CORE Geophysics and Drilling Collaborations
Round 11
2018

Cow Lagoon
EL26831

Project Title Holder: Sandfire Resources NL
Project Operator: MMG Exploration Pty Ltd

Map sheets
1:250 000 Bauhinia Downs SE5303
1:100 000 Batten 6065

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SUMMARY

Diamond drillhole NB18DD050 was drilled between the 21st August and the 3rd September, 2018 as part of Round 11 of the Northern Territory Geophysics and Drilling Collaborations Program.

The Cow Lagoon prospect is located 32 km north north-west of the McArthur River Mine, just north of the 2002 Geoscience Australia seismic line. The rationale for the drillhole was based on a favourable structural position for epigenetic mineralisation indicated by the fold and thrust seismic interpretation and an anticline in NTGS surface mapping. Nearby historical exploration has focused on the eastern side of the thrust, encountering thick Lynott Fm sediments and a deep facies Barney Creek Fm, both exhibiting gas shows. The presence of hydrocarbons and a favourable structural setting on the western side of the thrust, with potential for carbonaceous strata of the Lynott Fm and Barney Creek Fm, made this an attractive target for Century-style epigenetic base metal mineralisation.

NB18DD050 is interpreted to have drilled through thin cover into Lynott Formation sediments before passing through a 20 m thick interval of Reward Dolomite and into Barney Creek Formation. The Barney Creek Formation became strongly carbonaceous and variably pyritic from 369 m onwards and was commonly brecciated. Occasional sphalerite blebs were observed from ~190 m to ~600 m depth and were often associated with veins, concretions and nodules. The hole was terminated at 695 without testing the base of Barney Creek Formation. The decision to terminate the hole was based on the interpretation that the hole was no longer drilling down stratigraphy but rather alternately drilling down a steep anticlinal limb and into the brecciated hinge of the fold.

NB18DD050 provides supporting evidence towards the potential for epigenetic mineralisation in the Cow Lagoon area. The presence of texturally late blebby sphalerite and evidence for high volumes of fluid flow within carbon rich pyritic lithologies is encouraging. NB18DD050 was unable to test the entire Barney Creek Formation due to local structural complexity and potential still exists in the area.
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INTRODUCTION

MMG’s North Batten Joint Venture with Sandfire Resources comprises eleven granted exploration licences totalling an area of 3164 km².

The NTGS co-funded Cow Lagoon drillhole NB17DD050 is located on McArthur River Station near the northern boundary of EL26831 (Figure 1). The Cow Lagoon prospect is located 32 km from the McArthur River Mine and is accessible from Ryan’s Bend Road and a track network that has been used by MMG, Sandfire and Teck over the last decade to access the area. The drillhole required approximately 800 m of new track to be cleared.

MMG submitted an application to the Aboriginal Areas Protection Authority (AAPA) for heritage clearance of the proposed work area. The heritage clearance authority certificate (C2018/008) was granted on the 12th of February 2018.
Figure 1. Location of NB17DD050 with respect to MMG tenements, NTGS 250K geology and historical drilling.
REGIONAL CONTEXT

The McArthur Basin (c.1860 – c.1500 Ma) is exposed over an area of approximately 180,000 km² in the north-eastern Northern Territory (Ahmad et al. 2010). MMG’s ground holding covers a large portion of the north-south trending Batten Fault Zone in the south-eastern section of the wider McArthur Basin. Mid-Proterozoic intracratonic basin fill of up to ~10 km of exposed thickness is comprised of rift-phase Tawallah Group and sag-phase McArthur Group rocks, with additional later ‘stacked’ basins of mid- to late-Proterozoic Nathan and Roper Groups. The Batten Fault Zone is bound by mid-Proterozoic platform benches of the Wearyan Shelf to the east and Bauhinia Shelf to the west and is onlapped by the Cambrian Georgina and Carpentaria Basins. It unconformably overlies Palaeoproterozoic metamorphosed and deformed rocks of the Pine Creek Orogen to the west, Murphy Inlier to the south and Arnhem Inlier to the northeast (Ahmad et al. 2010).

The world-class SEDEX-style McArthur River Zn deposit has a total resource of 144 Mt at 11.2% Zn, 4.8% Pb and 48 g/t Ag (Ahmad et al. 2010). It is hosted in a pyritic carbonaceous shale sub-basin accommodated at the intersection between the basin-scale north-northwest-striking Emu Fault Zone which lies at (but does not necessarily define) the eastern edge of the Batten Fault Zone and the less pronounced east-west striking Bald Hills structural trend. The gently-dipping stratiform ore body occurs as eight separate lenses at the base of the Barney Creek Formation (1640 Ma) of the McArthur Group.

PREVIOUS EXPLORATION

The Cow Lagoon prospect is located north of the HYC depression and east of the Emu Fault, close to the 2002 Geoscience Australia seismic line. The seismic line helps inform a favourable structural position that makes this an interesting target for base metal mineralisation.

Historical drilling at nearby prospects (outlined below) is encouraging in showing thick accumulations of amenable carbonaceous, pyritic shale-rich stratigraphy (i.e. Barney Creek Formation and Caranbirini Member).

Yalco
The Yalco prospect has been explored by several companies over the past 20 years including Rio Tinto, MIM and Sandfire Resources. MMG has also drilled several holes at Yalco including NBDD005 (2014) and NBDD048 (2017).

The most comprehensive drilling campaign at Yalco was undertaken by Sandfire Resources who drilled 9 holes (BD-16 to BD-24) testing either IP or aEM geophysical targets. Holes BD-17, 18, 19, 20 and 21 tested the ~4 km strike of a northeast trending aEM feature, exhibiting similarities to one encompassing the HYC deposit to the southeast (Sandfire 2009 Annual Report). While no obvious occurrences of bedded Pb-Zn mineralization were observed, the program successfully intersected the favoured Barney Creek horizon and adjacent stratigraphic units in all the holes. Hole BD-19 had the most complete representation of all units, including >50 metres of the black pyritic BCF horizon. Holes BD-22, BD-23 and BD-24 extended the exploration to the north.

Ballyhoo
The Ballyhoo Prospect contains three diamond holes drilled by Rio Tinto in 2002. Each hole was collared in a separate structural domain. DD01BAL01 is the deepest and was interpreted to have terminated in the Yalco Formation at approximately 410m. DD01BAL01 contains 108m of variably pyritic and dolomitic shale interpreted to be Caranbirini Member thrust above the Yalco Fm. DD01BAL02 contains 128m of variably pyritic and dolomitic shale interpreted as Caranbirini Member. DD01BAL003 was collared too high in the sequence and was drilled entirely in Hot Springs Member. No significant base metals were intersected in these holes.
Yalco West
NBDD016 was drilled by MMG in 2015 to test a discreet TEMPEST and SMARTTEM conductive anomaly between two mapped northwest trending structures in a recessive zone of Barney Creek Formation west of Yalco. The hole intersected a tectonic fault zone, with the upper 235m of the hole comprising intensely oxidised and bleached rock making stratigraphic interpretation difficult. Saline groundwater and/or high clay content in the fault zone was interpreted as the likely source of the conductive EM response.

Alice
The Alice prospect was first tested by Sandfire Resources in 2011 with 4 RC holes to test a Pb geochemical anomaly in Balbirini dolomite of the Nathan Group and returned 4.0m at 5330ppm Pb in 11BLRC0142: 12 – 16m (downhole width). It was followed up by Sandfire with two diamond holes (12BLDD0022 and 12BLDD0023) in 2012. 12BLDD0023 intersected a sulphide-bearing chloritic siltstone responsible for the elevated Pb and 12BLDD022 returned 8m @ 954ppm Pb and 298ppm Zn: 70 – 78m (downhole width).

Cow Lagoon West
BRC1 & 2
In 1995, Normandy Exploration conducted a heli mag survey but concluded that it did not indicate any subtle structures in the area. Two RC holes were drilled (BRC1 & BRC2) to test the Caranbirini Member but due to high water flow, both holes were terminated earlier than planned prior to intersecting the target unit however they considered these holes a sufficient test of prospectivity in the top 100m.

82_5
Amoco Australia Petroleum drilled hole 82_5 to 455m in 1982 to test the source rocks and reservoir potential of the Lynott Formation. The hole intersected Donnegan member to 105m and Hot Springs to end of hole.

Cow Lagoon1
Armour Energy drilled petroleum well Cow Lagoon1 in 2012 to 1804.9m (true vertical depth) commencing in the Lynott Formation and ending in the Leila Sandstone of the Umbolooga Subgroup. Several gas shows were reported in the mud logs in the Lynott, Reward and Barney Creek Formations and the reservoir quality was considered good.

EXPLORATION CONCEPT

Sediment-hosted zinc sulphide deposits across the North Australia Zinc Belt, including McArthur River Mine, Century Mine, Lady Loretta and George Fisher-Hilton, all have key differences that distinguish them compositionally, lithologically, genetically and temporally from one another. MMG’s Geoscience team believes there is still potential to generate exploration target areas within existing ‘mature’ terranes.

The Century zinc-lead-silver deposit is located within the Lawn Hill Platform and the strataform sulphide mineralisation is hosted within shales and siltstones of the Lawn Hill Formation with similarities to other Zn-Pb deposits in North Australia. Broadbent et al. (1998) proposed a late diagenetic replacement model to explain the full range of deposit features, including the intimate association of pyrobitumen and sphalerite. In this model, metal bearing fluid from the Termite Range Fault interacted with locally derived hydrocarbons to precipitate sulphides. There is potential for a similar late diagenetic process of ore formation to occur within the Batten Fault Zone.

The 2002 Geoscience Australia (GA) seismic line crosses the Cow Lagoon prospect ~1 km south of the proposed collar location. The GA interpretation of the seismic data indicates the area west of the Emu Fault is dominated by west-dipping faults of a major thrust belt which propagated eastward after the deposition of the Roper Group (Figure 2). The proposed timing and scale of this fold and thrust event suggests there is potential for epigenetic base metal mineralisation within the Batten Fault Zone along these structures (Rawlings et al 2004).
Historical exploration has predominantly focused on the eastern side of the thrust, encountering thick Lynott Fm sediments and a deep Barney Creek Fm, both exhibiting gas shows. Armour Energy encountered several hydrocarbon shows in the CowLagoon1 well, 5.7 km to the south east of MMG's Cow Lagoon target (Figure 1). Gas shows were located in the Lynott Formation, Reward and Barney Creek Formations with the first at ~394m in undifferentiated Lynott Formation (CowLagoon1 Well Completion Report). Untested potential remains on the western side of the thrust.

The NTGS 1:100K surface mapping at Cow Lagoon indicates an anticline in the Hot Springs Member of the Lynott Fm (Figure 3) adjacent to a thrust propagation fault as interpreted from the seismic line. This thrust coupled with the mapped anticline represents a favourable structural position for epigenetic mineralisation.

Carbonaceous shales are known to occur in the Caranbirini Member, stratigraphically below the Hot Springs Member and in the Barney Creek Fm, stratigraphically below the Lynott Fm.
MMG undertook field mapping in 2018 and confirmed the presence of the anticline shown on NTGS maps. Structural measurements were collected in the vicinity of the collar location (within 500 m) and are plotted on the stereonet show in Figure 4 below. Field measurements suggest that the limbs may be dipping at a steeper angle than mapped on NTGS geology map sheets. The stereoplot shows the axial trend to be roughly north west-south east with the NE limb dipping at a much steeper angle than the SW. The drill hole was planned at a dip of -80° and an azimuth of 140° to avoid drilling down dip in the NE limb.

Figure 4: Stereoplot plot showing structural measurements taken in the vicinity (within 500 m) of the NB18DD050 collar location.
 DETAILS OF THE COLLABORATIVE PROGRAM

Drilling

NB18DD050 was drilled by Titeline Drilling during 22nd August – 3rd September and was terminated at a depth of 695.0m. Details are listed in Table 1 below. A summary log is presented in Table 2 below.

Table 1. NB18DD050 details

<table>
<thead>
<tr>
<th>Hole ID</th>
<th>Rig Type</th>
<th>Azimuth</th>
<th>Dip</th>
<th>Easting (GDA94)</th>
<th>Northing (GDA94)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB17DD050</td>
<td>UDR200D</td>
<td>140°</td>
<td>-80°</td>
<td>600552</td>
<td>8209909</td>
</tr>
<tr>
<td>From (m)</td>
<td>To (m)</td>
<td>Hole Type</td>
<td>Hole Diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td>2.7</td>
<td>Mud</td>
<td>HWT-PCD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>122.5</td>
<td>DD</td>
<td>HQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>122.5</td>
<td>695.0</td>
<td>DD</td>
<td>NQ2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sampling

Sampling of NB15DD050 consisted of 644 core samples analysed for 48 elements plus 71 QA/QC samples (standards, blanks and duplicates). Sample length was nominally 1 m (minimum 0.35 m, maximum 1.73 m). Standards, blanks and duplicates were each inserted routinely 3 times per one hundred samples. Standards and blanks consisted of certified reference materials including pouches of finely crushed rock and of coarse chips. Duplicates were sampled by cutting half-core in half again to obtain two quarter core samples, leaving half-core in the tray. Each quarter was bagged separately.

Analysis was completed at ALS in Townsville using their 48-element ME-MS61 method consisting of a fine crush followed by a four-acid digest and ICP-MS/AES finish.
RESULTS AND INTERPRETATION

Complete drillhole logging, surveying and assay data are included in the appendices. This section summarises the important results in terms of lithology, mineralisation, assays and interpretation.

Lithology

Detailed lithological logging of NB18DD050 is included as Appendix 6 and is summarised in Table 2 below.

Table 2: Summary log of NB18DD050.

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Interpreted stratigraphy</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8.5</td>
<td><strong>Cover</strong></td>
<td>Highly weathered oxidised clayey saprolite with conglomeratic intervals containing rounded to sub angular clasts.</td>
</tr>
<tr>
<td>8.5</td>
<td>24</td>
<td>Pmn (Pmnh?)</td>
<td>Siltstone and dolosiltstone with crypt algal textures and late carbonate veining. Folded and fractured, broken core. Some limonite staining on fracture surfaces.</td>
</tr>
<tr>
<td>24</td>
<td>136</td>
<td>Pmnc</td>
<td>Siltstone interbedded with shale and dolomitic siltstone, in places brecciated and veined with carbonate and silica. Carbonate-filled dewatering structures common throughout.</td>
</tr>
<tr>
<td>136</td>
<td>157</td>
<td>Pmx</td>
<td>Siltstone and dolomitic siltstone with coarse-grained sandstone at base.</td>
</tr>
<tr>
<td>157</td>
<td>369</td>
<td>Pmq</td>
<td>Interbedded siltstone and dolosiltstone with crossbedded horizons of fine sandstone. Interbeds of intraclastic breccia and poorly sorted conglomerate dispersed throughout. Early concretions and later spherical sil-cb nodules common throughout.</td>
</tr>
<tr>
<td>369</td>
<td>593</td>
<td>Pmq</td>
<td>Carbonaceous shale with interbeds of siliclastic and dolomitic siltstone. Common chaotic clast supported breccia, with angular clasts closely juxtaposed against each other. Very pyritic in places. Occasional sp blebs associated with silica alteration and nodules.</td>
</tr>
<tr>
<td>593</td>
<td>630</td>
<td>Pmq</td>
<td>Chaotic breccia zone of carbonaceous shale, siltstone and dolosiltstone clasts. Clast supported with sub-rounded to angular clasts usually between 1 and 15 cm wide and occasional zones of bedded material. Pyritic and carbonaceous shale-dominated from 601 m with proportion of clasts to matrix decreasing with depth.</td>
</tr>
<tr>
<td>630</td>
<td>695</td>
<td>Pmq</td>
<td>Carbonaceous shale, siltstone and dolomitic siltstone with common chaotic brecciation. Less pyritic than overlying lithologies.</td>
</tr>
</tbody>
</table>

Mineralisation & Assays

Occasional sphalerite blebs were observed from ~190 m to ~600 m depth and were often associated with veins, concretions and nodules. Sphalerite blebs are clustered, ~1mm in size and straw yellow (low-Fe sphalerite).

The epigenetic nature of sphalerite mineralisation is encouraging and the volumes of fluid flow lend weight to the theory that this area is prospective for epigenetic mineralisation. Texturally there doesn’t appear to be a correlation between pyrite and sphalerite, however the very fine grained pyrite may be intergrown with microscopic sphalerite.

The highest assay was 707 ppm in one sample (506 – 507 m) within pyritic Barney Creek Formation. The full assay results are reported in Appendix 5.
Interpretation

NB18DD050 is interpreted to have drilled through thin cover into Lynott Formation sediments before passing through a 20 m thick interval of Reward Dolomite and into Barney Creek Formation. The Barney Creek Formation in this hole becomes strongly carbonaceous and variably pyritic from 369 m onwards and is commonly brecciated.

The Barney Creek Formation (Pmq) intersected in NB18DD050 consists of two distinct parasequences. The first parasequence contains interbedded siltstone, dolomitic siltstone and carbonaceous shale as well as irregularly dispersed sedimentary breccias. Mottled patchy carbonate alteration is common within this interval and occasionally obscures primary bedding textures. In some zones carbonate and silica have selectively replaced bedding and clasts in sedimentary breccias and conglomerates (see Figure 5).

![Figure 5](image)

**Figure 5.** A) Selective sil-cb replacement/nodule growth in coarser beds at 275.5 m. B) Silica-replaced bed at 277 m. Quasi-colloform texture to silica banding. C) Carbonate replacing clasts in sedimentary breccias at 280 m. D) Selective bedding and clast replacement at 301.75 m.

Down-hole in the underlying parasequence there is an increase in carbonaceous shale and Pmq is commonly brecciated. Pyritic shale is common from ~420 m to ~670 m. Pyrite in shale is often finely disseminated but is also concentrated into thin laminations which may suggest replacement of thin, carbonate rich layers within the turbidites (Figure 6C and Figure 6D).

From ~370 m onwards the Barney Creek Formation is commonly brecciated with breccia thickness and intensity increasing with depth. Breccia clast size varies from mm scale to cobble sized shale clasts in a matrix of carbonaceous shale and rarer carbonate rich matrix. In some instances pyrite is observed to be selectively replacing clasts (Figure 6B).
Figure 6. A) Pyrite replacing platey carbonate? clasts in interbedded siltstone at 269.9 m. B) Pyrite replacing clasts in a breccia body at 549.6 m. C) Laminated, pyritic, carbonaceous shale with bedding-parallel calcite vein at 427 m. D) Laminated, pyritic, carbonaceous shale with vein breccia at 497.2 m E) Concretions/nodules in pyritic, carbonaceous shale with sediment warped around their margins at 528.8 m. F) Brecciated, pyritic, carbonaceous shale at 530.4 m.
Tensioal veins, hydobreccias with jigsaw-fit angular clasts and colloform silica infilling voids suggest that open space fill and fluid overpressure processes may have been at play. It is postulated that dilation related to formation of the anticline may have promoted fluid flow into the area which is encouraging for potential epigenetic mineralisation. Silica ± carbonate void fill is often associated with carbon rich ‘bituminous’ material which may indicate some mobilisation of the organic carbon within Barney Creek shales.

**Figure 7.** A) Angular carbonate-silica vein breccia with vugs in laminated siltstone and dolomitic siltstone from 163.7 to 166.4 m. B) Colloform silica with calcite and “bituminous” material in irregular fractures at 292.33 m. C) Jigsaw-fit carbonate vein breccia at 408.7 m. D) Brecciated shale and siltstone clasts in Pmq at 477.2 m. E) Broken carbonate concretions/nodular beds with spherical zoned silica-carbonate nodules in siltstone and dolomitic siltstone at 326 m.
Occasional sphalerite blebs were observed from ~190 m to ~600 m depth and were often associated with veins, concretions and nodules. Sphalerite blebs are clustered, ~1mm in size and straw yellow (low-Fe sphalerite). Figure 8 shows a number of examples of sphalerite blebs in a range of hosts.

The epigenetic nature of sphalerite mineralisation is encouraging and the volumes of fluid flow lend weight to the theory this area is prospective for epigenetic mineralisation. Texturally there doesn’t appear to be a correlation between pyrite and sphalerite, however the very fine grained pyrite may be intergrown with microscopic sphalerite.

Figure 8. A) Vein-hosted sphalerite blebs at 282.53 m. B) Sp blebs associated with carbonate concretions/nodules at 347.9 m. C) Sub-mm sp blebs hosted in silicified carbonaceous shale at 369.9 m. D) Vein-hosted sp blebs at 426.65 m. E) Vein-hosted sp associated with carbonate concretions/nodules with elevated Zn concentration in siliceous groundmass (pXRF) at 457.15 m. F) Pyrite replacing clasts in breccia of siltstone and pyritic shale with mm-scale interstitial blebs of sp at 549.6 m.
The hole was terminated at 695 m in Barney Creek Formation shales without testing the base of Barney Creek Formation. The decision to terminate the hole was based on the interpretation that the hole was no longer drilling down stratigraphy but rather alternately drilling down a steep anticlinal limb and into the brecciated hinge of the fold.

Intersecting brecciated lithologies complicated structural interpretation of the hole while drilling as the bedding angle often couldn’t be confidently measured. In many cases alpha angle measurements were confused by large rotated clasts within a breccia or local parasitic folding. The dominant moderate-to-shallow alpha angle of bedding throughout the hole suggests that the hole drilled mostly through the NE limb of the anticline.

CONCLUSION

NB18DD050 provides supporting evidence towards the potential for epigenetic mineralisation in the Cow Lagoon area. The presence of texturally late blebby sphalerite and evidence of high volumes of fluid flow within carbon rich pyritic lithologies is encouraging.

NB18DD050 was unable to test the entire Barney Creek Formation due to local structural complexity and potential still exists in the area.

REFERENCES

