Annual Report 2012

SEL 26/2005 (Sixth Annual Report)

8th July 2011 to the 7th July 2012

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Power down under

Summary

KUTh Exploration Pty Ltd (KUTh) currently holds two Special Exploration Licences in Tasmania for Category 6 minerals (geothermal substances). The principle target of KUTh's work on these tenements is the location of high-temperature Hot Rock geothermal resources suitable for development as Enhanced Geothermal System (EGS) power generators. This report covers work completed in the year 8/7/2011 – 7/7/2012 on tenement SEL 26/2005. This is the sixth Annual Report lodged for SEL 26/2005, which was initially granted on 7/8/2006 and subsequently renewed for a second five-year term on 7/8/2011. The tenement is located in the eastern half of Tasmania and covers an area of 7570km^2. Previous work conducted on this tenement has identified two inferred geothermal resources at Lemont in the central Midlands and Fingal in the northeast.

Delays in the proposed deep exploratory drill program have limited the annual expenditure on this tenement. No field work was conducted on SEL 26/2005 in the reporting year.

The majority of work programs initially proposed for the report year have been held over into the upcoming year. Work planned for the second year of SEL 26/2005 renewal includes:

- *Drill planning, engineering and site preparation at Lemont*
- *Deep drilling at Lemont (exploration slimhole)*
- *Contingent on encouraging results, reservoir characterisation testing, installation of seismic monitoring array, planning and engineering of deep appraisal wells*
- *Contingent on encouraging results, reappraisal of initial resource estimation, possibly to Indicated status; expansion of inferred model to include Tooms-Leake and Macquarie areas.*

KUTh ENERGY

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1 Introduction

KUTh Exploration Pty Ltd (KUTh) is a geothermal explorer based in Hobart, Tasmania, and is the holder of two current geothermal exploration licences in that State. The principle target of KUTh's work is the location of high-temperature Hot Rock geothermal resources suitable for development as Enhanced Geothermal Systems (EGS) power generators.

This combined annual report covers work completed in the period 8/7/2011 – 7/7/2012 on KUTh's tenement SEL 26/2005. This is the sixth Annual Report lodged for SEL 26/2005.

1.1 Tenement Status

KUTh Exploration Pty Ltd (KUTh) is a subsidiary of KUTh Energy Ltd and is the sole holder and operator of SELs 26/2005 and 45/2007 (Figure 1). All SELs were granted for initial periods of five years to search for geothermal substances (Category Type 6). Tenure details of SEL 26/2005, which was renewed for a second five-year term in 2011, are provided in Table 1.

Tenement Type	SEL
Number	26/2005
Commodity	Geothermal
Licensee	KUTh Exploration P/L
Operator	KUTh Exploration P/L
Area	7570km^2
Date Granted	7/08/2006
Date Renewed	7/08/2011
Expiry	6/08/2016

Table 1: Tenure details for SEL 26/2005.

1.2 Location and access

SEL 26/2005 includes much of central Eastern Tasmania, extending across the north and south Midlands areas and along the coast from Orford in the south to an area west of Scamander in the north (Figure 1). A number of highways traverse the area and provide access along with minor roads, farm and forestry tracks. Numerous areas are excluded from SEL 26/2005, including National Parks, Commonwealth land, a gas pipeline easement and various small historic and other features.

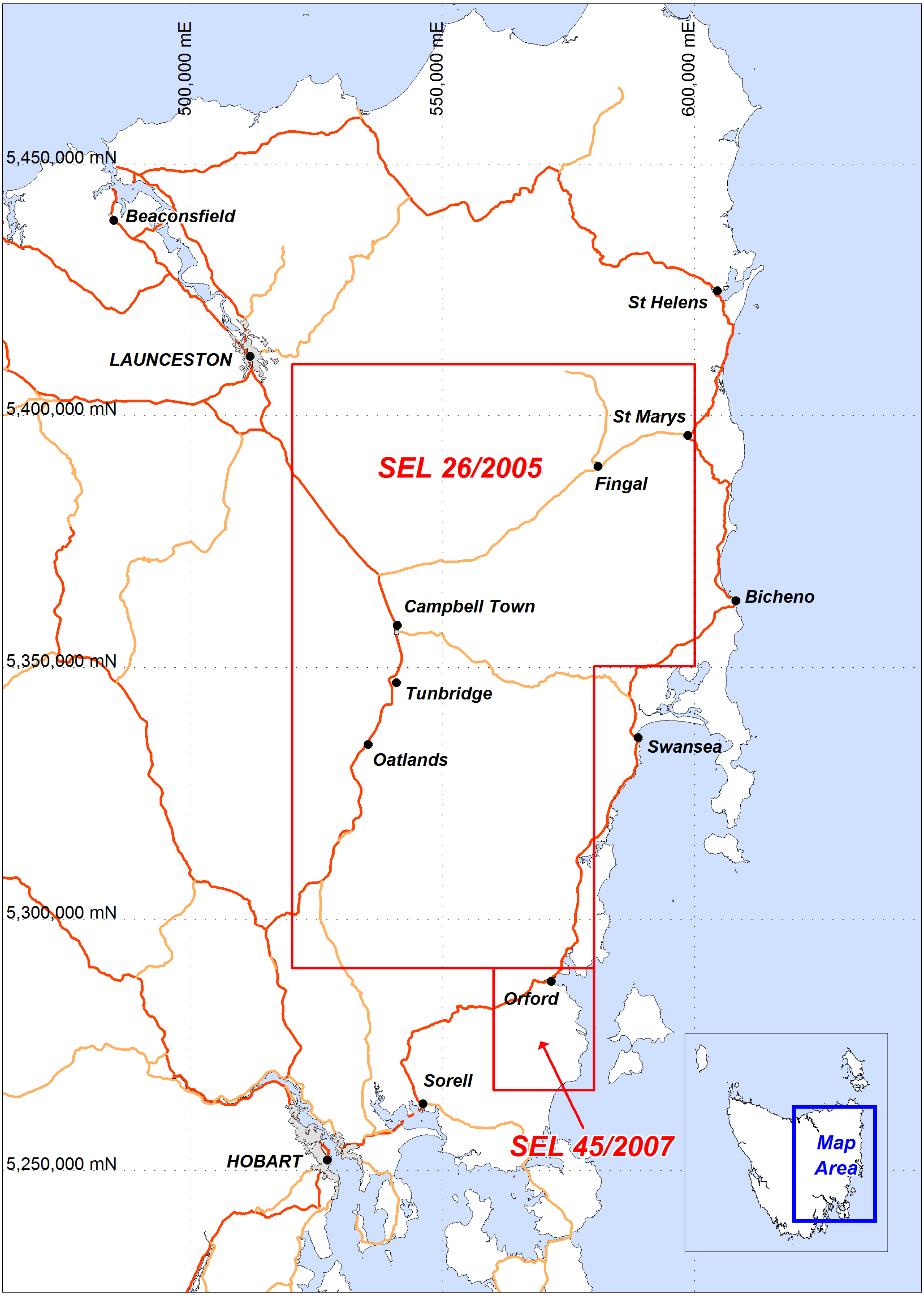

Figure 1: Location map of KUTh Energy Geothermal Special Exploration Licences in Tasmania (red) in relation to major roads (orange) and population centres. (Note this map does not indicate the location or extent of licence exclusions).

1.3 Topography and vegetation

Topography varies significantly across the tenement area and ranges from flat to undulating coastal and inland plains, to steep granite and dolerite ranges and tors. The maximum elevation range across the tenement area is greater than 1km, rising from sea level at the coast to peaks including Ben Lomond (1573m). Vegetation is dominated by dry eucalypt forest and developed pasture although considerable variation is present across the topographic range. Pockets of alpine moorland, wet eucalypt forest, native grassland and scrub, wetland and coastal scrub may be found at various locations across the tenement.

1.4 Geological setting

Tasmania is divided into two basement terrains located in the west and east of the State (Figure 2). Distinguished by age, lithology and deformation these two regions are 'believed to have been juxtaposed at a NNW trending dislocation' inferred to coincide with the Tamar Valley region in central Tasmania (Burrett & Martin, 1989). The Western Terrain comprises variably deformed and metamorphosed Pre-Cambrian basement, the now-deformed Cambrian volcanics and sediments of the Dundas Trough and Mt Read Volcanic Belt and the Ordovician-Silurian shelf sediments of the Wurrawina Supergroup. In the East, deformed low-grade meta-sediments of the Ordovician – Devonian Mathinna Supergroup comprise deep water turbidite deposits that are analogous to the ubiquitous Tasminide flysch of mainland eastern Australia. Similarities in the deformation and depositional style of the Mathinna Supergroup and mainland Tasminide units has led to numerous attempts to correlate the two, the Mathinna being compared variably to the Melbourne Trough and the Tabberabbera Zone of central and eastern Victoria (Powell & Baillie, 1992; Reed, 2001).

Across much of the state, basement is concealed by up to 1km of flat-lying Permian-Triassic sediments of the Tasmania Basin and the extensive thick (>300m) Jurassic dolerite sills which intruded these during Gondwana break-up. Mesozoic and Tertiary cover, including extensive dolerite, shale, silt and some coal formations, totally obscure the contact between the Pre-Cambrian Western and Palaeozoic Eastern terrains, which is inferred to underlie the tenement area.

Both Western and Eastern Terrains host Devonian granite, the most extensive intrusions being the slightly older batholiths in the East (Burrett & Martin, 1989). Exposures of Devonian-aged granite in the far north-east of the state are known to include highly-fractionated high-heat-producing (HHP) granites as part of three major suites (Figure 2; Burrett & Martin 1989). To the south and west of this area, the exposed granite plunges beneath cover which potentially provides the insulation necessary for a classic Hot Dry Rock or Enhanced Geothermal System (EGS) target. Complicating this picture is the presence of a known electrical conductivity anomaly initially observed in the northern Tamar Valley area and referred to as the Tamar Conductivity Zone (TCZ) (Figure 2; Hermanto, 1992). Coinciding broadly with the boundary of the East and West terrains, the TCZ has been interpreted an indicator of fluid in fractured permeable zones (Hermanto, 1992). Intersection between the TCZ and buried HHP granites may thus imply the presence of an existing fracture-permeable geothermal system in Eastern Tasmania.

2 Previous Exploration

KUTh Exploration is the first operator to undertake commercial geothermal exploration work in Tasmania. Legacy geothermal data available in this area are limited to a few early heat flow measurements recorded across the state in the 1950 – 1960s and early 1980s (Figure 2; Cull 1991). Although sparse and of variable quality, these data indicate the presence of high heat flows associated with Devonian granite in the north-east of the state. Heat production data from these granites are available from Collins et al, 1981, and include values of up to 60 μW/m^3 for granites at the Royal George Mine.

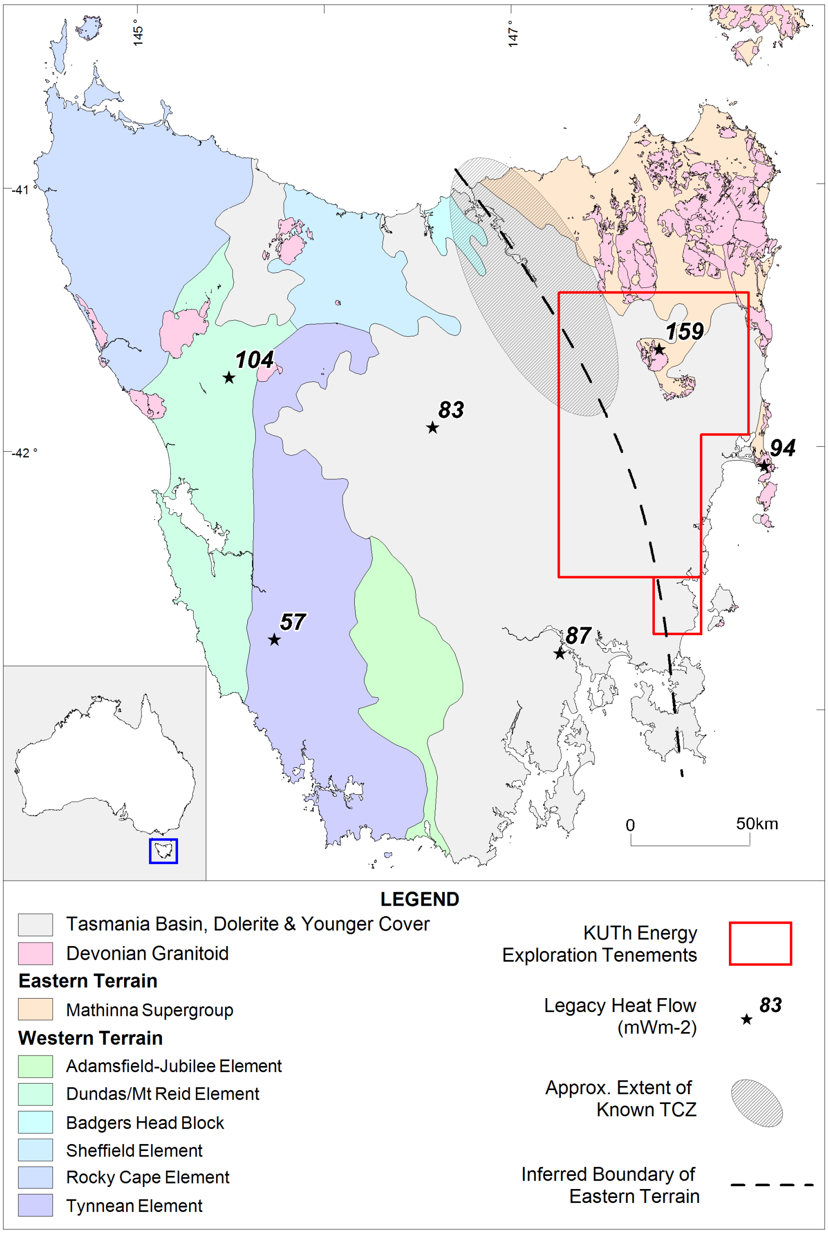

Figure 2: Regional geology of Tasmania showing the major crustal elements. Legacy heat flow data are as summarised by Cull (1991). Also shown is the approximate extent of the known TCZ prior to recent MT survey work.

The presence of the Jurassic dolerite across much of the tenement area has limited exploration for most commodities in this region. With the exception of small areas around Storeys Creek and Fingal in the north-east of the tenement, relatively few drill holes have been cut. Stratigraphical holes at Tunbridge and Ross provide the deepest information from the central tenement area but are both <1km deep. Attempts by KUTh in 2006 – 2007 to undertake a surface heat flow measurement program in existing core holes failed due to a lack of suitable historic open holes.

2.1 Potential Field Geophysics

Available legacy geophysical data include aeromagnetic and gravity coverages. Data quality was patchy leading to an early decision by KUTh to undertake infill gravity and aeromagnetic survey work across the south-east of the tenement area (Ward *et al.*, 2008; Goh & Holgate 2009; Holgate, 2011). Data derived from gravity survey work completed in two campaigns in 2007 and 2010 were provided to Dr David Leaman who used it to update the Tasmanian mantle-source model of Leaman and Richardson (2003). This updated model was then used to refine predicted depth to top granite (Figure 3).

An infill aeromagnetic survey was conducted in 2009 (Goh & Holgate, 2009). The results of this work are summarised in Figure 4 and are interpreted to indicate the presence of major crustal features (lineaments) within the Central Midlands area.

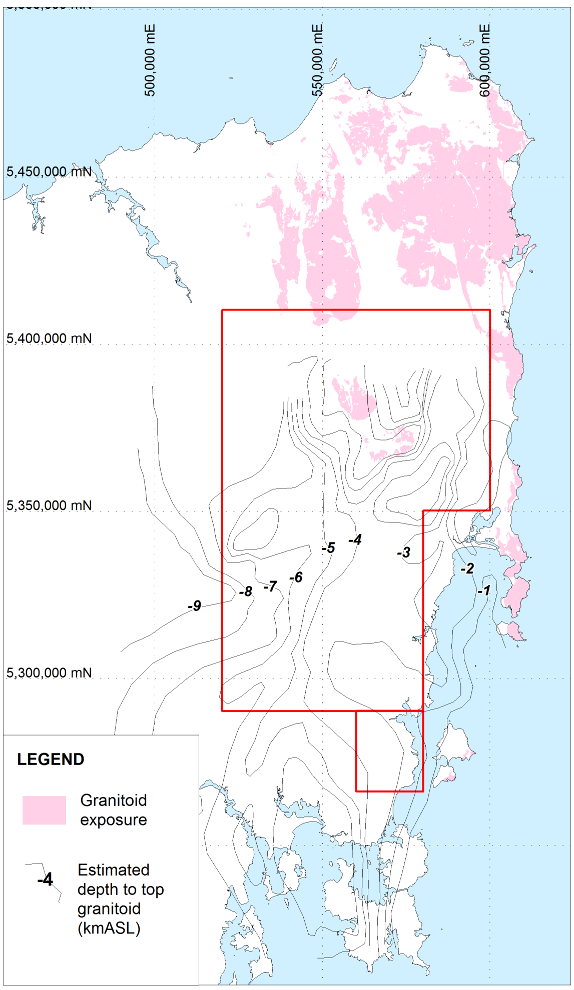

Figure 3: Map of granite outcrop with predicted depth (km above sea level) to top granitoid contours as interpreted by Leaman (2010).

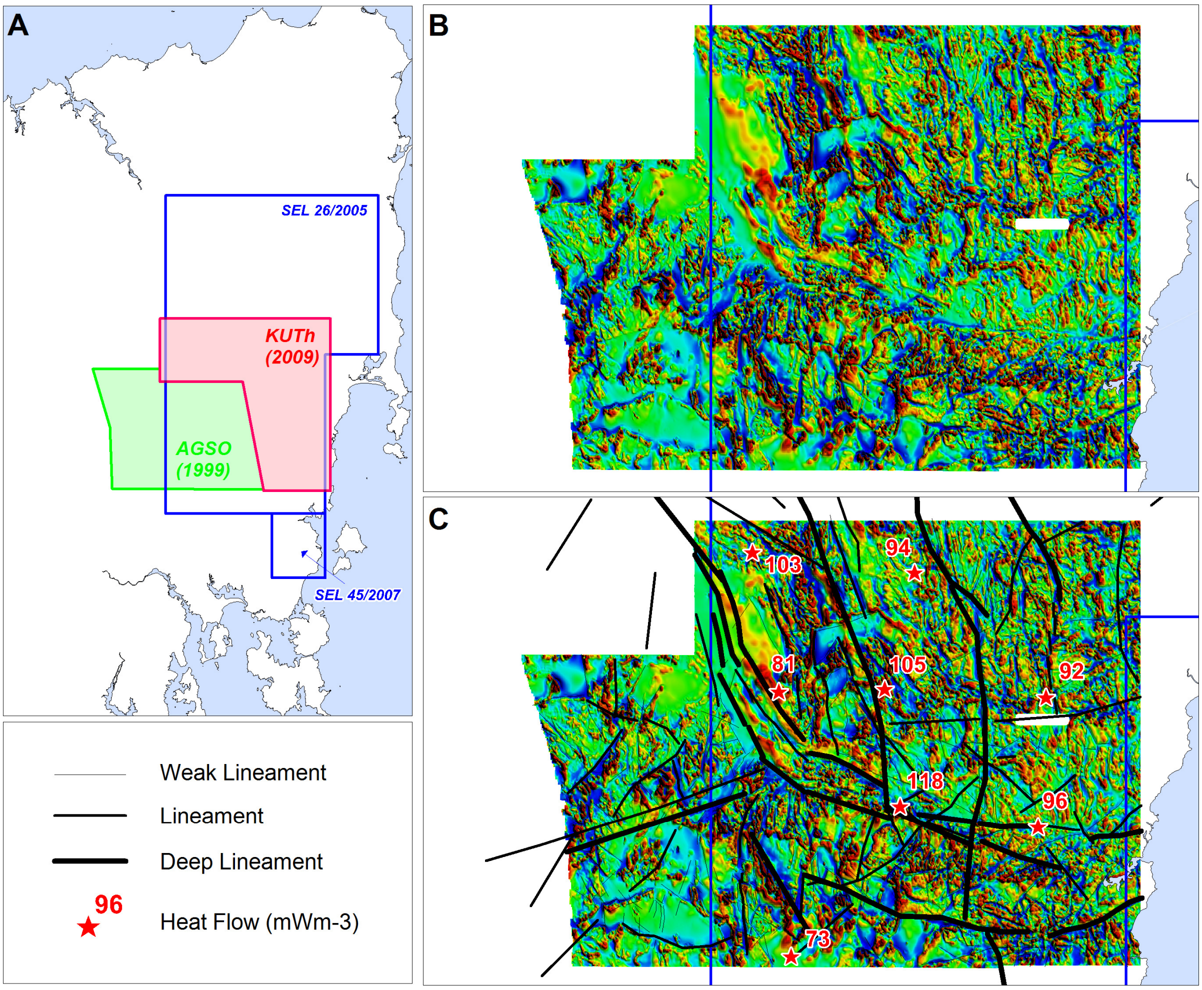

Figure 4: KUTh aeromagnetic data acquisition (a) location plan (b) Reduced-to-pole total magnetic intensity image and (c) interpreted lineaments.

The majority of magnetic lineaments identified under the survey area are interpreted as the signature of fault or fracture systems. Regionally, magnetic structure is dominated by a large, arcuate feature extending from the northwest to the eastern side of the survey area. This feature, which is interpreted to represent a major fracture zone, is also evident in gravity data and digital elevation models (Figure 5). The presence of this trend in both gravity and upward continued magnetic data supports the suggestion that it is a relatively major feature, penetrating to depth in basement. The fact that it is also strongly apparent in the DEM implies that it is likely to have been subject to post-Jurassic reactivation, most likely as part of a regional Tertiary rifting event that has been identified throughout much of this area (Burrett & Martin, 1989).

2.2 Rock Property Data

The company has established a significant rock thermal conductivity database for eastern Tasmania sourced variably from its own shallow drill program, academic partnerships and targeted legacy core sampling (Goh & Holgate 2009; Holgate & Goh 2010; Holgate, 2011).

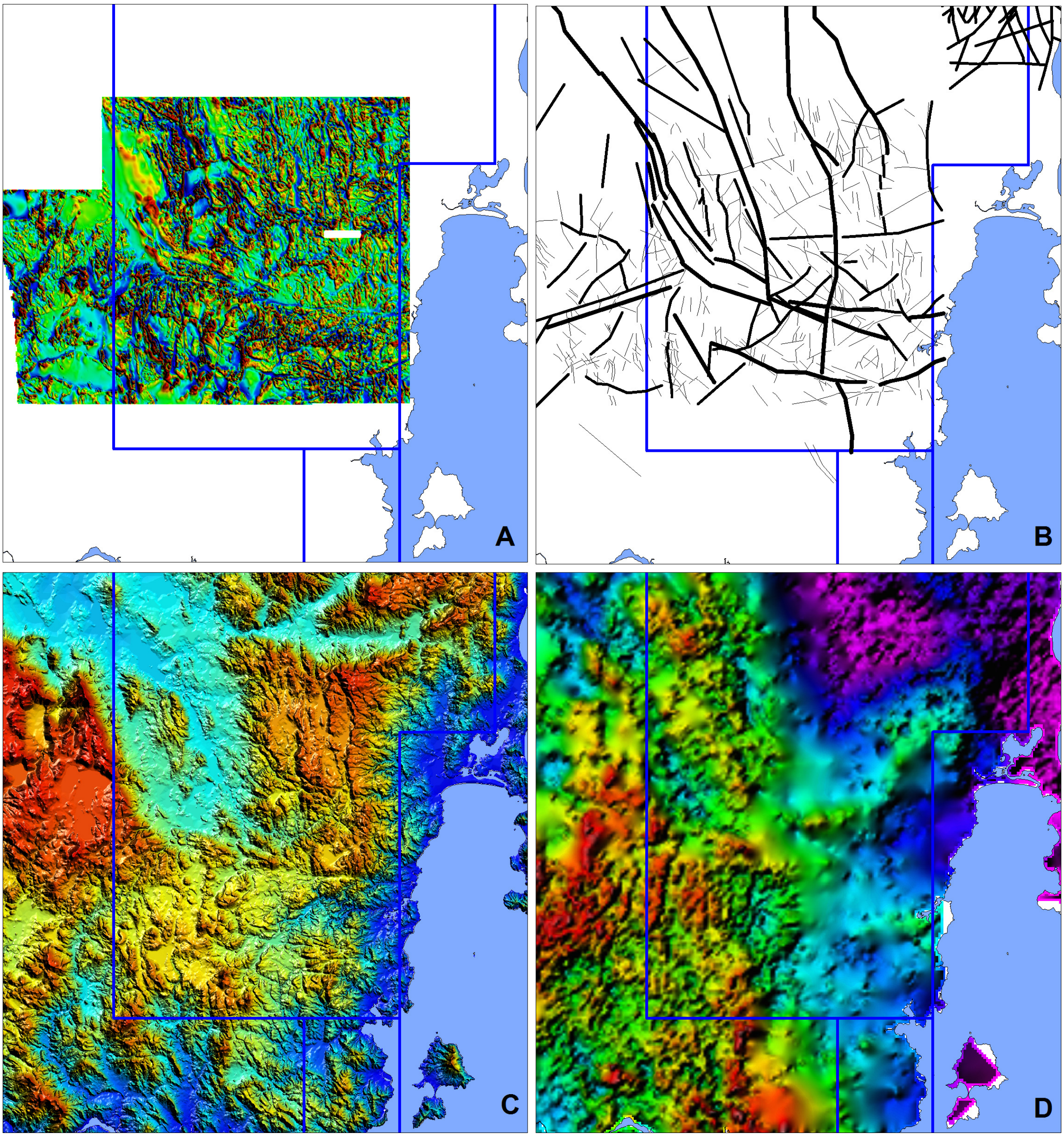

Figure 5: Map images of the Midlands area showing the KUTh tenement boundaries (blue) superimposed on (a) total magnetic intensity from combined KUTh/AGSO aeromagnetic surveys; (b) interpreted magnetic lineaments; (c) digital terrain image; and (d) residual Bouguer gravity anomaly (determined using the MANTLE07 model of Leaman, 2008).

2.3 Heat Flow Determination and Resource Estimation

Between 2007 and 2009 KUTh undertook a program of shallow drilling to enable systematic estimation of surface heat flow across the tenement area (Figure 6; Goh & Holgate, 2009). This work resulted in the identification of several significant thermal anomalies (where heat flow is >90mWm^{-2}) that display a good spatial correlation with the predicted location of buried granite (Figures 3 & 6). The largest observed anomaly extends ~4000km^{2} across the central portion of SEL 26/2005 and includes three zones of very high heat flow (>100mWm^{-2}) at Lemont and Macquarie in the Midlands and at Fingal in the far north-east. The largest and strongest of these thermal anomalies is that observed at Lemont.

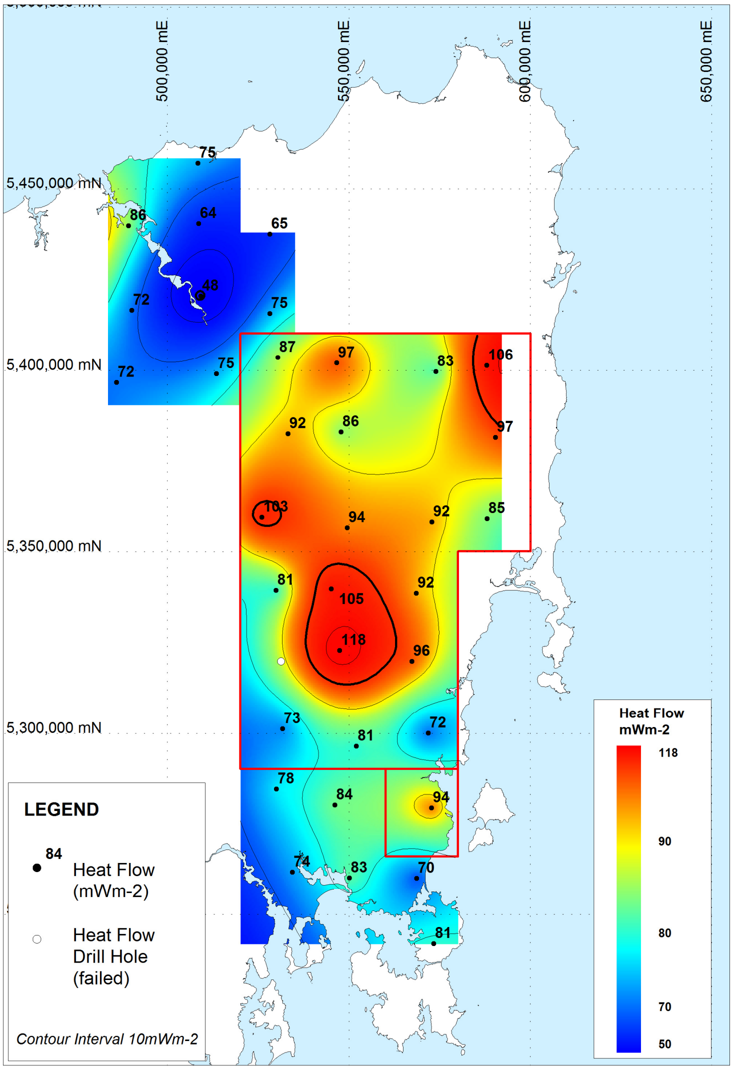

Figure 6: Results of KUTh Energy shallow heat flow drilling program across SEL 26/2005 (now partially surrendered).

Following on from this work three-dimensional (3D) conductive thermal modelling of the Lemont area was undertaken in 2009 using a combination of legacy and newly acquired geological and geophysical data. The results of this work (reported in Goh & Holgate 2009) inferred a contained heat resource of around 260,000PJ_{th} within a 1019km^3 reservoir located between 3 – 5km depth in the Lemont area (Figure 7). Temperatures predicted within the resource are up 200°C at 5km depth. Geothermal Plays initially identified at Lemont included a granite-related Hot Dry Rock target in the east and a less well defined but slightly hotter target in the west. Significantly, the conductive model inversion was found to be unable to account for the presence of extreme heat flow values in the western resource areas without the addition of a previously unrecognised geological unit. A non-unique conductive solution comprising an additional body of rock of either high heat production or high thermal conductivity (termed ‘Unit A’) was required in this area to enable model fit. This Unit may represent a previously unrecognised lithology (e.g. granitoid) or structure (highly foliated sediment). Alternatively, the additional heat flow into the western resource area could be the result of the advective movement of heat by fluids along localised permeable pathways. One or more of these scenarios could significantly influence the geothermal play model envisioned for this area.

In 2010 a second inferred resource estimation was completed at Fingal in the north-east of the State. Previously reported in Holgate & Goh (2010) this work inferred a contained heat resource of around 101,000PJ_{th} within a 384km^3 reservoir located in granite between ca.3 – 5km depth (Figure 7). Temperatures predicted within the resource are up 220℃ at 5km depth. The geothermal play identified at Fingal is exclusively a granite-related Hot Dry Rock target.

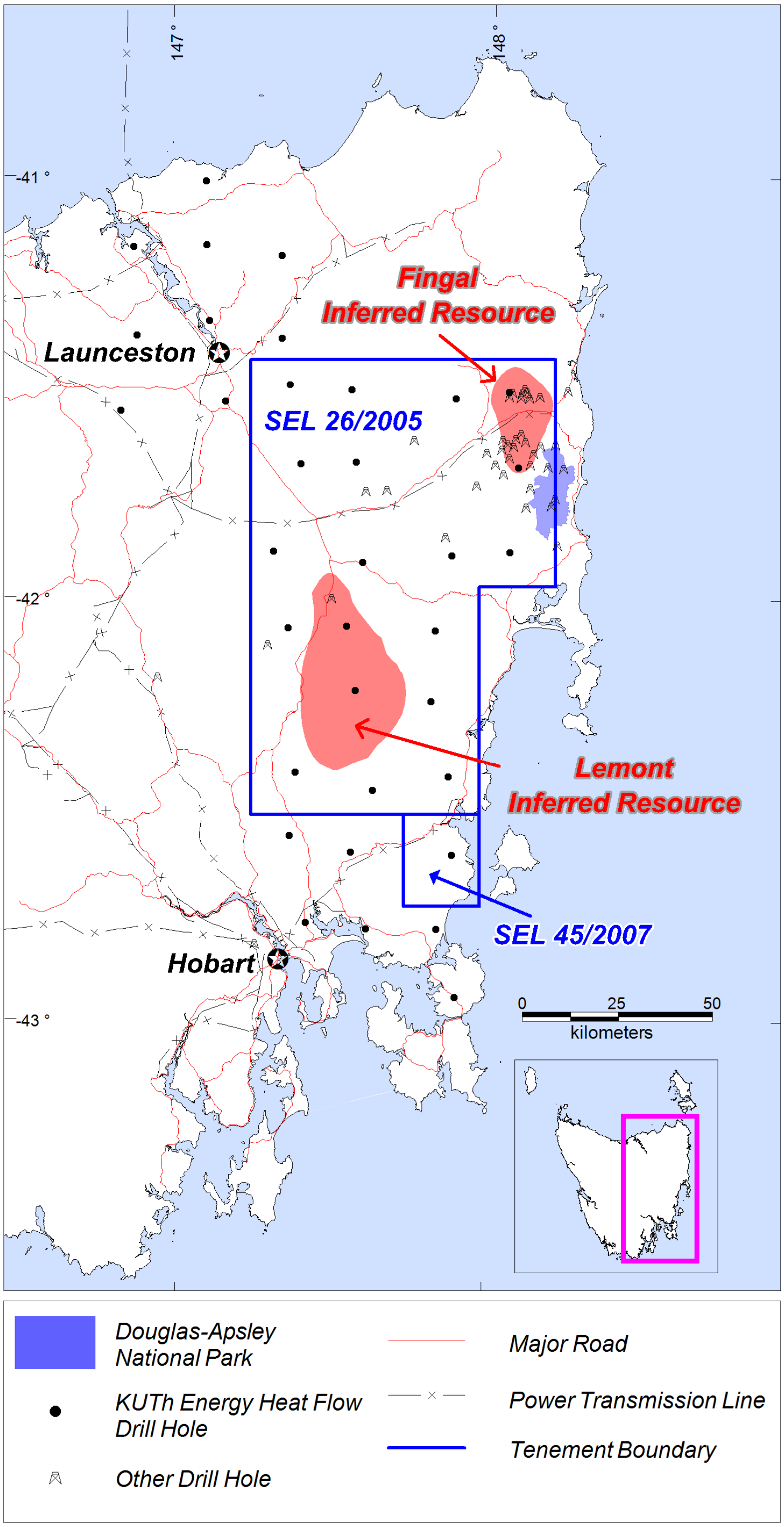

Figure 7: Location Map of Inferred Geothermal resource areas in SEL 26/2005.

2.4 Magnetotelluric Studies

Studies of magnetotelluric (MT) field data identifying a possible conductive anomaly in Northern Tasmania date back to the mid-1970's and are summarised in Hermanto (1992). This work consistently indicated the presence of a broad zone of anomalously high electrical conductivity, the *Tamar Conductivity Zone* or *TCZ*, approximately parallel to the NW trending axis of the northern Tamar Valley, and extending for some distance to the south (Figure 2). The TCZ was observed at depth beneath Mesozoic cover but no direct information was available regarding the nature or detailed structure of the geology associated with it. However, it was concluded that 'the most likely cause of the high conductivity anomaly was a combination of the presence of high conducting fluids and graphite in pores, cracks, and or fractured rocks' implying the potential for fracture permeability associated with this feature (Hermanto, 1992).

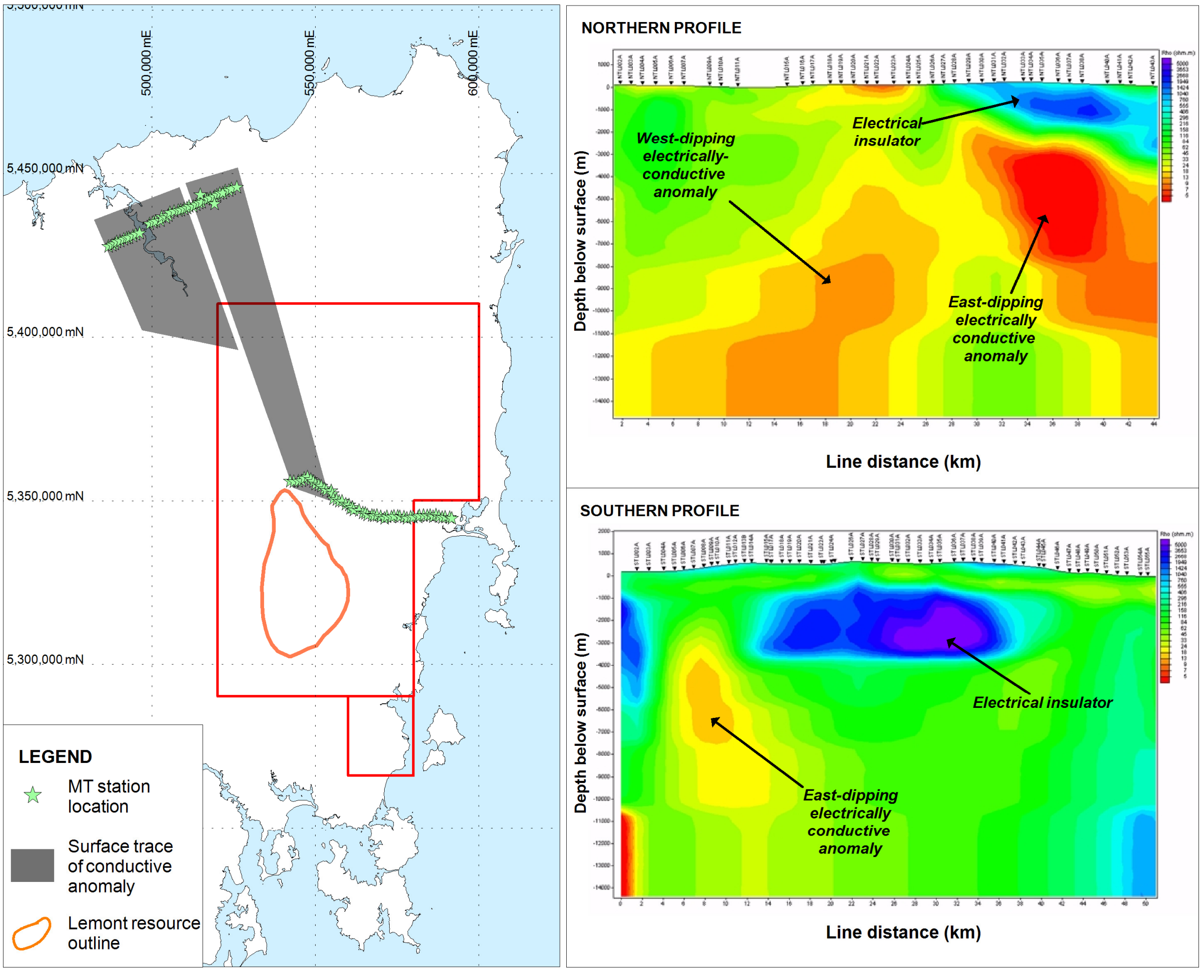

Figure 8: Results of the 2008 reconnaissance MT survey. Station locations (left) and 2D model results for northern (right, top) and southern lines (right, bottom). Models are inversions of TM and TE shifted data. Resistivity is range 5ohm.m (red) to 6000ohm.m (purple), maximum depth below surface is 14km, station spacings are ~1km, line distance northern line = 44km, southern line = 50km.

Between 2008 and 2010 KUTh successfully completed three programs of new MT data acquisition across the TCZ. The first, in 2008/2009, was designed to test the existence of the anomaly and involved the acquisition of new MT data along two east – west profiles in the far north and central Midlands areas of SEL 26/2005 (Ward *et al*., 2008; Goh & Holgate 2009). The results of this work are summarised as 2D models in Figure 8. Large east and west-dipping electrically-conductive basement features consistent with the known characteristics of the TCZ were successfully identified in the northern section line. Significantly, an equivalent east-dipping electrically conductive structure was also observed towards the western end of the southern line. This feature, which is interpreted as an extension of the TCZ, is open along strike immediately to the north of the high heat flow anomalies at Lemont and is of considerable interest given its interpretation as a geophysical signature of fluid-bearing fracture-permeable rock.

To further evaluate the southern extension of the TCZ, an expanded MT/TerraTEM survey was undertaken across SEL 26/2005 in 2009 and was followed by a third program of infill MT data acquisition in 2010. Data acquisition on the expanded array was designed to enable 3D MT modelling across the central Midlands area and resulted in the collection of 201 new stations arranged along three profile lines and a surrounding spaced grid (Figure 9). The results of this work were processed using 3D inversion modelling by WesternGeco EM (Geosystem). These data clearly indicate the presence of the TCZ within the resource area. Unexpectedly, the electrically conductive zone was observed to diverge in strike from NW/SE to EW immediately beneath the resource area (Figure 10).

Figure 9: Location map of the 2010 3D MT/TDEM survey array across KUTh Energy's Tasmanian tenements. Blue stars represent stage 3 (2010) MT stations, red stage 1 and 2 (2008/2009) MT stations. The white outline in the central tenement area indicates the surface extent of the Lemont Inferred Geothermal Resource. Background Image ©Google Earth.

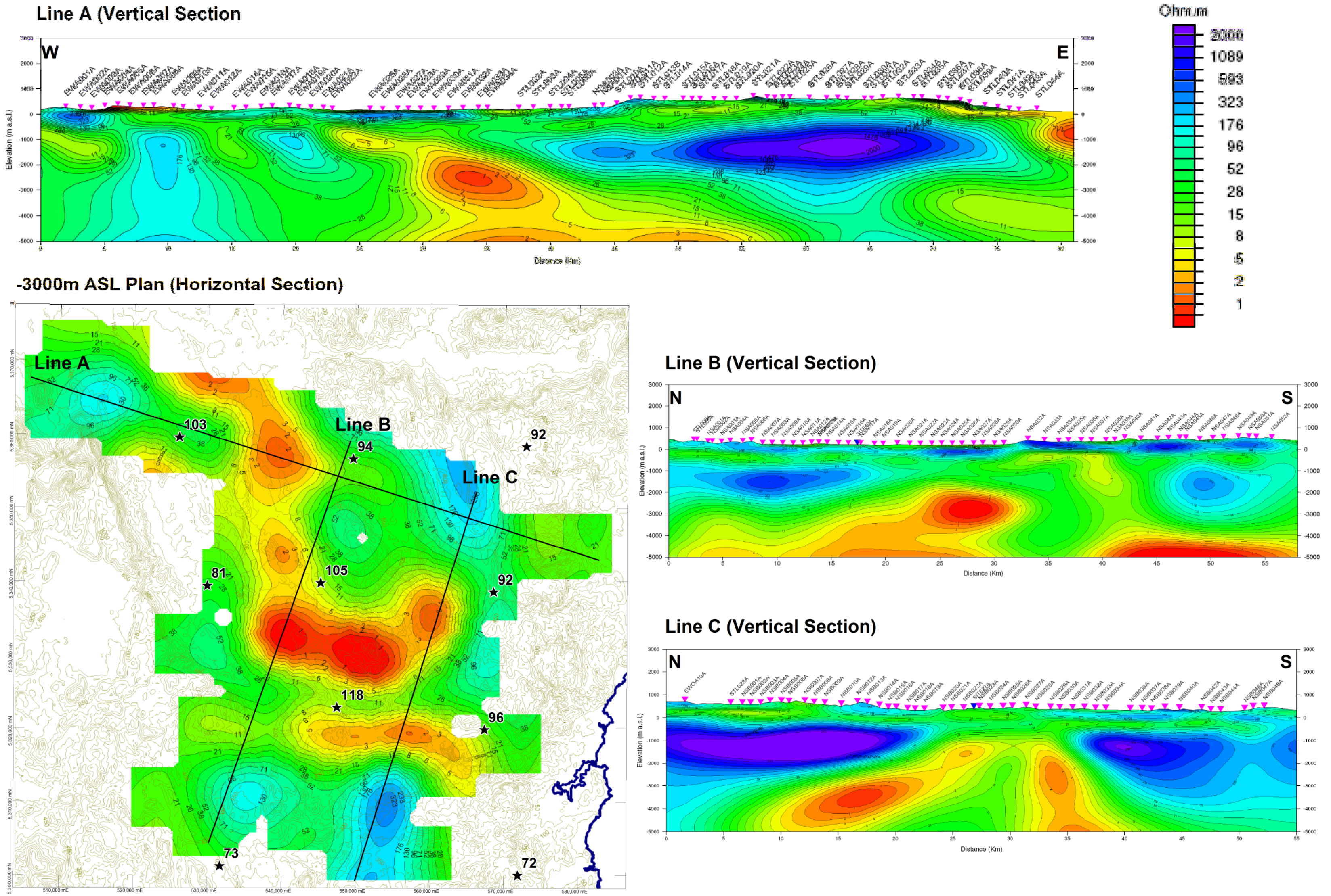

Figure 10: Selected results from the 2010 3D magnetotelluric survey presented as resistivity images. All images share the same scale (shown); warmer colours indicate increased electrical conductivity. Vertical section lines are as located on the -3000m ASL Plan. Vertical exaggeration of these sections is 2:1. The location of surface heat flow values (mWm^{-2}) from KUTh's shallow heat flow program are shown on the plan as black stars. Details of the modelling process are provided in Holgate & Goh (2010)

Visualised in 3D, the southern extension of the TCZ appears to be an east-dipping NW/SE striking planar structure in the NW of the infill survey area. To the south it diverges sharply to strike EW beneath the centre of the Lemont resource area. Two planar EW striking structures are observed in this area, a shallowly north-dipping anomaly in the north and a moderately southerly-dipping anomaly in the south. Vertical sections through these features indicate an inverted v-shaped electrically-conductive anomaly is laterally extensive beneath this area. The apogee of this structure is projected to lie beneath the anomalously hot Lemont bore hole (surface heat flow 118mWm^2). In all cases areas of high electrical conductivity are found to be basement features, commencing around 2km depth.

The striking spatial coincidence of apparently deep fractured zones (interpreted from gravity and aeromagnetic data), electrically conductive MT anomalies and anomalously high heat flow within the Lemont region has led to the development of a new conceptual play model for this area. Originally conceived as a relatively high temperature, low permeability Hot Rock prospect, Lemont now appears to host what may be a Naturally Fractured Hot Rock play (Figure 11) with potential for warm/hot fluids at depth along zones of fracture permeability. Following completion of the geophysical acquisition programs it has been determined that further definitive testing of this play model will require deep drilling.

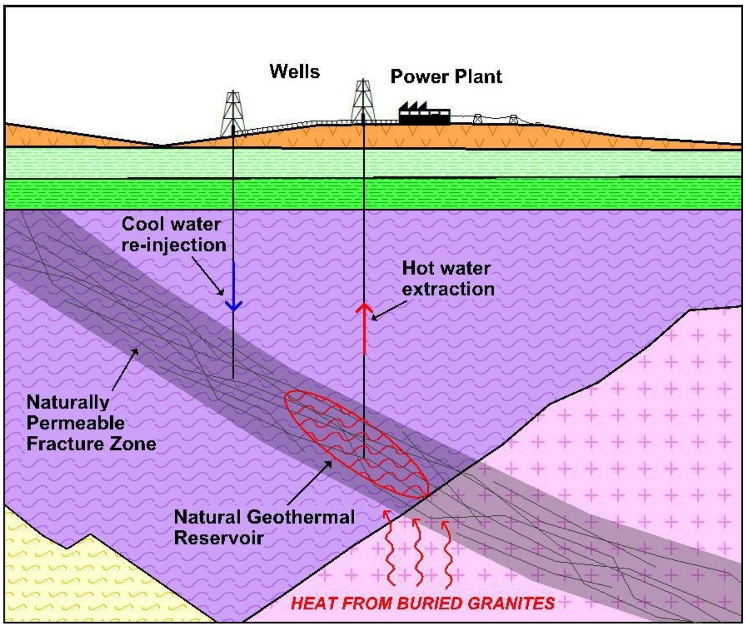

Figure 11: Diagrammatic illustration of Naturally Fractured Hot Rock play concept, Lemont, Tasmania.

2.5 Stress Modelling and Seismic Hazard

2D numerical fault stress-state modelling was undertaken across the NFHR play at Lemont (Holgate, 2011). Fracture location and orientation data based upon geophysical models were combined with stress data derived from an earthquake focal mechanism determined on a local earthquake (Holgate & Goh, 2010). The results of this work again indicated potential for permeable fracture systems at depth in this area.

In 2010, work was completed on a preliminary assessment of the natural earthquake hazard in NE Tasmania as a first step in the establishment of a seismic risk mitigation plan for geothermal development at Lemont and Fingal (Holgate, 2011).

3 Work Completed

No field work was undertaken on SEL 26/2005 during the reporting period. Work completed includes revision of existing resource updates.

3.1 Resource Updates

Inferred geothermal resource figures previously produced for the Lemont and Fingal areas were updated in keeping with recent changes made to the Australian Code for the Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (Edition 2, 2010). Significantly, the 2010 edition of the Code now defines a Geothermal Resource as *that portion of stored heat that can be recovered to surface* whereas previously it was simply the total stored heat. As a consequence of this change the updated values of the individual resources have varied significantly. This variance is purely technical in nature and should in no way be construed as a decrease in the energy potential of the individual plays.

Updated Inferred Resource Estimations at Lemont and Fingal are shown in Table 2. Full details of these updates are provided in Appendix 1 and 2 respectively. The updated Inferred Geothermal Resource estimations are now determined per individual depth slices of 500m as this is considered to better reflect the target thickness for an engineered Hot Rock development. Base temperature (plant rejection) from which the resource is determined has been raised from 70°C to 92°C.

The recovery factor now used to estimate the resources [in accordance with the 2010 Edition of the Geothermal Code] is 14% and is consistent with the values recommended by the Geothermal Lexicon for Resources and Reserves Definition and Reporting, Edition 2 (2010). The estimation of theoretical electrical power generation potential over 30 years was undertaken in accordance with the International Geothermal Association endorsed Global Protocol for estimating and mapping Enhanced Geothermal System potential (Beardsmore et al., 2010). Assumptions made in this calculation (reservoir temperature and power conversion efficiency) are detailed in Appendix 1 and 2.

Tasmanian Geothermal Resources (100% KUTh)			
Depth Interval (m)	**Updated Inferred Resource (PJ_{th})**	**Estimated Power Potential (MWe for 30 years)**	**Previous (PJ_{th})**
Lemont			
< 4,000	3,400	411	260,000 [14 July 2009]
4,000 – 4,500	11,000	1,391	
4,500 – 5,000	13,000	1,824	
Fingal			
< 3500	370	43	101,000 [9 March 2010]
3,500 – 4,000	2,300	291	
4,000 – 4,500	3,900	519	
4,500 – 5,000	4,800	685	

Table 2: Results of Tasmanian geothermal resource inventory update. All current resource figures are determined relative to an assumed base (reinjection) temperature of 92°C.

4 Research & Collaboration

Research and collaborative projects with KUTh support underway or completed during the reporting period are:

4.1 Ambient Seismic Energy Technique 2 (ASET2)

Work on the ASET2 project, a collaborative ARC-linkage partnership between KUTh and the UTAS led by Dr Anya Reading, Senior Lecturer in Geophysics at the UTAS completed in February 2012. Preliminary results of the project were reported in Holgate 2011. Final results are expected to be released as publications in selected scientific journals in the near future.

5 Discussion

Delays in the planned work program at Lemont and Fingal were brought about as a result of the collapse of an intended drilling partner (GlobeDrill) and ongoing issues with broader project financing. The latter are industry-wide issues caused by a combination of global financial conditions, government policy and project difficulties encountered by other EGS operators in Australia. The private investment market is currently extremely risk-averse making Government funding the only realistic option for progressing projects of this nature.

To this end KUTh has recently been cooperating with the *Geothermal Research Initiative* (GRI) to investigate the potential for joint research and development programs at its Tasmanian resources. The GRI is a collaboration of Australian research Institutions and organisations which have a common interest in geothermal research. Organisations represented in the GRI include the CSIRO, Geoscience Australia and the Geothermal Centres of Excellence at the Universities of Queensland, Melbourne, Adelaide and Western Australia. The GRI has recently identified permeability as a research priority for both exploration and development of geothermal resources, recognising that this property is key to achieving good flow (or production rate) from a geothermal reservoir. For some years now KUTh has pioneered the exploration for deep permeable zones through its *Naturally Fractured Hot Rock* play at Lemont. There are significant natural synergies between the Lemont project and the GRI's research directions which hold potential for future research and development collaborations at this site. Current Government funding models do not extend to these kinds of R&D projects although new, more appropriate models may come about with the announcement of the new *Australian Renewable Energy Agency* (ARENA) expected in July 2012. KUTh is currently working in partnership with the GRI and the Australian Geothermal Energy Association (AGEA) to lobby Government for a positive outcome for geothermal funding from ARENA. KUTh's aim in this task will be, at a minimum, to gain access to sufficient funds to undertake deep exploratory drilling at Lemont and determine the thermal significance (if any) of the known MT anomaly. To this end, work on deep drill planning at Lemont commenced in 2010 (Holgate, 2011) has continued throughout 2011 – 2012.

6 Conclusion and Recommendations

Work completed to date has successfully defined a number of significant targets for geothermal development in Eastern Tasmania. 3D geothermal modelling infers an aggregated Geothermal Resource of >350,000PJ_{th} at two sites at Lemont in the Midlands and Fingal in the northeast. Drill targeting and prioritisation has identified Lemont as the primary play. In the face of unavoidable delays planning remains underway for deep drilling in these areas.

Packaging of the project as an R&D site in conjunction with the GRI is considered the best prospect for accessing the Government funding that is necessary for continuation of this site investigation.

The proposed forward work program for the next year on SEL 26/2005 is:

Activities	Expenditure
• Drill planning, engineering and site preparation at Lemont • Deep drilling at Lemont (enhanced slimhole) • Contingent on encouraging results, reservoir characterisation testing, installation of seismic monitoring array, planning and engineering of deep appraisal wells • Contingent on encouraging results at CL, reappraisal of initial resource estimation, possibly to Indicated status; expansion of inferred model to include Tooms-Leake and Macquarie areas.	$3,430,000

Note that the forward expenditure commitment in year two of the licence renewal has been increased to compensate for the current year underspend caused by the delay in deep drilling.

7 Environment

Work conducted on the tenements in 2011/2012 resulted in no ground disturbances and hence no environmental or rehabilitation work has been required.

8 Expenditure

Delays to drilling have resulting in a significant underspend in the first year of the tenement renewal. Details of expenditure across the 12-month period are captured in Table 3 below.

	SEL 26/2005
Geoscience Costs	$
Geology	17,248
Geochemistry	-
Geophysics	3,575
Remote Sensing	-
Drilling & Gridding	
Gridding	-
Drilling	-
Land Access Costs	675
Rehabilitation Costs	-
Feasibility Study Costs	-
Other Costs	40,644
Administrative Costs	5,500
TOTAL 11/12	67,642
Total Expenditure (6 years)	3,775,252

Table 3: Expenditure on KUTh tenements SEL 26/2005 in the reporting period.

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10 Keywords

Geothermal exploration
Geothermal resource
East Tasmania
HDR (Hot Dry Rock)
HFR (Hot Fractured Rock)
EGS (Enhanced Geothermal System)
High Heat Producing (HHP) granite
Tamar Conductivity Zone (TCZ)
Magnetotelluric
Gravity

Appendix 1

Tasmania Project

Charlton-Lemont Geothermal Play

Statement of Geothermal Resources

SEL 26/2005

Annual Report 2012

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Tasmania Project:

Charlton-Lemont Geothermal Play

Statement of Geothermal Resources

Prepared for KUTh Energy Ltd

30 June 2011

Dr Graeme Beardsmore

(This document is formatted for double-sided printing)

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***Note**: This report has been prepared in accordance with the 'Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (2010 Edition)' and its associated Geothermal Lexicon. Neither Graeme Beardsmore nor Hot Dry Rocks Pty Ltd takes any responsibility for selective quotation of the report or if quotations are made out of context.*

1.0 Introduction

This Report updates the Geothermal Resource Report for the Charlton-Lemont Geothermal Play prepared by Hot Dry Rocks Pty Ltd (HDR) in June 2009. The update is in line with the requirements of the 'Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (2010 Edition)' [the 'Code']. Significantly, the 2010 edition of the Code defines a Geothermal Resource as that portion of stored heat that can be recovered to the surface, whereas the 2008 edition of the Code, under which the June 2009 Report was issued, defined a Geothermal Resource as the stored heat. The changes in Code requirements naturally result in substantially lower values of Resource, but this should not be interpreted as a downgrading of the energy potential of the Play.

The Charlton-Lemont Geothermal Play lies within Geothermal Exploration Licence SEL26/2005 in the eastern half of Tasmania (Figure 1), and represents an engineered geothermal system (EGS) target reservoir. KUTh Energy Ltd (KEN) aims to produce geothermal fluids from the reservoir for the purpose of electrical power generation. KEN controls 100% of SEL26/2005. The Play lies mainly on the 'Interlaken' and 'Oatlands' map sheets of the 1:50,000 Geology of Tasmania series (Brown *et al*., 2005[1]).

Relevant geothermal exploration data were extracted from a number of sources. KEN has drilled a significant number of shallow (<300 m) bores for the purpose of surface heat flow measurements (Figure 2). Data are also available for deeper lithological units from previous mineral exploration drilling, gravity interpretations and 2D seismic acquired for onshore oil exploration. These surveys and wells (Figure 1) generated relevant data for an interpretation of major geological structures and formation boundaries within the Tasmania Basin, and facilitated the construction of a 3D earth model for the region. Temperature was directly measured within the KEN heat flow wells using Precision Temperature Logging methods, and thermal conductivity was measured on core specimens from different locations and stratigraphic depths using a divided bar apparatus.

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[1] **Brown A.V. (comp), 2005.** Geology of Tasmania. Edition 2005.1. *Geological Atlas 1:50,000 digital series*. Mineral Resources Tasmania.

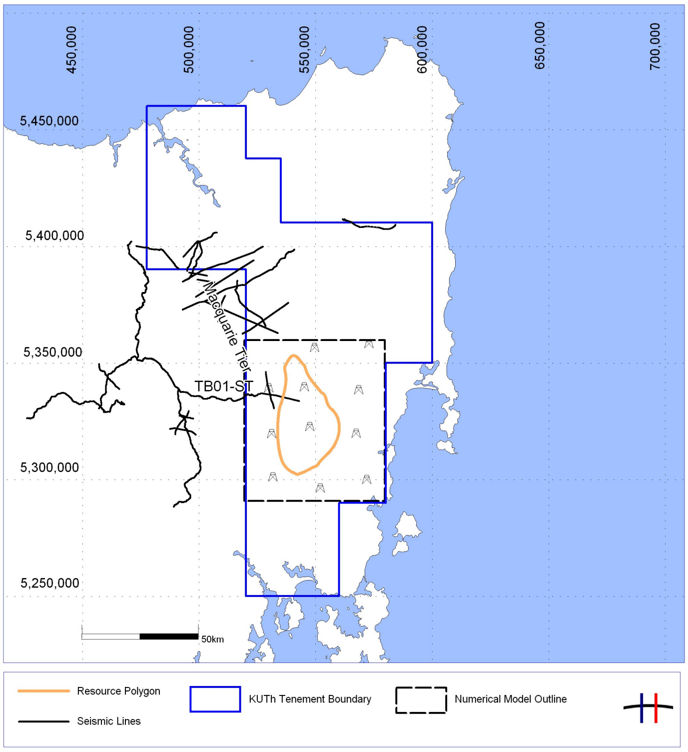

Figure 1. Location of SEL26/2005 in eastern Tasmania (blue); the area of the numerical earth model (black dashes—see Section 4) incorporating the Charlton-Lemont Geothermal Play (orange); drill holes and 2D seismic lines used to constrain the earth model.

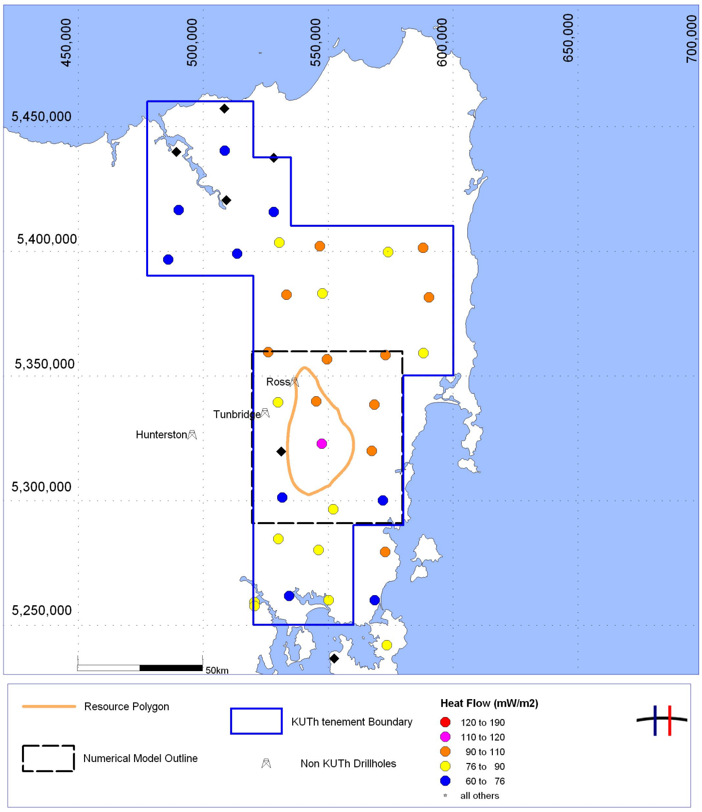

Figure 2. Locations of 'heat flow' wells and exploratory holes within SEL26/2005. Area of earth model (black dashed—see Section 4) and the Charlton-Lemont Geothermal Play (orange) also shown. Non heat-flow wells are named.

2.0 Geological setting

The structure and thermal properties of the geological formations provide the first order controls on temperature distribution within the Charlton-Lemont Geothermal Play. These must be understood in order to model heat flow and the temperature away from borehole control points. The Charlton-Lemont Geothermal Play lies in the central eastern area of the Tasmania Basin, an area comprised of Permo-Triassic foreland basin deposits and smaller Tertiary sub-basins bounded to the east and north by Devonian granites and to the west by the elevated Central Plateau Precambrian metasediments and dolomites. The Permo-Triassic succession unconformably overlies an Ordovician-Devonian turbidite sequence, which comprises the Mathinna Supergroup.

Surface outcrop is mostly Jurassic dolerite, Tertiary sediments, and some Permo-Triassic sedimentary rocks (Parmeener Supergroup). The deep geology of the Tasmania Basin is constrained by moderate quality 2D reflection seismic data, some interpreted geophysical (gravity) data, and a small number of exploratory drill holes.

2.1 Structure

The Charlton-Lemont Geothermal Play lies in the central eastern part of the greater Tasmania Basin, a Permo-Triassic foreland basin bounded to the east and north by Devonian granites and the Ordovician-Devonian Mathinna Supergroup metasediments. To the west, the basin terminates against the Western Tiers of the Central Plateau (outside the boundary of SEL26/2005). The basin succession comprises the Permo-Triassic sediments of the Parmeener Supergroup, which unconformably overlie the Mathinna Supergroup. The Permo-Triassic sediment pile is relatively thin, typically less than one kilometre thick though the central Midlands based on available well and seismic data.

An example of the structural style on the western margin of the Charlton-Lemont Geothermal Play is shown in seismic line TB01-ST (Figure 3). The structural style of the area is dominated by NE-dipping faults which sole into a shallow detachment at ~7.5 km depth.

The Mathinna Supergroup is a deep marine turbidite sequence, which was subsequently folded and faulted during the Tabberabberan Orogeny in the Middle

Devonian (Cayley *et al*., 2002[2]). While the provenance of the Mathinna Supergroup remains a matter of debate, many workers regard it as a southern extension of the Lachlan Orogen, which was accreted and cratonized during the Early-to-Late Palaeozoic (Gray *et al*., 2006[3]; Gray and Foster, 2004[4]).

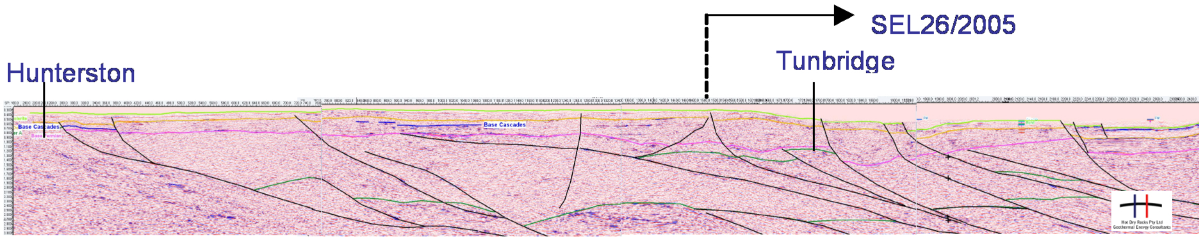

Figure 3. Seismic line TB01-ST from the Central Plateau of Tasmania in the west (left hand side of figure) to the Midlands in the east (right hand side of figure). Tenement SEL26/2005 is located over the eastern portion of the seismic line. The structural style is dominated by northeast dipping faults. Mathinna Supergroup rocks reach maximum depths of 3–5 km. Depth scale is seconds two-way-time. Line location is shown on Figure 1.

HDR interpreted the geological structure of the Charlton-Lemont Geothermal Play area from moderate quality 2D reflection seismic data, constrained by drilling intersections where possible (Cooper *et al*., 2009[5]). The interpretation shows the Mathinna Supergroup reaching depths of 3–5 km within SEL26/2005. A footwall high to the west of the tenement boundary (Central Tasmanian Tablelands) comprises Precambrian metasediments and dolomites, which might exist at depth within SEL26/2005 beneath the Mathinna Supergroup. There is no evidence of Mathinna Supergroup rocks being deposited on the footwall high to the west.

The Permo-Triassic succession is fault controlled with westward thickening of the succession in a number of half grabens (Cooper *et al*., 2009[5]). Some Permian faults sole into older Mathinna-aged faults, suggesting reactivation of older compressional structures. The Permian aged faults generally trend to the NNW with some change to

[2] **Cayley, R.A., Taylor D.H., Vandenberg, A.H.M. & Moore D.H., 2002.** Proterozoic-Early Palaeozoic rocks and the Tyennan Orogeny in central Victoria: the Selwyn Block and its tectonic implications. Australian Journal of Earth Sciences, 49, 225-254.

[3] **Gray, D.R., Foster, D.A., Korsch, R.J. & Spaggiari C.V., 2006.** Structural style and crustal architecture of eastern Australia: example of a composite accretionary orogen. Geological Society of America, Special Paper 414, 119-132.

[4] **Gray, D.R. & Foster, D.A., 2004.** Tectonic evolution of the Lachlan Orogen, southeast Australia: historical review, data synthesis, and modern perspectives. *Australian Journal of Earth Sciences*, 51, 773-817.

[5] **Cooper G., Waining B. & Pollington, N., 2009.** Interpretation of selected reflection seismic data in SEL26/2005, Eastern Tasmania. *Report prepared for KUTh Energy Ltd*.

the NW nearing the Macquarie Tier (Figure 1). Individual fault planes appear finite in length, with extension accommodated by fault overlap (relay ramps), producing *en echelon* geometry with apparent offset of half-grabens in plan view.

The Jurassic Dolerite most commonly forms a flat-lying sill, providing a blanket of thermally insulating rock typically >250 m in thickness (Leaman and Richardson, 1981[6]). Dolerite thickness may increase significantly in the region of feeder dykes, and dual or parallel intrusions have been observed in the vicinity of the Geothermal Play (Hergt *et al*. 1989[7]; Forsyth, 1989[8]). Data from seismic interpretation and drilling suggest a layer of at least 320 m across the Geothermal Play. Tertiary, and possibly Cretaceous, faulting produced some minor offsets in the dolerite.

2.2 Stratigraphy

For the purposes of this Geothermal Resource estimation, the stratigraphy of the Tasmania Basin (Table 1) has been simplified into six (6) units, namely:

- Jurassic Dolerite
- Upper Parmeener
- Lower Parmeener
- Mathinna Supergroup
- Granite
- Precambrian Basement

2.2.1 Jurassic Dolerite

The top ~300 m of the Tasmania Basin stratigraphy is dominated by a relatively uniform, flat-lying Jurassic Dolerite sill that effectively blankets the area of interest. The dolerite also occurs as minor sills and dykes and in thick feeder zones. This stratigraphic group includes thin overlying strata of Tertiary sediments, which have been mapped in areas such as the Longford Basin to the north of the area of interest.

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[6] **Leaman D.E and Richardson, R.G., 1981**. Gravity survey of the east coast coalfields. *Tasmanian Geological Survey Bulletin*, 60.

[7] **Hergt, J.M., McDougall, I., Banks, M.R. and Green, D.H., 1989**. Jurassic Dolerite in Burret CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia*, 15, 375 – 381.

[8] **Forsyth, S.M., 1989**. Upper Parmeener Supergroup, in Burrett CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 309-333.

Table 1. Simplified stratigraphy of the Tasmania Basin.

Age	Period	Rock Unit	Lithology
Cainozoic	Tertiary	Sediments and Basalt	Predominantly non marine gravel, sand, silt and clay sequences and some basalt.
Mesozoic	Jurassic	Dolerite	dolerite sills and dykes
	Triassic	Upper Parmeener Supergroup	Sandstone and siltstone and mudstone sequences.
	Late Carbon-iferous to Permian	Lower Parmeener Supergroup	Marine/shallow marine successions of glacial tillite, mudstone, siltstone and sandstones
	unconformity surface		
Palaeozoic	Devonian	Intrusive plutonic rocks (granites and granodiorites)	I-type and s-type granitoid bodies
	Early Ordovi-cian to Early Devonian	Mathinna Super-group	Micaceous quartzwacke turbiditic se-quences, and mudstone sequences.
Precambrian			Undifferentiated metasediments, dolomite, mafic volcanoclastics

2.2.2 Upper Parmeener

The Upper Parmeener Supergroup directly overlies the Lower Parmeener Supergroup. It is comprised of Late Permian to Triassic fluvial and lacustrine deposits including siltstone, sandstone and minor discontinuous coal seams (Forsyth, 1989[8]), and represents a probable transitional succession from the earlier marine sequences.

The Late Triassic sediments were possibly deposited by high sinuosity rivers and comprise volcanolithic sandstones with laterally extensive coal seams (of economic significance in the north-east of Tasmania). These sediments attain their maximum thickness of ~270 m in the Midlands (Forsyth, 1989[8]). The middle Triassic deposits consist of lithic sandstone and mudstone sequences deposited in a possible deltaic environment. These middle Triassic deposits also attain maximum thickness in the central Midlands and generally thin to the east. The earlier fluvial deposits of the Upper Parmeener Supergroup, up until the Late Permian, comprise sandstones, siltstones with some coal seams, carbonaceous silts and mudstones. The Late Permian to Early Triassic deposits show a tendency towards more quartz and feldspar dominated sand deposits (Forsyth, 1989).

2.2.3 Lower Parmeener

The Lower Parmeener Supergroup consists of late Carboniferous to Permian glacial tillites and related sediments, overlain by siltstones deposited in a quiet marine setting. A thin marine algal oil shale occurs near the base of this succession. Clarke (1989)[9] interpreted a number of half grabens, generated by Permian faulting, as supplying the accommodation space for the deposition of the Lower Parmeener marine succession. Subsequent fault movement continued to control deposition of siltstones and shallow water sandstone in to the Late Permian.

The Parmeener Supergroup unconformably overlies the Mathinna Supergroup, Precambrian basement and Devonian Granites.

2.2.4 Mathinna Supergroup

The Mathinna Supergroup is Ordovician to Devonian in age and comprised of a series of marine turbidite sequences. It has been extensively folded and reaches a thickness of 3–5 km throughout the area of interest. The Ordovician units include turbiditic sandstone and silts within a succession of slate and phyllites (Baille *et al*. 1989[10]). The Siluro-Devonian units of the Mathinna Supergroup contain more arenaceous rocks, including poorly sorted sandstones, siltstones and mudstones. Surface field mapping by Mineral Resources Tasmania in areas of exposure to the north of the Geothermal Play has also identified thick units of shale-siltstone as part of the Silurian-Devonian succession of the Mathinna Supergroup (D. Seymour, MRT unpublished). Towards the east, Leaman and Richardson (2003)[11] interpret Devonian Granites to intrude the sediments of the Mathinna Supergroup.

2.2.5 Granite

The eastern Tasmanian granites intruded the Ordovician to Early Devonian Mathinna Beds in the Early-Late Devonian (McClenaghan, 1989)[12]. Granite and granodorite plutons crop out in the north and east of Tasmania, and gravity data suggest that the

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[9] **Clarke, M.J., 1989**. Lower Parmeener Supergroup, in Burrett CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 295–308

[10] **Baille, P.W., Powell, C.M., Banks, M.R. & Hills P.B., 1989.** Mathinna Beds, in Burrett CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 234–237

[11] **Leaman, D.E. & Richardson, R.G., 2003.** A geophysical model of the major Tasmanian granitoids. Report Department of Mines Tasmanian, 2003/11, pp8.

[12] **McClenaghan, M.P., 1989.** Mid Palaeozoic Granitoids**.** in Burrett CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 253–261

granitoids continue beneath the Tasmania Basin and beneath the Charlton-Lemont Geothermal Play. Leaman and Richardson (2003)[11] interpreted the granitoids as deepening towards the west, although depth constraints from gravity modelling are imprecise.

2.2.6 Precambrian Basement

The Precambrian basement rocks underlying the resource area within the Tasmania Basin are not well known. Exposed Precambrian rocks to the west of the tenement and those intersected in drill holes suggest that the rocks have experienced a significant deformation history. These rocks comprise schists, sheared conglomerates, phyllites and dolomites. Specific lithologies from within the area of interest are known from intersections within older stratigraphic wells drilled by the Mineral Resources Tasmania (MRT), including Tunbridge Tier and Ross. They include a strongly altered and sheared sediment displaying carbonaceous and quartz materials in the Ross hole, and a finely laminated tectonite with low grade metamorphism in the Tunbridge Tier hole (Forsyth, 1989)[13].

3.0 Target reservoir

KEN aims to develop an Engineered Geothermal System (EGS) within the Charlton-Lemont Geothermal Play. The critical requirements for an EGS reservoir are that it lie within a target temperature range and have suitable hydro-geo-mechanical properties. Host rocks must be competent and strong enough to sustain open fracture networks. Upon reviewing the stratigraphy of the Charlton-Lemont Geothermal Play, HDR identified the principal target reservoirs as those units lying beneath the base Parmeener Supergroup (Figure 4). Reservoir targets include:-

- Mathinna Supergroup
- Devonian Granites
- 'Unit A' (See Section 4)
- Precambrian basement

[13] **Forsyth, S.M., 1989**. Geological Atlas 1:50,000 series. Sheet 61 (8313N). Interlaken. Explan. Rep. Geol. Surv. Tas.

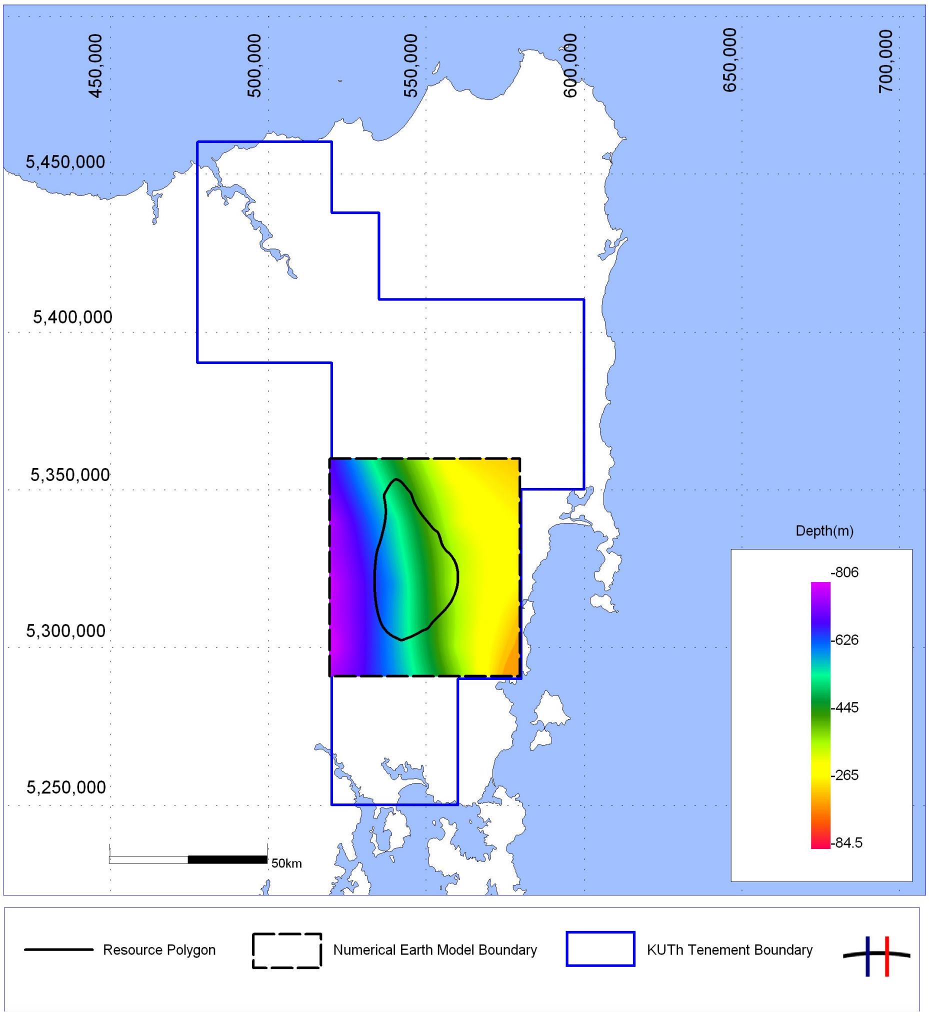

Figure 4. Interpreted depth to the top of the reservoir interval (base of the Parmeener Supergroup) in the Tasmania Basin, across the earth model (Section 4) and around the Charlton-Lemont Geothermal Play ("Resource Polygon").

4.0 3D earth model

HDR developed a numerical 'earth model' for estimating temperature within the target reservoirs. The earth model was constructed to cover an area of 60.0 km x 69.0 km (521000–581000 E, 5290000– 5359000N; AMG 94, Zone 55) to a depth of 7,000 m (Figure 5). The model divided the stratigraphy of the Geothermal Play into seven (7) units: **Dolerite**, **Upper Parmeener**, **Lower Parmeener**, **Mathinna Beds**, **Granite**, **'Unit A'** and **Precambrian Basement**.

HDR derived the geological structure of the modelled section of crust from a combination of data. KEN utilized existing MRT geological mapping data to construct regional cross-sections of the likely geology at depth. These cross sections also incorporated the results of gravity modelling (Leaman and Richardson, 2003)[11] to estimate the distribution and depth of granitoids. HDR reviewed KEN's procedure and agrees with the results. In addition, HDR interpreted regional reflection seismic data, which helped constrain the structural style of the Tasmania Basin and the likely thicknesses of the Mathinna Supergroup, the Permian succession and the Jurassic dolerite.

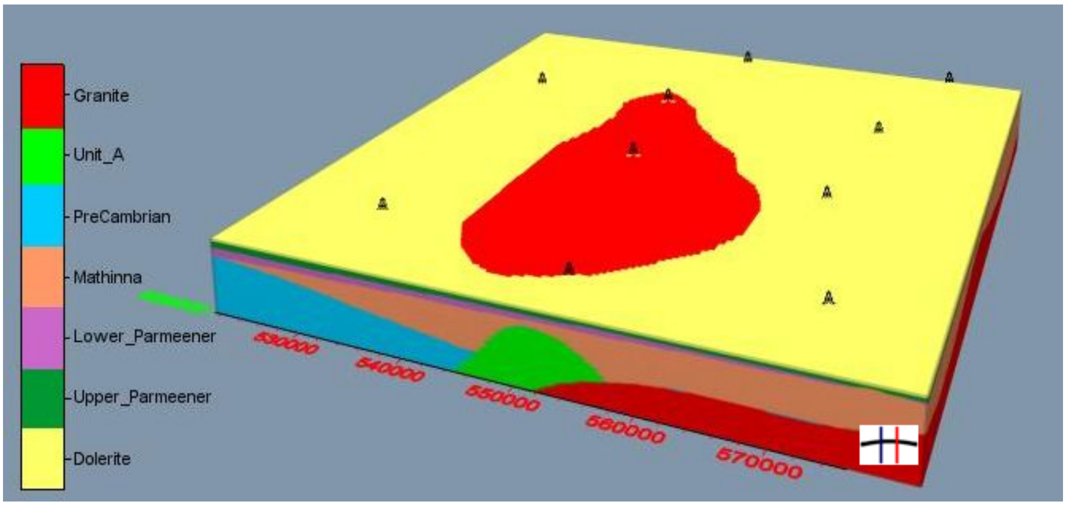

Figure 5. 3D image of the earth model showing the surface trace of the Charlton-Lemont Geothermal Play (red) and the locations of wells constraining the thermal state of the model. The earth model measures 60 km x 69 km x 7 km. North is to the top right of the figure.

The existence of an unconfirmed geological body, 'Unit A', is suggested by the thermal data (Section 5). In particular, elevated heat flow measurements in boreholes Lemont and Charlton-2 are inconsistent with smoothly varying subsurface geology in the Tasmania Basin. There are several possible explanations for 'Unit A'. These include:-

- A granodiorite ridge extending along the western margin of the granite isobaths. Leaman and Richardson (2003)[11] interpreted such a body from gravity data. A body with thermal conductivity and heat generation values consistent with a granodiorite can produce a suitable fit to the observed surface heat flow data.
- A zone of relatively high thermal conductivity Mathinna Supergroup, possibly associated with near-vertical cleavage. A body with thermal conductivity values within the upper quartile of those measured for the Mathinna Supergroup can produce a suitable fit to the observed surface heat flow data.

- A footwall high comprising high thermal conductivity rocks such as Precambrian dolomite.

The first and second possibilities listed above were each able to produce a reasonable fit to the heat flow data. For the purpose of this Resource assessment however, HDR assumed that 'Unit A' is a body of relatively high thermal conductivity Mathinna Supergroup lying immediately adjacent to the western edge of the interpreted Devonian granites. This is a conservative approach, as a less thermally conductive granodiorite body would result in slightly higher modelled temperature gradient in the reservoir due to its lower thermal conductivity.

Modelled temperature at depth is sensitive to the thermal conductivity values used in the model. HDR assigned single values of thermal conductivity to the each unit, based on data measured for KEN and summarised in Table 2. HDR considers the values assigned in this study to be reasonable averages for the relevant formations, but the number of measurements made on actual samples of the formations is currently insufficient to determine potential lateral and vertical variation. Uncertainty in projected temperatures and estimated Resource therefore increases with distance from, and depth beneath, borehole control points. Thermal conductivity was assumed isotropic for all units.

Table 2. Mean thermal conductivity values (at 25°C) and heat generation values assigned to earth model units

Unit	Thermal conductivity (W/mK)	Heat generation (μW/m^3)
Dolerite	2.17	0.00
Upper Parmeener	2.30	0.00
Lower Parmeener	2.12	0.00
Mathinna Supergroup	3.80	1.61
Granites	3.50	7.33
'Unit A'	4.80	1.61
Precambrian Basement	4.98	0.00

Triaxial measurements by HDR and Goh (2008[14]) have demonstrated anisotropic thermal conductivity in the Mathinna Supergroup. Surface mapping of outcropping Mathinna units to the north-east of the area of interest indicate significant variation in

[14] **Goh, H.K.H., 2008**. Properties of north eastern Tasmanian rocks for geothermal exploration petrophysical, geochemical and thermal characteristics of the Mathinna Group and Devonian granites. Unpublished Honours Thesis, University of Tasmania.

the foliation orientation, with sub-horizontal foliations associated with recumbent folding observed in the west and sub-vertical foliations associated with upright folding observed in the east (Reed, 2001)[15]. The orientation of the dominant foliation is unknown throughout the modelled area, where the Mathinna Supergroup is completely obscured by younger formations. However, by analogy, it may be assumed to vary considerably. HDR ran a number of 'high' and 'low' case models utilising the measured upper and lower values of Mathinna Supergroup thermal conductivity. For the purpose of this report, HDR utilised a 'median' case with average thermal conductivity.

Predicted temperature at depth decreases with increasing heat generation within the modelled depth interval. In this case, the impact is unlikely to be large within the sedimentary units and most probably lies well within the precision limits of this Resource assessment. The impact of heat generation within the Devonian granites, however, is likely to be more significant. While reported heat generation values of Tasmanian granites are highly variable, many samples of granite from eastern Tasmania have elevated values. Geochemical data from the Coles Bay Granite on the eastern margin of Tasmania, for example, show elevated levels of uranium and thorium (Champion *et al*., 2011)[16] suggesting heat generation values in the range 5–10 μW/m^3. Goh (2008)[14] derived mean values of 1.61 μW/m^3 and 7.33 μW/m^3, respectively, for heat generation within the Mathinna Supergroup and Granites. HDR assumes heat generation of 0 μW/m^3 for all other units except 'Unit A', which was ascribed the same value as the Mathinna Supergroup (Table 2).

5.0 Thermal data

HDR used the results of 1D heat flow modelling for 10 wells around the Charlton-Lemont Geothermal Play as constraints for subsequent 3D temperature modelling. Figure 6 shows a sample 1D heat flow model ('Lemont'). All locations of wells and heat flow values are presented in Table 3. The uncertainties quoted for the heat flow values in Table 3 were derived from the uncertainties in the thermal conductivity

[15] **Reed, A.R., 2001**. Pre-Tabberabberan Deformation in Eastern Tasmania: a Southern Extension of the Benambran Orogeny, *Australian Journal of Earth Sciences*, 48, 785-796.
[16] **Champion, D.C., Budd, A.R. and Wyborn, L.A.I**. (2011). OZCHEM National Whole Rock Geochemistry Database. http://www.ga.gov.au/meta/ANZCW0703011055.html.

values measured on the different stratigraphic units intersected by the wells. Temperature data were collected during high-precision (±0.001°C) temperature logging and contribute negligible uncertainty to the heat flow models.

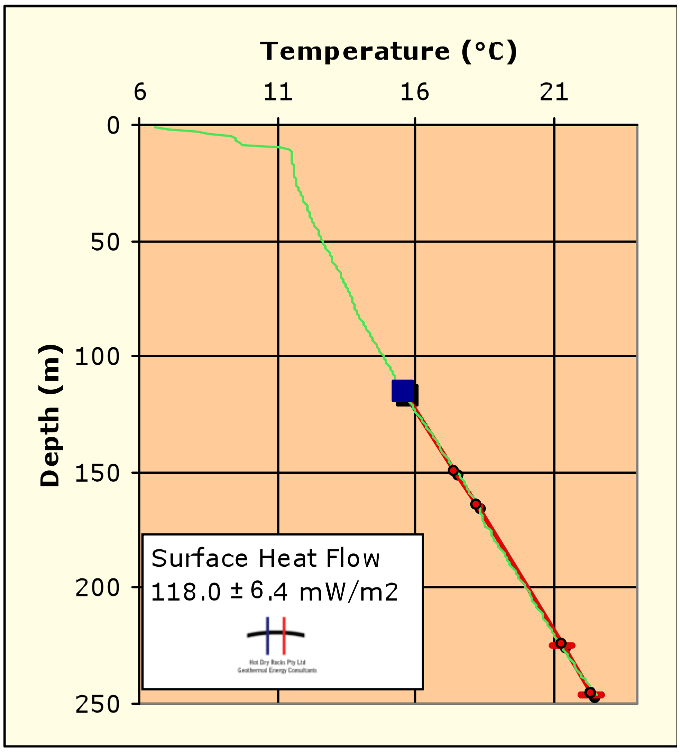

Figure 6. 1D conductive heat flow model of well 'Lemont'. Red line is the predicted temperature profile for a 1D conductive heat flow model and the green line is measured temperature profile. The blue square is the top of the cored (modelled) interval.

Table 3. Locations and values of heat flow constraints on the 3D temperature inversion. Coordinates are in GDA94 MGA Zone 55.

Well	East	North	Heat Flow (mW/m^2)
Tooms	567354	5319894	96 ± 2.5
Lake Leake	568510	5338586	92 ± 2.9
Snow Hill	572873	5358389	92 ± 2.3
Elizabeth	549501	5356701	94 ± 2.4
Charlton 2	545174	5339821	105.3 ± 1.9
Lemont	547437	5322898	118 ± 6.4
Woodsdale	552007	5296499	81 ± 3.2
Tiberious	531690	5301300	73 ± 3.9
Tunbridge	529875	5339428	81 ± 1.2
Bluestone Tier	571901	5300093	72 ± 0.6

The temperature data fit conductive models (within uncertainty limits) in each of the wells (although some showed evidence of shallow groundwater advection). There is no thermal, or other, evidence of convection within the drilled and logged intervals of the Charlton-Lemont Geothermal Play.

HDR assumed average surface rock temperature to be 13.5°C across the extent of the modelled area, based on extrapolations of temperature logs collected in shallow bores in the area. Note that average surface rock temperature is not necessarily equivalent to average surface air temperature, referred to in relation to ‘base temperature’ in Section 6.2 below. Average rock surface temperature is often higher than average air temperature due to insolation of solar energy.

6.0 Resource estimation methodology

6.1 Stored heat assessment

HDR utilised a ‘stored heat’ calculation for the target reservoirs as an interim step towards the Geothermal Resource assessment. A stored heat calculation estimates the total heat energy contained within a target volume. The method requires the estimation of the **volume**, **density**, **specific heat capacity** and **temperature** of the target reservoir formations, a consideration of the realistic lowest economically extractable temperature (‘**cut-off temperature**’) and the amount of thermal energy that might be extracted from the resource fluids (related to the ‘**base temperature**’).

6.2 Cut-off and base temperature

For the purpose of the stored heat calculations, HDR defined the cut-off temperature as *the minimum economic reservoir fluid temperature for commercial energy extraction*. The cut-off isotherm is an essential input to the volumetric stored heat calculations as it defines the upper surface of the reservoir volume. Similarly, for the purposes of the stored heat calculations, HDR defined the base temperature as *the temperature of the geothermal fluid once it has passed through a power conversion process, prior to reinjection*. The base temperature puts an upper limit on the amount of thermal energy that can be extracted from a Geothermal Resource of any given temperature. Both of these values depend strongly on the technology used to convert thermal energy into electrical energy.

It is technically feasible to generate power from geothermal fluid down to 100°C or lower (eg a geothermal plant at Birdsville in Queensland generates power from 98°C water), but the efficiency of power conversion at low temperatures makes it economically unviable in most situations. HDR assumed **a cut-off temperature of 150°C** as the minimum required for power generation from the Charlton-Lemont Geothermal Play.

Beardsmore *et al*. (2010)[17] published Version 1.0 of a Global Protocol for estimating and mapping EGS potential. At the time of writing, Version 1.1[18] of the Global Protocol remained unpublished, but had received the official endorsement of the International Geothermal Association. Version 1.1 was undergoing review for similar endorsement by the International Energy Agency, and publication was expected sometime in 2011. In line with both versions of the Global Protocol, HDR assumed a base temperature 80°C above the mean annual air temperature. Bureau of Meteorology records[19] indicate a mean annual air temperature of 12°C in eastern Tasmania, suggesting a **base temperature of 92°C** for the Geothermal Resource.

HDR believes the cut-off and base temperatures above are appropriate for low-temperature organic rankine cycle binary technology that KEN proposes to use for power generation. Should technological advances decrease the cut-off or base temperatures, the estimated Resource may increase over time.

6.3 Reservoir volume

The volume of an EGS reservoir is practically limited to rock that can be hydraulically stimulated to enhance its permeability. To estimate the actual volume requires consideration of the areal extent and thickness of the possible stimulated zone.

Notwithstanding the limitations below, there are practical upper and lower limits to the vertical extent of a reservoir interval. The minimum depth of potential reservoir is the deeper of the 150°C isotherm (for reasons explained in Section 6.2) or the base of the Parmeener Supergroup. As the Parmeener Supergroup is relatively shallow in this area, the inferred 150°C isotherm lies entirely within the target reservoir rocks

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[17] **Beardsmore, G.R., Rybach, L., Blackwell, D. and Baron, C.**, 2010. A protocol for estimating and mapping global EGS potential. *GRC Transactions*, 34, 301–312.
[18] **Beardsmore, G.R., Rybach, L., Blackwell, D. and Baron, C.**, in prep. A protocol for estimating and mapping global EGS potential, Version 1.1.
[19] http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/index.jsp?maptype=6&period=an#maps

and represents the top of the potential reservoir at all locations. HDR considers 5,000 m to be the maximum practical depth for drilling and fracturing a reservoir.

HDR (in consultation with KUTh Energy) defined the areal extent of the Charlton-Lemont Geothermal Play as the surface projection of the intersection of the inferred 150°C isotherm with the 4000 m subsurface depth. This outline is shown, for example, on Figure 5.

The vertical extent of an EGS reservoir is limited to the thickness of rock that can be hydraulically stimulated. HDR considers 500 m to be an appropriate aspirational target thickness for an engineered underground heat exchanger, based on a thickness of 350 m already demonstrated by Geodynamics Ltd part way into its total stimulation program in the Cooper Basin in Central Australia[20].

The total potential reservoir volume lying within the Charlton-Lemont Geothermal Play area, below the 150°C cut-off isotherm and above 5000 m, is 1020 km^3. The predicted minimum depth to the 150°C isotherm within the Geothermal Play area is about 3,560 m, within 'Unit A'. HDR considers each 500 m thick horizontal depth slice as a separate EGS target interval worthy of a separate Geothermal Resource estimate. The depth slices and respective volumes, divided across the different units, are given in Table 4.

Table 4. Estimated volumes of potential reservoir intervals

Depth	Volume (km^3) Total	Mathinna	Granite	'Unit A'	Basement
<4,000 m	**157**	83.5	1.35	60.8	11.1
4,000–4,500 m	**431**	123	43.7	168	96.7
4,500–5,000 m	**432**	23.6	63.4	174	171

6.4 Reservoir density and specific heat

Goh (2008)[14] measured the densities of specimens from the relevant formations. The Mathinna Supergroup (and hence 'Unit A') and the Precambrian Basement have densities of 2,720 kg/m^3. The Granite has a density of 2,580 kg/m^3.

[20] **Geodynamics Ltd**, ASX Announcement, 19 December 2003.

Specific heat is temperature dependent and typically increases with temperature. HDR has estimated a relationship for specific heat based on Equations 18 and 19 of Waples and Waples (2004)[21], assuming a reference temperature of 25°C and a surface Cp = 750 J/kgK:

Equation 1 $$CpT = (8.859x10^{-7} \times T^3) - (2.108x10^{-3} \times T^2) + (1.703 \times T) + 708.7$$

where CpT is the specific heat at temperature T(°C).

Goh (2008)[14] reported specific heat values for the formations, and these were lower than the values predicted by Equation 1. Goh cautioned, however, that "aluminium and brass samples used as calibration pieces returned a lower than expected heat capacity", so Equation 1 is preferred over the reported values.

6.5 Reservoir temperature

HDR utilized a numerical three-dimensional temperature inversion algorithm to estimate the temperature distribution and stored heat within the reservoir. The methodology incorporated the three-dimensional numerical earth model described in Section 4, constrained by the thermal data presented in Section 5.

The algorithm operated on the principle of 'inversion'. Known information about surface temperature and surface heat flow was entered into a software module. The algorithm 'voxelated' the earth model; that is, divided it into discrete rectangular prismatic cells, with the thermal properties of each cell determined by the geological unit within which the cell lay. The dimensions of the individual cells were 500 m by 500 m horizontally, by 70 m vertically. A numerical iterative process then computed in three dimensions the simplest distribution of temperature consistent with the observed surface heat flow distribution, while respecting the laws of conductive heat transfer and the thermal properties of the geological strata. The temperature dependence of thermal conductivity was also taken into account, using a formula published by Sekiguchi (1984)[22].

The algorithm employed did not exactly match the observed heat flow values, but optimised the fit to observed values within a predefined precision. The 'root mean

[21] **Waples, D.W. & Waples, J.S., 2004**. A review and evaluation of specific heat capacities of rocks, minerals, and subsurface fluids. Part 1: Minerals and nonporous rocks. *Natural Resources Research*, 13(2), 97–122.
[22] **Sekiguchi, K., 1984.** A method for determining terrestrial heat flow in oil basinal areas. *Tectonophysics*, 103, 67–79.

square' (RMS) misfit of the model to the heat flow constraints was 2.53 mW/m^2, which is less than the RMS uncertainty of the ten heat flow constraints (3.12 mW/m^2). The largest misfits were for wells 'Charlton-2' and 'Lemont'. The modelling algorithm was unable to fully reconcile the elevated heat flows observed in these two wells. The best-fit model underestimated heat flow at 'Charlton-2' by 5.9 mW/m^2 and underestimated heat flow at 'Lemont' by 4.6 mW/m^2. The misfit at 'Lemont', however, is within the heat flow uncertainty for that well (see Table 2). HDR therefore considers that the general fit of the model to the data is very good.

The 3D inversion process predicted potential reservoir temperatures in the range 150.0-198.5°C, with an average temperature of 169°C.

6.6 Recoverable thermal energy

The Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves, 2010 Edition ('The Code'), defines a Geothermal Resource as "the estimated Recoverable Thermal Energy." For the purpose of this Resource estimate, HDR has adopted a recovery factor of **14%**, consistent with the recommendation for "fracture dominated reservoirs where there is insufficient information to accurately characterise the fracture spacing", as given in the Geothermal Lexicon for Resources and Reserves Definition and Reporting, Edition 2 (2010).

7.0 Estimated Geothermal Resource

7.1 Total recoverable heat

The numerical algorithm revealed the simplest temperature distribution to explain the observed surface heat flow values. For each discrete cell of the reservoir units lying beneath the cut-off isotherm and above 5000 m, the stored heat was calculated from the volume, density, specific heat and temperature of the cell. The total stored heat in all individual cells was 194,800 PJ. This was divided between depth slices and potential reservoir units as shown in Table 5.

14% of the stored heat in any given depth slice and reservoir unit was assumed potentially recoverable, and these amounts are shown in Table 6.

Table 5. Estimated stored heat within potential reservoir intervals

Depth	Stored heat (PJ_{th})				
	Total	**Mathinna**	**Granite**	**'Unit A'**	**Basement**
<4,000 m	**24,120**	13,240	188.1	9,003	1,689
4,000–4,500 m	**76,410**	22,830	7,135	28,980	17,470
4,500–5,000 m	**94,230**	5,335	13,180	37,130	38,580

Table 6. Estimated heat recoverable from potential reservoir intervals

Depth	Recoverable heat (PJ_{th})				
	Total	**Mathinna**	**Granite**	**'Unit A'**	**Basement**
<4,000 m	**3,376**	1,853	26.33	1,260	236.5
4,000–4,500 m	**10,700**	3,196	998.9	4,058	2,446
4,500–5,000 m	**13,190**	746.9	1,846	5,198	5,401

7.2 Classification of Resource

7.2.1 Inferred Geothermal Resource

The Code defines an 'Inferred Geothermal Resource' as "*that part of a Geothermal Resource for which Recoverable Thermal Energy can be estimated only with a low level of confidence…This category of Geothermal Resource is inferred from geological, geochemical and geophysical evidence and is assumed but not verified as to its extent or capacity to deliver geothermal energy. There must be a sound basis for assuming that a Geothermal Play exists, estimating the temperature and having some indication of its extent.*"

HDR judged that **the recoverable heat estimated in Section 7.1 is best classified as an Inferred Geothermal Resource**. In reaching this decision, HDR took into account the following points:

- Gravity and 2D reflection seismic data provided the basis of an interpretation of the 3D geology of the Charlton-Lemont Geothermal Play, which defined the extent and thickness of the potential reservoir units.
- Drilling in the Charlton-Lemont Geothermal Play has not yet penetrated the Geothermal Resource.
- The lithological explanation of deep seismic reflections throughout Tasmania is currently unproven by drilling.

7.3 Tabulated Resource estimates

Table 7 states the estimated Geothermal Resource for different possible reservoir depth intervals and units in the Charlton-Lemont Geothermal Play, as classified by the criteria in Section 7.2.

Table 7. Estimated Geothermal Resource within the different possible reservoir depth intervals and units of the Charlton-Lemont Geothermal Play. Resource estimates are rounded to two significant figures.

Depth (m)	Unit	Recoverable Heat (PJ_{th})	Volume (km^3)	Inferred Geothermal Resource (PJ_{th})
<4,000	Mathinna	1,853	83.5	1,900
	Granite	26.33	1.35	26
	'Unit A'	1,260	60.8	1,300
	Basement	236.5	11.1	240
	TOTAL	*3,376*	*157*	***3,400***
4,000–4,500	Mathinna	3,196	123	3,200
	Granite	998.9	43.7	1,000
	'Unit A'	4,058	168	4,100
	Basement	2,446	96.7	2,400
	TOTAL	*10,700*	*431*	***11,000***
4,500–5,000	Mathinna	746.9	23.6	750
	Granite	1,846	63.4	1,800
	'Unit A'	5,198	174	5,200
	Basement	5,401	171	5,400
	TOTAL	*13,139*	*432*	***13,000***

8.0 Key Assumptions and Geological Constraints

Apart from the parameters described above, the following key assumptions underpin this Geothermal Resource estimate.

- It is technically unlikely that commercial production could be sustained from more than one EGS reservoir depth level at a time. The Geothermal Resource estimates, therefore, should not be stated in any way that implies they can be extracted simultaneously.
- The proposed product to be generated from the Geothermal Resource is electricity using commercially available organic rankine cycle binary plants utilizing air-cooling fans.
- The estimated Geothermal Resource does not include any additional heat that might conduct or convect into the reservoir volume during production.

- The estimated Geothermal Resource assumes that advective or convective processes within the Geothermal Play transfer no significant heat. Advective heat transfer with groundwater has been observed in some shallow wells. These occurrences are assumed to relate to shallow, gravity-driven systems. If convection occurs in the deeper sections, it will suppress geothermal gradients and reduce the estimated stored heat and recoverable Resource.
- The heat is contained entirely within the matrix of the reservoir rock and there is little expectation for significant *in situ* water.
- This work is based on a numerical model of a section of the Earth's crust. A model necessarily simplifies the true complexity of the Earth and as such is inherently prone to error. The results of modelling stated within this report have been generated using the best available estimates of critical parameters, but future work may yield new information that modifies or falsifies some of these assumptions. All modelling results should be treated as provisional.
- HDR is unaware of any geotechnical, access, environmental or land use issues that could affect future drilling locations or sterilise potential geothermal resource sectors within the Charlton-Lemont Geothermal Play.

9.0 Conversion to electricity

The figures presented in Table 7 above constitute the Geothermal Resource estimate for the Charlton-Lemont Geothermal Play. Equation 11 of Version 1.1 of the Global Protocol[18] provides guidance for estimating the theoretical potential for electrical power production from a given Geothermal Resource. Table 8 shows the outcome of such calculations for the Charlton-Lemont Geothermal Play. Note that the figures in the last column of Table 8 should not be quoted as a cumulative total, as it is technically unlikely that power could be generated concurrently from different depths.

Table 8. Estimated theoretical electrical power generation potential over a 30 year assumed plant life, derived from Equation 11 of Version 1.1 of the Global Protocol[18] and the Geothermal Resource estimates presented in Table 7.

Depth (m)	Unit	Recoverable heat (EJ_{th})	Assumed reservoir temperature (°C)	Conversion efficiency (%)	Power for 30 years (MW_e)
<4,000	Mathinna	1.853	160	11.5	226
	Granite	0.026	160	11.5	3.2
	'Unit A'	1.260	160	11.5	154
	Basement	0.237	160	11.5	29
	TOTAL				***411***
4,000–4,500	Mathinna	3.196	175	12.3	416
	Granite	0.100	175	12.3	130
	'Unit A'	4.058	175	12.3	528
	Basement	2.446	175	12.3	318
	TOTAL				***1,391***
4,500–5,000	Mathinna	0.747	190	13.1	103
	Granite	1.846	190	13.1	255
	'Unit A'	5.198	190	13.1	719
	Basement	5.401	190	13.1	747
	TOTAL				***1,824***

10.0 Future Work

The Code defines an 'Indicated Geothermal Resource' as "*that part of a Geothermal Resource which has been demonstrated to exist through direct measurements that indicate temperature and dimensions so that Recoverable Thermal Energy can be estimated with a reasonable level of confidence. Thermal Energy in Place has been estimated through direct measurements and assessments of volumes of hot rock and fluid, with sufficient indicators to characterise the temperature and chemistry. Direct measurements are sufficiently spaced so as to indicate the extent of the Thermal Energy in Place.*"

The Code defines a 'Measured Geothermal Resource' as "*that part of a Geothermal Resource which has been demonstrated to exist through direct measurements that indicate at least reservoir temperature, reservoir volume and well deliverability, so that Recoverable Thermal Energy can be estimated with a high level of confidence. The Thermal Energy in Place has been demonstrated to exist through direct measurements and assessments of drilled and tested volumes of rock and/or fluid within which well deliverability has been demonstrated, and which have sufficient indicators to characterise the temperature and chemistry. Direct measurements must be sufficiently spaced to confirm continuity.*"

Reclassification of any portion of the Inferred Geothermal Resource stated in this report to an Indicated or Measured Resource will require drilling and testing of the target reservoir to directly determine temperature and reservoir properties.

11.0 Competent Person

The information in this report that relates to Exploration Results, Geothermal Resources or Geothermal Reserves is based on information compiled by Dr Graeme Beardsmore, who appears on the Register of Practicing Geothermal Professionals maintained by the Australian Geothermal Energy Group Incorporated at the time of the publication of this report. Dr Beardsmore is employed by Hot Dry Rocks Pty Ltd (HDR), an independent company that provides consulting services to KUTh Energy Ltd.

Dr Beardsmore has sufficient experience relevant to the style and type of geothermal play under consideration and to the activity that he is undertaking to qualify as a Competent Person as defined in the Second Edition (2010) of the 'Australian Code for Reporting Exploration Results, Geothermal Resources and Geothermal Reserves'. Dr Beardsmore was assisted by other employees within HDR but takes sole responsibility and is accountable for the report as a Competent Person.

Dr Beardsmore consents to the public release of this report in its entirety.

Signed: G.R.B. ______________________ 30th June 2011

Graeme Beardsmore *Date*

Appendix-1 Glossary of terms in their context as used in this report

Base temperature	The temperature of the geothermal fluid once it has passed through a power conversion process, prior to reinjection.
Basement	The deepest geological horizon considered in an assessment.
Basin	A three dimensional accumulation of sediments, usually thicker on the down-thrown side of a major fault or in the centre (as defined by the outer geographic margins of basin succession).
Conversion efficiency	The proportion (%) of energy that can be converted from heat to electricity.
Cut off temperature	The minimum economic reservoir fluid temperature for commercial energy extraction.
Density	A physical property of matter, such as rocks, measured in mass per unit volume (eg kilograms per cubic metre, kg/m^3)
Earth model	A three-dimensional computer model of part the earth based on grided inputs such as depth maps from well data, gravity data or seismic mapping.
Fault	A break in geological strata caused by movement along a plane of weakness.
Footwall	The up-thrown (higher) portion of a fault block.
Heat Flow	The amount of thermal energy passing through a square metre at the earth's surface, usually expressed as milli-Watts per square metre (mW/m^2).
Heat Generation	The amount of heat generated by a rock through the natural decay of radiogenic elements, usually calculated in micro watts per cubic metre ($\mu W/m^3$).
Isotherm	A line or surface joining points of equal temperature.

Organic rankine cycle	An electricity production process whereby heat can be exchanged from a hot fluid to a cooler one via the use of a liquid organic compound which has a lower boiling point than the source fluid. Used in certain geothermal electricity generating plants where the fluid temperature is suitable.
Permeability	The ability of a rock to flow fluid, such as water, usually measured in milli-Darcies (mD).
Play	An accumulation of heat energy within the Earth's crust.
Porosity	The 'free' space in a rock, not occupied by minerals, cement or clay. A dimensionless unit, expressed as the % of rock volume that may hold fluid.
Reservoir	A body of rock with certain permeability and porosity characteristics that enable it to hold fluids of economic interest.
Rifting	The geological process in which tectonic plates extend and fault as plates begin to pull-apart.
Sandstone	A coarse grained sedimentary rock chiefly composed of sand-sized grains of silica, feldspar and/or lithic material.
Seismic line	A line across the ground surface along which a seismic survey (involving the reading of vibrations induced in the shallow earth by a source) has or will be read.
Specific heat	The amount of energy required to raise the temperature of 1 kg of substance by 1°C; otherwise known as relative heat capacity, usually measured in Joules per kilogram per degree Kelvin ($J\ kg^{-1}K^{-1}$).
Stored heat	The amount of geothermal energy 'trapped' as heat within a volume of rock. Quantified as in-place petajoules (PJ_{th}).
Thermal Conductivity	A measured property of a rock indicating its ability to transfer or 'conduct' heat energy, usually measured directly in Watts per metre Kelvin (W/mK).
Well	A bore hole

Appendix 2

Tasmania Project

Mt. Nicholas-Fingal Geothermal Play

Statement of Geothermal Resources

SEL 26/2005

Annual Report 2012

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Tasmania Project:

Mt.Nicholas-Fingal Geothermal Play

Statement of Geothermal Resources

Prepared for KUTh Energy Ltd

30 June 2011

Dr Graeme Beardsmore

(This document is formatted for double-sided printing)

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***Note**: This report has been prepared in accordance with the 'Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (2010 Edition)' and its associated Geothermal Lexicon. Neither Graeme Beardsmore nor Hot Dry Rocks Pty Ltd takes any responsibility for selective quotation of the report or if quotations are made out of context.*

1.0 Introduction

This Report updates the Geothermal Resource Report for the Mt. Nicholas-Fingal Geothermal Play prepared by Hot Dry Rocks Pty Ltd (HDR) in March 2010. The update is in line with the requirements of the 'Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (2010 Edition)' [the 'Code']. Significantly, the 2010 edition of the Code defines a Geothermal Resource as that portion of stored heat that can be recovered to the surface, whereas the 2008 edition of the Code, under which the March 2010 Report was issued, defined a Geothermal Resource as the stored heat. The changes in Code requirements naturally result in substantially lower values of Resource, but this should not be interpreted as a downgrading of the energy potential of the Play.

The Mt. Nicholas-Fingal Geothermal Play lies within Geothermal Exploration Licence SEL26/2005 in the eastern half of Tasmania (Figure 1), and represents an engineered geothermal system (EGS) target reservoir. KUTh Energy Ltd (KEN) aims to produce geothermal fluids from the reservoir for the purpose of electrical power generation. KEN controls 100% of SEL26/2005. The Play lies mainly on the 'St. Marys' and 'Ben Lomond' map sheets of the 1:50,000 Geology of Tasmania series (Brown *et al*., 2005[1]).

The Mt. Nicholas-Fingal Geothermal Play is centred on the Fingal Valley of NE Tasmania. The Fingal Valley has been a commercial producing coal region since the 1886. A number of historical coalmines, and one active mine (Cornwall Colliery), are located in the valley. Surface geology in the area is well constrained. Sub-surface geology is also well constrained from gravity modelling (granite isobaths) and a large number of coal exploration bores.

Relevant geothermal exploration data were extracted from a number of sources. KEN has drilled 35 shallow (<300 m) bores within SEL26/2005 for the purpose of surface heat flow measurements (Figure 2). Data are also available for deeper lithological units from previous mineral exploration drilling, gravity interpretations and 2D seismic acquired for onshore oil exploration, although most of the seismic data are located in the western portion of the tenement (Figure 1). These surveys and wells generated

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[1] **Brown A.V. (comp), 2005.** Geology of Tasmania. Edition 2005.1. *Geological Atlas 1:50,000 digital series*. Mineral Resources Tasmania.

relevant data for an interpretation of major geological structures and formation boundaries within the Tasmania Basin, and facilitated the construction of a 3D earth model for the region. Temperature was directly measured within the KEN heat flow wells using Precision Temperature Logging methods, and thermal conductivity was measured on core specimens from different locations and stratigraphic depths using a divided bar apparatus.

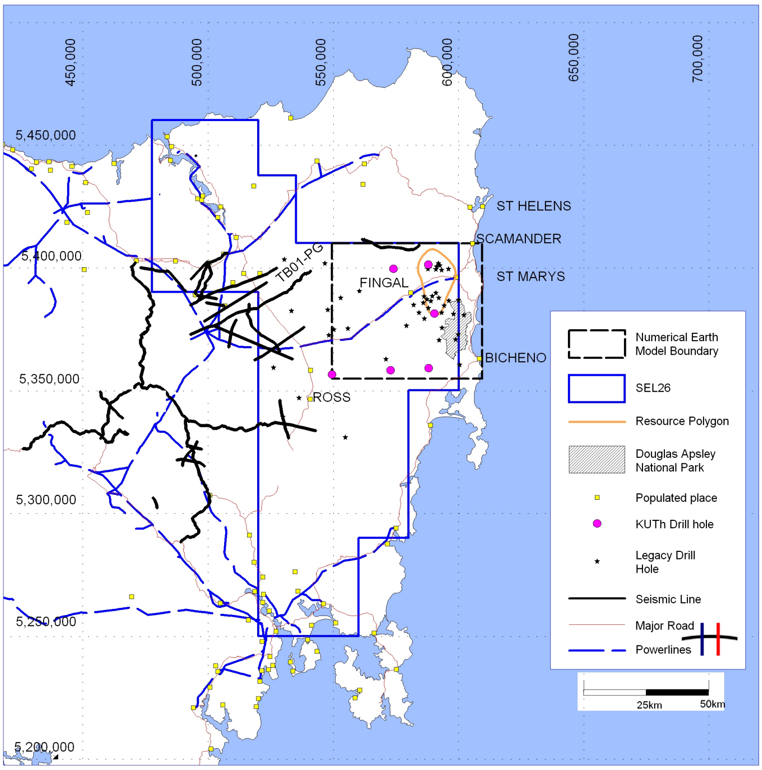

Figure 1. Location of SEL26/2005 in eastern Tasmania (blue); the area of the numerical earth model (black dashes—see Section 4) incorporating the Mt. Nicholas-Fingal Geothermal Play (orange); drill holes and 2D seismic lines used to constrain the earth model. Grid coordinates in AMG 94, Zone 55.

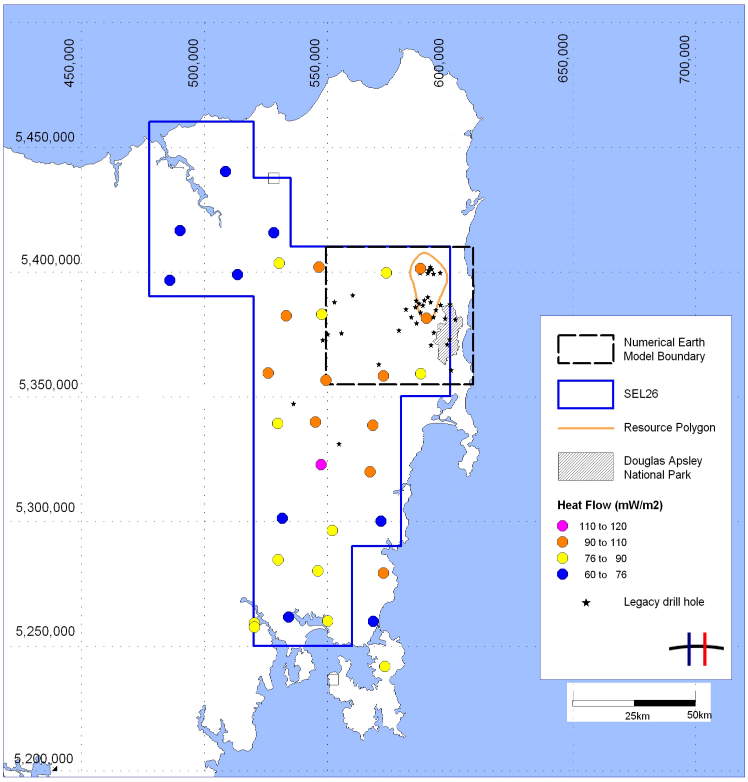

Figure 2. Locations of 'heat flow' wells and exploratory holes within SEL26/2005. Area of numerical earth model (black dashed—see Section 4) and the Mt. Nicholas-Fingal Geothermal Play (orange).

2.0 Geological setting

The structure and thermal properties of the geological formations provide the first order controls on temperature distribution within the Mt. Nicholas-Fingal Geothermal Play. These must be understood in order to model heat flow and the temperature away from borehole control points. The Mt. Nicholas-Fingal Geothermal Play lies in the NE portion of the Tasmania Basin, an area comprised of Permo-Triassic foreland basin deposits and smaller Tertiary sub-basins bounded to the east and north by Devonian granites and to the west by the elevated Central Plateau Precambrian metasediments and dolomites. The Permo-Triassic succession unconformably overlies an Ordovician-Devonian turbidite sequence, which comprises the Mathinna Supergroup.

Surface outcrop along the northern margin of the Fingal Valley is mainly Ordovician Mathinna Supergroup with some outcrop of the Permo-Triassic Parmeener Supergroup. Tertiary sedimentary rocks dominate the axis of the valley and the southern margin of the valley has a veneer of Jurassic dolerite, which crops out along the Fingal Tier. Devonian granites crop out to the east and north of the Play.

2.1 Structure

The Mt. Nicholas-Fingal Geothermal Play lies in the northeast part of the greater Tasmania Basin, a Permo-Triassic foreland basin bounded to the east and north by Devonian granites and the Ordovician-Devonian Mathinna Supergroup metasediments. To the west, the basin terminates against the Western Tiers of the Central Plateau (outside the boundary of SEL26/2005). The basin succession comprises the Permo-Triassic sediments of the Parmeener Supergroup, which unconformably overlie the Ordovician-Devonian Mathinna Supergroup. The Permo-Triassic sediment pile is relatively thin, typically less than 500 m thick within the Mt. Nicholas-Fingal area based on well intercepts.

An example of the structural style on the central northern area of SEL26/2005 is shown in seismic line TB01-PG (Figure 3), which approaches the northwest margin of the Mt. Nicholas-Fingal Geothermal Play (see Figure 1 for location). The structural style of the area is dominated by NE-dipping faults (half graben) established during the Permo-Triassic deposition of the Parmeener Subgroup and later reactivated during the Tertiary.

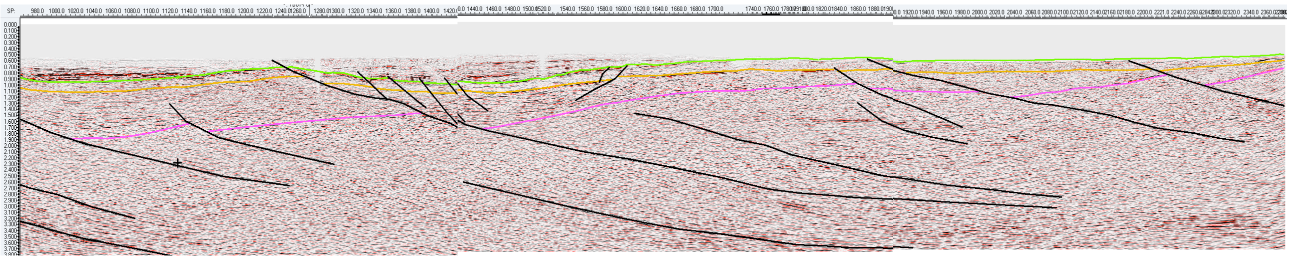

Figure 3. Northeast end of seismic line TB01-PG approaching the western margin of the Mt. Nicholas-Fingal Geothermal Play (at the right hand end of the line). The structural style is dominated by northeast dipping faults with thickening of the Permo-Triassic Parmeener Group towards the faults. Depth scale is in two-way-time. Base Permo-Triassic (Top Mathinna Supergroup) is pink, top Permo-Triassic is orange and top dolerite is green. Line location shown on Figure 1.

The Mathinna Supergroup is a deep marine turbidite sequence, which was subsequently folded and faulted during the Tabberabberan Orogeny in the Middle Devonian (Cayley *et al*., 2002[2]). While the provenance of the Mathinna Supergroup remains a matter of debate, many workers regard it as a southern extension of the

[2] **Cayley, R.A., Taylor D.H., Vandenberg, A.H.M. & Moore D.H., 2002.** Proterozoic-Early Palaeozoic rocks and the Tyennan Orogeny in central Victoria: the Selwyn Block and its tectonic implications. Australian Journal of Earth Sciences, 49, 225-254.

Lachlan Orogen, which was accreted and cratonized during the Early-to-Late Palaeozoic (Gray *et al*., 2006[3]; Gray and Foster, 2004[4]).

HDR interpreted the geological structure in the central and western portion of SEL26/2005 from moderate quality 2D reflection seismic data, constrained by drilling intersections where possible (Cooper *et al*., 2009[5]). Although largely outside the Mt. Nicholas-Fingal Geothermal Play, surface mapping and gravity data suggest that the structural style of the Play is consistent with that interpreted from seismic data in the west (Figure 3). That interpretation shows the Mathinna Supergroup reaching depths of 3–5 km within SEL26/2005. A footwall high to the west of the tenement boundary (Central Tasmanian Tablelands) comprises Precambrian metasediments and dolomites, which might exist at depth within SEL26/2005 beneath the Mathinna Supergroup. There is no evidence of Mathinna Supergroup rocks being deposited on the footwall high to the west.

The Permo-Triassic succession is fault controlled with westward thickening of the succession in a number of half grabens (Cooper *et al*., 2009[5]). Some Permian faults sole into older Mathinna-aged faults, suggesting reactivation of older compressional structures. The Permian aged faults generally trend to the NNW. Individual fault planes appear finite in length, with extension accommodated by fault overlap (relay ramps), producing *en echelon* geometry with apparent offset of half grabens in plan view.

The Jurassic Dolerite most commonly forms a flat-lying sill, providing a blanket of thermally insulating rock typically >250 m thick (Leaman and Richardson, 1981[6]). Dolerite thickness may increase significantly in the region of feeder dykes, and dual or parallel intrusions have been observed in parts of SEL26/2005 (Hergt *et al*. 1989[7];

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[3] **Gray, D.R., Foster, D.A., Korsch, R.J. & Spaggiari C.V., 2006.** Structural style and crustal architecture of eastern Australia: example of a composite accretionary orogen. *Geological Society of America, Special Paper* 414, 119–132.
[4] **Gray, D.R. & Foster, D.A., 2004.** Tectonic evolution of the Lachlan Orogen, southeast Australia: historical review, data synthesis, and modern perspectives. *Australian Journal of Earth Sciences*, 51, 773–817.
[5] **Cooper G., Waining B. & Pollington, N., 2009.** Interpretation of selected reflection seismic data in SEL26/2005, Eastern Tasmania. *HDRPL report prepared for KUTh Energy Ltd*.
[6] **Leaman D.E and Richardson, R.G., 1981**. Gravity survey of the east coast coalfields. *Tasmanian Geological Survey Bulletin*, 60.
[7] **Hergt, J.M., McDougall, I., Banks, M.R. and Green, D.H., 1989**. Jurassic Dolerite. In Burret, C.F. & Martin, E.L. (eds), Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia*, 15, 375–381.

Forsyth, 1989[8]). Tertiary, and possibly Cretaceous, faulting produced some minor offsets in the dolerite.

2.2 Stratigraphy

For the purposes of this Geothermal Resource estimation, the stratigraphy of the Tasmania Basin (Table 1) has been simplified into seven (7) units, namely:

- Tertiary
- Jurassic Dolerite
- Upper Parmeener
- Lower Parmeener
- Mathinna Supergroup
- Granite
- Precambrian Basement

Table 1. Simplified stratigraphy of the Tasmania Basin.

Age	Period	Rock Unit	Lithology
Cainozoic	Tertiary	Sediments and Basalt	Predominantly non-marine gravel, sand, silt and clay sequences and some basalt.
Mesozoic	Jurassic	Dolerite	Dolerite sills and dykes
	Triassic	Upper Parmeener Supergroup	Coals, sandstone and siltstone and mud-stone sequences.
	Late Carbon-iferous to Permian	Lower Parmeener Supergroup	Marine/shallow marine successions of glacial tillite, mudstone, siltstone and sandstones
	unconformity surface		
Palaeozoic	Devonian	Intrusive plutonic rocks (granites and granodiorites)	I-type and S-type granitoid bodies
	Early Ordovi-cian to Early Devonian	Mathinna Super-group	Micaceous quartzwacke turbiditic sequen-ces, and mudstone sequences.
Precambrian			Undifferentiated metasediments, dolomite, Mafic volcanoclastics

[8] **Forsyth, S.M., 1989**. Upper Parmeener Supergroup. In Burrett, C.F. & Martin, E.L. (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 309-333.

2.2.1 Tertiary

A thin veneer of mainly non-marine sandstone, siltstone and gravel lies in isolated sub-basins throughout the Tasmania Basin and very minor amounts crop out in the axis of Fingal Valley. A significant amount of Quaternary doleritic talus occurs at the base of most topographic highs such as Ben Lomond and the Fingal Tier.

2.2.2 Jurassic Dolerite

The top ~300 m of the Tasmania Basin stratigraphy is dominated by a relatively uniform, flat-lying Jurassic Dolerite sill that mainly crops out along the Fingal Tier—an elevated region in the southern portion of the Mt. Nicholas-Fingal Geothermal Play. The dolerite also occurs as minor sills and dykes and in thick feeder zones.

2.2.3 Upper Parmeener

The Upper Parmeener Supergroup directly overlies the Lower Parmeener Supergroup. It is comprised of Late Permian to Triassic fluvial and lacustrine deposits including siltstone, sandstone and discontinuous coal seams (Forsyth, 1989)[8], and represents a probable transitional succession from the earlier marine sequences.

The Late Triassic sediments were possibly deposited by high sinuosity rivers and comprise volcanolithic sandstones with laterally extensive coal seams (of economic significance in the northeast of Tasmania). Within the Geothermal Play area, these sediments attain their maximum thickness of ~200 m near Fingal. The Middle Triassic deposits consist of lithic sandstone and mudstone sequences deposited in a possible deltaic environment. The earlier fluvial deposits of the Upper Parmeener Supergroup, up until the Late Permian, comprise sandstones, siltstones with some coal seams, carbonaceous silts and mudstones. The Late Permian to Early Triassic deposits show a tendency towards more quartz and feldspar dominated sand deposits but are relatively poorly developed in the area (Forsyth, 1989)[8].

2.2.4 Lower Parmeener

The Lower Parmeener Supergroup consists of late Carboniferous to Permian glacial tillites and related sediments, overlain by siltstones deposited in a quiet marine setting. A thin marine algal oil shale occurs near the base. Clarke (1989)[9] interpreted a number of half grabens, generated by Permian faulting, as supplying the

[9] **Clarke, M.J., 1989**. Lower Parmeener Supergroup, in Burrett CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 295-308

accommodation space for the deposition of the Lower Parmeener marine succession. Subsequent fault movement continued to control deposition of siltstones and shallow water sandstone into the Late Permian.

The Parmeener Supergroup unconformably overlies the Mathinna Supergroup, Precambrian basement and Devonian Granites.

2.2.5 Mathinna Supergroup

The Mathinna Supergroup is Ordovician to Devonian in age and comprised of a series of marine turbidite sequences. It has been extensively folded and reaches a thickness of 3–5 km throughout the area of interest. The Ordovician units include turbiditic sandstone and silts within a succession of slate and phyllites (Baille *et al*. 1989)[10]. The Siluro-Devonian units of the Mathinna Supergroup contain more arenaceous rocks, including poorly sorted sandstones, siltstones and mudstones. Surface field mapping by Mineral Resources Tasmania in areas of exposure to the northwest of the Geothermal Play has also identified thick units of shale-siltstone as part of the Silurian-Devonian succession of the Mathinna Supergroup (D. Seymour, MRT unpublished). Towards the east, Leaman and Richardson (2003)[11] interpret Devonian Granites to intrude the sediments of the Mathinna Supergroup.

2.2.6 Granite

The eastern Tasmanian granites intruded the Ordovician to Early Devonian Mathinna Beds in the Early-Late Devonian (McClenaghan, 1989)[12]. Granite and granodorite plutons crop out in the north and east of the area of interest, and gravity data suggest that the granitoids continue beneath the Mt. Nicholas-Fingal Geothermal Play. Leaman and Richardson (2003)[11] interpreted the granitoids as deepening towards the west, although depth constraints from gravity modelling are imprecise.

2.2.7 Precambrian Basement

HDR assumes Precambrian basement rocks including schist, sheared conglomerate, phyllite and dolomite lie at the base of the succession within the Mt. Nicholas-Fingal

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[10] **Baille, P.W., Powell, C.M., Banks, M.R. & Hills P.B., 1989.** Mathinna Beds, in Burrett CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 234–237

[11] **Leaman, D.E. & Richardson, R.G., 2003.** A geophysical model of the major Tasmanian granitoids. Report Department of Mines Tasmanian, 2003/11, 8pp.

[12] **McClenaghan, M.P., 1989.** Mid Palaeozoic Granitoids**.** in Burrett CF & Martin EL (eds). Geology and Mineral Resources of Tasmania. *Special Publication of the Geological Society of Australia,* 15, 253–261

area. However, these have only been intersected by a limited number of wells in the central and western Tasmania Basin, outside the area of interest of this document (Forsyth, 1989[13]).

3.0 Target reservoir

KEN aims to develop an Engineered Geothermal System (EGS) within the Mt. Nicholas-Fingal Geothermal Play. The critical requirements for an EGS reservoir are that it lie within a target temperature range and have suitable hydro-geo-mechanical properties. The great majority of EGS projects globally have so far been attempted in granite because of that rock's considerable strength. Host rocks must be competent and strong enough to sustain open fracture networks. Upon reviewing the stratigraphy of the Mt. Nicholas-Fingal Geothermal Play, HDR identified the Devonian granites as the principal target reservoir.

4.0 3D earth model

HDR developed a numerical 'earth model' for estimating temperature within the target reservoirs. The earth model was constructed to cover an area of 60.0 km x 55.0 km (549500–609500 E, 5355000–5410000N; AMG 94, Zone 55) to a depth of 7,000 m (Figure 4). The model divided the stratigraphy of the Geothermal Play into five (5) units—**Dolerite**, **Upper Parmeener**, **Lower Parmeener**, **Mathinna Beds** and **Granite**—and incorporated surface topography.

HDR derived the geological structure of the modelled section of crust from a combination of data. KEN utilized existing MRT geological mapping and well data to construct a regional model of the likely geology at depth. These data also incorporated the results of gravity modelling (Leaman and Richardson, 2003)[11] to estimate the distribution and depth of granitoids. HDR reviewed KEN's procedure and agrees with the results. In addition, HDR interpreted regional reflection seismic data to the west of the Play, which helped constrain the structural style of the area.

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[13] **Forsyth, S.M., 1989**. Geological Atlas 1:50,000 series. Sheet 61 (8313N). Interlaken. Explan. Rep. Geol. Surv. Tas.

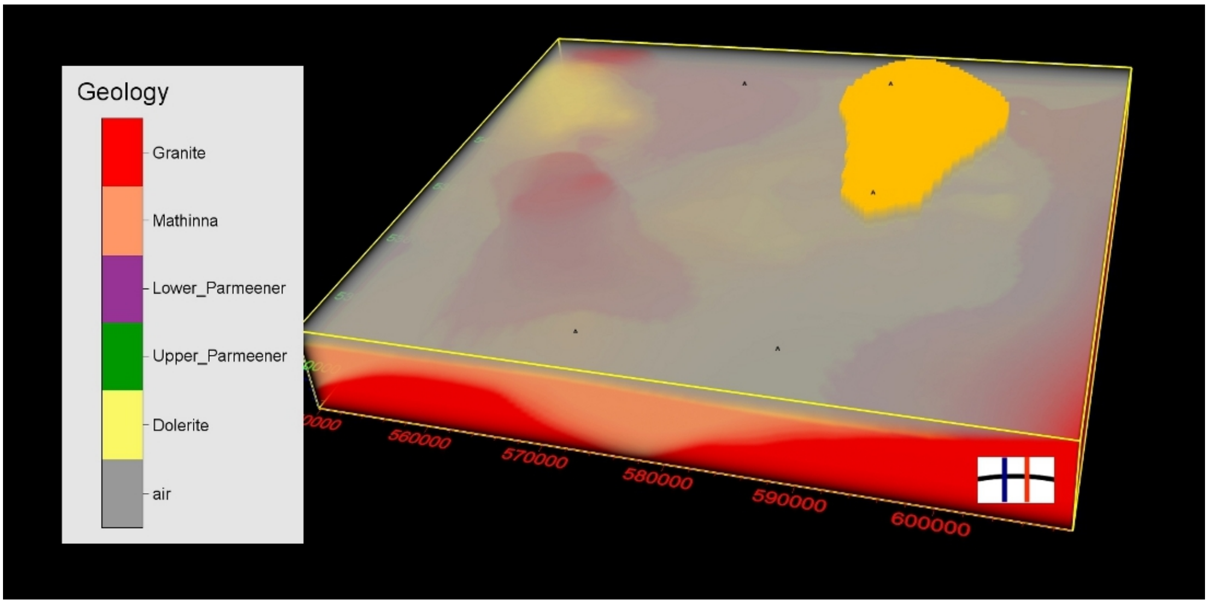

Figure 4. Representative view of the 3D numerical earth model, showing the surface trace of the Mt. Nicholas-Fingal Geothermal Play (pale orange region in upper-right of model) and the locations of wells (black dots) constraining the thermal state of the model. The earth model measures 60 km x 55 km x 7 km. North is to the top of the figure.

The Mt. Nicholas-Fingal Geothermal Play area is bordered by rugged topography, with the mountain region of Ben Lomond located to the northwest of the area. Digital surface geological maps and the Tasmanian digital elevation model (MRT) were also incorporated into the 3D earth model.

Modelled temperature at depth is sensitive to the thermal conductivity values used in the model. HDR assigned single values of thermal conductivity to each unit, based on data measured for KEN and summarised in Table 2. HDR considers the values assigned in this study to be reasonable averages for the relevant formations, but the number of measurements made on actual samples of the formations is currently insufficient to determine potential lateral and vertical variation. Uncertainty in projected temperatures and estimated Resource therefore increases with distance from, and depth beneath, borehole control points. Thermal conductivity was assumed isotropic for all units except the Upper and Lower Parmeener Supergroups.

Table 2. Mean thermal conductivity (at 25°C) and heat generation values assigned to earth model units

Unit	Thermal conductivity (W/mK) Horizontal	Vertical	Heat generation (μW/m^3)
Dolerite	2.17	2.17	0.00
Upper Parmeener	1.88	1.69	0.00
Lower Parmeener	2.09	2.05	0.00
Mathinna Supergroup	3.80	3.80	1.61
Granites	3.50	3.50	7.33

The bulk rock thermal conductivity of both the Upper and Lower Parmeener Supergroups is strongly influenced by the silty and coaly nature of these units in the Fingal Valley area. KEN provided detailed lithology logs for wells Fingal-1 and Mt. Nicholas-1. A subsequent conductivity-lithology mixing exercise demonstrated a minor difference between the derived horizontal mean conductivity (arithmetic mean) and vertical mean conductivity (harmonic mean), indicating minor thermal anisotropy as might be expected for finely bedded sedimentary rocks.

Triaxial measurements by HDR and Goh (2008)[14] have demonstrated anisotropic thermal conductivity in the Mathinna Supergroup. Surface mapping of outcropping Mathinna units in the area of interest indicates significant variation in the foliation orientation, with sub-horizontal foliations associated with recumbent folding observed in the west and sub-vertical foliations associated with upright folding observed in the east (Reed, 2001)[15]. Rocks of the Mathinna Supergroup crop out along the northern margin of the modelled area and within parts of the Fingal Valley axis. These rocks demonstrate multiple episodes of folding and deformation and typically exhibit a wide range of bedding orientations and a moderate to upright foliation. Further to the north and west the foliation angle is observed to vary widely and no information is known regarding variations in rock fabric with increasing depth in the Mathinna Supergroup.

The orientation of the dominant foliation is largely unknown throughout the south and east of the modelled area where the Mathinna Supergroup is completely obscured by younger formations. However, by analogy, it may be assumed to vary considerably. HDR ran a number of 'high' and 'low' case models utilising the measured upper and

[14] **Goh, H.K.H., 2008**. Properties of north eastern Tasmanian rocks for geothermal exploration petrophysical, geochemical and thermal characteristics of the Mathinna Group and Devonian granites. Unpublished Honours Thesis, University of Tasmania.

[15] **Reed, A.R., 2001**. Pre-Tabberabberan Deformation in Eastern Tasmania: a Southern Extension of the Benambran Orogeny, *Australian Journal of Earth Sciences*, 48, 785-796.

lower values of Mathinna Supergroup anisotropic thermal conductivity. The results of this work indicate that the expected temperature at depths approaching 5,000 m may vary significantly (by up to 10's of degrees Celsius) depending on the orientation of the dominant foliation in the Mathinna Supergroup. In the absence of definitive information on the local rock fabrics, this Geothermal Resource estimate is based on a mean case with an average dip of foliation of 45° throughout the modelled area.

Predicted temperature at depth decreases with increasing heat generation within the modelled depth interval. In this case, the impact is unlikely to be large within the sedimentary units and most probably lies well within the precision limits of this Resource assessment. The impact of heat generation within the Devonian granites, however, is likely to be more significant. While reported heat generation values of Tasmanian granites are highly variable, many samples of granite from eastern Tasmania have elevated values. Geochemical data from the Coles Bay Granite on the eastern margin of Tasmania, for example, show elevated levels of uranium and thorium (Champion *et al*., 2011)[16] suggesting heat generation values in the range 5–10 μW/m^3. Goh (2008)[14] derived mean values of 1.61 μW/m^3 and 7.33 μW/m^3, respectively, for heat generation within the Mathinna Supergroup and Granites. HDR assumed heat generation of 0 μW/m^3 for all other units (Table 2).

5.0 Thermal data

HDR used the results of 1D heat flow modelling for six (6) wells around the Mt. Nicholas-Fingal Geothermal Play as constraints for a subsequent 3D temperature model. Figure 5 shows a sample 1D heat flow model (Mt. Nicholas-1). All locations of wells and heat flow values are presented in Table 3. The uncertainties quoted for the heat flow values in Table 3 were derived from the uncertainties in the thermal conductivity values measured on the different stratigraphic units intersected by the wells. Temperature data were collected during high-precision (±0.001°C) temperature logging and contribute negligible uncertainty to the heat flow models.

[16] **Champion, D.C., Budd, A.R. and Wyborn, L.A.I**. (2011). OZCHEM National Whole Rock Geochemistry Database. http://www.ga.gov.au/meta/ANZCW0703011055.html.

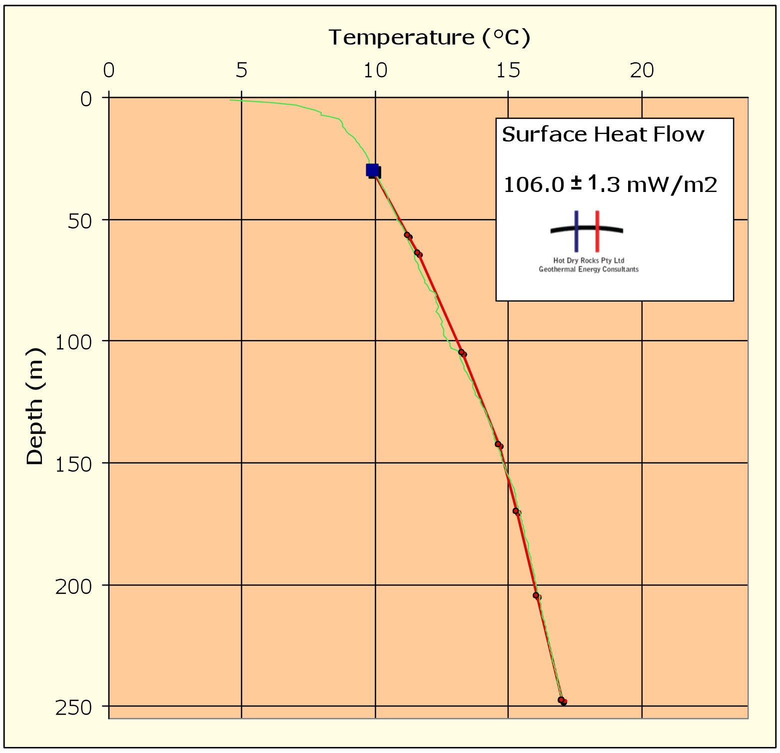

Figure 5. 1D conductive heat flow model of well 'Mt. Nicholas-1'. The red line is the predicted temperature profile for a 1D conductive heat flow model and the green line is the measured temperature profile. The blue square is the top of the cored (modelled) interval.

Table 3. Locations and values of heat flow constraints on the 3D temperature inversion. Coordinates are in GDA94 MGA Zone 55.

Well	East	North	Heat Flow (mW/m^2)
Tower Hill-1	573964	5399699	83 ± 1.0
Fingal-3	590381	5381540	97 ± 2.9
Snow Hill-1	572873	5358389	92 ± 2.3
Mt. Nicholas-1	587962	5401440	106 ± 1.3
Swan-2	588102	5359269	85 ± 1.2
Elizabeth-1	549501	5356701	94 ± 2.4

The temperature data fit conductive models (within uncertainty limits) in each of the wells. There is no thermal, or other, evidence of convection within the drilled and logged intervals of the Mt. Nicholas-Fingal Geothermal Play.

Surface temperature varied across the model in accordance with topographic elevation, constrained by temperature logs collected in shallow bores in the area.

6.0 Resource estimation methodology

6.1 Stored heat assessment

HDR utilised a 'stored heat' calculation for the target reservoir as an interim step towards the Geothermal Resource assessment. A stored heat calculation estimates the total heat energy contained within a target volume. The method requires the estimation of the **volume**, **density**, **specific heat capacity** and **temperature** of the target reservoir formation, a consideration of the realistic lowest economically extractable temperature ('**cut-off temperature**') and the amount of thermal energy that might be extracted from the resource fluids (related to the '**base temperature**').

6.2 Cut-off and base temperature

For the purpose of the stored heat calculation, HDR defined the cut-off temperature as *the minimum economic reservoir fluid temperature for commercial energy extraction*. The cut-off isotherm is an essential input to the volumetric stored heat calculation as it defines the upper surface of the reservoir volume. Similarly, for the purpose of the stored heat calculation, HDR defined the base temperature as *the temperature of the geothermal fluid once it has passed through a power conversion process, prior to reinjection*. The base temperature puts an upper limit on the amount of thermal energy that can be extracted from a Geothermal Resource of any given temperature. Both of these values depend strongly on the technology used to convert thermal energy into electrical energy.

It is technically feasible to generate power from geothermal fluid cooler than 100°C (eg the Birdsville Geothermal Plant in Queensland runs on 98°C water), but the efficiency of power conversion at low temperatures makes it economically unviable in most situations. HDR assumed **a cut-off temperature of 150°C** as the minimum required for power generation from the Mt. Nicholas-Fingal Geothermal Play.

Beardsmore *et al*. (2010)[17] published Version 1.0 of a Global Protocol for estimating and mapping EGS potential. At the time of writing, Version 1.1[18] of the Global Protocol remained unpublished, but had received the official endorsement of the

[17] **Beardsmore, G.R., Rybach, L., Blackwell, D. and Baron, C.**, 2010. A protocol for estimating and mapping global EGS potential. *GRC Transactions*, 34, 301–312.
[18] **Beardsmore, G.R., Rybach, L., Blackwell, D. and Baron, C.**, in prep. A protocol for estimating and mapping global EGS potential, Version 1.1.

International Geothermal Association. Version 1.1 was undergoing review for similar endorsement by the International Energy Agency, and publication was expected sometime in 2011. In line with both versions of the Global Protocol, HDR assumed a base temperature 80°C above the mean annual air temperature. Bureau of Meteorology records[19] indicate a mean annual air temperature of 12°C in eastern Tasmania, suggesting a **base temperature of 92°C** for the Geothermal Resource.

HDR believes the cut-off and base temperatures above are appropriate for low-temperature organic rankine cycle binary technology that KEN proposes to use for power generation. Should technological advances decrease the cut-off or base temperatures, the estimated Resource may increase over time.

6.3 Reservoir volume

The volume of an EGS reservoir is practically limited to rock that can be hydraulically stimulated to enhance its permeability. To estimate the actual volume requires consideration of the areal extent and thickness of the possible stimulated zone.

Notwithstanding the limitations below, there are practical upper and lower limits to the vertical extent of a reservoir interval. The minimum depth of potential reservoir is the deeper of the 150°C isotherm (for reasons explained in Section 6.2) or the top of the Devonian Granite. HDR considers 5,000 m to be the maximum practical depth for drilling and fracturing a reservoir.

HDR determined (in consultation with KUTh Energy) the areal extent of the possible Mt. Nicholas-Fingal geothermal reservoir using the combination of isothermal and geological constraints described in the previous paragraph. The outline of this area is shown, for example, on Figure 4.

The vertical extent of an EGS reservoir is limited to the thickness of rock that can be hydraulically stimulated. HDR considers 500 m to be an appropriate aspirational target thickness for an engineered underground heat exchanger, based on a thickness of 350 m already demonstrated by Geodynamics Ltd part way into its total stimulation program in the Cooper Basin in Central Australia[20].

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[19] http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/index.jsp?maptype=6&period=an#maps
[20] **Geodynamics Ltd**, ASX Announcement, 19 December 2003.

The total potential reservoir volume within the Mt. Nicholas-Fingal Geothermal Play, below the 150°C cut-off isotherm and above 5000 m, is 384 km^3. The predicted minimum depth to the 150°C isotherm within the Geothermal Play area is about 3,200 m, just east of Mt. Nicholas. HDR considers each 500 m thick horizontal depth slice as a separate EGS reservoir target worthy of a separate Geothermal Resource estimate. Specifically, the depth slices and respective volumes are:

<3,500 m depth	18 km^3
3,500–4,000 m depth	98 km^3
4,000–4,500 m depth	134 km^3
4,500–5,000 m depth	134 km^3

6.4 Reservoir density and specific heat

Goh (2008[14]) measured the densities of specimens of the Devonian granites and determined a mean density of 2,580 kg/m^3.

Specific heat is temperature dependent and typically increases with temperature. HDR has estimated a relationship for the specific heat of granite based on Equations 18 and 19 of Waples and Waples (2004)[21], assuming a reference temperature of 25°C and a surface Cp = 750 J/kgK:

Equation 1 $$CpT = (8.859\times10^{-7} \times T^3) - (2.108\times10^{-3} \times T^2) + (1.703 \times T) + 708.7$$

Where CpT is the specific heat at temperature T(°C).

Goh (2008)[14] reported specific heat values for the granite lower than the values predicted by Equation 1. Goh cautioned, however, that "aluminium and brass samples used as calibration pieces returned a lower than expected heat capacity", so Equation 1 is preferred over the reported values.

6.5 Reservoir temperature

HDR utilized a numerical three-dimensional temperature inversion algorithm to estimate the temperature distribution and stored heat within the reservoir. The methodology incorporated the three-dimensional numerical earth model described in Section 4, constrained by the thermal data presented in Section 5.

[21] **Waples, D.W. & Waples, J.S., 2004**. A review and evaluation of specific heat capacities of rocks, minerals, and subsurface fluids. Part 1: Minerals and nonporous rocks. *Natural Resources Research*, 13(2), 97–122.

The algorithm operated on the principle of 'inversion'. Known information about surface temperature and surface heat flow was entered into a software module. The algorithm 'voxelated' the earth model; that is, divided it into discrete rectangular prismatic cells, with the thermal properties of each cell determined by the geological unit within which the cell lay. The dimensions of the individual cells were 500 m by 500 m horizontally, by 50 m vertically. A numerical iterative process then computed in three dimensions the simplest distribution of temperature consistent with the observed surface heat flow distribution, while respecting the laws of conductive heat transfer and the thermal properties of the geological strata. The temperature dependence of thermal conductivity was also taken into account, using a formula published by Sekiguchi (1984[22]).

The algorithm employed did not exactly match the observed heat flow values, but optimised the fit to observed values within a predefined precision. The 'root mean square' (RMS) misfit of the model to the six heat flow constraints was 1.38 mW/m^2. The model fit the heat flow data within uncertainty limits (Table 3) for all wells except Swan 2, which lies outside the Geothermal Play area.

The 3D inversion process predicted potential reservoir temperatures in the range 150.0–220.0°C, with an average temperature of 177.5°C.

6.6 Recoverable thermal energy

The Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves, 2010 Edition ('The Code'), defines a Geothermal Resource as "the estimated Recoverable Thermal Energy." For the purpose of this Resource estimate, HDR has adopted a recovery factor of **14%**, consistent with the recommendation for "fracture dominated reservoirs where there is insufficient information to accurately characterise the fracture spacing", as given in the Geothermal Lexicon for Resources and Reserves Definition and Reporting, Edition 2 (2010).

[22] **Sekiguchi, K., 1984.** A method for determining terrestrial heat flow in oil basinal areas. *Tectonophysics*, 103, 67–79.

7.0 Estimated Geothermal Resource

7.1 Total recoverable heat

The numerical algorithm revealed the simplest temperature distribution to explain the observed surface heat flow values. For each discrete cell of the reservoir units lying beneath the cut-off isotherm and above 5000 m, the stored heat was calculated from the volume, density, specific heat and temperature of the cell. The total stored heat in all individual cells was 80,740 PJ_{th}. This was divided between depth slices as follows:

<3,500 m depth	2,618 PJ_{th}
3,500–4,000 m depth	16,528 PJ_{th}
4,000–4,500 m depth	27,572 PJ_{th}
4,500–5,000 m depth	34,023 PJ_{th}

14% of the stored heat in any given depth slice was assumed potentially recoverable:

<3,500 m depth	367 PJ_{th}
3,500–4,000 m depth	2,314 PJ_{th}
4,000–4,500 m depth	3,860 PJ_{th}
4,500–5,000 m depth	4,763 PJ_{th}

7.2 Classification of Resource

7.2.1 Inferred Geothermal Resource

The Code defines an 'Inferred Geothermal Resource' as "*that part of a Geothermal Resource for which Recoverable Thermal Energy can be estimated only with a low level of confidence…This category of Geothermal Resource is inferred from geological, geochemical and geophysical evidence and is assumed but not verified as to its extent or capacity to deliver geothermal energy. There must be a sound basis for assuming that a Geothermal Play exists, estimating the temperature and having some indication of its extent.*"

HDR judged that **the recoverable heat estimated in Section 7.1 is best classified as an Inferred Geothermal Resource**. In reaching this decision, HDR took into account the following points:

- Gravity, surfacing mapping and regional 2D reflection seismic data provided the basis of an interpretation of the 3D geology of the Mt. Nicholas-Fingal

Geothermal Play, which defined the extent and thickness of the potential reservoir units.

- Drilling in the Mt. Nicholas-Fingal Geothermal Play has not yet penetrated the Geothermal Resource.
- The lithological interpretation of deep seismic reflections throughout Tasmania is currently unproven by drilling.

7.3 Tabulated Resource estimates

Table 4 states the estimated Geothermal Resource for different possible reservoir depth intervals in the Mt. Nicholas-Fingal Geothermal Play, as classified by the criteria in Section 7.2.

Table 4. Estimated Geothermal Resource within the different possible reservoir depth intervals of the Mt. Nicholas-Fingal Geothermal Play. Resource estimates are rounded to two significant figures.

Reservoir	Depth Interval (m)	Recoverable Heat (PJ_{th})	Volume (km^3)	Inferred Geothermal Resource (PJ_{th})
Devonian Granite	<3,500	367	18	**370**
Devonian Granite	3,500–4,000	2314	98	**2300**
Devonian Granite	4,000–4,500	3860	134	**3900**
Devonian Granite	4,500–5,000	4763	134	**4800**

8.0 Key Assumptions and Geological Constraints

Apart from the parameters described above, the following key assumptions underpin this Geothermal Resource estimate:

- It is technically unlikely that commercial production could be sustained from more than one EGS reservoir depth level at a time. The Geothermal Resource estimates, therefore, should not be stated in any way that implies they can be extracted simultaneously.
- The proposed product to be generated from the Geothermal Resource is electricity using commercially available organic rankine cycle binary plants utilizing air-cooling fans.
- The estimated Geothermal Resource does not include any additional heat that might conduct or convect into the reservoir volume during production.

- The estimated Geothermal Resource assumes that advective or convective processes within the Geothermal Play transfer no significant heat. Advective heat transfer with groundwater has been observed in some shallow wells. These occurrences are assumed to relate to shallow, gravity-driven systems. If convection occurs in the deeper sections, it will suppress geothermal gradients and reduce the estimated stored heat and recoverable Resource.
- The heat is contained entirely within the matrix of the reservoir rock and there is little expectation for significant *in situ* water.
- This work is based on a numerical model of a section of the Earth's crust. A model necessarily simplifies the true complexity of the Earth and as such is inherently prone to error. The results of modelling stated within this report have been generated using the best available estimates of critical parameters, but future work may yield new information that modifies or falsifies some of these assumptions. All modelling results should be treated as provisional.
- HDR is unaware of any geotechnical, access, environmental or land use issues that could affect future drilling locations or sterilise potential geothermal resource sectors within the Mt. Nicholas-Fingal Geothermal Play.

9.0 Conversion to electricity

The figures presented in Table 4 above constitute the Geothermal Resource estimate for the Mt. Nicholas-Fingal Geothermal Play. Equation 11 of Version 1.1 of the Global Protocol[18] provides guidance for estimating the theoretical potential for electrical power production from a given Geothermal Resource. Table 5 shows the outcome of such calculations for the Mt. Nicholas-Fingal Geothermal Play. Note that the figures in the last column of Table 5 should not be quoted as a cumulative total, as it is technically unlikely that power could be generated concurrently from different depths.

Table 5. Estimated theoretical electrical power generation potential over a 30 year assumed plant life, derived from Equation 11 of Version 1.1 of the Global Protocol[18] and the Geothermal Resource estimates presented in Table 4.

Depth Interval (m)	Recoverable heat (EJ_{th})	Assumed reservoir temperature (°C)	Conversion efficiency (%)	Power for 30 years (MW_e)
<3,500	0.367	150	11.0	43
3,500–4,000	2.314	167	11.9	291
4,000–4,500	3.860	183	12.7	519
4,500–5,000	4.763	200	13.6	685

10.0 Future Work

The Code defines an 'Indicated Geothermal Resource' as "*that part of a Geothermal Resource which has been demonstrated to exist through direct measurements that indicate temperature and dimensions so that Recoverable Thermal Energy can be estimated with a reasonable level of confidence. Thermal Energy in Place has been estimated through direct measurements and assessments of volumes of hot rock and fluid, with sufficient indicators to characterise the temperature and chemistry. Direct measurements are sufficiently spaced so as to indicate the extent of the Thermal Energy in Place.*"

The Code defines a 'Measured Geothermal Resource' as "*that part of a Geothermal Resource which has been demonstrated to exist through direct measurements that indicate at least reservoir temperature, reservoir volume and well deliverability, so that Recoverable Thermal Energy can be estimated with a high level of confidence. The Thermal Energy in Place has been demonstrated to exist through direct measurements and assessments of drilled and tested volumes of rock and/or fluid within which well deliverability has been demonstrated, and which have sufficient indicators to characterise the temperature and chemistry. Direct measurements must be sufficiently spaced to confirm continuity.*"

Reclassification of any portion of the Inferred Geothermal Resource stated in this report to an Indicated or Measured Resource will require drilling and testing of the target reservoir to directly determine temperature and reservoir properties.

11.0 Competent Person

The information in this report that relates to Exploration Results, Geothermal Resources or Geothermal Reserves is based on information compiled by Dr Graeme Beardsmore, who appears on the Register of Practicing Geothermal Professionals maintained by the Australian Geothermal Energy Group Incorporated at the time of the publication of this report. Dr Beardsmore is employed by Hot Dry Rocks Pty Ltd (HDR), an independent company that provides consulting services to KUTh Energy Ltd.

Dr Beardsmore has sufficient experience relevant to the style and type of geothermal play under consideration and to the activity that he is undertaking to qualify as a Competent Person as defined in the Second Edition (2010) of the 'Australian Code for Reporting Exploration Results, Geothermal Resources and Geothermal Reserves'. Dr Beardsmore was assisted by other employees within HDR but takes sole responsibility and is accountable for the report as a Competent Person.

Dr Beardsmore consents to the public release of this report in its entirety.

Signed: G. R. B.   30th June 2011

Graeme Beardsmore   *Date*

Appendix-1 Glossary of terms in their context as used in this report

Base temperature	The temperature of the geothermal fluid once it has passed through a power conversion process, prior to reinjection.
Basement	The deepest geological horizon considered in an assessment.
Basin	A three dimensional accumulation of sediments, usually thicker on the down-thrown side of a major fault or in the centre (as defined by the outer geographic margins of basin succession).
Conversion efficiency	The proportion (%) of energy that can be converted from heat to electricity.
Cut off temperature	The minimum economic reservoir fluid temperature for commercial energy extraction.
Density	A physical property of matter, such as rocks, measured in mass per unit volume (eg kilograms per cubic metre, kg/m^3)
Earth model	A three-dimensional computer model of part the earth based on grided inputs such as depth maps from well data, gravity data or seismic mapping.
Fault	A break in geological strata caused by movement along a plane of weakness.
Footwall	The up-thrown (higher) portion of a fault block.
Heat Flow	The amount of thermal energy passing through a square metre at the earth's surface, usually expressed as milli-Watts per square metre (mW/m^2).
Heat Generation	The amount of heat generated by a rock through the natural decay of radiogenic elements, usually calculated in micro watts per cubic metre ($\mu W/m^3$).
Isotherm	A line or surface joining points of equal temperature.

Organic rankine cycle	An electricity production process whereby heat can be exchanged from a hot fluid to a cooler one via the use of a liquid organic compound which has a lower boiling point than the source fluid. Used in certain geothermal electricity generating plants where the fluid temperature is suitable.
Permeability	The ability of a rock to flow fluid, such as water, usually measured in milli-Darcies (mD).
Play	An accumulation of heat energy within the Earth's crust.
Porosity	The 'free' space in a rock, not occupied by minerals, cement or clay. A dimensionless unit, expressed as the % of rock volume that may hold fluid.
Reservoir	A body of rock with certain permeability and porosity characteristics that enable it to hold fluids of economic interest.
Rifting	The geological process in which tectonic plates extend and fault as plates begin to pull-apart.
Sandstone	A coarse grained sedimentary rock chiefly composed of sand-sized grains of silica, feldspar and/or lithic material.
Seismic line	A line across the ground surface along which a seismic survey (involving the reading of vibrations induced in the shallow earth by a source) has or will be read.
Specific heat	The amount of energy required to raise the temperature of 1 kg of substance by 1°C; otherwise known as relative heat capacity, usually measured in Joules per kilogram per degree Kelvin (J $kg^{-1}K^{-1}$).
Stored heat	The amount of geothermal energy 'trapped' as heat within a volume of rock. Quantified as in-place petajoules (PJ_{th}).
Thermal Conductivity	A measured property of a rock indicating its ability to transfer or 'conduct' heat energy, usually measured directly in Watts per metre Kelvin (W/mK).
Well	A bore hole