Meteorite impacts to gold and nickel deposits

The discovery of *prima facies* evidence for impact structures in the Eastern Yilgarn, Western Australia

Robert (Bob) Bingley Watchorn

Bob Watchorn and Associates Pty Ltd
Email: bobwatchorn123@yahoo.com

A large circular feature was observed by the author in gravity data of the Yilgarn region of Western Australia in May 1999. The discovery in August 2013 of *prima facies* evidence on many of the documented rings associated with this structure confirmed it to be of impact origin. The rings of this impact structure, the Watchorn Impact Structure (hereafter termed WIS), extend 560 km north–south and 480 km east–west diameter. From the impact structure's relationship with geological features the age of the impact is estimated at between 2.7–2.64 Ga. This is one of the largest and oldest impact structures worldwide. There are numerous other probable impact structures observable right across the Yilgarn from Mount Magnet to the Albany Frazer Tectonic zone east of Norseman.

In the Eastern Yilgarn there is an empirical correlation between the largest nickel, gold, copper, silver–lead–zinc and rare earth deposits and the rings of WIS and other probable impact structures. The age of the mineralisation is between 2.72 Ga and 2.60 Ga.

These relationships means a paradigm shift is required for identifying impact structures and reworking the lithological, structural and mineralisation history in the Yilgarn. This may apply to Archaean Cratons worldwide.

This paper is divided into three sections:

A. Examination of impact structures in the Yilgarn.
B. Q&A: areas for discussion and further study.
C. Exploration trip to verify ring morphology and find *prima facies* evidence for impact structures.

Due to space considerations, Sections B and C shall be deferred until the next issue. In the interim, the author welcomes feedback from readers (Note: opportunity exists for select queries and replies to be published within section B). – Editor

A. Examination of impact structures in the Yilgarn

General observations. The surface of the Moon, Venus and Mars illustrate the important role impact cratering plays in the geological process. However, on the Earth's surface, only about 170 impact craters have been recorded (Koeberl and Anderson 1996). Very few have been positively identified by the observation of meteorite debris and shock structures, as most of these craters are masked by periods of erosion and sedimentation and the meteoritic material is widely dispersed (Dentith *et al*. 1999).

Large ring structures of proven impact origin are Vredefort in South Africa (ca 300 km diameter, 2.02 Ga age), Sudbury in Canada (ca. 250 km diameter, 1.85 Ga age) and Chicxulub in the Gulf of Mexico (180 km diameter, 65 Ma age).

In Australia there are 35 confirmed impacts, 22 unconfirmed impacts and 10 sites with identified impact ejecta (spherules).

Evidence in the Archaean Pilbara Craton of several impact spherulite ejecta horizons confirm that large impacts occurred around 2.5, 2.63, 2.7 and 3.4 Ga adjacent to the Pilbara Craton (Hassler and Simonson 2001; Byerly *et al*. 2002).

Only one verified Archaean impact structure has so far been found in the Yilgarn, Yarrabubba (30–70 km diameter, 2.65 Ga age) located 70 km SW of Meekatharra (Mc Donald *et al*. 2003).

According to Blewett *et al*. (2012) the Eastern Yilgarn Craton is characterised by short duration, even catastrophic crust forming events between 2.775 Ga and 2.655 Ga.

Megascopic evidence of multiple probable impact structure discoveries in the Eastern Yilgarn, Western Australia

Gravity. In May 1999 the author was using a gravity database to examine the Eastern Yilgarn Craton for large basement tapping structures as a source of mineralisation. A 250 km diameter circular feature (plus smaller central circular features) was consistently observed on the images when the 1st horizontal derivative of the gravity data was examined on the ER Mapper software program (Watchorn 1999). The data was examined using various sun angles at different azimuths to highlight fault and circular features. It was generally found that steeper sun angles gave a deeper view of the crust. This hypothesis was checked using the known geological features interpreted from the seismic traverse in figure 52, p. 92 in Blewett and Czarnota (2007).

The centre of the feature is located at an approximate longitude of 121°25′E and latitude 28°25′S, 50 km north of the town of Leonora.

The circular feature was examined on topographic, fact geology, interpretive geology, magnetics and Landsat images.

At mid depth (5–10 km) depths on the 1st horizontal derivative gravity data there is observed the larger 250 km diameter outer ring with a central high (Figure 1).

Looking deeper (10–15 km) the Yilgarn rift structures are observed as are two concentric rings with diameters of 55 km and 95 km respectively in the centre of WIS (Figure 2).

There is strong evidence of central rings and some outer rings of four other probable impact structures extending from Leonora to Mt Weld south of Laverton. There is a less well developed, or earlier, central ring near Kookynie which is the centre of the 500 km diameter ring described by O'Driscoll and Campbell (1997). This ring structure I have named the O'Driscoll probable impact structure in honour of a mentor Tim O'Driscoll.

There are arcuate features located 50 km NE through to 50 km NW of Kalgoorlie that suggests an earlier cluster of impact structures, as they are dismembered by the NNW rift fault zones. These structures are visible in the deeper gravity data (Figures 1 and 2), but unlike the WIS are not visible in the shallower gravity data (Figure 3). This lack of surface expression may mean that they impacted during the early stages of volcanism

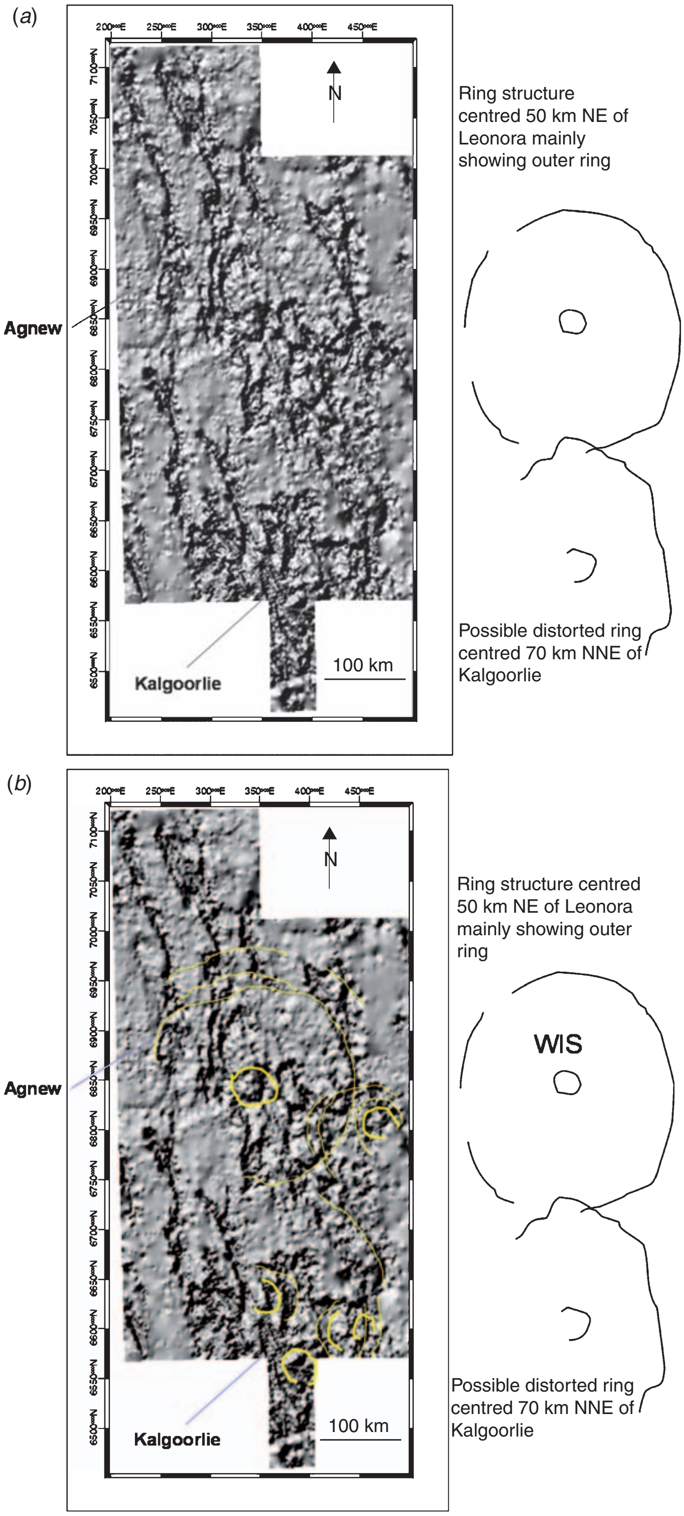

Fig. 1. *(a) Gravity image showing the mid depth ring structures (5–10 km) in the Eastern Yilgarn. (b) Gravity image showing annotated mid level ring structures in the Eastern Yilgarn.*

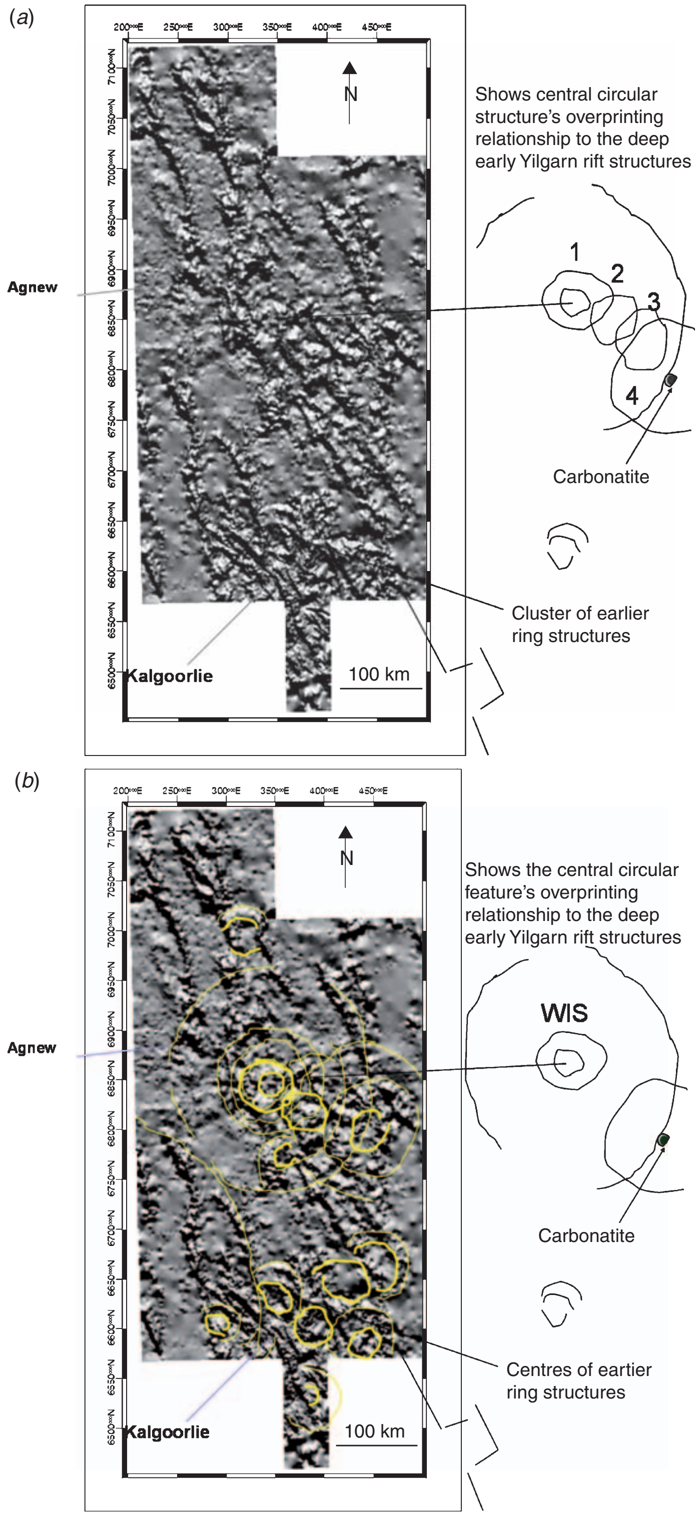

Fig. 2. *(a) Gravity image showing deeper ring structures (10–15 km) in the Eastern Yilgarn. (b) Gravity image showing annotated ring structures in the Eastern Yilgarn.*

and precipitated the extrusion of the deeply sourced Kambalda Komatiites and subsequent stratigraphy. They may also have provided the mineralisation as did the Sudbury impact.

The outer Gravity ring of the WIS is clear on the gravity image highlighting the shallower (0–5 km) features (Figure 3).

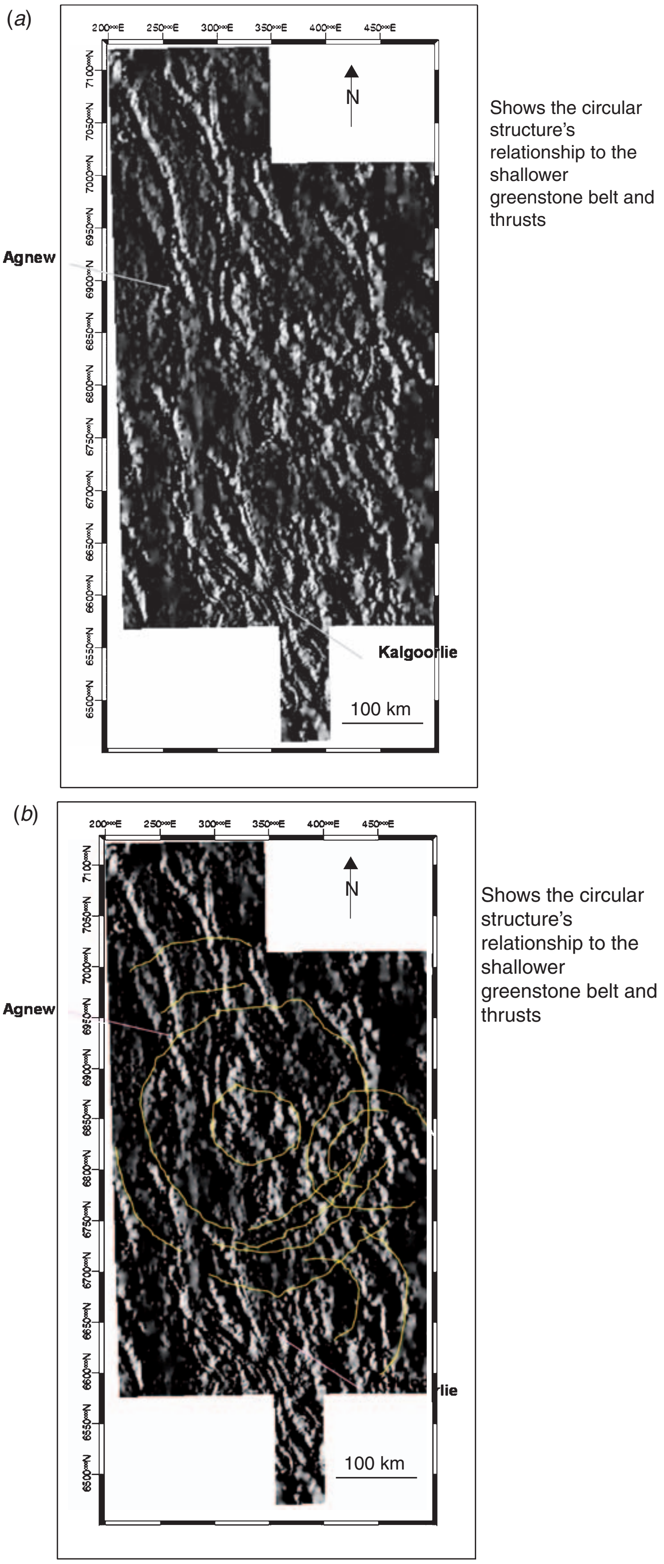

Fig. 3. *(a) Gravity image showing shallow ring structures (0–5 km) in the Eastern Yilgarn. (b) Gravity image showing annotated shallow ring structures in the Eastern Yilgarn.*

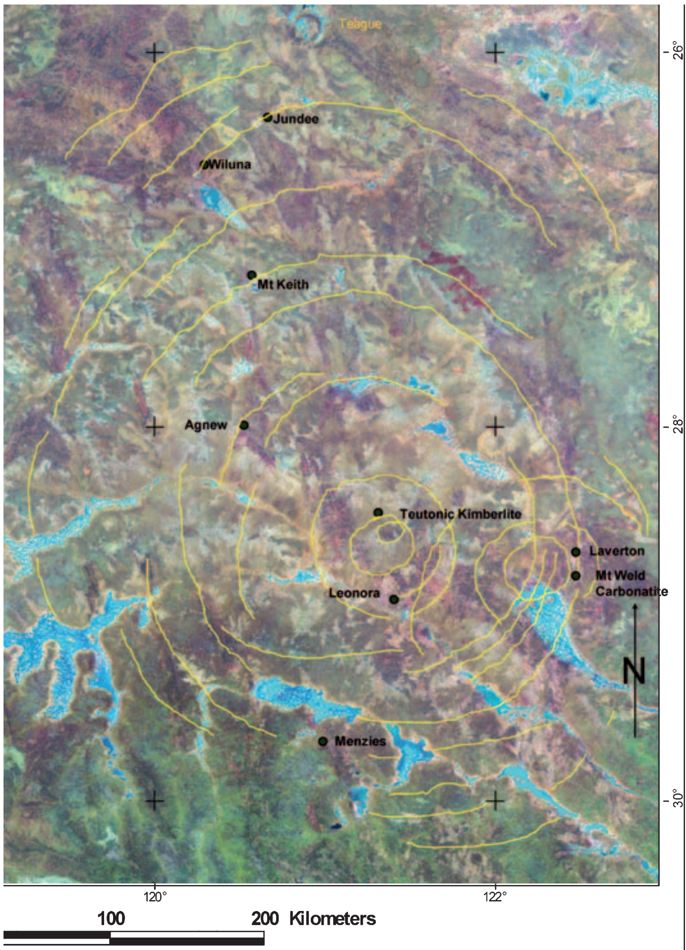

Fig. 4. *Landsat image of the Eastern Yilgarn showing interpreted arcuate features.*

Landsat. There are many arcuate features observed on the Landsat image. The most northern ring passes north of Wiluna and Jundee and arcs down to the east of Laverton and the southern edge passes south of Menzies. The *prima facies* evidence discovered suggests these Landsat rings represent the maximum dimensions of the WIS with dimensions 560 km NS and 480 km EW (Figure 4).

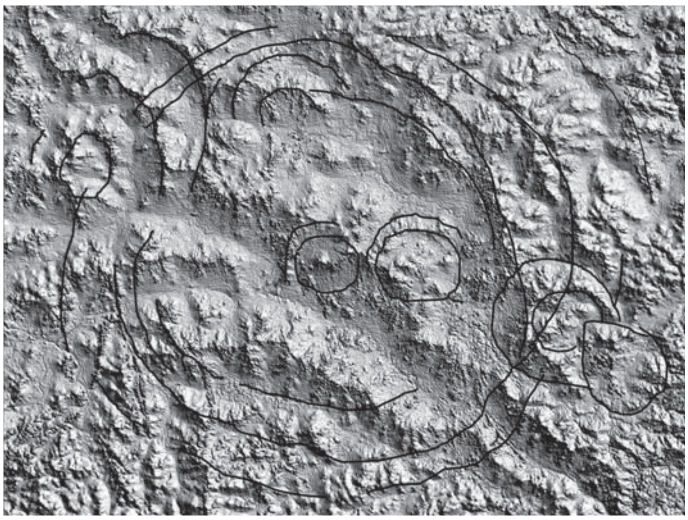

Fig. 5. *Detailed topographic image of the Eastern Yilgarn showing interpreted ring and arcuate features.*

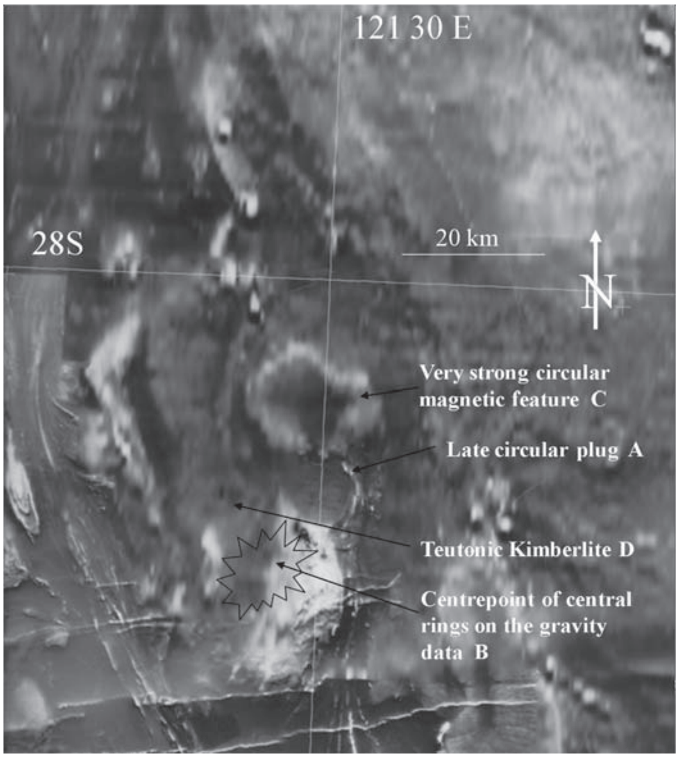

Fig. 6. *TMI aeromagnetic image showing the magnetic ring structures at C, the centre of the gravity ring structures at B and the EW Proterozoic dykes near the bottom of the image.*

Geography. The WIS has a topographic imprint that is still observable. The last major period of erosion on the Yilgarn was the Permian ice sheet glaciation that over-deepened areas of weaker rock, which later became lakes, river systems and finally the salt lake system seen on the Landsat and DEM images. The centre and rim of the WIS are now topographic highs 50–100 m above the surrounding plains and the mid area is of lower elevation. Many of the salt lake systems and subsidiary creek systems still follow the impact ring structures (Figures 4 and 5).

Topography. Digital Elevation Model (DEM) was examined on ER Mapper using sunangles to highlight the WIS rings. The north and northeast rim stood out clearly and about 50 percent of the rest of the rim was visible in the more elevated topography between the lake systems. Numerous other circular features are evident (Figure 5).

Magnetics. The circular feature observed within the gravity data correlates with the magnetics, in terms of the locality, to that of highly magnetic, contorted granite, at the south area of the Bundarra Dome at B (Western Terraces). In addition two concentric ring structures were visible in the magnetic data. These rings, termed the Mt Redcliffe Magnetic Ring Structure (C), have a diameter of 50 km and are centred about 20 km north of the centre point of the WIS (B). Between and partially overlapping the centre points of the gravity and magnetic rings is a very sharp later circular feature (A). Adjacent to these circular features is the Teutonic Kimberlite dyke, evidence of mantle tapping fracture systems.

The EW Proterozoic dykes (below B) place a minimum age on the Impact structures of approximately 2.4 Ga (Turek and Compston 1971) (Figure 6).

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