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Notes

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COMMENT

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Bartolini and Larson (2001) touch on a fundamental question in global tectonics, i.e., the relationship between the origin of the Pacific plate and the breakup of Pangea. The authors link the birth of the Pacific plate ca. 175–170 Ma with the start of Pangea's breakup ca. 190–180 Ma near Africa. They suggest that the initial plate separation of Pangea increased subduction rates at its outer margins and altered the plate boundaries in the Pacific superocean, leading to the formation of the Pacific plate. In this view, the formation of the Pacific plate is a consequence of the breakup of Pangea. Transfer of plate movements is mainly achieved by intralithospheric reorganizations.

The African plate came into existence, at low latitudes, as a consequence of the middle Mesozoic breakup and later disintegration of the supercontinent. The drift of North America and the Gondwana fragments were directed away from Africa (Fig. 1). Long-lived, large-scale diverging plate movements and widespread extensional deviatoric stresses are clearly documented by the evolution of the African plate.

The Pacific plate originated in the center of the Izanagi-Farallon-Phoenix ridge-ridge-ridge (RRR) triple junction ca. 175–170 Ma at equatorial paleolatitudes (Larson and Chase, 1972; Hilde et al., 1977). The triple junction was located in the midst of an assemblage of oceanic plateaus and continental fragments, the Pacifica Archipelago (Pavoni, 1991). Due to the growth of the Pacific plate and diverging movements of neighboring plates, the Pacifica Archipelago was dispersed and its fragments later incorporated into the circum-Pacific orogenic belts (Fig. 1).

At present, the Pacific plate and the African plate represent the two major plates of Earth. Both plates are of "circular" shape. They are centered in antipodal position on the equator (Pavoni and Müller, 2000). The center of the African plate is at 10°E and 0°N (pole A); the center of the Pacific plate is at 170°W and 0°N (pole P). Poles P and A mark the centers of long-lived lithospheric divergence in the Pacific and anti-Pacific hemispheres, respectively. The arrangement of the two plates reveals a fundamental hemispherical symmetry or bipolarity in global tectonics.

Geophysical investigations show that the same fundamental Pacific–anti-Pacific bipolarity is evident in the large-scale distribution of seismic velocity variations in the lower mantle (Richards et al., 1988). Regions of pronounced reduced seismic velocities are found deep in the mantle beneath the central Pacific as well as beneath Africa. Laterally reduced seismic velocities indicate upwelling flow. The long-lived lithospheric divergences in the Pacific and anti-Pacific hemispheres are thus fed by upwellings in the underlying mantle. However, laterally increased seismic velocities associated with the subduction of slabs in the circum-Pacific orogenic belt mark the downwelling flow in the mantle (Pavoni, 1991). A bicellular pattern of convection seems to govern the arrangement of plates at Earth's surface.

Considering the arguments presented here, a transfer of plate movements based primarily on intralithospheric reorganization, in conjunction with a pulse in subduction activity ca. 175–160 Ma, appears inadequate to explain the location of birth and the long-lived evolution of the Pacific and African plates. The formation of the Pacific plate is

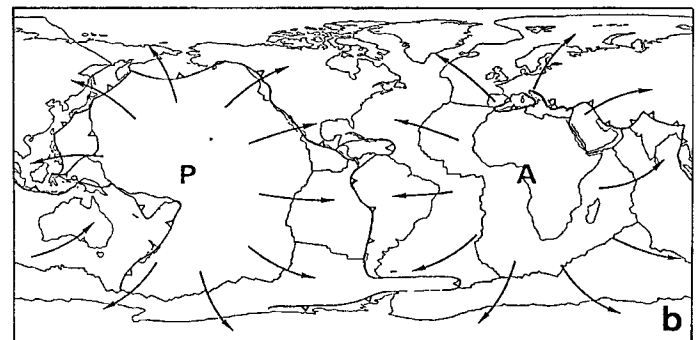
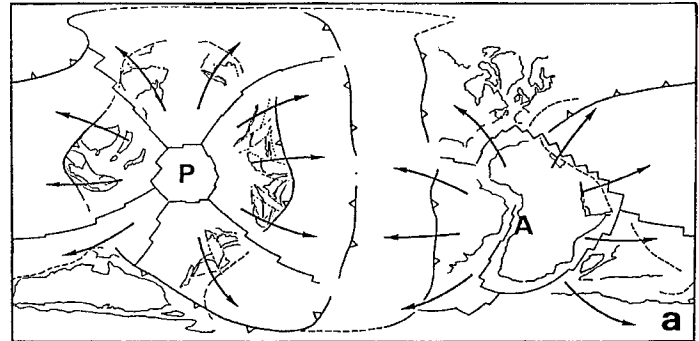


Figure 1. Schematic representation of geotectonic bipolarity and paleogeographic evolution of lithosphere in Pacific and Eurafican hemispheres (after Pavoni, 1991). World maps in cylindrical equidistant projection. Contour lines of continents and continental fragments are partially indicated. Single lines indicate divergent and transform boundaries. Lines with barbs indicate convergent boundaries. Arrows indicate large-scale, diverging movements of plates away from spreading centers P and A. (a) Stage of breakup of Gondwana and Pacifica ca. 130 Ma (see text). A north-south-trending zone of convergence, subduction, and downwelling between the two spreading centers is indicated. (b) Present configuration of Earth's lithosphere. Pacific plate and African plate are centered on equator in antipodal position.

not just a secondary effect of the beginning breakup of the supercontinent near Africa. The breakup of the lithosphere of the ancestral Pacific region and the breakup of Pangea around Africa are manifestations of deep-seated, hemispherically symmetric processes, i.e., thermal convection, in Earth's mantle. The birth of the Pacific plate as well as the formation of the African plate are part of these manifestations.

REFERENCES CITED

- Bartolini, A., and Larson, R.L., 2001, Pacific microplate and the Pangea supercontinent in the Early to Middle Jurassic: *Geology*, v. 29, p. 735–738.
- Hilde, Th.W.C., Uyeda, S., and Kroenke, L., 1977, Evolution of the western Pacific and its margins: *Tectonophysics*, v. 38, p. 145–165.
- Larson, R.L., and Chase, C.G., 1972, Late Mesozoic evolution of the western Pacific Ocean: *Geological Society of America Bulletin*, v. 83, p. 3627–3644.
- Pavoni, N., 1991, Bipolarity in structure and dynamics of the Earth's mantle: *Eclogae Geologicae Helveticae*, v. 84, p. 327–343.
- Pavoni, N., and Müller, M.V., 2000, Geotectonic bipolarity, evidence from the

pattern of active oceanic ridges bordering the Pacific and African plates: *Journal of Geodynamics*, v. 30, p. 593–601.

Richards, M.A., Hager, B.H., and Sleep, N.H., 1988, Dynamically supported geoid highs over hot spots: Observation and theory: *Journal of Geophysical Research*, v. 93, p. 7690–7708.

REPLY

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We thank Nazario Pavoni for pointing out his previous observations of approximate bipolar symmetry in present-day global tectonics and deep mantle seismic velocities (Pavoni, 1991). The latter observation has been generally confirmed, especially by more recent analyses of teleseismic S-waves (Grand et al., 1997). However, in his comment, Pavoni also suggests this bipolarity extended back to at least the Middle Jurassic and that associated deep mantle plume activity (“upwelling in the underlying mantle”) caused the near simultaneous initial breakup of the Pangea supercontinent and the formation of the Pacific microplate. This interesting speculation contrasts with ours, which is that the Pangea breakup caused the formation of the Pacific microplate by transmitting stress changes through the plates themselves to the plates beneath the Pacific superocean.

Because the time of the initial Pangea supercontinent breakup (the separation of North America from Africa) is imprecisely known and very little remains unsubducted from the former plates beneath the Middle Jurassic superocean, it is nearly impossible to either disprove or support our speculation or Pavoni’s. However, we argue by analogy with the Early Cretaceous breakup of the Gondwanaland supercontinent in the Southern Hemisphere and the near simultaneous changes in plate motions in the Pacific that changes in stresses transmitted through the tectonic plates are also likely to have been the case for the Jurassic events.

The Gondwanaland breakup and roughly antipodal changes in plate velocities and plate boundary configurations in the Pacific occurred during a time of well-known and dated magnetic reversals (Channell et al., 1995), which left characteristic magnetic anomaly patterns (Cande et al., 1989) marking these tectonic events in three ocean basins. Gondwanaland breakup began with the separation of South America and Africa off South Africa at magnetic anomaly M11 time (131 Ma). This was followed closely by the separation of India from

Australia off western Australia at M10 time (129 Ma). In the Pacific, near simultaneous velocity changes occurred at various boundaries of the Pacific plate. The Pacific–Farallon spreading ridge rotated clockwise about 20° at M10N time (130 Ma) and at the same time the Pacific–Phoenix spreading ridge propagated an additional 700 km into what is now the Central Pacific Basin (Nakanishi et al., 1992). Sometime between M14 and M11 the Magellan microplate was born near the Pacific–Farallon–Phoenix triple junction (Tamaki and Larson, 1988). It then lived out its short tectonic life and died with the cessation of spreading at the Magellan Trough at M9 time (128 Ma).

The nearly synchronous timing of the above Early Cretaceous tectonic events suggests they were somehow related. Although the Gondwanaland breakup probably was triggered beneath Brazil by the Parana mantle plume, there is almost no evidence for a corresponding pulse in mantle plume activity forming oceanic plateaus on the Pacific plate at that time. This lack of evidence for mantle plume activity beneath the Pacific is not absolute proof there was none, as it all might have occurred on surrounding plates, which are now mostly subducted. However, that seems unlikely to us. Conversely, the nearly identical ages of these events suggest that the forces causing changes in plate velocities and plate boundary configurations in the Pacific were rapidly transmitted from the newly fragmented Gondwanaland supercontinent. The internal rigidity of the plates would allow this change in driving forces to be transmitted rapidly and globally through the plates themselves. We speculate that the same type of force transfer in the Middle Jurassic also caused the formation of the Pacific microplate in response to the breakup of Pangea by separation of North America away from Africa.

REFERENCES CITED

- Cande, S.C., LaBrecque, J.L., Larson, R.L., Pitman, W.C., III, Golovchenko, X., and Haxby, W.F., 1989, Magnetic lineations of the world’s ocean basins (one chart): American Association of Petroleum Geologists, Tulsa, Oklahoma.
- Channell, J.E.T., Erba, E., Nakanishi, M., and Tamaki, K., 1995, Late Jurassic–Early Cretaceous time scales and oceanic magnetic anomaly block models, *in* Berggren, W.A., et al., eds., *Geochronology, time scales and global stratigraphic correlation*: Society for Sedimentary Geology Special Publication 54, p. 51–63.
- Grand, S.P., van der Hilst, R.D., and Widiyantoro, S., 1997, Global seismic tomography: A snapshot of convection in the Earth: *GSA Today*, v. 7, no. 4, p. 1–7.
- Nakanishi, M., Tamaki, K., and Kobayashi, K., 1992, A new Mesozoic isochron chart of the northwestern Pacific Ocean: Paleomagnetic and tectonic implications: *Geophysical Research Letters*, v. 19, p. 693–696.
- Pavoni, N., 1991, Bipolarity in structure and dynamics of the Earth’s mantle: *Eclogae Geologicae Helveticae*, v. 84, p. 327–343.
- Tamaki, K., and Larson, R.L., 1988, The Mesozoic tectonic history of the Magellan microplate in the western central Pacific: *Journal of Geophysical Research*, v. 93, p. 2857–2874.