



**REPORT TO SUPPORT  
SPECIAL EXPLORATION APPLICATION  
FOR  
DEEP HOT ROCK GEOTHERMAL ENERGY**

**Prepared for  
Gullewa Geothermal Pty Limited**

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## **1. INTRODUCTION**

The ability of deep hot rock geothermal energy to generate emission free base load electricity is now widely recognised. The potential energy resource is immense and the technologies required to access this resource to generate electricity at commercially competitive prices are rapidly evolving as the industry matures.

The Australian Government now recognises the potentially important role geothermal energy could play in reducing emissions and has introduced policies designed to stimulate investment in the industry.

Favourable geology, supportive infrastructure and ready market access are prerequisite conditions for the commercial generation of deep hot rock geothermal electricity. Western and northern Tasmania are assessed as attractive areas for investment in this steadily emerging industry.

## 2. CONCEPT OF GEOTHERMAL ENERGY

Geothermal energy is heat energy derived from the earth.

The earth is essentially a large ball of hot molten and semi-molten rock with a diameter of 12,740 km. On the outside of this molten mass is a thin hard outer *crust*, typically 20-60 km thick.

Approximately 99% of the earth's mass is greater than 1,000° C. This heat is generated by a combination of primordial heat energy associated with the development of the planet and radiogenic heat associated with the natural decay of radioisotopes within the earth.

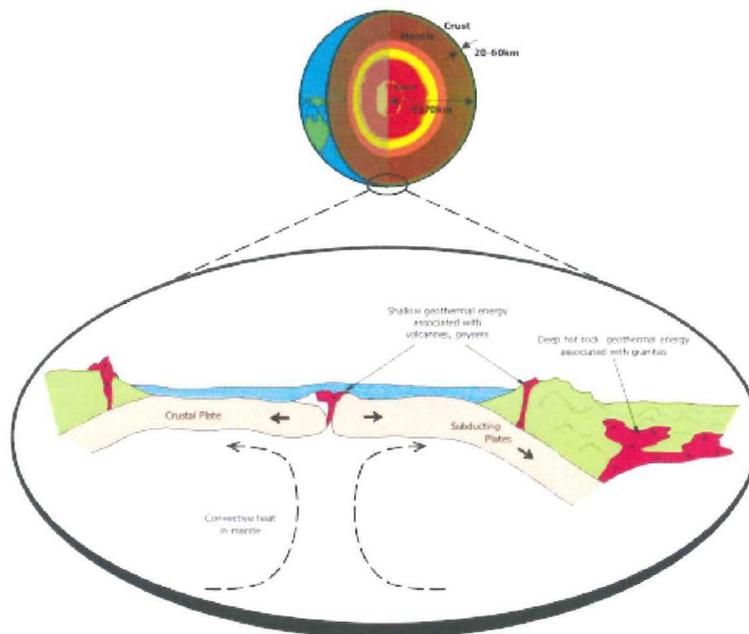


Figure 1. Different styles of geothermal energy are present in the earth's crust.

Existing technologies allow us to tap the heat energy only in the top section of the earth's crust, generally to a maximum depth of 5-7 km below surface. Within this accessible thin skin, there are various geological processes in action which generate heat.

One well-known heat source is associated with the continually moving margins of the earth's crustal plates, commonly marked by volcanoes, geysers and hot spring fields, which form where plates are either spreading apart (mid-ocean ridges) or colliding and subducting.

A second major heat source is associated with certain large granite bodies known as plutons, which have intruded into the upper, accessible sections of the earth's crust. In this instance, heat is generated by the natural decay of radioisotopes within the granite over geological time. This style of heat energy is referred to as *deep hot rock geothermal energy*.

Geothermal energy resources are widely harnessed around the world for two major purposes:

- non-electric direct heating
- electric power generation

*Non-electric direct heating resources* are derived from lower temperature geothermal sources and are typically accessed either by relatively shallow drill holes specifically drilled for this purpose, or as a by-product of electric power generation (cascade-usage). Global installed capacity is currently 15,000 MW and increasing rapidly.

Most geothermal *electric power generation* is currently derived from relatively shallow sources associated with volcanic and hot spring activity around crustal plate margins. Global installed capacity is approximately 9,000 MW and steadily increasing, largely as a result of improved operational technologies. A limiting feature of this form of electricity generation is that it is restricted to areas of volcanic and tectonic activity. Unfortunately, Australia does not possess such areas and has to date not benefited from a geothermal electric power generating industry.

However, in recent years the potential to commercially generate electric power from extensive deep hot rock geothermal resources within Australia has been recognised.

### **What is deep hot rock geothermal energy?**

Temperature in the earth's crust normally increases with depth at a rate, termed the *geothermal gradient*, of approximately 25-30° C per kilometre. The concept of deep hot rock geothermal energy relies on identifying areas where the normal geothermal gradient is enhanced.

This can occur above certain granitic bodies which are self-heating due to their abnormally high content of the radiogenic elements potassium, thorium and uranium. As these elements naturally decay, they produce minute amounts of radiogenic heat which accumulates over geological time.

Granites with high potassium, thorium, uranium contents are known as high heat production granites. The heat energy they produce is measured in micro-watts per cubic metre of granite ( $\mu\text{W}/\text{m}^3$ ).

The global average for granites is  $3 \mu\text{W}/\text{m}^3$ , and granites producing  $>8 \mu\text{W}/\text{m}^3$  can be considered as 'hot rocks'. The amount of heat produced per cubic metre is small, but the volume of available granite can be very large.

Hot granites at depth have the potential to enhance the normal geothermal gradient. Recent studies indicate the most productive temperature range for commercial geothermal electric power production from a pumped well is  $150\text{-}200^\circ\text{C}$ . In areas underlain by hot granites, these optimum temperatures should be reached at depths between 3-6 kilometres.

Once these hot areas have been located, the process of generating geothermal power involves drilling large diameter holes down into the heat source, developing a reservoir of fractures in the hot rocks, pumping water from surface down into this hot reservoir and extracting the heated water to surface up adjacent drill holes. The hot water is then passed into a binary heat exchanger which produces steam to generate electrical power. Lower temperature 'waste' heat from this process can be used for cascading direct-heat applications before the cooled water is returned underground to repeat the cycle.

Key factors in successful deep hot rock exploration are:

- presence of a source of heat, in this case large volumes of high heat production granites at practical depths
- presence of insulating cover rocks to confine the heat generated by the granites
- capacity to develop a permeable reservoir within the hot rocks, either naturally or artificially
- proximity to infrastructure and electricity markets

### 3. POTENTIAL OF APPLICATION AREA

Available information suggests the prerequisite geological conditions for commercial geothermal energy production may be present in western and northern Tasmania.

The fundamental geology of this area (Figs 2 and 3), consists of two large masses of metamorphosed Precambrian rocks, separated by a belt of Cambrian sediments and volcanics, including the Mt Read Volcanic Arc, all of which are variably overlain by thick basins of Palaeozoic sediments. In the Tertiary, parts of the area were covered by thick flows of basalt which may assist in enhancing the insulation of geothermal systems.

Important from a geothermal energy perspective was the extensive intrusion of granites in the Cambrian and Devonian-Carboniferous periods.

The Cambrian granites (Fig 4) intruded along the full length of the Mt Read Volcanic Arc. Their surface and subsurface distribution is known from detailed mapping, drilling and geophysical surveys.

In the Devonian-Carboniferous Period, several large granite batholiths intruded the region (Fig 5). They are variable in composition and their surface and subsurface distribution is well understood from surface mapping, drilling and geophysical surveys, particularly gravity surveys.

Collectively, the Cambrian and Devonian-Carboniferous granites are directly or indirectly linked to the formation of most of the major mineral deposits in the region including Mt Lyell, Henty, Rosebery, Renison, Averbury, Zeehan, Bischoff, Cleveland, Kara and King Island.

Knowledge of the subsurface distribution of the granites is important for identifying areas with the highest geothermal energy potential. If the granites are too shallow, it is unlikely that the minimum necessary temperatures will be attained. If they are too deep, the cost of evaluation and development will be prohibitive. The optimum depth range is 3-6 km. Geophysical modelling, supplemented with drilling data, has identified extensive areas of western and northern Tasmania underlain by either Cambrian or Devonian-Carboniferous granites within that depth range.

For the granites to be a potential source of geothermal energy, they must contain elevated levels of the radioisotopes of potassium, uranium and thorium which produce heat as they naturally decay deep beneath the surface. The capacity of a particular granite to generate heat can be assessed by measuring its content of these three elements, and expressing these as units of metric heat production in micro watts/cubic metre ( $\mu\text{W}/\text{m}^3$ ).

Heat generating data from granites in western and northern Tasmania has been acquired by various airborne and ground radiometric surveys, surface sampling of granite outcrop and sampling of core from drill holes which intersected granite. These data, recently collated into a single data base by Mineral Resources Tasmania and Geoscience Australia, demonstrates encouragingly high heat generating unit levels from widespread

areas (Fig 6). Data indicate the Heemskirk and Renison granites have average values of  $7.26 \mu\text{W}/\text{m}^3$  and  $8.27 \mu\text{W}/\text{m}^3$  respectively, which is more than twice the global average of  $3 \mu\text{W}/\text{m}^3$ . Some samples from the Heemskirk and Renison Granites were in excess of  $10 \mu\text{W}/\text{m}^3$  which is the average of the Cooper Basin granodiorite 'hot rocks'. The available elemental data also gives average Heat Production values of  $7.74 \mu\text{W}/\text{m}^3$  and  $8.65 \mu\text{W}/\text{m}^3$  (one sample) for the Housetop and Dalcoath granites respectively, with a maximum value in the Housetop Granite of  $13.63 \mu\text{W}/\text{m}^3$ . No Heat Production data are available on the Cambrian Dove Granite which intrudes Mt Read Volcanics on the south-east margin of the application area (Fig 7).

These anomalous values are well above the crustal average for such rocks, and comparable with those of the Cooper Basin area in South Australia which is currently the subject of advanced geothermal energy evaluation and development.

In addition to the direct measurement of the heat generating capacity of the granites, a further measure of the deep hot rock geothermal potential of an area can be deduced from *heat flow measurements* derived from temperature and conductivity measurements in existing drill holes. Heat flow, measured in milli watts/m<sup>2</sup> (mW/m<sup>2</sup>), is the surface expression of heat being conducted from depth through a body of rock. It is a function of both temperature and the bulk thermal conductivity of rocks.

There are limited existing heat flow data available in western and northern Tasmania. The only published heat flow value is a reading of  $104\text{mW}/\text{m}^2$  obtained from a drill hole near Rosebery. This is a relatively high heat flow value and compares with a global average of about  $60\text{mW}/\text{m}^2$  for rocks of similar age. Independent thermal modelling of these data, based of known stratigraphy in the general Renison-Rosebery area plus limited down-hole temperature data, suggests there is a reasonable chance of exceeding workable geothermal power generation temperatures ( $>150^\circ\text{C}$ ) at depths below 4,000m.

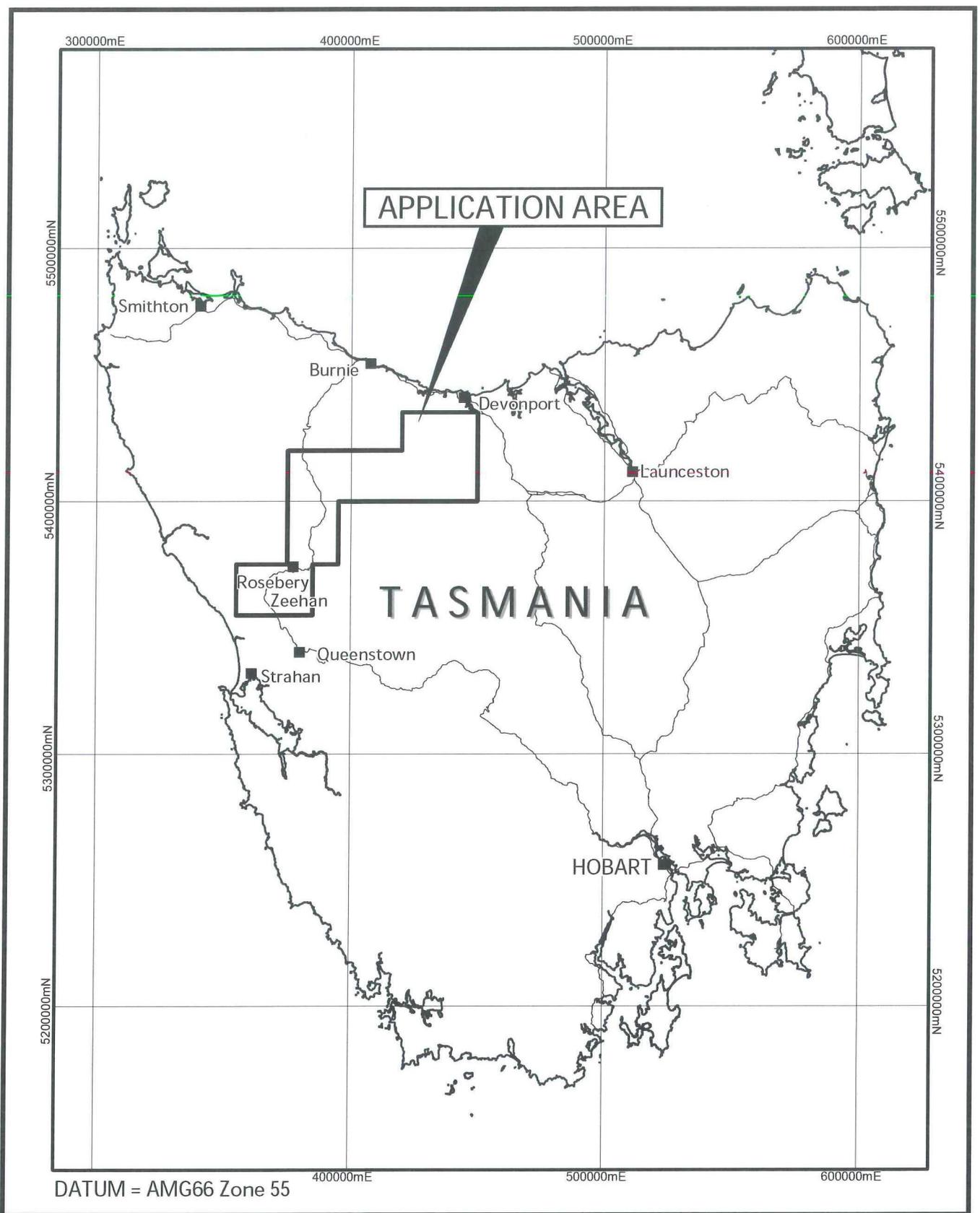
Whilst acknowledging the limitations of this sparse currently available data, the initial thermal modelling result is encouraging and supports the view that there is a reasonable chance that the prerequisite conditions necessary to develop a deep hot rock geothermal source may be present in western and northern Tasmania. The modelling work to date provides a sound basis for more extensive and rigorous on-going data acquisition.

***In summary***, the combination of extensive areas of granites at the optimum 2-6 km depth, with high heat generating and heat flow levels, highlights the deep hot rock geothermal energy potential of the application area.

Key prospectivity factors which determined the application area selection were:

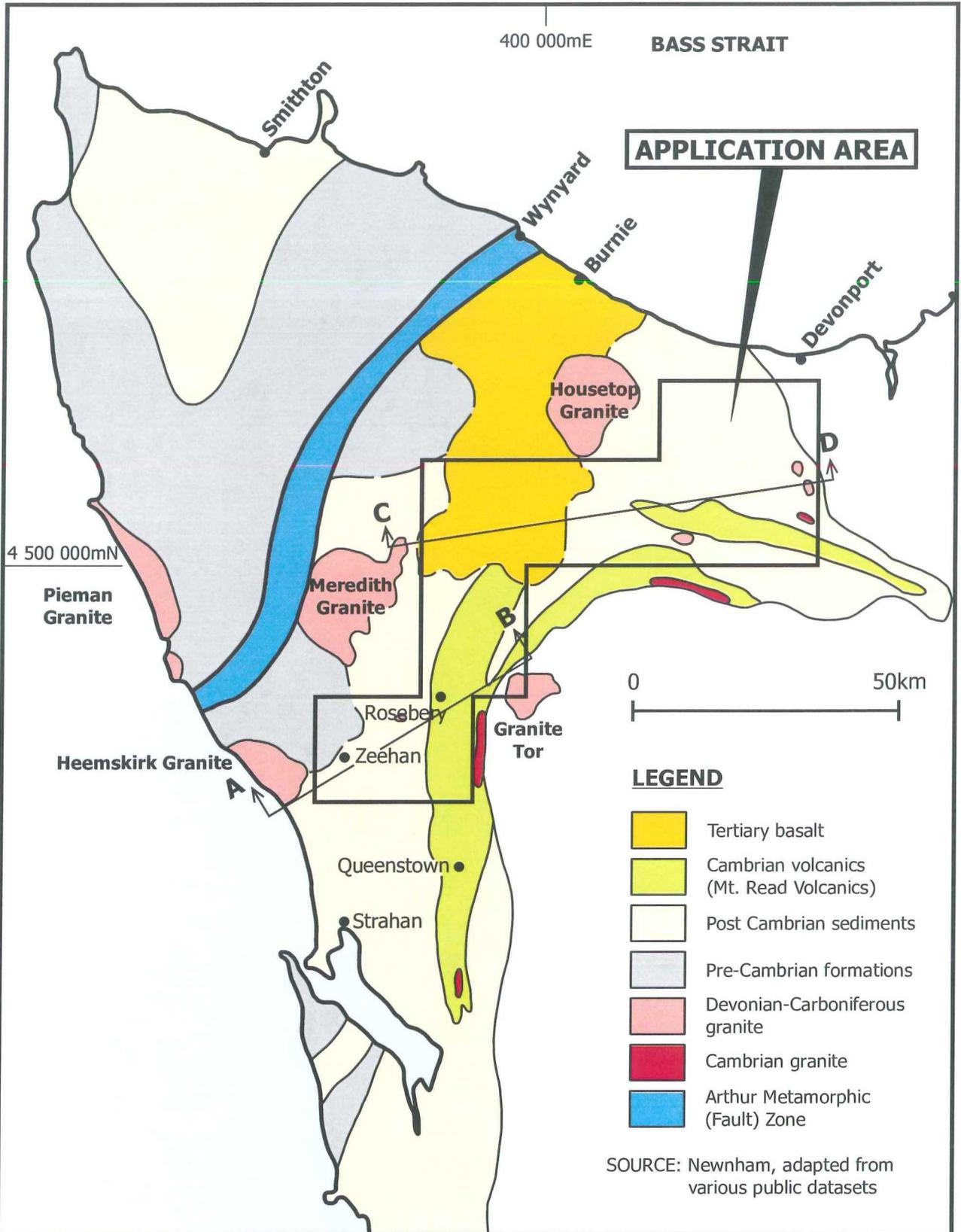
- predicted presence of large volumes of granite in the 3-6 kilometre depth range
- excellent infrastructure and close proximity to markets and the National Electricity Grid (Fig 8)
- high temperatures experienced in deep underground mines in the region
- potentially good quality insulating cover rocks above the granites.

Because of the intensely mineralised nature of much of the application area, the region has been extensively drilled over the past 50 years, and this drill hole data base will be invaluable in the early phases of geothermal exploration

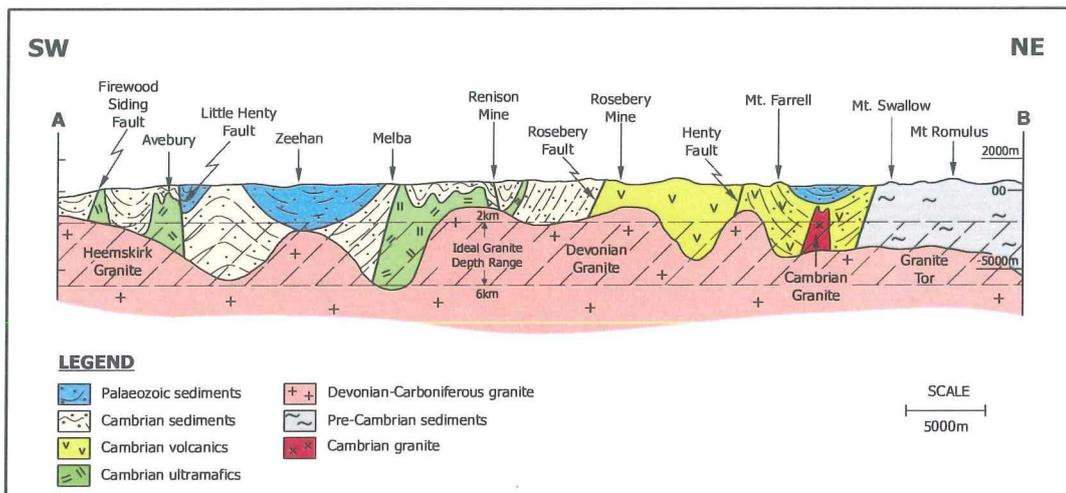


CATEGORY 6 - GEOTHERMAL SUBSTANCES  
 SPECIAL EXPLORATION APPLICATION AREA  
 LOCATION PLAN

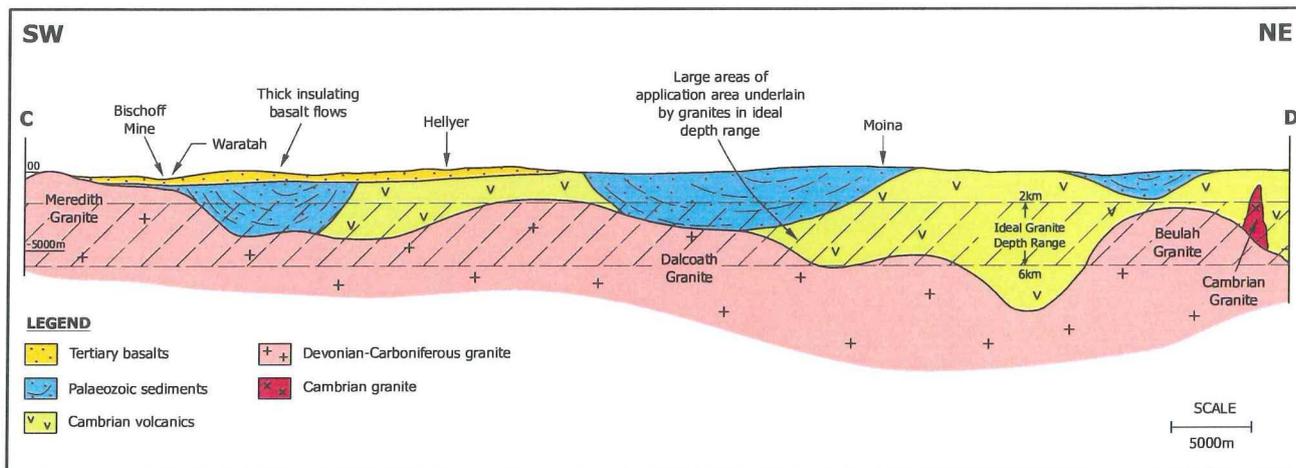
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**CATEGORY 6 - GEOTHERMAL SUBSTANCES**  
**SPECIAL EXPLORATION LICENCE APPLICATION AREA**  
**REGIONAL GEOLOGY**  
**NORTH-WEST TASMANIA**

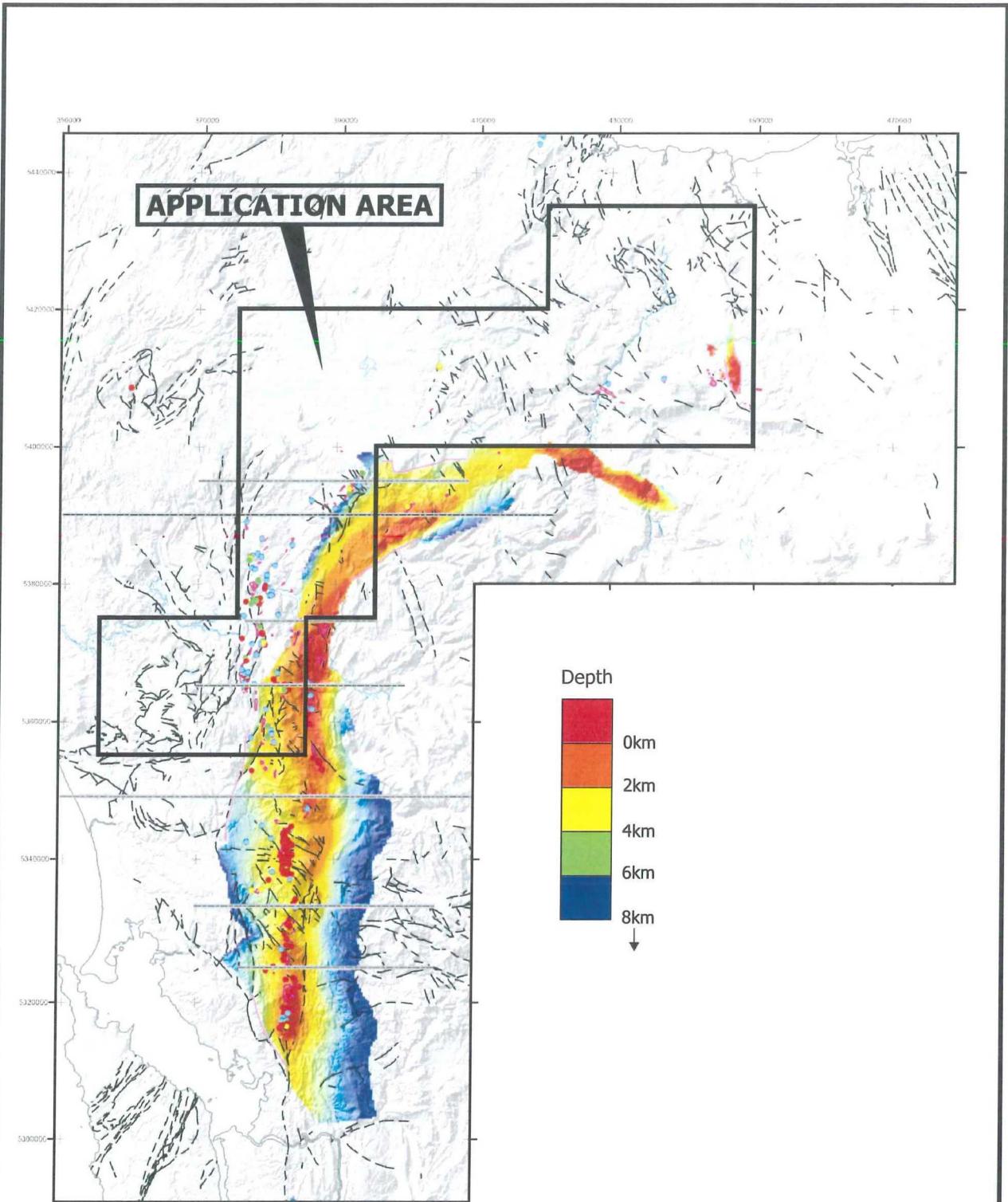


Geological Section of Heemskirk ridge (Section A-B on Plan).



Geological Section of Meredith-Dalcoath Granite ridge (Section C-D on Plan).

**CATEGORY 6 - GEOTHERMAL SUBSTANCES  
SPECIAL EXPLORATION LICENCE APPLICATION AREA  
GEOLOGICAL CROSS SECTIONS**

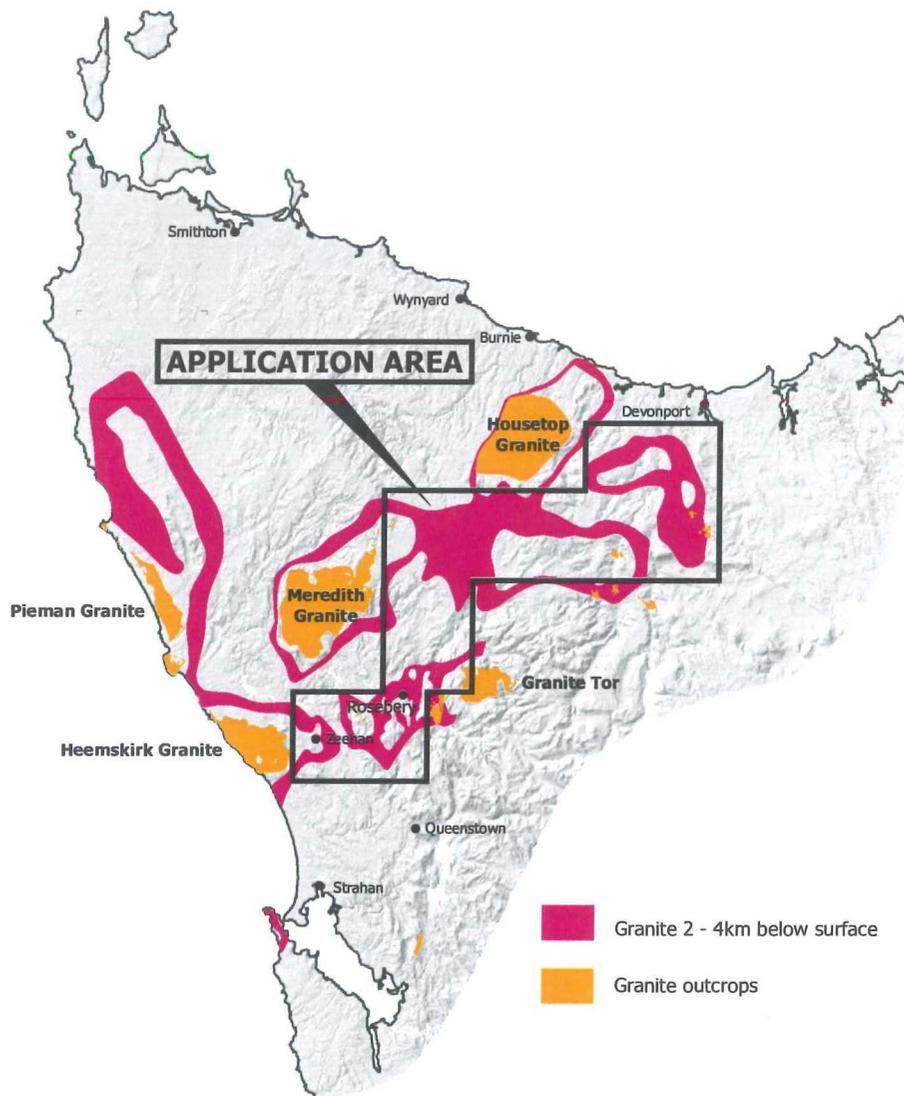


SOURCE: Mineral Resources Tasmania ©

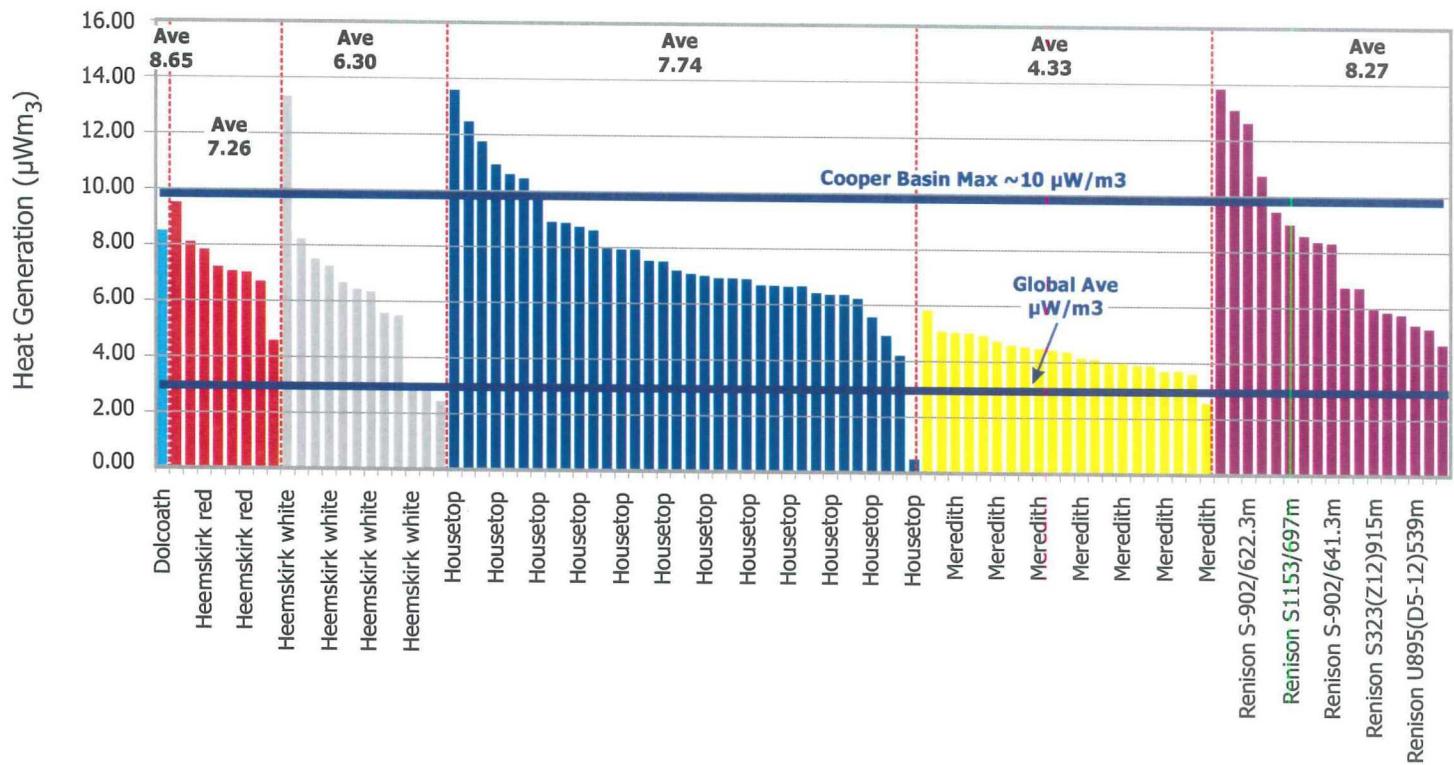
**CATEGORY 6 - GEOTHERMAL SUBSTANCES  
 SPECIAL EXPLORATION LICENCE APPLICATION AREA  
 SUB-SURFACE DISTRIBUTION OF CAMBRIAN GRANITES  
 WITHIN APPLICATION AREA**

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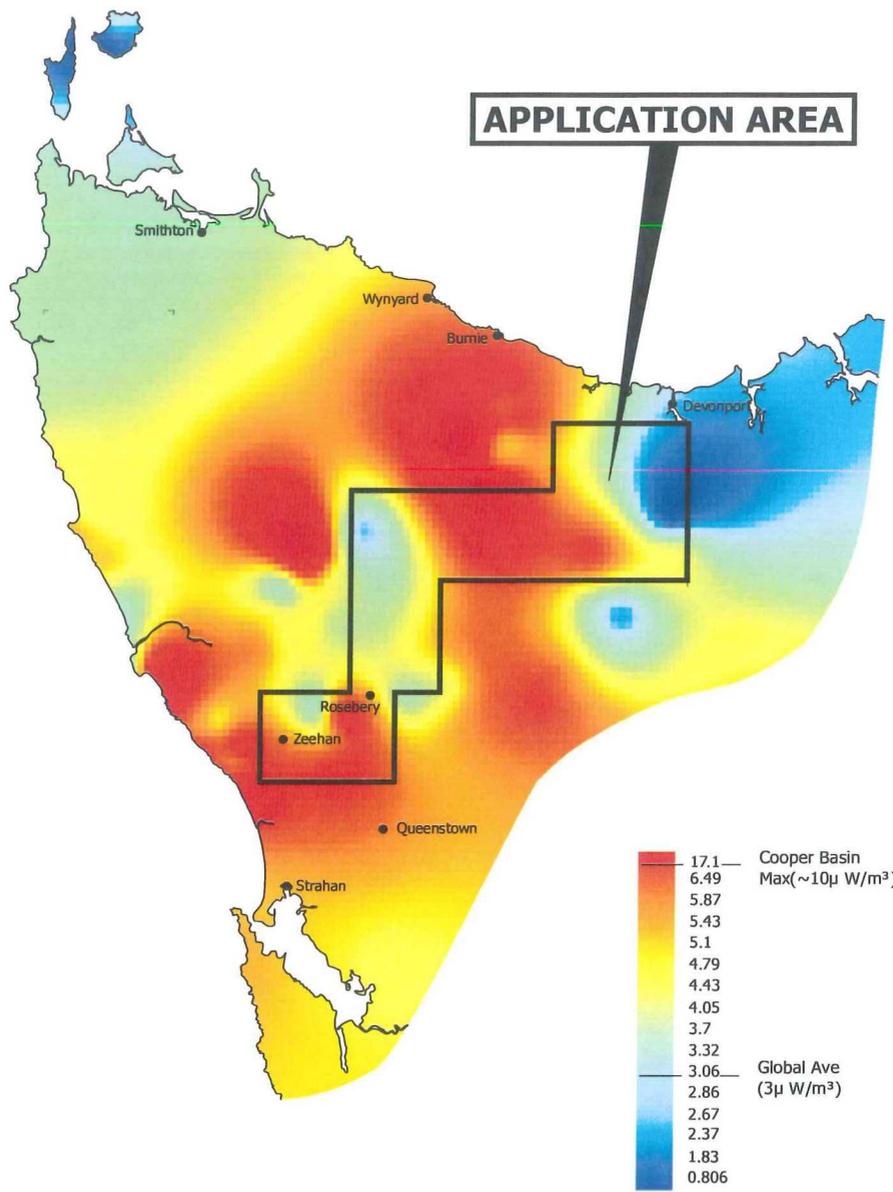
Figure 4



**CATEGORY 6 - GEOTHERMAL SUBSTANCES  
 SPECIAL EXPLORATION LICENCE APPLICATION AREA  
 SURFACE AND SUB-SURFACE DISTRIBUTION OF  
 DEVONIAN-CARBONIFEROUS GRANITES**

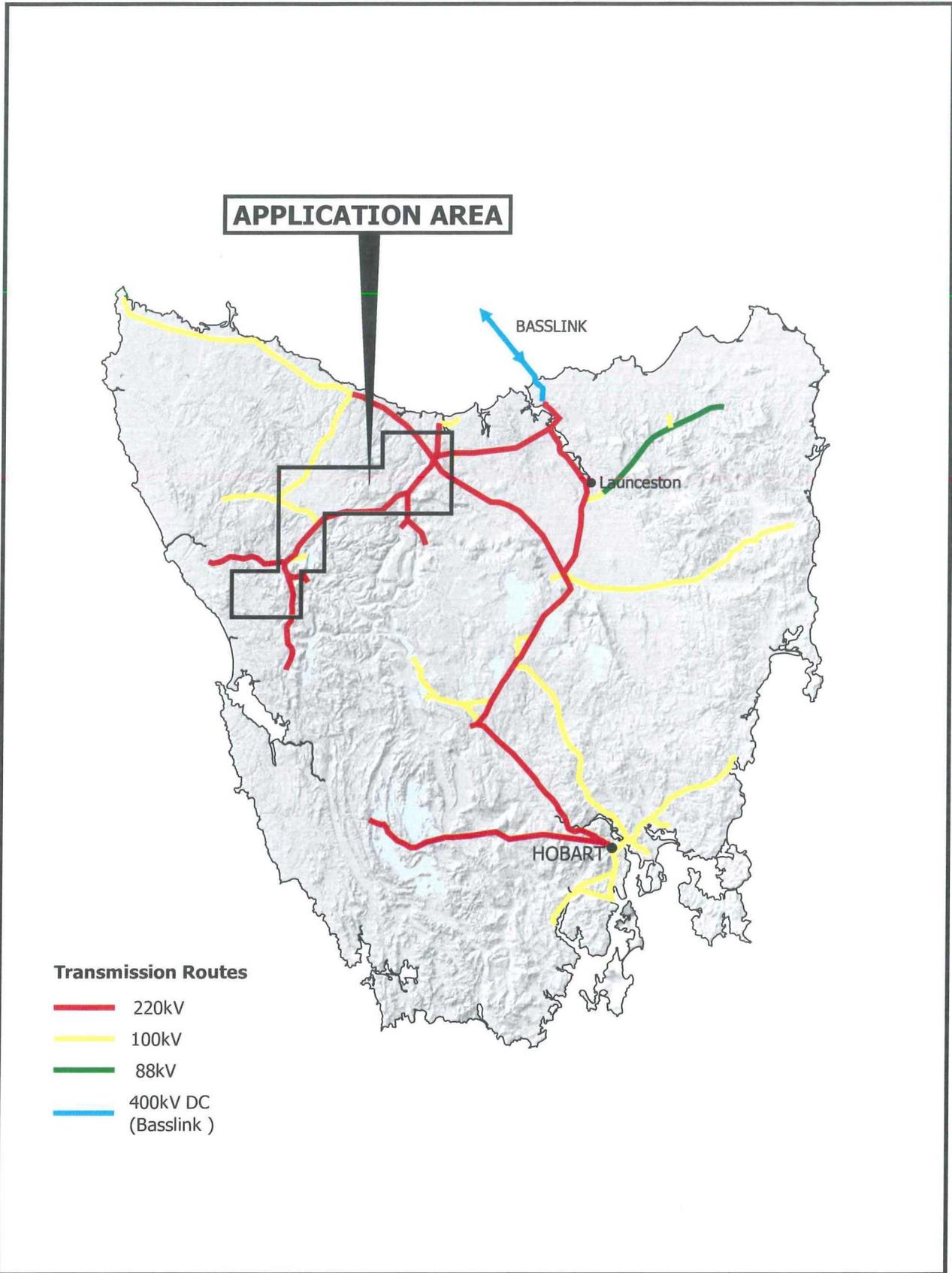


**CATEGORY 6 - GEOTHERMAL SUBSTANCES**  
**SPECIAL EXPLORATION LICENCE APPLICATION AREA**  
**HEAT GENERATION ( $\mu\text{W}/\text{M}_3$ ) CALCULATED FROM GA CHEMICAL ANALYSES**  
**(NATURAL ISOTOPIC ABUNDANCE METHOD)**  
**FOR WESTERN TASMANIAN GRANITES (AT A DENSITY OF 2.7G/CM3).**



Heat Production ( $\mu$  W/m<sup>3</sup>).

**CATEGORY 6 - GEOTHERMAL SUBSTANCES**  
**SPECIAL EXPLORATION LICENCE APPLICATION AREA**  
**HEAT PRODUCTION ( $\mu$  W/M<sup>3</sup>)**  
**SPATIAL PLOT OF ESTIMATED HEAT PRODUCTION UNITS FOR**  
**DEVONIAN-CARBONIFEROUS GRANITES IN**  
**WESTERN AND NORTHERN TASMANIA.**



**APPLICATION AREA**

BASSLINK

Launceston

HOBART

**Transmission Routes**

- 220kV
- 100kV
- 88kV
- 400kV DC (Basslink)

**CATEGORY 6 - GEOTHERMAL SUBSTANCES  
SPECIAL EXPLORATION LICENCE APPLICATION AREA  
TASMANIA HIGH VOLTAGE POWER GRID**

#### 4. PROPOSED WORK PROGRAM

The initial work program objectives are:

- demonstrate the opportunity and potential within the application area for the commercial development of deep hot rock geothermal energy
- target 1-2 high priority areas which warrant testing at depth with deep drill holes.

To achieve these objectives the following tasks will be completed within the first two years of operations:

- Quantify the *heat generating capacity of the granites* within the project areas by extensive sampling and assaying of both outcropping granite and existing drill hole intersections of granite. These data will supplement existing heat generating data and will be used to highlight areas potentially underlain by high heat generating granites.
- Acquire *heat flow, temperature and thermal conductivity* data in areas selected on the basis of favourable granite depth and granite chemistry. The aim of this important work is to identify high heat generating areas, overlain by insulating cover rocks and will be undertaken in selected areas on existing drill holes and cores that are accessible.

By combining acquired heat generating, heat flow, conductivity and gravity data sets, it will be possible to identify 1-2 areas having high potential for the commercial development of deep hot rock geothermal energy.

It is important for the initial work program to result in a highly focused outcome because the next stage of evaluation requires deep drilling.

**Year 1 Objective:**            *Identify 4-6 focused areas of high geothermal prospectivity.*

Program components:

- complete heat generation studies on granite outcrops and existing drill cores
- complete conductivity studies on existing drill cores
- locate and case as many existing deep drill holes as possible and complete down-hole temperature logging, heat flow and conductivity studies
- undertake modelling studies to focus Year 2 work

**Year 2 Objective:**

*Identify 1-2 focused areas of very high prospectivity warranting testing with 3,000-5,000 m long drill holes*

Program components:

- continue locating and refurbishing former drill holes
- complete heat flow and conductivity studies on these holes
- model results to evaluate and rank these areas
- apply for Federal Government grants to accelerate drill testing of the most prospective areas
- design a deep hole drill program and identify resources necessary to complete drilling and associated down-hole studies

<b>TASK</b>	<b>Year 1 (\$)</b>	<b>Year 2 (\$)</b>
<b>Year 1:</b>		
<i>Conductivity and heat generation studies on existing drill cores</i>	20,000	
<i>Refurbish existing drill holes</i>	40,000	
<i>Heat flow tests down existing drill holes</i>	30,000	
<i>Model results from all surveys</i>	10,000	
<b>Year 2:</b>		
<i>Identify and refurbish existing drill holes in several selected areas</i>		50,000
<i>Heat flow and conductivity tests down refurbished drill holes</i>		30,000
<i>Model results</i>		10,000
<i>Design drill hole program for 1-2 top priority areas</i>		10,000
<b>BUDGET ESTIMATE TOTALS</b>	<b>100,000</b>	<b>100,000</b>