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Report

The Kola Super-deep Borehole SG-3— First Look at the Deepest Hole of the World

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Introduction

In the last decades international and interdisciplinary geoscientific research projects such as "Upper Mantle Project", "Geodynamic Project" and "Deep Sea Drilling Project" (DSDP) have substantially contributed to better understanding of the earth's structure and development. The theory of Plate Tectonics in particular very much benefitted from this. While DSDP was focused on the oceanic crust, which is only 150 million years old, the investigation of the much older — four billion years — continental crust is a new and complimentary task of similar or even greater dimension and interest. The cost for such expensive projects may be justified by the need for future mineral and energy resources as well as for developing technologies for their exploitation. The forecast of volcanic and seismic hazards would be additional aspects.

In 1962 the Soviet Union established an "Interdepartmental Scientific Council" on "The Investigation of the Earth's Interior and Super-Deep Drilling". More than 20 ministries, agencies and the USSR Academy of Sciences are represented in this Council. Similar activities are going on in other countries more or less simultaneously. In the Federal Republic of Germany the "Geokommission" of the German Research Society (DFG) has launched in 1978 a continental deep-drilling programme (KTB). The final decision for the location of the first super deep hole is expected in 1985/86. Similar activities are in operation in France carried out by the "Bureau de Recherches Géologieque et Minieres" (BRGM) and the "Centre National de la Recherche Scientifique" (CNRS) backed by the French government. The USA stand by. A 10 km deep drilling operation is proposed in 1985 in the southern Appalachians. Similar efforts are known from Australia, Canada, Iceland, Japan, Sweden, Switzerland and UK. In consequence of these developments the "International Union of Geodesy and Geophysics" (IUGG) and the "International Union of Geological Sciences" (IUGS) have jointly established in 1981 a Coordinating Committee "Continental Drilling" within their international and interdisciplinary new project "Dynamics, Composition and Evolution of the Lithosphere", abbreviated "The International Lithosphere Program" (ILP).

Currently the Soviets lead the way

In connexion with the International Geological Congress in August 1984 in Moscow the USSR Ministry of Geology has invited a small number (31) of distinguished international geoscientists to take a look at the deepest borehole of the world: the Kola super-deep hole SG-3 near the mining town of Zapoliarny, located 110 km NW of Murmansk in the Pechenga (formerly Petsamo) copper-nickel mining district (Fig 1). SG-3 is the first of eleven deep and super-deep boreholes, that should elucidate the deep geological structure and assist the search for mineral deposits. These key boreholes are part of a network of long seismic profiles covering the USSR territory.

Kola SG-3 began to drill in May 1970. Nine years later, on June 6, 1979 it had reached a depth of 9,584 m and had therewith beaten the existing deep drilling record held by the hydrocarbon well Bertha Rogers in Oklahoma, USA. On August 10, 1984 Kola SG-3 was drilling at a depth of 12,046 m. After another five years the envisaged target of 15,000 m may be reached.

Some technical, geological and geophysical details

In the sixties the USSR began to develop home-made technologies for super-deep drilling and geological and geophysical logging in boreholes 10–15 km deep. Kola SG-3 is being drilled by means of the so-called turbo-drill method with continuous coring. The bit (215 mm diameter) is rotated by a downhole turbine set in motion by the pressure of the mud in combination with a high-torque gear. By this the drill pipe string is not rotated. Light weight aluminium alloy pipes instead of steel pipes are used. The roundtrip-operations (retrieval and reinsertion of the 12 km drill pipe) takes not more than 18 hrs. Special instruments control and record more than 30 drilling operations and data. For the first time in the USSR a home-made bottom-placed telemetering system is successfully employed. The information from the bottom is transmitted to the surface via a hydraulic communication channel. The hole is uncased. Due to a heavy waterinflow in 1,800 m it must be cased later down to a depth of 2,000 m. The well dip was calculated to be less than $1^{o}30'$ per 1,000 m. The average dip over the whole depth is 10^{o}. That means a horizontal deviation of 560 m in 11,000 m and, due to dipping and stress increasing with depth, 750 m in 12,000 m.

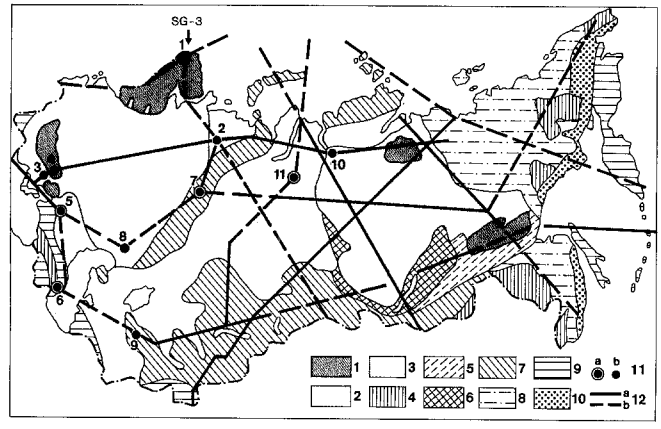

Fig 1 Location of deep and super-deep boreholes and deep seismic profiles in the USSR

1 — Kola SG-3; 2— Timan-Pechora; 3 — Krivoi Rog; 4— Dnieper-Don; 5 — Kuban; 6 — Saatly; 7 — Urals; 8 — Caspian Area; 9 — Muruntay; 10 — Norilsk; 11 — Tyumen

Geologic areas: 1 — schields; 2 — old platforms; 3 — young platforms; 4 — median massifs; 5 — Prebaikalian; 6 — Baikalian; 7 — Palaeozoic; 8 — Mesozoic; 9 — Kainozoic (5–9: folded areas); 10 — volcanogenic belts; 1 — boreholes (a: super-deep; b: deep), numbers identify location; 12— deep seismic profiles (a: accomplished; b: designate)

The hole has sunk a Proterozoic complex down to 6,842 m. It shows four phases of development: (1) formation of the Archean basement; (2) subplatform accumulation of andesite-basaltic products and sandy-carbonate sediments; (3) picrite-basaltic volcanism and subsequent ultrabasic intrusions; (4) folding and metamorphism at temperatures between 300°C and 600°C with a geothermal gradient of 10°C per 100 m.

Between 6,842 m and 12,000 m the Archean gneissic-granite complex is up to 66 % represented by rhythmically bedded sequences of biotite and two-mica plagio-gneisses. These rocks have experienced folding and metamorphism at 750–900°C and 500–110 MPa about 2,700–2,800 years ago.

Ultrabasic intrusions with copper-nickel sulphide ores (Sudbury type) which are mined in open cast mines on the Kola peninsula were also found in similar composition in depths of 1,500–1,800 m.

Indications of magnetite, phlogopite and muscovite mineralization have been found deeper than 9.500 m. Thick zones of crushed rocks were sunk between 4,500 and 11,000 m, the rock fragments being cemented by quartz, calcite and sulphides of copper, iron, lead, zinc, nickel and cobalt. From this it can be assumed that in depths deeper than 5,000 m the formation of hydrothermal ore deposits is possible.

Contrary to the hitherto opinion, in depths deeper than 4,500 m tectonically heavily stressed rocks have been found with a relatively high permeability and with a circulation of highly mineralized fluids with bromine, iodine and some heavy metals. They contain also gases (He, H, N, CH_4 and other hydrocarbons). According to isotope dating the CO_2 is partly Archean gas, i.e., mantle-derived, partly of biogenic nature (Proterozoic gas). Traces of very early life are represented by micro-fossils in sandstones and conglomerates of two billion years old metamorphic rocks.

Considerable discrepancies have been discovered between seismic profiling and other geophysical data and the facts provided by the drilling results. So the "basaltic layer" (Conrad Discontinuity) was predicted at a depth of about 7,000 m, but the hole penetrated in 6,842 m into granites and gneisses, strongly metamorphosed up to the granulitic stage. The existence of a low velocity zone between 4,500 and 9,000 m was found with inversion of velocity and density. This mighty low-velocity-channel may be responsible for processes of metamorphism and granitisation, for the ore mineral zoning and for the distribution of radioactive elements. Zones with an extreme concentration of U, Th and K have been found in connection with secondary microcline granites.

Geothermal measurements carried out on the surface in the vicinity of the Kola location have shown a geothermal gradient of 1°C/100 m. The hole has shown a gradient of 2.5°C in a depth of 3,000 m. In 12,000 m a temperature of 205°C was measured on the bottom of the hole. From this it can be assumed that the old crystalline shields may be not as "cool" as it is usually supposed.

There are surely many other interesting results, that cannot be mentioned in this summarizing report. The voluminous book (490 pages) about the Kola super-deep hole, published by the Ministry of Geology of the USSR at the occasion of the International Geological Congress in Moscow will surely contain much more details. It is a great pity that it is written exclusively in Russian. The geoscientists of the world will be very eager to have an English translation as soon as possible.

The USSR super-deep drilling project Kola SG-3 on the Kola peninsula will be, without any doubt, a milestone in the development of super-deep drilling technology as well as in the history of the studies of the deep structures and composition of the continental crust by super-deep drilling.