GEOLOGIE EN MIJNBOUW VOLUME 50 (4), p. 619–624 1971

ISOTOPIC DATING IN THE KAMATIVI TIN BELT, SOUTHERN RHODESIA

H.N.A. PRIEM, N.A.I.M. BOELRIJK, E.H. HEBEDA, E.A.Th. VERDURMEN and R.H. VERSCHURE[1)]

ABSTRACT

Rb-Sr measurements point to an Eburnian age (around 2150 million years) for the granites and tourmaline pegmatites in the Kamativi area, southern Rhodesia. From Rb-Sr and K-Ar mineral dates it is evident that a tectonothermal event affected the area in Kibaran time, about 970 million years ago; the emplacement of the tin-bearing pegmatites was probably connected with this event.

INTRODUCTION

Geologically, the Kamativi area in southern Rhodesia forms part of the Kalahari Craton of southern Africa. Two main units can be distinguished in the area, the Precambrian Basement System and the Permo-Triassic Karroo Formation (F i c k, 1960). The Basement System is made of a belt of metamorphosed and tectonized sediments, intruded by elongated masses of biotite granite and numerous tourmaline pegmatites. From field and structural relationships it is concluded that both granites and tourmaline pegmatites were emplaced at the latest stages of the regional folding movements. Granites and metasediments are intersected by dolerite dykes. The youngest rocks of the System are complex tin-bearing pegmatites, which cut through dolerites, granites, tourmaline pegmatites and metasediments. The whole Basement System is unconformably overlain by sandstones of the Karroo Formation (see fig. 1).

Tin is mined from the complex pegmatites which contain, in addition to cassiterite, also Ta-Nb, Li and Be minerals. There is no direct relation between these pegmatites and the granites. Further details concerning the geology of the Kamativi Tin Belt may be found in F i c k (1960).

Rb-Sr whole-rock measurements were made on three granite samples (68 Rho 4, 5 and 6), while biotites separated from these rocks were studied by the Rb-Sr and K-Ar methods. From a tourmaline pegmatite (68 Rho 3), microcline was analyzed by the Rb-Sr method and muscovite according to both the Rb-Sr and K-Ar methods. A tin-bearing pegmatite (68 Rho 1), finally, was investigated by dating albite and muscovite according to the Rb-Sr method and both the Rb-Sr and K-Ar methods, respectively. The sampling sites are shown in fig. 1 and listed in table 1.

EXPERIMENTAL PROCEDURES AND CONSTANTS USED

Splits of crushed and pulverized whole-rock samples were analyzed for their Rb and Sr contents by X-ray fluorescence spectrometry. The separated minerals were analyzed by stable isotope dilution, using spikes enriched in ^{87}Rb and ^{84}Sr. For the isotope measurements a 20 cm, 60° mass-spectrometer with digital output was used, utilizing thermal ionization and multiplier detection. A single Ta

1) Z.W.O. Laboratorium voor Isotopen-Geologie, De Boelelaan 1085, Amsterdam-11.

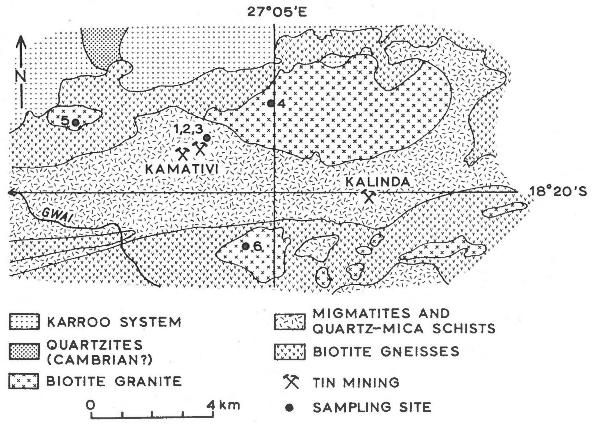

Fig. 1
Geological sketch map of the Kamativi area, southern Rhodesia (simplified after Watson, 1962), showing the locations of the samples analyzed. The numbers 1-6 correspond to the sample numbers 68 Rho 1-68 Rho 6.

filament source was employed for all measurements. The $^{87}Sr/^{86}Sr$ ratios were measured directly on unspiked strontium for the whole-rocks and calculated from the isotope dilution runs for the minerals. Correction for effects of isotope fractionation and mass discrimination was made by normalizing to $^{88}Sr/^{86}Sr = 8.3752$.

The X-ray fluorescence data were obtained on a Philips PW 1220 semi-automatic X-ray spectrometer equipped with a 2 kW Mo X-ray tube and a (200) LiF analysing crystal. Mass absorption coefficients for both sample and external reference standard were estimated by measurement of the intensity of the Compton scattering of the Mo Kα primary beam.

Potassium determinations were made by flame photometry with a lithium internal standard and a CsAl buffer. Argon was extracted in a bakeable glass vacuum apparatus and determined by standard isotope dilution techniques (using ^{38}Ar as a tracer) in a Reynolds-type glass mass-spectrometer; the measurements were made by the static method.

All calculations were made using the following constants:

$$^{87}Rb : \lambda_\beta = 1.47 \times 10^{-11} yr^{-1};$$

$$^{40}K : \lambda_e = 5.85 \times 10^{-11} yr^{-1},$$

$$\lambda_\beta = 4.72 \times 10^{-10} yr^{-1}, \text{ and}$$

$$\text{abundance } ^{40}K = 0.0118 \text{ atom \% total K.}$$

TABLE 1
Investigated samples and locations.

68 Rho 1	Muscovite- and cassiterite-bearing albite pegmatite	Kamativi Mine about 1 km NE of Mine Office. Depth 183 m below surface.
68 Rho 3	Muscovite-bearing tourmaline pegmatite	idem
68 Rho 4	Gneissose porphyric biotite granite	Quarry about 3.2 km NE of Kamativi Mine Office.
68 Rho 5	Biotite granite	Outcrop about 3.6 km WNW of Kamativi Mine Office.
68 Rho 6	Gneissose porphyric biotite granodiorite	Outcrop about 3.9 km SE of Kamativi Mine Office.

RESULTS AND DISCUSSION

The analytical results are shown in table 2 and table 3. The Rb-Sr data are also plotted in an isochron diagram of $^{87}Sr/^{86}Sr$ versus $^{87}Rb/^{86}Sr$ (fig. 2). From these data, the following may be concluded:

1. A Rb-Sr isochron analysis of only three granite whole-rock samples with a fairly narrow range in Rb/Sr ratios is not warranted. The calculated individual whole-rock ages, assuming an initial $^{87}Sr/^{86}Sr$ ratio of 0.705, are:

2043 ± 80 million years for 68 Rho 4,
2206 ± 100 million years for 68 Rho 5, and
2630 ± 400 million years for 68 Rho 6.

(Errors based upon estimated maximum errors of 2% for Rb/Sr and 0.5% for $^{87}Sr/^{86}Sr$).

The age of these granites may be taken at, approximately, 2150 ± 100 million years. Their emplacement can thus be placed within the *Eburnian Orogenic Episode*, an important episode of orogeny, metamorphism and granite emplacements in large parts of the African continent (e.g., Clifford, 1968). The sedimentary series were intruded by the granites and must therefore be older than 2150 ± 100 million years.

2. The biotites separated from the granites yield much lower Rb-Sr ages, pointing to "overprinting" by a more youthful event of Sr isotopic homogenization within the rock systems:

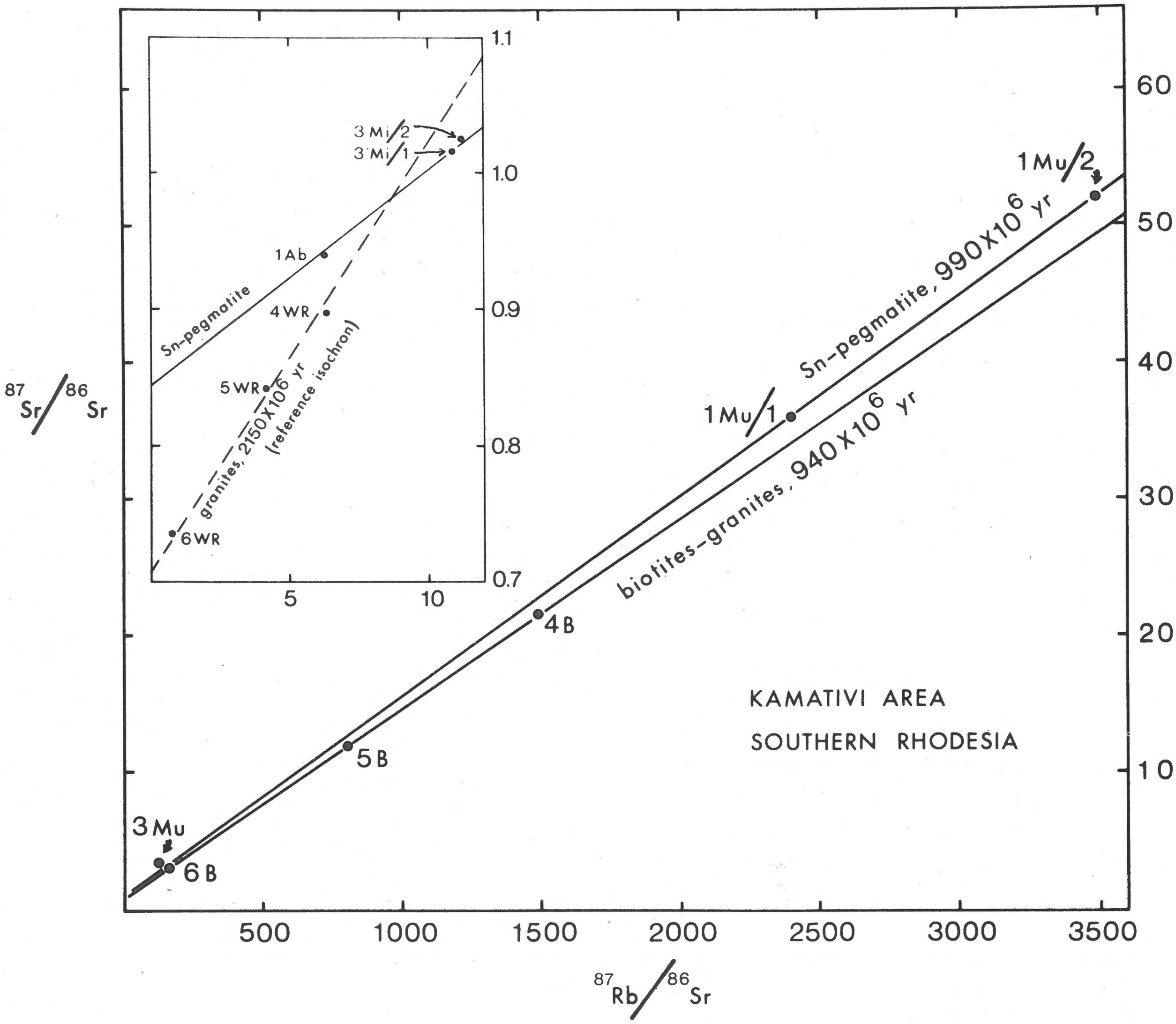

Fig. 2
$^{87}Sr/^{86}Sr$ versus $^{87}Rb/^{86}Sr$ plot of all samples measured from the Kamativi Tin Belt in southern Rhodesia. WR, whole-rock; B, biotite; Mu, muscovite; Ab, albite; Mi, microcline. The numbers 1-6 correspond to the sample numbers 68 Rho 1-68 Rho 6 in table 2 (see also table 1). The 940 x 10^6 yr isochron applies to the biotites separated from the granites, the 990 x 10^6 yr isochron to the albite and muscovite from the tin-bearing pegmatite. The 2150 x 10^6 yr isochron is shown as a "reference isochron" of the three granite whole-rock samples.

biotite 68 Rho 4, age 927 million years,
$^{87}Sr/^{86}Sr$ homogenization ratio 0.810
biotite 68 Rho 5, age 943 million years,
$^{87}Sr/^{86}Sr$ homogenization ratio 0.784
biotite 68 Rho 6, age 955 million years,
$^{87}Sr/^{86}Sr$ homogenization ratio 0.726

The "overprinted" Rb-Sr age of the biotites may thus be taken at 940 ± 30 million years, which is in fairly good accordance with their K-Ar age of 988 ± 20 million years. The tectonothermal event responsible for the rejuvenation of the biotites may be dated at about 970 million years. This "updating" can be placed within the *Kibaran Orogenic Episode,* an important event that affected an extensive zone in the Congo and Kalahari Cratons (Nicolaysen & Burger, 1966; Clifford, 1968).

TABLE 2
Rb-Sr data

Sample Nr	Material	Rb ppm Wt	Sr ppm Wt	$^{87}Sr/^{86}Sr$	$^{87}Rb/^{86}Sr$
68 Rho 1	muscovite (1)	4989	26.7	35.96	2402
	(2)	5198	26.0	52.11	3490
	albite	37.3	17.9	0.9394	6.17
		39.3	18.3	0.9395	6.37
68 Rho 3	muscovite	411	11.9	3.154	124
		407	12.5	3.037	115
	microcline	404	110	1.017	10.9
		413	110	1.025	11.2
68 Rho 4	whole-rock	190*	88.7*	0.8996	6.32
				0.8956	
	biotite	1068	6.50	21.48	1464
		1082	6.29	21.66	1519
68 Rho 5	whole-rock	151*	106*	0.8391	4.17
				0.8458	
	biotite	763	5.80	12.45	818
		767	5.89	11.70	782
68 Rho 6	whole-rock	144*	514*	0.7371	0.81
				0.7369	
	biotite	579	13.0	2.938	157
		567	12.7	2.981	158

* X-ray fluorescence spectrometry. The measured Rb/Sr ratios (Wt/Wt) are

for 68 Rho 4: 2.142,
for 68 Rho 5: 1.422, and
for 68 Rho 6: 0.280

TABLE 3
K-Ar data.

Sample Nr	Material	K %Wt	Radiogenic ^{40}Ar ppm Wt	Atmospheric ^{40}Ar (% total ^{40}Ar)	Age[1] million years
68 Rho 1	muscovite	8.17	0.747	4.1	997
		8.04	0.758	3.3	
68 Rho 3	muscovite	8.70	0.798	3.4	988
		8.71	0.799	2.5	
68 Rho 4	biotite	7.37	0.673	2.6	985
		7.32	0.669	1.9	
68 Rho 5	biotite	6.80	0.623	2.8	988
		6.80	0.624	3.1	
68 Rho 6	biotite	7.35	0.669	4.2	982
		7.38	0.672	2.1	

[1] Maximum error estimated at ± 2%.

3. The Rb-Sr data of the microcline and the muscovite from the tourmaline pegmatite do not fit with the 2150 ± 100 million years whole-rock age of the granites, nor with the "overprinted" 970 million years age of the biotites. However, the calculated microcline age, assuming an initial $^{87}Sr/^{86}Sr$ ratio of 0.705, is 1915 million years, fairly close to the whole-rocks age of the granites. Calculation of the muscovite Rb-Sr age yields an intermediate value of 1350 million years, while this mineral reveals a Kibaran K-Ar age of 988 ± 20 million yerars. These data may be interpreted as to indicate that the tourmaline pegmatite was formed in Eburnian time, coeval with or slightly younger than the granite emplacements, and influenced by the Kibaran tectonothermal event. This event had none or very little effect on the Rb-Sr system of the microcline, but caused partial loss of radiogenic ^{87}Sr from the muscovite. The K-Ar clock of the muscovite was wholly reset by the Kibaran event.

4. The tin-bearing pegmatite gives a muscovite-albite isochron age of 990 ± 15 million years with an initial $^{87}Sr/^{86}Sr$ ratio of 0.848. The K-Ar age of the muscovite is concordant, 997 ± 20 million years. These data may be explained in two different ways:

a. The pegmatite was formed prior to the Kibaran Episode, but, as follows from the geological relationships, after the termination of the Eburnian orogeny and the intrusion of the dolerites (between, roughly, 2000 and 1000 million years ago). The K-Ar age of the muscovite and the muscovite-albite Rb-Sr isochron age would then represent the time of Kibaran "overprinting", while the high initial $^{87}Sr/^{86}Sr$ ratio of the muscovite-albite isochron would reflect isotopic homogenization in the pegmatite system.

b. Emplacement of the pegmatite took place 990 ± 15 million years ago in Kibaran time, the high initial $^{87}Sr/^{86}Sr$ ratio being due to assimilation of strontium enriched in ^{87}Sr from the country rocks during its invasion. (The metasedimentary country rocks were then already over 1000 million years old). Alternatively, it could be imagined that the $^{87}Sr/^{86}Sr$ ratio of the albite (which determines the initial ratio of the isochron) is anomalous high. Such a phenomenon has been described, for example, from pegmatites in the Middletown Area, Connecticut, by Brookins et al. (1969), where late-stage cleavelandites are anomalously enriched in radiogenic ^{87}Sr; the source of this strontium is thought to have been other zones within the crystallizing pegmatite. Albites with similar enrichments in "excess" ^{87}Sr were also reported by Riley (1970) from zoned pegmatites in the Black Hills, South Dakota.

Tentatively, a Kibaran emplacement age is preferred by the present authors. Kibaran ages were also established for tin mineralizations elsewhere in southern Africa. The intrusions of complex tin-bearing pegmatites in the Kenhardt and Gordonia Districts of the north-western Cape Province were dated by means of U-Pb measurements at about 1000 and 940 million years (Burger et al., 1965). For the tin granites and associated tin-bearing pegmatites of southern Kivu and central Katanga, Cahen et al. (1967) concluded on the basis of Rb-Sr isochron studies (also taking into account earlier U-Pb measurements) to emplacement ages between, roughly, 950 and 850 million years (the intrusions being post-tectonic with regard to the Kibaran folding movements between 1300 and 1200 million years ago); the granites and pegmatites likewise have unusually high initial $^{87}Sr/^{86}Sr$ ratios.

Furthermore, taking into account pre-Continental Drift reconstructions, it may be of interest to note that tin granites and tin-bearing pegmatites of about 1000 million years old are also known from western and south-eastern Brazil, respectively (Priem et al., 1966, 1971).

CONCLUSIONS

From the isotopic data it may be concluded that the granites of the Kamativi area were emplaced in Eburnian time, approximately 2150 ± 100 million years ago. The tourmaline pegmatites were probably also formed in this period. A tectonothermal event, the Kibaran Orogenic Episode, affected the area about 970 million years ago. The tin-bearing pegmatites were presumably formed 990 ± 15 million years ago, in connection with the Kibaran event.

ACKNOWLEDGEMENTS

The investigated samples were provided by the Kamativi Tin Mines Ltd. (Billiton Maatschappij N.V.), Rhodesia. This work forms part of the research programme of the "Stichting voor Isotopen-Geologisch Onderzoek", supported by the Netherlands Organization for the Advancement of Pure Research (Z.W.O.).

REFERENCES

Brookins, D.G., H.W. Fairbairn, P.M. Hurley and W.H. Pinson (1969) – A Rb-Sr geochronologic study of the pegmatites of the Middletown area, Connecticut. Contr. Min. Petr. 22, p. 157-168.

Burger, A.J., P.J. Hugo and F.W.E. Strelow (1965) – Radiometric dating of certain pegmatites in the Kenhardt and Gordonia Districts, Cape Province. South African Dept. Mines, Annals of the Geol. Survey 4, p. 87-98.

Cahen, L., J. Delhal, and S. Deutsch (1967) – Rubidium-strontium geochronology of some granite rocks from the Kibaran Belt (central Katanga, Rep. of the Congo). Kon. Museum Midden-Afrika Tervueren, Annalen, Reeks IN-8°, Geol. Wetensch., Nr. 59, 65 pp.

Clifford, T.N. (1968) – Radiometric dating and the pre-Silurian geology of Africa. In: "Radiometric dating for geologists", edited by E.I. Hamilton and R.M. Farquhar (Interscience Publishers), p. 299-416.

Fick, L.J. (1960) – The geology of the tin pegmatites at Kamativi, southern Rhodesia. Geol. Mijnb. 39 (Billiton Maatschappij Centennial Volume), p. 472-491.

Nicolaysen, L.O. and A.J. Burger (1966) – Note on an extensive zone of 1000 million-year old metamorphic and igneous rocks in southern Africa. In: "Interprétation géologique des mesures effectuées au spectromètre de masse dans le domaine de la géochronologie absolue". Coll. Intern. C.N.R.S. No. 151, Nancy 1965, p. 293-518.

Priem, H.N.A., N.A.I.M. Boelrijk, E.H. Hebeda, R.H. Verschure and E.H. Bon (1966) – Isotopic age of tin granites in Rondônia, N.W. Brazil. Geol. Mijnb. 45, p. 191-192.

Priem, H.N.A., N.A.I.M. Boelrijk, E.H. Hebeda, E.A.Th. Verdurmen, R.H. Verschure and E.H. Bon (1971) – Granite complexes and associated tin mineralizations of "Grenville" age in Rondônia, western Brazil. Geol. Soc. America Bull. 82, p. 1095-1102.

Riley, G.H. (1970) – Isotopic discrepancies in zoned pegmatites, Black Hills, South Dakota. Geochim. Cosmochim. Acta 34, p. 713-725.

Watson, R.L.A. (1962) – The geology of the Kamativi and Lubimbi areas. Southern Rhodesia Geological Survey Bulletin No. 57, 42 pp., with geological map 1 : 100.000.