ANNUAL REPORT ON EXPLORATION LICENCE
8451
VELKERRI PROJECT
20/10/96 to 19/10/97
TANUMBIRINI 1:250,000 SHEET SD53-02
VOLUME 1 OF 1

Commodities: Zinc, Lead, Copper, Silver

Author: M Busbridge

Date: November 1997

Accepted by: [Signature]

Distribution: ■ NT Department of Mines and Energy (1)
□ Normandy Exploration - Darwin (1)
□ Normandy Exploration - Adelaide (2)

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Report No. 22046
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ABSTRACT

The Velkerri Project targets shale-hosted Zn-Pb mineralisation in Middle Velkerri black shales of the Roper Group along the northern margin of the Beetaloo Sub-basin. This basin margin is well-defined by regional gravity data and is the interpreted location of a major NW structure, the Mallapunyah Fault (Accommodation Zone). Metaliferous brines, generated from deeper in the sub-basin, are interpreted to have been expelled towards the basin margins along sandstone aquifers and focussed by north trending structures into structural and chemical traps of carbonaceous black shales of the Velkerri Formation, where precipitation of Zn-Pb sulphides may have occurred.

Most of the licences are covered by Cambrian and younger cover.

Previous work by Pacific Oil and Gas has been acquired and used to provide data on depth of cover and stratigraphy.

Work carried out previously by Normandy has included open file data compilation, regional aeromagnetics surveying, gravity surveying and the drilling of three diamond drillholes.

Much of this exploration was completed on EL's 8463, 8464 and 8465. These tenements were relinquished this year (1997) and the final reports lodged.

Exploration on EL 8451, which was partially reduced earlier this year, has been deferred. Upon granting of EL(A) 9647, the two licences will be explored contiguously by a regional exploration programme of aerial geophysics and bedrock RAB drilling.
1. INTRODUCTION

Exploration Licence 8451 is the remaining granted tenements of the Velkerri Project.

The original group of licences were acquired as a result of a McArthur Basin study undertaken by Dr. J.V. Wright and Mr P.C. Smith. This study employed petroleum style concepts and basin analysis and used a combination of regional magnetic and gravity data, published geological maps and mineral occurrences and any other available open file data to generate targets for base metal exploration. The principal target is a world class shale-hosted Zn-Pb orebody.

The Velkerri Project tenements target the "hanging wall" of the Mallapunyah Fault (Accommodation Zone) on the northern margin of the Beetaloo and Larrimah sub-basins. Metal rich brines, generated from deeper in the Beetaloo Sub-basin, are interpreted to have been expelled northwards along sandstone aquifers and focussed by northerly trending structures into carbonaceous black shale traps, along the basin margin/Mallapunyah Fault Zone where precipitation of Zn-Pb sulphides may have occurred. The potential host rocks for mineralisation are the carbonaceous black shales of the Velkerri Formation (particularly the Middle Velkerri) of the Roper Group of Mesoproterozoic Age.

Outcrop of Proterozoic rocks within the licences is poor due to extensive Cambrian, Cretaceous and Cainozoic cover.

2. LOCATION, ACCESS AND PHYSIOGRAPHY

The licence is located on the Tanumbarini 1:250,000 map sheets (Figure 1).

The Stuart and Carpentaria Highways provide sealed access to the licence. Unsealed station tracks and roads provide additional limited access of these sealed roads.

Much of the area is drained by the upper tributaries of the north-east flowing Arnold and Hodgson Rivers.

Watercourses flow at intervals after rain during the wet season, but are dry for most of the year. Large water-holes survive the dry season.

Three broad physiographic divisions occur within the project area. These are the Barkly-Birdum Tableland, the Gulf Fall and the Daly River Basin.

By far the dominant unit is the Barkly-Birdum Tableland or the Sturt Plateau as it is known in the north-west of the area. It is mainly formed of Cretaceous sediments (which are capped with duricrust and are a remnant of an early Tertiary land surface), and Tertiary sediments (overlying Cambrian limestone). Drainage is poorly developed and has had little modifying effect on the original laterite surface. Creeks are widely spaced, meandering, typically poorly defined and discontinuous. The edge of the Tableland is marked in places by a 30 to 50 metre scarp of lateritized Cretaceous sediments. Scarp-retreat is active in the
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VELKERRI

TENEMENT STATUS

Author: M.J.Bultridge / A.L. Homer
Date: November 1987
Scale: 1:1,000,000

NTD 1381 Fig 1
headwaters of the upper tributaries of the Hodgson River. Elsewhere the margins are bevelled through erosion by streams developed on the downwarp surfaces of the Tableland.

The Gulf Fall comprises the area from which almost all the early Tertiary land surface has been eroded. The Gulf Fall is subdivided into several units, two of which, Mature Gulf Fall and the Nutwood Downs Basin, occur within the project area. Mature Gulf Fall is characterised by broad flat valleys lying between strike-ridges of sandstone which have a relief of about 70 metres. The main rivers are aggrading, and anastomosing stream patterns are developed in the broad valleys. The topography within the Gulf fall is mainly controlled by Proterozoic structure; most of the prominent hills are formed along strike ridges or are developed adjacent to faults.

The drainage basin of the upper Hodgson River (the Nutwood Downs Basin) is about 50 metres above the level of the lower Hodgson River. Drainage is through a narrow gorge of sandstone. The Basin is formed on Cambrian sediments and volcanics and is enclosed by scarps of Cretaceous rocks on three sides. The volcanics form rolling 'downs' type hills and are partly surrounded by rough jointed sandstone.

3. TENURE
Current tenement data is detailed below:

<table>
<thead>
<tr>
<th>EL NAME</th>
<th>EL NO</th>
<th>AREA (km²)</th>
<th>BLOCKS</th>
<th>DATE GRANTED</th>
<th>COVENANT</th>
<th>COMMENT</th>
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<tbody>
<tr>
<td>Arnold</td>
<td>8451</td>
<td>203</td>
<td>63</td>
<td>20/10/94</td>
<td>$16,000</td>
<td>Formerly 500 blocks</td>
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During the year, the Velkerri Project tenement holdings were rationalised, with EL's 8463, 8464 and 8465 being surrendered and 8451 reduced from 500 to 63 sub-blocks

4. REGIONAL GEOLOGY

The licences are located in the north-western McArthur Basin.

The McArthur Basin comprises the principal element of the North Australian Platform Cover, a group of mid-Proterozoic basins which unconformably overlie the Palaeoproterozoic North Australian Orogenic Province.

The basin outcrops over an area of about 200,000 km² and contains up to 12,000m of relatively undeformed and unmetamorphosed sedimentary rocks which are subdivided into four groups or Mega sequences, separated by regional unconformities.

Lowermost is the Tawallah Group, which mainly consists of sandstones with subordinate volcanics, fine-grained clastics and rare carbonates, up to 4,500m thick and about 1700-1800 Ma old.

Overlying this are the McArthur and Nathan Groups which both largely comprise evaporitic and stromatolitic cherty dolostones interbedded with dolomitic sandstone and shale, totalling up to 5,500m. The McArthur Group hosts the
headwaters of the upper tributaries of the Hodgson River. Elsewhere the
margins are bevelled through erosion by streams developed on the downwarp
surfaces of the Tableland.

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VELKERRI PROJECT

SUMMARY STRATIGRAPHIC COLUMN
BEETALOO SUB-BASIN

(after Pacific Oil and Gas).

Note: Informal names used by Pacific are shown in quotation marks.
sandstone and shale, totalling up to 5,500m. The McArthur Group hosts the giant McArthur River (HYC) shale-hosted Zn-Pb-Ag deposit. The McArthur Group is estimated to be between 1600-1700 Ma old.

Uppermost is the significantly younger Roper Group which consists of up to 5,000m of alternating quartz-rich sandstones, siltstones and mudstones, estimated to be at least 1430 Ma old.

The McArthur Basin overlies and is bounded to the north-west, north-east and south-east by basement, but it is concealed by younger basins to the east, north, and south-west. The Beetaloo Sub-Basin is shown in Figure 2 juxtaposed with the major structural and tectonic elements identified in the Tawallah and McArthur Groups, which are attributed to a rift model in which a north-south trough and adjacent shelves are dissected by north-west trending faults and a west-north-west trending basement rise, the Urapunga Tectonic Ridge (UTR). A cratonic sag basin or platform setting is preferred for the Roper Group.

**TENEMENT GEOLOGY/STRATIGRAPHY**

Proterozoic outcrop within the licences is very limited due to extensive Cambrian, Cretaceous and Cainozoic cover.

Pacific Oil and Gas (POG), through their extensive petroleum exploration in the Beetaloo Sub-basin, have developed a detailed understanding of the area. Much of the following is extracted from a paper by Lanigan, Hibbard, Menpes and Torkington (POG), included in the APEA Journal 1994, Volume 34, part one.

The summary stratigraphic section drilled in the Beetaloo Sub-basin by POG, is outlined below and shown in Figure 3. Regional Geology of the tenements (EL 8451, and EL(A)9647) is shown in Figure 4.

**Corcoran Formation:**

This formation comprises upward fining cycles dominated by dark grey to black planar-laminated silty mudstone and claystone with thinly interbedded sandstone and siltstone increasing in abundance up section and passing gradationally into the Bessie Creek Sandstone.

**Bessie Creek Sandstone:**

Predominantly grey, fine to coarse quartz sandstone, massive to planar- and cross-bedded with rare clasts and thin beds of mudstone. Only fully penetrated in the sub-basin in Altree-2, (POG petroleum hole) where it is 442m thick, the Bessie Creek Sandstone demonstrates a dramatic thickening south of the UTR, where it is typically less than 80m thick.

**Velkerri Formation:**

This dominantly mudstone formation outcrops poorly and, apart from a few BMR and Amoco holes, has only been drilled by POG, who informally subdivide it as follows. Thicknesses in the Beetaloo Sub-basin are up to twice those
encountered over the UTR, but similar to Broadmere-1 (Amoco Petroleum hole). Best outcrop of the Velkerri Formation can be seen within EL(A) 9647 (figure 4).

'Lower' Velkerri Formation

Grey (commonly bluish) claystone to silty mudstone, mostly massive to chaotically bedded in the upper half with thin planar-laminated intervals which increase in thickness, frequency and organic content towards the base, dominating the lower half. Thin sandstone interbeds become increasingly common near the base, providing a gradational contact with the underlying formation. The two fully penetrated sections in Altree-2 and Walton-2 (POG petroleum hole) are around 300m thick. The upper contact is usually sharp, often associated with thin carbonate units, and marked by a gamma log kick.

'Middle' Velkerri Formation

Dark grey to brownish black claystone, mudstone and minor siltstone, massive to finely planar-laminated and dominantly organic-rich, comprising three broad pulses mostly ranging 4-7 per cent Total Organic Carbon (TOC), with intervening zones of variable organic content. Complete sections in Altree-2 and McManus-1, and an eroded section in Walton-2, range 280-350m thick. This unit is sharply defined at the base, with a rapid increase in TOC, phosphorous, pyrite and base metals (most notably copper, zinc, molybdenum, nickel and vanadium) marking the rapid transition from the typical disorganised blue claystone of the Lower Velkerri into a massive organic rich rock. Where least affected by maturation, TOC values range up to 12.5 per cent, but generally TOC values are in the range of four to six per cent in the more massive units. Downhole geophysical logs show a characteristic triple peak response to the three massive organic units, the high gamma count reflecting uranium concentrations of up to 15 ppm in the more organic-rich layers.

'Upper' Velkerri Formation

Grey mudstone and siltstone with lesser fine sandstone, planar-laminated to thinly bedded with occasional cross-laminae in sands and silts. Dewatering/loading structures become common towards the top, where the sand proportion is highest. Apart from the basal increase into the 'Middle' Velkerri Formation this interval contains little organic material. The only complete section is 461m in McManus-1.

McMinn Formation:

The established McMinn Formation stratigraphy comprises the Moroak Sandstone Member conformably overlain by the Kyalla Member, which is conformably overlain by the Bukalorkmi Sandstone Member, with a ferruginous oolitic unit, the Sherwin Ironstone Member, occasionally present in the upper Moroak to mid-Kyalla interval. The Bukalorkmi Sandstone Member and the uppermost Roper Group unit, the Chambers River Formation appear to be absent from the Beetaloo Sub-basin, either because they were never deposited or were subsequently eroded by the base 'Jamison Sandstone' unconformity.

Moroak Sandstone Member
It comprises intervals of planar-laminated to thinly interbedded silty mudstone and sandstone alternating every few metres with intervals of sandstone, which become increasingly common and thicker up section and pass gradationally into a 200m thick sandstone top.

*Kyalia Member*

Medium grey to black, variably organic-rich and commonly silty mudstone, with thin planar interbeds and laminae of light grey siltstone to fine sandstone, occasional thicker sandstone units, and common slumping and dewatering structures. In some wells thin beds of coarser, well rounded (pisolitic-oolitic) grains with a relatively iron-rich sideritic/glaucocitic matrix occur sporadically and are possibly incipient examples of the Sherwin Ironstone facies. Maximum thickness drilled in the sub-basin is 742m.

*Jamison Sandstone*:

White to light grey commonly argillaceous, very fine to coarse quartz sandstone with subordinate felspathic and lithic grains, often conglomeratic at the base. Sections of up to 162m have been drilled.

*Hayfield Mudstone*:

Greenish grey to patchily dark reddish brown, commonly silty mudstone, with subordinate interbedded/laminated siltstone to fine sandstone. Up to 450m has been drilled in the sub-basin. It unconformably overlies different upper Roper Group strata across the sub-basin, suggesting its deposition was preceded by a period of uplift and erosion. Similarly, Lower Cambrian strata overlie it with an unconformity which cuts to varying levels, suggesting another period of uplift and erosion after the 'Hayfield Mudstone' was deposited. Also, it is younger than the dolerite sills which intrude the upper Roper Group. From these observations it is thought to be a previously unknown sequence, probably of Neoproterozoic age.

*Phanerozoic*:

Five subdivisions have been applied to the Phanerozoic section, based on tentative comparisons with formally defined strata from the region.

Lowermost is a light brown, texturally mature sub litharenite which is friable, porous and permeable due to sparse cementation and minimal compaction. Labelled 'Cambrian Sandstone', it is distinctly different from the underlying sandstones, with highly variable thickness (0-63m) and patchy distribution.

Above it a dark greenish/brownish basalt, which occurs extensively across all but the southern end of the sub-basin with drilled thicknesses up to 440m, is correlated with the Antrim Plateau Volcanics.

Overlying this, a massive limestone with occasional thin mudstone subintervals occurs across the entire sub-basin with drilled thicknesses up to 237m and is correlated to the Tindall Limestone. This passes conformably into an argillaceous sandstone and dolomitic siltstone with interbedded limestones which peter out up section. Encountered up to 178m thick, this unit is correlated to the Jinduckin Formation.
Uppermost is a poorly consolidated mudstone, siltstone and sandstone sequence often capped with Tertiary laterite, and occasionally with a conglomeratic base. It has drilled thicknesses up to 135m and is correlated with the Lower Cretaceous Mullaman Beds.

**STRUCTURE**

POG's exploration demonstrated that the gravity low on which the Beetaloo Sub-basin was identified broadly coincides with a largely flat-lying thick upper Roper Group section overlain by a previously unknown sandstone and mudstone package with warped margins towards which the strata are increasingly folded and faulted. An important feature of these margins is that they are dominantly erosional, indicating that the Beetaloo Sub-basin is at least a largely post-depositional feature containing the remnants of an originally more extensive sequence. This observation supports the cratonic sag basin setting for Roper Group deposition.

Major stratigraphic thinning has occurred to the north and north-west of the Beetaloo Sub-basin, but is generally not observed within it. Localised thickness changes on the northern margin suggest some syn-Roper Group movement in that area, possibly associated with reactivation along the Mallapunyah Fault Zone. Thinning of the lower Kyalla Member over a broad north-south trending antiform, informally called the Arnold Arch, in the central north-east of the sub-basin suggests some syn-depositional growth and possibly provides a focus for migration of hydrocarbons out of the adjacent lows.

Folding and faulting within the Beetaloo Sub-basin occurs mostly as discrete fault zones up to 10 kilometres wide, between which the strata are flat-lying or show only slight regional dip. The fault zones are mostly interpreted to trend north-west and largely consists of wrench-related strike-slip and reverse faults producing en-echelon antiformal (positive) flower structures. The intensity, frequency and level in the stratigraphy of these zones appears to increase towards the Mallapunyah Fault Zone (which they parallel), but some are also interpreted to be present in the southern part of the sub-basin.

The nature and timing of structural events in the Beetaloo Sub-basin, including those that formed it, is poorly understood, but appears dominated by two major compressional/tranpressional episodes evidenced by differential truncation beneath the base 'Jamison Sandstone' and base Cambrian unconformities. Since the Cambrian, there appears to have been only regional events which have included broad tilting, resulting in relative uplift towards the north of the sub-basin.

**HYDROCARBON MATURATION HISTORY**

The area explored by Pacific may be divided into three zones of varied maturation history. In the north-eastern quadrant, maturation is by normal burial and the oil generation zone is located within the Velkerri Formation. The north-western quadrant shows a similar level of regional maturation, but dolerite sills emplaced at various levels within the Velkerri Formation have caused highly variable and locally very high maturity.
Oil generation within the basin has been complex, with an early phase of sill-generated oil pre-dating major structuring, and later regional maturation following, in some areas at least, a major phase of structuring and erosion.

5. **CURRENT EXPLORATION (20/10/96 TO 19/10/97)**

Exploration within EL 8451 has been deferred until the granting of EL(A) 9647, when the two tenements will be explored contiguously.

6. **CONCLUSIONS AND RECOMMENDATIONS**

Exploration of the Velkerri Group of licences has been ongoing and systematic for three years. Although exploration success in the form of a discovery has not been forthcoming, the current model remains valid. The remaining tenure of the Velkerrie Project contains the geological features most suited to the existence of an economic base metal deposit in terms of source and host rocks, fluid pathways and suitable trapping mechanisms.

Upon granting of EL(A) 9647, exploration of EL 8451 will consist of a regional Helimagnetic survey (approx 2000 line kms), and regional and infill RAB drilling over the targeted Velkerri shales along interpreted structures, where present.
7. EXPENDITURE

Total expenditure for EL 8451 amounted to $8,885. Details are listed below for the period 20 October 1996 to 19 October 1997.

Employee Costs

- Salaries and Wages
- Office Rental and Utilities $4,998.70

Operating Costs

- Office Supplies/Printing $36.00
- Courier/Freight/Postage $50.00
- Publications/Maps/Subscriptions $0.00
- Travel/Accommodation/Meals $104.30
- Equipment Maintenance/Repairs $0.00
- Equipment Purchases (under $500 only) $73.75
- Vehicle Operating Costs $320.80
- Drafting Services and Supplies $70.22
- Computing Services/Supplies $340.00
- Safety $28.00

Specialist Services

- Legal Fees $25.37

Overheads and Related Costs

- Regional Office Allocation $2,071.20
- Depreciation $766.66

TOTAL $2,837.86

TOTAL $8,885.00
FORWARD WORK PROGRAMME AND EXPENDITURE FOR EL 8451 FOR THE PERIOD
20/10/97 TO 19/10/98

Future work in EL 8451 will be carried out in conjunction with the adjoining ELA 9647 upon grant.

The work program may include magnetic and gravity surveying and RAB drilling.

Program costs are estimated at $26,000 as detailed below:

- EMPLOYEE COSTS $10,000.00
- DRILLING $7,000.00
- GEOPHYSICS $5,000.00
- ASSAYS $2,000.00
- OVERHEADS AND RELATED COSTS $2,000.00

TOTAL: $26,000.00
REFERENCES


BIBLIOGRAPHIC DATA-SHEET

REPORT NUMBER: 22046

REPORT TITLE: ANNUAL REPORT ON EXPLORATION LICENCE 8451, 8451 VELKERRI PROJECT FOR THE PERIOD 20/10/96 to 19/10/97

PROSPECT NAME: VELKERRI PROJECT

TENEMENT NUMBER: 8451

OWNER/JV PARTNERS: MINORCO 49%

COMMODITY(IES): ZINC, LEAD, COPPER, SILVER

TECTONIC UNIT(S): McARTHUR BASIN, BEETALOO BASIN

STRATIGRAPHIC UNIT: VELKERRI FORMATION, ROPER GROUP, KYALLA MEMBER, JAMISON SANDSTONE

1:250,000 MAP SHEET(S): TANUMBIRINI (SD53-02)

1:100,000 MAP SHEET(S):

KEYWORDS: MATURATION HISTORY STRUCTURE LEAD ZINC TOTAL ORGANIC CARBON CARBONACEOUS SHALES SANDSTONE METALLIFEROUS BRINES FAULTS MID PROTEROZOIC STRATIGRAPHY McARTHUR BASIN