

with evolution at the molecular level. Provine adds that much of the initial negative reaction to the neutral theory resulted from the deep-seated assumption that molecular evolution is a reflection of phenotypic evolution, a confusion that to some extent exists today. What the neutral theory argues is the opposite—these two levels of evolution are largely independent, making it difficult to extrapolate from phenotypic evolution to evolution at the molecular level. Provine concludes that the neutral theory bifurcates the study of evolution into separate disciplines, molecular and phenotypic. This pessimistic view may indeed be largely correct, at least until we have a much deeper understanding of developmental genetics. Ironically, it may be the fruits of Kimura's contributions to the enterprise (quantitative genetics) that tenuously connects these disciplines that will reunify them.

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The Assembly of Pangea

Evolution of Laurussia. A Study in Late Paleozoic Plate Tectonics. PETER A. ZIEGLER. Published for the Royal Geological and Mining Society of The Netherlands by Kluwer, Norwell, MA, 1989. x, 102 pp., illus., + plates. \$69. International Lithosphere Programme Designated Publication no. 0163.

This book is one of a new generation representing a distinctive approach to the interpretation of earth history. Maps are used to show how continents, island arcs, and other objects have moved across the surface of the earth through geologic time. The maps incorporate information about changes in the extent of the seas over the continents, where and when mountains were built, and very much more. Not only are an understanding of plate tectonics and the use of paleolatitudinal indicators essential to construction of the maps, a wealth of diverse information from the archives of historical geology is also required. The models embodied in the maps can be tested because they must be tectonically and environmentally consistent not only in space but also as they evolve through time.

Ziegler has already published two books giving sequences of maps. In this volume he turns his attention to the 150-million-year interval between the end of the Silurian and the end of Permian times, during which the supercontinent of Pangea was assembled by successive collisions: first between much of Europe and North America to make "Lau-

ruссия," and then between Laurussia and Gondwana. After a final episode joining Siberia and Kazakhstan to Laurussia, Pangea remained largely in one piece for about 100 million years. Many critical events in the assembly of Pangea took place within or on the borders of Europe, extending into the Ural mountains and the Arctic in one direction and the Appalachians in the other, so that a European perspective such as Ziegler's is essential.

There are eight main chapters, an introduction, and a final discussion. The chapters relate to eight colored, fold-out maps (whose publication was subsidized by Shell International Petroleum) that show the progress of Pangea's assembly between 410 and 250 million years ago in areas that are now mainly in North America, Europe, and the Arctic. There is also a less detailed set of ten maps for the entire Western Hemisphere (the other hemisphere was largely oceanic and has left little record).

The way to use the book is to fold out a map while reading the corresponding chapter. The text is condensed, but Ziegler has been generous in citing references, devoting 78 pages to text and 23 to references. Features of the synthesis that particularly impressed me included 800-kilometer anticlockwise motion of Europe with respect to North America and Greenland over the 60 million years that followed the closing of an ocean on the site of the Northern Appalachian and Caledonian mountains and the perhaps related opening and closing of a small ocean basin extending from Brittany to Poland over about the same interval. The evolution of this basin and the mountain building and collapse that followed its closure constitute the "Hercynian"—a mountain-forming event long considered enigmatic because it was thought to be unlike modern mountain-building episodes. Ziegler's approach confirms that the Hercynian mountains can be understood as products of the kinds of processes operating today.

Those who wish to go further in looking at questions raised by Ziegler's syntheses will need the local stratigraphic charts characterizing discrete time intervals, which are the essential building blocks for a study of this kind. Without them the reader cannot assess the exact evidence on which particular inferences have been based; however, publication of these charts would have produced a much larger and more expensive book.

I found the European material most comprehensive. It is the peripheral areas, Africa, Asia, and the Arctic, that seem to offer the clearest opportunities for further work. One topic, for example, that warrants attention is a thick wedge of sediment in Libya and Tunisia representing material eroded from

the Hercynian mountains during the latest Paleozoic. This basin is of more than local interest because it has sometimes been suggested that erosion of the Hercynian mountains yielded little sediment.

Evolution of Laurussia represents progress in synthesizing what happened during a dramatic interval in the earth's history but, as the author stresses in a postscript, also serves to identify further challenges.

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