GERMAN APPROACHES TO CONTINENTAL DEEP DRILLING

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For most earth scientists outside the USSR, plans for deep continental crustal drilling seem unrealistic. It will be even harder to convince money-spending organizations or personalities of their feasibility. Therefore, we ourselves should continually have in mind an introduction to lectures that Patrick Winston from MIT uses to sell Artificial Intelligence: "If you are a skeptic, I want to make you a believer – and if you are a believer, I want to make you a skeptic."

Aims

As skeptics, we all know that the different catalogues of aims for deep continental drilling that we would like to achieve have some Utopian aspects. This may even be true for two general ideas some of us promote in Germany.

1. Deep continental drilling, as a project for basic science, should be launched as a demonstration that earth sciences need to become as important sciences as some others, which spend much more money, but have a longer tradition of cooperation, such as nuclear physics or space research.

In Germany, we are stimulated by the historical success of the Deep Sea Drilling Project and thus some members of the Senate Commission for Geoscientific Cooperative Research (Geo-Commission) of the Deutsche Forschungsgemeinschaft (DFG), an organization similar to the National Science Foundation of the U.S., began relevant discussions in 1977. A memorandum was presented to our Minister for Science and Technology (BMFT) in July 1980 and was published as Report XI of the Geo-Commission in 1981. It was a very timely memorandum because a Peer Committee of the Ministry was just setting priorities for big projects in basic sciences such as neutron research, heavy ions, elementary particles, and synchroton radiation, and they added a research vessel and the drilling proposal to their discussion.

2. A large project is normally a good tool to focus scientific potential from different specialities and to expose them to critical comments. Whoever was lucky enough to spend some time aboard *Glomar Challenger* will certainly agree.

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Observation of the Continental Crust through Drilling I (ed. by C.B. Raleigh)

3. Specific scientific aims and tasks for deep continental drillers are listed in many catalogues. Some topics in *our* list are:

- to explain geophysical crust heterogeneities (as illustrated by seismic velocities, electric resistance, magnetic properties) by petrological studies, in situ measurements and laboratory experiments to better calibrate existing or planned geophysical surveys and to better understand materials and structures of the upper and lower continental crust, whatever these units may mean.

- to investigate gas/fluid/rock interactions in situ and in the laboratory by analyzing crustal permeabilities, constituents, transport of the mobile phases to better understand crustal deformation, metamorphism, magma generation and ore formation, to pay special attention to the thermal regime in general and around 300°C and to try to learn for Hot Dry Rock Projects.

- to measure physical parameters in order to expand our knowledge of stresses in different crust depths, of earthquake mechanisms, and of geotechnical behaviour of the crust.

- to prepare methods to use the bore-hole as deep crust lab as long as possible, measuring suitable geophysical or geochemical parameters in situ repeatedly. Final depths should be more than 10,000 m.

Site Selection

To meet all these requirements, it would be ideal to drill at different sites with different aims, as it is planned in the USA. We try to concentrate first on a single hole and to select a site to reach the lower continental crust where we can hope to get some results for all of the aims mentioned above. After detailed discussions of some 40 site proposals by several working parties and a reduction of four sites (Figs. 1 and 2), an international workshop in Neustadt/Weinstraße (November 1983) recommended to continue geoscientific investigations in two areas, and to promote further methodological and technological preparations. Up to now, the DFG has spent 4 million DM from special funds of the Ministry (BMFT) on some of these scientific preparations (1981-1983), and will continue to do so. Final decision for the first drill site is planned in late 1985.

Our central European crystalline basement, as part of our roughly 30 km thick crust, is as variegated as political Europe and has the same complicated history.

1. Different elements were consolidated during several Precambrian and during Caledonian and Hercynian cycles (Fig. 3). Parts were repeatedly remobilized as illustrated by sometimes very long ranges in absolute age datings.

2. Most of these rocks are buried in Central Europe or are additionally influenced by Alpine cycles. Bigger outcrops of crystalline rocks are only to be found in areas uplifted and eroded essentially in Cenozoic time, as, for example, in the Black Forest and in the forests bordering the Bohemian Massif, besides the smaller Harz, Spessart, and Odenwald mountains (Fig. 4).

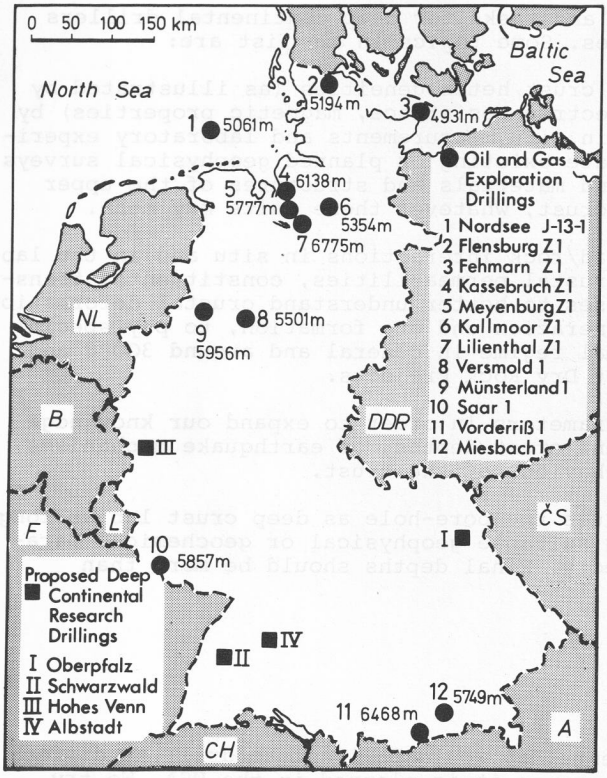

Fig. 1. Location of oil and gas exploration drillings deeper than 5000 m *(dots)*, and locations of discussed deep continental research drill sites *(squares)* in the Federal Republik of Germany. (After Vidal et al. 1981)

Direct information from covered crystalline rocks from oil industry bore-holes penetrating the sedimentary sequences or from xenoliths is rare.

Therefore, in November 1983, the Geocommission and the International Consulting Committee recommended both an eastern (Oberpfalz = Upper Palatinate) and a western site area (Schwarzwald = Black Forest) (Figs. 4 and 5) to be further investigated by continuous seismic reflection and further geological, geophysical, geothermal, geochemical, and petrological exploration. Additionally, shallower holes in both areas should give better estimates of temperature and, eventually, geochemical gradients. The pre-site surveys are in a final stage now.

Up to now, both areas have their pros and cons depending on the main aims to be achieved and we have now a neutral situation because, considering our present state of knowledge, it is easy to predict that both sites will produce surprises. In both areas mineralizations, thermal and CO_2 springs are known. In the Black Forest, granulites in the gneisses signal deeper crustal rocks. The central part is a young uplift and very active present circulation of fluids is obvious. But perhaps interesting messages from the mantle were therefore lost.

The Oberpfalz situation is a more sealed one but perhaps also tectonically a more complicated one, situated near the boundary (suture line) of two classic units of the Variscan Central European Cordillera (see Fig. 4).

DSDP ODP CONTINENTAL DEEP DRILLING

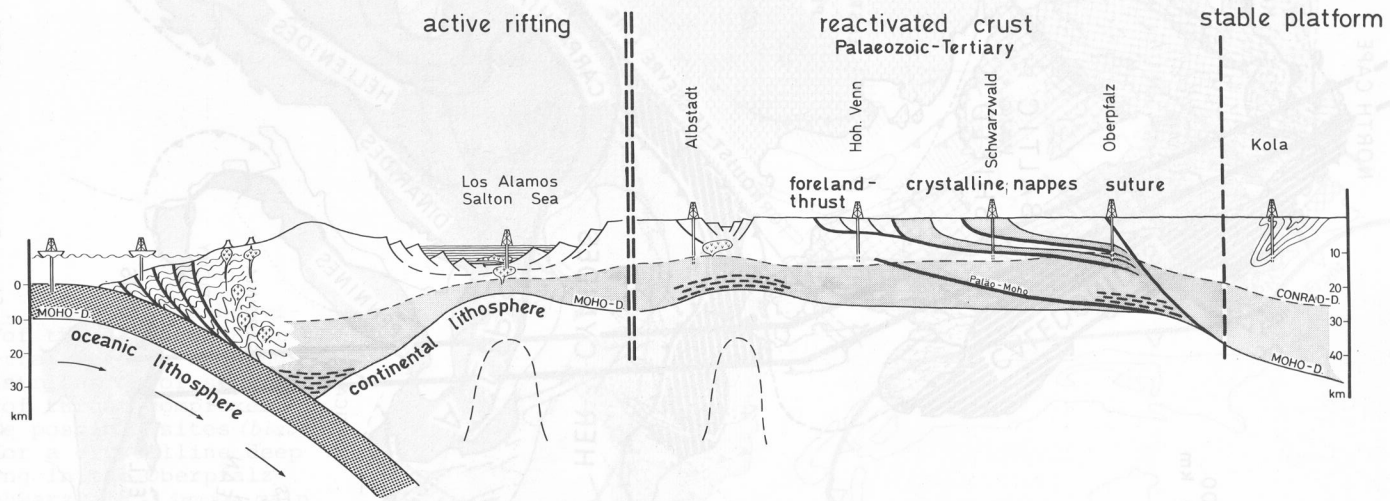

Fig. 2. Schematic overview of the position of deep drilling projects in the oceanic and continental crust. The present and planned borings for scientific purposes are situated in various types of crust. The Ocean Drilling Program (ODP) as a successor of the Deep Sea Drilling Program (DSDP) is aimed preferably at the transitional zone from oceanic to continental crust. In addition to geothermal borings (Los Alamos), continental deep drillings mainly serve to the exploration of crustal structures (Althaus et al. 1984b)

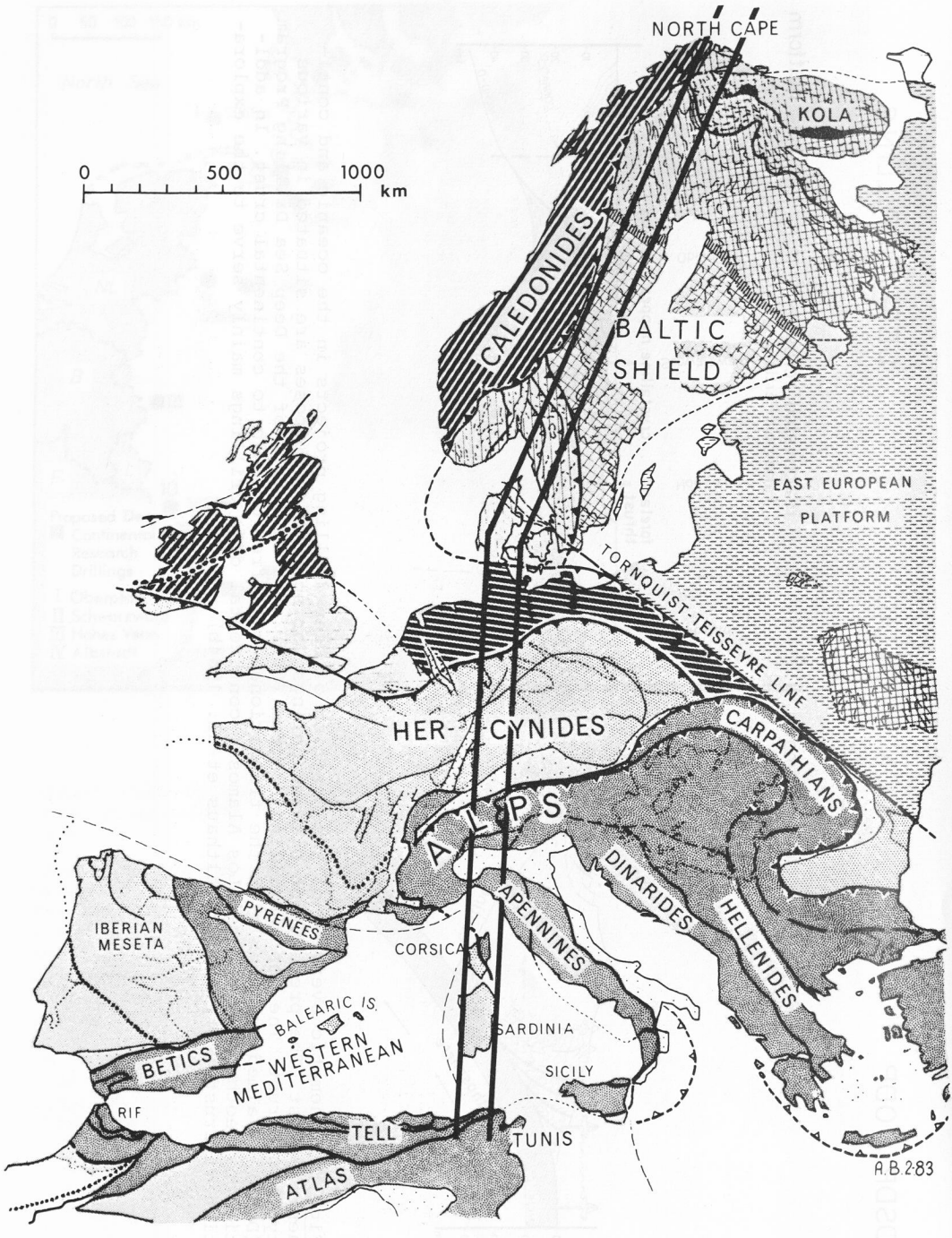

Fig. 3. Main Tectonic units of Europe (after Berthelsen 1983) and the area of the European Geotraverse EGT. (Giese 1983)

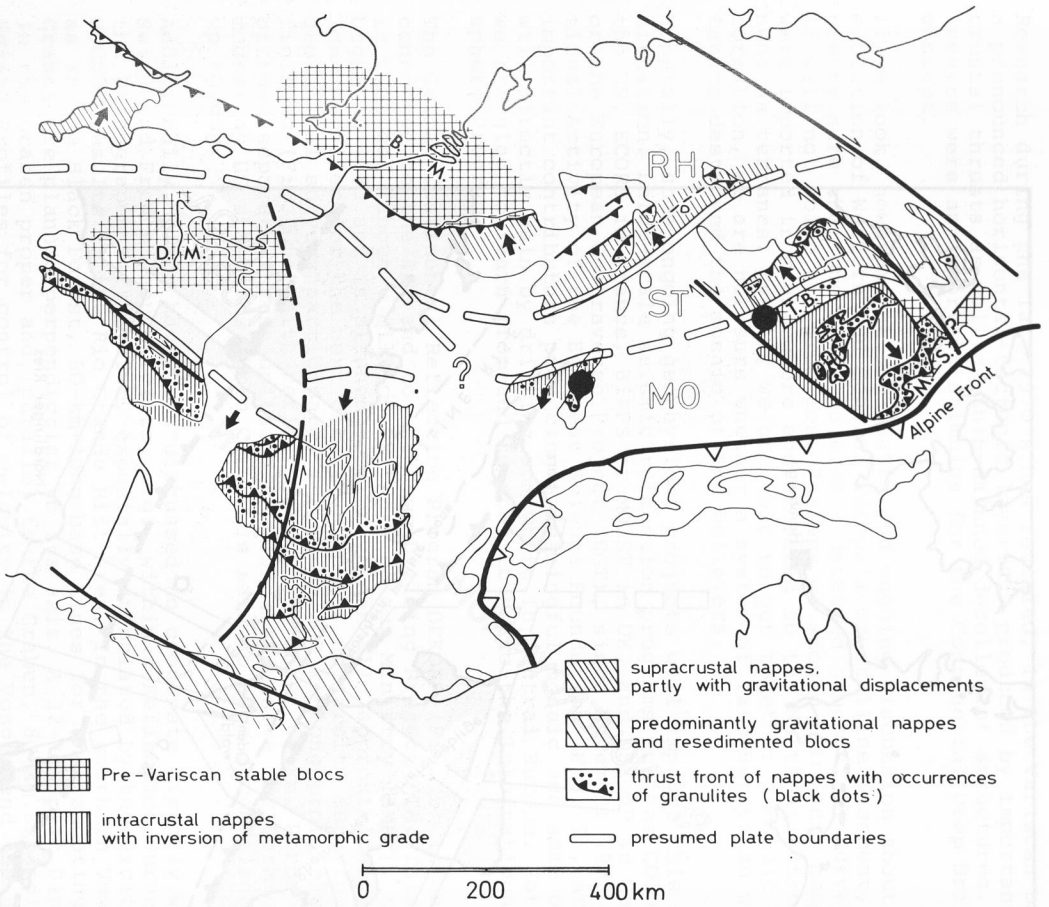

Fig. 4. Structural subdivisions of the Variscan Belt of Central Europe, showing the distribution of several types of thrust complexes and the possible sites *(black dots)* for a crystalline deep drilling in the Oberpfalz and Schwarzwald. *Arrows* main transport direction; *RH* Rhenohercynian Zone; *ST* Saxothuringian Zone; *MO* Moldanubian Region; *L.B.M.* London/Brabant Massif (Caledonian); *D.M.* Domnoneo-Mancellian (Cadomian) and Icartien (Lower Proterozoic); *T.P.* Tepla/Barrandean (Cadomian); *M.S.* Moravo-Silesian (Cadomian). (After Behr et al. 1984)

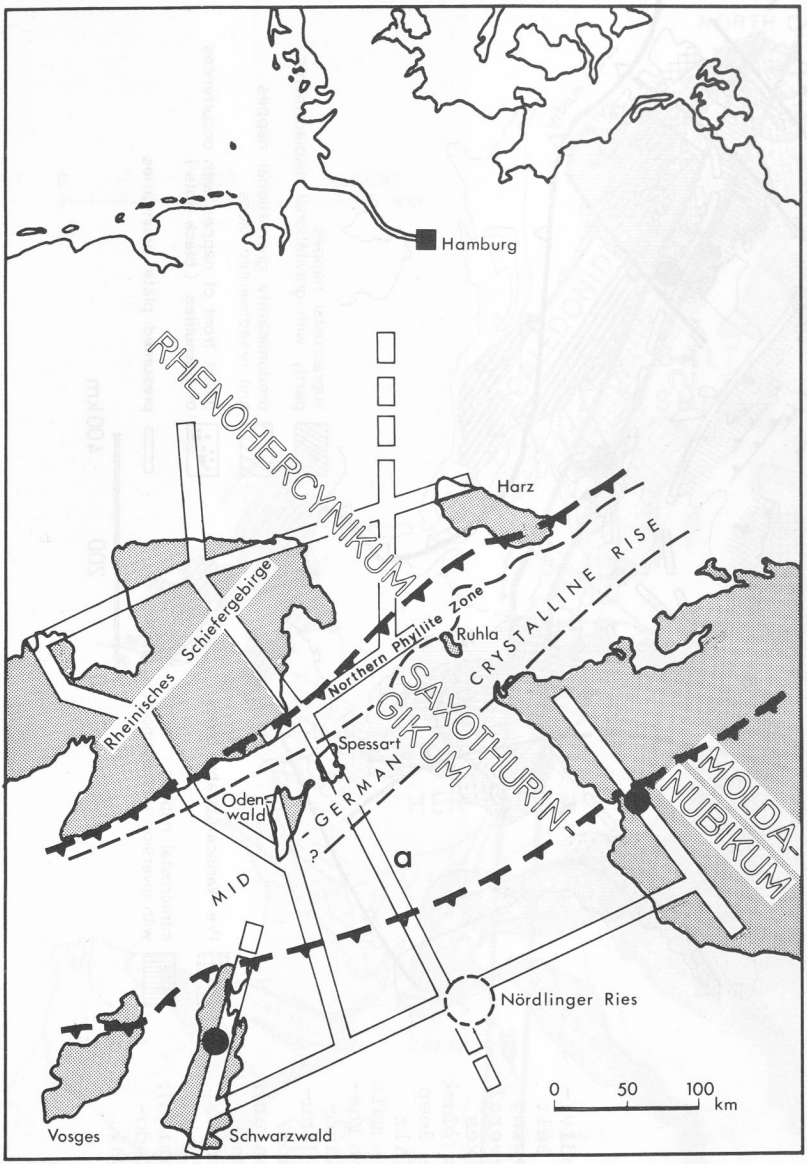

Fig. 5. The German Continental Reflection-Seismic Program traverses (DEKORP) with the possible deep drilling sites Oberpfalz and Schwarzwald. (After Althaus et al. 1984a)

Research during the late 1970's has revealed, in the Variscan basement, a pronounced horizontal-tectonic layering, produced by important intracrustal thrusts as well as thin-skinned decollement structures. These results were an important stimulus for the Continental Deep Drilling concept.

If we look, however, at the heated and ongoing discussion about the evolution of Western and Central Europe's crystalline basement, it is pretty sure that one hole and even a detailed geophysical survey around it will not solve all problems. Perhaps we should learn that many parts were imported from elsewhere and accreted to the North Atlantic Continent as terranes. Even if we are able to put together a mosaic of information, we are not sure whether a system of late Hercynian wrench faults destroyed the mosaic of the believers.

Hopefully, some ongoing geophysical projects will improve this complex situation. Large-scale seismic reflection programs such as COCORP in the US, ECORS in France, BIRPS or MOIST in UK, and DEKORP in Germany, or the European Geotraverse Project (EGT), since November 1982 an Additional Activity of the European Science Foundation (Fig. 3), are all important contributors producing a meaningful mosaic and some of them will directly gain by drilling somewhere in Central Europe. Naturally, we are glad to learn from and to contribute to the International Lithosphere Program.

The German Continental Reflection Program DEKORP (Fig. 5) is especially connected to the EGT and to the Deep Drilling Project KTB. This program is financed (about 6 million DM/year) by our Ministry (BMFT), too. It began in 1983 and is planned to produce annually approximately 200 km long profiles for the next decade. Numerous university departments and geological surveys participate. The first 200 km long profile was just finished (Fig. 5, a) with reflectors down to about 60 km. Perhaps some of them separate thrust units. This looks impressive for Germany, but modest by US standards where COCORP is said to have accomplished 5200 km up to now.

Additionally, plans have been discussed to cooperate directly with Swiss and French geophysicists, e.g., within a Reflection Survey of the Rhinegraben Rift System, especially stimulated by the exciting COCORP results in the Rio Grande Rift Area. In the southern Vosges, as in the Black Forest, 60-km-long base lines for undershooting the Graben are planned perpendicular to its axis. A 32-km Split Dip Spread in the Graben proper and, parallel to the Graben, 80-km Expanding Spread Profiles for control of velocity in the Vosges and the Black Forest will complete this experiment.

Even if everything runs smoothly, the results will solve only some old problems and produce many new ones. But enough skepticism. As believers, we easily can predict progress from both drill sites in structural and dynamic geology in general and especially for the bordering area of a continent welded together from Laurentia, now called the US, Canada and Greenland and Fennosarmatia. Therefore, both parts now separated by the Atlantic should be interested.

All the other aims such as research in fluids, heat, stresses, deep crustal labs, are valid for all deep holes planned or drilled in Laurentia and Fennosarmatia. Hopefully, all of them will add exciting and surprising results to the Kola-Drill-Hole results that we have heard about up to now.

Problems

Up to now, we were optimists and we have to continue to be optimistic when we mention some more open problems.

1. Is the German scientific potential sufficient for such a large experiment?

In a general way, we hope so. The DFG, for example, has brought together during the last years scientists with similar problems in special programs like the Priority Program *Vertical Movements and Their Causes as Exemplified in the Rheinische Schild Area* (1976-1982), or the Göttingen Special Collaborative Program *Earth Crust* (1969-1981). Recently, books like *Plateau Uplift* or *Intracontinental Fold Belts* have summarized the results. An active Priority Program *Kinematics of Rock-Forming Processes* will be terminated 1986. Furthermore, we shall take care to develop and to finance accompanying scientific programs to strengthen the potential for evaluating the drilling as the Priority Program *Lower Continental Crust* or the Special Collaborative Program 108 *Stress in the Lithosphere* in Karlsruhe.

Nevertheless, we hope that many colleagues from abroad can be encouraged to contribute with their own ideas, to participate in measurements and in the evaluation of geophysical, geochemical, petrological data and materials.

2. What is the technological state of the art?

Although previous experience with drilling and measuring at such depths is limited, the consulting committee is optimistic to be able to cope with electronics and measurement techniques under possible aggressive fluids, high pressures and temperatures above about 250°C. To get better ideas about the temperature gradient to be expected, a ca. 2500 m deep preliminary drill hole is planned at the final drill site before the actual deep drilling begins. It allows a geological study of the uppermost profile sections in which afterwards a casing must be set.

Naturally, many technical problems remain. For example, up to now, even in German sediment deep drill holes, the drill bit touched the rocks only 36.8% of the time.

3. What are the ideas for managing such an experiment?

Several models have been discussed. Some of them are very much related to the Deep Sea Drilling Project. Ideally, the organization should:

- guarantee close cooperation of universities, Geological Surveys, and industry,
- enable foreign participation,
- guarantee for the next decade effective continued preparation, drilling, evaluation, and publication of the results,
- take care of follow-up like deep crustal lab studies or further research with the core material and other data.

4. What are the estimated costs?

Again, we are both skeptics and believers. Skeptic towards all existent figures between 100 and 500 million marks, and believers that earth scientists could use much more and spend the money well.

Acknowledgments. Planning of research of this magnitude and breadth could not have been carried out without the help and goodwill of many persons and institutions.

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