Figure 1: The "discovery" Google Earth image of the Hickman Crater. The crater is around 260m in diameter.

Hickman Crater

John Bunting

The Hickman Crater is 36 km north of Newman in the Pilbara region of Western Australia at 119°41'E 23°02'S. It was discovered in July 2007 by Arthur Hickman of the Geological Survey of Western Australia when he was using Google Earth. The circular nature of the feature, the flat floor and the raised rim hinted at a simple meteorite impact crater (Figure 1). Subsequent field and laboratory work by Andrew Glikson (Glikson et al., 2008) and, later, by Arthur Hickman (Hickman et al., 2008), found evidence to support an impact origin, including:

- fracturing and shattering of rhyolite and BIF;
- slickensides on blocks of rhyolite;
- radiating and plumose fractures;
- cryptocrystalline goethite veins with margins of altered rhyolite (hydrothermal alteration?);
- microfractures in quartz phenocrysts.

During a field visit to prepare for this excursion further evidence, possibly more diagnostic, for an impact origin was found, but this still needs confirmation by laboratory work.

Figure 2: Panorama of crater showing low hills of ejecta in SW (left-hand side). Note four-wheel drive vehicle for scale.

The Hickman Crater is in remote and hilly country high on the dissected plateau of the Ophthalmia Range. At the time of discovery (2007) there were no vehicular tracks near the crater (Figure 1). Current Google Earth imagery (October 2011) shows numerous tracks in and around the crater – the result of interest by Newman-based tour operators, independent visitors and mineral exploration companies, particularly Atlas Iron. Public access to the crater is via the Marble Bar road from Newman, then the road along the BHP Iron Ore railway and a track into the Poonda rock art site (Figure 3). Just before the rock art a track to the left heads southeast then west into the hills on a tortuous route to the crater. On this excursion we have permission from Atlas Iron to take a shorter route via the Atlas exploration camp (where we will camp for the night).

The following description of the crater is taken mainly from the work by Glikson et al. (2008) and Hickman et al. (2008 and PowerPoint presentation), plus the field visit by the organisers of this excursion, with regional geology from various GSWA publications.

Geological setting

The Hickman Crater straddles the contact between the Woongarra Rhyolite and the overlying Boolgeeda Iron Formation near the top of the early Paleoproterozoic Hamersley Group, on the southern flank of an east-southeast-plunging anticline (Figure 3). Beyond the influence of the crater dips are generally 15-25° to the south-southwest (Tyler, 1994).

The Woongarra Rhyolite is a regionally concordant giant lavalike felsic sheet, with an average thickness of 400 m and an area of at least 37 500 km^2 (Trendall, 1995). It has been subdivided into a lower unit, a median raft complex, and an upper unit. The rhyolite of the upper unit, with which we are dealing at Hickman, is commonly porphyritic and dark grey, with a subconchoidal fracture. Surface weathering has resulted in colours ranging from cream to buff and pinkish brown. In thin section phenocrysts of plagioclase and quartz (commonly resorbed) sit in a fine-grained, snowflake-textured matrix (Trendall, 1995).

Several features described by Trendall from the upper unit of the Woongarra Rhyolite could be important in understanding the Hickman Crater, in that they could be mistaken for impact-related effects, although none has been specifically identified. Autobrecciation is common near the top of the upper unit, with angular fragments commonly in the 10-100cm range. Flow layering is also present, although more common in the lower unit. Some plagioclase phenocrysts have coronas of micrographic intergrowths of quartz and feldspar. A feature of the contact with the overlying Boolgeeda Iron Formation is peperite, which is a mixture of fragmented magmatic and sedimentary material thought to have formed by intrusion of magma into wet sediment (Trendall, 1995). The intrusion of hot magma into the wet sediment caused vaporization of the water and explosive brecciation.

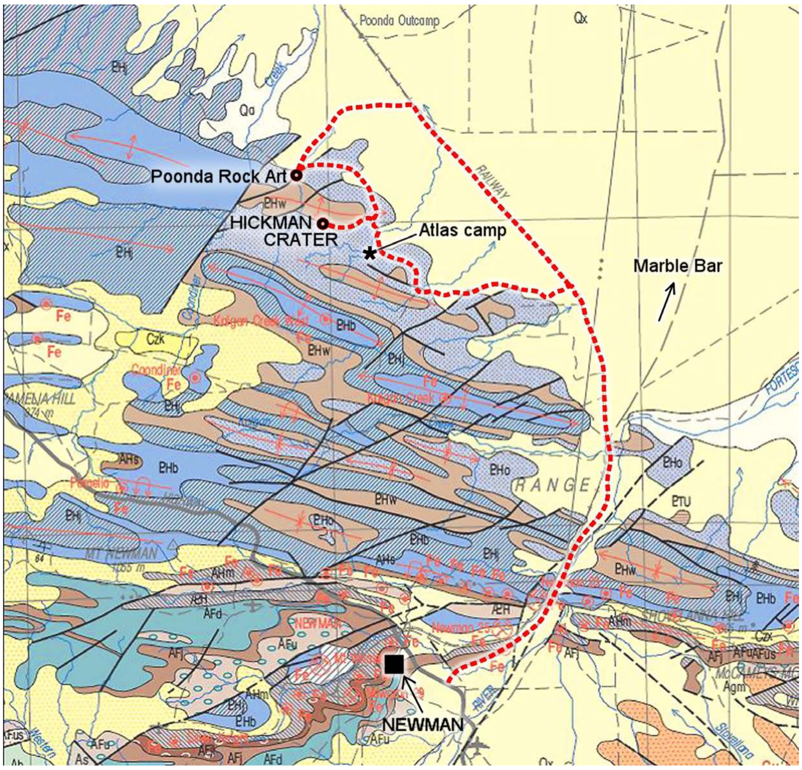

Figure 3: Regional geology, showing the position of Hickman Crater. PHb – Boolgeeda Iron Formation; PHw – Woongarra Rhyolite. Base map from GSWA Bulletin 144, Plate 1B.

The Boolgeeda Iron Formation consists of flaggy ironstone and iron-rich shale. The grey-black fine-grained ironstone, although loosely described as banded iron-formation (BIF), lacks the distinctive meso- and micro-banding of the BIF lower in the Hamersley Group (Weeli Wolli Formation, Brockman Iron Formation and Marra Mamba Iron Formation).

BIFs in the Pilbara contain some of the largest iron ore deposits in the world, principally in the Brockman and Marra Mamba Iron Formations and in channel and detrital iron deposits derived from them. Until recently the ironstones of the Boolgeeda Iron Formation were considered too low grade for mining, but the recent boom in the iron ore industry has seen a reappraisal of the Boolgeeda.

Metamorphism in the Hamersley Group is low-grade, reaching only lower greenschist facies. Open folds, on a regional and outcrop scale, have east-southeast axes, associated with weak axial surface cleavage and axial lineation. Gentle regional cross-folds have created a doubly plunging dome-and-basin pattern.

Crater Description

The Hickman Crater is almost circular (Figure 1), with a rim diameter of 250-270 m (average 260 m). The northern, eastern and southern rims, about 70% of the crater circumference, are uplifted 15-20 metres above the surrounding plateau surface and 20-30 m above the flat crater floor. The inner walls form steep, unstable slopes with numerous fallen blocks on the slopes and around the base (Figure 2 and Figure 4). Around the rim, bedding in the iron formation and crude flow layering in the rhyolites have been disrupted, steepened and in places overturned. Beyond the upturned rim,

Figure 4: Eastern wall and rim of the crater, with letter box.

Figure 5: Southwestern rim of the crater, with low ejecta-covered hills in the centre of the photograph. To the left is the "spillway", where the ejecta-blocked creek drains to the south.

angular fragments of rhyolite form an apron around the crater, with isolated fragments up to 300 m north of the crater. This is interpreted as part of an ejecta blanket.

The western/southwestern rim of the crater is lower and entirely covered with rhyolite and minor iron-formation ejecta (Figure 5). A pre-impact creek that enters the crater from the northwest would originally have flowed south, but it now terminates on the flat 170 m diameter crater floor. After heavy rain the floor of the crater must form a small lake. Alluvium deposited on the crater floor could be up to 20 m thick, and presumably overlies any impact-generated and fall-back breccia.

The exit point of the creek to the south has been blocked by an ejecta layer that now forms a lip about 3 m above the crater floor (Figure 5). This lip would be a spillway if the crater were to fill with water, with the overspill following a small creek that is eroding the ejecta downslope towards a major east-flowing creek.

Asymmetry of the crater

The ejecta-covered and topographically lower southwest portion, and distal ejecta up to 300m to the north, impart an asymmetry to the crater that prompted Glikson et al (2008) to suggest a south to north trajectory for the projectile, with a moderate angle of impact; however an abundance of rhyolite ejecta over Boolgeeda Iron Formation west-southwest of the crater may imply a west-southwest-directed impact (Hickman, pers. comm. in Glikson et al, 2008).

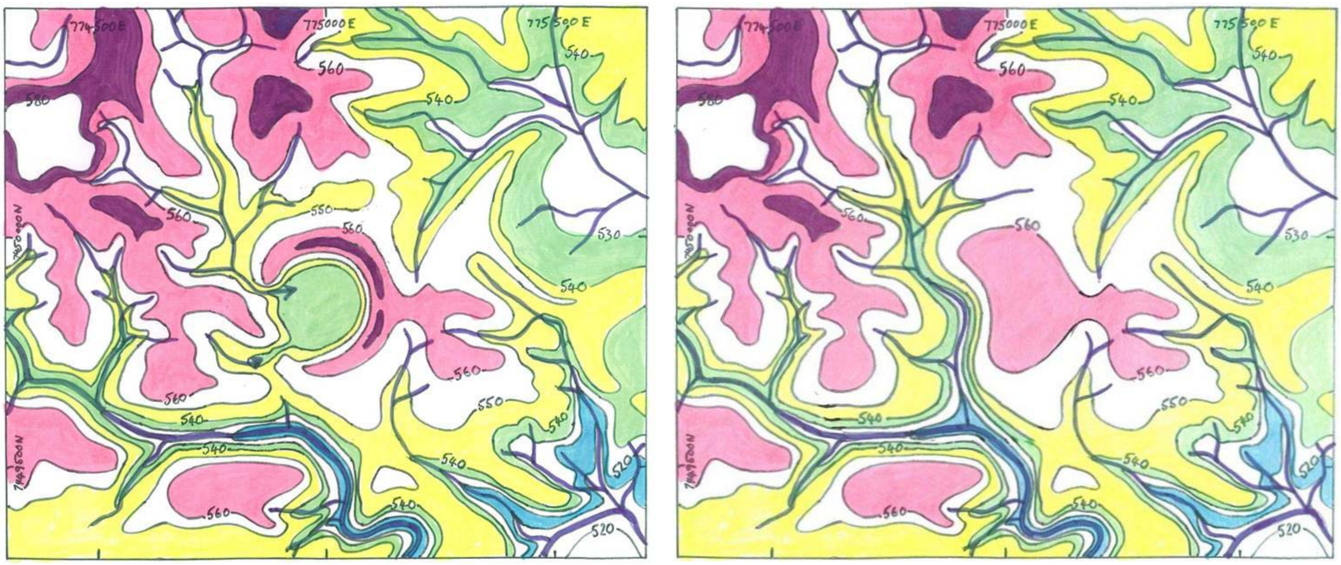

Figure 6: 6a – Present topography of the crater area; 6b – Reconstruction of topography prior to impact. Contours in metres above sea level. Field of view of each map is about 1400 metres. From Hickman et al. (2008) Powerpoint presentation.

On the basis of the preparatory field visit, the organisers of this excursion are of the opinion that the asymmetry is related to the pre-impact topography (Figure 6). Pre-impact the southeast- to south-flowing creek would almost certainly have flowed through a small gorge in the Woongarra Rhyolite and especially in the Boolgeeda Iron Formation. This is the typical situation for creeks of this size in this region. The impact, on the sloping plateau above and east of the creek, would have excavated a crater along an arc from northwest through east to south. Given that the point of impact was probably 30 m above the bed of the creek, and the base of the transient cavity was perhaps 30-40 m below the point of impact (on the basis of a 10 m iron projectile – Glikson et al., 2008), much of the energy of the impact would have dissipated sideways to the west and southwest, sending the ejecta into, across and down the creek rather than forming an upturned rim.

Age of the crater

The precise age of the impact is not known. Based on the drainage patterns and state of preservation of the rim impact may have been a few tens of thousand to possibly 100 000 years ago (Glikson et al., 2008). Preliminary isotope work on fracture surfaces indicates possibly 50 000 years as a good estimate (Hickman, pers. comm.). Research to refine this figure could include further isotope work on fracture surfaces, pollen analysis from a drillhole to the base of the crater-fill sediments, and carbon isotope analysis of any carbonaceous material.

Excursion localities

Warning: The steep inner rim of the crater is unstable and dangerous. We advise that you should not try to climb down from or up to the rim, but if you do, please accept the risk involved.

Because the excursion area is reasonably compact we are not going to suggest many specific localities, rather a general tour that could be modified depending on time and interests. We will park the cars near the southeast rim, where local tour operators have erected a letter box (Figure 4. MGA 775012E 7449717N) containing information about the crater and a visitors book.

There is a good view of the whole crater (Figure 2).

From the Letter Box walk northeast along the crater rim to view the upturned contact between the Boolgeeda Iron Formation and the Woongarra Rhyolite (MGA 775100E 7449780N).

The iron-formation is contorted and fractured. On the rhyolite look for shattered surfaces, slickensides, some of the goethite veining/nodules. From the eastern/northeastern rim you can walk downslope to see rhyolite blocks and fragments forming the ejecta blanket.

From the Letter Box, a walk down the slope, over rhyolite ejecta and BIF outcrop, takes you to the spillway (Figure 5). To the left (south) scramble down the slope into the small creek that is the post-impact rejuvenation of the pre-impact creek as it erodes through the ejecta layer.

The view to the south of the larger east-draining creek illustrates the low cliffs forming a gorge in Boolgeeda Iron Formation, typical of this region, which would be similar to that postulated for the north-south creek destroyed by the impact. BIF ejecta become more abundant as you descend the creek, and eventually the creek crosses BIF outcrop. Some of the BIF is weathered and brecciated (Figure 7a. MGA 774900E 7449630N), and 10 m further south boulders of BIF have slickensides and cross-cutting 2-3 mm veins that could be pseudotachylite (Figure 7b).

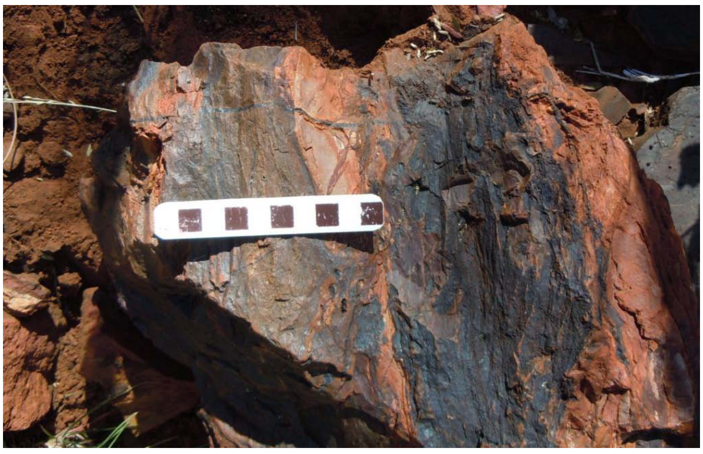

Figure 7: 7a – Brecciated BIF in rejuvenated creek below "spillway"; 7b – Boulder (ejecta?) of BIF with Fe-rich vein. Scale is in centimetres.

Returning to the spillway, walk into the crater and along its western side.

The low hills are entirely of rhyolite blocks, some of them car-size, that could be outcropping bedrock, but are more likely to be large masses of ejecta. In the hills further west, above a small creek, outcrop of flaggy BIF and ferruginous shale of the Boolgeeda is covered by ejecta fragments of both BIF and rhyolite. Look for pre-impact folds, cleavage and lineation. At MGA 273290E 7446600N fracture cleavage and lineation are well developed in thinly bedded (strike 300°/20° S) cherty, in part jaspilitic, BIF (Figure 8a, b). From here there is a good view north into the valley of the pre-impact creek system that drains southeast into the crater (Figure 9).

Figure 8: 8a – Outcrop of typical Boolgeeda Iron Formation; 8b – Fracture cleavage and lineation on cherty BIF. Scale is in centimetres.

Walk down the slope to the creek where it cuts the rim of the crater.

The creek here has cut a course between abutments of rhyolite, some of which may be outcropping upturned bedrock, but some is certainly blocks that have fallen down the slope. The narrow course of the creek has cut down into rhyolitic bedrock through about 1.5 m of crudely bedded pebbly alluvium.

Figure 9: View to NE from Figure 8a, showing SE-draining creek and, at right of picture, the abutment at the western end of the northern crater rim.

On the northeast side of the creek at the bottom of the inner wall of the crater, look for a large block of rhyolite that has fallen from the crater wall (Figure 10a. MGA 774754E 7449687N). The block features numerous slickensides and complex fracturing. Note also the black iron-rich coatings, of unknown composition and origin but post-slickensides and perhaps related to post-impact weathering (Figure 10b).

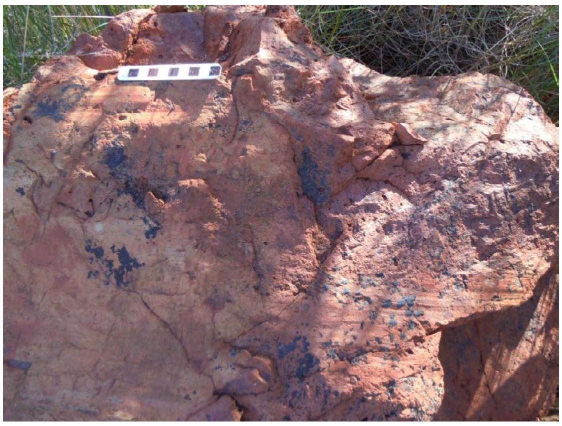

Figure 10: 10a – Fallen block of fractured rhyolite with slickensides; 10b – Detail from 10a, showing slickensides and black ferruginous coatings. Scale is 10 centimetres.

From here it is possible to walk back to the cars, either back along the creek, up the outside of the crater and east then south along the rim, or along the bottom of the inside eastern wall of the crater.

If taking the outside route, about 100 m north of the rim is Glikson's location H34 (Figures 2 and 7 in Glikson et al., 2008), at which you can see various veins and cavity fillings of iron-rich cryptocrystalline material in rhyolite.

References

Glikson, A. Y., Hickman, A. H. and Vickers, J., 2008, Hickman Crater, Ophthalmia Range, Western Australia: evidence supporting a meteorite impact origin: Australian Journal of Earth Sciences, 55, p 1107-1117.

Hickman, A. H., Glikson, A. Y. and Vickers, J., 2008, A newly discovered meteorite impact crater, Ophthalmia Range, Western Australia: Geological Society of Australia, Abstracts No. 89, p 133-134. (Also Powerpoint presentation, www.dmp.wa.gov.au/documents/Hickman_Crater.ppt).

Trendall, A. F., 1995, The Woongarra Rhyolite – a giant lavalike felsic sheet in the Hamersley Basin of Western Australia: Geological Survey of Western Australia, Report 42.

Tyler, I. M., 1994, Geology of the Newman 1:100 000 Sheet, Western Australia. Map Sheet SF50-16-2851, Explanatory Notes: Geological Survey of Western Australia.

Notes