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TUBULAR FOSSILS IN THE BAUXITES AND THE UNDERLYING SEDIMENTS OF SURINAM AND GUYANA

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ABSTRACT

This paper presents a description of the possible plant fossils and burrows in the bauxite belt which extends through Surinam and Guyana.

The possible plant fossils are defined as roots, treetrunks, and branches forming horizontal layers of roots in the underlying sediments and the basal part of the bauxites. The plant fossils show external textures, and internal structures which may be taken to be cuticulae. Within the bauxites burrows of various diameters may be seen. Internally, they either show the typical "Stopfgefüge" or lack structure entirely.

The presence of plant roots and burrows proves that a large proportion of the bauxite in the bauxite belts of Surinam and Guyana originates from sediments formed in either a mangrove environment, a fresh-water marsh environment, or a brackish swamp environment.

The bauxites of the coastal plains in Surinam and Guyana originate partly from Precambrian basement and partly from Tertiary sediments and were formed through weathering on intersected plateaus. In some places where the bauxites rest on sediments, tubular fossils are found in great quantities in the top section of the underlying sediments and in the lower section of the bauxite profile. These fossils, which until now have been almost ignored, will receive a special treatment here. They were mentioned briefly as "Tubular Concretions" by van K e r s e n (1956).

Early in 1970 I had the opportunity to visit many of the quarries in operation and the abandoned workings in Surinam and Guyana belonging to BILLITON Maatschappij, SURALCO and DEMERARA Bauxite Co. to collect numerous specimens there. The companies gave me their generous support throughout, and I should also like to thank Mr. COUTINHO of SURALCO for contributing a large number of tubular fossils which proved to be extremely instructive material.

GENERAL

As will be demonstrated later, the tubular fossils may be classified as:

1. possible plant remains
2. concretionary formations around roots
3. burrows.

They were formed in situ under synsedimentary to early diagenetic conditions and thus present autochthonous relic textures in the underlying sediment or bauxite, which make it possible to comment upon the nature of the source rock and the type of environment in which the sediment was formed.

The tubular fossils consist mainly of gibbsite, with impurities of kaolinite, heavy minerals and hydrated oxides of iron, but organic matter is absent.

RELATIONS BETWEEN THE TYPE OF SEDIMENT AND THE TYPE OF TUBULAR FOSSIL

In Surinam the bauxites rest in many places upon what is indisputably pre-Bauxitic sediment. The investigations carried out here make it seem probably that this is also the case in Guyana. The sediments

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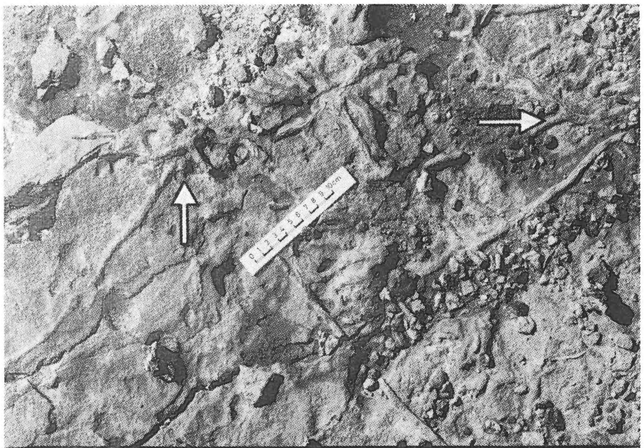

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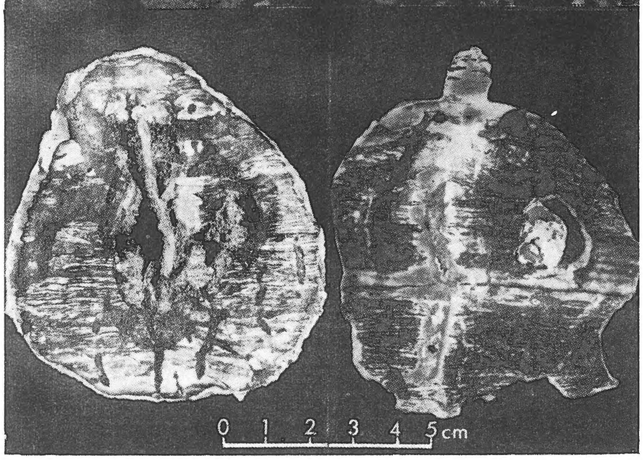

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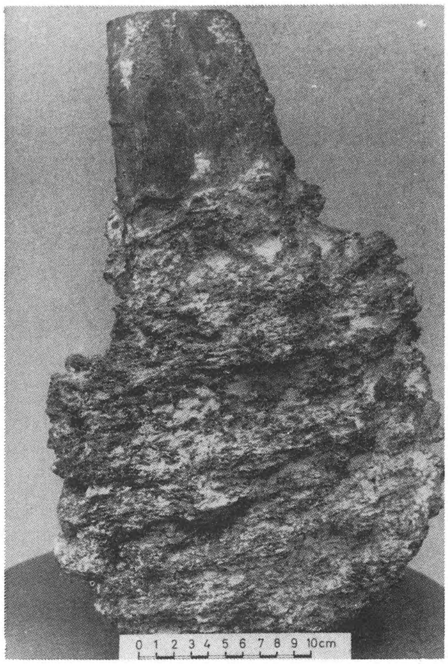

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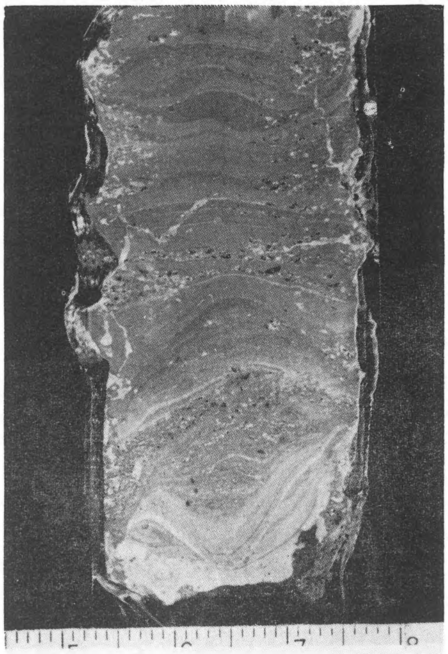

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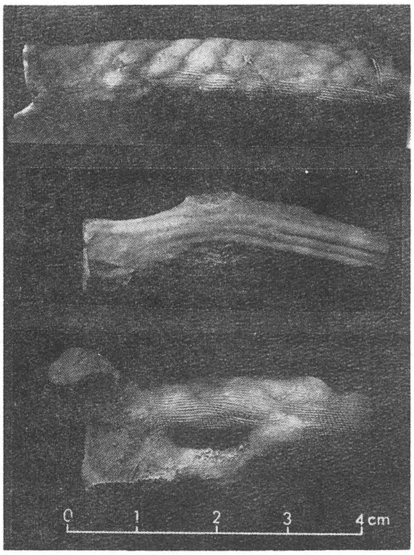
Plate I

1. Fossilised roots, some branching, some radiating from a centre, in horizontal layers on the "sand-strata" – St. Helena, Onverdacht, Surinam.
2. Root layers reaching vertically into the clay from a "sandstratum", St. Helena, Onverdacht, Surinam.
3. Concretions with indicated horizontal stratification penetrated by roots. Soft gibbsite filling in the centre (specimen 208 b); in the transitional zone between bauxite – underlying sediment. St. Helena, Onverdacht, Surinam.
4. Treetrunk, basal bauxite. Para mine, Onverdacht, Surinam. Collection – Billiton Maatschappij Laboratory
5. Plant remains with lengthwise grooving externally and irregular layering internally, with the alternation of fine gibbsite layers and layers of heavy minerals (specimen 430 d). Topibo de Vrijheid, Paranam, Surinam.



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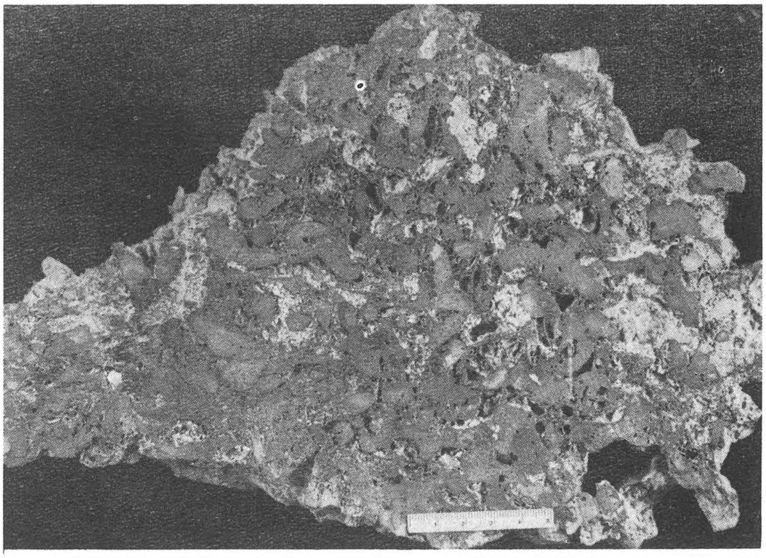

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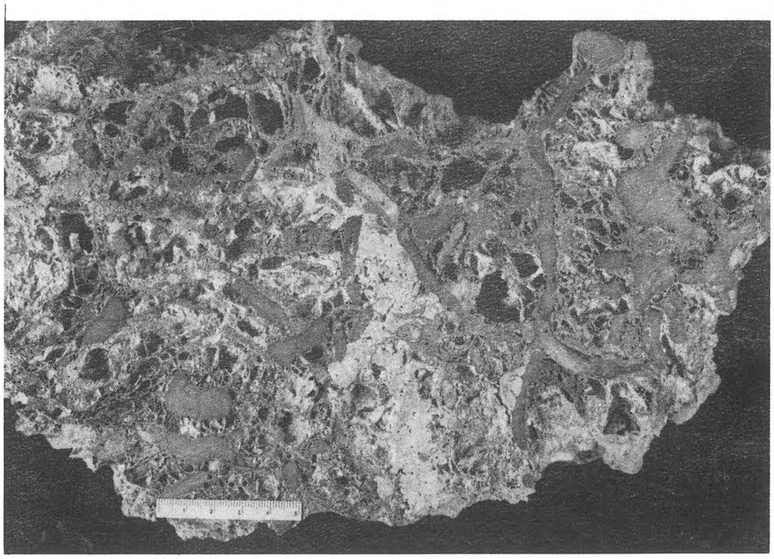

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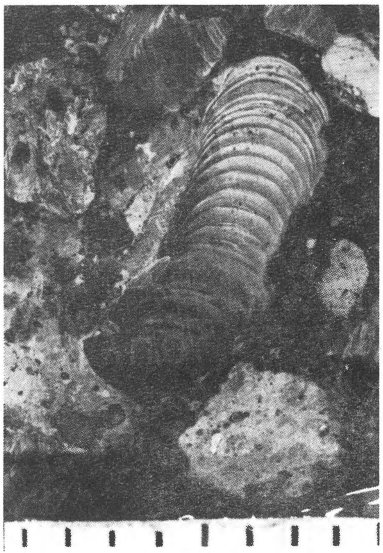

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Plate II

6a. Plant remains with a plate-like pattern and superimposed lengthwise grooving (specimen 4 d). Topibo de Vrijheid, Paranam, Surinam.
b. Plant remains with broad ribbing and superimposed lengthwise grooving (specimen 4 i). Topibo de Vrijheid, Paranam, Surinam.
c. Plant remains with simple lengthwise grooving (specimen 8 a). Three Friends, Mackenzie, Guyana.
7. A bauxite base, with a large number of burrows with porous internal texture, closely interspersed (specimen 184). Pit No. 392, Para mine, Onverdacht, Surinam.
8. A bauxite, base, with interspersing and intersecting burrows in cellular bauxite (specimen 183). Pit No. 392, Para mine, Onverdacht, Surinam.
9. Remains of burrows filled with internal "Stopfgefüge" in breccia-like bauxite (specimen 85/15; profile I, Area I), Kankantrie mine, Onverdacht, Surinam.

take the form of irregularly alternating arenaceous and kaolinitic strata, which show the characteristics of turbulent sedimentation and have undulating surfaces (fig. 1). There are also slumping structures.

undulating baseline of the bauxite which reaches several metres into the sediment at the deepest points. This indicates a relief landscape with a valley system.

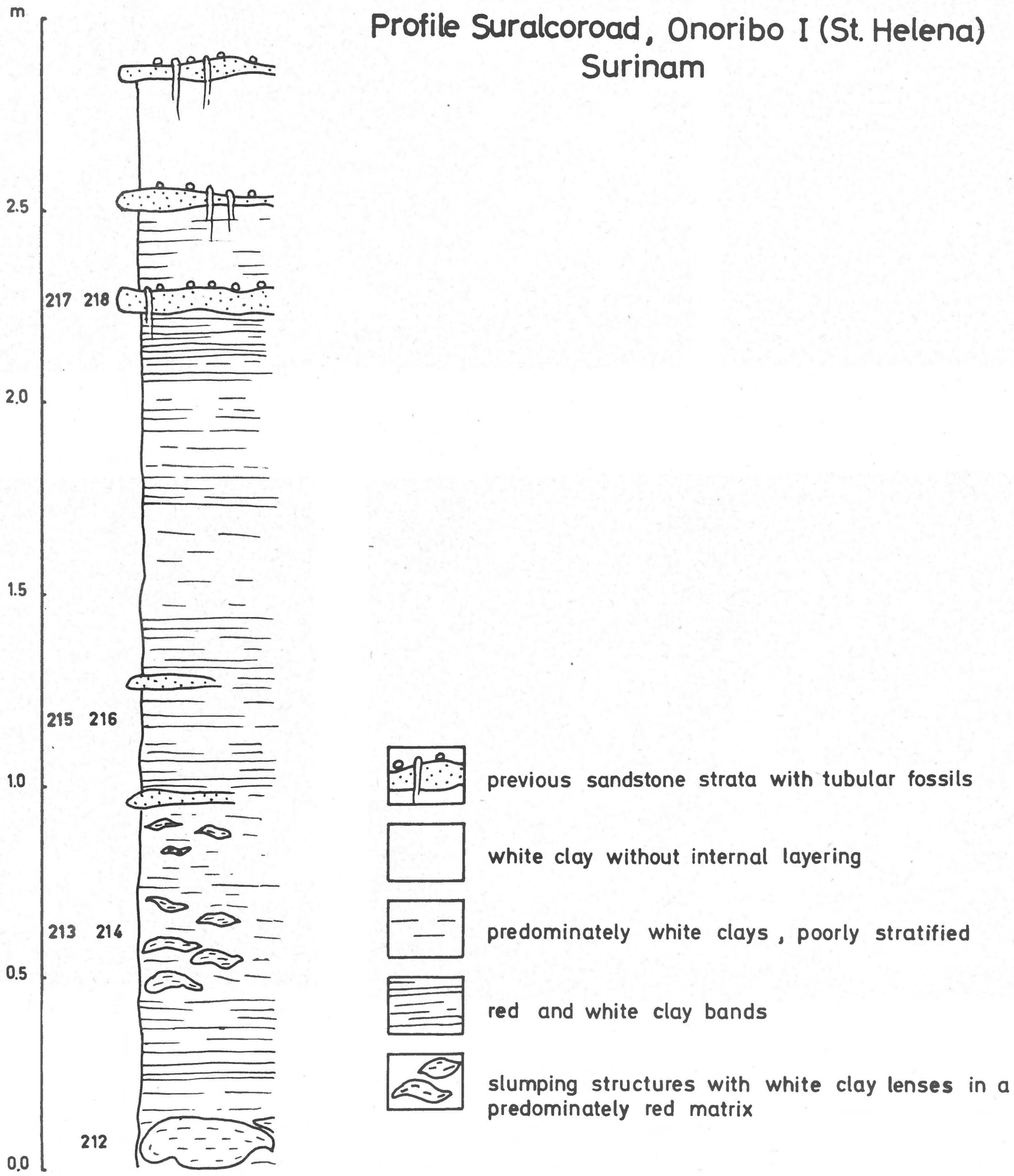

Figure I

The boundary between the underlying sediments and the bauxite cannot be exactly drawn either on mineralogical grounds or by reference to the presence of the fossils.

1. The overall picture from mapping is that of an

2. In individual quarries one may observe either a well-defined boundary between the underlying clay and the overlying bauxite (Kankantrie-mine/Onverdacht, Surinam; Three Friends/Guyana) or a transitional zone, in which there are inclusions of gibbsite-bauxite (previously sand-

stone) strata in the kaolinitic clay, the number of which increases towards the surface; these are finally replaced by pure bauxite.

The tubular fossils may be observed in

1. the gibbsitized sandstone strata of the underlying sediment
2. the top sections of the kaolinite bedrock
3. the lower part of the bauxite.

The tubular fossils therefore extend from the upper part of the sediment through the boundary area into the bauxite.

Most of the tubular fossils have not been preserved sufficiently well for a positive identification either as plant remains or as burrows. However, where identification is possible, it may be observed that plant remains (layers of root) only occur in the underlying sediment and the transitional zone between the bedrock and the bauxite. Burrows do not appear to be present in this area. In the lower part of the bauxite there is a zone where plant-remains and burrows occur together; this horizon is replaced higher up by a zone with burrows. There is a general decrease towards the surface of the bauxite in the number of burrows.

In the following a distinction will be made between the horizon of possible layers of root and the burrow-zone.

THE HORIZON OF POSSIBLE LAYERS OF ROOTS

In order to identify the possible plant remains as accurately as possible, they were sent for verification to Prof. Mägdefrau, Institute for Special Botany, University of Tübingen, Prof. Pons and Dr. Slager, Laboratories for Regional Soil Science, Wageningen, and to Dr. Gottwald, Institut für Holzbiologie (Wood-biology), Bundesanstalt für Holz- und Forstwirtschaft in Hamburg.

As internal structures are almost completely absent (see below) the morphology was the most decisive factor. All those who handled the specimens agreed that they could be plant remains, but that a closer identification and a comparison with recent material was out of the question. Thus plant remains are discussed below despite a degree of uncertainty.

The fossils that have been preserved are mainly roots, very few trunks and no leaves or fruits.

Until recently the layers of roots have attracted very little attention. V a n K e r s e n (1956) mentions "tubular concretions" in the transitional zone between underlying clay and bauxite at Topibo de Vrijheid. However, he did not consider them to be plant remains, for he writes (p. 284): "The ribbed surface shows a great resemblance to the surface structure of the roots of some palm trees. Besides this fluting at the outside nothing points to an organic structure".

REGIONAL DISTRIBUTION

In Surinam layers of roots (see fig. 2) in what were previously coarse sandstone strata (now layered gibbsite-bauxite), in the clay underlying the bauxite, and in the basal part of the bauxite are widely spread. They are authochthonous:

a) on sandstone layers and clays under the bauxite and in the basal part of the bauxite at
   - St. Helena (Onoribo I)/Onverdacht
   - Topibo de Vrijheid/Paranam
   - Rorac
   - the new railway cutting – Ricanaoplateau/Moengo
   - various locations on the Adoemakondre II-plateau/Moengo;
b) elsewhere in the basal part of the bauxite at
   - Kankantrie mine/Onverdacht
   - Para mine/Onverdacht.

In many abandoned workings root fragments have been uncovered by weathering and are readily collected as hand specimen.

In Guyana layers of roots also occur in the underlying kaolinitic clay, in the basal part of the bauxite, in the "underclay" at

- Three Friends, Mackenzie
- Kwakwani and Mombakka and
- in the deeper profile sections of the bauxites at Montgomery/Mackenzie and
- Kamakabra III/Itunie-area.

These are incomplete statements; they depend in part upon my own observations, and in part upon the specimen that Mr. COUTINHO of Suralco was good enough to place at my disposal.

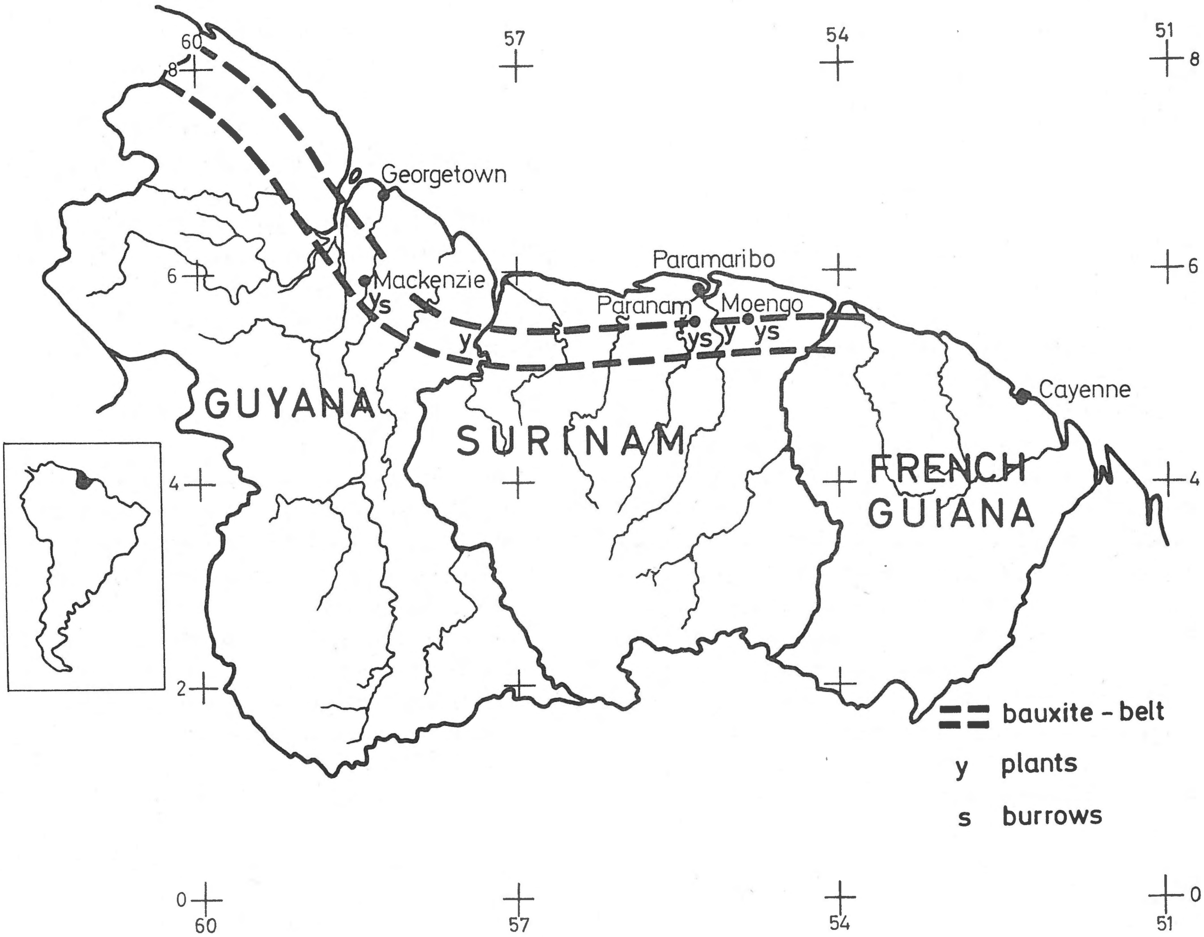

Figure 2

THE SPATIAL POSITIONING OF THE ROOT LAYERS

Little can be said about the spatial positioning on the individual plateaus owing to the small number of quarries. A variation in the density of the vegetation, probably a result of the relief of the landscape at that time, may be definitely proved.

In the underlying sediments or the transitional zone to bauxites the best spatial preservation of the root layers may be seen on the many coarse-grained strata of the profile. There was no single process of root penetration from above; the plant growth must have occurred in a chronologically repeated process.

The roots in the "sandstone"-strata lie horizontally on the surface of the layers and branch out horizontally. Roots of all thicknesses between 1 and 10 mm ϕ are present (see plate I, 1). Very few roots (vertically) penetrate the hard layers and the soft clay beneath (see plate I, 2). The area around the roots in the red clay is frequently bleached. Root systems with horizontally and vertically branching roots of varying thicknesses, covering a profile of 1-1,5 metres, are occasionally present in the basal layers of the bauxite. Further above the tubular roots gradually disappear.

THREE TRUNKS

Tree trunks have been very rarely preserved. In Billiton Maatschappij's collection there is a well developed, vertically ribbed tree trunk with a thick clump of roots (plate I, 4). A poorly developed trunk with roots is present in the pre-bauxite clays of St. Helena in Onverdacht. Another smaller trunk with a clump of roots was recovered from this location.

CONCRETIONARY FORMATIONS AROUND ROOTS

In the transitional zones between underlying sediment and bauxite, characterized by alternating strata of gibbsitized sandstone strata with clay (as at St. Helena/Onverdacht, new railway cutting at Moengo), bulbous concretions are present, varying between 1-25 cm in size. The majority consists of gibbsite bauxite in which there are traces of hydrated iron oxides. Kaolinite is also present as an impurity.

Many concretions show:

- the relics of the sandstone layering from which they have developed (plate I, 3)
- hollow spaces inside which are partially filled with soft gibbsite or kaolinite
- the penetration of single thick roots or a network of thinner roots.

It cannot be proved that all the concretions have the same origin. However it seems certain that some of these concretions may be regarded as fossilized root bulbs.

THE FINE STRUCTURE OF THE ROOTS

The roots display variation in their state of preservation, in most cases showing an irregular and rough surface. Thick roots overgrown by a network of thin branching roots, and the branching of thick roots to form networks of thinner roots, are characteristic.

Three different types of roots may be distinguished by their surfaces (plate II, 6).

a. Surfaces with plate-like protrusions covered with fine lengthwise ribbing.
b. Surfaces with broad ribs running lengthwise, which in themselves show finer ribbing.
c. A surface with simple lengthwise ribbing.

This lengthwise ribbing is shown not only by the fine roots, but also in larger dimensions by stems 1-2 cm in diameter and by treetrunks. Prof. Mägdefrau wrote: "They may be roots, but I cannot say any more about them. I know of no recent comparable specimen which would accord with the fossils".

The cross-sections are mostly lacking in structure; occasionally the tubular fossils are hollow inside. In many cases an outer area with a cellular network structure 15-20 μ in width may be seen in cross-section (fig. 3). The structure is such that in polarized

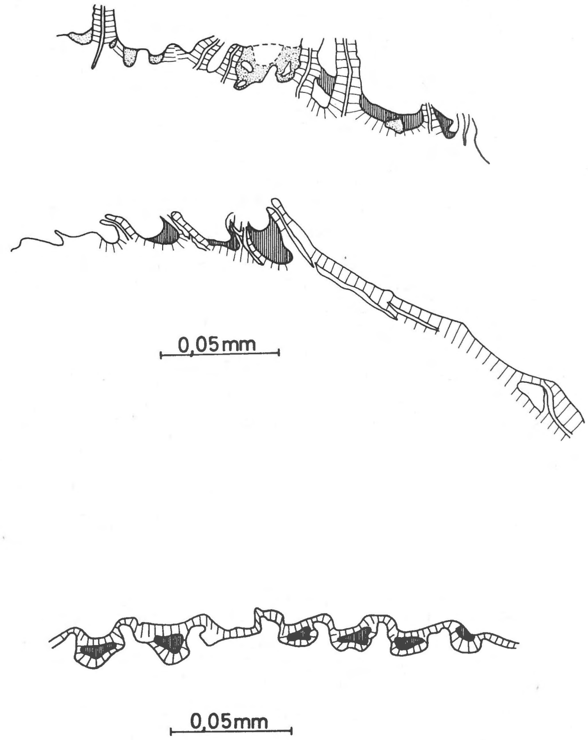

Figure 3

light brown pores may be seen below the ribs. In this outer area the coarse crystallization and the radial structure of the gibbsite may be observed. Very occasionally small tubes with a hollow interior may be seen branching away from the surface.

Mr. Gottwald, Institut für Holzbiologie (wood biology) of the Bundesanstalt für Holz- und Forstwirtschaft in Hamburg said that these structural elements could with a high degree of reliability be taken to be root cuticulae.

Neither carbon nor hydrocarbon have been preserved in the area of root layers. The organic matter appears to have been oxidized completely. The roots and stems now consist entirely of dense gibbsite bauxite with low iron and silica content and a pinkish to white colour.

Vertically positioned stems or roots (with external ribbing) are occasionally filled with coarser material, which displays irregularly alternating layers of fine gibbsite and granular layers with a large number of heavy minerals (plate I, 5).

Obviously they died during the process of sedimentation; only the very resistant cuticulae were preserved and the inner cavity was included in the advancing sedimentation.

AREA OF BURROWS

No literature has as yet been produced about the burrows. Van Kersen probably meant to include them in his description "tubular concretions".

REGIONAL DISTRIBUTION

They do not occur in the bedrock but first appear in the basal part of the solid bauxite.

The bauxite has been mined out in many places so that it is no longer possible to make observations.

Certain burrows are present at (fig. 2):

Surinam:
- Adoemakondre II-plateau/Moengo
- Kankantrie Mine/Onverdacht
- Para Mine/Onverdacht
- St. Helena (Onoribo I)/Onverdacht

Guyana:
- Kamakabra III (Itunie-area).

THE SPATIAL POSITIONING OF THE BURROWS

Burrows have never been found in the prebauxitic sediment or in the transitional zone. The first burrows occur in the bauxites. They were particularly noticed in the Onverdacht area.

The burrow penetration gradually ceases further higher up without a sharp boundary being present. In Pit 392 at the Para Mine there is a cellular bauxite layer above it, followed by a zone where burrow-fossils as well as root-fossils occur. Burrows are also present in the Kankantrie-Central workings.

There is no cellular bauxite layer. The first burrows that may be authenticated are contained in the highest part of the zone penetrated by roots. They increase in number higher upwards.

The mid 1-3 metres of bauxite are penetrated by burrows in Pit 392 at the Para mine and in the whole area of the Kankantrie mine (plate II, 7, 8).

Structures of a residual breccia predominate in the upper part of the bauxite; a textural feature of these are fragments of burrows, which are often heavily corroded. This would seem to indicate that the burrows were present in the highest parts of the bauxite profiles.

Burrows varying between 0.1-1.0 cm in diameter are present; they have obviously been made by different animal species. The burrows are mainly vertical, but apart from this all other directions were also frequently chosen. Branchings in the burrows were occasionally found, and the burrows frequently intercross.

In the quarry of the Kankantrie mine it is particularly noticeable that the animal population was not spread evenly all over the plateau, but that densely-populated and thinly-populated areas occur. In individual cases it is difficult to distinguish between burrows and roots of a certain size. It is therefore impossible to comment upon the frequency of the burrows in an area where root penetrations has also occurred.

THE FINE STRUCTURE OF THE BURROWS

The inner construction of the burrows is characterized by:

1. lack of orientated structure, with a granular texture of what was previously sandstone;
2. the "Stopfgefüge"[2]) of the inner material, often typical of the burrows (plate II, 9).

Such "Stopfgefüge" are produced by worms in different ecologies, i.e. worms from marine, fresh water and brackish water environments. Dr. Slager refers also to corresponding structures produced by rainworms. These structures are therefore no indication of the type of environment that was present. Mineralogically the burrows consist of hard submicroscopic fine grained, pink to white gibbsite which lies in a softer gibbsitic matrix.

[2]) Stopfgefüge means "filled-up texture".

CONCLUSIONS

In conslusion, the following may be said about the tubular fossils:

1. They may be divided into
   - possible plant remains
   - burrows.
2. The possible plant remains probably consist mainly of roots; stems and twigs are also present, but there are no leaves or fruits.
3. The plant remains consist of hard pink to white gibbsite; they show external sculpturing and there are textural features in a thin outer skin which may be taken to be remains of a cuticula.
4. The type of sedimentary environment changed when the root layers formed. The irregular fan-shaped type of sedimentation yielding poorly sorted layers in what was probably a marine environment, was replaced by a slow steady sedimentation parallel to the coast.
5. The prebauxite sediments in the Moengo and the Paranam area, which contain layers of roots, must be placed chronologically just before the sediments from which the bauxites developed without a long pause.
6. Root horizons and clastic sediments alternate vertically in the profile; for this reason it may be concluded that bauxite source rocks formed as a coastal deposit upon which vegetation developed.
7. The lower boundary of the bauxite in the Kankantrie mine and on the Adoemakondre II-plateau indicates a relief formed by valley systems. It also indicates a change in the type of sedimentation. The relationship between this relief and the distribution of the vegetation is still unknown. We do not know whether the vegetation grew more densely in the gullies, on the slopes or on the plateaus.
8. There is no root penetration to be seen in the higher parts of the bauxite strata.
9. The burrows occur exclusively in the bauxite. The density of the burrows varies in the vertical as well as in the horizontal plane. In the deeper parts of the bauxite the burrows acted as a stabilising framework which hindered the formation of residual breccias.
10. The varying diametres of the burrows indicate various species of burrowing animals. Some of the burrows are structureless, others display "Stopfgefüge".
11. The combination of burrowing organisms and vegetation rich in roots, in a long narrow strip through the whole of Surinam and Guyana, proves that the area parallel to the coast was either a mangrove, a brackish or a fresh water swamp environment at the time of the source rock sedimentation from which bauxites later developed. The continuation of the sedimentation indicates a mangrove swamp.

REFERENCES

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