—geobotanical studies of individual territories (the Kazakh Branch and the Kola Base), extending the pasture acreage and raising its productivity, measures aimed against salinification of the soil, work on increasing fodder resources, etc.

A number of botanical gardens, the high-mountain soil-and-botanical station on the Pamir Mountains and the Polar botanical gardens in Kirov study the local flora, raise various species of decorative plants and have introduced the cultivation of several wild-growing plants.

(To be Concluded)

IMAGINARY SUBMARINE CANYONS[1]

By Dr. FRANCIS P. SHEPARD

DIVISION OF WAR RESEARCH, UNIVERSITY OF CALIFORNIA, SAN DIEGO, CALIF.

THE VEATCH-SMITH SUBMARINE CONTOURS

FOR some years the discovery of the great submarine canyons along the oceanic slopes off the east coast filled many of the outstanding geological theorists with misgivings. They were less disturbed by the deeply submerged canyons with the characteristics of river valleys off California, since this coast was well known to be unstable, but river canyons off the supposedly stable east coast were unthinkable; and to make matters worse, charts were showing that submarine canyons were practically universal. Assuredly the continents of the world could not all have been moving up and down many thousands of feet during the late part of geological time. Into the breech at the critical moment stepped a series of maps of outstanding workmanship which appear to have taken at least the eastern part of the country by storm. These maps were the result of painstaking contouring by A. C. Veatch and by his collaborator, Paul Smith.[2] The contours, as both Veatch and Smith have frankly admitted, are based on the hypothesis that the submarine slopes have a stream-cut type of topography. Accordingly, the contours show a great mass of gullies and valleys even out at the greatest depths where there are few soundings. These small valleys shown on the maps have been seized on eagerly without any apparent attempt to determine their basis and are now established as the pièce de resistance of three new hypotheses advocating submarine origin of the canyons. Two of these have appeared in books[3] and a third as a short article.[4] The maps have also been reproduced in many textbooks and have been the source from which a model reposing in the American Museum of Natural History was drawn. Even *Life* magazine recently reproduced a picture of this model with mention in garbled form of one of the new hypotheses.

Since the tendency of late has been to regard these gullies as the typical submarine valleys and accordingly to disregard the great rock-walled canyons which have been revealed by years of scientific exploration of the sea floor, it might be well to give the scientific public some insight on the basis of these supposed gullies and their relation to the problem of the history of the ocean floors. Regarding these contours one must admit in all fairness that they represent long painstaking effort. Certainly it would have been difficult to fit stream-dissected slope topography more perfectly into the soundings than has been done. On the other hand, the contouring could have been executed with the same care in attempting to show what actually existed out on these submarine slopes off the east coast. That this was not done is indicated by the fact that the same soundings were contoured by a series of six topographers and geologists of the U. S. Geological Survey and by the present writer and his co-worker, K. O. Emery, and in no case did these closely spaced small valleys appear in the contoured maps which resulted. Instead of these myriads of gullies a series of relatively large canyons (shown also by Veatch and Smith) are revealed on the slopes. The canyons are of the type which recent theories have so meticulously avoided. In a forthcoming paper, Emery and the writer will present in some detail the abundant evidence which is thought to reject the gully hypothesis of contour interpretation of these soundings off the east coast. It may be sufficient to state here that any one who has a conviction of the existence of these gullies need only return to the original data and attempt to contour some portion of the deep outer slopes bearing in mind that unavoidable errors of observation increase with depth.

A SUBMARINE ORIGIN OF THE CANYONS

The recent hypotheses which attempt to explain submarine canyons as formed without emergence include

[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 214.

[2] Special Paper 7, Geological Society of America, 1939.

[3] D. W. Johnson, "The Origin of Submarine Canyons," Columbia University Press, 1939; R. A. Daly, "The Floor of the Ocean," Univ. of North Carolina Press, 1942.

[4] W. H. Bucher, *Bull. Geol. Soc. Amer.*, Vol. 51, pp. 489–512.

in order of their appearance: R. A. Daly's muddy density currents, D. W. Johnson's artesian springs, and W. H. Bucher's tsunamic sea waves (also called tidal waves or seismic sea waves). In defending these hypotheses the advantage of the gully concept provided by the Veatch-Smith maps is very evident, since none of these processes could account for huge canyons. All these authors have referred to canyons like those off the California coast as a different phenomenon from the submarine valleys which they are trying to explain. They all imply that submarine valleys in general are of the nature of the Veatch-Smith gullies.

Daly's idea that muddy currents moved down the ocean slopes during glacial stages might conceivably be used to explain small gullies cut into a muddy slope, but even for this explanation Daly had to draw on the now discredited idea that the outer continental shelves are or were great mud banks. Bucher's tsunamis (tidal waves) must set up occasional strong currents on the ocean floor, but it would be amazing if these rare manifestations could have cut more than small valleys into the ocean slopes. Furthermore, the distribution of submarine canyons shows no relationship to the areas where these waves occur. Also the waves are of a nature which should produce erosion on projections rather than in valley-like indentations. Johnson's artesian springs require high land along the coast with water-bearing layers dipping seaward and extending under the shelf and outcropping on the outer slopes. Even under these ideal and rare conditions, excavations on the slope by the artesian springs could produce only small valleys, which should have many basin depressions along their length. Even the fanciful Veatch-Smith contours show nothing of this sort. For further objections to these hypotheses the reader may refer either to the Johnson or Daly book which are most successful in discounting the other's hypothesis or to the writer's discussion of the subject in which an attempt was made to give facts favorable and unfavorable to each hypothesis.[5]

LEAVING HAMLET OUT OF THE PLAY

If all this attempt to explain submarine valleys is dealing with a purely fictitious concept, the situation would appear to approach the ridiculous. Are the typical submarine valleys of the world of the order of these hypothetical east coast gullies or are they comparable to the well-known California rock-walled canyons? All the available evidence suggests that the latter is the case. The Coast and Geodetic Survey charts provide abundant evidence of the existence of canyons thousands of feet deep and extending many miles into the outer edge of the continental shelf. H. C. Stetson's well-known investigations have shown that many of the sea canyons have rocky walls. Most of the information regarding other submarine valleys comes from the charts of the world. All available charts have been studied by the writer and the soundings indicate clearly that the great majority of the known submarine valleys are large canyons, that is, canyons comparable in dimensions with those which cut great mountain walls. Furthermore, the bottom notations reveal that rock is present on the canyon sides in numerous places. These statements may be easily verified by examination of the charts from the various coasts of the world.

Is it reasonable to present a hypothesis which disregards such great submarine canyons as the huge Hudson Canyon which can be traced for miles off New York, the canyon off the Congo, which is a hundred and twenty miles long and extends 18 miles into the coast in the Congo estuary, the huge Fosse de Cap Breton off southwestern France, the equally large Canal de Nazare off the Portuguese coast which appears to be cut in granite, the canyon off the Indus which crosses a 60-mile shelf off the Indus River or the rock-walled canyons off Ceylon, to mention a few all off relatively stable coasts? If we consider all these great canyons as well as all the canyons off unstable coasts as exceptional, just what will we have left? We are not only excluding Hamlet from the stage, but all the other actors.

RIVER EROSION

Despite the enthusiastic abandonment of the river erosion hypothesis by these recent writers the facts continue to favor the idea. All the detailed surveys of the submarine canyons have revealed distinctly river valley characteristics.[6] Characteristically these canyons the world over are V-shaped, steep rock-walled, winding valleys with branching tributaries. A very large per cent. are located off river mouths and some of them are obviously submarine continuations of land canyons. The explored canyons off California contain numerous rounded pebbles even at depths as great as one mile below sea level. Many other observations indicate the submergence of the land margins. The case may not be rigidly established, but it is substantial and should not be thrown aside just because it presents a difficulty in the path of certain preconceived hypotheses. It is to be hoped that if there are future suggestions of causes of submarine canyons, they will be evolved after a careful study of the facts or preferably after field investigation of the canyons.

[5] Special Paper No. 31, Geological Society of America, 1941.

[6] Charts of many are available in Special Paper 31, Geological Society of America.