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GEOTHERMAL ENERGY PROSPECTS

for

TASMANIA

by

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A PDF copy of this paper is on the enclosed CD.

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‘Those who dream in the dusty recesses of their minds wake in the day to find it was vanity: but the dreamers of the day are dangerous men, for they may act out their dream with open eyes, to make it possible.’

T.E. Lawrence, *Seven Pillars of Wisdom*

INTRODUCTION

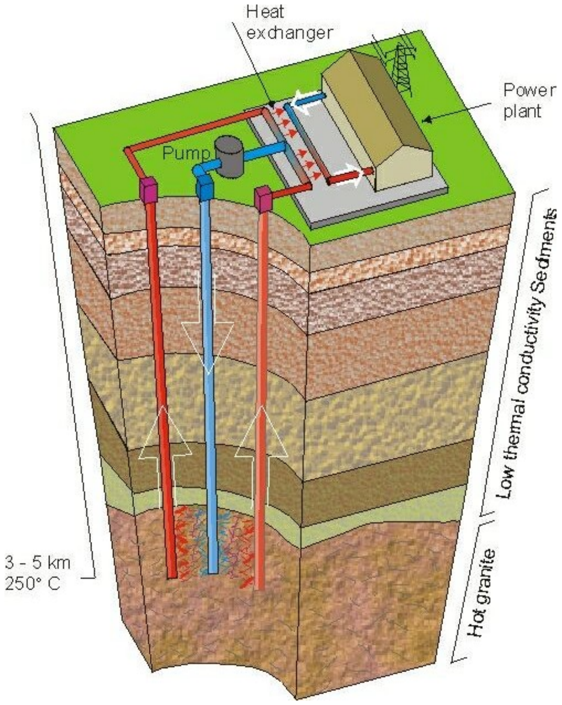
It has been known since Newstead and Beck (1953) reported measurements from the central plateau, that Tasmania has an unusually high terrestrial heat flux in excess of $80mWm^{-2}$. Values of up to $159mWm^{-2}$ have been recorded associated with the more radioactive granites. Geothermal gradients measured in the few deep boreholes available indicate geothermal gradients ranging from over 40°C/km in the Permo-Triassic sedimentary/Jurassic dolerite cover to 30°C/km in more thermally conductive rocks. There are gradients of up to 60°C/km in restricted sedimentary intervals of the Permian sediments. These gradients are associated with heat fluxes of around $85mWm^{-2}$. Based on these observations and the geology of Tasmania there is a good probability that with careful site selection suitable Hot Dry Rock (HDR) resources for electric power generation might be found.

GEOTHERMAL CONCEPTS

High temperature steam and water associated with recent volcanic activity have been used to generate electricity for many years in several countries. The Geysers in California is a well known example. These fields are at a sufficient temperature to produce dry or wet steam for use in a traditional steam power plant.

In more recent times binary power plants have been developed for the successful commercial generation of power from geo-fluids in the temperature range 100-200°C. These power plants use a closed geo-fluid circuit to heat a fluid usually driving a closed loop organic Rankine Cycle power plant although working fluids such as carbon dioxide have been used. The fluids are more typically mixtures of isobutane and isopentane and by matching the mixture to the temperature output may be enhanced (Iqbal *et al*, 1976). The upper temperature limit is set by the stability of the organic fluid. The Kalina Cycle (OCEES, 2003) which uses an ammonia-water mixture with the mix varying through the process is claimed to provide even better energy recovery (40% better is claimed in Geodynamics Ltd promotional material) and is just coming into use in a significant geothermal power plant. Binary plants are available off the shelf in modular form from a number of manufacturers making for easy development given a suitable energy source.

Figure 1. HDR schematic
From ANU website http://hotrock.anu.edu.au



The lower temperature geo-fluids for a binary power plant may be produced in a variety of ways. At Ormesa (there are further details below) the fluids come from sandstone units in an area of high heat flux and temperature gradients. This example also shows how the technology is advancing. Simply by recently updating/upgrading plant and better management 20% more output was generated with no extra wells. There has been a great deal of research into energy production from HDR In its classical form the energy source is a good source of heat e.g. hot granite with enhanced heat production due to high levels of the radioactive elements uranium, thorium and potassium (K^{40}) overlain by an insulating cover of sediments to provide a high geothermal gradient. Two wells are drilled into the

granite which is hydraulically fractured by pumping in water under high pressure (Figure 1). The fracturing produces a micro-earthquake swarm which can be mapped
seismically to detail the fractured zone. Hot water is extracted from one well and the spent fluid re-injected in the other. In effect a heat exchanger is created in the fractured rock. An example is the European Union effort at Soultz-sous-Forét which is well documented- see for example www.geothermie.de/egec-geothernet/ prof/hdr/**european**_hdr_activities.htm and a pilot plant producing 10MWe is scheduled for commissioning this year (2005).

In Australia Geodynamics Ltd and Petratherm Ltd have floated on HDR projects in South Australia. Their prospectuses are available on line and in the attached CD and are well worth reading.

Geodynamics Ltd raised $1.1M seed capital and obtained an R&D Start Grant of up to $5M. Their IPO sought to raise $11.5-15.5M via 50¢ shares. Their targets are HDR in the Cooper Basin (SA), Hunter Valley (NSW) and southwest Queensland. Backing involves ANU and CSIRO which would have helped their research grant application.

Petratherm is seeking hot spots warmed by Thermally Anomalous Granites (TAG) and Radiogenic Iron Oxide (RIO) deposits and Ehanced Natural Thermal Systems (ENTS) in the South Australian Heatflow Anomaly (SAHA). This is an area with heat flow very similar to that measured in Tasmania. Petratherm raised some $4M by IPO. They failed in an R&D grant application which is not surprising given the makeup of the ARGC. Backing involves the University of Adelaide.

To illustrate the performance of moderate temperature binary cycle the following figures are given by Sonnelitter *et al* (2000) from the commercially successful Mesa field in California:

Plant Name	Geo-Fluid Temperature °C	Geo-Fluid Flow Rate (US GPM)	Average Energy Production (MWhr/Month)	Plant Availability Factor
Ormesa I	146	11,428	13,398	99.5%
Ormesa II	157	8,818	12,109	98.05%
Ormesa IH	141	6,066	4,576	99.73%
Ormesa IE	137	5,969	6,116	97.62% ed

Geothermal energy is very important in some countries e.g. The Philippines generate 70% of their electricity from this source.

HDR PLAYS in TASMANIA

A major problem in formulating a very detailed survey of the possibilities is the paucity of deep geological information in Tasmania. While there are deep oil holes in the offshore basins the deepest onshore hole in Tasmania is the Shittim #1 hole on north Bruny Island which passes through the sediments and dolerites of the Tasmania Basin for 1568m before passing into slate/phyllite/marble basement. Total depth is 1635m. MRT has drilled most of the other holes to about or over 1km to investigate stratigraphy. Noteable are holes at Coles Bay in granite, at Tunbridge through the Tasmania Basin and at Stanley through Cambrian Volcanics.

The positions of granites are important. Leaman & Richardson (2003) have produced an image of the gravity field in Tasmania (Figure 2.). This they interpreted to give an estimate of the depth to the top of the granites (Figure 5) which is the best estimate available at present. Tradeoffs between denser dolerite and lighter sediments result in inaccuracies in these depth estimates.

Collins *et al* (1981) conducted a scintillometer survey of outcropping granites in Tasmania which gives estimates of the uranium, thorium and potassium(K^{40}) contents of the granites. This allows a calculation of heat production in the granites. They demonstrated that the granites associated with tin/tungsten mineralization have high concentrations of these radioactive elements with consequent high heat production i.e. they are TAGs. The Coles Bay borehole was sited in a hot granite with very high heat production. Such radiometrically hot granites would be good sources for HDR if sufficiently insulated by cover rocks. Without cover they afford a geothermal gradient of some 30°C/km.

Starting in the early 1950's and continuing through the 1970's heat flow measurements were made in Tasmanian boreholes. The results are shown in Table 1. The heat flux is, with the exception of Olga Ridge, a site probably unsuited to such measurements, at least $80mWm^{-2}$ which is double that which might be reasonably expected. At Storeys Creek and Coles Bay, sites with hot granites, the heat fluxes are significantly higher again reaching $159mWm^{-2}$ at Storeys Creek.

These heat fluxes are shown in the Australian context in Figure 3. The highest heat flux in this dataset is in northeastern Tasmania. Recently Holdgate & Chopra (2004) have produced a map of estimated temperatures at 5km depth for Australia. Their mapped values for Tasmania seem surprisingly low on the data available to me.

The source of the high heat flow in Tasmania is enigmatic but several possibilities are:

- Hot granites are widespread at depth. R.G. Richardson of MRT (pers. comm.) considers this unlikely but it remains a possibility with the mapped granite topography representing only the higher parts of a larger mass.
- The basement rocks in Tasmania are enriched in radioactive elements producing a regional thermal anomaly as observed around Olympic Dam in South Australia. There is no evidence whatsoever to support this in the form of rocks with enhanced radiation levels.
- There is evidence for a Cretaceous thermal event in Tasmania probably associated with extensional events in the separation of Australia and Antarctica. Syenites were intruded at this time. There was also the intrusion of the Jurassic dolerites and volcanic activity in the middle Tertiary. All these events indicate an extensional environment. The mantle may still be anomalously hot under Tasmania. Extensional basins may have anomalous temperatures from hot mantle rocks for hundreds of millions of years after extension (Zhang, 1993).
- The SAHA is associated with the Central Australian Conductivity Anomaly, a little understood zone of enhanced electrical conductivity. There is a similar conductivity structure

along the Tamar Valley and to the south which may be something similar. Perhaps these phenomena are associated with higher heat flow.

But the actual source is not critical here, only the existence of the high heat flow is important. Given we have high heat flows, hot granites and assorted cover rocks what are the HDR possibilities? They are outlines in the schematics below (Figure 6). The conclusion is that it is reasonable to expect temperatures in the range 190-270 °C provided the pre Permian sediments are of similar conductivity to the Tasmania Basin materials. Case B in Figure 6 is the optimum target.

LOCALITY	Hole ID East	North	Hole Depth m	Heat Flux mWm^{-2}	Thermal Conductivity $Wm^{-1}°C^{-1}$	Thermal Gradient °C/km	Spot Temp °C@m
Glenorchy [W]	Glen-1 520900	5256200	614	87	2.30° ± 3%	40.4°±0.5%	
Storeys Creek [J]	SC4 560780 [#]	5390368		159	5.11	30.8	
Coles Bay [G]	ColesBay-1 606451	5336888	1008	102.3 - 93	2.87-3.87	29	37@830
Tunbridge [G]	RG-145 524510	5334875	914		1-2*	41	45@780
Stanley [N]	Stanley-DOM1 352738	5480111	1000		3-4*	27.8	36@830
Great Lake [N]	DDH5001 488400 [#]	5369450	320	85.4	1.98	43.2	21@315
Great Lake [J]	DDH5084 DDH 5154			83.7	2.27	33.8	
Dee Tunnel [N]	DDH7005 462000 [#]	5323300	96	86.2	2.02	42.7	12@96
Roseberry [N]	EZ 48R EZ 52R 379600	5374360	209 274	104.9	3.62	29	17.8@209 17.2@274
Olga Ridge [W]	400450	5264400	1100	57	2.80° ± 16%	18.4°±2%	

Notes: Geothermal Gradient is an average. Units and coordinates have been converted.

[+] minimum value

[#] estimated position. The DDH holes are from the Hydro Electric Commission, The EZ holes from the Electrolytic Zinc Co. and exact locations may be available on more extensive search

* These are likely ranges. Determinations were to be made after publication but the results cannot be found in MRT and I have been unable to locate the author. Neither has Dr. Geoff Green of MRT been able to locate them in other MRT files.

[G] Green, D.C. (1989).

[J] Jaeger, J.C. & Sass, J.H. (1963)

[N] Newstead, G. & Beck, A. (1953)

[W] Wronski, E.B. (1977)

Table 1. The heat flow measurements made in Tasmania.

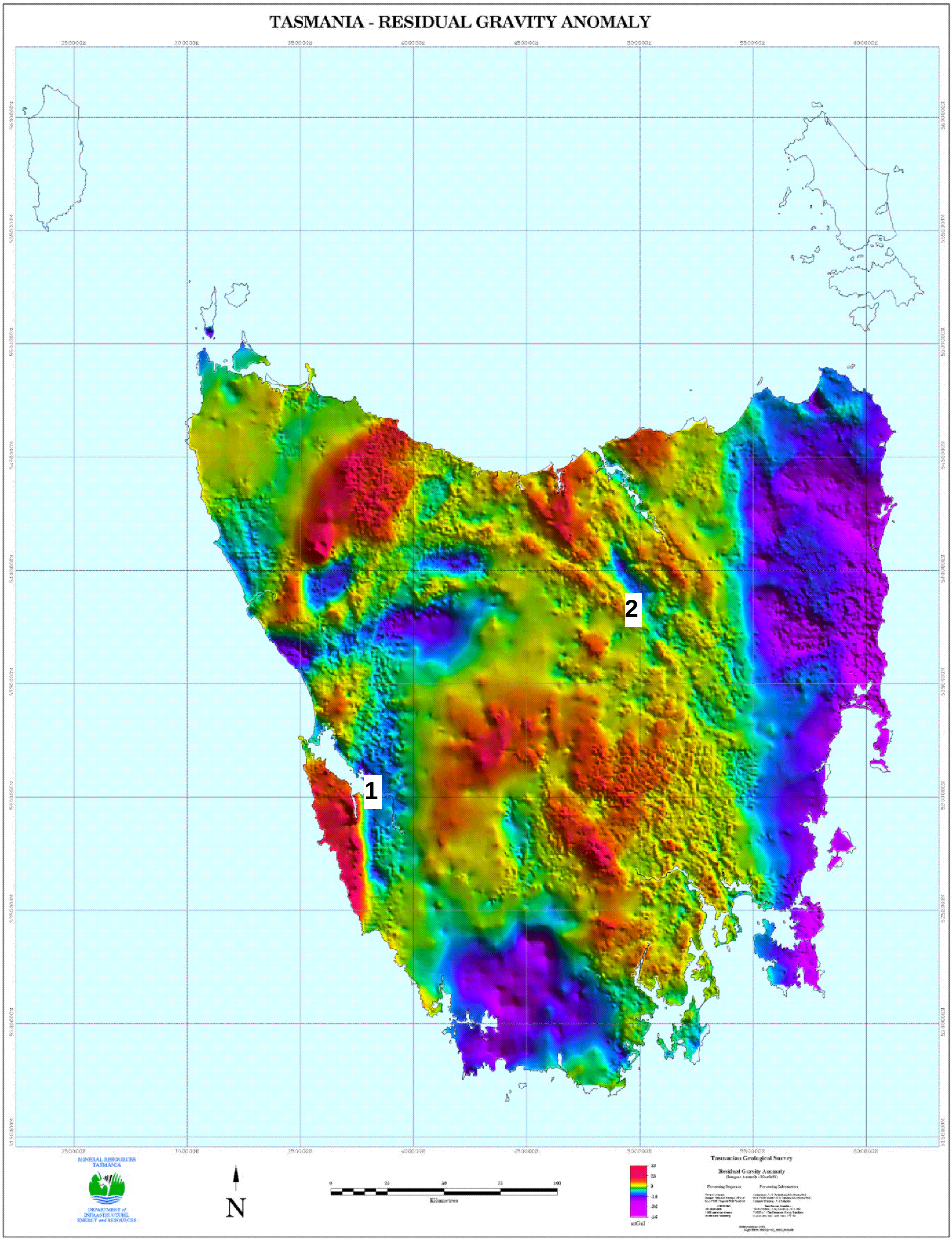


Figure 2. A gravity field image of Tasmania

The blue and purple areas (gravity lows) are, with the exception of the area at the eastern end of Macquarie Harbour (1) and Cressy (2) associated with shallow low density granites. Part of the Macquarie Harbour area may reflect the presence of Cambrian granitoids but at least some of the area south of Macquarie Harbour reflects Tertiary sediments in a graben. From Leaman & Richardson (2003).

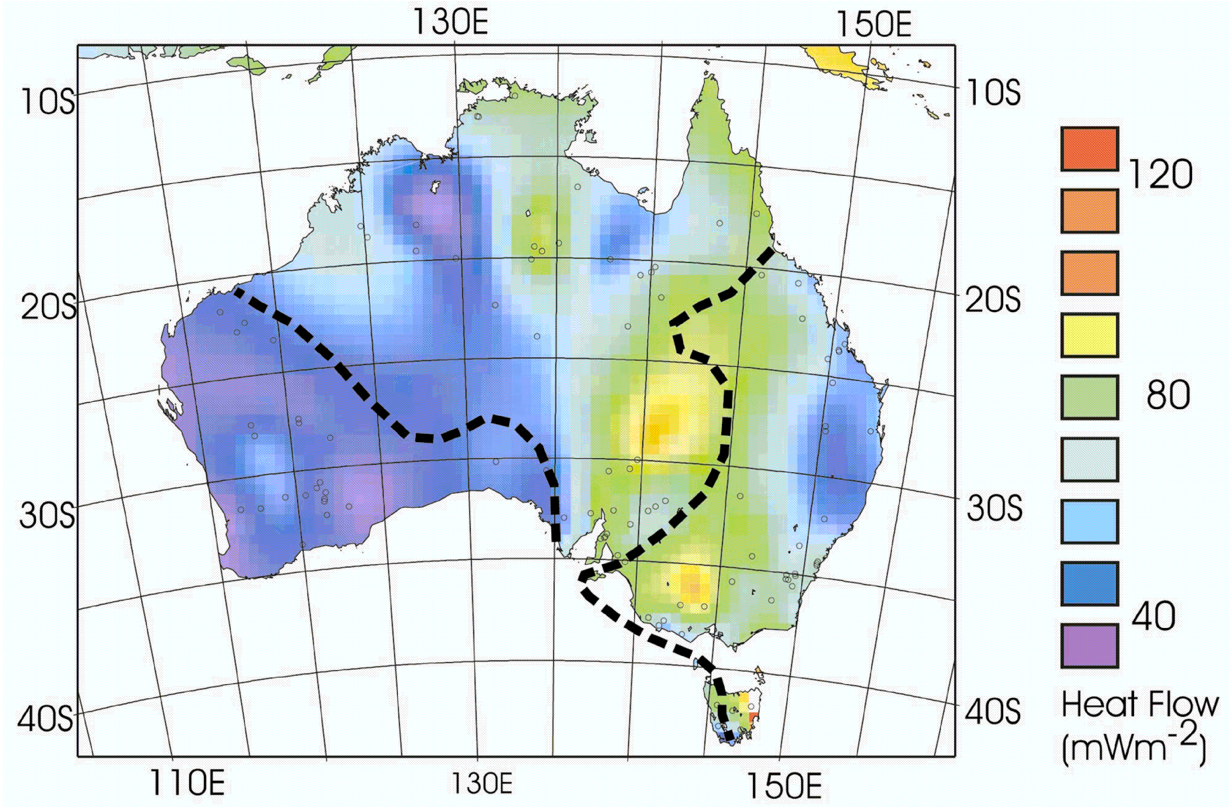


Figure 3. Australian Surface Heat Flow.

A map of heat flow measurements in Australia from Cull (1982). Note that the highest measurement of all is in northeast Tasmania.

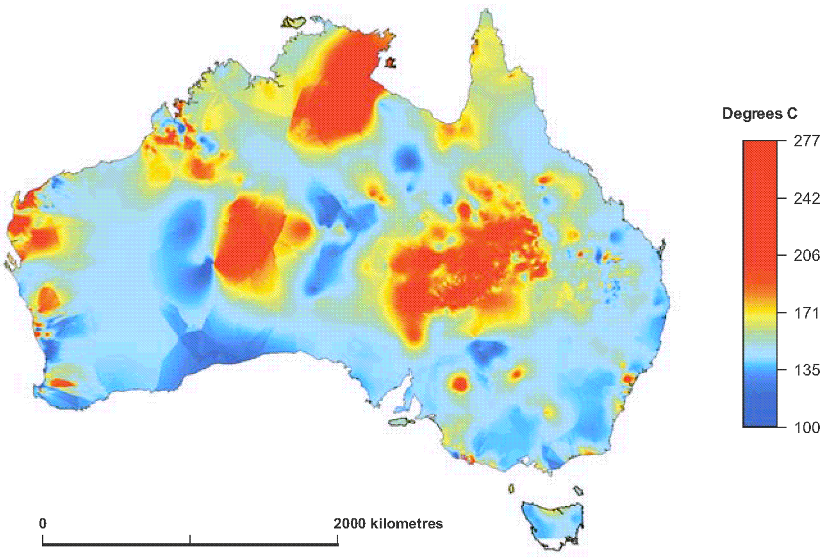


Figure 4. Estimated temperatures at 5km depth.

From Holdgate & Chopra (2004)

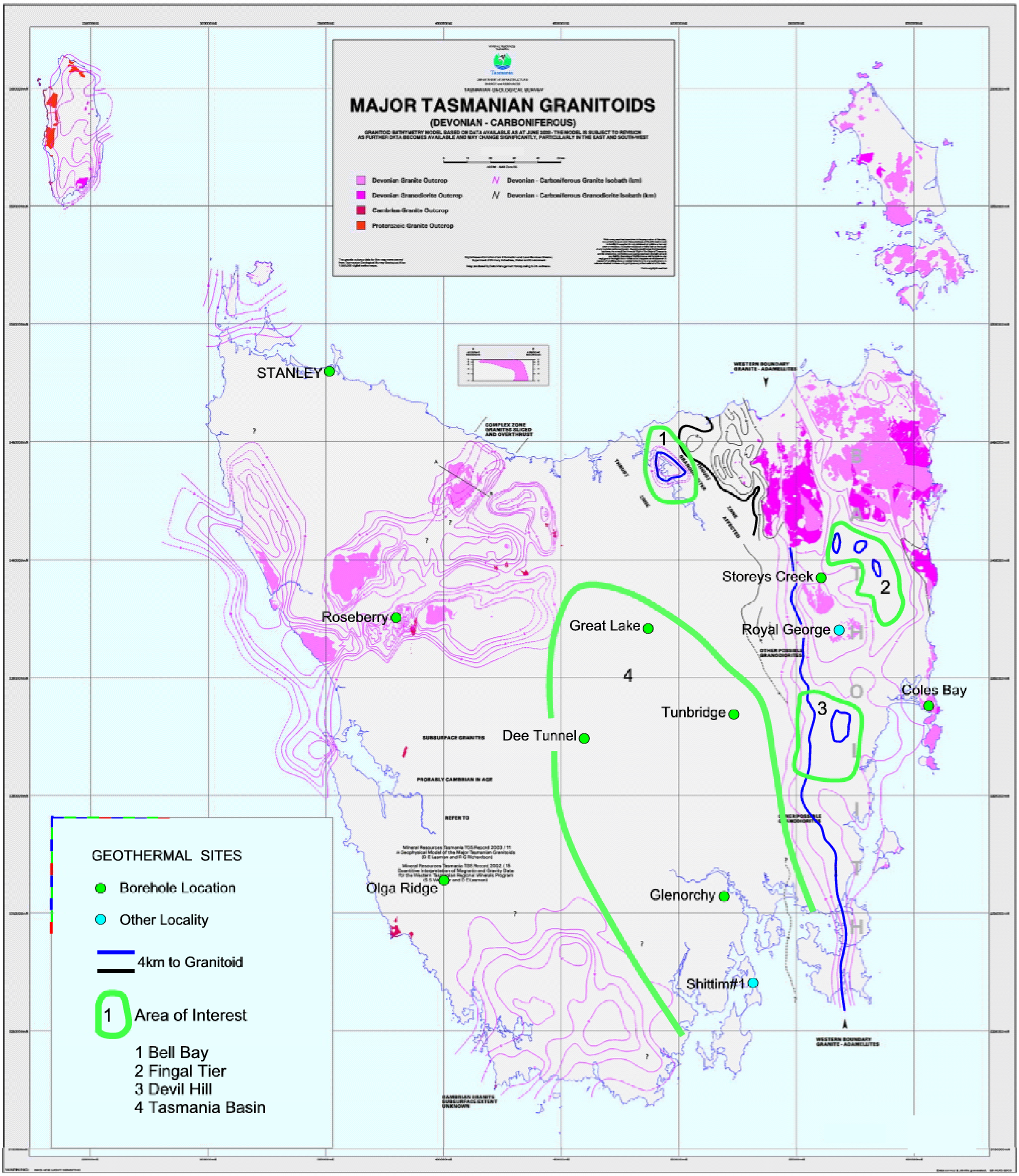


Figure 5. Granite topography, Geothermal Measurements & Areas of Interest.

Base map is from Leaman and Richardson (2003).

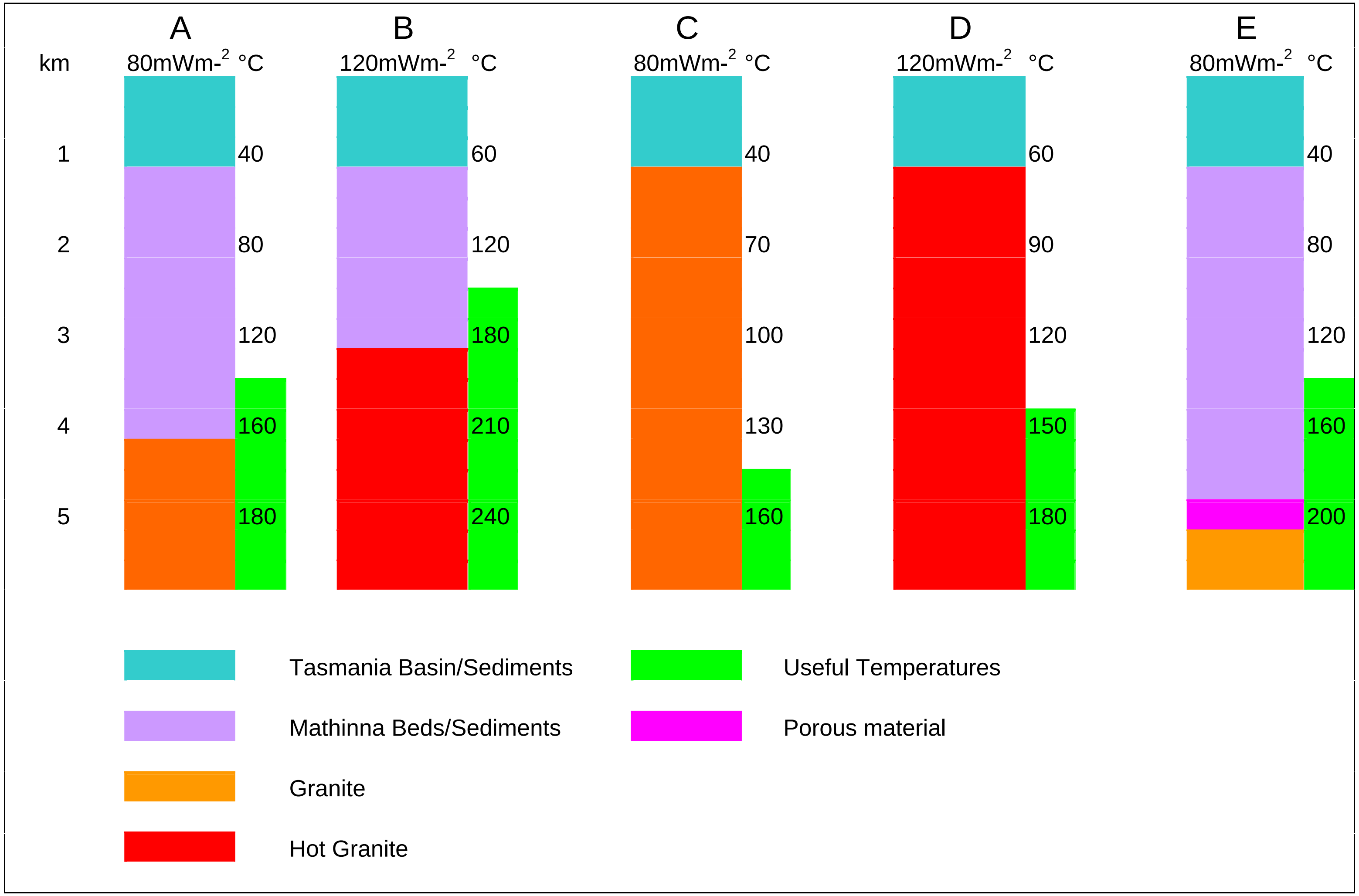


Figure 6. Thermal Scenarios for eastern Tasmania.

Various thermal profiles for Tasmania. There are two groups: the first is sourced by a granite or other source producing the typical Tasmanian heat flux of $80 mWm^{-2}$. The second has a hot granite (TAG) giving a heat flux of $120 mWm^{-2}$ through the same types of rocks. The top part of the sedimentary blanket may be the sediments and the intrusive dolerites making up the materials of the Tasmania Basin. The thermal properties of the Mathinna Beds in northeastern Tasmania are unknown and here are assumed to be similar to the Tasmania Basin material. Case E includes the possibility that porous media capable of acting as a heat exchanger might be found near the top of a granite. Plausible temperatures at 5km range from 180-270°C.

POTENTIAL AREAS of INTEREST

Here I consider some specific areas of interest where the probabilities of obtaining 180-270°C fluids are highest. I have confined myself to the eastern half of Tasmania and ignored possibilities associated with the eastern extremities of the granites in southwest Tasmania although there are cool thermal springs at Hastings located over an apparently structure controlled edge of the granite. These areas of interest are shown in Figure 5.

1. Bell Bay

   There is an area with an indicated cover of ~4km over granites which could make a good target. The thermal blanket would be a mixture of Tasmania Basin materials and the Mathinna Beds. There may be structural complexities but their details are unknown. The area contains part of the Tamar Conductivity Anomaly which may be like the Central Australian Conductivity anomaly which is associated with the South Australian Heat Flow Anomaly. Bell Bay has immense logistical advantages. It is the location of major electricity consumers with corresponding transmission infrastructure. It is also the site of Tasmania's thermal power station and is the connection point for the Basslink cable across Bass Strait. Access is easy. Other things being equal this would be the most attractive area. It may be possible to supply steam to the proposed pulp mill or to co-generate with it. The area of interest includes Launceston as a potential consumer area.

2. Fingal Tier

   This is an area with ~4km cover of Tasmania Basin materials and Mathinna Beds over probably very hot granites. The adjacent granites at Storeys Creek and Royal George have very high heat production and the geothermal flux may be double that found elsewhere in Tasmania. Bearing in mind we know nothing of the thermal properties of the Mathinna Beds temperature gradients may also be very high. This is basically an excellent target, possibly better thermally than Bell Bay but it lacks the infrastructure that Bell Bay offers nor is access as good.

3. Devil Hill

   There is a large area of ~4km cover of Tasmania Basin material and Mathinna Beds over possibly hot granites and this too is potentially an excellent target. The area is further from known hot granites than Fingal Tier.

4. The Tasmania Basin

   This is an area covered by Permo-Triassic sediments intruded in the Jurassic by dolerites. There is a consistently high heat flux and temperature gradients of about 40°C/km. The reason for the high heat flux is elusive. Temperature gradients in one part of the Tunbridge hole reach 60°C/km. If suitable rocks to develop a heat exchanger are available this is a large area target with excellent access and infrastructure. A representative area including the Tunbridge borehole would be of interest as would an area about Hobart as a potential major consumer area.

5. Other Exotic Possibilities - ENTS

   There may be some potential for ENTS in Tasmania. To illustrate the importance of enhanced natural hydrothermal circulation the heat flow anomaly at Soultz-sous-Forét is partly due to fluids circulating across part of the Rhine Graben, picking up heat on the way, and delivering it to Soultz. The western edge of the east coast granites is a wall of varying steepness and certainly represents one of several very prominent north-south structures in

Tasmania. This structure affect the Jurassic dolerites and has a long active history. There is also at least one major east-west structure with a large horizontal offset visible on regional aeromagnetics running through the granites from the central east coast. Both structures and their intersection may provide natural porosity in or in contact with the granites. This may have interesting thermal effects and exploration potential.

AN EXPLORATION/ DEVELOPMENT PROGRAM

The existing Tasmanian data is very encouraging but my review reveals some gaping holes in our knowledge. The lack of deep structural information might be partly filled by seismic reflection data procured by Great Southland Minerals and its associates. We know this exists but is currently unavailable to us. It should become available by efluxion of time through MRT in the not too distant future. The other really critical factor is the lack of thermal conductivity measurements for large parts of the potential thermal blanket over the granites. Thus a first approximation to an exploration/ development program would be:

- While there seems little interest in geothermal prospecting in Tasmania at present (The Mineral Resources Act has long made provision for geothermal exploitation (Category 6 Exploration Licences,) but there has never been an application) it would be prudent to secure a position in the promising areas. Further, it will be impossible to raise exploration funds without secure title. The licensing costs for geothermal exploration licences are unfavourably high in comparison with South Australia but a special exploration licence may help in this regard. The areas shown in Figure 7 give critical and representative cover but may need extending depending on results.
- Enough seed capital should be raised to carry us to the first decision point.
- Any existing boreholes should be temperature logged to determine geothermal gradients and any available core should be measured for thermal conductivity and thermal diffusivity. The aim is to define areas of extra high temperature and heat flux associated with extra hot granites. Beardsmore (2005) demonstrated this type of effect from a granite source in the southern Carnarvon Basin (WA). This would be relatively inexpensive compared with subsequent operations.
- Conduct drilling of shallow holes to fill any gaps in the data obtained above.
- This reaches the **First Decision Point**. The next stage will be expensive and at this stage a significant amount of capital will be needed - say $10-15M. Exploration of off-take agreements should have started or agreements be in place.
- Drill the first deep hole up to 5km, but hopefully say 3km in the best target. This is likely to change our appreciation of Tasmanian geology and will need very thorough revision of the data before proceeding further. At this stage the temperatures, possible heat exchanger rocks and general feasibility should be much better known. The first reasonably concrete numbers could be put on generating economics. The first absolute control on granite topography will emerge.
- This reaches the **Second Decision Point**. The decision is whether to commit to a second or deflected hole and establish a rock heat exchanger. From here on engineering will become a rapidly increasingly dominant part of the project.
- The characteristics of the heat exchanger and energy possibilities need thorough investigation.
- This reaches the **Third Decision Point**. A final economic assessment may be made. Further capital will be needed but might be raised on a bankable feasibility study. Off the shelf generating plant etc may be arranged if the results are favourable. A full scale generating operation expandable in modules will start operation.
- The possibilities of further heat extraction from the waste fluids for low grade heating in domestic, manufacturing and agricultural undertakings located about the plant should not be overlooked. The fluids would still be re-injected in a closed loop but at lower temperatures.
- This reaches the **Fourth Decision Point.** The decision is whether to expand. Successful operation would give excellent opportunities for expansion as the potential suitable areas are large.

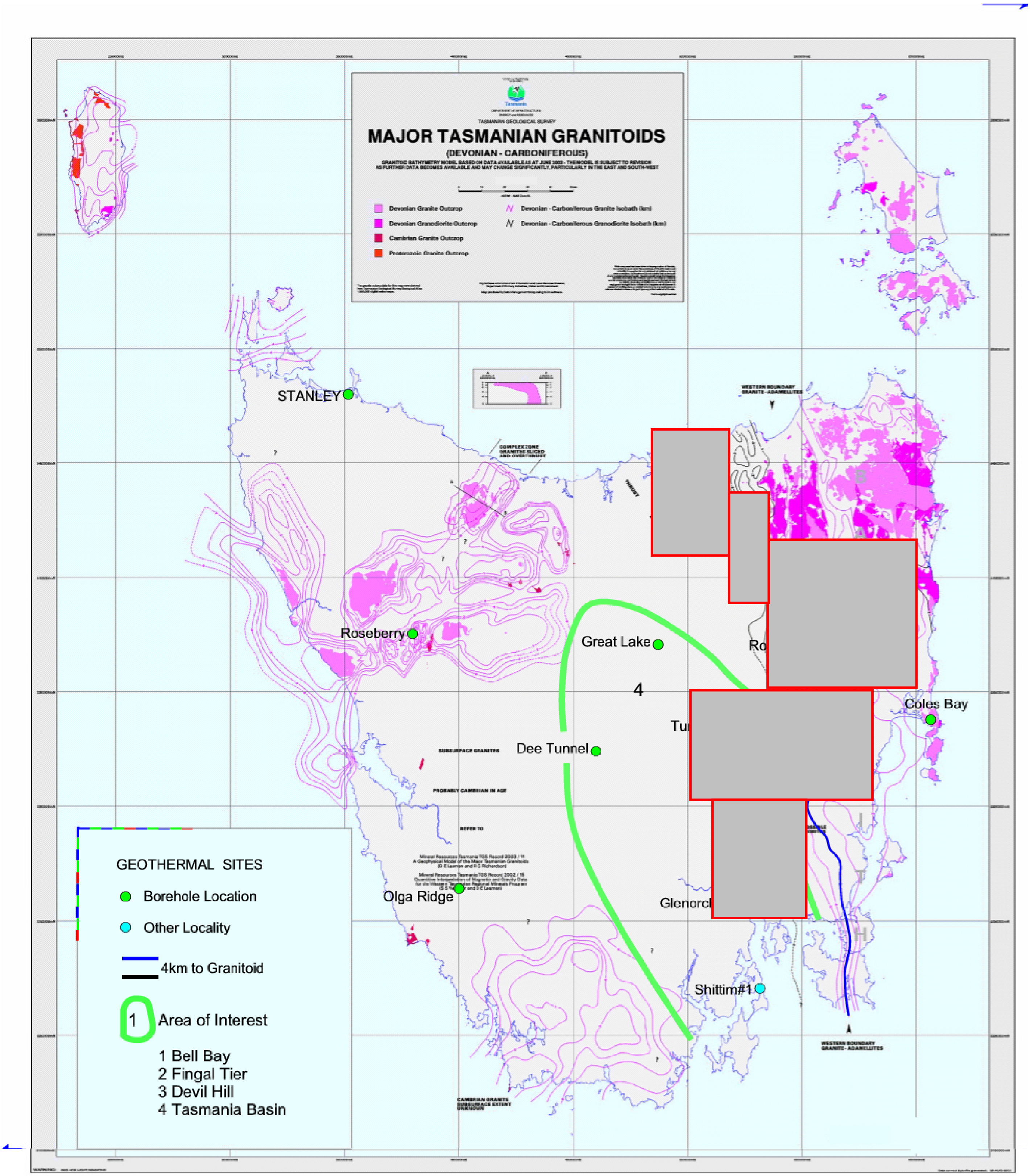


Figure 7. Tenements for initial investigations.

These areas take in Bell Bay, the eastern granites with appropriately covered areas and a representative section of the Tasmania Basin including the Tunbridge borehole. The area is some 13,000 km^2. It may be desirable to include more of the Tasmania Basin (Area 4).

ECONOMIC CONSIDERATIONS

Tasmania currently generates electricity from three sources:

- Hydroelectric systems which were, in the past, the only source.
- A Thermal power plant at Bell Bay originally fired by oil but converted to natural gas following the completion of a Victoria-Tasmania pipeline by Duke Energy.
- Wind farms. These have recently been built and development continues.

Tasmania is currently an isolated monopoly electricity market but in the near future it will be connected to the mainland by the Basslink submarine cable. Hydro, wind and geothermal power are renewable energy. Geothermal power is eligible for renewable energy certificates (REC) under present government schemes.

The hydroelectric system is from time to time production limited by drought which is why the thermal power plant was added. Wind power may be more reliable in Tasmania than elsewhere but will always be a 'lumpy' supply making for inefficient use of transmission facilities and requiring comparable backup capacity elsewhere. Hydro power is ideal for peak generation and offers an efficient energy storage if reverse pumped or simply not used.

The principal industrial users in Tasmania are the aluminum smelter at Bell Bay, the zinc refinery at Risdon and the ferro-manganese plant at Bell Bay. Most generating capacity is in the west with most demand towards the east of the state.

HDR geothermal power is ideal for base load generation, is a pollution free closed loop system, occupies very little land area, is treated as a renewable source of energy and unlike the hydro system does not generate environmental problems with large flooded water areas and flow modifications to river systems. Nor does HDR compete with other uses for water as does hydro generation e.g. the competition between irrigation and hydro power for limited water resources. Wind farms are reported to be distressingly noisy and create visual and faunal problems to the extent that a permit has just been refused in Victoria (July 2005) because of concerns for wedge tail eagles.

Adding geothermal base load capacity would free hydro capacity for peak generation including sales to the mainland via Basslink and possibly allow more reverse pumping of the hydro schemes. It would also open the possibility of further large base load industries in Tasmania. Thus there should be synergies between the two sources. This suggests the possibility of a strategic alliance with the Aurora/Transend groups. Alternatively it may be possible to locate geothermal plant very close to the major consumers at Bell Bay in northern Tasmania obviating the need for major transmission systems thus avoiding any dependence on existing infrastructure or suppliers but this depends, of course, on further successful investigations.

The outlay on an HDR facility is essentially up front with very low operating costs. This is similar to the state's hydro schemes. As outlined above there are significant exploration risks, higher than where there is data from numerous deep oil wells but this would diminish with experience in the Tasmanian environment. An important point is that if we can come up with a supply of geothermal fluid in the temperature range 150-200°C or even somewhat lower generation is quite feasible. As plant is available off the shelf costing of plant and the electricity generated cost are readily calculated once the source characteristics are known.

It would seem likely that to investigate and prove up a geothermal resource would require at least $10-15M expenditure. On top of that capital for generating plant etc. would be required.

The possible economic success of such a project may be illustrated by reference to Ormesa (Sonnelitter *et a*l 2000). A US$50M loan for the 24MW Ormesa I project was fully repaid approximately 1 year after the loan was funded. The project was expanded from a nameplate capacity of 30MW in 1986 to 72MW by 1989.

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BACKGROUND READING

There is a large literature, mostly available on the web. I recommend the presentation by W.J. Lund as an entrée followed by the article on Ormesa by Campbell *et al* and the articles by Burns *et al* and Alexander on the Australian geothermal industry together with the Geodynamics Ltd prospectus. The reader may find the enclosed CD helpful.

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