Using neural networks to predict thermal conductivity from geophysical well logs

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Abstract

Terrestrial heat flow is important to predict present-day basin temperatures and hydrocarbon maturation. In a number of areas, oil exploration is virtually the only usable source of data to obtain heat flow estimates. This is for example the case on continental margins, which thermal regime remains poorly known. Reliable values of heat flow can be derived from oil exploration data, provided that thermal conductivity is obtained with a sufficient accuracy. Previous methods involve (1) correlations between well logs and calibrated thermal conductivity, (2) empirical models based on mineral or lithological content. None of these methods gives objective or universal outcomes.

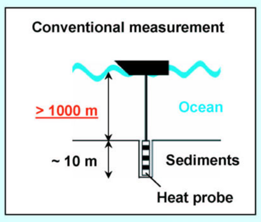
In order to obtain such a general process, we have developed a new method based on the neural network technique, and relating a set of geophysical well logs to thermal conductivity.The method has been calibrated on ODP data, which accounts for several thousands of conductivity measurements and five types of geophysical well logs (Sonic, Density, Neutron, Resistivity and Gamma-ray). This set has been used to train multi-layer perceptrons (MLP) and find an empirical relationship between well logs (MLP inputs) and thermal conductivity (MLP output). MLP are a class of neural networks that can perform efficient function approximation without any a priori knowledge, provided that a sufficiently large number of data exists. Validation tests suggest that thermal conductivity can be obtained with a ~15% level of confidence.

The method is applied in an ongoing GATOR project (Global Analysis of Temperature from Oil Exploration) to characterize the worldwide thermal regime of continental margins. Preliminary results on the South African and South Australian margins thermal regimes are presented.

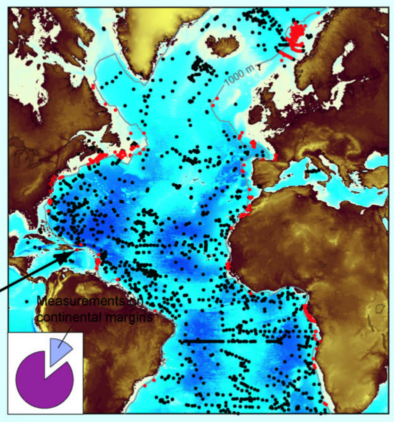
Part I - Questions on the thermal regime of continental margins

1) We know so little...

Conventional measurements cannot be performed in shallow water depth



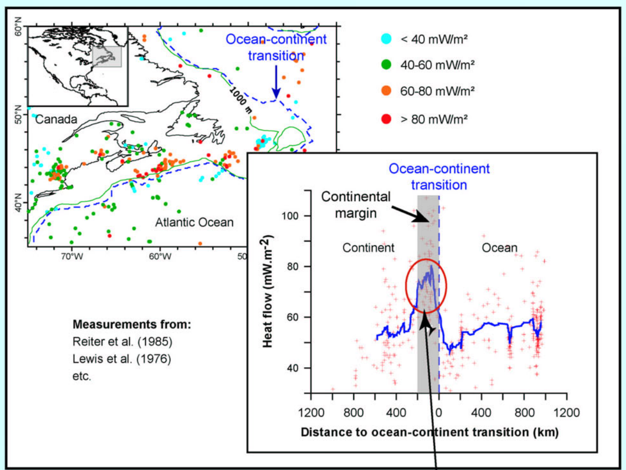
Consequently few measurements have been performed on continental margins (most of them being derived... from oil data)



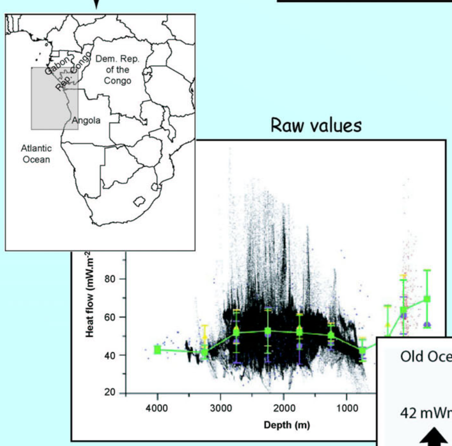
Global heat flow database (Pollack et al., 1991, updated by F. Lucazeau), Atlantic Ocean. Red dots: measurements on continental margins.

2) ...though "anomalous" regimes have been observed

On the Canadian margin



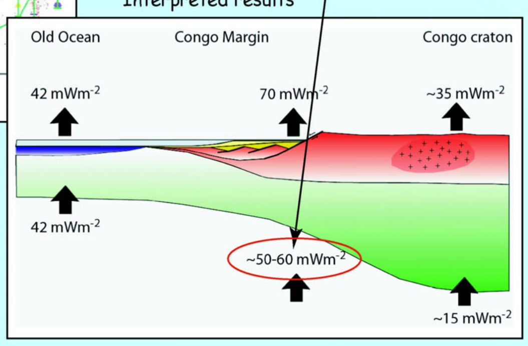
On the Congo margin



from Lucazeau et al. (2004)

Locally high heat flow on margins!

Interpreted results

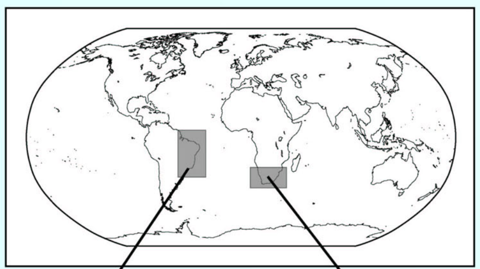


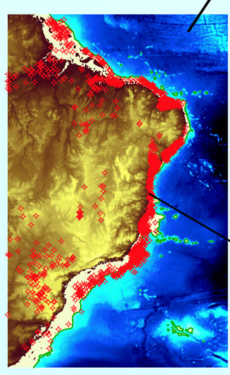
➡ These examples raise some questions on the thermal regime of continental margins. We need more studies. But where can we find data?...

3) Oil exploration is the only usable source of data...

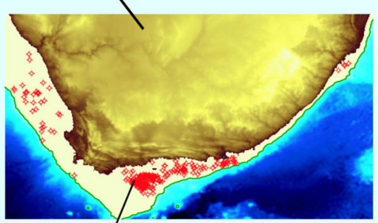
Many oil exploration data are available on continental margins

Examples





Brazilian margin



South African margin

Oil exploration wells

Oil wells are **deep enough** to reach zones undisturbed by seasonal variations of temperature

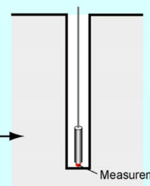
Results from deep offshore wells can be compared to conventional measurements

4) ...but the estimation of thermal conductivity remains problematic

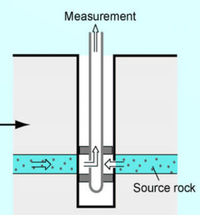
Temperature + thermal conductivity are needed to estimate heat flow...

Concerning temperature:

we have bottom-hole temperatures (BHT) measured during logging phases...



...and measurements on fluids during drillstem tests (DST)



On the other hand, direct measurements of **thermal conductivity** are very seldom

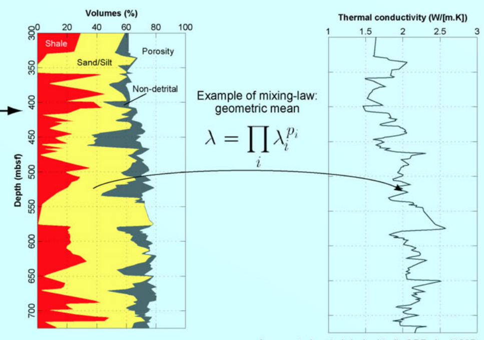
→ Indirect methods are employed:

- Lithological or mineralogical decomposition and application of a mixing-law

PBS: not straightforward, not objective

- Linear regression thermal conductivity/well log(s)

PB: not universal (localized to particular lithologies and/or areas)



from goutorbe et al. (submitted), ODP site 1109D

➡ A reliable method to estimate thermal conductivity from oil exploration data is still needed!