ISOTOPIC AGES IN THE HIGH-GRADE METAMORPHIC COEROENI GROUP, SOUTHWESTERN SURINAME

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ABSTRACT

Priem, H.N.A., N.A.I.M. Boelrijk, E.H. Hebeda, S.B. Kroonenberg, E.A.Th. Verdurmen & R.H. Verschure (1977). Isotopic ages in the high-grade metamorphic Coeroeni Group, southwestern Suriname. Geol. Mijnbouw, 56, p. 155-160.

Six whole-rock samples from the high-grade metamorphic Coeroeni Group in southwestern Suriname define a Rb-Sr isochron age of 2042 ± 97 Ma with initial $^{87}Sr/^{86}Sr = 0.7027 \pm 0.0039$ ($\lambda^{87}Rb = 1.39 \times 10^{-11}\ a^{-1}$; errors at 95%confidence level). This isochron relationship dates the event of high-grade metamorphism during the Trans-Amazonian Orogenic Cycle. The initial $^{87}Sr/^{86}Sr$ value does not record a substantial pre-metamorphic crustal history. K-Ar and Rb-Sr analyses of separated minerals (4 hornblendes, 2 muscovites and 6 biotites) yield a highly discordant age pattern, ranging from about 2000 to 1200 Ma (omitting one hornblende containing excess radiogenic argon). This pattern is interpreted as reflecting various degrees of resetting of Trans-Amazonian ages due to a low-grade metamorphic event 1200 ± 100 Ma ago (the Nickerie Metamorphic Episode). The order of mineral dates fits into the common order of radiogenic nuclide retentivities, corresponding to a temperature of about 350°C during the low-grade metamorphism.

INTRODUCTION

The high-grade metamorphic rocks of the Coeroeni Group in southwestern Suriname form part of the catazonal core of the Guiana Shield, a belt of high-grade rocks stretching over some 1000 km through the shield from the headwaters of the Uraricoera River in Brazil to near Paramaribo in Suriname. This belt of catazonal rocks has been designated as the Central Guiana Granulite Belt by Kroonenberg (1976). In western Suriname the high-grade metamorphic terrain is surrounded by complexes of granitic rocks and co-magmatic acid to intermediate volcanics, with minor gabbroic plugs. A Rb-Sr isochron investigation of this granitoid-volcanic basement all over Suriname yielded an age of 1920 ± 40 Ma (Priem *et al.*, 1971), relating it to the Trans-Amazonian Orogenic Cycle that had a wide extension in the eastern half of the South American continent.

The Coeroeni Group rocks occupy the area of the Boven Corantijn, Coeroeni and Lucie rivers in southwestern Suriname. An elaborate geological and petrological study of this terrain by Kroonenberg (1975a, 1975b, 1976) shows that it consists of migmatitic quartzofeldspathic and pelitic gneisses with minor amphibolites, quartzites, calcsilicate rocks, marbles and ultramafic rocks. Three phases of metamorphism can be recognized, an older kinematic and prograde phase under conditions of low-pressure amphibolite to granulite facies, a second static and retrograde phase under conditions of higher-pressure amphibolite facies, and a third cataclastic phase under conditions of greenschist to prehnite-pumpellyite facies. During the first phase a metamorphic zoning developed (Fig. 1): an outer sillimanite-muscovite zone (zone I, amphibolite facies) separated by a narrow sillimanite zone (zone II, amphibolite facies) from a central orthopyroxene zone (zone III, granulite facies). The second phase is recorded by the replacement of cordierite in pelitic gneisses by a great variety of mineral parageneses (various combinations of minerals such as quartz, biotite, muscovite, sillimanite, andalusite, staurolite, garnet, ferrogedrite, chlorite, dumortierite and tourmaline), and by the formation of garnet (+ hornblende) rims between ferromagnesian minerals and plagioclase in amphibolites. The impact of the third phase is displayed by cataclasis and mylonitization, and the incipient formation of low-grade

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mineral assemblages (characterized by minerals such as epidote, zoisite, chlorite, actinolite, albite, prehnite, pumpellyite, stilpnomelane and magnesioriebeckite). This youngest phase of low-grade metamorphism is correlated with the Nickerie Metamorphic Episode, a tectonothermal event affecting western Suriname and southern Guiana and dated by Priem *et al.* (1971) at 1200 ± 100 Ma.

Geological relationships indicate that high-grade metamorphism and anatexis in the Coeroeni Group rocks were older than and unrelated to the Trans-Amazonian magmatism. The present study was undertaken to investigate the isotopic age relationships in this high-grade metamorphic terrain, especially whether there is any age record indicating a substantial pre-Trans-Amazonian history.

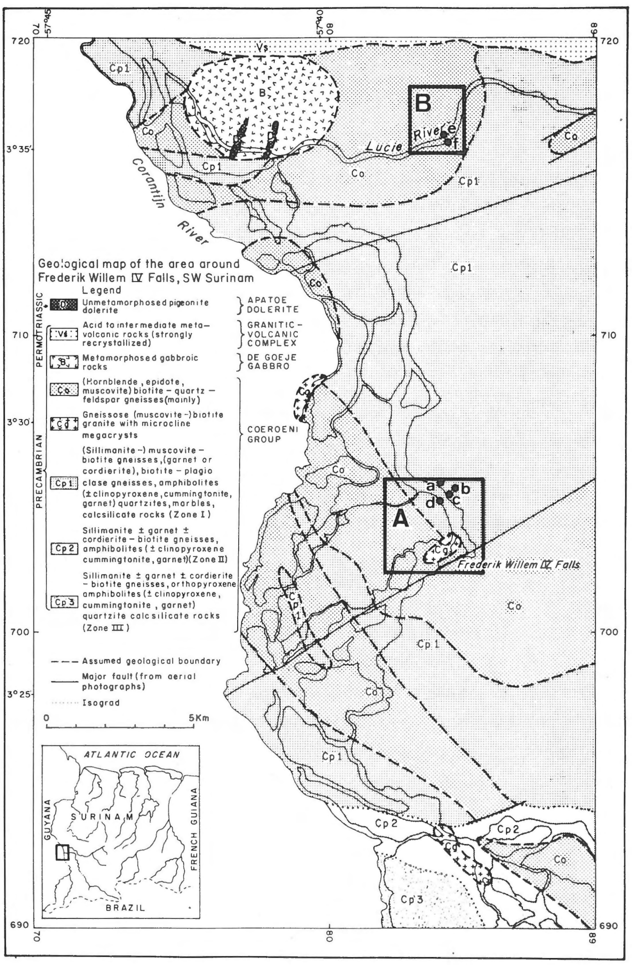

Fig. 1.
Geological map of the Corantijn River area around the Frederik Willem IV Falls and the confluence with the Lucie River in S.W. Suriname (after Kroonenberg, 1976). Ages of the Apatoe Dolerites and the Granitic-Volcanic Complex are 221 ± 10 Ma (Priem et al., 1968) and 1920 ± 40 Ma (Priem et al., 1971), respectively. The investigated Coeroeni Group samples are from core drillings at the sites of the projected spillway in the Corantijn River (area A) and the projected diversion dam in the Lucie River (area B). Sampling locations: a (VCK 4), 75 Sur 179 and 180; b (VCK 10), 75 Sur 181 and 182; c (VCK 11), 75 Sur 183; d (VCK 13), 75 Sur 184; e (VLK 1), 75 Sur 185; f (VLK 4), 75 Sur 186. The spillway in the Corantijn River and the diversion dam in the Lucie River are to be constructed in connection with a hydroelectric power project.

A Rb-Sr whole-rock isochron investigation was made of six samples from core drillings at the site of a projected spillway in the Corantijn River, below the Frederik Willem IV Falls. Separated minerals (green hornblende, biotite and muscovite, all formed during the first phase of metamorphism), both from these samples and from core drillings at the site of the projected diversion dam in the Lucie River, were investigated according to the Rb-Sr and/or K-Ar methods. All investigated samples come from the outer sillimanite-muscovite zone (zone I). They are listed in Table 1 and the sampling sites are shown on the map of Fig. 1. The drill cores below the Frederik Willem IV Falls (samples Sur 179 to 184) consist predominantly of migmatitic biotite gneisses (± muscovite ± sillimanite), with locally intercalated (garnet-)amphibolite layers and, in core drilling VCK 10, a thin layer of siliceous dolomitic marble; they clearly show the effects of the three metamorphic phases. The drill cores from the Lucie River (samples Sur 185 and 186) are fairly homogeneous biotite-hornblende gneisses, locally showing some mylonitization.

EXPERIMENTAL PROCEDURES AND CONSTANTS

Whole-rock powder aliquots were taken from the crushed and pulverized samples. Hornblendes and micas were separated by means of a modified Frantz isodynamic separator (Verschure & IJlst, 1969) and a laboratory overflow centrifuge (IJlst, 1973b) employing a set of stabilized heavy liquids (IJlst, 1973a). The purity of the mineral concentrates was over 99.9%.

Rb, Sr and Rb/Sr were measured by X-ray fluorescence spectrometry for whole-rocks (Verdurmen, 1977) and by mass-spectrometric isotope dilution for micas. Both Rb and Sr were separated by means of ion-exchange chromatography. The $^{87}Sr/^{86}Sr$ ratios were determined directly on unspiked Sr for whole-rocks and calculated from the isotope dilution runs for micas. All isotopic Rb and Sr measurements were made on a 20 cm, 60° Nier-type mass-spectrometer with digital output and multiplier detection; the $^{87}Sr/^{86}Sr$ ratios were adjusted to the value 0.7081 in the Eimer & Amend $SrCO_3$ standard. The errors in the Rb-Sr data are estimated at 1.0% for Rb/Sr, Rb and Sr, 0.2% for $^{87}Sr/^{86}Sr$ measured on unspiked Sr, and 0.5% for $^{87}Sr/^{86}Sr$ calculated from the isotope dilution run. The Rb-Sr isochron and errors were computed by means of a least-squares regression analysis according to York (1966, 1967). The isochron errors are quoted at the 95% confidence level as calculated from the analytical data.

Potassium was analyzed by flame photometry with lithium internal standard and CsAl buffer. Argon was extracted in a bakeable glass vacuum apparatus and determined by isotope dilution techniques in a Reynolds-

75 Sur 179	pegmatite (6.0-7.0 m)	Corantijn River, spillway location below Frederik Willem IV Falls (VCK 4)
75 Sur 180	garnet amphibolite (8.0-10.0 m)	
75 Sur 181	biotite-sillimanite-muscovite gneiss (13.5-14.0 m)	Idem (VCK 10)
75 Sur 182	biotite-sillimanite-muscovite gneiss (17.5-18.0 m)	
75 Sur 183	amphibolite (30.0-31.0 m)	Idem (VCK 11)
75 Sur 184	biotite gneiss (13.0-14.0 m)	Idem (VCK 13)
75 Sur 185	biotite-hornblende gneiss (16.0-17.0 m)	Lucie River, dam location (VLK 1)
75 Sur 186	biotite-hornblende gneiss (11.0-12.0 m)	Idem (VLK 4)

Table 1.
Investigated samples of Coeroeni Group rocks (core drillings). (See Fig. 1).

type glass mass-spectrometer; all measurements were made by the static method. For K and Ar the analytical errors are estimated to be within 1% and 2%, respectively.

The age calculations were made using the following constants:

$$^{87}\mathrm{Rb} : \lambda = 1.39 \times 10^{-11} a^{-1};$$
$$^{40}\mathrm{K} : \lambda_e = 5.85 \times 10^{-11} a^{-1},$$
$$\lambda_\beta = 4.72 \times 10^{-10} a^{-1}, \text{ and}$$
$$\text{abundance } ^{40}\mathrm{K} = 0.0118 \text{ atom percent total K.}$$

Where necessary, ages quoted from the literature have been recalculated.

RESULTS AND DISCUSSION

The Rb-Sr whole-rock data are listed in Table 2 and plotted in the $^{87}Sr/^{86}Sr$–$^{87}Rb/^{86}Sr$ diagram of Fig. 2. Table 3 gives the Rb-Sr and/or K-Ar data and calculated ages of the separated hornblendes and micas; the measured mineral ages are also shown in the diagram of Fig. 3.

A Rb-Sr isochron age of 2042 ± 97 Ma with an initial $^{87}Sr/^{86}Sr$ value of 0.7027 ± 0.0039 is defined by the six whole-rock samples (Fig. 2) and may be interpreted as

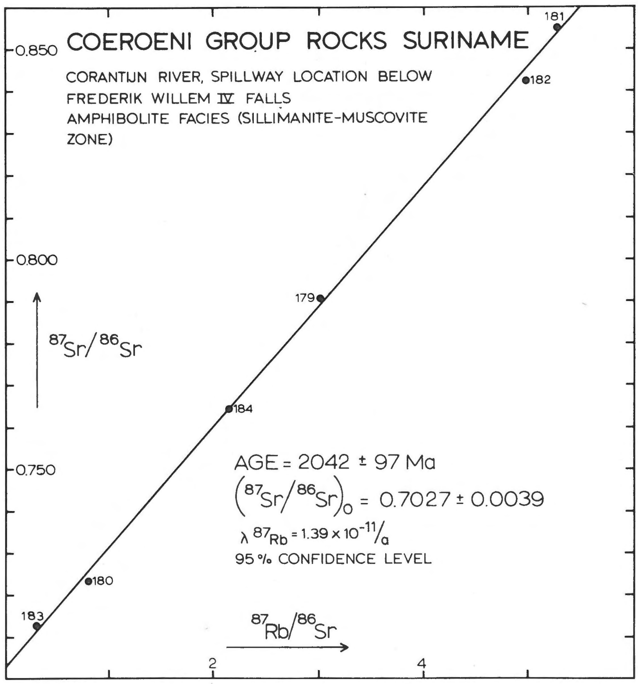

Fig. 2.
Isochron plot of the Coeroeni Group samples.

Sample Nr.	Rb[1)] (ppm Wt)	Sr[1)] (ppm Wt)	Rb/Sr[1)] (Wt/Wt)	$^{87}Sr/^{86}Sr$[2)]	$^{87}Rb/^{86}Sr$
Sur 179	146	142	1.028	0.7908	3.00
Sur 180	34.8	126	0.2773	0.7235	0.804
Sur 181	210	118	1.787	0.8551	5.25
Sur 182	184	109	1.695	0.8426	4.97
Sur 183	17.6	170	0.1036	0.7127	0.300
Sur 184	151	206	0.7350	0.7644	2.14

Table 2.
Rb-Sr whole-rock data of Coeroeni Group Rocks.

1) X-ray fluorescence spectrometry. Mean of duplicate analyses. Estimated error of 1.0% for Rb/Sr.

2) Mean of duplicate analyses. Direct measurements on unspiked Sr. Estimated error 0.2%.

Sample Nr.[1)]	Rb (ppm Wt)	Sr (ppm Wt)	$^{87}Sr/^{86}Sr$	Calculated Rb-Sr age (Ma)[2)]	K (% Wt)	rad. ^{40}Ar (ppm Wt)[3)]	Calculated K-Ar age (Ma)
Sur 180 bio	552	17.3	2.8307	1357 ± 35	6.69	1.00	1452 ± 50
	550	18.6	2.6556		6.71	1.02	
	552	17.4	2.8027			1.06	
						1.06	
Sur 180 hbl					0.492	0.112	1898 ± 60
					0.493	0.116	
Sur 181 bio	672	5.75	27.549	1573 ± 40	7.98	1.29	1514 ± 50
	670	5.78	27.219		7.99	1.33	
						1.31	
Sur 181 mu	299	20.0	1.9850	1843 ± 50	8.83	1.49	1509 ± 50
	299	20.0	1.9821		8.82	1.40	
						1.40	
						1.45	
Sur 182 bio	628	6.81	16.689	1647 ± 45	7.63	1.23	1494 ± 45
	624	6.57	17.055		7.69	1.23	
Sur 182 mu	289	22.9	1.7726	1870 ± 55	8.63	1.43	1568 ± 50
	290	22.8	1.7778		8.52	1.51	
						1.50	
Sur 183 hbl					0.379	0.130	2442 ± 125
					0.371	0.133	
					0.369		
					0.376		
Sur 184 bio	612	9.81	7.7947	1655 ± 40	7.37	1.15	1426 ± 75
	613	9.89	7.7978		7.38	1.07	
Sur 185 bio	366	24.6	1.4975	1219 ± 35+	7.57	1.27	1536 ± 50
	369	25.3	1.4853		7.59	1.27	
Sur 185 hbl					0.988	0.222	1868 ± 55
					0.992	0.224	
Sur 186 bio	369	68.0	0.9756	1178 ± 45+	7.01	0.980	1367 ± 70
	369	67.7	0.9771		7.02	1.010	
Sur 186 hbl					0.909	0.222	1963 ± 60
					0.914	0.223	
					0.920		
					0.912		

Table 3.
Rb-Sr and K-Ar mineral data of Coeroeni Group rocks.

1) bio, biotite; mu, muscovite; hbl, hornblende.

2) Calculated with reference to the Rb-Sr data of the corresponding whole-rock samples (Table 2), except for the figures marked+ which are based upon an assumed initial $^{87}Sr/^{86}Sr$ ratio of 0.710 (the whole-rock samples Sur 185 and 186 have Rb/Sr ratios of 0.069 and 0.074, respectively).

3) The contribution of atmospheric ^{40}Ar to the total ^{40}Ar lies below 7% for all analyses.

reflecting the time of gneissification during the high-grade metamorphism. This age falls within the range of the Trans-Amazonian episode, but may be somewhat higher than the age of the Trans-Amazonian granitic magmatism in Suriname (1920 ± 40 Ma). No pre-metamorphic crustal record is shown by the initial $^{87}Sr/^{86}Sr$ value, which falls within the general range of initial values of crustal rocks. Earlier speculations that there may have been a prolonged time interval between the two phases of high-grade metamorphism, the second belonging to the Trans-Amazonian episode and the first much older (Kroonenberg, 1975b), are thus not supported by the results of this study. The two recorded phases of high-grade metamorphism may be interpreted as representing the successive prograde and retrograde stages of a single metamorphic event in Trans-Amazonian time (see also Kroonenberg, 1976).

The minerals display a highly discordant age pattern of Rb-Sr and K-Ar ages (Fig. 3), but, with the exception of the hornblende in sample Sur 183, all measured ages lie between about 2000 and 1200 Ma. This pattern can be interpreted as reflecting various degrees of resetting of Trans-Amazonian ages due to the Nickerie Metamorphic Episode 1200 ± 100 Ma ago. An order of mineral dates appears as follows: hornblende K-Ar 1910 ± 50 Ma (3 dates), muscovite Rb-Sr about 1860 Ma (2 dates), biotite Rb-Sr ranging from 1650 to 1180 Ma (6 dates), muscovite K-Ar about 1530 Ma (2 dates), and biotite K-Ar ranging from 1540 to 1370 Ma (6 dates). This pattern accords very well with the common order of radiogenic nuclide retentivities towards metamorphic overprinting, except for the biotites in Sur 180, 185 and 186 which have K-Ar dates > Rb-Sr dates. An explanation for the behaviour of the latter biotites may be that during the Nickerie Metamorphic Episode (essentially an event of transcurrent movement, shearing and mylonitization with only low-grade to very-low-grade metamorphism) besides the common heating effects leading to partially or wholly reset ages by diffusive loss of radiogenic Sr and Ar, locally also processes of base-exchange with circulating hydrothermal solutions were operative; as the result of such processes, radiogenic ^{87}Sr would leave the biotite in exchange for common Sr (K u l p & E n g e l s, 1963).

The anomalously high K-Ar age of hornblende Sur 183 has to be explained as a case of excess radiogenic argon. Possibly, this argon was acquired as the result of high external environmental ^{40}Ar pressure due to crustal degassing during the Nickerie Metamorphic Episode (see H e b e d a *et al.*, 1973).

Trans-Amazonian ages have thus been preserved in the hornblende K-Ar and muscovite Rb-Sr systems. All other systems were partially or wholly reset under the greenschist to pumpellyite-prehnite facies conditions prevailing during the Nickerie Metamorphic Episode. The best estimates at present for the temperatures at which minerals become effectively closed systems to radiogenic argon and strontium (diffusion-threshold temperatures) may be taken at 550 ± 50°C for hornblende K-Ar, 500 ± 50°C for muscovite Rb-Sr, about 380°C for muscovite K-Ar, and 300 ± 50°C for biotite Rb-Sr and K-Ar (see, for example, H a n s o n & G a s t, 1967; F r e y *et al.*, 1976). Following these estimates, the discordant age pattern in the Coeroeni Group rocks corresponds to a temperature of the order of 350°C during the Nickerie Metamorphic Episode. Such a temperature fits very well into the conditions of the low-grade to very-low-grade metamorphism indicated by the mineral assemblages formed during this Episode (K r o o n e n b e r g, 1976).

The measured dates falling within the Trans-Amazonian time-span appear to be in the order whole-rock Rb-Sr isochron > hornblende K-Ar > muscovite Rb-Sr. This can be interpreted as the discordant age pattern produced by a slow cooling rate of the crustal block after the termination of the high-grade metamorphic conditions.

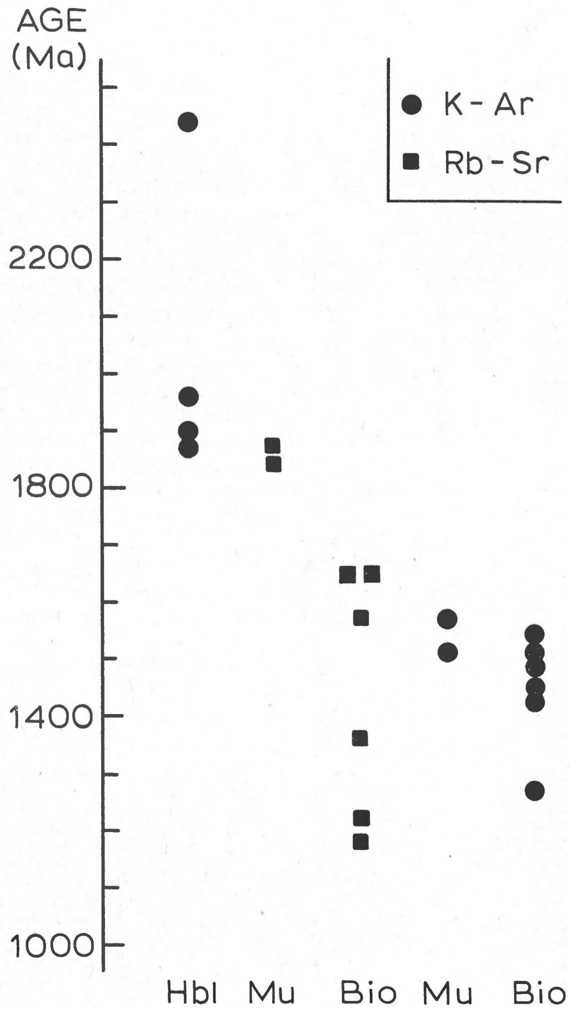

Fig. 3.
Diagram showing the measured Rb-Sr and K-Ar ages of hornblendes, muscovites and biotites from Coeroeni Group rocks.

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