COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Report No. 47

STROMATOLITES FROM THE PARADISE CREEK AREA, NORTH-WESTERN QUEENSLAND

BY

W. A. ROBERTSON

Issued under the Authority of Senator the Hon. W. H. Spooner, M.M.,
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Minister : SENATOR THE HON. W. H. SPOONER, M.M.
Secretary : H. G. RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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C O N T E N T S

/59

FOREWORD

In recent years geologists of the Bureau of Mineral Resources have collected abundant specimens and field observations on Precambrian calcareous algae, commonly referred to as "Collenia". These collections represent fossils from almost the whole of the geological column of the Precambrian of northern Australia. Moreover, algae have been collected and observed in the field in the same region also in Cambrian and Ordovician rocks.

The main value of these fossils consists in the recognition of the great antiquity of vegetable life and its continuity from Precambrian into the lower Palaeozoic.

Three following problems, however, require study and discussion and their solution may have some value in stratigraphy: (1) the taxonomy, (2) the stratigraphy - the vertical distribution of particular forms and assemblages, and (3) the environment aspect of the algae.

The taxonomy of the algae is controversal. It seems appropriate at the present stage of knowledge to abstain from a formal taxonomic nomenclature that, if applied, will refer only to forms collected in one area and in a single formation. The problem of taxonomy will, however, arise when a number of occurrences are adequately described from other areas and from rocks of various ages. It is evident that identical forms should have one and the same name and different objects should have different names.

The problem of the stratigraphic distribution of the algae has two separate aspects. The first refers simply to recording of the occurrence of algal forms in the local geological columns. This may help in the stratigraphy of confined areas and regions and be used for short-distance correlation. The second aspect of the problem refers to the value of the algae for inter-regional correlation and the possibility that they and their assemblages may serve as markers of geological time and help in building up a relative time-scale of the Precambrian of Australia. The proper approach to these problems is a study of the forms in the field and in the laboratory; the findings of the study should be assembled in well illustrated reports. Thus a basis for a comparative morphology of the algae will be built up.

An organized presentation of the material will serve also toward the solution of the third problem, of the environmental aspect of the algae - their ecology, and the physico-chemical conditions of the precipitation of dolomite and calcite that constitute the fossils.

The present paper is the first attempt to describe occurrences of Australian Precambrian algae to serve the purposes as outlined above. One hopes that other papers will follow and a comparison of all the results obtained may disclose the limits of the stratigraphic reliability of the algae and help to sort out characters that are significant for the understanding of these fossils.

A.A. Öpik.

SUMMARY

Three major and several minor forms of stromatolites deposited by calcareous algae, mainly from the Lower Proterozoic Paradise Creek Formation of north-western Queensland, are morphologically described and illustrated. They are shown to indicate shallow shelf environment. Over short distances they are useful horizon indices. They are compared with stromatolites described from other areas, and it seems that the common forms will not prove helpful for correlating separated regions.

INTRODUCTION

This report describes specimens and photographs of stromatolites collected by a field party of the Bureau of Mineral Resources during the 1957 field season from the Proterozoic of north-western Queensland. The specimens occur in dolomitic and silicified beds of the Paradise Creek Formation (Carter, Brooks, and Walker, in preparation).

Denmead (1937) first noted the forms described below as "Sub-hemispherical Form" of stromatolite between Mt.Kelly and Paradise Valley: another form, described below as "Cylindrical Form", was described by Honman (1938), but he was doubtful of its algal origin. Keble, of the National Museum, Melbourne, examined specimens received from Honman and considered that the beds are unfossiliferous and the specimens probably examples of cone-in-cone structure. Many of the specimens closely compare with forms already described from America, Britain, and Russia, but a few (Pl.4, Fig.2; Pl.5, Fig.4; Pl.12, Fig.1; Pl.14,Fig.1) appear to be new forms.

The author wrote the report at the request and with the help of Dr. A.A. Öpik and E.K. Carter, so that notice of the stromatolite specimens collected by the Bureau of Mineral Resources in north-western Queensland might appear in print without delay. E.K. Carter and F. de Keyser took most of the photographs and gave valuable assistance with the stratigraphy and setting. Dr. A.A. Öpik and Miss J.Gilbert-Tomlinson gave invaluable palaeontological advice.

STRATIGRAPHY

All specimens here described were found in rocks that are believed to be Proterozoic. The oldest rocks in the area are basic volcanics of the Eastern Creek Formation. These are overlain by a thickness of more than 3,000 feet of quartzite, with subordinate conglomerate, sandstone, and siltstone, of the penecontemporaneous Myally and Judenan Beds. Overlying these is about 2,000 feet of red and purple banded siltstone of the Gunpowder Creek Formation, on which the Paradise Creek Formation rests conformably.

Most of the stromatolites are found in the Paradise Creek Formation, of which about 5,000 feet is exposed in the area mapped. The succession predominantly consists of banded and fragmental dolomite, with silicified bands and sandstone beds that tend to occur in groups forming ridges; individual beds range widely in thickness, but are generally less than 20 feet thick.

About 200 miles north-north-west of Paradise Creek, specimens were collected from the Upper Proterozoic Wollogorang Formation and Karns Dolomite.

The oldest rocks from which specimens (Pl.5, Fig.4; and Pl.22, Fig.1) were collected, the Judenan Beds of the Waggaboonyah Range, are stratigraphically at least 3,000 feet below the next stromatolites encountered (Text Fig.1).

The maximum development of the "Sub-hemispherical" concentric stromatolites occurs in dolomite between two silicified beds above the dolomitic sandstone horizon (Text Fig.1).

Massive development of the stromatolites may be seen above the dolomite in three suites of silicified biostromal beds in the hills to the south of Paradise Creek (Pl.1)(α , β, and γ in Text Fig.1), which, together with the intervening dolomite, silty and sandy sediments, are about 300 feet thick. The lowest of these (γ in Text Fig.1), 50 to 100 feet thick, contains many of the "Wavy Laminae" form and is overlain by 20 to 40 feet of bedded cherts, siltstone and silty dolomite. Resting on this is the middle suite of silicified biostromal beds (β in Text Fig.1), also 50 to 100 feet thick. It is composed largely of stromatolites, mainly of the "Wavy Laminae" form (Pl.5, Fig.1 and Pl.15, Fig.1) with specimens intermediate between it and the "Cylindrical" form (Pl.12, Fig.2). It is separated from the top (α) by a 20 to 50 foot layer of silicified siltstone and dolomite. The top suite is 100 feet thick and consists mainly of "Cylindrical" form stromatolites (Pls. 2, 6, 7, 8, 9, and 10), in which diameters range from 3 to 6 centimetres.

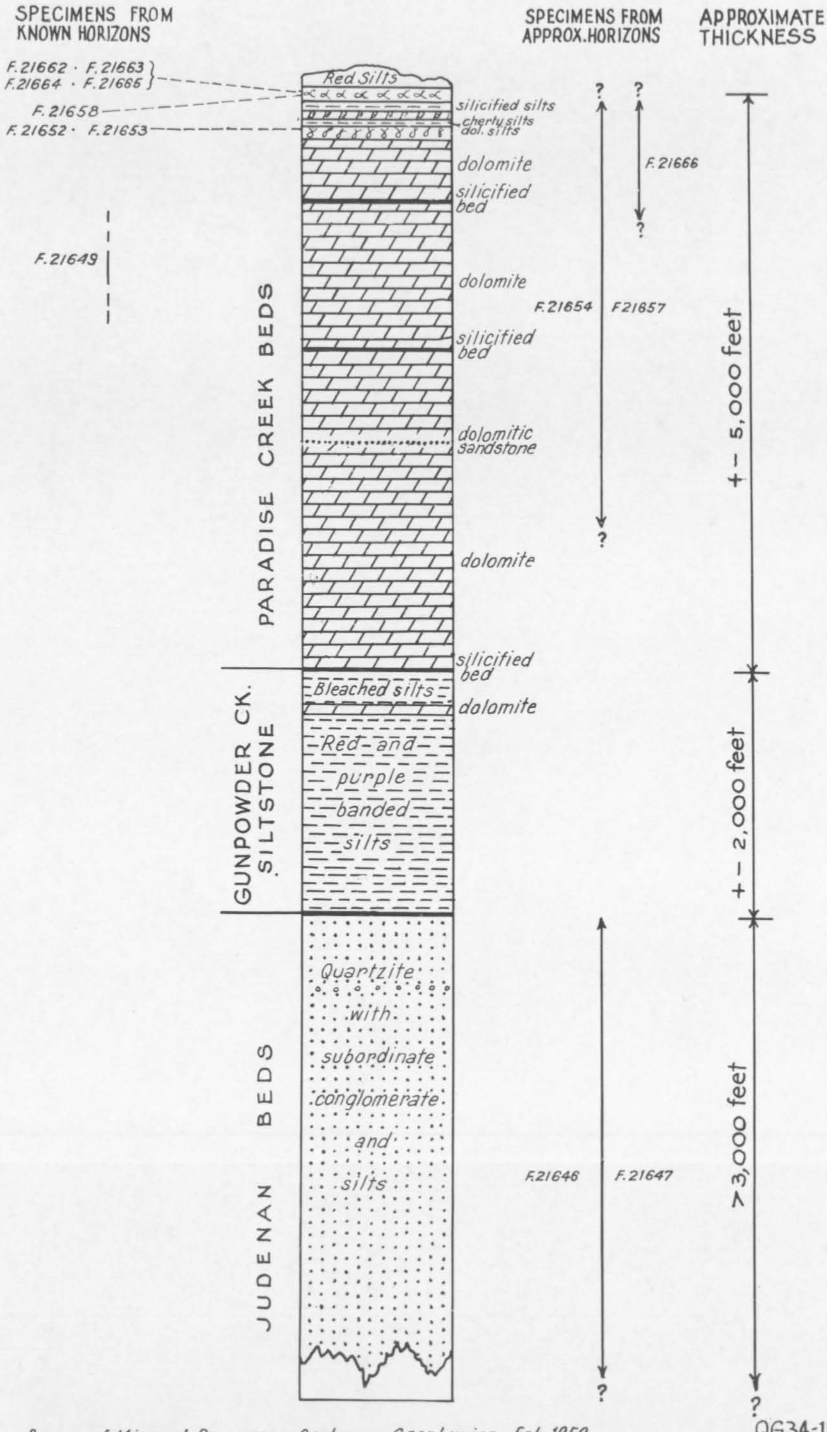
<u>Alteration</u>

By analogy with more recent stromatolites of similar appearance (Johnson and Konishi, 1956) it seems probable that those found in the Paradise Creek Formation were originally deposited as calcium carbonate, with only subordinate magnesium (Johnson, 1937), and were dolomitized soon after (Anderson, 1950). The high porosity of the deposit facilitated dolomitization and later silicification. The alteration makes the retention of fine structures very improbable (but this has not been checked as yet because no thin sections of the specimens have been cut). The "Sub-hemispherical" form is dolomitic, and only in a few places are there intermediate specimens that show selective silicification; by contrast the

FIG 1.

STRATIGRAPHICAL COLUMN

APPROXIMATE POSITIONS OF FOSSIL ALGAE SPECIMENS.



Bureau of Mineral Resources Geology & Geophysics. Feb 1959

QG34-13

"Wavy Laminae" and "Cylindrical" forms and most of the "Sub-spherical" and "Conical" forms are commonly silicified, and in places the "Cylindrical" form shows selective silicification, laminae being silicified, but separated by a dolomitic matrix.

In areas where ore-bearing solutions are in evidence the porous nature of the stromatolitic beds may lend itself to solution, and the beds tend to form channelways for the migrating solutions, and favourable beds for deposition (Ohle and Brown, 1954a).

THE STROMATOLITES

Walcott (1914) was the first to recognise that stromatolites are of algal origin: a stromatolite has been defined (Howell et alia, 1950) as a mineral copy or cast of the external form of an algal colony. Thus each lamina represents one growth stage in the development of the colony.

Stromatolites collected from the Paradise Creek area vary widely in form, but they have important features in common (See Appendix). Parallel laminae, usually 0.5 - 2.0 mm. thick, invariably form the basis of the structure. The laminae are all convex upwards, and where they pass continuously from crest to crest (Pl.3, Fig.2; Pl.13,Fig.1; Pl.15, Fig. 2) they meet in a sharp angle. The interspaces between the laminae are as wide as or slightly wider than the laminae.

Three forms common in the Paradise Creek Formation, "Cylindrical" "Wavy-Laminae" and "Sub-Hemispherical, are first illustrated. The names are descriptive. The "Cylindrical" form has discontinuous laminae, the "Wavy-Laminae" and "Sub-Hemispherical" continuous laminae. The wavelength of the "Wavy-Laminae" form is less than 5 cm., whereas that of the "Sub-Hemispherical" form is greater than 15 cm. Seven rarer forms are given descriptive names and illustrated.

Cylindrical Form

Vertical columns of circular cross-section, 3 to 10 cm. in diameter, constitute the Cylindrical form (Pl.2 and 6 to 11). Spaces between columns are 1 to 3 cm. wide and partly filled with detritus. The cylinders are made up of laminae 0.2 to 1.0 mm. thick that form cones with apical angles ranging from 30^{o} to 45^{o}, concentric with the cylinders (Pl.2, Fig.1 and 4; Pl.10, Fig.2). The laminae are not continuous between the cylinders. In some specimens (Pl.11, Fig.1), the apex of the cone is rounded, so that the laminae are nearly hemispherical at the apex, and are tangential to the walls of the cylinder. The laminae and interspaces tend to thicken towards the apices of the cones. Some of the most highly silicified specimens (Pl.1, 8, Fig.2), have angular walls. This may be due to selective silicification, as it appears to be most marked where the silicification has reached an advanced stage. One section (Pl.11, Fig.1) shows cylinders of about 10 cm. diameter passing upward into cylinders with a diameter of about 3 cm. The relationship between the two, unfortunately, is not clear.

Well developed Cylindrical form stromatolites in the Paradise Creek area appear to be confined stratigraphically to the α horizon (see Text Fig.1), although forms intermediate between them and the Wavy Laminae form do occur at lower horizons (Pl.12, Fig.2). Most specimens are completely silicified.

Wavy Laminae Form.

The laminae in the Wavy Laminae form may be seen in well preserved specimens (Pl.3, Fig; Pl.13, Fig.1) to pass continuously from crest to crest. Many of the specimens, unfortunately, are partly replaced by silica veinlets which tend to attack the troughs between the crests (Pl.5, Fig.1). The troughs either form a sharp angle, or, where curved, the radius of curvature is much smaller than that of the crests. The wavelength, or distance between centres as seen in transverse section, varies widely, but appears to fall into two groups: in one group it ranges from 0.5 to 1.5 cm. whereas in the other the range is from 2 to 5 cm. The amplitudes of the waves range from a small fraction of a wavelength up to nearly half a wavelength, and tend to increase upwards in a colony. Weathered surfaces produce a very characteristic convoluted pattern (Pl.15, Fig.1). The specimens are all silicified. Maximum development is in the γ horizon (see (Text Fig.1) but the form also occurs in the silicified bands within the dolomite lower in the succession.

Sub-Hemispherical Form.

The Sub-hemispherical form is widespread in and beyond the area mapped. It is essentially dolomitic, although where it occurs near a silicified horizon (Pl.4, Fig.3; Pl.17, Fig.1), the laminae are somewhat silicified. The laminae are very thin, ranging from less than 0.1 to 0.4 mm., while the interspaces range from 0.2 to 4.0 mm. They are arranged concentrically about centres that are 15 to 50 centimetres apart (Pl.17, Fig.2). Irregular laminae on the edge of centres are continuous between one centre and the next. The maximum development of the Sub-hemispherical form occurs between two thin silicified beds in the Paradise Creek Formation above the dolomitic sandstone (see Text Fig.1). The form is similar to the Wavy Laminae form, but on a larger scale.

Other Related Forms

Sub-spherical Form: The Sub-spherical form consists of concentrically laminated structures, with diameters of 15 to 30 cm., that form knobs on the bedding planes (Pl.25, Fig.2). They are most abundant in the γ horizon. At one place a variety probably intermediate between this form and the Wavy Laminae form was photographed (Pl.25, Fig.1).

Dome-like Form: The Dome-like form is a large variety with thick concentric, crenulated laminae convex outwards from the centre. It has been found not only in the Paradise Creek area (Pl.20; Pl.21, Fig.1), but also about 200 miles to the north-north-west in Upper Proterozoic Karns Dolomite. These appear to be isolated biohermal colonies. Their top surface is spherical but their lower surface has not been clearly seen and the relationship with the bedding underneath is obscure.

<u>Black Spheres</u>: Silicified "Black Spheres" have been found at one locality only, in the γ horizon (Pl.26 and Pl.27), with a radius of 10 to 50 cm. They do not appear to contain laminae and cannot therefore be called stromatolites. The cementing material between the spheres is a breccia composed of elongated disoriented slabs of rock.

<u>Hermal Form</u>: Plate 24, Fig.2 shows a specimen with a spherical crenulated upper surface that appears similar to the weathered surface of the Wavy Laminae form. The diameter is about 23 cm. The specimen appears to be a biohermal form similar to the Wavy Laminae form.

<u>Sub-Conical Form</u>: (a) A silicified conical specimen (Pl.23) was collected from the dolomitic succession. It has an apical angle of about 45 degrees and a basal diameter of at least 15 cm.

(b) Two specimens were collected from a silicified dolomitic siltstone in the quartzite at a horizon at least 5,000 feet below the main stromatolitic beds. They are composed of conical laminations 1 to 2 mm. thick that tend to thicken at the apex of the cone and form sharp angles between the cones (Pl.5, Fig.4). The cones are oval in transverse section (Pl.22, Fig.1) - possibly owing to tectonic deformation - sub-parallel, and branching. They form a colony traceable along a steeply dipping bed about a foot thick.

<u>Branching Tubular Form</u>: (a) Only one branching specimen (Pl.2, Fig.2, and Pl.24, Fig.1) was found in the main silicified biostromal beds (see Text Fig.1). It is made up of sub-parallel branching tubes with diameters of 1 to 1.5 cm. The tubes, which are roughly circular in transverse section, consist of rather irregular parallel laminae which tend to be convex upwards in the middle of the tubes. The specimen is completely silicified, and occurred near the base of the α horizon.

(b) F.de Keyser also found branching tubes (Pl.5, Fig.2and 3) with laminations convex upwards, and finely crenulated, with diameters up to 1 cm., in weathered kaolinitic siltstone. The weathered material was too crumbly to obtain specimens.

<u>Intermediate Forms</u>: Many of the specimens fall readily into one of the forms described above; others appear to fall between two forms. Especially notable are specimens intermediate between the Cylindrical and Wavy Laminae forms. Plate 5, Fig.1 shows a Wavy Laminae form in which many of the upward convex positions of the laminae are separated by unlaminated vertical quartz veinlets. A specimen from the Wollogorang

Formation (Pl.12, Fig.1) shows small cylinders, 1 to 2 cm. in diameter, developing on bedded dolomite, with the laminae passing, in places, from one incipient cylinder to the next.

Mode of Growth

A study of the stromatolites does not disclose the mode of growth of the algae. The algae appear to have precipitated calcium carbonate as a by-product of photosynthesis (Twenhofel, 1919; Wilson and Anderson, 1954).

The stromatolites grew either outwards from a centre, forming concentric laminae, or upwards by addition of parallel laminae (Johnson, 1940). In places they appear to have started growth concentrically, later layers developing only on the upper surface (Anderson, 1950; Fenton and Fenton, 1937).

Ecology

The ecology of the stromatolites can be deduced both by comparison with recent algal deposits and by a study of the ancient sediments in which they are preserved.

Recent blue-green algae (How, 1931) grow in shallow seas, in moderately disturbed water, where sedimentation is slow enough for them to avoid burial, and light is adequate for photo-synthesis. They grow in warm or cool, fresh or salt water (Twenhofel, 1919). Thus they require a shallow shelf or lake environment (Cloud, 1942).

Walcott (1914), in his study of Algonkian formations of the Cordilleran area of western America, concluded that the fossil algal flora in that region flourished in shallow lakes, comparable in area to the Great Lakes of the St.Lawrence.

Factors important in controlling algal development are (Anderson, 1950) gas exchange area, light absoprtion area, stability, relative upward growth, and rate of colonization; to these we may add upward convexity, and available supply of food, especially nitrogen (Opik,1954). Perhaps water sufficiently cool to preclude denitrification by bacteria is needed, or maybe the ancient algae could exploit atmospheric nitrogen directly. In turbulent water, where stability was necessary, the Wavy Laminae form should develop, but if precipitation was relatively rapid, the Cylindrical form would be better adapted to successful growth, as the cylinders could protrude through the sediment and the algae reach the light necessary for photosynthesis.

In the Paradise Creek area some features indicate shallow water. The underlying Judenan quartzite commonly contains current, wave, and interference ripple-marks, cross-bedding, and mud cracks. Some ripple-marks and mud-cracks also occur in the Gunpowder Creek Formation. In the overlying Paradise Creek Formation oolitic beds, cross-bedding, and ripple-marks have been observed. Here the sedimentary structures indicate a shallow-water environment, in which algae could be expected to flourish.

Reaction to slight changes of environment, rather than taxonomic differences, caused the stromatolites to assume different forms (Fenton and Fenton, 1933; Anderson, 1948; Cloud, 1942). Each type described above is probably due to carbonate deposition by an assemblage containing more than one species of alga.

Comparisons with Described Species from Other Localities

Specimens similar to the Cylindrical form have been found at Acacia Well and Bitter Spring in the East MacDonnell Ranges, and named Cryptozoon australicum (Howchin, 1914). They differ only in that the cylinders are more widely spaced. Mawson and Madigan (1930, p.426) also found specimens similar to this form in the MacDonnell Ranges, which they compared with Greysonia basaltica Walcott. E.J. Malone and O.N. Warin (verbal communication) found specimens closely resembling the Cylindrical forms in the Celia Creek Dolomite, Rum Jungle, N.T., of Lower Proterozoic or Archaean age.

Wavy Laminae stromatolites have been found in the Cambrian Limeport Limestone of eastern Pennsylvania (Howell et alia, 1950), where they have been named Archaeozoon undulatum Bassler. Fenton & Fenton (1937, p.1948 and Pl.16, Fig.1 and 2) have described Collenia expansa, which appears to conform closely to the Wavy Laminae form. Maslov (1939) has described another similar form as Collenia umbella. Finger-rock (Ohle and Brown, 1954a, 1954b), described from the Southeastern Missouri lead district, has been latterly ascribed to the genus Collenia Walcott, and strongly resembles Plate 5, Fig.1.

Johnson (1937) has described stromatolites from the Oligocene of South Park, Colorado, that are similar to the Wavy Laminae form of the Paradise Creek area. Mawson and Madigan (1930, p.426) found a similar form in the Pertaknurra Series of the MacDonnell Ranges, said to have "a resemblance to Cryptozoon undulatum of the American Ozarkian formation".

Specimens (Fenton & Fenton, 1937, p.1946, and Pl.15; Traves, 1954) that resemble the Subconical form (Pl.23; Pl.5, Fig.4; Pl.22, Fig.1) have been referred to Collenia frequens Walcott.

Specimens similar to the Sub-hemispherical form, described by Johnson (1946, Pl.21) from the Mississippian, are referred to Malacostroma concentricum Gürich, and Twenhofel (1919) has named a comparable type from the Lower Huronian Kona Dolomite, Masquette, Michigan, Collenia kona.

CONCLUSIONS

A study of outcrops of stromatolites in the field, and specimens in the laboratory, leaves no doubt that they are of organic origin. They appear to be deposits precipitated by algae, and as no trace of the plants which formed them can be seen in the fossil, the type of plant can only be inferred (Garside, 1931), mainly by comparison with recent forms. Most workers refer them to the family Spongiostromata in the sub-phylum Cyanophyta. The stromatolites were formed in a shallow shelf environment. They tend to concentrate along definite horizons that are useful markers over limited areas. Most forms appear to differ mainly because of changes in environment, and from a comparison of the common forms that occur in different geological ages, it seems unlikely that it will prove possible to use stromatolites for correlation between separate regions.

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APPENDIX

DIMENSIONS OF FIGURED SPECIMENS

Form and Specimen	Simple or branching/-	Continuous or separated.	Spacing of centres	Shape	Thickness of laminae	Spacing of laminae	Similar forms noted in other localities.	Remarks
Cylindrical Pl.2 Figs.1 & 2 Pl.10, Fig.1	S	S	One only	Cylindrical, laminae, conical, convex upwards to centre of cylinder, concentric about centre.	0.5-1 mm.	0.5-1 mm.	Collenia Walcott Cryptozoon australicum (Howchin, 1914), Greysonia basaltica (Walcott,1914), Collenia okunaika (Maslov, 1939)	
Pl.2,Figs.3 & 4	S	S	6-9 cm.	Cylindrical, laminae conical, slightly irregular, nearly symmetrical about centre of cylinder	1-2 mm.	1-3 mm.	As above.	
Pl.6,Figs.1 & 2 Pl.7,Figs.2 & 3	S	S	4-7 cm.	Cylindrical, cylinders up to 3 feet in length, laminae not normally visible in outcrop.	-	-	As above	
Pl.8,Fig.2 Pl.9,Fig.2	S	S	4-8 cm.	Cylindrical, laminations not visible, walls tend to be angular.	-	-	As above.	Highly silicified , obscuring laminae, and possibly causing angular outline.
Pl.8,Fig.1 Pl.10,Fig.2	S	S	5-9 cm.	Cylindrical, laminated in cones, concentric with cylinders.	1-2 mm.	1-3 mm.	As above.	Photographs selected to show conical laminations.
Pl.11, Fig.1	S	S	3-10 cm.	Cylinders laminated in cones, concentric with cylinders.	1-2 mm.	1-3 mm.	As above.	Two distinct sizes with abrupt change between them.
Intermediate cylindrical-Wavy Laminae Pl.12,Fig.1 & 2	S	S	3-5 cm.	Cylindrical, with conical laminae which in places pass from one cylinder to the next.	1-2 mm.	1-3 mm.		
Wavy Laminae Pl.3, Figs.1&2 Pl.12,Fig.1	S	C	2-4 cm.	Wavy Laminae, crests smooth, curved, troughs tend to be angular.	0.5-1mm.	0.5-2mm.	Collenia umbella (Maslov, 1939), Archaeozoan undulatum Bassler	Confined to completely silicified bands, commonly about 1 foot thick, in dolomite successions.
Pl.14, Fig.2 Pl.15, Fig.2	S	C	2-6 cm.	Wavy laminae, crests smooth, curved, troughs more angular, characteristic brain-like upper surface on bedding plane.	0.5-1mm.	0.5-2mm.	As above.	

Form and Specimen	Simple or branching/- Continuous or separated.		Spacing of centres	Shape	Thickness of laminae	Spacing of laminae	Similar forms noted in other localities.	Remarks
Wavy Laminae Pl.4, Fig.1	S	-	0.5 - 1.5 cm.	Laminae convex upwards, not sufficiently well preserved to see troughs.	0.1 - 0.5 mm.	0.1-1 mm.		Example of poorly preserved specimen, recognised in association with well preserved forms.
Pl.5, Fig.1	-	C	0.5-1.5cm.	Wavy laminae, convex upwards, troughs angular in places, elsewhere troughs obscured by silica veinlets.	Two types 0.5-1 mm. 0.1 mm. or less.	0.5-1 mm. 0.1 mm.	"Fingered Rock": Ohle & Brown later identified as Collenia.	
Sub-hemi-spherical Pl.3, Fig.2) Pl.17, Fig.1)	-	C	15 cm.	Irregular, conical to spherical.	Major 4-8 mm. Minor 0.5 - 4.0 mm.	Up to 5 cm. 0.5-4 mm.		Laminae silicified ferruginous, the interspaces dolomitic
Pl.18, Fig.1& 2) Pl.19, Fig.2)	-	C?	15 cm.	Undulating to concentric laminae convex upwards, appears to consist of centres joined on outer fringes by undulating laminae.	0.1 mm.	0.2-1.0mm.	Collenia kona (Twenhofel,1919)	Similar in shape to Wavy Laminae form, but on a much larger scale, and occurring in dolomite.
Sub-spherical Pl. 25.	S?	-	20 cm. Irregular	Appear on bedding planes as concentric spherical or oval laminae.	2.20 mm often not well laminated.	Not known.		Possibly of algal origin, as associated with other types. Highly silicified.
Dome-like Pl.20, Figs.1&2) Pl.21, Fig.1)	S	C	60 cm.	Approaching spherical but base not seen, laminae crenulated.	1 cm.	Not known.		Silicified at Paradise Creek, dolomitic specimens found in Karns Dolomite.
Black Spheres Pls. 26 & 27.)	S	S	30 cm.	Silicified black spheres, with interstitial breccia composed of elongated disorientated plates.	None	-		Probably not of algal origin.
Sub-conical Pl.5, Fig.4) Pl.22, Fig.1)	B	C	1-3 mm.	Conical laminae, the cones have an oval cross-section, and in places form folds on the flanks, which make branches.	0.5-2mm. Thicker at apices	0.2-0.5mm.		From a silicified dolomitic siltstone in the Judenan Beds.
Pl.23, Figs.1&2)	-	-	One only	Conical laminae with apical angle 45°.	0.2-1mm.	0.2-1 mm.		From a silicified ferruginous bed in dolomite.
Branching Tubular Pl.24, Fig.1)	B	S	1-1.5cm.	Irregular, radiating cylinders in which the walls are not touching.	0.5-1mm.	0.5-1 mm.		Completely silicified.

EXPLANATION OF PLATES

Plate 2

Fig.1 Cylindrical Form. Specimen F.21662b. Locality 13. Paradise Creek Formation. Vertical section through a single tube, showing the upward convexity of the laminae towards the centre of the cylinder. X1.

Fig.2 Cylindrical Form. Specimen F.21662a. Locality 13. Paradise Creek Formation. Transverse section of specimen illustrated in Fig.1, showing the concentric nature of the laminae. X1.

Fig.3 Cylindrical Form. Specimen F.21664a. Locality 14. Paradise Creek Formation. Plan of group of stromatolites. Compare Plate 7, Fig.1. X.1/3.

Fig.4 Cylindrical Form. Specimen F.21664b. Locality 14. Paradise Creek Formation. Vertical section through top left hand cylinder of Fig.3. X.1/3.

Plate 3

Fig.1 Wavy Laminae Form. Specimen F.21653b. Locality 12. Paradise Creek Formation. Transverse section showing spacing of crests giving concentric laminae. X1.

Fig.2 Wavy Laminae Form. Specimen F.21653a. Locality 12. Paradise Creek Formation. Vertical section of specimen illustrated in Fig.1, showing broad upward convexities and sharper concavities of the laminae. X1.

Plate 4

Fig.1 Intermediate Form. Specimen F.21652. Locality 6. Paradise Creek Formation. Vertical section showing patches of laminae convex upwards. X1.

Fig.2 Branching Form. Specimen F.21658. Locality 11. Paradise Creek Formation. Vertical Section. Compare Plate 24, Fig.1. X $\frac{1}{1.8}$.

Fig.3 Sub-hemispherical Form. Specimen F.21665. Locality 14. Paradise Creek Formation. Weathered plan showing thick and thin lamillae. X $\frac{1}{4.4}$.

Fig.4 Intermediate Form. Specimen F.21668. Locality, south-west corner of Westmoreland 4-mile sheet. Wollogorang Formation. Intermediate between Cyldrical and Wavy Laminae forms. X $\frac{1}{2.3}$.

Plate 5

Fig. 1 Wavy Laminae Form. Specimen F.21657. Locality 1. Paradise Creek Formation. Vertical section showing nearly vertical quartz veinlets between the upward convexities of the laminae. X $\frac{1}{1.8}$.

Figs. 2 and 3. Branching Form. Locality 3. Paradise Creek Formation. Vertical section. X1.

Fig. 4 Sub-conical Form. Specimen F.21647. Locality 17. Judenan Beds. Vertical section. Compare Plate 22, Fig. 1. X1.

Plate 6

Fig. 1 Cylindrical Form. Locality 14. Paradise Creek Formation. Massive development on hillside.

Fig. 2 Cylindrical Form. Locality 11. Group showing external shape.

Plate 7

Fig. 1 Cylindrical Form. Specimen F.21664. Locality 14. Paradise Creek Formation. Transverse section of a group. Compare Plate 2, Fig. 3. X $\frac{1}{2.9}$.

Fig. 2 Cylindrical Form. Specimen F.21663, Locality 11. Paradise Creek Formation. Group of four. X $\frac{1}{3}$.

Fig. 3 Cylindrical Form. Locality 11. Paradise Creek Formation. Gently dipping group.

Plate 8

Fig. 1 Cylindrical Form. Locality 14. Paradise Creek Formation. Transverse view showing concentric arrangement of laminae.

Fig. 2 Cylindrical Form. Locality 14. Paradise Creek Formation. Transverse view showing angular outline of highly silicified specimens.

Plate 9

Fig. 1 Cylindrical Form. Locality 14. Paradise Creek Formation. Oblique view showing conical laminae and in places masking of laminae by silicification.

Fig. 2 Cylindrical Form. Locality 14. Paradise Creek Formation. Castle-like outcrop, with 3 feet of cylinders exposed.

Plate 10

Fig.1 Cylindrical Form. Specimen F.21662a. Locality 13. Paradise Creek Formation. Transverse section. Compare Plate 2, Fig.2. X1.

Fig.2 Cylindrical Form. Locality 14. Paradise Creek Formation. Weathered vertical section exposing conical laminae.

Plate 11.

Fig.1 Cylindrical Form. Locality 18. Paradise Creek Formation. Two different diameters of cylinders exposed in steeply dipping strata.

Fig.2 Intermediate Form. Locality 14. Paradise Creek Formation. Showing relationship with bedding.

Plate 12

Fig.1 Intermediate Form. Specimen F.21668. Locality south-west corner of Westmoreland 4-mile sheet. Wollogorang Formation. Intermediate between Cylindrical and Wavy Laminae forms. Compare Plate 4, Fig.4. X $\frac{1}{2.3}$.

Fig.2 Intermediate Form. Locality 14. Paradise Creek Formation. Intermediate between Cylindrical and Wavy Laminae forms.

Plate 13

Fig.1 Wavy Laminae Form. Specimen F.21653a. Locality 12. Paradise Creek Formation. Vertical section. XI.

Fig.2 Wavy Laminae Form. Locality 15. Paradise Creek Formation. Forming cliff beside Paradise Creek.

Plate 14

Fig.1 Wavy Laminae Form. Locality 15. Paradise Creek Formation. Closer view of cliff in Plate 13, Fig.2.

Fig.2 Wavy Laminae Form. Locality 15. Paradise Creek Formation. Weathered brain-like upper surface.

Plate 15

Fig.1 Wavy Laminae Form. Specimen F.21654. Locality 2. Paradise Creek Formation. Weathered brain-like surface from beds dipping 55°W. X $\frac{1}{3.5}$.

Fig.2 Wavy Laminae Form. Locality 19. Paradise Creek Formation. Vertical section in beds dipping steeply east.

Plate 16

Fig.1 Sub-hemispherical Form. Locality 7. Paradise Creek Formation. In dolomite beds dipping gently to the north-east.

Fig.2 Sub-hemispherical Form. Locality 7. Paradise Creek Formation. Well-developed individual colony, showing concentric laminae, in same bed as Fig.1.

Plate 17

Fig.1 Sub-hemispherical Form. Specimen F.21665. Locality 14. Paradise Creek Formation. Specimen showing thick and thin laminae. Compare Plate 4, Fig.3. X $\frac{1}{4.4}$.

Fig.2 Sub-hemispherical Form. Locality 7. Paradise Creek Formation. Transverse section showing irregular parallel laminae in beds dipping gently north-east.

Plate 18

Fig.1 Sub-hemispherical Form. Specimen F.21649a. Locality 8. Paradise Creek Formation. Transverse section. X$\frac{1}{2}$.

Fig.2 Sub-hemispherical Form. Specimen F.21649b. Locality 8. Paradise Creek Formation. Vertical section. X$\frac{1}{2}$.

Plate 19

Fig.1 Cylindrical Form. Locality 20. Paradise Creek Formation. Transverse view.

Fig.2 Sub-hemispherical Form. Specimen F.21649c. Locality 8. Paradise Creek Formation. Vertical section. X$\frac{1}{2}$.

Plate 20

Fig.1 Dome-like Form. Locality 15. Paradise Creek Formation. Vertical section showing top part of sphere.

Fig.2 Dome-like Form. Locality 15. Paradise Creek Formation. Area around Fig.1.

Plate 21

Fig.1 Dome-like Form. Locality 15. Paradise Creek Formation. Vertical section showing junction of two colonies.

Fig.2 Intermediate Form. Locality 14. Paradise Creek Formation. Close-up of a portion of Plate 11, Fig.2.

Plate 22

Fig.1 Sub-conical Form. Specimen F.21646. Locality 17. Judenan Beds. Showing bifurcations. Compare Plate 5, Fig.2. X$\frac{1}{2}$.

Fig.2 Dome-like Form. Locality 15. Paradise Creek Formation. Weathered upper surface of a dome.

Plate 23

Fig.1 Conical Form. Specimen F.21666a. Locality 21. Paradise Creek Formation. Transverse section. X1.

Fig.2 Conical Form. Specimen F.21666b. Locality 21. Paradise Creek Formation. Vertical section. X1.

Plate 24

Fig.1 Branching Form. Specimen F.21658. Locality 10. Paradise Creek Formation. Vertical section showing laminae convex upwards. X $\frac{1}{1.8}$.

Fig.2 Hermal Form. Locality 9. Paradise Creek Formation. Transverse view of small, isolated colony.

Plate 25

Fig.1 Sub-spherical Form. Locality 5. Paradise Creek Formation. Transverse view showing concentric laminations.

Fig.2 Sub-spherical Form. Locality 8. Paradise Creek Formation. Specimens on bedding plane.

Plate 26

Fig.1 Silicified Black Sphere. Locality 16. Paradise Creek Formation. Showing interstitial breccia.

Fig.2 Silicified Black Spheres. Locality 16. Paradise Creek Formation. Black spheres and interstitial breccia.

Plate 27

Fig.1 Silicified Black Spheres. Locality 16. Paradise Creek Formation. Elongated fragments in interstitial material between spheres.

Fig.2 Silicified Black Spheres. Locality 16. Paradise Creek Formation. Showing sphere and interstitial breccia.

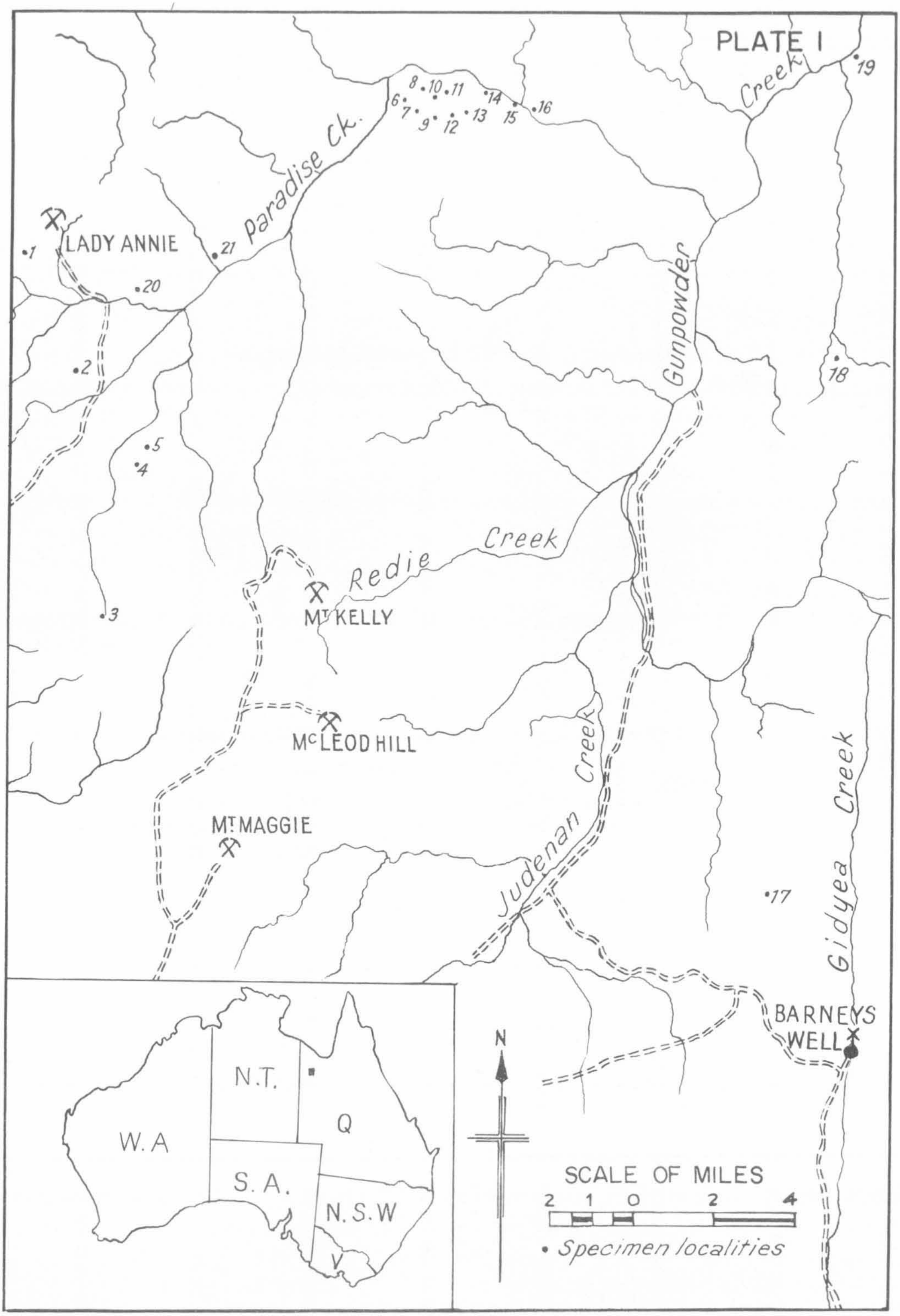
PLATE I
Paradise Ck.
LADY ANNIE
Gunpowder
Creek
Redie Creek
MT KELLY
McLEOD HILL
MT MAGGIE
Judenan Creek
Gidyea Creek
BARNEYS WELL
N.T.
Q
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S.A.
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SCALE OF MILES
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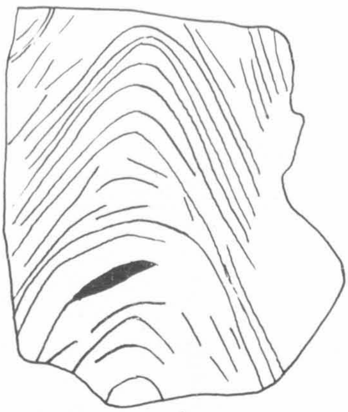
PLATE 2



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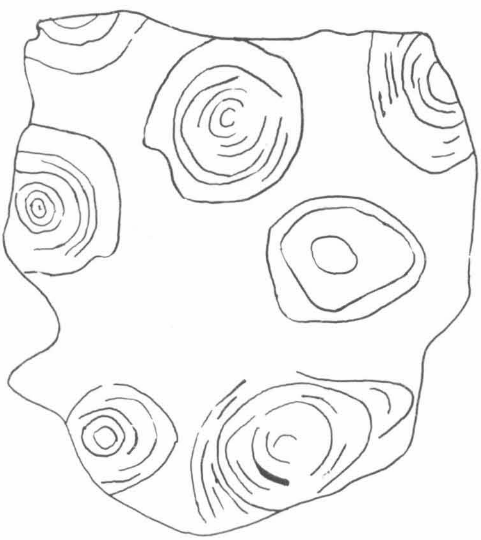

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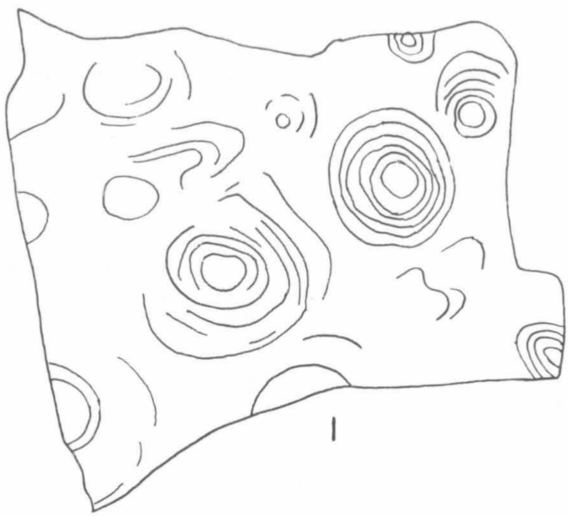
PLATE 3



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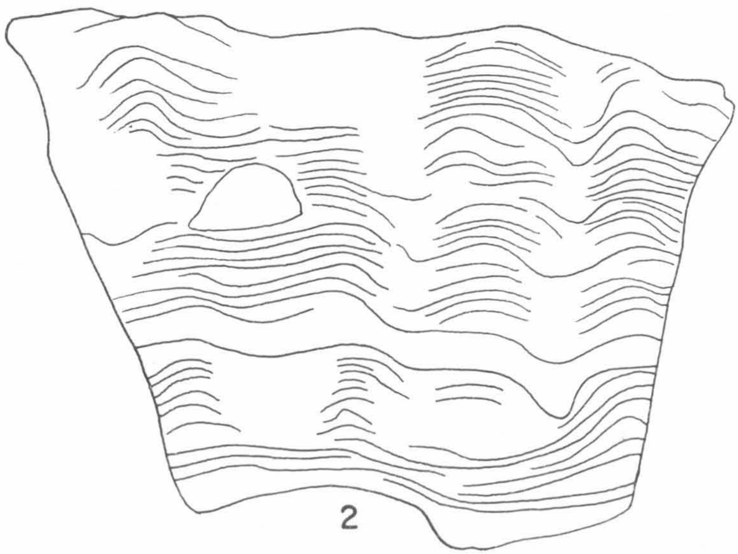

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PLATE 4

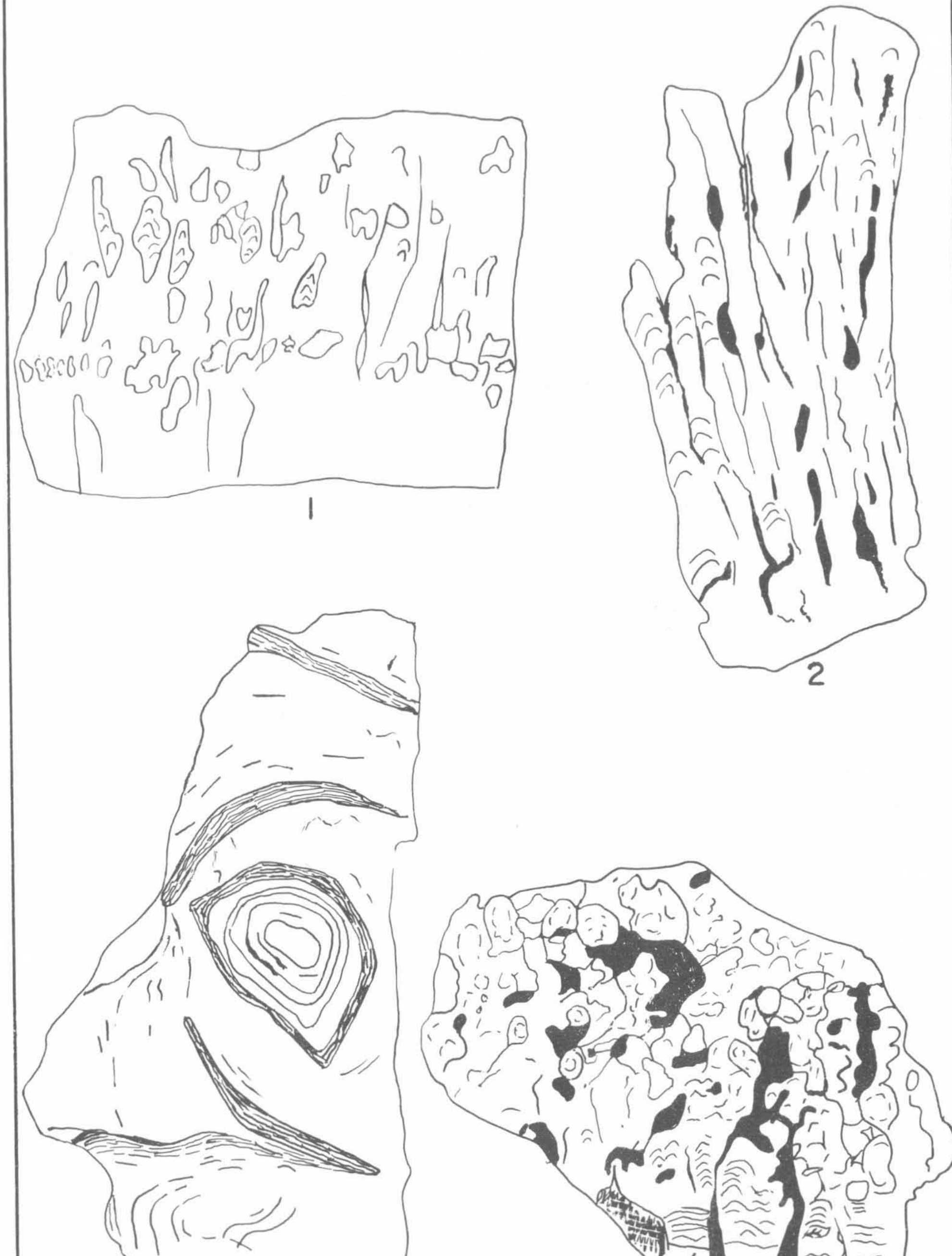
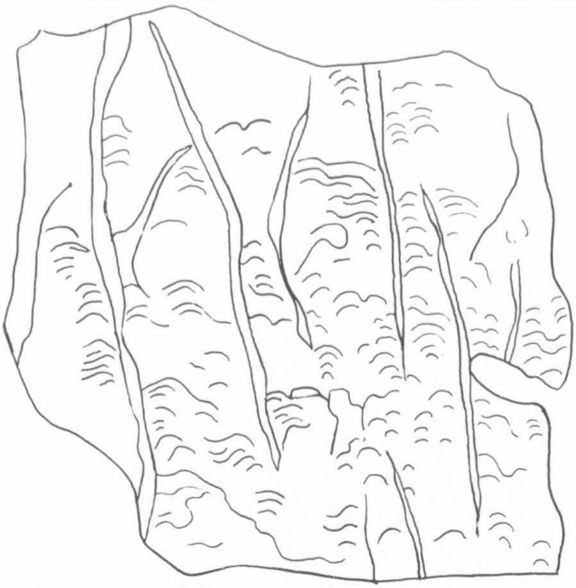


PLATE 5



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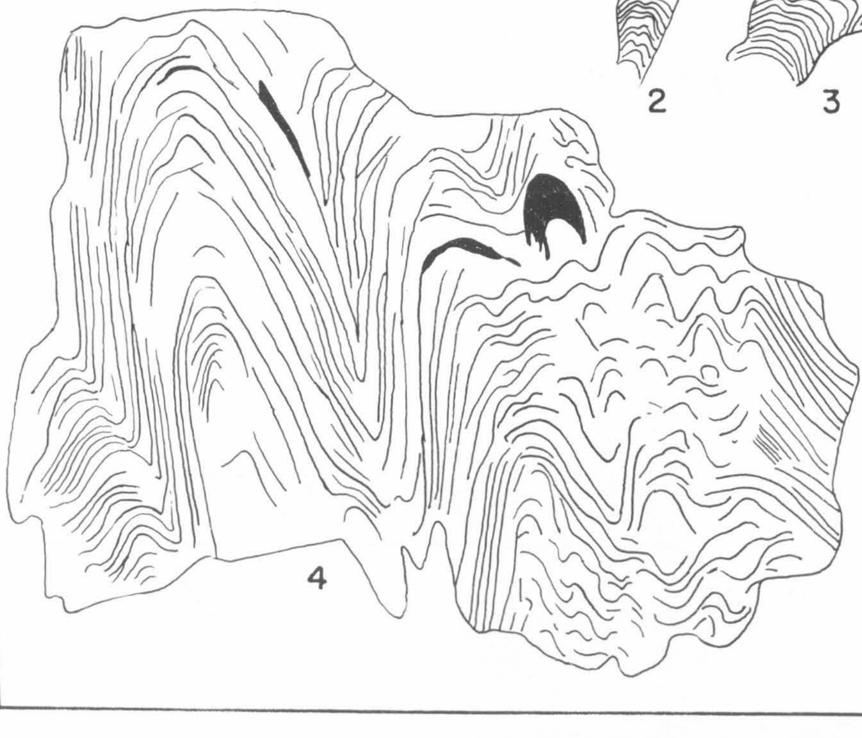

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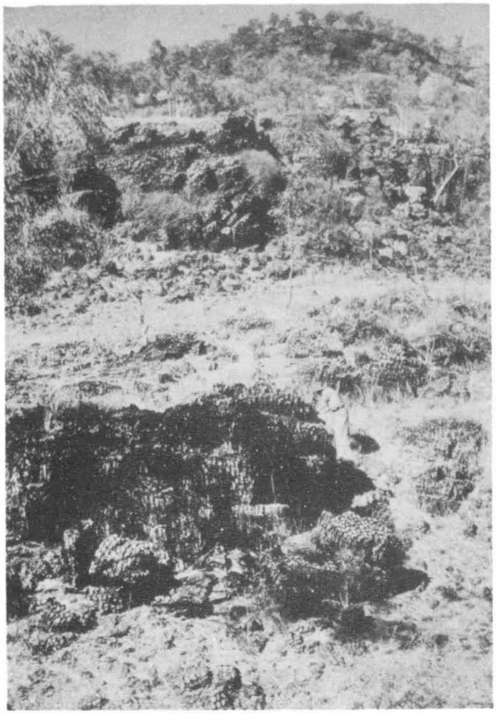

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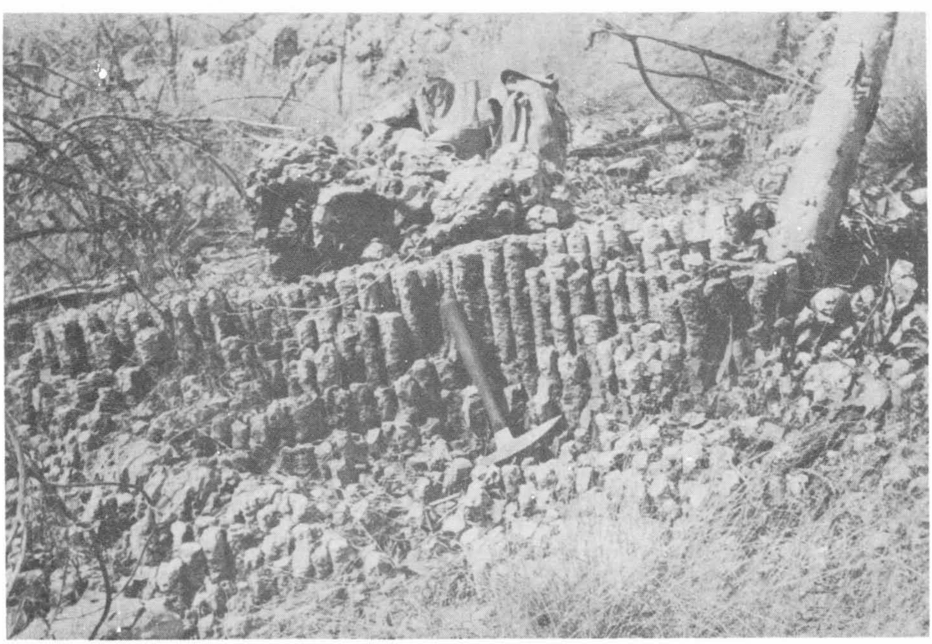

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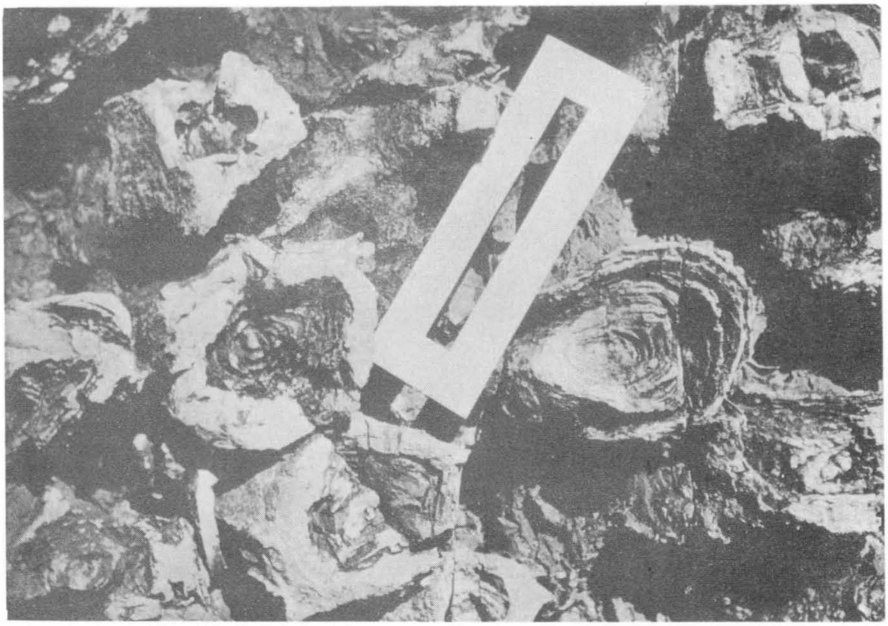

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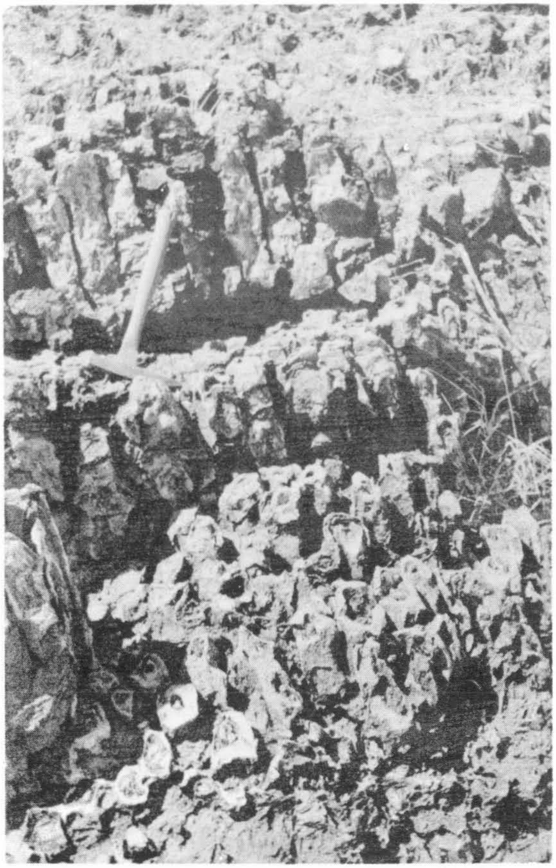

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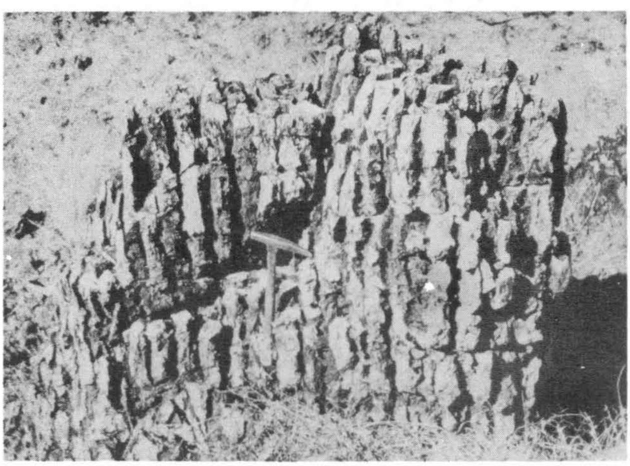

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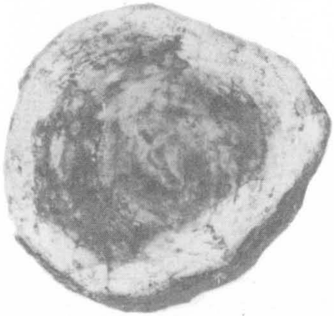

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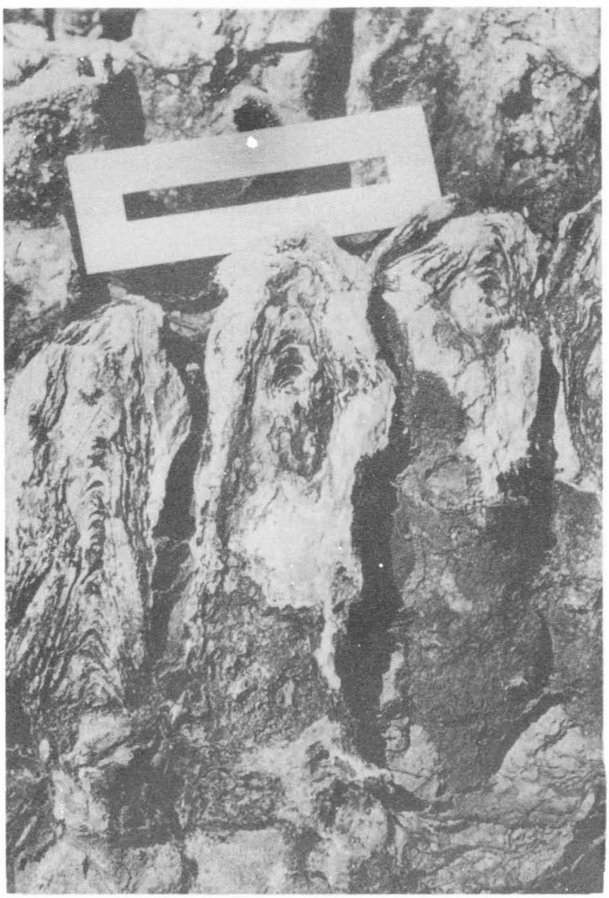

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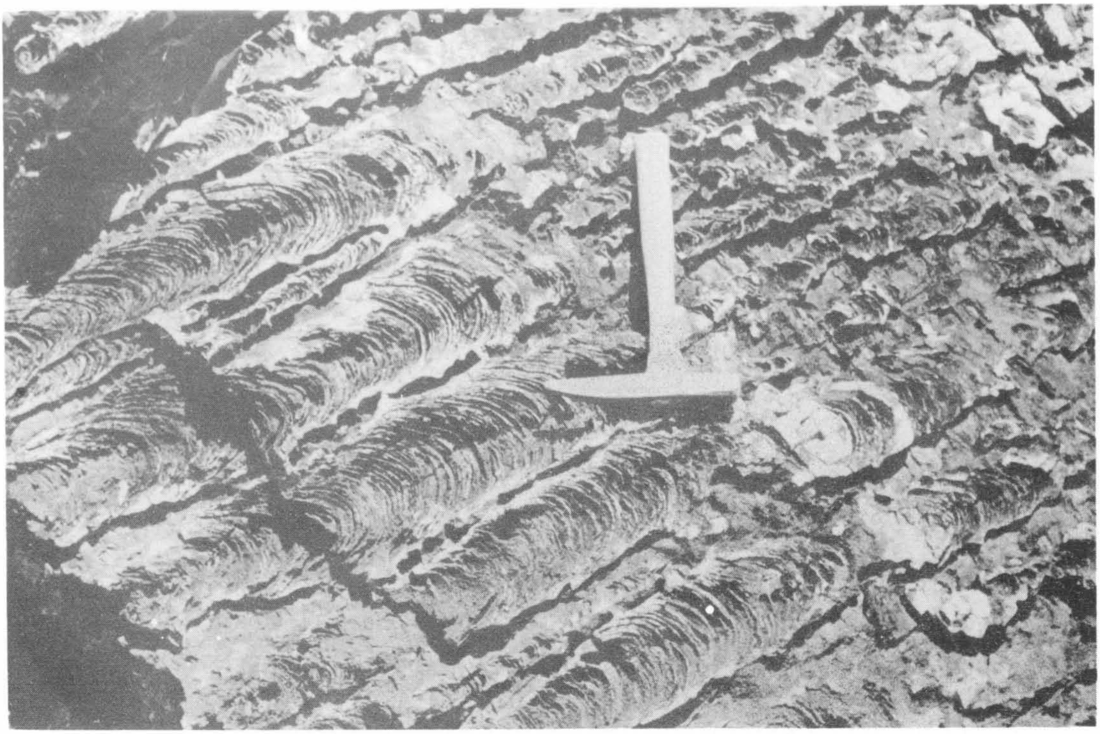

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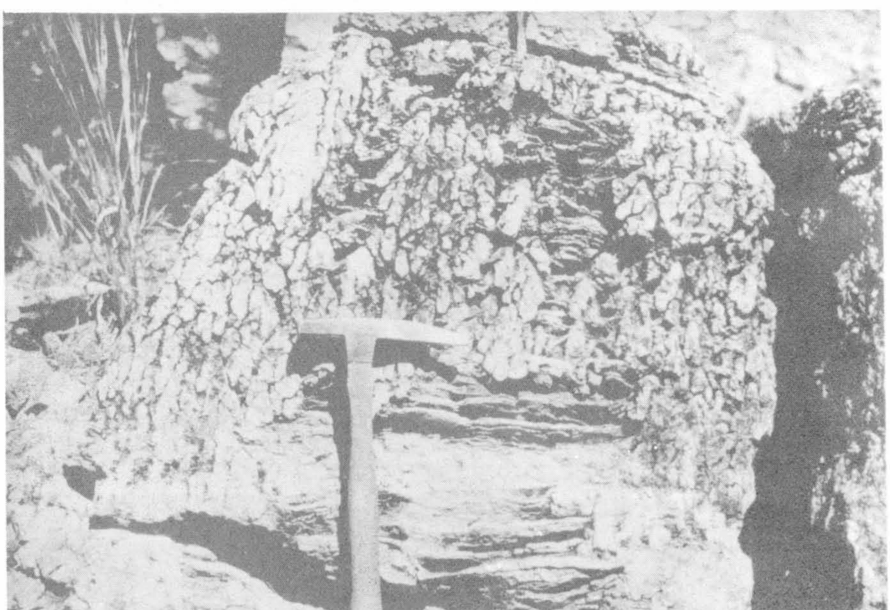

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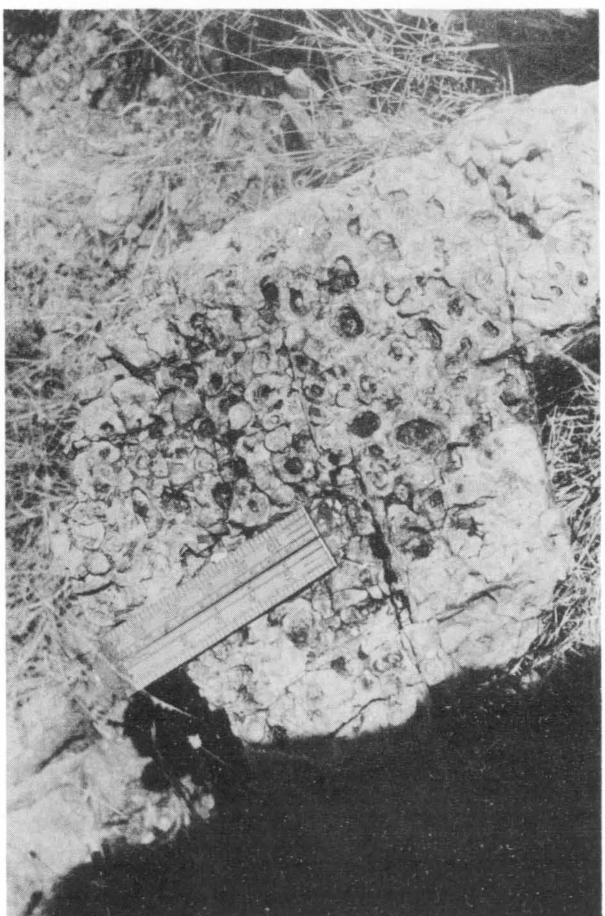

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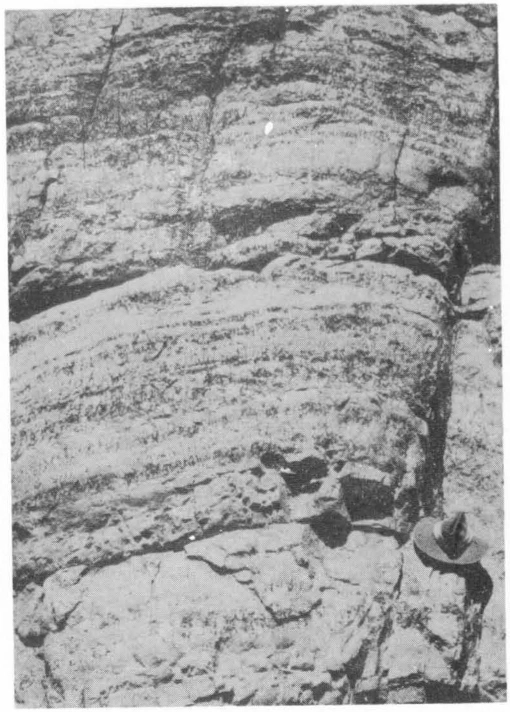

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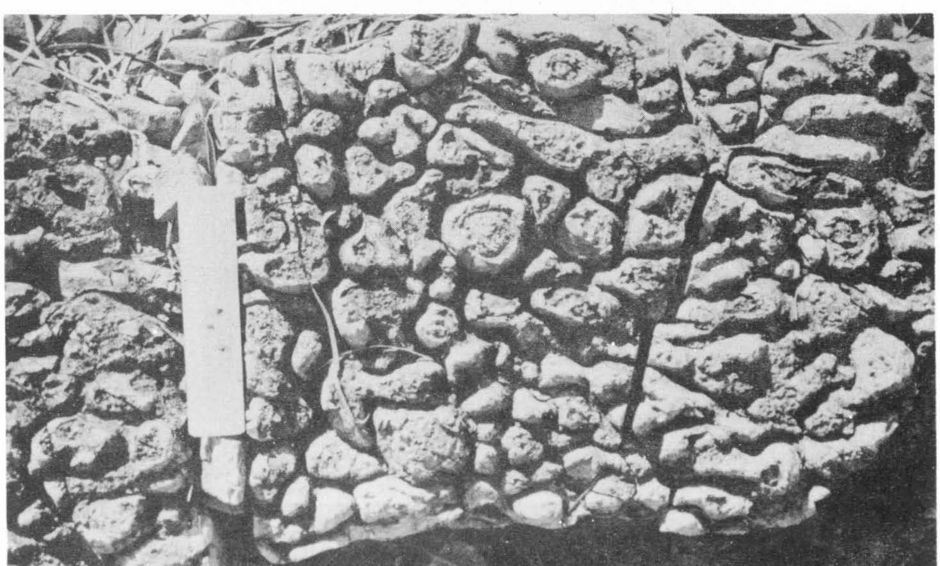

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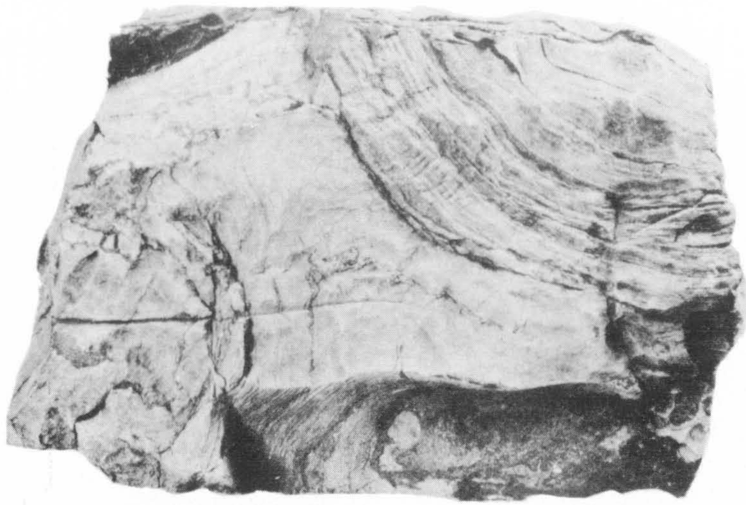

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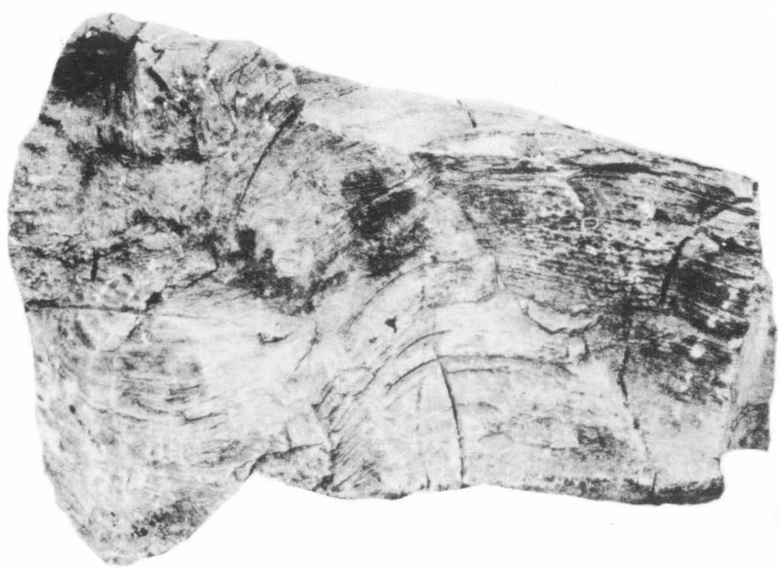

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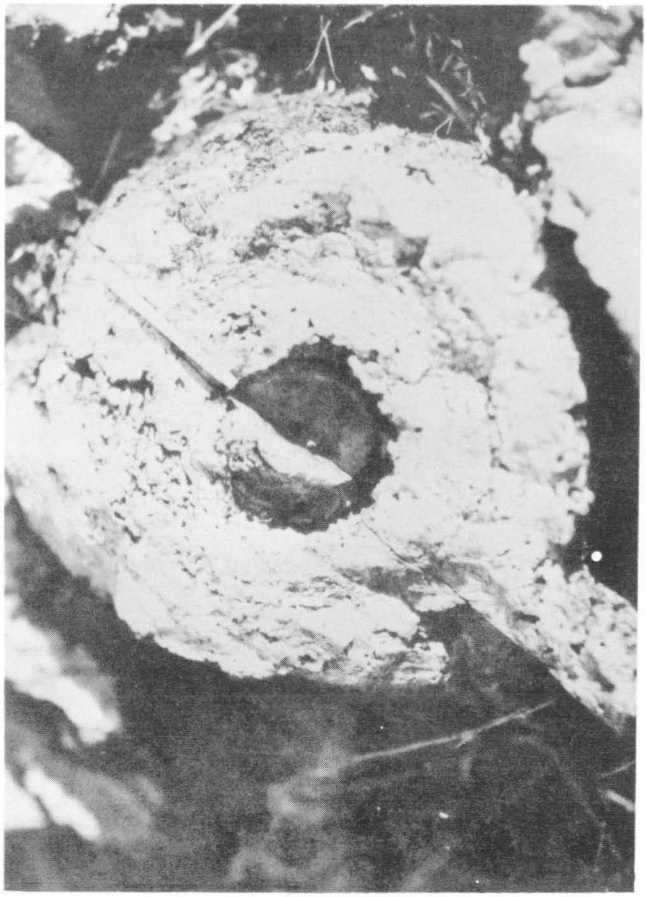

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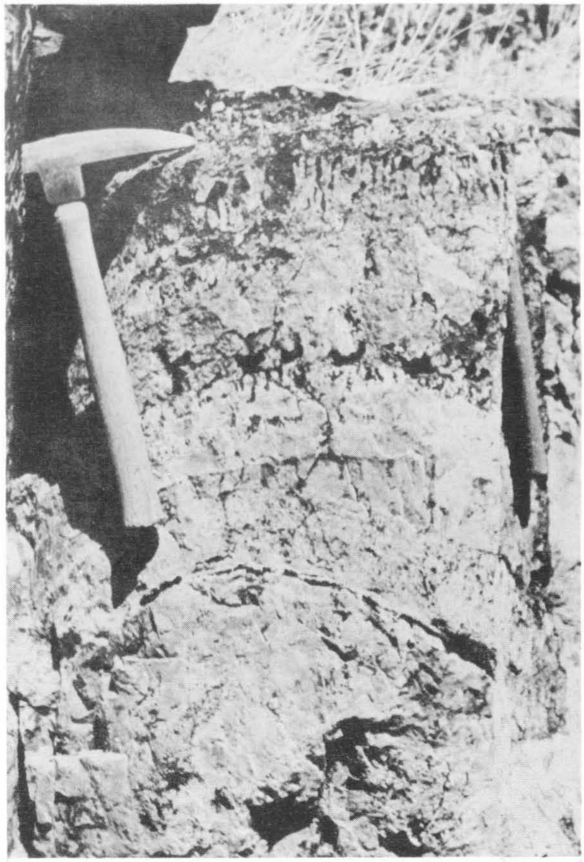

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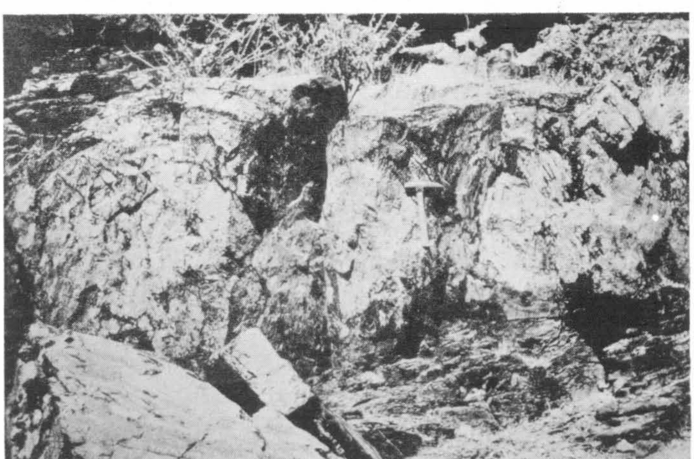

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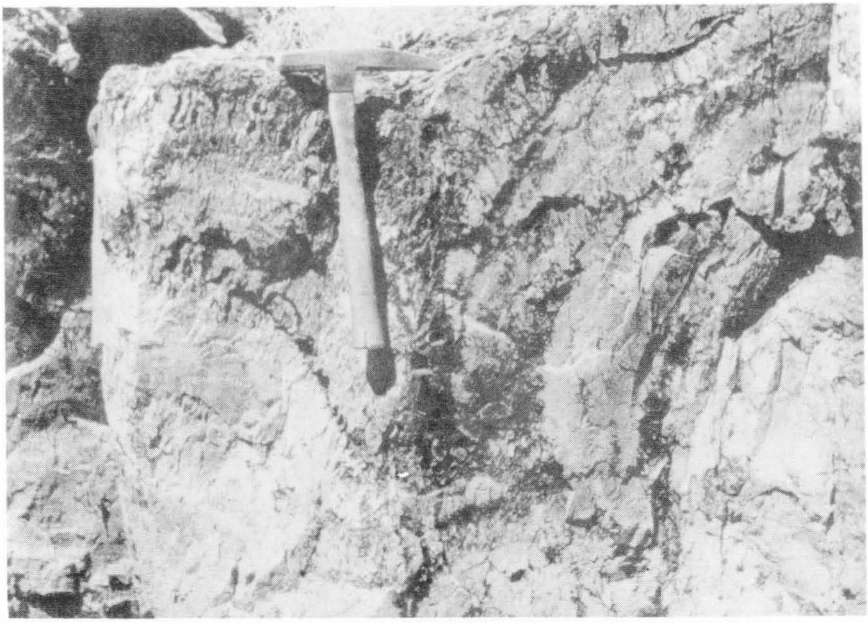

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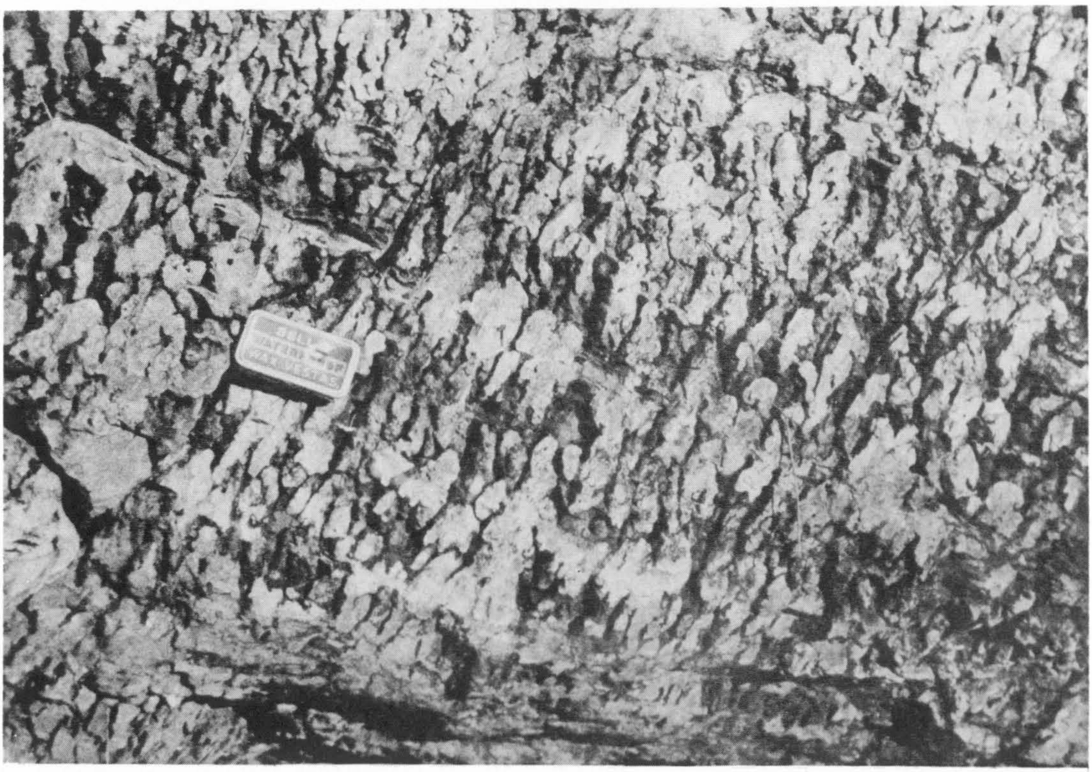

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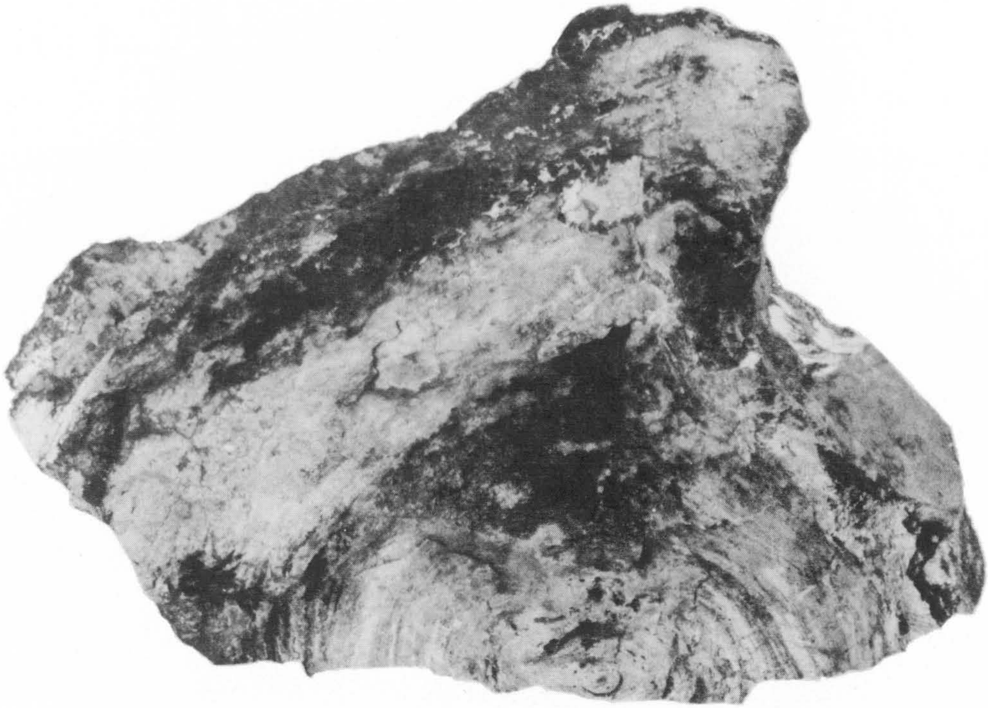

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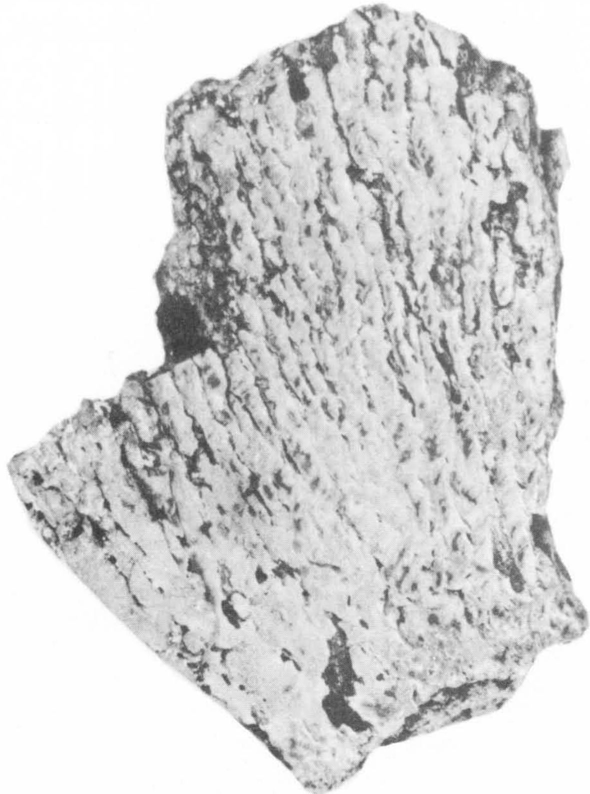

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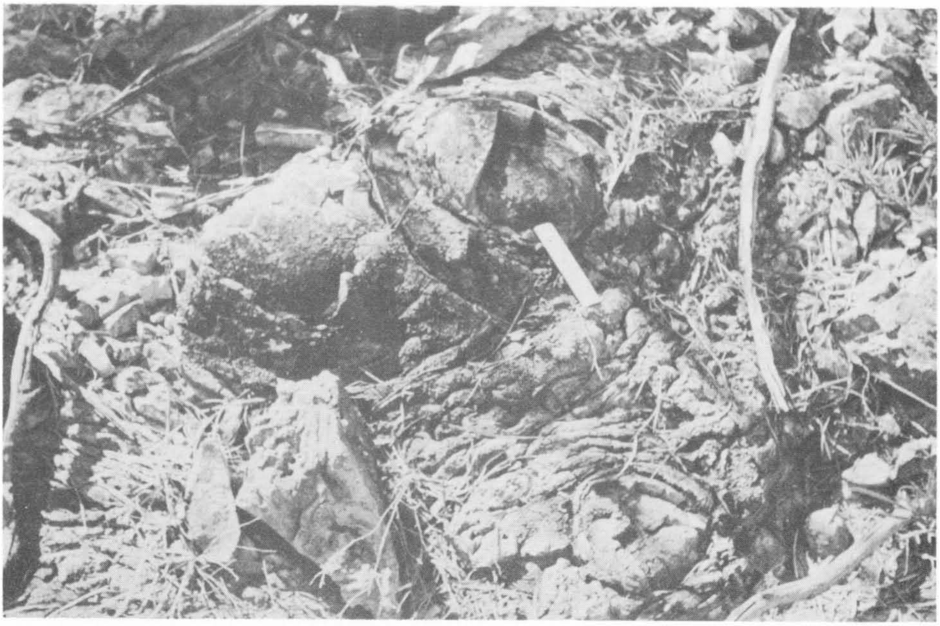

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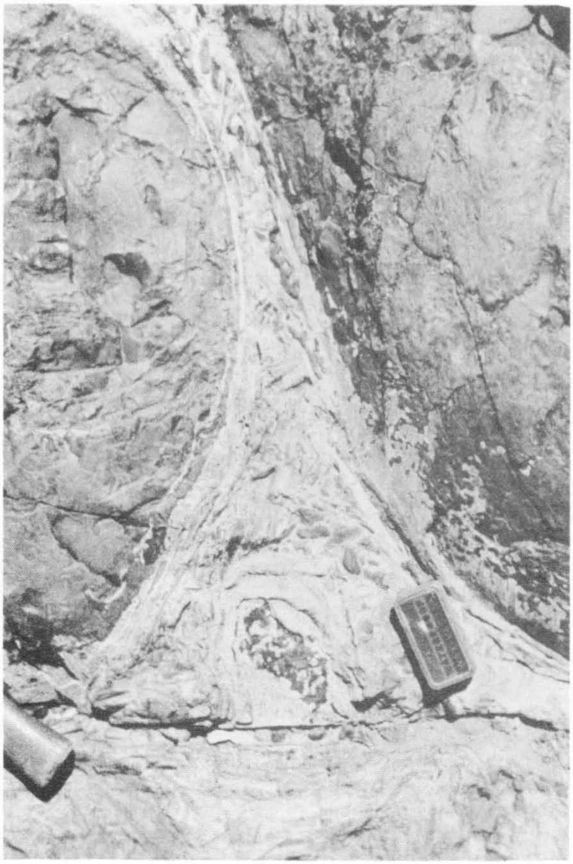

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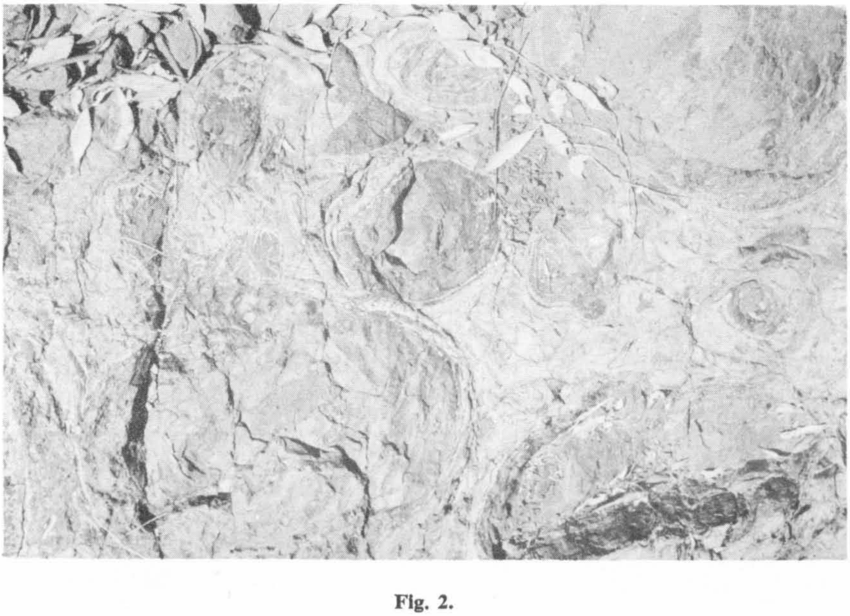

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