CORRESPONDENCE

The geology of southern Guyana

SIR – As a former Director of the Geological Survey of Guyana (1957–62) it gives me great pleasure to welcome a memoir by Dr J. P. Berrangé (1977) which describes the geology of the rather inaccessible region of southern Guyana with a most up-to-date professional competence, thus completing in terms of reconnaissance geology a survey of Guyana begun in 1868 by two government geologists and continued over the years, in spite of the logistic difficulties inherent in mapping in a country largely covered with Amazonian rainforest. The detailed descriptions of the Precambrian of southern Guyana given by Dr Berrangé are of great value and constitute a notable contribution to the study of the petrological development of Precambrian basement rocks.

There are, however, two important points on which Dr Berrangé disagrees with previous interpretations by the Geological Survey, and I would like to state briefly why I question his following conclusions:

(1) that a laterite, the Nappi Laterite Formation in the interior of Guyana, can be correlated with the high-grade commercial bauxites of the coastal area; and

(2) that the important Kanuku Complex of predominantly granulitic rocks covering an area of more than 22000 km^2 should be grouped in the $\sim$ 2000 Ma Trans-Amazonian cycle rather than in the $>$ 2500 Ma Archaean as previously accepted.

To clarify my objections to both these conclusions I attempt, with the help of a location map (Fig. 1), to present the facts and principles involved and the reasons for which I think Dr Berrangé's interpretations are misleading.

1. The Nappi Laterite Formation

One of the chief tasks undertaken by the Geological Survey of Guyana in 1957 was to define the age and horizon of the outstandingly valuable high-grade bauxites in the coastal areas of Guyana and Surinam (Bleackley, 1964). It was decided to undertake a stratigraphical study based on pollen analysis, in which we were fortunate to obtain the services of Professor T. van der Hammen of the Netherlands, and which was financed by the governments of Guyana and Surinam as well as by the chief bauxite producers. This resulted in a report (van der Hammen & Wijmstra, 1964) which concluded that there was only one commercial bauxite horizon of Middle to Upper Eocene age, and not two Horizons, a high and a low level, as previously postulated. In tropical climates laterite, more or less aluminous, tends to form extensive regoliths on sub-horizontal rock surfaces and when enriched in alumina may, as in Guyana, pass to commercial bauxite: thus geomorphology is an important factor in the occurrence of bauxite deposits. A comprehensive study of the geomorphology of the Guiana Shield based on our own observations as well as on the work of neighbouring countries was therefore undertaken and disclosed (McConnell, 1968) evidence of a stepped series of planation surfaces (pediplains) of which the most relevant are a 'Kopinang' Surface at *c.* 700 m a.s.l. in the interior, dated Late Cretaceous to Early Tertiary, and an End-Tertiary 'Rupununi' pediplain which fringes the whole shield at about 100 m a.s.l. These two features correspond well with the early Tertiary 'Sul-Americana', and Late Cainozoic, two-stage 'Velhas' surfaces described by King (1957) in eastern Brazil. The Guyana surfaces are affected, as are those of the comparable African and Brazilian surfaces, by a marked coastal monocline which brings the wide-spread Early Tertiary surface down below sea-level at the Atlantic coast. This explains why commercial bauxite is found not only adjacent to the coast, but on relic plateaus in Surinam (Fig. 1) at altitudes of 700 m (Lely Mountains), 600 m (Nassau Mountains), and 450 m (Bakhuis Mountains), some 100–150 km from the coast.

The Nappi Laterite which Dr Berrangé now wishes to correlate with the Early Tertiary commercial bauxites of the coastal areas, lies in what is called the 'North Savannas' depression in the Rupununi District of the interior of Guyana (Fig. 1), about 450 km from the coast; it was regarded by McConnell (1968) as marking the Rupununi End-Tertiary surface at 100–150 m a.s.l. The North Savannas depression is remarkable in that it has been shown by aero-magnetic and gravity surveys to represent a steep-sided graben in the basement, filled with 3–4 km of sediments containing a Jurassic-Lower Cretaceous pollen flora (van der Hammen & Burger, 1966). The Nappi Laterite has formed over these

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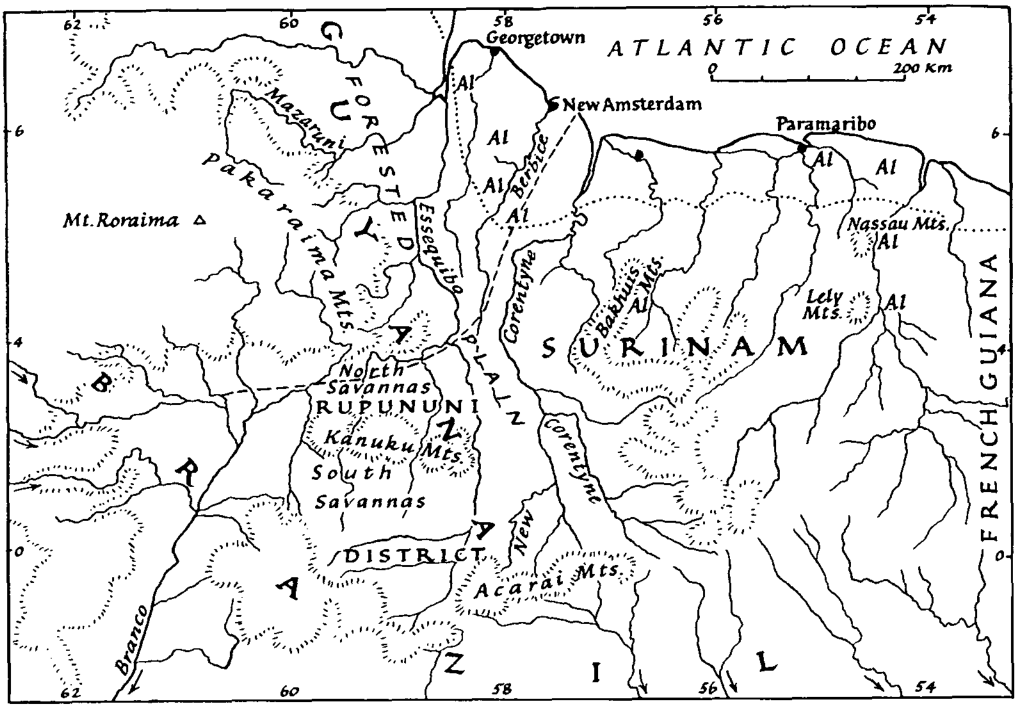

Figure 1. Location map of southern Guyana with portions of Surinam and Brazil. Dotted line: limit of coastal sediments; broken line: postulated course of Proto-Berbice River; A1: known deposits of high-grade bauxite.

sediments (Sinha, 1968), and laterite at a similar altitude is widely distributed over the 'interior peneplain' of Guyana at about 100 m rising as pediments on valley slopes to some 200 m.

The North Savannas depression is some 50 km wide and 120 km long, in the interior of Guyana, running about E–W, bounded to the N by the Pakaraima Mountains and to the S by the Kanuku Mountains, a partly upfaulted range about 120 km long and 30 km wide, rising to some 900 m a.s.l., and ending abruptly both to E and W. The Rupununi Surface, forming the floor of the depression, is an extension of the great interior peneplain of Guyana, largely covered with Amazonian rainforest. It envelops the Kanuku Mountains passing them both to E and W, continuing southwards for some 100 km, carrying relic hills of an older landscape, and rising as a pediment from 100–150 m to as much as 300 m at the base of the mountains forming the boundary with Brazil. This plain is bordered to the NE and E by the mountains of Surinam, but to the W it grades into a similar plain, with wide savannas, in the Rio Branco Province of Brazil. This vast area of comparatively low altitude, penetrating to the centre of the Guiana Shield, owes its origin to a former master river, the Proto-Berbice (Fig. 1), which drained a large area of mountains and was enabled by the easily eroded rocks of the North Savannas graben to break through the central backbone of the shield and flow through the valley now occupied by the Berbice into the Atlantic near the site of New Amsterdam. After having travelled and overflown these areas on many occasions, the writer was privileged in 1966, thanks to the Government of Surinam, to take part with Dutch and Surinam geologists in a wide-ranging flight over the highlands of southern Surinam and Guyana, from which this great area was clearly visible as a classic pediplain descending slowly to the N towards the Kanuju Mountains and the plains beyond, and originating in the pediments fringing the southern mountains. The Late Tertiary and Quaternary geology of this whole area is complicated by the fact that the headwaters of the Proto-Berbice River were captured by the Rio Branco, a tributary of the Amazon, during the period when the Rupununi Surface was being planed.

In his memoir Dr Berrangé has attempted a re-interpretation of the local geomorphology. The Geological Survey accepted the great interior pediplain in the Rupununi District as representing the End-Tertiary and Late Tertiary Surfaces, corresponding with the dicyclic Velhas Surface of King

(1957), and rising gradually southwards towards pediments at 200–300 m a.s.l. at the base of the mountains on the boundary with Brazil. Dr Berrangé, however, has now proposed that the Rupununi Surface is succeeded to the S by two surfaces: a Late Tertiary 'Kuyuwini' Surface (230–260 m) and an Early Tertiary 'Oronoque' Surface (275–305 m) correlated respectively with the Early Velhas and Sul Americana Surfaces of L. C. King (1957). On the basis of regional geomorphology the writer considers the small scarps recognised by Dr Berrangé between these two surfaces to be of little significance and postulates that a 700 m planation in the adjacent mountains of Surinam and Brazil (Guerra, 1957) represents the Early Tertiary, Sul Americana Surface. This is very much higher than the 'Oronoque' Surface, but there is no question here of extensive Tertiary faulting. This high planation corresponds with the high relic plateaus of the Lely, Nassau and Bakhuis Mountains described above as carrying the high grade bauxites characteristic of the Early Tertiary. Dr Berrangé mentions the regional work of L. C. King, but omits reference to a report by Professor King (1964), produced at the request of the Surinam Government, showing that only two marked pediplanations were recognisable in Surinam: namely a lower surface at some 100 m rising as pediments to the mountains, and an early high surface at some 700 m. It is, therefore, most unlikely that the 'Oronoque' Surface, as described by Dr Berrangé, is of Early Tertiary age.

Sinha (1968, p. 115) notes that the Nappi Laterite rests directly on the Mesozoic sediments eroded by the Proto-Berbice River at an altitude of 300–325 ft (*c.* 100 m) which corresponds to the Rupununi Surface. The principal reason for which Dr Berrangé correlates the Nappi Laterites with the Early Tertiary coastal bauxites appears to be his reinterpretation of the local planations as described above, in which the 'Oronoque' surface is regarded as Early Tertiary, and, in his Figure 20 (1977) he shows this surface as being downwarped in the North Savannas Rift Valley to *underlie* the Nappi Laterite, whereas by a cross-over the Rupununi (End Tertiary) Surface would overlie and plane the same laterite. There are two facts in this interpretation which I wish to query: (1) it is difficult to believe that the Early Tertiary surface could have been downwarped to fit so closely with the regional average altitude of the End-Tertiary Rupununi surface characteristic of both the extensive interior plains of Guyana, and the Rio Branco Province of Brazil (Guerra, 1957); and (2) since planation surfaces are usually regarded as having been etched deeply into the bed-rock of earlier landscapes, thus destroying their regoliths, how could the End-Tertiary surface lie horizontally on the laterite of an Early Tertiary surface? Without strong evidence, which I have not found in Dr Berrangé's memoir, should not the simpler explanation be accepted? Namely, that the primary Nappi Laterite formed directly on the Rupununi Surface, which is continuous with the interior forested plain of Guyana and the Rio Branco Province of Brazil, all of Late Tertiary age. Later sedimentary deposits, including a possibly detritic laterite, would have formed in the Pleistocene during or after the capture of the Proto-Berbice by the Rio Branco. The formation of laterites and bauxites on sub-horizontal planations is associated with climatic events and in this connection it is of interest that while the Cretaceous–Tertiary boundary is widely represented by a climatic event, it is also now being suggested by some authorities that the end of Tertiary time may be marked by a global climatic event contemporaneous with the Messinian of the Mediterranean basin.

It is true that the formation of the North Savannas graben indicates considerable vertical movement in the area, but this faulting has been shown by Berrangé & Dearnley (1975) to be connected with the South Atlantic rifting of Jurassic and Early Cretaceous age, contemporaneous with the sedimentary fill of the graben, and the continuity of surface and laterite levels at either end of the trough renders it unlikely that there has been much local movement in the Tertiary. Late faulting has been observed, but is planed by the Late Tertiary surface. Both scarps of the graven are of basement and are 'fault-line' scarps. It is of general interest (see below) that the southern scarp of the rift is formed by the Kanuku Mountains, consisting of relatively fine-grained and erosion-resistant rocks of the Kanuku Complex (Singh, 1966; Berrangé, 1977), consisting largely of granulitic migmatites. Similar rocks form the Bakhuis Mountains in Surinam some 200 km to the ENE. Although the Mesozoic rocks of the graben bottom out rapidly in this direction, the dislocation limiting the granulitic rocks to the N can be followed to the Bakhuis Mountains by geophysical methods, but as this mountain block is capped by the Early Tertiary planation carrying commercial bauxites at an altitude of 450 m, little Tertiary movement relative to the general level of the shield can have taken place. The altitude of the Early Tertiary surface is dependant on the general seaward slope of the pediplain, accentuated perhaps by the proximity of the coastal monocline.

Finally, I disagree with Dr Berrangé's revision of the stratigraphy of the Corentyne Group (1977,

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p. 79 et seq.) and support the previous decision of the Geological Survey, following its general practice of not correlating formations on lithological grounds alone, *not* to correlate the white sands of southern Guyana with the coastal Berbice Formation (formerly White Sands Formation) of the Cerentyne Group. This is because some white sand deposits in the interior are found to be merely surface drift bleached by the acid waters common in Amazonian forest country (see also Berrangé, 1977, p. 84), and a term 'White sands, in part residual', notation 'Slp', was introduced in the Provisional Geological Map of British Guiana 1962 (see Williams, Cannon & McConnell, 1967).

2. The Kanuku Complex

The following remarks about the age of the Kanuku Complex of southern Guyana are aimed at simplifying the overall geological picture of the Guiana Shield rather than the details, of which Dr Berrangé gives an excellent account. He also agrees in the main with the conclusions of the Geological Survey (Williams, Cannon & McConnell, 1967) that the shield has an Archaean core, with a fringe of supracrustal formations to the north, probably of Lower Proterozoic age, some 200 km wide, stretching WNW–ESE for more than 2000 km from Venezuela to French Guiana. A minimum age for these supracrustals is fixed by the solid dating at about 2000 Ma (Snelling, 1963; Snelling & McConnell, 1969) of the so-called Akawaian thermotectonic episode with granite emplacement. This episode is widespread in the Guiana Shield (Choubert, 1964; Kalliokoski, 1965; Priem *et al.* 1966), and since it also occurs in Brazil, has been named the Trans-Amazonian Thermotectonic Episode by Hurley & Rand (1968). My main disagreement with Dr Berrangé is that in his provisional geochronological table (p. 6) he places the Kanuku Complex of relatively anhydrous granulites and migmatites in a Trans-Amazonian Cycle box dated 2020 ± 100 Ma, whereas the Geological Survey (McConnell, 1958) had regarded them as of older basement or Archaean age.

In French Guiana, thanks to the early availability of air photography, the composition and sequence of Lower Proterozoic supracrustals, equivalent to those of Guyana, had been well worked out in the 1940s (Choubert, 1949, 1966), but was only achieved in Guyana in 1959 (Williams, Cannon & McConnell, 1967) owing to the difficulty of obtaining photocover over the rainforest. It was then found that the supracrustals of northern Guyana were not a 'volcanic series' as previously mapped, but a eugeosynclinal assemblage metamorphosed chiefly in the greenschist facies, with at the base pelitic metasediments with some inter-layered basic volcanics, followed conformably by pebbly sandstones and conglomerates of the greywacke series with rare fine-grained igneous rocks, metamorphosed, but probably of the spilite-keratophyre suite. This assemblage resembles superficially the supracrustals of French Guiana but differs by the wide-spread presence of graded bedding, sub-aqueous volcanism and lack of unconformities between formations. Later it was shown (McConnell & Williams, 1970) that these Lower Proterozoic rocks of the Guiana Shield had been deposited in two separate basins: (1) a Guyana-Venezuela eugeosynclinal basin, and (2) a shallower French Guiana-Surinam basin: both of these metamorphosed and granitised by the *c.* 2000 Ma episode. Hurley & Rand (1971) also pointed out that a close comparison can be made across the Atlantic between the granulitic Archaean formations of Venezula and Liberia; and generalised studies (McConnell & Williams, 1970; Choubert, 1974) have also shown similarities between the Birrimian of West Africa with its manganese deposits, and equivalents in the Lower Proterozoic of the Guiana Shield. The *c.* 2000 Ma Eburnean thermotectonic episode of West Africa (Bonhomme, 1962) also matches closely the Trans-Amazonian across the ocean.

The importance of dating the Kanuku Complex, now clearly correlated with the rocks of the Bakhuis Mountains to the NE in Surinam, lies in the demonstration (McConnell & Williams, 1970) that it formed a WSW–ENE dorsal separating the two depositional basins just mentioned. In Guyana the deepwater sequence appears to pass to the W and S into a shelf facies represented by the acid-intermediate lavas, tuffs and agglomerates previously described by Grantham (1936), with orthoquartzitic rocks, indicating the proximity of an older basement (Williams, Cannon & McConnell, 1967); although the actual junctions are concealed by faulting and by the Proterozoic Roraima Formation of tabular quartzitic sandstones and shales which sits on the centre of the shield giving rise to the Pakaraima Mountains. It should be noted that the supposed unconformity between the deepwater and shelf formations mentioned by Berrangé (1977, p. 49) lies in a structurally disturbed area, and for this and other reasons had been previously rejected by officers of the Geological Survey.

Dr Berrangé has described in some detail the metamophic facies of the Kanuku Complex, and has

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accepted the date of 2020 ± 100 Ma (Spooner, Berrangé & Fairburn, 1971) as significant, therefore placing the complex in the Trans-Amazonian Cycle. However, the Geological Survey has described evidence (e..g. Singh, 1966) indicating that the present metamorphic facies of the Kanuku rocks is in some way associated with the emplacement of the huge South Savannas Granite (now included in the Southern Guyana Granite Complex) of Trans-Amazonian age, with which they are in contact, and which can be observed to intrude and permeate them. It is, therefore, here suggested that the apparent age of *c.* 2000 Ma is due to the pervasive influence of the Trans-Amazonian episode, and does not give the significant geological age of this complex (e.g. Hurley, Fairburn & Gaudette, 1976).

Dr Berrangé agrees with the view of the Geological Survey in correlating the Kanuku Complex with the similar granulitic Imataca Complex in the Venezuelan portion of the Guiana Shield. Much work has been done on the Imataca (e.g. Kalliokoski, 1965; Hurley & Rand, 1971; Martin, 1974) and results recently published (Montgomery & Hurley, 1978) indicate a complicated story involving a protolith dated 3.4–3.7 b.y., and a 'pervasive age' for the complex of 2800 Ma based on whole-rock Rb-Sr work. The Kanuku Complex extends to the NE into Surinam where it forms the Bakhuis Mountains (Dahlberg, 1974), and Gaudette *et al.* (1978) have now published work giving a Rb-Sr whole-rock age of 2817 ± 57 Ma on four specimens from the Bakhuis Mountains and two from Venezuela, thus indicating that the significant age of the Kanuku Complex should be taken as Archaean, in spite of its Trans-Amazonian metasomatism.

It must be added that Dr Berrangé's careful work on the Kanuku Complex has disclosed metasediments and gneisses which he terms 'Proto-Kanuku Complex' and compares with the Imataca Complex, assigning them a > 3000 Ma age and placing them in an Archaean box in the same Provisional Geochronological Table (p. 6) for Southern Guyana in which the Kanuku Complex is placed higher up in a Trans-Amazonian or Akawaian box. He also recognized that these Proto-Kanuku rocks had undergone a metamorphism of an age comparable with that of the Imataca, which he placed at 2700 Ma. Dr Berrangé has not separated these 'Proto-Kanuku' rocks on his map, and I suggest that they may merely represent portions of an Archaean Kanuku Complex which have to some extent escaped the intense Trans-Amazonian metamorphism.

In view of the interest of the close comparison which can be made between the rocks of the W African and Guiana Shields and its bearing on the nature of Atlantic rifting (McConnell, 1969) I suggest that it is important to emphasise the Archaean age of the granulitic formations of the Kanuku and Bakhuis Mountains, and their consequent close relationship with the Imataca of Venezuela and the Liberian of W. Africa.

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