Precambrian Palaeolatitudes for Australia

– an update –

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Introduction

Palaeolatitudes for Precambrian Australia were last reported in 1988[1]. A serious limitation at that time was the sparseness of palaeomagnetic data. While the Australian Precambrian still lacks palaeomagnetic data on the whole, two intervals within it have since become much better defined. These are the late Palaeoproterozoic to earliest Mesoproterozoic and late the Mesoproterozoic to middle Neoproterozoic. Improvements to the former resulted from multidisciplinary studies in the 1990s by AGSO to provide a geological framework for mineral exploration in northern Australia; improvements to the latter are largely due a quest led by the University of Western Australia to determine the configuration of the late Proterozoic supercontinent Rodinia. This report incorporates the improvements in data for an update on Australian Precambrian palaeolatitudes.

Palaeomagnetic determination of palaeolatitudes

The derivation of palaeolatitudes by use of palaeomagnetism is based on the geocentric axial dipole hypothesis – when averaged over time, the geomagnetic field may be represented by that of a magnetic dipole located at the centre of the Earth and aligned along its rotation axis. A period of few thousand years is generally considered sufficient to average out the components in the geomagnetic field that cause it to differ from that of the geocentric axial dipole. Given such a dipole field, the palaeolatitude may be calculated from its inclination at any particular locality using the equation:

$$\tan I = 2 \cot p,$$

where I is the inclination of the field and p is the palaeo-colatitude of the locality.

The inclination of the ancient geomagnetic field is obtained by analysing the magnetic records of rock formations.

The validity of the geocentric axial dipole hypothesis can be tested by using global palaeomagnetic data (for its dipole character) together with palaeoclimatic data (for axial alignment). Such tests confirm that the dipole field was a good approximation of the geomagnetic field during the Phanerozoic[2]. Similar data are not available for the tests in the Precambrian. Therefore, to obtain Precambrian palaeolatitudes, it is necessary to assume that the same processes within the conductive outer liquid core of the Earth which generated the Phanerozoic geomagnetic field had operated in earlier times.

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[1] Idnurm, M. and Giddings, J.W., 1988. Australian Precambrian polar wander: a review. Precambrian Research, **40/41**, 61-88.

[2] Merrill, R.T., McElhinny, M.W. and McFadden, P.L., 1996. The magnetic field of the Earth: Palaeomagnetism, the core, and the deep mantle. Academic Press, San Diego, 528 pp.

Palaeolatitude database

The palaeomagnetic poles, their geochronological ages and the respective 95% (or alternatively 2sd) uncertainties used in this update are listed in Table 1. Also listed are the rock formations and geological units from which the data were obtained. The Ps and Cs in the References column of the table give the sources of the palaeomagnetic (P) geochronological (C) data. Some palaeomagnetic poles used in the 1988 summary have since been contested, and are therefore omitted. These include the poles for the Gawler Range Volcanics[3] and a Yilgarn dykes suite (YE)[4].

Palaeolatitude vs time diagrams

Figure 1 shows the variation of palaeolatitude in time with Alice Springs taken as the reference locality. A detail for the interval 1.8 – 1.6 Ga in which the plot is particularly well defined is shown in Fig. 1a. The Precambrian structural units from where the palaeolatitudes were obtained are coded by colour. Error bars in the diagrams indicate 95% (or 2sd) confidence limits.
It is possible that the Precambrian units were not assembled in their present-day configuration – especially during the Archaean, if not subsequently. If so, a palaeolatitude estimate would be valid for only that unit (and any others attached to it) from which the data were obtained. The reference locality would then need to be imagined as a fictitious, or projected, reference point relative to the particular structural unit(s).

Palaeolatitudes may be estimated by interpolation between successive points in the diagrams, provided the gap is not large. Trend lines, or rather bands, are shown in the figures to assist interpolation. The band for the Archaean is highly tentative, pending a substantial increase in data.

A disadvantage of the palaeolatitude-time diagrams is that each applies only to a particular reference locality. Palaeolatitudes of other localities may differ substantially, depending on their distance from the reference locality and on the orientation of the continent relative to the geographic pole. This is illustrated in Fig. 2 where palaeolatidudes for Alice Springs (23.7°S, 133.9°E) are compared with those of the Tanami mine (20.0°S, 129.7°E) approximately 600 km to the northwest. The palaeolatitude difference ranges from -5° to +5°.

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[3] P.W. Schmidt quoted in: Idnurm, M., Giddings, J.W. and Plumb, K.A., 1995. Apparent polar wander and reversal stratigraphy of the Palaeo-Mesoproterozoic southeastern McArthur Basin, Australia. Precambrian Research, **72**, 1-41.

[4] Halls,H. C. and Wingate, M.T.D., 2001. Paleomagnetic pole from the Yilgarn B (YB) dykes of Western Australia: no longer relevant to Rodinia reconstructions. Earth and Planet. Sci. Lett., **187**, 39-53.

Palaeogeographic diagrams

Figures 3a to 3g show Australia relative to the geographic (strictly, time-averaged palaeomagnetic) pole at 19 different times during the Precambrian. This type of representation overcomes the problem of determining palaeolatidudes of different locations as it allows interpolation between palaeolatitude lines. The diagrams, however, have the drawback that the rate of latitudinal change in the time interval between successive diagrams (palaeogeographic 'snapshots') is not clear, making it difficult to estimate palaeolatitudes for in-between times. The palaeogeographic diagrams also do not convey the sometimes substantial uncertainties in the palaeolatitude estimates. In general, the best approach is to use the time variation and palaeogeographic diagrams in conjunction, while keeping in mind that the Australian Precambrian units may not have been in their present day configuration.

Table 1. Palaeomagnetic poles used in palaeolatitude determination

Structural unit and rock formation	Pole Latitude deg. N	Pole Longitude deg. E	A95 dp,dm deg.	Age Ga	Reference	Pole Acronym	Pallat. Alice Spr. deg. N	Pallat. Tanami deg. N
Adelaide Geosyncline								
Elatina Formation	-52.4	347.1	3.7,7.4	.65-.60	P1,C1	EF	8.6	10.6
Bunjeroo Formation	-18.1	16.3	6.5,11.8	0.59	P2,C2	BF	16.2	14.4
Amadeus Basin								
Pertatataka Formation, Ringwood Mbr	-65	278	8,15	.73+/- .05	P3,C3	PR	-2.9	1.6
Arunta Block								
Stuart Dykes	10	262	10	1.06+/-.04	P4,C4	SD	38.8	43
Gawler Block								
GA dykes	-61	51	9	1.47+/-.20	P5,C5	GA	-24	-22.9
Hamersley Basin								
Mount Roe Basalt	52	358	6,9	~2.8	P6,C6	RB	46.2	40.9
Kimberley Block								
Hart Dolerite	-29	226	24	1.790+/-.004	P7,C7	HD	-9.5	-4.3
Elgee Formation	-4.4	210	3.3,6.5	1.704+.007/-.014	P8,C8	LG	-14.5	-10.6
McArthur Basin								
Hobblechain Rhyolite	-17.6	209.9	11.9	1.725+/-.002	P9,C9	HR	-19.4	-14.8
West Branch Volcanics	-15.9	200.5	11.3	1.709+/-.010	P10,C10	WBV	-27.4	-23
Amos Formation	-66.5	178.4	4.5	1.614+/-.004	P11,C11	AFB	-39	-34.1
Balberini Dolomite, lower	-66.1	177.5	5.7	1.609+/-.003	P12,C12	BDBL	-39.5	-34.6
Balberini Dolomite, upper	-52	176.1	7.5	1.589+/-.003	P13,C13	BDBU	-47.3	-42
Lynott Formation	-75.1	162.8	6.2	1.636+/-.004	P14,C14	LYN	-36.5	-32.2
Lynott Formation	21.5	78.3	5.9		P14a,C14a	LYNO		
Tatoola Sandstone	-52.7	182.2	10.7	1.648+/-.003	P15,C15	TAT	-43.5	-38.2
Wollogorang Formation	-17.9	218.2	7.2	1.730+/-.003	P16,C16	WFK	-12.1	-7.4
Mount Isa Block								
Lakeview Dolerite	9.5	311.1	17.4	1.116+/-.012	P17,C17	IAR	75.6	79.4
Peters Creek Volcanics	-26	221	4.8	1.724+/-.002	P18,C18	PCVU	-12.6	-7.5

Table 1. Palaeomagnetic poles used in palaeolatitude determination *(cont.)*

Structural unit and rock formation	Pole Latitude deg. N	Pole Longitude deg. E	A95 dp,dm deg.	Age Ga	Reference	Pole Acronym	Pallat. Alice Spr. deg. N	Pallat. Tanami deg. N
Musgrave Block								
Giles Complex	18	307	23,29	~1.078	P19,C19	GC	81.4	86.8
Kulgera Dyke Suite	-17	266	12	1.090+/-.032	P20,C20	KG	28	33.3
Northampton Block								
Basic dykes, Northampton Block	-47.1	317.3	8	.748+/-.016	P21,C21	NDD	19.1	22.6
Pilbara Block								
Duffer Formation	-44	266	7	3.452+/-.016	P22,C22	DFM	9.3	14.5
Millindinna Complex	12	341	7,8	2.86+/-.02	P23,C23	MIL	61.8	58.9
Black Range dyke	32	334	9	>/~ 2.7	P24,C24	BR	70.4	65.2
Mundine dykes, WA	-43.8	314.1	5.1	.755+/-.003	P25,C25	MDS	21	24.6
Pine Creek Inlier								
Plum Tree Creek Volcanics	-29	195	14	1.825+/-.004	P34,C34	PTV	-35.6	-30.6
Yilgarn Block								
Ravensthorpe dykes	38	316	26	2.45+/-.10	P26,C26	RD	75.6	71.2
Widgiemoolta dykes	9	337	8	2.37+/-.03	P27,C27	WD	63.5	61.4
YE dykes	-28	0	31	~2.45	P28,C28	YE	21	21.7
YF dykes	-25	282	14	~1.66	P29,C29	YF	32.3	37.6
Morawa lavas	20	59	17	1.36+/-.14	P30,C30	ML	-5	-10.1
Albany-Fraser Mobile Belt								
Bremer Bay & Whalebone Point area	74.4	303.8	12.2,14.7	~1.2	P31,C31	BB1	39	35.5
Mount Barren Group	55.8	325.7	11.9,13.9	~1.2	P32,C32	MBG	56.7	52.2
Bangemall Basin								
Bangemall Basin sediments	-33.8	275	8.3	1.070+/-.006	P33,C33	BBS	21.6	26.9

Table 1 References

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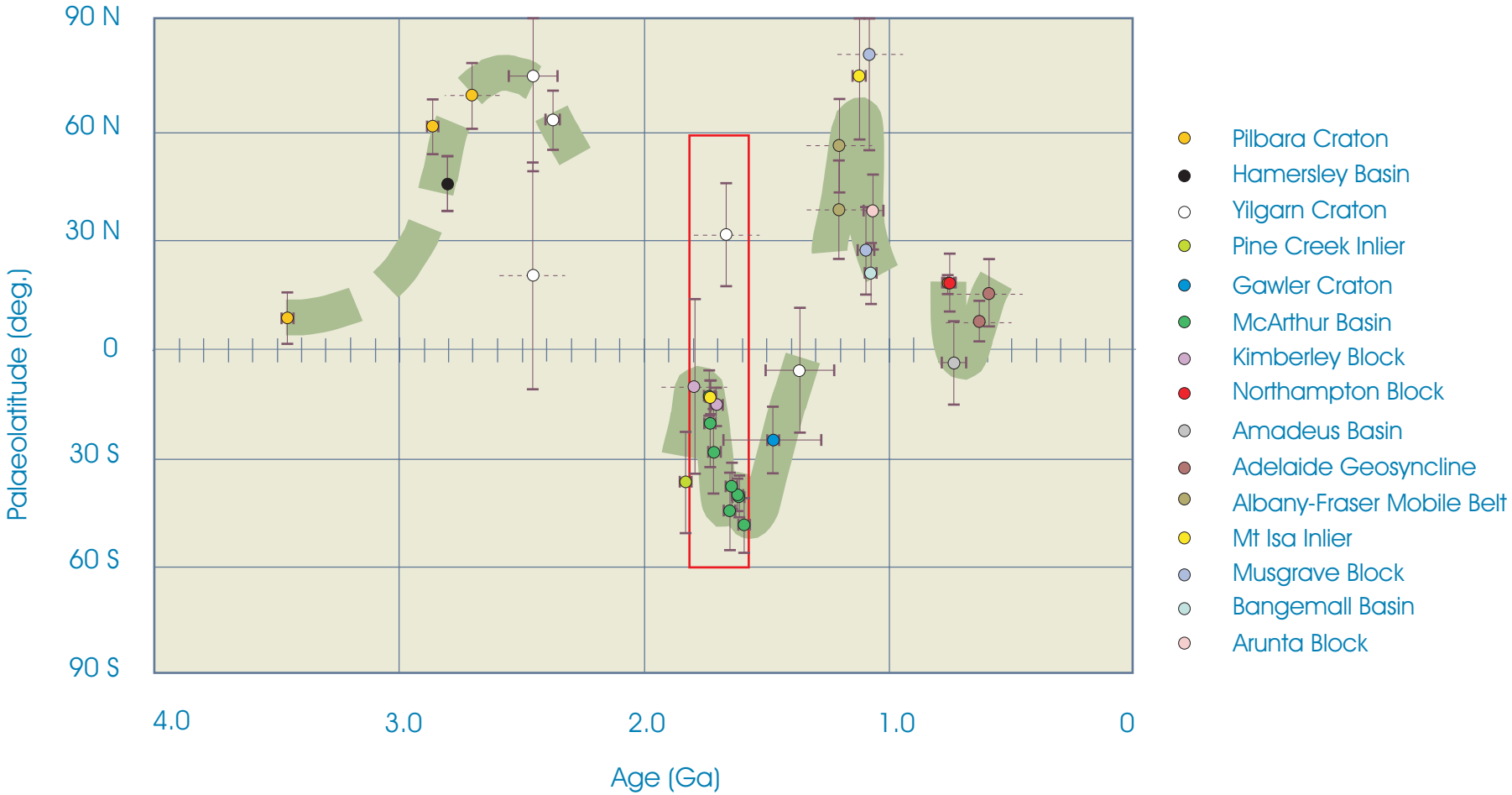


Fig.1 Precambrian palaeolatitudes for Australia with Alice Springs as the reference locality. 95% (or 2sd) confidence intervals are shown in solid lines. Broken lines signify approximate ages. Area in rectangle is expanded in Fig.1a.

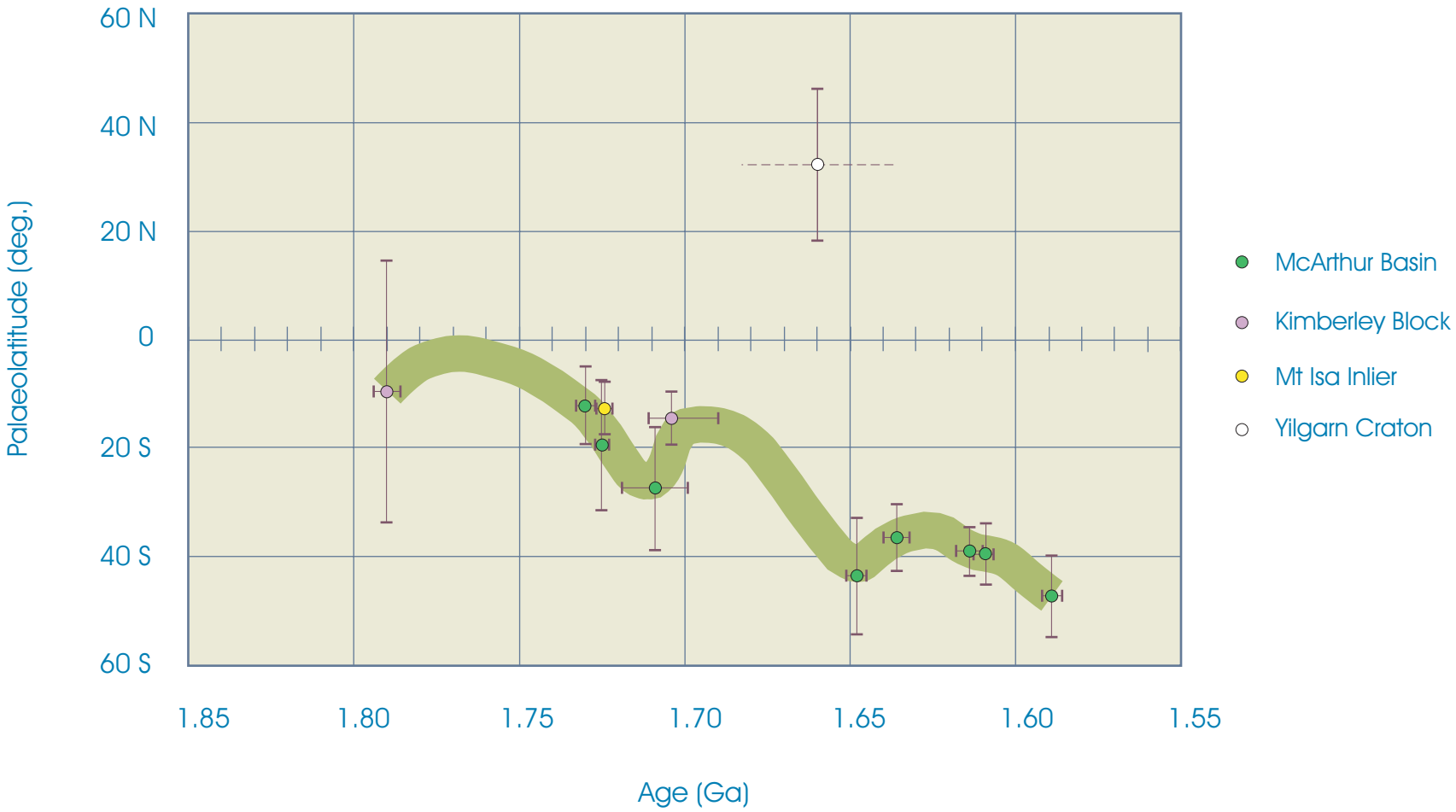


Fig.1a Detail of Fig.1 for the interval 1.8 to 1.6 Ga.

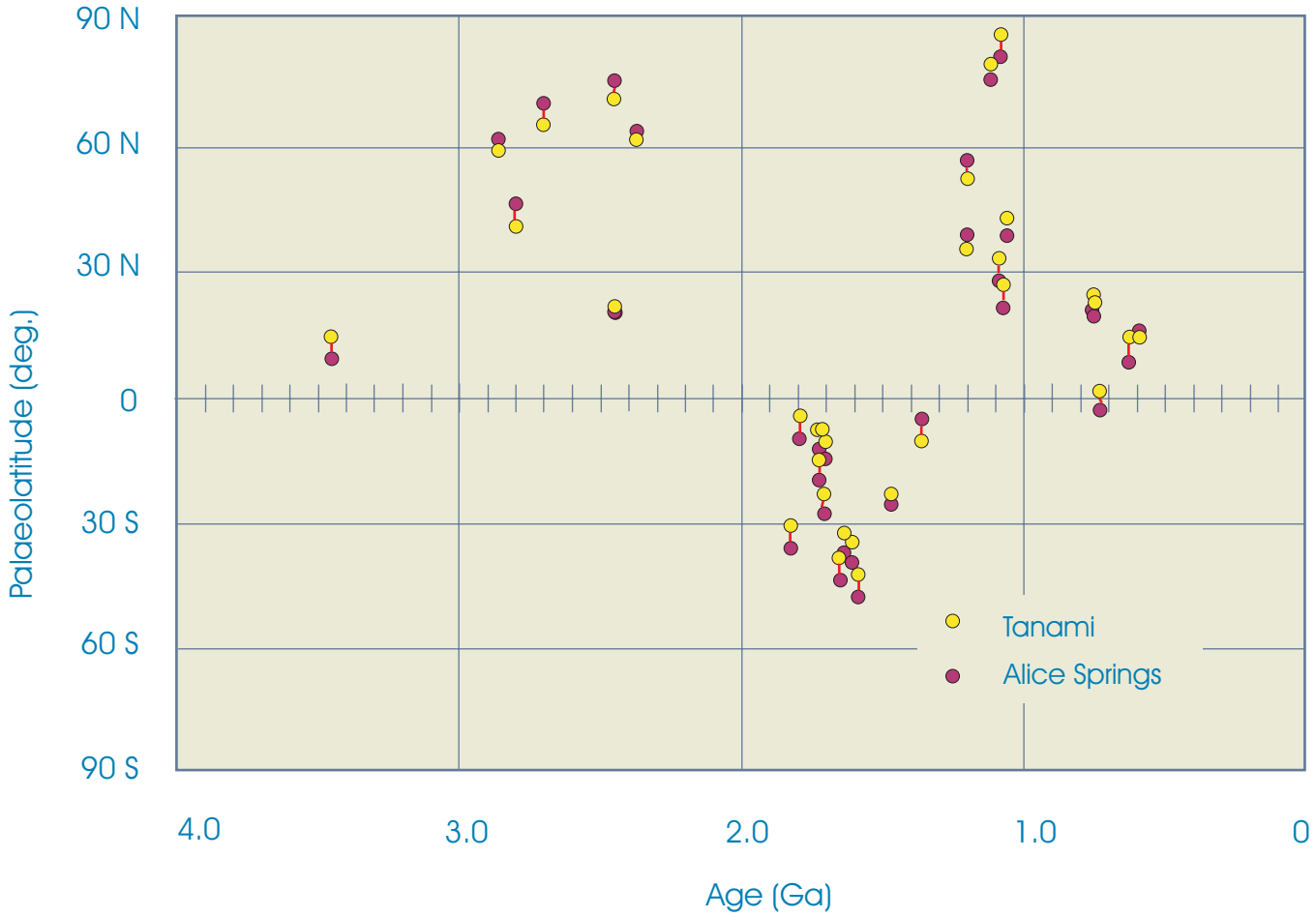
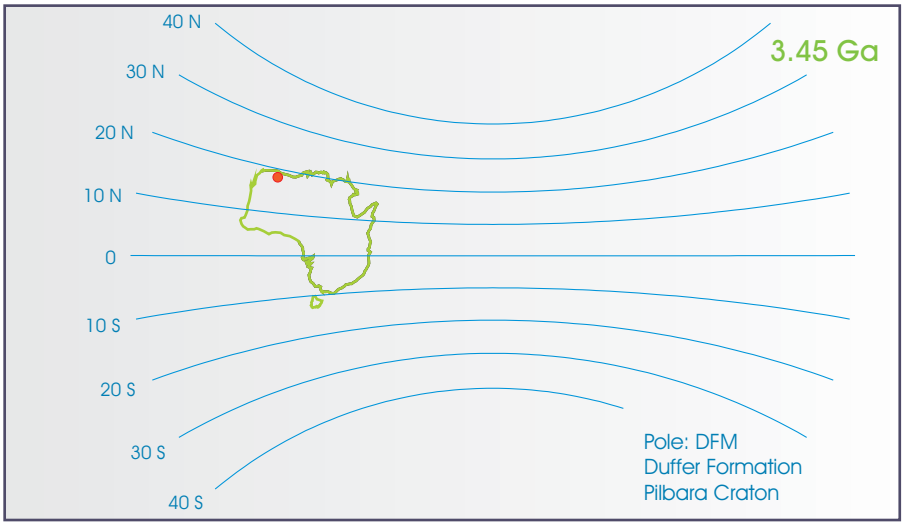
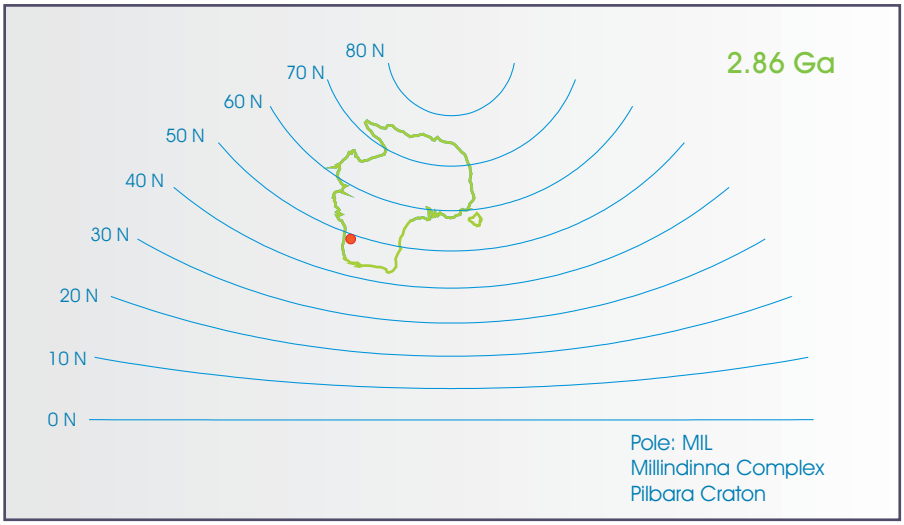


Fig.2 Comparison of palaeolatitudes of Alice Springs and the Tanami mine. Corresponding palaeolatitudes that differ by more than a few degrees are shown linked.





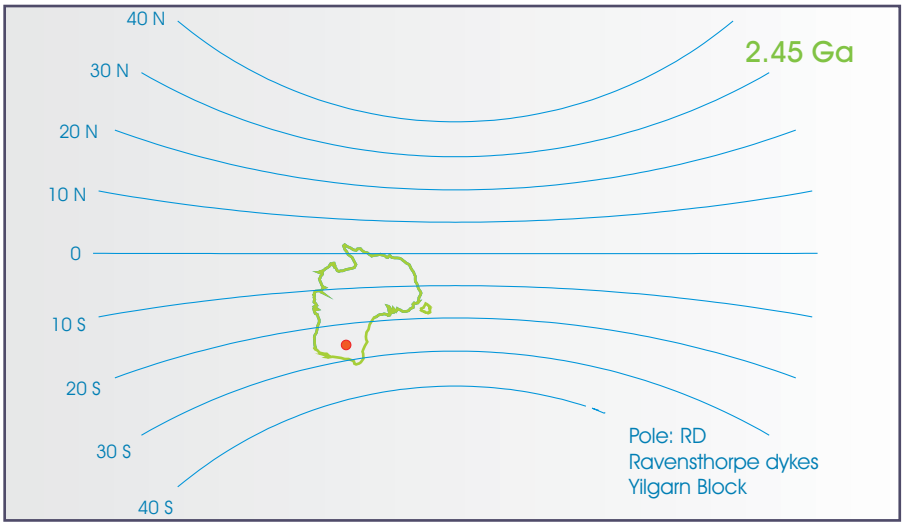


Fig. 3a Figs.3a - 3g show palaeolatitudes of various Australian structural units (located by red dots) during the Precambrian.

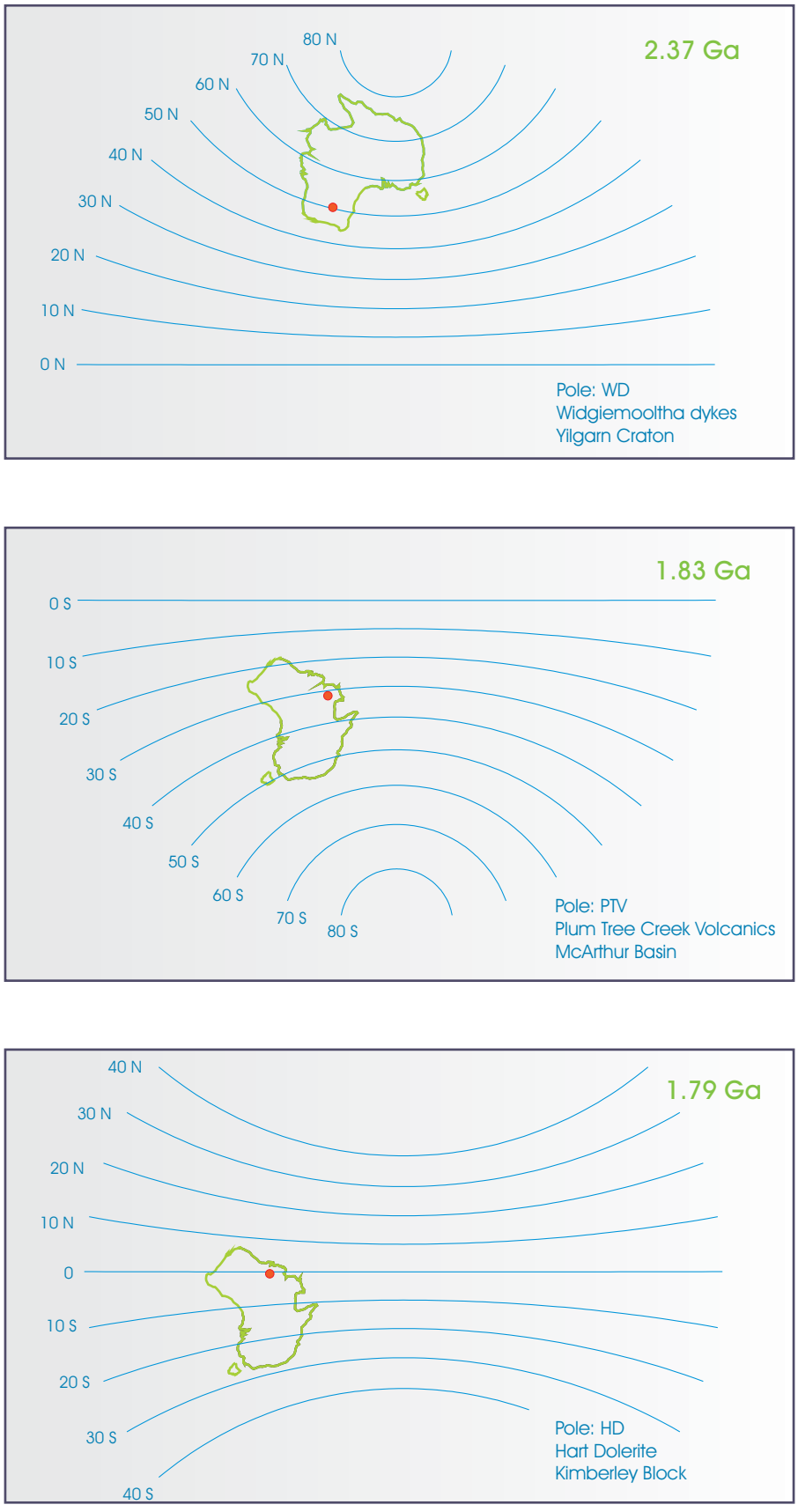
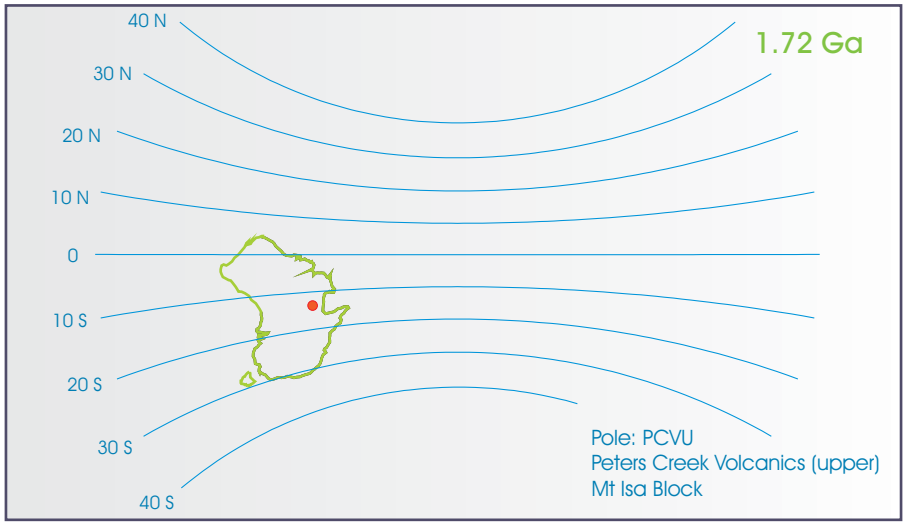
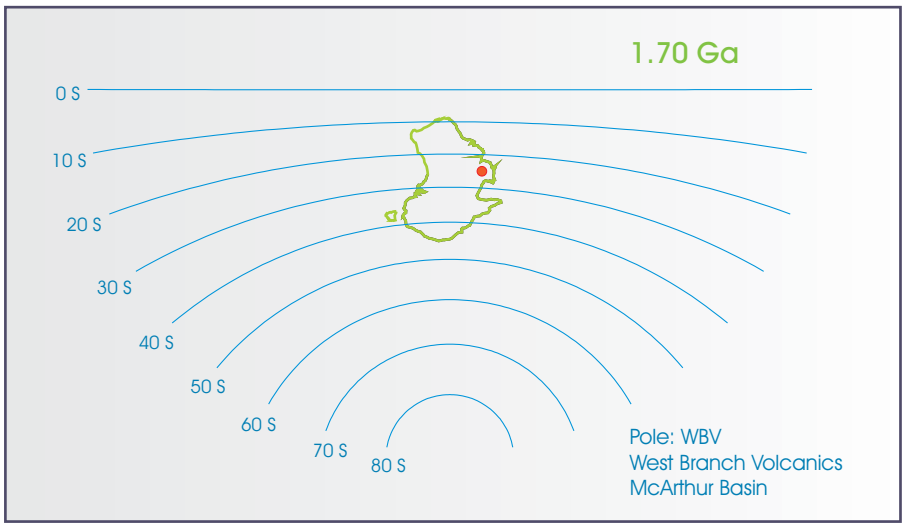

2.37 Ga
80 N
70 N
60 N
50 N
40 N
30 N
20 N
10 N
0 N
Pole: WD
Widgiemooltha dykes
Yilgarn Craton
1.83 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: PTV
Plum Tree Creek Volcanics
McArthur Basin
1.79 Ga
40 N
30 N
20 N
10 N
0
10 S
20 S
30 S
40 S
Pole: HD
Hart Dolerite
Kimberley Block

Fig. 3b


1.72 Ga
40 N
30 N
20 N
10 N
0
10 S
20 S
30 S
40 S
Pole: PCVU
Peters Creek Volcanics (upper)
Mt Isa Block


1.70 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: WBV
West Branch Volcanics
McArthur Basin

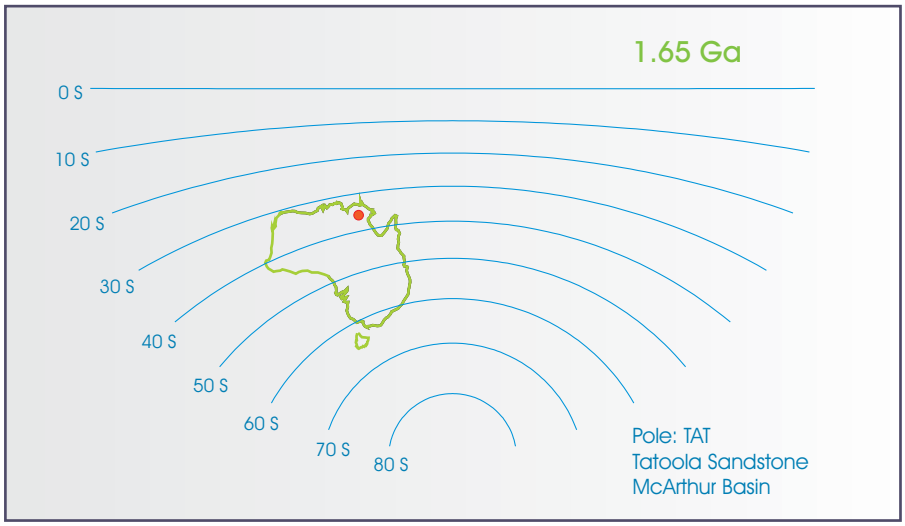
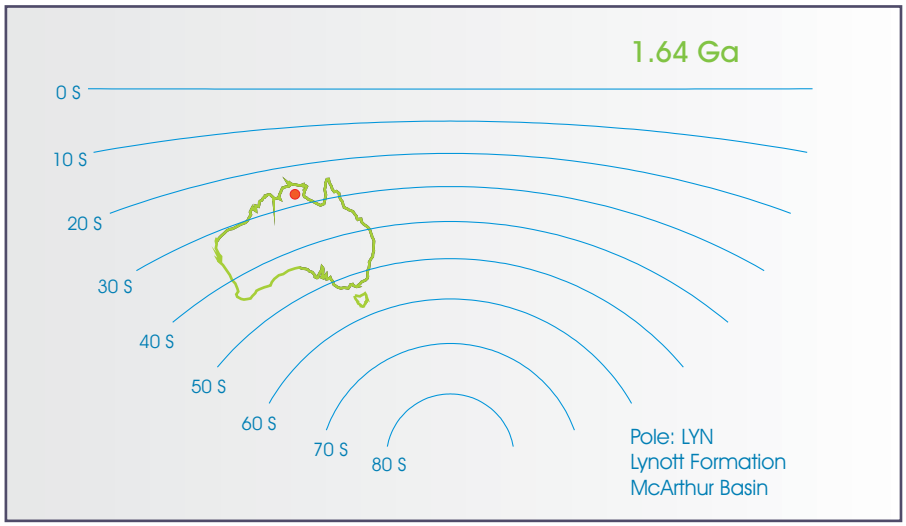
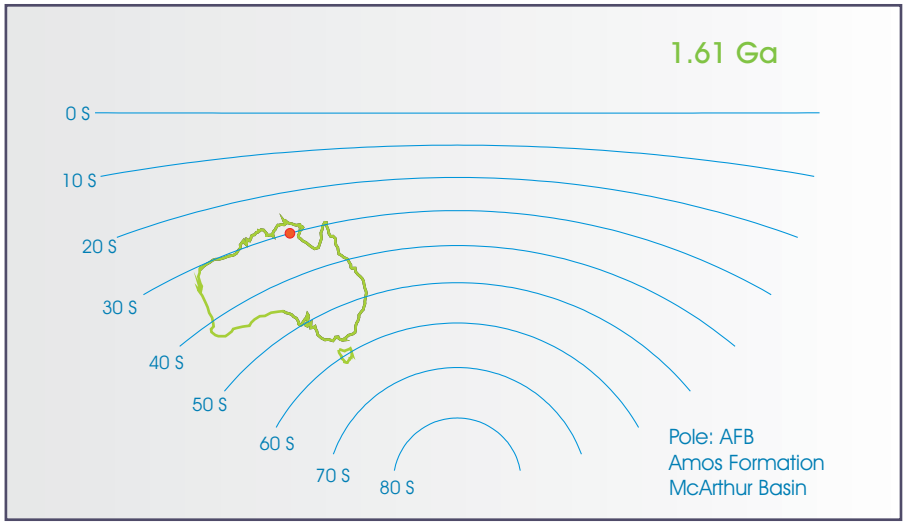

1.65 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: TAT
Tatoola Sandstone
McArthur Basin

Fig. 3c


1.64 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: LYN
Lynott Formation
McArthur Basin


1.61 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: AFB
Amos Formation
McArthur Basin

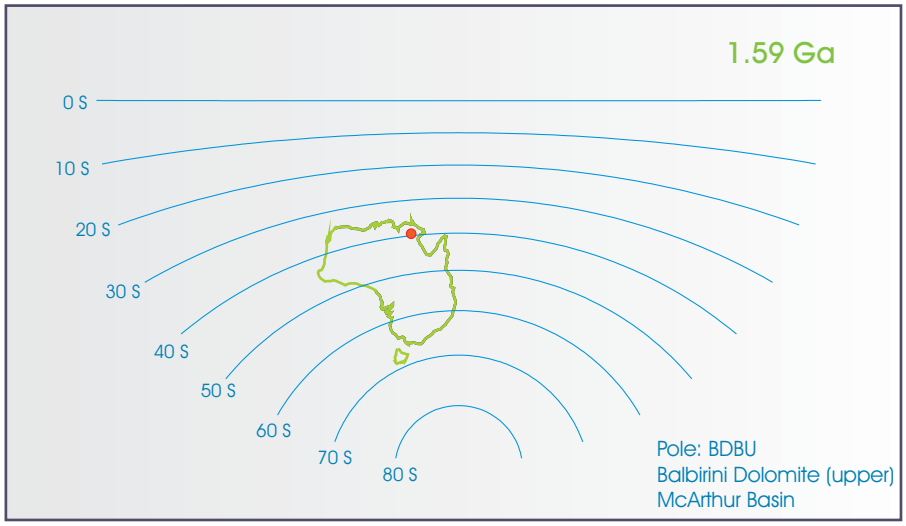
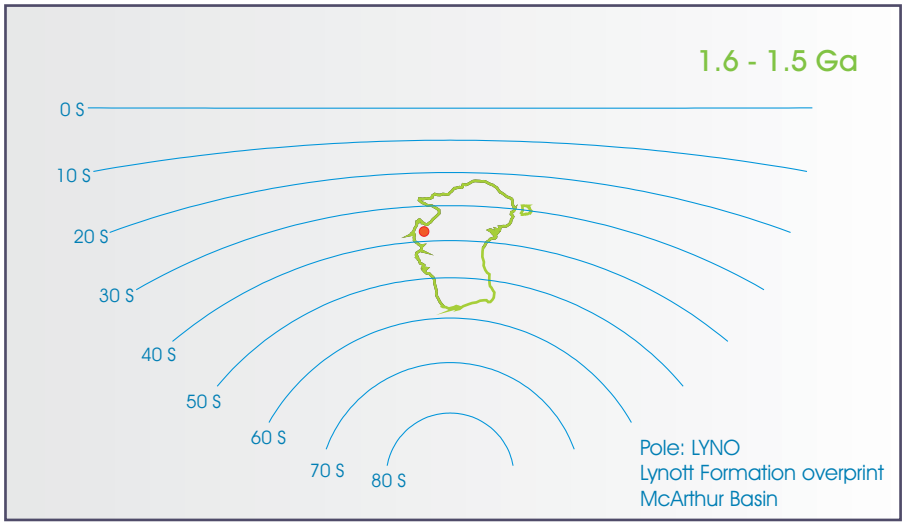
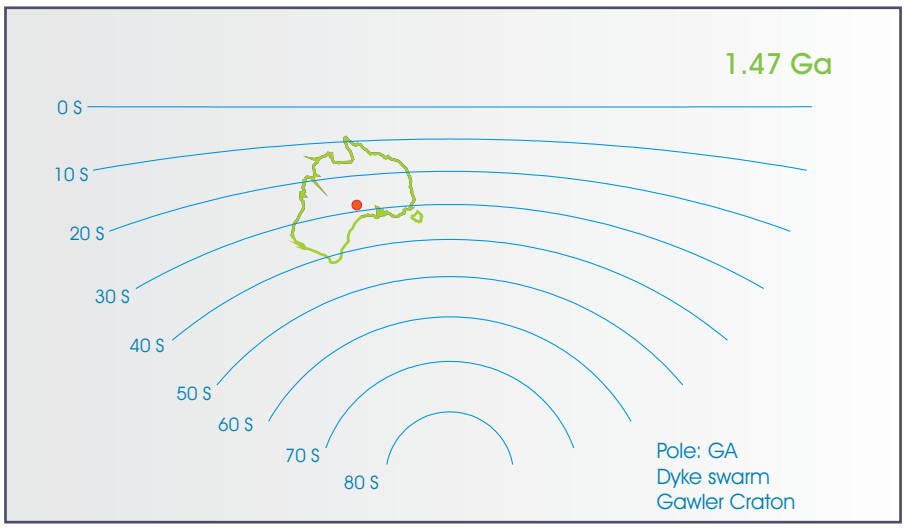

1.59 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: BDBU
Balbirini Dolomite (upper)
McArthur Basin

Fig. 3d


1.6 - 1.5 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: LYNO
Lynott Formation overprint
McArthur Basin


1.47 Ga
0 S
10 S
20 S
30 S
40 S
50 S
60 S
70 S
80 S
Pole: GA
Dyke swarm
Gawler Craton

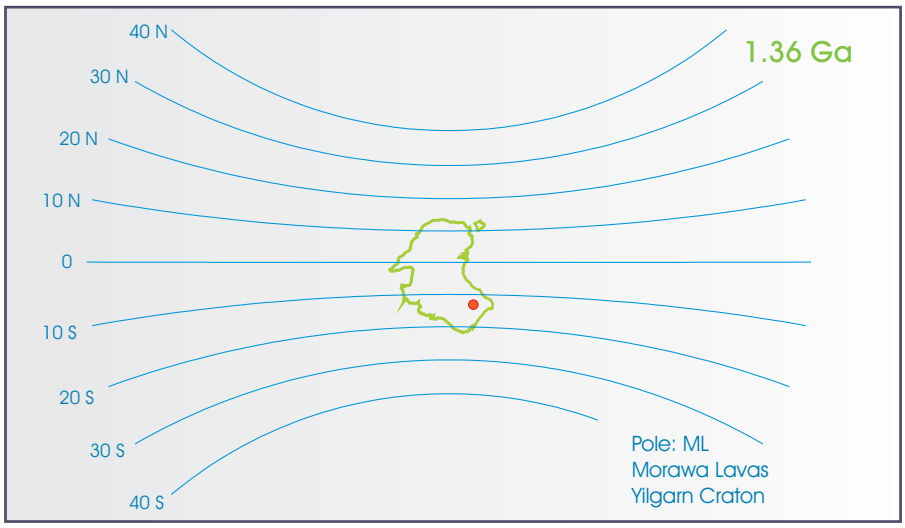
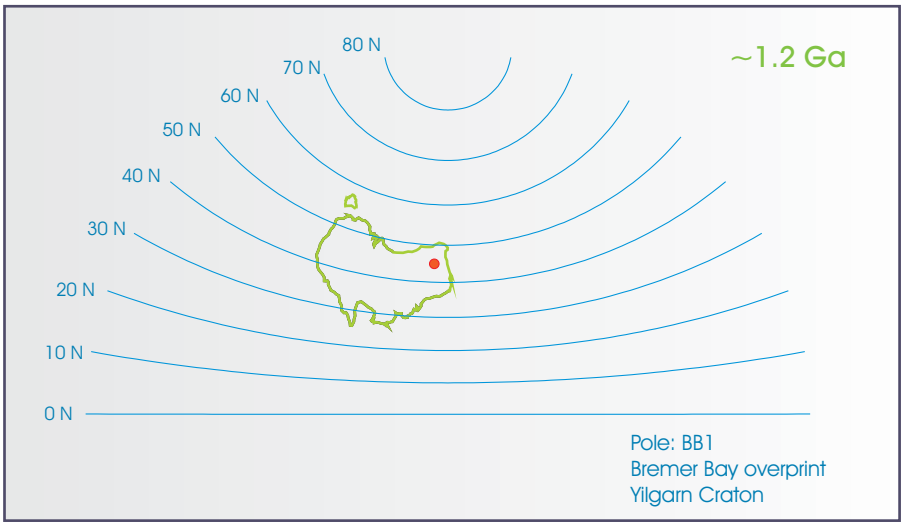
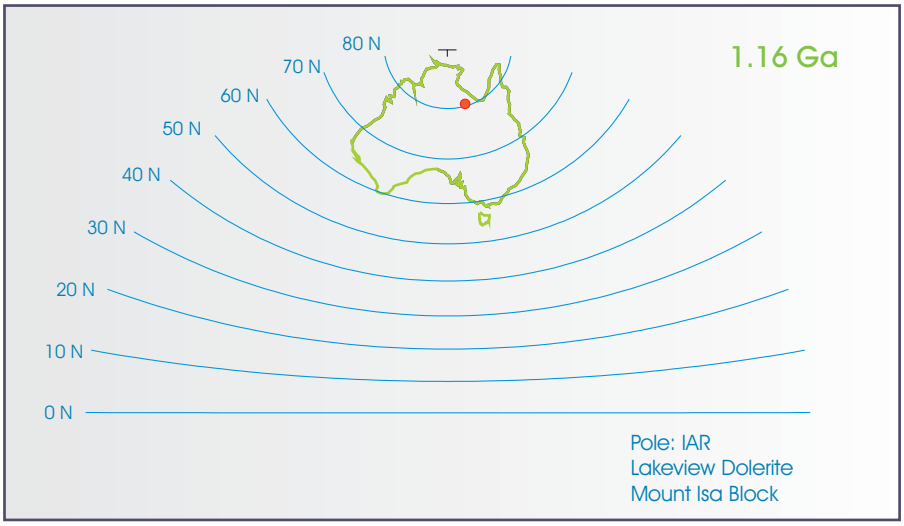

1.36 Ga
40 N
30 N
20 N
10 N
0
10 S
20 S
30 S
40 S
Pole: ML
Morawa Lavas
Yilgarn Craton

Fig. 3e


~1.2 Ga
80 N
70 N
60 N
50 N
40 N
30 N
20 N
10 N
0 N
Pole: BB1
Bremer Bay overprint
Yilgarn Craton


1.16 Ga
80 N
70 N
60 N
50 N
40 N
30 N
20 N
10 N
0 N
Pole: IAR
Lakeview Dolerite
Mount Isa Block

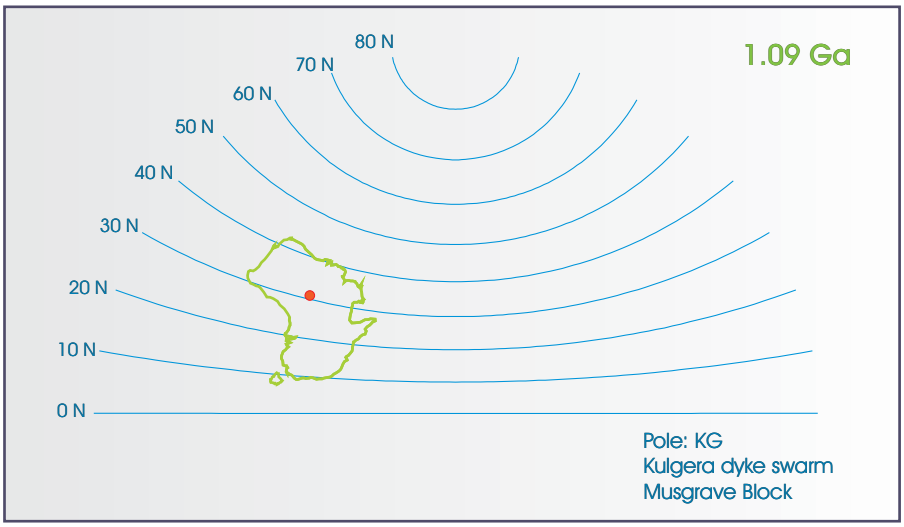

1.09 Ga
80 N
70 N
60 N
50 N
40 N
30 N
20 N
10 N
0 N
Pole: KG
Kulgera dyke swarm
Musgrave Block

Fig. 3f

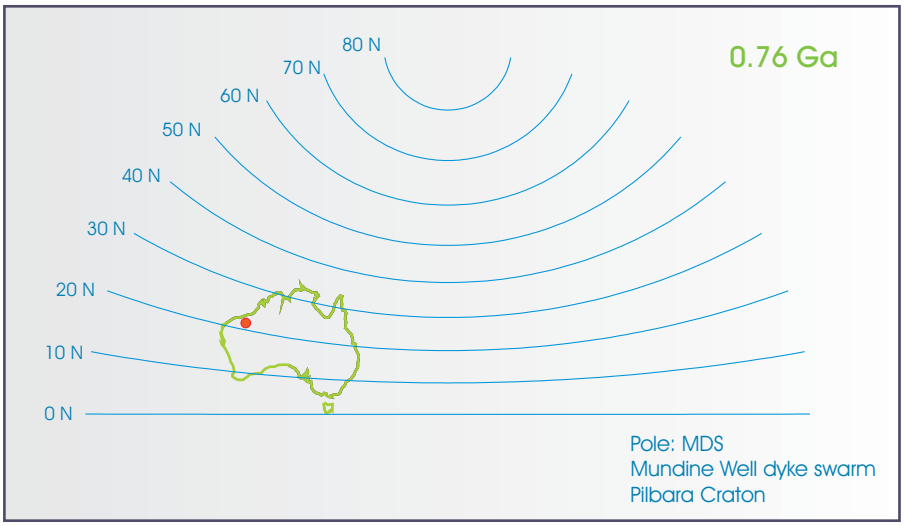

80 N
70 N
60 N
50 N
40 N
30 N
20 N
10 N
0 N
0.76 Ga
Pole: MDS
Mundine Well dyke swarm
Pilbara Craton

Fig. 3g