

## The Central Tasmanian Geothermal Anomaly: A Prospective New EGS Province in Australia

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**Keywords:** Tasmania, heat flow, exploration, EGS, MT Survey

### ABSTRACT

Recent exploratory work undertaken by KUTH Energy Ltd across the eastern third of Tasmania has identified a new Australian geothermal province. Drilling and heat flow measurement on a 20 x 20km grid has defined a spatially continuous heat flow anomaly  $>90\text{mWm}^{-2}$  and over  $4100\text{km}^2$  in extent. Interpretation of independent geophysical data (gravity) suggests that this anomaly is associated with the sub-cropping extension of high-heat-producing granite bodies known to occur in the north-east of the state. Buried beneath successive layers of around 1km of insulating Triassic-Permian sediments intruded by Jurassic dolerite dykes (Tasmanian Basin) and up to 5km of poorly constrained Ordovician-Devonian flysch, these granites present a significant target for Enhanced Geothermal System (EGS) development. Information from recently completed geophysical surveys, including magneto-telluric (MT) data, has contributed to the knowledge and understanding of both the geothermal potential and the broader crustal architecture of this region.

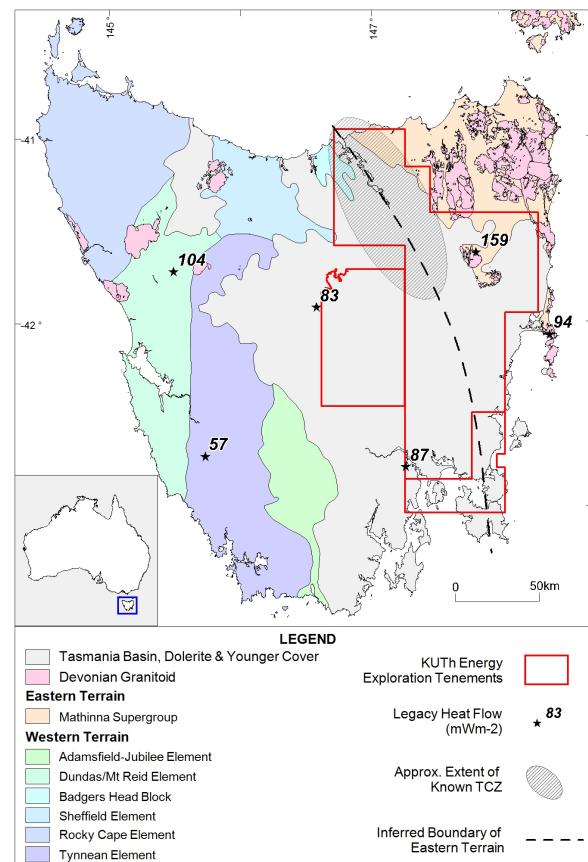
### 1. INTRODUCTION

Lying to the south of the Australian mainland, the island of Tasmania has a long history of mineral exploration and development but has only recently been considered as a target for geothermal exploration. 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 1; Burrett & Martin 1989). Legacy surface heat flow measurements associated with these rocks at Storey's Creek and Coles Bay are high (over  $90\text{mWm}^{-2}$ ) (Jaeger & Sass, 1963; Cull, 1991) and correspond to an average heat production in the granites of  $\sim 8\mu\text{Wm}^{-2}$  (Goh, 2008).

To the south and west of this area, the exposed granite plunges beneath cover containing extensive dolerite, shale, silt and coal formations which potentially provide 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 observed in the northern Tamar Valley area and referred to as the Tamar Conductivity Zone (TCZ) (Figure 1; Hermanto, 1990). Although initially relatively poorly defined, the TCZ was interpreted an indicator of fluid in fractured permeable zones (Hermanto, 1990). Intersection between the TCZ and buried HHP granites may thus imply the presence of an existing fracture-permeable geothermal system in Eastern Tasmania.

In 2007 KUTH Energy Limited commenced a systematic geothermal exploration program across its tenement area in Eastern Tasmania (Figure 1) with the aim of evaluating the

apparent geothermal potential of this region. The initial program phase, which was designed to identify local targets for future geothermal development, is now nearing completion and has yielded a variety of results with implications not just for geothermal potential but also for the broader geological understanding of this area.



**Figure 1:** Location map showing the major Tasmanian crustal elements and legacy heat flow data as summarized by Cull (1991)

### 2. REGIONAL GEOLOGY

Tasmania is divided into two basement terrains located in the west and east of the State (Figure 1). 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 on which was deposited 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. Both Western and Eastern Terrains are host to Devonian granite, the most extensive intrusions being the slightly older batholiths in the East (Burrett & Martin, 1989).

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 cover totally obscures the contact between the Pre-Cambrian Western and Palaeozoic Eastern terrains. The nature and location of this feature, which may coincide in part with the TCZ, remains contentious (Burrett & Martin, 1989; Rawlinson *et al.*, 2007; Reed 2001). 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 Tabberabbera Zone of central and eastern Victoria (Powell & Baillie, 1992; Reed, 2001).

### 3. EXPLORATION METHODOLOGY & RESULTS

Thick Jurassic Dolerite sequences cover much of the surface of Eastern Tasmania and complicate the exploration process by obscuring the geology at depth. Standard geophysical techniques such as aeromagnetic data acquisition are not able to provide interpretable information beneath this layer, which is strongly magnetized. Whilst seismic data acquisition through the dolerite is possible it has not been widely applied in the area of interest and, where available, is of relatively poor quality. Likewise, relatively few drill holes have been sunk through the dolerite, the thickness and apparent lack of mineralization in the unit precluding previous exploratory work.

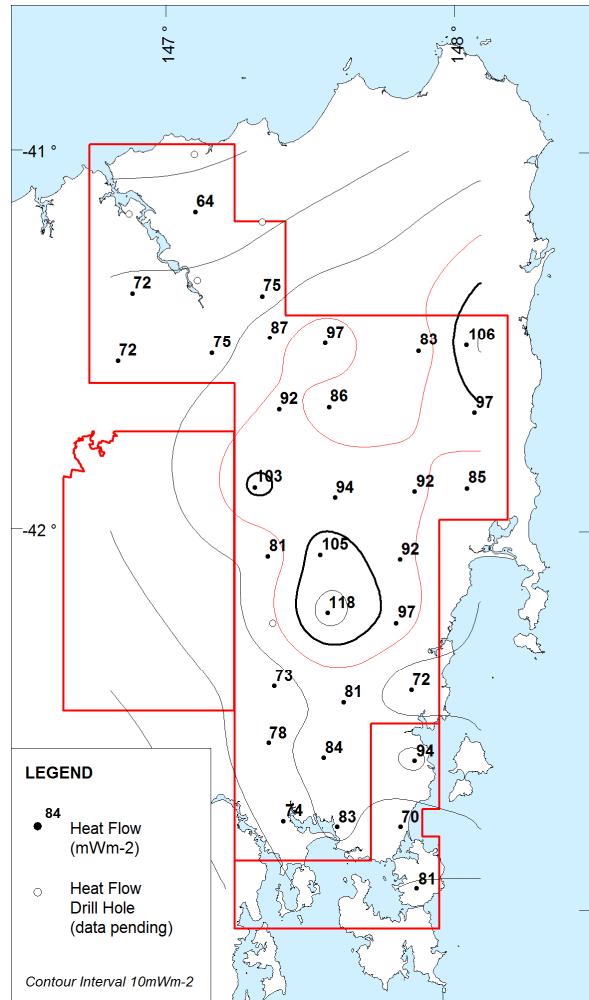
To effectively explore this region for its geothermal potential a variety of techniques were required that were capable of discerning key elements of the EGS target beneath the dolerite cover. Critical amongst these were the magnitude and distribution of heat flow, the depth of insulator (depth to top granite), the quality (thermal properties) of the insulator and the location and nature of the TCZ. The size of the area under investigation further necessitated that any technique used should be economically applicable at a regional scale. To meet these needs, a program was devised that comprised shallow drilling for surface heat flow determination, gravity interpretation, rock property determination and Magneto-Telluric (MT) data acquisition.

#### 3.1 Surface Heat Flow Determination

A program of pattern drilling of shallow boreholes was designed to investigate surface heat flow across the tenement area. Holes were drilled on a 20km grid spacing at 36 locations. In all cases the holes were percussion drilled to 100m with diamond core cut to total depth at ~250m. Precision temperature logs were recorded down hole at least twice in the months after drilling to ensure that thermal relaxation was complete. Thermal conductivity values were determined on core samples using a divided bar apparatus. Surface heat flow was determined for each hole by application of 1D thermal modeling.

At the time of writing, surface heat flow data were available for 31 holes with five holes still outstanding (Figure 2). Heat flows determined to date are of high quality and

reliability with analytical uncertainties typically <5%. The data are spatially consistent, defining a large area (>4100km<sup>2</sup>) of anomalously high heat flow (>90mWm<sup>-2</sup>) in the central portion of the tenement area.



**Figure 2: Contoured surface heat flow field for Eastern Tasmania based upon new data acquired during KUTH Energy's recent exploration program. The 90mWm<sup>-2</sup> contour, shown in red, encloses an area of over 4100km<sup>2</sup> inside the tenement area**

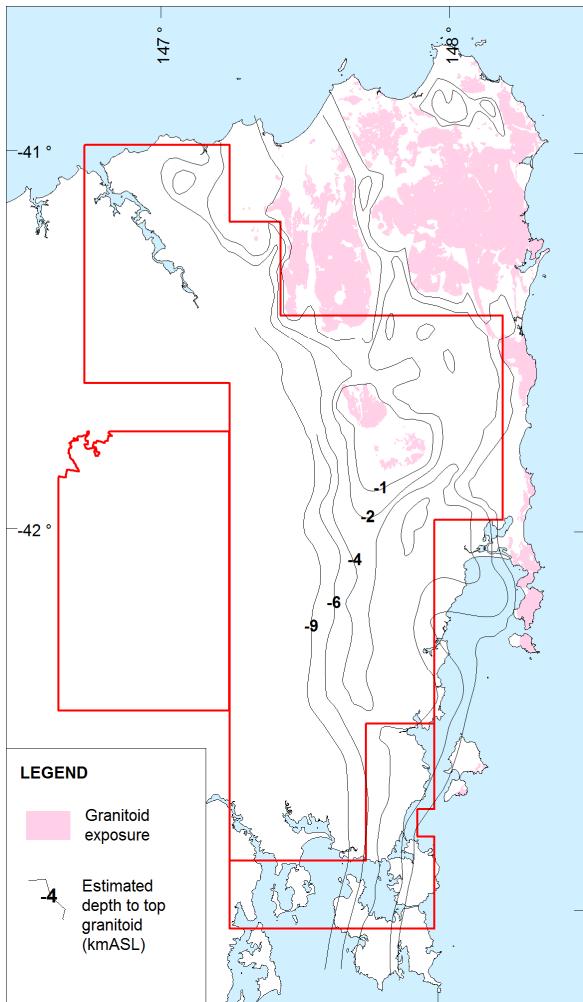
#### 3.2 Gravity Interpretation

Estimation of the depth to top granitoid was undertaken by Dr. David Leaman using source modeling of gravity data and following the method of Leaman and Richardson (2003). An infill survey of ~500 gravity stations was undertaken to improve the regional gravity coverage across the tenement area. These data were used to create an updated version of the Tasmanian mantle source model MANTLE07. This model was in turn used to determine the residual Bouguer gravity anomaly from which the depth and shape of top granitoid was interpreted (Figure 3).

#### 3.3 Rock Property Determination

Rock units predicted to overlie the granites in significant thicknesses are the Jurassic Dolerite, the Tasmania Basin sediments (Parmeener Supergroup) and the Mathinna Supergroup. Thermal conductivity values determined from these rocks by divided bar analysis from KUTH drill core are summarized in Table 1 together with data from an independent study of this region (H. Goh, 2008). These results confirm the relatively good insulating properties of

both the Dolerite and the Tasmania Basin sediments. Predictably, the turbidite sequences of the Mathinna Supergroup display variable thermal conductivities, depending upon rock type and grainsize. Of particular interest in these units, however, was the observation of a strong anisotropy associated with the development of fold axial cleavage (Figure 4). This effect, which was observed most strongly in fine-grained mudstone and shale, serves to significantly reduce the insulating advantage of the fine-grained lithologies wherever heat flow is directed along the cleavage plane.



**Figure 3:** Contoured surface showing estimated depth to top granitoid. Image combines new data derived from KUTh Energy's gravity data acquisition with the existing contours of Leaman and Richardson (2003)

### 3.4 Magneto-Telluric Survey

An MT survey, comprising 96 stations located at 1km intervals along two E-W lines, was undertaken to better constrain the nature and location of the TCZ anomaly (Figure 5). Full tensor time series data were collected for ~12 hours at each site to ensure resolution of apparent resistivity and phase data in the range 300-0.01Hz.

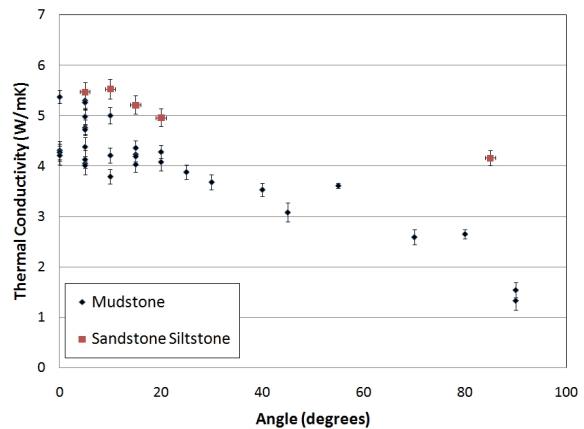
2D modeling of data generated by this survey was performed by Dr Adele Manzella of the *Consiglio Nazionale delle Ricerche-Istituto di Geoscienze e Georisorse* (CNR-IGG) in Italy. Data were found to be of high quality with relatively few incidences of major signal noise. As part of the modeling Dr Manzella applied a

systematic process of data validation to identify, correct or remove poor or biased data. A manually derived 'static shift' correction was applied to compensate for distortion effects produced in the electromagnetic field by near-surface features.

**Table 1.** Thermal conductivity values (W/mK) determined from core for Eastern Tasmanian rocks. Values in italics are taken from Goh (2008). All values are from wet samples.

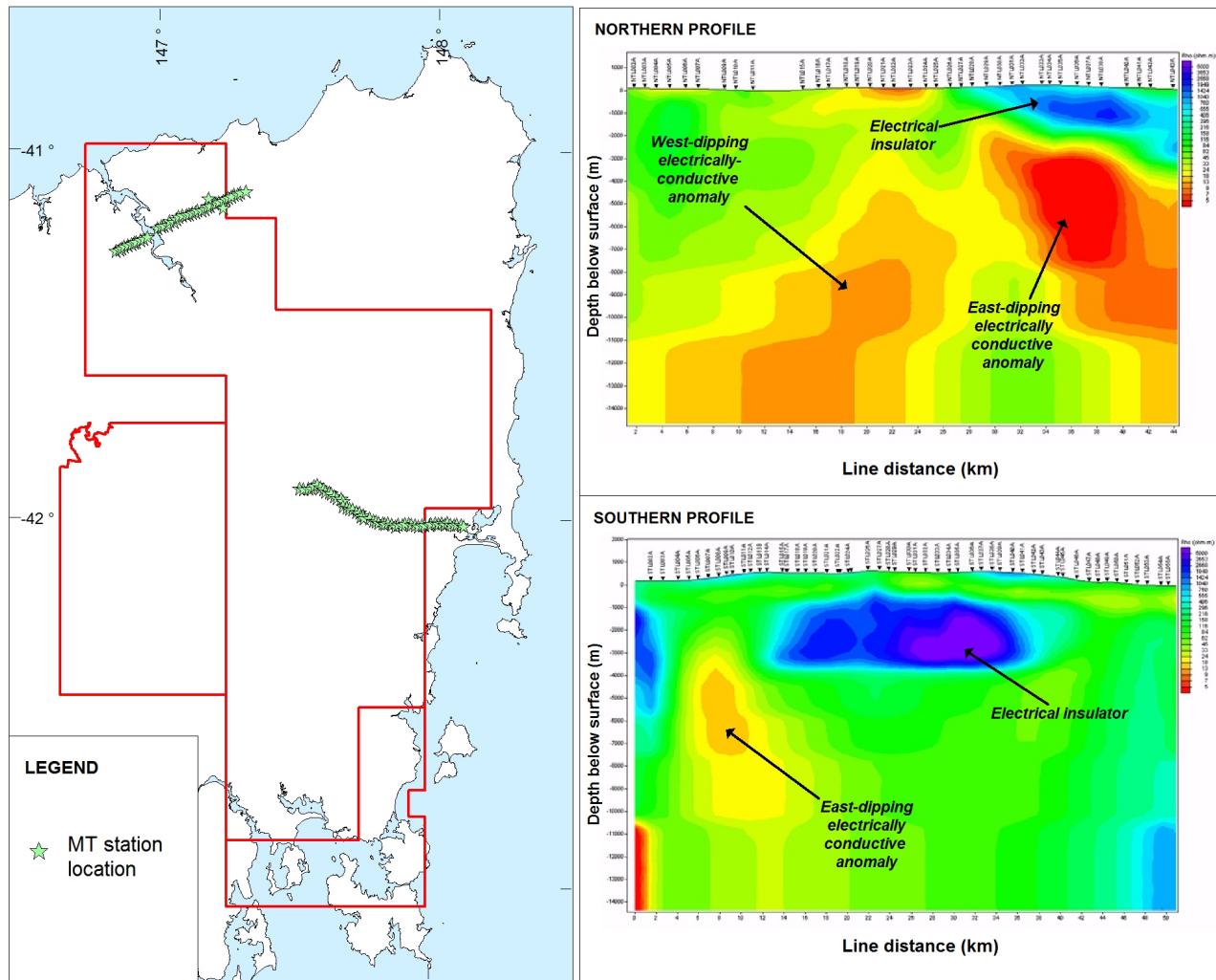
Unit	Lithology	n	Mean	2 $\sigma$
<b>Jurassic Dolerite</b>	dolerite	97	2.17	0.35
<b>Parmeener</b> <b>(Tasmania Basin)</b>	sandstone	17	3.54	1.85
	siltstone/mudstone	19	2.39	1.83
<b>Mathinna</b>	sandstone	8	4.48	1.27
		24	4.38	1.48
	siltstone/mudstone	18	3.64	1.24
		16	3.44	1.28
	shale	18	2.71	1.36
<b>Devonian Granite</b>	granite	31	3.48	0.4

The 2D models produced by Dr Manzella for this survey are presented in Figure 5. In both cases these models have been refined by the use of *a priori* constraints regarding the location of resistive bodies determined in 1D inversion models. No assumptions were made regarding the location, size or intensity of electrically conductive anomalies or of the nature or distribution of the existing geology. Comparisons of TE, TM and joint TE-TM inversion models for the two lines indicated a good agreement for the northern line whilst the southern line displayed significant differences indicating these data are influenced by 3D effects.



**Figure 4:** Thermal conductivity versus foliation angle (0° = vertical foliation) for the Mathinna Supergroup. Results indicate a strong thermal anisotropy that is most distinct in the finer grained lithologies

The models derived from the MT data indicate the presence of large electrically conductive bodies within the crust in the vicinity of both survey lines. In the northern profile, a strong east-dipping conductive body is observed at a depth of 2.5km and is interpreted to have a thickness of no less than 2km. This body, together with a weaker west-dipping conductor, confirms the presence of the 'Tamar Conductivity Zone' (TCZ) in this region.



**Figure 5: MT survey location and 2D modeled profile results for two lines across Eastern Tasmania. Models are inversions of TM and TE shifted data. Resistivity range 50ohm.m (red) to 6000ohm.m (purple), maximum depth below surface is 14km, line distance northern line = 44km, southern line = 50km**

An east-dipping electrically-conductive anomaly is also identified at the western end of the southern MT profile at a depth of 3.5 - 4km. This body lies directly along strike from the east-dipping feature identified in the northern profile and is interpreted to be an extension of the TCZ along the Tamar Lineament (Figure 6).

An electrically insulating anomaly is seen located to the east of the interpreted east-dipping TCZ anomaly in both the northern and southern profiles. At present the identity of the geological feature causing this anomaly remains speculative.

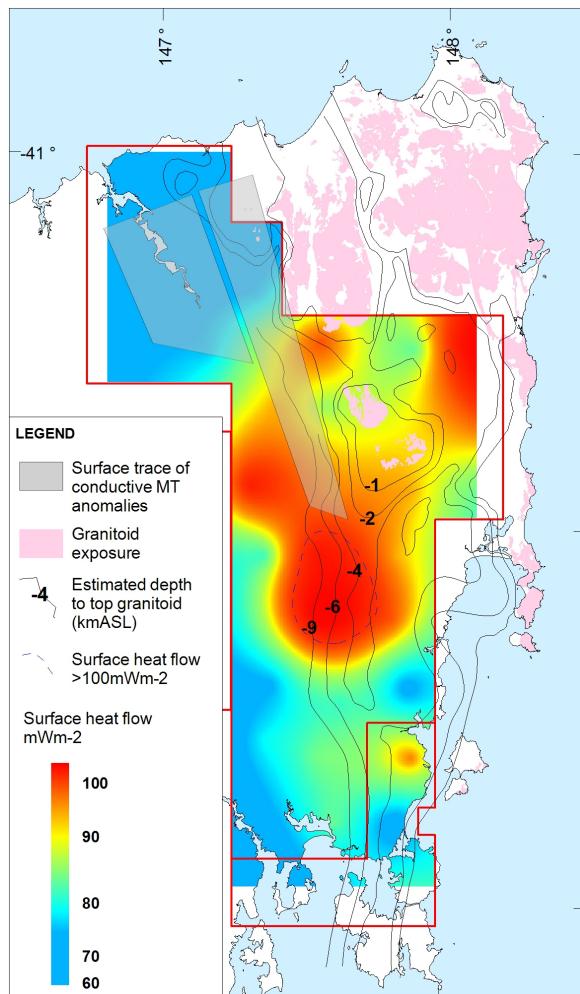
## DISCUSSION

Collation of new and existing data for Eastern Tasmania indicates the presence of a significant thermal anomaly in the centre of this region (Figure 6). A large area of elevated heat flow ( $\sim 4100\text{km}^2 > 90\text{mWm}^{-2}$ ) is seen to spatially coincide with the predicted extension of known granite bodies 3-4km under cover. Flat-lying Mesozoic cover sequences of the Tasmania Basin and intrusive Jurassic Dolerite sills provide up to 1km of good insulating cover at surface. Beneath these lie the deformed flysch of the Paleaeozoic Mathinna Supergroup, the insulating qualities of which have been shown to depend upon the orientation of its structural grain. Evidence from field mapping in the north-east indicates that the Mathinna comprises an older

recumbently folded unit in the West which is juxtaposed against younger upright folded sequences in the East (Powell *et al.*, 1993). Recent data suggests that the contact between these units is faulted implying that the older strata may occur at depth in the east (Reed, 2001; D. Seymour *pers. comm.*). This in turn suggests that the Mathinna section at depth will contain a mixture of upright and horizontal foliations and is therefore likely to be a moderate to good thermal insulator. Combined, these data confirm the potential of this area as a Hot Rock or EGS development target. Further geothermal modeling work to estimate a thermal resource and predict temperature distribution with depth in this area is now underway.

MT survey work has confirmed the existence of the Tamar Conductivity Zone in the north and increased its known extent into the south where it remains open along strike from an area of very high heat flow ( $> 100\text{mWm}^{-2}$ ). Whilst the nature of this feature is not uniquely defined, its geometry and location suggest that it is a crustal scale structure, most likely a fault or fracture system. It is plausible that this system may be permeable, containing electrically conductive fluid and/or hydrothermal alteration minerals. The possibility of a southern extension of this feature, and of its relationship to the area of very high heat flow, remains open. Further MT survey work is currently in progress to address these issues by better defining the 3D conductivity structure of the southern region.

The identification of possible crustal-scale structures in the vicinity of the Tamar Valley may also be significant to the interpretation of the overall crustal architecture of Tasmania. There is a strong spatial coincidence between the eastern conductive zone of the TCZ and a crustal-scale boundary identified in velocity structure models from local teleseismic tomography data (Rawlinson *et al.*, 2006). This feature, which juxtaposes high P wave velocities in the West with relatively low velocities in the East, is interpreted as evidence that, unlike the West, the Eastern Tasmania terrain may be underlain by dense rocks with an oceanic affinity (Rawlinson *et al.*, 2006). These data are supported by offshore seismic transects which suggest both a significant change in the character of the crust beneath north-eastern Tasmania and identify the presence of major east-dipping structures in this region (Drummond *et al.*, 2000; MRT, 2003). The TCZ may thus represent the uppermost expression of a boundary between the Eastern and Western Tasmania Terrains.



**Figure 6: Data compilation of KUTh Energy Ltd's new geothermal exploration results in Eastern Tasmania**

Viewing the TCZ from the perspective of a crustal terrain boundary it is interesting to examine similarities between it and analogous major crustal boundaries of the Lachlan Fold Belt on the mainland. Reed (2001) concluded from surface mapping work that the Mathinna Supergroup was correlated to the Tabberabbera Zone in eastern Victoria and compared the contact between the Western and Eastern Tasmanian Terrains to the Mt Wellington - Governor Fault system. Assuming that the conductive MT anomalies represent

fracture zones, the geometry of the TCZ, with converging west- and east-dipping structures, is similar to that observed in the Mt Wellington-Governor Fault system (Foster & Gray, 2000). Correlation of these two features remains speculative, however, and further data on the deep crustal relationships in this region, including evidence for a major west-dipping structure, is required.

## CONCLUSIONS

A program of systematic geothermal exploration undertaken across Eastern Tasmania has identified a significant new geothermal province. A broad area of anomalously high heat flow ( $>90\text{mWm}^{-2}$ ) is found to spatially coincide with high-heat-producing granite at depth beneath insulating cover. Hot Rock or EGS targets in this area may be further enhanced by the potential for *in situ* fracture permeability associated with the Tamar Conductivity Zone. This feature, which has been detected by an MT geophysical survey and which may represent a major crustal terrain boundary, remains open along strike from an area of very high heat flow ( $>100\text{mWm}^{-2}$ ). These targets will be further delineated by exploratory work as part of KUTh Energy's ongoing Tasmanian work program.

## ACKNOWLEDGEMENTS

The authors acknowledge the work of Hot Dry Rocks Pty Ltd, who performed the geothermometry and heat flow modeling for SEL 26/2005 and SEL 45/2007, and Shane Evans of Moombarriga Geosciences, for his work on the MT data acquisition.

## REFERENCES

- Burrett, C.F. and Martin, E.L.: Geology and Mineral Resources of Tasmania, *Special Publication Geological Society of Australia*, **15**, (1989).
- Cull, J.P.: Heat Flow and Regional Geophysics in Australia, in *Terrestrial Heat Flow and the Lithosphere Structure*, Cermak, V. and Rybach, L. (Eds), Springer-Verlag, (1991), 486-500.
- Drummond, B.J., Barton, T.J., Korsch, R.J., Rawlinson, N., Yeates, A.N., Collins C.D.N. and Brown, A.V.: Evidence for Crustal Extension and Inversion in Eastern Tasmania, Australia, During the Neoproterozoic and Early Palaeozoic, *Tectonophysics*, **329**, (2000), 1-21.
- Foster, D.A. and Gray D.R.: Evolution and Structure of the Lachlan Fold Belt (Orogen) of Eastern Australia, *Annual Review of Earth and Planetary Science*, **28**, (2000), 47-80.
- Goh, H.K.H.: Properties of North-Eastern Tasmanian Rocks for Geothermal Exploration, University of Tasmania, Honours Thesis, *unpublished*, (2008).
- Hermanto, M.R.: Magnetotelluric Investigations of the Tamar Lineament, University of Tasmania, PhD Thesis, *unpublished*, (1990).
- Jaeger, J.C. and Sass, J.H.: Lee's Topographic Correction in Heat Flow and the Geothermal Flux in Tasmania, *Geofisica Pura E Applicata*, **54**, (1963), 53-63.
- Leaman, D.E. and Richardson, R.G.: A Geophysical Model of the Major Tasmanian Granitoids, *Tasmanian Geological Survey Record*, 2003/11, (2003).
- Mineral Resources Tasmania (MRT): 2003 Tasmanian 3D Model, <http://www.ga.gov.au/map/web3d/tasgo/>

Powell, C. McA. and Baillie, P.W.: Tectonic Affinity of the Mathinna Group in the Lachlan Fold Belt, *Tectonophysics*, **214**, (1992), 193-209.

Powell, C. McA., Baillie, P.W., Conaghan, P.J. and Turner, N.J.: The Mid-Paleozoic Turbiditic Mathinna Group, Northeast Tasmania, *Australian Journal of Earth Sciences*, **40**, (1993), 169-196.

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

Rawlinson, N., Reading, A.M. and Kennett, B.L.N.: Lithospheric Structure of Tasmania from a Novel Form of Teleseismic Tomography, *Journal of Geophysical Research*, **111**, (2006), B02301.