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An Account of the Meeting for Informal Discussion Held on Friday 14 November 1969

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An account of the meeting for informal discussion held on Friday 14 November 1969

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The meeting for informal discussion began with the short papers, by Green, O'Hara and Walker, which are printed in this volume and were offered and discussed under the heading 'Petrogenesis'. These were followed by a discussion under the general heading 'Ocean crust structure and ophiolites' on which I have notes on 39 contributions.† No written contributions were received and the account which follows is a personal one based on these notes; it has not been checked with individual contributors and if any are misrepresented I offer my apologies.

Introducing the discussion on the oceanic crust Matthews stressed the need to reconcile the relatively uniformly layered picture of the crust given by seismic refraction measurements, which is well established at least on the ocean basins, with the much less strongly layered assemblage of rock types revealed by petrologists. In particular we have to take note of the surprising uniformity of velocity in layer 3 which has a worldwide average of 6.69 km s^{-1} with a standard deviation of only 0.26 km s^{-1} (Raitt 1963). It would be of great interest to have many more determinations of seismic velocity on specimens of deep-sea amphibolites and greenschists. Matthews presented a cartoon showing a possible view of the formation and composition of the oceanic crust. This cartoon, modified in the light of some of the subsequent comments, is shown in figure 1. It was successful in provoking discussion.

It was the sense of the meeting that there is real doubt about the possibility of any hard and fast assignment of petrologic types to the seismic layering. Melson expressed doubt about the desirability of attempting to decide any general structure like that shown in figure 1, on the grounds that it would inevitably be used as a new dogma in teaching, but Watkins felt that a standard sequence would be useful as something on which to pin the indisputable variability of the crust to which van Andel had drawn attention. Wiseman reminded us that the crustal layering was best established in the ocean basins, whereas almost all our dredged rocks come from the mid-ocean ridges. Rothstein drew attention to the inconsistency of using the term pyrolite, a hypothetical rock type, in the same way in the diagram as the names gabbro and serpentinite.

Stressing the variability of the oceanic crust Moores asked whether the thickness of the seismic layering varied with spreading rates and van Andel, thinking in terms of a metamorphic front dividing layers 2 and 3, queried whether the ratio of their thicknesses varied with time as slabs of the crust moved away from the crest of the mid-ocean ridge where they were formed. He emphasized the possibility of systematic differences between crust generated at fast and slow spreading ridges. Cann said that so far as he knew the total thickness of the crust did not depend upon the rate of spreading and outlined his published ideas about the distinctions between fast- and slow-spreading ridges (Cann 1968): fast-spreading ridge, thick layer 3. Melson pointed out

† I have notes taken by me and by Dr Cann on contributions from Dr F. Aumento, Dr M. Bass, Dr E. Bonatti, Dr J. R. Cann, Professor I. G. Gass, Dr D. H. Green, Dr D. H. Matthews, Dr W. G. Melson, Dr E. M. Moores, Mr M. Osmaston, Dr A. T. V. Rothstein, Dr J.-G. Schilling, Dr V. S. Sobolev, Dr Tj. H. van Andel, Dr F. J. Vine, Dr N. D. Watkins and Dr J. D. H. Wiseman. To others who may have spoken I offer apologies.

that so far no ultramafic rocks had been dredged from the Pacific even from deep fracture zones and wondered whether this implied any real difference.

There was considerable discussion of the rock types that go to make up the layered crust. Aumento pointed out that seismic velocities measured in gabbros fell in the range of layer 3, whereas metabasalts might occur in layers 2 or 3. However, Bass stressed the role of intercommunicating pores in laboratory velocity determinations. Cann suggested a predominantly greenschist layer 2 and an amphibolite and gabbro layer 3. In the context of metamorphic facies it is worth pointing out that the names given in the cartoon, figure 1, are drawn from experience of regional metamorphism (heat + stress) on land, whereas, as Dr Shido had made clear in the meeting, at sea we were dealing with a sort of 'widespread thermal' metamorphism (heat + abundant water).

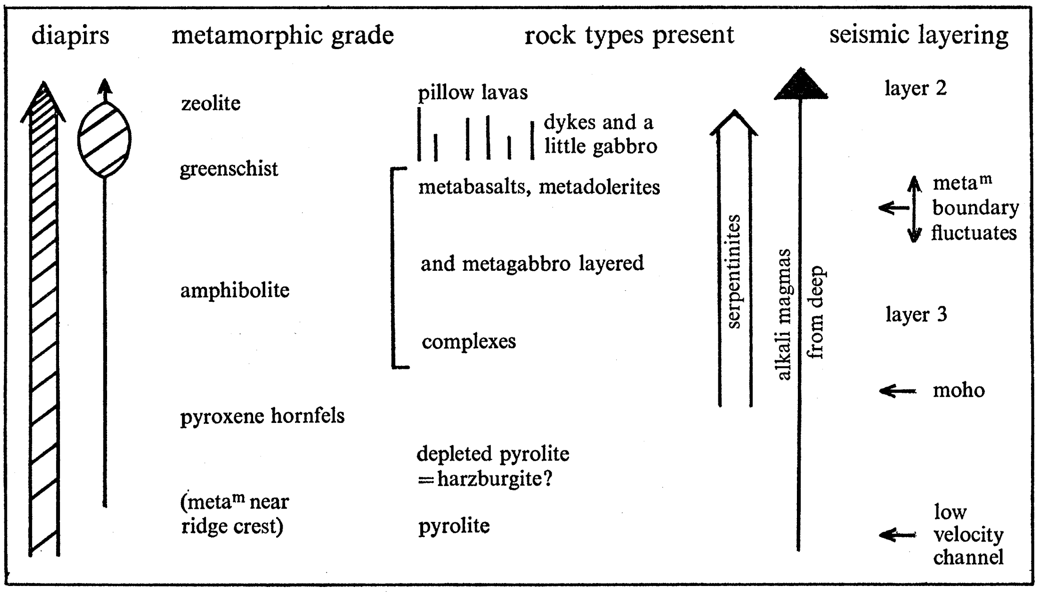

FIGURE 1. This cartoon presents a currently plausible view of the oceanic crust and is not intended as a new gospel for teaching to undergraduates. The shading in the arrow on the left represents partial melting buffered by H_2O in an ascending diapir of upper mantle material. Some diapirs may attain the surface. The term pyrolite is used for a mixture of basalt and peridotite (Green & Ringwood 1967). Depleted pyrolite is pyrolite from which some basalt has been driven by partial melting.

The late Professor H. Hess had always advocated the view that layer 3 consisted of 60 % serpentinized peridotite, forming a hydrated skin on the upper mantle. The view was not without its supporters in the discussion. Osmaston said that if layer 3 were basaltic in composition then a lot more heat would be coming out than is observed, so it must be serpentinite. Aumento said it could not be, because serpentinite was too magnetic and had too low a seismic velocity. Vine said that most serpentinites found on the ocean floor had been remobilized and diapirically intruded. This process had reduced their seismic velocity. The serpentinites on Cyprus appeared to range from diapiric to relatively undisturbed. There was great variation in their intensity of magnetization but in any case their magnetic vectors are randomly directed. The diapirs come up brittle fractures (faults) and have very confused magnetics. Undisturbed serpentinites—ones formed hydrothermally, *in situ*, from peridotites which they perfectly pseudomorph—acquire their remanent magnetization in the direction of the ambient field at the time they are formed, but the fact that the directions of magnetization in Cyprus were so random suggests that this process was insignificant there. If one applied similar reasoning to the ocean floor, where magnetization seemed confined to the upper part of the layer 2, it followed that the serpentinites must be very largely diapirically intruded bodies. Hess had argued by analogy with land outcrops of ophiolite, reasoning that the mafic zone in them is too thin to be equivalent to the whole of the oceanic crust and that therefore layer 3 under the oceans is serpentinite. Melson said that he felt that ultramafics, especially 60 % serpentinized peridotites, must be important in layer 3 because they are so often dredged. Van Andel said that the serpentinites dredged at 43° N all came from a single isolated hill; he suggested that serpentinites are preferentially extruded from leaking fracture zones.

Looking yet farther into the earth Sobolev said that the inclusions found in Kimberlite pipes indicate the presence within the upper mantle of differentiated intrusive bodies. There was also eclogite found in them, so that we should expect layered gabbro complexes, anorthosites and eclogites in the upper mantle.

Steering the meeting into discussion of the ophiolites on land that are widely believed to represent thrust slices of ancient oceanic crust, Matthews said that, marine geophysicists having given the lead, he felt that the ball was now going to pass more into the land geologist's court. We must be able to find the suture lines where continental plates had collided in the past: if India has recently bumped into Asia the bruise should still show. Moores remarked that perhaps it does: the work of Dr Sitter, Brouwer and Gansser pointed to the N. Pyrenean Fault, the Insubric line, the Varda zone in Greece, the Indus suture line (melange zone) and the Celebes as being of this kind.

Turning to the Troodos Massif in Cyprus Moores suggested that there one might equate the pillow lavas with layer 2 and the metadolerites with layer 3. Gass remarked upon the very sharp contact between the zeolite facies and the greenschist facies rocks there and said that it would be of interest to seek for layer 3 velocities, perhaps by marine seismic techniques around Cyprus. Replying to Bass, Moores enumerated six other sheeted complexes similar to the one in the Troodos including examples on Macquarie Island, in the Hindu Bagh and in Oman.

Discussing the mechanism of formation of the ophiolite complexes Moores said that dykes appear sometimes to have come in so fast that they do not show any chilled margin and simply produce a graded doleritic crust. Green mentioned the Musa Valley (New Guinea) ophiolite complex where diapirs seem to have risen to very near the surface before separating off liquid, thus achieving a very high degree of partial melting. Melson inquired whether St Paul's Rocks could be such a diapir and Green replied that some small diapirs, maybe including St Paul's Rocks, appear to move too slowly to lose any liquid at all; the Lizard complex was a case in point. Schilling remarked that the trace element ratios were very sensitive to small variations in the degree of partial melting, but very little fractionation appeared to have taken place.

At the request of Dr Akiho Miyashiro, the appointed chairman of the Subcommittee of Oceanic Petrography of the Commission on Petrology of I.U.G.S., a list of five names was agreed for his consideration as members of his Subcommittee. The meeting also considered whether it could agree on a name for the chemically distinctive group of basalts characteristically erupted at the crest of the mid-ocean ridges and first designated oceanic tholeiites by Engel, Engel & Havens (1965). After discussion a vote was taken:

for abyssal basalts	5
for ocean floor basalts	7
for no specific name	13

References (Matthews)

Cann, J. R. 1968 Geological processes at mid-ocean ridge crests. *Geophys. J. R. astr. soc.* **15**, 331–341.

Engel, A. E. J., Engel, C. G. & Havens, R. H. 1965 Chemical characteristics of oceanic basalts and the Upper Mantle. *Bull. geol. Soc. Am.* **76**, 719–734.

Green, D. H. & Ringwood, A. E. 1967 The genesis of basaltic magmas. *Contr. miner. Petrol.* **15**, 103–190.

Raitt, R. W. 1963 The crustal rocks. In *The sea*, vol. 3 (ed. M. N. Hill), pp. 85–102. London: Interscience.

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