McMenamin, Mark A. S. (1998) *Discovering the First Complex Life: The Garden of Ediacara*. Cambridge: Cambridge University Press.

Reunite Rodinia!

> The theory of Wegener [continental drift] is to me a beautiful dream, the dream of a great poet. One tries to embrace it and finds that he has in his arms but a little vapor or smoke; it is at the same time both alluring and intangible. -Pierre Termier[1]
>
> We have known since the days of Kant that scientific arguments must never be founded on analogies, but the authors are dead serious about these poetic digressions. -Peter Westbroek[2]
>
> The continental land drift continued; increasingly the ocean penetrated the land as long fingerlike seas providing those shallow waters and sheltered bays which are so suitable as a habitat for marine life … [with] the further separation of the landmasses and, in consequence, a further extension of the continental seas … these inland seas of olden times were truly the cradle of evolution. -The Urantia Book[3]
>
> -- (McMenamin 1998: 173)

The last quotation in this chapter's epigraph describes the Proterozoic breakup of the supercontinent Rodinia. This amazing passage, written in the 1930s, anticipates scientific results that did not actually appear in the scientific literature until many decades later. This unusual source is *The Urantia Book*.[4] The name *Urantia* refers to planet Earth. (McMenamin 1998: 173)

Like the *Book of Mormon* and L. Ron Hubbard's *Dianetics*, *The Urantia Book* is a modern attempt to found a new religion. But the teachings of *The Urantia Book*, as promoted by the Urantia Foundation and the Urantia Brotherhood,[5] are more mainstream than either Mormonism or dianetics. Promotional literature of the Urantia organization inserted into new copies of the book state the following:

> We hope your experience with the URANTIA teachings will enhance and deepen your relationship with God and your fellowman, and provide renewed hope, comfort, and reassurance in your daily life.

What more could one ask for in a religion? Well, for starters, one could hope for accurate geology and profound scientific truths in its sacred literature, something both the devout and the skeptics alike find lacking in much of the Bible. (McMenamin 1998: 173-174)

The comments concerning Rodinia's breakup and its influence on animal evolution are found in part III, "The History of Urantia" in *The Urantia Book*. According to the first page of this chapter, "these papers were sponsored by a Corps of Local Universe Personalities acting by authority of Gabriel of Salvington." The critical section 8 of Paper 57, titled "Crustal Stabilization, The Age of Earthquakes, The World Ocean and the First Continent," is "presented by a Life Carrier, a member of the original Urantia Corps [who visited our planet hundreds of millions of years ago] and now a resident observer." The following Paper 58, "Life Establishment on Urantia," is attributed to "a member of the Urantia Life Carrier Corps now resident on the planet." (McMenamin 1998: 174)

Clearly we are not dealing here with an orthodox scientific treatise. Nevertheless, the anonymous members of the Urantia Corps hit on some remarkable scientific revelations in the mid-1930s. They embraced continental drift at a time when it was decidedly out of vogue in the scientific community. They recognized the presence of a global supercontinent (Rodinia) and superocean (Mirovia), in existence on earth *before* Pangea. From *The Urantia Book*:

> 1,000,000,000 years ago … [t]he first continental land mass emerged from the world ocean…. 950,000,000 [years ago] … presents the picture of one great continent of land and one large body of water, the Pacific Ocean.[6]
>
> 800,000,000 years ago … Europe and Africa began to rise out of the Pacific depths along with those masses now called Australia, North and South America, and the continent of Antarctica, while the bed of the Pacific Ocean engaged in a further compensatory sinking adjustment. By the

> end of this period almost one third of the earth's surface consisted of land, all in one continental body.[7]

Of course I am being selective here in my choice of quotations, and there are reams of scientifically untenable material in *The Urantia Book*. However, the concept of a billion-year-old supercontinent (the currently accepted age for the formation of Rodinia) that subsequently split apart, forming gradually widening ocean basins in which early marine life flourished, is unquestionably present in this book. (McMenamin 1998: 174)

Orthodox scientific arguments for such a proposal did not appear until the late 1960s, and a pre-Pangea supercontinent was never described until Valentine and Moores made the attempt in 1970. The Urantia Corps not only had the age of the formation of Rodinia approximately correct at 1 billion years, but they also were first to link breakup of Rodinia to the emergence of animals (even if the mode of appearance was implantation by extraterrestrials). Furthermore, they even got the timing of that approximately correct at 650 to 600 million years ago ("These inland seas of olden times were truly the cradle of evolution").[8] (McMenamin 1998: 174-175)

This book was unknown to me until it was brought to my attention by J. J. Johnson in October 1995. I obtained a copy of the book from the Smith College library and noted the 1955 (eighth edition 1984) publication date. What could possibly explain such precocious insight from such an unexpected corner? Perhaps it has to do with a lively, unconstrained, but nevertheless informed imagination. John K. Wright has noted how outrageous hypotheses "arouse interest, invite attack, and thus serve useful fermentative purposes in the advancement of geology."[9] But what about outrageous religions? (McMenamin 1998: 175)

I wrote back to Johnson on January 15, 1996, asking him whether he could confirm that the passages he had referred me to were indeed written in 1955. In a letter dated January 24, he replied that the section of interest was "put into the English language in 1934," making it even more ahead of its time than I had thought. (McMenamin 1998: 175)

Johnson congratulated me on my fossil discovery south of Tucson (see chapter 9) and for my "appreciation for the Truth." He then invited me to contact the Fellowship for Readers of *The Urantia Book*. He gave me a contact address, telephone number and fax for the Fellowship and advised me to contact John Hales and to consider attending an event called the Flag Conference. I consider Johnson's (unsuccessful) attempt to convert me to his religion to be a very friendly overture, and although I cannot become a Urantia proselyte, I wish the members of this faith all the best. (McMenamin 1998: 175)

Assuming for the moment that space voyagers are not responsible for life's origin and history on this planet, one wonders how the *Urantia Book* authors arrived at the concept of a Proterozoic supercontinent, and the link between breakup of this supercontinent and the emergence of complex life in the ensuing rift oceans, 30 years before most geologists accepted continental drift and nearly four decades before scientists had any inkling that Rodinia existed. The anonymous authors responsible for the critical part of section 3 evidently possessed a high level of geological training, and while writing in the 1930s must have known of Wegener's ideas on continental drift. Perhaps he or she was, or had contact with, an expatriate from Nazi Germany. Whatever the identity of the author, this person proceeded to speculate about the relationship between evolutionary change and the breakup of a Proterozoic supercontinent in an exceptionally fruitful way. Perhaps this was because the thought and the writing of this person were not fettered by the normal constraints of the (too often highly politicized) scientific review process. (McMenamin 1998: 175-176)

Cases such as this one (which is by no means unique) are an exercise in humility for me as a scientist. How can it be that discovery of Rodinia, *plus* a fairly sophisticated rendering of the evolutionary implications of the rifting of Rodinia, falls to an anonymous author engaging in a work of religious revelation decades before scientists find out *anything* about the subject? Perhaps this is an important aspect of religion-a creative denial of certain aspects of reality in order to access a deeper truth. (McMenamin 1998: 176)

I am not advocating an abandonment of a disciplined scientific peer review process, but I can't help but wonder whether science would benefit by having scientists themselves or friends of science systematically

scan the various nonscientific literatures for writings such as those appearing in *The Urantia Book*. Scientists would ordinarily ignore and dismiss such writings, but a discerning eye might pick up some gems. (McMenamin 1998: 176)

The concept of Rodinia therefore has a shockingly unexpected intellectual pedigree. When does the concept finally enter the conventional scientific channels? In articles published in the early 1970s, James W. Valentine and Eldridge M. Moores traced the geological history of the continents and spoke of a Precambrian supercontinent.[10] This continent was subsequently called proto-Pangea, pre-Pangea, Pangea I, the Late Proterozoic Supercontinent, ur-Pangea, or simply the Precambrian supercontinent. While writing *The Emergence of Animals*, Dianna McMenamin and I grew weary of these cumbersome names and proposed the name *Rodinia* for the ancient supercontinent. The corresponding superocean also needed a name, and we decided to call it Mirovia. Here is the key passage from Emergence of Animals[11]:

> Mirovia is derived from the Russian word *mirovoi* meaning "world or global," and, indeed, this ocean was global in nature. Rodinia comes from the infinitive *rodit*, which means "to beget" or "to grow." Rodinia begot all subsequent continents, and the edges (continental shelves) of Rodinia were the cradle of the earliest animals.

Curiously, The Urantia Book also refers to Mirovia, the "world ocean."[12] Here are my notes regarding the name from p. 17 of my 1987 composition notebook:

> 5/12/87 This book would be a good opportunity to "name" "paleo-Pangaea" and "proto-Panthallasa"
>
> How about:
> Ur-something
> Rodinia from Russian rod: genus rodit: beget, come up, grow
>
> Eomaria
> Paleomaris
> Mirovian Ocean from Russian mirovoj: World, Global, see pp. 19-20
> [the entry on composition notebook pp. 19-20 *follows*:]
> 5/21[/87] Fedonkin, "Organicheskii Mir Venda" 1983 1210 pp. 4-5.
> The glaciation at the beginning of the Vendian period, known under the name of the Laplandian or Varangian Glaciation, may have had catastrophic results for many groups of the organic world which inhabited the world ocean. (translation M. McMenamin, 5/21/1987)

As correctly pointed out by John J. W. Rogers, the word *Rodinia* is also derived from the Russian word *rodina*, meaning "motherland."[13] The term links the northern and southern hemispheres as well because of its phonic similarity to the Precambrian Rhondonia terrane of South America. (McMenamin 1998: 176-177)

Figure 8.1 shows the first reconstruction of Rodinia, as drawn by Valentine and Moores in 1970. It isn't much as reconstructions go, showing simply a circular supercontinent bisected by a linear mountain belt running from east to west. Simple as it is, this reconstruction was a reasonable first attempt. Valentine and Moores felt that this linear mountain chain was a result of continental collision and suturing, resulting in a series of linked Precambrian mountain ranges they called the Pan-African-Baikalian system. Valentine and Moores's next image shows the breakup of Rodinia, and in this image the circular supercontinent is cut into slices like pieces of a pizza. The four chunks were, clockwise from 9 o'clock, North America, Baltica, Asia, and Gondwana. (McMenamin 1998: 177)

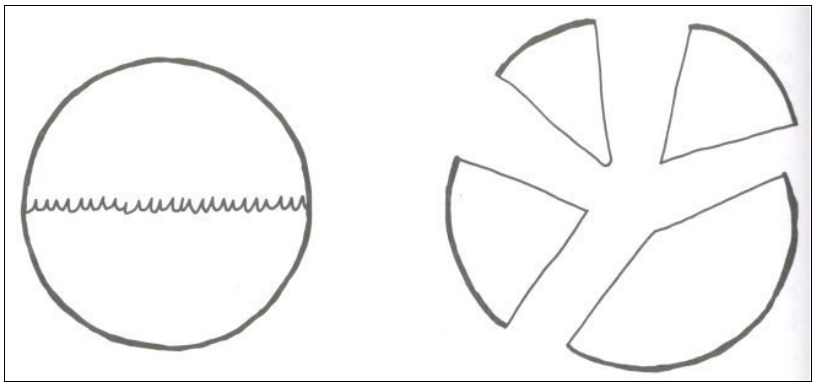

Figure 8.1: The first reconstruction of Rodinia, published in 1970. Intact supercontinent shown on left, fragmentation of supercontinent into pie-shaped wedges on the right.

Modern reconstructions of Rodinia (figure 8.2) place Australia and Antarctica as the missing piece along the west (present-day coordinates)coast of North America. This suggestion, first made by Charles W. Jefferson in 1978, has the advantage of satisfying a paleobiogeographic conundrum discussed below.[14] Jefferson's insight was first published as an abstract for the Geological Association of Canada and appeared in 1980 as an abstract for the twenty-sixth session of the International Geological Congress in Paris. Jefferson argued, "North America, Australia and Antarctica were joined from more than 1,500 to 550 m.y. ago. . . . [T]he continents separated by Lower Cambrian time and Australia together with Antarctica drifted away to join [Gondwana]." (McMenamin 1998: 177-178)

Figure 8.2: The modern reconstruction of Rodinia, shown as a schematic for a proposed Rodinia medallion. Various continental blocks are portrayed as follows: I. = India, ANT. = Antarctica, AUS. = Australia, N.AM. = North America, SIB. = Siberia, G. = Greenland, B. = Baltic.

This reasoning is prophetic, although Jefferson does have North America, Australia, and Antarctica juxtaposed for a longer stretch of geological time (1500 to 550 m.y.) than is now thought to have been the case (1000 to 700 m.y.). At the time Jefferson's abstracts were published, many geologists were skeptical of Jefferson's claims, and some thought that he was badly over interpreting his data. As the title of his abstract indicates, he was basing his continental reconstruction on lithostratigraphic correlation of the strata without other lines of evidence such as biostratigraphic correlation or paleobiogeographic similarity between North America and Australia/Antarctica. Many scientists were thus unwilling to accept Jefferson's scheme. Nevertheless, a map reconstruction of Australia and North America juxtaposed was published in 1985 by R. T. Bell and Jefferson. (McMenamin 1998: 178)

Jefferson shrewdly considered the paleobiogeographic implications of his theory, however, and in an unpublished manuscript around 1980 with the same title as the 1978 and 1980 abstracts, Jefferson predicted

that the Ediacara-type biota would be found near the base of the Backbone Ranges Formation in northwestern Canada. Such fossils do occur in northwestern Canada, but lower in the section, in the Blueflower and Sheepbed Formations. I would like to renew Jefferson's prediction, which has not yet been fully confirmed, that *Dickinsonia*, *Spriggina*, and *Tribrachidium* may indeed occur in the Backbone Ranges Formation, and a concerted effort should be undertaken to find them there. (McMenamin 1998: 178-179)

I was the first to publish a paleobiogeographic analysis of the problem, "premature" as it may have been.[15] As I pointed out in 1982, distinctive members of the Ediacaran biota, including *Dickinsonia*, *Spriggina*, and *Tribrachidium* (three of the most recognizable of the Ediacaran genera), appeared in what would seem to be opposite ends of the world, namely, the White Sea region of Russia (on the continent of Baltica) and the Flinders Ranges of Australia.[16] Fedonkin had missed this in his 1983article, assuming that the Ediacaran biota was uniformly cosmopolitan.[17] In my 1982 paper I noted the similarity between what I called the "benthic Ediacaran fauna" of Baltica and Australia and urged that this link betaken into account in any attempt to reconstruct Neoproterozoic plate positions. This posed a major problem for J. D. A. Piper's Proterozoic supercontinent reconstructions of the 1980s, which had assumed a considerable paleogeographic separation between Australia and Baltica. Bruce Runnegar[18] and Simon Conway Morris[19] agreed with Fedonkin that the forms must be cosmopolitan despite (or maybe because of) the profound geographic separation. (McMenamin 1998: 179)

My paleobiogeographic suggestion forced reevaluation of the faulty reconstructions and led to a better reconstruction by Stephen K. Donovan of the supercontinent.[20] Later, other geologists[21] used new geological data to revive Jefferson's original insight, thus answering the question[22] of whether there had been an oceanic margin to western North America since Archean time.[23] There is now a strongly emerging consensus on the main features of the Rodinia reconstruction.[24] (McMenamin 1998: 179-180)

There were not (and are still not) occurrences of the key taxa (*Dickinsonia*, *Spriggina*, and *Tribrachidium*) on the land masses thought to have been between Australia and Baltica in the late Proterozoic. Thus, it appears as if I had correctly pointed out that Australia and Baltica must have been much closer to one another during the Proterozoic then they are today in order to account for the distinct similarities between the fossils. Most geological models for Rodinia before 1990 could not account for this paleobiogeographic linkage. Bruce Runnegar categorically stated in 1982 that the "present great-circle distance between these two sites is about 130°, and it is unlikely to have been less than 90° in the past."[25] In my and Dianna McMenamin's first Rodinia reconstruction, we tried to account for the biogeographic similarity by putting Baltica right up against Australia. The North America-Australo-Antarctica[26] link received confirmation in 1991. (McMenamin 1998: 180)

In 1994 Guy Narbonne reported the discovery of an interesting but diminutive new Ediacaran fossil, *Windermeria*, as a possible *Dickinsonia* relative,[27] and indeed it may be, but alternatively, it could be more closely related to members of the Erniettidae. In any case, in the Rodinia reconstruction current by 1995, the distinctive Ediacaran forms of Baltica and Australia were not too distant and must have (unless there are much worse sampling errors in the recovery of these fossils than now suspected) remained close together until the demise of these rather late Ediacaran forms. (McMenamin 1998: 180)

In John Rogers's 1996 review, he sees Rodinia forming about 1 billion years ago as the amalgamation of four smaller supercontinents: Ur, Arctica, Baltica, and Atlantica. This scheme is actually a descendant of one proposed in 1969 by Patrick M. Hurley and John R. Rand in which, in their figure 9, they identify two "coherent" groupings of continents, plotted on the reconstruction of Pangea as a base map.[28] Hurleyand Rand's northern grouping included what Rogers now calls Arctica (plus Baltica), and their southern grouping includes what Rogers calls Atlantica plus Ur. (McMenamin 1998: 180)

In Rogers's rendering, Ur (named for the German word *Ur*, "original," and what may be the world's oldest city, Ur of the Chaldees) is composed of southeastern Africa, Madagascar, most of India, and most of Antarctica. Ur is linear or C-shaped, an unusual shape for a supercontinent. (McMenamin 1998: 180)

Arctica consists of Greenland, Siberia, and the Canadian Shield craton of North America. Baltica, as before, consists of northern Europe west of the Urals. Atlantica is composed of eastern South America and western Africa. (McMenamin 1998: 180-181)

Rogers has Arctica and Baltica combining to form the supercontinent Nena at about 1.5 billion years ago (an acronym for northern Europe and North America).[29] Geologists are wonderfully adept at the generation of jargon and in the coining of new terms, but this is by no means a gratuitous exercise. In addition to providing an essential verbal short hand, new terms, when accepted, demarcate advances in understanding.

At 700 million years ago, Rogers has Rodinia splitting into East Gondwana, West Gondwana, and Laurasia. The two halves of Gondwana come together and remain together throughout the Paleozoic.[30] The two halves of Gondwana unite at about the time of the Cambrian boundary, and by 300 million years ago, Gondwana and Laurasia have united to become Pangea (figure 8.3). This would be an example of supercontinental episodicity that has been called the Sutton Cycle.[31] (McMenamin 1998: 181)

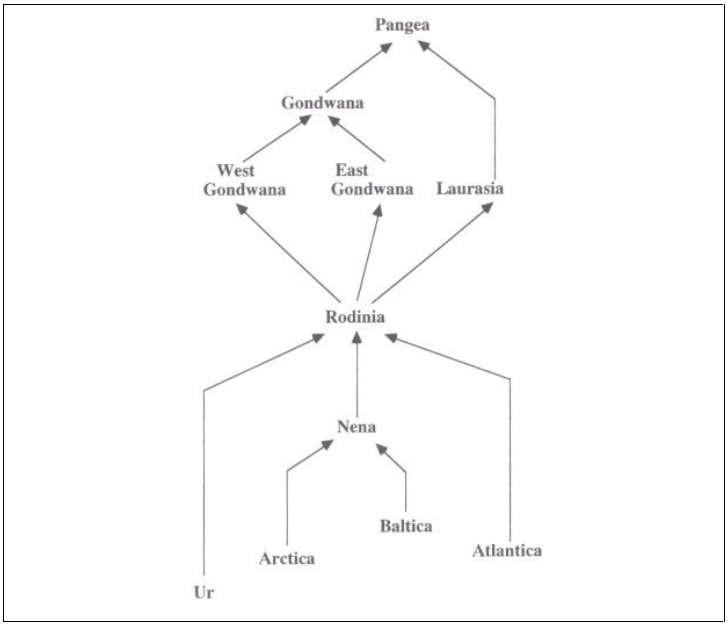

Figure 8.3: Diagram showing rearrangements of supercontinents over the last several billion years. Rodinia was formed approximately 1 billion years ago; Pangea formed approximately 300 million years ago.

Adapted from J. J. Rogers, "A History of Continents in the Past Three Billion Years," *The Journal of Geology* 104 (1996): 91-107.

Rogers's analysis now allows one to construct a preliminary geological map of Rodinia (figure 8.4). The major rift fractures are present on this map, as are subsidiary rift features such as those revealed by deep seismic reflection profiling and other methods.[32] (McMenamin 1998: 182)

Rodinia was formed during a 1-billion-year-old mountain-building event (orogeny) called the Grenville orogeny. The name Grenville is taken from the township of Grenville, Quebec, in the vicinity of the St. Lawrence River.[33] The bedrock of this region consists of marbles inter-stratified with gneisses, metamorphically deformed rocks that give evidence of a major Precambrian orogeny. This orogeny resulted from the fusion of Ur, Nena, and Atlantica, plus other scattered continental blocks such as East Antarctica. When continents collide in this fashion, oceanic crust is destroyed by subduction and the melted remains of the sub-ducted oceanic slabs return to the surface as the granites and andesites of the billion-year-old Grenville orogenic belt. (McMenamin 1998: 182)

From west to the east, the geologic map of Rodinia looked as follows. On the west end is Ur, consisting of cratons (continental interior blocks)in the 3-billion-year-old age range and in the 2- to 1.5-billion-year-oldage range. On the east-central edge of Ur, in what appears to be a gigantic C-shaped embayment in Rogers's reconstruction, is a thrust belt[34] of Grenville age.[35] (McMenamin 1998: 182)

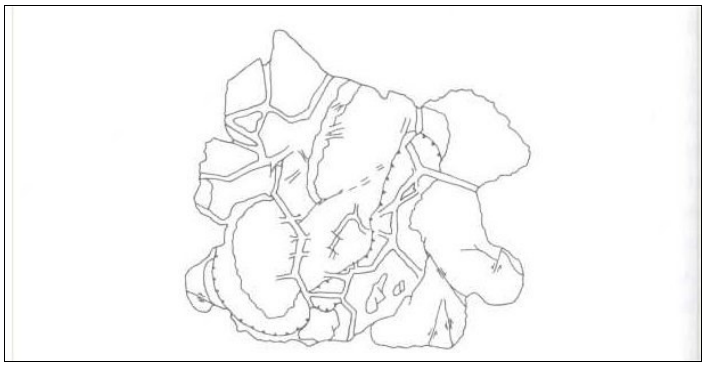

Figure 8.4: Geological map of Rodinia. Orientation roughly the same as in figure 8.2; see figure 8.2 for an explanation of the continent masses. Prominent features on this geological map include the rift canyons (linear regions marked with double lines) and the Great Thrust Fault (marked by a single line with "teeth" on the right side). Displacements on vertical faults are marked by arrows. Note the North American mid-continent rift zone just below the center of this map.

This thrust belt has several small patches of 3-billion-year-old crustal blocks. The rocks were thrust to the west, and a dark line with teeth on the map denotes the westernmost limit of thrusting. South of this is an interior magmatic belt, also of Grenville age. Nested into the Nena embayment is most of East Antarctica, recognizable as a huge pre-Grenville craton 2.4 billion years in age. Continuing east into North America, we have here a cratonic core, the central part of the Canadian Shield, like East Antarctica a pre-Grenville craton 2.4 billion years in age. This cratonic core is surrounded by 2- to 1-billion-year-old juvenile crust, accreted around the ancient cratonic core as a number of smaller plates. Paul Hoffman has called this the "United Plates of America."[36] To the north is yet another pre-Grenville craton 2.4 billion years in age: Siberia. Siberia is composed of the roughly coeval Aldan and Anabar shields. (McMenamin 1998: 183) Like Ur, North America also has a thrust belt on its eastern margin.[37] Northwest of the northeasterly part of the limit of thrusting line is an approximately 1.5-billion-year-old orogenic belt stretching from maritime Canada into the Scandinavian peninsula. The limit of thrusting can be traced into Scandinavia as well, which is why Baltica is joined in this reconstruction with North America along the northeast coast of Greenland. This thrust fault is the largest and longest in earth history, and could be called the Great Thrust. To the east of the thrust limit line is an exterior thrust belt, just across the thrust line from the southern-most extent of the 1.5-billion-year-old orogenic belt. East of that are the paired interior magmatic belt and exterior thrust belt, respectively, of Atlantica. In the south of Atlantica is a 1.5-billion-year-old orogenic belt, associated with the Tanzania craton (2.4 billion years old) and the West Nile craton (1.5 to 2 billion years old). (McMenamin 1998: 183)

As Rodinia began to break up between 1 billion and 500 million years ago, major rift systems formed between western North America and Australia/Antarctica (the Australo-American Trough) and between eastern North America and Atlantica, the nucleus of West Gondwana. Rogers has East Gondwana (Ur) heading west and Atlantica pivoting counterclockwise. I think that Ur must then go east and north in order to get Australia close enough to Baltica for them to share late (*Dickinsonia, Tribrachidium*) Ediacarans.[38] (McMenamin 1998: 183)

In any case, the various fragments of Gondwana collide in the wake of these rifting events to form the great southern continent. These collisions led to what geologists for years have called the Pan-African orogeny. The andesites and granites formed and uplifted by these Gondwanan collisions have been implicated in the injection of significant amounts of phosphorus into seawater, perhaps triggering the Cambrian explosion. (McMenamin 1998: 183-184)

We are referring here to convulsive tectonic events on a global scale. The title of another of Paul Hoffman's papers (he deserves an award for creative scientific paper titles) is "Did the Breakout [from Rodinia] of Laurentia Turn Gondwanaland Inside-Out?"[39] We are surely dealing, in the rifting of Rodinia, with a profound tectonic event that alters the surface of the earth. (McMenamin 1998: 184)

However, there is something unusual about the configuration of the Rodinia supercontinent. As first pointed out by Kent C. Condie of the New Mexico Institute of Mining and Technology in Socorro, there is less juvenile crust (formed of granite and related rocks) than one would expect for a supercontinent of this size.[40] Episodic isotopic ages in rocks forming juvenile crust, along with neodymium isotopic data, indicate the presence of three major pulses of continental growth in earth history: at 2.6—2.5, 2.0—1.7, and 1.3—1.0 billion years ago and some growth in the last 700 million years. However, there is a paucity of juvenile crust in the 1.3—1.0 interval, called the Grenville interval. This indicates that during the Grenvillian collisions that formed Rodinia, there were few additions (from submarine plateaus, magmatic additions from the mantle, continent-margin arcs) of juvenile crust. Condie surmises that either there is a large quantity of undocumented Rodinian juvenile crust, or 1.3—1.0 billion years ago "was not a time of extensive mantle plume activity." If, as a result of decreased plume activity, fewer submarine plateaus formed between 2.1 and 1 billion years ago, then less juvenile material could be incorporated into the newly forming Rodinia as various continental fragments collided with one another. A lesser number of submarine plateaus would have been produced, meaning that there would be a smaller volume of oceanic terranes (composed of juvenile crust) that could be accreted to an assembling Rodinia. Perhaps the Great Thrust (which would relieve orogenic stresses) also has something to do with the paucity of juvenile crust. (McMenamin 1998: 184)

Condie's results should not be taken to infer that there was a paucity of collisional tectonics in the 1.3—1.0 billion years ago—quite the contrary. The Coal Creek serpentinite[41] was emplaced into the volcanic arc sediments of the Llano Uplift, Texas, implying that brittle plate collisions were important during the formation of Rodinia at 1.2 to 1 billion years ago.[42] Perhaps the brittleness of these collisions and the rarity of juvenile crust during this time are results of the same geological factors governing the collision of the continental fragments and volcanic arcs that became Rodinia. (McMenamin 1998: 184-185)

The breakup of Rodinia follows much later. Early evidence for its fragmentation begins between 900 and 700 million years ago with sedimentary sequences of northwestern Scotland called the Stoer Group and the Sleat-Torridon Group.[43] The history of Rodinian breakup evidently extends over hundreds of millions of years.[44] (McMenamin 1998: 185)

---

[1] See p. 29 in H. W. Menard, *The Ocean of Truth* (Princeton, N.J.: Princeton University Press, 1986).

[2] P. Westbroek, "The Oceans Inside Us," *The London Times Higher Education Supplement*, November 3, 1995.

[3] See p. 663 in Urantia Foundation, *The Urantia Book* (Chicago: Clyde Bedell, 1955 [first written 1934]).

[4] Urantia Foundation, 1955.

[5] The name *Urantia* may be derived from Urania, the personification of astronomy.

[6] Page 660.

[7] Page 662.

[8] See pp. 663-664.

[9] J. K. Wright, "Foreword," in C. H. Hapgood, *Maps of the Ancient Sea Kings*, pp. ixx (Philadelphia: Chilton Books, 1966).

[10] J. W. Valentine and E. M. Moores, "Plate-Tectonic Regulation of Faunal Diversity and Sea Level: A Model," *Nature* 228 (1970): 657-659.

---

[11] See p. 95, M. A. S. McMenamin and D. L. S. McMenamin, *The Emergence of Animals: The Cambrian Breakthrough* (New York: Columbia University Press, 1990).

[12] Page 660.

[13] J. J. W. Rogers, "A History of Continents in the Past Three Billion Years," *The Journal of Geology* 104 (1996):91--107; C. Zimmer, "In Times of Ur," *Discover* 18 (1997):18-19.

[14] C. W. Jefferson, "Correlation of Middle and Upper Proterozoic Strata Between Northwestern Canada and South and Central Australia," *Geological Association of Canada*, *Program with Abstracts* 13 (1978):429; C. W. Jefferson, "Correlation of Middle and Upper Proterozoic Strata Between Northwestern Canada and South and Central Australia," *International Geological Congress, 26thSession, Paris, Abstracts* 2 (1980):595; R. T. Bell and C. W. Jefferson. "An Hypothesis for an Australian-Canadian Connection in the Late Proterozoic and the Birth of the Pacific Ocean," in *Proceedings Pacific Rim Congress* 87. *An International Congress of Geology, Structure, Mineralization and Economics of the Pacific Rim. Gold Coast, Australia*, 26-29 August 1987, pp. 39-50 (Parkville, Australia: The Australasian Institute of Mining and Metallurgy, 1987).

[15] See M. F. Glaessner's letter in chapter 5.

[16] M. A. S. McMenamin, "A Case for Two Late Proterozoic-Earliest Cambrian Faunal Province Loci," *Geology* 10 (1982):290-292.

[17] M. A. Fedonkin, "Ekologia dokembrijskikh metazoa belomorskoj bioty," in L. A. Nevessaya, ed., *Problemy ekologii fauny i flory drevnikh bassejnov*, pp. 25-33 (Moscow: Akademiya Nauk SSSR, Trudy Paleontologicheskogo Instituta, Tom 194, Izdatel'stvo "Nauka," 1983).

[18] B. Runnegar, "Oxygen Requirements, Biology and Phylogenetic Significance of the Late Precambrian Worm *Dickinsonia*, and the Evolution of the Burrowing Habit," *Alcheringa* 6 (1982):223-239.

[19] S. Conway Morris, "The Ediacara Biota and Early Metazoan Evolution, " *Geological Magazine* 112 (1985):7781.

[20] S. K. Donovan, "The Fit of the Continents in the Late Precambrian," *Nature* 327 (1987):130-141.

[21] E. M. Moores, "The Southwest U.S.-East Antarctic (SWEAT) Connection: A Hypothesis," *Geology* 19 (1991):425-428; I. Dalziel, "Pacific Margins of Laurentia and East Antarctica-Australia as a Conjugate Rift Pair: Evidence and Implications for an Eocambrian Supercontinent," *Geology* 19 (1991):598-601; M. E. Brookfield, "Neoproterozoic Laurentia-Australia Fit," *Geology* 21 (1993):683-686; I. W. Dalziel, "Earth Before Pangea," *Scientific American* 272 (1995):58-63; E. Moores, "The Story of Earth," *Earth* 5 (1996):30-33; E. M. Moores and R. J. Twiss, *Tectonics* (New York: W. H. Freeman, 1995).

[22] J. P. N. Badham, "Has There Been an Oceanic Margin to Western North America Since Archean Time?" *Geology* 6 (1978):621-625.

[23] P. E. Hoffman and J. P. N. Badham, "Comment and Reply on 'Has There Been an Oceanic Margin to Western North America Since Archean Time?' " *Geology* 7 (1979):226-227; W. F. Tanner, "Comment on 'Has There Been an Oceanic Margin to Western North America Since Archean Time?' " *Geology* 7(1979):6.

[24] J. J. W. Rogers, "A History of Continents in the Past Three Billion Years," *The Journal of Geology* 104 (1996):91-107; T. H. Torsvik, M. A. Smethurst, J. G. Meert, R. Van der Voo, W. S. McKerrow, M. D. Brasier, B. A. Sturt, and H. J. Walderhaug, "Continental Break-Up and Collision in the Neoproterozoic and Palaeozoic: A Tale of Baltica and Laurentia," *Earth Science Reviews* 40 (1996):229-258; I. W. D. Dalziel, "Neoproterozoic-Paleozoic Geography and Tectonics: Review, Hypothesis, Environmental Speculation," *Geological Society of America Bulletin* 109 (1997):16-42; R. Unrug, "Rodinia to Gondwana: The Geodynamic Map of Gondwana Supercontinent Assembly," *GSA Today* 7 (1997):1-6.

[25] Runnegar, 1982, p. 223.

[26] To which we alluded in *Emergence*, p. 99.

[27] G. M. Narbonne, "New Ediacaran Fossils from the Mackenzie Mountains, Northwestern Canada," *Journal of Paleontology* 68 (1994):411-416.

---

[28] P. M. Hurley and J. R. Rand, "Pre-Drift Continental Nuclei," *Science* 164 (1969):1229-1242.

[29] C. F. Gower, A. B. Ryan, and T. Rivers, "Mid-Proterozoic Laurentia-Baltica: An Overview of Its Geological Evolution and a Summary of the Contributions Made by This Volume," in C. F. Gower, T. Rivers, and A. B. Ryan, eds., *Mid-Proterozoic Laurentia-Baltica, Geological Association of Canada Special Paper* 38 (1990):120.

[30] Unrug, 1997.

[31] J. Sutton, "Long-Term Cycles in the Evolution of Continents," *Nature* 198 (1963):731-735; P. F. Hoffman, "Speculations on Laurentia's First Gigayear (2.0 to1.0 Ga)," *Geology* 17 (1989):135-138.

[32] M. A. Noe-Nygaard, "Comparaison entre les roches grenues appartenant adeux orogénies Précambriennes voisines au Groënland," *Colloque International de Pétrographie sur "Les échanges de matières au cours de la genèse des roches grenues acideset basiques*," C. N. R. S., *Colloque* 68 (1955):61-75; A. J. Pedreira, "Possible Evidence of a Precambrian Continental Collision in the Rio Pardo Basin of Eastern Brazil," *Geology* 7 (1979):445-448; Z. Garfunkel, "Contributions to the Geology of the Precambrian of the Elat Area," *Israel Journal of Earth Science* 29 (1980):25-40; J. A. Brewer, L. D. Brown, J. E. Steiner, J. E. Oliver, and S. Kaufman, "Proterozoic Basin in the Southern Mid-Continent of the United States Revealed by COCORP Deep Seismic Reflection Profiling," *Geology* 9 (1981):569-575; A. Piqué, "North-western Africa and the Avalonian Plate: Relations During Late Precambrian and Late Paleozoic Time," *Geology* 9 (1981):319-322; J. J. Peucat, P. Vidal, G. Godard, and B. Postaire, "Precambrian U-Pb Zircon Ages in Ecologites and Garnet Pyroxenites from South Brittany (France): An Old Oceanic Crust in the West European Hercynian Belt?" *Earth and Planetary Science Letters* 60 (1982):70-78; J. F. Lindsay, R. J. Korsch, and J. R. Wilford, "Timing the Breakup of a Proterozoic Supercontinent: Evidence from Australian Intracratonic Basins," *Geology* 15 (1988):1061-1064; H. J. Harrington, R. J. Korsch, and D. Wyborn, "The Rodinian Breakup Zones in the Transantarctic Mountains and Southeastern Australia," *Geological Society of Australia Abstracts* 41 (1996):183.

[33] C. R. Van Hise and C. K. Leith, *Pre-Cambrian Geology of North America, U.S. Geological Survey Bulletin No. 360* (Washington, D.C.: Government Printing Office, 1909).

[34] A thrust belt is a large body of rock that has been thrust over other rocks along a low-angle thrust fault.

[35] Approximately 1 billion years in age.

[36] P. F. Hoffman, "United Plates of America, the Birth of a Craton: Early Proterozoic Assembly and Growth of Laurentia," *Annual Review of Earth and Planetary Sciences* 16 (1988):543-603.

[37] H. O'Sullivan, *Explorations Between Lake St. John and James Bay* (Quebec: Department of Colonization and Mines, 1901); O. O'Sullivan, "Explorations Along the National Transcontinental Railway from La Tuque Westward, " *Geological Survey of Canada, Summary Report* (1907):67; H. C. Cooke, "Some Stratigraphic and Structural Features of the Pre-Cambrian of Northern Quebec, " *Journal of Geology* 27 (1919):65-382; A. Ludman, "Significance of Transcurrent Faulting in Eastern Main and Location of the Suture Between Avalonia and North America," *American Journal of Science* 281 (1981):463-483; G. M. Young, "The Grenville Orogenic Belt in the North Atlantic Continents," *Earth-Science Reviews* 16 (1980):277-288; M. D. Max, "Extent and Disposition of Grenville Tectonism in the Precambrian Continental Crust Adjacent to the North Atlantic," *Geology* 7 (1979):76-78.

[38] For an alternative explanation, see C. Franklin, "A Biogeography of the Assembly of Gondwana," Unpublished master's thesis, Mount Holyoke College, South Hadley, Mass., 1997.

[39] P. F. Hoffman, "Did the Breakout of Laurentia Turn Gondwanaland Inside-Out?" *Science* 252 (1991):1409-1412.

[40] K. C. Condie, "Rodinia and the Missing 1-Ga Juvenile Crust," in *Proterozoic Evolution in the North Atlantic Realm, Program and Abstracts*, pp. 3940(Goose Bay, Labrador: Canadian Geoscience Council, 1996).

[41] A green, snakeskin-colored rock representing a hydrothermically altered basalt, an ophiolite, or a stranded fragment of ancient seafloor crust.

[42] J. R. Garrison, Jr., "Coal Creek Serpentinite, Llano Uplift, Texas: A Fragment of an Incomplete Precambrian Ophiolite," *Geology* 9 (1981):225-230.

---

[43] A. D. Stewart, "Late Proterozoic Rifting in NW Scotland: The Genesis of the 'Torridonian,' " *Journal of the Geological Society of London* 139 (1982):413-420.

[44] I. W. D. Dalziel, "Neoproterozoic-Paleozoic Geography and Tectonics: Review, Hypothesis, Environmental Speculation," *Geological Society of America Bulletin* 109 (1997):16-42.