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Investigations of the Earth’s Crust
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During 1962 March 19–22, thirty-one distinguished geophysicists met under the auspices of UNESCO to discuss informally the present position and future programme for the investigation of the Earth’s crust and Upper Mantle. This booklet preserves these discussions together with nineteen written contributions which had been submitted previously and which state very briefly the particular interests and opinions of some of the invited participants.

The original purpose of the meeting was mainly to discuss “...lack of uniformity in instrumentation and large divergences (which) exist about interpretation”. This obviously refers to the seismic methods and, in fact, about three-quarters of the text deals with seismology. The booklet ends with a list of eight recommendations—though to whom they are directed is not quite clear.

**Explosion Seismology**

As far as instruments are concerned the text mainly gives a recitation of some of the instruments which are in use or in development. Apparently, there was a negligible amount of discussion on the effects of distortion produced by present equipments and on why new instruments are required. This is a pity because seismology badly needs better data. For instance, it is seldom realised that for faithful recording of ground motion the natural period of the detector should be about 15 times that of the predominant period in the seismic pulse. This ratio is probably never achieved and so it is essential for proper correlation (which is the essence of seismic interpretation) that instruments should be very carefully matched. It was stated that an FM magnetic recording system cost about twice as much as a conventional paper recorder. In view of the many advantages of magnetic recording its additional cost is many times repaid in quality of results.

On the operational side it was agreed that the spacing between spreads on a refraction line should generally be about 10 km and within the spread the geophones should be spaced apart by about 0.5 km or less. No comment was made on the use of horizontal geophones though their records often materially assist in the interpretation of late arrivals.

Much of the report is taken up with the presentation of new results from various areas. In view of the fact that these are almost invariably interpreted as a series of crustal layers overlying the Mantle it was timely that one of the formal recommendations of the conference states that “...premises as to horizontal layering and to uniformity of structure and velocity should be avoided”. Although there are undoubtedly well authenticated instances of discontinuous increases in velocity due to change of material—one near Ivrea in the Western Alps is described on page 15—the only general statement which may be made about the velocity in the crust is that it increases with depth. In this regard, a set of results interpreted as a two layer crust was shown to fit just as well to the continuous variation with depth predicted from laboratory measurements on the variation with pressure of the velocity of ‘granite’.
All investigators find that the velocity of $P_n$ varies from one region to another. Results quoted seem to show that the variations are greater under the oceans (7.6–8.6 km/s) than under the continents, though this might be due to lack of reversed profiles on land. In any case, it is obvious that the Upper Mantle is variable. It was pointed out that laboratory measurements indicate that the higher velocities for $P_n$ could not be due to a quasi-isotropic distribution of olivine but required either a non-random distribution of the crystals or the presence of minerals with an intrinsically higher velocity. On the assumption that the Upper Mantle is composed predominantly of olivine it may be worth measuring $P_n$ velocities over different parts of hypothetical convection cells in order to discover whether there is any systematic variation which may be explained by crystal orientation in the convection currents.

Workers from Japan have so far not recorded velocities higher than 7.6 km/s but they are not yet ready to conclude that this velocity refers to the Mantle.

No workers report unambiguous normal incidence reflections from the Moho. There is the well known statistical result from W. Germany which indicates one reflector within the crust and another at its base, but similar studies on 1000 records in the U.S.A. give no such indication. Neither have normal incidence reflections been identified in the USSR.

Very little mention was made of the use of $S$ waves or of the value of amplitude studies. It seems certain to me that merely obtaining large numbers of refraction records is not going to add much to our knowledge of the Earth's crust unless better techniques—in both observation and interpretation—are used. I place no reliance on correlation of late arrivals between separated spreads unless either the individual events are at least twice the ambient amplitude or they are quantitatively supported by amplitude and/or orbital motion measurements. If $P_n$ is observed, then interpreting the time–distance plot in terms of parallel layers of constant velocity is useful as a means of rapidly and simply obtaining an approximate depth to the Moho. A proliferation of such interpretations will undoubtedly yield reliable depths and velocities for the Upper Mantle but I believe that only more sophisticated analyses will aid in our understanding of the Earth's crust. Further, it is essential to plan the operation in the light of what can be achieved with present methods of interpretation. A few small surveys unambiguously interpreted would come as a welcome relief to the welter of vague interpretations which get into print.

Near Earthquakes and Surface Waves

Near earthquakes have two real advantages over explosions. They occur within and beneath the Earth's crust and they are, usually, generators of clear $S$ waves. One contributor illustrated the use of these advantages and stated that for one group of twenty-eight earthquakes the foci tend to lie either at the top or bottom of the crust. If a low velocity layer exists in the crust a study of near earthquakes should help to detect it.

Surface-wave methods are a powerful aid in determining gross crustal structure and Upper Mantle variations. It was stated that there was general agreement that proper matching of the dispersion curves requires the crustal velocity to increase with depth, though whether this is consistent with the wave guide interpretation of $L_q$ was not made clear. Results from temporary stations gave the depth of the Moho as $51 \pm 5$ km under the Alps and $17 \pm 4$ km under the Mediterranean.
Off the Californian coast, surface waves have been used to obtain the mean slope of the Moho under the continental margin.

In order to aid seismologists without access to a high speed computer it was suggested that a Handbook of Theoretical Dispersion Curves should be compiled, however, this suggestion was not incorporated into the final recommendations of the meeting.

To an outsider the most significant contribution was the mention of a recent computer programme for matching an observed dispersion curve to one computed from a theoretical model. The programme alters the parameters of the model until a best fit, in the least squares sense, is obtained. Because surface waves show up a velocity decrease just as easily as a velocity increase, the study of shorter periods should be an extremely valuable addition to refraction methods when studying the crust.

**Laboratory Measurements of Rock Velocities**

For a given rock type velocity increases with depth, for the effect of pressure is much greater than that of temperature. As noted above, a wide variation in the velocity of $P_n$ requires either variations in crystal orientation or variations in composition.

Eight tables of rock velocities are presented, including one which gives the range of Poisson’s ratio for acidic rocks as $0.12-0.24$ and for intermediate and basic rocks as $0.20-0.36$.

It was encouraging to note that some experiments have been done in which three velocities were measured on a single specimen and that consistent values were obtained for the two elastic constants; this seldom happens for measurements made at atmospheric pressure, which are often useless.

**Miscellaneous Methods**

Brief reports are included on measurements and interpretation of the gravity, magnetic and electromagnetic fields and on heat flow.

It was agreed that the average crustal density was well above 2.67 g/cm$^3$—one value given was 2.84. It was also agreed that Bouger anomalies could usually be reconciled with seismic measurements. This seems to imply that the increase of velocity with depth is due to compositional changes in addition to the effects of pressure.

Recent determinations of oceanic heat flow confirm that its average value is about 1 $\mu$cal/cm$^2$/sec, the same as on continents, but values nearly eight times normal are found locally.

**Deep Boreholes**

In addition to the well known Mohole series, a number of deep boreholes are planned in the USSR and a European group proposes to drill some deep holes in the Alps. A special committee framed a special resolution emphasising the importance of obtaining first hand information of rock properties.

**Conclusions**

This admirably edited booklet keeps the freshness of an informal discussion without retaining too much of the awkward syntax and verbosities of verbatim reporting.
A large increase in funds is now available for seismic studies. This is essential for the proper provision of equipment and for increasing the number of surveys. It is profoundly to be hoped, however, that a large number of the scientists attracted to this growing field will concentrate on developing better methods of interpretation. Better instruments are also needed but here the problems are in sight of solution.

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