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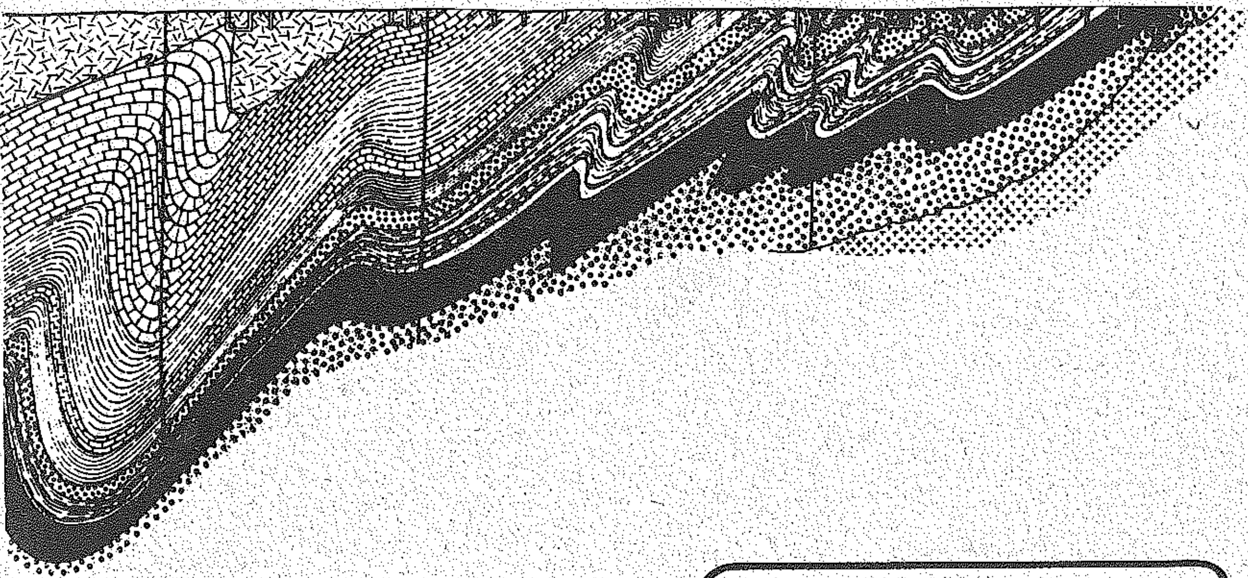

ECONOMIC GEOLOGY

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ALGAL STRUCTURES IN SEDIMENTS OF THE VENTERSDORP SYSTEM

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ALGAL STRUCTURES IN SEDIMENTS OF THE VENTERSDORP SYSTEM

ABSTRACT

Algal structures have been discovered in a local facies of impure dolomitic limestones of the Ventersdorp System intersected in a borehole WNW. of Wesselsbron in the Orange Free State. They are separated from the well-documented occurrences of similar structures in the younger Dolomite Series of the Transvaal System by two unconformities, two periods of sedimentation, and one or two phases of volcanicity. The stromalites indicate that the Ventersdorp dolomitic limestones and associated marls are of primary origin. They were probably deposited in shallow lakes in an area of low relief after eruptions of acid and basic volcanic rocks. The discovery provides a link between the accepted prevalence of biogenic processes 2000 million years ago during the time of deposition of the Transvaal System and the problematic origin of oolitic structures in the Swaziland System formed more than 3000 million years ago.

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ALGAL STRUCTURES IN SEDIMENTS OF THE VENTERSDORP SYSTEM

CONTENTS

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ALGAL STRUCTURES IN SEDIMENTS OF THE VENTERSDORP SYSTEM

INTRODUCTION

Algal structures in Ventersdorp sediments were first noticed by Dr. E.S. Antrobus of the Anglo-American Corporation of South Africa, Ltd., and brought to the attention of the writer while both were investigating borehole cores in the Corporation's core-yard. The writer logged the core as part of a program of research on the Ventersdorp System currently being undertaken by the Economic Geology Research Unit of the University of the Witwatersrand.

As these stromatolites occur in stratigraphic horizons well below the Dolomite Series, from which Young (1932) had obtained and described many similar structures, it was felt that further investigation would provide additional evidence in support of previous conclusions that biogenic processes have been active almost since the beginning of recorded geological time in South Africa.

In a review of the occurrences of Precambrian fossils in South Africa and North America, Harington and Cilliers (1963) deduced that the algal structures in the Dolomite Series were approximately 2000 million years old. Nicolaysen (1962, p.579) has summarized evidence from which he infers that the Ventersdorp volcanicity could have taken place about 2100 million years ago. In rocks older than the Ventersdorp System, Ramsay (1963) has noted the presence of oolitic structures in rocks of the Barberton Mountain Land. These oolites are present in the Fig Tree Series of the Swaziland System and are considered to be of biogenic origin. According to Nicolaysen (1962, p.575) the Swaziland System is more than 3000 million years old. Stromatolites recorded by Macgregor (1940, p.9-16) in the Bulawayan System of the Basement Complex of Southern Rhodesia are older than 2680 million years (Ahrens, 1955).

ACKNOWLEDGEMENTS

The writer wishes to express his indebtedness to the directors of Anglo-American Corporation of South Africa, Limited, for making borehole cores and descriptive files of the Ventersdorp System available to the Economic Geology Research Unit for study. Thanks are due to Dr. E.S. Antrobus for drawing attention to the presence of the algal structures. Helpful advice was obtained from Professor E. Mendelssohn and Drs. G. Hart and E. Plumstead of the Department of Geology of the University of the Witwatersrand. Acknowledgement is made of Mr. M. Hudson's contributions in the form of photographs of the algal structures.

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STRATIGRAPHIC POSITION

A. LOCALITY

The cores in which the algal structures were discovered were obtained from Borehole No. 1, drilled on the farm Ellenboogleegte No.288, in the Wesselsbron district of the Orange Free State. The accompanying map, Fig.1, gives the position of the site relative to the nearest outcrops of the Ventersdorp System, and to the Bothaville area (hatched), for which a generalized stratigraphic column of the Ventersdorp System has been compiled by the writer.

B. STRATIGRAPHY

(a) Position in General Stratigraphic Column

In Fig.2, the zones containing algal structures are shown against the principal stratigraphic subdivisions of the Ellenboogleegte borehole. These are correlated through two intermediate boreholes, the sites of which are shown in Fig.1, with the type column of the Bothaville area. Unconformable relationships are indicated by wavy lines.

The Karroo System (K) in the northwestern Orange Free State is virtually horizontal and only a few hundred feet thick. The nearest borehole intersections of the Transvaal System (T) are about 15 miles to the east and northeast of Bothaville, where the System is covered unconformably by the Karroo System and forms part of the core of the syncline flanking the Vredefort Dome (Borchers, 1961, diagr. No.2). The stromatolites described by Young (1932, 1934, 1940) from other localities occur near the base of the Dolomite Series. Since the underlying Black Reef Series is less than a hundred feet thick, the algal horizon is thus close to the base of the Transvaal System.

The Transvaal System in turn overlies the Ventersdorp System unconformably, the highest subdivision of the latter being denoted by the symbol A. The Bothaville column represents an aggregate of type-sections, with subdivision L being somewhat shortened to show the contact with the Upper Division of the Witwatersrand System. There are great variations in the thickness of each subdivision.

The symbol P denotes Archean pre-Witwatersrand rocks.

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(b) Succession and Lithology

A brief comparative description of the succession and lithology of the Ventersdorp System in the Ellenboogleegte borehole and in the Bothaville area is as follows (the depths indicated are below the collar which is at an approximate elevation of 4200 feet above sea level):-

Stratigraphic Symbol	Ellenboogleegte Borehole No. 1	Bothaville Area
A	600' - 2657' green and dark green amygdaloidal lavas; slightly porphyritic; small white phenocrysts of felspar and dark minerals in some flows.	dark green amygdaloidal lavas; some flows have small white phenocrysts of felspar, others of dark minerals.
B	2657' - 3335' conglomerate (rounded pebbles smaller than 4", of banded chert, grey lava, quartzite and hornfels) to about 2675 feet. quartzite pale grey, yellow-grey to dark grey; poorly bedded and cross-bedded; dark shale bands with sharp contacts, scoured tops; clay pebble conglomerates common. below 2889' shale and alternating calcareous quartzite and limestone bands. from 3289' to 3335' basal conglomerate with rounded pebbles smaller than 3", of quartz porphyry, pumice-like lava (flattened), pale green lava, fine-grained sediments, tuffs; sharp lower contact.	quartzites, conglomerates, subordinate dark shales; constitutes a cycle starting and ending with conglomerate; upper conglomerate has pebbles of quartz, quartzite, shale, quartz porphyry, lava and banded chert; clay pebble conglomerates present; basal conglomerate has rounded pebbles of quartz, jasper, dark shale, quartzite, yellow-green shale, green lava, porphyry and granite; sharp lower contact.

Stratigraphic Symbol	Ellenboogleegte Borehole No. 1	Bothaville Area
R	<u>3335' - 4072'</u> rhythmically-bedded dark grey shale, pale grey carbonate and dirty marls to 3525' below 3447' bedding becomes undulating ("wavy") and algal structures appear. lava from 3525' to 3780', green-grey, porphyritic to diabasic; bleached flow tops in upper flows. from 3780' to 4072' dark dense mudstone grading at 3800' into bedded shale and impure dolomitic limestone containing algal structures between 3874' and 3960' from 3960' to 4010' highly calcareous section, grading into black shale. from 4065' to 4072' green-grey faintly laminated fine-grained rock, possibly a tuff.	lavas, green-grey porphyritic and amygdaloidal; intercalated carbonaceous shale, tuffs, quartzites and conglomerates; two types of lava: one with porphyritic to diabasic texture, other characterized by narrow flows of fine granularity; upper flow tops are bleached; succession and lithology of units variable.
M	<u>4072' - 4200'</u> green-grey quartz-felspar porphyry, quartz grains visible under hand lens; phenocrysts densely packed and range in size up to $\frac{1}{2}$", no amygdaloidal top. End of Hole	quartz and felspar porphyries, minor intercalated sediments; subordinate green-grey amygdaloidal lavas; thin tuffaceous bed may overlie the porphyry
N		agglomerates, conglomerates, tuffs, tuffaceous and calcareous shales, impure calcareous rocks

Stratigraphic Symbol	Ellenboogleegte Borehole No. 1	Bothaville Area
L		lavas, green-grey, fine-grained amygdaloidal; pyroclastics

(c) Structural Aspects

Subdivisions A and B occur in gently undulating fashion throughout the northwestern Orange Free State and are separated from R by a regional unconformity. There are numerous pebbles of quartz porphyry and andesitic lava in B. Evidence that the succession is not inverted in the borehole is afforded by the amygdaloidal tops of lava flows, clay pellet conglomerates overlying narrow shale beds, gentle dips which do not exceed 15^{o}, the upright position of the algal growths, and the correct sequence of the major subdivisions. There are no signs of faulting in the core. The lowermost portion of the Ventersdorp System, L, is restricted to the Bothaville area, where it overlies the Upper Division of the Witwatersrand System, UW.

From Fig.2 it is clear that the sediments containing the algal structures post-date the quartz porphyry (M) situated in the middle of the stratigraphic column of the Ventersdorp System. The quartz porphyry can be traced into the Bothaville area where its relationship to the Transvaal System is known. The sediments in which the algal structures occur can thus be seen to occur well below the base of the Dolomite Series. They form only a minor proportion of the constituents of a predominantly volcanic system.

Of the surrounding boreholes, only one, nine miles to the northeast on the farm Bovenlandsplaats 116, has brought to light sediments akin to the algal limestones. A borehole on the farm Claudinasdal 26, seven miles west of Hoopstad, showed that the uppermost algal horizon had been eroded prior to the deposition of subdivision B. The sediments of the lower horizon range from arenaceous to argillaceous in composition. The algal limestone facies thus appears to be only local, and similar to the small detached bodies of dolomitic limestone described by Nel (1935, p.80) in the Ventersdorp System of the Western Transvaal.

ALGAL AND ASSOCIATED SEDIMENTARY STRUCTURES

The algal structures are very similar to those of the Dolomite Series described by Young (1932, 1934, 1940), Young and Mendelssohn (1948) and Toens (1961), and of the Bulawayan System described by Macgregor (1940). The structures are generally called stromatolites. Similar structures have been recorded in certain lakes of the present day where calcareous growths result from the precipitation of carbonate by algae known as Cyanophycae or blue-green algae. Stromatolites are technically termed Spongiostromata. This section of algae is divided into two sub-sections; the Oncolithi and the Stromatolithi. Young considers the mode of origin of both types to be similar (1932, p.34).

The various types of growths have no definite connection with particular phylogenetic genera of algae, but have been classified according to form-genera i.e. the shape of the structure which may grade imperceptibly from one into another (Johnson, 1961, p.204). Young (1940, p.18) attributes the gradations to changes in the conditions of sedimentation. Johnson (1961, p.204-207) points out that stromatolites cannot be used for dating, since similar structures occur from the Precambrian to the present time. They do, however, contribute to our knowledge of the environment of deposition of the enclosing strata. Algae have their greatest development in shallow water, from just above tide-level to depths of 10 to 12 feet, though they may exist at greater depths. Young (1934) states that the Oncolithi are associated with para-ripples, indicating that currents of relatively high velocity existed at the time of growth.

The specimens were cut, smoothed, and etched with dilute hydrochloric acid. Carbonaceous material clouded the dilute solution during etching. The ease with which the rock effervesced indicated that calcite is a prominent constituent. The sludge contained mostly very small grains of quartz and some carbonaceous material. Young (1932, p.31) found that the dolomitised areas usually appear as light-coloured fine aggregates of dolomite rhombs against a darker background of calcite containing specks of carbon.

A thin-section of stromatolite from a depth of 3447' in the borehole showed it to be covered with a layer of carbonaceous material. The body itself has lamellae of varying thickness forming a mammillary structure composed of various carbonates. All details are destroyed in portions which are recrystallised. Carbon specks occur in the hollows between the mammillae. The three uppermost lamellae have coatings of carbon. Cellular structures, which are normally rare, were not observed in the specimen. The overlying sediment is rhythmically laminated carbonate, containing specks and stringers of carbon arranged in layers. Additional lenticular laminae fill the relatively depressed areas. No clastic particles were noticed. After staining the slide with Mitchell's dye (Mitchell, 1956), the laminated carbonate proved to consist of alternating layers of fine-grained calcite and dolomite. The algal structure could be seen to be predominantly dolomitic, with irregular layers of coarse-grained calcite. From the study of thin-sections, it was deduced that a lime mud derived from an adjacent area was transported by currents and smothered the algae.

The greatest variety of algal structures occur in the specimen from 3481 feet (Fig.3). Near the top is a cluster of Oncolithi, detached algal structures of spherical, conical, elliptical and mammillated shape. The nuclei from which they grew can be seen in the centrally-cut growths. They are less than 5 mm in diameter. Biogenic layers alternating with ordinary sedimentary laminations indicate the algal growths to have been repeatedly smothered by lime mud, further evidence of a shallow water environment.

The algal structures lower down are similar to those which Young described but did not classify (1934, Pl.V, Fig.1 and 1940, Pl.V1). He considered these also to indicate shallow water deposition (1940, p.17-18). Very similar to the "dentate structures" of Macgregor (1940, Pl.111 and 1V), are growths found at 3475 feet (Fig.4). (See also Toens, 1961, Pl.XV, Fig.2). The specimen taken at 3888' exhibits the structure of Collenia and has developed on a slight mound caused by the accumulation of dessicated mud fragments (Fig.5). These mud fragments constitute an "edgewise conglomerate", indicative of periodic dessication (Young, 1934, p.159). Such conglomerates are more abundant in the marls and also occur high up in the borehole, e.g. at 3115 feet. An excellent specimen of Cryptozoon structure appears at 3876 feet. If has the shape of an inverted cone with a rounded top. Smaller growths of the same type occur in close proximity (Fig.6).

Some of the structures have all their protuberances inclined in one direction, as if their growths were influenced by slow, steady currents. The specimens from 3475 and 3481 feet illustrate this tendency.

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CONCLUSIONS

The algal structures occur in a local facies of impure dolomitic limestones of the Ventersdorp System, and are separated from the occurrences in the younger Dolomite Series of the Transvaal System by two unconformities, two periods of sedimentation, and one or two phases of volcanicity.

Nel found it difficult to decide whether the dolomitic limestones of the Ventersdorp System in the Western Transvaal are secondarily altered tuff beds or whether they represent former calc-sinter deposits (1935, p.81). He considered the calcite in tuffaceous shales to be secondary (p.80). The writer, on the evidence of the stromatolites, submits that they are primary carbonate rocks, and that their "secondary" appearance is merely due to partial recrystallization. Of the specimen at 3481 feet about 15 per cent has been recrystallized, and the original sedimentary structures obliterated. The good state of preservation of the algal structures, especially of the mechanically deposited rhythmic laminae, shows that subsequent metamorphic affects are not pronounced.

The environment in which these algae grew is considered to have been shallow lakes which occasionally dried up to a certain extent. At the time of algal growth the lakes received very little clastic material because of an assumed generally flat topography. Transitions from limestone through marl to calcareous and dolomitic shale, however, indicate that at times fine-grained products of weathering were introduced. Greater variations in the dips of the mechanically deposited limestone would be apparent had they been of calc-sinter or travertine origin.

In such an environment facies changes can be expected and must be allowed for in stratigraphic interpretations. The flat topography must be borne in mind during the structural interpretation of isopach maps. The theory of endogenous domes as the mode of extrusion of the quartz porphyry (Truter, 1949, p.1X) may have to be revised unless proof can be found for the existence of an extensive unconformity between the quartz porphyry and the lacustrine sediments.

It is of interest to note that Young and Mendelssohn (1948, p.58) discovered volcanic fragments in algal domes of the Dolomite Series; that many lakes and swamps were developed in the Basin and Range Province of Utah and Nevada after the extrusion of acid volcanics (Osmond, 1960, p.38); and that the formation of the Lake Taupo region of New Zealand was preceded by a period of acid volcanicity (Martin, 1961). A terrestial lacustrine environment thus appears to follow on a period of volcanicity in many instances.

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The discovery of these organic structures renders more acceptable the possibility that biogenic processes might also have been active in the older Witwatersrand rocks and might have played a part in the deposition of "carbon" in the form of seams and granules in the quartzites and conglomerates of the Witwatersrand System. The Black Reef conglomerates of the Transvaal System, with their mineral assemblages so similar to the Witwatersrand banket, are much younger than the algal structures of the Ventersdorp System.

The calcareous horizons in lower sedimentary subdivisions of the Ventersdorp System and in the Kimberley Shale horizon of the Witwatersrand System might be worth close scrutiny for algal structures.

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KEY TO FIGURES

Fig. 1 : Locality map of Borehole EBL.1.

Fig. 2 : Principal stratigraphic subdivisions of Borehole EBL.1 compared with those of Boreholes U.1 and LRQ.1. and with the type section of the Bothaville area. The datum line is the present surface.

Fig. 3 : Specimen of core from a depth of 3481 feet in Borehole EBL.1. Graduated scale in centimetres and millimetres. Detached structures of Oncolithi near top. Other attached algal structures below centre. Note alternating laminated and biogenic sections.

Fig. 4 : Specimen of core from a depth of 3475 feet in Borehole EBL.1. Graduated scale in centimetres and millimetres. Algal structures showing tendency to form lobes, and the inclination of the protuberances in one direction. Limestone is recrystallized at top and opposite the 9 cm. line.

Fig. 5 : Specimen of core from a depth of 3888 feet in Borehole EBL.1. Graduated scale in centimetres and millimetres. Collenia structure developed on a mound of mud fragments or "edge-wise conglomerate".

Fig. 6 : Specimen of core from a depth of 3876 feet in Borehole EBL.1. Graduated scale in centimetres and millimetres. One large and two small Cryptozoon structures, well-preserved in spite of dolomitization of surrounding rock.

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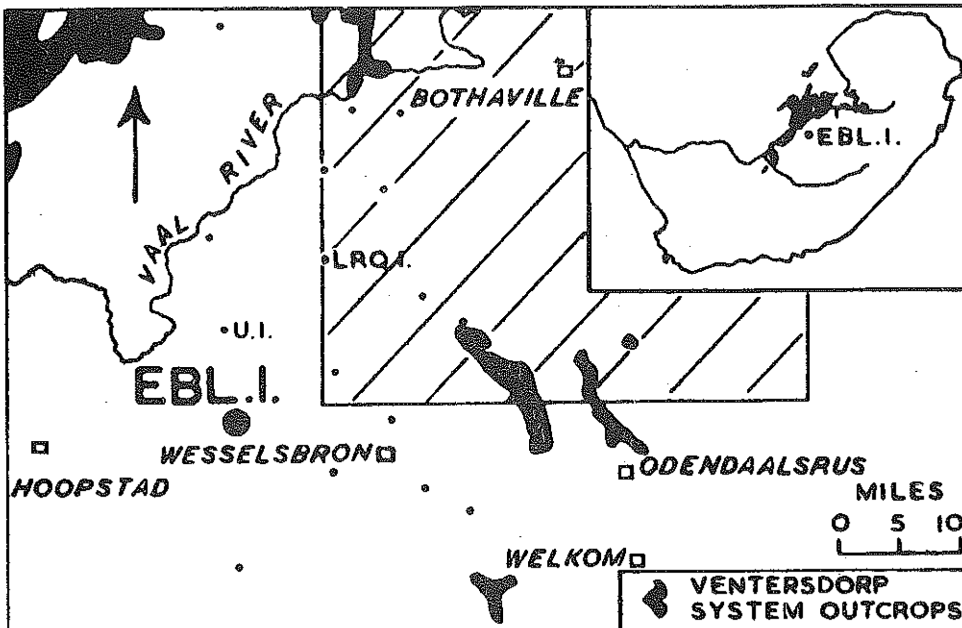
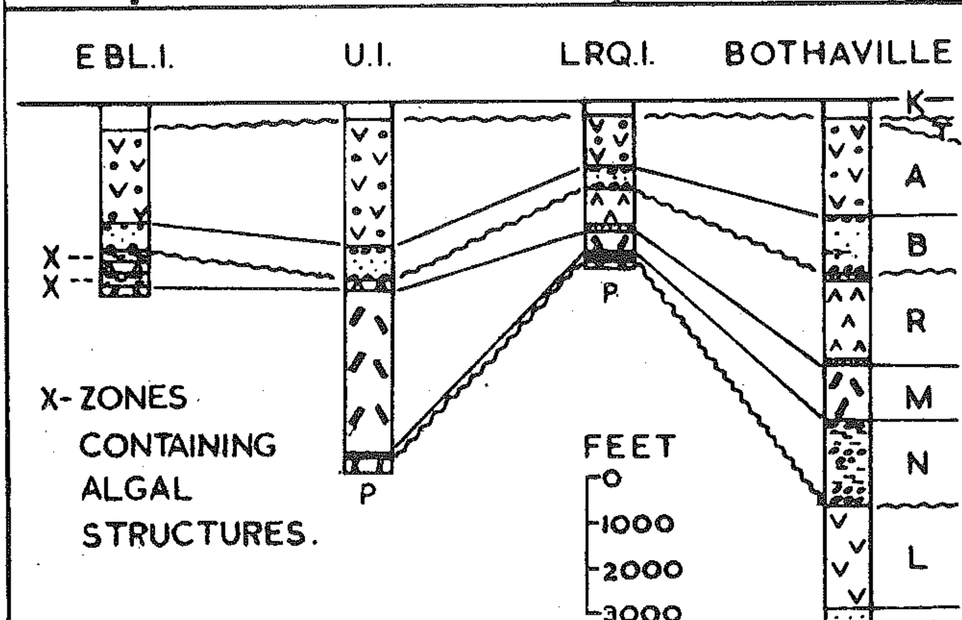

BOTHAVILLE
VAAL RIVER
•EBL.I.
•LRQ.I.
•U.I.
EBL.I.
WESSELSBRON
HOOPSTAD
ODENDAALSRUS
MILES
0 5 10
WELKOM
VENTERSDORP SYSTEM OUTCROPS
• BOREHOLES
FIG. I.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X-ZONES CONTAINING ALGAL STRUCTURES.
FEET
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FIG. 2.

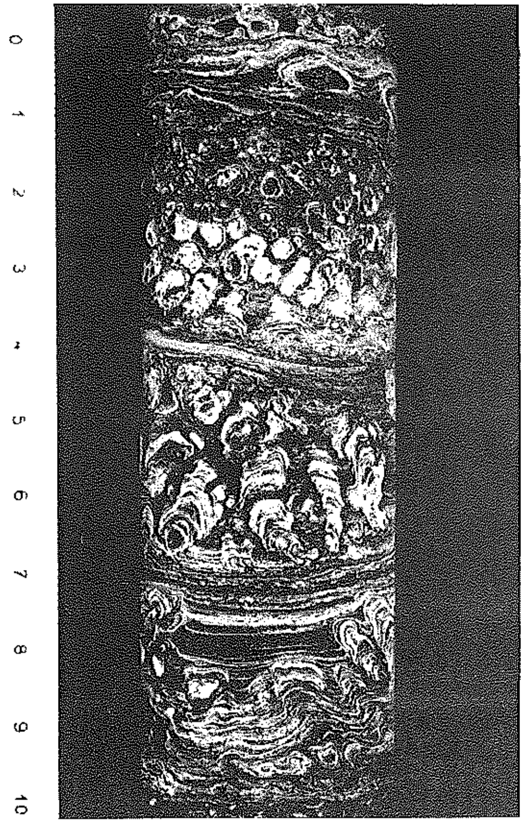

FIG. 3

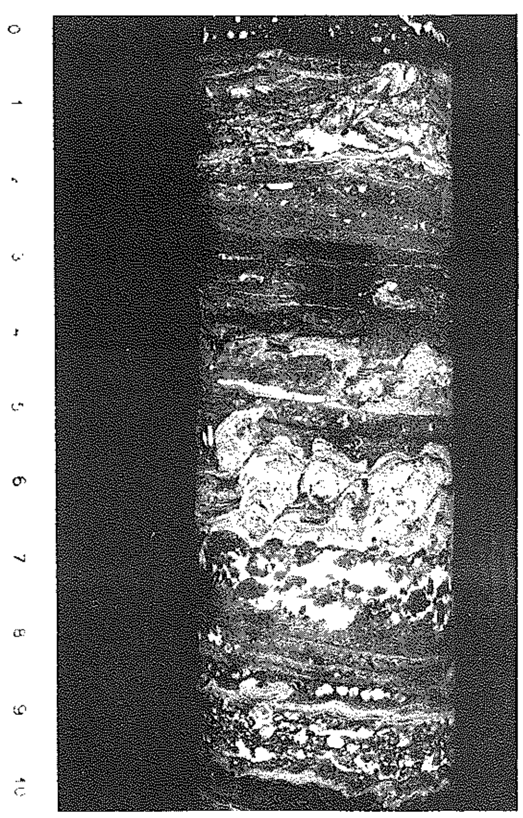

FIG. 4

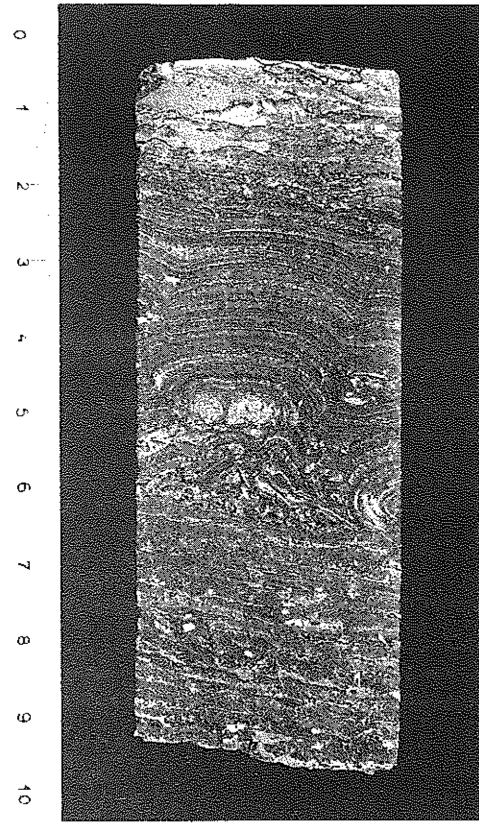

FIG. 5

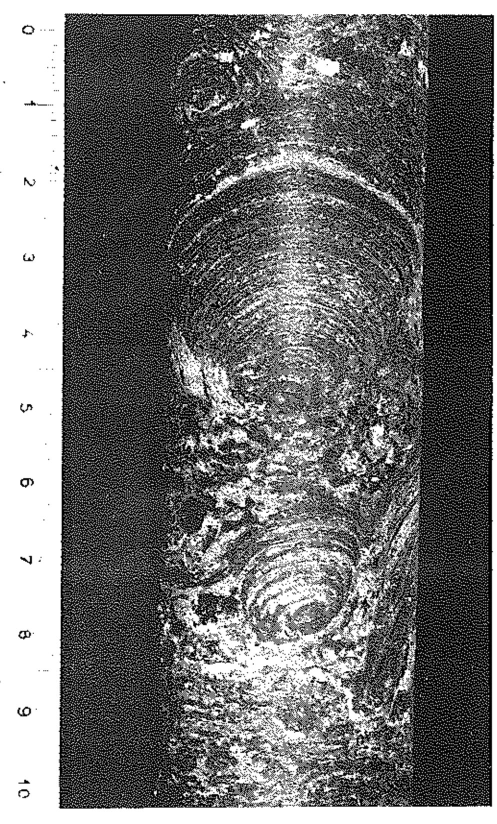

FIG. 6