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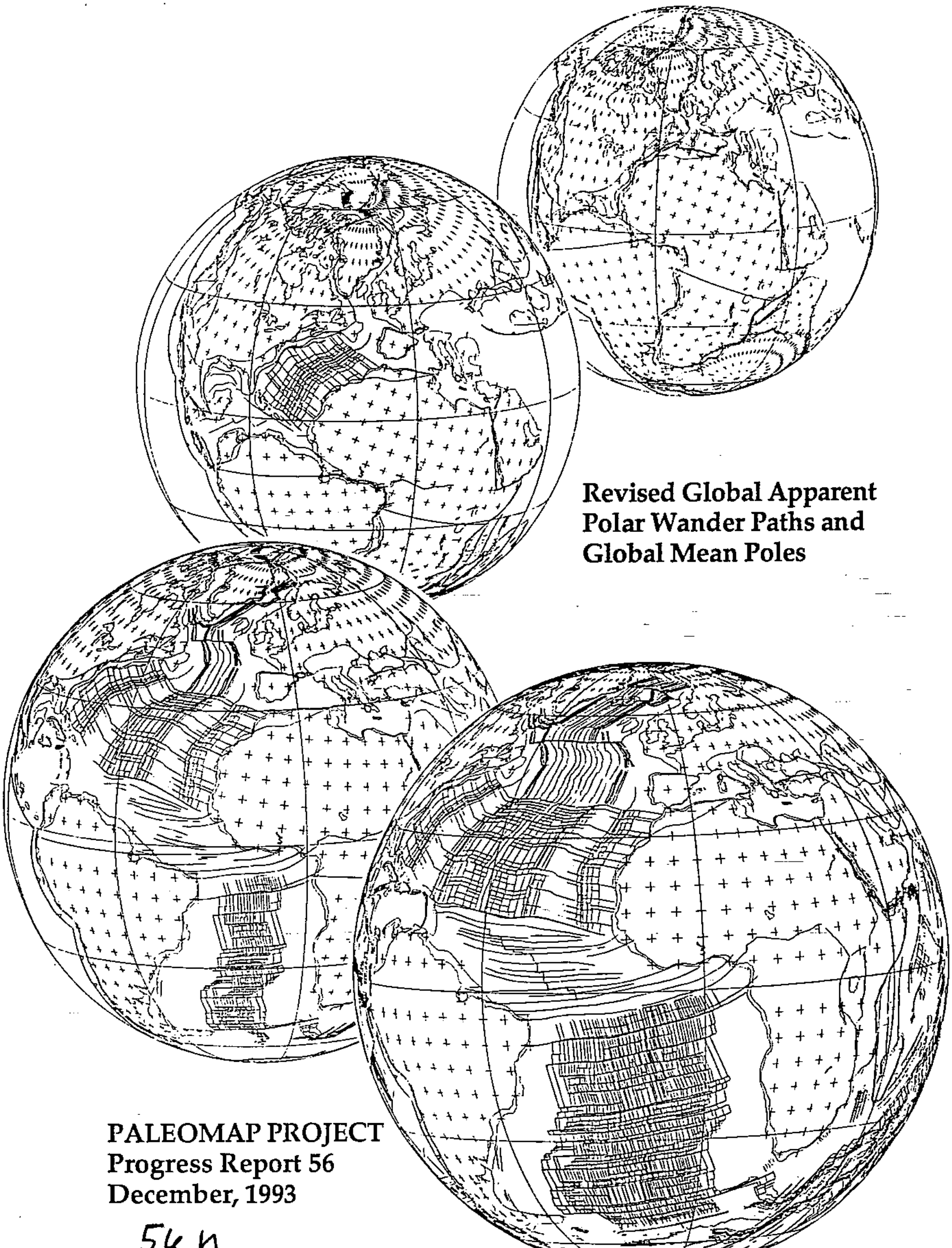

Revised Global Apparent Polar Wander Paths and Global Mean Poles

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Introduction

Apparent magnetic pole wander paths result from two main factors: lithospheric plate motions and the so-called "magnetic memory" of igneous and sedimentary rocks. The declination and inclination of remnant magnetization indicate directions and distance to the paleomagnetic pole. As soon as a lithospheric plate changes its position with respect to the absolute frame (with respect to the Earth's rotation axis), the paleomagnetic pole appears to be different from the geographic pole. Thus, paleomagnetic data provide the best basis for plate tectonic reconstructions, especially for the Early Mesozoic and Paleozoic. The problem is that the large uncertainties in paleomagnetic determinations can result in unreliable plate paleopositions. Moreover, paleomagnetic data indicate only azimuthal orientations and paleolatitudes of lithospheric blocks and do not provide any longitudinal control. In fact, it is possible to rotate a paleomagnetic pole back to the geographic one in different ways using an infinite number of poles of rotation. Any point on the great circle bisecting and perpendicular to the line connecting paleomagnetic and geographic poles can be used as the pole of finite rotation that will restore the paleomagnetic pole to the geographical pole. At the same time, the plate paleoposition with respect to the absolute frame depends on the choice of this finite rotation pole. The possible plate paleopositions might be quite different; only paleolatitudes would be the same, but paleolongitudinal positions are undetermined.

A method utilizing apparent polar wander paths instead of the separate mean paleomagnetic poles for the definite time slices seems to be very important for plate-tectonic analysis. Apparent polar wander paths reveal the tendency of plate paleomotions (Van der Voo, 1990a), and, when coupled with hot spot tracks, can constrain both the latitudinal and longitudinal plate paleopositions. This approach was applied to the Siberian continent "absolute" reconstructions of Zonenshain et al. (1985). Using independently obtained hot spot and paleomagnetic tracks of plate paleomotion at any time interval, it is possible to calculate reliable stage poles of plate rotation, with respect to the absolute frame and then to build a model of plate finite rotation for the earlier period by vector circuit, if finite rotations for the later time are known.

Data and methods

Apparent polar wander paths are most reliable if paleomagnetic data for the entire global plate ensemble are taken into account. Individual paleomagnetic poles might be rotated in any continental reference frame to obtain a global apparent polar wander path. Global apparent wander paths were obtained in the coordinates of the main continental blocks back to Silurian time (430 Ma), using paleomagnetic pole summaries of Van der Voo (1993) and Khramov (1992) and the global plate tectonic model of the PALEOMAP Project (Scotese and Becker, 1993). In the global plate tectonic model, major and minor blocks that have moved separately were taken into account. The model of plate rotations was constrained using a variety of geological data, data on linear magnetic anomalies, paleomagnetic data and a hot spot volcanic dataset (Muller, 1993). Using the global plate tectonic model, the most individual paleomagnetic poles can be reconstructed satisfactorily.

Reliable paleomagnetic determinations were selected from the combined dataset for calculating the global apparent wander paths. Van der Voo (1990b) proposed seven reliability criteria for paleomagnetic data analysis dealing with rock age and age of magnetization, statistics, laboratory demagnetization, field tests of the age of magnetization, structural control, presence of reversals, and the possibility of remagnetization. A quality factor (from 0 to 7) is assigned to a result based on the number of criteria satisfied. Only data with quality factor not less than 3 were selected for analysis of apparent polar wander paths. Individual poles are sometimes assigned by long time intervals up to 50-150 Ma. For each pole, the best fit age within the applied time interval was obtained using rotation in the absolute frame. After rotation with respect to the absolute reference frame, paleomagnetic poles are clustered about the geographic pole and rotations for the best fit ages should be characterized by minimum deviations. Paleomagnetic poles with the minimum deviation more than 30° (about 10% of the whole dataset) were excluded from the analysis.

Results

After data had been sorted, 1089 individual paleomagnetic poles were selected for global apparent polar wander paths calculation. The selected individual paleomagnetic poles were rotated in the reference frames of North America, South America, Europe, Siberia, India, North China, South China, Africa, Australia and Antarctica. Global mean paleomagnetic poles with respect to each continent's reference frame were calculated from the present back to the Early Silurian in a time interval of 10 million years (Table 1). The resulting global apparent polar wander paths with ellipses of confidence for mean poles and individual paleomagnetic data for each continent are shown in Figures 1-10. For North America, Europe, North China, South China, results are presented as North poles; for South America, India, Africa, Australia and Antarctica, results are presented as South poles. Small deviations (< 10°) of the global mean poles from the geographic pole in the absolute reference frame (Table 1) confirm the reliability of obtained results. Calculated global apparent polar wander paths are most reliable for the Mesozoic and Late Paleozoic (alpha95 = 3-5°) and the best results are from the Early Permian. Global mean poles for the Early Carboniferous and Devonian grouped poorly (alpha95 = 6-9°) and must be recalculated in future using new data or special data selection. The sharp turns in the global apparent polar wander paths for North America, South America, Europe, Africa, Australia and Antarctica correlate with major tectonic events. These curves have sharp changes at the Early Permian (280 Ma) that coincide with the collision of Laurussia and Gondwanaland, and in the Early Jurassic (200 Ma) coinciding with the initial break up of Pangea. Indian, Australian and Antarctic global apparent polar wander paths also demonstrate changes during Early Cretaceous time (130 Ma), when India separated from Antarctica and Australia. Antarctic and Australian curves have one more change in the Late Cretaceous (90 Ma) that coincide with the time of their separation. The global apparent polar wander path for North China is characterized by changes in the Late Triassic (220 Ma) and Late Jurassic (150 Ma), marking the stages of collision the of North China with the Amurian plate and Eurasia.

In order to control obtained results, individual paleomagnetic poles were rotated with respect to the absolute reference frame. Deviations of the "absolute" mean poles from the geographic pole for each time slice usually do not exceed 10°, the worst deviation of 16.5° was obtained for the Middle Devonian.

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FIGURE CAPTIONS

Figure 1. North American global apparent polar wander path and global individual pole dataset rotated with respect to North America.

Figure 2. North American global apparent polar wander path and paleomagnetic data for North America.

Figure 3. South American global apparent polar wander path and paleomagnetic data for South America.

Figure 4. European global apparent polar wander path and paleomagnetic data for Europe.

Figure 5. Indian global apparent polar wander path and paleomagnetic data for India.

Figure 6. North China global apparent polar wander path and paleomagnetic data for North China.

Figure 7. South China global apparent polar wander path and paleomagnetic data for South China.

Figure 8. African global apparent polar wander path and paleomagnetic data for Africa.

Figure 9. Australian global apparent polar wander path and paleomagnetic data for Australia.

Figure 10. Antarctic global apparent polar wander path and paleomagnetic data for Antarctica.

Figure 11. Global apparent polar wander path with respect to the absolute reference frame.

TABLE 1. GLOBAL MEAN PALEOMAGNETIC POLES

Time interval (Ma)	N. America lat,lon	S. America lat,lon	Europe lat,lon	India lat,lon	North China lat,lon	South China lat,lon	Africa lat,lon	Australia lat,lon	Antarctica lat,lon	Hot spots lat,lon	N
5-15 lT	84,-178	-85,-10	85,177	-85,82	85,-177	82,-171	-84,7	-85,82	-86,-3	85,180	43
15-25 lT	79,-177	-82,-12	80,180	-80,78	80,-174	73,-172	-80,12	-80,78	-81,2	80,-177	30
25-35 lT	80,179	-83,-26	82,174	-76,102	82,-178	71,-173	-80,18	-76,102	-83,-3	83,179	19
35-45 eT	80,-178	-84,-32	82,175	-70,109	82,-178	69,-171	-79,28	-70,109	-84,2	84,177	10
45-55 eT	77,174	-80,-36	79,168	-65,103	79,173	65,-175	-76,24	-69,107	-83,-6	83,156	33
55-65 eT	74,-174	-80,-21	78,179	-52,100	78,-175	63,-171	-73,34	-66,106	-82,11	83,173	84
65-75 lK	75,-157	-83, 3	80,-154	-35,104	79,-149	64,-159	-73,53	-62,117	-85,63	88,-140	59
75-85 lK	71,-146	-80,32	77,-133	-21,107	76,-130	61,-149	-66,65	-55,118	-81,94	84,-85	42
85-95 eK	75,-170	-83,-17	78,-163	-20,107	78,-158	63,-163	-67,57	-58,133	-88,-165	86,-109	39
95-105 eK	72,155	-77,-54	73,165	-20,101	73,169	60,178	-64,44	-63,144	-81,-82	85,159	31
105-115 eK	73,165	-82,-45	75,179	-12,104	75,-176	60,-173	-60,61	-57,143	-83,-121	85,-175	16
115-125 eK	75,176	-87,14	77,-166	-3,113	77,-159	62,-164	-55,77	-47,147	-77,-172	86,-117	31
125-135 eK	74,165	-86,-10	75,-173	3,115	80,-147	65,-158	-52,76	-44,146	-75,180	84,-145	18
135-145 eK	74,170	-88,31	75,-163	8,121	80,-125	65,-149	-50,81	-39,148	-69,177	83,-123	39
145-155 lJ	76,139	-85,-112	76,168	-1,124	85,-159	70,-162	-56,77	-44,161	-68,-154	85,178	16
155-165 lJ	78,139	-85,-170	79,172	0,130	86,-108	72,-151	-56,86	-40,168	-61,-152	88,-141	29
165-175 mJ	72,122	-85,-126	73,160	-4,128	86,-167	71,-163	-56,79	-44,171	-62,-142	85,-172	27
175-185 mJ	69,112	-83,-108	69,151	-5,128	85,161	71,-171	-57,74	-46,172	-63,-138	83,-179	22
185-195 eJ	68,95	-78,-20	69,134	-10,130	84,94	76,176	-62,71	-47,-179	-59,-130	85,152	24
195-205 eJ	65,84	-73,-118	65,123	-15,131	77,69	82,143	-66.64	-48,-172	-56,-123	85,140	29

TABLE 1. GLOBAL MEAN PALEOMAGNETIC POLES (continuation 1)

Time interval (Ma)	N. America lat,lon	S. America lat,lon	Europe lat,lon	India lat,lon	North China lat,lon	South China lat,lon	Africa lat,lon	Australia lat,lon	Antarctica lat,lon	Hot spots lat,lon	N
205-215 lTR	62,83	-71,-110	62,122	-17,129	72,58	83,85	-66,57	-51,-171	-56,-119	85,131	31
215-225 lTR	60,86	-72,-103	61,126	-16,127	68,47	85,35	-63,56	-52,-175	-59,-118	86,100	24
225-235 mTR	57,96	-72,-80	57,136	-13,120	68,39	83,-107	-57,52	-56,176	-66,-115	86,84	55
235-245 eTR	48,106	-65,-56	48,145	-10,109	71,32	69,-132	-47,44	-64,160	-74,-95	87,122	92
245-255 lP	51,117	-69,-35	51,157	-2,110	60,15	58,-117	--42,54	-57,149	-80,-124	89,131	55
255-265 lP	52,120	-70,-27	53,160	2,111	50,18	52,-114	-40,57	-54,147	-81,-144	87,80	38
265-275 eP	52,133	-68,-3	53,173	10,110	38,15	42,-110	-33,64	-47,139	-79,165	87,-42	21
275-285 eP	49,133	-65,-5	50,173	11,107	36,17	37,-116	-31,62	-48,134	-81,149	87,-45	28
285-295 lC	44,126	-60,-17	44,166	6,101	47,14	33,-129	-30,53	-54,128	-87,99	89,91	46
295-305 lC	39,127	-55,-16	40,167	8,97	54,7	26,-137	-26,51	-55,120	-84,60	89,165	23
305-315 lC	37,128	-53,-16	37,168	8,94	56,3	15,-145	-24,49	-55,116	-81,49	89,-173	25
315-325 mC	33,126	-50,-26	33,165	2,90	51,1	-7,-154	-25,42	-61,111	-78,14	87,139	29
325-335 eC	32,121	-50,-37	33,160	-6,91	20,32	-24,-163	-29,35	-69,114	-76,-17	84,80	14
335-345 eC	29,122	47,-40	30,162	-8,88	-29,61	-44,-173	-29,31	-71,108	-72,-18	85,71	9
345-355 eC	28,112	-45,-55	29,152	-19,90	-49,108	-56,163	-35,21	-82,119	-65,-39	80,53	10
355-365 lD	22,112	-38,-56	22,152	-21,83	-48,147	-69,113	-31,15	-84,69	-59,-32	84,42	22
365-375 lD	18,111	-34,-54	18,150	-21,79	-45,153	-68,84	-27,13	-80,46	-56,-26	84,40	19
375-385 mD	27,114	-42,-42	28,153	-10,84	-58,156	-81,80	-26,27	-73,93	-28,-15	74,-13	10
385-395 eD	10,111	-24,-44	11,151	-15,66	-45,134	-64,52	-13,13	-67,40	-50,-5	87,25	13
395-405 eD	3,104	-17,-49	3,144	-21,59	-37,133	-56,57	-11,4	-64,21	-42,-9	82,89	21

TABLE 1. GLOBAL MEAN PALEOMAGNETIC POLES (continuation 2)

Time interval (Ma)	N. America lat,lon	S. America lat,lon	Europe lat,lon	India lat,lon	North China lat,lon	South China lat,lon	Africa lat,lon	Australia lat,lon	Antarctica lat,lon	Hot spots lat,lon	N
405-415 lS	3,110	-8,-47	4,150	-20,50	-32,124	-48,49	-3,1	-55,18	-34,-4	83,100	15
415-425 lS	17,121	-5,-38	17,161	-11,46	-34,114	-47,36	5,5	-48,28	-33,7	85,12	16
425-435 eS	11,130	14,-38	6,173	-12,27	-17,103	-28,33	20,-7	-31,17	-14,10	84,177	10

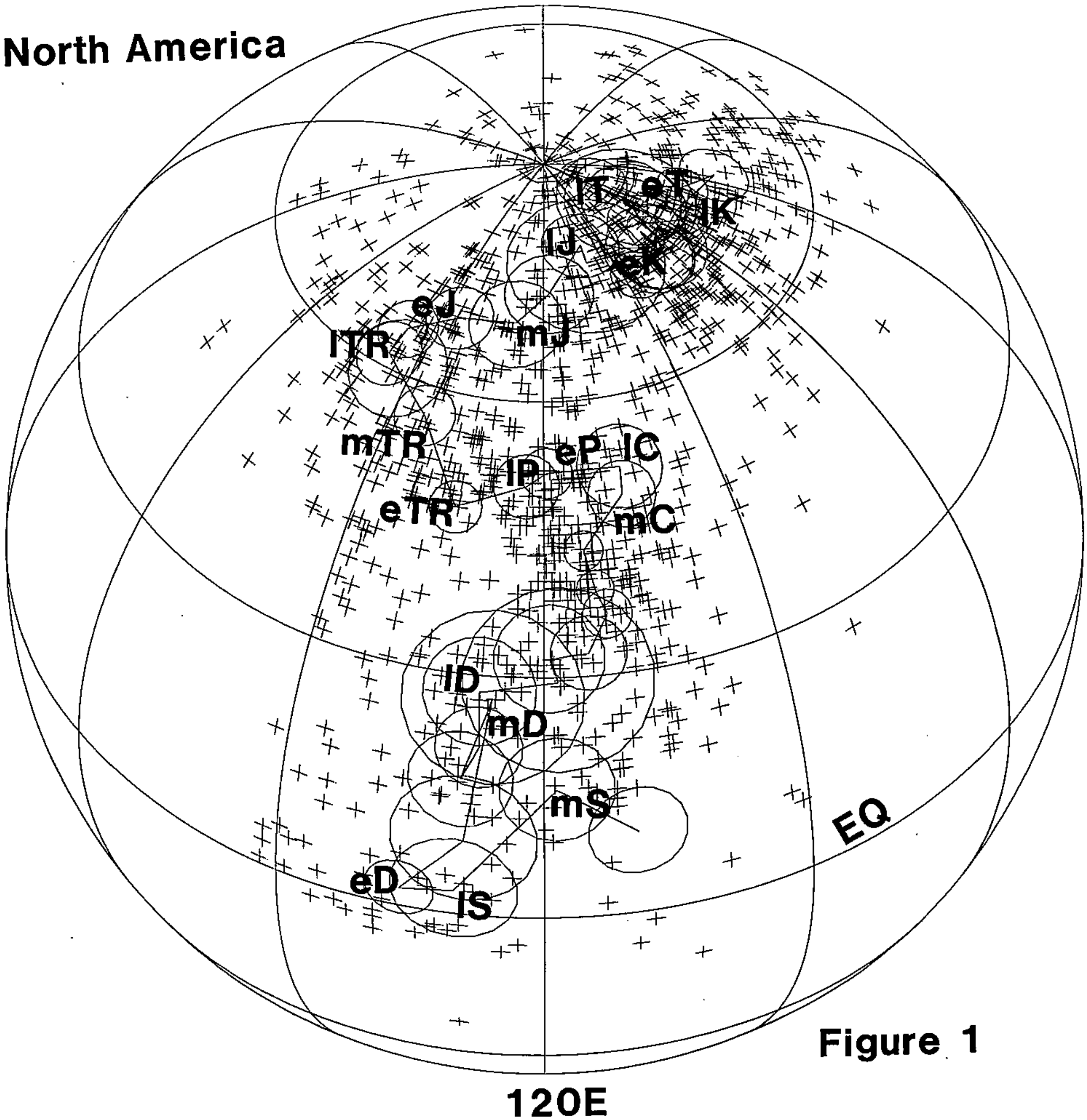
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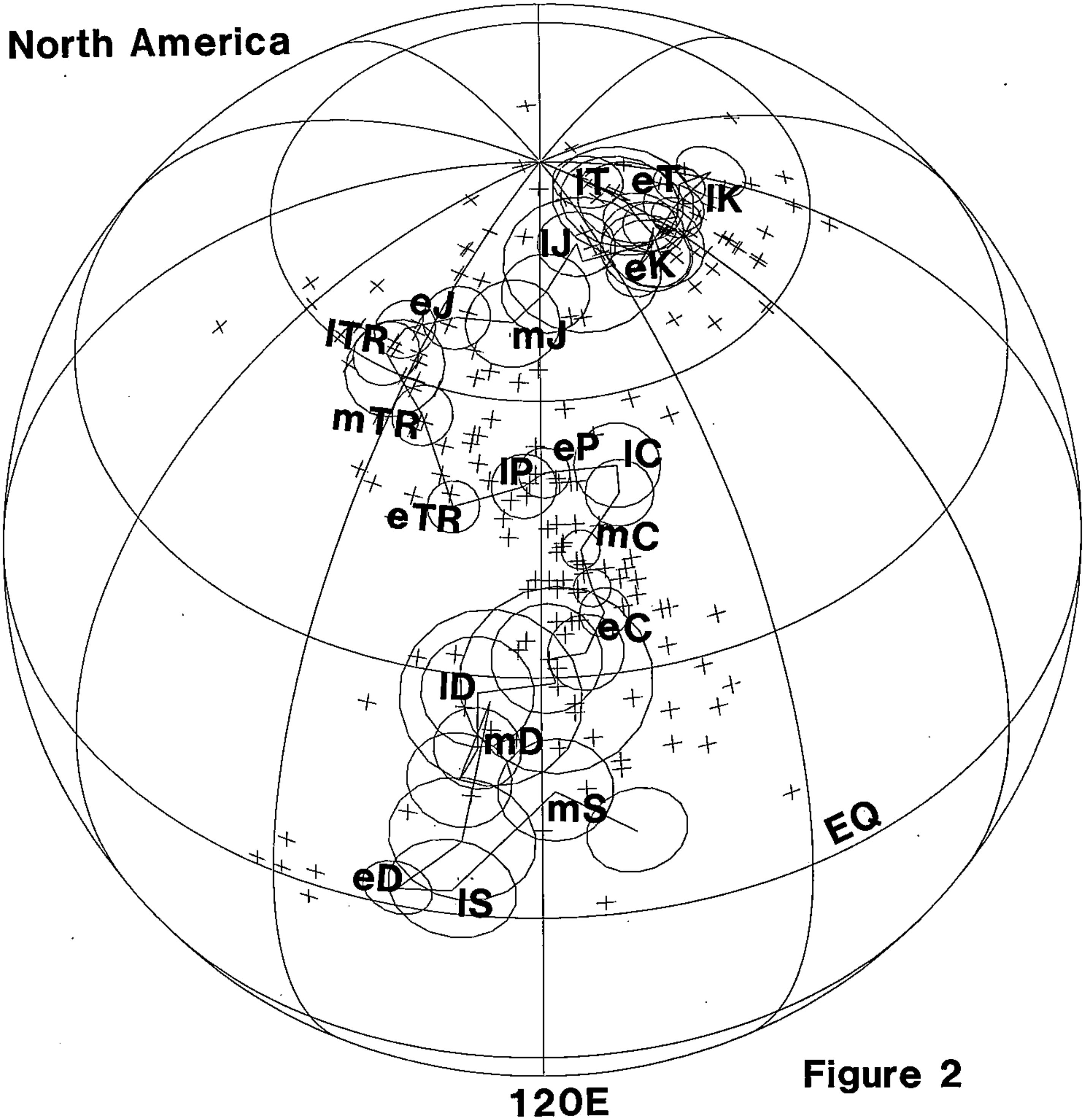
Figure 1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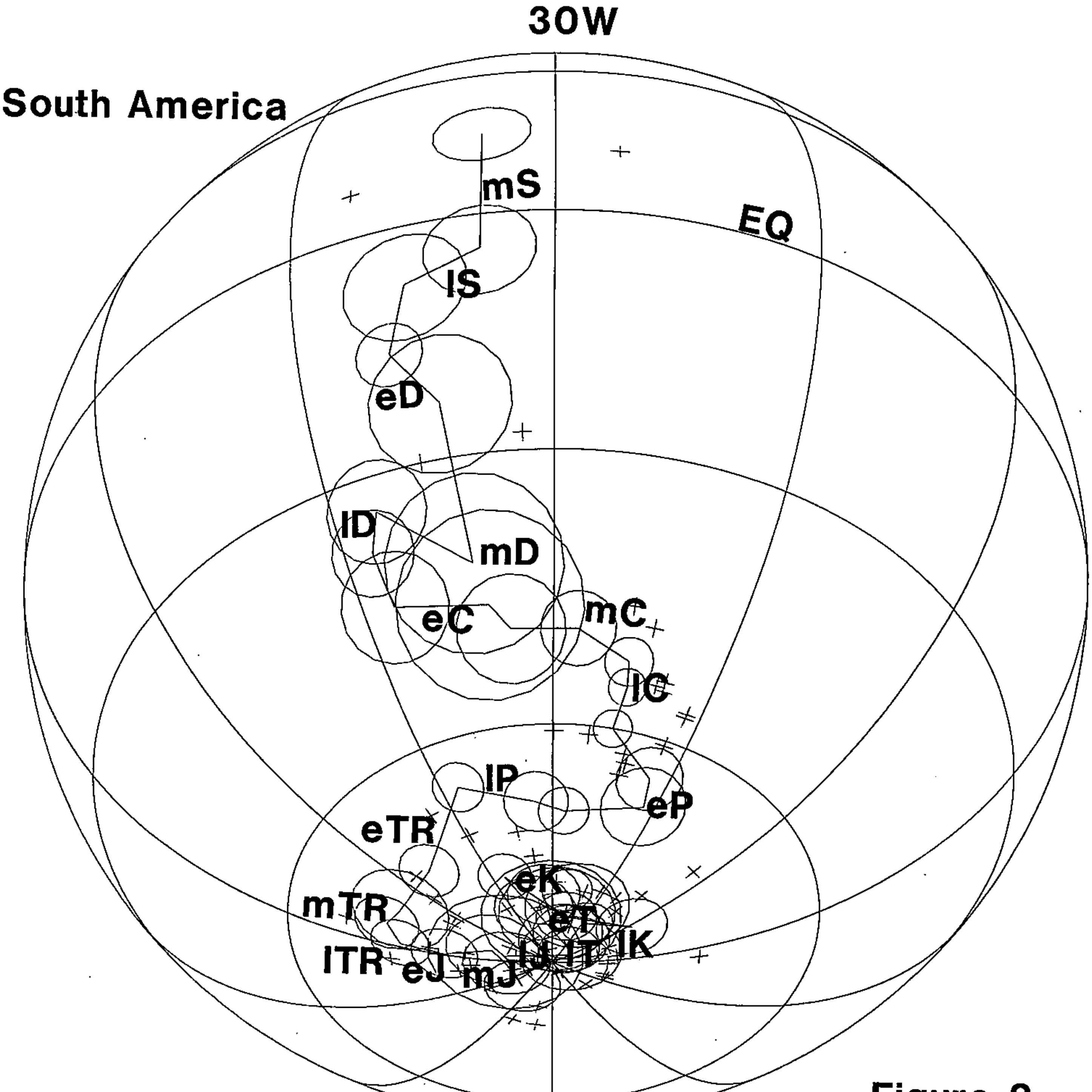
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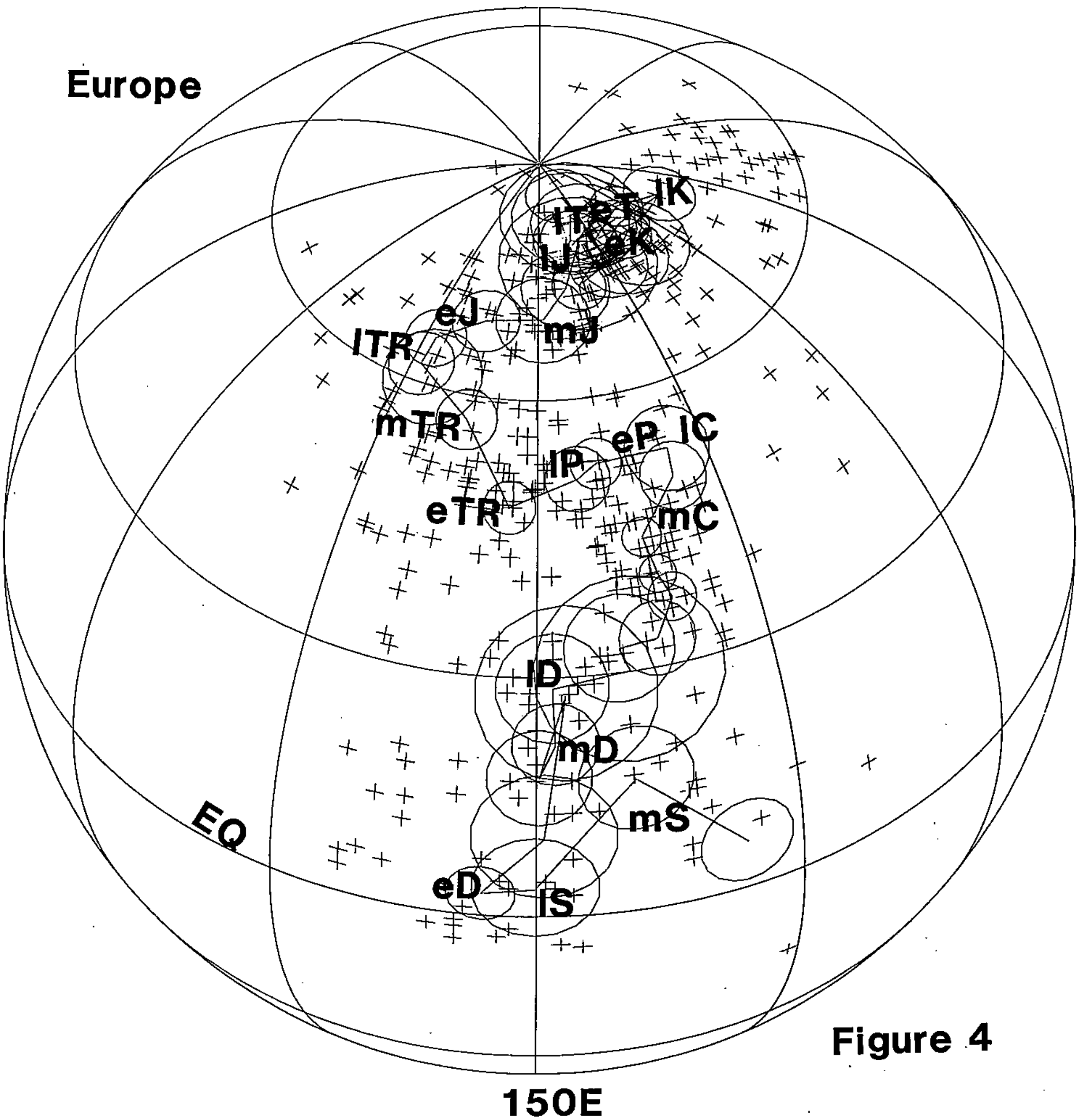

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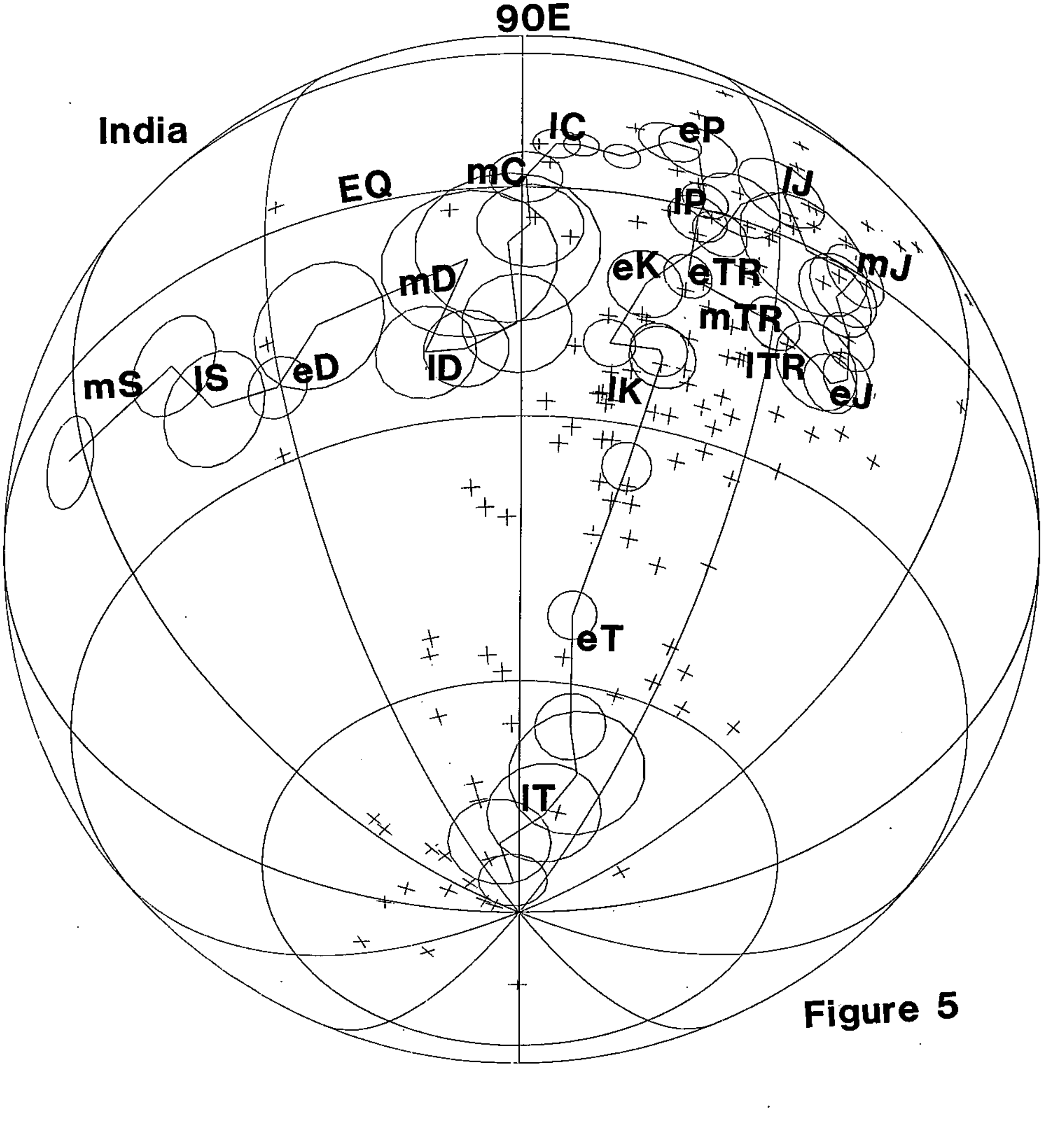

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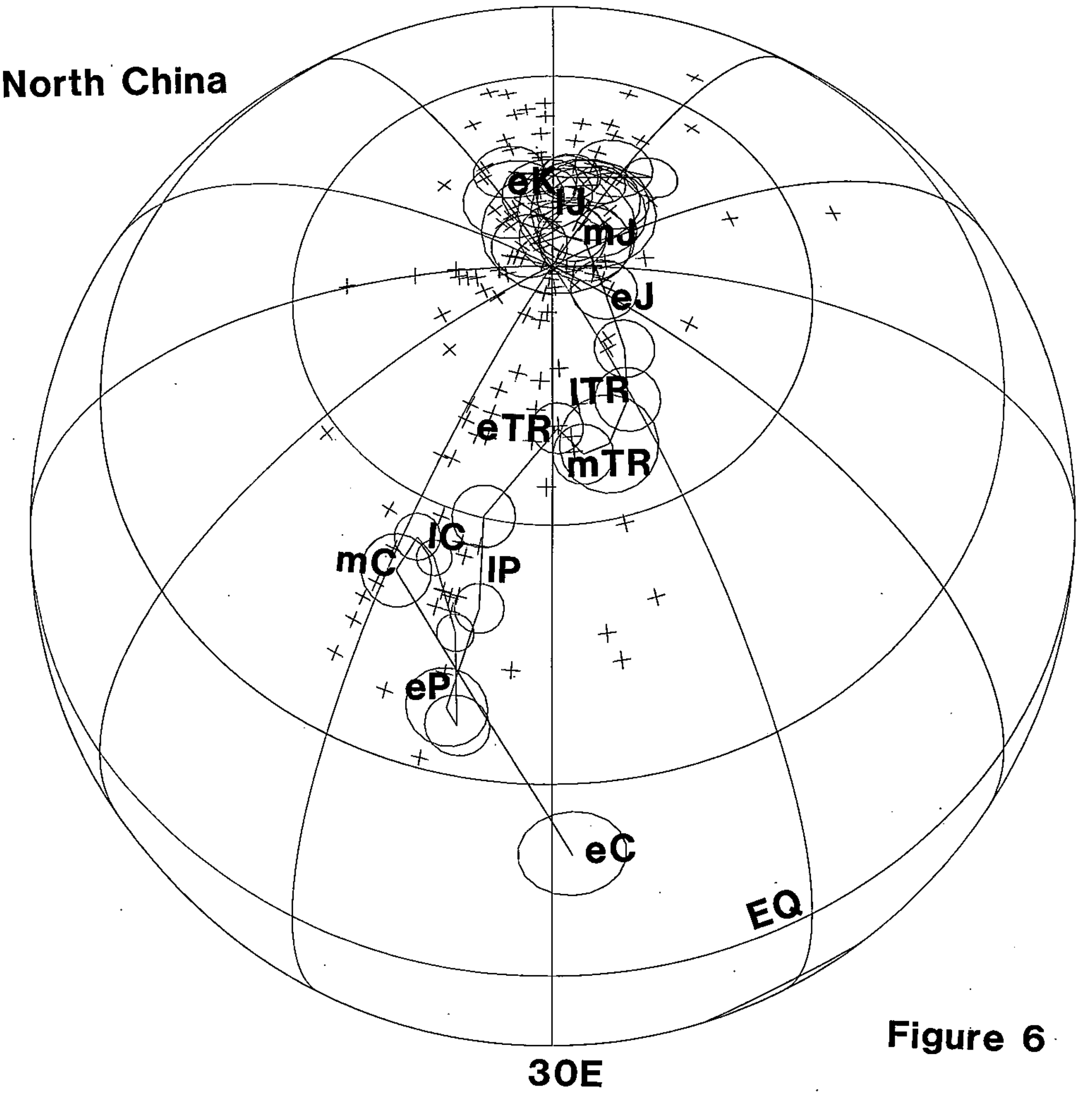
Figure 5



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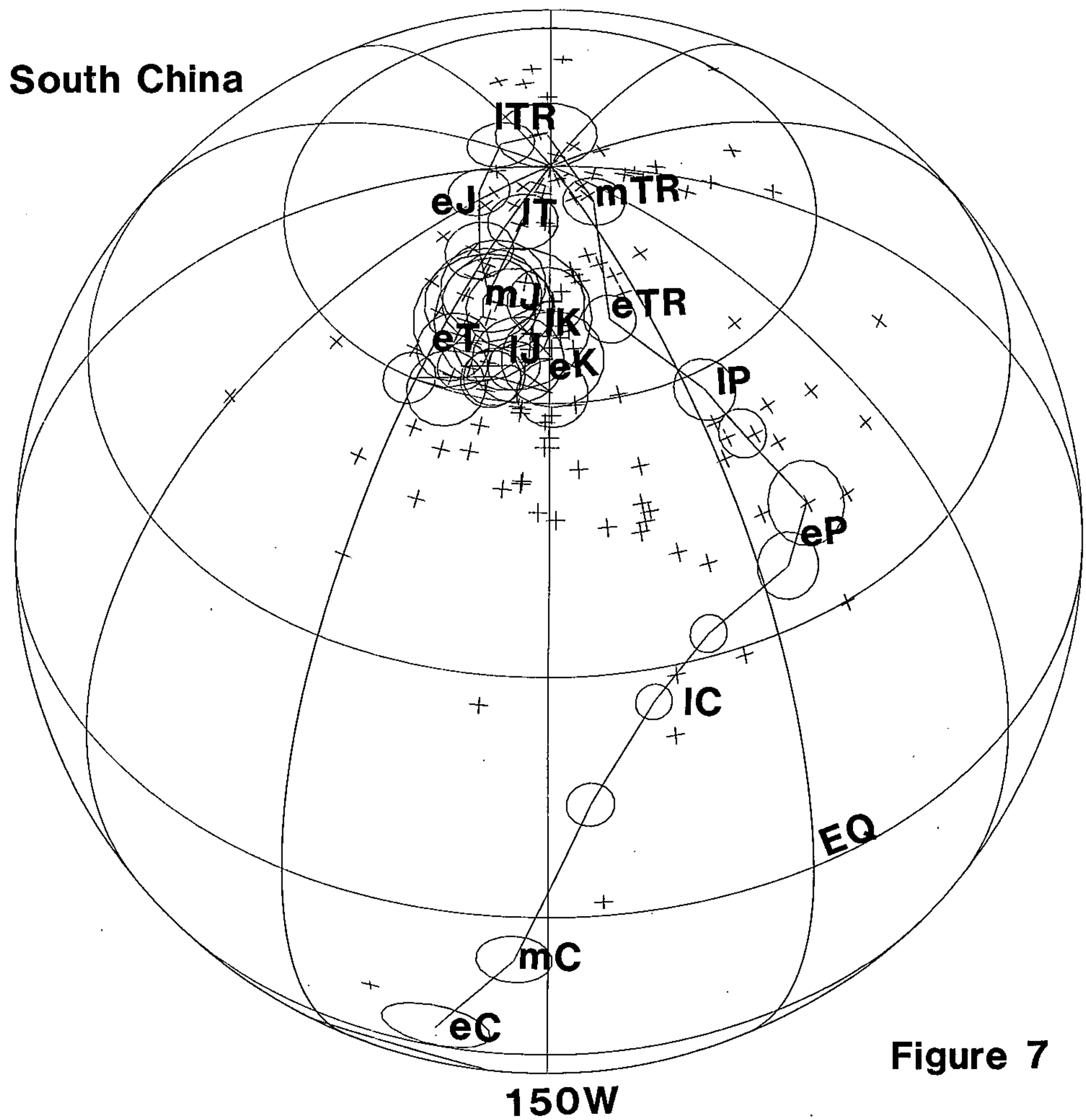

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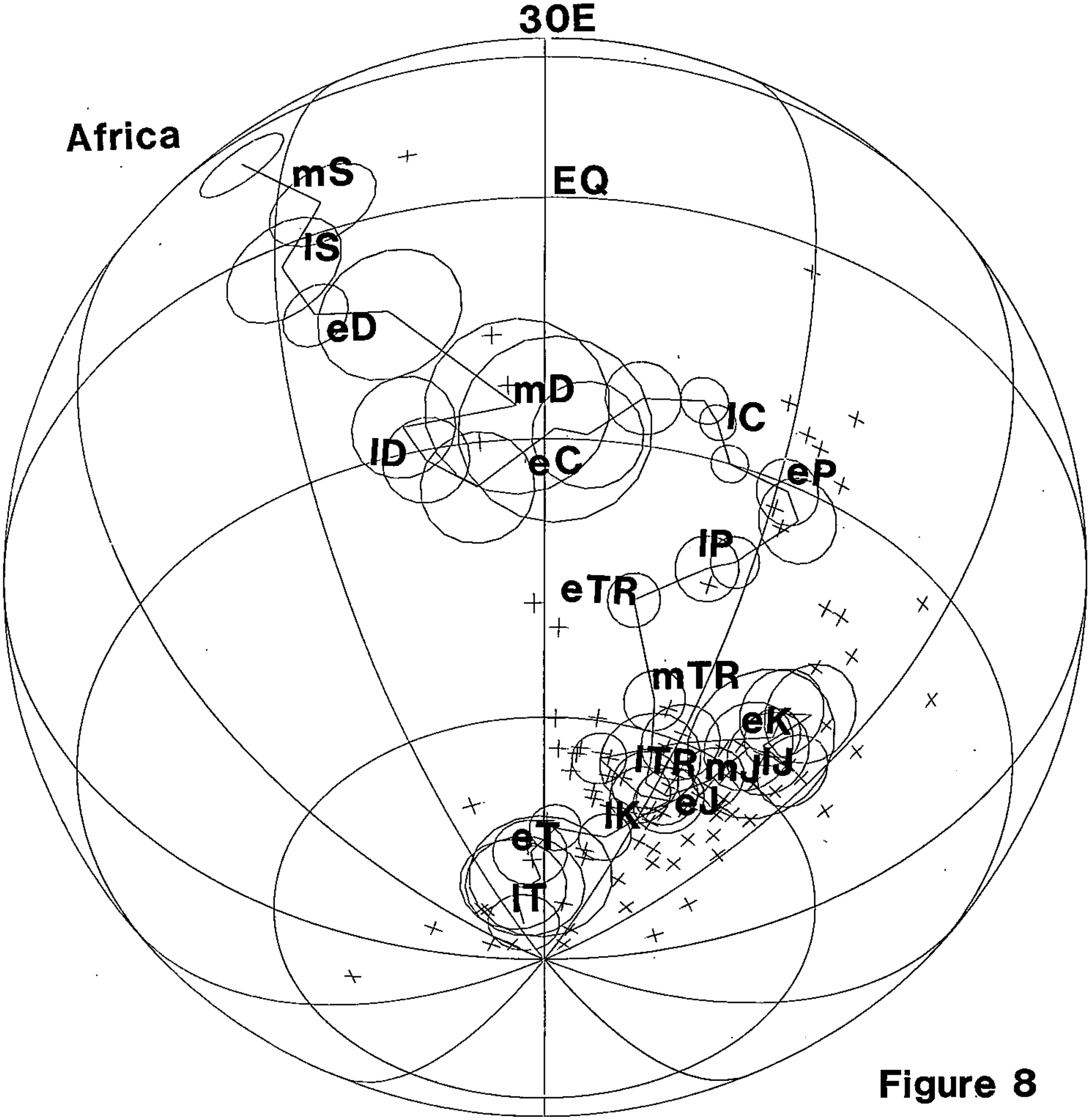
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Figure 8

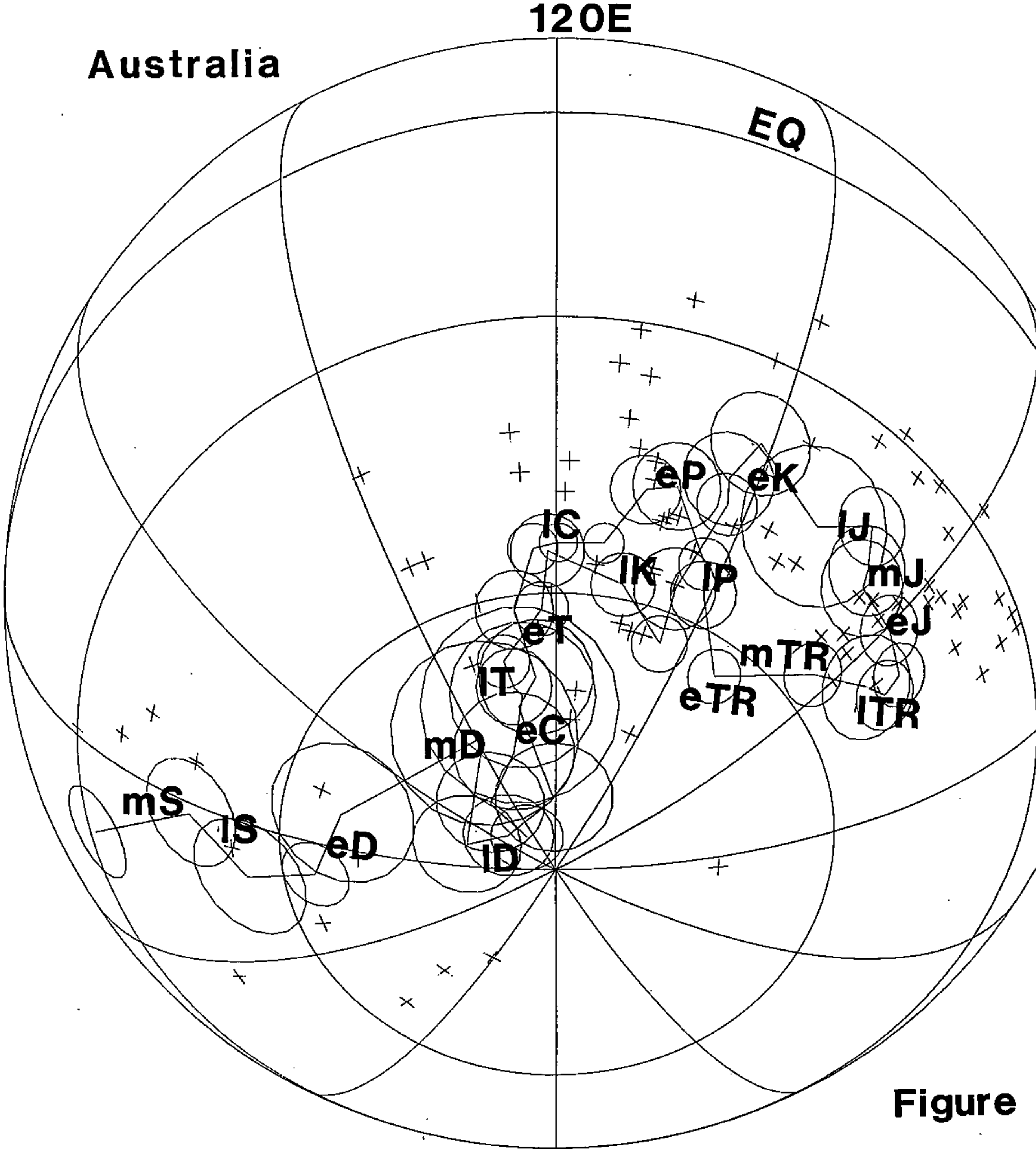
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Figure 9

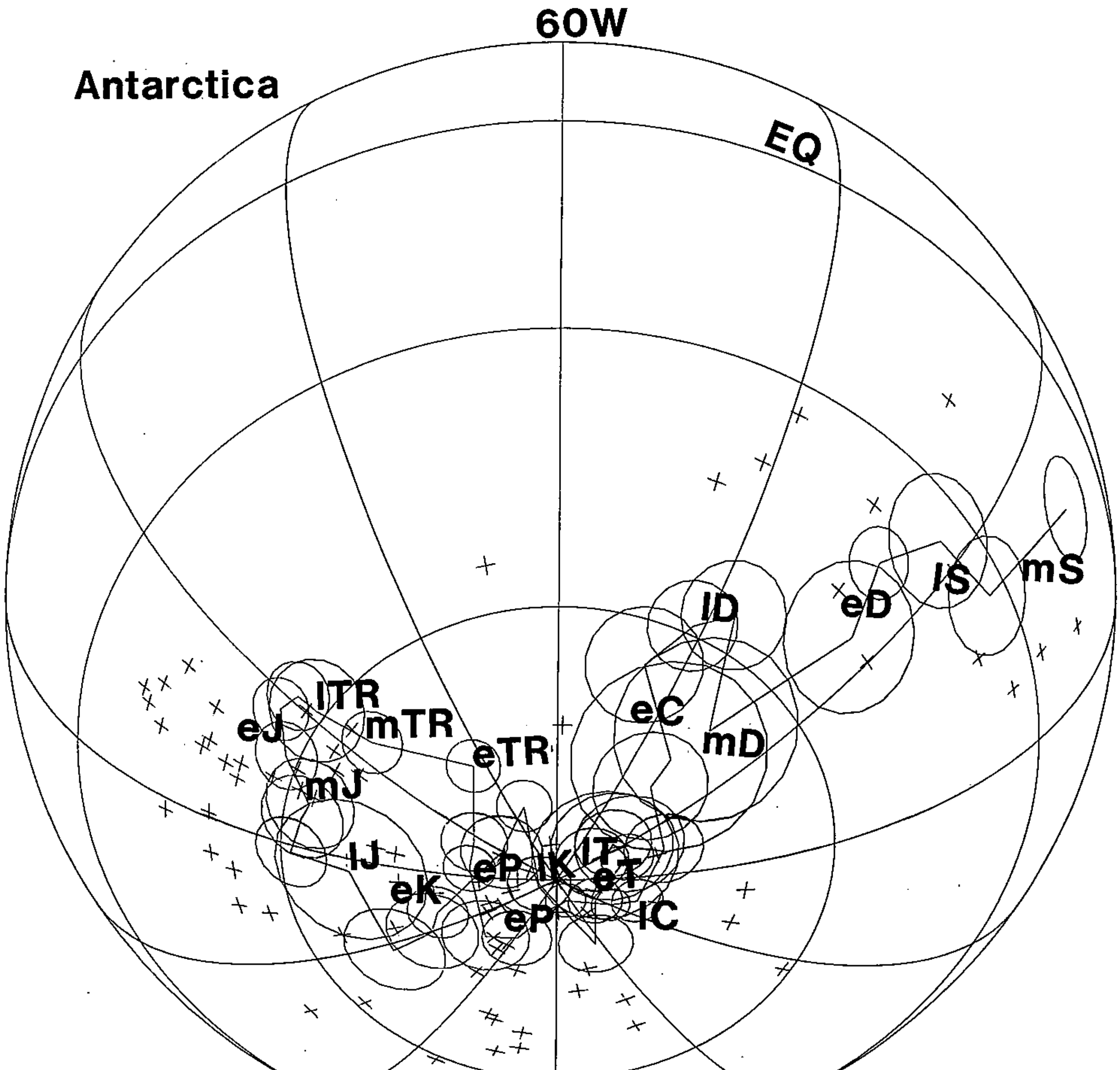
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Figure 10

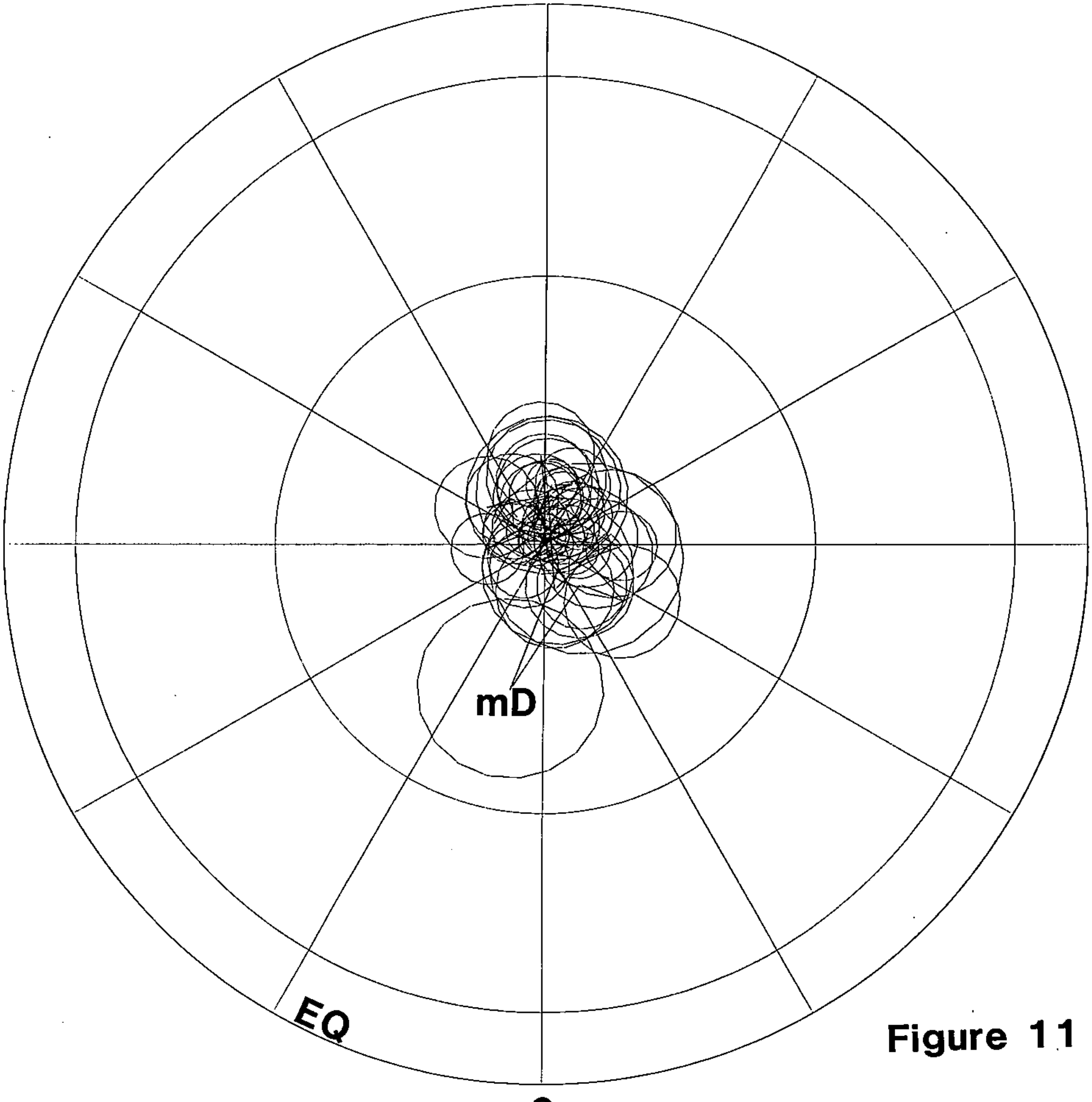

Figure 11