

RUBIDIUM-STRONTIUM BIOTITE DATES IN THE GASCOYNE PROVINCE, WESTERN AUSTRALIA

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ABSTRACT

New Rb-Sr whole-rock isochrons and two-point biotite and whole-rock isochrons suggest that the Gascoyne Province was generated at about 1.6 Ga, in part at least from a basement of Yilgarn rocks. Continuation of the 1.6 Ga event into the Yilgarn Block suggests that the two provinces have not been substantially displaced relative to one another since that date. Later activity, a thermal event or uplift at 0.8 Ga, is suggested by two-point biotite and whole-rock isochrons. This activity may have been greater, or later, near the west-central part of the province, where biotite dates are younger, than at the northern and southern margins of the province.

INTRODUCTION

The Gascoyne Province, a triangular area of gneiss, granitoid, and metasediment, lies north of the Archaean Yilgarn Block, between latitudes 23° and 26° South (Fig. 1). The transition from Yilgarn Block into Gascoyne Province is initially expressed by tectonic reworking, the appearance of over-printed fabrics, and further to the north, by the appearance of metamorphosed sediments and intrusive granitoids. It is distinguished from the Yilgarn Block by more intense deformation, younger radiometric ages, and predominantly east-west tectonic trends.

To the east, the Gascoyne Province is covered by weakly metamorphosed sedimentary rocks of the Bangemall Group (approximately 1.0 Ga. old), and to the west by Phanerozoic sediments of the Carnarvon Basin. Isotopically, transition with the Yilgarn Block is seen in relics of Yilgarn whole-rock Rb-Sr dates as far north as Dunawah Well, 110 km into the Gascoyne Province, and by Sm-Nd model ages of considerable antiquity that extend into the Gascoyne Province (Fletcher and others, 1983).

Three previous Rb-Sr studies have dealt with the geochronology of the area. De Laeter (1976) published whole-rock and mineral data on samples collected from the western part of the Gascoyne Province by J. Daniels during 1970-71. Williams, Elias, and de Laeter (1978) added dates from the eastern part of the province. Libby and de Laeter, (1979) after a study of the distribution of biotite dates near Perth, drew attention to the similarity between the westward decrease of biotite dates in the Gascoyne area, the Perth area, and the southwestern part of the state near Donnybrook.

The present study records new biotite and whole-rock dates from the northwestern corner of the Gascoyne Province (Wyloo sheet), further Rb-Sr (whole-rock and biotite) dates from the central part of the Gascoyne Block, and two biotite dates from an adjacent part of the Yilgarn Block. The biotite dates (about 1.6 Ga) from Yilgarn rocks adjacent to the Gascoyne Province are about the same as whole-rock dates within the Gascoyne Province. The event which reset whole-rock systems in the Gascoyne Province appears to have extended, at lower temperature, into adjacent parts of the Yilgarn Block.

Although biotite dates become progressively younger to the west, trend-surface studies incorporating new data from the northwestern corner of the block indicate that the gradient of this decrease is less than that shown by Libby and de Laeter (1979) and much less than the gradient in the Yilgarn Block near Perth.

Sample material was blasted from three exposures at Errabiddy, and from two to four samples from each shot point were used to construct a local isochron. These isochrons, which are apparently younger than associated Rb-Sr biotite dates, are tentatively attributed to low-temperature resetting consequent on saussuritization of plagioclase.

ANALYTICAL PROCEDURES

The methods of analysis used during this study are essentially the same as reported by de Laeter and others (1981). The value of $^{87}\text{Sr}/^{86}\text{Sr}$ for the NBS 987 standard measured during this project was 0.7102 ± 0.0001 , normalized to a $^{88}\text{Sr}/^{86}\text{Sr}$ value of 8.3752.

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Measured Rb and Sr values and Rb/Sr ratios, determined by x-ray fluorescence spectrometry, are listed with mass-spectrometric determinations of $^{87}\text{Sr}/^{86}\text{Sr}$ in Table 1. Errors accompanying these data are at the 95 per cent confidence level. We believe the values of Rb and Sr are accurate to ± 7 per cent; however, the measured Rb/Sr ratios may not correspond precisely with ratios which would be derived from the separate Sr and Rb values listed. A decay constant of $1.42 \times 10^{-11} \text{a}^{-1}$ has been used for ^{87}Rb (Steiger and Jäger, 1977). Regression of the whole-rock data has been carried out using the least-squares fit of McIntyre and others (1968)

RESULTS FROM ERRABIDDY, ROCKY BORE, AND ROADSIDE BORE

New analytical data on biotite from Errabiddy, Rocky Bore, and Roadside Bore are listed in Table 1 together with data from the whole-rock splits of the same samples which were analyzed and published earlier (Williams and others, 1978).

Dates generated from 2-point isochrons on mineral and whole-rock pairs are listed in Table 2. The data from Errabiddy are plotted on an isochron-type ($^{87}\text{Sr}/^{86}\text{Sr}$ vs $^{87}\text{Rb}/^{86}\text{Sr}$) diagram in Figure 2.

TABLE 1. ANALYTICAL DATA, ERRABIDDY, ROCKY BORE, ROADSIDE BORE, WINNING POOL

Sample	Rb	Sr	Rb/Sr	$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$
ERRABIDDY					
47046	185	125	1.51 ± 0.02	4.40 ± 0.50	0.83217 ± 0.00053
47047 w.r.	173	187	0.93 ± 0.01	2.71 ± 0.03	0.81427 ± 0.00034
47047 b.t.	799	9	87 ± 1.0	354 ± 4	4.9006 ± 0.0006
47048	110	140	0.79 ± 0.01	2.31 ± 0.02	0.80994 ± 0.00037
47049	61	140	0.44 ± 0.01	1.28 ± 0.02	0.80836 ± 0.00051
47050	75	110	0.68 ± 0.01	1.98 ± 0.02	0.81704 ± 0.00048
47051 w.r.	190	149	1.28 ± 0.01	3.76 ± 0.04	0.83864 ± 0.00048
47051 b.t.	653	8	82.0 ± 0.8	319 ± 3	4.2571 ± 0.0004
47052 w.r.	372	75	4.87 ± 0.05	14.4 ± 0.1	0.94290 ± 0.00058
47052 b.t.	612	13	48.0 ± 0.05	166 ± 2	2.7503 ± 0.0002
47053 w.r.	187	146	1.27 ± 0.01	3.75 ± 0.04	0.87251 ± 0.00051
47053 b.t.	849	35	24.4 ± 0.3	78 ± 1	1.7707 ± 0.0002
			$23.6 \pm$	$75 \pm$	$1.7450 \pm$
47054 w.r.	232	131	1.91 ± 0.02	5.61 ± 0.06	0.89331 ± 0.00050
47054 b.t.	955	8	123 ± 2	625 ± 6	8.4862 ± 0.0009
ROCKY BORE					
47040 w.r.	190	145	1.30 ± 0.01	3.81 ± 0.04	0.85230 ± 0.00038
47040 b.t.	979	23	42.2 ± 0.4	166 ± 2	4.4491 ± 0.0003
ROADSIDE BORE					
47075 w.r.	110	150	0.74 ± 0.01	2.15 ± 0.02	0.78208 ± 0.00039
47047 b.t.	840	24	35.1 ± 0.4	134 ± 1	3.9900 ± 0.0006
WINNING POOL					
60741 w.r.	128	502	0.256 ± 0.003	0.741 ± 0.007	0.73736 ± 0.00031
60741 b.t.	996	15	66.7 ± 0.7	245 ± 2	3.5129 ± 0.00084
60743 w.r. (a)	390	1 180	0.333 ± 0.003	0.96 ± 0.01	0.72851 ± 0.00041
60740 w.r.	230	447	0.514 ± 0.005	1.49 ± 0.01	0.74927 ± 0.00035
60740 b.t.	1 075	24	44.3 ± 0.4	149 ± 2	2.42187 ± 0.00093
60745 w.r. (a)	595	501	1.19 ± 0.01	3.46 ± 0.03	0.77512 ± 0.00029
60748 w.r.	532	418	1.27 ± 0.01	3.70 ± 0.04	0.80424 ± 0.00016
60744 w.r.	373	280	1.35 ± 0.01	3.91 ± 0.04	0.80557 ± 0.00025
60744 b.t.	1 507	18	84.4 ± 0.8	31 ± 3	4.3758 ± 0.00098
60749 w.r.	459	318	1.46 ± 0.01	4.26 ± 0.04	0.81237 ± 0.00041
60749 b.t.	1 281	25	51 ± 0.05	179 ± 2	2.8912 ± 0.00051
60742 w.r.	464	303	1.53 ± 0.02	4.46 ± 0.04	0.81372 ± 0.00028
60742 b.t.	1 525	24	63.1 ± 0.6	229 ± 2	3.3300 ± 0.00077
60746 w.r.	740	162	4.59 ± 0.05	13.67 ± 0.1	1.03038 ± 0.00025
60747 w.r.	710	100	7.13 ± 0.07	21.54 ± 0.2	1.18061 ± 0.00038

(a) Not included on isochron

The dates from Errabiddy biotite and whole-rock pairs are 814, 760, 835, 847, and 858 Ma, and are typical of biotite dates determined earlier from the Gascoyne Province (de Laeter, 1976). On the other hand, dates from Rocky Bore (1 545 Ma) and Roadside Bore (1 695 Ma), in the Yilgarn Block, adjacent to the Gascoyne province, are substantially older than Gascoyne dates but younger than biotite dates from more central parts of the Yilgarn Block (Libby and de Laeter, 1979).

Whole-rock analyses of samples from Errabiddy station plotted by Williams and others (1978) clearly failed to define a single isochron (Figure 3). When samples were sorted into sets, each set from a single shot point, data within each set plotted along a line (Fig. 2). The line defined by each set was sub-parallel to the line from each other set, and encouraged the authors to believe that these lines may represent isochrons. The dates generated by this means ranged from 725 Ma to 783 Ma and had initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios that averaged about 0.805. These dates were slightly younger than preliminary biotite and whole-rock two-point isochron dates from the same sample.

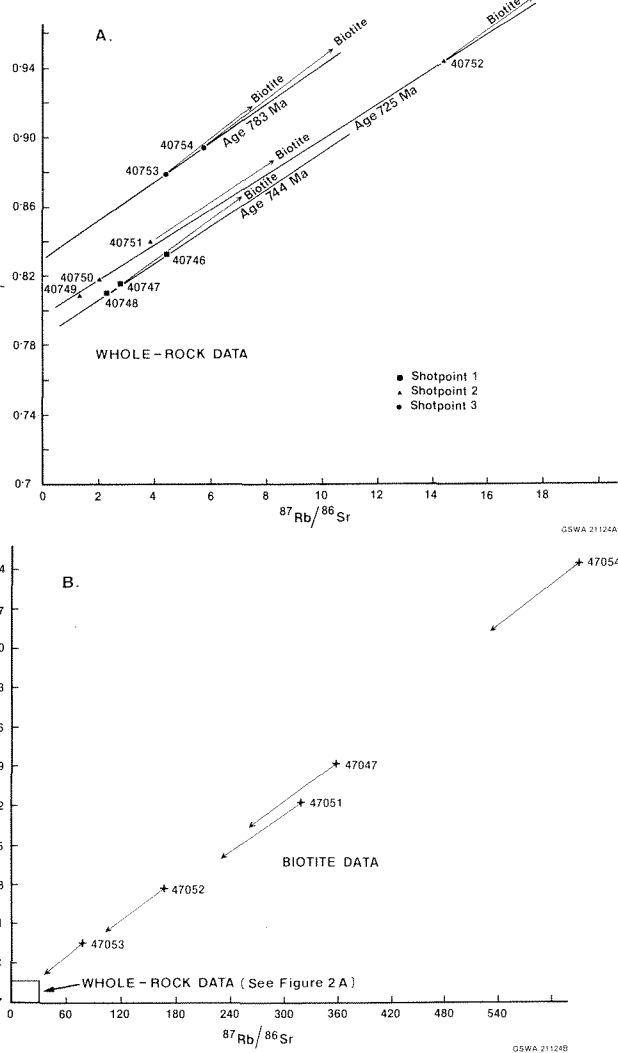


Figure 2. A—Isochrons, whole-rock data from Errabiddy B—Isochrons, biotite and whole-rock data from Errabiddy.

To check the apparent anomaly of mineral dates which are older than associated whole-rock dates, biotite from two samples (47052 and 47053) was re-analyzed, and biotite was separated from a further three of the original samples (samples 47047, 47051, and 47054). These five new analyses, together with analyses of associated whole rocks (Table 2), confirm that the apparent biotite and whole-rock dates are older than the associated whole-rock isochrons. The biotite date from sample 47047 is 814 Ma, whereas the whole-rock date from samples 47046, 47047, and 47048 (shot point 1) is 744 Ma. The biotite date from sample 47051 is 760 Ma and from 47052 is 835 Ma, whereas the whole-rock date from samples 47049, 47050, 47051 and 47052 (shot point 2) is 725 Ma. The biotite date from sample 47053 is 847 Ma and from 47054 is 858 Ma, whereas the whole-rock date from these samples (shot point 3) is 783 Ma (Table 2 and Fig 3).

None of the sets of whole-rock values contains sufficient elements to properly evaluate any of the whole-rock isochrons. In the single case where four points are available (shot point 2, samples 47049 to 47052), the points are not strictly collinear, and the resulting curve is concave downward (Figure 3).

Available data seem inadequate to establish a reason for the whole-rock dates to be younger than associated biotite dates. Explanations can be suggested but have not been tested on the material at hand. It seems possible that the obvious extensive saussuritization of plagioclase was within, or at least continued into, the temperature range between 200°C and 300°C; as a result Sr in plagioclase was mobilized, but Sr in biotite was trapped above its closure temperature. The whole-rock isochron was rotated to a younger apparent date while biotite retained its earlier values.

If this model is correct, then the biotite ages and whole-rock isochron dates may represent dates of points in the cooling history of the body rather than dates of discrete events.

In any case, there is no reason to believe that the biotite at Errabiddy has responded to conditions which were different in principle to those at the other biotite localities in the Gascoyne Province.

WINNING POOL

Eleven samples from three localities on the Winning Pool 1:250 000 sheet were collected. Samples 60740 to 60748 are from Woolcadgia Pool, sample 60749 is from a locality south of White Hills and 60750 is from Bee Well Creek. Bee Well Creek is 100 km south of Woolcadgia Pool, and the locality south of White Hills lies between the two.

TABLE 2. Rb-Sr WHOLE-ROCK AND BIOTITE DATES FROM THE GASCOYNE PROVINCE AND VICINITY

Locality	Sample Number (a)	Biotite date (b)	Initial ratio (c)	Comments
ROBINSON RANGE SHEET				
Errabiddy Shot point 1	47046	814	0.7827	Whole-rock isochron date = 744 Ma, $R_i = 0.7854$ (e)
	47047			
	47048			
Shot point 2	47049	760	0.7978	Whole-rock isochron date = 725 Ma, $R_i = 0.7973$ (e)
	47050			
	47051			
	47052			
Shot point 3	47053	847	0.8271	Whole-rock isochron date = 783 Ma, $R_i = 0.8305$ (e)
	47054	858	0.8245	
Rocky Bore	47040	1 545		Whole-rock isochron date = $2\ 603 \pm 149$ Ma, $R_i = 0.7095 \pm 0.0065$ (e)
Roadside Bore	47075	1 695		Whole-rock isochron date = $2\ 461 \pm 92$ Ma $R_i = 0.7058 \pm 0.0021$ (e)
WINNING POOL SHEET				
Woolcadgia Pool	60740	794	0.7323	Model 1 whole-rock isochron date: $1\ 532 \pm 13$ Ma with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ of 0.7192 ± 0.0006 MSWD is 41.6. The preferred model 4 date is $1\ 529 \pm 85$ Ma with an R_i of 0.7194 ± 0.0040
	60741	797	0.7289	
	60742	785	0.7637	
	(d) 60743			
	60744	766	0.7626	
	(d) 60741			
	60746			
S. of White Hills	60747			
	60748			
	60749	831	0.7616	

- (a) Samples for which isotopic data is available
(b) Biotite and whole-rock, 2-point isochron dates
(c) Initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio on the biotite-whole-rock join
(d) Not used in determination of whole-rock isochron date
(e) Whole-rock dates after Williams and others, 1978. Initial ratios are approximate, calculated from data of Williams and others, 1978.

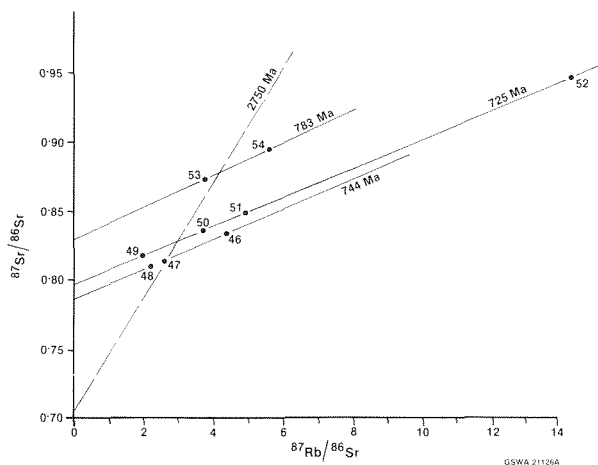


Figure 3. Whole-rock isochrons from individual shotpoints at Errabiddy, after Williams and others, 1978. The first three digits of sample numbers have been omitted for clarity. Samples 47046, -47 and -48 are from one shotpoint; samples 47049, -50, -51 and -52 are from a second shotpoint, and samples 47053, and -54 are from a third.

Analytical results for ten whole-rock samples and for biotite splits from five of these samples are listed in Table 1. Dates derived from a whole-rock isochron and from biotite and whole-rock pairs are shown in Table 2. The same data are represented graphically on a $^{87}\text{Rb}/^{86}\text{Sr}$ vs $^{87}\text{Sr}/^{86}\text{Sr}$ isochron plot in Figure 4A. Vectors from five whole-rock points are directed

toward associated biotite plots which lie off the diagram. Figure 4B is similar, but at a smaller scale, and shows the biotite data.

The whole-rock data fail to establish an isochron; however, if three points, 60743, 60745, and 60750 are discarded, a low-precision isochron is formed by the remaining points at $1\ 532 \pm 0.0006$ Ma and a mean square of weighted deviates (MSWD) of 41.6. The preferred model 4 date is $1\ 529 \pm 85$ Ma with an R_i of 0.7194 ± 0.0040 .

Five biotite and whole-rock dates are 794, 797, 785, 766 and 831 Ma yielding a mean biotite date of 795 Ma.

The three discarded, anomalous, whole-rock data points are reasonably collinear by themselves and define a reasonable date of $1\ 390$ Ma and a reasonable R_i of about 0.707. However, neither petrographic nor field characteristics provide a clear reason to believe that this line is a true isochron, recording an event distinct from that of the accepted isochron. Several of the samples (60746, 60747, 60748, and 60750) are described as late phases (pegmatite or late granitic dykes); however, only one of these is in the isotopically anomalous group. Although another anomalous sample (60745) is described as a xenolith from a late dyke, data from a sample of the dyke itself

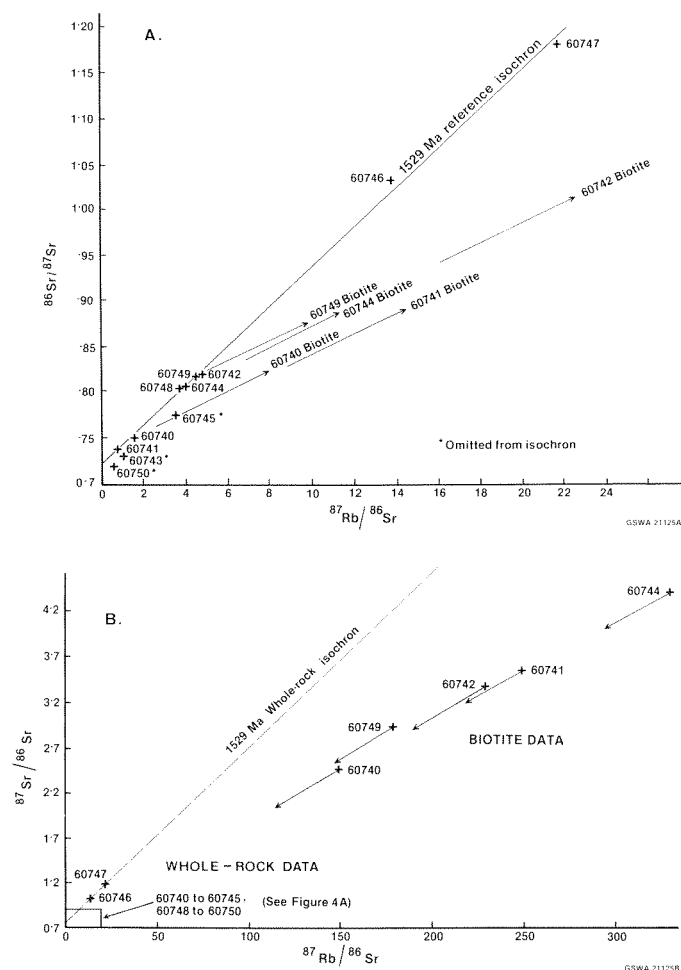


Figure 4. A—Isochron, whole-rock data from the Winning Pool sheet.
B—Isochrons, biotite and whole-rock data from the Winning Pool sheet.

plot near the accepted isochron. Two of the anomalous samples have distinct penetrative deformation but the third does not. Thus there is no external reason to assign separate events to the main isochron and the “isochron” defined by the three anomalous samples.

The scatter of data from both “accepted” and “anomalous” groups, together with variable deformation in the rock and relatively young biotite dates, indicates that the rocks have experienced heating after the event identified by the isochron date. Furthermore, the high R_i (0.7194) shows that the rock was not derived from the mantle at the isochron date. If single-stage evolution, isochemical processes, and representative sampling are assumed, then a mantle derivation date of 1 706 Ma is suggested by strontium-evolution analysis.

In contrast to the disturbed character of the whole-rock isochron, biotite dates at 794, 797, 785, 766 and 831 Ma are reasonably consistent, the more anomalous sample (60749, at 831 Ma) is from south of White Hills, some 35 km from Woolcadgia Pool, where the other samples were collected. The mean of these dates is well within one standard deviation of the mean of all Gascoyne biotite dates.

DISCUSSION AND CONCLUSIONS

Both whole-rock data from the Gascoyne Province and biotite data from adjacent parts of the Yilgarn Block (Roadside Bore and Rocky Bore) yield dates of approximately 1.6 Ga. The 1.6 Ga biotite dates in the Yilgarn Block can reasonably be attributed to marginal effect of the main plutonic event of that age in the Gascoyne Province. This conclusion may provide an argument that the relative positions of the Yilgarn Block and Gascoyne Province have remained effectively fixed since the 1.6 Ga event.

The further analyses of biotite from Errabiddy confirm earlier observations that the biotite dates are younger than associated local apparent whole-rock dates. This situation may be brought about by the updating of the whole-rock isochron by mobilization of Sr in plagioclase during low-temperature saussuritization.

The first-order trend surface on biotite Rb-Sr dates (Fig. 6) which includes recent data has much the same trend as a similar surface published earlier (Libby and de Laeter, 1979), but the gradient of the surface has been substantially reduced by the new data. A first-order trend surface is generated by fitting the data to a linear (first-order) equation. The surface formed is a plane. A section with individual values projected to a line normal to trend surface isopleths (Fig. 5) shows that the scatter of values at most localities exceeds the entire range of the surface within the area mapped.

A second-order surface (Fig. 7) is likewise poorly fitted, but suggests that dates near the centre of the basin may be younger than at the north and south margins of the basin. A second-order surface is generated by fitting the data to a quadratic (second-order) equation. Horizontal sections through the surface so formed are parabolas.

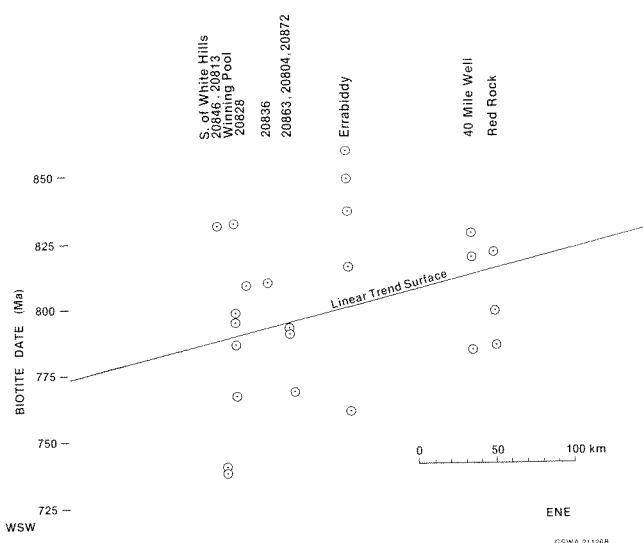


Figure 5. Individual sample values projected onto a section normal to the first-order trend surface.

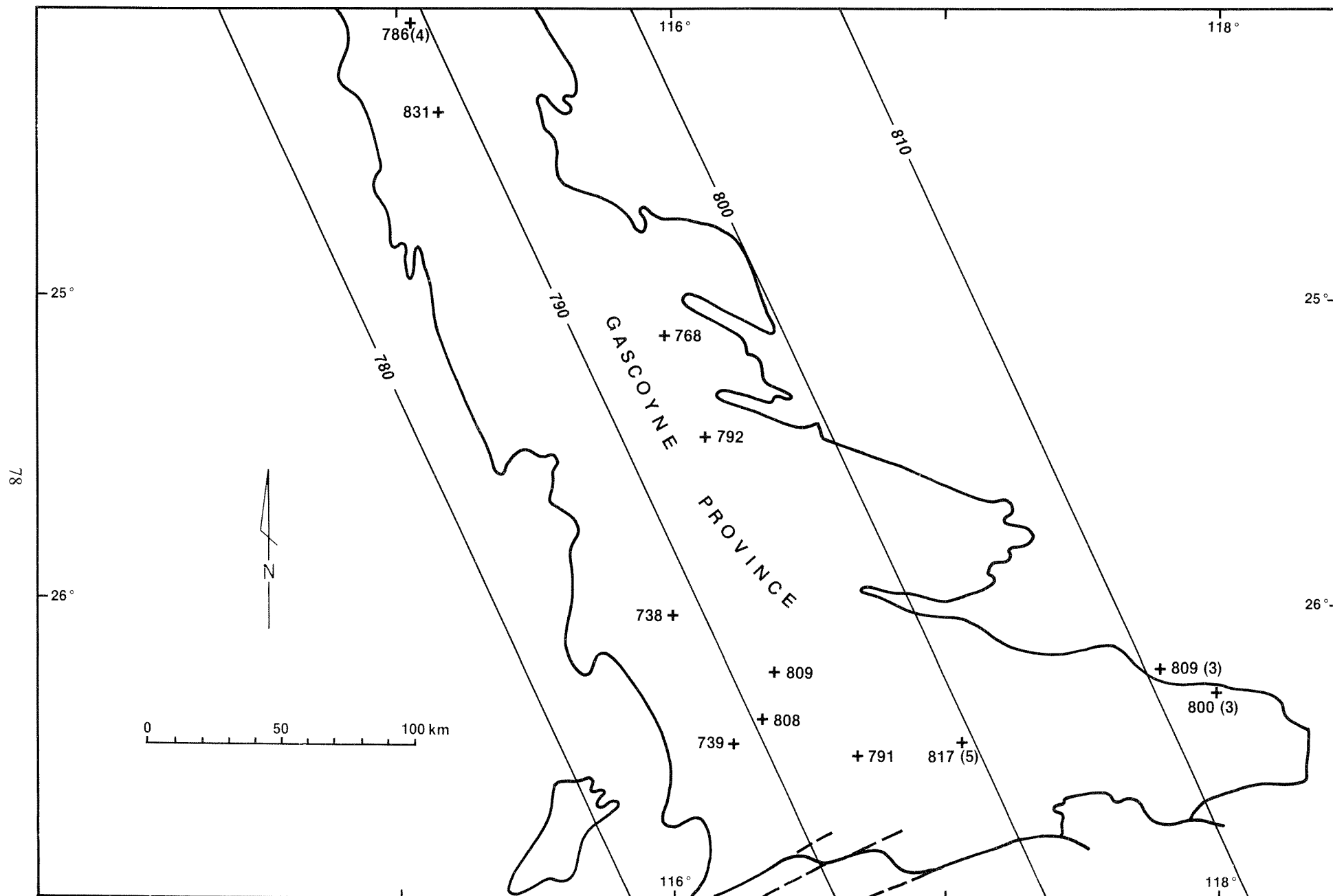
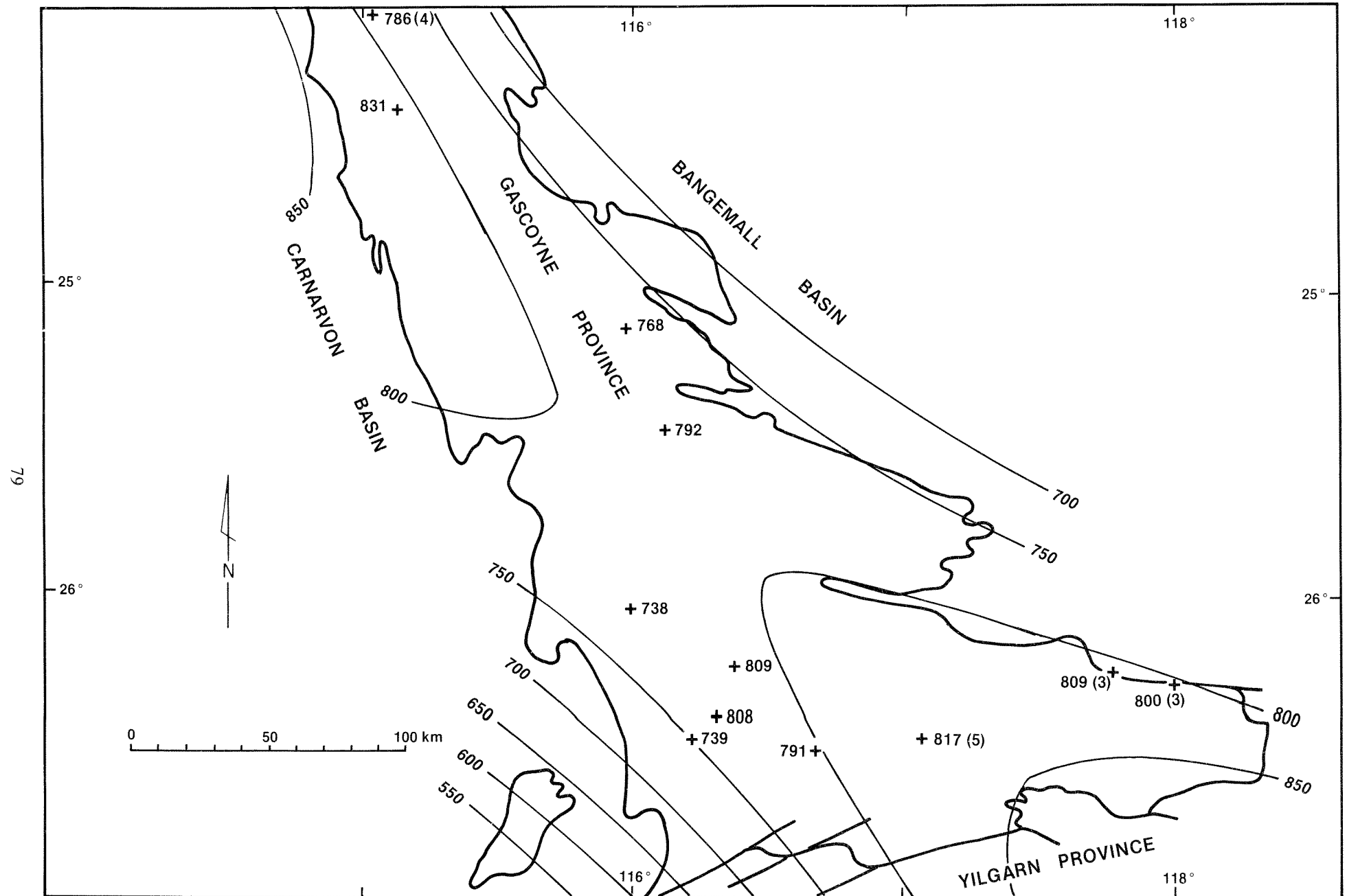


Figure 6. First-order trend surface on biotite dates from the Gascoyne Province. Multiple dates from a single locality have been averaged from the number of determinations shown in curved brackets. Values are in millions of years.



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Figure 7. Second-order trend surface on biotite dates from the Gascoyne Province. Multiple dates from a single locality have been averaged from the number of determinations shown in curved brackets. Values are in millions of years.

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