4. Geology

4.1 Pre-Spud Geological Well Prognosis

Well Name: Lamont Pass #3

Target Formation(s): Lynott, Reward, Barney Creek and Coxco Dolomite

Table 5: Geologic description of the prognosed formations.

Formation	Top [m]	Probable Content
Lynott Formation Undifferentiated	Surface	Thin bedded dolomitic siltstone and shale, in part carbonaceous and pyritic; silty dololutite, dololutite; minor fine grained dolarenite and lenses of slump breccia; uncommon ripples and evaporate mineral casts.
Reward Dolomite	620	Dololutite, stromatolitic dololutite, silty dololutite and dolarenite with lesser sandy dolarenite, dolorudite and sandstone; laminated, thin to massive bedded, cross-bedded, brecciated and slumped; pseudomorphs softer sulphate evaporates; onkoids, ooids, small silica spheroids; pseudomorphs after pyrite (pyritohedron).
Barney Creek Formation	790	Thin bedded to laminated, dolomitic, carbonaceous and pyritic shale and siltstone, doloutite, rare breccia and sandstone; occasional gypsum casts; talus slope breccia adjacent to Emu Fault.
Coxco Dolomite	1290	Grey crystalline dololutite with radiating, needle-like gypsum crystal pseudomorphs normal to bedding; rare conical stromatolites; thin intervals of dolomitic shale and siltstone.

4.2 Along Hole and True Vertical Depth of Seismic Marker and Reservoir Horizons

Table 6: Well log formation tops for Lamont Pass #3, TD = 1275.2 m.

Geologic Tops	Drilling Depth [m]	Structural Tops (KB:90.6) [m]
Lynott Formation - Undifferentiated	Surface	90.6
Reward Dolomite	612	-521.4
Barney Creek Formation	649	-558.4
Coxco Dolomite (equivalent)	867	-776.4
Myrtle Shale	972	-881.4

4.3 Geological Interpretation of the Well Data

4.3.1 Log Adjusted Lithology Description

Lynott Formation: The Lynott Formation, a unit of dololutite, dolarenite and dolomitic siltstone and sandstone, is generally the thickest and most widespread of the formations which make up the Batten Subgroup. This formation is comprised of the Donnegan, Hot Spring and Caranbirini Members as you progress down stratigraphy, respectively. The Lynott Formation is seen as a regressive sequence.

Donnegan Member: Typically comprises buff to red-brown, thin bedded, often ferruginous, fine-grained dolomitic sandstone with interbeds of dolomitic siltstone and dololutite. A characteristic feature of the Donnegan Member is the presence of botryoidal quartz nodules (cauliflower cherts) which have probably formed by replacement of anhydrite nodules. The quartz nodules range from a few millimetres up to 10 cm in diameter, often have an enterolithic structure, and exhibit displacive growth along fractures and bedding planes. Pseudomorphs after gypsum and mud cracks are common at various levels.

Hot Spring Member: The base of the member is taken to be either the first coarse sandstone bed or prominent stromatolitic dolostone bed in the conformable succession with the Caranbirini Member. It ranges up to about 350 m in thickness, although exposures in the southeast are poor and shallow-dipping, making it difficult to estimate true thickness. The Hot Spring Member is a variable unit including dolomitic siltstone, silty dololutite, stromatolitic dolostone, dolarenite, sandy dolarenite and dolomitic quartz sandstone and thin beds of intra-clast breccia. The most common rock type is thin-bedded dolomitic siltstone which is often deeply weathered and silicified. Sedimentary structures include cross-bedding, ripple marks and rare mud cracks. Stromatolitic horizons are silicified and form prominent beds of blue-grey, often banded, chert.

Caranbirini Member: The Caranbirini Member is typically a poorly exposed unit of very thin-bedded to laminated, buff to yellow and grey, dolomitic siltstone and shale with interbeds of massive and laminated dololutite, similar in appearance to the Barney Creek Formation. It is usually deeply weathered and leached and occurs in low, rubbly, often flaggy outcrops. Pink to dark red and purple weathered pyritic shales, sometimes with small nodules of iron oxides after pyrite, form in the upper parts of the unit, whereas white, weathered, bituminous shales are common lower in the unit. There are rare, thin inter-beds of fine-grained, cross-bedded sandstone and dolarenite, but coarse sandstone and stromatolitic dolostone are absent. The upper part of the unit is more dolomitic and is characterised by small, vertical to inclined, chert and calcite-filled irregular fenestrae which may represent evaporate casts. Emergent, evaporitic conditions at this level are indicated by the presence of ripple marks, mud cracks, hopper halite casts, small chert spheroids and tepee structures.

In Lamont Pass #3 well the Lynott Formation appears to be represented by the Caranbirini Member which was predominately a DOLOMITE, medium grey-medium dark grey, hard, microcrystalline, very fine laminations, highly fractured in part, firm, medium grey infill, calcite infilled fractures to 1mm, minor dark bituminous infill, common even yellow fluorescence with BRECCIATED DOLOMITE that was light to medium grey, hard, microcrystalline containing multiple brecciation events, brecciated clasts within calcite fractures that were infilled with some chert (fenestrae?), common bituminous flecks, calcite filled fractures >5mm, minor

SANDSTONE beds and trace pyrite. A consistent streaming blooming cut was observed with an even yellow fluorescence and occasionally live dark brown to black oil.

Umbolooga Subgroup

The top of the Umbolooga Subgroup consists of the Reward Dolomite, Barney Creek Formation (HYC Pyritic Shale Member, W-Fold Shale Member), Coxco Dolomite and Teena Dolomite progressing down stratigraphy, respectively.

The **Reward Dolomite** is a widespread, highly variable dolostone unit which marks the top of the Umbolooga Subgroup. The thickness ranges from a few tens of metres in the west to several hundred metres in the vicinity of the McArthur River mine. The contact with the Barney Creek Formation is generally conformable and often gradational. The lower part of the formation consists of pink, buff and grey, laminated and thin bedded dololutite with interbeds of dolomitic siltstone and sandstone, sandy dolarenite and sandy intraclast breccia. Dolomitic beds often contain small chert spheroids. Thin beds of potassium-rich, pink, siliceous, possibly tuffaceous material occur at some levels. The upper part of the formation is marked by a zone of intense silicification. In the west it is deeply weathered, silicified, chaotic breccia containing large, unsorted, angular dolostone clasts in a coarse, poorly sorted sandstone matrix with thin interbeds of dololutite and dolomitic sandstone. The Reward Dolomite often contains minor base metal mineralisation along the disconformity where the dololutite is black and has a bitumous odour when broken. The Reward Dolomite was deposited in an environment similar to the Barney Creek Formation, very shallow water to emergent conditions under which sediments accumulated in small bodies of standing water.

In the Lamont Pass #3 well the Reward Dolomite was penetrated at 612 meters and consisted of DOLOMITIC META-SILTSTONE, medium dark grey, moderately hard, phyllitic, weakly foliated, moderately fractured, carbonaceous, minor pyrite as stringer veins and occasionally disseminated, dolomitic bands and clasts, with a petroliferous odour and streaming and blooming milky white cut. Common interbedded dark gray to black carbonaceous hard SILTSTONE with DOLOMITE that was light gray to gray, hard microcrystalline, minor very fine grained sand/silt bands, minor calcite vein, trace pyrite and fractured common surfaces with carbonaceous coating, minor oil fluorescence with milky grain cut in fractures.

The **Barney Creek Formation** is a unit of dolomitic shale, siltstone and dololutite which is usually only poorly exposed in low, discontinuous rubbly ridges in the west, northeast and southeast of the McArthur River Region. The formation is usually less than 150 m thick but thickens to about 700m near the Emu Fault Zone near the McArthur River deposits. The formation is divided into three members: the HYC Pyritic Shale Member, W-Fold Shale Member and the Cooley Dolomite Member. The Cooley Dolomite is restricted to the HYC Sub-basin to the west of the Western Fault, and 20 km north.

In the Lamont Pass #3 the Barney Creek Shale was penetrated at 649 meters and a DOLOMITIC SILTSTONE that was light grey to medium dark grey, hard blocky, laminated in part, cryptocrystalline dolomitized, minor calcite veining, very weak fluorescence no cut with DOLOMITE that was grey to brown, hard, blocky, cryptocrystalline, trace very fine grained disseminated pyrite, with PYRITIC SILTSTONE, black, very fine grained laminated, very fine grained pyrite in part with clastic wedges of BRECCIATED DOLOMITE: light gray - pink - brown, hard, microcrystalline, predominantly brecciated, white-pink calcite-silica parallel

veining (to 20mm), dolomite clasts, calcareous infill, common pyrite in veins, no cut or fluorescence, siderite coating fracture surface

The **Coxco Dolomite Member** is almost certainly evaporitic and is a massive, dark grey, sometimes vaguely bedded dololutite unit. It contains numerous interbeds of pink, buff or orange-weathering, potassium rich, possibly tuffaceous, and mudstones in the area adjacent to the McArthur River deposits. The Coxco Dolomite Member is characterised by the presence of acicular crystal casts which typically take the form of radiating aggregates of needles, rarely more than 2 mm in diameter and up to 6cm long. Minor disseminated sphalerite, galena and chalcopyrite have been noted at several localities in the Coxco Dolomite Member.

In the Lamont Pass #3 the Coxco Dolomite Member 'equivalent' was penetrated at 867 meters. The reservoir was described as light to medium gray, hard, microcrystalline, clast supported dolomite-siltstone breccia with common stock-work veining cross-cutting the dolomitic matrix, extensive pyrite-calcite & carbonaceous, occasionally pyritic and no cut or fluorescence.

4.3.2 Reservoir Quality

At the Lamont Pass #3 the reservoir quality was very tight and where developed was predominately fractured and vuggy.

4.3.3 Source Rock Quality

The Barney Creek Shale is likely the source rock for hydrocarbons in the Lamont Pass area. The quality of its overall potential will require further laboratory analysis.

4.3.4 Hydrocarbon Indications

The chromatograph recorded gas while drilling. A top seal was penetrated at 260 meters in the Lynott Formation, which appeared to have had the highest concentration of free gas and where the first indications of liquid hydrocarbons occurred.

4.3.5 Trap integrity

The trap integrity is controlled by compartmentalization by faulting and the seal is tight rocks in the Lynott Formation. Some surface water was penetrated above 210 meters before penetrating the trap at 260 meters.

4.4 Discussion of the relevance of the Well Data to the Evaluation of the Hydrocarbon Potential of the Area

The Lamont Pass #3 was designed to test for hydrocarbons along the trend of the regional Emu Fault and was located 25 km north of the 2012 gas discovery at the Glyde #1 ST1 well. The closest offset to the Lamont Pass #3 well is the Amoco mineral core-hole 82-6 that reached a total depth of 300 m into the Lynott Formation. Lamont Pass #3 was designed to test a gravity anomaly that was imaged from a detailed airborne gravity survey flown in January 2013 over the Glyde Sub-basin. Subsequent models and structure maps were

compiled from the survey and a positive flower model was generated for the Lamont Pass area. The positive flower structure is a result of right-lateral movement of the present day Emu Fault and a northwest trending lineament (Calvert sets). In addition, a well-developed mapped shear zone and dilatational jog associated with the local faulting was targeted as these structural weaknesses allow for focused flow of circulating hydrothermal fluids. The hydrothermal fluids are responsible for enhancing reservoir quality and the development of hydrothermal dolomites (HTD). The Emu and Calvert paleo-fault sets were growth structures and have caused considerable erosional, thickness and facies variation to the local stratigraphy. These variations allow for unconformity horizons and interbedded syn-depositional breccia's (Cooley) to develop and become charged from the surrounding Barney Creek or Lynott source rocks.

Hydrocarbons were first encountered at 260 meters at Lamont Pass #3 in the Lynott Formation. Numerous connection gases and minor shows of up to 100 units were recorded in addition to weak to fair milky blooming and residual ring cuts to 391 meters. Due to shallow water influx above the top seal the well was subsequently cased at 304 meters to isolate the water zones that were approximately located at 204 meters & 254 meters.

HQ coring commenced at 391 meters in the Caranbirini Member Lower Lynott Formation on fluid and background gas decreased to 2-5 units. The well continued to encounter bitumen, blooming, milky streaming hydrocarbon cuts and some live oil to 780 meters. At a depth of 535 meters the well penetrated live oil in fractures and in a hydrothermally altered dolomitic reservoir in the Caranbirini Member.

The Barney Creek Shale source rock was penetrated at 649 meters and was interbedded with Cooley Dolomite Members. The Cooley's are angular clastic wedges of Batten Subgroup and Umboolooga Subgroup rocks that were formed during periods of low stand deposition along growth faults These wedges are sealed within the Barney Creek source rock are can have the potential for hydrocarbon storability where reservoir enhancement has occurred. The clastic wedges penetrated in the Lamont Pass #3 had hydrocarbon cut, but were predominately tight. The Barney Creek shale has been described as oil bearing shale and had a consistent cut with minor connection gases. At 816 meters a 75 meter section of brecciated rock was penetrated that hosted a massive sulphide stock-work before penetrating the targeted Coxco Dolomite 'equivalent' at 867 meters. The last occurrence of hydrocarbon cut occurred at the top of the massive 816 meter Cooley breccia wedge.

The Coxco is a widespread reservoir that is associated with a significant unconformity at the base of Barney Creek and has been described as a karsted or brecciated paleo surface with hydrothermal overprinting and considered a member of the Teena Dolomite. In the Lamont Pass #3 well the reservoir is likely a Cooley Dolomite or Coxco 'equivalent' and was charged with minor amounts of gas and some hydrothermal alteration was present. The base of this breccia unconformably overlaid the Myrtle Shale of the Tooganinie Formation and the Teena Dolomite, Mitchell Yard and Mara Dolomite Members of the Emmerugga Dolomite were eroded off. This may explain the why there was a significant amount of clastic wedge material derived from these formations interbedded with the Barney Creek at this location. The well remained in the Myrtle Shale to the total depth of 1275.2 measured depth with no significant hydrocarbon shows penetrated.

Appendices

I. Copy of the well completion data includes -
    a. Logs
    b. Mudlog Data
    c. Daily Drilling Reports
    d. Daily Geology Reports
    e. Daily mudlogging Reports