GEOLOGIE EN MIJNBOUW VOLUME 48 (2), p. 189-199 1969

GEOLOGICAL AND GEOPHYSICAL EVIDENCE FOR A RIFT VALLEY IN THE GUIANA SHIELD[1])

R.B. McCONNELL[2]) D. MASSON SMITH[3]) and J.P. BERRANGE[3])

ABSTRACT

Geological and geophysical evidence points to the existence in the Guiana Shield between latitudes 3° N and 4° N of a steep-walled graben structure which is filled with a thick packet of sediments of which the uppermost is the Takutu Formation showing rare outcrops beneath a blanket of laterite and Quaternary alluvium. The Takutu Formation has been dated on palynological evidence (van der Hammen and Burger, 1966) as Jurassic to Cretaceous. A gravity reconnaissance was carried out over the western portion of the structure and revealed anomalies which indicate a depth to basement of several km. The strike of the geological structure appears to be ENE-WSW over 160 km, with a width of 50 km, and it is suggested that it is in the nature of a rift valley: it has been considered to constitute a major structural break which divides the folded Precambrian formations of Guyana into northern and southern geological provinces.

INTRODUCTION

The Guiana Shield forms the nucleus of the northeastern corner of the South American continent and consists chiefly of metasediments, metavolcanics and crystalline rocks of early Precambrian age, with a surface of low relief averaging 100-150 m in altitude and dominated by extensive forested pediplains rising towards their watersheds. Above this uniform surface a number of isolated hills, mountains and mountain ranges reach heights of up to 1,000 m, and, in the centre of the Shield the Pakaraima Mountains, formed by tabular Precambrian sandstones, display a succession of forested plateaus rising to isolated summits such as Ayanganna (1,900 m) and Roraima (2,770 m). On the western portion of the Shield, in the Rio Branco province of Brazil and the Rupununi District of Guyana, are large savanna areas covering a pediplain at the 100-150 m level (McConnell, 1968). One branch of this plain forms the ca. 50 km wide flat-bottomed valley between latitudes 3° 10'N and 3° 50'N that extends to the east-northeast for about 160 km from the Takutu and Ireng Rivers. Although two thirds of this valley is forested (east of the Rupununi River) we propose to refer to it as the North Savannas Basin.

It has been shown (McConnell, 1959; Barbosa and Andrade Ramos, 1959) that this depression was the course of a proto-Berbice River which took the drainage of the upper Rio Branco basin to the Atlantic up to the end of the Tertiary, when the Rio Branco was captured by the Amazon.

GEOLOGICAL SETTING

Mapping in Guyana by the Geological Survey Department has shown that it is difficult to correlate the early Precambrian rocks from the north to the south of the country (McConnell and Dixon, 1960) and hence, in the interests of objective classification, they are regarded as belonging to distinct northern and southern geological and structural provinces (McConnell, Williams, Cannon and Snelling, 1964). The limit between these provinces corresponds to the North Savannas Basin which was therefore considered to follow a major structural break of considerable age, rejuvenated in Mesozoic and Cenozoic times as a rift valley.

To the north of this rifted zone lies the Mazaruni

---

[1]) Published by permission of the Director, Institute of Geological Sciences

[2]) Streatwick, Streat near Hassocks, Sussex, U.K.

[3]) Institute of Geological Sciences, London.

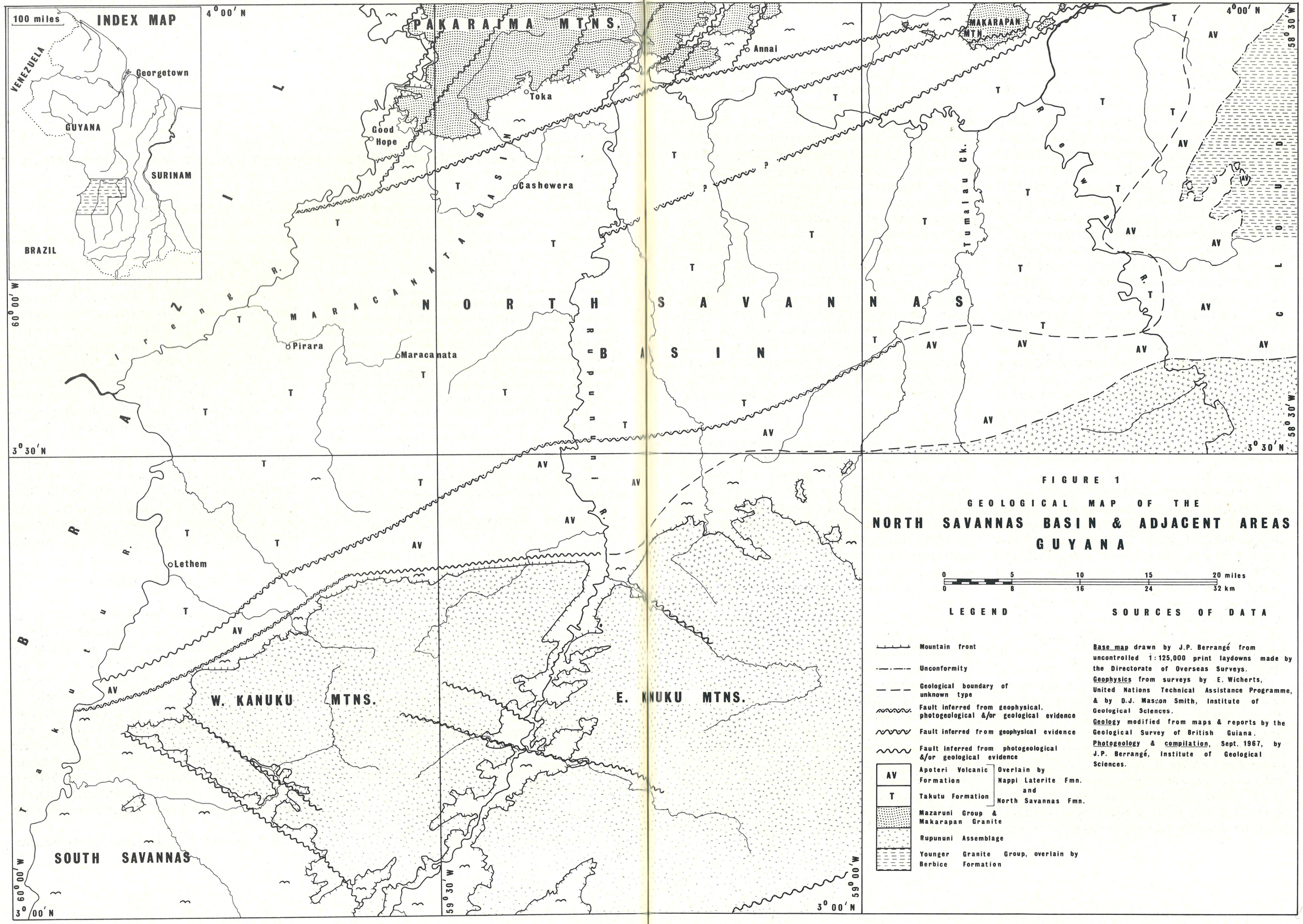


FIGURE 1

GEOLOGICAL MAP OF THE

NORTH SAVANNAS BASIN & ADJACENT AREAS GUYANA

0 5 10 15 20 miles
0 8 16 24 32 km

LEGEND

- Mountain front
- Unconformity
- Geological boundary of unknown type
- Fault inferred from geophysical, photogeological &/or geological evidence
- Fault inferred from geophysical evidence
- Fault inferred from photogeological &/or geological evidence
- AV — Apoteri Volcanic Formation
- T — Takutu Formation
  - Overlain by Nappi Laterite Fmn. and North Savannas Fmn.
- Mazaruni Group & Makarapan Granite
- Rupununi Assemblage
- Younger Granite Group, overlain by Berbice Formation

SOURCES OF DATA

Base map drawn by J.P. Berrangé from uncontrolled 1:125,000 print laydowns made by the Directorate of Overseas Surveys.

Geophysics from surveys by E. Wicherts, United Nations Technical Assistance Programme, & by D.J. Masson Smith, Institute of Geological Sciences.

Geology modified from maps & reports by the Geological Survey of British Guiana.

Photogeology & compilation, Sept. 1967, by J.P. Berrangé, Institute of Geological Sciences.

Group (Williams et al., 1967) of the early Precambrian (minimum age ca. 2,500 m.y.), consisting principally of a eugeosynclinal succession of metasediments and metavolcanics, which have been folded, metamorphosed, and locally granitized with the emplacement of the Younger Granite Group dated at 2,000-1,800 m.y. To the south of latitude 5°N these rocks lose their eugeosynclinal character and appear to be approaching the margin of an ancient continental area (McConnell et al., 1964; Kalliokoski, 1965) which may have occupied the present location of the Rupununi District in very early Precambrian times. Immediately to the north of the North Savannas Basin lies a southern extension of the Pakaraima Mountains which are here formed by the rhyolitic and dacitic volcanics of the Iwokrama Formation, and their associated granophyric granite plutons. All belong to the Mazaruni Group and strike ENE-WSW to E-W. Makarapan Mountain, which dominates the plain by some 600 m, is formed of riebeckite granite giving a good apparent potassium-argon age of ca. 2,500 m.y. (Snelling, 1965; Snelling et al., 1969). It has been regarded as younger than the surrounding rocks of the Mazaruni Group (Carter, 1962; Williams et al., 1967, p. 42) but Berrangé, as a result of recent mapping, considers that there is insufficient evidence for this age relationship.

The southern margin of the valley is marked by the impressive northern scarp of the Kanuku Mountains which rise to ca. 1,000 m. These mountains have an average width of about 50 km and extend east-northeast for some 160 km from the Brazilian border to the Rewa River. The Kanuku Mountains are formed chiefly of streaky biotite and biotite-garnet gneisses in the amphibolite and granulite facies of metamorphism; with these rocks are associated hypersthene granulites as well as charnockitic gneisses and granulites. This complex strikes E-W to NE-SW, approximately parallel to the North Savannas Basin.

The zone of rocks of the Kanuku Group just described has been mapped geologically from the Brazilian border to the Kwitaro and Rewa Rivers (Barron, 1962a; Singh, 1966), and, although the characteristic rocks have not been specifically recorded in traverses of the Lower Rewa, the Essequibo or the Corentyne Rivers, where the projection of the strikes would lead them to be expected, Morris (1959) noted garnet-biotite gneisses, rare granulites and bands of tough green quartzite adjacent to the Rewa River at latitude 3°30'N, and high grade garnet-sillimanite gneisses near King William IV Falls on the Essequibo. These rocks appear to be akin, in rock type and metamorphic facies, to those further west. Alternatively, granitization may have been more pronounced in these areas, and the Kanuku rocks may have become unrecognizable. This is suggested by recent photogeological interpretation (Berrangé, 1967) which shows that whereas west of the Rupununi River heterogeneous migmatites pre-dominate, to the east of this river more homogeneous granites and granulites are the main rocks. In addition, continuity to the east-northeast is indicated by the recognition (Janssen, 1963, 1963a) that the northern portion of the Bakhuis Mountains of Surinam (4°40'N, 57°W) consists of pyroxene granulites and gneisses, with associated charnockites, which have been correlated with the Kanuku Group. These mountains are about 30 km wide, rise to ca. 450 m and are bounded by faults striking NE-SW. Aeromagnetic surveys have shown that these high grade gneisses strike southwest to link up with the projection of the Kanuku Group at the Corentyne River.

The South Savannas are chiefly underlain by the South Savanna Granite whose emplacement has been dated by Snelling (1965) as 1,880-2,075 m.y. by whole rock Rb-Sr determinations on a series of samples. Contact relations show the rocks of the Kanuku Group to be older than the South Savanna Granite (Barron, 1962a; Singh, 1966) and they have been regarded (McConnell et al., 1964) as a metamorposed and granitized remnant of an older nucleus of the Shield which supplied sediments to the Barama and Mazaruni groups, and acted as basement to them. This interpretation is based on structural relationships, a detailed geologic and petrographic study of the various units (Singh, 1966) and the regional lithological zoning of the Mazaruni Group which indicates shallowing southwards.

Amygdaloidal augite andesite lava flows which appeared to underlie conformably the sediments of the Takutu Formation were recognized by Dixon (1959; Carter, 1962) near Apoteri, where the Rupununi River joins the Essequibo, and Berrangé now proposes to include them in an *Apoteri Volcanic Formation* which he describes as follows in an unpublished report (Berrangé, 1967) :

"Amygdaloidal andesitic and basaltic lavas were mapped on the Essequibo River near Apoteri, at

several localities on the Rupununi River for a distance of eight miles north of the Kanuku fault scarp, and north of the fault zone exposed in the Takutu River. These rocks are respectively medium greenish-grey, aphanitic to fine-grained, amygdaloidal lavas. Both types invariably show vertical polygonal jointing and the flow tops are either horizontal or dip at less than 20°. Morris (1959) recorded vesicular andesites on the Rewa River, and photogeological observations indicate that gently dipping effusives form numerous low hills to the east of this river. Similar amygdaloidal lavas that locally have a pahoehoe structure are found in Brazil near Nova Olinda and south of the Serra Tucano (Barbosa and de A. Ramos, 1961). This means that lava flows are now known to occur at intervals over a distance of ca. 320 km, much of it along the downthrow side of the southern boundary fault of the rift valley. The lavas appear to lie unconformably on the Precambrian basement and to be overlain by the Takutu Formation . . . (although) there is somewhat inconclusive evidence to suggest that the lavas and the sediments may be interlayered and therefore of similar age."

The plain between the Takutu and Ireng Rivers and longitude 58°30'W is underlain by rocks of the Takutu Formation which are only found in drill holes and widely scattered outcrops in the banks of the larger rivers. Although the Takutu and Apoteri Volcanic formations are overlain by extensive laterites and alluvial deposits, there is no reason to doubt that they extend over most of the plain as shown in Figure 1. These rocks have been described (Bleackley, 1962; Morris, 1958, 1959 and 1962) as red, chocolate-brown and grey shales and mudstones (locally carbonaceous), with intercalations of red and purple sandstones and siltstones that are locally micaceous and commonly current-bedded. Pelites predominate over the entire plain but arenites are relatively more abundant in the east, especially along the Rewa River. The Takutu Formation is generally horizontal or nearly so, but dips up to 40° are found locally and are probably due to faulting during and/or after sedimentation.

In a previous publication (McConnell, 1959) a Permo-Triassic age had been adopted for the Takutu Formation on the basis of plant remains and ostracods found by Morris (1958) in a section on the Takutu River near Lethem, but following palynological work on shallow borehole cores by van der Hammen and Burger (1966) the age of the formation is now firmly established as Jurassic to Cretaceous. These writers describe the Takutu Formation as trough-shaped, with a roughly E-W strike, and state that a borehole near Lethem, on the south side of the trough, traversed principally mudstones and shales, with intercalated sandstones, containing from 137 to 342 feet, a rich *Classopollis* flora strongly suggesting a (pre-Purbeckian) Jurassic age. A borehole near the northern boundary, north-east of Cashewera (Fig. 1), showed sandy mudstones in the lower part, and contained at 234 and 237 feet a pollen flora of (pre-Aptian) Lower Cretaceous age. The strata in this borehole can possibly be correlated, as van der Hammen and Burger suggest, with those at the top of the Lethem borehole, whilst a third borehole near Pirara, in the centre of the trough, penetrated principally unfossiliferous reddish sandstones which could be still higher in the succession. The base of the succession may of course be considerably older as geophysical surveys have shown that this trough contains several thousand metres of sediments. It is of interest that a well-defined fossil footprint was discovered in sandstone of the Takutu Formation near Lethem by J.W. Carter and was identified by W.E. Swinton (personal communication) as either that of a bird or of a small dinosaur.

The Apoteri Volcanic Formation and the Takutu Formation are overlain with marked unconformity by an extensive capping of laterite that gives rise to a characteristic ridge and *baixa* topography over much of the North Savannas Basin. Various types of residual and transported laterite, and lateritic red earth, are found, and it has been estimated (Sinha, 1968) that the laterite is up to 50 m thick in places. The bulk of the laterite was formed in Pliocene-Pleistocene times (Bleackley, 1962), although lateritization has probably continued at intervals since then and is certainly occurring today. The lateritic rocks have been named the *Nappi Laterite Formation* (Berrangé, 1967).

The Takutu Formation, the Apoteri Volcanic Formation and the Laterites are extensively carpeted with unconsolidated Quaternary deposits derived largely from the adjecent highlands to the north and south. These deposits, referred to as the North Savannas Formation, are silty to sandy loams, and coarse sands and clays that have been unevenly spread over the plain by rivers, sheet-wash, and by winds during the Quaternary to sub-Recent arid phase. They are thickest adjacent to the mountain

fronts where extensive alluvial fans are found, and elsewhere sections over 10 m thick have been measured in the banks of the Takutu, Ireng and Rupunini Rivers (Bleackley, 1962). They are most extensive in the region known as the Maracanata Basin lying between the Ireng River and an imaginary arc joining Pirara, Maracanata and Cashewera. This depression is the site of a former lake and is still swampy for a large part of the year, its drainage being deranged and flowing both west to the Ireng and east to the Rupununi River. The Rego channel meanders across the basin between the two above mentioned rivers and in parts is clearly a misfit stream, its bed having been carved out by a previously greater river. It is thought that originally the primitive Ireng, Uraricuera and Takutu Rivers drained into a lake (Maracanata Basin) and thence northeast into the Atlantic via the proto-Berbice River (McConnell, 1959).

STRUCTURE

The North Savannas Basin is bounded to the south by the north wall of the Kanuku Mountains, and where this scarp projects to the Takutu River the rocks are highly silicified and fractured over a distance of nearly a kilometre (Berrangé, 1967). As indicated on Fig. 1 the north face of the mountains is therefore assumed to be the eroded remnant of a fault scarp, and this can be traced east-northeast for 60 km as far as the Rupununi River. Further east the scarp is less well defined, but a combination of geological, photogeological and geophysical observations suggests that the boundary between the Apoteri Volcanic Formation and the Kanuku Group corresponds over part of its length to a fault striking E-W to ENE-WSW almost as far as the Rewa River. The western Kanuku Mountains form a deeply dissected highland mass the average elevation of which decreases gradually southward toward the South Savannas, the actual border between the two physical regions being a relatively straight fault scarp trending ESE-WNW. This is probably a normal fault with the downthrow on the South Savannas side. The western Kanukus are separated from the eastern Kanukus by the north-northeast flowing Rupununi River which possibly follows a zone of faulting. The western Kanukus are therefore considered to be a triangular-shaped horst bounded on all three sides by faults and sloping gently southwards. Although many strong faults have been recognized in the eastern Kanuku Mountains they merge gradually southwards into the forested 100 m pediplain.

The northern limit of the basin is not so well marked and the Quaternary cover embays the rocks of the Mazaruni Group which rise less steeply from the plain. Geophysical investigations indicated the existence, underneath the alluvium near the northern mountain front, of faults striking ENE-WSW. Subsequent photogeological studies and field work (Berrangé, 1967) have locally confirmed the existence of these faults which in some cases apparently join up with a very strong, closely spaced, set of faults striking NE-SW through the Mazaruni metavolcanics and granophyric granites.

The Takutu Formation has not been mapped on the ground further east than longitude 58°30'W, but photogeological observations suggest that basic lavas form mesas at least as far east as the Berbice River, and that faulting continues up to the Surinam border. However, the graben shallows markedly towards the east in this area and its place seems to be taken by a belt of biotite granites (Barron, 1962b) which continues at least as far as the Corentyne River. These granites are believed to belong to the Younger Granite Group and to separate rocks of the Mazaruni Group belonging to the northern geological province (McConnell et al., 1964) from the uncorrelated gneisses and gneissose granites forming the southern geological province of Guyana: the photogeological work now in progress may provide an answer to this problem.

GEOPHYSICS

In 1963 a United Nations aerial geophysical survey was in progress in British Guiana, and although the North Savannas Basin was not scheduled for detailed survey, six pairs of magnetic profiles were flown across it in a north-south direction at intervals of about 15 km (Fig. 2). The area covered is bounded by the Takutu and Rewa Rivers. Over the basement rocks to the north and south of the Takutu sediments there are strong changes in the magnetic field approaching 1,000 gamma per mile, but on crossing the margin of the sediments the changes fall to 25 gamma per mile or less. This suggests that the Takutu rocks are non-magnetic and

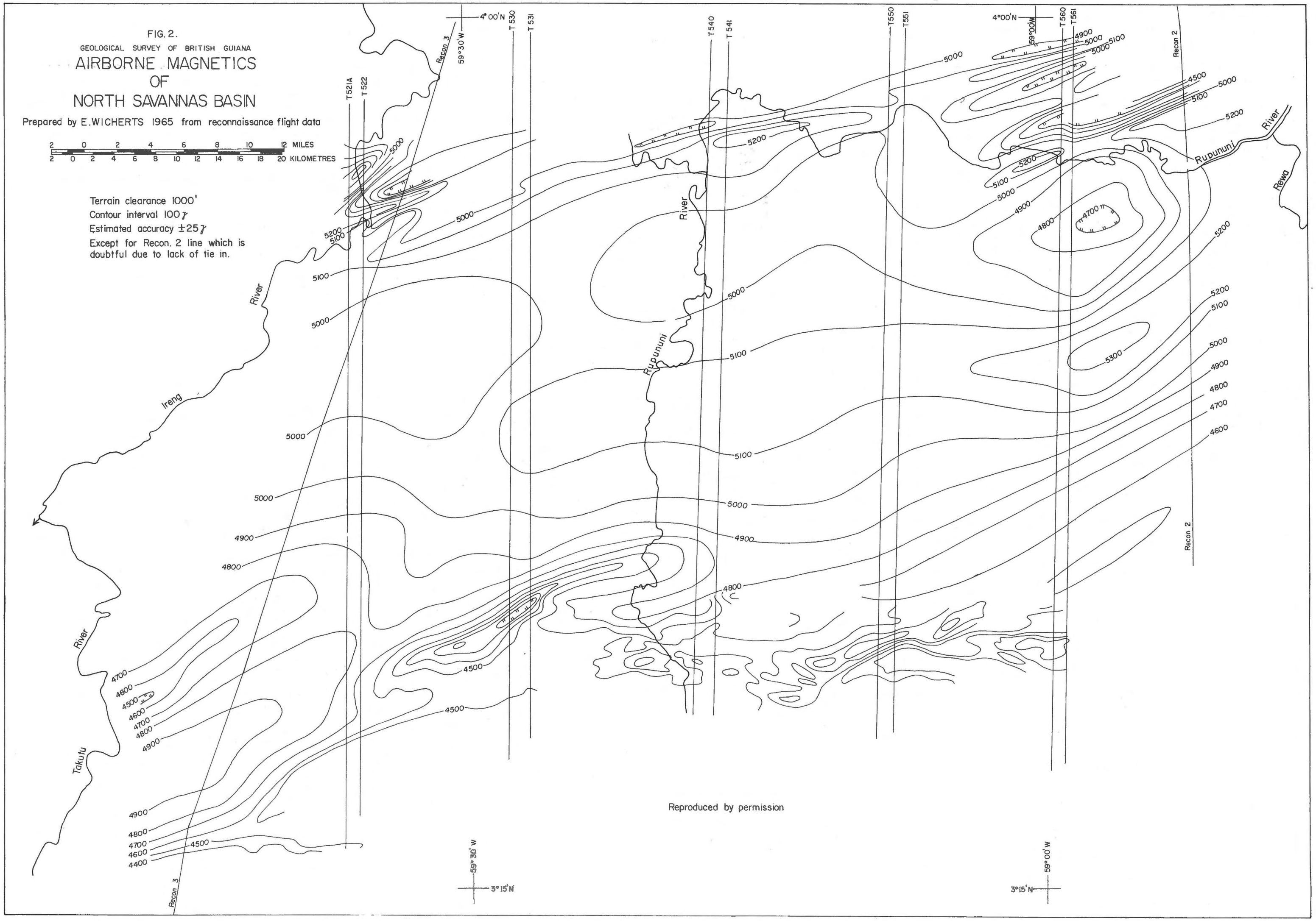


FIG. 2.
GEOLOGICAL SURVEY OF BRITISH GUIANA
AIRBORNE MAGNETICS OF NORTH SAVANNAS BASIN
Prepared by E. WICHERTS 1965 from reconnaissance flight data

that the basement rocks which produce strong magnetic anomalies to the north and south plunge to a considerable depth below the sediments. Furthermore, the abruptness of the decrease in magnetic disturbance on crossing the basement-sediment contact shows that it is steeply dipping. The character of magnetic anomalies can be used to give a rough measure of the thickness of sediments overlying magnetic basement. Over most of the Takutu sediments the magnetic field is too little disturbed to give a reliable estimate of depth, and the most that can be said is that the basement is nearly everywhere at a depth of several thousand metres, and that the structure has the form of a steep-walled graben.

In the same year a geophysical team from Overseas Geological Surveys was engaged in gravity and magnetic surveys in the coastal region. Since the

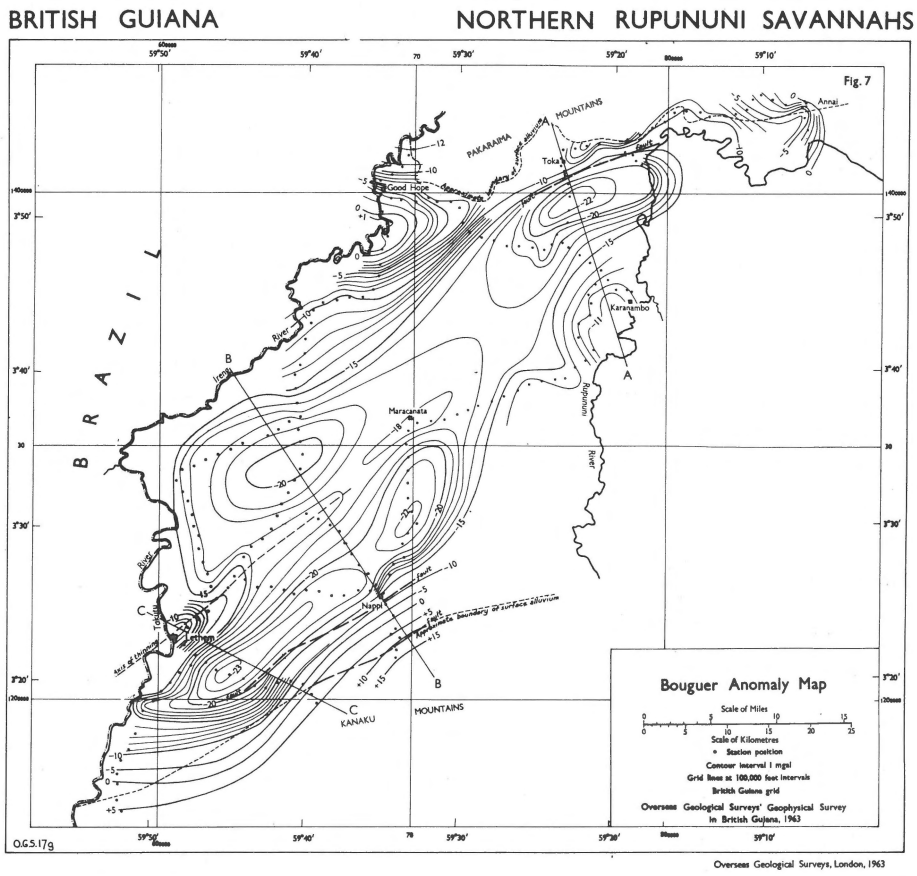


Fig. 3
Bouguer anomaly map of North Savannas Basin, Rupununi District, Guyana.

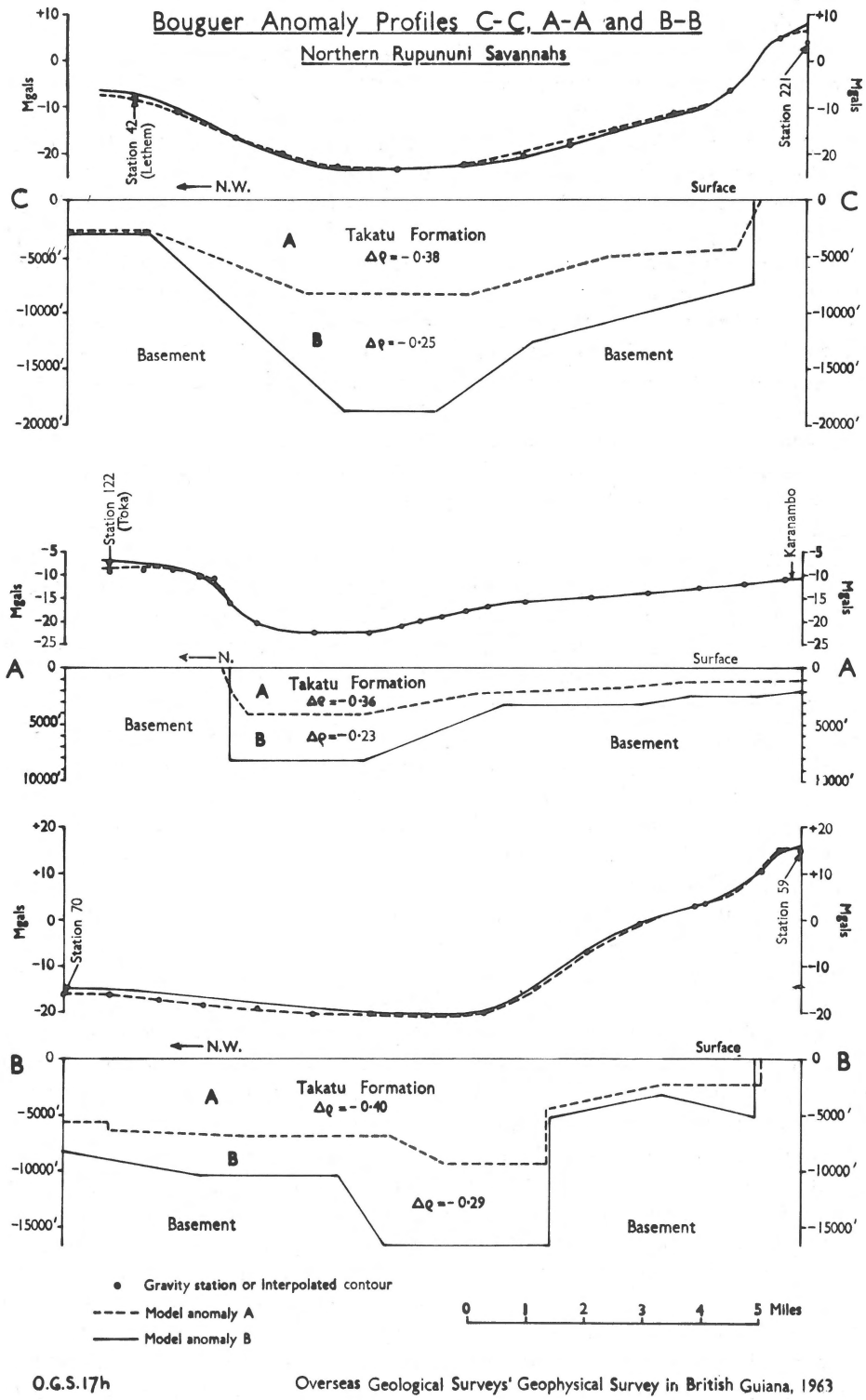


Fig. 4
Bouguer anomaly profiles, North Savannas Basin, Rupununi District, Guyana.

structure suggested by the aeromagnetic results was likely to produce marked gravity anomalies the opportunity was taken to make a gravity reconnaissance of the more accessible west part of the North Savannas Basin comprising about one-third the exposure of the Takutu sediments. The results of the gravity survey confirm the aeromagnetic indication of a graben or rift type of structure.

In the few days available for the survey about 200 gravity stations were established in an area of about 3,000 sq.km. This station density is too coarse for an accurate delineation of the anomaly but is sufficient to show its general trend and the positions of the contact of the Takutu sediments with the basement in a few places. The area is covered with photogrammetric preliminary plots so that the stations could be fairly reliably located. There are no known elevations in the area. This necessitated the use of altimeters to obtain the levels of the gravity stations since there was insufficient time to attempt optical levelling. Although the effect of air pressure changes was partially eliminated by reoccupying certain stations it is thought that errors in the relative elevations between the more distant parts of the survey may reach 20 m which is equivalent to about 4 mgal. in the Bouguer anomaly. Terrain and isostatic corrections were not applied, but since the topographic relief is low and the area only about one hundred metres above sea level this should not introduce serious additional error. The accuracy of this survey thus falls well below that normally required for reliable quantitative interpretation, but since the anomalies observed are large, some useful semi-quantitative results can be obtained.

The western half of the Takutu exposure is covered with an elongated gravity low, 40 km wide, and 90 km long, with the long axis striking NE-SW (Fig. 3). This trend is not parallel to the ENE-WSW trend of the Takutu outcrop but in view of the lack of gravity information in the eastern part of the outcrop the apparent difference in trend may not be significant. Anomaly values in the centre of the structure are 20 to 35 mgal. less than over the basement.

At present these anomaly fluctuations cannot be related accurately to the thickness of sediments because the density contrast between the sediments and underlying basement is not known. It is therefore necessary to give a range of thickness corresponding to a likely range of density contrasts. Since the Takutu sediments are now believed to be of Jurassic-Cretaceous age a reasonable range of density contrasts would be 0.2 to 0.4 gm/cc. Assuming the sediments to be in the form of a uniformly thick infinite slab their thickness would range from 4,000 to 2,400 m for the smaller contrast, to 2,000 to 1,200 m for the larger contrast. Since the sediments are not of infinite extent the actual maximum thicknesses will be somewhat larger (Fig. 4). Steep gravity gradients are observed when crossing the contact to the north and south. These show that the contact dips steeply and is therefore probably faulted. The throws of the faults vary from 600 to 3,000 m depending on the density contrast assumed. There is some evidence for a step in the basement floor inside the boundary which may imply multiple faulting, but the anomaly could equally well be caused by simple faulting at the contact combined with internal downwarping of the floor. To the south, the geological and gravity indications of the boundary fault coincide with the margin of the surface alluvium which covers the savanna area. To the north the gravity indication of the fault is under alluvial cover and lies several km south of the edge of the savanna where outcrops of the basement appear. Here river erosion appears to have cut into the Pakaraima foothills to extend the savanna beyond the margins of the Takutu Formation. Another interesting feature of the anomaly is that the minima appear to be separated by an axial belt of less negative anomaly. The gravity gradients associated with this belt are generally too low to say whether it represents a thinning of the sediments along the axis of the graben or an increase in the density of the underlying basement, but at the southwest end of the belt the gradients are steep anough to imply a marked decrease in sediment thickness.

The magnetic and gravity anomalies are consistent as regards the margins of the structure, the steep gravity gradients coinciding with the onset of magnetic disturbance when passing from the sediments to the basement rocks. At Lethem and Good Hope gravity highs are associated with corresponding zones of increased magnetic relief suggesting local thinning of the sediments. Elsewhere within the basin the magnetic relief is very low due to greater depth to the magnetic basement, and changes in sediment thickness which may be indicated in the

gravity field are not therefore reflected in the magnetic field.

Wicherts (1965) gives an unpublished interpretation of the aeromagnetic and gravity results. Wicherts, who was project manager of the U.N. aerial survey, supervised a small shallow drilling programme, redrew the gravity map from the original data and constructed a contoured map showing depth to basement. He favoured a low density for the Takutu sediments on the assumption that they contained evaporites. It seems to us preferable to leave the question of the nature and exact thickness of the Takutu sediments open for the present. The gravity and magnetic results have established beyond doubt the graben or rift nature of the structure but cannot be expected to yield much more reliable quantitative information due to uncertainty in the physical properties of the sediments, although further gravity and magnetic observations would locate the boundary fault more reliably where it occurs under alluvial cover. A seismic survey combined with deep drilling would be necessary to obtain an accurate picture of the interior of the structure.

RIFT VALLEY STRUCTURE

The term "rift valley" was first applied by J.W. Gregory (1896) to the remarkable faulted valley structures which extend some 3,500 km from Ethiopia to Mozambique down the eastern side of the African continent. These rift valleys are in part steep-sided graben structures, and are characterized by (1) great length of strike, (2) an average width of 30-60 km, and (3) localized volcanism with alkali-rich magmas associated with nearly half of the total length of the overlapping rift valleys.

It is therefore concluded that the North Savannas Basin, between the Takutu and Ireng rivers in the west and longitude 58°30'W in the east, is a true rift valley for the following reasons:

(a) It is an elongate graben, about 50 km wide and 160 km long, bounded by steeply dipping faults.

(b) The depression is the site of low magnetic relief and negative gravity anomalies, which are interpreted as being due to a sedimentary infilling attaining several km in thickness.

(c) Andesitic and basaltic lavas of probable post-Proterozoic age occur along the southern and eastern margin of the basin.

(d) In view of the characteristic association of alkali-rich volcanism with rift valleys it is of interest that the riebeckite granite of Makarapan Mountain, provisionally dated as ca. 2,500 m.y. B.P., is the only alkali-rich rock so far reported in Guyana.

(e) The feature appears to form part of an important fracture system dividing two geological provinces of the early Precambrian. If the Bakhuis Mountains horst can be correlated with the Kanuku Moutains horst, then the fracture system extends for at least 450 km.

REFERENCES

Barbosa, O. & Andrade Ramos, J.R. de (1959) – Territorio do Rio Branco (Aspectos principais da geomorphologia, da geologia e das possibilidades minerais de sua zona setentrional); Div. Geol. Miner. Brasil, Bol. 196, 46 p.

—— (1961) – Principal aspects of the geomorphology and geology in the Territory of Rio Brano, Brazil. Proc. Fifth Inter-Guiana Geol. Conf., Georgetown, 1959, Abstract and Map, p. 33-6.

Barron, C.N. (1962a) – The geology of the South Savannas Degree Square. Geol. Surv. Brit. Guiana, Bull. 33, 29 pp.

(1962b) – Kurupukari SE Quarter Degree Sheet 0458 SE. Geol. Surv. Brit. Guiana, Geological Atlas, 1 : 200,000.

Berrangé, J.P. (1967) – Progress report on photogeological mapping of Guyana south of 4° latitude – Operation El Dorado. Inst. Geol. Sciences, London, Photogeological Div., Rep. No. 24, Unpublished.

Bleackley, D. (1956) – The geology of the superficial deposits and coastal sediments of British Guiana. Geol. Surv. British Guiana, Bull. 30, 46 pp.

—— (1962) – The North Savannas of the Rupununi District. Geol. Surv. British Guiana, Rec. 1, p. 7-20.

—— (1964) – Bauxites and Laterites of British Guiana. Geol. Surv. British Guiana, Bull. 34, 156 pp.

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

Dixon, C.G. (1959) – Notes on the rocks exposed in the river bed at Apoteri. Geol. British Guiana, Rep. CGD 1/59. unpubl., 3 pp.

Gregory, J.W. (1896) – The Great Rift Valley. London, John Murray, 405 pp.

Hammen, T. van der & Wijmstra, T.A. (1961) – A palynological study on the Tertiary and Upper Cretaceous of British Guiana. Leidse Geol. Meded., 30, p. 183-241.

Hammen, T. van der & Burger, D. (1966) – Pollen flora and age of the Takutu Formation (Guyana). Leidse Geol. Meded., 38, p. 173-180.

Janssen, J.J. (1963) – Bauxite in the Adampada-Kabalebo area, Surinam. Proc. Sixth Inter-Guiana Geol. Conf., Belem-Macapa, in press.

—— (1963a) – Reconnaissance exploration for bauxite in the Adampada-Kabalebo area, 1961-1963. Geol. and Mining Service, Surinam, unpub. report.

Kalliokoski, J. (1965) – Geology of North-Central Guayana Shield, Venezuela. Bull. geol. Soc. Am., 76, p. 1027-50.

McConnell, R.B. (1959) – Fossils in the North Savannas and their significance in the search for oil in British Guiana. Timehri (Georgetown), 38, p. 65-84.

—— (1968) – Planation surfaces of Guyana. Geogr. Journ., 134, p. 506-520.

McConnell, R.B. & Dixon, C.G. (1960) – A geological map of British Guiana. Int. Geol. Congr., XXI Session, Norden, Pt. 9, Precambrian Stratigraphy and Correlations, p. 39-50.

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

Morris, P.I. (1958) – The western Kanuku Moutains and adjacent area. Geol. Surv. British Guiana, Ann. Rept. 1957, p. 69-70.

—— (1959) – Geological reconnaissance of Makarapan and parts of the Essequibo, Rewa and Rupununi rivers. Geol. Surv. British Guiana, Ann. Rept. 1958, p. 33-34.

—— (1962) – The geology of the western Kanuku Moutains and the adjacent area. Geol. Surv. British Guiana, Records 1, p. 43-48.

Singh, S. (1964) – Middle Rupununi River-Upper Rewa River survey. Geol. Surv. British Guiana, Ann. Rept. 1961, p. 35-36.

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

Sinha, N.K.P. (1968) – Geomorphic evolution of the northern Rupununi Basin, Guyana: McGill University Savanna Research Project, Savanna Research Series No. 11, 131 p.

Snelling, N.J. (1965) – The geochronology of British Guiana. Age Determination Unit, Overseas Geol. Surv. Rept. 65/3, unpubl., 15 pp.

Snelling, N.J. & McConnell, R.B. (1969) – The geochronology of Guyana. Geologie en Mijnbouw 48/1.

Wicherts, E. (1965) – Interpretation of the geology of the Takutu basin, Rupununi, British Guiana. Unpubl. rept.

Williams, E., Cannon, R.T. & McConnell, R.B. (1967) – The folded Precambrian of northern Guyana related to the geology of the Guiana Shield. Geol. Surv. Guyana, Records vol. 5, 60 p.