gravity device. Hundreds of dredgings of rock also have been taken with large geological dredges. Currents have been measured in a score of different places on the ocean bottom both in and out of submarine canyons. The echo-sounding device on the *E. W. Scripps* has also been employed particularly to find out about the nature of the outer termination of the canyons off southern California. Parallel investigations of the east coast canyons have been undertaken by H. C. Stetson on the *Atlantis*.

Dr. Bullard states that the hypothesis that the submarine canyons are due to river cutting must be abandoned because the canyons extend to too great depths. However, it should be remembered that sea shells are found at high elevations in most mountain ranges. Before abandoning the river erosion hypothesis, would it not be better to look at some of the evidence from the canyon investigations? This evidence will, I think, prove disconcerting to those who wish to rule out the subaerial cutting. Thus we have found well-rounded gravel in cores and dredgings along the axis of many of the canyons and extending out to depths of so much as 5,000 ft. In places this gravel is mixed with shells which are certainly not of a deep-water variety. We have also found the water-worn gravel and even rounded cobbles on the banks off the California coast out to depths of 3,000 ft. At the head of the great Monterey submarine valley the deep fill shown by well cores gives unmistakable evidence of submergence great enough to account for at least a thousand feet of the submergence implied by the canyons.

The detailed surveys of the California submarine canyons reveal their close resemblance to the river canyons of the adjacent lands. These canyons are cut for the most part in rock. They have V-shaped cross-sections, winding courses, a river-like pattern of tributaries, and as continuous an outward slope as is typical of river canyons. While submarine processes are undoubtedly important in preventing the canyons from becoming filled, as is shown, for example, by the finding of submarine landslides, no process either of landslides or of submarine currents has as yet been detected which would appear to account for the canyon characteristics as well as that of subaerial origin. Our investigations show that the currents are not concentrated in the canyons nor do they attain proportions which could be expected to produce these great sea-floor gashes in the relatively short periods available for their excavation through the late Tertiary rocks found on their walls. These investigations cannot be said to have completely solved the mystery of the canyons, but they should at least show that one should not lightly dismiss the idea of subaerial excavation as has Dr. Bullard and as have various American writers in recent articles.

Dr. Bullard refers to the continental shelf as a mass of sediments built out on a gently sloping surface of rock. Possibly this interpretation may apply to some continental shelves, but again the evidence is largely in the opposite direction. Most of the dredging operations both on the outer portion of the continental shelf and on the walls of submarine canyons which cut into the shelf margin have revealed the presence of rock. This is not only true off the California coast, where the evidence is incontrovertible, but also is the case off the New England coast where Stetson found well-consolidated Cretaceous rock at a depth of a few hundred fathoms near the shelf edge. When Dr. Bullard refers to the 8,000 ft. of sediments overlying the rock on the continental shelves off both sides of the Atlantic, he should qualify the statement by noting that it is not easy to distinguish between soft sedimentary rock and recent sediments in geophysical determinations. Also Ewing's work off eastern United States is only thought by that writer to imply a thick section of sediments and sedimentary rocks overlying the granite basement.

The statement that the edge of the shelf does not represent a fault scarp but is simply the outer edge of the sediment pile is also one that is subject to debate. The continental slopes show a close topographical resemblance to the fault scarps of the lands. Judging from deltas, they are distinctly too steep for normal sedimentary accumulations. The finding of rock in many places on the slopes is also significant in this connexion. Their straightness further implies fault origin. The deep water at the base of these slopes, despite the evidence that sediments are accumulating much faster at the slope base than on the slopes, indicates that diastrophism must be keeping the base depressed. Finally, the common presence of troughs in the ocean floor adjacent to the continental slopes and the seismicity of these zones lend support to the idea that the continental slopes are tectonic. Here again, however, it is best to reserve judgment until more evidence is available. Submarine geology is still too much in its infancy to make positive statements advisable.

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August 13.

IN Prof. Shepard's interesting communication he differs from me on two main points. First, he thinks that the "canyons" were probably formed by subaerial erosion, whereas I do not know how they were formed; but I feel fairly certain that at any rate on the east coast of the United States the land has not recently stood thousands of feet higher than at present. To me it is inconceivable that the flat-lying sediments of the coastal plain can have been raised and lowered without leaving a trace in their structure and without affecting the physiography except near the outer edge. In California, broadly speaking, anything may happen. Large changes have occurred recently and are presumably still in progress, and there is nothing inherently impossible in assuming large relative movements of sea and land. It is the extension of the movements to practically the whole length of the shores of all the oceans that raises such great difficulties.

The second difference is that I suggested that the form of the continental shelf might be due to sedimentation whilst Prof. Shepard regards it as probably tectonic. This is not a matter on which I would wish to be dogmatic and it is a question which can be settled by mapping some discontinuity past the edge. The most promising horizon for this purpose seems to me to be the Palæozoic or Pre-Cambrian floor underlying the sediments under the continental shelf of the eastern United States and western Europe.

I agree that most of the shelf consists of well-consolidated sediments. Last year it was found that the velocities of seismic waves on the shelf south of Ireland were as great as 10,000 ft./sec. at a depth of a few thousand feet.

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