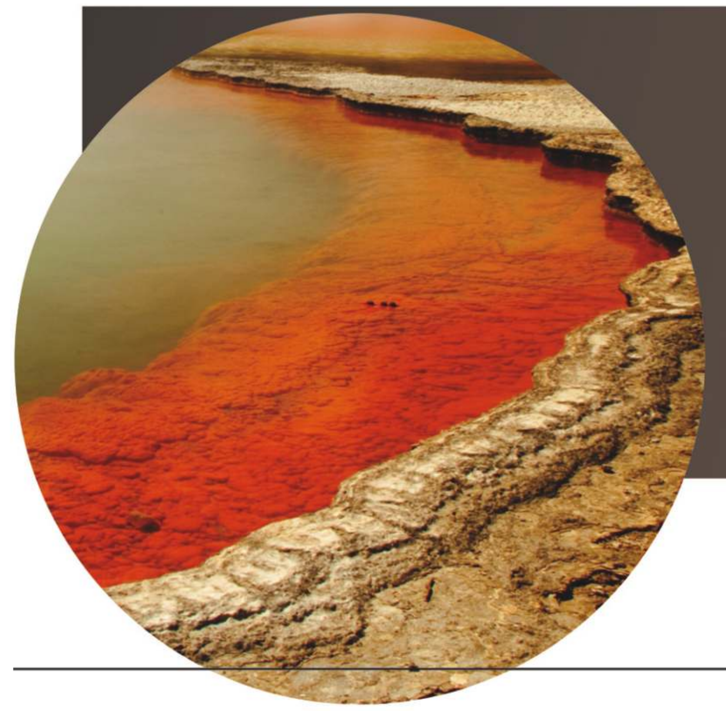

A proposed new method for inferred geothermal resource estimates: heat in place density and local sustainable pumping rates

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1 Introduction

Motivation for this study:

1) Optimise numerical methods for geo-thermal resource evaluation

2) Combine different methods for a map based analysis

=> Where are the most promising locations in a geothermal resource area?

Heat in place analysis and estimates of sustainable pumping rate are standard methods in geothermal exploration of hot sedimentary aquifers and enhanced geothermal systems (e.g. Tester et al., 2006).

Shortcomings of the standard method are:

1) The available heat in place (Muffler and Cataldi, 1978) is evaluated for a whole resource area (large scale);

2) Sustainable pumping rates (e.g. Gringarten, 1978) are only performed for one particular target location (local scale).

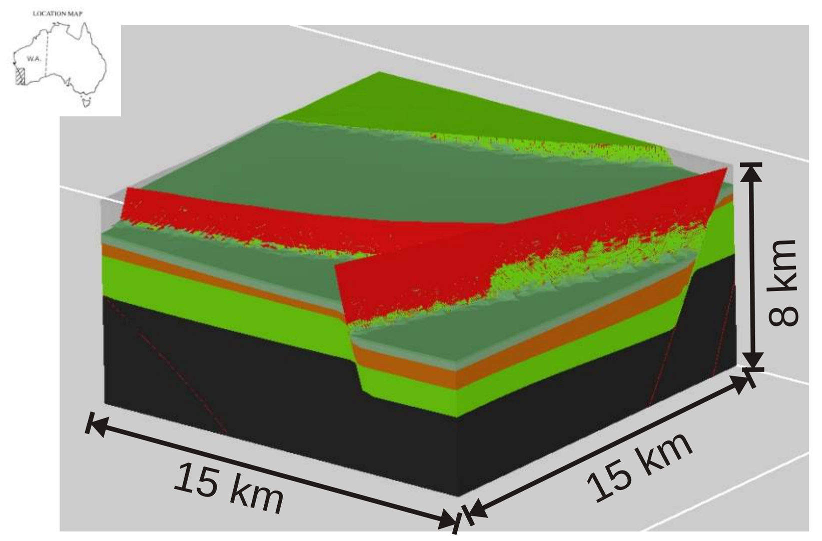
We present here a method to overcome this scale dependence and propose that it is possible to evaluate both heat in place and estimates of sustainable pumping rate on a map basis.

2 Our Approach

All estimations are directly based on geothermal fluid and heat flow simulations. We developed an approach that combines geological modelling and flow simulation (Wellmann, 2009). In the work presented here, we use the result of the simulation to calculate relevant resource estimation values at each grid cell.

A Combination of geological modelling and geothermal simulation

Geological Model

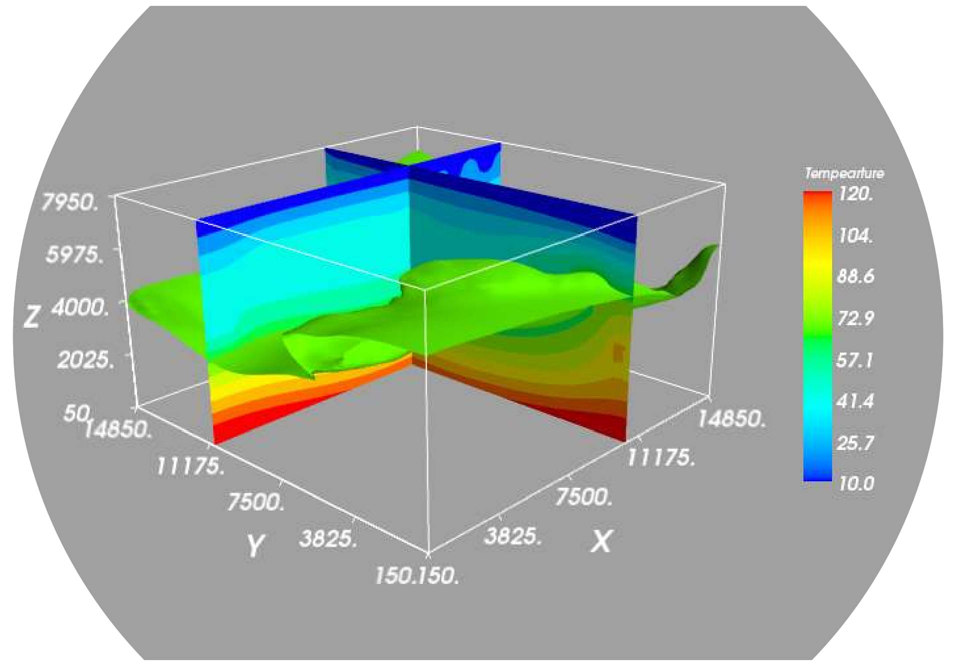


Structural model of an area in the North Perth Basin, Western Australia: Extension Graben Structure, basement (dark gray) overlain by permeable sedimentary formations (top formation is transparent). Model created with GeoModeller (Calcagno et al., 2008).

Fluid and heat flow parameters

Name	Unit	Permeability [m²]	Porosity [%]	Heat Production [W/m³]	Thermal Conductivity [W/(m K)]
Yarragadee	6	1.00E-12	25	0	2.2
Cadda	5	1.00E-17	5	0	3.8
Cattamarra	4	1.00E-15	20	0	3.2
Woodada_Kockatea	3	1.00E-17	1	0	2.5
Permian	2	1.00E-15	10	0	2.75
Basement	1	1.00E-17	1	1.00E-05	3

Fluid and heat flow parameters are assigned to the units of the geological model. In this case, we assign a single value for each unit. Probability functions or functions of depth are also possible. The units here are according to the geological model from bottom (Basement) to top (Yarragadee).

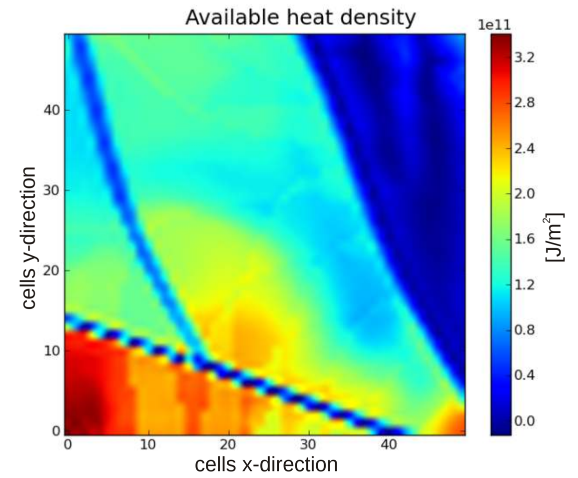


Simulation Settings

All other settings (convergence criteria, boundary conditions, transient/ steady-state, etc.) are defined according to the simulation problem and the simulation software. We used SHEMAT (a fully coupled fluid and heat flow simulator) for the exapmles shown here (Clauser and Bartels, 2003).

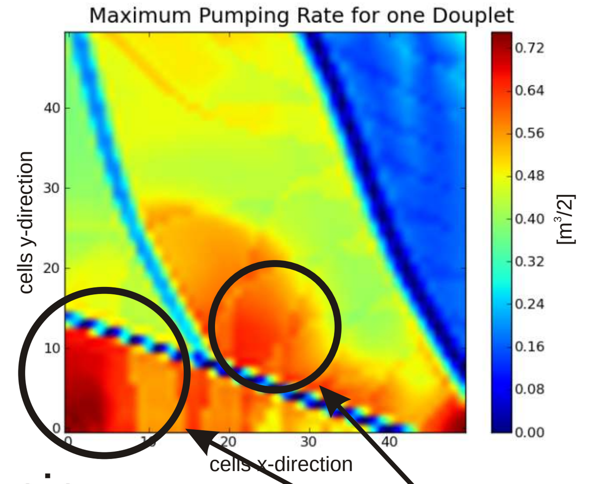
B Mapping heat in place density and sustainable pumping rates

Heat in place density



We calculate the available heat in place in an integral calculation at every cell centre of the discretised model and scale the result with the size of the cell. The obtained map of heat in place density provides a valuable insight into the distribution of heat in the resource area.

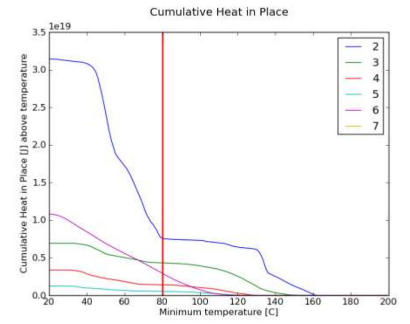
Sustainable pumping rates



We combine analytical estimations for a sustainable pumping rate (Gringarten, 1978) with the geological model and the flow simulation to evaluate a maximal sustainable pumping rate for a well douplet at each cell location.

We can clearly identify locations within the whole resource area showing promising heat in place density and high sustainable pumping rates. This is not possible with the standard approaches.

Temperature threshold analysis



For geothermal applications, it is important to know which portion of heat is available above a minimum temperature threshold (e.g. 80 °C for direct heat use air conditioning). We combine simulated temperature field and geological model to evaluate the relative available heat in a cumulative plot.

3 Why is it important?

Allows identification of promising targets within one resource area, directly based on important considerations (temperature and expected sustainability).

Integration into one workflow enables flexible model update during exportation (i.e. when new data become available) and allows hypothesis testing and sensitivity studies.

Outlook: combine with uncertainty simulation for geological models (Wellmann, 2010) to take uncertainty of initial geological model into account.

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