A Target Reservoir/Seal Couplet and Potential Petroleum System in the Goyder Formation, Northern Amadeus Basin.

Summary

- **This petroleum system has been neglected for the duration of exploration in the Amadeus Basin mainly because of the lack of early success, due largely to the failure to intersect a viable trap, and also because studies concentrated on the Horn Valley Siltstone. The target sequence is present at Mereenie field (4-way dip closure) but has only been penetrated in two wells, one of which recorded gas shows; there is a possibility of a tight gas leg in this structure. The other main 4-way dip closure trap, Palm Valley field, does not include any wells deep enough to assess this play.**

- **As with all petroleum systems the starting point hinges on viable source rocks. An almost complete lack of core has hindered definition of such but elog response , particularly in Alice-1 and Orange-2, indicates intervals of carbonaceous shales have been largely overlooked. It is now interpreted that transgressive carbonaceous shales are prominent in the underlying Upper Shannon Formation. This unit is defined by up to 20 laterally extensive, carbonate rich upward shoaling cycles. Nearly all are capped by transgressive shales each 2-4 m thick.**

- **These transgressive shales are the key to the petroleum system. The log response (high GR, relatively high interval transit time) , and the fact that a proportion of black shale occurs in cuttings samples, provide key evidence of the petroleum system.**

- **Oil migration and entrapment focussed on the Lower Goyder Sandstone (LGS) which has regional extent in the northern Amadeus Basin, and provides the only conventional reservoir between the Dingo Sandstone and Pacoota Sandstone, a sedimentary section spanning up to 1200 m of basically "tight" Cambrian shales and carbonates.**

- **Regional seal is provided by a dolomite / siltstone sequence capping the Goyder Formation; there is clear partitioning of aquifer salinities above and below this seal.**

- **Future exploration should target traps in the northern Amadeus Basin east of Mt Winter-1. In terms of entrapment the viable plays are analogous to those relevant to the HVS petroleum system. Four way dip closures would have highest priority but this reservoir / seal couplet is an attractive target wherever fault dependent traps can be implied or indeed halo plays. The play has very wide extent and offers a new and separate target immediately below the Pacoota Sandstone, and indeed seismic mapping at this level would be sufficient to define traps in the underlying Goyder Formation.**

- **It is recommended all future drill holes targeting the HVS/Pacoota plays in the northern Amadeus Basin be deepened to test the Goyder petroleum system.**

Introduction

In the northern and eastern portions of the Amadeus Basin, the late Cambrian Goyder Formation includes a widespread reservoir/seal couplet which provides a new supplementary target in this part of the basin. The lower Goyder reservoir/seal couplet (LGS) has sheet like extent and hydrocarbon shows are recorded at this stratigraphic level in Alice-1, Temp Vale-1 and Mereenie West-1. It is believed regional flushing by fresh meteoric ground waters has destroyed at least some potential oil pools formed at this level. The sheet like extent of this target gives preference to 4-way dip closures. It is a fair quality reservoir in terms of primary porosity but fracturing is also recognised in some wells eg in Orange-1 the reservoir records cycle skipping on the sonic log which is indicative of fracturing.

The only deep stratigraphic test at Mereenie field, and available to Central, is East Mereenie #4. In this well the Pertatataka, Julie, Arumbera , Chandler and Giles Creek formations are absent whereas early Cambrian Tempe Formation lies unconformably on Bitter Springs Formation. The Mereenie structure clearly underwent major uplift and erosion during the Petermann Ranges Orogeny (Late Neoproterozoic to early Cambrian) prior to major compression during the later Alice Springs Orogeny (Devonian- Carboniferous). This is true of other major structural trends like the Finke-Highway Anticlinal Trend and the Gairdner Anticline; these need to be further investigated as regards applicability of the LGS play. The latter is present over Mereenie field and gas shows were recorded in West Mereenie-1 hinting at a tight gas leg over the structure.

A lower Shannon lenticular sandstone is described as an adjunct to the LGS play in the northern Amadeus Basin (Figure 2). The Middle Cambrian Shannon Fm blankets a wide area and is up to 640 m thick in Wallaby-1, Alice -1, Dingo-1, Orange-1 and Highway-1(Fig.3). A lenticular reservoir in the lower Shannon Formation warrants further attention and the stratigraphic zone should be monitored during all future drilling. The sandstone is well developed in Waterhouse 2 and is probably present in Waterhouse-1. This lenticular porous reservoir is encased in a thick sequence of interbedded shales and carbonates of the lower Shannon Formation and as such is unlikely to have been flushed by meteoric waters. A petrophysical assessment, assuming relatively high salinity formation water, results in relatively high hydrocarbon saturations in the Waterhouse -2 sandstone (Fig.2); hydrocarbon saturations of 60% are present assuming a salinity of 10,000 ppm NaCl equ. Aquifer salinities in nearby wells are as high as 50,000 ppm in this zone and application of this Rw would result in much higher hydrocarbon saturations of about 80- 90%. This zone should be carefully monitored in Waterhouse 3. Waterhouse 3 should be carefully monitored through this zone.

Regional Seals

The presence or absence of regional seals has played a fundamental role in controlling movement of fresh aquifer waters through Amadeus Basin reservoirs. The most important regional seals relevant to the Goyder Fm/Larapinta Group are discussed separately below. Regional seismic mapping of these locally thick seals to high grade prospective areas and establish play fairways will be an important part of upcoming exploration programs.

1)Stokes Siltstone

The Stokes Siltstone is generally acknowledged as the key regional seal to productive reservoirs in the underlying Pacoota – Stairway section. The presence of fracturing in the latter, which is a key to reservoir performance, dictates that a particularly thick seal (Stokes is

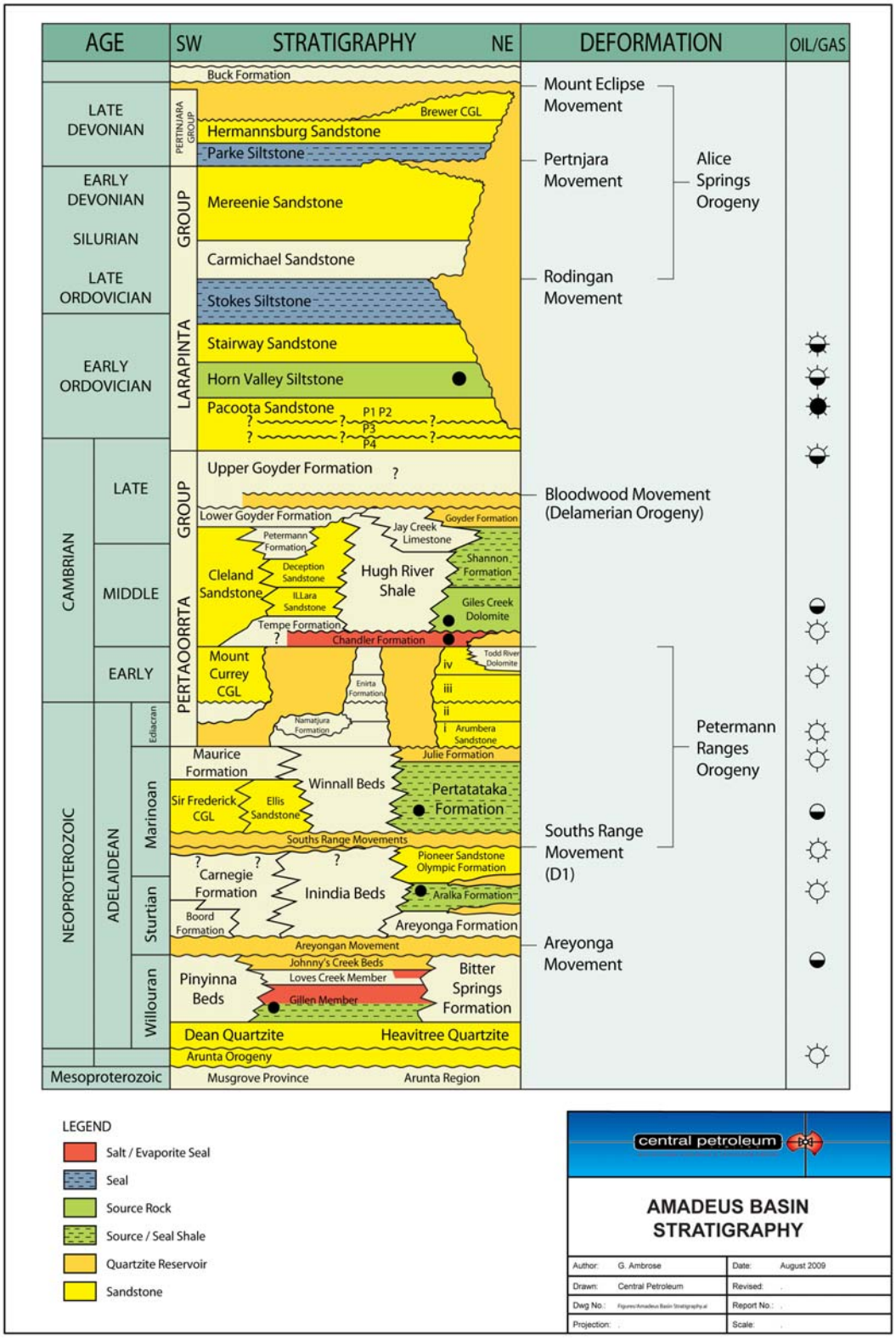

Figure 1: Amadeus Basin Stratigraphy

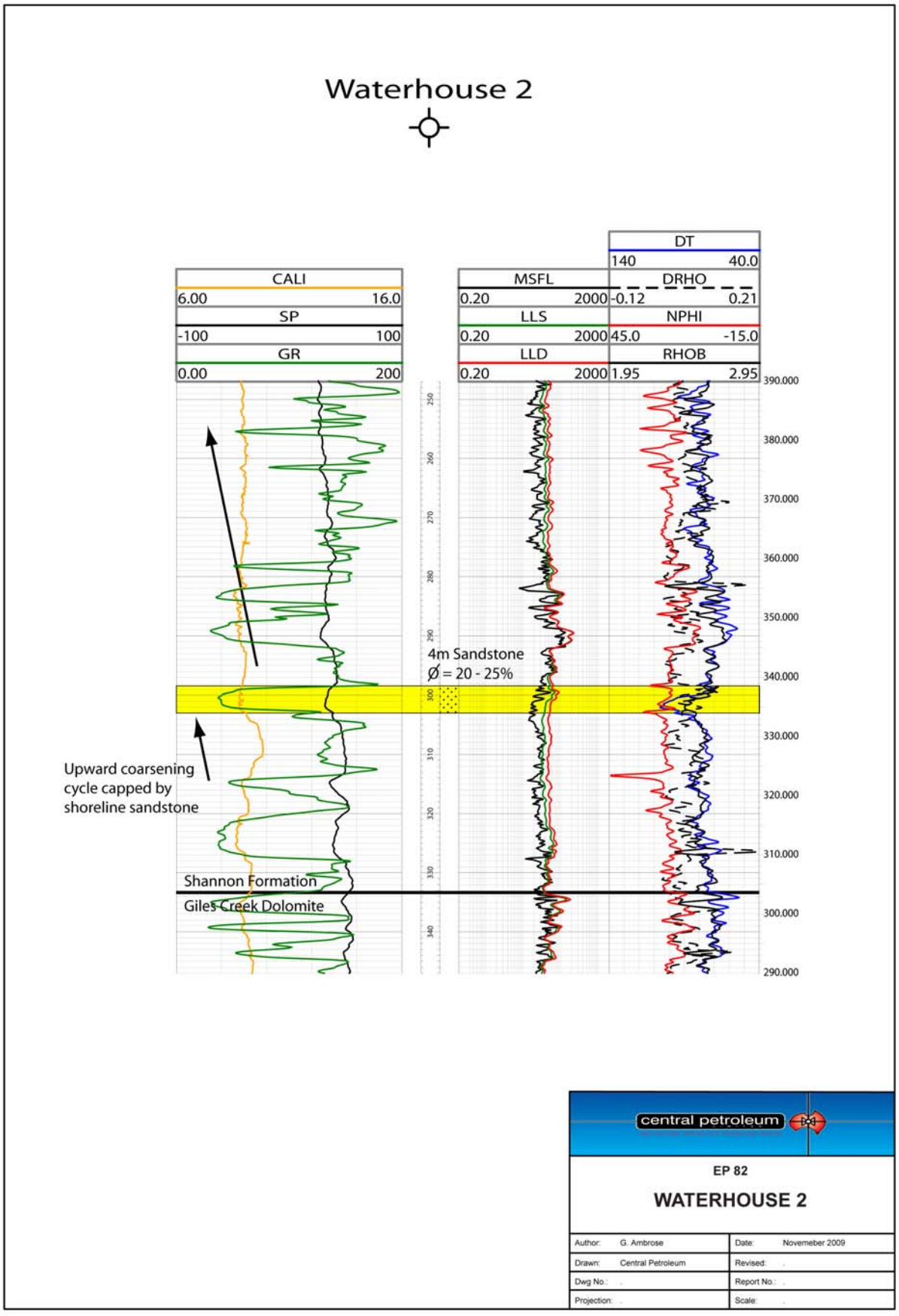

Figure 2: Porous lenticular lower Shannon Sandstone - ? hydrocarbon saturated.

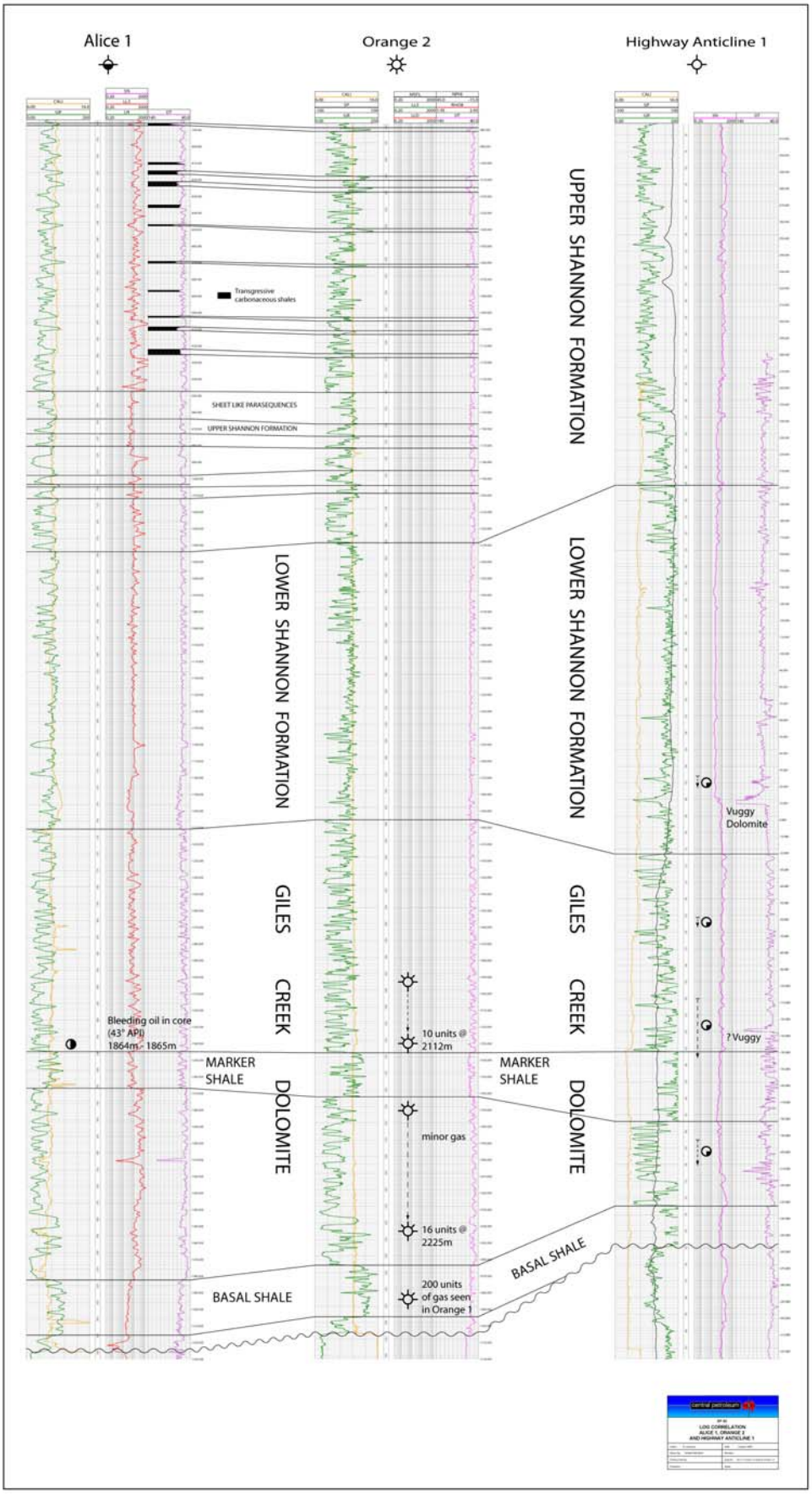

Figure 3: Cambrian Cross-section. Note the vuggy dolomite in the Lower Shannon Formation in Highway-1 correlates with the sandstone in Waterhouse-2.

approximately 220 m thick over the Meeenie structure) is required for blanket seal. However, in certain instances both the Horn Valley Siltstone (~100 m thick) and Middle Stairway Member (~120 m thick) can act as seals in their own right; eg in West Walker-1 the Horn Valley Siltstone probably seals the Pacoota Sandstone whereas in East Mereenie 4, the Middle Stairway Siltstone Member (MSW) probably seals the lower Stairway reservoir section.

Note that the MSW may offer opportunities for unconventional gas considering at least one small gas flow (75 mcfd) from this unit was recorded in this shaly section 70 m above the Lower Stairway Sandstone reservoir section (East Mereenie 4). The middle Stairway Siltstone Member is of interest in that:
1) It may be a viable source rock,
2) The shale could seal off the upper Stairway reservoir and provide hydrocarbon charge.
3) There is potential for unconventional shale gas in this zone.

2) Upper Goyder Formation Seal

Thick dolomites and siltstones in the upper Goyder Fm form a semi-regional seal. This is illustrated in the Dingo field (Dingo-4) where fresh formation water (~500 ppm) is recorded in the overlying Ordovician Pacoota Sandstone whereas below the upper Goyder Formation seal the salinity of formation waters in the Upper Shannon Formation reaches ~50,000 ppm. The recognition of this seal, which is capable of partitioning aquifers, is important as it appears to have controlled migration of hydrocarbons generated in the Lower Goyder/ Upper Shannon formations. However, seal could be compromised by fracturing in some structures subjected to even just mild compression.

3) Hugh River Shale Member (Shannon Formation)

This multicoloured shale member which occurs in the lower Shannon Formation is a good seal where present as verified by aquifer partitioning eg in Bluebush-1 aquifer salinities above and below this seal are 2000 ppm and 10000 ppm respectively.

Lower Goyder Sandstone : Hydrocarbon Indications

The LGS has only been intersected at Dingo field and Moomba field and also in the following exploration wells:- Alice-1, Wallaby-1, Orange 1-2, West Walker-1 and Temp Vale-1. It probably also occurs in several wells which were not deepened to this level (eg Tent Hill-1, Palm Valley field wells). Poor to moderate oil shows, including both residual and live oil shows, were recorded in Alice-1 but on test the zone produced fresh water. In Temp Vale-1 minor live and dead oil shows occurred in the LGS but the zone appears to be water saturated. Gas shows were recorded in West Mereenie -1 but a DST failed to recover hydrocarbons.

Lower Goyder Sandstone : Reservoir / Seal

An outline of Lower Goyder Formation sandstone reservoirs in key wells occurs below.

Alice-1: The lower Goyder Formation sandstone (LGS) has been tested in Alice -1 where it recovered 174 m of muddy fresh water from the uppermost part of the sand; the lower zone was not tested but over 2 m of sand with poor to fair porosity was recovered in core. The top seal appears to have been breached over this structure.

Dingo field: The LGS produced water in Dingo-4; here the reservoir is about 4 m thick and comprises a very fine grained to fine grained dolomitic sandstone, in part siliceous with poor to fair porosity. In Dingo-3 the neutron density log indicates a total of 4 m of porous sandstone over 2 zones. In Dingo-1 the

LGS was not described on the composite log but was noted on the mudlog where it comprised fg-mg dolomitic sandstone (7m gross) with 2 m of net sand displaying poor intergranular porosity; water salinities just below this zone recorded 48,000 ppm Nacl equ. The LGS in Dingo-2 comprised 3 m of net sand in two intervals comprising vfg to fg dolomitic sandstone.

Orange field: In Orange-2, the LGS comprised 6 m of dolomitic sandstone with fair to good porosity and a flow of fresh water was sealed off with a cement plug. The top seal was probably prejudiced by an anonymously high sand content and / or fracture development in the seal. Orange-1 recorded 10 m of mg dolomitic sandstone with some intergranular porosity and also fracture development in the lower part as signified on the sonic log

Wallaby-1: In this well the LGS comprises 6 m of porous dolomitic sandstone which on test recovered 697 m of fresh water. The top seal also appears to have been breached in this well.

Mereenie field : The Goyder Formation was penetrated in Mereenie East 4 and West Mereenie-1. Weak gas shows in the latter failed to produce hydrocarbons on test but the formation was probably damaged by the 11 pound/gallon mud system which would also have suppressed gas shows. It is possible there is a tight gas leg in the LGS over the Mereenie structure. The Goyder Formation was never penetrated over the Palm Valley structure.

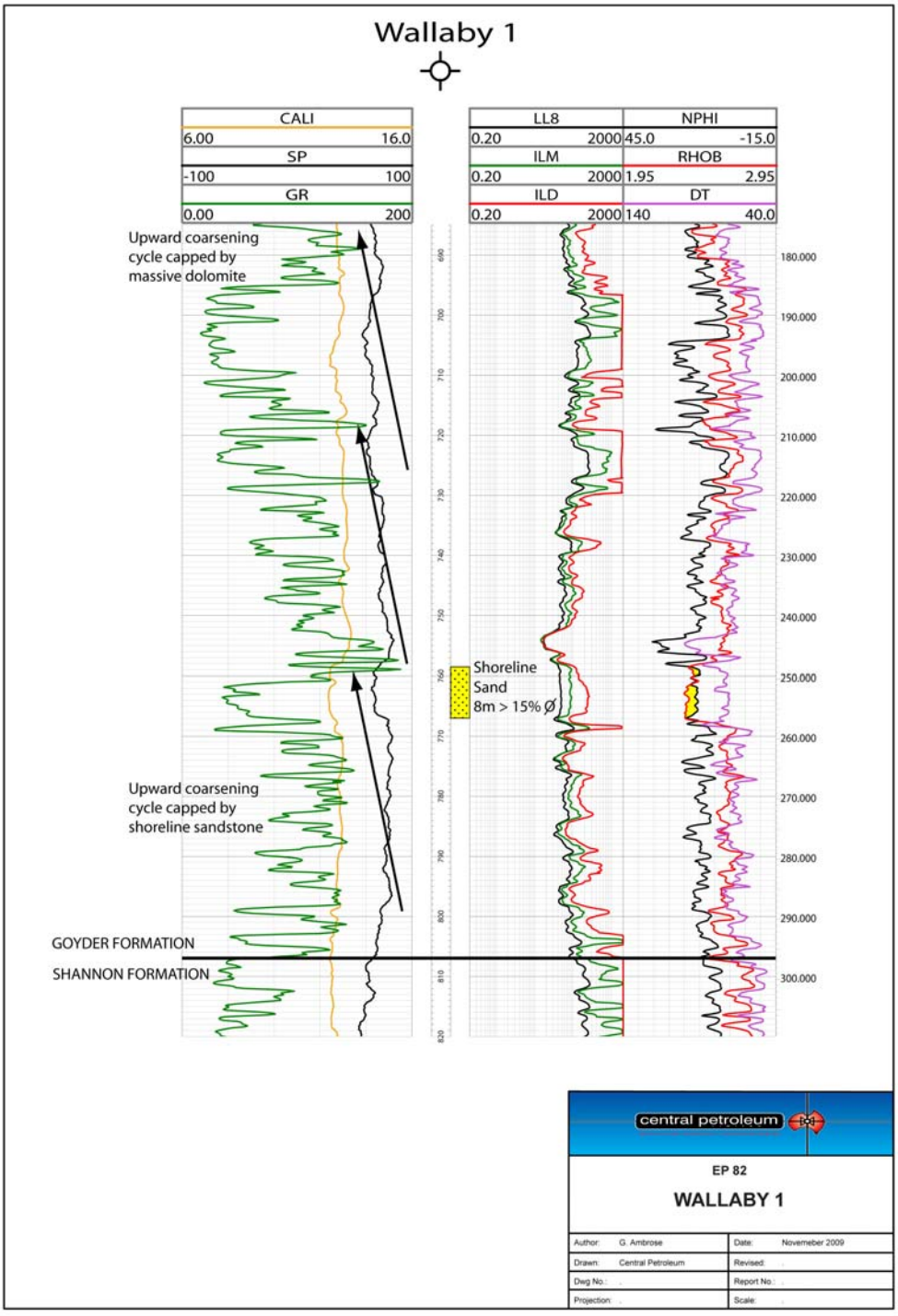

Figure 4: Lower Goyder Sandstone capped and sealed by overlying dolomites.

Lower Goyder Sandstone : Source

The main source for potential hydrocarbons in the Goyder Formation are intraformational shales such as those cored in Alice -1 and also carbonaceous shales in the upper Shannon Formation recognised on logs in the same well (Fig.3); these shales are expected to be widespread in the central-northern portion of the basin but data is extremely sparse.

Lower Goyder Sandstone : Hydrocarbon Potential

This study has projected the LGS as a viable reservoir / seal couplet and estimates of its prospectivity should be noted in assessment of future drillable prospects. It is doubtful that this target has ever been intersected within four – way dip closure thus explaining the lack of success and its relative neglect. There may be a tight gas leg over the Mereenie structure and perhaps over Palm Valley where drilling has not penetrated to this level.

The reservoir, source and seal for the LGS play have regional extent from the Mt Winter area eastwards to the Dingo/Orange area. The LGS is largely eroded from the Finke – Highway trend (Central Ridge) but does occur to the west in West Wlaker-1, Temp Vale-1, East Johnny's Creek-1 and Mereenie field. Thus the play is definitely manifest in the northern half of the basin and this horizon should be addressed in all regional and prospect seismic mapping in this area. In addition, for all drilling in the basin as a whole, this stratigraphic level should be carefully monitored for hydrocarbon indications.

Conclusions

The Goyder Formation includes a previously neglected petroleum system and target reservoir-seal couplet. This assertion is important when considering regional and prospect mapping projects in the northern Amadeus Basin. Hydrocarbon shows and a possible tight gas leg at Mereenie field support an earlier concept, based largely on log response and minor core, of high gamma ray shales providing viable source rocks in the upper Shannon Formation and Goyder Formation.