Letters

Geophysical Research Shaft

A far-reaching modern social development is the massive financial backing which can, with increasing ease, be obtained for organized group attacks on new areas of basic knowledge. One thinks immediately of the large accelerators of the AEC, of the upper-air exploration programs, of the IGY, and of the artificial satellite. In general, none of these programs has immediate economic or national defense purposes; rather, their support by various governmental and private agencies reflects a general understanding of the ultimate utility of all physical knowledge. Although massive public support of science undoubtedly entails some undesirable consequences, the very technologic resources thus made available for scientific purposes mean the opening up of research areas otherwise inaccessible. Scientists in all fields should be aware of this opportunity.

The purpose of this note is to suggest one such possibility: a geophysical penetration of the earth's crust. I am not a geophysicist, nor am I qualified expertly to discuss the novel engineering problems involved. Nevertheless, a comparison of such an exploration with, say, the artificial satellite project (with regard to basic scientific worth, to possible practical uses, and to the expense of developing the technology involved) would seem immediately to confirm the suggestion that crustal penetration should be thought about, discussed, and evaluated by the scientific community. If the consensus is then that such a project would be valuable and feasible, we might expect on the afore-mentioned general grounds to find support forthcoming.

There appear to be many geophysical problems that could be profitably investigated by a physical penetration of the earth's crust and by an examination of the composition, properties, and physical condition of the mantle below the Mohorovičić Discontinuity. Among these are the following. (i) Knowledge of the variation of the earth's magnetic field below the surface could show whether its origin is in the crust or, alternatively, is the result of magnetohydrodynamic mechanisms in the core. (ii) Knowledge of the temperature variation below the surface is important for discussions of the earth's heat balance, radioactivity, and evolution. (iii) Knowledge of pressure, temperature, and density conditions at the outer boundary of the mantle are required for the numerical integrations in geophysical theories of Earth, Venus, and Mars. (iv) Geophysical theories of continent building require knowledge of the ultrabasic mantle material and of its relation to the basalt layer and to the granitic continental basement. (v) Penetration of the crust could shed light on the validity of the isostasy concept; this in turn has important and practical geodetic consequences. (vi) The earth's crust apparently has an unusually high radioactive content; it is important to determine whether this is actually so, and whether the radioactive elements have been fractionated out of the mantle. (vii) Knowledge of the composition of the mantle and, hence, of by far the largest part of the earth's mass is of great interest for astrophysical discussions of cosmic abundances. Furthermore, as in any scientific exploration, one cannot estimate in advance the importance of the new and unexpected phenomena and conditions that would be encountered; for example, it was suggested to me, not necessarily in jest, that the mantle might prove diamondiferous.

The site of the research shaft would be chosen so that the depth of the Mohorovičić Discontinuity was there a minimum. While this indicates drilling from an oceanic island, the logistic convenience of a continental location would also be a factor. Presumably seismic and volcanic complications should be voided. Sedimentary overlay per se is uninteresting, and ground water and other seepages could be avoided by seeking exposed Archean rock. I cannot adequately judge the relative importance of these factors.

It is, however, clear that present well-drilling technology would be inadequate to achieve the vertical depth required—perhaps 10 miles. One might, instead, imagine a small-bore (perhaps 12 inches in diameter, 30° down-slant) shaft, drilled into the granitic and basaltic rock by remote-controlled equipment. The power transmission from surface to drill could be by electric cable; rock removal, by belt or hydraulic means. The temperatures encountered should not be excessive (perhaps a few hundred degrees centigrade); the extreme pressures would probably require the use of heavy drilling muds for hydrostatic compensation.

Although estimation of costs for such a project is extremely difficult until preliminary site surveys and a technologic feasibility study have been made, I might point out that the large-scale rock tunneling on the surface costs perhaps $1 million per mile. We might expect that the proposed small bore, the use of modern remote-controlled instrumentation, and especially the absence of complicating seepage and ventilation problems would greatly reduce the cost from that of conventional tunneling. So this cost might well be commensurate with that of many modern group attacks on other basic areas of science, as is indicated in the first paragraph. I should like to thank James Garvey for many discussions, and for encouragement in this matter.

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Teachers, Second Class?

In the letter by J. W. Still [*Science* **124**, 408 (31 Aug. 1956)] there is an implication that is frequently made by members of university staffs. The concept here implied is that one cannot be an effective teacher unless one worships the deity of research. This is too rarely challenged by those who teach in colleges and secondary schools where research is limited or does not exist. Perhaps the idea has developed because the top positions in the universities are open only to research personnel.

Why is research (of the classical type) essential for effective teaching? Does an expert on mice give a better course in general zoology or even in mammalogy? Does a protozoologist have greater insight into the evolutionary picture? I doubt it. In fact, this may often be a detriment by distorting the balance of the presentation.

There are individuals in any university who are strictly research persons, not because there is no need for them as teachers, but because they cannot teach. We do not call them second-class researchers for this reason. But one who teaches and does not do research is considered second rate.

Actually, a good college teacher keeps up with a far greater variety of scientific literature than the professional research