JARVIK, E. 1959. Dermal fin rays and Holmgren's principle of delamination. K. Svenska Vetensk-Akad. Handl. (4)6:1–51.
KUHN, T. S. 1970. The structure of scientific revolutions, second edition. University of Chicago Press.
KUHN, T. S. 1977. Second thoughts on paradigms. *In* Suppe, F. (ed.), The structure of scientific theories, second edition. University of Illinois Press, Urbana.
LINDSTRÖM, T. 1949. On the cranial nerves of the cyclostomes with special reference to *N. trigeminus*. Acta Zool. Stockh. 30:315–458.
LØVTRUP, S. 1977. The phylogeny of Vertebrata. John Wiley and Sons, New York.
MILES, R. S. 1971. The Holonematidae (placoderm fishes), a review based on new specimens of *Holonema* from the Upper Devonian of Western Australia. Phil. Trans. R. Soc. London (B)263:101–234.
MILES, R. S. 1973. Relationships of acanthodians. *In* Greenwood, P. H., R. S. Miles, and C. Patterson (eds.), Interrelationships of fishes. Academic Press, New York. pp. 63–103.
MILES, R. S. 1975. The relationships of Dipnoi. Colloq. Internat. C.N.R.S. 218:133–148.
MILES, R. S. 1977. Dipnoan (lungfish) skulls and the relationships of the group: a study based on new species from the Devonian of Australia. Zool. J. Linn. Soc. 61:1–328.
NELSON, G. J. 1969. Gill arches and the phylogeny of fishes, with notes on the classification of vertebrates. Bull. Amer. Mus. Nat. Hist. 141:475–552.
ØRVIG, T. 1962. Y a-t-il une relation directe entre les arthrodires ptyctodontides et les holocephales? Colloq. internat. C.N.R.S. 104:49–61.
OSTROM, J. 1976. *Archaeopteryx* and the origin of birds. Biol. J. Linn. Soc. 8:91–182.
PATTERSON, C., AND D. E. ROSEN. 1977. Review of ichthyodectiform and other Mesozoic teleost fishes and the theory and practice of classifying fossils. Bull. Amer. Mus. Nat. Hist. 158:83–169.
SHELLIS, R. P., AND A. E. W. MILES. 1974. Autoradiographic study of the formation of enameloid and dentine matrices in teleost fishes using titrated amino acids. Proc. R. Soc. London (B)185:51–72.
STENSIÖ, E. A. 1927. The Downtonian and Devonian vertebrates of Spitsbergen Part I Family Cephalaspidae. Skrift. Svalbard og Ishavet 12:xii + 1–391.
WALKER, A. D. 1972. New light on the origin of birds and crocodiles. Nature 237:257–263.

Syst. Zool., 27(3), 1978, pp. 379–381

The Expanding Earth.—S. Warren Carey. 1976. Elsevier Scientific Publishing Company, Amsterdam and New York. x + 488 pp. $32.95.

This is the tenth book in the Developments in Geotectonics series. Although its theme is global tectonics, it has wide application to historical biogeography as well. In 1956 at the University of Tasmania in Hobart, Carey (1958) unveiled a revolutionary work, ranking in insight and vision with Argand's (1977 translation) efforts with Asian tectonics and Brock's (1972) global symmetry and pattern book. Carey has walked alone and in this new book presents a synthesis of his thinking over the 20-year period of plate tectonics revolution. Despite some recent attempts to make the developments in plate tectonics (formerly known as "continental drift") intelligible to biogeographers and paleontologists (e.g., Corbet, 1973; Hughes, 1973; also notably Axelrod and Cracraft), historical biogeography still suffers from the lack of generally accepted methods (Nelson, 1969). Classically, biogeographers have been ignorant of geology, or at least relied upon geologists for theory. Yesterday's land bridges are replaced by today's literal joining up of continents. Actually, historical biogeography depends on geology.

The task of biogeographers should now be to test the various continental drift reconstructions to see which model best fits the biogeographic data. I have done so for the Caribbean region and find that Carey's 1962 (figs. 99–102) Upper Jurassic model fits butterfly distributions best, of a host of those proposed, only one of which can be correct (Shields and Dvorak, in press). Similarly, Wild (1975) found that the Madagascar position alongside Kenya and Tanzania fits the phytogeographic evidence best, for the lower Upper Cretaceous. Krassilov (1975) has established that the Korea/Japan separation occurred in the Early Cretaceous (Hautervian), based on the differentiation of vegetation of South Primorye and Japan at that time. Carey's reconstructions for the Mediterranean (figs. 91–94), Indo-Australia (fig. 178), and Southwest Pacific (fig. 193) should now be put to the biogeographic test. I have proposed (Shields, 1977) a Gondwanaland reconstruction that accords well with the Lemuria land-bridge theory but should be tested in more detail by using zoogeographic and phytogeographic data. It also overcomes Carey's India-Gondwana paradox.

Carey's views do not embrace much from the 60's and 70's plate tectonics bandwagon. He takes bitter issue with the idea of subduction (pp. 54–79) and neglects a large body of evidence in its favor, in Don Quixote fashion. Only the Pacific needs trenches on a present-sized earth, not Africa and Antarctica too, as Carey claims. Also his battle against compressional orogenesis appears flimsy. Neither argument affects the book's thesis. He believes new crust is added at the trenches, which simply is not true for South America, SW Pacific, Indonesia, etc. He assumes continents moved away from "deckenschrund ridges" (e.g., Asia, Australia) in the Tertiary, but it is more logical to assume the reverse. Some of his western North American fault blocks and shear patterns seem fanciful; e.g., the Montana-Florida lineament violates his own Caribbean reconstructions. Carey's method of closing the west coast of India against the east coast of Arabia

(Arabian sphenochasm, fig. 2) violates the seafloor spreading pattern in the Arabian Sea. It is too bad Carey could not present a Pacific Ocean closure (other than fig. 170) in his comprehensive earth synthesis. Instead, he clings to the idea that the Alaskan orocline must be straightened, thus creating a Jurassic Pacific, with an "EoPacific" starting in Permo-Carboniferous times. However, there is no evidence for such an ocean from DSDP drilling, and Packer and Stone have shown that the Jurassic paleomagnetic data indicate the Gulf of Alaska was closed instead of open then. If Carey's idea about subduction were true, this ancient sea should still be preserved. But where is it? The North Pacific grew on only one side of a spreading ridge on Carey's model, and the Pacific itself grew eastward.

Sections of this book were published elsewhere prior to its publication, a common practice which makes for needless repetition. Unfortunately, Carey is largely ignorant of many recent developments in plate tectonics, though in turn his work has presented a challenge to plate tectonics. But the beauty of Carey's book is that it solves zoogeographic puzzles, and gives blueprints to the biogeographer who now should sketch his distributions onto them.

Carey rightly notes that the Malay Peninsula and Indonesia were closely related to Australia throughout the Phanerozoic, contrary to the wide Tethys Ocean separation in Pangaean models. Continuity is required in early Cambrian archaeocyathids, Cambrian trilobites, Ordovician cephalopods, Devonian brachiopods, Carboniferous foraminifera, Early Triassic amphibians, and Jurassic *Buchia-Belemnopsis* faunas. A single cosmopolitan temnospondyl amphibian fauna existed in the Early Triassic, implying links between the principal continental areas. Carey points out other paradoxes with plate tectonics theory, such as the Pacific perimeter expanding and the Arctic paradox. Paleomagnetic positions and rotations confirm Wegener's and Carey's predictions.

In some ways the book is anachronistic, in others *avant garde*. Illustrations are liberal and well selected. Carey is one of the few workers to use tracing from globes instead of flat surfaces. His survey of historical events and papers bearing on earth expansion is very thorough and fair. Much of the book answers criticisms that have been lodged against earth expansion. The index is not as thorough as desired. Sometimes he presents too much detail, asides, pedantic precision, etc., that obscure main points. Carey has travelled around the world and knows many places and scientists firsthand. He writes succinctly and well, a great composite in the manner of Holmes.

Most biogeographers who use plate tectonic models do so blindly. There is a need for testing models and for becoming educated enough to construct one's own model. During this century, geology metamorphosed from the Dark Ages into the Space Age. Some of the better texts one can read to help "catch up" on the revolutionary developments are by Coulomb (1972), Wilson (1972), Tarling and Runcorn (1973), Corbet (1973), Hallam (1973), Cox (1973), and Uyeda (1978). Plate tectonics differs little from earth expansion except in the Pacific region, and in the size of the earth. An expanding earth may not be readily apparent, but it is difficult to understand why many tectonicists steadfastly reject the idea without delving into it more deeply. With an expanding earth, uniformitarianism is negated.

Carey offers the following constraints on reconstructions. All blocks must retain the same topological relation to other blocks. They may become separated by new oceanic crust, or be offset by even large distances along megashears, or may be rotated. Only new oceanic crust may be inserted to separate blocks. Reconstructions can only be reached by removing oceanic crust and shifting along megashears, or unwinding impressed oroclines. The reconstruction must be homogeneous tectonically, and integrated geologically, with respect to petrology, palaeontology, palaeogeography, geochemistry, geochronology, and sedimentary provenance. The reconstruction, if correct, should yield unexpected integration and synthesis of previously nonrelated matters.

Certain biogeographic facts (among many), not discussed by Carey, are indicative of an expanded Pacific, which was closed in the Early Jurassic and fully opened in the Late Cretaceous. Southeastern Australia, Tasmania, Chile, and Argentina have many different organisms in common. Relationships among the floras of Mexico, Central America, and eastern Asia are even greater than between eastern North America and eastern Asia. Late Cretaceous ceratopsian and hadrosaurian dinosaurs are found in the trans-North Pacific region. The Neotropical termite fauna is closer to that of Indo-Malaya than to any other fauna, and the relations of the Neotropical and Ethiopian termite faunas are through the Indo-Malayan region and not by way of an Antarctic connection. Most of the primitive Lepidopteran families (Micropterigidae, Hepialidae, Neopseustidae, Castniidae, Megathymidae) are best developed or restricted to both sides or to either the east or west sides of the Pacific. Some tropical butterflies, e.g., the Ithomiinae, Heliconiinae, and Morphidae, are confined to the Neotropics and Indo-Australian regions, and are entirely absent from Africa. In the Riodinidae butterflies, the subfamily Nemeobiinae (16 genera) has tribes confined primarily to the Indo-Australian and Oriental regions (Nemeobiidi) and Neotropical region (Euselasiidi, Corrachiidi, Helicopidi). The other subfamily (Riodininae, 107 genera) has three tribes, all Neotropical.

Carey's book has profound implications for historical biogeography. It is simply a matter of finding the correct continental configuration prior to drift, for insights into the mega-evolution of various biota. Carey went through a plate tectonics phase before developing an expanding earth. Perhaps we all

should.—*Oakley Shields, Agri-Science Laboratories Inc., 2122 Granville Ave., West Los Angeles, California 90025.*

REFERENCES

ARGAND, E. 1977. Tectonics of Asia (trans. & ed. by A. V. Carozzi). Hafner Press, New York.

BROCK, B. B. 1972. A global approach to geology. A. A. Balkema, Cape Town.

CAREY, S. W. (convener). 1958. Continental drift, a symposium. University of Tasmania, Hobart.

CORBET, E. H. 1973. Wandering lands and animals. E. P. Dutton Co., New York.

COULOMB, J. 1972. Sea floor spreading and continental drift. D. Reidel Pub. Co., Dordrecht, Holland.

COX, A. (ED.). 1973. Plate tectonics and geomagnetic reversals. W. H. Freeman and Co., San Francisco.

HALLAM, A. 1973. A revolution in the earth sciences: from continental drift to plate tectonics. Clarendon Press, Oxford.

HUGHES, N. F. (ED.). 1973. Organisms and continents through time. Special Papers in Paleontology, no. 12, 334 pp.

KRASSILOV, V. A. 1975. Paleobotanical evidence on the origin of Japan Sea. Pacific Geol. 10:43–46.

NELSON, G. J. 1969. The problem of historical biogeography. Syst. Zool. 18:243–246.

SHIELDS, O. 1977. A Gondwanaland reconstruction for the Indian Ocean. J. Geol. 85:236–242.

SHIELDS, O., AND S. K. DVORAK (in press). Butterfly distribution and continental drift between the Americas, the Caribbean, and Africa. J. Nat. Hist.

TARLING, D. H., AND S. K. RUNCORN (EDS.). 1973. Implications of continental drift to the earth sciences, 2 vols. Academic Press, London and New York.

UYEDA, S. 1978. A new view of the earth: moving continents and moving oceans. W. H. Freeman and Co., San Francisco.

WILD, H. 1975. Phytogeography and the Gondwanaland position of Madagascar. Boissiera 24:107–117.

WILSON, J. T. (ED.). 1972. Continents adrift. W. H. Freeman & Co., San Francisco.

Syst. Zool., 27(3), 1978, pp. 381–388

SYSTEMATICS AND THE POPPERIAN PARADIGM

This is the third, and last, in a series of book reviews concerning the work of Karl Popper. The first two (Platnick and Gaffney, 1977, 1978) dealt with Popper's principal relevant writings, while this one surveys some of the critical literature on Popper's ideas that should be of interest to systematists. Much of this literature (presently growing at a rapid rate) is, admittedly, of more interest to philosophers than to scientists. The problems emphasized often appear peripheral to those issues that seem most significant to the practice of science; this is no doubt one reason why so few scientists take the trouble to investigate philosophy. We have advocated the study of Popper's ideas because of his position as the leading proponent of the hypothetico-deductive method; hence, our concern here is both to point out where the books reviewed below may be helpful in understanding Popper's views, and to report on whatever substantive arguments concerning the hypothetico-deductive method they contain.

The Philosophy of Karl Popper.—Paul Arthur Schilpp (ed.). 1974. The Library of Living Philosophers, vol. 14, Open Court, La Salle, Illinois. 2 vols., xvi + 1323 pp. $30.00

These volumes represent the most substantial single contribution to the Popper literature. They are divided into four parts, of which the first is devoted to Popper's autobiography, now published separately under the title *Unended Quest* and reviewed elsewhere (Platnick and Gaffney, 1978). Part Two consists of 33 descriptive and/or critical essays on Popper's work by various philosophers, scientists, historians, and statesmen. These are followed (Part Three) by a 250-page response by Popper ("Replies to My Critics") and (Part Four) by an 80-page bibliography of Popper's writings, complete through 1973. Almost all of the essays are informed and interesting, and Popper's replies include some of his most incisive and delightful writing. Although the hardcover price is not unreasonable for so much material, it is greatly to be hoped that a softcover edition of at least Parts Two and Three will be forthcoming (as has been the case for some previous volumes in the series), for the books deserve to be widely read.

Obviously, a short review cannot do justice to the wealth of material included, and we will try to describe only some of the highlights. Several of the essays are devoted to criticism of Popper's use of falsifiability as a criterion of demarcation between science and non-science. Only one of the criticisms raised appears to be serious, namely, that the criterion appears to lead to an untenable position in that spatiotemporally unrestricted existential statements (statements like 'There are black swans' or 'Some black swans exist') must be considered non-scientific (or metaphysical, in Popper's sense) because they cannot be falsified. We would have to search the entire universe, through all time, to falsify such statements, an obvious impossibility. But, as William Kneale points out, "suppose that on some occasion when I have been rashly dogmatic about the behaviour of fish out of water a biologist reminds me, in an unrestricted existential statement, that there are after all lungfish which can breathe on dry land. I do not dismiss his remark as irrelevant metaphysics, but humbly accept it as