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The geothermal conditions in the Rhine Graben - a summary

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A data base of borehole measurements collected over decades indicate that generally elevated temperatures prevail in the Rhine Graben (Fig. 1). For example at 1 km depth, instead of having the expected 40° C, the temperature range extends up to 140° C. The presentation at the 73rd ASP Convention addressed the geothermal conditions and processes, which are responsible for this feature.

The Rhine Graben, being part of the European Mid-Continental Rift System (Cloetingh et al. 2005), is characterized by thinned crust (and therefore higher heat flow; see Fig. 2), respectively by mantle proximity (e.g. ^{3}He anomalies; Clauser et al. 2002). The temperature field is characterized by generally elevated values in the topmost 2 kilometers, in an inhomogeneous pattern: relatively high and low temperatures can be located close to each other (Pribnow & Schellschmidt 2000). Recently there is increasing evidence for convective heat transfer, at least in parts of the Rhine Graben subsurface (see e.g. Aquilina et al. 2000). Convection cells develop to quite some extent within the crystalline basement; numerical model simulations show that the cells can extend over several kilometres (Bächler et al. 2003). Water circulation velocity in the cells attains values up to cm/yr (Fig. 3 from Kohl et al. 2000). Convective heat transfer results in highly non-linear temperature-depth profiles, like the one measured at the European EGS project site at Soultz-sous-Forêts (France): relatively high temperatures at shallow depth, and anomalously low temperature gradients underneath (Fig. 4). It is still an open question in which Graben realms could such features be present (potentially also at the Basel Deep Heat Mining site?); the data density for depths > 3 km is very low.

The Rhine Graben has generally favourable conditions for geothermal energy development and utilization (FESA 2005): generally elevated subsurface temperatures, regional aquifers at suitable depth (e.g. Buntsandstein, Upper Muschelkalk), extensional tectonics (provides vertical permeability). The first successful application, the Riehen/BS district heating system, started to operate in

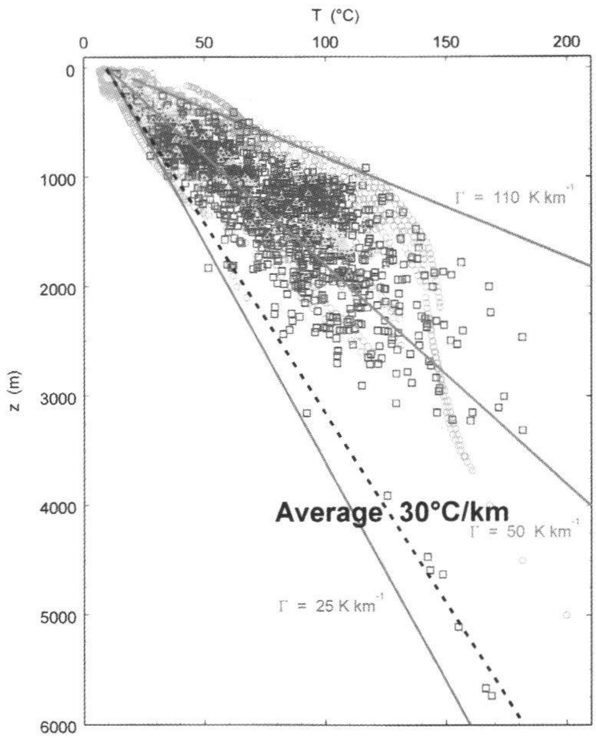

Fig. 1: Compilation of borehole temperature measurements in the Rhine Graben (from Münch et al 2005; modified). Most data plot above the average geothermal gradient line with 30° C/km.

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Summary of a talk given at the VSP/ASP annual convention, Rheinfelden, Switzerland, June 2006.

1994 and was later extended into Lörrach in Germany (Oppermann 2001). Nowadays there is a large number of geothermal projects, especially in Germany, at various stages of planning and realisation (Table 1; a further 26 projects have been initiated). Hopefully they will be successful.

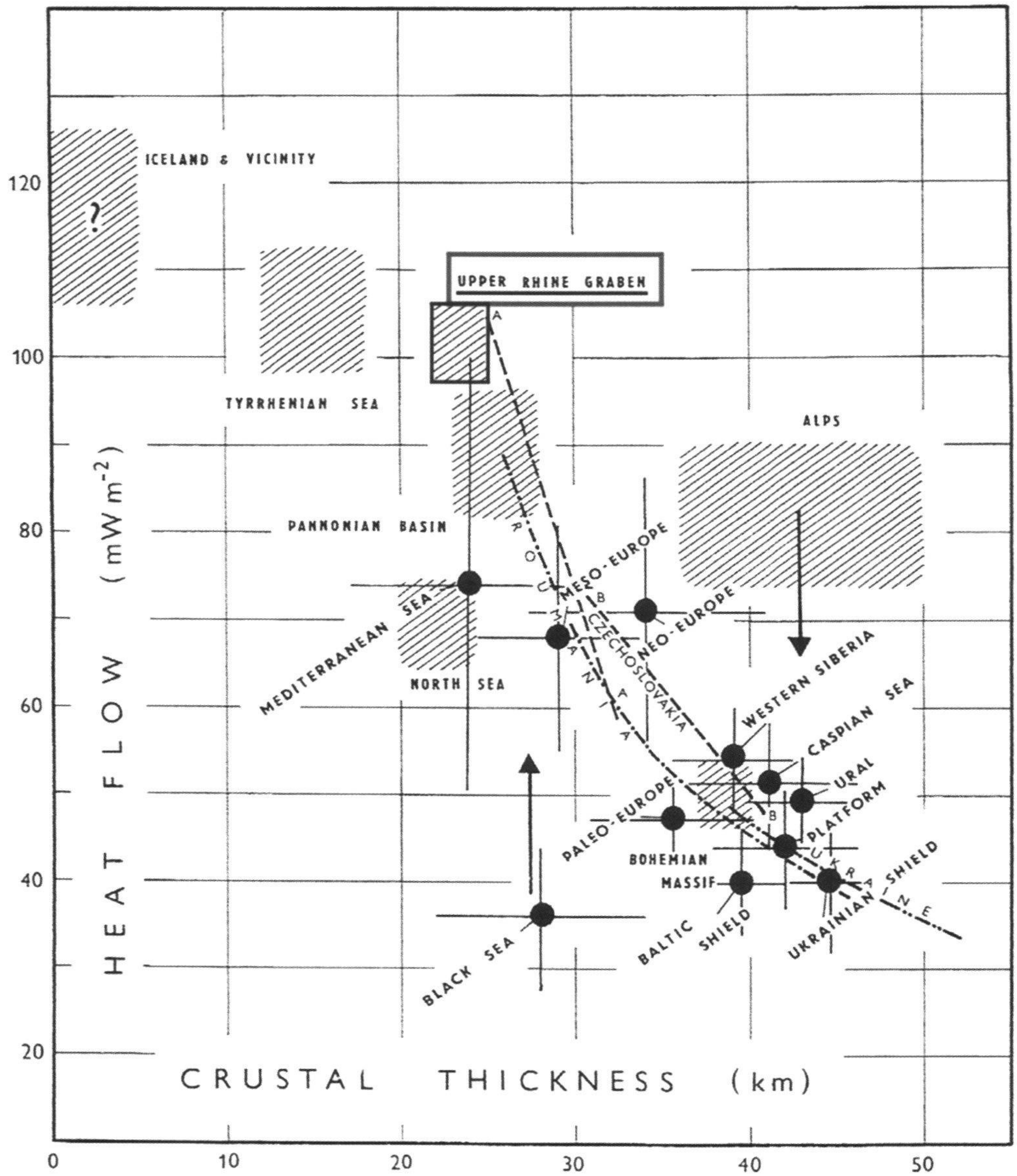

Fig. 2: The Rhine Graben heat flow data (see box) confirm the general rule of decrease with increasing crustal thickness (early data from Čermák & Rybach 1979; later confirmed by new measurements of Clauser & Villinger 1995).

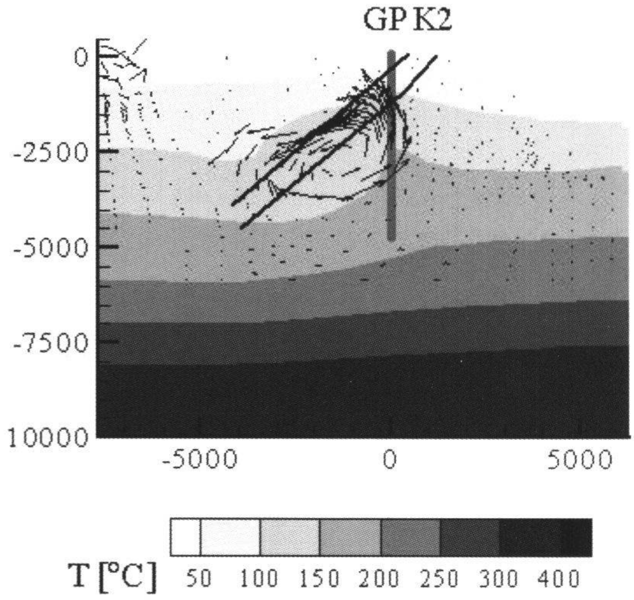

Fig. 3: Convection cell with details of the temperature and fluid flow field in the realm of well GPK2 at Soultz-sous-Forêts, France; result of numerical model calculations to fit the borehole temperature measurements in GPK2 (see Fig. 4). The flow velocities in the central model domain have been scaled down by a factor of 20 in order to represent even smaller components. The maximum fluid (= water) velocities exceed several cm/year. From Kohl et al. 2000.

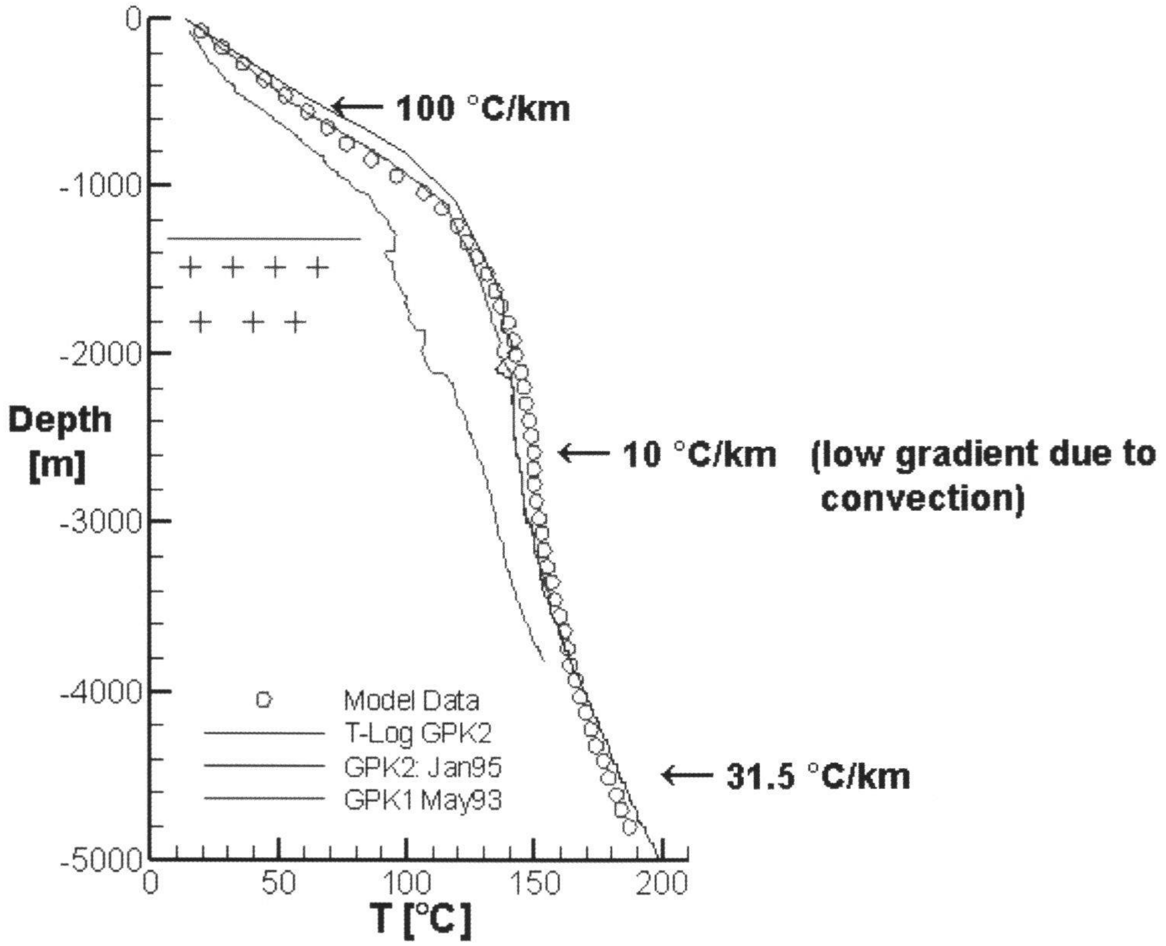

Fig. 4: Temperature logs in the well GPK2 at Soultz-sous-Forêts, France: Comparison of measured (solid lines) and modelled (circles) temperatures. Convection causes high near-surface gradients, low gradients below and normal values further down. Crystalline basement top is also indicated. From Kohl et al. (2000), modified.

Project	Horizons	Depth	Temp.	Flow	Power	Status
Bruchsal	Buntsandstone	2000 m	130° C	> 20 l/s	500 kW	Circulating Power plant installation
Speyer	Buntsandstone	2900 m	150° C	> 20 l/s/well	5.4 MW	9 wells planned 1st well completed
Offenbach	Muschelkalk	2800 m	150° C	100 l/s	4.8 MW	1st well completed
Bellheim	Muschelkalk	ca. 2900 m, drilling	?	80-100 l/s	ca. 5 MW	1st well completed
Riedstadt	Rotliegendes	2300 m	140° C	70 l/s	3 MW	Early preparation phase
Karlsruhe	Muschelkalk	3100 m	150° C	75 l/s	2.8 MW	Early preparation phase
Landau	Muschelkalk Buntsandstone Granite	3000 m	150° C	70 l/s	2.5 MW	1st well completed 2nd well in progress
Kehl	?	2500-3000 m	130° C	20-30 l/s	?	Early preparation phase
Ettenheim	Crystalline	5000 m	170° C	?	3-5 MW	Feasibility study

Tab. 1: Some geothermal utilization projects in the Rhine Graben (status February 2006, from Baumgärtner 2006).

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