Reports

Caribbean Eocene Volcanism and the Extent of Horizon A

Abstract. *Layer A and its correlative layer A″ in the Caribbean have been interpreted as chert layers produced by Eocene volcanism. Exposures of Eocene volcanic rocks in Puerto Rico and the Dominican Republic may represent layer A interbedded with coarser volcanic debris and preserved near early Tertiary volcanic centers.*

The ideas of workers in several geographic areas and fields of geology have converged in the interpretation of reflecting horizons found throughout the western North Atlantic. First seen on continuous profiles during oceanographic surveys (*1*), layer A was penetrated and sampled during the JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) program (*2*), where it was discovered that hard siliceous beds containing Radiolaria and diatoms formed the reflecting horizons. An age of Early to Middle Eocene was determined (*2*). Previously, pyroclastic material of Late-Early to Early-Middle Eocene was identified in dredge hauls along the Atlantic coast of North America, from Long Island southward to South Carolina, and in rocks and sediments of Eocene age (*3*). We suggest that the pyroclastic material is derived from Eocene volcanic centers in Puerto Rico and elsewhere in the Caribbean and that layer A correlatives crop out on several Caribbean islands (*4*).

The occurrence of fine volcanic material mixed into nonvolcanic clays on the Atlantic coast (*3*) suggests a distant location for the volcanism. As a result of their examination of rocks from the Universidad formation of Cuba (*3, 5*), Gibson and Towe suggest that the volcanic source is to the south. This formation contains a 10- to 15-m siliceous limestone and chalk member, which is interpreted as a deep-sea deposit comparable in depth to the Eocene to Miocene Oceanic formation of Barbados (*5*) and which shows slumping, cross-bedding, and other evidences of instability. In these strata Gibson and Towe find the clinoptilolite-opal/cristobalite-montmorillonite suite indicative of altered volcanic glass (*3*). Although this volcanic component increases in relative amount to the south, the actual volcanic center must have been distant.

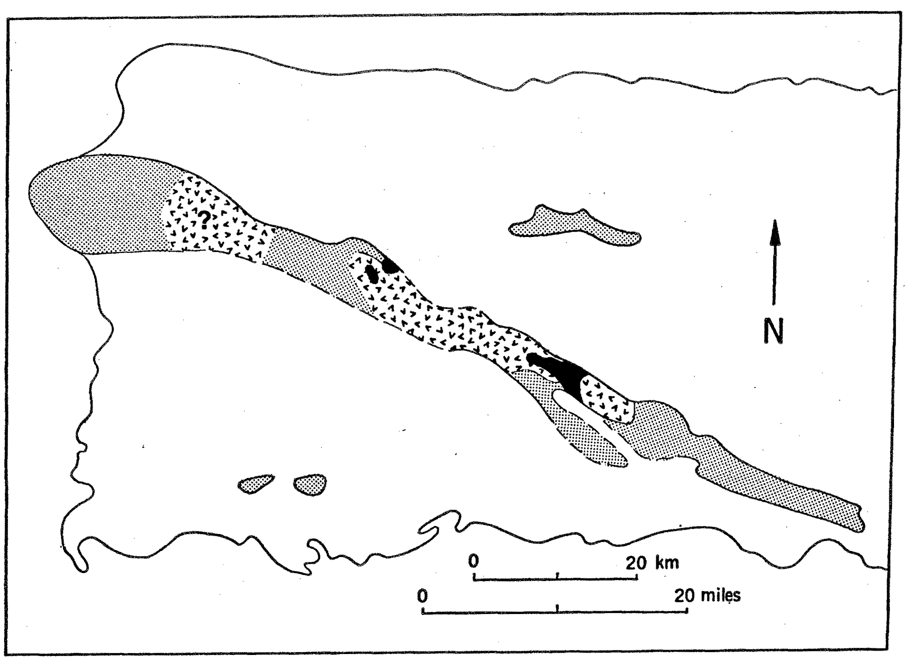

Fig. 1. Eocene volcanic sequence in central and western Puerto Rico. Dark areas, dacite and andesite plugs; v's, volcanic breccias and lavas; stippled areas, fine-grained pyroclastic rocks and sedimentary rocks (*6, 7*). Boundaries are faults and unconformities, although a latest Maestrichtian volcanic series lies apparently conformably beneath lower Tertiary rocks in several places. Detailed mapping is not yet completed in the northwestern and southwestern parts of the volcanic sequence.

Working in the eastern Greater Antilles, we came to the same conclusions as Gibson and Towe, from a different suite of rocks (*4*). Geological mapping in Puerto Rico (*6, 7*) and the Dominican Republic (*8*) established the presence of extensive volcanic sequences, named the Jacaguas group in Puerto Rico and the Imbert formation in the Dominican Republic. As much as 3000 m of dacite and andesite volcanic rocks occur in south-central Puerto Rico, cut by dacite and andesite volcanic plugs toward which the pyroclastic and effusive rocks thicken (*9*) (Fig. 1). Graywackes, volcanic sandstones, mudstones, tuffs (including cherty, green, vitric tuff), and some limestone are interbedded with the lavas and breccias (*10*). The cherty, light green, vitric tuff, the glass now devitrified largely to montmorillonite, is an important marker unit for this sequence in Puerto Rico and may well be correlative with the cherty horizons (often green) found in the JOIDES samples. Some units such as the Jicara formation in southwestern Puerto Rico are comprised almost entirely of this lithofacies.

The age of the Jacaguas has been determined as Paleocene to Middle Eocene on the basis of studies of planktonic Foraminifera (*7*), although fossils as old as Maestrichtian have been identified in a few places (*10*). The group is conformable with a Maestrichtian volcanic unit (*6, 7, 10*) and overlain unconformably by Lower Oligocene clastic and carbonate rocks containing no pyroclastic components (*11*).

The Imbert formation in northern Dominican Republic probably represents the same suite of rocks: "a 1000-m-thick succession of fine-grained, graded, bedded, calcareous tuffs which grade upward into vitric andesite and dacite tuffs, with rare interbedded green radiolarian cherts and thin white aphanitic limestones" (*8*). The Imbert, Paleocene to Lower Eocene by foraminiferal data, rests unconformably upon volcanic rocks of unknown age; it was eroded to provide detritus for early Late Eocene conglomerates.

Other areas of Early and Middle Eocene volcanic activity in the Caribbean are a center including easternmost Cuba (*12*), eastern Jamaica (*13*), and northwestern Haiti (*14*), and another center in the northeastern Caribbean near St. Bartholomew (*15*). A lower Tertiary volcanic center near Tobago has been suggested (*14*), on the basis of the correlation of undated dacite and andesite volcanic rocks deformed in a pre-Miocene orogeny (*16*). As dacitic volcanism occurs elsewhere in the Caribbean in the latest Cretaceous and early Tertiary, this correlation may be tentatively accepted. The generally dacitic and andesitic volcanism of this age is more silicic than the Middle and Upper Cretaceous andesitic and basaltic volcanism, and also more silicic than the post-Eocene basalt-andesite volcanism of the Lesser Antilles. Volcanic activity occurred elsewhere around the North Atlantic Ocean during early Tertiary time—for example, in Scotland, Ireland, and Greenland. This activity was dominantly basaltic, however, and probably not directly related to layer A.

Thus, a Caribbean source for siliceous material is provided in Early and Middle Eocene times by a series of volcanic centers near eastern Cuba, near the northern Dominican Republic, in central Puerto Rico, near St. Bartholomew, and possibly near Tobago. Pyroclastic deposits or components of deposits from these eruptive centers occur in western Cuba and along the eastern coast of North America. Layer A in the North Atlantic and layer A″ in the Caribbean (*17*) probably represent the deep-water equivalent of these pyroclastic deposits—radiolarian-bearing cherty rocks. Distribution of the volcanogenic material to the north and east of the volcanoes could be due in part to atmospheric dispersal and in part to movement by ocean currents such as the Gulf Stream, as suggested by several authors (*3, 4*).

Thick Eocene deposits, coarse-grained volcanic fragments, and lavas have not yet been found in layer A or A″. They seem to be restricted to the island exposures, owing in part to the natural increase in coarseness and volume near volcanic vents. In addition, the apparent sharp landward boundaries of layers A and A″, shown in profiles crossing the Greater Antilles (*4*), may have been produced when ancient trench systems trapped the bulk of the volcanic deposits, thus permitting only fine current- or air-borne ash to enter the main ocean basins.

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17. Results from legs 4 and 5 of the JOIDES program demonstrate that layer A in the western North Atlantic is lithologically and chronologically equivalent to layer A″ in the Caribbean. The Maestrichtian age originally determined by Saito and others [see (*1*)] must have been from strata below layer A. A complete discussion of these correlations is given by J. Ewing, C. Windisch, and M. Ewing [*J. Geophys. Res.* **75**, 5645 (1970)].
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L-Asparaginase Induced Immunosuppression: Inhibition of Bone Marrow Derived Antibody Precursor Cells

Abstract. *The cooperation between bone marrow and thymus cells in restoring the hemolytic antibody response to sheep erythrocytes in immunosuppressed recipients was markedly inhibited when donor mice were treated with* L*-asparaginase, a known inhibitor of lymphocyte function. The marrow cell population was shown to be a major target for the immunosuppressive activity of asparaginase, since thymus cells from enzyme-treated animals interacted with marrow cells from normal animals to generate immunocompetent cells.*

L-Asparaginase (L-asparagine amidohydrolase) is a potent inhibitor of many malignant lymphoreticular cell tumors, both in vitro and in vivo (*1*). Furthermore, lymphoid cells incubated in vitro with this enzyme lose most of their ability to undergo blastogenic transformation when stimulated with phytohemagglutinin or antigens (*2*). Other recent studies have shown that treatment of mice, rats, or rabbits with asparaginase markedly depresses the immune response to sheep erythrocytes, *Escherichia coli* somatic antigen, serum proteins, or skin allografts (*3*). However, the mechanism behind the immunosuppressive effects of this enzyme is still unkown. A plausible working hypothesis suggests that relatively high levels of exogenous L-asparaginase in the circulation of an individual prevents sufficient quantities of asparagine from reaching rapidly dividing lymphoid cells, either malignant or those stimulated by antigen, thus resulting in their "starvation" (*1–3*). Nevertheless, the exact mode of action of this enzyme as a suppressor of either neoplastic cells or immunocytes is not known.

Adoptive cell transfer procedures with lymphoid cells are often used in experimental models designed to determine cell sources involved in specific immune responses. Recent studies from a number of laboratories have produced ample evidence that several cell types may "cooperate" in the immune response, especially when thymus-dependent antigens are involved (*4*). For example, it is now quite clear that cell populations derived from the thymus and bone marrow may interact in vivo to generate immunocompetent cells to sheep erythrocytes when transferred to