# Rocks that are too hot to handle

SIR—It has recently been announced[1,2] that the German Science Foundation (DFG) project to drill a bore-hole (KTB) 14-km deep to investigate the deep structure of the Earth's crust has had to modify its objectives, because the unexpectedly high temperatures encountered (about 110 °C at depths of 3,700 m)[3] indicate that at the target depth the rock will be too hot to drill. This is despite the fact that the drilling site in the Oberpfalz (see figure) was chosen because of the predicted low temperatures at depth.

Questions arise as to why these predictions[4], made on the basis of thermal conductivity, magnetic, magnetolluric and seismic reflection studies, were misleading, and whether the present situation could have been predicted by other means. Shortly before the final choice of site was made, we performed isotope analyses of trace amounts of helium dissolved in deep well waters in the Oberpfalz area[5]. We expected to find $^3He/^4He$ values close to $10^{-8}$, the average natural production ratio for He in the crust. To our surprise we measured some values greater than $10^{-6}$ (see table). In the absence of excess $^3He$ derived from the decay of tritium generated by atmospheric testing of nuclear weapons, this could be explained only by the presence of a significant proportion of primordial He released from the Earth's mantle. This situation is most commonly found in active volcanic regions, particularly the axial zones of actively spreading mid-ocean ridges, which have a $^3He/^4He$ ratio of around $10^{-5}$.

These were some of the highest ratios then measured in continental Europe. We took further samples from the Egergraben, a young half-graben structure that displays clear evidence of recent volcanic activity. Here the values were higher still (see table), very close to those on ocean ridges. The rift is 150 km long and trends ENE–WSW directly into the Oberpfalz.

We concluded[6] that the only plausible explanation of such He compositions in continental areas was that they had been modified by transient releases of mantle-derived volatiles associated with the emplacement of basaltic magmas in the crust. It is possible that the Egergraben rift is propagating to the west, that we are detecting the precursors to that process and that He serves as a tracer for a geological process that is otherwise undetectable (E.G., R.K.O'N. and E.R.O., manuscript in preparation). Moreover, we showed that if the contemporary emplacement of basalt was as widespread as He measurements made throughout Europe indicated, over geological time such emplacement has probably made a major contribution to the growth of the continents[7].

The observations of high temperatures in the Oberpfalz seem to provide some support for our hypothesis. They could, however, have a completely different explanation: abnormal crustal concentrations of heat-producing elements or refraction of heat flow by complex geological structures are both conceivable, but neither quantitatively explains the observations. Their contribution should, however, become apparent from further drilling, which should also show whether the temperatures have been raised above conductive equilibrium values by hot fluids ascending convectively through fissures and pore spaces in the rocks.

If the emplacement of magmas was too recent for them to have yet crystallized, they will still be at a temperature of about 1,000 K and the thermal gradient will steepen rapidly as the magmatic body is approached. If the body has solidified sufficiently, it may be possible to drill into it. In either case the body is probably sufficiently young for the thermal transient associated with its emplacement not to have yet reached the surface and for the helium degassed from it not to have entirely dissipated. The thermal anomaly observed could thus be generated by a family of igneous bodies that might be the forerunners of surface volcanoes such as are seen in the Egergraben.

Our prediction, based on the He measurements, that the KTB Project "drilling will provide some surprises"[6] seems to have been vindicated[8].

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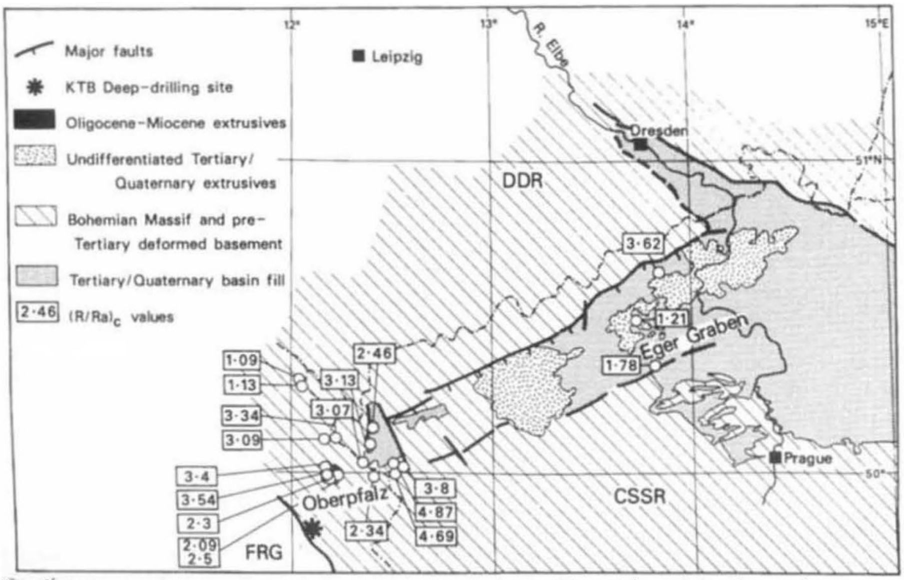
Helium isotope composition of $CO_2$-rich waters and gases from the Oberpfalz and the Egergraben.

| Location | g/w* | He/Ne | $(R/R_a)_c$† | % mantle helium‡ |
|---|---|---|---|---|
| **Bohemian massif** | | | | |
| *Oberpfalz, Fichtelgebirge (FRG)* | | | | |
| Kondrau | w | 29 | 3.07 | 35.5 |
| Thiersheim | w | 35 | 3.09 | 35.7 |
| Pechofen-holzel | w | 5 | 2.09 | 24.2 |
| Sophien-reuth | w | 47 | 2.50 | 28.9 |
| Hohenberg | w | 8 | 3.34 | 38.6 |
| Pechbrunn | w | 49 | 3.54 | 40.9 |
| Neualben-reuth | w | 366 | 2.34 | 27.0 |
| Marxgrun | w | 22 | 1.13 | 13.1 |
| Wiesau | w | 2 | 2.30 | 26.6 |
| Alexanders-bad | g | 84 | 3.40 | 39.3 |
| Mahring | w | 8 | 0.66 | 7.6 |
| Bad Steben | w | 184 | 1.09 | 12.6 |
| Nagel | w | 8 | 0.66 | 7.6 |
| *Egergraben (CSSR)* | | | | |
| Kynzvart | g | 9 | 3.80 | 43.9 |
| Cheb | g | 84 | 3.13 | 36.2 |
| Smardock | g | 3 | 4.69 | 54.2 |
| Bilina | g | 3 | 1.21 | 14.0 |
| Soos | g | 4 | 2.46 | 28.4 |
| Podebrady | g | 4 | 0.90 | 10.4 |
| Louny | g | 481 | 1.78 | 20.6 |
| Prameny | g | 2 | 4.87 | 56.3 |
| Teplice | g | 14 | 3.62 | 41.8 |

* Water or gas sample.
† Measured $^3He/^4He$ ratio in the crust, normalized to that in air ($R_a$).
‡ Percentage mantle helium calculated according to: mantle He (%) = $((R/R_a)_c \times R_a - R_c) \times 100/(R_m - R_c)$, with $R_a = 1.4 \times 10^{-6}$, $R_c$($^3He/^4He$ ratio of radiogenic helium produced in the crust) = $1.5 \times 10^{-8}$ and $R_m$($^3He/^4He$ in mantle) = $1.2 \times 10^{-5}$.




$^3He/^4He$ ratios $R$ (given relative to the ratio in air, $R_a$) in the Oberpfalz and the Egergraben.

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