

## Paleobiogeography of the Ancient Pacific

Cathryn R. Newton proposes (1) a pantropic model invoking eastward, trans-Pacific dispersal to explain fossils of Tethyan (Ocean) affinity occurring in Paleozoic and lower Mesozoic rocks of the American Cordillera. The pantropic model is held to be preferable to the displaced terrane and the Hispanic Corridor models.

It is difficult to find convincing arguments for a pervasive longitudinal component in the displacement of most allochthonous terranes. The main exception is the Cache Creek terrane (confused with the Cassiar terrane in Newton's figure 1), which contains Permian faunas of Tethyan (Ocean) affinity that differ from coeval faunas in flanking terranes (2); this situation is difficult to square with the pantropic model. Permian (2) and Jurassic (3) faunas link nearly all the other terranes to the eastern Pacific, where most of them were involved in tectonic interaction with each other and with the craton during the Triassic and particularly the Middle Jurassic, when the Cache Creek ocean basin closed (2, 4).

While it is too speculative to hypothesize a Hispanic Corridor (a seaway linking the Pacific and Tethyan oceans) for the pre-Jurassic world, this is not the case for the Jurassic. Early Jurassic marine strata are known from deep-sea drilling off Morocco and eastern Canada, and drilling off the Blake Bahama plateau shows Callovian sediments resting on oceanic basalt. At the western end of what would have been the Corridor, in eastern Mexico and Venezuela (5), Early and Middle Jurassic marine rocks have been found. The possibility of a marine strait floored by ocean basalt in the Middle Jurassic preceded by a marine connection across the continental crust in the Early Jurassic is not precluded by the present meager geologic evidence.

The Tethyan realm is recognized in the Jurassic as a low latitude, circumglobal biogeographic unit. Within this realm, certain Early Jurassic organisms are restricted to the eastern Pacific and the western end of the Tethyan Ocean, pointing to a Hispanic Corridor as the most viable means of maintaining genetic continuity between these populations [(3), and references therein; (6)]. The work on the bivalve *Weyla* is particularly interesting, but *Weyla* first occurs in the east Pacific, where it lived throughout the Early Jurassic. It did not appear in the western Tethys Ocean until the Pliensbachian, which implies an eastward, not a

westward, migration through the Corridor at that time (6). It spread further eastward into Tethys during the Toarcian. The Hispanic Corridor model is also supported by a quantitative study of bivalve endemism conducted by Hallam (7) showing progressive faunal convergence between the western Americas and Europe from the Early to the Middle Jurassic.

As always, paleobiogeographic, geophysical, and geologic evidence must be in agreement for a hypothesis to be acceptable. Work on the apparent polar wander path for North America indicates a change in absolute plate motion for North America associated with rifting in the central Atlantic and the Gulf of Mexico (8) during the Late Triassic to the Early Jurassic (Carnian to Pliensbachian); active drifting occurred thereafter. This plate reorganization correlates with Late Triassic to Early Jurassic structural deformation on the western margin of North America, culminating in the so-called Dunlap and Ochoco orogenies in Nevada and Oregon, respectively, now known to have occurred in the Pliensbachian (8, 9).

Caution is necessary in using the Indo-West Pacific province as an analog for, and in support of, a Permo-Triassic pantropic model. At the time of Pangaea, the Pacific was some 3000 km wider than it is now, and Fallaw (10) has demonstrated that its effectiveness as a barrier to dispersal declined steadily after the Early Jurassic, when the ocean began to narrow. Modern biogeographic data that would have a more realistic bearing on this problem concern those Indo-West Pacific faunas from the margin of Africa (rather than the western Pacific) that have dispersed to the western Americas. Such a distance begins to approach the width of the Permo-Triassic Pacific, but it is not clear from Newton's report how common such distributions are. It can also be argued that the probability of transoceanic dispersal is much greater in the modern Pacific because the latitudinal temperature gradient is high, the eastern portal of Tethys is closed, and the Panamanian land bridge exists, all of which increase current strength by enhancing gyral circulation (11).

PAUL L. SMITH

Department of Geological Sciences,  
University of British Columbia,  
Vancouver, B.C., V6T 2B4, Canada

GERD E. G. WESTERMANN

Geology Department, McMaster University,  
Hamilton, Ontario, L8S 4M1, Canada

## REFERENCES AND NOTES

1. C. R. Newton, *Science* **242**, 385 (1988).
2. J. W. H. Monger, *Bull. Soc. Geol. Fr.* **26**, 255 (1984).
3. P. L. Smith and H. W. Tipper, *Palaos* **1**, 399 (1986).
4. R. C. Speed, *J. Geol.* **87**, 279 (1979); L. C. Struik, *Geol. Surv. Can. Pap.* **87-15** (1987), p. 19; M. E. Rusmore *et al.*, *Geology* **16**, 891 (1988); H. W. Tipper, *Geol. Assoc. Can. Spec. Pap.* **27** (1984), p. 113.
5. P. E. Bartok *et al.*, *Geol. Soc. Am. Bull.* **96**, 1050 (1985); R. Schmidt-Effing, in *The Origin of the Gulf of Mexico and the Opening of the Central Atlantic*, R. Pilger, Ed. (School of Geoscience, Louisiana State University, Baton Rouge, 1980), pp. 79-86; R. E. Sheridan *et al.*, *Geol. Soc. Am. Bull.* **93**, 876 (1982); W. Rieggraf, H. Luterbacher, R. M. Leckie, *Init. Rep. Deep Sea Drill. Proj.* **79**, 671 (1984); J. Exton and F. Gradstein, *Geol. Assoc. Can. Spec. Pap.* **27** (1984), p. 13.
6. S. E. Damborenea and M. O. Manceñido, *Paleogeogr. Paleoclimatol. Paleoecol.* **27**, 85 (1978); S. E. Damborenea, *Paleontogr. Abteil. A* **199** (nos. 1-3), 113 (1987); *ibid.* (nos. 4-6), p. 23.
7. A. Hallam, *Paleogeogr. Paleoclimatol. Paleoecol.* **43**, 181 (1983); P. L. Smith, *Geosci. Can.* **15**, 261 (1988).
8. S. R. May and R. F. Butler, *J. Geophys. Res.* **91**, B11, 519 (1986).
9. J. S. Oldow *et al.*, *Tectonics* **3**, 201 (1984); P. L. Smith and H. W. Tipper, *Proc. Int. Subcomm. Jurassic Stratig. Symp. Lisbon*, in press.
10. W. C. Fallaw, *Am. J. Sci.* **283**, 166 (1983).
11. R. W. Grigg, *Science* **240**, 1737 (1988).
12. We thank H. W. Tipper and M. J. Orchard for helpful discussion.

14 February 1989; accepted 2 October 1989

Newton (1) presents a pantropical model of steady-state dispersal across the ancient Pacific "Panthalassa" ocean to explain the affinities of Permian to Jurassic biotas occurring in the former Tethys and in displaced terranes of Cordilleran North America. This model is built on a number of loosely connected ideas supported with data that do not appear to withstand critical examination. Growing evidence that a series of oceanic and continental fragments originating in the western or central Panthalassa were swept across this ocean, eventually to become accreted to both the eastern and western Pacific margins (2), imparts special meaning to "Tethyan" occurrences within these regions. In arguing against long-distance tectonic displacement of terranes, a call is made for Tethyan province biotas being pantropical in their dispersal, with decreasing diversities across the former Pacific Ocean basin.

In this context, we believe Newton's comparisons between the present Pacific and the Panthalassa are not entirely valid. In the Permian and Jurassic, species diversities appear to have been orders of magnitude less, and Pangaea reconstructions including the Tethys seaway produce a much wider and differently configured ocean than exists today. Also the proposed steady-state, diversity attenuation model rests on Newton's statement (p. 389) that an eastward decrease exists in the proportion of both Permian and Triassic Tethyan faunas found within Cor-

dilleran localities. This has not been documented. There is little difference in the diversity of Late Triassic reefal cnidarians and sponges in terranes in central-western Nevada, western Idaho, the Yukon, and southeastern Alaska; and their diversities are similar to those of biotas in the distant Alpine Tethys (3–5). Newton may find low Tethyan affinities among Triassic bivalves, but we disagree with her statement (p. 388) that “Tethyan” species represent only a minor part of the diversity in most Cordilleran terranes.” Most Triassic terranes contain sponges, spongiomorphs, corals, bivalves, ammonites, brachiopods, crinoids and microproblematica, which are 52 to 100% Tethyan (3–6). Among these, a number of species are found to occur only in the western Tethys and in specific Cordilleran terranes. To say that Tethyan species are pantropical because they can also be found in western North America, Peru, south China, Japan, and Siberia is unjustified because such species also occur within suspect terranes. Without knowledge of the geographic location and extent of displacement of these circum-Pacific terranes, we believe one cannot say they support a valid pantropical model. Triassic species of non-Tethyan corals known only from a Siberian terrane and two terranes on opposite sides of the Pacific in Cordilleran North America (4) could be interpreted as the kind of mirror image expected if both originated together in the ancestral Pacific and subsequently were tectonically dislocated to adjacent sides of the Pacific.

Permian biotas do not fit the model. Biotas in tropical areas of Asia and cratonal North America are very distinct, and neoschwagerinid fusulinids and waagenophyllid corals are indicators of Tethys because there was so little dispersal across the Pacific Ocean basin. Only one occurrence of neoschwagerinids is known in cratonal North America, and the few North American occurrences of waagenophyllids are in displaced terranes. Supposed mixtures of Tethyan and North American species in the eastern Klamath and Hayfork terranes are not real, because (i) the eastern Klamath terrane contains highly endemic biotas from a third province with very few Tethyan taxa, and (ii) the Hayfork terrane is a collage of rocks that was not assembled until the Triassic (7), thus providing no evidence of Permian biogeography.

Temporal changes in biogeographic patterns dictated by the longitudinal displacement model can be tested with faunal data from the Wallowa terrane. Well-dated late Triassic reefal biotas show strong Tethyan components, while a Jurassic biota nearly 50 million years younger yields corals and mol-

lusks unrelated to those of Tethys and closely related to those of the craton (8). Such changing temporal patterns suggest tectonic terrane convergence toward North America, resulting in isolation from the Tethys and free larval exchange with cratonal faunas.

There is paleomagnetic evidence of significant amounts of longitudinal (tectonic) movement in many of the Cordilleran terranes. Terrane trajectory paths based on the goodness of fit of paleomagnetic data (9) suggest that for some terranes like Wrangellia that from only the Middle Jurassic to the time of Cretaceous accretion to North America more than 60° of eastward displacement is accountable. Wrangellia is one terrane “most generally accepted as truly exotic to North America” (10).

Without concrete evidence of diversity attenuation across terranes, a pantropical model is difficult to apply to biotic patterns from Cordilleran terranes. On the other hand, the longitudinal displacement idea is testable. Faunal similarity data can be tested (i) against projected relative motions of Pacific terranes derived from paleomagnetic data, (ii) by recognition of species restricted exclusively to the western Tethys and specific terranes, (iii) with endemic patterns within groups of oceanic terranes and mirror-image patterns occurring on adjacent sides of the Pacific, and (iv) by recognizing changing temporal patterns of paleogeographic affinities.

GEORGE D. STANLEY, JR.

Department of Geology,  
University of Montana,  
Missoula, MT 59812

THOMAS E. YANCEY  
Department of Geology,  
Texas A&M University,  
College Station, TX 77843

#### REFERENCES AND NOTES

1. C. R. Newton, *Science* **242**, 385 (1988).
2. M. G. Audley-Charles and A. Hallam, in *Gondwana and Tethys*, M. G. Audley-Charles and A. Hallam, Eds. (Oxford Univ. Press, Oxford, England, 1988), pp. 1–4.
3. G. D. Stanley, Jr., *Univ. Kansas Paleontol. Contrib.* **65** (1979), p. 1; *U.S. Geol. Surv. Prof. Paper* **1435** (1986), p. 23.
4. \_\_\_\_\_ and M. T. Whalen, *J. Paleontol.* **63**, 800 (1989).
5. B. Senowbari-Daryan and R. P. Reid, *Can. J. Earth Sci.* **24**, 882 (1987).
6. E. Kristan-Tollmann and A. Tollmann, *Mitt. Österr. Geol. Gesell.* **76**, 213 (1983).
7. T. E. Yancey, C. H. Stevens, R. A. Hanger, *Geol. Soc. Am. Abstr.* **20**, 308 (1988); C. H. Stevens, T. E. Yancey, R. A. Hanger, *Geol. Soc. Am., Spec. Pap.*, in press; G. C. Gray, *Tectonics* **5**, 1043 (1986).
8. G. D. Stanley, Jr., and L. Beauvais, *J. Paleontol.*, in press; J. D. White *et al.*, in preparation.
9. D. C. Engebretson, A. Cox, R. G. Gordon, *Geol. Soc. Am. Spec. Pap.* **206**, 56 (1985); M. G. Debiche, A. Cox, D. Engebretson, *ibid.* **207**, 49 (1987); A. Cox, M. G. Debiche, D. C. Engebretson, in *The Evolution of the Pacific Ocean Margins*, Z. Ben-Avraham, Ed. (Oxford Univ. Press, Oxford, England, 1989), pp. 20–35.

10. P. J. Coney, *ibid.*, pp. 43–52.

10 April 1989; accepted 2 October 1989

*Response:* I thank my colleagues Paul Smith, Gerd Westermann, George Stanley, and Thomas Yancey for their comments. I particularly appreciate Smith and Westermann’s comments and corrections concerning the distribution of the important Jurassic bivalve *Weyla* and Stanley and Yancey’s information concerning their unpublished work on Permian through Jurassic faunas (their references 7 and 8). These two groups present five summaries of the two different models—marine corridors and longitudinal displacement—that have traditionally been used to account for “Tethyan” faunal anomalies in the American Cordillera. It was precisely this disparity in corridor-versus-displacement interpretation of “Tethyan” Cordilleran faunas that prompted me to propose an alternative, steady-state hypothesis of pantropic dispersal, against which these other models can be tested.

I propose a more general, dispersal-based pantropic model (1) that can provide an effective starting point for paleobiogeographic testing. I suggest that a steady-state model should be tested first and that only where faunal anomalies are quantitatively beyond that expected by dispersal models should other hypotheses, such as corridors and longitudinal displacement, be invoked. The goal of this dispersal-based model is to provide a general, initial model that can be tested before ad hoc explanations of marine corridors or longitudinal displacement are invoked. My article did not suggest that marine corridors cannot exist or that longitudinal translation has not taken place; these can be plausible explanations. Rather, I proposed a new protocol for paleobiogeographic testing that involves explicit, quantitative consideration of dispersal mechanisms before alternatives are invoked. In few previous studies (2) has dispersal been given thorough consideration.

The pantropic model makes only two modest claims for comparison between the modern tropical Pacific and the ancient Pacific basin (sometimes called Panthalassa). First, it asserts that some ancient species likely had teleplanic larvae (3) comparable to those of modern invertebrates. This is a reasonable assertion, if one judges from the numerous studies that have compared the larval shell morphology of living and fossil invertebrates (4). Second, equatorial marine species dispersing by means of teleplanic larvae from the Tethyan seaway into other regions would likely show a gradient of attenuated “Tethyan” diversities comparable to the attenuated diversities of Indo-West Pacific (IWP) species in the central and

## In Reply: Paleobiogeography of the Ancient Pacific

George D. Stanley Jr. and Thomas E. Yancey

*Science* **249** (4969), 680-681.

DOI: 10.1126/science.249.4969.680-a

### ARTICLE TOOLS

<http://science.sciencemag.org/content/249/4969/680.2.citation>

### PERMISSIONS

<http://www.sciencemag.org/help/reprints-and-permissions>

Use of this article is subject to the [Terms of Service](#)

---

*Science* (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.

© 1990 by the American Association for the Advancement of Science