GEOLOGIE EN MIJNBOUW VOLUME 48 (2), p. 201-213 1969

THE GEOCHRONOLOGY OF GUYANA [1])

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ABSTRACT

The Precambrian rocks of Guyana occur in two geological provinces separated by a structural break followed in part by an infilled rift valley which traverses the country to the immediate south of latitude 4°N. North of this structure the folded and more or less metamorphosed sedimentary and volcanic rocks of the Barama-Mazaruni Assemblage and the gneissose granitic rocks of the Bartica Assemblage are intruded by members of the Younger Granite Group, and all are overlain with marked unconformity by the tabular, continental deposits of the Roraima Formation. Both the Roraima Formation and the pre-Roraima rocks are cut by dolerite dykes and sills which constitute the Younger Basic Intrusive Group, including the Roraima Intrusive Suite and a minor dyke suite. Age determinations indicate a younger limit to the post-Barama-Mazaruni-Bartica diastrophism of c.2000 m.y. This diastrophism is now termed the Akawaian episode and is believed to correspond closely in time to the emplacement of most of the Younger Granites. One member of the Mazaruni Group is possibly older than c.2500 m.y. A younger limit to the Roraima Formation of c.1700 m.y. is set by K-Ar and Rb-Sr age determinations on the dolerites of the Roraima Intrusive Suite and on micas of a contact hornfels in the Roraima Formation.

In the southern geological province the major rock unit is the South Savanna Granite which intrudes high-grade gneisses (granulite facies) of the Kanuku Group and metasediments of the Marudi Group. A uranium-lead determination, though affected by uranium leaching, sets a maximum limit to the age of this granite of 2075 m.y., and Rb-Sr determinations indicate emplacement at c.1850 m.y. The granite shows evidence of dynamic metamorphism, and K-Ar determinations on micas suggest an age of c.1200 m.y. for this metamorphism. The Kanuku gneisses and South Savanna granites are cut by dolerite dykes, one of which has been dated at 450 m.y.

INTRODUCTION

The Precambrian rocks of Guyana form part of the geographical and geological unit called the Guiana Shield. It forms the nucleus of the north-eastern part of the South American continent and is divided from its counterpart, the Brazilian Shield, by an early Palaeozoic downwarp now occupied by the wide valley of the Amazon River. In contrast with some of the other great shield areas of the world the Guiana Shield has only recently become the object of intensive geochronological studies.

The present investigation was undertaken in association with the Geological Survey of British Guiana (now Guyana) and the work has been restricted to this territory. Only two age determinations had been made before this and one of these is of dubious value (McConnell, 1958).

OUTLINE OF THE GEOLOGY OF GUYANA

A summary of the geology of Guyana (Figure 1) has been given by McConnell, Williams, Cannon and Snelling (1964), and is now amplified in a more detailed study, unfortunately long delayed in publication (Williams et al., 1967). These authors showed that the country can be divided into two geological provinces (Wilson, 1939) by a structural break, which is followed for a distance of at least 100 miles by an infilled rift valley which traverses the country to the immediate south of latitude 4°N (McConnell, Masson

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[1]) Paper presented at the VII[th] Guiana Geological Conference, Paramaribo, November 1966 (revised April 1968).

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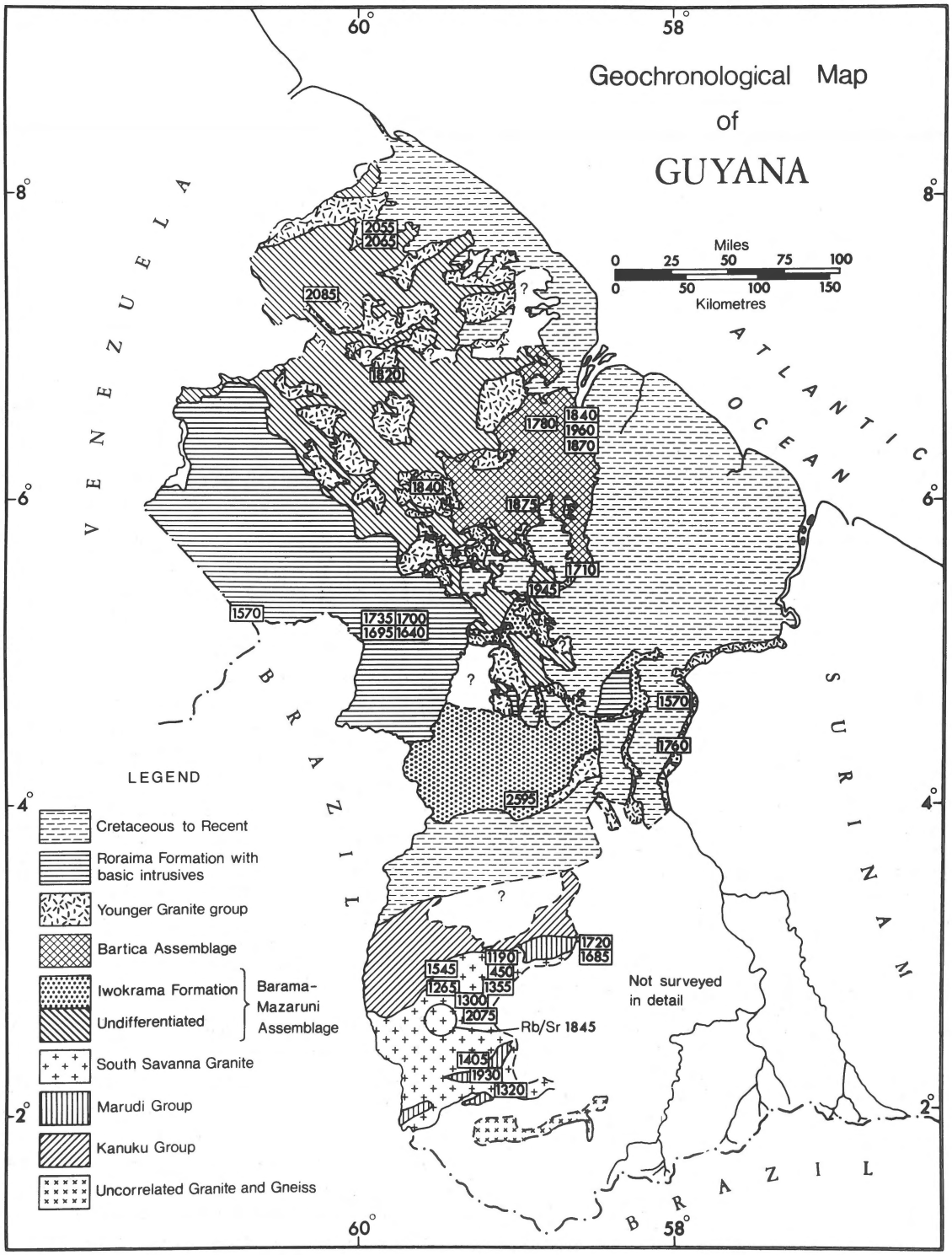


Fig. 1
Diagrammatic geological map of Guyana showing location of specimens dated by Isotope Geology Unit, Institute of Geological Sciences. Ages in millions of years.

TABLE 1

Potassium-argon and rubidium-strontium age measurements on members of the Roraima Intrusive Suite.
Data from McDougall et al. 1963.

Sample No.	Analysed sample	% K	$^{40}Ar.rg/^{40}K$	K:Ar age m.y.	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
GA 687	Plagioclase	0.461	0.1822†	1840	16.9	390	0.1246	0.7053+
"	Pyroxene	0.0573	0.1641	1720	-	-	-	-
"	K feldspar	-	-	-	340.6	257.3	3.809	0.7935+
"	Whole rock	-	-	-	39.6	234.5	0.486	0.7163+
GA 688	Plagioclase	0.444	0.1705	1760	18.7	430	0.125	0.7056+
"	Pyroxene	0.0708	0.1604	1690	3.08	24.0	0.369	0.7135+
"	K feldspar	-	-	-	331.9	145.2	6.575	0.8577*
"	Whole rock	-	-	-	105.4	154.3	1.964	0.7538+
GA 689	Plagioclase	0.4123	0.2227	2085	-	-	-	-
"	Whole rock	-	-	-	17.4	209.5	0.239	0.7087+
GA 690	Plagioclase	0.741	0.1476	1600	-	-	-	-
"	Pyroxene	0.164	0.1568	1670	-	-	-	-
GA 691	Plagioclase	0.419	0.1553	1660	-	-	-	-
"	Pyroxene	0.110	0.1397	1540	-	-	-	-
GA 692	Plagioclase	0.660	0.1486	1610	-	-	-	-
"	Pyroxene	0.139	0.1567	1670	-	-	-	-

† Average of two argon determinations. $+^{87}Sr/^{86}Sr$ ratio measured. $*\ ^{87}Sr/^{86}Sr$ ratio calculated.

Decay constants. ^{87}Rb-^{87}Sr $\lambda = 1.39 \times 10^{-11} yr^{-1}$. ^{40}K $\lambda\beta = 4.72 \times 10^{-10} yr^{-1}$. e $0.584 \times 10^{-10} yr^{-1}$.

Isotopic abundance of ^{40}K = 0.0119 atom percent.

Sample location:

GA 687 Quartz dolerite from a horizontal sill intruding the Roraima Formation. Kamarang Airstrip at confluence of Kamarang and Mazaruni rivers. 5°53′N. 60°36′W.
GA 688 Pegmatitic dolerite from same sill as GA 687 and same locality.
GA 689 Quartz dolerite from lower zone of the Main Sill intruding the Roraima Formation. Near Muribang River. 4°57′N. 59°41′W.
GA 690 Quartz dolerite from a sheet intruding basement rocks, North East Ridge. 6°8′N. 59°39′W.
GA 691 Quartz dolerite from the centre of the Tumatumari intrusion. 5°22′N. 59°00′W.
GA 692 Quartz dolerite from the Eagle Moutain sill intruding the plane of unconformity between the Roraima Formation and the basement. 5°14′N. 59°07′W.

Smith and Berrangé, 1967). South of this structure the granulitic biotite-garnet and charnockitic gneisses of the Kanuku Group and the metasediments of the Marudi Group, both intruded by the extensive South Savanna Granite (Singh,-1966), constitute the Rupununi Assemblage. North of this structure we have the Barama-Mazaruni Assemblage formed by a great variety of more or less metamorphosed sedimentary and volcanic rocks, folded and impressed with a steeply dipping foliation, and the gneissose granitic rocks of the Bartica assemblage believed to have been formed by granitization of the Barama-Mazaruni Assemblage, itself invaded by a series of granites which are in part

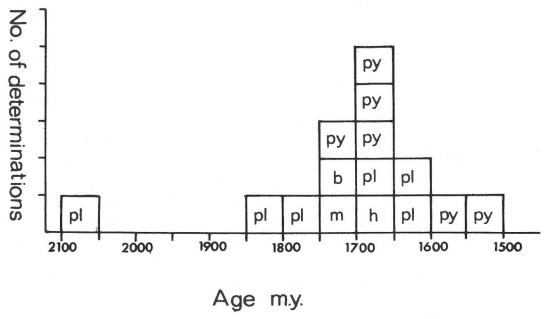


Fig. 2
Distribution diagram of K-Ar age determinations on minerals from the dolerites of the Roraima Intrusive Suite, and on micas from a hornfels-shale of the Roraima Formation overlying the Main Sill. py = pyroxene; pl = plagioclase feldspar; m = muscovite; b = biotite; h = hornblende. Analytical data are given in tables 1 and 2.

conformable and in part cross-cutting. This is the Younger Granite Group which may be composed of granites of different ages but which are younger than the Barama-Mazaruni Assemblage and older than the Roraima Formation.

The main orogeny of the Barama-Mazaruni and the emplacement of the Younger Granite Group was followed by deep erosion and on the resultant erosion surface a thick deposit of sandstone and conglomerates of detritic continental origin (the Roraima Formation) was laid down.

The deposition of the Roraima Formation was followed by a period of tensional faulting during which doleritic and gabbroic rocks of the Younger Basic Intrusive Group were emplaced on lines varying from N-S to ENE-WSW. H a w k e s (1966a; 1966b) has shown them to be divided into two distinct suites, the Roraima Intrusive Suite (Precambrian) and the Minor Dyke Suite (? Mesozoic). The former are defined as a consanguineous suite of tholeiitic dolerites which have been strongly differentiated and occur in the Roraima Formation as two massive sills, termed the Main Sill and the High Level Sill, and also cut the underlying Younger Granites and rocks of the Barama-Mazaruni Assemblage as dykes, inclined

TABLE 2
Potassium-argon and rubidium-strontium age measurements on members of the Roraima Intrusive Suite and metamorphosed Roraima Shale. Determinations by Age Determination Unit. Overseas Geological Surveys.

Reference No.	Analysed sample	% K	$^{40}Ar.rg/^{40}K$	K:Ar age m.y.	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
OGS.63.7. OGS.64.22	Muscovite	7.97	0.1665	1735	494.7	68.7	22.28	1.369+
OGS.63.8 OGS.64.23	Biotite	6.27	0.1614	1700	601.0	24.6	85.53	2.826*
OGS.63.9	Hornblende/pyroxene	0.24	0.1559	1665				
OGS.63.80	Pyroxene	0.068	0.1432	1570				

Decay constants as in Table 1. $^{+87}Sr/^{86}Sr$ ratio measured. $^{*87}Sr/^{86}Sr$ ratio calculated.

Sample location:

OGS.63.7 & 8, OGS.64.22 & 23 — Mica hornfels, immediately at upper contact of Main Sill, Kopinang River valley

OGS.63.9 — Dolerite from the middle zone of the Main Sill three mls. true north of Velgraad airstrip

OGS.63.80 — Dolerite from the western scree slopes of Mt. Roraima, at approximately 5°12′N; 60°47′W. The source of this sample is the High Level Sill intruded between the middle and upper members of the Roraima Formation. Its base in this area lies at about 5000 ft above sea level (Vailey, 1961).

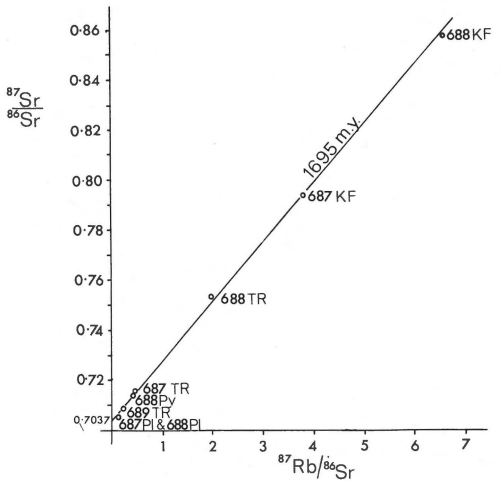


Fig. 3
Plot of $^{87}Rb/^{86}Sr$ versus $^{87}Rb/^{86}Sr$ for the Roraima Intrusive Suite. TR = total rock; KF = potassium feldspar; Pl = plagioclase feldspar; Py = pyroxene. Data from McDougall, Compston and Hawkes, 1963. See also table 1.

sheets and sills. The Minor Dyke Suite comprises numerous small dykes of undifferentiated dolerite, not exceeding 150 m in width.

AGE DETERMINATION

(a) *The Roraima Intrusive Suite and Roraima Formation*

The Roraima Intrusive Suite includes some of the best dated rocks in the country (McDougall, Compston and Hawkes, 1963; Snelling, 1963 and 1964). The results of all the relevant K-Ar determinations are shown diagramatically in Fig. 2 and the analytical data are given in tables 1 and 2. The Rb-Sr data from the basic intrusives are plotted in Fig. 3 in such a way that for a co-genetic and co-eval group of igneous rocks the co-ordinate points will fall on a straight line (conventionally described as an isochron) the slope of which is directly proportional to their age (Nicolaysen, 1961). In the present instance the points for the analysed total rocks and individual minerals fall on an isochron corresponding to an age of *1695 ± 66 m.y. This is in excellent agreement with the maximum between 1650 and 1700 m.y. on the K-Ar distribution diagram.

* Value revised according to procedure of York (1966).

The same treatment has been given in Fig. 4 to rubidium-strontium determinations on the biotite and muscovite from a mica hornfels contact rock overlying the Main Sill at the head of the Kopinang River whose K-Ar ages were previously reported (Snelling, 1963). The age as calculated (1640 ± 30 m.y.) is again in good agreement with the values quoted above, though lower than the K-Ar ages of 1735 and 1700 m.y. (Table 2). In calculating this age it must be assumed that during thermal metamorphism of this Roraima Formation shale the growth of the metamorphic minerals was accompanied by strontium isotope homogenization.

The data on the dolerites were interpreted in a different way by McDougall et al. (1963), who carried out 13 K-Ar determinations which gave ages ranging from 1540 m.y. to 2091 m.y. Weighting their average in favour of the oldest ages (two determinations on plagioclase from GA 689) they therefore adopted an age of 2085 ± 40 m.y. for the Main Sill (Hawkes, 1966a), although suggesting that other sills might be younger. In this connection the writers think it is important to note that both samples (GA 687 and 689) giving a high K-Ar age were collected just below widely developed planation surfaces shown by Bleackley (1964, Fig. 14 and Pl. 14A) to have been subjected to intense leaching with the development of exceptionally thick laterites, it is therefore suggested that potassium may have been leached from the rock at this point, thus lowering the original K-Ar ratio. Evidence has since been given (McConnell, 1966) that these plana-

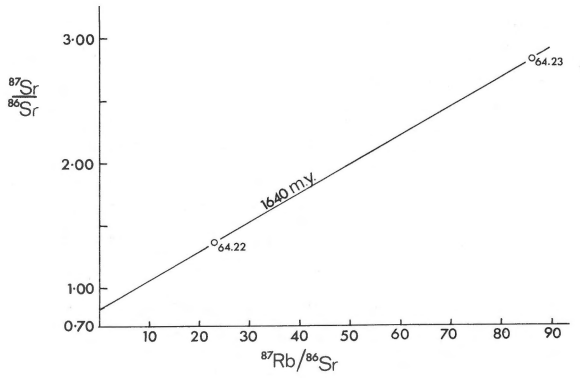


Fig. 4
Plot of $^{87}Rb/^{86}Sr$ versus $^{87}Rb/^{86}Sr$ for micas from a hornfels-shale overlying the Main Sill, Roraima Intrusive Suite. Data in table 2.

tion surfaces, termed the Kaieteur and Kopinang surfaces, have a wide extension throughout the Guiana Shield and hence represent major horizons of tropical weathering. On the other hand the possibility of these high ages being due to excess argon has been suggested by Priem et al. (1968).

Considering their Rb and Sr determinations McDougall et al. (loc. cit.) further proposed that the best estimate of the age of the Kamarang sill (Main Sill) was 1850 m.y. This result was given by the two whole rock samples from this locality, GA 687 and 688 (Table 1). They noted that the potassium feldspars from these two samples gave younger apparent ages and this, they suggested, was due to the leakage of radiogenic strontium. Sample 688 contains a relatively large amount of potassium feldspar and they considered it reasonable to suspect that the whole-rock sample also may have lost a small fraction of its total radiogenic strontium. They thus concluded that 1850 m.y. may only be a minimum age for this particular dolerite. They suspected that a better estimate of the true age of the dolerites could be obtained by excluding the points for 688 whole-rock and the two potassium feldspars from consideration. By following this procedure they obtained an age of 2170 ± 280 m.y. by least squares fit to the points for 687 whole-rock, 687 plagioclase, 688 pyroxene and plagioclase and 689 whole-rock. Relating this age with that which they had adopted from their potassium-argon measurements. McDougall et al. proposed an age of at least 2090 m.y. for the dolerites now shown to belong to the Main Sill, although suggesting that some of the intrusives might be younger.

The writers accept that the scatter of the points about the best fit isochron may well be greater than can be attributed to experimental error alone and that this carries with it the implication that all the sills may not necessarily be exactly the same age, that the isotopic composition of their strontium at the time of intrusion may have varied slightly, and that the analysed specimens may not have remained closed chemical systems with respect to Rb and Sr. However, in view of the limited data available, we cannot accept that it is possible to exclude some of the specimens from consideration and in arriving at an estimate of the Rb-Sr age of these dolerites we consider it best to give all the data equal weight.

On balance the writers favour an age of 1695 ± 66 m.y. for the Roraima Intrusive Suite. We would consider this to be a "best estimate" and would not altogether exclude the possibility that the dolerites were intruded during a relatively long period of time and that some may be as old as 1850 m.y. However, we are unconvinced by the arguments of McDougall et al. that the Lower Kopinang and Kamarang sills are circa 2100 m.y. old. If such a high age is accepted it becomes necessary to postulate considerable loss of both radiogenic argon and strontium from nearly all the samples analysed (in all six distinct mineral species) and to attribute this to some metamorphic event for which there is no other evidence. Furthermore there is considerable evidence that the pre-Roraima rocks of Guyana and Surinam were subjected to a major tectono-magmatic event at circa 2000 m.y. - the Akawaian episode. This diastrophism sets an older limit to the age of the Roraima Formation and its basic intrusives, in addition, time must be allowed for uplift following the Akawaian episode, for the development of the pre-Roraima erosion surface, and for the deposition of the Roraima Formation itself, before intrusion of the dolerites.

The younger age for the dolerites of the Roraima Intrusive Suite is supported by recent work by Priem, Hebeda, Boelrijk and Verschure (1968) who have divided the dolerites in Surinam into two main periods of intrusion which they correlate with the Roraima Intrusive Suite and the Minor Dyke Suite as defined by Hawkes (1966a). The dolerites of the earlier intrusive period are dated 1690 ± 100 m.y. ago on the basis of K-Ar determinations of 4 specimens, and were found to be petrologically similar to the tholeiitic and highly differentiated Roraima Intrusive Suite.* The age of the younger group of undifferentiated dolerites is given as 221 ± 10 m.y., corresponding to the Permo-Triassic period.

Some additional comment is necessary concerning the age of the Roraima Formation. Barbosa and Ramos (1959) have suggested that it really con-

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* Priem, Boelrijk, Hebeda, Verschure and Verdurmen (1968a) have also reported a Rb-Sr whole rock determination on a "porphyry-tuff" from the upper part of the Roraima Formation at Tafelberg, Surinam, which gives an age of 1717 ± 60 m.y. (recalculated using a half-life of ^{87}Rb of 5.0×10^{10} yrs; these workers consider that both the deposition of the Roraima sediments and the subsequent intrusion of dolerites took place, approximately, 1600-1700 million years ago.

TABLE 3

Age determinations on samples from the Barama-Mazaruni and Bartica Assemblages. Decay constants as in table 1.

Reference No.	Sample	% K	^{40}Ar.rg./^{40}K	Age m.y.
OGS.63.5/Z.205	Aegirine augite	0.49	0.2189	2065 ± 100
OGS.64.17/T.520	Hornblende	0.515	0.2229	2085 ± 100
OGS.61.42/F.1725	Muscovite	8.12	0.2018	1960 ± 60
OGS.64.14/F.1374A	Muscovite	8.57	0.1867	1870 ± 55
OGS.63.22/F.1720	Biotite	7.83	0.1727	1780 ± 55
OGS.64.12/F.1373A	Biotite	7.57	0.1824	1840 ± 50
OGS.63.49/M.552	Biotite	6.47	0.1881	1875 ± 55
OGS.64.18/F.2894A	Hornblende	0.645	0.1987	1945 ± 100
OGS.64.10/T.406	Biotite	6.44	0.1818	1840 ± 50
OGS.64.11/F.2864A	Biotite	6.84	0.1628	1710 ± 50
OGS.63.51/Cour. 2	Biotite	7.70	0.1435	1570 ± 50
OGS.63.50/C.868	Biotite	7.60	0.1698	1760 ± 55
OGS.64.16/C.2908	Total rock	1.67	0.1792	1820 ± 80
OGS.64.14/G.154	Riebeckite	0.59	0.3266	2595 ± 125

Nature and location of sample

OGS.63.5/Z.205 * Kaituma granite. Quarry near Kaituma 7°43′N, 59°25′W. Younger granite intruding Barama Group.

OGS.64.17/T.520 Hornblende-biotite gneiss. Gneiss complex in Upper Barama River. 7°17′N, 60°13′W.

OGS.61.42/F.1725 Kartabu granite. A late phase of the Bartica granitization. Kartabu quarry, near Bartica. 6°22′N, 58°42′W.

OGS.64.14/F.1374A Leucocratic facies of Kartabu granite, location as above.

OGS.63.22/F.1720 Porphyroblastic gneiss from Bartica Assemblage. 6°10′N, 58°35′W.

OGS.64.12/F.1373A Augen gneiss within biotite gneisses. Ampa Bay Quarry, Essequibo River. 6°31′N, 58°34′W.

OGS.63.49/M.552 Hornblende-biotite gneiss, Puruni Mouth, Mazaruni River. 6°01′N, 59°13′W.

OGS.64.18/F.2894A Tigri granite (adamellite), Essequibo River. Younger Granite Group. 5°24′N, 58°52′W.

OGS.64.10/T.406 Adamellite from centre of the Morabisi granite, Younger Granite Group. 6°6′N, 59°40′W.

OGS.64.11/F.2864A Trondhjemite from Mariaba granite, Younger Granite Group. Essequibo River. 5°29′N, 58°39′W.

OGS.63.51/Cour.2 Uncorrelated granite, Governor Falls, Corentyne River. 4°38′N, 57°50′W.

OGS.63.50/C.868 Uncorrelated granite, Wanatoba Falls, Corentyne River. 4°20′N, 58°00′W.

OGS.64.16/C.2908 Fine-grained quartz-mica schist, Cuyuni River. 6°48′N, 59°43′W. Cuyuni River Formation, Mazaruni Group.

OGS.64.14/G.154. Riebeckite from Makarapan granite intrusive into granophyres within the Iwokrama Formation of the Mazaruni Group. 3°59′N, 58°47′W.

*A Rb-Sr determination has been made on the potash feldspar from this granite with the following results:

OGS.65.19/Z.205. Potash feldspar, Kaituma granite. Location as above.

Rb ppm 595.6. Sr ppm 195.8 ^{87}Rb/^{86}Sr 9.012

^{87}Rb/^{86}Sr 0.9665.

Age (assuming initial ^{87}Rb/^{86}Sr of 0.705) = 2055 ± 100 m.y.

sists of two formations of quite different ages, the boundary occuring at the slight unconformity which locally separates the lower and middle Roraima of Guyana, and that the upper formation is Carboniferous or younger. Determination 63.80 (table 2) was made specifically to test this view, the pyroxene being separated from a dolerite derived from the High Level Sill which marks the boundary between the middle and upper members of the Roraima Formation in the Mt. Roraima area (Bailey, 1961; Bateson, 1966). The age determination leaves no doubt that the whole of the Roraima Formation is of comparable antiquity.

(b) *The Barama-Mazaruni and Bartica Assemblages*

The dominantly argillaceous metasediments of the Barama Group and the overlying greywackes and volcanics of the Mazaruni Group together with their granitized equivalents, which constitute the Bartica Assemblage, extend across northern Guyana. Towards the south the predominantly volcanic rocks of the Iwokrama Formation have been included in the Mazaruni Group and are intruded by the Makarapan granite, the riebeckite of which has given a K-Ar age of 2595 m.y. (table 3). This determination appears to set a younger limit to the age of the Iwokrama Formation and probably to the sediments and volcanics in the Barama and Mazaruni Groups generally, however it needs further confirmation before any definite conclusions can be drawn.

All the other ages relevant to the Barama-Mazaruni and Bartica assemblages are significantly younger than 2595 m.y. and probably reflect a major pre-Roraima diastrophism. The younger limit to this diastrophism is believed to be set by rubidium-strontium and potassium-argon ages on minerals from the post-Barama Group Kaituma Granite (2055 m.y.

and 2065 m.y. respectively) and potassium-argon ages of 1945 m.y. on hornblende from the Tigri Granite which intrudes volcanics of the Mazaruni Group, 1960 m.y., on muscovite from the Kartabu Granite, a late phase of the Bartica metamorphic episode, and 2085 m.y. on hornblende from gneisses along the upper Barama River which may be equivalent to the Bartica Assemblage. Each of these determinations has an experimental uncertainty of about ± 90 m.y. so little significance can be attached to the differences and their average of 2015 ± 80 m.y. (say c.2000 m.y.) can be accepted as the best estimate of the younger limit to the post-Barama-Mazaruni-Bartica diastrophism.

It should be emphasized that this age is an average obtained by selecting the maximum age from the main units and it does not necessarily represent any specific geological event. However, it is highly likely that in fact it corresponds closely to the time of intrusion of some of the Younger Granites. We consider that this phase of granite emplacement is now reasonably well defined and it is proposed to designate it as the *Akawaian episode* (Williams, Cannon and McConnell, 1967).

Ages by both the potassium-argon and rubidium-strontium methods of 1800-2000 m.y. have also been reported by Choubert (1964) from French Guiana and Priem, Boelrijk, Verschure and Hebeda (1966 and 1967) from Surinam. The analysed samples were micas and total rocks from granites and pegmatites which, in the main, can probably be correlated with the Younger Granite Group of Guyana. Choubert also lists some ^{207}Pb: ^{206}Pb ages on uranium bearing minerals. Most of these results give ages of circa 2000 m.y. but one alluvial zircon gives an age of 3880 m.y. (average of four determinations). These results must be treated with caution. Not only was a new analytical method used, but since only ^{206}Pb: ^{206}Pb ages were given, it is impossible to say whether or not there had been any recent leaching of uraniam or lead and hence the reliability of the ages cannot be adequately assessed. These remarks apply particularly to the high age of 3880 m.y. As far as the writers are aware there are no other reliable terrestrial ages of such great antiquity and the possibility of loss of uranium or radon, both of which will lead to high ^{207}Pb: ^{206}Pb ages, must certainly be considered in this instance.

It will be observed that some of the other K-Ar

TABLE 4

Potassium-argon age determinations on samples from the Rupununi Assemblage. Decay constants as in table 1.

Reference No.	Sample	% K	$^{40}Ar_{rg.}/^{40}K$	Age m.y.
OGS.63.67/X.383	Biotite	8.19	0.0971	1190 ± 45
OGS.63.66/Tabtau	Biotite	8.28	0.1096	1300 ± 50
OGS.63.71/X.279	Biotite	7.28	0.1052	1265 ± 50
OGS.63.70/X.421	Muscovite	9.13	0.1641	1720 ± 70
OGS.63.75/X.421	Biotite	7.63	0.1590	1685 ± 70
OGS.63.72/X.399	Biotite	7.69	0.1400	1545 ± 60
OGS.61.33/A.116	Biotite	7.19	0.1161	1355 ± 55
OGS.62.63/W.390	Biotite	8.31	0.1118	1320 ± 50
OGS.62.73/W.387	Biotite	8.15	0.1220	1405 ± 55
OGS.63.73/C.7	Biotite	5.22	0.1967	1930 ± 70
OGS.64.26/X.238	Plagioclase	1.02	0.0295	450 ± 25
OGS.64.27/X.238	Pyroxene	0.096	0.0296	450 ± 40

Nature and location of sample

OGS.63.67/X.383	Strongly porphyritic biotite granite – South Savannas. 1 ml. S.E. of Shiwirtau. 2°55′N, 59°12′W.
OGS.63.66/Tabtau	Tabtau granite – South Savannas. Tabtau mountain. 2°52′N, 59°16′W.
OGS.63.71/X.279	Strongly cataclased porphyritic biotite granite – South Savannas. The biotite in this specimen is thought to have undergone complete recrystallization during shearing. Sand Creek bed, 0.5 ml. S. of Cheppirariwau mouth. 2°55′N. 59°18′W.
OGS.63.70/X.421) OGS.63.75/X.421)	Strongly porphyritic biotite granite, Rewa River 3°02′N, 58°40′W.
OGS.63.72/X.399	Low-grade unmigmatized biotite schists forming an enclave in South Savanna Granite, and occurring in the Milliwau Creek, Kwitaro River. These schists are tentatively equated with Marudi Group rocks. 3.5 mls. W. of Milliwau mouth, 3°03′N. 58°55′W.
OGS.61.33/A.116	South Savanna Granite, near Awariwau, 2°38′N, 59°13′W.
OGS.62.63/W.390	South Savanna Granite? , Bat Mountain 2°10′N, 59°10′W.
OGS.62.73/W.387	Marudi granite. 2°15′N. 59°12′W.
OGS.63.73/C.7	Mica schists of the Marudi Group. 2°15′N, 59°12′W.
OGS.64.26/X.238) OGS.64.27/X.238)	Fresh dolerite dyke composed of plagioclase, pyroxene, interstitial quartz, potassium-feldspar and minor iron oxide. Cutting South Savanna Granite near Arakwai mouth. 3 mls. S. of Dadanawa. 2°47′N. 59°32′W.

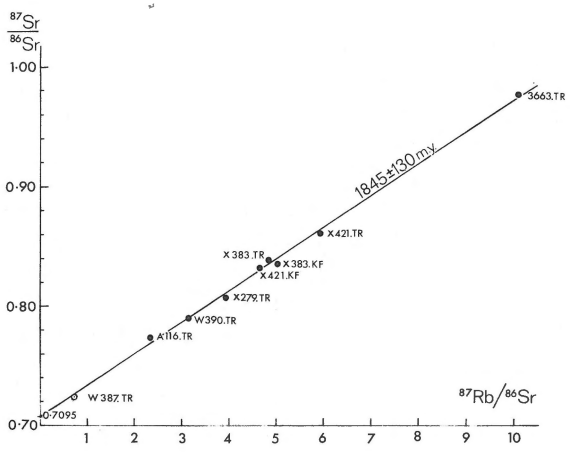


Fig. 5
Plot of $^{87}Rb/^{86}Sr$ versus $^{87}Sr/^{86}Sr$ for the South Savanna Granite as explained in text. Analytical data given in table 5. TR = total rock; KF = potassium feldspar.

determinations on micas from these pre-Roraima rocks are appreciably younger than c.2000 m.y. and that the discrepancies are probably greater than could be attributed to experimental errors. To some extent the younger ages may well indicate emplacement of the Younger Granites over an extended period of time. However, ages younger than about 1800 m.y. must almost certainly be attributed to argon loss since there is no evidence of post-Roraima granites. Micas rarely show evidence of 100% argon retentivity and losses of up to 5% probably occur in consequence of slight lattice imperfections. Furthermore, the potassium-argon age reflects not so much the time of crystallization of the rock or mineral concerned, but rather the time when the temperature of the rock fell below some threshold value, above which argon was able to diffuse out of the mineral as soon as it was formed, and below which such diffusion virtually ceased. It has been argued that for micas this threshold temperature may be as low as 100°C (Hurley, Hughes, Pinson and Fairbairn, 1962). In simple geological environments such as a relatively shallow igneous intrusion in a non-orogenic region, cooling is rapid, the threshold temperature is reached soon after actual crystallization, and the apparent age is for all intents and purposes the same as the time of intrusion. Such a situation is envisaged for the Roraima Intrusive Suite. In a deep-seated, regionally metamorphosed environment, however, temperatures may remain above this threshold value for micas for relatively long periods after initial crystallization. It is possible that in this segment of the Guyanese basement, temperatures remained above the critical value for micas at least until the regional uplift which must have accompanied the development of the pre-Roraima erosion surface. This could well have been as recent as 1800 m.y. Argon loss from the micas in these pre-Roraima rocks may also have been brought about by the thermal effects of the Younger Basic Intrusives at c.1700 m.y. and by volcanic activity during the deposition of the Roraima Formation, as indicated by the presence of tuffs.

(c) The Rupununi Assemblage

As indicated above the rocks of the Rupununi Assemblage constitute a separate province. The largest lithological unit is the South Savanna Granite which intrudes high grade gneisses of the Kanuku Group and metasediments of the Marudi Group. These rocks are fortunately well exposed in savannas

TABLE 5

Rubidium-strontium age determination data from the South Savanna Granite.

Reference No.		Rb ppm	Sr ppm	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr$
OGS.65.15	3663.T.R.	326.1	95.9	10.082	0.977
OGS.65.13	X421.T.R.	281.5	139.7	5.905	0.861
OGS.65.14	X421.K.F.	346.2	217.4	4.628	0.832
OGS.65.11	X383.T.R.	186.1	113.1	4.814	0.838
OGS.65.12	X383.K.F.	298.9	173.7	5.033	0.835
OGS.65.10	X279.T.R.	210.8	156.2	3.938	0.807
OGS.65.18	W390.T.R.	192.0	176.8	3.171	0.790
OGS.65.17	A116.T.R.	152.8	191.2	2.321	0.774

0.7095 ± 0.0042

Data for OGS.65.16 W.387 W.R. Marudi granite, see table 4.

Rb 39.3 Sr 357.8 $^{87}Rb/^{86}Sr$ 0.724 $^{87}Sr/^{86}Sr$ 0.724

Notes:
(1) For sample location refer to Table 4. Sample OGS.65 3663. T.R. is the same specimen as OGS.63.66/Tabtau in Table 4.
(2) T.R. = total rock and K.F. = potash feldspar.
(3) Ages calculated for $\lambda = 1.39 \times 10^{-11} yr^{-1}$.
(4) Rb and Sr determined by isotope dilution analysis. In all cases the $^{87}Sr/^{86}Sr$ ratio was measured directly.
(5) The slope and intercept of the Rb-Sr isochrons reported in this paper have been determined following the procedure developed by York (1966).

and hills, and Barron summarized the geological history of the area as follows (Barron, 1962, p. 23) "The South Savanna Granite was emplaced within an assemblage of metamorphic rocks, including the Kanuku Group gneisses of the granulite and amphibolite facies in the northwest, and the Marudi and Kuyuwini Groups of the amphibolite facies in the south-west. Notable boundary effects of the South Savanna Granite are the developments of the Kusad and the Mushiwau granodiorites. At some later date the rocks were subjected to crustal stresses which commonly caused recrystallization of the biotite and locally culminated in the development of mylonite".

So far age determination work has been virtually restricted to the South Savanna Granite and other granitic rocks. No reliable determinations have as yet been made on the gneisses of the Kanuku Group and only one determination has been made on a biotite from the metasediments of the Marudi Group. The resultant age of 1930 m.y. (table 4: 63.73) sets a reliable younger limit to the age of these metasediments.

Potassium-argon ages on micas from the South Savanna Granite range from 1190-1720 m.y. (table 4) and are considered to reflect the effects of the essentially dynamic metamorphism recognized by Barron. The best estimate of the age of this metamorphism is given by the youngest K-Ar ages i.e. circa 1200 m.y. It is of interest to note that a chemical age of 1090-1160 m.y. was determined in 1941 on an euxenite which appears to have been derived from a mylonite zone in the Kanuku gneisses (McConnell 1958, p. 42); although the uncertainties of the chemical age and the doubts about the actual paragenesis of this mineral limit the usefulness of this age, it is at least in accordance with the above observations. The best estimate of the time of intrusion of the South Savanna Granite was considered to be given by U : Pb and Th : Pb determinations on an eluvial monazite derived from this granite (Darnley, 1960). The calculated ages are slightly discordant and range from 2075 and 2305 m.y. Darnley recommended the Th : Pb age of 2270 m.y. The significance of this stage has been questioned by Singh (1965 and personal communication) who suggested that the monazite might be xenocrystic and have been derived from enclaves which are abundant in some areas. Rubidium-strontium age determinations were made in the hope that the results might resolve this ambiguity. The analytical data are given in table 5 and isochron plot is shown in fig. 5.

In fig. 5 the slope of the isochron has been calculated from total rock and potash feldspar data derived from samples which unquestionably represent South Savanna Granite, together with the sample of the Bat Mountain Granite. This granite is separated from the main body of the South Savanna Granite by the schist belt of Marudi Mountain. Lithologica lly it is identical with the South Savanna Granite. It will be noticed that the two potash feldspars fit the isochron as well as the total rock samples indicating that the metamorphic episode which disturbed the radioactive K-Ar clocks in the micas was not sufficiently intense to disturb the Rb-Sr relationships in the potash feldspars. Calculation of the isochron slope excluding the feldspar data does not significantly affect the results. The Marudi granite sample W.387 has not been included in the calculation since geological evidence indicates that it is intrusive into the main mass of the South Savanna Granite (Carter, 1962). The age calculated from the isochron slope is given in fig. 5. Pending evidence to the contrary 1845 ± 130 m.y. (say c.1850 m.y.) is here adopted as the best estimate of the time of emplacement of the South Savanna Granite.

As indicated above the Marudi granite data were excluded from these discussions since the field observations suggest that this rock mass may be neither co-eval or co-genetic with the South Savanna Granite. The Rb-Sr ratio of this sample is so low that a meaningful age cannot be calculated and the fairly good fit of this sample to the isochron is not necessarily of any geochronological significance. The best estimate of the age of this rock unit is given by the K-Ar determination (Table 4, OGS.62.73.) but because of the pervasive effects of the shearing referred to above this can only be regarded as a younger limit.

It is of course inevitable that comparison will be made between the isochron age of c.1850 m.y. and the Th:Pb age recommended by Darnley from monazite believed to have been derived from the South Savanna Granite. At first glance the results would appear either to support Singh's view that the monazite is xenocrystic, or suggest that the South Savanna Granite is in fact a composite body made up of granites of different ages. However, the ages calculated by Darnley are slightly discordant and show a somewhat unusual but nevertheless character-

istic pattern. The enrichment in radiogenic lead is so great that uncertainties in the common lead correction have no significant effect on the ages and the slight discordance must be attributed to gains and/or loss of parent and/or daughter isotopes. As far as the uranium isotopes and the ^{206}Pb and ^{207}Pb isotopes are concerned the discordant pattern of $t(^{207}Pb/^{206}Pb) < t(^{207}Pb/^{235}U) < t(^{206}Pb/^{238}U)$ can be adequately explained by assuming uranium loss; if this is the case the best age is given by the $^{207}Pb/^{206}Pb$ ratio and even this could be too high depending on the time when the loss of uranium occurred (Kulp, Bate and Broecker, 1954). Bearing in mind the experimental errors involved the $^{207}Pb/^{206}Pb$ age of 2075 m.y. probably does not differ significantly from the Rb-Sr isochron age.

The age of the mica from the Marudi Group schists is very similar to the isochron Rb-Sr age of the engulfing South Savanna Granite suggesting that the metamorphism of these schists may have occurred contemporaneously with the orogeny that saw the emplacement of the South Savanna Granite.

The gneisses of the Kanuku Group and the South Savanna Granite itself are cut by dolerite dykes. These are unsheared and unmetamorphosed and clearly post-date the regional shearing. Age determinations on one sample indicate a Middle Ordovician age (table 4).

The similarity of the ages given by the South Savanna Granite in the Southern Province and the members of the Younger Granite Group of the Northern Province is particularly striking and it is natural to correlate the two events and to argue that the division of the country into two geological provinces should be discontinued. However, the difficulty of correlation across the profound structural break along the 4° N parallel, the absence of the Roraima Formation and the c.1700 m.y. dolerites in the southern province, and the absence of the c.1200 m.y. dynamic metamorphism in the northern province are sufficient to justify the continuation of this division. Moreover, the Kanuku Group has not been recognized north of the 4°N parallel.

CONCLUSIONS

Although many details remain to be filled in, the available age determinations indicate that the geochronology of this segment of the Guiana Shield can be summarized as follows:

a) *Northern Province*

(i) c.2500 m.y. Intrusion of riebeckite granite, minimum age of the Iwokrama Formation and probably of the Barama-Mazaruni Assemblage. This event requires further verification.

(ii) c.2000 m.y. Minimum age of the main phase of the post-Barama-Mazaruni-Bartica orogeny. Probable date of emplacement of most members of the Younger Granite Group. Akawaian episode.

(iii) 2000 m.y. – 1800 m.y. (approximately). Development of pre-Roraima erosion surface. Possibility of intrusion of some members of the Younger Granite Group.

(iv) 1800 m.y. - 1700 m.y. (approximately). Deposition of Roraima Formation.

(v) c. 1700 m.y. Emplacement of the Roraima Intrusive Suite.

TABLE 6

Age determination on monazite panned from weathered South Savanna Granite at Wariwau Outstation, Rupununi District. Data from Darnley (1960), chemical analysis by Miss Olwyn James (National Chemical Laboratory) and isotopic analysis by E.R. Preece (Atomic Energy Research Establishment, Harwell).

%U 0.211 %Th 4.930 %Pb 0.614

Isotopic composition of lead

$\%^{204}Pb$ 0.020 ± 0.002 $\%^{206}Pb$ 13.0 ± 0.1

$\%^{207}Pb$ 1.91 ± 0.02 $\%^{208}Pb$ 85.1 ± 0.1

Calculated ages

t. $^{207}Pb/^{206}Pb$ ..... 2075 m.y.

t. $^{207}Pb/^{235}U$ ..... 2185 m.y.

t. $^{206}Pb/^{235}U$ ..... 2305 m.y.

t. $^{208}Pb/^{232}Th$ ..... 2270 m.y.

Common Pb correction on hypothetical composition corresponding to an age of circa 2300 m.y.
204 : 206 : 208 = 1 : 16.20 : 15.53 : 35.77

Decay Constants:

$^{235}U\ \lambda = 9.7216 \times 10^{-10}\ yr^{-1}$

$^{238}U\ \lambda = 1.5369 \times 10^{-10}\ yr^{-1}$

$^{232}Th\ \lambda = 4.8813 \times 10^{-11}\ yr^{-1}$

$^{238}U/^{235}U = 137.7$

b) *Southern Province*

(i) c.1850 m.y. Emplacement of the main mass of the South Savanna Granite and minimum age of the Kanuku and Marudi granite.

(ii) < 1850 m.y. > 1400 m.y. Emplacement of the Marudi Groups.

(iii) c.1200 m.y. A tectono-thermal event with widespread shearing and development of major mylonite zones.

(iv) 450 m.y. Intrusion of basic dykes unrelated to the Roraima Intrusive Suite in the Northern Province.

ACKNOWLEDGEMENTS

We are indebted to Mrs. A.D. Richards and Mr. D,C. Rex who were responsible for many of the new Rb:Sr and K:Ar age determinations and to Mrs. J. Crisford for preparation of the analysed materials. Thanks are due to Drs. R.T. Cannon, S. Singh and Mr. C.N. Barron for much advice and helpful discussion regarding the geology of Guyana and to Drs. McDougall, Compston and Priem for discussion of the dating of the Roraima Intrusive Suite. Particular mention must also be made of Dr. E. Williams whose work and influence has done much to elucidate the geology of northern Guyana.

The Isotope Geology Unit of the Institute of Geological Sciences is at present housed in the Department of Geology and Mineralogy at Oxford and we are indebted to the University of Oxford for the facilities they provide. The results are published by permission of the Directors of the Institute of Geological Sciences of Great Britain and the Geological Survey of Guyana.

REFERENCES

Bailey, P.B.H. (1961) – Roraima NW and Roraima SW: Quarter Degree Sheets 0560 NW and SW. Geol. Atlas Brit. Guiana, 1:200,000. Geol. Surv. Brit. Guiana.

Barbosa, O., and Ramos, J.R. de A (1959) – Territorio do Rio Branco. Div. Geol. Min., Rio de Janeiro, Bol. 196, 46 pp.

Barron, C.N. (1962) – The geology of the South Savanna degree square. Geol. Survey Brit. Guiana. Bull. 33, 29 pp.

Bateson, J.H. (1966) – Some aspects of the geology of the Roraima Formation in British Guiana. Trans. 3rd Caribbean Geol. Conf., Jamaica, April 1962, p. 144-150.

Bleackley, D. (1964) – Bauxites and laterites of British Guiana. Geol. Surv. Brit. Guiana, Bull. 34, 156 pp.

Carter, J.W. (1962) – Unpublished M.Sc. thesis, University of London.

Carter, M.W. (1962) – Kurupukari SW, Quarter Degree Sheet 0458 SW, Geol. Atlas Brit. Guiana, 1:200,000. Geol. Surv. Brit. Guiana.

Choubert, Boris (1964) – Ages absolus du Précambrian guyanais. C.R. Acad. Sc. Paris. 258, p. 631-634.

Darnley, A.G. (1960) – Monazite from South Savanna Granite. Rupununi District, British Guiana. Age Determination Report No. 15. Geological Survey of Gt. Britain, Atomic Energy Division. (Unpublished)

Hawkes, D.D. (1966a) – The petrology of the Guiana dolerites. Geol. Mag., 103, p. 320-335.

—— (1966b) – Differentiation of the Tumatumari--Kopinang dolerite intrusion, British Guiana. Geol. Soc. Am. Bull. 77, p. 1131-1158.

Hurley, P.M. (1961) – The basement of Central and South America, or how not to date a continent. New York Acad. Sci. Anns., 91, p. 571-575.

Hurley, P.M., Hughes, H., Pinson, W.H., and Fairbairn, H.W. (1962) – Radiogenic argon and strontium diffusion parameters in biotite at low temperatures obtained from Alpine Fault uplift in New Zealand. Geochim. et Cosmochim. Acta 26, p. 67-80.

Kulp, J.L., Bate, G.L., and Broecker, W.S. (1954) – Present status of the lead method of age determination. Amer. Journ. Sci. 252, p. 345-365.

McConnell, R.B. (1958) – Provisional stratigraphic table for British Guiana. Report on the Geological Survey Dept. for the Year 1957. Appendix 1. Government of British Guiana.

—— (1966) – Notes on the erosion bevels and geomorphology of British Guiana. Trans. 3rd Caribbean Geol. Conf., Jamaica, April 1962, p. 151-159.

McConnell, R.B., Williams, E., Cannon, R.T. and Snelling, N.J. (1964) – A new interpretation of the geology of British Guiana. Nature, 204, p. 115-118.

McConnell, R.B., Masson Smith, D. and Berrangé, J.P. (1969) – Geological and Geophysical evidence for a rift valley in the Guiana Shield. Geol. en Mijnb. 48, p. 189

McDougall, I., Compston, W., and Hawkes, D.D. (1963) – Leakage of radiogenic argon and strontium from minerals in Proterozoic dolerites from British Guiana. Nature 198, p. 564-567.

Nicolaysen, L.O. (1961) – Graphic interpretations of discordant age measurements on metamorphic rocks. New York Acad. Sci. Anns., 91, p. 198-206.

Priem, H.N.A., Boelrijk, N.A.I.M., Verschure, R.H., and Hebeda, E.H. (1966) – Isotopic age determinations on Surinam rocks. Geol. en Mijnb. 45, p. 16-19.

—— (1967) – Isotopic age determinations on Surinam rocks, 2. Geol. en Mijnb. 46, p. 482-486.

Priem, H.N.A., Hebeda, E.H., Boelrijk, N.A.I.M. and Verschure, R.H. (1968) – Isotopic age determinations on Surinam rocks, 3. Proterozoic and Permo-Triassic basalt magmatism in the Guiana Shield. Geol. en

Mijnb. 47, p. 17-20.

Priem, H.N.A., Boelrijk, N.A.I.M., Hebeda, E.H., Verschure, R.H., and Verdurmen, E.A.Th. (1968a) – Isotopic age determinations on Surinam rocks, 4. Ages of Basement rocks in northwestern Surinam and the Roraima tuff at Tafelberg. Geol. en Mijnb. 47, p. 191-196.

Singh, S. (1965) – Proc. Geol. Soc. London., no. 1619.

—— (1966) – Geology and petrology of part of the Guiana Shield in the South Savanna-Rewa area of Guyana. Geol. Surv. Guyana, Bull. 37, 127 pp.

Snelling, N.J. (1963) – Age of the Roraima Formation, British Guiana. Nature 198, p. 1079.

Idem (1964) – In Annual Report 1963. Overseas Geological Surveys. H.M.S.O.

Williams, E., Cannon, R.T. and McConnell, R.B. (1967) – The folded Precambrian of northern Guyana related to the geology of the Guiana Shield. With data on geochronology by N.J. Snelling. Geol. Surv. Guyana, Records vol. 5, 60 pp.

Wilson, M.E. (1939) – The Canadian Shield: Geology of North America. p. 232-311 in E. Krenkel, Editor, Geologie der Erde, Berlin, Verlag von Gebruder Bornträger, 643 pp.

York, D. (1966) – Least squares fitting of a straight line. Can. J. Phys. 44, p. 1079-1086.