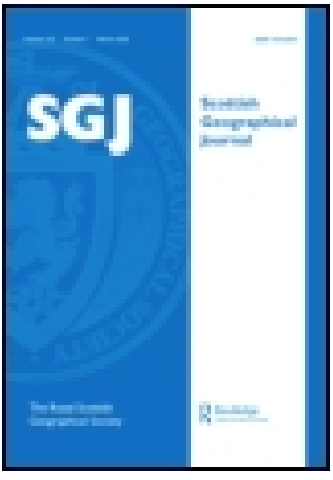

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of this character have been brought against the Portuguese. Their Government is most inoffensive, and I am glad of an opportunity to bear witness to the humanity and kind-heartedness of its agents in dealing with the natives. I have also to acknowledge the ready help which they have rendered to us in matters concerning the welfare of the natives, and the equal treatment which they have meted out to Protestants and Catholics, to English and Portuguese alike.

In conclusion, is it too much to hope that the sword will now remain in its scabbard in Africa, and that all nationalities and sections shall join hands in the most noble of all enterprises, viz., the uplifting of the native races, and equipping them for the prominent part which they are destined to take in the development of their country? There is a great task before us. For ages past the land has been drained of its best life to supply plantations with *slave labour*, as if the Continent of Africa only existed for that purpose.

At the dawn of this twentieth century a new light has been thrown across the darkness, and a new era has commenced in the history of Africa in which the African shall be recognised as a fellow-man and a fellow-worker. Let the Angel of Peace fly aloft, and let Civilisation spread her silver wings over the length and breadth of the Continent; then shall the wilderness become a garden, and Africa shall become the pride of all the nations, and the black man and the white man shall rejoice together, in peace and in love.

THE EVOLUTION OF THE ANTILLES.

By J. D. Falconer, M.A., B.Sc.

Alexander von Humboldt enunciated two great ideas about the structure of the New World. In the one he insisted upon the geological continuity of the great mountain-systems from Alaska to Fuegia: in the other he asserted that between the twin continents there was formerly intercalated a third element, a third America, now represented only by the submerged mountain-chain of the Antilles. Modern scientific research, while it has largely modified the former, has strongly confirmed the latter idea, and has afforded us data from which the geography of the lost land at different periods can be at least partially restored.

Omitting for the moment all details of the central region, we may take first a general survey of the origin of the New World and its connection with the Antilles. It will be readily granted that the presence of a complex of Archæan or pre-Cambrian rocks appearing now at the surface over wide areas, or partially covered by unconformable strata of later age, indicates the probable distribution of the dry land at the beginning of Palæozoic time. The most extensive development of Archæan gneisses, schists, and plutonic intrusions in America occurs in the Laurentian district of Canada, stretching from the St. Lawrence and the Great Lakes away to the north-west along the

valley of the Mackenzie River. A similar complex occurs in the highlands of Brazil and Guiana, and appears in different parts of the chains of the Andes, the Rockies, the Appalachians, the mountains of North Venezuela and Guatemala and the islands of the Greater Antilles. Connecting together the various tracts, we may picture the site of the New World occupied in these early times by two great Mediterraneans. The northern was bounded to the NW. by the Laurentian Mountains and encircled on the other sides by groups of islands occupying the sites of the Appalachians and the Rocky Mountains, the Antilles and Guatemala. Similarly the southern was bounded on the east and north by the archipelagoes of the Andes and of Venezuela, while on the west it washed the shores of the Guiana and Brazilian highlands and the Tandil and Ventana heights. The Caribbean Sea was probably also delineated at this time by groups of islands on the east and west, connecting together the transverse ridges of the Antilles and North Venezuela. Thus from the very beginning the plans for the New World were drawn out and the foundations of the great mountain-chains were laid, and the story of the succeeding ages is largely the history of the building of the mountains and the filling up of the seas.

During Palæozoic times great longitudinal troughs or geosynclinals were formed on either side of the primitive mountain ridges, and into these the waste of the highlands was washed. As the result of gentle lateral compression, the floors of these great basins gradually sank, while the intervening ridges as slowly rose. Possibly connected also with the formation of these geosynclinals to the north and south was the elevation of the central region. The entire district between the Equator and the Tropic of Cancer was, with the probable exception of a large inland sea on the site of the Caribbean, apparently high and dry during the whole of the Palæozoic era. Progress in mountain-building, however, was slow until the close of Palæozoic time. Then orogenic activity manifested itself chiefly in the east of North America in the upheaval in a series of longitudinal folds of the Appalachian system, including the whole of the eastern half of the United States. North America to the east of the ninety-fifth parallel was now for the most part finished, and has never been again entirely submerged. Minor ridges were formed in the Nevada district in the west and in the vicinity of Lake Titicaca in South America. The remarkable feature of this period, however, is the existence of continuous land from Hudson Bay to the Orinoco, while the western portions of both continents were still drowned in water with the exception of the protaxes of the future mountains.

This condition of affairs continued until well on in the Mesozoic era. It was not until the close of Jurassic time that the floors of the great geosynclinals were disturbed to any great extent. Then, however, the Sierra Nevada and the coast ranges of the north were upheaved as well as the principal chain of the Andes, south of Peru. The Mexican plateau was elevated in early Cretaceous times, and the great Mediterraneans were shallowed especially in the north, where fresh water or marshy conditions largely prevailed at this time. Subsidence speedily

followed, however, until towards the close of the Cretaceous period the maximum depression was experienced in North and South America. Simultaneously with this second subsidence began the sinking of the two transverse mountain-chains of the Antilles and North Venezuela, which had up to this time formed an extensive tract of land. Only small islands, smaller even than the present Antilles, remained above the surface, while the Atlantic and the Pacific Oceans again mingled their waters across Central America. The end of the Cretaceous was marked however by great orogenic activity. The Rocky Mountains, the Northern Andes, and the Venezuelan coast ranges were now upheaved, followed later by the mountains of the Antilles. Igneous eruptions were a marked feature of both the earlier and the later stages. The lavas of Wyoming, Montana, Yellowstone Park, and the western Cordillera of Ecuador were poured out at or near the close of the Cretaceous. Probably about the same time also the volcanoes of Central America were established along an independent line, and the ancient lavas were accumulated on the site of the Lesser Antilles.

Thus in early Tertiary times the Americas had largely assumed their present aspect. The elevation of the mountain-ranges, however, and of the continents as a whole, was much less than it is at present. The Gulf of Mexico was continuous with the Atlantic over the peninsula of Florida: Central America was represented by a volcanic archipelago: the Antilles were farther invaded than now by the Caribbean Sea, and great lakes covered the interior of both continents. The extensive elevation of the continental areas was the work of Tertiary times. Great longitudinal geoanticlinals were slowly formed, and much faulting and fracturing took place along old and new lines of weakness. The Miocene saw Florida united through the Bahamas with the Antilles, and the maximum elevation over the whole of the New World was reached in early Pleistocene times, when the Antillean plateau formed a complete land connection between North and South America. The bridge was soon after broken and shattered, probably through subterranean movements connected with the establishment of the transverse volcanic fissure in Mexico and the faulting of the Venezuelan coast. The general elevation, however, appears to have had little effect on Central America, across which the waters of the Pacific entered the Caribbean Sea during the whole of the Tertiary era. Various minor upheavals and oscillations of level not yet fully investigated have affected the central archipelagoes in Tertiary and recent times.

We come now to the more detailed account of Central America and the Antilles. It is important to note in working out the history of this region that nowhere east of Tehuantepec between the fifth and twenty-fifth parallels do there occur fossiliferous deposits which can be definitely assigned to any period earlier than the Lower Cretaceous, while the Cretaceous beds themselves are always more or less disturbed, often contorted and metamorphosed, and everywhere overlaid in the low grounds by the later Tertiary deposits. It is at once apparent that dry land existed here until Jurassic times, and that extensive upheaval took place at the beginning of the Tertiary era.

Beginning with Central America, we are at once struck with the great line of volcanoes which extend along the Pacific coast from Soconusco in Guatemala to Chiriqui in Panama. The volcanoes, many of which are now extinct or dormant, are arranged along two fissures, which meet at an obtuse angle in the Bay of Fonseca. The whole system is entirely independent of the other volcanic bands in North and South America, although it probably dates back with them to post-Cretaceous times. It is believed that these volcanoes have played a large part in building up the narrow neck of land which now unites the two continents. Suess[1] draws attention to the curious fact that the displacement of the craters in the successive eruptions has taken place in every case along transverse lines of fracture of varying length according to the number of the eruptions, and always in the direction of the Pacific. At each of the original points of eruption there seems to have been formed a fissure normal to the principal volcanic axis, and along these fissures the volcanoes are marching in line towards the Pacific. On the Atlantic side of Central America there exists, although overshadowed by the lofty volcanoes, what appears to be at first sight a second range of mountains, approaching the coast in the Bay of Honduras and converging to meet the volcanic series in Guatemala and Costa Rica. Investigation has shown, however, that this is really not one continuous range but a complex of transverse and longitudinal intersecting ridges which never attain individually any great length. These mountains are entirely without relation to the volcanic line, which truncates them along the Pacific margin and only accidentally coincides with them in the north-west and south-east. All are composed of ancient gneisses and schists with intrusive granites, syenites, and other plutonic rocks, followed in places by Cretaceous sandstones, conglomerates, and limestones, the whole overlaid towards the coast, and especially in Yucatan, by thick Tertiary deposits. These mountains are connected beyond Tehuantepec with the ancient crystalline rocks of the Mexican sierras and with a similar complex in Panama beyond the termination of the volcanic line.

In Colombia we find the Andes dividing into four distinct ranges immediately north of Ecuador. Of these the most westerly, the Choco mountains, are probably continued as the crystalline Veragua range of Panama. Farther east come the Western and Central Cordilleras, separated by the Cauca valley. These, like the coast range, are very imperfectly known. The Eastern Cordillera, however, has been studied by Hettner. It sweeps round to the north-east into Venezuela, where it bifurcates to surround the Gulf of Maracaibo on the west and south. The southern branch, the Sierra de Merida, is prolonged in Venezuela to meet the Carib mountains, which skirt the coast from the Gulf of Triste to Trinidad. The two ranges meet at an obtuse angle in the much folded and contorted district of Barquisimeto. The structure of these ranges is the same throughout. A central zone of ancient crystalline and eruptive rocks is flanked on either side by Cretaceous strata, frequently at high angles, which in Trinidad become the storehouses of bitumen. The isolated district of the Sierra de Santa Marta and the peninsula of Goajira are entirely composed of ancient crystalline and schistose rocks,

[1] *La Face de la Terre*, 1897.

with the Maracaibo Cretaceous to the south, and Sievers suggests that they represent the beginning of another range now submerged, which ran parallel to the Carib mountains through the islands of Oruba, Curazoa, and Buen Aire. Miocene deposits are said to occur in several places along the coast, especially in the peninsula of Paraguana, while, according to Suess, the later Tertiaries have penetrated into the interior through the Gulf of Barcelona and disappear beneath the llanos of the Orinoco. If this is so, the extensive faulting so apparent along the Caribbean shore must be referred to pre-Miocene times. But it is permissible to doubt the occurrence of Miocene deposits in this region, on account of their total absence in the island of Trinidad,[1] while the broken Pleistocene bridge to the north seems to favour the more recent origin of the fault. The Gulf of Maracaibo is believed by Hettner and Sievers to occupy the centre of another faulted basin. Readjustments appear to be still taking place along the coast. The districts of Caracas and Cumana are noted for their earthquakes, and the Gulf of Curiaco is said to have been formed by a great convulsion which took place not long before the discovery of America. Volcanic action, though now quiescent, is accountable for the larger part of the island of Tobago and for an alleged extensive accumulation of recent lavas between the gulfs of Curiaco and Paria.

The islands of the Greater Antilles from Cuba and Jamaica to the Virgin islands all exhibit the same geological structure. The mountains show a central axis of gneiss, granite, and ancient eruptive rocks, followed by alternations of glauconitic sands, marls, and unfossiliferous siliceous limestones with layers of asphalt, the whole frequently metamorphosed into black schists, quartzites, and marbles. This series is analogous to the lower beds of the European Flysch. These are followed by fossiliferous limestones of middle Cretaceous age, the whole overlaid in the low grounds by thick Tertiary and recent deposits of orbitoitic and coralline limestone. The same crystalline axis and the same general succession is found in the mountains of Trinidad and North Venezuela, in Guatemala and Honduras, and, according to Suess, in parts of Barbados and Guadeloupe. This similarity of structure suggests a common origin, and the trend of the insular mountains indicates their former existence as a series of connected ridges. The centre of the Antillean group was apparently in the eastern part of the island of Haiti, from which two ridges diverged towards the west. One passed through the north-western peninsula of Haiti, the Sierra Maestra of Cuba, the Great and Little Caymans, and the Misterios banks to Guatemala. The other ran from the south-western peninsula of Haiti, through the Blue mountains of Jamaica and the Pedro and Serranilla banks to Honduras. The mountains were continued to the east as a single range, now largely submerged, which curved sharply round through Barbados to Trinidad and Venezuela.

The majority of the Lesser Antilles are of volcanic origin, composed of recent lavas covering a more ancient igneous basement, which is referred to late Cretaceous or early Eocene age.[1] They represent the remains of a line of volcanoes which were established about the same time as those of Central America, and had, like the latter, an Archæan

[1] Spencer, *The Windward Islands. Trans. Canad. Inst.*, 1901.

and Cretaceous ridge to the east, portions of which are still visible in Guadeloupe and Barbados. The bituminous pits of the latter island indicate its intimate relation with Trinidad. Some of the smaller islands, for example Anegada, Sombrero, and Barbuda are entirely composed of white limestone, and probably rise on a similar igneous foundation. The deposits appear to be of Oligocene age overlaid by Pleistocene. Peculiar deposits of radiolarian and foraminiferal marl and red clay occur in Barbados and Trinidad, and pass under the Oligocene limestone. They are believed to have been accumulated in abysses of the ocean at a depth of two miles or more during the period of maximum depression.

The Bahamas and the Bahama Bank connect Florida with Haiti and Puerto Rico. They are supposed to have an Archæan axis, but no borings yet made have gone below the Cretaceous. White foraminiferal limestone of Oligocene age, composed largely of the tests of *Orbitoides Mantelli*, forms the surface rock, and is flanked by Pleistocene deposits in these islands as throughout the Antilles. This absence of any deposits of Miocene or Pliocene age throughout the archipelago appears to indicate the existence of dry land conditions during that period; and that the islands were so far elevated as to form a continuous land connection between Florida and Venezuela is confirmed along various lines of evidence. Remains of early Pleistocene elephants and large rodents have recently been found in a limestone cavern in the island of Anguilla. Guadeloupe has also furnished the remains of a small Pleistocene South American elephant. These animals must have migrated from the continent during the period of maximum elevation. Further, Agassiz has shown that the fauna of the deepest parts of the Gulf of Mexico and the Caribbean Sea bears a greater resemblance to the deep-sea fauna of the Pacific than to that of the Atlantic. This indicates not only a continuous isthmus between North and South America, but the free passage of the Pacific across Central America. Bland has shown further that the land snails of the islands from Cuba to Antigua are closely related to those of Mexico and Central America, while those of Antigua and St. Kitts to Trinidad have South American affinities. The Gulf of Mexico became an inland sea subject to periodical invasions of the Pacific, for the shore deposits include between the Oligocene limestone and the recent marine accumulations the peculiar *Grand Gulf Series* which appears to be of fresh or brackish water origin.

The Antillean plateau was submerged and shattered by extensive faulting soon after the beginning of Pleistocene times. The volcanoes of Mexico may perhaps have some connection with this subsidence. Although many of these are now dormant or extinct, the cones are still perfect and have evidently been exposed to denudation for a comparatively short time. Moreover they are all set on a transverse line which runs approximately along the nineteenth parallel. The prolongation of this line passes along the truncated southern border of the Sierra Maestra in Cuba, and through some of the deepest parts of the Caribbean Sea into the Brownson Deep. This may possibly indicate the line of one of the larger faults, and if the fracture of the Venezuelan

coast may be referred to the same period, the two faults would form a trough into which the Antilles would sink with increasing downthrow towards the east. Since this great subsidence the islands have been undergoing gradual elevation, a series of terraces, well seen in Barbados, having been cut out of the new coral reefs as the land was rising. Central America has also shared in the recent oscillations. Biological observation has shown that while the marine molluscs and fish are on the whole of distinct species on either side of the isthmus, a large number of fish but very few molluscs are identical. This points to a subsidence of comparatively short duration within recent times. The whole configuration of the land and the distribution of the islands in the New World may be explained according to Suess by the interaction of two sets of waves of compression advancing originally at right angles to each other. If of equal inertia, the result of their meeting would be the production of a complex of intersecting ridges as in the Brazilian highlands. If the inertia of the one should exceed that of the other, the stronger would simply be deflected and the weaker absorbed. On this theory the primitive Andean ridges were deflected in Colombia successively to the east and west by waves advancing from the north. Similarly the transverse Antillean ridge was deflected towards the south by a wave advancing from the east which was itself deflected towards the west along Florida and the Bahamas. Again the interaction of deflected Mexican waves and transverse waves produced the complex mountain-system of Guatemala and Honduras, the Sierra de Comayagua being possibly the remains of a wave with a north and south front. Moreover the great upheavals at the end of Mesozoic times were again the result of two sets of waves which were deflected in the same way as before, the Archæan ridges forming stable axes along which the mountains were folded. According to this theory the inertia of the meridional waves and the consequent mountain-building would appear to have been always greater than that of the equatorial waves in the New World, while the opposite was the rule in the Old World.

The recent volcanic disturbances in St. Vincent and Martinique are evidently connected with readjustments along the line of weakness which, as we have seen, has existed there since the beginning of Tertiary times. Dust from the Soufrière was carried on May 7 as far as Barbados against the prevailing wind, and therefore necessarily in the upper reaches of the atmosphere. The constitution of the dust gives us some interesting information about the nature of the molten rock which filled the crater. The particles are never so large as one-thirtieth of an inch, and may be readily separated into sizes by means of sieves. The largest are mostly fragments of vesicular and glassy lava, grey, brown, or red in colour, floating readily on water, and when crushed, exhibiting a few microlites of felspar. Associated with these are broken crystals of felspar, amphibole, pyroxene, and magnetite. The magnetite is very abundant, and often occurs in perfect crystals showing octahedral and dodecahedral faces. It can be readily extracted from the dust by passing a magnet through it. The felspars sometimes occur in perfect tabular crystals, but usually they are fragmentary, broken either regu-

larly along the cleavage planes or quite irregularly with a glassy fracture. Often they exhibit a peculiar pitted surface, as if they had suffered mutual attrition in the air. They frequently show zonal structure in polarised light and always exhibit the characteristic striation of plagioclase felspar. Glass cavities and inclusions of small crystals of magnetite are abundant. In specific gravity they range from labradorite to anorthite, and are therefore fairly basic soda-lime varieties. The pyroxene is of two kinds, monoclinic and rhombic. The monoclinic is green, very slightly dichroic, with a high extinction angle, and never in good crystals. The rhombic, however, is frequently idiomorphic in short stout prisms, of a reddish brown colour, strongly dichroic through yellow and green, and giving a straight extinction. Both varieties have numerous inclusions, and the rhombic is perhaps the more abundant of the two. The amphibole is very sparingly present, and is represented by a few elongated crystals of brown hornblende. All the larger particles are coated with fine dust, which is composed simply of comminuted pumice and microscopic fragments of crystals.

Taking the constitution of the dust as a fair index to that of the magma, we find that the minerals in the ash correspond exactly to the phenocrysts of the rock known as hypersthene andesite. This, then, is the rock which would have been formed if the lava had flowed out at the surface. It would have consolidated as a dark-coloured glassy rock, studded with numerous porphyritic crystals of felspar and pyroxene. It is interesting to compare the constitution of this recent dust with that from the eruption of the Soufrière in 1812. A sample of the latter, also collected in Barbados, is much finer in grain, thus indicating either a less intense explosion or weaker air currents at the time of eruption. The dust, however, is practically composed of the same minerals, with the rhombic pyroxene in greater excess. This identity in composition would therefore also be a feature of the magmas in the reservoir. The only conclusion that can be drawn from this is, that ninety years is not a sufficiently long period for the production of any extensive differentiation in the magma. It is more probable that there would be a difference in type between the products of these recent eruptions and the old basement lavas[1] which underlie all the islands of the Lesser Antilles. It may be hoped that some of the numerous scientific men who have been despatched to the spot will thoroughly investigate this interesting point. These volcanoes, as we have already seen, are entirely independent of any of the other volcanic groups in America, so that a comparison between their products is not of great value. One point brought out by such a comparison, however, is the predominance amongst recent American lavas of rocks of intermediate type as a whole, and among these, of hypersthene andesite in particular.

The accompanying illustration shows the town of St. Pierre, Martinique, before the late eruption. The background shows the slopes of Mount Pelée. We are indebted for the loan of the block to the Royal Mail Steam Packet Company, London.

[1] Of these lavas little is known. Porphyrites and greenstones are said to be common, and Zirkel mentions the occurrence of trachytes in Martinique.