STRATIGRAPHIC RESULTS OF DIAMOND DRILLING OF THE HUNTERSTON DOME, TASMANIA: IMPLICATIONS FOR HYDROCARBON POTENTIAL.

Reid C.M., Chester A, Stacey A.R. and Burrett C.F. (in prep)

(with x figures tables etc)

INTRODUCTION

The geology of this region of Central Tasmania was first described in any conclusive detail by Fairbridge (1949), after regional mapping work for the Hydro-Electric Commission. Fairbridge described the Permian and Triassic rocks of the area and their structural relationship with Jurassic dolerite intrusives, and was the first to note the presence of a domal structure southeast of Lake Echo. This structure was named the Hunterston Dome, after the pastoral property which covers this area. Fairbridge gave an accurate description of the local Permian geology and gentle dip of the strata. The Oatlands 1:250,000 map of this region (Gulline & Forsyth, 1976) was based on Fairbridge (1949) and maps the Hunterston Dome as occurring within the upper marine series of the Permian and does not include Triassic rocks. However the "sandy facies" of Fairbridge (1949), outcropping on the eastern and north-eastern limb of the dome, is in fact the lower part of the freshwater Triassic.
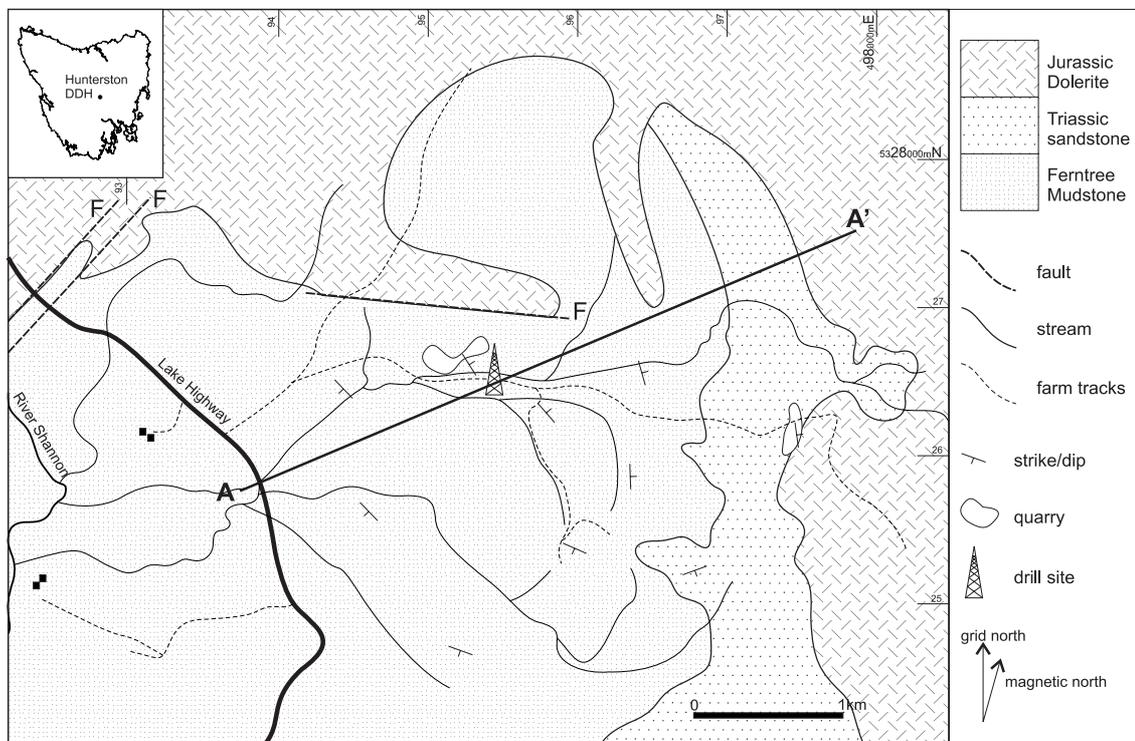

FIG. 1 – Locality map and geology in the immediate vicinity of the Hunterston DDH.

The Hunterston area provides some of the only Permian (Lower Parmeener Supergroup) outcrop through the central Highlands region, however only the marine series above the freshwater interval is exposed. The nature of the lower marine interval of the Lower Parmeener Supergroup is also unknown, although extensive tillites and pyritic mudstones are known to the east (Forsyth 1989) and southwest (Jago 1971). However, to the northwest in the DuCane area conglomerates and siltstones are present (MacLeod *et al.* 1961) in place of the pyritic mudstones of the Quamby Mudstone and Woody Island Siltstone known from elsewhere in the Tasmania Basin. The nature of the pre-Parmeener basement is unknown in the region from the Florentine Valley to the southwest and Western Tiers to the north.

The Hunterston dome is of interest in hydrocarbon exploration within the Tasmania Basin, and was first drilled in August 1997 for Great South Land Minerals. The initial method was of 6 inch down hole hammer drilling to a depth of 336m. In July 2002 drilling recommenced with diamond core drilling (HQ, 63 mm diameter to 974m and NQ, 45 mm diameter to base) to a total depth of 1324m, drilling through Parmeener sediments into a Precambrian basement. The drill core is stored at Mineral Resources Tasmania, Mornington Store.

STRATIGRAPHY
Dolerite
Dolerite was encountered in the Hunterston DDH from 134 to 784.4m, totalling 650m thickness, and represents multiple intrusive events (Leaman, *pers. comm.*). The dolerite is massive and generally fine to medium grained. Baking effects on underlying Parmeener sediments are readily visible in core sample for approximately 20m beneath the margin of the dolerite. Vitrinite reflectance values of samples 65-85 m beneath the dolerite do not indicate significantly elevated temperatures.

Upper marine sequence
Ferntree Mudstone correlate 0-134m
This section of the hole was produced by hammer drill and the resultant chip material shows little about this monotonous sequence of predominantly mudstone. Because of the lack of stratigraphic detail in this section it is unknown if and how much of the sequence has been displaced by movement associated with dolerite intrusion.
Cascades Group correlate 784.4 – 848.5m
The lower margin of the dolerite contacts directly with fossiliferous siltstones of the Cascades Group. From 784.4 – 811.5m, fossiliferous baked siltstone, baking effects decreasing downward into grey bioturbated fossiliferous siltstone. Fossils are abundant, of brachiopods, molluscs and bryozoans, with fenestrate dominant horizons present. Fossils become thin shelled and less common from 798m. Weathered and bioturbated clay horizons are present at 801m and 811m. From 811.5 – 838.8m, bioturbated siltstone and sandy siltstone with scattered fossils in upper part, and granules and scattered pebbles throughout. From 838.8m – 848.5m, bioturbated pyritic mudstone and siltstone, with bioturbated sandstone and a prominent pebble horizon at 842.5m. The lowermost part of this sequence, immediately above the Liffey Group, is of black mudstone with wispy bioturbation and heavy pyritisation.

The effects of contact metamorphism associated with the dolerite have destroyed much of the skeletal detail of the bryozoans, however a Bernacchian age is indicated by the presence of *Levifenestella expansa* in the richly fossiliferous siltstones at 797.5m. The presence of Bernacchian species is in keeping with the Cascades Group in the Tunbridge Tier DDH where a probable Bernacchian age is indicated for the lower 45m

of Cascades beds. This age and the thinness of the fossiliferous sequence indicates some loss of Parmeener Supergroup section in association with dolerite intrusion, given that the base of the Ferntree Mudstone is upper Lymingtonian in age.
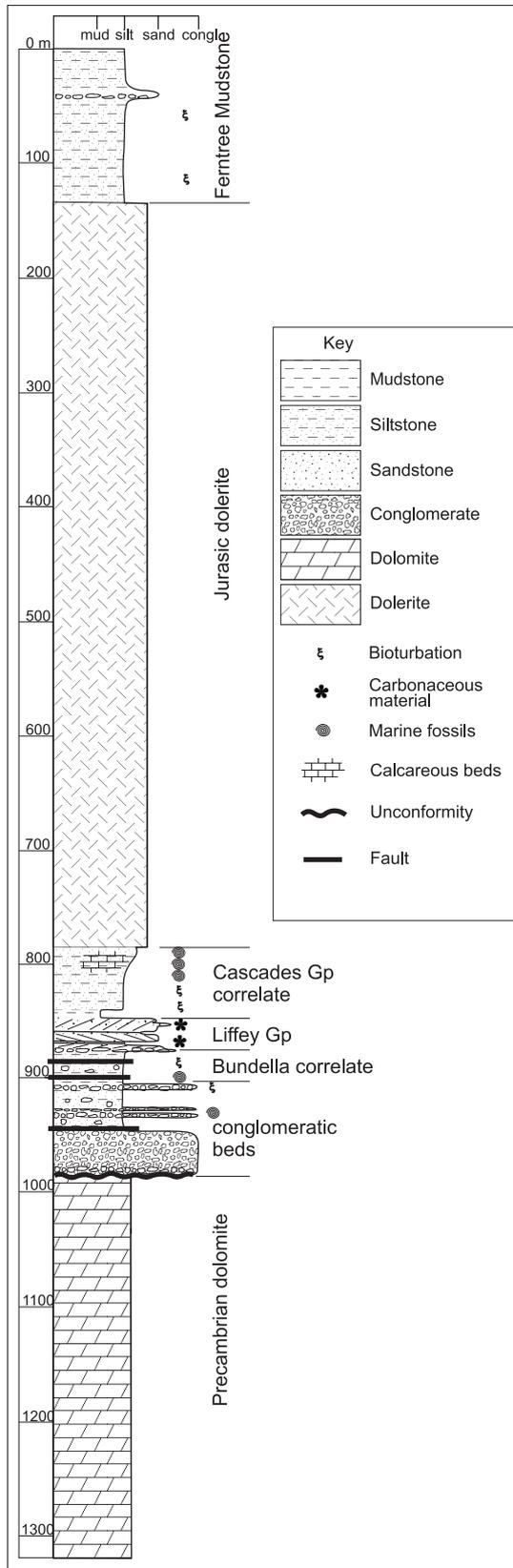

FIG. 2 – Schematic stratigraphic column of the Hunterston DDH.

Freshwater beds
Liffey Group 848.5 – 870.1m
 The Liffey Group is divided into three units, the uppermost, from 848.5 to 853.6m, of carbonaceous silt laminated and cross-bedded fine micaceous sand. The sandstone is bioturbated at its upper boundary with the overlying marine unit. Thin carbonaceous siltstone bands occur in the lower part, and a prominent coarse sandstone with plant fragments at 850.45-850.7m. The middle unit, from 853.6 to 862m, is of thinly laminated carbonaceous sandy siltstone. Soft sediment deformation and pyritisation is common. Soft sediment deformation is intense at 855.5m. The siltstone becomes gritty at 860m and grades in the lower unit, from 862-870.1m. The lower unit is similar to the uppermost and is of carbonaceous laminated micaceous fine sand, with minor soft carbonaceous silt horizons. The grain-size increases downward with medium to coarse sand over the last two metres. The base of the Liffey Group is sharp and conglomeratic at 870.1m.

Lower marine sequence
Bundella Mudstone correlate 870.1-900m
 The top six metres of the Bundella Mudstone is bioturbated silty pebbly sandstone, fining rapidly to a dark grey-black foraminiferal siltstone. Black siltstone grades to a grey bioturbated siltstone, typical of the Bundella Mudstone, by 876m. The main body of the Bundella Mudstone correlate is of grey siltstone, that becomes increasingly pebbly downwards. Fossils are not common, with only rare horizons containing brachiopods and trepostome bryozoa.
Conglomeratic beds 900-980m
 The typical fossiliferous lower Bundella Mudstone facies and Woody Island Siltstone are absent from the drillcore, and are replaced by conglomerates, conglomeratic siltstones and pebbly siltstone. From 900 to 908.5m are poorly sorted silty conglomerates and pebbly siltstones. Clasts are generally rounded, up to 7cm in diameter, and of dolomite, chert and limestone, volcanic clasts are rare. From 908.5 to 949m pebbly siltstone predominates, with isolated bands of conglomerate and conglomeratic siltstone. The siltstone becomes better sorted and darker from 924m to 944m. Bands of silty conglomerate and conglomeratic siltstone are common from 944 to 949m. From 949 to the base of the Parmeener sequence at 980m conglomerates and conglomeratic sandstone dominate. Clasts are of mostly dolomite, with some sandstone and metamorphic clasts occurring. Rounding is variably subangular to well rounded, with some well-sorted well-rounded conglomerate beds, within poorly sorted subangular to rounded conglomeratic sandstones. Poorly sorted conglomeratic sandstones, with wispy carbonaceous silt bands, dominate the lowermost 18m. The basal beds are of dolomitic conglomerate on a basement of Precambrian dolomite.

Basement
Precambrian Dolomite 980.5-1323.6.
 Below the Permian section there is an unconformable contact to Precambrian dolomite. At 977.8m a sharp erosional contact between conglomerate and massive dolomite occurrs at an angle of approximately 85° to the core axis. The dolomite dips approximately 25° in the opposite direction. The core was not oriented nor was the direction of drilling checked.
Much of the core is broken and crumbly but competent sections show complex calcite veining patterns, many veins having breaks and displacements due to minor faulting.

Two veins sets occur, fine and generally less than 1mm thick, and larger 10-20mm, both cross cut each other and the bedding. The larger calcite veins are more common below 1250m.

Bedding planes vary from near horizontal to vertical and are rarely consistent for more than 500mm. In most cases bedding is convoluted and in places shows slump structures. Stylolites were observed in a number of places outlined by graphitic material.

Dolomite colour varies from grey to black, the darker materials generally being finer grained. Interbeds of greenish sandstone, and red and green chert, also occur. Sandstone interbeds occur at 1173-1180m, 1253-1266m, 1318m and 1320m and thin chert beds occur at 1015m and 1300m. Two small intervals at 1025m and 1036m have dark coloured oolites approximately 5mm across in a lighter grey matrix.

The dolomite sequence is non-fossiliferous except at 1180m where remnants of stromatolites occur. Poor preservation does not allow closer identification. At 1170m a 50mm section appears to be algal laminated. In a number of places core breakage may have occurred along algal laminated layers.

Pyrite occurs as fine disseminations and as crystals on partings from 1041m, becoming more prevalent between 1235-1247m. Where pyrite is prominent fine dissolution cavities are present, particularly in thicker calcite veins. Decomposed black clay occurs towards the bottom of the hole.

Textures become schistose from 1240m. A black sheen is visible on bedding surfaces and this became pervasive towards the bottom of the hole. Cleavage becomes crenulated and from 1320m the core can be described as schist. The last two metres were partly decomposed and pyrite crystals up to 1mm across were present in this section.

Lithologic correlation.

The Precambrian dolomite intersected at Hunterston reveals some similarities to the Black River Dolomite of northwestern Tasmania. The interbeds of green coloured basaltic sandstone in the Hunterston core, are similar to beds in the Black River Dolomite. The small intervals within the Hunterston core with oolitic texture appears to be similar to oolitic textures noted from the Black River Dolomite (pers. comm. Calver, 2002). A third similarity with the Black River Dolomite was the presence of intervals of chert. The Black River Dolomite has been correlated with the Crimson Creek Formation of western Tasmania (Adabi 1997; Calver 1998) and the Weld River Group of south-central Tasmania (Calver 1989). All these groups are recognised as Neoproterozoic (~750-650 Ma) (Calver 1998). Widespread distribution of these similar aged dolomites may indicate that a possible Neoproterozoic carbonate platform existed.

Stratigraphic correlation.

The stromatolite within the Hunterston core are not identifiable, however Calver (1998) mentions the occurrence of *Baicalia burra* in clasts within diamictite at the top of the Black River Dolomite in northwestern Tasmania, and Adabi (1997) also recorded *Baicalia burra* within Crimson Creek Formation at Renison. Griffin and Preiss (1976) described the occurrence of *Baicalia burra* from diamictite overlying the Smithton Dolomite and made a comparison with the Skillogalee Dolomite in South Australia. It is possible the remnants of stromatolites in the Hunterston core are also *Baicalia burra* and thus could provide a means of correlation with other Tasmanian, and possibly mainland, Precambrian dolomites.

The complex minor faulting and intersecting veining patterns noted in the core indicate a complex tectonic history and a number of episodes of movement. Bedding directions,

where visible, vary from near horizontal to vertical (as measured from the core axis) and these directions constantly changed indicating that the drilled section passed through multiple folds. The extremely contorted bedding near the bottom of the hole may indicate proximity to a thrust plane, contortions being due to drag folding. The presence of black clay, evidence of decomposition of the dolomite, in this region may have been due to fluids introduced along a permeable thrust plane. Disseminated pyrite also noted in this region may have been precipitated from introduced fluids.
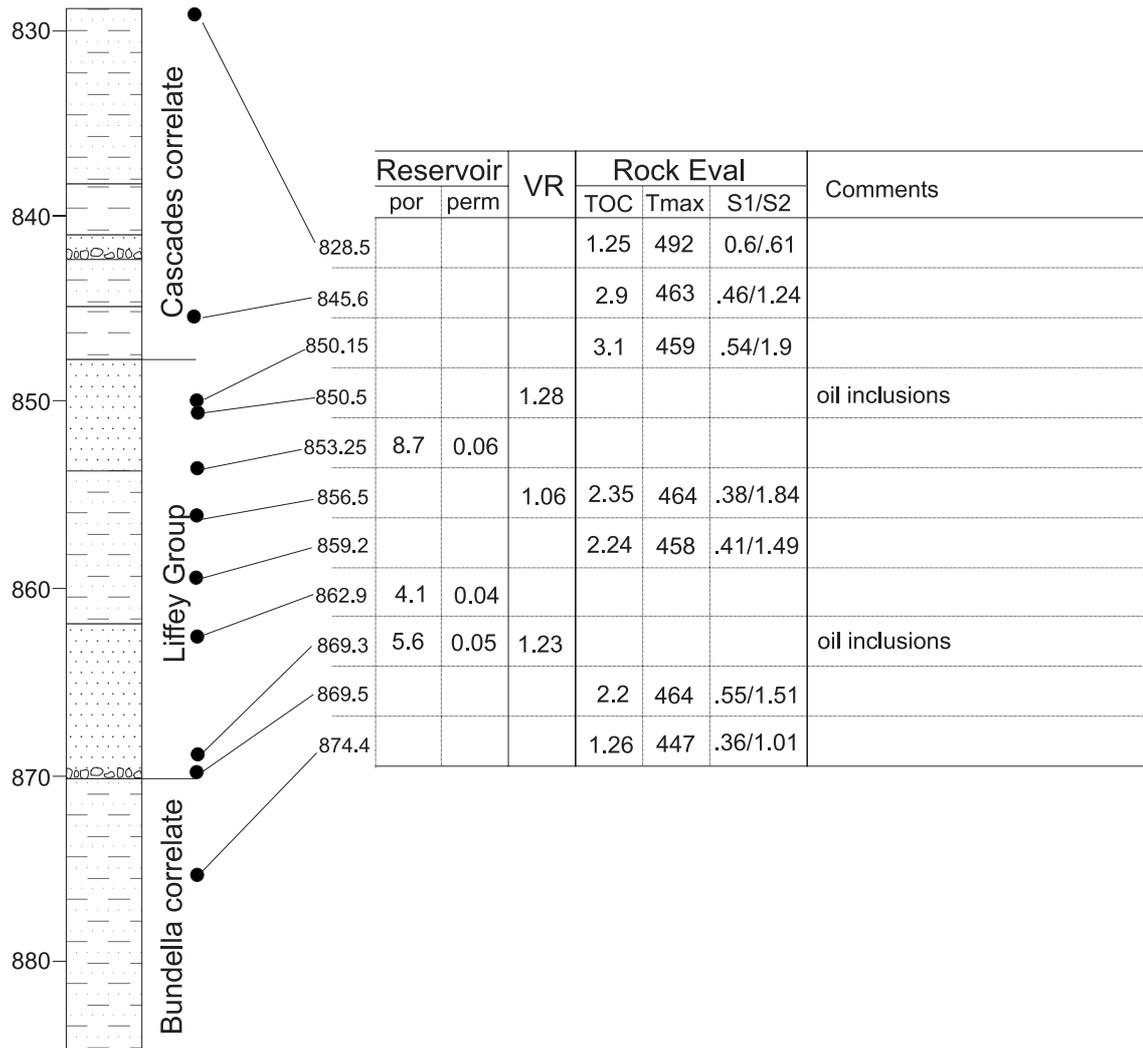
HYDROCARBON PROSPECTIVITY

Depth	Reservoir por	Reservoir perm	VR	Rock Eval TOC	Rock Eval Tmax	Rock Eval S1/S2	Comments
828.5				1.25	492	0.6/.61	
845.6				2.9	463	.46/1.24	
850.15				3.1	459	.54/1.9	
850.5			1.28				oil inclusions
853.25	8.7	0.06					
856.5			1.06	2.35	464	.38/1.84	
859.2				2.24	458	.41/1.49	
862.9	4.1	0.04					
869.3	5.6	0.05	1.23				oil inclusions
869.5				2.2	464	.55/1.51	
874.4				1.26	447	.36/1.01	

FIG. 3 – Summary data for the Liffey Group and adjacent rocks. Data given for principle potential source and reservoir rocks.

Source rock

 The Woody Island Siltstone, which is regionally extensive across the Tasmania Basin, and may be considered an appropriate potential source rock, is absent in the Hunterston DDH. The conglomeratic mudstones at this stratigraphic level, whilst often having a dark mud matrix are not of source quality. Toward the base of the conglomeratic beds

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wispy carbonaceous mud lenses appear in the matrix, however these are too thin to be of significance.

However, potential hydrocarbon source rocks are contained within the carbonaceous siltstones and sandstones of the Liffey Group. Discrete coal beds are not developed but the quantity of plant fragments and carbonaceous mud show comparable TOC and SPI (Figure 3) indicators to this unit elsewhere in the Tasmania Basin. Samples from the Liffey Group, underlying marginal marine beds of the Bundella Mudstone, and overlying marginal marine beds of the Cascades Group were analysed for vitrinite reflectance. Only the Liffey Group samples actually contained vitrinite in the dispersed organic matter (Cook, 2002), all samples contained inertinite. The contact to the base of the dolerite sill complex is at 784.4m, 44.1m above the Cascades sample, 66.1, 72.1 and 84.9m above the Liffey Group samples and 90m above the Bundella sample. The relative consistency in the reflectance of inertinite and vitrinite material indicates that heating effects of contact metamorphism are negligible at this distance from the dolerite intrusion.
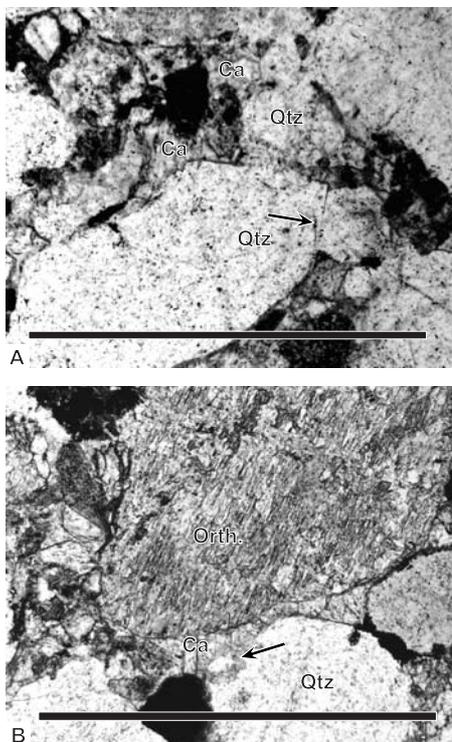

FIG. 4 - Diagenetic features of Liffey Group sandstone in the Hunterston DDH, sample at 850.5m, all scale bars 1mm. A, plane light showing quartz overgrowths, with barely visible grain boundaries indicated by arrow. B, plane light view showing perthitic dissolution of orthoclase feldspar, calcite cement, and dissolution of quartz cement and quartz grain and replacement with calcite cement, arrow. Qtz = quartz, Ca = calcite, Orth = orthoclase feldspar.

Reservoir rock

Traditional potential hydrocarbon reservoir rocks exist within the sandstones of the Liffey Group, as they do across much of the Tasmania Basin. However in the Hunterston DDH, the negative effect of proximity to dolerite intrusions is shown. Calcite is precipitated at elevated temperatures or lowered pH. The overlying limestones have contributed carbonate to the pore fluids, increasing pH, with temperature elevated from the intrusion. Carbonate cementation is later than both silica and clay, but may destroy both (Fig. 4). In many samples original quartz clasts have been eroded, and

orthoclase feldspar has been pervasively replaced by calcite. In the Hunterston DDH carbonate cement is well developed, and it is the late dissolution of carbonate that produces a secondary porosity. However connectivity of pore spaces is low, and hence permeability is low.

Down hole fault zones

There is potential for localised reservoirs within the brecciated fault zones in the lower marine sequence. Several of these brecciated zones occur around 900m depth, each with an associated "hallow" of carbonate dissolution, and replacement by silica, ranging from 0.5 to 10m in thickness. The dissolution of carbonate material is assumed to be by fluids introduced along fault structures. The degree of brecciation is severe, and the high porosity and permeability led to loss of drilling pressure, indicating such horizons would be highly suitable reservoirs, providing there is a suitable seal on the fault away from the zone of dissolution.

Near the base of the Lower Parmeener Supergroup in the Hunterston DDH at 957m, one such dissolution horizon, involving strong carbonate dissolution and siliceous replacement of a conglomerate, over 3m, has not been brecciated and the porosity and permeability can be seen to be very high.

Gas

The drilling program of July 2002 included gas measurement during drilling by OME Resources. Background levels of gas remained low, with a maximum of 40 units (0.4 % by volume in air) encountered in the sandstones of the Liffey Group. However as the hole was diamond drilled the volume of cuttings from which gas could be measured and/or collected is small and is not a definitive indicator of true gas content.

Structure

Figure 1 shows the local strike and dip of beds that form a dome like structure. The drillhole is placed to be at the estimated central position of this domal structure. The Hunterston Dome, is reflected at the surface in Permian and Triassic sediments, and is assumed to continue as a subsurface feature. The seismic data is not at a scale appropriate to determine the subsurface dip of the Parmeener beds, however broad domal structure is seen in the underlying Precambrian dolomites. However the seismic data does prove the continuity of the eastern outcropping dolerite with the intrusion encountered between 134m and 784m in the hole. On a regional scale it appears there is only one major dolerite body across the central Midlands, and in the local Hunterston area forms a shallow dipping basin, as partly shown in Fig. X. The deformation producing the Hunterston Dome, either preceded or was conincident with dolerite intrusion. Dips adjacent to the dolerite contact east of the DDH site steepen towards the boundary, and may indicate bed drag effects.
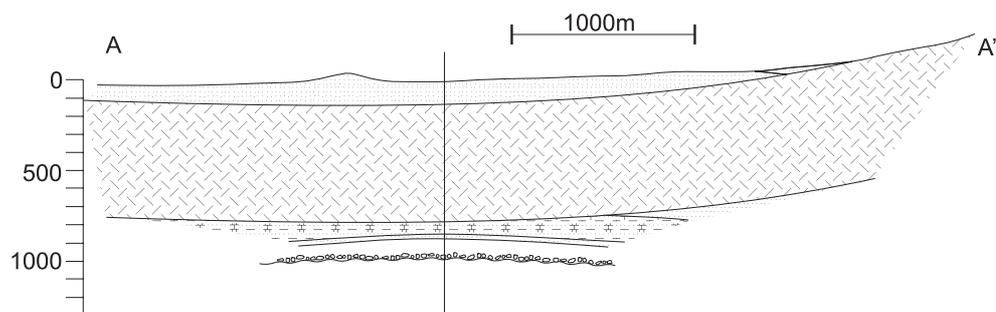

FIG. 5 – Schematic cross section along the line A-A' (location shown in Fig. 1). The vertical to horizontal exaggeration is 1:1.

Hydrocarbon summary

Thick source rocks are absent from the Hunterston DDH, although thin beds exist in the Liffey Group. While the porosity and permeability of potential reservoir sandstones in the Liffey Group are poor, destroyed by diagenetic effects associated with dolerite intrusion, there are indications of the presence of oil. Oil inclusions within both silica and carbonate in the sandstones, indicates generation and/or trapping of hydrocarbons before the final diagenetic phase. A possible scenario is of hydrocarbons generated before dolerite intrusions that have been locally expelled by carbonate fluids.

PALAEOGEOGRAPHY

Permo-Carboniferous glacial erosion and retreat has produced conglomeratic beds of rounded pebbles of Precambrian dolomite, supported in a silty matrix, immediately on top of the massive Precambrian dolomite. It is hard to conceive that all of the sedimentation from Cambrian to Carboniferous could have been eroded when nearby thousands of metres of deposition from this time interval can be observed. It is likely that the Permian deposits lie over the end of a thrust sheet of Precambrian dolomite as shown in Figure 1. A series of thrusts can be traced in Fossey Mountains region of northern Tasmania (Woodward, Gray et al. 1993) and the existence of stacked thrusts in the area drilled has been interpreted from geophysical data (Leaman, Symonds et al. 1973; Leaman 1988; Leaman 2001).

In the Hunterston area the geology of associated thrust blocks is unknown. The closest outcrops of Precambrian dolomite occur near Hastings Caves, in southern Tasmania, where it is in faulted contacts with Ordovician Gordon Limestone. Further drilling near Hunterston could resolve the structural complexities of the region.

CONCLUSIONS

The stratigraphy encountered in the Hunterston DDH included the Cascades Group, freshwater Liffey Group and Bundella Mudstone as expected. The basal conglomerates and absence of Woody Island Siltstone, and tillite, proved the extension of the regional high to the northwest through this central part of the Tasmania Basin. Dolerite intrusion has mobilised carbonate, and reduced reservoir quality within the Liffey Group, however direct heating effects are not seen. Therefore measured vitrinite reflectances within the Liffey Group show background maturity of organic matter. From this it can be concluded that the central Tasmania Basin is mature for hydrocarbons.