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Comment and Reply on "Galápagos Islands: A Holocene analogue to the Wallowa accreted terrane, western North America"

COMMENT

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Malmquist (1991) proposed that the Galápagos Islands are a Holocene analogue to the ancient Wallowa accreted terrane of Oregon and Idaho, on the basis of similarities between the ecology and biogeographic affinities of fossil bivalve faunas from the late Holocene of the Galápagos Islands and the Upper Triassic Martin Bridge Limestone of the Wallowa terrane in Hells Canyon. We applaud Malmquist's attempt to reconstruct paleogeography, but we are concerned that readers may be misled into believing that the Wallowa terrane originated in the Triassic, rather than in the late Paleozoic, and in a tectonic setting similar to that of the Galápagos Islands (spreading ridge) rather than in an island arc. Major difficulties exist in carrying the Galápagos model back 210 m.y. We believe that (1) the modern Galápagos Islands represent fundamentally different tectonic and paleogeographic settings from the Wallowa terrane and (2) the Hells Canyon carbonate sequence and fossil deposit do not represent similar depositional environments.

Age, Tectonic Setting and Paleolatitude of the Wallowa Terrane. Malmquist's statement in both his abstract and his introduction that "the Wallowa terrane *originated* about 18° from the Triassic equator as a volcanic island arc . . ." (our italics) is misleading because it gives the reader the distinct impression that the Wallowa terrane *originated* during the Triassic. Geological evidence indicates that this terrane came into existence in the late Paleozoic (Vallier, 1977). The Upper Triassic Martin Bridge Limestone containing the fossil bivalves at Hells Canyon was deposited nearly 100 m.y. later on a late Paleozoic and early Mesozoic volcanic pedestal. Chemistry of the Permian and Triassic volcanic rocks and the stratigraphic sequence provide evidence for the Wallowa terrane's island-arc origin (Vallier, 1977). The Galápagos Islands, in contrast, formed along and near a spreading ridge.

Paleomagnetic data suggest that the Wallowa terrane was never south of the paleoequator as shown by Malmquist in his Figure 1. In the Early Permian it was at north latitudes (Harbert et al., 1988), possibly several hundred kilometres farther north than in the Middle and Late Triassic when, according to Hillhouse et al. (1982), it was about 18° north or south of the equator. Because the Permian paleomagnetic data indicate a north paleolatitude for the Wallowa terrane, it seems logical to conclude that the Wallowa terrane was also at a north latitude in the Late Triassic.

Biogeographic Affinities and Paleoecology. There exists conjecture on not only how far the Wallowa terrane was from North America but also its Triassic position in the ancestral Pacific Ocean. Malmquist's (1991) data on bivalves from shell beds at Hells Canyon, Oregon (based on Newton, 1987; Newton et al., 1987), assumed ecologic and paleogeographic analogues with the Galápagos to conclude that the Wallowa terrane was situated at comparable offshore distances. Malmquist may have been overly optimistic about the potential of the Galápagos fauna to resolve Triassic paleogeography.

Ecological and geographical conclusions may not be justified by the quantitative data. (1) The fauna at Urvina Bay, Isabela Island, may not be typical of the Galápagos Islands as a whole because it is sheltered and not as influenced by the cool upwelling that bathes other parts. Locally abundant, thin patch reefs and large in situ colonial reef corals (Glynn and Wellington, 1983) attest to a distinct shallow-water reef community that developed *coincident with* volcanism. The limestone at Hells Canyon developed in the absence of volcanism and did not have a comparable faunal community. It contains mixed associations of foraminifers, sponges, corals, spongiomorphs, echinoids, crinoids, and molluscs. There are no reefs or large reef-building corals, and deposition ranges from shallow water to deeper, open shelf settings that were rapidly subsiding (Whalen, 1988). The bivalves and other Triassic fossils are in storm beds (shell beds) near the top (deeper) part of the section. Broken or abraded remains, unlike in the Galápagos, suggest that in all likelihood many organisms never lived together, but instead represent mixed communities. (2) Statistical data expressed as percentages of ecologic preferences and geographic affinities of taxa between the two regions (Malmquist, 1991) form the basis of comparison. In his statistical treatment, Malmquist omitted mention of actual species diversity between the Galápagos and Hells Canyon shell beds. Although the histogram percentages are used to imply species similarities in ecology and geographical affinities for the two regions, there exists a great disparity in diversity. A total of only 35 bivalve taxa has been recognized from one or two shell beds in Hells Canyon (Newton et al., 1987). Newton (1987, p. 1127) stated that 54% of these cannot be assigned confidently to species! Faunal diversity varies widely in the Galápagos, but according to James (1984), more than 800 species of bivalve molluscs are present. Such disparities certainly could affect the comparisons and presumed analogy. Nevertheless, data on the bivalves of Hells Canyon suggest low levels of commonality with the Tethys, much endemism, and some links to the North American craton and South America. However, 24 species of corals and spongiomorphs collected from the same beds in Hells Canyon reveal 71% conspecificity with Tethys and western Pacific occurrences and, unlike bivalves, reveal no links with the craton and only one species in common with South America (Stanley and Whalen, 1989). It would be interesting to see how Galápagos corals compare. (3) Present-day composition of the Galápagos marine faunas may have resulted from recent tectonic and biogeographic processes unknown in the Triassic Wallowa terrane. Unlike the Wallowa example, the Galápagos are situated at the southern limits of reef building; in the recent past, profound evolutionary and biogeographic events associated with the rising of the Panamanian land bridge (about 3.1 Ma) have affected the Galápagos. Frequent El Niño events in the Galápagos also could exert as much influence on the species composition and diversity as does distance and isolation.

REPLY

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Stanley and Vallier's Comment has clarified some misleading statements in my paper (Malmquist, 1991). However, I stand by my conclusion that comparison of fossil bivalve faunas from the Galápagos Islands and the Wallowa accreted terrane corroborates the allochthonous, low-latitude origin of the Wallowa terrane and suggests that it lay in the eastern Pacific during the Triassic. I address Stanley and Vallier's claims in the order they presented them.

Age. Stanley and Vallier point out that a statement in both my abstract and introduction suggests that the Wallowa terrane originated during the Triassic. I agree that my statement in the introduction is misleading. I provided an accurate assessment in the abstract, where I stated that "the Wallowa terrane originated as an island arc, and . . . it lay in the eastern proto-Pacific during the Late Triassic."

Tectonic Setting. Stanley and Vallier maintain that I implied that the Wallowa terrane originated in a tectonic setting similar to that of the Galápagos. As I stated in my paper, my goal was to show how "ecologic similarity between the Wallowa and Galápagos faunas provides additional evidence for the allochthonous, *oceanic-island-arc* origin of the Wallowa terrane" (italics added). I make no claim that the Wallowa terrane originated as anything other than an island arc.

Paleolatitude. Stanley and Vallier "suggest that the Wallowa terrane was never south of the paleoequator" as I showed in Figure 1 (Malmquist, 1991). However, in the Hillhouse et al. (1982) paper that Stanley and Vallier cite in their Comment and that I cited in my paper, Hillhouse et al. reported that "the preponderance of northerly declinations and upward inclinations . . . supports the arguments for the origin of Wrangellia in the *southern* hemisphere" (italics added), and they stated that the Wallowa–Seven Devils volcanic arc is a part of Wrangellia. More recent evidence suggests that the Wallowa terrane was north of the Permian equator (Harbert et al., 1988), but in either case, my results did not depend on the polarity chosen, as I clearly stated in my paper. My primary intent was to delimit the *longitudinal* position of the Wallowa terrane.

Biogeographic Affinities and Paleoecology. Stanley and Vallier state that my "ecological and geographical conclusions may not be justified" because "there exists a great disparity in diversity" between the bivalve faunas at Hells Canyon and Urvina Bay. This argument is based on incorrect information. James (1984) listed 44 bivalve species in the Galápagos, not 800, as Stanley and Vallier claim. The number 800 is the total number of bivalve species in the entire Panamic province. The diversity of the fossil bivalve faunas at Hells Canyon and Urvina Bay is actually quite similar: 13 species at Urvina Bay (Malmquist, 1990) and 35 in the Hells Canyon shell beds (Newton et al., 1987). The number of species is even closer, 13 compared to 19, if, as Stanley and Vallier point out, only 54% of Newton's (1987) 35 bivalve taxa at Hells Canyon are identifiable to species level.

Stanley and Vallier also argue that the fossil faunas of Hells Canyon and Urvina Bay are not comparable because the former accumulated in deeper water and differs in faunal composition. I disagree. As I stated in my paper, I believe the faunas "are similar enough for meaningful comparison." The intertidal to shallow subtidal carbonate deposits at Urvina Bay compare well with the "carbonate lithofacies of the Martin Bridge limestone" which "can be characterized by a number of carbonate microfacies that indicate deposition in a supratidal to shallow-shelf setting" (Stanley and Whalen, 1989). In regard to faunal composition, Stanley and Vallier state that the Martin Bridge fauna "contains mixed associations of foraminifers, sponges, corals, spongiomorphs, echinoids, crinoids, and molluscs," and "no reefs or large reef-building corals." This is comparable to the fauna at Urvina Bay, which contains sponges, annelids, molluscs, arthropods, echinoderms, tunicates, and "small isolated coral communities and reefs" (Colgan, 1991).

Finally, Stanley and Vallier argue that the Urvina Bay fauna is atypical of the Galápagos as a whole because it is sheltered from upwelling and thus harbors a significant coral community (Glynn and Wellington, 1983). However, as Glynn and Wellington (1983) also pointed out, there are 16 other areas throughout the archipelago with significant coral communities, including the entire eastern shore of the largest island (Isabela); and at least two coral communities on all but the smallest island (Wolf). Urvina Bay may be atypical of the western shore of Isabela Island, but it is quite representative of the entire island group. Thus, I still consider the fossil bivalve fauna at Urvina Bay a meaningful analogue in helping to broadly define the paleolatitudinal position of the Wallowa terrane.

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