Geophysics

Continental interior in view

from Roger N. Anderson

ANOTHER frontier of geological exploration may at last be yielding to curiosity and advancing technology. After the great geological expeditions to the Moon, and dramatic discoveries of the ocean floor made over the last twenty years, the attention of a surprisingly large number of geologists worldwide is turning back to the original geological problem: the internal workings of the continents.

We know very little about how the continents form and deform. What we infer comes from remote-sensing with the use of classical geophysical and geochemical techniques such as seismology, gravity, petrology and mineralogy. But the sources of these observations are always at the surface. Although we can build elaborate models of the continental interiors, we shall never be able to verify these concepts without looking inside the continents. Experiments to this end are now being planned in several countries. The tool used to sample the inside of the Earth is the drillbit.

A remarkable coincidence of planning means that several countries will begin programmes of deep crustal drilling in 1986. German plans, outlined by E. Seibold at a conference* earlier this year, are to drill to at least 7 km through the Hycenian overthrust in the Black Forest. The aim is to understand how huge masses of rock could have slid several hundred kilometres over only slight slopes in the geological past. High pore pressures are suspected essentially to have floated these masses over other rock, but not a single measurement of pore pressure is yet available from such a shear zone. Scientists in Sweden, the United States, France, Austria and Japan are also planning to begin deep continental drilling in 1986.

Why are so many national programmes focusing on the drillbit at about the same time? Technology is probably the major driving factor. The international oil industry has developed in the drillbit a remarkable technology ideally suited for geological purposes as well as for hydrocarbon exploration. F. Schuh (Atlantic Richfield), for example, presented the conference with an entirely feasible design for a 50,000 foot well into crystalline rock. Several speakers (including G. Olhoeft and B. Dennis, US Geological Survey; P. Lysne, Sandia; M. Mathews, Los Alamos) offered a staggering array of geophysical and geochemical measurements and *in situ* experiments that can now be accomplished in a deep hole. It is now possible to measure

accurately the pore pressure, permeability, electrical and thermal conductivity, sonic, ultrasonic and seismic character of the wellbore as well as the exact chemical composition of the rock and pore fluids that are being drilled through.

It was not just these visions of technology that captured imaginations at the conference but also the accomplishments of continental drilling projects already well underway. Although not in attendance, the Russians dominated this phase of the meeting. They have been drilling deep into the continent for over 10 years, and at one hole on the Kola peninsula, they have made extraordinary discoveries. The current dogma holds that the deep crust is void of minerals and fluids because fractures, abundant at the surface, cannot remain open to fluid flow at great pressures. The Russians have found just the opposite: at 13 km depth, they encountered open fractures, mineralization and abundant evidence of fluid transport. They even discovered liquid sulphur, which is hydrolysed in the drilling mud to form sulphuric acid which eats away their drillbit.

The highlight of the conference was P. Robinson's (Dalhousie University) report of results from an international group, supported by Canada, the UK and US, that is drilling through the Troodos Ophiolite on Cyprus. Deep penetration of the pillow basalts and underlying sheeted dike com-

plex, has shown that Troodos is made neither from ordinary sea floor, nor from back-arc basin sea floor as has long been thought, but is instead the inside of an island arc. Moreover, M. Salisbury (Scripps Institution of Oceanography), using technology supplied by the British company British Plaster Board, has conducted a complete suite of geophysical measurements inside the hole, or logs. This revealed that the internal plumbing of an island arc produces layered structures almost identical to the crustal layers of the ocean floor. Hence the mistaken origin of the complex.

By August 1984, this collaboration had drilled to within 180 m of the MOHO, the seismic discontinuity between the Earth's crust and mantle. The penetration of that barrier — originally the aim of the Deep Sea Drilling Project — now looks likely to be achieved first by the Troodos drilling project. We eagerly await information on what lies beneath it.

The conference ended with an air of great optimism. Participants had heard from Bob Luth (Sandia) of a greater than 1 m penetration of magma inside Kiluea Volcano, Hawaii, and from W. Elders (University of California, Riverside) that drilling was about to begin in the 350°C waters of the Salton Sea geothermal area. Our understanding of the Earth was revolutionized by plate tectonics, which arose from exploration of the ocean floor. The exploration of the interior of the continents promises to further that understanding by a similar degree. □

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Archaeology

Kin-groups in Megalithic burials

from C.J. Scarre

MEGALITHIC tombs are among the most impressive neolithic monuments of western Europe, and a principal source of information about social organization in that period. Communal burial was the prevalent rite and in cases in which a tomb has not suffered too severely from the attentions of nineteenth-century antiquarians or been destroyed by a landowner, the archaeologist can expect to find large quantities of human remains. Despite their evident potential, however, analyses of such bone assemblages all too often fail to go beyond estimating the number and stature of the individuals represented and commenting on any obvious traces of injury and disease. How much more information this material holds is vividly demonstrated by the recent work at La Chaussée-Tirancourt, where the study of osteological abnormalities has allowed a series of distinct burial populations to be identified which may correspond to the different kin-groups using

the tomb.

La Chaussée-Tirancourt lies a few kilometres west of Amiens and is a megalithic monument of the 'allée couverte' type, with a burial chamber 9 m long and 2 m wide. By careful excavation over several years, Claude Masset and his team have recovered the remains of 356 individuals, 60 in layer V towards the bottom of the chamber and almost 300 in layer III higher up¹ (see figure). Within layer V, four separate 'zones' of burials were identified, while in layer III the human remains were concentrated in 'cases', which probably had originally been compartments or containers of wood or other organic material long since perished. At the end of its use the tomb was sealed by a substantial deposit of chalk and earth, on the surface of which fierce fires were lit, leaving a thick layer of ash. Curiously, the customary megalithic capstones are absent in this instance: the roofing of the chamber before the final

*Observation of the continental crust through drilling, supported by the US Department of Energy, Geological Survey and National Science Foundation, held in Tarrytown, New York, 20-25 May, 1984.