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Rb-Sr DATA ON SOME PEGMATITES IN THE DAMARA OROGEN (NAMIBIA)

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ABSTRACT

Close association in space and time of Li-, Sn- and barren pegmatites with granites suggests a link by differentiation. However, Rb-Sr data support this hypothesis only for the barren pegmatites. The Li- and Sn-pegmatites, on the other hand, have far too high initial ($^{87}Sr/^{86}Sr$) ratios to be such differentiates. These ratios are also much higher than they should be if the pegmatites were products of equilibrium melting of Damaran meta-pelites or meta-greywackes and much lower than would be expected if they were partial melts of the pre-Damaran basement. It is proposed to explain the high ($^{87}Sr/^{86}Sr$) ratios by disequilibrium melting of high Rb/Sr minerals like biotite and/or muscovite which preferentially enter the melt and thus extract radiogenic Sr and rare elements from metasediments.

1. INTRODUCTION

The late Precambrian Damara Orogen of Namibia forms part of the Pan African belt. Models of its evolution - probably on a rifting continental crust - as well as studies on its tectonic, metamorphic and geochemical character are discussed in two monographs edited by Martin and Eder (1983) and Miller (1983). The orogen was affected by only one major regional metamorphism which occurred late-to post-tectonically as shown by the isograds which cut all tectonic structures (Hoffer, 1977). The high-grade Central Zone of the orogen is characterized by low pressure/high temperature metamorphism (anatexis at 2,5-3 kb, Hoffer, 1977; Puhan, 1979) and by the intrusion of numerous large granite plutons whose Rb-Sr whole rock ages lie between 459 and 553 Ma (Haack *et al.*, 1983a, b). This Central Zone contains an abundance of small and large pegmatites some of which are mineralized with Be, Nb, Ta, Li, Sn and U. Their occurrence in the granite-rich zone suggests genetic links with these magmatic rocks either by differentiation or as products of the same thermal event. It is the purpose of this paper to examine Rb-Sr data on the pegmatites and nearby granites in order to test the possible genetic relationship.

2. ANALYTICAL RESULTS

The analytical procedure is described in detail elsewhere (Haack *et al.*, 1980). The calculations are based on the following constants: $\lambda_{Rb} = 1,42 * 10^{-11}a^{-1}$, common ($^{86}Sr/^{88}Sr$) = 0,1194, common ($^{84}Sr/^{86}Sr$) = 0,0572, common ($^{85}Rb/^{87}Rb$) = 2,593. The value obtained for the Sr standard NBS SRM 987 was 0,71039 ± 0,00022. The Sr ratios were corrected by the factor 0,71014/0,71039. Unless otherwise stated, all errors are 2σ (either the analytical precision or the scatter error, whichever is the larger one).

2.1 Pegmatites associated with the Donkerhuk Granite

The Donkerhuk Granite and its associated white and pink pegmatites were studied, amongst others, by Faupel (1974), Nieberding (1976) and Sawyer (1978). The pegmatites are of two types: white dykes with abundant

TABLE 1: Pegmatites associated with Donkerhuk Granite

		$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Rb (ppm)	Sr (ppm)
R89	white pegmatite	18,99 ± 0,03	0,8534 ± 0,0005	186	28,8
R92	white pegmatite	20,31 ± 0,05	0,8647 ± 0,0005	246	34,7
R96	white pegmatite	22,84 ± 0,05	0,8835 ± 0,0002	192	24,8
R106	white pegmatite	27,76 ± 0,02	0,9209 ± 0,0003	159	16,9
R97	pink pegmatite	88,58 ± 0,03	1,3583 ± 0,0004	270	9,4
R98	pink pegmatite	84,0 ± 1,5	1,324 ± 0,003	244	8,9
Overall analytical precision (2σ)		± 1,2 %	± 0,12 %		
Donkerhuk Granite (Blaxland *et al.*, 1979)					
R110		2,527	0,73089	150	172,1
R114		7,63	0,76805	240	91,5
R115		6,118	0,75758	174	83,0
R116		2,876	0,73251	173	174,8
R113		9,778	0,78437	265	78,9

Age R89–R106 white pegmatites: 538 ± 40 Ma (2σ), R_i = 0,708 ± 0,012 (2σ); MSWD = 0,39.
R97 and R98 pink pegmatites: model ages (with R_i = 0,708) 515 Ma.
For comparison: age of Donkerhuk Granite 521 ± 15 Ma, R_i = 0,712 ± 0,001 (Blaxland *et al.*, 1979).
Donkerhuk Granite + white pegmatites: 527 ± 6 Ma (2σ), R_i = 0,7113 ± 0,0007 (2σ); MSWD = 0,840.

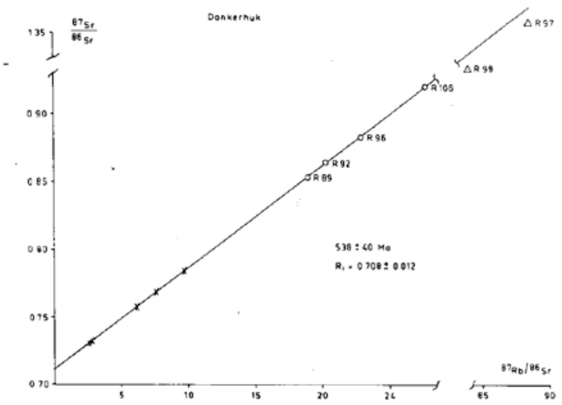

Fig. 1: Rb-Sr data for white pegmatites (circles), and pink pegmatites (triangles) associated with the Donkerhuk Granite (crosses).

coarse muscovite and spessartine-rich garnet (up to 4 mm in diameter) and pink dykes with only some small thin flakes of muscovite and small garnets (about 1 mm in diameter).

In some of the pegmatites beryl or columbite/tantalite are occasionally found, but most of them are not mineralized. Pegmatites analysed in this study are barren and occur on the farm Onanis along the road from Swakopmund via Anschluß to Windhoek and include material from several different pegmatite veins. The data for the white pegmatites (see Fig. 1, Table 1) plot on an isochron whose slope corresponds to an age of 538 ± 40 Ma with an initial ($^{87}Sr/^{86}Sr$) ratio of 0,708 ± 0,012. Within the limits of error this cannot be distinguished from the result for the Donkerhuk Granite whose age is 521 ± 14 Ma and whose initial ($^{87}Sr/^{86}Sr$) ratio is 0,711 ± 0,001 (Blaxland *et al.*, 1979). If the data points for the granite and the white pegmatites are regressed together the result is: t = 527 ± 3 Ma (2σ), R; = 0,7113 ± 0,0007 (2σ), MSWD = 0,84 (analytical error on $^{87}Sr/^{86}Sr \leq 0{,}05$ %, on $^{87}Rb/^{86}Sr \leq 1$ %). The data for the pink pegmatites (triangles in Fig. 1) do not fall on this isochron and were not used for the regression. However, this observation is not necessarily proof of a different origin because they plot only slightly below the isochron. Perhaps some Sr was lost from these samples which consist mainly of feldspar with only very little mica. Therefore, it will be assumed that all pegmatites of the area are cogenetic.

2.2 Li-pegmatite of the Rubicon mine

The Rubicon pegmatite occurs in a medium- to high-grade metamorphic environment south-east of Karibib. It is the largest of several pegmatites which contain abundant Li¬minerals but also minerals of Be, Bi, Cs, Nb, Ta and a host of rare phosphates. A detailed description is given by Roering and Gevers (1964) and Roering (1964). The main ore bodies at Rubicon are a discontinuous zone of rich Li and Be mineralization stretching for a total length of almost 1 km and, on average, 30-45 m wide. Roering (1964) considers the Rubicon pegmatite as late tectonic and related in space and

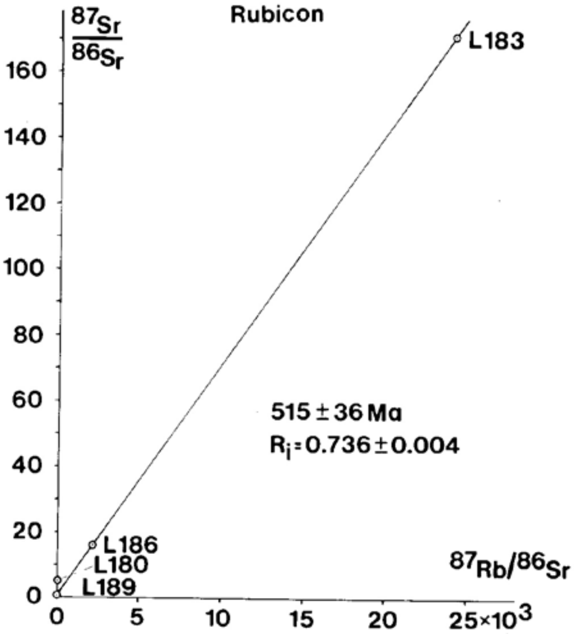

Fig. 2: Rb-Sr data for minerals from the Rubicon Li-mine. The amblygonite point (L 189) practically fixes the initial ($^{87}Sr/^{86}Sr$) ratio. The Rb/Sr and ($^{87}Sr/^{86}Sr$) ratios of muscovite (L 183) are extremely high. The apatite point (L 180) above the intercept indicates Sr incorporation somewhat after crystallization. (The apatite was a rather small crystal, about 3 × 1 × 1 cm) (errors 2σ)

TABLE 2: Data on the Rubicon pegmatite

		$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Rb (ppm)	Sr (ppm)
L189	amblygonite $LiAlPO_4(OH,F)$	0,07030 ± 0,00008	0,7363 ± 0,0003	1,38	56,8
L180	apatite	1,5046 ± 0,0022	4,9042 ± 0,0006	5,19	14,1
L186	K-feldspar	2057,6 ± 1,8	16,353 ± 0,004	8 834	31,4
L183	muscovite	24 159 ± 161	171,7 ± 0,28	13 192	28,0
Overall analytical precision		± 2%	± 0,32%		

Ages: pair K-feldspar/amblygonite: 532 ± 11 Ma, R_i = 0,736 ± 0,002;
pair K-feldspar/muscovite: 493 ± 11 Ma, R_i = 1,89 ± 0,45;
pair muscovite/amblygonite: 497 ± 10 Ma, R_i = 0,736 ± 0,002;
3-point isochron muscovite/K-feldspar/amblygonite 515 ± 36 (2σ) Ma, R_i = 0,736 ± 0,004, MSWD = 2,44.
For comparison: age of nearby Goas Granite 515 ± 20 Ma and R_i = 0,7166 ± 0,0006 (Blaxland *et al.*, 1979).

TABLE 3: Data on the tin pegmatite of Uis

		$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Rb (ppm)	Sr (ppm)
L154	whole rock	3,435 ± 0,005	0,75728 ± 0,00025	834	706
L158	whole rock	8,519 ± 0,025	0,79787 ± 0,00015	1 778	609
L158	muscovite	11 992 ± 55	86,68 ± 0,07	5 647	12,8
L153	whole rock	24,37 ± 0,04	0,89761 ± 0,00009	1 307	158
L156	whole rock	26,86 ± 0,02	0,92545 ± 0,00007	1 653	182
L157	whole rock	54,88 ± 0,009	1,12183 ± 0,00009	2 284	125
Overall analytical precision (2σ)		± 2 %	± ,08 %		

Ages: whole rock: 496 ± 30 (2σ) Ma; R_i = 0,734 ± 0,004 (2σ), MSWD = 2,24, muscovite 503 ± 10 Ma; R_i = 0,737 ± 0,002.

For comparison: Rb/Sr whole rock age of Sorris-Sorris Granite 495 ± 15 Ma, R_i = 0,7091 ± 0,0015 (Hawkesworth *et al.*, 1983) granites along the Omaruru river: 459–553 Ma, R_i = 0,7056–0,7135 (Haack *et al.*, 1980).

time to late-tectonic intrusive granites. He concurs with Smith (1965, p. 68) who thinks that the pegmatites of the central Damara Orogen, although locally intrusive, are in general derived from the sediments in their immediate environment.

The minerals of the Rubicon pegmatite are all of gigantic size. Therefore, only minerals, never whole rocks could be analysed. The data are listed in Table 2 and plotted in Fig. 2. The data for amblygonite, K-feldspar and muscovite plot on one straight line whose slope corresponds to an age of 515 ± 36 Ma. The initial ($^{87}Sr/^{88}Sr$) ratio of 0,736 is essentially given by amblygonite. It is remarkable how well this Li-phosphate discriminates against Rb in a Rb-rich environment. As often observed, the point for apatite lies above the intercept indicating that apatite acted as a Sr acceptor for some time after its crystallization. The age of 515 Ma is approximately the mean of the values obtained for the mineral pairs and the same as that for the nearby Salem-type granite on Goas (Blaxland *et al.*, 1976). However, differentiation from the latter is excluded because the initial ($^{87}Sr/^{86}Sr$) ratio of 0,736 of the pegmatite is far too high. It cannot be directly derived by any equilibrium process from the Damaran metasediments either because 515 Ma ago their ($^{87}Sr/^{88}Sr$) ratio was only about 0,717 ± 0,004 (data collected in Table 1, Haack *et al*., 1983a). On the other hand, derivation from the basement as represented by the Fransfontein and the Abbabis inliers as well as the Etusis Formation is excluded because 515 Ma ago their Sr isotope ratios were between 0,77 and 0,85, i.e. far too high to be the protoliths of the pegmatites (see data collected in Table 4).

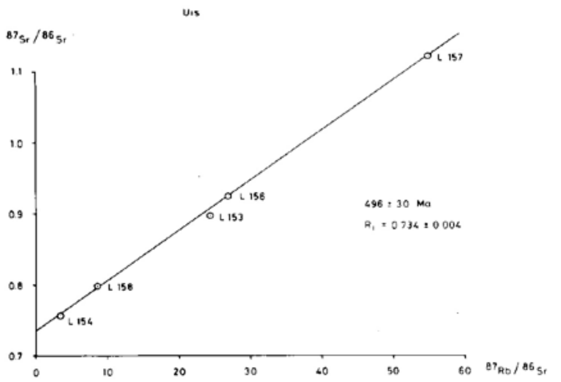

Fig. 3: Rb-Sr data for the Uis tin pegmatite (errors 2σ).

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2.3 Tin pegmatite of the Uis mine

Uis is the only tin deposit of Namibia which is exploited. It consists of several bodies of white pegmatite mineralized with cassiterite. The pegmatite is post-tectonic. The samples which all come from the same pit (K5) consist mainly of large crystals of K-feldspar with varying amounts of coarse muscovite and some albite and quartz.

The Rb-Sr age of 496 ± 30 Ma (Fig. 3) might suggest differentiation from a granite of the type Sorris-Sorris which was dated by Hawkesworth *et al*. (1983) as 495 ± 15 Ma old. However, this hypothesis has to be rejected because the initial Sr isotope ratios of 0,737 for the pegmatite and 0,709 for the Sorris-Sorris Granite are too different (see Table 3). Calculations show also that it cannot have differentiated from one of the other northern granites either, even if one supposes that the age of 496 is not the intrusion age but indicates some stage of cooling. Even assuming that its real age is 530 Ma does not lower the initial ($^{87}Sr/^{86}Sr$) sufficiently to make this hypothesis plausible. As in the case of the Rubicon pegmatite derivation from the basement is highly improbable for similar reasons.

3. DISCUSSION

Dating pegmatites by the Rb-Sr method is notorious for unreliable results because of the loss and redistribution of Sr from the feldspars. However, even if the ages obtained should not necessarily be taken at their face value the data do permit hypotheses on the origin of the pegmatites either from granites or from other source rocks.

The data on the barren pegmatites in the vicinity of the Donkerhuk Granite are compatible with the hypothesis that they are differentiates of this granite. For the giant mineralized pegmatite of Rubicon and Uis a similar genetic relationship with nearby granites is excluded. Likewise, any model involving equilibrium partial melting of basement, Etusis or Kuiseb Formation cannot provide melts with an initial Sr isotope ratio of around 0,736. On the other hand, Roering (1964), Roering and Gevers (1964) and Smith (1965) put forward arguments to support the idea that the pegmatites, although locally intrusive, are in general derived from their immediate environment which is the Kuiseb Formation.

How can these mutually exclusive views be reconciled with one another and how can it be explained that the pegmatites are broadly coeval with their nearby granites? One way to raise the initial ratio of the pegmatites is to assume that they existed for 1-2 Ma as separate melts in magma chambers and thus achieved internal Sr equilibration at a high ratio because of their extremely high Rb/Sr ratios. If this is at all a viable possibility, it requires a very static and quiet geological environment. Otherwise such large volumes of liquid could not be kept in a sort of magma chamber for any appreciable length of time and would always escape. The surroundings into which the pegmatites intruded were not static. The area was, on the contrary, in rapid uplift at that time (Haack, 1976). We do, therefore, not favour the model that the pegmatites existed long enough as liquids to raise their initial ($^{87}Sr/^{86}Sr$) ratio from 0,715 to 0,736. Alternatively, the pegmatites could have remained at sufficiently high temperature in the solid state to allow Sr equilibration. However, this possibility seems unlikely in view of the large size of the crystals (the analysed amblygonite fragment, e.g. was more than 10 cm long and 5 x 3 cm thick).

We propose here a different way to obtain a highly radiogenic initial ($^{87}Sr/^{86}Sr$) ratio. If a reaction decomposes biotite and the reaction product is removed before it can completely equilibrate its Sr with the restite, an easy way is provided to obtain melts or solutions with highly radiogenic Sr. Biotite does not readily accept Sr but is rich in Rb. Typical ($^{87}Rb/^{86}Sr$) ratios are 200-1 500. It therefore quickly accumulates radiogenic Sr which will be released to a melt or solution on the decomposition of the biotite. Biotite decomposition reactions occur during high grade metamorphism when cordierite, K-feldspar and melt are formed. The following model calculations may serve to illustrate the point. Let us assume a biotite with the typical ($^{87}Rb/^{86}Sr$) ratio of 800 had existed for 20 Ma before it decomposed 515 Ma ago. Its ($^{87}Sr/^{86}Sr$) ratio had increased from 0,715 to 0,942 by then and the whole-rock (B7Sr/^{86}Sr) ratio to 0,717 (initial ratio of granite). Under these assumptions 8 % of the total Sr is derived from the biotite. If muscovite is the main decomposing mineral, the proportion of muscovite-derived Sr must be several times higher, because the ($^{87}Rb/^{86}Sr$) ratios of muscovite generally are < 100, often <50.

The proposed mechanism can also explain the high concentration of rare metals in pegmatites because in most rocks these metals are concentrated in biotite (Haack, 1969). Hence, it is the ideal mineral whose decomposition can yield fluids with highly radiogenic Sr which at the same time are enriched in rare elements. In addition, this model explains the contemporaneity with the granites. Both can be derived from the same source rock by the same thermal event, i.e. the peak of regional metamorphism. The difference is that the granites comprise at least a major portion of the parent rock and presumably have more or less equilibrated with their restites. The pegmatites originated from a highly selective disequilibrium process like incipient incongruent melting or high-grade biotite (muscovite) decomposition reactions with a quick removal of the liquid.

TABLE 4: Data on basement rocks (granitic gneiss) from the 1-2 Ga old Abbabis inlier

		$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Rb (ppm)	Sr (ppm)
S159		7,387	0,8991	303,0	121,1
S163	junction	7,594	0,9080	302,9	117,8
S164	Anschluß/	7,472	0,9034	307,4	121,5
S165	Abbabis road	9,531	0,9207	326,6	101,5
Arithmetic mean		7,996	0,907		

Mean ($^{87}Sr/^{86}Sr$) 515 Maago: 0,849.
For comparison: Mean ($^{87}Sr/^{86}Sr$) of granitic Fransfontein basement inlier in the North of the central zone 515 Ma ago was 0,786 (based on data by Clifford *et al*., 1969).
Rb/Sr age of this inlier 1 547 ± 20 Ma, R_i = 0,708.
Mean ($^{87}Sr/^{86}Sr$) ratio of a migmatite of the Etusis formation overlying the Abbabis inlier 515 Ma ago was 0,775 (based on data by Downing and Coward, 1981).

4. CONCLUSIONS

Rb-Sr data on granites and associated pegmatites permit evaluation of the differentiation hypothesis. Comparable initial ($^{87}Sr/^{86}Sr$) ratios suggest that the barren pegmatites associated with the Donkerhuk Granite are most probably differentiates. In contrast, the economically important Snpegmatite of Uis and Li-pegmatite of Rubicon cannot be differentiates of nearby granites. They probably owe their origin to the decomposition of biotite (or perhaps muscovite) from metasediments either by melting or by K-feldspar-forming reactions during high-grade regional metamorphism. It might then be asked whether the precondition for the concentration of rare elements in these pegmatites is the presence of a metasediment in which the rare elements were already enriched or whether quite normal concentrations of Li, Be, Sn, etc., are sufficient to form deposits, provided the melts or solutions can accumulate. Perhaps a greater volume of metasediment has to be processed in the case of economic pegmatites.

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