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Basin Development Across Lapetus

Project No. 40079

Final report on Rb-Sr whole rock dating of mudrock suites from the Lake District and Southern Uplands.

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by

Jane Evans

Introduction

Recent work in Wales has shown that mudrocks yield Rb-Sr whole rock ages that are commonly isochrons and which have a precision between 6 and 16 Ma. These ages date the time at which the sediment passed through the smectite-illite transition (Evans 1996). The technique has considerable potential for understanding basin subsidence as the dates mark the time at which the sediments passed though c. 90 °C, and could thus be used to map basin subsidence. In areas where thick, unfossiliferous mudrock sequences exist it also provides a simple method of placing a minimum age on sedimentation which, in areas of rapid burial, will be very close to the time of deposition of the sediment.

This study was planned to extend the study of British mudrocks by looking at low grade mudrocks from the Lake District and Southern Uplands. Ordovician samples were chosen because there was a significant time difference between deposition and the possible complicating factor of Acadian metamorphism at c 400 Ma. Laterally equivalent samples (two localities within the *Clingani* Zones) with different burial histories were collected from the Southern Uplands to see if sediments of the same ages gave different burial results.

The data is presented in Table 1 and the regression diagrams are given in Fig 1-7.

Analytical methods

Whole-rock samples, each of about 8 kg, were cleaned in de-ionised water and weathered surfaces were split off before rock powders were made.

Rb/Sr ratios were determined by X-Ray fluorescence; precision is ± 1.0% (2σ) for concentrations > 50 ppm, and this level of long term consistency has been proven to apply to ages calculated from favourable Rb/Sr spreads by repeatedly analysing 'in-house' isochron sets (Pankhurst & Rapela 1995, Pankhurst and Ingham, 1991).

Regressions of the isotope data utilised the York-Williamson regression with errors of 1% 2σ on the $^{87}Rb/^{86}Sr$ ratio and 0.02% 2σ or the $^{87}Sr/^{86}Sr$ ratio.

Four samples were selected from the Skiddaw Group Dodds Wood samples for illite separation with a view to undertaking Ar analysis of the fine illite fractions. The separations were completed but on the retirement of Dr C.C. Rundle the Argon line was not available for use so the material has not been analysed for K-Ar.

Results

Lake District Suites

Skiddaw Group, Dodds Wood, Late Arenig, NY 2363 2785

12 samples generate a regression line giving an age of 427 ± 34 Ma, initial $^{87}Sr/^{86}Sr$ ratio of 0.714503 with an MSWD of 3.2 (Fig.1). The error on the regression age is considerable but it still gives a result which is younger the sedimentation age of 480 Ma (Harland et al 1990). The slope is not dependent upon single samples. The initial ratio above 0.71, the low MSWD, the even spread of data and the age, which is younger that deposition, are all features seen in data from Wales and suggest that the regression is dating a real geological event.

Rebecca Hill Quarry slates- Ashgill

The Rebecca Quarry slates give a 7 point regression line with an age of 447 ± 24 Ma, and initial ratio of 0.7091 ± 0.0008 MSWD = 8.8 (Fig. 2) . The points are well spread along the line. The deposition age of the slates is well within error of the younger range of error on the age, although the slope of the line gives a Caradoc age. This line should be considered as of use.

Brathay Quarry

Six samples from Brathay quarry give an age of 485 ± 84, initial ratio of 0.7117 ± 0.0022, MSWD = 5.6 (Fig. 3) The low values and limited spread of Rb-Sr data have resulted in the large errors on the age. which means that the line does not provide useful geochronological information.

Little Cockup locality, Basal Arenig, NY 2551 3326

The seven samples plot in a cluster, and so, although they are in isotopic equilibrium, as shown by MSWD of <2, there is a large error on the slope of the line leading to an age of 377 ± 88, initial ratio of 0.7171 ± 0.0047 (Fig.4). The imprecision of the age makes the regression on little use.

Skiddaw slates, Wythop cottage- Late Arenig

It was decided not to proceed with the Wythop cottage samples because the data from the other suites was inconclusive.

Southern Uplands Suites

Dob's Linn Caradoc, Clingani Zone.

Six samples regress to give and age of 582 ± 57 Ma, an initial ratio of 0.70515 ± 0.0047 with an MSWD of 8.5 (Fig 5). The age is greater than the deposition age of the sediments, the initial ratio is low, within the range of magmatic rocks, and the slope is controlled by a single low point. These features make the line unreliable, and likely to be caused by the mixing of two isotopically distinct components within the sediment.

Dob's Linn Maximus Zone 196 159

This suite of eight samples shows features similar to the *Clingani* Zone regression. The data are scattered and given 541 ± 48, initial ratio of 0.7077 ± 0.0026, MSWD of 74 (Fig. 6a). The slope of the line is controlled by the two low points , there is a high point lying above the line. Removal of the high point results on a regression of 514 ± 30, IR of 0.70875 ± 0.0016 and a reduced MSWD of 26 (Fig. 6b) . However this is also an unreliable regression.

Broadlaw, Caradoc, Clingani Zone 347 533

Nine samples from Broadlaw give a wide spread of $^{87}Rb/^{86}Sr$ ratios between 1 and 10 but also have a large amount of scatter on the data (Fig. 7a). If the very deviant point BL8 is removed, the data regress to give 551 ±38 Ma, 0.7044 ±0.0020, with and MSWD of 106 (Fig 7b). The over steep line, leading to the pre-deposition age, the low initial ratio suggest that this is a mixing line, an interpretation supported by the distribution of the points. There are a cluster of four points with $^{87}Rb/^{86}Sr$ ratios around 8 which might represent a more radiogenic source and then another four equally spaced down towards a value of 1 and 0.704, suggesting an igneous source of detritus.

Discussion.

The study appear to be inconclusive with respect to its original aims of dating the smectite illite transition in the Lake District and Southern Uplands. However it is interesting in that it provides a very different set of data from similar rocks in Wales, and this may highlight differences in the nature of the rocks and the processes they underwent. The Southern Uplands suites show features of mixing. Dob's Linn is famous for its bentonite horizons and thus, in retrospect, it is not surprising that the Dob's Linn suites (*Maximus, Clingani* and the Broadlaw equivalent) display features which can be explained by the mixing of a volcanic component with an other more radiogenic component.

The Lake District data is, perhaps more comparable with Welsh data. The Skiddaw group data from Dodd's Wood give data which fit the criteria for dating the smectite illite transition. The Little Cockup data is in isotopic equilibrium, suggesting rehomogenisation of the isotopes after deposition, but unfortunately it has too limited a range of $^{87}Rb/^{86}Sr$ ratios to provide useful data. The Rebecca Quarry may have re-equilibrated during a post deposition event.

A comparison of this study with published work (Evans 1996) generates the following queation; Why do the Rb-Sr whole rock systems of mudrocks from the Lake District and Southern Uplands not reset in the manner observed in the Welsh mudrocks sequences given they are known to have gone through the smectite illite transition. Two main causes are likely;

1) The clastic detritus from which they formed does not break down or re-equilibrate as easily as the material in the Welsh basin.

2) There was less fluid movement and therefore less opportunity to move Sr and Rb around within the mudrocks and allow re-equilibration of the isotope systems.

Conclusions

The data from the Lake District and the Southern Uplands highlight the fact that controls on the isotope systems in these areas were different from those which operated in Wales under the same diagenetic- low grade conditions.

References

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W.B. Harland, W.B., Armstrong, R.L., Cox, A.V., Craig L.E, Smith A.G. andSmith, D.G, 1990. A geologic time scale 1989. Cambridge University Press, 263 pp, 1990.

Pankhurst, R.J. and Rapela, C.R. 1995. Production of Jurassic rhyolite by anatexis of the lower crust of Patagonia. Earth and Planetary Science Letter. 134, 23-26.

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Rb and Sr concentrations and isotope ratio measurements of whole rock
Rb-Sr suites fom the Lake District and Southern Uplands.

Sample	Rb ppm	Sr ppm	Rb/Sr ppm	87Rb/86Sr	87Sr/86Sr
LAKE DISTRICT					
Skiddaw group, Dodds Wood locality, late Arenig NY 2363 2785					
locality number NY22NW 476					
DODD1	167.35	121.03	1.383	4.013	0.738749
DODD2	151.08	94.27	1.603	4.653	0.74294
DODD3	166.92	109.32	1.527	4.432	0.741133
DODD4	172.54	102.34	1.686	4.895	0.743952
DODD5	165.22	101.42	1.629	4.730	0.742889
DODD6	163.76	109.68	1.493	4.334	0.740658
DODD7	172.45	102.41	1.684	4.889	0.744329
DODD8	168.35	99.99	1.684	4.889	0.744359
DODD9	173.76	126.71	1.371	3.980	0.738904
NY 2370 2774				0.000	
DODD10	163.69	112.64	1.453	4.218	0.740585
DODD11	167.85	100.51	1.670	4.849	0.744299
DODD12	163.3	101.73	1.605	4.660	0.742907
Rebecca Hill quarry slates -Ashgill Grid Ref?					
REB1	146.37	188.79	0.775	2.247	0.723359
REB2	143.94	233.86	0.615	1.783	0.720615
REB3	138.74	211.59	0.656	1.900	0.72079
REB4	156.55	153.77	1.018	2.951	0.728007
REB5	163.46	133.1	1.228	3.561	0.731306
REB6	146.21	140.87	1.038	3.009	0.728631
REB7	148.13	294.81	0.502	1.455	0.718378
REB8	157.86	123.17	1.282		
REB9	151.93	147.41	1.031		
Brathay Quarry Grid Ref					
BRATH1	110.12	167.27	0.658		
BRATH2	115.86	170.47	0.680		
BRATH3	111.52	172.21	0.648	1.877	0.724726
BRATH4	108.37	157.43	0.688	1.995	0.725104
BRATH5	111.61	179.48	0.622	1.802	0.724317
BRATH6	113.18	177.92	0.636	1.844	0.724544
BRATH7	111.22	203.11	0.548	1.587	0.722655
BRATH8	115.17	160.47	0.718	2.080	0.726274
Little Cockup locality, Basal Arenig (NY 2551 3326)					
CK1	156.2	119.580	1.306	3.789	0.737458
CK2	161.3	122.500	1.316	3.820	0.737553
CK4	159.1	123.450	1.289	3.740	0.737121
CK5	154.8	121.090	1.279	3.710	0.73689
CK6	145.6	116.920	1.245	3.613	0.736514
CK7	153.7	122.920	1.251	3.628	0.736435
CK8	138.5	110.500	1.253	3.636	0.736728
Skiddaw slates, Wythop cottage locality- Late Arenig. Grid Ref					
WITH1	147.04	149.8	0.982		
WITH2	157.23	150.11	1.047		
WITH3	133.97	117.91	1.136		

WITH4	140.74	115.1	1.223		
WITH5	137.75	114.53	1.203	3.490	0.736552
WITH6	145.23	120.66	1.204		
WITH7	137.55	119.84	1.148	3.330	0.735238
WITH8	135.94	120.7	1.126		
WITH9	140.1	124.63	1.124		

SOUTHERN UPLANDS

Dob's Linn Clingani zone Grid Ref

CLING1	114.99	51.9	2.216	6.442	0.758437
CLING2	118.88	52.71	2.255	6.559	0.760111
CLING3	110.88	54.44	2.037	5.919	0.753047
CLING5	100.52	51.17	1.964	5.709	0.75318
CLING7	108.05	68.81	1.570	4.559	0.743108
CLING8	115.69	54.8	2.111	6.137	0.755973

Dob's Linn maximus zone (196 159)

MAX1	113.99	65.17	1.749	5.080	0.747304
MAX2	120.53	64.2	1.877	5.454	0.749409
MAX3	82.07	107.74	0.762	2.208	0.724975
MAX4	122.21	68.15	1.793	5.208	0.746937
MAX5	82.3	104.2	0.790	2.289	0.72571
MAX6	153.28	74.28	2.064	6.000	0.757601
MAX7	133.2	80.73	1.650	4.790	0.742922
MAX8	114.66	73.44	1.561	4.532	0.74066

Broadlaw, Clingani zone (347 533)

BL1	88.98	103	0.864	2.503	0.722552
BL2	82.56	32.1	2.572	7.482	0.762947
BL3	57.97	23.52	2.465	7.167	0.759865
BL4	55.29	19.9	2.778	8.085	0.766946
BL5	55.54	26.73	2.078	6.037	0.750297
BL6	71.03	167.65	0.424	1.227	0.714241
BL7	57.37	23.37	2.455	7.140	0.760977
BL8	54.62	15.89	3.437	9.994	0.757543
BL9	155.09	120.7	1.285	3.728	0.737039

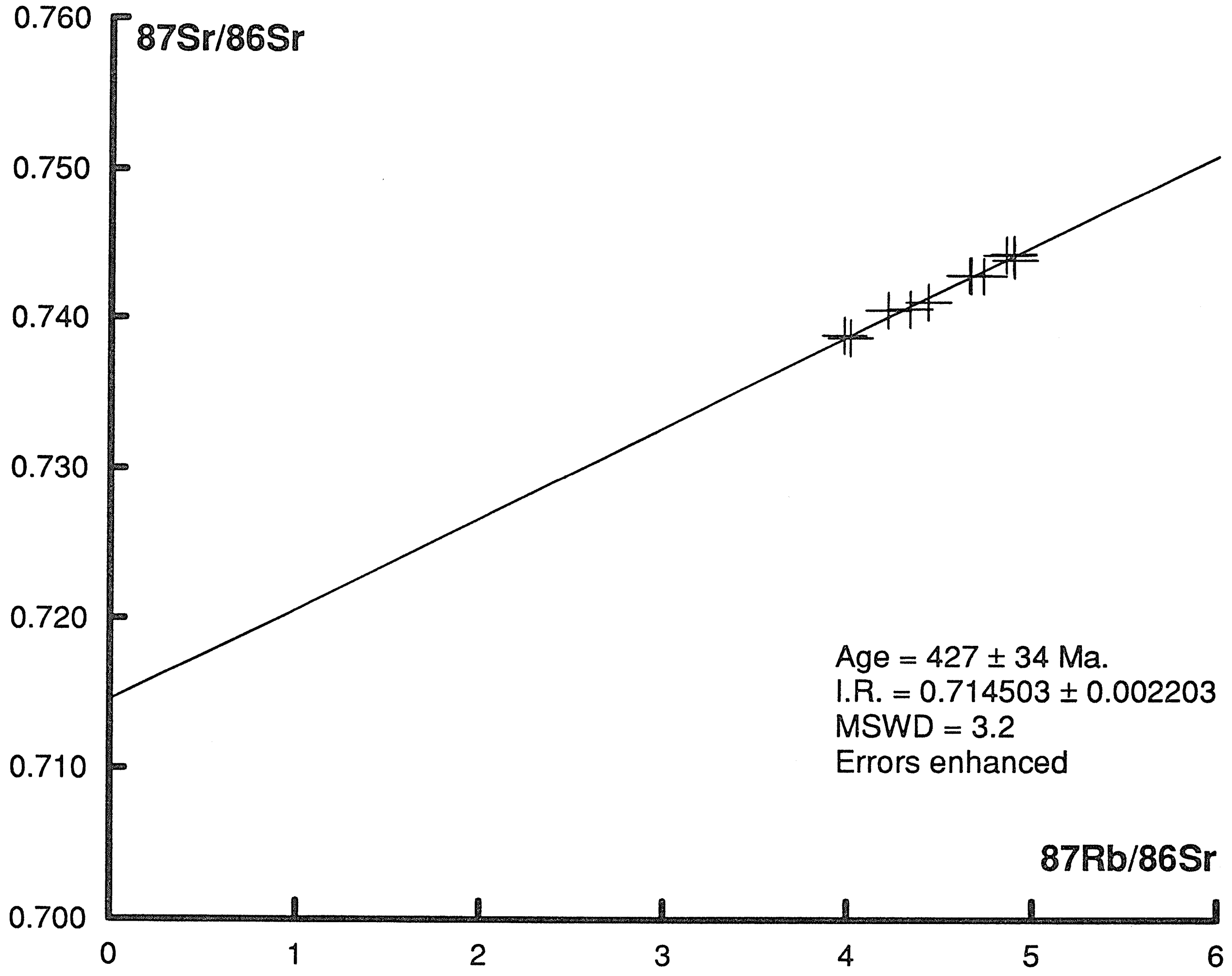

Figure 1. Rb-Sr whole rock regression of data from Dodd's Wodd, Lake District.

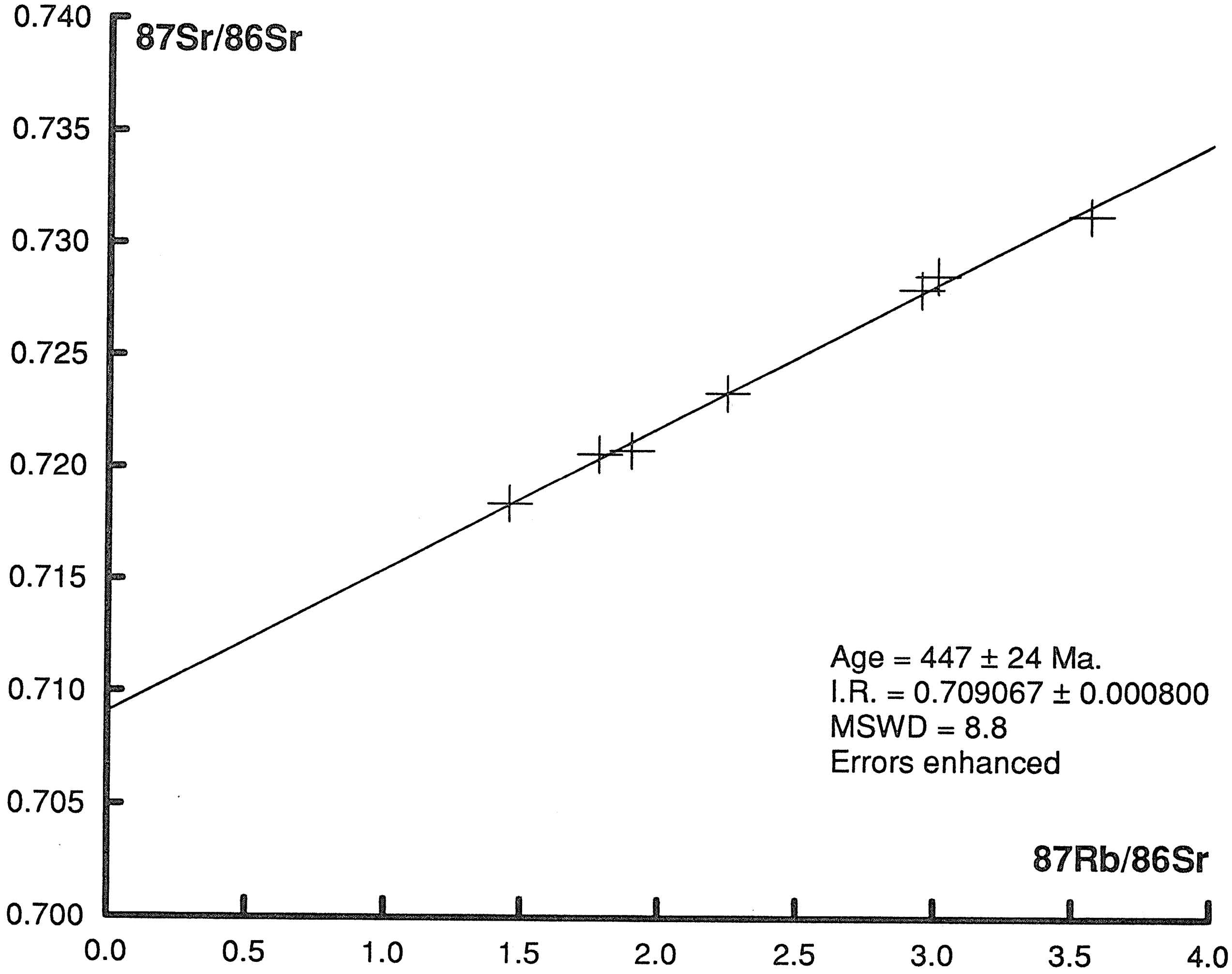

Figure 2. Rb-Sr whole rock regression of data fromRebecca Hill Quarry, Lake District.

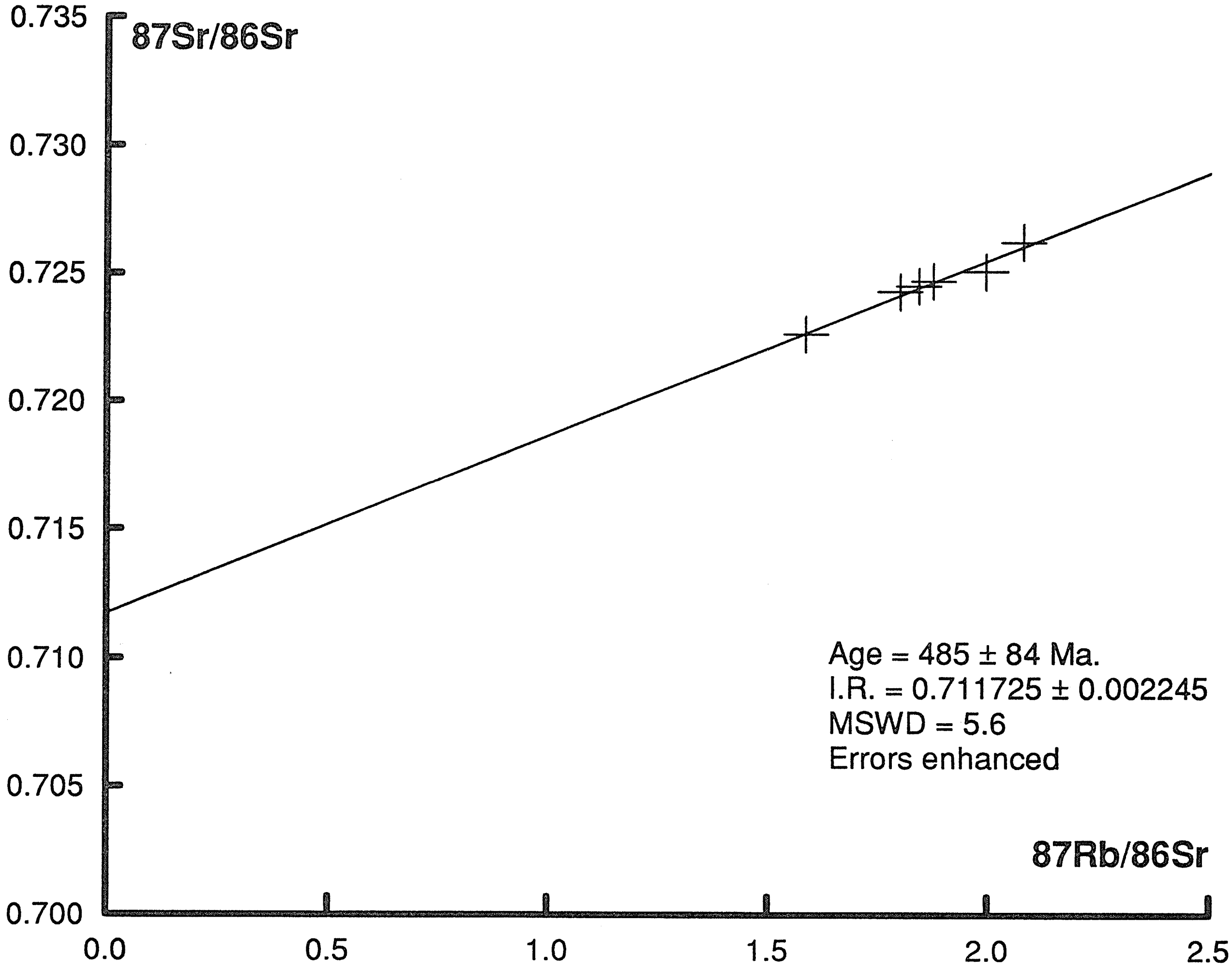

Figure 3. Rb-Sr whole rock regression of data from Brathay Quarry, Lake District.

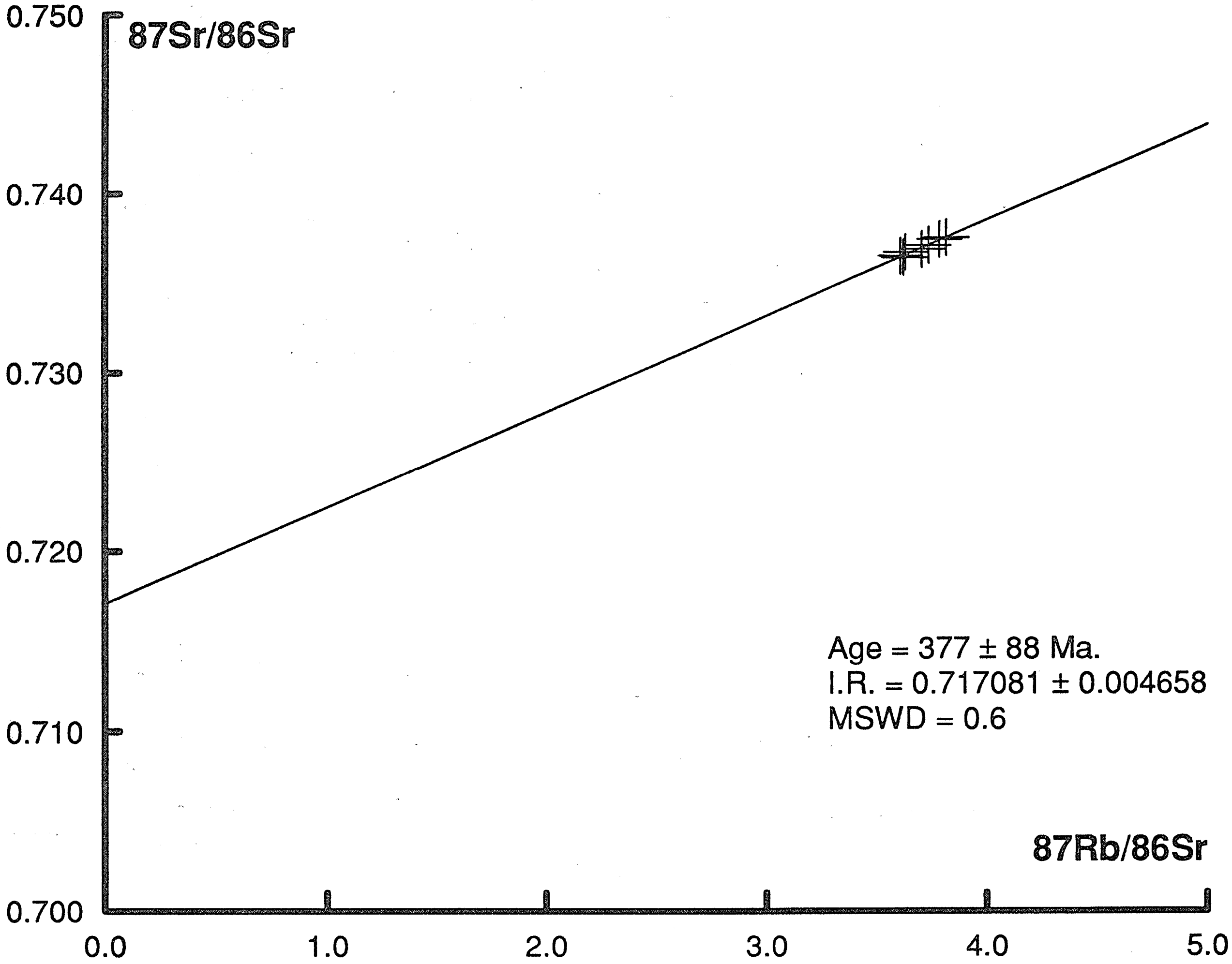

Figure 4. Rb-Sr whole rock regression of data from Little Cockup locality, Lake District.

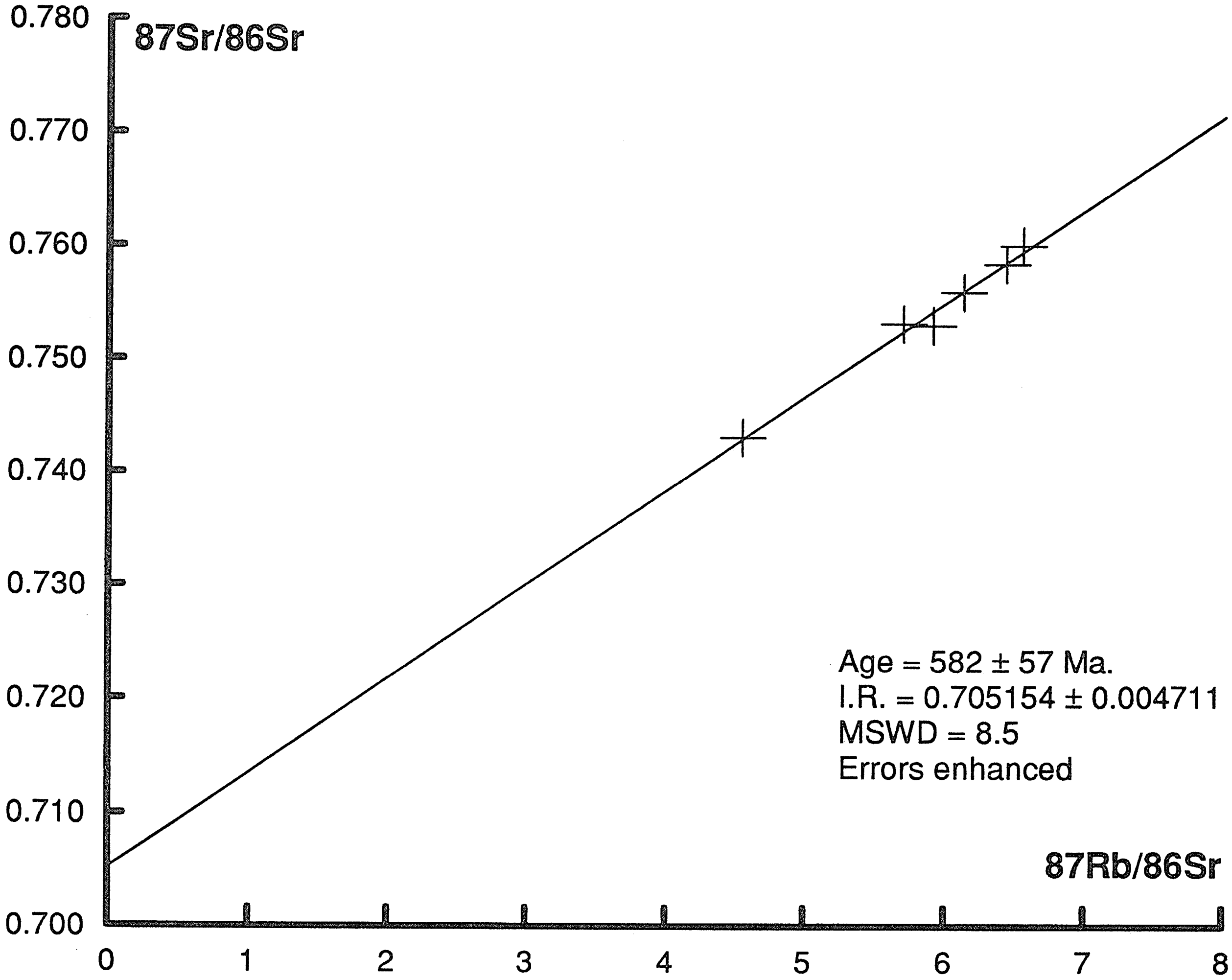

Figure 5. Rb-Sr whole rock regression of data from Dob's Linn, *Clingani* Zone Southern Uplands.

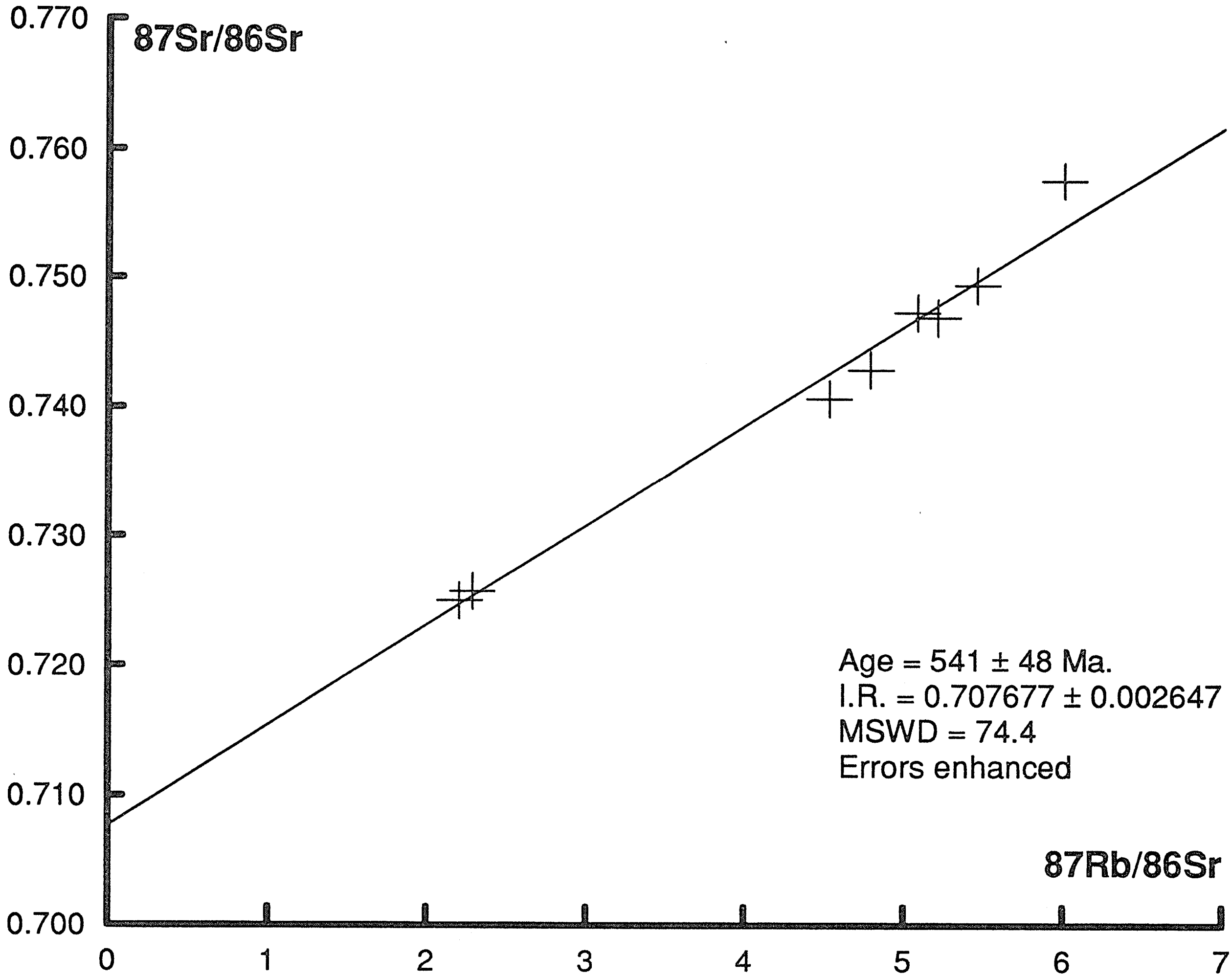

Figure 6. Rb-Sr whole rock regression of data from Dob's Lin *Maximus* Zone, Southern Uplands.

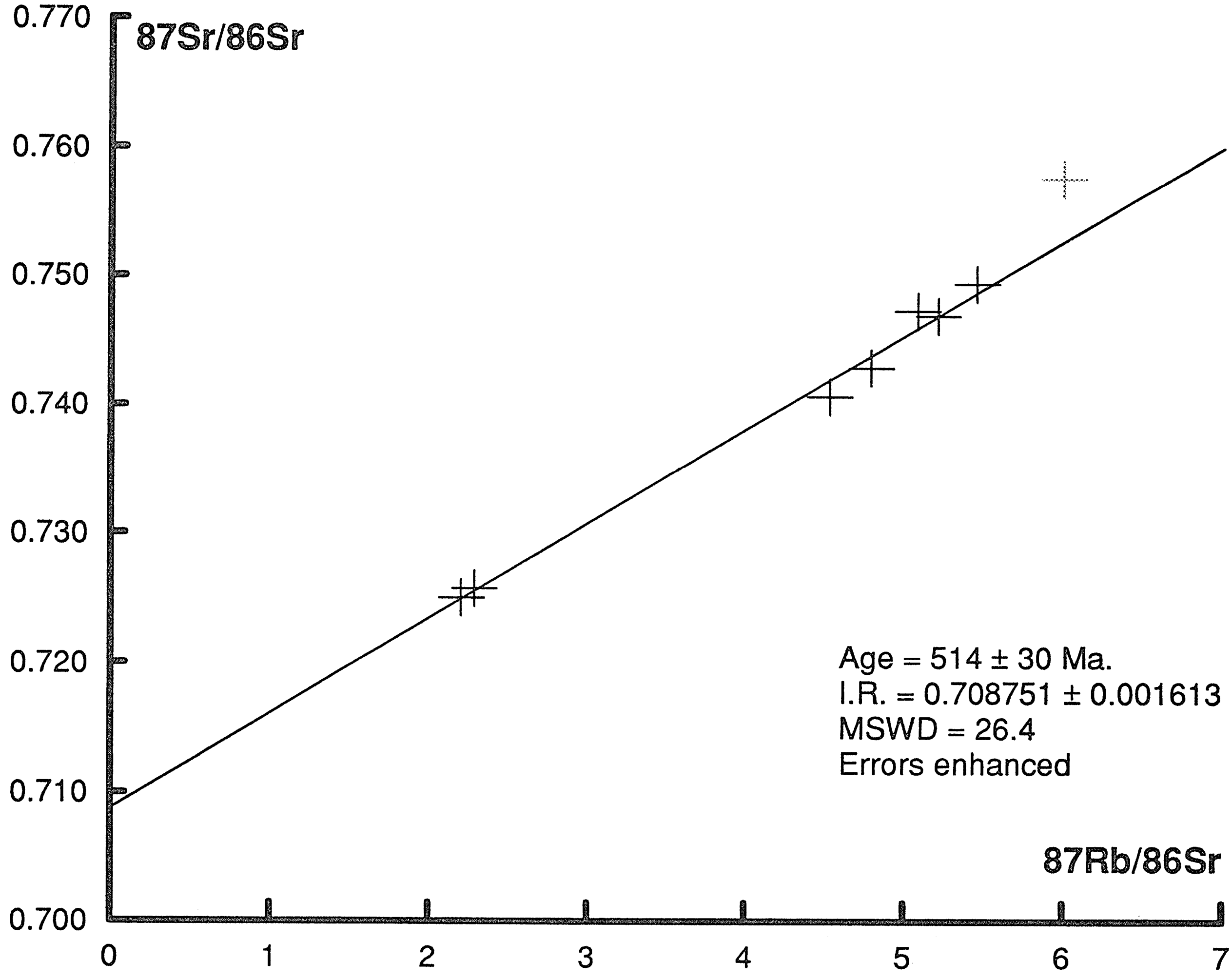
87Sr/86Sr
0.770
0.760
0.750
0.740
0.730
0.720
0.710
0.700
0
1
2
3
4
5
6
7
87Rb/86Sr
Age = 514 ± 30 Ma.
I.R. = 0.708751 ± 0.001613
MSWD = 26.4
Errors enhanced

Figure 6b.

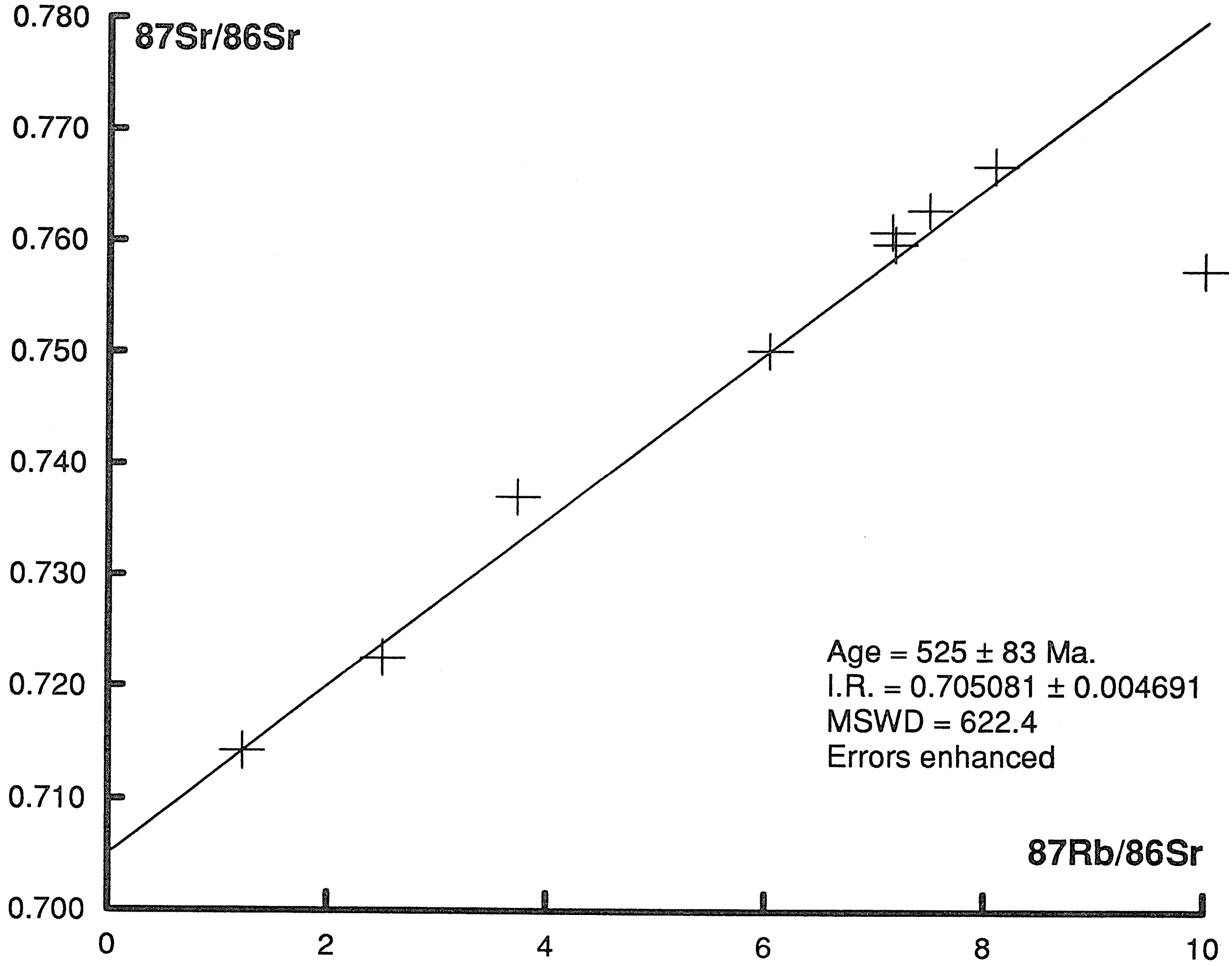

Figure 7. Rb-Sr whole rock regression of data from Broadlaw, *Clingani* Zone, Southern Uplands.

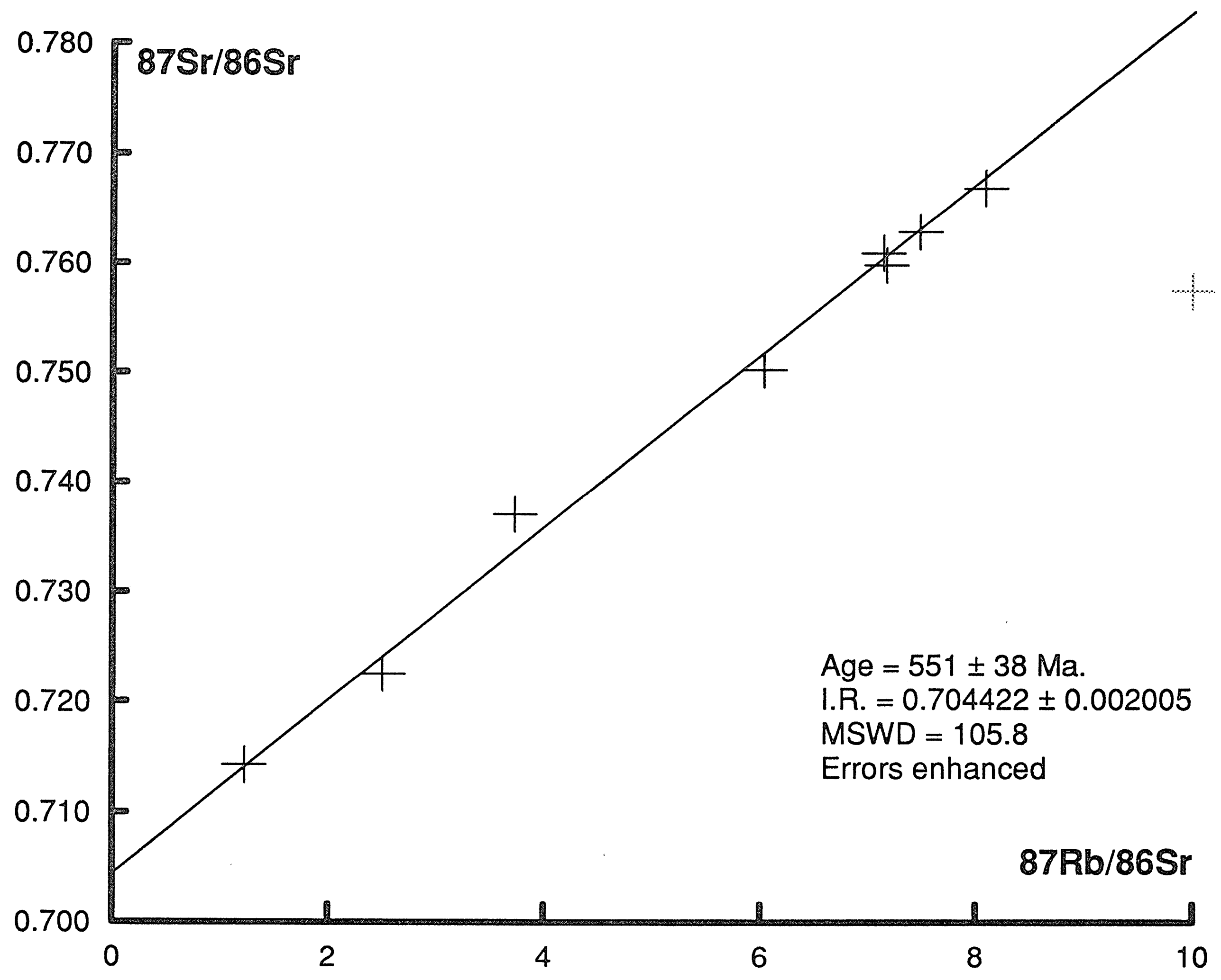
87Sr/86Sr
0.780
0.770
0.760
0.750
0.740
0.730
0.720
0.710
0.700
Age = 551 ± 38 Ma.
I.R. = 0.704422 ± 0.002005
MSWD = 105.8
Errors enhanced
87Rb/86Sr
0
2
4
6
8
10

Figure 7b