in 1962 and 1963 (carried out by the Geological Survey of Norway for the University of Bergen) have shown that a rather large magnetic anomaly exists south of Kristiansand: remnants of a possible tertiary volcanic centre are perhaps localized there.

KARSTEN STORETVEDT

Department of Geophysics,
University of Bergen,
Norway.

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GEOLOGY

Age of the Transition in the Pre-Cambrian Atmosphere

RECENTLY published age determinations[1,2] together with other figures[3] from British Guiana can be used to give more information about the Pre-Cambrian atmosphere. Rutten[4] has suggested that a tentative age of 1,000 million years for the oldest geological 'red beds' indicates a provisional minimum age for the present oxygenic atmosphere. He further suggests that the transition between the latter and an earlier anoxygenic atmosphere occurred between 2,000 and 1,000 m.y. ago. Older 'red beds' occur in British Guiana and it is postulated here that the above transition was probably between 3,000 and 2,500 m.y. ago.

The Roraima Formation[5,6] consists of usually flat-lying sandstones and conglomerates with notable jasper horizons enabling a three-fold classification. The formation is several thousand feet thick and covers an area of approximately 175,000 square miles in British Guiana, Brazil and Venezuela with outliers in British Guiana (Berbice) and Surinam (Tafelberg). The sandstones are usually pink and the jaspers red or green. Approximately vertical cliffs several thousand feet high define the margins, forming the pink-coloured walls to flat-topped mesas, which are such a striking feature of the Roraima Formation (Mount Roraima is the setting of Conan Doyle's *Lost World*).

The Muruwa Formation[7] appears to underly the Roraima Formation, forming a low-lying belt, approximately 20 miles wide, east–west across central British Guiana. Lithologically the rock-types are remarkably similar to the Roraima Formation, differing mainly in being folded about gently plunging fold-axes.

The pink colour of the sandstones of both formations and, in particular, the deeper red of the jaspers of the Roraima Formation and the cherty mudstones of the Muruwa Formation appear mainly due to haematite and limonite. Following Rutten[4], and actualistic reasoning, these sediments were probably deposited under oxygenic conditions and, as shown below, appear to be the oldest types of these deposits (unequivocally dated) so far known.

Dolerites of the Younger Basic Intrusive Group form large sills intruding the Roraima Formation. McDougal, Compston and Hawkes[1], from several determinations on pyroxenes and plagioclases from these dolerites, suggest an age of intrusion of just over 2,000 m.y. Snelling and McConnell[3] consider the latter age is probably too high, and from determinations on pyroxenes from similar dolerites, muscovite and biotite from the associated hornfelses, and a re-interpretation of the data of McDougal *et al.*, suggests the best estimate of the age of emplacement of the intrusives to be 1,675 ± 100 m.y.

However, of immediate importance to the present note is that all the present data suggest a minimum age of the Roraima Formation of about 1,700 m.y.

In addition, the Roraima Formation unconformably overlies the Barama–Mazaruni Assemblage[8] and some of the granites of the Younger Granite Group. It has been suggested[8] that a post-Roraima granite may occur in Surinam, but the evidence is not conclusive. Minor acid dykes[9] intrude the Roraima but no post-Roraima intrusive granites have been mapped in British Guiana. Snelling[3] has dated several granites from the Younger Granite Group, the oldest within the northern eugeosyncline being the Kaituma Granite (2,065 ± 100 m.y.). In addition, the Kartabu Granite of the Bartica assemblage[10] has been dated at 1,960 ± 60 m.y. A preliminary outline of the geology of British Guiana was recently published in *Nature*[11].

Two granites intruding the Muruwa Formation have been dated[3] at 1,570 ± 50 and 1,760 ± 55 m.y., but Snelling (personal communication) has reservations about these dates. However, one granite intruding the Iwokrama Formation (which appears to overly conformably the Muruwa Formation) has been reliably dated[3] at 2,595 ± 125 m.y.

It can be clearly stated, therefore, that the Roraima Formation is older than its intrusive dolerites and must be in excess of 1,700 m.y. Geological evidence strongly suggests that the Muruwa Formation is older; this is confirmed by the oldest granite noted above, which is approximately 2,600 m.y. and gives a minimum age to the Muruwa Formation of about 2,500 m.y.

A minimum age of 2,015 m.y. has been suggested[3] for the main phase of the post-Barama–Mazaruni–Bartica orogeny (the last major pre-Roraima orogeny), and this age is probably also the date of emplacement of many members of the Younger Granite Group. Any Pre-Cambrian tectonism modifying the ages of the rocks underlying the Roraima Formation must, of course, be limited by the flat-lying sedimentary deposits of the Roraima Formation, which are, therefore, probably younger than 2,000 m.y. —approximately 1,800–1,700 m.y. has been suggested[3] for their deposition.

A tentative age of 2,000 m.y. for the youngest sediments deposited under anoxygenic conditions has been suggested by Rutten[4], though he notes that these deposits may range from 2,000 to 3,000 m.y. It seems likely from the above data that an oxygenic atmosphere was extant about 1,800 m.y. ago (Roraima Formation) and at least 2,500 m.y. ago (Muruwa Formation), and that any transition from a previous anoxygenic atmosphere occurred before 2,500 m.y., probably between 3,000 and 2,500 m.y. The overlapping of these ages with the suggested range (2,000 to 3,000 m.y.[4]) for the sediments deposited under an anoxygenic atmosphere clearly indicates that more data are required, particularly concerning the environment of the youngest sediments deposited under anoxygenic conditions (which may not, in all cases, reflect an anoxygenic atmosphere).

The above age determinations of British Guiana rocks (except for those in McDougal *et al.*[1]) were made by Dr. N. J. Snelling[2] at the Age Determination Unit, Overseas Geological Surveys in the Department of Geology and Mineralogy, University of Oxford.

R. T. CANNON

Department of Geological Sciences,
McGill University, Montreal.

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