

# Exploration History and Interpretation of the Spear Creek Structure, Walhallow

JN Dunster  
Northern Territory Geological Survey  
March 2009

Mapsheets: Walhallow 250K, Kilgour 100K  
Tenure: EL 2385, EL 4237, MCN 980 to MCN 983, EL 7854  
MODAT: Spear Creek - Zn, Pb, diamonds

## Summary

A circular feature topographic feature at Spear Creek has been previously interpreted as a possible kimberlite or Redbank-style pipe and targeted for mineral exploration. The structure has been mapped, geophysically surveyed and drilled on several occasions. Minor base metals were found in the surface limestone and ironstone and in the McArthur Group sedimentary rocks in the subsurface. Microdiamonds were found in loam samples within the structure and in streams draining from it. However, microdiamonds from drillcore from within the structure were interpreted as contamination. The circular feature has previously been interpreted as an impact structure and this is discussed in detail.

## Introduction

An enigmatic circular multi-ring topographic feature, about 850 m in diameter, at 17°16'37.5"S 135°50'03"E was first noticed during aerial photograph interpretation and regional geological mapping in the early 1960s (Plumb and Rhodes 1964) but was not considered worthy of special attention. Since then, the structure has attracted the interest of exploration companies and academics over several decades. The surrounding area is a black soil plain underlain by the Cambrian Top Springs Limestone which unconformably laps out to the north onto dolomitic clastic rocks of the Proterozoic McArthur Group. Two multi-national exploration companies have targeted the Spear Creek structure.

## Work by Dampier Mining

EL 2385 was granted to Dampier Mining Company Limited (Dampier - a precursor of Broken Hill Propriety Company Limited) in July 1980 for a period of only twelve months. They targeted the Spear Creek structure (which they termed W4) as a result of a systematic regional aerial photo-interpretation searching for circular features that could be similar to the Redbank breccia pipes that host copper mineralisation in the McArthur Basin. During their brief period of tenure, Dampier Mining mapped the structure, undertook geochemical sampling, magnetometer traversing and percussion drilling.

The structure was mapped as three concentric ridges. The innermost was shown as silty shale and shaly siltstone with an iron-rich weathering surface of possible conglomerate or agglomerate. This inner zone also contains patchy outcrops of concretionary ironstone described as having alternating compact and porous layers. The latter has cavity fillings of chalcedony and dolomite rhombs. The inner area also contains a 40 m x 10 m outcrop of brecciated and silicified nodular grey limestone. None of these lithologies were like the Redbank pipes and, collectively, were also atypical for Cambrian Top Springs Limestone and/or Cretaceous sedimentary rocks. The middle ridge of up to 5 m relief consists of siltstone and shale which dip at 10° to 30° towards the centre. This is overlain by a well bedded iron-rich conglomerate or breccia, again unlike Redbank. The outer ridge is up to 15 m high and is only present on the southern half of the structure. It consists of siliceous siltstone and highly micaceous to calcareous sandstone. The sandstone is brecciated in part. The outer ridge dips consistently away from the centre of the structure. Further from the centre, particularly on the eastern flank of the outer ridge, spheroids of barite from 2 cm to 40 cm across were found sitting on what was presumed to be Cretaceous siltstones. Dampier proposed two explanations for the Spear Creek structure. It might be the result of a forceful upward movement to give the outward dips of the outer ridge, followed by collapse to give

the inner inward dips. Limestone was then deposited in the central crater. Alternatively, Cretaceous clastic rocks might have collapsed into a doline in the Cambrian limestone. Dampier surface sampled the area, including intensively within the structure. Highest AAS values returned were Cu 470 ppm, Pb 90 ppm, Zn 2500 ppm, Ag 0.5 ppm, Co 260 ppm, Mn 9900 ppm, Ba 58.2% (from a barite nodule). Base metal assays were repeated by XRF to avoid any affect of high barium. It is important to note that some anomalous base metals were found outside the structure.

Three kilometre-long north-south and east-west cross lines of magnetometer data were collected over the structure. Both these showed a magnetic low coincident with the centre of the structure.

Three percussion drillholes totalling 141 m were drilled. SPC 1 was targeted on the middle ridge, SPC 2 was sited lightly outboard of the central ridge and SPC 3 was drilled directly into the very centre of the structure. SPC 1 intersecting only micaceous siltstone and variably calcareous claystone to 39 m and was terminated prematurely when circulation was lost. SPC 2 reached 51 m in similar claystone. The lithologies intersected in the centre of the feature were quite different. Ferruginous impure limestone was logged from 10 m to 42 m. This became more siliceous to total drillhole depth of 51 m. The best downhole geochemical results from Analabs AAS were Cu 60 ppm, Pb 180 ppm, Zn 1450 ppm, Mn 4100 ppm and Ba 4000 ppm from separate samples. Ag was almost always below the 0.5 ppm level of detection. Neither the downhole samples nor surface samples from within the structure were assayed for Ni. However some unlocated reconnaissance rock chip samples from within the structure (their ADL series) were assayed by AMDEL. Two of five samples returned in excess of 500 ppm Ni and both had >1500 ppm Zn.

Petrographic studies of samples from within the structure revealed several unusual lithologies. Locally very abundant siliceous spheres averaging 0.1 mm in diameter were noted in a kaolinitic siltstone (samples W 4/16 and W 4/25). The spheres were interpreted as radiolaria or diatoms. Sample W 4/25 also had goethite spheres, presumably replacing silica. Sample W 4/26 was also atypical. It was described as a massive, compact structureless goethite with numerous fractures infilled with barite and believed to be a fragment from a vein. Barite veins are concentrated around the outer circumference of the structure and there are few examples of ironstone hosting barite veins. Samples SG 12 and 12a are described as ironstone found outside the structure itself. SG 12 was extensively brecciated with many subparallel fractures now filled by kaolinite and opaline silica. The fracturing was of such an extent that only long thin goethite slivers remain. Sample 12a, also an ironstone, contains barite and siliceous spheres similar to the ?radiolaria described above.

EL 2385 was relinquished because the levels of copper-lead-zinc geochemistry were considered insufficient to warrant further work. Their work is summarised in [Dampier Mining Pty Ltd \(1981\)](#).

### **Work by CRA Exploration**

CRA Exploration Pty Ltd (CRA) held EL 4237 over the Spear Creek structure from June 1983 until June 1985. CRA was initially attracted to the area because of the detection of single microdiamonds in two of five loam samples within the Spear Creek structure. Follow-up sampling resulted in the detection of a single chromite in a drainage sample from the structure and five more microdiamonds in loam samples from within the EL. In September 1985, CRA was granted MCN 980 to MCN 983 to give them secure tenure for up to another ten years while they continued to investigate the Spear Creek structure as a possible kimberlite pipe. CRA's work is documented by [Colliver \(1984, 1985\)](#) and [Colliver and Bubner \(1987\)](#).

Early work on EL 4237 included a detailed ground magnetic survey. Readings were taken over the structure at 10 m spacing on 50 m to 100 m spaced lines. An equidimensional magnetic low of 50 nT corresponded with the centre of the structure. The outer rim of the topographic feature was a relative magnetic high, creating an annular magnetic high with a magnetic low at its centre.

The whole structure was geologically mapped at 1:5000 and the centre was mapped at 1:2000. An interpreted cross-section that included drillholes was produced. The reports contain little commentary on the maps. However, these maps provide much more detail than the earlier Dampier work and allow some extremely useful insights. Firstly, the very core of the structure was mapped as “highly ferruginised . . . brecciated ironstone” which occurs nowhere else. This was surrounded by, and intercalated with unbedded vuggy, silicified limestone. Secondly, the inner limestone and ironstone core was surrounded by concentric beds at 100 m, 225 m to 300 m and 350 m to 450 m from the centre. These are herein designated as (i), (ii) and (iii). Of these, (i) is mapped as “possibly baked” “chippy” (ie fractured or highly fissile) siltstone overlain by conglomerate and polymict breccia which dip radially outwards, whereas (ii) is comprised of the same breccia overlain by a repeat of the “possibly baked” “chippy” siltstone and another, possibly unconformably or structurally overlying, unbedded breccia unit only exposed on the southsouthwest of the structure; all of unit (ii) except the unbedded breccia dips inwards inferring that there is a concentric ring syncline between (i) and (ii). While (iii) appears to dip mostly outwards, it is in fact a concentric anticline around the structure. It is mapped as less disturbed, but still locally brecciated, siltstone and micaceous sandstone with barite veining. Thirdly, CRA mapped and/or interpreted 18 radial faults through the structure. In fact, all faults shown on their map are radial. This structural configuration is critical in understanding the structure.

Further work by CRA on EL 4237 included the drilling of DD83SC1 about 70 m east of the centre of the structure. This drillhole cored cavernous steeply-dipping limestone and disturbed to highly brecciated calcareous and silicified limestone to 86 m. Contrary to the previous reports of “radiolaria”, no material suitable for identification by palynology could be obtained. This unit was underlain by 11.3 m of supposedly flat-lying partly silicified limestone. CRA interpreted the top 86 m as possible Cretaceous and the “undisturbed” limestone as Top Springs Limestone. However, the detailed log for the hole indicates that this lower unit also contains silicified siltstone from 95.5 m to 97.8 m which is described as having bedding at 65° to the core axis (ie dipping 25°) and having brittle fractures. This was underlain by a conglomerate/agglomerate with bedding at 10° to 20°. These dips are atypical of the area. The agglomerate is underlain by a 16 m section of vesicular flow basalt now referred to the Helen Springs Volcanics (originally called Peaker Piker Volcanics and now recognised as part of the Kalkarindji continental flood basalt province). The volcanics were underlain by indurated dolomitic sandstone and limestone of the McArthur Group. Traces of native copper and galena were observed, showing that the base metal mineralisation is not confined to the younger rocks. An attempt to drill a fence of four drillholes across the structure during 1983 had to be abandoned due to technical difficulties. In 1984, another attempt was made to complete the planned fence of drillholes. This too was abandoned after PD84SC2A, spudded 50 m to the west of the centre of the structure, lost circulation at 66 m in cavernous formation (presumably the same limestone first intersected at 15 m). In August 1986, drillhole DD86SC2B was successfully completed to 150 m as redrill of the unsuccessful DD86SC2A. DD86SC2B is located 60 m northwest of the centre of the structure. It cored cavernous and silicified limestone and calcareous siltstone to 102 m, underlain by 11 m of weathered and altered basalt. Laboratory measurements of the magnetic properties of the basalt show magnetisation to be mostly induced (Koenigsberger ratio 0.17-0.26) with susceptibilities ranging 0.059-0.09 SI units and a large variation in the inclination of the magnetic vector. These data were regarded as inconclusive in explaining the observed magnetic response over the structure. As in DD83SC1, 110 m away, this basalt was underlain by almost flat-lying McArthur Group sedimentary rocks.

Geochemical assays of surface rock chips gave some unusual results including percent levels of Ti in both a sandstone and a breccia. A “concentrically banded ironstone” (sample 964389) yielded 2150 ppm Zn, 415 ppm Ni, 1250 ppm Ti and 335 ppm Cu.

Surface samples 964384 to 964389 were collected as a representative suite of sandstone, limestone, siltstone, breccia and ironstone (Colliver 1984). Petrological studies (Colliver 1985) of these samples described many as having relict vitric and lapilli-like textures and embayed quartz similar to volcanoclastic grains. The thin section descriptions also suggested

that some lithologies sampled in outcrop were tuffaceous, but this was not supported by drill core descriptions. The thin section descriptions of surface samples seemed inconsistent with their field descriptions and their mapped lithologies.

Single microdiamonds were supposedly recovered from two half-core samples in DD83SC1 and five were recovered from another sample. No kimberlitic indicator minerals whatsoever were found. The microdiamonds were described as pale yellow, with light frosting and an elongate cubic-octahedron form. Their identification proved problematic. It was eventually concluded that they were most likely fragments of diamonds from the drill bit. Notably, the diamond saw used to cut the core was overlooked as a source of contamination. No attempt was made to analyse the remaining core to negate any possible contamination. Nor did contamination of the core samples explain the microdiamonds found in surface loam samples within the structure or those in creeks draining from it.

In May 1986, two INPUT EM traverses were flown over the Spear Creek structure and a highly conductive zone was found to coincide exactly with the structure as expressed at the surface. The drillholes did not provide any solid evidence as to the source of the conductivity anomaly.

However, the drillholes had demonstrated that a presumably continuous, but deformed, sheet of basalt underlies the structure and that any possibility of a preserved diatreme, volcanic plug, or kimberlite pipe within the structure could be discounted. CRA could only explain the INPUT signature as saline groundwaters in a cavernous collapse structure. The company concluded that the structure was either a doline in the Top Springs Limestone (containing saline water unknown from elsewhere) and that this happened to exactly coincide with a locally thinner basalt sheet (to account for the negative magnetic anomaly), or that a small post-Cambrian diatreme or diaper had penetrated the basalt sheet and then withdrew to create slumping of unconsolidated Cretaceous sediment. The former was the most favoured model.

### **Work by BHP**

During the mid 1990s, BHP Minerals Pty Ltd (BHP) undertook regional exploration of several contiguous ELs as part of their McArthur River Project. Their exploration philosophy included examining circular structures as possible kimberlite pipes and using EM to search for Cu-Pb-Zn and Mn. This included a 1995 PROTEM line called Traverse 6 across the Spear Creek structure in their EL 7854. This survey was ostensibly to investigate the possibility of significant base metal mineralisation in the McArthur Group. The PROTEM failed to identify any significant “basement” conductors at the depth of the McArthur Group rocks. EL7854 was also examined for its manganese potential. 4 RC holes (218m) were completed outside the structure for manganese but no significant values were obtained. Trap site samples were taken from downstream of the Spear Creek structure. The site of a previously reported chromite was resampled. All the BHP samples were negative for microdiamonds and diamond indicator minerals. The BHP work is summarised by [Paterson \(1996, 1997\)](#).

### **Work by NTGS**

Contrary to the original drill log interpretations of Colliver (1984) and Colliver and Bubner (1987), palaeontological analysis (Kruse 1991) has established that the entire cored supra-basalt interval in drillholes DD83SC1 (and by analogy, DD86SC2) is Top Springs Limestone. The fauna denotes a widespread assemblage indicative of the Middle Cambrian sequence 1 (Ordian). No Cretaceous or younger rocks are involved.

### **Observations**

The previous interpretations of exploration data cannot explain the following:

- elevation of the Top Springs Limestone around the rim of the structure to a higher topographic level than the surrounding area
- an equidimensional magnetic low of 50 nT that corresponds with the centre of the structure while the outer rim of the topographic feature is a relative magnetic high, creating an annular magnetic high with a low at its centre

- an apparent circular depression in, or thinning of, the volcanics based on geophysics, exactly coincident with the surface feature
- steeply dipping, highly disturbed and brecciated bedding especially towards the centre of the structure
- concentric bedding, some of which dips in and some out, making the surface structure a series of concentric ring folds
- a well developed radial fault pattern
- rocks of lithologies that apparently came from within the structure now found further outboard and outside the structure itself
- evidence of locally pervasive brittle deformation including reduction of rock to long thin slivers
- the unusual association of base metal mineralisation and problematic microdiamonds in the absence of any kimberlitic indicator minerals
- iron-rich lithologies including conglomerates and breccias that apparently only occur in the near surface within the structure itself; the most intensely ferruginous and brecciated ironstone lithology only being present at the very centre of the structure
- anomalous geochemistry including high Ni and Ti levels that cannot have been sourced from sediments or the underlying volcanic rocks
- the presence of locally abundant 0.1 mm diameter siliceous spheres that were not detected in palynology

Some of these same observations were also made by Peter Haines in the early 2000s. Haines *et al* visited the structure in 2000 and also examined drill core and thin sections.

### **Interpretations**

The previous interpretations of a doline in Top Springs Limestone or a deflated piercement structure such as a withdrawn diatreme are not consistent with the above observations. [Haines and Rawlings \(2002\)](#), [Haines \(2004\)](#) and the present author all suggest that the Spear Creek structure is a possible impact site. While unequivocal evidence such as shatter cones, melt breccia or impact microtextures has yet to be identified, it best explains the geophysical signature and the existence of a complex multi-ring concentrically-folded circular structural feature which would not normally be associated with intrusion or solution collapse. That is not to say that solution collapse has not affected the structure; it has; as it does any exposed limestone in this area. The magnetic signature of the Cambrian basalt under the structure could be explained by a variation in either depth from surface or thickness or both. This is compatible with the impact theory; solution collapse is not. The radial faults that extend through all the units mapped on the surface are also consistent with an impact feature, as are the unusual breccias and the more intense subsurface deformation towards the centre of the structure. The pervasive brittle fracturing is more consistent with an impact origin than intrusion or solution collapse. The tiny siliceous spheres that were called radiolaria might be impact spherules. The concentration of highly ferruginous lithologies at the centre of the structure may even represent the weathered residue of an iron meteorite. A meteorite may also explain some of the unusual geochemistry such as enrichment in Ni and Ti. While, it is tantalising to think that at least some of the microdiamonds found in the structure might be of impact origin, this is unlikely for the microdiamonds supposedly recovered from the drilling given the nature of the host rocks. Thus, the scenario presented here is that Spear Creek structure resulted from the impact of an iron meteorite into Cambrian Top Springs Limestone or younger strata. The impact penetrated far enough to affect the volcanics, either creating a thinning under the surface feature and a corresponding annular bulge or, more likely, simply folding and faulting the basalt into a subsurface crater shape. All the mapped and drilled material in the structure is now interpreted to be of Cambrian age and separate Cretaceous sedimentary rocks or younger rocks do not need to be involved.

### **Implications for Mineralisation if it is an Impact Structure**

If the Spear Creek structure is of impact origin, there are several implications for exploration.

It obviously shows that not all circular features in this area are necessarily related to either a Redbank-style breccia pipe or an intrusive, kimberlitic or otherwise.

The first proposition is that the rather insignificant base metal occurrences (which extend into the underlying McArthur Group) and the microdiamonds are merely coincidental and were discovered simply because the explorers chose to focus on a feature that provided outcrop where otherwise there is none.

Alternately, the assumption that impact played some role in the mineralisation, presents several possibilities. Conceivably, the base metal mineralisation could have been produced or enhanced either as a function of impact (syn- or pro-genetic) or as a result of a local hydrothermal cell established within the structure (epigenetic). There are well documented cases of such mineralisation associated with other impact structures (eg Grieve and Masaitis (1994), Hawke (2004), Grieve (2005), Pirajno (2005), Reimold *et al* (2005) and Hawke and Dentith (2006)).

## References

- Colliver IC 1984. Annual report on exploration licence 4237, Kilgour NT, year ending 19 June 1984. CRA Exploration Pty Ltd. Northern Territory Geological Survey Open File Company Report CR1984-0139.
- Colliver IC 1985. EL 4237, Kilgour, NT, final report to 7 June 1985. Northern Territory Geological Survey Open File Company Report CR1985-0262.
- Colliver IC and Bubner GJ 1987. Spear Creek MCs N 980-983, final report for period ending 18 November 1986 (dated January 1987). Northern Territory Geological Survey Open File Company Report CR1987-0002.
- Dampier Mining Pty Ltd 1981. Exploration Licence 2385, Spear Creek, Northern Territory, Final Report. Northern Territory Geological Survey Open File Company Report CR1981-0265.
- Grieve RAF 2005. Economic natural resource deposits at terrestrial impact structures. Geological Society, London, Special Publications 248, 1-29.
- Grieve RAF and Masaitis VL 1994. The economic potential of terrestrial impact craters. *International Geology Review* 36 105-151. American Geological Institute.
- Haines PW 2004. Impact structures, possible impact structures, and circular features of uncertain origin in the Northern Territory (unpublished NTGS report).
- Haines PW and Rawlings DJ 2002. The Foelsche structure, Northern Territory, Australia: an impact crater of probable Neoproterozoic age, *Meteoritics & Planetary Science*, 37, 269-280.
- Hawke PJ 2004. The geophysical signatures and exploration potential of Australia's meteorite impact structures. Thesis for Doctor of Philosophy at the University of Western Australia, School of Earth and Geographical Sciences.
- Hawke PJ and Dentith MC 2006. The exploration potential of Australia's meteorite impact craters. ASEG extended abstracts 2006 (1).
- Kruse PD, 1991. Cambrian fauna of the Top Springs Limestone, Georgina Basin. *The Beagle, Records of the Northern Territory Museum of Arts and Sciences* 8, 169-188.
- Paterson TA 1996. Partial relinquishment report, Walhallow Project, ELs 7854 and 7855, period ending 10 December 1995. BHP Minerals Pty Ltd. Northern Territory Geological Survey Open File Company Report CR19967-0212.
- Paterson TA 1997. Final report for the Walhallow project ELs 7854 and 7855, McArthur Basin, BHP Minerals Pty Ltd. Northern Territory Geological Survey Open File Company Report CR1997-0079.
- Pirajno F 2005. Hydrothermal processes associated with meteorite impact structures: evidence from three Australian examples and implications for economic resources. *Australian Journal of Earth Sciences* 52, 587-605.
- Plumb KA and Rhodes JM 1964. Walhallow 1:250 000 geological series explanatory notes. Bureau of Mineral Resources, Canberra.
- Reimold WU, Koeberl C, Gibson RL and Dressler BO 2005. Economic mineral deposits in impact structures: a review IN Koeberl C and Henkel H (ed) *Impact Tectonics*. Springer, Berlin, Germany, 479-552.