tal ability and outstanding social cooperation. The need for research on the biology of man is obvious; methods for conducting the investigations are fairly well worked out; and there is lacking only the leadership to develop an adequate research program and the funds to carry it out.

# GEOSYNCLINES IN CONTINENTAL DEVELOPMENT[1]

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GEOSYNCLINES, from the derivation of the word, are great depressions in the crust of the earth. The term has been applied both to large surface depressions and to thick sediments that have filled such sinking areas. The latter concern the stratigrapher. Study of the geosynclines in the interior of North America reveals several classes that differ in original form, in the derivation of their rocks and in their structural and volcanic histories.

In the early Paleozoic, a half-billion years ago, the central part of the continent, the craton, was depressed less than belts on each side, the miogeosynclines. The Cambrian system, first of the Paleozoic, is the earliest that is sufficiently known to permit reconstruction of the whole of the continent. Lower Cambrian is absent in the continental interior, but thick in the bordering belts, beyond a line from west of the Mackenzie through western Alberta, Wyoming and Arizona, and one from Labrador and the St. Lawrence through eastern New York and the Appalachians to Alabama; younger Cambrian is very thin on the craton, thickening beyond its margin. The craton was essentially a platform separated by flexures from the deeper-sinking miogeosynclines.

The more peripheral areas are so little known that there have been several conceptions of their character. Dana's hypothesis of Archean protaxes, popular last century, considered present crystalline ranges to have persisted from early times. The widely accepted theory of borderlands, developed principally by Schuchert, placed long-lived "Cascadia" and "Appalachia" on opposite sides of the continent; these were described as great lands of crystalline, principally granitic rocks, extending from well within the present coasts to beyond the oceanic shores, and persisting from the beginning of the Paleozoic to or beyond the close. The theory of marginal volcanic troughs considers regions beyond the miogeosynclines to have had deep sinking belts of sediments and marine volcanic rocks—eugeosynclines, with smaller areas in linear islands.

The theory of marginal volcanic troughs is supported by direct evidence and induction. The known sections of Cambrian and succeeding Ordovician are of miles of slates, cherts and volcanic rocks, with interbedded coarser detritus such as might have come from nearby islands. In the West, where early Paleozoic is rarely exposed, the persistence of thick marine volcanics in Paleozoic and earlier Mesozoic rocks throughout the belt suggests that the unknown early Paleozoic is similar. Thus the continent is conceived as having the interior craton separated by flexures from the deeper sinking miogeosynclines, with more peripheral belts of eugeosynclines and linear islands.

The edge of the craton did not persist as a simple flexure, as is shown in comparing successive stages of the Middle Ordovician, second Paleozoic system, along the eastern margin and in contrasting them with the mid-Paleozoic Lower Devonian. The Adirondack line can be drawn from Quebec city through the Adirondack Mountains and southern Pennsylvania to western Virginia. Successive limestone units thicken eastward from the line, then thicken westward, subsequently thin toward the line from each side and finally the limestone on the west changes to thickening shale on the east. At any time conditions were similar along one side of the line, and in contrast to those on the other. As a result of the movements, the sediments are thinner along the line than on either side. If one draws the same line on a map showing thicknesses of the Lower Devonian limestones there is little correlation, for the maxima of that series lie near the line in the Virginias and pass considerably to the east in New York.

The Upper Ordovician illustrates a third type of geosyncline, the deltageosyncline, in which thick detrital sediments within the craton were derived from uplift beyond the margin. The deltageosynclinal deposits formed in a semilenticular depression centered in Pennsylvania; they coarsen toward highlands made of rocks of the earlier geosynclinal belts to the east. Stratigraphy is similar in sections radiating from the source. Silurian sediments have similar form, but whereas the Upper Ordovician are pre-orogenic, coarser lithologies gradationally overlapping the finer away from the source, the post-orogenic Silurian has the finer gradationally overlapping the coarser toward the source. The Middle and Upper Devonian of New York is a classic section of part of a pre-orogenic deltasyncline; stratigraphic relations were misunder-

[1] Summary of an illustrated lecture presented to many of the affiliated societies of the American Association of Petroleum Geologists during March, 1944, sponsored by the Distinguished Lectures Committee of the Association.

stood until it was recognized that most of the fossils are not limited so much by age as by association with lithologies that intersect chronologic planes. The deltageosyncline is a geometric form; lines of equal thickness—isopachs, reflecting depression, do not conform necessarily to the lines of similar lithology—isoliths, influenced by the many factors affecting the surface of deposition.

The autogeosyncline is illustrated by the middle and late Paleozoic of southern Michigan. There is strong correlation between the basin structure, shown by contours of depression on a single stratigraphic plane, and the isopachs of Silurian and younger Paleozoic sediments. Successive rock units are thickest in the center of the state because that area was sinking most rapidly, the structure developing as the deposits were laid. The Illinois Basin developed similarly during the late Paleozoic. The autogeosyncline in Michigan and the deltageosynclines in Pennsylvania are separated by a less depressed belt that is the northern end of the Cincinnati arch. Autogeosynclines form within the craton without a complementary highland; the causes of their advents and passings are obscure, but they have definite durations. The present structures of some basins reflect their autogeosynclinal origin; other autogeosynclines have been folded and faulted so as to obscure the earlier behavior, or are concealed by sediments of different structural pattern.

The early geosynclines have striking correlation or coincidence with some major structures of the continent. The western belts retained much of their early character until the middle Mesozoic. There are very few west-derived sediments in the miogeosynclinal belt, and they can have come from uplifted eugeosynclinal rocks. In the Nevadian revolution of the mid-Mesozoic late Jurassic, the belt that included eugeosynclines was thrust on the miogeosynclinal belt in some areas, such as central to southwestern Nevada, and was invaded by batholiths. The resultant highlands spread detritus eastward to form the great deltageosynclinal belt of the Cretaceous on the western craton. In the Laramian[2] revolution at the close of the Mesozoic, the miogeosynclinal belt was thrust on the craton along much of its length, and invaded locally by batholiths; folds and minor thrusts formed in the deltageosynclinal belt on the craton. Subsequently, block-faulting in the Cenozoic era behind the thrusts produced the present Basin Range structure.

In the East the eugeosynclinal belt was thrust on the relatively narrow miogeosynclinal belt in the Taconian revolution at the close of the Ordovician. Deltageosynclines extended on the craton before and after the orogeny. Deposition in the eugeosynclinal belt terminated with folding and intrusion of batholiths in the Shickshockian disturbance of the later Devonian. In the southern Appalachians, the Appalachian revolution at the close of the Paleozoic thrust rocks of the Ordovician miogeosynclinal belt on the craton. Subsequently, normal faults developed in the lee of the thrusts, producing the rift-bounded geosynclines (taphrogeosynclines) of the early Mesozoic Triassic of the Atlantic Coast. Thus the structural sequence in the East closely resembles but antedates that in the West. The times of some of the events in each region are not as precisely known as the statements suggest. Moreover, this is but a description of the development of two orogenic belts; one must not assume that all had the same history.

The relationship of the Appalachian Structural Front, the northwestern major fold of the mountain system, to early geosynclines, emphasizes their plurality. The Front lies within the late Paleozoic Lower Pennsylvanian miogeosyncline from Alabama to central Virginia, where the folds trend northward in an arc into central Pennsylvania, leaving the miogeosyncline to enter an area having thick medial Paleozoic deltageosynclines. The folds tend to coincide with the area of greatest thickness of sediment, but the latter is composed of geosynclines of different types and ages. The cratonal flexure of the Lower Pennsylvanian miogeosyncline lies west of the Adirondack line, defining the Ordovician miogeosyncline, crosses it about Maryland, and is to the east in the north. Thus there is not an Appalachian geosyncline, but there are geosynclines of several sorts and of differing ages in the Appalachian region.

This has been an endeavor to emphasize distinctions among North American geosynclines, and express them in classification. Not all geosynclines are as typical, for some have been formed under plural influences, others are of sorts that have not been considered. The discussion may give a better understanding of the continental plan—if it encourages closer analysis of the deposits that confront the geologist, it will serve a good purpose.

[2] Nomenclature is simplified by considering the Laramides to be the structures of the Laramian revolution, the Nevadides, those of the Nevadian, etc.

# OBITUARY

## JESSE G. M. BULLOWA

IN the death of Dr. Jesse G. M. Bullowa, since 1928 clinical professor of medicine at New York University College of Medicine, science lost a keen and competent research worker, medicine an experienced practitioner and teacher and numerous patients a skilful