Workshop 1
Defining, exploring, imaging and assessing reservoirs for potential heat exchange
Potsdam, Germany, 6-8/11/2006

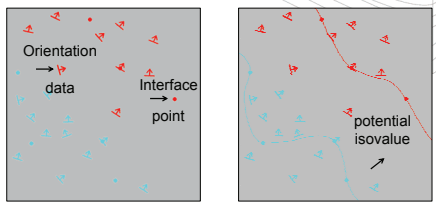
How 3DGeoModeller helps to define and assess a geothermal reservoir: The Limagne case-study (French Massif Central)

For more information 3dweg.brgm.fr and www.geomodeller.com

By constructing a 3D geological model, geologists in charge of defining and exploring a geothermal reservoir can test different geological hypotheses using the data they have collected. Then the resulting 3D geometrical model can be used to calculate geological volumes, heat flow and related computations depending on the geometry of the reservoir.

An original methodology has been developed in BRGM (French Geological Survey) to interpolate at the same time geological contacts locations and dips of the formations. The model is calculated by co-kriging these 2 types of data to obtain a 3D potential field. A geological pile allows automatic computation of intersections and volume reconstruction using the geological history of the area and the relationship between geological units. 3DGeoModeller software has been developed for geologists to apply this methodology to their data.

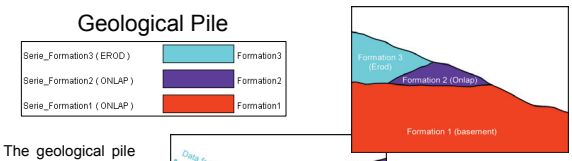
Interpolation method using 3D potential field



> The potential field method allows to interpolate in the whole 3D space of the area. It considers the limits between geological bodies as isopotential surfaces while their orientations represent the gradients of the potential.

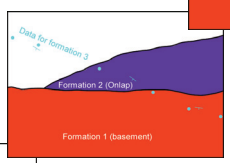
> Principle in 2 dimensions for 2 geological interfaces. The method needs the position of the interfaces between geological bodies to be known at some places. It also requires orientation vectors (azimuths, dips and polarities) of the geological structures measured on field. Dip measurements are not necessarily located on the geological interfaces. When the potential field is calculated, the potential value is known for every point in 3D space. A range of potential values defines a geological body.

Generalisation with multiple potentials

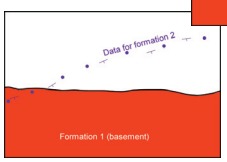


> Each step of the geological history is associated to a potential field.

> The geological pile contains the chronological succession of the formations and their relationships.

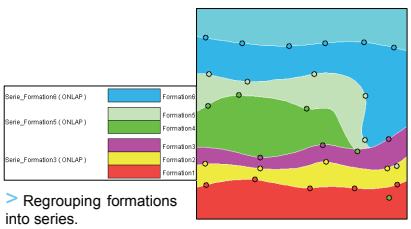


> A given potential field has a behaviour parameter (Erod or Onlap) which controls its relation with older geological bodies (potential fields already interpolated).



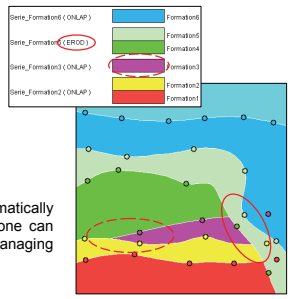
> According to their definition, isopotential surfaces can not be secant or have common points. Two adjacent interfaces contained in a given potential have a sub-parallel behaviour. A geological body can settle and stop on (Onlap relation) or erode (Erod relation) another.

Same dataset, different geological pile



> Regrouping formations into series.

> Only the intergace points are shown. Orientation data are not plotted.



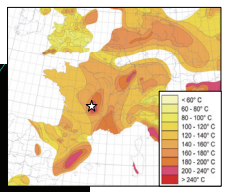
> Intersections between geological bodies are automatically governed by the geological pile. By using this tool, one can focus on geological interpretation without managing intersections purposes.

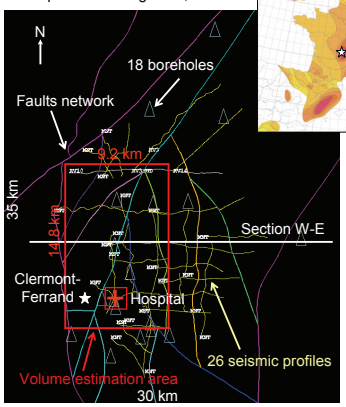
3DGeoModeller was used in the Clermont-Ferrand basin where a new hospital is planed to be built. The Limagne area is characterized by a 100°C geothermal anomaly at 1.5km depth. A 35 km x 30 km x 5 km 3D model was set in order to study the feasibility of heating the new building by geothermal power. Field, drill holes and seismic data collected over the last 25 years were input in the software. The inconsistencies in their respective interpretations were checked and turned into a coherent 3D interpretation of the whole area. The 3D model was then used to compute volume of the geological formations of the reservoir. The next step will be to calculate the heat flow by meshing the geometry of the 3D model.

This work is supported by ADEME (French Agency for Energy and Environment).

The Limagne d'Allier basin

> European map of the temperatures extrapolated at 5 km depth from Hurtig et al., 1991.

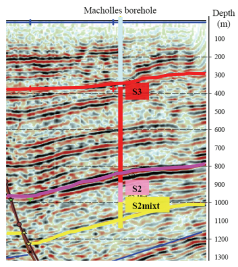




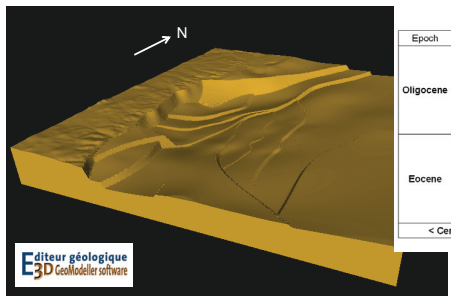
> The Limagne d'Allier Tertiary basin is located north of Clermont-Ferrand, oriented NNE to NS and bounded by regional faults. The Allier basin has been investigated more thoroughly than the other basins since it is deeper and displays higher temperature gradients.

> Modelled area. The model was built using boreholes and seismic profiles collected over the last 25 years.

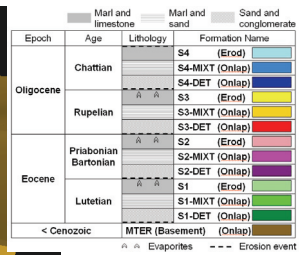
> Estimation of the detritic volumes computed from the geometrical model (see the map on left hand side for location).



> Checking and fixing incoherencies. Seismic profile displaying spatial inconsistencies at Macholles borehole: S2MIXT surface has been set 100 m higher in the well than on the seismic profile and S2 surface 30 m lower.

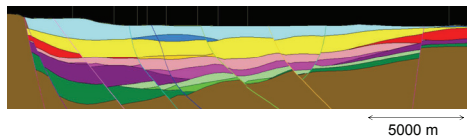


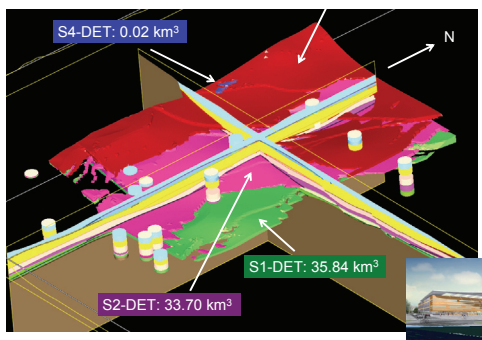
> Basement (30km x 35 km to 5 km at depth), S-SE view. Geometry of the basement is built using the relative displacements of the fault blocks, given by the seismic sections and the boreholes, coupled to the basement surface derived from gravimetric inversion.



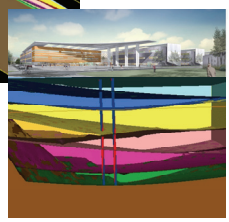
> Lithostratigraphic column and geological pile.

> Section W-E (see the map on left hand side for location).



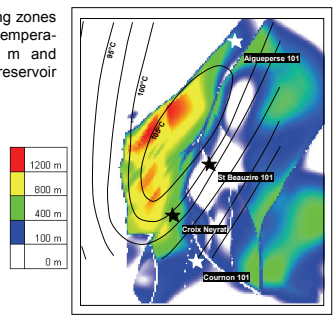


> The target geothermal reservoirs corresponds to detritic rocks such as sand, sandstone and fluvial conglomerate because they have a higher probability of containing levels of permeable porous sandstones.



> A doublet to heat the future hospital?

> Most promising zones by combining temperatures at 1,500 m and cumulative reservoir thicknesses.



> **References**

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- Genter et al. (2005), WGC05, Antalya, Turkey.
- Lajaunie Ch. et al. (1997), Mathematical Geology, 29(4), 571–584.

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