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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE GEOLOGICAL HISTORY OF THE ANTILLEAN REGION[1]

IN selecting a subject for the address of the retiring vice-president of Section E, I have taken the most interesting but least known portion of one in which I have been very much interested during the past twenty years and more, namely, the paleogeography of North America. The portion dealt with on this occasion is the known geological development of the greater Antillean region, that is, the seas and lands bounded by the perimeters of the Gulf of Mexico and the Caribbean mediterranean.

The deciphering of the geological development of this greater Antillean region began with the versatile and philosophical Alexander von Humboldt. In June, 1799, he and the botanist Bonpland set out for Central and South America to study their physical geography and tropical botany. Humboldt first studied Venezuela and the Orinoco country, and later traveled more than a year in Cuba. After visiting western South America, he devoted the year 1803 to Central America. True to his training, Humboldt was an ardent Wernerian, and yet the leading student of volcanoes of his time. His most valuable results, however, are his geographic descriptions.

The geographic and geologic literature of the greater Antillean region is very voluminous, embracing the results of a host of workers, widely scattered in several languages. It is, indeed, altogether too extensive to be presented in brief form. The first important work on the stratigraphy and structure of the Greater Antilles is the report on the "Geology of Jamaica" by James G. Sawkins and his English associates, published in 1869. But the father of Antillean geology is undoubtedly Robert T. Hill, whose work in Panama, Jamaica, Cuba and the Lesser Antilles forms the broad foundation on which all subsequent work must be built. The stratigraphic succession, and especially the marine faunal correlation from place to place, have been worked out more recently by T. Wayland Vaughan and his associates. Voluminous additional paleontologic work is by Gil-

[1] Address of the vice-president of Section E—Geology, American Association for the Advancement of Science, New York, N. Y., December 28, 1928.

bert D. Harris and students trained by him. Our knowledge of Haiti we owe to W. P. Woodring and C. Wythe Cooke; that of Porto Rico, to Charles P. Berkey and his coworkers of the New York Academy of Sciences; while the intricate problem of the coral islands, as seen in the Lesser Antilles, is ably presented by W. M. Davis in two recent books.

The grander geological features. Before turning to the detailed geology of this part of the world, it will be well to take a rapid look at the more general geology of the lands bounding the Gulf of Mexico and the Caribbean mediterranean. The clearly dated geologic history of the Greater Antilles is more especially of Cretaceous and Cenozoic times, and only in western Cuba are there fossiliferous strata of Middle and Upper Jurassic ages. Beneath the latter, however, there is a deformed and metamorphosed basement, usually ascribed to the Paleozoic, which on the basis of Central American history should be of Permian and Carboniferous formations.

By general assent the Greater Antilles include Cuba, Jamaica, Haiti-Santo Domingo, Porto Rico and the Virgin Islands. Cuba is clearly the oldest of the Antillean islands, already in existence in Paleozoic time. The other islands begin with volcanics, most of which appear to be of Upper Cretaceous time, but those in Porto Rico are of Lower Cretaceous age; all seem to lie upon a Paleozoic foundation. To the east of the Virgins are other limestone-capped islands, most of which also belong to the Greater Antillean arc. Probably all of these northeastern Windward Islands are submarine volcanic growths of early Cenozoic time, which have risen into lands at different times, been beveled across, then subsided deeply and accumulated a thick cap of limestones. All the northern states bordering the Gulf of Mexico are also of Cretaceous and Cenozoic times, and nearly all of eastern Mexico as well.

Central America, however, has an ancient core of deformed Pre-Cambrian crystallines and metamorphics, which are well exposed in Honduras, southern Guatemala and Chiapas, and Oaxaca. This old protaxis disappears beneath the Mesozoic covering strata of southwestern Mexico. The Central American part of this protaxis trends east and west, and is slightly curved to the south. It is widely overlapped on the north flank by Upper Carboniferous, Permian, Cretaceous and Cenozoic formations, but on its southern side it is questionable if there ever were marine overlaps older than the Cenozoic. On the other hand, there was no Costa Rica and Panama apparently before late Cretaceous time.

The northern area of South America in Venezuela and Colombia is also very largely composed of Cretaceous and Cenozoic formations, and while there are older ones in the mountain cores of these republics, none appear to go back of the Middle Devonian. These fossiliferous Paleozoic strata, however, rest on an older foundation that apparently is of Proterozoic time. Much of the northern borderland is now foundered into the depths of the Caribbean Sea, and the island of Barbados is its most northeasterly outpost. Tobago and northern Trinidad are other portions of this foundered borderland, which has been called Paria by Guppy.

This much-generalized account of the broader geology of the Central American-Antillean lands seems to bring out the fact that in late Proterozoic time the Cordillera of western North America ended before attaining Oaxaca. Here another ancient protaxis appears with a northwest-southeast strike, but soon changes its course to one with a nearly east and west direction but convex to the south, and so continues through Honduras and apparently across the Caribbean Sea into Jamaica and possibly even beyond Haiti and Porto Rico. To the east of Haiti the old protaxis subsides more and more, and is covered with late Mesozoic and early Cenozoic volcanics.

Appearance of the Gulf of Mexico. Immediately to the north of this Central American-Antillean protaxis there lies a folded foreland that was much the widest across Cuba, and beyond it occurs what Suess has called the "Gulf of Mexico plate." This "plate" of nearly horizontal strata also includes the states bordering the Gulf of Mexico from Texas on the west to Florida on the east, and the latter state appears to have continued unbroken into the Bahama banks. During Paleozoic time this foreland-plate subsided very little, even though the waters of the Atlantic Ocean extended across it as shallow seas to enter the geosynclines of Mexico and Appalachis. Finally, in the Middle Jurassic, there began in the northern hemisphere a great oceanic transgression, and in keeping with it first Mexico and then the Gulf of Mexico began to subside, though most of the present form of the Gulf came with the late Cretaceous. Its greater depth, on the other hand, was developed especially during the Cretaceous and Eocene, with further deepening during Oligocene and Pliocene times. Even now the bottom of the Gulf of Mexico is not creased with folds or much disfigured by normal faulting, as is that of the Caribbean Sea. On all sides it is a gradually deepening basin going down to over 12,000 feet, except in the east where it is deformed by upfaulted Yucatan and the adjacent downfaulted Yucatan straits; both blocks are tilted to the west.

Caribbean mediterranean. To the south of the Central American-Antillean protaxis the structural condition of the Caribbean mediterranean is very different. Here the Antillean borderland fronting the Caribbean Sea was always narrow and much of it has sunk into the abyss. The Caribbean waterway is now an abyssal and overdeepened one, but it appears to have had at all times depths greater than 10,000 feet, and is regarded by Suess as the western end of his Tethyian mediterranean. It differs from the Gulf of Mexico not only in being a vastly older and far more complex basin situated between two continents, but also in being greater in area and depth. Furthermore, its bottom shows northeast-southwest trending folds and troughs; and in addition it consists of two basins, a greater western and more folded one, with depths down to 14,100 feet, ending south of Haiti and Porto Rico in a supplementary fault trough 17,100 feet deep, and a smaller but still deeper eastern and less folded trough, the Tanner Deep, with a maximum depth of over 17,000 feet. On the other hand, in Cenozoic time most of the Parian borderland of South America was also downfaulted to depths ranging to nearly 17,000 feet, and much of western Antillea was faulted into the abyss during the Pliocene, changing the former structural synclinal valley here into the long and narrow Bartlett Deep with present depths of over 19,200 feet. Farther north, other parts of Antillea were downfaulted into a less deep basin, the Antillean Sea, which goes down, however, to nearly 15,000 feet.

Costa Rica-Panama land-bridge. Now the question arises, when was the ancient Caribbean opening into the Pacific closed by the land-bridge of Panama and Costa Rica that now unites South and North America? The direct evidence of the oldest volcanics in Panama shows that they are unconformably overlain by late Eocene faunas (Claibornian), and accordingly this basement is usually assigned to the early Eocene. On the basis of the late Mesozoic faunas, however, the California ones are seen to be so different from those of the same age in Mexico and the Gulf States as to support the conclusion that the land-bridge was more or less completed during Lower and Upper Cretaceous time. Its formation appears to have been started by the late Jurassic crustal movements, which developed here a submarine ridge that was studded by volcanoes. Previous to the late Jurassic, however, the Caribbean is believed to have been widely open into the Pacific.

The early Cenozoic stratigraphy of southern Central America and that of California and the West Indies region are everywhere so much alike that it is plain that the Costa Rican portal was again more or less widely open as a shallow sea beginning with the Upper Eocene (Claibornian) and ceasing with the close of Lower Miocene time. Since then, elevation has here dominated over subsidence, and the Costa Rican-Panama portal has remained closed. However, another but short-lived marine portal came into existence, this time to the north of Central America across the Isthmus of Tehuantepec. It was certainly open during early Pliocene time, and probably also during the late Miocene, permitting the marine faunas of the Gulf of Mexico to spread west and thence north into southern California as far as Carrizo Creek, where Atlantic corals and mollusks are known.

Central American-Antillean land-bridge. Previous to the late Eocene and apparently back into Proterozoic time, it is certain that Central America connected widely across the Honduran-Nicaraguan banks with Jamaica and Haiti-Santo Domingo. It was then easy for the floras and faunas of both North and South America to spread into the Greater Antilles. Beginning probably as early as the Middle Eocene, the South American connection was again severed by the Panama-Costa Rica portal, a shallow sea that continued almost into Middle Miocene time. To the north of Nicaragua, however, there was during this time continuous land into North America. On the other hand, late in the Miocene and during early Pliocene time, the Tehuantepec portal came into existence, breaking this northern connection and stopping any South American migrants during this interval from getting into North America; but the waves of South American organisms could still spread to a limited extent into the Greater Antilles. With the Pliocene, the Antilles were completely separated into their present entities, while South and North America could freely interchange their life forms.

The Caribbean volcanic arc. In the east, the Caribbean Sea during Paleozoic and most of Mesozoic time appears to have been widely open to the Atlantic, but when the deeply submerged ridge came into existence on which the Lesser, volcanic Antilles originated, is not known. From this ridge there arose in the north, certainly as early as late Eocene time, many submarine volcanoes that made islands extending to Martinique in the south. This crescent of volcanoes is convex toward the Atlantic, and the completed series appears to have spread from north to south, with the Grenadines certainly the youngest of the series. There is, however, no direct geologic or submarine evidence to prove that the Caribbees at any time were a continuous land-bridge connecting South America with the Greater Antilles, as inferred by some zoogeographers. In the south these volcanoes are perched on the top of the subsided Parian borderland, and in the north they are parasitic growths on the western side of the older volcanoes, now covered by limestones and making the eastern terminus of the Greater Antillean series.

Barbados. The geology of Barbados is well known through the work of English naturalists, and it is doubly interesting since the island is covered by 350 feet of unmistakable oceanic deposits. Barbados lies in a hinge, or very mobile area, between the continent of South America and the Caribbean abyss, and the oceanic deposits of the island include even Red Clay, giving good ground for holding that the subsidence may have been to a depth of 10,000 to 12,000 feet. The series begins with shallow-water deposits, followed by the oceanic series of Globigerina and radiolarian oozes, and finally by Red Clay; and these are overlain first by shallower-water foraminiferal ooze and then by coral-reef rock. In addition, the oceanic Echini confirm the depth at which the oozes formed. This great subsidence, if such it actually is, took place essentially during Miocene time, and in the Pliocene Barbados rose again into shallow waters. Vaughan thinks that the subsidence may have been to about 5,000 feet. On the other hand, T. C. Chamberlin (*Jour. Geol.,* 22: 141–143, 1914) advances the "alternative assumption that the benthos life and correlated conditions were carried up to unusual levels by upwelling currents about the island after it reached the stage of moderate submersion." The carrying "up to unusual levels by upwelling currents" is possible, for such occurrences are known in the present Pacific off South America, but one wonders if the abyssal Echini could have lived in "moderate depths." For the present the conclusion appears warranted that Barbados and the whole of the north margin of Paria during the Miocene had sunk to a depth of at least 5,000 feet, and that Barbados rose a similar amount during the Pliocene, and 1,100 feet higher during the Pleistocene, this being the present highest stand of the island. That Paria was very mobile in Miocene time is attested by the 14,000 feet of strata of that age in Trinidad and northern Venezuela.

The Bahamas. In speaking of the flat Gulf of Mexico plate, it was said that the Bahamas were but a continuation of Florida. It may be added that the southeastern Bahamas, and those of the medial region facing the Atlantic as well, appear to be volcanic additions now covered deeply with limestone deposits. Their submarine slopes show this, since they are much like those of the Bermudas, which have proved to be limestone caps on a subsided volcano that also grew up from the ocean bottom. If the outer Bahama islands have no volcanic bottoms, then we must assume that the steep and irregular submarine slopes are organic reef-growths on this now deeply subsided part of the plate. Of the two hypotheses, we prefer that of volcanic addition. On the other hand, the Florida-Bahama plate does not appear ever to have had dry land connection with the Antilles.

Times of diastrophism. In the Central American-Antillean region there were at least four times of major mountain-making, three of folding and one of faulting with local folding. (1) The oldest and most obscure one appears to be of Proterozoic time. Here the basement rocks are largely granites and highly metamorphosed sedimentaries that were peneplained before the late Paleozoic seas transgressed across them. When the marine invasion of Paleozoic time began is not known, but beneath the dated formations of Upper Carboniferous and Permian times there are others some thousands of feet thick, and it may therefore well be that marine Devonian is present, as is often assumed. As no Devonian is known in eastern Mexico, where the oldest Paleozoic strata are of Lower Carboniferous time, it appears more natural, however, to assume that the marine invasion of northern Central America was also of this time.

(2) The second orogeny took place in Central America after the deposition of the Lower Permian and evidently in the middle of late Permian time, since no marine formations of Triassic age are known anywhere other than in northern Mexico, where they are of the Upper Triassic. It is also fairly certain that orogeny took place in late Paleozoic time in western and central Cuba. Even though these mountains of Cuba do not connect with Central America, the late Paleozoic east-west mountain ranges of British Honduras, as stated by Sapper and others, do appear to have continued into the Caymans and southeastern Cuba, while those of Guatemala and Honduras extended across the Honduran-Jamaican banks into the island of Jamaica.

(3) Late in Cretaceous time began the third and best-known orogenic deformation. This was of great strength, with the foldings very extended, and along much the same lines as those of the late Paleozoic. It appears to have come to a conclusion before middle Eocene time. On the other hand, it is very probable that the mountain ranges of British Honduras now made the dominant anticlinorium, which appears to have extended unbroken across the Antillean Sea through the Caymans into southeastern Cuba, thence striking diagonally across Haiti-Santo Domingo into Porto Rico and the Virgins, and finally terminating in Anguilla and Barbuda. It is convex to the north. Another but subsidiary anticlinorium extended through southern Guatemala into northern Honduras

and across the Honduran banks, but may not have attained Jamaica. Between these anticlinoria lay a valley that during the late Cenozoic subsided beneath the sea and in Pliocene time was faulted into the present Bartlett Deep.

(4) The fourth diastrophic time began late in the Miocene and was of greatest force during the Pliocene, bringing on the present high stand of the Central American-Antillean lands and the overdeepening of the Caribbean Sea. These crustal movements were mainly of the epeirogenic kind, very extensive block-faultings with local compensating foldings.

Long separation of North and South America. About a century ago Humboldt taught that "The two American continents are practically dominated by a continuous Cordilleran system, running like a backbone through South, Central, and North America, connecting the whole western border of the hemisphere into one great mountain system" (Hill, 1898, pp. 158–161). About half a century later, Suess modified Humboldt's view of the American Cordillera, holding that the mountain chains of Mexico run into those of Oaxaca, and there, turning east through Guatemala and Honduras, continue through the Greater Antilles, finally swing south with the strike of the Lesser Antilles, and are joined to the east-west ranges of Venezuela, which are but a spur of the Andean system. Sapper, on the other hand, between the years 1894 and 1905, showed that the mountains of northern Central America trend mainly east and west, while those of southern Central America are much younger and of a totally different origin, namely, volcanic. Hill, better than any one before him, brings out the fact that the north-south trending Rocky Mountains cease in the "great scarp" of Mexico to the north of Tehuantepec; that the similarly striking Andes terminate in northwestern Colombia and eastern Panama; and that all the structure lines of northern Central America, the Greater Antilles, the Caribbean Sea, and the north coast of Venezuela are transverse to the great northern and southern chains of mountains, since their average strike is east and west. This great orogenic system, which Hill calls the Antillean system, makes the highland frame for the ancient Caribbean mediterranean on the north and south. The reason why this east-west trending has not been fully appreciated earlier, Hill states, is due "to the overwhelming proportions of the adjacent volcanic mountains." These latter developed in Cenozoic time "diagonally across the western ends of the east and west folds of the Caribbean configurations," in one series fringing the Pacific side of Chiapas, Guatemala and Honduras, and in another western Nicaragua and all of Costa Rica and Panama.

Paleogeography

With this presentation of the broader geological facts and conclusions, we may turn now to the paleogeography of the Central American-Antillean region, but without reproducing here the nine paleogeographic maps. These will be published in the *Bulletin* of the Geological Society of America.

Late Paleozoic time. Back of the Upper Carboniferous, the paleogeography of the Antillean region is obscure and will be considered at another time. Then North America continued more broadly south into Central America, which in turn continued eastward into the Greater Antilles, at least as far as Porto Rico. It should, however, be kept clearly in mind that it is only since Cretaceous times that the Gulf of Mexico has attained its present great size and depth. Accordingly, in Paleozoic time the southern part of the North American platform was broadly rounded and bounded on the south by a mountain range that terminated eastwardly in the Antillean peninsula. Over this part of the platform the Atlantic Ocean spread shallow-water seas from time to time, but to the south of the mountain front lay the deep Pacific Ocean and the Caribbean mediterranean. South of the latter waterway was the Parian borderland of South America. There was then no Costa Rica-Panama and Lesser Antilles, and Florida and the Bahamas were of the flat-lying plate or foreland of Antillea. After Lower Permian time the whole of the Central American-Antillean folded land was again in the throes of decided mountain-making whose trends were in general east-west but curved to the south.

Jurassic time. Following the Upper Permian orogeny there was little change in the geography of the Antillean region, other than in its topography, during the whole of Triassic time. Early in the Jurassic, however, Atlantic waters were again invading most of eastern Mexico more and more widely, and finally in the middle part of this period the same sea began to spread across western Cuba, attaining its maximum late in the Jurassic both in Cuba and Mexico. At this time or shortly afterward, the eastern end of the Antillean geanticline began to grow submarine volcanoes, and more and more of them developed to the east with time, rearing their cones as island masses.

Cretaceous time. With the early Cretaceous, a tremendous change was inaugurated by the widespread and deep subsidence beginning in the western part of the Gulf of Mexico plate, and in consequence inundating widely most of Mexico, Texas and the northern portions of Central America. There also appeared for the first time the Venezuelan geosyncline, which connected in the southwest with the far greater and older Andean one. Closure of the Caribbean opening into the Pacific appears to have been begun early in the Cretaceous by the elevation of a submarine ridge replete with volcanoes.

The Cretaceous flood attained its greatest spread in the north during the later part of the period, spreading far through western North America, over the Gulf border states as far as Illinois, and narrowly along the Atlantic border as far as Massachusetts. The Cretaceous flood also spread widely over the area of the Greater Antilles, especially in Cuba, Jamaica, Santo Domingo and Porto Rico, and in South America the earlier inundation was maintained. At the same time the western side of the Rocky Mountains was rising and pushing the marine invasion farther to the east, as is attested by emergence not only in the United States, but all through western Mexico and Central America as well. The Costa Rica-Panama land-bridge may have been completed before the close of the Cretaceous.

Early Eocene time. Long before the close of the Cretaceous, mountain-making had begun in Mexico, and later, crustal folding and elevation became general throughout Central America and the Greater Antilles, out to the eastern end of the Antillean arc. This dominant anticlinorium, which is curved to the north, extended through British Honduras and thence across the Caymans through southeastern Cuba, striking diagonally over Santo Domingo through medial Porto Rico and the Virgin Islands; farther east the submerged part of the ridge was studded with volcanoes, now the northern or limestone islands of the Lesser Antilles. Another but lesser anticlinorium, curved, however, to the south, extended through southern Guatemala and northern Honduras, and died out across the Honduran banks. Many other Laramides came into existence in Colombia during the late Cretaceous, being the northern terminations of the Andean system, with a northeastern spur that finally strikes east and west through northern Venezuela.

Apparently all the Greater Antilles with the exception of western Jamaica were emergent during early Eocene time, when the Laramide movements were completed. The same appears to have been true of the Costa Rica-Panama land-bridge, though much volcanic activity was general to this region well past the middle of the Eocene. The Bermudas are believed to have been emergent islands in Eocene time, with their volcanic activity exhausted before the close of this epoch.

Upper Eocene time. In Upper Eocene time, when submergence was again very widespread in the Gulf border states, the Greater Antilles were also more or less inundated, affecting Jamaica, Cuba and Haiti most, and Porto Rico only a little along the south shore. Colombia and Venezuela were likewise widely in flood, and most of Costa Rica as well, but Panama only marginally. Barbados was also submerged, and apparently all of the submarine volcanoes of the Caribbee arc north of St. Vincent had grown above sea-level into islands.

Oligocene time. The flood inaugurated in the late Eocene was most widespread during the Oligocene in the Greater Antilles and northern Guatemala, and especially so in Cuba and Jamaica. The Costa Rica-Panama land-bridge was almost everywhere covered by a shallow sea again widely uniting the Caribbean Sea with the Pacific Ocean. Barbados was emergent, and Florida appears as an island. The Bermudas, on the other hand, had gone beneath sea-level.

Miocene time. The Oligocene flood is continued locally—as in northern Guatemala and in Haiti-Santo Domingo—into Lower Miocene time, but in general this epoch is a time of emergence, becoming more and more so until a climax is attained in the Pliocene. Costa Rica is still completely submerged in the early Miocene, but in the middle portion of this epoch becomes emergent, after which time only the Caribbean shore of the entire connecting land is under water. Northern South America is still widely submerged in Miocene times, when very thick clastic formations were laid down. Barbados may have gone down 5,000 feet or more, and in keeping with this great subsidence is the very great loading of Paria with detritus. Florida has now made its appearance as a peninsula. The Bahamas may have been above sea-level in late Miocene time, but more probably during the Pliocene. The Bermudas also appear to be emergent.

Pliocene time. The Pliocene is almost everywhere the time of widest and highest emergence, and throughout Antillea there is tremendous fracturing and downfaulting. The old synclinal valley between Cuba and Jamaica—a sea since the Oligocene—is faulted into the Bartlett Deep, and Yucatan is deeply separated from Cuba, giving rise to the Antillean Sea. Eastern Honduras and Nicaragua and their banks are also let down to below sea-level, but Barbados has risen to near sea-level.

The marine overlaps of Pliocene time are small and marginal, the exception being the south side of the Gulf of Mexico where these marine waters flood all of Yucatan, northern British Honduras, northern Guatemala and the marginal states of southern Mexico north to Tampico; and probably during the late Miocene, but certainly in the early Pliocene, the

Gulf of Mexico for the first time communicated freely with the Pacific Ocean through the Tehuantepec portal. After middle Pliocene time this portal also was closed, and the whole of Central America has remained ever since an emergent and rising area. The Bermudas were submerged for at least a part of Pliocene time.

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THE BIOLOGICAL ARTICLE AND THE OBLIGATIONS OF ITS AUTHOR[1]

An address on an occasion like this gives one an opportunity to present some phase of current work that he deems of general interest or to discuss questions of concern to the group. Most of us would be inclined to agree that it is much more interesting to find out new facts and to discuss them with others than it is to give attention to questions of writing or publication. Having but recently lifted my head above an accumulated mass of manuscripts, the impression is strong in my mind of the evident weaknesses in our methods of publication and of the possibilities for improvement. The problem of methods of communication between investigators has existed since the beginning of scientific work. Merely as a matter of record, one writing is possibly sufficient, but to spread information of discoveries most profitably requires multiple copies. It was easy in the time of Leeuwenhoeck for him to sit down and indite a letter to the Royal Society describing his discovery of the new organisms in infusions and his delight and wonder in them. A natural forward step from this was for organizations to commit to the printed page a record of the discoveries of their members. In fact, all our means of communication are the result of these spontaneous responses to the necessities of the moment. We accordingly have organs of societies which represent the efforts of a limited group; we have journals which have been established through the energy and enterprise of individuals; there are the publications of research institutions which have been developed in response to their needs for recording and disseminating results of their studies and, finally, there are those journals which have been established by commercial houses which have, either through interest in scientific work or through a belief in the value of advertising, seen the advantage of attaching their names to serials.

Science is so new and of so rapid a development that its procedures are still largely empirical and only roughly adapted to the present scope and complexity of the field. This is particularly true of our publications. Some have a long and honorable history, largely because of fortunate connections. Many have lapses and others have changed relations or subject-matter and so have survived. Most of our old journals are those having scientific connections either with incorporated societies or institutes, or those with business associations. All these experiences are natural under the circumstances and present valuable suggestions for future conduct if carefully studied. As scientists we should feel the challenge to take stock of these experiences and to devise means for getting our communications shaped to modern requirements and for providing an effective and convenient system of journals to meet the needs of all groups of biologists and all aspects of the subject.

The fundamental question which we have to consider is: Are publications incidental in their relations to biological progress and so to be left unconsidered, or are they essential elements of the program and deserving of careful planning and management? In the developmental stage of our subject it was natural that progress should be tentative and without comprehensive plans. In its present state, has not the time arrived for careful study and planning? Here we have to consider whether anything else can be done to improve the service of our journals without sacrificing the essential freedom of investigators to work in the manner best adapted to produce results.

If we hope to improve the character of scientific papers it is imperative that we give thought at the same time to where they are to appear, for the character of the article depends in part at least upon the medium available for its publication. The problem then is to discover the course which will make most easy and profitable the use of written records of our discoveries and which will run the least risk of smothering individual initiative and opportunity.

As a necessary preliminary to any future action we must stop to consider our present situation. In doing this we find that there are usually produced about 40,000 titles annually, scattered through some seven or eight thousand periodicals and filling perhaps 500,000 pages. The consideration suggests itself that while this is a staggering total, there are represented a great variety of subjects, so that the individual worker with limited interests is not necessarily concerned with the whole output. While this is certainly true it is also evident that with a growing output there inevitably follows increasing personal limitation of contacts, because each of us has but a limited time to give to reading, and the more that is employed in searching the less there remains for actual reading. While the subject itself is rapidly broadening and ex-

[1] Address delivered before Section F—Zoology, of the American Association for the Advancement of Science, New York, N. Y., Friday evening, December 28, 1928.