Technical Papers

Tertiary Boulders in the Cretaceous of Puerto Rico

Raoul C. Mitchell
Mayagüez, Puerto Rico

Recently the author found some Tertiary boulders high in the interior of Puerto Rico where Cretaceous pyroclastics and sediments occur. Eight boulders, ranging from 4″–16″ in diameter, were found within an area of a few square yards in a stream bed. In composition they are silty and sandy, tan-colored marls with white inclusions of calcite, and they contain glauconite in small amounts. The boulders are subangular but smooth, though their surfaces are somewhat pitted. The only identifiable fossils are some poorly preserved foraminiferal forms belonging to the genera *Triloculina, Quinqueloculina,* and *Pyrgo.* On lithologic and faunal grounds, the boulders appear to belong to the upper part of the San Sebastián formation (Table 1).

The boulders were found up the left fork of a small, unnamed south-bank tributary that joins the Río Guaba 4 miles downstream from the source of the latter. The locality is in Barrio Indiera Fría, Municipality of Maricao, about 3 miles southeast of the town of Maricao (Fig. 1). The boulders lie at an elevation of 2160′. The source of the fork lies about 600′ southeast of the site, and the main east-west watershed of the island is about 1500 yards due south of the source at an elevation of 2660′. The rocks in the immediate vicinity include blue-black limy shales and brownish andesitic tuffs, which are probably the Peñuelas Shales of Mitchell (*1*). Badly weathered serpentines, saussuritized quartz-diorites, and diabases are present in the region, also.

Hubbard (*2*) is the only previous worker on the geology of Puerto Rico who mentioned finding a Tertiary boulder within the Cretaceous. His boulder occurred "in the channel of the Río Guayaba 2 miles SE of Aguada," which would place the locality at an elevation of 100′–160′ and approximately 1½ miles from the nearest Tertiary outcrop. He suspected that this boulder belonged to the Lares formation. A search was made for it without success. The local inhabitants do not know where the Río Guayaba is, and the topographic maps do not indicate it; probably Hubbard used the wrong name.

The nearest north coast Tertiary outcrop to the Guaba boulders is the San Sebastián formation, which is 10 miles away, the elevation of the top and base being 1148′ and 984′, respectively. To the south, the nearest Tertiary outcrop—the Lower Ponce Member—is 14 miles away. Thus, in the longitude of the boulders, the north and south coast Tertiaries are separated by 24 miles, with a maximum altitude of 2660′ between them.

A diligent search in the vicinity has failed to reveal any exposures of Tertiary rock *in situ.* In some scattered localities near at hand, however, there are soils that have a close similarity to the loams and silty clay loams of the Moca soils group of Roberts (*3*), which are extensively developed in the region of the San Sebastián formation between Moca and San Sebastián. Further, along the road from San Sebastián to Lares the writer has observed boulders, cobbles, and pebbles of Cretaceous rocks which could be considered as typical basal material of the San Sebastián formation. These two observations suggest the possibility of Tertiary rock *in situ* beneath the surface, but direct evidence of Tertiary outcrops is lacking. When consideration is given to the slope (10°) of the tributary from

TABLE 1

Subdivisions of the Tertiary of the North and South Coastal Plains of Puerto Rico

Thickness (ft)	North coast	Age	South coast	Thickness (ft)
1100	Aymamon Limestone	Lower Miocene	Upper Ponce Member	1312
246	Aguada "			
754	Cibao			
393	Guajataca Member			
	Marl	Lower Miocene to Middle Oligocene	Lower Ponce Member	2952
1312	Lares Limestone			
984	San Sebastián Formation		Juana Diaz Formation	2148

its source to the junction with the Río Guaba, the very steep valley sides (45° slopes and more are common), the angular nature of the boulders, it is to be presumed that gravity has been a more important agent of transportation than running water in any movements of the material.

The Tertiary formations of the north and south coast illustrate a marine onlap onto the Cretaceous rocks of the interior, but, as observed today, the oldest strata occur farthest inland because of more extensive erosion of the younger beds. The older Tertiary deposits at the outcrop areas have a somewhat higher dip than the younger strata, and the Tertiary of the south coast dips more steeply than that of the north coast. It is assumed that these are not initial dips but were acquired by tilting during the late Miocene uplift of the island.

Two possible explanations may account for the presence of Tertiary material high in the Cretaceous interior: (1) it may represent remnants of Tertiary deposition in an advancing sea within an embayment penetrating far into the interior of the island, or (2) it may represent remnants of Tertiary deposits which once covered the island—at least the western part.

Regarding the first possibility, there seems little doubt that an axis of subsidence extends in a NW–SE direction from the general region of San Sebastián on the north to Ponce on the south. The strike-profile of Zapp (*4*) clearly shows a deep embayment some 35 miles wide in the general longitude of San Sebastián, and it is here that the north coast Tertiary is not only thickest but also penetrates farthest south in its outcrop areas. The pre-Tertiary surface upon which deposition took place was highly irregular, and its relief was probably of the order of 1000′–2000′, perhaps more. From the end of Cretaceous to Middle Oligocene time, the island was undergoing denudation, and it is quite possible that the maximum elevation of Puerto Rico at the beginning of Tertiary deposition was considerably higher than the present 4400′. In spite of several attempts that have been made to correlate the Tertiary of the north and south coasts, a close agreement has not been reached, and Meyerhoff (*5*) is of the opinion that the northern and southern marine areas coalesced only in the region of Vieques Island, east of Puerto Rico. Thus, taking an average thickness for the north and south coast Tertiary of 5000′, even after a submergence of this amount, the island was not completely inundated, but a mountain axis of Cretaceous rocks still persisted in separating the Tertiary formations of the north and south coasts.

The second hypothesis, that the Tertiary once coalesced over the mountainous interior, deserves mention. Until recently, it was thought that Tertiary strata occur only along the north and south coasts. However, McGuinness (*6*) reports the finding of late Miocene faunas in core samples taken from depths of 80′–220′ in water wells in Mayagüez. Recently the writer has inspected cores taken during the construction of the

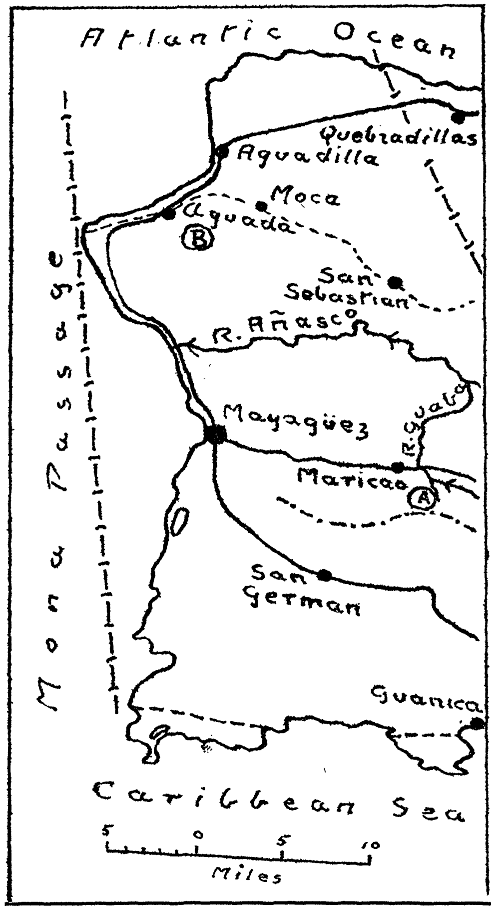

FIG. 1. Western Puerto Rico, showing boulder location and other features. *A*, Guaba boulders; *B*, approximate location of Hubbard's boulder; – – – – –, limits of the north and south coast Tertiary; –.–.–.–.–, main E–W watershed of the island; –|–|–|–, axes of subsidence; ~~~~, main roads.

Darlington Apartments in Mayagüez. The foraminifera *Archaias aduncus* (Fichtel & Moll) or *Archaias angulatus* (Fichtel & Moll) was identified from samples at a depth of 65′–68′. These species have been mentioned by Galloway and Heminway (*7*) as common in the Los Puertos (Aymamen Limestone) and Ponce formations, and the genus *Archaias* is considered indicative of the Upper Miocene Bowden Marls of Jamaica (*8*). We can therefore accept the presence of Tertiary at shallow depths, at least in the Mayagüez area of western Puerto Rico. As neither the McGuinness nor the Darlington samples came from great depth (maximum 220′), it is not known whether older strata lie below the late Miocene. The name Guanajibo formation has been proposed by McGuinness for these late Miocene beds.

We do not know whether strata younger than Lower Miocene may have been deposited along the north and south coasts, and later removed by erosion. The uplift giving rise to the St. John peneplain occurred in late Miocene–early Pliocene time, and hence it is possible that beds younger than Lower Miocene were laid down along the north and south coasts. McGuinness (*6*) mentions a possible NNW–SSE axis of depression along the extreme western edge of Puerto Rico, and perhaps this sagging preserved later Miocene deposits along the west coast, whereas the higher arching to the east resulted in the erosion of contemporaneous deposits. Therefore it is conceivable that deposition took place along the north, south, and west coasts of the island. No known Tertiary rocks occur along the east coast, but Tertiary is presumed to underlie the shallow Vieques Sound, and Lower Miocene strata appear at the surface in southern and eastern Vieques Island, which, according to Meyerhoff (*5*), show a gradational fauna—i.e., gradational between the north and south coast faunas of Puerto Rico. The eastward tilting of both the St. John and the Caguana peneplains has carried the Tertiary down to lower levels in eastern Puerto Rico and in the islands farther east.

In Jamaica the White Limestone of Upper Eocene–Middle Miocene age forms a framework around the Cretaceous rocks of the Blue Mountains, extending as high as some 4000′, with Blue Mountain Peak rising to 7300′. It is the opinion of Trechmann (*9*) that the White Limestone once formed a covering over the Cretaceous of the highest areas, although today the north and south coast outcrops of this limestone are 24 miles apart. He believes that in post-Middle Miocene time, the Blue Mountains were raised at least 3000′. In Puerto Rico, remnants of the older, or St. John, peneplain occur at an elevation of 3000′ in the Adjuntas–Lares region and descend to 1500′ in eastern Puerto Rico and to 1000′ in the western part of the island. This peneplain was elevated in earth movements associated with world-wide diastrophism toward the end of the Miocene. It is not unreasonable, therefore, to postulate that the Tertiary formations of the north, south, and west coasts of Puerto Rico, which seem comparable to the Upper White Limestone–Bowden Marl of Jamaica in regard to faunal content and age, also covered the island of Puerto Rico.

Both these explanations are based on the supposition that Tertiary *in situ* occurs at elevations as high as 2160′. The possibility of Tertiary *in situ* beneath the surface in the Río Guaba region cannot be excluded, even although none has been found, and we are dealing here with boulders, not outcrops. As remarked previously, the subangular boulders appear to belong to the upper part of the San Sebastián formation, and there are indications in the vicinity that the Cretaceous boulders, cobbles, and pebbles may have formed the basal material of the same formation. The presence of these "exotic" upper boulders now lying in a milieu of basal material can be accounted for by gravitational movement down the steep Cretaceous surfaces, in the manner of scree formation.

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Quantitative Studies on Proteolipide as Incitant of Disseminated Encephalomyelitis in Mice

Chloe Tal[1] and Peter K. Olitsky

Laboratories of The Rockefeller Institute for Medical Research, New York

The identification of the agent present in brain tissue that produces experimentally disseminated (allergic or isoallergic) encephalomyelitis that bears certain resemblance to the human demyelinating encephalitides has been advanced recently by the finding that proteolipide (*1*), a new type of lipoprotein, can reproduce the affection in mice (*2*).

In view of the fact that there has been no uniformity of opinion hitherto on the chemical nature of the incitant of the experimental disease (*3*), it was thought desirable to report additional evidence for consideration of brain proteolipide as the etiological factor of the experimental encephalomyelitis in mice. The evidence is based on a quantitative study of its encephalitogenic potency and derives, first, from the correlation of its concentration with the degree of reaction in mice and, second, from the inability of brain tissue of newborn mice to produce encephalomyelitis, for their tissues do not contain proteolipide (*4*). With respect to the first, the data collected concern (*a*) the number of reactors after injection and (*b*) degree of the reaction; (*c*) the number of days from the first injection to onset of signs; (*d*) the number of injections needed to induce a reaction and (*e*) the minimal time required to bring about a maximum reaction, presented in Table 1 as number of days times number of injections. In Table 1 will be found a summary of one example of a repeated experiment.

The preparation of mouse brain proteolipide followed the method of Folch and Lees (*1, 2*), and the proteolipide was obtained from 150 fresh brains (which weighed 60 g) of 2–4 months old W-Swiss mice. An additional test was made with proteolipide

[1] Postdoctoral research fellow of the National Institute of Mental Health, National Institutes of Health, USPHS.