PALEOBIOGEOGRAPHY: TRACKING THE COEVOLUTION OF THE EARTH AND ITS BIOTA

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BIOGEOGRAPHY is a scientific discipline with a rich intellectual heritage extending back at least to the 18th century, and the discipline figured prominently in the development of ideas on evolution (see review in Lieberman, 2000). During the development of ideas on evolution, an important analogy was recognized between patterns of change in organisms across geographic space and patterns of change in organisms through geological time. For instance, Alfred Russel Wallace argued that, "If we now consider the geographical distribution of animals and plants upon the Earth, we shall find all the facts beautifully in accordance with, and readily explained by, the present hypothesis (Evolution). A country having species, genera, and whole families peculiar to it, will be the necessary result of its having been isolated for a long period....The phenomena of geological distribution are exactly analogous to those of geography. Closely related species are found associated in the same beds, and the change from species to species appears to have been as gradual in time as in space." (Wallace, 1855 in Brooks, 1984, p. 75). Charles Darwin felt it was important enough to remark in the very introduction to his On the Origin of Species that, "...when on board H.M.S. 'Beagle,' as naturalist, I was much struck with certain facts in the distribution of the organic beings inhabiting South America, and in the geological relations of the present to the past inhabitants of that continent. These facts, as will be seen in the latter chapters of this volume, seemed to throw some light on the origin of species-that mystery of mysteries" (Darwin, 1859, p. 1).

The fact that Wallace and Darwin recognized the connection between geographic differentiation and macroevolutionary divergence probably ultimately derives from their understanding of the work of Charles Lyell (1832) and his famous dictum, "As in space, so in time". It also ties together, in an important way, the sciences of biogeography and paleontology, and it is clear that there is a long-lasting connection between these two fields, realized in the discipline of paleobiogeography. This long history, however, is not an impediment and does not prevent paleobiogeography or biogeography (and of course paleontology) from remaining relevant and topical to this day. Results from biogeographic and paleobiogeographic research still continue to make important contributions to the fields of evolutionary biology, geology, and conservation biology (Brooks and McLennan, 2002). This continued relevance is partly due to the development of new techniques including phylogenetic methods, molecular approaches to investigate systematic relationships, and Geographic Information Systems. The continued relevance also stems from the recognition that some of the topics early biogeographers debated are still debated today and have implications for core research paradigms. As a useful example, we note that Charles Lyell (1832) lamented the loss of biodiversity caused by the human introduction of exotic species and considered it partly a problem of biogeography. Today, the biodiversity crisis continues unabated, and it is recognized that it is caused at least in part by invasive species; it is also currently recognized that the impact of invasive species is a topic that can usefully be approached as a biogeographic and paleobiogeographic phenomenon (Rode and Lieberman, 2004).

Paleobiogeography (and its closely allied intellectual cousin biogeography) is an intriguing

and vibrant research area partly because many diverse topics are subsumed under its broad umbrella. This presented one of the exciting challenges when it came to assembling this volume: identifying a suitably broad range of topics and papers that were at the same time synthetic. Thankfully, our contributors rose to the challenge, producing a diverse and innovative set of papers. One broad theme consistently emerging from the various papers is the powerful control Earth history change exerts on evolution. This validates the fossil record as one of the key places to study evolutionary patterns and processes; it also suggests that patterns of organismal evolution and distribution can help us understand the sequence of important geological events (Hallam, 1977; Lieberman, 2000). Further, another broad theme that emerges is that this topic can be approached using a variety of different techniques, while considering a variety of different systems spanning much of the Phanerozoic, including the modern. These themes emerge in the contributions of our participants, which we summarize alphabetically: Dan Brooks and Kaila Folinsbee use their paper to focus on the ebb and flow of evolutionary diversification through time and the relationship between biogeography and paleobiogeography; Ann Budd and Nathan Smith's paper presents phylogenetic analyses of corals to consider biogeographic patterns of evolutionary diversification in the Pacific and Atlantic; Russ Graham's paper focuses on patterns of ecological change in Quaternary mammal communities; Bruce Lieberman's paper presents case studies and analyses as evidence that geological and climatic changes are the fundamental pacemakers of evolution; Lisa Park's and Elizabeth Gierlowski-Kordesch's paper focuses on the paleobiogeography and evolution of Paleozoic lake faunas; Carl Stock's paper presents an analysis of the nature of biogeographical barriers; Alycia Stigall Rode's paper provides an application of Geographic Information Systems to the study of paleobiogeography and mass extinctions; Peter Ward's paper focuses on how changing oxygen levels through time may have had an important influence on patterns of biogeographic endemicity; and finally Anne Yoder's paper considers the biogeography of Madagascar.

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REFERENCES

BROOKS, D. R., AND D. A. MCLENNAN. 2002. The Nature of Diversity. University of Chicago Press. Chicago. 676 p.

BROOKS, J. L. 1984. Just Before the Origin: Alfred Russel Wallace's Theory of Evolution. Columbia University Press. New York. 304 p.

BROWNE, J. 1983. The Secular Ark. Yale University Press. New Haven, Connecticut. 273 p.

DARWIN, C. 1859. On the Origin of Species. Facsimile of the 1st ed. Harvard University Press. Cambridge, Massachusetts.

HALLAM, A. 1977. Jurassic bivalve biogeography. Paleobiology, 3:58-73.

LIEBERMAN, B. S. 2000. Paleobiogeography: Using Fossils to Study Global Change, Plate Tectonics, and Evolution. Plenum Press/Kluwer Academic Publishers. New York. 208 p.

LYELL, C. 1832. Principles of Geology (1st ed.), Vol. 2. University of Chicago Press. Chicago, IL.

RODE, A., AND B. S. LIEBERMAN. 2004. Using GIS to study the biogeography of the Late Devonian biodiversity crisis. Palaeogeography, Palaeoclimatology, Palaeoecology, 211:345-359.

WALLACE, A. R. 1855. On the law which has regulated the introduction of new species. Annals of the Magazine of Natural History, 2nd series, 16:184-196.