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Editorial

Assembly and break-up of Rodinia: introduction to the special volume

The notion of a Meso-Neoproterozoic supercontinent is entrenched in the geological literature (Piper, 1976; Bond et al., 1984; McMenamin and McMenamin, 1990; Dalziel, 1991, 1992; Hoffman, 1991; Karlstrom et al., 1999; Dalziel et al., 2000), although the configurations differ widely (Fig. 1a–c). A number of names has been proposed for this supercontinent including Ur-Gondwana (Hartnady, 1986, 1991), Palaeopangea (Piper, 2000), Kanatia (Young, 1995) and Rodinia (McMenamin and McMenamin, 1990). The name 'Rodinia', which takes its name from the Russian verb 'rodit' meaning 'to beget' or 'to grow', is most commonly used. Rodinia is the supercontinent that gave birth to all subsequent continents, and its continental shelves were the cradle of the earliest animals (McMenamin and McMenamin, 1990, p. 95). The corresponding global ocean surrounding Rodinia is called Mirovoi. The life cycle of the Rodinia supercontinent is represented by its birth in a series of late Meso- to early Neoproterozoic collisions lumped under the term 'Grenvillian', and by its death recorded in late Neoproterozoic rift and passive margin successions as the supercontinent broke up (Dewey and Burke, 1973; Bond et al., 1984; Dalziel, 1991, 1992; Moores, 1991; Hoffman, 1991; Powell et al., 1993, 1994). The supercontinent's death led to a series of icehouse events that, if proven to be synchronous, could represent a unique climatological period in Earth history (Kirschvink, 1992; Hoffman, 1999; Evans, 2000). The death of the supercontinent also heralded the advent of modern biota (McMenamin and McMenamin, 1990) and possibly the formation of a short-lived daughter supercontinent (Bond et al., 1984) called Pannotia (Powell, 1995). The final death throes of Rodinia may also have triggered a period of extremely rapid continental motion or true polar wander (Kirschvink et al., 1997; Evans, 1998; Meert, 1999). The history for the development of the Rodinia supercontinent concept is described in detail by Dalziel (1997), and the assembly and break-up of the Rodinia supercontinent is the subject of International Geological Correlation Project (IGCP) No. 440. This volume resulted from two symposia at EUG 10 (1999, Strasbourg) related to Mesoproterozoic continental assembly and subsequent break-up, and Cadomian–Baikalian–Pan African events in Eurasia and Gondwanaland.

Although the Rodinia configuration has held sway in the geological literature for the past decade, it is not without its critics (for example, Piper, 2000; Sears and Price, 2000). One of the major problems in constraining the configuration has been a lack of reliable palaeomagnetic poles for the different elements of Rodinia (Powell et al., 1993; Meert, 2001). Fig. 2 shows the various cratons that make up Rodinia along with the age ranges of reliable palaeomagnetic results (i.e. those satisfying at least three of the seven quality

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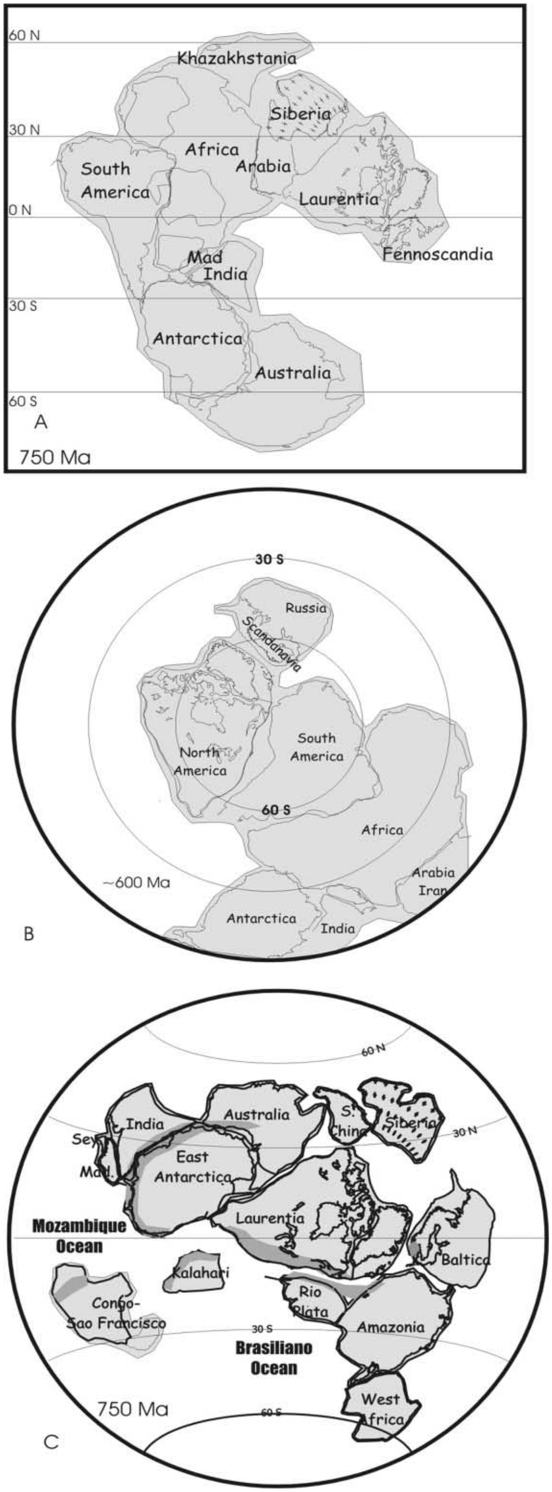

Fig. 1.

indices of Van der Voo (1990)). For example, there are no palaeomagnetic data to constrain the position of the South American, Madagascan, West African and East Antarctic blocks in the Rodinia configuration. An early test of the Antarctic–Laurentian connection by Gose et al. (1997) suggested that the Coats Land, Maudheim and Grunehogna provinces were likely to have been part of the Kalahari craton, but this is now drawn into question by the recognition of widespread late Neoproterozoic orogenesis in East Antarctica (for example, Shiraishi et al., 1994; Jacobs et al., 1998; Fitzsimons, 2000a). There is only a sparse Neoproterozoic database for the Congo, Kalahari, Siberian and Indian cratons, insufficient to provide stringent tests of continental configurations. The late Mesoproterozoic to middle Neoproterozoic database for Laurentia is fairly well constrained, but palaeomagnetic arguments about the relative positions of Baltica and Laurentia are contentious (Weil et al., 1998; Walderhaug et al., 1999). The Australian database is fairly robust from about 600 Ma onwards, but the few extant poles from Australia during the mid-Neoproterozoic suggest that if the Rodinia configuration is correct, Australia had already separated from Laurentia by 750 Ma (Wingate and Giddings, 2000). Thus, the few palaeomagnetic tests for the existence of Rodinia provide mostly negative evidence. Nevertheless, palaeomagnetic studies can provide important constraints on the existence and configuration of any supercontinent, provided the poles have tight age control and are well documented.

This volume begins with a paper by Buchan and co-authors describing the attributes of 'key' palaeomagnetic poles for testing reconstructions. The paper points out that there are two indepen-

Fig. 1. Some of the current variations of the postulated late Precambrian supercontinents. (a) The Proterozoic supercontinent 'Palaeopangea' as envisioned by Piper (1976, 2000), and reconstructed using 750 Ma poles from Laurentia. (b) The late Neoproterozoic supercontinent envisioned by Bond et al. (1984). This reconstruction is more or less equivalent to the supercontinent Pannotia (Powell, 1995; Dalziel, 1997). (c) The supercontinent Rodinia at 750 Ma slightly modified from Dalziel (1997) and Weil et al. (1998). Darker grey shading, the 'Grenvillian'-aged (1300–900 Ma) belts within the supercontinent.

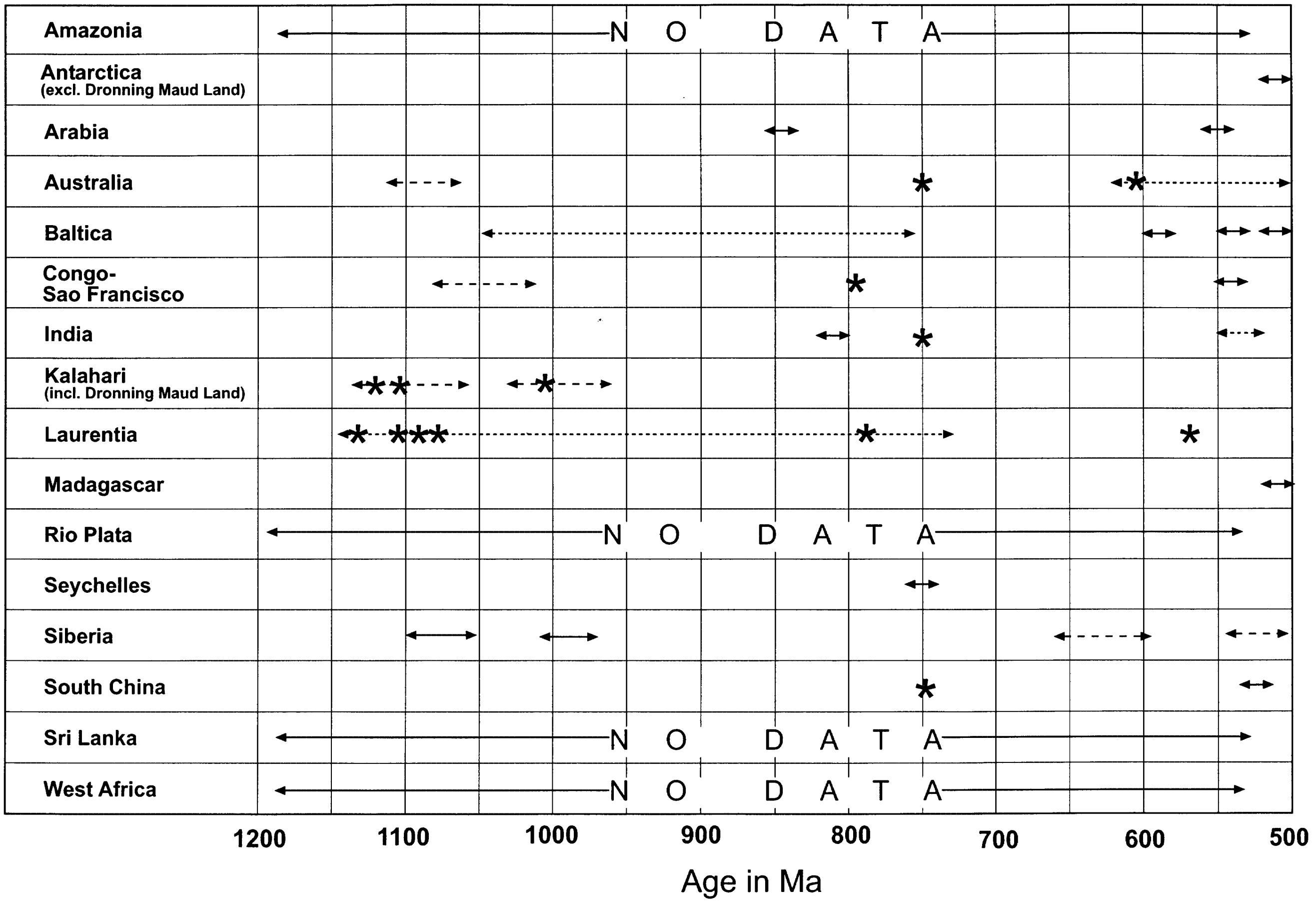

Fig. 2. Cratonic blocks of Rodinia and the age ranges of good palaeomagnetic control: solid lines with arrows, individual poles; fine dashed lines, time spans with nearly continuous palaeomagnetic control; coarser dashed lines, time spans with intermittent palaeomagnetic control. Data are taken from the 2000 edition of the global palaeomagnetic database, or from information in this issue. * Positions of the most reliable palaeopoles, including the key poles identified by Buchan et al. (this volume).

dent uncertainties that have to be taken into account in using palaeomagnetic poles to position continents. One is the experimental uncertainty associated with palaeomagnetic data, and the other is the uncertainty associated with the age of the palaeopole. These uncertainties are cumulative and introduce an uncertainty in the position of a continent that is larger than the experimental uncertainty associated with the palaeomagnetic pole. To these two uncertainties, we add a third uncertainty associated with the structural corrections that are applied to the palaeomagnetic analytical data. Commonly, the orientation of palaeohorizontal is known only approximately to within a few degrees, or is assumed from regional geological relationships. The uncertainty is rarely quantified, and as yet is not included in the estimates of uncertainty for palaeomagnetic poles. Buchan and co-authors highlight the paucity of reliable palaeomagnetic results for Rodinia, but offer a useful review of the extant data considered as ‘key poles’ for the Rodinia supercontinent, and point out constraints that can be used to evaluate alternative reconstructions.

Powell and co-authors provide a summary of late Mesoproterozoic palaeomagnetic poles for the Kalahari craton, including its extension as the Grunehogna craton of East Antarctica, and show that, at 1105 Ma, the Kalahari craton lay astride the Equator. They present evidence for a segment of the Kalahari Apparent Polar Wander Path (APWP) from ca. 1140 Ma to ca. 1000 Ma, and show that, although it has a similar shape, it is different from the Keweenawan Loop of Laurentia. This information is used to argue that the Kalahari craton was not attached to the Laurentian craton at 1100 Ma, but that it could have joined Rodinia after 1060 Ma, possibly by 1020 Ma. They argue that the Namaqua–Natal fold belt faced away from Laurentia, which contrasts with the suggestion by (Dalziel et al., 2000) that the Namaqua–Natal belt faced Laurentia as part of a continent–continent collision zone around 1100 Ma between the Kalahari craton and the Llano–West Texas region of SW Laurentia.

Torsvik and co-authors document new palaeomagnetic data from 750 Ma (U–Pb) co-genetic mafic dikes and granites from the Seychelles microcontinent, and use this to reconstruct Seychelles adjacent to India, placing both as outboard continental terranes in Rodinia. The development of the Seychelles is considered to result from subduction beneath the peripheral continents of East Gondwanaland. Interestingly, these data combined with new palaeomagnetic data from the 755 Ma Mundine dykes of Australia (Wingate and Giddings, 2000) challenge the notion of a united East Gondwanaland. The idea that much of East Gondwanaland was not amalgamated until the Cambrian has additional support from recent work (Meert and van der Voo, 1997; Fitzsimons, 2000a,b; Meert, 2001), but these new data from Seychelles provide the first strong palaeomagnetic support for the idea.

Perhaps one of the more enduring controversies regarding the make-up of the Rodinia supercontinent is the position of Siberia against present-day northern Laurentia along with the timing of the rift to drift transition (Hoffman, 1991; Condie and Rosen, 1994; Pelechaty, 1996; Frost et al., 1998; Rainbird et al., 1998; Ernst et al., 2000; Sears and Price, 2000). This volume contains several papers regarding these issues, beginning with new palaeomagnetic data from Siberia and central Mongolia by Kravchinsky and co-authors, who raise the possibility that the Siberian platform was not fully assembled until after the Early Cambrian. No doubt this will present additional issues to consider in evaluating Precambrian Siberian–Laurentian connections.

The final palaeomagnetic paper is by Pisarevsky and co-authors, who present inclination-only data from a continuous stratigraphic corehole in the late Mesoproterozoic to Ordovician Officer Basin of Australia. The data indicate a low-latitude position for Australia during much of the Neoproterozoic, which has implications for tectonic reconstructions and global icehouse models. The paper also highlights the anomalous position of the pole from the Walsh tillite (Li 2000), which indicates either a hitherto unknown excursion of the Australian APWP, or uncertainty in the age of acquisition of the magnetisation.

As already noted, both the position and orientation of Siberia during the Meso-Neoproterozoic is contentious. Equally debatable is the timing of the rift to drift transition (Hoffman, 1991; Pelechaty, 1996; Khain et al., 1997; Sears and Price, 2000) and the timing of the first convergent orogenic activity on Siberia's different margins. Kuzmichev and co-authors present evidence for emplacement of ophiolites stitched by calc-alkaline intrusions to the present-day southern margin of Siberia at ~ 800 Ma, showing that subduction had commenced beneath this Mesoproterozoic to early Neoproterozoic passive margin. Given that the present-day southern margin of Siberia is generally placed at the edge of Rodinia, facing out towards the World ocean, this is in itself not a problem. However, Vernikovsky and Vernikovskaya, in discussing the timing of collisional and extensional events in the Taimyr region, conclude that the break-up of Rodinia commenced shortly after 800 Ma and that ca. 740 Ma intra-oceanic ophiolites were emplaced on the northwestern margin of the Siberian craton at around 600 Ma. The implication is that both margins of Siberia faced oceanic realms before 600 Ma, which suggests that Siberia had broken away from Laurentia well before the end of the Neoproterozoic. Salnikova and co-authors outline the evidence for emplacement of terranes along the southern margin of Siberia at around 550 Ma. They discuss the age of Palaeozoic granites in the Tuvino-Mongolian Massif (TMM) (central Asian mobile belt) and suggest that the TMM is composed of several different metasedimentary sequences juxtaposed during the latest Neoproterozoic and Cambrian.

The position of Baltica in Rodinia is crucial to many continental reconstructions, most of which place the present-day Scandanavian margin against West Greenland or NE Laurentia until its (?) mid-Neoproterozoic break-up. The corollary is that the southeastern margin on the other side faced away from the core of Rodinia, possibly towards the Meso- and Neoproterozoic World ocean. Watt and Thrane present new SHRIMP zircon ages for earliest Neoproterozoic (950–920 Ma) intrusive rocks in East Greenland, formerly regarded as an extension of the late Mesoproterozoic Grenville orogen. There is limited, equivocal, evidence for deformation pre-dating the 930 Ma granites, but evidence for the presence of a true 'Grenville' orogeny is lacking. What is evident is that the Krummedal supracrustal succession was almost certainly derived, in part, from detritus from the Grenville belt. The Krummendal sediments were then intruded by granites and migmatised between 930- and 900 Ma. The tectonic nature of this event is unclear, but a suite of cross-cutting mafic dykes restricted to the Krummendal succession suggests it could possibly be a Riphean rifting event. Glasmacher and co-authors provide new geochronological and geological constraints on the history of Beloretzk terrane in the SW Urals, which suggest that the southeastern margin of Baltica was a passive margin during the Mesoproterozoic and most of the Neoproterozoic, but was converted to a transpressional margin at around 600 Ma. During Vendian–Cambrian time, the SE margin of Baltica lay adjacent to the peri-Gondwana Cadomian/Avalonian terranes. This idea is supported by the interpretation of provenance signals in Riphean and Vendian sandstones discussed by Willner and co-authors. Collectively, these two papers argue that late Vendian thrusting occurred in the SW Urals as part of terrane accretion to the Baltic margin. Svenningsen presents new geochemical and geochronological data from the Sarek dyke swarm in northern Sweden. This large dyke swarm is found in the Caledonian nappes, and the geochemistry indicates a tholeiitic magma source. The age of the dykes is constrained by U–Pb zircon dates to 608 ± 1 Ma, and Svenningsen argues that they reflect the onset of sea-floor spreading in the Iapetus Ocean. Scarrow and co-authors present evidence from the Polar Urals on the northeastern margin of Baltica for mid-Neoproterozoic intra-oceanic ophiolite formation, which was emplaced on this margin of Baltica between 560 and 510 Ma. The evidence from the Polar and SW Urals is consistent with the conversion of a long-lived Mesoproterozoic and Neoproterozoic passive margin to a convergent or transpressional margin from 600 Ma onwards. In turn, this leads to the interpretation that the Ural margin of Baltica lay inboard of a continuation of the Cadomian arc system that exists further to the east in late Precambrian continental reconstructions.

The last four papers deal with tectonic elements in Africa, the Arabian–Nubian shield region and Brazil. Tack and co-authors provide a synthesis of the West Congo fold belt, including new geochronology that shows there is no late Mesoproterozoic orogenic belt along the Atlantic coast. New SHRIMP zircon dates from silicic rocks in a bimodal volcanic province show that rifting occurred along the West Congo belt from ca. 1000 Ma until 910 Ma, but this did not lead to continental break-up in the Congo. The 2.1 Ga basement of the western Congo extends to the Sao Francisco craton of South America, where a platformal succession of Mesoproterozoic and Neoproterozoic rocks is overthrust by the 800–560 Ma Aracuai belt that lies between the Congo and Sao Francisco cratons. Pedrosa-Soares and co-authors discuss the narrow ocean that opened between the Congo and Sao Francisco cratons. Ophiolitic fragments suggest that rifting started by 800 Ma in a small ocean, widening southwards and forming an arm of the Adamastor Ocean. This ocean was closed during the final stages of western Gondwanaland assembly during the interval from 625 to 575 Ma. Jung and co-authors examine trace element and isotopic evidence for Pan-African granites in the Damara Belt (Namibia) and conclude that the Cambrian-age 'collision' of the Kalahari and Congo cratons formed as a result of intracontinental deformation with no evidence for the closure of a significant ocean. In the final paper, Loizenbauer and co-authors provide evidence from the Meatiq core complex in the Eastern Desert of Egypt for extensional tectonics around 800 Ma, when continental extension was associated with break-up of the East African margin of Rodinia. Further extension occurred later during orogenic collapse following collision between 660 and 620 Ma. Data from the Meatiq complex are compatible with other models proposed for rifting, collision and continental escape in NE Africa (Stern, 1994; Blasband et al., 2000).

The eclectic array of 17 papers in this volume contributes significantly to our understanding of the growth, development and death of the Rodinia supercontinent. Collectively, they provide additional evidence for initial rifting of the supercontinent, commonly around 800 Ma, subduction of oceanic crust at the periphery of the supercontinent, and the eventual reorganisation of cratonic elements and terranes. At the very least, this series of papers suggests that the name 'Rodinia' is entirely apropos!

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References

Blasband, B., White, S., Brooijmans, P., De-Boorder, H., Visser, W., 2000. Late Proterozoic extensional collapse in the Arabian-Nubian Shield. J. Geol. Soc. Lond. 157, 615–628.

Bond, G.C., Nickeson, P.A., Kominz, M.A., 1984. Breakup of a supercontinent between 625 and 555 Ma: new evidence and implications for continental histories. Earth Planet. Sci. Lett. 70, 325–345.

Condie, K.C., Rosen, O.M., 1994. Laurentia–Siberia connection revisited. Geology 22, 168–170.

Dalziel, I.W.D., 1991. Pacific margins of Laurentia and East Antarctica–Australia as a conjugate rift pair: evidence and implications for an Eocambrian supercontinent. Geology 19, 598–601.

Dalziel, I.W.D., 1992. On the organisation of American plates in the Neoprotertozoic and the breakout of Laurentia. GSA Today 2 (11), 237–241.

Dalziel, I.W.D., 1997. Neoproterozoic–Paleozoic geography and tectonics: review, hypothesis and environmental speculation. Bull. Geol. Soc. Am. 109, 16–42.

Dalziel, I.W.D., Mosher, S., Gahagan, L.M., 2000. Laurentia–Kalahari collision and the assembly of Rodinia. J. Geol. 108, 499–513.

Dewey, J.F., Burke, K.C.A., 1973. Tibetan, Variscan and Precambrian basement reactivation: products of continental collision. J. Geol. 81, 683–692.

Ernst, R.E., Buchan, K.L., Hamilton, M.A., Okrugin, A.V., Tomshin, M.D., 2000. Integrated paleomagnetism and U–Pb geochronology of mafic dikes of the Eastern Anabar shield region, Siberia: implications for Mesoproterozoic paleolatitude of Siberia and comparison with Laurentia. J. Geol. 108, 381–401.

Evans, D.A.D., 1998. True polar wander, a supercontinental legacy. Earth Planet. Sci. Lett. 157, 1–8.

Evans, D.A.D., 2000. Stratigraphic, geochronological, and paleomagnetic constraints upon the Neoproterozoic climate paradox. Am. J. Sci. 300, 347–433.

Fitzsimons, I.C.W., 2000a. A review of tectonic events in the East Antarctic Shield, and their implications for Gondwana and earlier supercontinents. J. Afr. Earth Sci. 31 (1), 3–23.

Fitzsimons, I.C.W., 2000b. Grenville-age basement provinces in East Antarctica: evidence for three separate collisional orogens. Geology 28, 879–882.

Frost, B.R., Avchenko, O.V., Chamberlin, K.R., Geldsetzer, H.H.J., 1998. Evidence for extensive Proterozoic remobilization of the Aldan shield and implications for Proterozoic plate tectonic reconstructions of Siberia and Laurentia. Precamb. Res. 89, 1–23.

Gose, W.A., Helper, M.A., Connelly, J.N., Hutson, F.E., Dalziel, I.W.D., 1997. Paleomagnetic data and U–Pb isotopic age determinations from Coats Land, Antarctica: implications for Neoproterozoic plate reconstructions. J. Geophys. Res. 102, 7887–7902.

Hartnady, C.J.H., 1986. Was North America (Laurentia) part of southwestern Gondwanaland during the Late Proterozoic era. S. Afr. J. Earth Sci. 82, 251–254.

Hartnady, C.J.H., 1991. Plate tectonics: about turn for supercontinents. Nature 352, 476–478.

Hoffman, P.F., 1991. Did the breakout of Laurentia turn Gondwanaland inside-out? Science 252, 1409–1412.

Hoffman, P.F., 1999. The break-up of Rodinia, birth of Gondwana, true polar wander and the snowball earth. J. Afr. Earth Sci. 28, 17–34.

Jacobs, J., Fanning, C.M., Henjes-Kunst, F., Olesch, M., Paech, H.-J., 1998. Continuation of the Mozambique Belt into East Antarctica: Grenville-age metamorphism and polyphase Pan-African high-grade events in central Dronning Maud Land. J. Geol. 106, 385–406.

Karlstrom, K.E., Harlan, S.S., Williams, M.L., McClelland, J., Geissman, J.W., Åhäll, K.-I., 1999. Refining Rodinia: Geologic evidence for the Australia–western US connection in the Proterozoic. GSA Today 9 (10), 1–7.

Khain, V.E., Gusev, G.S., Khain, E.V., Vernikovsky, V.A., Volobuyev, M.I., 1997. Circum-Siberian Neoproterozoic ophiolite belt. Ofioliti 22, 195–200.

Kirschvink, J.L., 1992. Late Proterozoic low-latitude global glaciation: the snowball Earth. In: Schopf, J.W., Klein, C. (Eds.), The Proterozoic Biosphere. Cambridge University Press, Cambridge, pp. 51–52.

Kirschvink, J.L., Ripperdan, R.L., Evans, D.A., 1997. Evidence for a large-scale reorganization of Early Cambrian landmasses by inertial interchange true polar wander. Science 277, 541–545.

Li, Z.X., 2000. New palaeomagnetic results from the ‘cap dolomite’ of the Neoproterozoic Walsh Tillite, northwestern Australia. Precamb. Res. 100, 359–370.

McMenamin, M.A.S., McMenamin, D.L.S., 1990. The emergence of animals: The Cambrian breakthough. Columbia University Press, New York, 217 pp.

Meert, J.G., 1999. A paleomagnetic analysis of Cambrian true polar wander. Earth Planet. Sci. Lett. 168, 131–144.

Meert, J.G., 2001. Growing Gondwana and rethinking Rodinia. Gondwana Res., 4 (in press).

Meert, J.G., van der Voo, R., 1997. The assembly of Gondwana 800–550 Ma. J. Geodynam. 23, 223–235.

Moores, E.M., 1991. Southwest U.S.-East Antarctic (SWEAT) connection: a hypothesis. Geology 19, 425–428.

Pelechaty, S.M., 1996. Stratigraphic evidence for the Siberia–Laurentia connection and Early Cambrian rifting. Geology 24, 719–722.

Piper, J.D.A., 1976. Palaeomagentic evidence for a Proterozoic supercontinent. Phil. Trans. R. Soc. Lond. A280, 469–490.

Piper, J.D.A., 2000. The Neoproterozoic supercontinent: Rodinia or Palaeopangea? Earth Planet. Sci. Lett. 176, 131–146.

Powell, C.McA., 1995. Are Neoproterozoic glacial deposits preserved on the margins of Laurentia related to the fragmentation of two supercontinents?: comment. Geology 23, 1053–1054.

Powell, C.McA., McElhinny, M.W., Li, Z.X., Meert, J.G., Park, J.K., 1993. Paleomagnetic constraints on timing of the Neoproterozoic breakup of Rodinia and the Cambrian formation of Gondwana. Geology 21, 889–892.

Powell, C.McA., Preiss, W.V., Gatehouse, C.G., Krapez, B., Li, Z.X., 1994. South Australian record of a Rodinian epicontinental basin and its mid-Neoproterozoic breakup ($\sim$700 Ma) to form the Palaeo-Pacific Ocean. Tectonophysics 237, 113–140.

Rainbird, R.H., Stern, R.A., Kudoley, A.K., Kropachev, A.P., Heaman, L.M., Sukhorukov, V.I., 1998. U–Pb geochronology of Riphean sandstone and gabbro from southeast Siberia and its bearing on the Laurentia-Siberia connection. Earth Planet. Sci. Lett. 164, 409–420.

Sears, J.W., Price, R.A., 2000. New look at the Siberian connection: No SWEAT. Geology 28, 423–426.

Shiraishi, K., Ellis, D.J., Hiroi, Y., Fanning, C.M., Motoyoshi, Y., Nakai, Y., 1994. Cambrian orogenic belt in East Antarctica and Sri Lanka: implications for Gondwana assembly. J. Geol. 102, 47–65.

Stern, R.J., 1994. Arc assembly and continental collision in the Neoproterozoic East African Orogen: Implications for the assembly of Gondwanaland. Ann. Rev. Earth Planet. Sci. 22, 319–351.

Van der Voo, R., 1990. The reliability of paleomagnetic data. Tectonophysics 184, 1–9.

Walderhaug, H.J., Torsvik, T.H., Eide, E.A., Sundvoll, B., Bingen, B., 1999. Geochronology and paleomagnetism of the Hunnedalen dykes, SW Norway: implications for the Sveconorwegian apparent polar wander loop. Earth Planet. Sci. Lett. 169, 71–83.

Weil, A.B., Van der Voo, R., MacNiocall, C., Meert, J.G., 1998. The Proterozoic supercontinent Rodinia: paleomagnetically derived reconstructions for 1100–800 Ma. Earth Planet. Sci. Lett. 154, 13–24.

Wingate, M.T.D., Giddings, J.W., 2000. Age and paleomagnetism of the Mundine Well dyke swarm, Western Australia: implications for an Australia–Laurentia connection at 750 Ma. Precamb. Res. 100, 335–357.

Young, G.M., 1995. Are Neoproterozoic glacial deposits preserved on the margins of Laurentia related to the fragmentation of two supercontinents? Geology 23, 153–156.

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