Using neural networks to predict thermal conductivity from geophysical well logs

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Part II - Inside the methodology

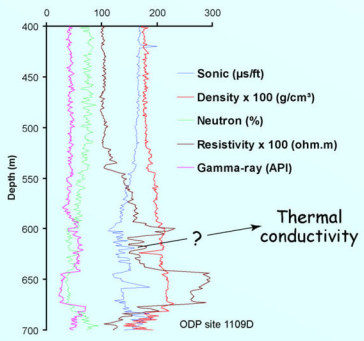
1) What do we want?

In oil exploration wells, well logs are the only source of high-resolution, objective data

We assume that there **must** exist a relation thermal conductivity = f(well logs)

We wish to obtain an estimation of this relationship based on known patterns {well logs, thermal conductivity}

We choose well logs related to porosity, mineralogy, structural characteristics: Sonic, Density, Neutron, Resistivity and Gamma-ray



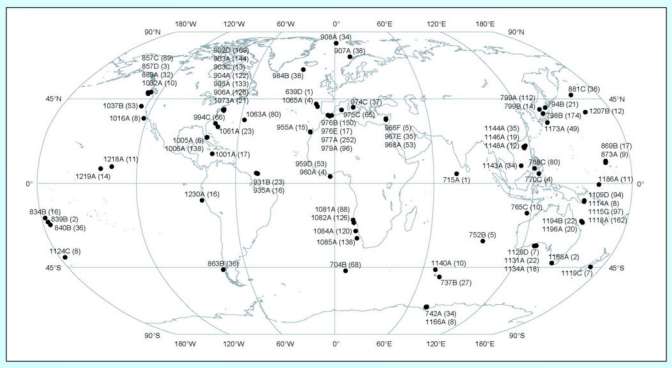
Our preferred method: estimating thermal conductivity directly and only from well logs

➡ First task: find examples of thermal conductivity associated with well logs

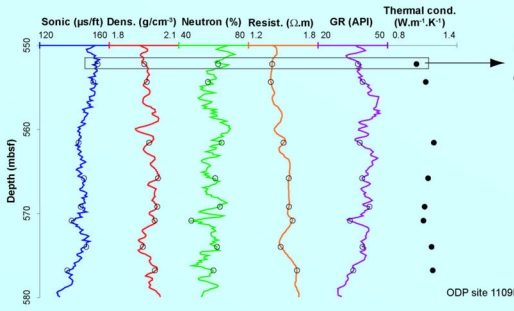
2) Building a comprehensive data set {thermal conductivity + well logs}

Ocean Drilling Program (ODP) provides a database of well logs and thermal conductivity measurements... We just have to associate them!

ODP sites with both well logs and thermal conductivity measurements on cores



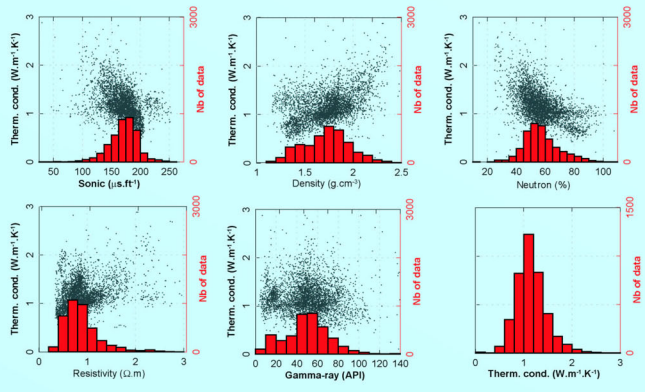
➡ Virtually all lithological contexts are represented



Thermal conductivity measurements are associated with corresponding well logs values

➡ We have been able to build up a comprehensive data set with more than 4000 thermal conductivity measurements associated with corresponding values of well logs

Distributions of the data and cross-plots of thermal conductivity vs. corresponding well logs values



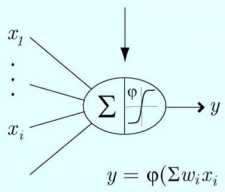
The distributions reflect ODP conditions (depth < 1200 mbsf): thermal conductivity, wave speed, density, resistivity are low; porosity neutron is medium to high

➡ **Deeper samples are needed to complete the data set!**

3) Using neural networks as function approximators

Neural networks form a class of non-linear and adaptive systems originally based on the study of the brain (McCulloch and Pitt, 1943)

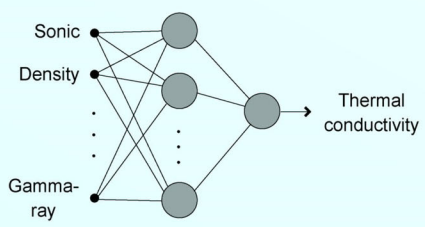
A (mathematical) neuron is simply a non-linear function of the following form:



$$y = \varphi(\Sigma w_i x_i + \theta)$$

...and a neural network is a network of interconnected neurons.

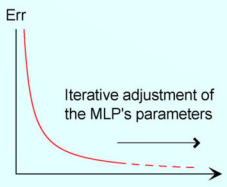
We use **layered** neural networks, so-called multi-layer perceptrons (MLP), to obtain an approximation of the relation thermal conductivity = f(well logs)



...because MLP are universal approximators (Cybenko, 1989).

Rumelhart et al. (1986) proposed an elegant and efficient optimization algorithm ("backpropagation") to minimize the error of the MLP:

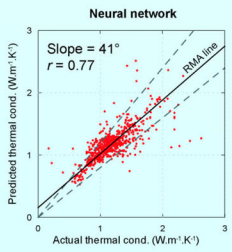
$$\text{Err} = \sum \left[\begin{array}{c}\text{Actual thermal conductivity} \\ \text{(from data set)}\end{array} - \begin{array}{c}\text{Predicted thermal conductivity} \\ \text{(output of neural network)}\end{array} \right]^2$$



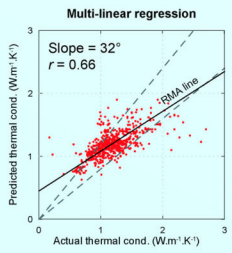
4) Predictions performances of the neural networks

The predictions of the neural network are tested on an **independant** subset, not used during the optimization of the network's parameters.

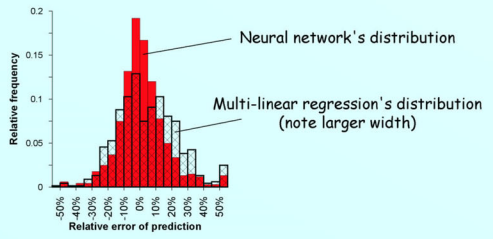
Predictions performances of the neural network are fairly good...



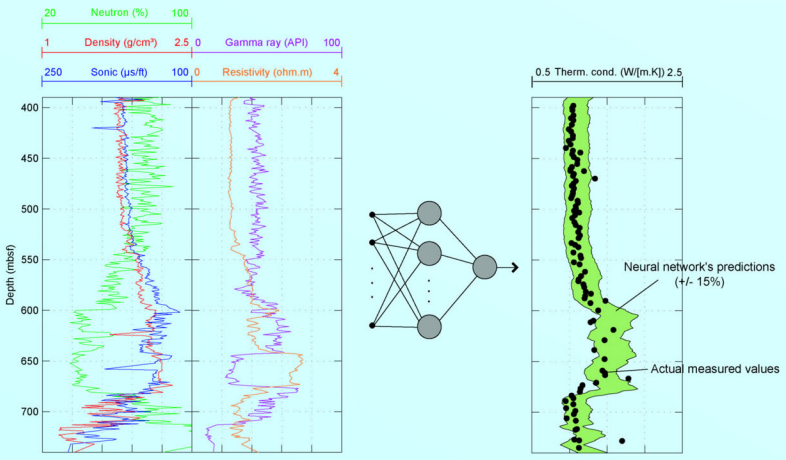
...much better than a classical multi-linear regression on the same data set



The distribution of the predictions' relative errors shows that a ~15% level of confidence can be expected



We also test predictions along ODP site 1109D, after **removing** it during the optimization phase.



➡ The trend is accurate!