PRECAMBRIAN PALAEOSOLS AT THE BASE OF THE RORAIMA FORMATION IN SURINAM[1]

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ABSTRACT

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A red transition zone with granitic fragments between the Roraima sandstones and the underlying granite at Kappelsavanna, Tafelberg and Emma Range is argued to represent a pre-Roraima palaeosol. The mineralogical and micromorphological characteristics of the palaeosol indicate an origin in an arid or semi-arid climate.

INTRODUCTION

Extensive parts of the Precambrian Guiana Shield in northern South America are covered with a thick sequence of horizontal sandstone and conglomerate beds with minor intercalated tuffs, collectively known as Roraima Formation or Roraima Group (REID, 1974; KEATS, 1976). The easternmost outlier of this formation is the Tafelberg (Table Mountain) in central Surinam, first seen by the Coppename expedition in 1901 (BAKHUIS, 1902), and first visited by Stahel and IJzerman in 1926 (STAHEL, 1927; IJZERMAN, 1931). Smaller outliers were discovered in the Emma Range (WENSINK, 1968), the Wilhelmina Mountains (VERHOFSTAD, 1971) and the Käyser Mountains (BOSMA ET AL., 1978). Speculations on the age of the formation ranged from Mesozoic to Precambrian, until dolerites intrusive into the formation in Guyana were established to be of Precambrian age (MCDOUGALL ET AL., 1963; SNELLING, 1963). Recent age determinations on intercalated ignimbritic volcanics from the Tafelberg yielded a Rb/Sr isochron age of 1599 ± 18 Ma (PRIEM ET AL., 1973).

During the 1958 Tafelberg expedition headed by Dr. D. C. Geijskes (itinerary: GEIJSKES, 1959), the geologist H. Beckering Vinckers discovered an outcrop SW of the Kappelsavannah, the low sandstone area surrounding the Tafelberg (Fig 1), in which the contact between the Roraima sand-

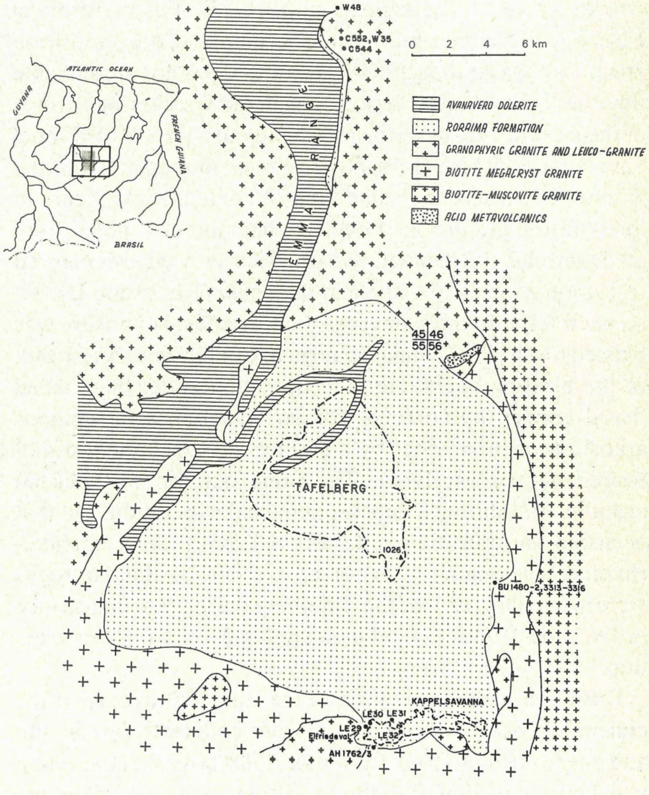

Fig. 1
Location of contacts with palaeosol. Geology after unpublished maps by Bosma and Kroonenberg.

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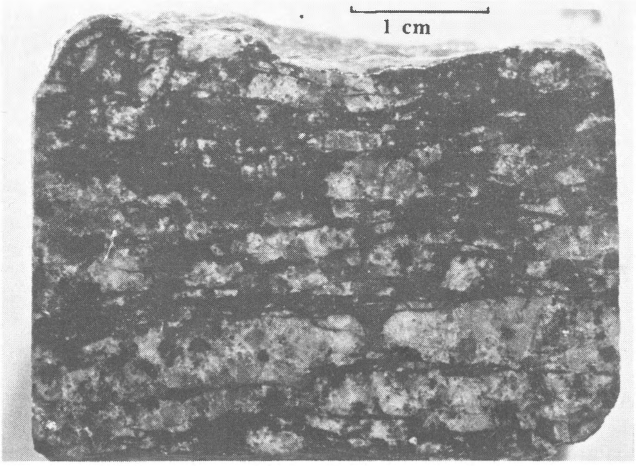

Fig. 2
Weathering of granite following microcracks parallel to the granite-sandstone contact. Drill core LE 29, 32 m depth, near Elfriedeval.

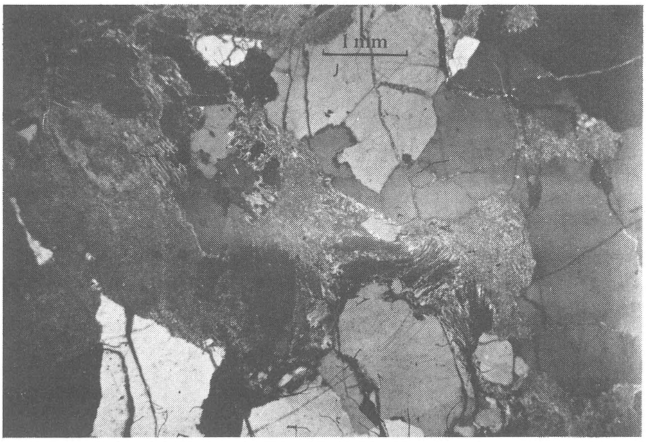

Fig. 3
Weathering microcracks and exfoliation of biotite. Crossed polarizers. AH 1762 SW of Kappel Savannah.

stones and the underlying granite was exposed (Elfriedeval). Between the granite and the sandstone he described a 'quarter-metre wide metamorphosed layer (. . .) with the appearance of red jasper-like indurated tuff' (BECKERING VINCKERS, 1961), which he interpreted to prove the granite to be intrusive into the sandstone. The observation formed a hotly debated issue which even now is not yet completely settled (cf. COLVÉE ET AL., 1975; KLOOSTERMAN, 1975). Later visitors at Elfriedeval doubted the hornfelsic nature of the transition zone. VAN DER LINGEN (1963-a, b) states: 'It is not unthinkable that the 'contact zone' represents an old weathering surface of the granite'. He describes a second outcrop SW of Kappel Savannah, in which the sandstone rests immediately on the granite, but where the same kind of contact rock occurs in joints in the granite. In 1966 five diamond drill holes were made through the contact, two of which showed a similar red transition zone of 20 - 30 cm in thickness (LE 29 and LE 32, respectively). In the same year the Elfriedeval exposure was blasted for the 7th Guiana Geological Conference. As a result of the blasting operations, the transition zone, then called 'basal arkose' by LOEMBAN TOBING (1966) and 'ferruginous arkosic transition zone' by BISSCHOPS (1969), largely disappeared (BISSCHOPS, 1966). The same outcrop was blasted again in 1971 during a geochronological expedition. On that occasion the transition zone was referred to as a 'granitic-rhyolitic agglomerate' (PRIEM ET AL., 1973). Similar rocks were also collected E of the Tafelberg during reconnaissance in 1965 and 1971. No field data are available from this location.

During the 1959 expedition to the Emma Range, two specimens of 'basal conglomerate' were collected, one in situ and one from talus scree, (WENSINK, 1968; BOSMA & CUP, 1968), which are very similar to the transition zone rocks from the Tafelberg and surroundings.

During the preparation of the new Geological Map of Surinam all samples from the area were reexamined by the present author. On that occasion the microscopic similarity between the red transition zone rocks, and weathered granitic rocks and the soil materials derived from them as described by BISDOM (1967-a, b) and KROONENBERG (1971), led to the working hypothesis of a palaeosol origin.

DESCRIPTION OF THE TRANSITION ZONE

Parent rock

Two different types of granitic parent rock have been encountered in the Tafelberg area: (1) a fine-grained leucogranite, with only small amounts of muscovite and biotite, at Elfriede Falls, drill core LE 29 and the outcrop E of Tafelberg; and (2) a medium-grained biotite granite, SW of the Kappel Savanna and in drill core LE 32. In the Emma Range the same rock types are found, as well as some granophyric granite. Locally quartz veins and greisen-like muscovite-quartz rocks are encountered (drill hole LE 30). The granites show the effect of hydrothermal alteration: biotite is commonly chloritized, microcline is turbid with brown submicroscopic alteration products, and plagioclase is partly sericitized. These phenomena are not restricted to the granites under the palaeosol, but have been observed in the whole granitic area around the Tafelberg.

Weathered granite

In some outcrops and drill cores the granite immediately below the contact is dark-red to purple stained, especially along fine cracks not present in the fresh rock. In polished hand specimens (Fig. 2) and thin sections (Fig. 3) these 'weathering microcracks' (BISDOM, 1967-a) run partly parallel

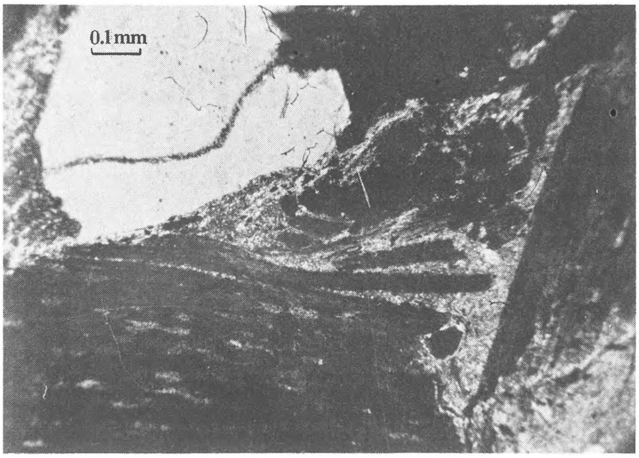

Fig. 4
Exfoliation of biotite. AH 1762, SW of Kappel Savannah. Crossed polarizers.

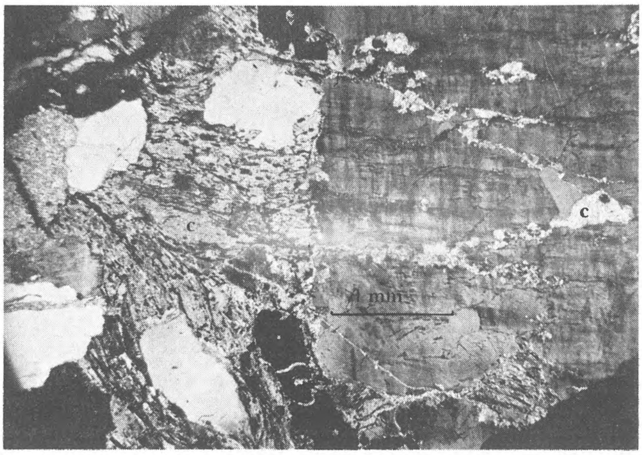

Fig. 5
Carbonate (c) in weathering microcracks in feldspar and biotite. LE 32-14B, depth 52 m, Kappel Savannah. Crossed polarizers.

to the contact surface, partly along grain contacts but also commonly in random directions traversing microcline and quartz irrespective of crystallographic directions. The larger cracks become filled with extremely fine clayey-micaceous material. Plagioclases are mostly completely altered into this material, which will be referred to as *plasma* in the sense of BREWER (1964; for definition see below). At high magnifications minute blood-red droplets (probably of hematite) are observed in the plasma, which cause the red stain of the weathered granite. Micas begin to exfoliate (Figs. 3 and 4): individual cleavage sheets become loosened and curl up, the resulting openings being filled with plasma. In some drill cores the plasma in weathering microcracks is carbonaceous instead of micaceous; no carbonate was present in the fresh rock (Fig. 5).

Palaeosol

Macroscopically the palaeosol is not a 'soil' in the ordinary sense of the word, as it is a hard rock with no macroscopically visible porosity. It consists of a dark purplish-red fine groundmass, with a colour varying between 7.5 R 2/2 and 7.5 R 4/4 according to the Munsell soil colour chart, in which scarce angular granitic fragments 'float', attaining a size of about 3 cm (Fig. 6).

Following the nomenclature of BREWER (1964) for the microscopic description of soils, soil material consists of skeleton grains, plasma and voids. *Skeleton grains* are defined as individual grains which are relatively stable and not readily translocated, concentrated or reorganized by the processes of soil formation; they include mineral grains and resistant organic bodies larger than colloidal size. *Plasma* is defined as that part of the soil material which is capable of being or has been moved, reorganized and/or concentrated by the processes of soil formation; it includes all the material, mineral or

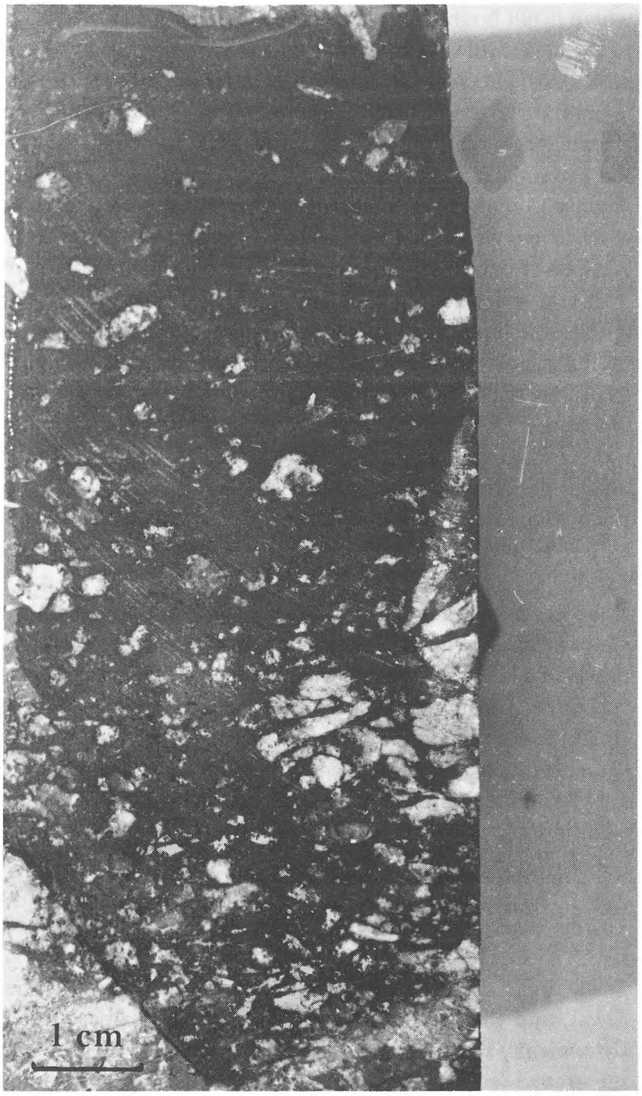

Fig. 6
Macroscopical appearance of palaeosol in drill core LE 29, 32 m depth, near Elfriedeval.

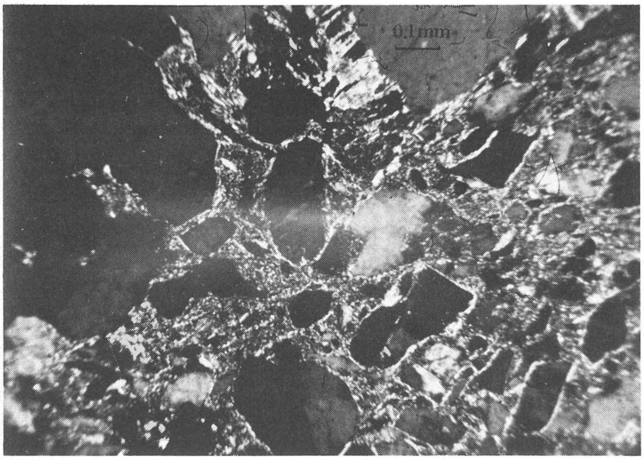

Fig. 7
Skelsepic plasmic fabric, AH 1722, Elfriedeval, crossed polarizers.

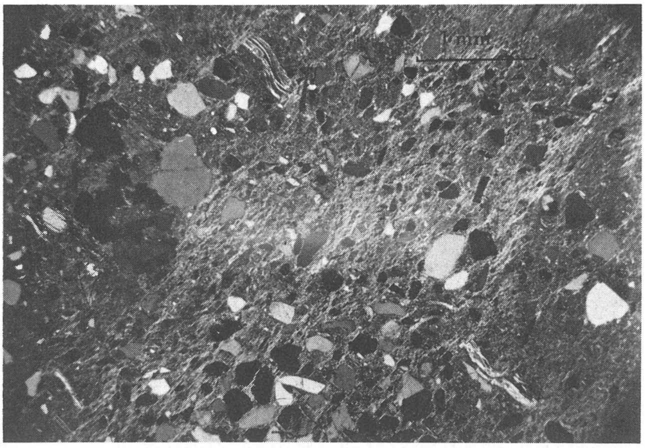

Fig. 8
Masepic plasmic fabric, AH 1723, Elfriedeval, crossed polarizers.

organic, of colloidal size and relatively soluble material which is not bound up in the skeleton grains (BREWER, 1964). In the palaeosol skeleton grains and plasma are arranged in a *porphyroskelic basic structure,* i.e. 'after the manner of phenocrysts in a porphyritic rock' (BREWER, 1964). Voids are absent, probably due to compaction after the deposition of the Roraima sandstones. The *skeleton* consists of unsorted angular granitic rock fragments and mineral grains, all in a more or less weathered state as described above. The *plasma* consists of extremely fine clayey-micaceous aggregates (domains) in which no single mineral grains can be discerned, but which still show birefringence by aggregate polarization. A preliminary X-ray survey of the plasma shows a predominance of 10 Å minerals (illite-muscovite; cf. also WENSINK, 1968), and minor 16 Å clay minerals. The clayey-micaceous material is mixed with minute red hematite droplets. Locally the plasma domains show some parallel orientation: such *plasma separations* are *pedological features,* indicators of soil formation (BREWER, 1964). Plasma separations may be oriented parallel to skeleton grains (*skelsepic plasmic fabric*; Fig. 7), or be not associated with skeleton grains or voids (*masepic plasmic fabric*, Fig. 8). Skelsepic plasmic fabric has also been noted in plasma in weathering cracks in rock and mineral fragments. Other pedological features are the development of single, more or less idiomorphic carbonate crystals (*'intercalary crystals'*: BREWER, 1964) within the plasma of drill hole LE 32. Elsewhere replacement of carbonate from the weathered granite by clayey-micaceous plasma has been noted (Fig. 9).

Transported palaeosol

Some rocks, especially the most recent samples from Elfriedeval, and the specimens collected E. of Tafelberg, macroscopically resemble the palaeosol, but have a slightly lighter orange-red colour, and apart from the angular granitic fragments also contain a certain amount of subrounded to well-rounded skeleton grains resembling those of which the overlying sandstone is composed (Fig. 10). The Emma Range samples even contain coarser rounded quartz grains (up to 1 cm), but still contain much more palaeosol-like plasma than the ordinary conglomerates in the higher parts of the Tafelberg. Extremely fine-grained clay pellets have also been noted. This mixed material, which has also been encountered in joints in the granite, may be the result of local colluviation phenomena.

Sandstone

The sandstone overlying the palaeosol is a pink to white medium-grained well-sorted quartz arenite to arkosic arenite, consisting of well-rounded to subrounded quartz grains of about 300 microns average grain size, with minor K-feldspar, muscovite and biotite and rare well-rounded grains of apatite and garnet, and with a clayey to sericitic matrix. The sandstones are often very homogeneous, except for an occasional siltstone lamina. In some drill cores (LE 29) sandstones with a bimodal grain-size distribution were encountered, consisting of a few well-rounded quartz grains of 2-3 mm in size, 'floating' in normal sandstone (quartz arenite) with an average grain size of 300 microns. True conglomerates have not been encountered at short distances from the palaeosols; they seem confined to the escarpments of the Tafelberg itself, representing a much higher part of the sequence. Here the sandstones are also of a different character; they are mostly redder in colour and harder, almost quartzitic, due to the predominance of clear secondary quartz or chert as a cementing material. Small-scale cross-bedding has been noted occasionally in the lower part of the section near the palaeosol, and is common in the higher parts. Heavy-mineral analyses of the sandstones above the contact show a clear predominance of unstable minerals such as biotite, apatite and garnet

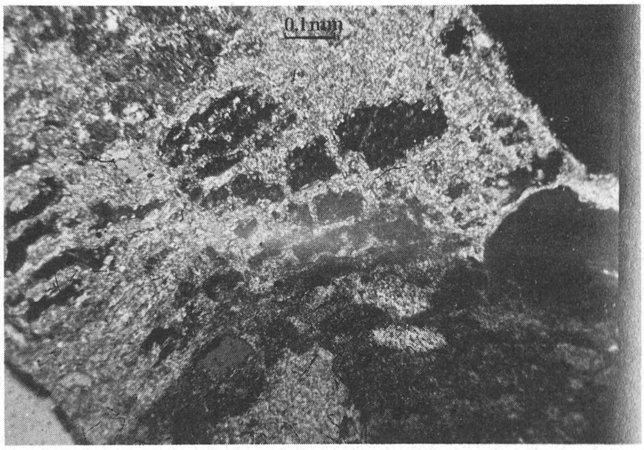

Fig. 9
Replacement of carbonate (c) by clayey-micaceous plasma. Carbonate in extinction position. Drill core LE 29-9, 32 m depth, near Elfriedeval. Crossed polarizers.

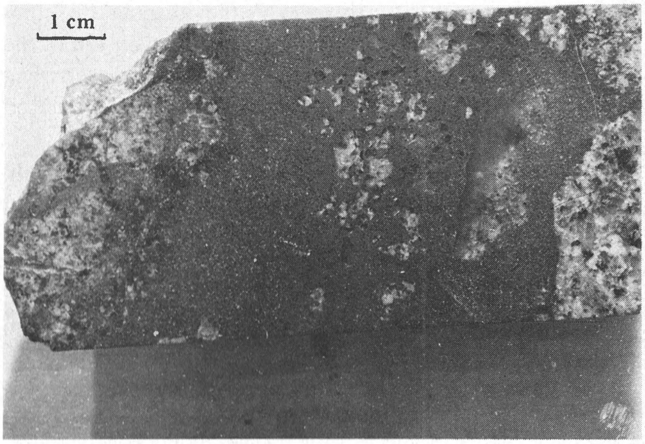

Fig. 10
Palaeosol with granitic fragments mixed with rounded sand grains in a joint in granite. The well-sorted sand grains are concentrated along the walls of the joint. Drill core MXB, Elfriedeval.

(KROOK, 1965). Much higher up the section, in the escarpments of the Tafelberg, intercalations of bright red jasper-like rocks occur, which superficially resemble the palaeosols. Microscopically they differ from them completely, however, by the presence of spherulitic textures, a turbid felsitic groundmass and the occurrence of very strongly pleochroic piemontite. These rocks may indeed be of volcanic origin. Of undoubtedly volcanic nature are the cream-coloured or striped ignimbritic rocks in the same part of the section (GEIJSKES, 1959; PRIEM ET AL., 1973; cf. also IJZERMAN, 1931).

DISCUSSION

In the following the various hypotheses regarding the origin of the transition zone between granite and sandstone will be briefly discussed. To start with the weathered granite, one could argue that the breakdown of feldspars and micas could be the result of hydrothermal action. However, the presence of plasma-filled microcracks distinguishes this material from hydrothermally altered granites such as encountered deeper in the same drill holes and in other areas near the Tafelberg. These cracks cannot have been produced by cataclasis, as quartz never shows any sign of stress such as undulatory extinction or Boehm's lamellae. Moreover, the exfoliation of the micas is distinct from the effect of hydrothermal alteration, as the weathered micas underwent a considerable volume increase, whereas e.g. chloritized micas remain confined to the outlines of the former biotite crystals (cf. KROONENBERG, 1971).

As to the palaeosol itself, a contact-metamorphic origin of this material (BECKERING VINCKERS, 1961) is highly unlikely, as there are no indications of recrystallization, whereas such clayey material is likely to change into cordierite- or andalusite-bearing hornfels at fairly low temperatures. The absence of any grain-size sorting and layering pleads against a purely sedimentary origin of the palaeosol s.s., as does the angularity of the skeleton grains and the preservation of fragile structures such as exfoliated micas. There is equally little evidence for volcanic interference: all rock fragments are granitic, and there are no individual mineral grains which could possibly represent phenocrysts. The groundmass is micaceous-clayey throughout, and does not at all resemble devitrified glass, felsite or any other common volcanic groundmass.

Instead, the great resemblance between this material and weathered granites and related soils (BISDOM, 1967-a, b; KROONENBERG, 1971), and its exclusive occurrence at an unconformity between granite and sandstone strongly plead for a palaeosol origin. This is still corroborated by the presence of pedological features such as plasma separations and intercalary carbonate crystals.

CONDITIONS OF SOIL FORMATION

Crystallization of carbonate is a feature common to soils in arid and semi-arid climates, in which evaporation exceeds precipitation. Chemical weathering was probably not very intensive, judging by the nature of the clay minerals, and by the preservation of easily weatherable minerals such as biotite in the palaeosol. The red colour of the palaeosol and the absence of evidence for iron mobilization by reduction and oxidation may point to good drainage conditions – although mobilization of iron in Precambrian soils might have been more difficult than in recent ones due to the absence of terrestrial plant and animal life, and hence of chelating substances and reduction-enhancing micro-organisms. Plasma separations such as encountered in the palaeosol are generally interpreted to be due to stress applied to the soil, often as a result of expansion on wetting of dry soils (GREENE-

KELLY & MACKNEY, 1970). However, in the present case, compaction after the deposition of the sandstones on top of the palaeosol may also have played a role, as textures resembling skelsepic plasmic fabric have occasionally been encountered in sandstones as well.

The discontinuity and thinness of the palaeosol indicate that erosional processes may have truncated the soil profile. Part of the soil material appears to have been transported and mixed with sand grains resembling those of the overlying sandstone. The homogeneity and good sorting of the sandstone and the rounding of the mineral grains, as well as the presence of bimodal quartz arenites (PETTIJOHN ET AL., 1972, p. 218), may point to eolian interference (cf. KROOK, 1965; BISSCHOPS, 1969). Indications of fluvial to deltaic deposition have been mentioned (BISSCHOPS, 1969; PRIEM ET AL., 1973), but a systematic study of sedimentary structures still awaits to be done.

The overall picture emerging is that of a lowland granitic area in an arid to semi-arid climate, with a thin red soil cover, in which as a result of upwards migration of soil water, carbonate precipitated. Erosional processes, possibly sheet wash, locally stripped the fresh bedrock clean, leaving only some soil material behind in the joints in the granite. On top of this landscape (wind-blown?) sands were deposited. In the first stage of sand deposition mixing with soil material took place during short rain showers. With increasing sand deposition the whole granitic landscape disappeared under the sediment cover.

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