A 195 Ma Terrane in a 165 Ma Sea: Pacific Origin of the Caribbean Plate

Homer Montgomery
Programs in Geosciences, University of Texas at Dallas, P.O. Box 830688, Richardson, TX 75083, and Department of Geology, University of Puerto Rico, Mayaguez, PR 00681

Emile A. Pessagno, Jr.
Programs in Geosciences, University of Texas at Dallas, P.O. Box 830688, Richardson, TX 75083

James L. Findell
Department of Earth Sciences, Dartmouth College, Hanover, NH 03755

ABSTRACT

Tectonic models purporting to describe the origin of the Caribbean plate can be divided into two broad categories conflicting on the point of in situ origin vs. genesis in the Pacific realm followed by eastward transport relative to the American plate. Important elements of Caribbean geology including Cayman Trough spreading, the presence of the Lesser Antilles and Aves volcanic arcs, incompatible crustal juxtapositions, complicated plate geometry, truncated structural trends, fossils that originated at higher latitudes, and a lengthy geologic record of eastward progression strongly suggest allochthonous origin. However, none of these is conclusive proof.

The discovery of a Caribbean plate island terrane significantly older than the Caribbean Sea assures that in situ models are incorrect. The Bermeja Complex of southwestern Puerto Rico, located on the northeastern corner of the Caribbean plate, exposes Lower Jurassic chert. Deposited on a deep ocean floor, radiolarian chert from the Bermeja is late Pliensbachian (~195 Ma) in age, predating an open marine connection between the North Atlantic and the Pacific by ~30 m.y.

INTRODUCTION

The origin of the Caribbean plate, a small plate intruding into the much larger Atlantic plate (Fig. 1), has remained a subject of intense controversy since the inception of plate tectonics. Did the Caribbean plate form more or less in place or was it entirely engulfed by large-scale westward movement of the Americas? Several plate-tectonic models interpreting the tectonic evolution of the Caribbean, such

Thanks, Boston, for a Magnificent Meeting—6452 Attend

by Sandra Rush, Communication Consultant

Boston was a perfect host city for the 106th annual meeting of the Geological Society of America. We were treated to a week of perfect weather, and even the foliage stayed on the trees longer than usual, so that two weeks after the colors peaked, we still enjoyed a dazzling palette. Of course, the Annual Meeting Committee, headed by General Chairman James W. Slehan, S., J., helped to make this meeting truly enjoyable with one of the most diverse and scientifically compelling technical programs we’ve seen. It wasn’t surprising that Boston turned out to be a well-attended meeting—6452 registrants—second only to the 1998 Centennial Celebration in Denver (7478 registrants). Of the 2349 abstracts accepted for this meeting, 615 were presented in 40 theme sessions and 254 in 25 symposia—a real logistical challenge to fit into the four-day meeting agenda. The range of topics was diverse, as usual, with an underlying theme of geological awareness related to health, education, environment, and other current public issues. Field trips before, during (half-day), and after the meeting took advantage of the wealth of New England geology from the Atlantic Ocean to the White Mountains, from Connecticut to Maine, among some of the most picturesque environments in the nation. The spectacular, no-overcoat weather enhanced not only the field trip program, but also the guest tour program. All tours were filled to capacity as guests and their guests went bird watching, museum hopping, and investigating the nearby historic communities of the second-best-known “city by the bay.”

Special Sessions Look Into Current Issues

But Boston’s scenic setting, enhanced by its harbor, does not immediately reveal the environmental problems the harbor presents. The second Annual Environmental Forum, held Sunday afternoon and cosponsored by the GSA Institute for Environmental Education (IEE) and the GSA Geology and Public Policy Committee, addressed the cleanup of Boston Harbor and the effect of this cleanup on Massachusetts Bay. This topic is a locally controversial one, as the court-mandated plan to clean up the harbor involves discharging sewage effluent through a new ocean outfall into the bay, with as-yet-undetermined effects. Each year at the Annual Meeting, the environmental forum addresses issues involving effects on the environment and public policy of the meeting site. Monday’s keynote symposium focused on the highly dependent connection between human health and the environment, and linked health directly to the geological sciences. The symposium identified solutions to health-related geologic problems and the prudent use of geologic assets to ensure that future generations will have adequate natural resources and a nontoxic environment. The health and

This field trip stop at Nahant Island, East Point, Boston Harbor, affords a view of the Lower Cambrian Weymouth Formation, composed of nodular mudstone and limestone, with intrusions of Ordovician Nahant Gabbro and numerous mafic dikes.

Boston continued on p. 2
Caribbean continued from p. 1

as that of Burke et al. (1984), relied on a Pacific origin for Caribbean terranes. A lighting rod for offshore theories, the origin and development of the Caribbean plateau have attracted numerous enduring alternative hypotheses based on the concepts of geosynclines, expansion, contraction, and mantle surge, all apparently attempting explanation without including plate tectonics. Antithetical ideas are well contrasted in sequential papers by Pindell and Barrett (1990) and Morris et al. (1990).

The Caribbean plate is a mosaic of poorly dated, over-thickened, oceanic, continental, intermediate, and accretionary crust that somehow filled the spreading gap between North and South America. The Caribbean plate collage is separated from adjoining plates by subduction zones on the east and west and by regions of strike-slip faulting along the north and south. Pindell (1996) presented seven arguments for a Pacific origin for the Caribbean plate. Additional stratigraphic and faunal data suggesting Pacific origin were also presented by Schellens et al. (1990) and Montgomery et al. (1992). Given exhaustive justifications for the allochthonous nature of the plate, much, but certainly not all, of the work of the last decade has converged on a Pacific origin. In addition, broad plate-tectonic scenarios modeling the U.S. Cordilleran and Tethys (Moore, 1970) and mantle flow models (Alvarez, 1982) essentially predicted Pacific origin for reasons mostly independent of Caribbean geology.

Dooming in situ formation is the discovery of Early Jurassic (upper Pliensbachian) radiolarians from the Bermeja Complex chert in southwestern Puerto Rico. This occurrence predates the Middle Jurassic opening of the North Atlantic Ocean and the Caribbean Sea. Here we review plate-tectonic evidence for Pacific origin of the Caribbean plate and present the first discussion of an Early Jurassic fauna from the region.

**BERMEJA COMPLEX, PUERTO RICO**

The Bermeja Complex, spread across the southwestern part of Puerto Rico, has long been recognized as geologically similar to the island because of its greater age (in part), its lithologic character, and its clearly separate tectonic history. Stratigraphic studies in Sierra Bermeja are difficult to conduct and interpret because of the chaotic and discontinuous nature of the component serpentinite, amphibolite, basalt, and chert. Extensive deformation and metamorphism have destroyed most primary textures, bedding, and lithological relations. The lack of continuity of stratigraphic contacts and the inclusion of blocks of diverse size, lithology, and age (ranging through 100 Ma) with many adjacent to or “floating” in serpentinite suggest an episodic melting.

Jurassic cherts crop out along the northern and northwestern margin of Sierra Bermeja (Fig. 2) in patches ranging from suitcase-sized blocks to exposures a few tens of square metres in area mostly adjacent to basalt or serpentinite. Upper Jurassic red ribbon chert in the Bermeja Complex is similar in age and physical appearance (Fig. 3) to chert in the La Debrade Basement Complex, Guadeloupe, and in the Duarte Complex, Hispaniola (Montgomery et al., 1992). Outcrop P982.1 (Fig. 4) is located in an arroyo at the northwestern corner of Sierra Bermeja (Puerto Rico Grid Coordinates X = 78740 and Y = 19380. Volckmann, 1984). Highly tectonized and badly weathered greenish, grayish, brownish green chert.

**GEOLOGISTS KNOW SERVICE IS SECOND NATURE TO DWIGHTS.**

Dwights won't second guess Mother Nature, but we will always expedite any energy data you need for decision making, from scout tickets to production data. Just call us, toll free. Tell us where you are looking and when you want your data. You've got it! Naturally.

Please call 1-800-468-3381

Dwights
Energy Data, Software & Information Services

---

GSA TODAY, January 1994
Caribbean continued from p. 3

and brownish chert collected across an exposure of a few square metres yielded two poorly preserved but abundant Jurassic radiolarian faunas of nonoverlapping ages (Fig. 5).

The younger fauna (P92.1A) is early late Toarcian (Zone 4, middle Subzone 4a to lowermost Subzone 4d) in age. The older fauna (P92.1B, Fig. 6) is clearly of Early Jurassic age and is broadly comparable with Radiolaria of the Maude Formation (Plensbachian to Toarcian) in the Queen Charlotte Islands, British Columbia (Pessagno and Whalen, 1982) and of the Nyckel (upper Plensbachian) and Hyde (lower Toarcian) formations, in east-central Oregon (Yeh, 1987). Numerous partial specimens of Parataurinita? n. sp. are solid evidence of Lower Jurassic strata, because the genus is restricted to a range from upper Plensbachian to middle Toarcian (Yeh, 1987).

The specimen Lastornum? n. sp. is recorded as late Plensbachian to Bajocian (7) by Iozaki and Matsuda (1985); from the Mino belt, Circular Bemoullis sp. with twisted spines is considered to be a primitive representative of this group. Common Acanthochius hexagonus and rare Pantactinum sp. (late Triassic to Early Cretaceous) are of little biostratigraphical utility. Poorly-preserved specimens of Lopaturum sp. (late Plensbachian to Bajocian) are abundant, Broken Aves spp. are similar to specimens shown by De Wever (1982) from the Liassic (Early Jurassic) of Turkey and to Aves and Pareras spp. shown by Takemura (1966) from the Mino belt.

Fossil age assignments based on Mino belt biostratigraphy are highly suspect, because the Mino belt is a melange with no megafossils associated with the chert. Also problematic is that the Mesozoic (Jurassic) Japanese radiolarian zonation is not calibrated by utilizing ammonite-based chronostatigraphic data. Comparisons of Caribbean radiolarians with closely calibrated Early Jurassic faunas from Oregon and the Queen Charlotte Islands are valid. P92.1B specimens of Parataurinita? n. sp. are identical to an unnamed species in our collection restricted to the upper Plensbachian part of the Queen Charlotte Maude Formation. Similar, but not identical morphotypes were shown by Yao (1972) from the Mino belt, Japan. The particular Parataurinita? morphotype common in the Bemoula and the upper Plensbachian part of the Maude Formation indicates that the P92.1B fauna is of late Plensbachian age (~195 Ma with reference to the 1983 Decade of North American Geology [DANAG] time scale).

PLATE TECTONIC EVIDENCE FOR PACIFIC CARIBBEAN PLATE ORIGIN

Geologic evidence presented by Pindell (1990) suggests a Pacific origin for the Caribbean Plate. First, the Lesser Antilles and Aves Ridge volcanic arc complexes in the eastern Caribbean plate provide a continuous record of westward-slipping subduction since early Late Cretaceous, indicating relative convergence for that entire time span. In addition, at least 1000 km of offset has clearly occurred since the Cayman Trough since middle or late Eocene time as indicated by the deeper, probably oceanic crustal part of the Cayman Trough and by the paleogeographic reconstruction of Cuba, Hispaniola, Puerto Rico, and the Aves Ridge fragments of the once-continuous Greater Antillean arc (Draper and Barros, 1988; Pindell and Barrett, 1990).

Middle Cretaceous stratigraphic sequences of the Caribbean and Proto-Caribbean, the original seaway between North and South America, have been juxtaposed at suture zones around the Caribbean. The Caribbean sequence includes intrusive and volcanic rocks, volcaniclastic sandstone, tuff, and tuffstone on most of the islands, as well as allochthonous thrusts of Colombia and Venezuela and the interior of the Caribbean Plate. The Proto-Caribbean suite includes mainly Jurassic rift-related deposits and subsequent passive margin sections without tuffs in autochthonous sequences of Yucatan, Florida-Bahamas, and northern South America, implying spatial separation at least until the Campanian. Geomorphological incompatibility is obvious between a pre-Aptian Caribbean plate and the Aptian size and shape of the Proto-Caribbean sea. Plate separation by the Aptian was far insufficient to have accommodated

Figure 4. P92.1 outcrop, Bemoula Complex, Puerto Rico. Mixed Upper and Lower Jurassic radiolarian assemblages are in no coherent stratigraphic order.
Caribbean continued

Schmidt (1983) presented evidence of a Calevonian age for the origin of the Caribbean. Therefore, we assume that a fully open Proto-Caribbean-Atlantic seaway was a Calevonian event with an age of ~165 Ma (1983 DNA time scale).

How old is the Caribbean plate? The answer to this question depends on where you look. Deep sea drilling of oceanic crust south of Hispaniola yielded Turonian basin (Edgar et al., 1973), but drilling did not reach true oceanic basement. At least part of the Caribbean plate (La Désirade, Bermeja, and Duarte) is Jurassic. Lower Jurassic radiolarian chert establishes Bermeja as the oldest known island terrain on the Caribbean plate.

What is the significance of red ribbon chert? Red ribbon chert interbedded with basalt in ophiolitic complexes was presumed to have originated at mid-ocean ridges (Hopson et al., 1981). The characteristic MnFeO-rich imbers of the chert are probably due to hydrothermal activity at an active ridgecrest such as has been observed at the Galapagos and East Pacific rise spreading ridges (Hopson et al., 1981). The Caribbean Jurassic red cherts are dark and MnFeO-rich, and most are interbedded, or at least associated, with basalt.

Discussion of one other possible Jurassic terrane is of importance. The Puerto Plata basin complex exposed along the north coast of the Dominican Republic contains pillow lavas with jasper mnds and other volcanic rocks with chert and limestone nodules and limestone masses. The limestone contains Late Cretaceous (early Campanian) radiolarians in Pi- acid residues. A few samples of greenish chert produced rare and poorly preserved radiolaria including possible Vallisupus hopsoni, a Late Jurassic (Tithonian) form. The Puerto Plata basin complex is located on the northern side of the Greater Antillean arc and is thought to be a remnant of Proto-Caribbean crust. This exposure is unlike the La Désirade, Bermeja, and Duarte terranes because it lacks red ribbon chert.

Development of the Greater Antillean arc during Cretaceous time remains a subject of debate: did subduction proceed from the south or the north? Island-arc magnetism occurred in Hispaniola, Puerto Rico, the Virgin Islands, Jamaica, and Cuba during the Early Cretaceous. The arc probably began subducting the Farallon plate from the south with polarity flipping during the Aptian (Pinellol, 1993), and moving in a relative northeastward direction into the gap between North and South America (Fig. 7) subducting the Proto-Caribbean plate.

Caribbean continued on p. 6

The Caribbean-South American Plate Boundary and Regional Tectonics

edited by W.E. Banfield, R. H. Hargraves, and R. Shyam, 1984

The continuing debate on the evolution of the Caribbean plate and boundaries is a reflection of the complexity of the regional geology. Since the description of the plate, the plates have been opened and closed, rotated and translated, that, combined with obduction and accretion of displaced terranes, has resulted in the highly magmatic geology we see today. These 28 papers reflect the complexity of the terranes of the area and the need for diverse approaches and sources of data essential for understanding its history. Analytical tools of the 1970s and 1980s and regional plate kinematic synthetics along with stable isotope data provide evidence for the radial, large-scale rotations and translations in the tectonics associated with recent "subduction." This evidence indicates that these processes, once thought to have occurred prior to the early Eocene, are continuing today. Well illustrated, including an attractive color map showing major geologic provinces of the Caribbean region. No specialist in the Caribbean or in island arc terranes can afford to be without this book.

The Caribbean Region

edited by G. Dengo and J. G. Carr, 1990

The result of a major international effort involving authors and organizations from 15 countries, this volume summarizes the complex geology and tectonic evolution of the Caribbean plate and its relation to the adjacent North American, South American, West Africa, and Atlantic plates. Focus on regional geology and geophysics, magnetic, mineralogical, and volcanic provinces; metamorphic features; geologic histories, and stratigraphy and mafic textures. Contributing views for the Hispaniola and Centrosidente geologic provinces are presented in chapters on plate tectonics and marine surge

Figure 6. Age ranges of radiolarian chert from Jurassic Caribbean terranes. The lines are drawn through the minimum possible age ranges and are longer where biostratigraphic control is weaker. Kimmeridgian-Tithonian pairs are after Pasagno and Binney. Pliensbachian-Turonian pair is after 1983 DNA time scale. Some of the Puerto Rico (PR) sample locations are shown in Figure 2. Dominican Republic sample D92.1 was taken near Jarico, D92.5 near El Aguaclote, and D92.13 from the Puerto Plata basin complex east of Malon Bay. La Désirade samples are from cherts on the east and west ends of the island. Large Format Thin Sections

Logitech's new TS6 system allows you to prepare standard 30mm thin sections on microscope slides up to 150 x 100mm without hand finishing.

A greater understanding of sample structure can be achieved.

LARGE FORMAT THIN SECTIONS

Logitech Product Group, Struers Inc., 26100 First Street, Westlake, Ohio 44145
Telephone: (216) 871 0071
Telefax: (216) 871 8188

ANOTHER HIGH QUALITY PRODUCT FROM LOGITECH

SAVE 50% on all 3!

30 sections on microscope slides up to 150 x 100mm without hand finishing

50% included individually, or

SAVE 50% on all 3! 150 x 100mm thin sections, 30 sections on microscope slides up to 150 x 100mm

SALE 9% 472-1999

USA Publishers Sales, P.O. Box 949

5
Caribbean continued from p. 5

The plate-tectonic arguments presented cannot be explained within the confines of its intra Caribbean plate evolution. The discovery of early Jurassic radiolarians in Puerto Rico significantly predating the opening of the Proto-Caribbean crust is the presence of Lower Jurassic chert in a Middle-Jurassic sea cannot be explained without the possibility that Pangaea never existed.

ACKNOWLEDGMENTS

Support was provided by National Science Foundation grants EAR-9117397 (to Pessagno and Montgomery) and OCE-85-15333 (to Montgomery through the EPS80 program at the University of Puerto Rico). We thank P. W. Irwin, C. D. Biome, and R. A. Moore for reviewing the manuscript and for helpful suggestions. Jim Joyce and Hans Schleekeus contributed greatly to our understanding of the Bergeromorpha. John Lewis was instrumental in the discovery of Jurassic radiolarians in the Duarte Complex.

REFERENCES CITED


GSA BULLETIN EDITORS NEEDED

GSA solicits applications and nominations of two persons to serve as Editors of the Bulletin. The terms of the current Editors will end on December 31, 1994, and the new Editors will begin three-year terms at that time. A phased transition should begin in the fall of 1994. These are not salaried positions, but GSA pays expenses for secretarial assistance, mail, and telephone at the editor’s location and for travel to GSA headquarters. GSA headquarters staff conducts copy-editing and production activities.

Interested persons should submit a resume and a brief letter describing relevant qualifications, experience, and objectives. Nominations should include a letter of support and the nominee’s written permission and must be received by January 15, 1993.

Nominations should be sent to the GSA Bulletin. These are not formal applications and nominations should be sent BEFORE FEBRUARY 18, 1994 to F. Michael Wahl, Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

EDITOR DUTIES

1. Ensure that the Bulletin remains one of the premier journals in the geological sciences.

2. Select and maintain an appropriate Board of Associate Editors.

3. Maintain expeditious manuscript flow.

4. Make decisions regarding acceptance of submitted manuscripts in concert with recommendations of reviewers and Associate Editors.

5. Advise authors about necessary revisions.

6. Organize the content and select cover design for each issue of the Bulletin.

7. Keep the Committee on Publications and the GSA headquarters staff informed about the flow of manuscripts and other Bulletin business.

8. Respond promptly to inquiries from authors and prospective authors.

EDITOR QUALITIES

1. Broad background and active research in the geological sciences with particular emphasis on regional geology (including geomorphology, geophysics, geochemistry).

2. Good oratory and written skills. Willingness to invest approximately one day per week.


4. Breadth of knowledge of the geological research activities of both national and international scope.

5. Good English language skills.

6. Objectivity.

7. Scientific maturity.

8. Patience, courtesy, tact, and firmness in dealing with authors.

Institutions interested in hosting a presentation by one of the lecturers should contact GSI-USGS for more information and an application form. The application deadline is Friday, April 1, 1993.

Please contact Johanna Adams at JOI-USGS, 1755 Massachusetts Avenue, NW, Suite 800, Washington, DC 20036, phone (202) 232-3900, fax (202) 232-8020, Internet: joil@nets.com, joil.usgs.