Precambrian Research 244 (2014) 207–225

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Mesoproterozoic paleogeography: Supercontinent and beyond

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ARTICLE INFO

Article history:
Received 28 February 2013
Received in revised form 7 May 2013
Accepted 21 May 2013
Available online 30 May 2013

Keywords:
Mesoproterozoic
Global
Paleogeography
Supercontinent
Paleomagnetism

ABSTRACT

A set of global paleogeographic reconstructions for the 1770–1270 Ma time interval is presented here through a compilation of reliable paleomagnetic data (at the 2009 Nordic Paleomagnetic Workshop in Luleå, Sweden) and geological constraints. Although currently available paleomagnetic results do not rule out the possibility of the formation of a supercontinent as early as ca. 1750 Ma, our synthesis suggests that the supercontinent Nuna/Columbia was assembled by at least ca. 1650–1580 Ma through joining at least two stable continental landmasses formed by ca. 1.7 Ga: West Nuna (Laurentia, Baltica and possibly India) and East Nuna (North, West and South Australia, Mawson craton of Antarctica and North China). It is possible, but not convincingly proven, that Siberia and Congo/São Francisco were combined as a third rigid continental entity and collided with Nuna at ca.1500 Ma. Nuna is suggested to have broken up at ca. 1450–1380 Ma. West Nuna, Siberia and possibly Congo/São Francisco were rigidly connected until after 1270 Ma. East Nuna was deformed during the breakup, and North China separated from it. There is currently no strong evidence indicating that Amazonia, West Africa and Kalahari were parts of Nuna.

1. Introduction

There has been a growing interest in the hypothesised pre-Rodinian supercontinent, variously called Nuna, Columbia, or Hudsonland (e.g., Hoffman, 1997; Meert, 2002; Pesonen et al., 2003; Zhao et al., 2002, 2004). One of the main geological arguments used for this hypothesis is in the presence of 2.1–1.8 Ga orogens in a majority of continents (e.g., Zhao et al., 2004), and it was suggested that some or all of these orogens resulted from the assembly of this supercontinent. However, most reconstructions are highly speculative in nature, mainly due to the lack of adequate high quality paleomagnetic data to provide independent constraints.

At the 2009 Nordic Paleomagnetic Workshop in Luleå (Sweden; Elming and Pesonen, 2010), it was concluded that there are about one hundred late Paleoproterozoic to Mesoproterozoic paleopoles (most of them are from Laurentia, Baltica, Siberia and Australia) of 'reasonable' quality and they can be used for late Paleo- to Mesoproterozoic reconstructions. In this study we slightly updated the Luleå data compilation utilising more recently published paleomagnetic and geochronological results (Table 1). Most of the paleopoles in Table 1 are considered to be of high quality, but we have also included some less reliable poles (shown in italics), which were used only as a "second-order" constraints for paleogeographic reconstructions. In most cases these less reliable poles are either poorly dated or have not averaged out secular variation of geomagnetic field and are therefore marked as Virtual Geomagnetic Poles (VGPs). Hereafter we shall call them 'non-key' poles. In the following sections we use (directly and indirectly) about a hundred ca. 1800–1000 Ma poles in an attempt to reconstruct the global distribution of continents and the history of their drift in the late Paleoproterozoic and much of the Mesoproterozoic (mainly the 1770–1270 Ma time internal). The paleogeography of the 1270–1000 Ma time period is enigmatic and has to be analysed separately and published elsewhere. However, we consider few elements of this late Mesoproterozoic paleogeography to provide some clues for understanding of older events.

The paleomagnetic data presented in Table 1 and Fig. 1 clearly demonstrate that both temporal and spatial distributions of the 1800–1000 Ma data are very uneven. Even from the paleomagnetically most thoroughly studied Laurentia there are still not enough data for the construction of a reliable Apparent Polar Wander Path (APWP) for the entire period. Paleomagnetic databases for other continents are even less complete, and paleopositions of some continents (e.g. South China, Rio de La Plata, São Francisco, West Africa) are not paleomagnetically constrained at all.

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http://dx.doi.org/10.1016/j.precamres.2013.05.014

Table 1
Selected 1800–1000 Ma paleomagnetic poles (modified from the Luleå Workshop 2009 compilation).

#	Rockname	Continent	Age (Ma)	Plat (°N)	Plong (°E)	A_{95} (°)	Reference
1770 Ma							
1	Late. Svecofennian Rocks, Mean	Fenn	~1800	49.6	221.0	10.8	Elming and Pesonen (2010)
2	Småland Intrusions	Fenn	1784–1769	45.7	182.7	8.0	Pisarevsky and Bylund (2010)
3	Shoksha Formation	Fenn	1780–1760	39.7	221.1	4.0	Pisarevsky and Sokolov (2001)
4	Hoting Gabbro	Fenn	1760–1740	43.0	233.3	10.9	Elming et al. (2009b)
5	Ropruchey Sill	Fenn	1754–1748	39.1	216.6	6.7	Fedotova et al. (1999), Lubnina et al. (2012)
6	Korosten Pluton	Sarm	1770–1740	25.1	171.0	4.0	Elming et al. (2001)
7	Dubawnt Group	Lau	1820–1750	7.0	277.0	8.0	Park et al. (1973)
8	Jan Lake Granite	Lau	1759–1757	24.3	264.3	16.9	Gala et al. (1995)
9	*Frere Formation*	*WAC*	*1900–1800*	*45.2*	*40.0*	*1.8*	Williams et al. (2004)
10	*Elgee-Pentecost Formations*	*NAC*	*1834–1740*	*5.4*	*31.8*	*3.2*	Schmidt and Williams (2008), Wingate et al. (2011)
11	Xiong'er Group	N.Chi	~1780	50.2	263.0	4.5	Zhang et al. (2012)
12	Taihang Dykes	N.Chi	1772–1766	36.0	247.0	2.8	Halls et al. (2000)
13	Basic Dykes Group II	Am	1802–1798	42.0	180.0	5.0	Onstott et al. (1984)
14	Colider Volcanics	Am	1796–1782	63.3	118.8	11.4	Bispo-Santos et al. (2008)
15	Avanavero Intrusions	Am	1791–1786	48.4	207.9	9.6	Reis et al. (in press)
1720 Ma							
16	Peters Creek Volc., upper part	NAC	1729–1725	26.0	41.0	4.8	Idnurm (2000)
17	Wollogorang Formation	NAC	1730–1723	17.9	38.2	7.2	Idnurm et al. (1995)
18	Fiery Creek Formation	NAC	1712–1706	23.9	31.8	10.4	Idnurm (2000)
19	West Branch Volcanics	NAC	1712–1705	15.9	20.50	11.3	Idnurm (2000)
20	Cleaver Dykes	Lau	1745–1736	19.4	276.7	6.1	Irving et al. (2004)
21	*Chaya Dyke 1 VGP*	*Sib*	*1755–1749*	*40.0*	*280.0*	*5.7*	Vodovozov et al. (2007), Gladkochub et al. (2010)
22	*Chaya Dyke 2 VGP*	*Sib*	*1755–1749*	*39.0*	*270.0*	*5.3*	Vodovozov et al. (2007), Gladkochub et al. (2010)
23	*Angara-Kan Granite VGP*	*Sib*	*1739–1729*	*42.9*	*289.6*	*5.3*	Didenko et al. (2009)
24	Ulkan Granite[a]	Sib	1730–1725	48.0	278.8	4.4	Didenko et al. (2013)
25	Elgetei Formation[a]	Sib	1736–1728	18.1	210.6	3.6	Didenko et al. (2013)
1650 Ma							
26	Sipoo Quartz Porphyry Dykes	Ba	1643–1623	26.4	180.4	9.4	Mertanen and Pesonen (1995)
27	Wiborg Quartz Porphyry Dykes	Ba	1641–1621	30.2	175.4	9.4	Neuvonen (1986)
28	Mallpunyah Formation	NAC	1665–1645	35.0	34.3	3.1	Idnurm et al. (1995)
29	Tooganinie Formation	NAC	1651–1645	61.0	6.7	6.1	Idnurm et al. (1995)
30	Emmerugga Dolomite	NAC	1653–1635	79.1	22.6	6.1	Idnurm et al. (1995)
31	Balbirini Dolomite, lower part	NAC	1617–1606	66.1	357.5	5.7	Idnurm (2000)
32	*Bathlaros Kimberlite*	*Kal*	*1700–1600*	*30.0*	*8.2*	*8.9*	Hargraves (1989)
1580 Ma							
33	Kumlinge-Brändö Dykes	Ba	1590–1562	12.2	182.0	6.7	Pesonen and Neuvonen (1981)
34	Föglö-Sottunga Dykes	Ba	1589–1528	27.8	187.5	9.0	Pesonen and Neuvonen (1981)
35	Western Channel Diabase	Lau	1593–1587	9.0	245.0	6.6	Irving et al. (1972), Hamilton and Buchan (2010)
36	Balbirini Dolomite, upper part	NAC	1592–1586	52.0	356.1	7.5	Idnurm (2000)
37	*Van Dyk Mine Dyke.*	*Kal*	*1650–1550*	*12.4*	*13.9*	*7.0*	Jones and McElhinny (1966)
1500 Ma							
38	Rödö basic dykes	Ba	1513–1497	41.6	201.7	9.5	Moakhar and Elming (2000)
39	Ragunda Formation	Ba	1519–1493	51.6	166.6	7.1	Piper (1979)
1470 Ma							
40	*Fomich Mafic Intrusions*	*Sib*	*1564–1452*	*19.2*	*257.2*	*4.2*	Veselovsky et al. (2006)
41	Bunkris/Glysjon/Oje Rocks	Ba	1478–1460	28.3	179.8	13.2	Bylund (1985), Söderlund et al. (2005)
42	St.Francois Mountains	Lau	1492–1460	−13.2	219.0	6.1	Meert and Stuckey (2002)
43	Kyutingde, Sololi intrusions, Siberia	Sib	1497–1449	33.6	253.1	10.4	Wingate et al. (2009)
44	Lakhna Dykes, India	Ind	1468–1462	36.6	132.8	14.0	Pisarevsky et al. (2013)
1450–1420 Ma							
45	Ladoga-Valaam Intrusions	Ba	1464–1440	11.8	173.3	7.4	Salminen and Pesonen (2007), Shcherbakova et al. (2008)
46	Michikamau Intrusion	Lau	1465–1455	−1.5	217.5	4.7	Emslie et al. (1976)
47	Spokane Formation	Lau	1470–1445	−24.8	215.5	4.7	Elston et al. (2002)
48	Snowslip Formation	Lau	1463–1436	−24.9	210.2	3.5	Elston et al. (2002)
49	Purcell Lava	Lau	1450–1436	−23.6	215.6	4.8	Elston et al. (2002)
50	Rocky Mountain Intrusions, Mean	Lau	1445–1415	−11.9	217.4	9.7	Elming and Pesonen (2010)
51	Mistastin Pluton	Lau	1450–1400	−1.0	201.5	7.6	Fahrig and Jones (1976)
52	Tobacco Root Dykes A	Lau	1497–1399	8.7	216.1	15.5	Harlan et al. (2008)
53	Tieling Formation	N.Chi	1458–1416	11.6	187.1	6.3	Wu et al. (2005)
54	Nova Guarita Intrusives	Am	1423–1415	47.9	65.9	7.0	Bispo-Santos et al. (2012)
55	Indiavai Intrusion	Am	1423–1409	57.0	69.7	8.6	D'Agrella-Filho et al. (2012)
1380 Ma							
56	McNamara Formation	Lau	1407–1395	−13.5	208.3	6.7	Elston et al. (2002)
57	Pilcher, Garnet Range, Libby rocks	Lau	1407–1362	−19.2	215.3	7.7	Elston et al. (2002)
Formations							
58	Victoria Fjord Dolerite Dykes	Gre	1384–1380	10.3	231.7	4.3	Abrahamsen and Van der Voo (1987)
59	Midsommersoe Dolerites	Gre	1384–1380	6.9	242.0	5.1	Marcussen and Abrahamsen (1983)
60	Zig-Zag Dal Basalts	Gre	1384–1380	12.0	242.8	3.8	Marcussen and Abrahamsen (1983)
61	N. China Sills	N.Chi	1367–1333	5.9	359.6	4.3	Chen et al. (2013)
62	*Chieress Dyke VGP*	*Sib*	*1386–1382*	*5.0*	*258.0*	*6.7*	Ernst et al. (2000)