Geothermal Energy in the Perth Basin, Australia Comparisons with the Rhine Graben

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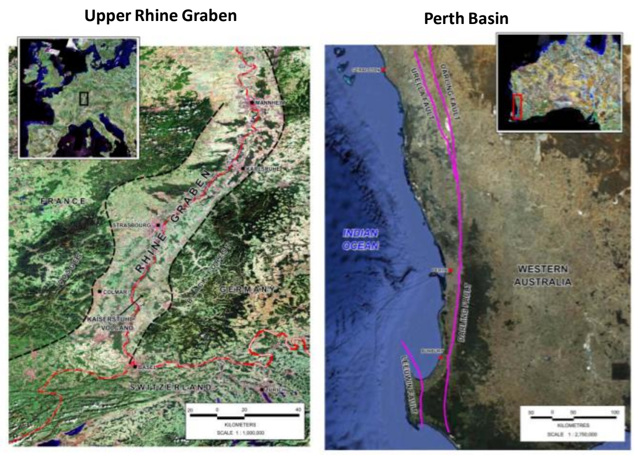
Abstract

Unlike the Rhine Graben where commercial scale geothermal power and direct heat projects have been operating for some time, geothermal developments in the Perth Basin are only at the gestation stage. Over the next two years Green Rock Energy Limited plans to carry out a commercial demonstration project in Perth which is likely to be the first commercial scale direct heat project of its type in Australia. This has only become possible since July 2009 when Green Rock Energy along with the University of Western Australia was awarded the first rights to explore for and produce geothermal energy in the state of Western Australia. This followed the introduction of the State's first geothermal legislation in 2008 when the Petroleum Act was amended to include geothermal energy.

This direct heat project is designed to prove the concept of recoveering geothermal energy from hot sedimenary aquifers in the central Perth Basin to directly cool and heat buildings in the Perth Metropolitan area. To assist the Company to achieve this objective in December 2009 the Australian Government announced that it was offering Green Rock Energy Limited a grant of $7 million from its Geothermal Drilling Program to assist the funding of the Company's project to air-conditon the main campus at University of Western Australia in the Perth Metropolitan area. The funding agreement was signed in September 2010. One week later the Western Australian State Government announced that Green Rock Energy was to be offered a further grant of $5.4 million for the same project. Funds from both Governments will be provided in stages and each Government requires the Company to provide the balance of required funds from other sources. Financing of geothermal exploration projects in Australia may differ from typical funding of projects in Germany. Most funds in Australia are obtained from shareholders in companies listed on the Australian Securities Exchange.

Both the Rhine and the Perth basins are favourably located near infrastructure. The Rhine Graben is the locus of a substantial portion of Germany's population and industrial muscle and is a major transport hub. The Perth Basin straddles Australia's south western coast where most of the State of Western Australia's population of 2.3 million and power infrastructure are located. This favourable location close to markets together with Perth Basin's geothermal energy resource potential presents the opportunity to supply energy for electricity production and direct heat use including air-conditioning and desalination of water.

Both basins share one key thing in common: their geothermal systems have little surface expression at the surface hence drilling is required to map the sub-surface heat resources. Knowlege of the extent and distribution of geothermal energy in the Perth Basin and its exploration and development is only at an early stage and may be 20 years behind the Rhine Graben. In both grabens the existing knowledge was mainly derived from the petroleum industry where there is a history of petroleum production. Petroleum exploration and production started much earlier in the Rhine, with the Forst-Weiher Field discovered between 1934 and 1936. Production ceased there by the 1960's but continues at present in the Perth Basin. Petroleum drilling commenced in the Perth Basin in the 1950s and resulted in the discovery of more than 13 oil and gas fields. Data derived from petroleum wells are rather sparsely distributed and focused in limited areas where petroleum fields have been discovered, mainly in the northern Perth Basin. Only 250 petroleum wells have been drilled and 23,985 km of 2D seismic and 2,838 km^2 of 3D seismic acquired in the Perth Basin. In contrast, over 5,000 wells have been drilled in the Rhine but around 90% of them were less than 600 metres depth.

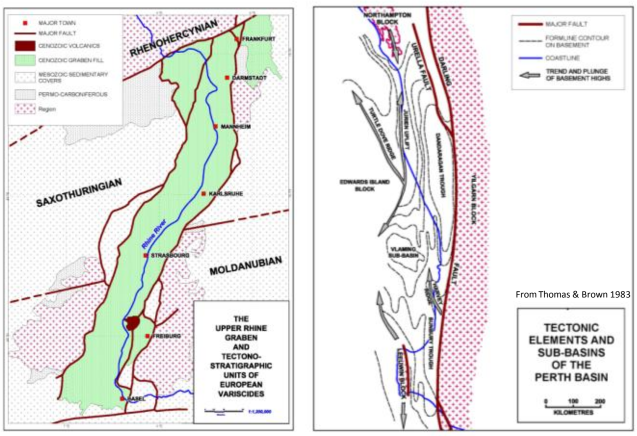


Both the Rhine Graben and Perth Basins are N-S trending sediment filled extensional rifts. The Perth rifting is over 200Ma older and has a much thicker sediment fill. The Perth Basin is a 1,000 km long rift or half graben containing a thick sequence of sediments in places up to 15 kilometres deep. This rifting produced the series of deep, north-south trending basins along the western margin of the Yilgarn Craton. Sediment deposition commenced with extension during the Permian (~290 Ma) and continued to the Early Cretaceous (~138 Ma). The Basin was uplifted during the final separation of Western Australia and greater India during the breakup of Gondwana.

Rifting in the 300km long Rhine Graben commenced much later in the Middle Eocene. Graben sinking and shoulder lifting continues to this day with the maximum sediment fill being around 3.4km in the Upper Rhine Graben.

There are substantial geological differences between the Rhine Graben and Perth Basin, in particular the much younger age, shorter graben, thinner sedimentary pile thickness of the former and current tensional and seismically active tectonic stress regime of the Rhine Graben compared to the compressional and relatively seismically inactive regime of the Perth Basin. Even so there are important similarities in their structural setting, extensional tectonic origins, thick sedimentary successions which overlie hot crystalline basements, high heat flows and evidence of the existence of substantial geothermal energy resource potential.

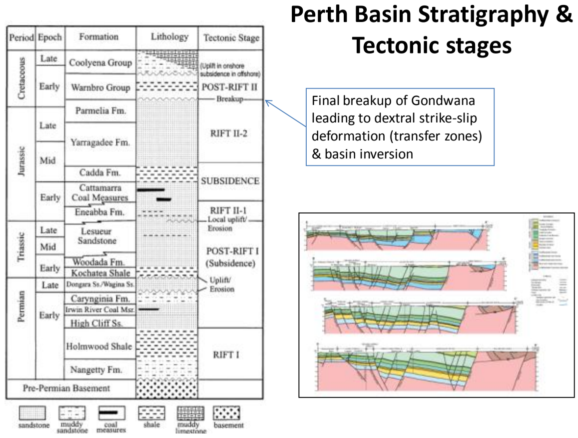
Geological Maps



Both basins have vertical structural asymetry with the sedimentary fill being geater in the eastern flank than the western flank and higher graben shoulders on the east flank in the case of the Rhine. This is considered to have important influences on regional ground water flow in the Rhine. Similarly the hills marking the NS trending Darling Fault forms the eastern boundary fault of the Perth Basin and is also expected to have an influence on ground water flow.

In the Rhine the current stress regime is strike slip with the maximum horizontal stress being oriented approximately NW/SE. In contrast to the Rhine, the early extensional tectonic regime of the Perth Basin is now overprinted by an essentially compressional setting as the Australian plate migrates NW with a rotational component at the relatively fast geological rate of nearly 7 cm per year. The contemporary stress regime for the Perth Basin has been interpreted to be a transitional reverse to strike-slip faulting stress regime with an approximate east-west maximum horizontal compression direction. Stress field data for the Perth Basin are derived mainly from petroleum well borehole breakouts and drilling-induced tensile fractures from 34 measurements as shown in the World Stress Map. This is important for targetting wells to tap critically stressed faults and fracture directions.

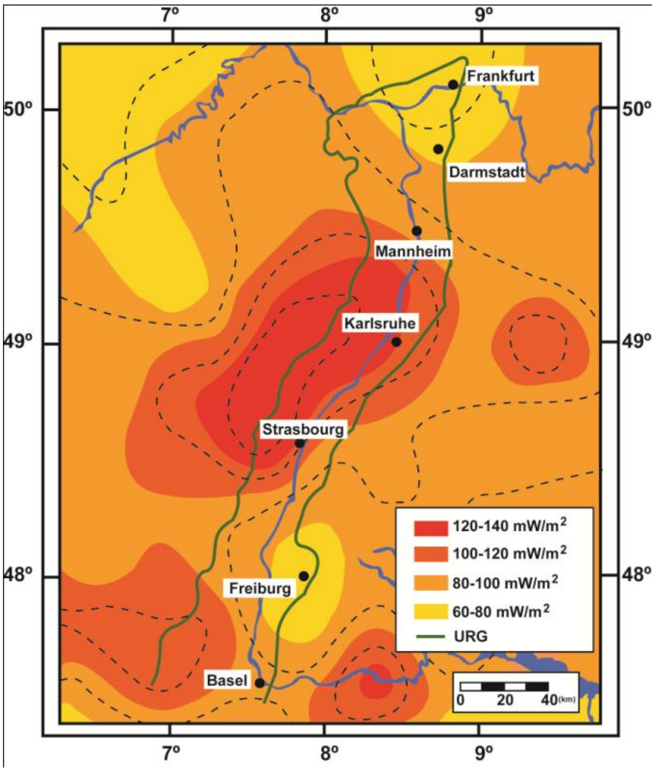
Perth Basin Stratigraphy & Tectonic stages



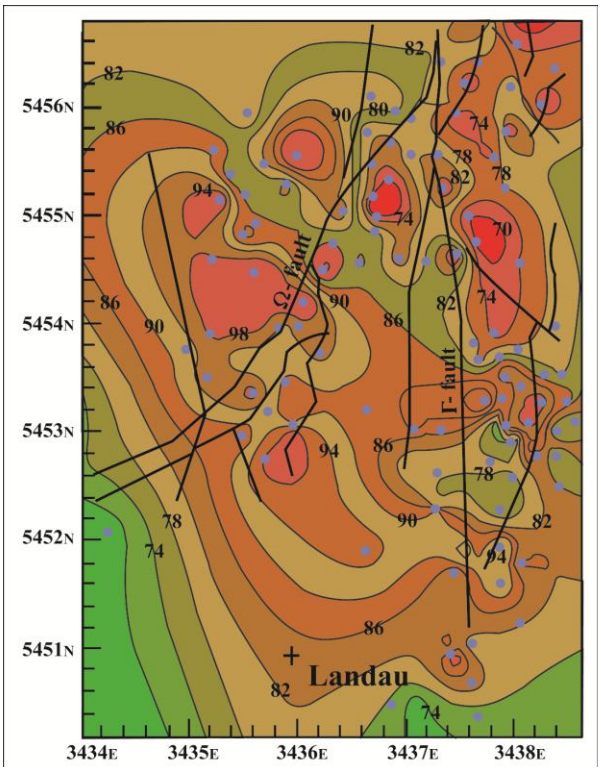
From Song & Cawood, 1999

Geothermal energy has been recovered to power electricity generation from both sediments and granites in the Rhine Graben at Soultz sous Forêts and Landau. Heat flows of up to 150mW/m^2 have been recorded in both grabens. Thermal anomalies occur along the western rim of the Rhine Graben. This is has been attributed to enhancement of a conductive basal heat flow of 70-80mW/m^2 by convection. Some of these sites were mapped as early as 1929 where a temperature of 50ºC at depth of 400 metres was known at Soultz.

At Landau convective hot spots have temperatures of 55°C at a depth of 500m & 98°C at a depth of 1,000m. There is considerable evidence for convective water flows in the Rhine Graben, particularly in the western flank where a pattern of adjacent hot and cold spots was found. This is generally considered to be the surface expression of deep convective geothermal systems. At Soultz there is a large reservoir with a similar fluid chemistry. The same geothermal fluid is found in different wells and in different lithologies including sediments and granite basement. Geothermal water at Soultz has salinities of around 100g/l and pH of 5.



Source: From Schwarz 2005 & Lichen 2005



Landau: Temperatures at 1000m (°C)
Grid in kms (Gauss-Krüger
Source: Charissé 2007

It is early days yet but evidence is emerging of convective flows in the shallow sedimentary sequences in the Perth Basin. It is not known if this reflects any deeper convection.

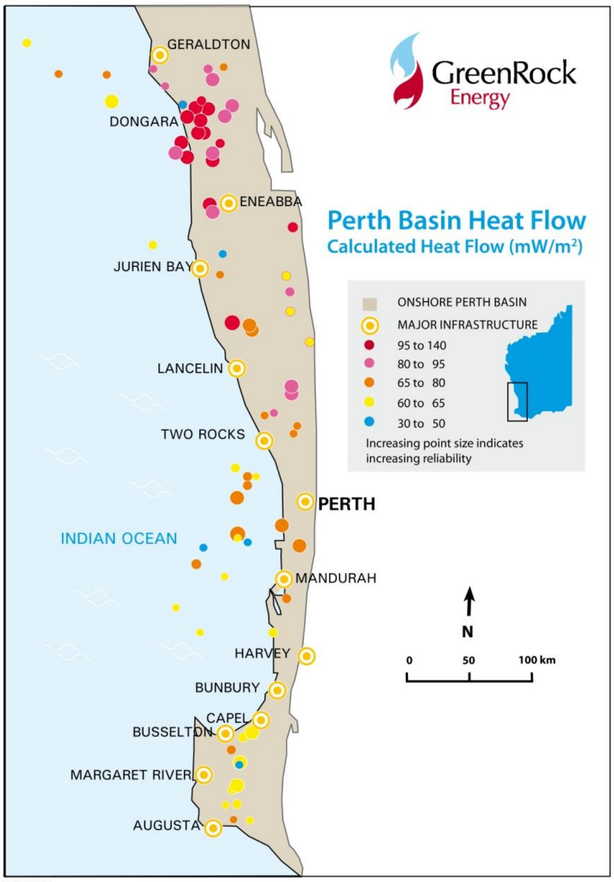
In the Rhine Graben in recent years the emphasis has shifted from targeting temperatures of around 200ºC at depths of 5,000 metres where natural flow rates from fracture permeability have proven to be inadequate to targetting shallower depths of 2,500m to 3,500 metres where tempertures of 150ºC to 160ºC and substantially higher flow rates can be expected from natural faults and fractures.

With its thick sequences of sandstones, the presence of thermal insulating shales and coals and high heat flows the Perth Basin has potential to house geothermal energy resources in the form of hot sedimentary aquifers (HSA) and hot rocks. The source of the heat flows in the Perth Basin may be radioactive basement rocks and radiogenic sedimentary horizons. The Perth Basin contains some of the worlds largest mineral sands deposits many of which are rich in radiogenic thorium minerals at shallow depths.

The highest known heat flows in the Perth Basin have been determined from petroleum wells in or near producing oil and gas fields in the northern Perth Basin. Green Rock holds nine Geothermal Exploration Permits in this region near high voltage power grids connected to Perth's major power markets. Heat flows exceed 100mW/m^2 within these Permits. Temperatures of around 160°C are expected in hot sedimentary aquifers at depths less than 4,000m which is sufficient to generate electricity commercially at this location provided that sufficient geothermal water flow rates can be achieved.

Unlike Germany, electricity generated from geothermal energy in Australia does not benefit from any feed in tariff arragement and retail electricity prices in Australia are substantially lower than Gemany's. In general this means that higher recovered temperatures or flow rates are required in Westen Australia to ensure commercial viability. However generators of renewable energy including geothermal energy are entitled under Federal legislation to sell Renewable Energy Certificates (REC's) in addition to selling the electricity they generate. In the absence of feed in tariffs in Western Australia electricity is sold to utilities via power purchase agreements.

Within Green Rock's permits in the North Perth Basin petroleum wells have proven good primary water permeabilities in sandstone reservoirs down to depths of around 2,700 metres but there is some limited evidence of substantially lower permeabilities at greater depths where temperatures above 150ºC would be expected. Much less is known about the potential for good water flows from natural fault or fracture permeability as this has not been targetted by the petroleum industry there.



Source: Hot Dry Rocks Pty Ltd 2008

In the central Perth Basin near the city of Perth heat flows are lower and temperatures expected at depth are likely to be insufficient for commercial generation of electricity but should be adequate for direct heat uses such as purification of water by distillation and for air-conditioning of buildings. Viability depends on attaining sufficient permeabilities from the aquifers. Within the Perth city area, where petroleum wells and deep seismic data are lacking, most of the useful temperature and permeability data have come from deep water bores, the deepest of which extend to only about 1000 metres but have sufficiently high water flow rates from natural matrix or granular permeability. On the basis of petroleum wells outside the Perth Permit areas good permeabilities are expected in Perth at least down to depths of 2,500 metres.

Geothermal energy has been recovered from aquifers beween 750 and 1,000 metres deep in Green Rock's Permit GEP1 in metropolitan Perth. This geothermal water is used to heat a number of major swimming centres including the Challenge Stadium Aquatic Centre where the World Swimming Championships have been held twice in the past decade.

Drilling Water Well in Perth for Heating Aquatic Centres

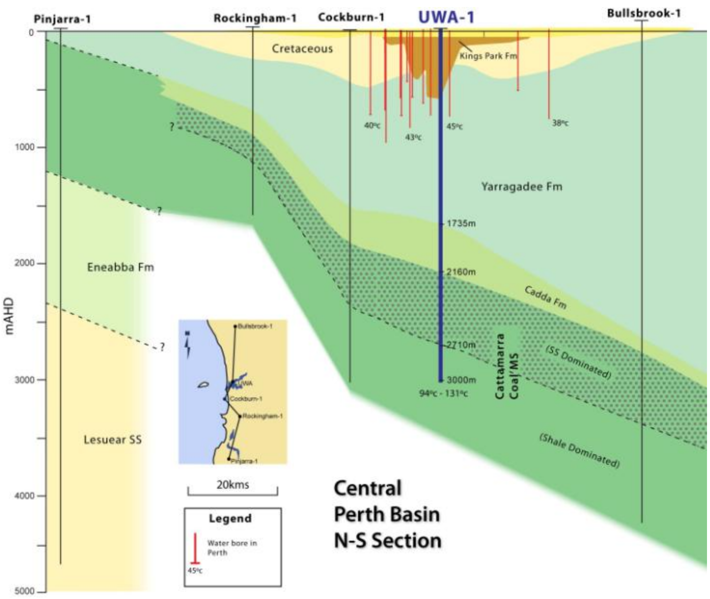
To develop opportunities in GEP1, Green Rock Energy, plans to carry out a commercial demonstration project to recover geothermal energy from hot sedimentary aquifers beneath the main Perth campus at the University of Western Australia (UWA). This project will be the first stepping stone to larger commercial developments in Perth.

The demonstration project is designed to replace a significant portion of the UWA's electrical powered air-conditioning with geothermal powered absorption chillers for its air-conditioning and heating needs. Absorption chillers, like the one shown below, are commercially available in Australia.

Commercial viability of this project at the UWA campus will depend on obtaining adequate geothermal temperatures and water flow rates from the sandstone aquifers at depth. Geothermal water temperatures of between 80ºC and 100ºC are required for commercial operation of the absorption chillers which will provide chilled water for the campus. Expected temperatures at the target depths of 2.5km to 3km in Perth should be adequate as indicated by estimated heat flows determined from temperature profiles measured in deep water bores and petroleum wells.

Absorption Chiller

For this first project at the UWA campus, one production and one injection well will be drilled to around 2.5 to 3 kilometres deep to recover geothermal energy from sandstone aquifers in the fluvial Yarragadee Formation and Cattamarra Coal Measures. Drilling wells to these depths should not present any particular difficulty as there is abundant history of petroleum wells drilled without significant problems in the Perth Basin. Preparatory site work and well design is underway to enable this drilling to be carried out in 2011. Seismic acquisition will be completed to optimise well design and orientation prior to drilling.



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