-30 cm wide, suggesting a narrow dyke-like form. The breccia is pale pink/cream with irregular angular fragments up to 2 cm across (Figure 14). Although some fragments are granitic some are of a fine-grained felsic rock of uncertain origin. Also puzzling are small fragments of deformed mafic material.

Figure 16: Hand specimen of impact breccia showing granitic fragments (e.g. bottom left) and deformed mafic fragments (dark). Note the vertical pseudotachylite vein near right edge. The orange-brown parts are surface weathering.

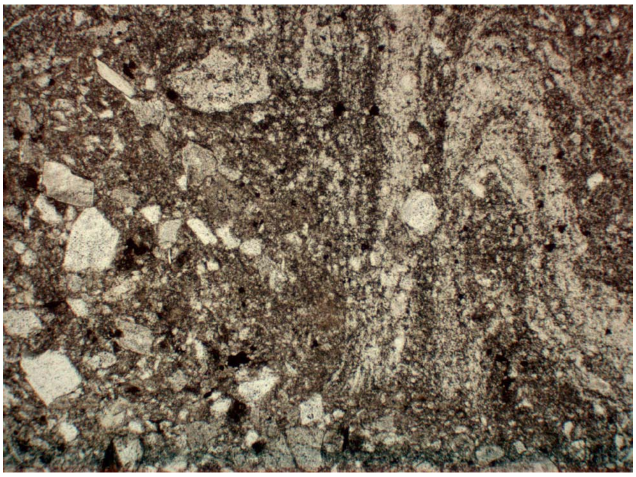


Figure 17: Microbreccia showing folded flow banding. Plane-polarised light. Field of view: 2.9mm across.

In thin section (Figures 17, 18a and 18b) the groundmass is shown to be angular fragments, about 1 mm across, of deformed quartz, feldspar (including microcline and albite) and muscovite, set in a finer matrix with a grain size <0.1 mm. Some folding may represent fluidization of the matrix (Figure 17).

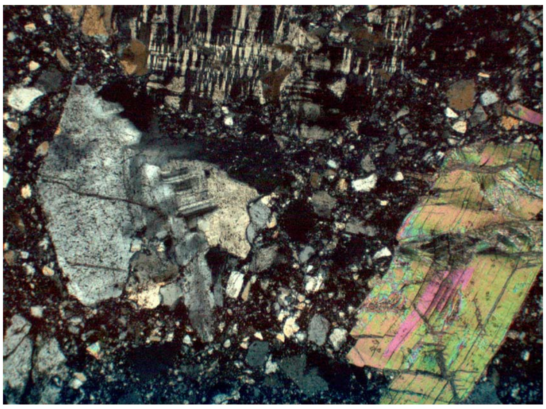


Figure 18a (left): Coarse granite (left centre), microcline (top) and muscovite fragments in microbreccia. Plane-polarised light.

Figure 18b (right): Same view as 16a. Crossed Nicols.

Field of view is about 2.9mm across.

Return the 2.8 km N to the E-W fence, turn right and return to the main road. Turn left and drive for about 2.0 km to park on the left side of the road near MGA 680450E 6993060N. Locality 5 is a traverse from here up the hill to the SW.

Locality 5: Granophyre contact

Before walking up the hill to the south, inspect the Yarrabubba Granite immediately north and south of the road. There are some weak crescentic shatter surfaces, a pale green sericitised “pseudotachylite” dyke, and remobilised quartz veins.

Walk southwest over the granite outcrops and up the low hill, about 400 metres. On the way look for remobilised quartz veins, fractured (almost brecciated) granitic pegmatite, and more of the pale green “pseudotachylite” dykes.

At Locality 5 MGA 680190E 6992740N we are on the contact between the Yarrabubba Granite to the NE and a lobe of Barlangi Granophyre to the SW. The quartz in the granite has a distinctive sugary texture – the result of granulation of the original coarse grains. The slightly weathered granophyre is similar to that on Barlangi Rock. The contact can be followed to the NW for about a kilometre. In places the actual contact is exposed or nearly so, and it appears (inconclusively) that the contact dips at a low angle to the NE i.e. the granite overlies the granophyre. Locally the complex shape of the contact again suggests a very shallow dip. The granophyre can be traced for about 600m across strike. The SW contact against granite is less well exposed, but again can be traced for a kilometre or so.

Close to the northern granite-granophyre contact there are numerous scree fragments of black pseudotachylite. The rock is similar to the black veins at Locality 3b, but coarser grained. Relict patches of granulated quartz, rimmed by red feldspar similar to the dyke at Locality 2b, are set in a dark siliceous micro-brecciated matrix that contains some faint skeletal texture. The size of the scree fragments suggests that they originated in veins or small dykes up to 20 cm wide. None has been found in outcrop. Given that the black pseudotachylite is very hard and resistant it is possible that the scree fragments represent a lag deposit of veins long since removed by erosion.

Return to the main road. This ends the Yarrabubba part of the excursion. Drive NW to Meekatharra, about 90 km.

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Notes