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BIOSTRATIGRAPHIC STUDIES OF STROMATOLITES FROM THE PROTEROZOIC EARAHEEDY GROUP NABBERU BASIN, WESTERN AUSTRALIA

DEPARTMENT OF MINES
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BIOSTRATIGRAPHIC STUDIES OF STROMATOLITES FROM THE PROTEROZOIC EARAHEEDY GROUP, NABBERU BASIN, WESTERN AUSTRALIA

by

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FOREWORD

Western Australia is ideally situated to test the methods of stromatolite biostratigraphy which have been employed by geologists from the USSR for several decades, but which have never been extensively adopted in other parts of the world. The Proterozoic of this State includes numerous sedimentary sequences which have well documented geochronological and stratigraphic time constraints, in addition to containing diverse stromatolite morphologies. This bulletin presents the results of systematic studies carried out as a contribution to the assessment of the biostratigraphic potential of stromatolites in Western Australia.

The eastern part of the Nabberu Basin provides an important reference section for stromatolite correlation, both in Australia and world-wide. The Earaheedy Group, with an age of approximately 1 700 Ma, contains twelve taxa, many of them new. Each of these forms has a distinctive morphology which is consistent with time-distribution patterns emerging elsewhere in the world, and the studies presented here resolve some of the anomalies previously reported in stromatolite ranges.

This Bulletin not only includes information of practical value to those engaged in mineral exploration, but will be a most useful reference work which helps to fill in a gap in the world literature regarding Proterozoic stromatolite taxonomy.

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5 January 1983

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ABSTRACT

Systematic studies of stromatolites from the Proterozoic Earaheedy Group of the Nabberu Basin were carried out in conjunction with a regional mapping programme at a scale of 1:250 000. The purpose of these studies was to determine the distribution of the various stromatolite forms in relation to stratigraphic units, and to continue the empirical studies begun by Walter (1972) and Preiss (1972) to test the suitability of Proterozoic stromatolites for biostratigraphic correlation. A diverse assemblage of twelve taxa is now recognized in the Earaheedy Group. The form *Tarioufetia yilgarnia* Preiss 1976 is transferred to the group *Externia* Semikhatov 1979. The forms *Minjaria granulosa* and *Tungussia heterostroma* of Preiss 1976 are combined in the single form *granulosa* and placed in a new group *Windidda*. New forms have been placed in the groups *Pilbaria* (*Pilbaria deverella*) and *Omachtenia* (*Omachtenia teagiana*). Descriptions are given of six new groups and forms: *Carnegia wongawolensis, Earaheedia kuleliensis, Murgurra nabberuensis, Nabberubia toolooensis, Yandilla meekatharrensis* and *Yelma digitata*. A possible new form of *Ephyaltes* is also recorded. *Ephyaltes* form indet., *Externia yilgarnia, Murgurra nabberuensis, Omachtenia teagiana* and *Yandilla meekatharrensis* are present in the Yelma Formation; *Pilbara deverella* and *Yelma digitata* occur in both the Yelma and Frere Formations. *Carnegia wongawolensis, Nabberubia toolooensis, Windidda granulosa* and cf. ?*Kulparia* form indet. occur in the Windidda Formation and *Earaheedia kuleliensis* is restricted to the Kulele Limestone.

None of the stromatolite forms from the Earaheedy Group are known from sequences elsewhere in Australia; however, no other stromatolite sequences are known to be the same age as the considered age of the Earaheedy Group. The groups *Pilbaria* and *Externia* occur in sequences of equivalent age in Canada, Africa and other parts of Australia. Digitate stromatolites similar to *Yelma digitata* are also known from sequences of approximately the same age in other parts of the world. The revised taxonomic status of *Minjaria granulosa, Tarioufetia yilgarnia* and *Tungussia heterostroma* eliminates the anomalous occurrence of three late Proterozoic groups in the early Proterozoic, previously considered to be a problem in stromatolite correlations. The presence of distinctive new stromatolites in the Earaheedy Group and the distribution of some of them in relation to taxa previously described, support the feasibility of stromatolite biostratigraphy in the lower Proterozoic.

BIOSTRATIGRAPHIC STUDIES OF STROMATOLITES FROM THE PROTEROZOIC EARAHEEDY GROUP NABBERU BASIN, WESTERN AUSTRALIA

INTRODUCTION

Biostratigraphic studies of stromatolites in Western Australia have been made in conjunction with the programme of regional geological mapping at 1:250 000 scale. Stromatolites are now known from many Proterozoic basins in Western Australia and a diverse assemblage occurs in several carbonate units in the 1.7 b.y. old Earaheedy Group in the Nabberu Basin of Western Australia (Fig. 1). The stromatolite groups and forms[1] described in this report are useful local stratigraphic markers, and a characteristic assemblage occurs in each formation. Many of the taxa have not been described previously; however, some of the groups have a widespread geographical distribution and appear to be restricted to approximately the same time horizon throughout the world. Problems previously encountered in biostratigraphy (Preiss, 1977) can be attributed, to some extent, to the taxonomy used, rather than to the stromatolites themselves. This suggests that the principles of intercontinental correlations based on stromatolites require re-examination (Semikhatov, 1978b, Bertrand-Sarfati and Walter, 1981).

PREVIOUS STUDIES

The earliest record of fossils from the Nabberu Basin is the mention of a sample collected by Talbot from a locality "seven miles south of Wongawall" (Talbot, 1913, p. 13) which was forwarded to R. Etheridge, Jr., for identification. Etheridge commented that "in the less dense portion there is certainly a queer, half obliterated polygonal structure which to my eye may be the remains of a coral, such as minute *Favosites* but is altogether too problematical to speak definitely." The specimen (GSWA registered specimen 12505) has been re-examined and is not a fossil, and the polygonal structure referred to by Etheridge is probably a group of mud flakes.

The first stromatolites from the basin were collected by K. H. Morgan (GSWA fossil sample nos. F5017, F5018, F5019) and described by Edgell (1964) as *Collenia undosa* Walcott. Morgan (1966, p. 16) reported that east of Windidda homestead and south of Lake Carnegie, "Dolomite beds contain algal fossils", but precise localities were not given. The specimens are poorly preserved but show some resemblance to *Yelma digitata* new group and form and are probably from the Frere Formation. The presence of algal structures in the Proterozoic rocks of the Nabberu area was also mentioned by Sanders and Harley (1971).

Walter, Goode and Hall (1976) described microfossils from stratiform stromatolites and oncolites in the Frere Formation. At about the same time Preiss (1976a) published descriptions of columnar stromatolites from the Windidda and Frere Formations. Four taxa were described—cf. ?*Kulparia, Minjaria granulosa, Tarioufetia yilgarnia* and *Tungussia heterostroma*—from localities in the eastern part of the Earaheedy Sub-basin. Hall and Goode (1978) illustrated and briefly described stromatolites from the western part of the Earaheedy Sub-basin but systematic studies were not carried out. Bunting (in prep.) gives a detailed description of large elongate domes in the Kulele Limestone and presented a palaeogeographical reconstruction based on the direction of elongation. A review of the stratigraphic occurrences of stromatolites throughout the Western Australia Proterozoic has recently been published (Grey, 1979), and their significance in biostratigraphic studies discussed (Grey, 1982).

METHODS AND TERMINOLOGY

The stromatolites described in this report were collected by various members of the Geological Survey of Western Australia (GSWA), in particular, by J. A. Bunting and R. D. Gee during regional mapping of the Nabberu Basin between 1975-1979; by W. D. M. Hall of BHP Ltd; and by the author in conjunction with M. R. Walter and S. M. Awramik in September 1977.

Samples were collected from 16 of the 22 known stromatolite-bearing localities in the Nabberu Basin (Fig. 2) and were studied by the methods outlined by Walter (1972) and Preiss (1976b). The method of serial reconstruction established by Hofmann (1976a) was used where practicable and serial reconstructions were redrawn by members of the

[1] In stromatolite studies the terms group and form are used instead of genus and species (Walter, 1972, p. 14).

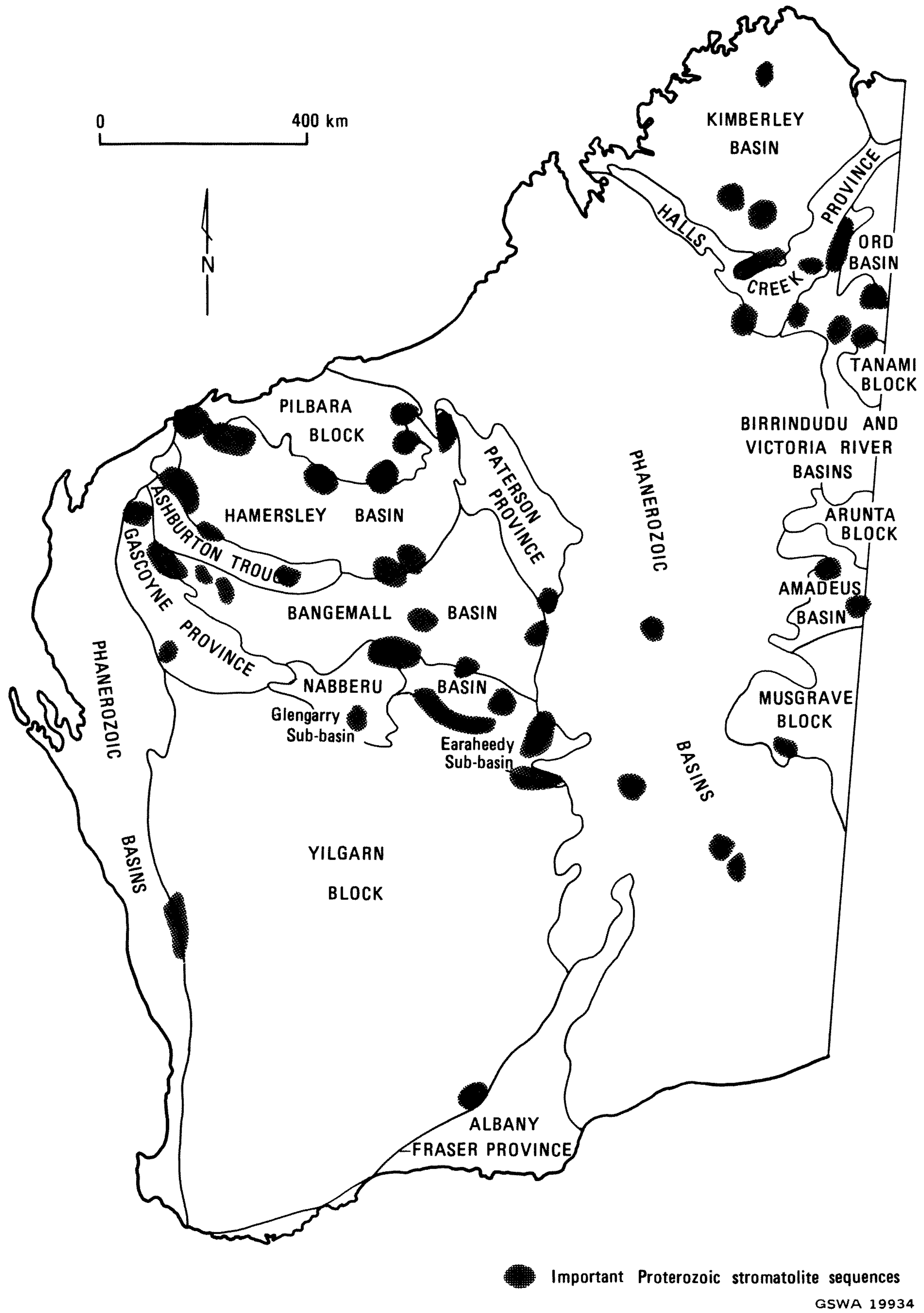


Figure 1. Map showing location of Nabberu Basin, Western Australia in relation to main tectonic units. Stippled areas indicate major Proterozoic stromatolite-bearing sequences.

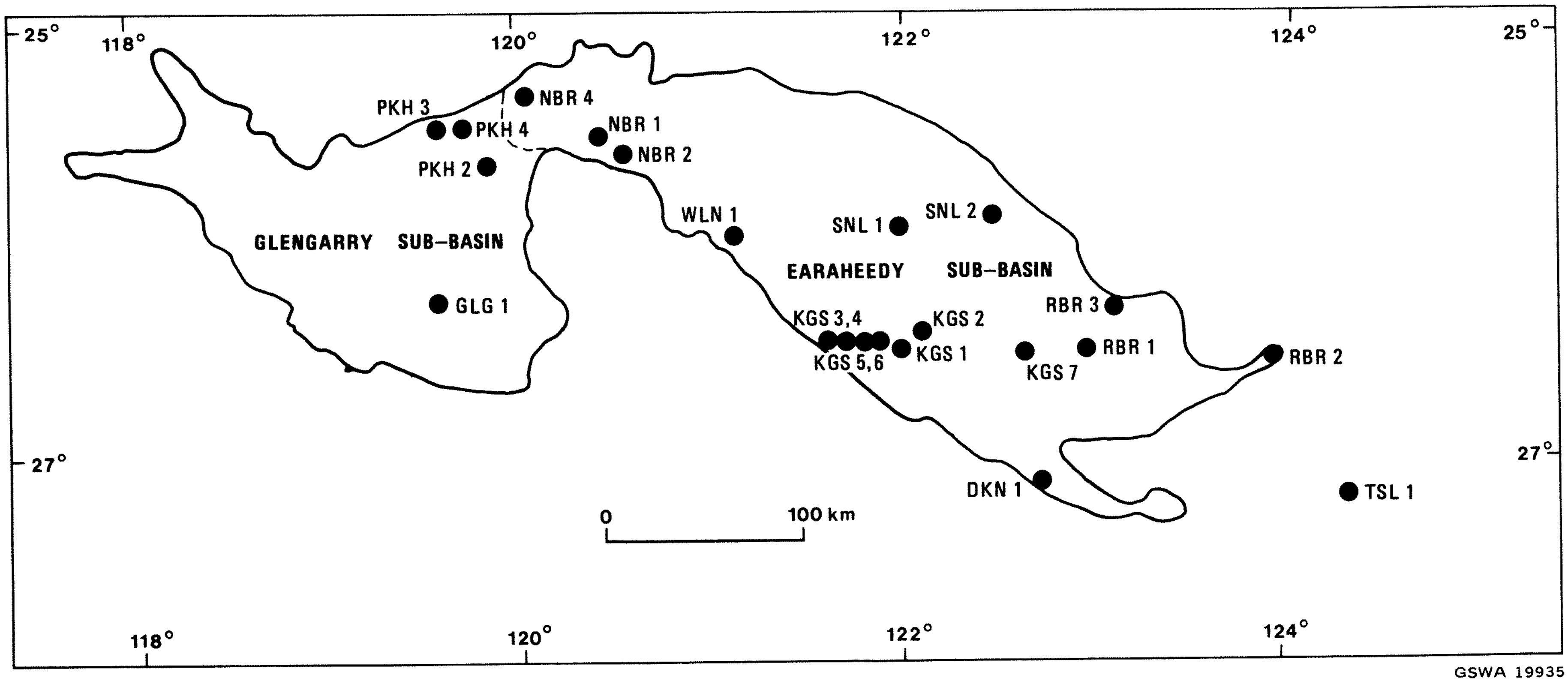


Figure 2. Stromatolite localities in the Nabberu Basin.

Drafting Division of the Western Australian Mines Department. GSWA fossil catalogue numbers, prefixed by the letter F, are used in this report and material is stored in the GSWA fossil collection. Localities are identified by GSWA fossil locality numbers which consist of a three-letter code for the relevant 1:250 000 geological map sheet, followed by an accession number (for example NBR1). Details are given in the Appendix.

Morphological descriptions and terminology are those of Hofmann (1969a), Walter (1972) and Preiss (1976b) and are generally consistent with the terminology used by Russian authors.

Arguments in favour of binomial nomenclature for stromatolites have been discussed by many authors, among them Cloud and Semikhatov (1969), Krylov (1976) and Bertrand-Sarfati and Walter (1981). Debate has arisen because stromatolites are most probably formed by an association of organisms, principally cyanobacteria, but the practice of using Linnean nomenclature for the products of those associations is now well established and is followed here.

Where field data are inadequate for the three-dimensional nature to be determined, the term "stromatolite buildup" (Heckel, 1974, p. 92) is used to refer to that part of the carbonate mass containing stromatolites. Otherwise the terms bioherm and biostrome, as defined by Walter (1972, p. 9), are used.

In recent years, stromatolite buildups with distinctive lateral and vertical variations in morphology have been recognised and called "bioherm series" (Krylov, 1976; Walter and others, in prep.). In a bioherm series, the morphological variations are considered to be sufficiently distinctive for each variation to receive a separate binomial, and an additional binomial is used for the total structure (Krylov, 1976, fig. 5). The criteria used for the recognition of forms within a bioherm series have not so far been clearly defined; Krylov (1976, p. 41) refers to "morphologically varied constructions with the same microstructure". In the material from the Earaheedy Group the range of variation within most of the individual stromatolites is not sufficiently diverse for them to be regarded as bioherm series, with the exception of a few cases in which a change in gross morphology and in the shape of the laminae is also accompanied by changes in the microstructure, and which are therefore excluded from Krylov's concept of a bioherm series. Bertrand-Sarfati and Walter (1981) refer to the combination of microstructure and laminae shape as "fabric". In this study of Earaheedy Group stromatolities, I regard changes in the fabric accompanied by changes in gross morphology as being indicative of a major change in the microbial community forming the stromatolites. Such changes are treated as separate taxa. Other samples show no major variation in fabric, and changes in gross morphology are restricted to the development of branching and of wall structures. These features are considered to be a normal growth response of the microbial community, and probably reflect such factors as the need to develop a greater surface area. Such variations probably do not indicate a change in the microbial community and are considered not to have major taxonomic significance. This follows the approach of Semikhatov and others (1967, translation in Walter, 1972, p. 16) more closely than the system proposed by Krylov (1967, p. 23-24).

The term "individual" (Walter, 1972, p. 13) has previously been used to refer to the bushy branching columns of the type commonly found in the Earaheedy Group (Fig. 3A). The "individual" was defined by Walter as "A group of columns arising from a single basal column or a discrete stromatolite within which the laminae are continuous." The term "individual" therefore includes both branching forms and non-branching discreet columns. A more specific term seems to be required for small, bushy branching structures, and the term "fascicle", (derived from a latin word *fasciculus-i* (masc.) meaning a bundle) is here proposed for individuals consisting of a group of columns which have a common point of origin, have developed by branching, and which have only minor variation in fabric throughout the structure (Fig. 3A). Each fascicle usually has a basal structure, which may be a single column, a nodule, a dome or a set of stratiform laminae. Columns with a consistent pattern of branching arise from this basal structure. Variations within the fascicle are usually restricted to features associated with the development of branching and/or wall structures, and to minor variations in fabric which can also be linked to the development of branching and walls. The binomial is applied to the whole structure of the fascicle. Several closely spaced fascicles may form a bioherm or biostrome (Fig. 3B).

STROMATOLITE BIOSTRATIGRAPHY

In spite of the fact that a stromatolite biostratigraphy has been in use in the USSR, particularly in the last two decades (Semikhatov, 1976; Chumakov and Semikhatov, 1981), studies in other parts of the world have reportedly given rise to ambiguous results (Preiss, 1976a, 1977). Both Walter (1972) and Preiss (1972b, 1973, 1974, 1976a, 1976b, 1977) used an empirical approach in the study of Australian stromatolites and attempted to make world-wide correlations, in particular between Australia and the sequences already well established in the USSR. The initial studies (Walter, 1972; Preiss, 1972b, 1973 and 1974) looked promising, but problems soon developed.

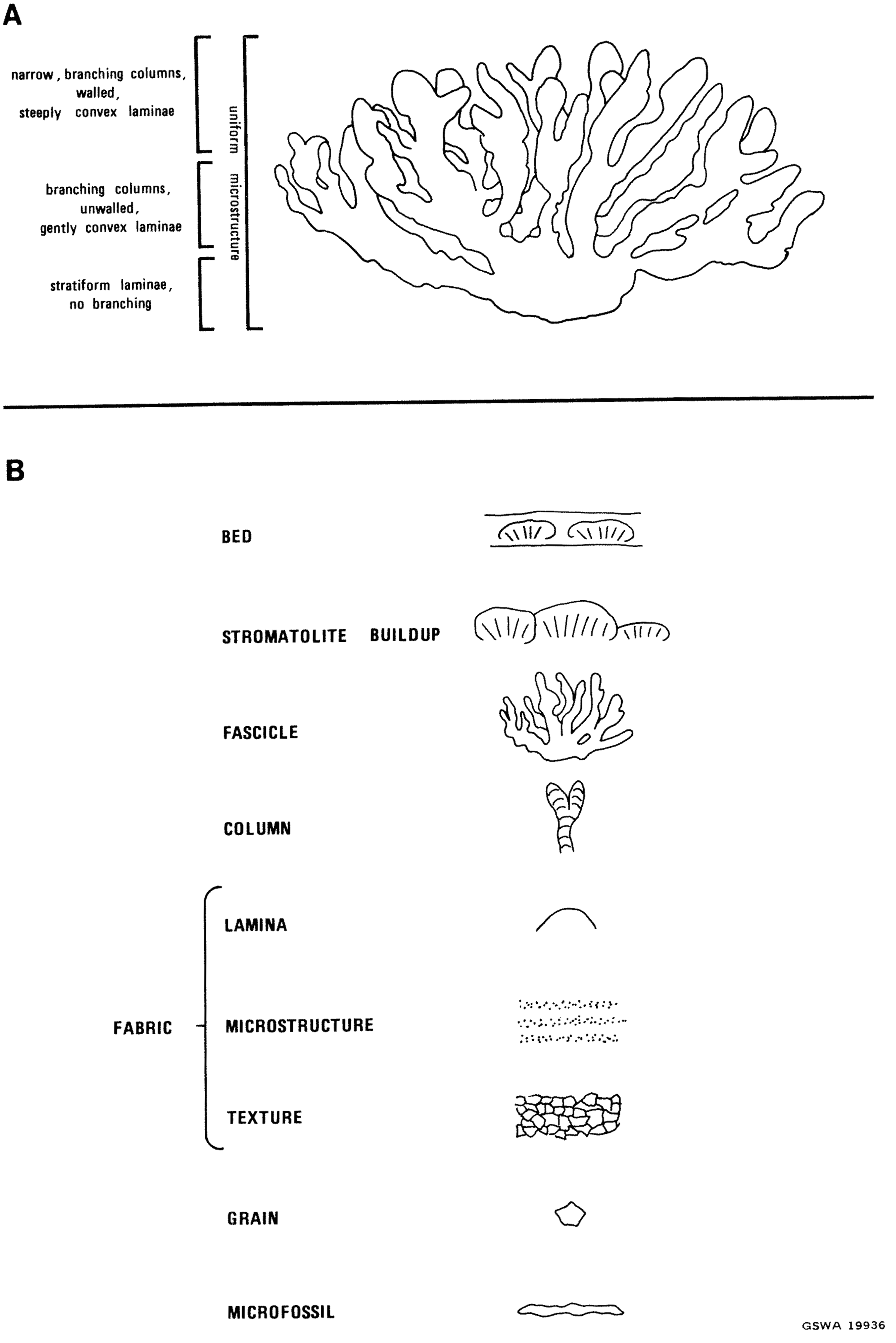


Figure 3. The fascicle. A. Typical bushy individual (*Murgurra nabberuensis*, Yelma Formation) which would constitute a single fascicle. B. The relationship of the fascicle to other stromatolite components (after Hofmann, 1977).

Preiss (1976a) examined stromatolites from the 1.7 b.y. old Nabberu Basin of Western Australia and assigned them to late Proterozoic (Riphean) groups, considerably extending the known time-ranges of these groups. In Canada, Donaldson (1976) reported the occurrence of late Proterozoic (Riphean and Vendian) stromatolites from early Proterozoic (Aphebian) rocks. These anomalies led Preiss (1977) to urge caution in basing intercontinental correlations on stromatolite groups. He also pointed out that forms appear unusable at the moment in biostratigraphy because very few are known to have a widespread geographical distribution. Because of such problems the concept of stromatolite biostratigraphy has not received the rigorous investigation required to test its practicality.

Such a study requires the determination of time ranges for defined taxa, and must be based on geochronological and stratigraphic data (Preiss, 1977). This empirical approach is based on a purely morphological classification, in which similar structures in the rock record are compared, without a phylogenetic relationship necessarily being implied. If identical taxa are present at a single time horizon and absent at all other time horizons, the fossil can be used as a stratigraphic marker. There has been a tendency in recent years for such an appraisal of time distributions to become lost in arguments about the influence of environment on morphology.

Monty (1977) reviewed the evolution of concepts of the nature and ecological significance of stromatolites. He discussed the significance of the bias introduced into the literature by a threefold dogma: that stromatolites are intertidal or shallow-water structures; that they form by the trapping and binding of detrital particles; and that their overall morphology is controlled by environmental processes. Monty reiterated his own conclusion that this dogma is too narrow a concept, and that "... stromatolites are *algally controlled* structures built by *co-ordinated societies* of primitive organisms (blue-green algae and bacteria)."

There is a growing body of evidence which supports Monty's view. Many recent studies indicate that "even with strong environmental factors, morphogenesis can be greatly influenced by biological processes" (Walter, 1977, p. 566). It now seems that although large-scale features, such as the elongation of domes to form seif stromatolites (Playford, 1980), are determined by environmental processes, smaller scale features, such as lamina shape and branching pattern, are biologically controlled. The various lines of evidence indicate that the problem is more complex than at first supposed, but this is hardly surprising if the wide range of stromatolite environments, and the large number of interacting agents which may influence morphological shape are considered. However, there is increasing evidence to suggest that the enormous diversity found in both the gross morphology and the fabric of stromatolites is closely related to the composition of the microbial community which forms them, and that evolutionary changes in this composition will be reflected by the stromatolites.

Walter (1972, p. 92-98) reviewed ideas about the probable role of cyanobacteria in controlling gross morphology and microstructure, and concluded that biological factors played an important part. Golubic and Focke (1978) showed that four geographically distinct populations of a modern stromatolite-building cyanobacterial species, growing under different ecological conditions (ranging from the turbulent subtidal environment of a coral reef to a muddy intertidal environment of a sheltered embayment), always produced remarkably similar stromatolites. Walter, Bauld and Brock (1976), studied hot spring environments of Yellowstone National Park. Walter (1977, p. 569) concluded that the significance of this work is "that it demonstrates that in quiet-water, metazoan-poor environments, biological processes can dominate in stromatolite morphogenesis." Awramik (1976, 1977) found that morphologically distinctive stromatolites, from the Gunflint Iron Formation, contained distinctive microbiotic assemblages peculiar to the stromatolite morphologies. Monty (1974, p. 590-592), discussed the conservative nature of cyanobacteria and considered which aspects of their evolution should be detectable in the fossil record. Awramik and others (1976), outlined a possible evolutionary development of stromatolite-building organisms.

From the various studies which have been carried out it seems reasonable to conclude that the first appearance of a micro-organism or changes in the composition of microbial assemblages would be reflected in stromatolite morphology. It is also probable that biochemical evolution occurred (Gebelein, 1976; Walter, 1977, p. 564) in species which were morphologically conservative, affecting the interaction between the organisms and its building activities, and hence the stromatolite morphology. Thus at least some of the changes in stromatolites during the Proterozoic were probably related to microbial evolution (Gebelein, 1976, p. 510), and may have left their traces in the fossil record. Such changes would most probably find expression in the fabric and branching patterns of stromatolite taxa and these characteristics are both considered to be important taxonomic criteria in this report. Bertrand-Sarfati and Walter (1981) discuss the need for the selection and weighting of characters of biological significance for use in a taxonomy intended for biostratigraphic and palaeobiologic use.

Any attempt to establish a biostratigraphy presupposes a sound taxonomy, with well-defined taxa showing relatively narrow ranges. Stromatolite taxonomy is still beset by many problems and this is emphasized by the fact that recently it has become evident that the paradox of 'younger' stromatolites in the early Proterozoic may not really exist (Semikhatov, 1978b, Bertrand-Sarfati and Walter, 1981). The majority of the early systematic studies were restricted to the late Proterozoic (Riphean). Donaldson (1976) and other Canadian geologists did not publish systematic descriptions to confirm their identifications, and Preiss (1976a) had only a limited amount of material available. Some 53 forms have now been described from pre-Riphean rocks (Bertrand-Sarfati and Walter, 1981) and include a study by Semikhatov (1978a) of stromatolites from the Canadian Shield which indicates that many of the 'Riphean' identifications are invalid, and that the stromatolites in question belong to new groups (Semikhatov, 1978b). Some of the Earaheedy Group stromatolites, described either by Preiss (1976a) or in this report, belong to these new Canadian taxa or are very similar to them, or show resemblances to other Aphebian groups from northern Europe (Makarikhin, 1978; Krylov and Perttunen, 1978) and South Africa (Bertrand-Sarfati and Eriksson, 1977). Such results emphasize the conclusion of Bertrand-Sarfati and Walter (1981), that by paying more attention to taxonomy, many of the problems of biostratigraphy can probably be resolved.

There are now several strong lines of evidence to suggest that stromatolite biostratigraphy is both theoretically and empirically possible. Most stromatolite forms and many groups have a restricted vertical range, although some may occur in restricted geographical areas (Preiss, 1977; Chumakov and Semikhatov, 1981). Anomalies reported at group level, especially in attempts at intercontinental correlation, are probably due to the need to refine stromatolite taxonomy, and the problems experienced with stromatolite biostratigraphy result more from a lack of data than from the unsuitability of stromatolites themselves.

STRATIGRAPHIC DISTRIBUTION OF STROMATOLITES IN THE NABBERU BASIN

The term Nabberu Basin was introduced by Hall and Goode (1975) for a complex arcuate belt of early Proterozoic sedimentary rocks lying with angular unconformity along the northern margin of the Archaean Yilgarn Block (Fig. 1). Bunting and others (1977) recognized two sub-basins; the western Glengarry Sub-basin and the eastern Earaheedy Sub-basin (Fig. 2). In the Glengarry Sub-basin, the Glengarry Group (composed of thick shelf, trough and volcanic sequences) and the Wyloo Group, which are lithologically similar, are proposed by Gee (1979a), to have formed the major depositional units of the geosynclinal sequence, the Capricorn Orogen. Branching columnar stromatolites are present in the Wyloo Group (Walter, 1972; Grey, 1979), but the only stromatolites so far reported from the Glengarry Group are elongate domes near the base of the Maraloou Formation, 12 km southwest of Mount Russell (Elias and others, 1979), and a few poorly preserved stratiform and domed stromatolites from localities in the same general vicinity, (Bunting, pers. comm., 1979; Gee, pers. comm., 1980).

The Glengarry Group is unconformably overlain by the Earaheedy Group, which occurs in the Earaheedy Sub-basin (Bunting and others, 1977). Stratigraphic units in the Earaheedy Group (Fig. 4) were first described by Hall and Goode (1975) and were formally defined by Hall and others (1977). Detailed descriptions of the various units have been given by Hall and Goode (1978) and Bunting (pers. comm.), and in descriptions of mapping carried out at the 1:250 000 scale for the following sheets: Duketon (Bunting and Chin, 1979), Glengarry (Elias and others, 1979), Kingston (Bunting, 1980), Nabberu (Bunting and others, 1979), Peak Hill (Gee, 1979b), Robert (Jackson, 1978), Stanley (Commander and others, 1979), Throssel (Bunting and others, 1978), Wiluna (Elias and Bunting, 1978). The generalized geology of the Earaheedy Sub-basin is shown in Figure 4. The age of deposition of the Earaheedy Group is approximately 1.7 b.y. (Bunting and others, 1977), based on K-Ar and Rb-Sr isotopic dates obtained from glauconite samples (Preiss and others, 1975). Preliminary work on lead isotopes from galena samples (J. Richards, pers. comm., 1979) gives results consistent with an age of 1.7 b.y. The Earaheedy Group is overlain by an undated sequence, the Scorpion Group (Bunting and others, 1979) which contains stromatolites, including conical forms (Grey, 1979).

The Earaheedy Group is subdivided into the Tooloo and Miningarra Subgroups (Hall and others, 1977) (Fig. 1). The Tooloo Subgroup consists of the Yelma, Frere and Windidda Formations, and all three units are stromatolitic. In the Miningarra Subgroup, stromatolites are known only from the Wongawol Formation and the Kulele Limestone. Only the stromatolitic units are considered further. The distribution of the described stromatolite forms is shown in Figure 5.

YELMA FORMATION

The Yelma Formation, the oldest unit of the Earaheedy Group, is dominantly clastic, consisting largely of quartz arenite with minor shale, chert and carbonate. The carbonate lenses, which have a diverse stromatolite assemblage, occur near the top

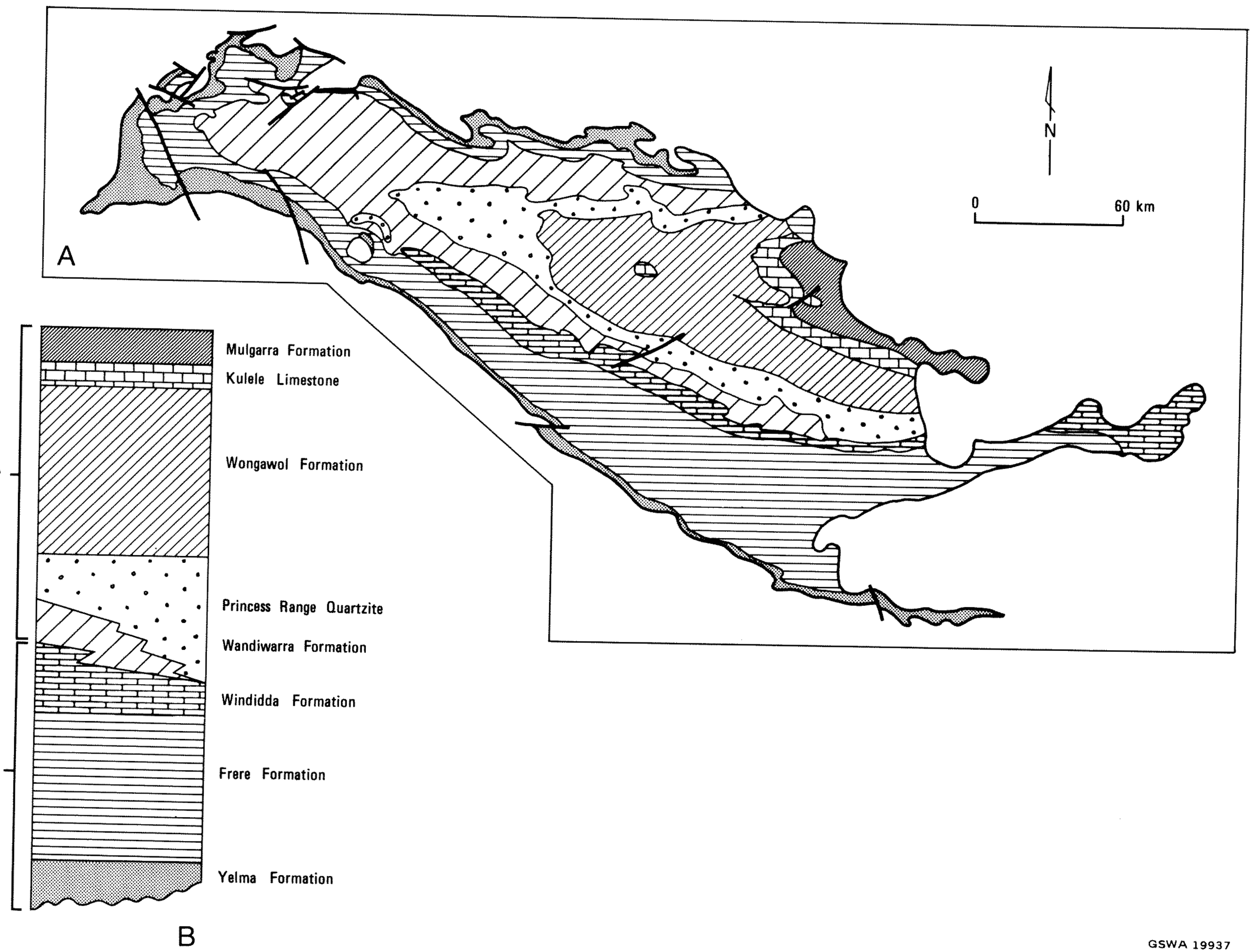


Figure 4. A. Generalized geology of the Earaheedy Sub-basin.
B. Generalized stratigraphy of the Earaheedy Group (both A and B are based on Hall and others 1977).

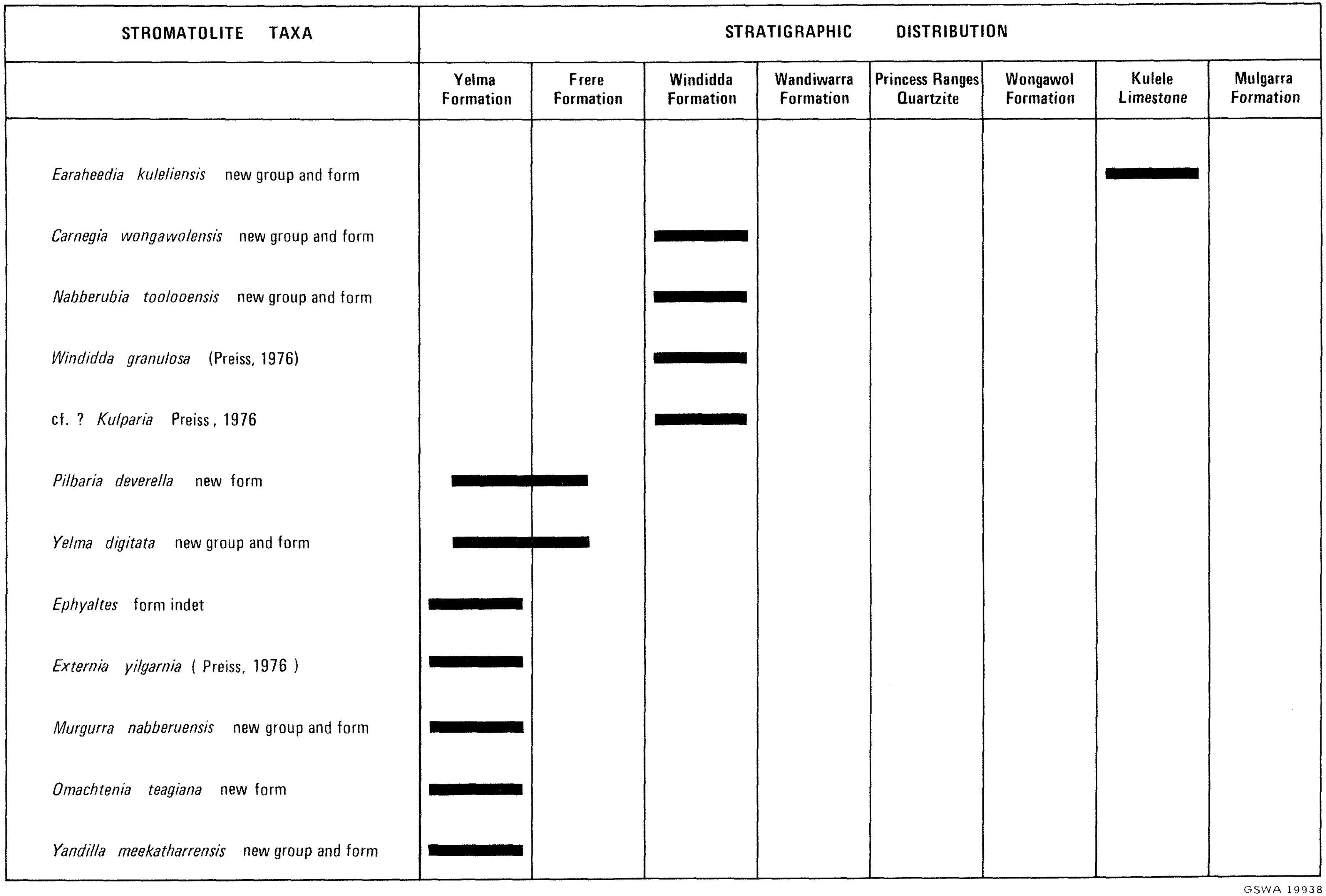


Figure 5. Stratigraphic ranges of stromatolite taxa in the Earaheedy Group.

of the Yelma Formation. Many of the chert horizons contain poorly preserved stromatolitic banding. Stromatolites are present at the following localities (Fig. 2):

(1) In the southeastern part of the basin a locality in northeast Duketon (DKN1) has been described by Preiss (1976a) and Bunting and Chin (1979) and contains abundant stromatolites in a carbonate band 3-5 m thick. The predominant form is *Externia yilgarnia* (Preiss, 1976a).

(2) Approximately 4.5 km east of No. 5 Well, near Sweeney Creek (NBR2) a band of grey stromatolitic limestone occurs in an outcrop of quartz arenite. The limestone has been partially silicified (Pl. 1B) to a cream or pale-green chert (Bunting and others, 1979). The outcrop is quite extensive and numerous small domes occur around the margins of an area of well-developed columns of *Omachtenia teagiana* new form.

(3) A carbonate unit 3.5 km southeast of Sweetwaters Well on the shore of Lake Nabberu (NBR1) (Bunting and others, 1979) was originally included in the Frere Formation (Hall and Goode, 1978, p. 158), but is now placed in the Yelma Formation (Bunting, pers. comm.). The unit is approximately 10 m thick and consists of laminated, pale-grey dolomite with abundant stromatolites and rare oolites, and is overlain by shale and granular iron-formation. Stromatolites are present at several horizons, forming a cyclic sequence.

Murgurra nabberuensis new group and form occurs in small rocky outcrops in the lake bed at the southern end of the locality; and at an isolated outcrop to the northeast. This horizon is probably overlain by a bed of domed stromatolites (Pl. 1A) which outcrops in the lake bed several hundred metres to the northwest of the *M. nabberuensis* outcrops.

The domed stromatolites increase in size and number in a northeasterly direction and are up to 1 m in diameter, although many are smaller. Their height is usually between 15 and 20 cm. The domes are pseudo-columnar or cumulate, and have bulbous or nodular cross-sections. No branching was observed and they have not been formally named. In plan they are rounded or ovate, or occasionally polygonal. Laminae are gently convex to steeply convex and are finely banded with alternating light-grey to cream laminae 1-5 mm thick, and dark-grey to brown laminae 7-10 mm in thickness. The laminae are usually wavy and column walls are poorly defined. In places the domes have been replaced by chert, and there are numerous stylolites concordant with the laminae. The domes frequently contain patches of galena.

The domed stromatolites are overlain by a biostrome of *Yelma digitata* new group and form. Patches of galena are present at this horizon and are occasionally concentrated in the interstitial areas between the columns (Pl. 28B).

Above this lower *Yelma digitata* horizon are patchy outcrops of *Pilbaria deverella* new form. Some calcretization occurs at this horizon. Above the *Pilbaria deverella* horizon is a layer of flat-laminated stromatolitic dolomite. This cycle is repeated several times, although the domes are not always present, and are never as well developed as in the basal cycle. Because of the rubbly nature of the outcrop it is difficult to determine the precise relationships between the various forms and to decide how many cycles are present, although there are at least three. The lowermost ferruginous chert band, which marks the base of the Frere Formation, occurs a few metres above the topmost *Yelma digitata* horizon.

(4) Near Combine Well (PKH2) (Gee, 1979b) a grey dolomite, similar to the one at Sweetwaters Well, contains poorly preserved specimens of *Yelma digitata*.

(5) A locality near Lake Gregory (PKH3) (M. Hall, pers. comm. 1980), consisting of dark-grey dolomite, contains very poorly preserved columnar stromatolites tentatively identified as *Pilbaria deverella*.

(6) A second locality near Lake Gregory occurs 4 km northwest of Edgingunna Well (PKH4) (Gee, 1979b) where grey dolomite 30-50 cm in thickness contains ?*Yelma digitata* and *Ephyaltes* form indet.

(7) Five kilometres east of Phar Lap Well (GLG1) a sandstone sequence, originally placed in "unassigned Proterozoic" (Elias and others, 1979) but which may correlate with the Yelma Formation (Bunting, pers. comm.), passes upwards through interbedded carbonate and sandstone into a thick sequence of stromatolitic dolomite in which the principal form is *Yandilla meekatharrensis* new group and form.

FRERE FORMATION

The Frere Formation consists dominantly of ferruginous shale and granular iron-formation with minor chert and carbonate. Branching columnar stromatolites have so far only been collected from the carbonate horizons, although stratiform stromatolites and oncolites are present about 2.5 km northeast of Camel Well (WLN1). Walter, Goode and Hall (1976) have reported abundant microfossils from this locality. Stromatolites are present at the following localities:

(1) Near Simpson Well (NBR4) (Bunting and others, 1979) a pale grey to white carbonate approximately 35 m thick overlies a chert horizon. *Pilbaria deverella* occurs in a stromatolitic band 2 m in thickness, approximately 25 m above the base.

(2) Poorly preserved stromatolites (possibly *Omachtenia teagiana)* occur in carbonates 20 km north of Buldya Soak at an isolated outcrop assigned to the Frere Formation (Bunting and others, 1978) in northeast Throssel (TSL1).

(3) Stromatolites have been reported from south of Lake Carnegie, east of Windidda homestead, although the precise locality is not known. Samples F5017, F5018 and F5019 were described as *Collenia undosa* by Edgell (1964); however, they are possibly the basal part of *Yelma* digitata.

WINDIDDA FORMATION

The Windidda Formation is mainly grey to pink, laminated dolomite or limestone, interbedded with maroon or grey mudstone (Bunting, 1980). Stromatolites are prolific throughout the formation and the majority are probably *Carnegia wongawolensis* new group and form. Samples have been described from the following localities.

(1) Preiss (1976a) described an unamed stromatolite from Ida Range (RBR2).

(2) Preiss also described cf. ?*Kulparia, Minjaria granulosa* and *Tungussia heterostroma* from Mount Elisabeth (RBR1) (Jackson, 1978). Examination of new material from Mount Elisabeth shows that *M. granulosa* and *T. heterostroma* have identical fabrics and are different parts of a fascicle, and are therefore combined into a new taxon, *Windidda granulosa* (Preiss). Small columns of *Nabberubia toolooensis* new group and form are also present in the samples illustrated by Preiss (1976).

(3) The lower part of the Windidda Formation is well exposed in a gorge 6 km south of Windidda homestead (KGS1) (Bunting, 1980). Stromatolites are abundant and consist of bulbous structures formed by closely spaced columns which encrust nodules of chert or mudstone. Two forms have been identified from the gorge section, *Carnegia wongawolensis* new group and form and *Nabberubia toolooensis* new group and form. *Carnegia wongawolensis* is abundant in the lower and middle parts of the Windidda Formation and is present as weathered-out nodules in Wongawol Creek and tributaries (KGS3, 4, 5) (Bunting, 1980). (4) The middle part of the Windidda Formation is exposed north of Tooloo Bluff, 3 km south of Windidda homestead (KGS2) (Bunting, 1980) and contains unnamed small domed stromatolites and *Carnegia wongawolensis.*

(5) Similar domed stromatolites and *Carnegia wongawolensis* are also present in the upper part of the formation north of Wongawol Creek at the contact with the Wandiwarra Formation (KGS6) (Bunting, 1980).

WONGAWOL FORMATION

Commander and others (1979) and Hall and Goode (1978) report the presence of poorly preserved stromatolites in the Scholl Creek Member of the Wongawol Formation.

KULELE LIMESTONE

The Kulele Limestone consists of several interbedded limestones of which the commonest is pink, thickly bedded, and contains oolites in addition to elongate domes (Pl. 1C), large stromatolite domes (Pl. 1D) and occasional columns.

(1) A dolomite near Mount Lancelot (RBR3) containing poorly preserved stromatolites (Jackson, 1978) is now placed in the Kulele Limestone (Bunting, pers. comm.)

(2) Large, elongate, domed stromatolites occur at Mount Hosken (SNL2) (Commander and others, 1979).

(3) A locality near Thurraguddy Bore (SNL1) has been described in detail by Bunting (in. prep.); some of the domed structures described by him are formed by the columnar stromatolite *Earaheedia kuleliensis* new group and form.

(4) North of Lake Carnegie, 4 km north of Bulljah Pool (KGS7) (Bunting, 1980) there are elongate domes with alignments similar to those at Thurraguddy Bore.

BIOSTRATIGRAPHIC SIGNIFICANCE

WITHIN THE EARAHEEDY GROUP

The Earaheedy Group has a diverse assemblage of stromatolite forms. Twelve taxa have been recognized from 22 localities. The stratigraphic distribution of the stromatolites is shown in Figure 5. Seven forms are present in carbonate units near the top of the basal Yelma Formation. *Pilbaria deverella*, and possibly *Yelma digitata* also occur in carbonate lenses in the overlying Frere Formation. None of these seven forms have been observed in the Windidda Formation, which contains four taxa. Only one form has been recognized in the Kulele Limestone in the upper part of the Earaheedy Group.

At the moment it is not clear whether this distribution of stromatolite forms represents zonation or is related to environmental factors. Nevertheless, it provides a useful tool for the recognition of lithostratigraphic units in the Nabberu Basin.

OTHER AUSTRALIAN ASSEMBLAGES

Stromatolite assemblages of the early and middle Proterozoic have not been extensively studied in other parts of Australia. The distribution of stratigraphic units of approximately the same age as the Earaheedy Group containing stromatolites is shown in Figure 6. Evidence for the ages and ranges of the various stromatolitic units in Western Australia has been summarized by Grey (1979) and is not repeated here. Preiss and Forbes (1981) and Grey (1982) have reviewed the occurrences for the rest of Australia. On present knowledge no other stromatolite-bearing sequences have the same time-range as the Earaheedy Group, and none of the sequences slightly younger or older than the Earaheedy Group are known to contain an assemblage of such great diversity.

Digitate stromatolites, identified as *Katernia perlina* Bertrand-Sarfati and Eriksson (1977) occur in the Koolpin Formation in the Pine Creek Geosyncline, Northern Territory (Crick and others, 1980). These stromatolites are smaller, have shorter columns and more divergent branching than the digitate form *Yelma digitata* from the Earaheedy Group. The Koolpin Formation is considered to be between 2 000 and 2 300 m.y. old (Crick and others, 1980, p. 276).

The Wyloo Group (approximately 2.0 b.y.) is older than the Earaheedy Group, and Gee (1979b) has discussed the probable stratigraphic and structural relationships of the two units. Stromatolites have been reported from several localities (Grey, 1979) but little systematic work has been carried out. Walter (1972) described *Patomia* form indet., *Pilbaria perplexa* and an unnamed form, and Grey (1981) has recently reported a small digitate form probably belonging to the group *Asperia*. The limited evidence suggests that the sequences do not have any forms in common, although both contain *Pilbaria* and small digitate stromatolites. Such results are consistent with the disparate ages suggested for the two sequences.

In the Kimberley area, stromatolites are abundant in the Elgee Siltstone from which Semikhatov (1978) recorded *Kussoidella* form indet. (=Kussiella form indet. of Cloud and Semikhatov, 1969), and unnamed stromatolites are common in the slightly younger Hibberson Dolomite. The Elgee Siltstone is older than 1 800 ± 25 m.y. (Compston and Arriens, 1968).

There are several sequences slightly younger than the Earaheedy Sub-basin succession (Grey, 1979). These include the Birrindudu Group, the Talbot Well Formation and the Lake Willson Beds in the Birrindudu Basin; the Limbunya Group, which crops out extensively in the Victoria River Basin and may extend southwards into the Birrindudu Basin; the Bungle Bungle Dolomite, which occurs in the eastern Kimberley region; the McArthur Group and Dook Creek Formation of the Mount Rigg Group in the McArthur Basin; and the Paradise Creek Formation in the Mount Isa Inlier. The age of these stromatolitic sequences is between 1.5 and 1.7 b.y. but they are most probably younger than the Earaheedy Group and it is possible that they are closer in age to the stromatolitic Scorpion Group which overlies the Earaheedy Group, but only detailed systematic studies will show how closely the various assemblages can be matched. None of the taxa reported so far from any of these basins are identical with those from the Earaheedy Group.

The Tolmer and Bullita Groups, which occur in the Victoria River Basin, are even younger than the sequences listed above, and are therefore considerably younger than the Earaheedy Group. None of the stromatolites reported from the Tolmer and Bullita Groups resemble forms from the Earaheedy Group.

Part of the form described as *Inzeria tjomusi* by Cloud and Semikhatov (1969) from the Tolmer Group does resemble an unnamed stromatolite occurring in both the Yeneena Group and the Waltha Woora Formation (Grey, in prep.). A correlation between the Yeneena Group and the Waltha Woora Formation has been suggested by Hickman (1983). The age of deposition of the Yeneena Group is probably between 1 132 ± 21 and 1 333 ± 24 m.y. (Chin and de Laeter, 1981).

Comparison of the Earaheedy Group assemblage with Australian assemblages from considerably younger (for example the Amadeus Basin, the Adelaide Geosyncline), or considerably older (for example the Hamersley Basin), Proterozoic rocks shows very little similarity. Thus, none of the Earaheedy forms have been found elsewhere in Australia, although *Pilbaria* and digitate forms are known from sequences which are slightly older. Results from Australia confirm the findings of Semikhatov (1980, p. 244) that Riphean stromatolites of the USSR show "the unrepeated and undirectional character of their successions."

INTERCONTINENTAL COMPARISONS

As the taxonomic status of the various forms becomes clearer, the possibility of intercontinental correlation becomes more feasible. In recent publications (Bertrand-Sarfati and Eriksson, 1977; Makarikhin, 1978; Krylov and Perttunen, 1978; Dolnik, 1978 and Semikhatov, 1978a, 1978b; Bertrand-Sarfati and Walter, 1981) several authors have recognized the need for new taxa for early Proterozic stromatolite groups. Study of material from the Earaheedy Group reinforces this necessity.

Six of the stromatolites recognized in the Earaheedy Group, *Carnegia wongawolensis*, *Earaheedia kuleliensis*, *Murgurra nabberuensis*, *Nabberubia toolooensis*, *Yandilla meekatharrensis* and *Yelma digitata* are sufficiently distinctive to be

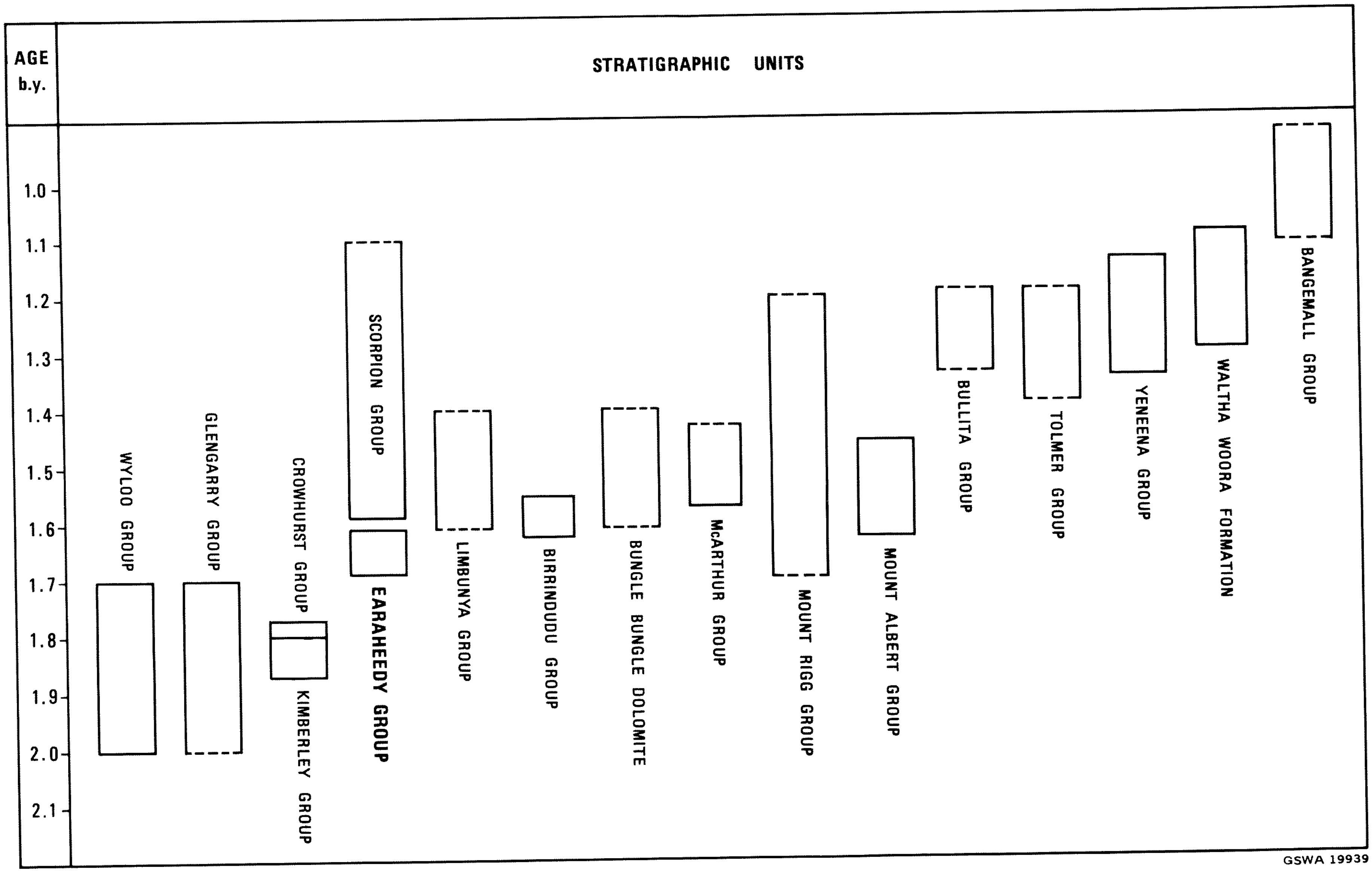


Figure 6. Distribution of early and middle Proterozoic stromatolite-bearing units in Australia. Time constraints are based on the most recently available geochronological and stratigraphic data available.

assigned to new groups and forms. *Tarioufetia yilgarnia* was placed in the late Proterozoic group *Tarioufetia* by Preiss (1976a) because of its distinctive tussocky microstructure; examination of the type form of *Tarioufetia* indicates that there are differences in the arrangement of the tussocks and *yilgarnia* is here transferred to the early Proterozoic *Externia* Semikhatov 1978. Preiss (1976a) also described forms of *Minjaria* and *Tungussia*, groups which are usually restricted to later Proterozoic rocks; these forms are here placed in the new group *Windidda*. The specimen which Preiss (1976a) assigned to the late Proterozoic *Kulparia* (cf. ?*Kulparia* form indet.) was described from a single sample and Preiss was in some doubt (p. 17) about its taxonomic position. Lack of additional material does not allow this identification to be confirmed. Only one of the groups now recognized in the Earaheedy Group, is also present in much younger (late Proterozoic) rocks, and this is *Omachtenia*.

The problem of the anomalous occurrence of late Proterozoic groups in early Proterozoic rocks is thus gradually being solved as taxonomy is refined (Semikhatov, 1978b; Bertrand-Sarfati and Walter 1981).Walter (1972, p. 25) stated that "... it is useful and realistic to have numerous narrowly defined groups" and it is probably significant that groups which recur at several time-horizons in the geological record are those which are broadly based. In many existing groups, the diagnosis is too vague and broad ranging to prevent the inclusion of numerous and often very diverse forms. The recognition of possible evolutionary trends becomes more likely when narrowly defined groups, each containing a small number of forms, are used.

The distribution of selected groups and forms which occur in the Earaheedy Group and in stratigraphic units of similar age in Australia and overseas is shown in Figure 7. *Pilbaria* is represented by several forms in rocks of slightly different ages in Australia, South Africa and Canada. The precise relationships of the digitate stromatolites *Asperia*, *Katernia* and *Yelma* require further investigation, but the evidence at present suggests that subtle variations occur in this type of stromatolite in rocks of slightly different ages. *Externia* occurs both in Canada and in Morocco as well as in Australia, in sequences with approximately the same time distributions. *Ephyaltes* is represented by two forms in the southern Urals of the USSR, and is probably also present in Canada; both sequences are approximately the same age as the Earaheedy Group. Identification of the Earaheedy specimens to form level is necessary to determine the possibilities of correlation.

In this work except in cases where the evidence is convincing and based on the comparison of actual specimens, new groups have been created in preference to placing forms in existing groups, in the hope that this will avoid some of the problems which have been encountered with previously suggested biostratigraphic proposals. The possibilities for intercontinental correlation are emphasized when such a cautious approach is adopted, and a consistent pattern of distribution of groups and forms with time can still be recognized (Figs. 7 and 8). Although comparative studies are at an early stage, there is some suggestion that there is a correlation between the Wyloo Group and the Rocknest Formation and between the Earaheedy Group, the Et-then Group, the Satkin Suite and the Sibley Formation (Fig. 8).

ASSEMBLAGE DIVERSITY

An interesting feature of the Earaheedy Group assemblage is its great diversity (Grey, 1982). Awramik (1971), Bertrand-Sarfati (1972b) and Monty (1974) recognized a general increase in diversity of columnar stromatolites from early Proterozoic to Vendian times, followed by a marked decrease in diversity. In Australia the relationship between numbers of forms and their temporal distribution is apparently more complex (Grey, 1982), with high diversity (at least 12 forms) in the 1.7 b.y. Earaheedy Group, low diversity (5 forms) in the 1.1 b.y. Bangemall Group, followed by high diversity in the late Proterozoic sequences of the Adelaide Geosyncline (Preiss, 1972b, 1973, 1974) and Amadeus Basin (Walter, 1972). The lack of stromatolite studies in many Australian successions, and the problem of compiling data for other continents, has made it difficult to determine whether this apparent decrease in diversity can be recognized elsewhere.

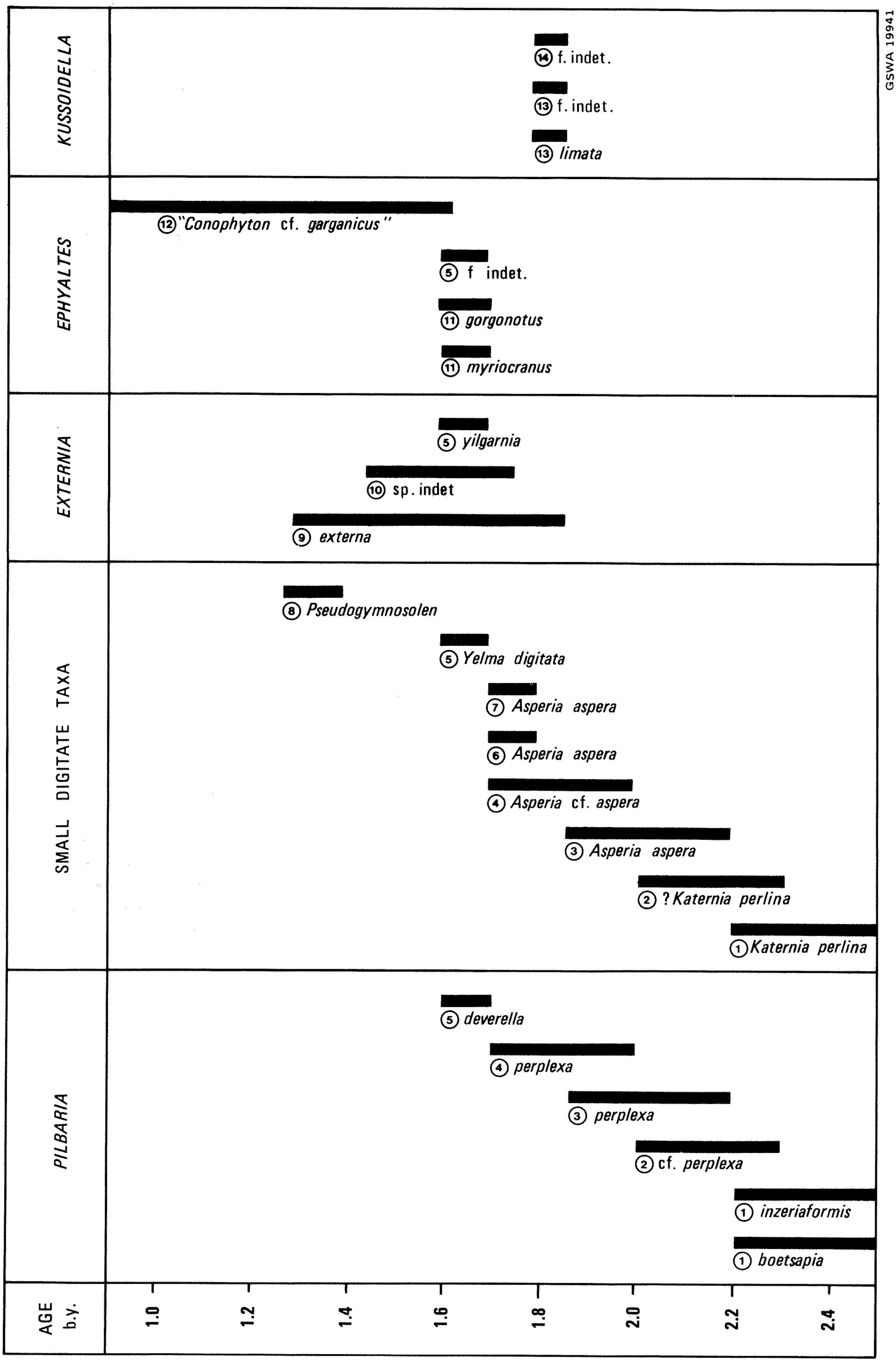
CONCLUSIONS

A diverse stromatolite assemblage is present in the 1.7 b.y. old Earaheedy Group in Western Australia. The samples collected, with the exception of a few groups or poorly preserved material, belong to new groups and forms. Within the basin a stratigraphic sequence can be recognized and should prove a useful lithostratigraphic tool. Documented occurrences from stratigraphic horizons elsewhere in Australia indicate that none of the Earaheedy forms are present. However, none of the other stromatolite-bearing sequences are thought to be coeval with the Earaheedy Group. The evidence at present suggests that the Earaheedy assemblage is restricted to a relatively narrow time-range. It has been necessary to erect new groups in describing material from the Nabberu Basin, and this parallels the experience of authors working on Aphebian material from Canada, northern Europe and South Africa. In view of the problems which have been associated with intercontinental correlations previously, correlation

	WYLOO GROUP	GLENGARRY GROUP	KIMBERLEY GROUP	CROWHURST GROUP	EARAHEEDY GROUP	SCORPION GROUP	LIMBUNYA GROUP	BIRRINDUDU GROUP	BUNGLE BUNGLE DOLOMITE	McARTHUR GROUP	MOUNT RIGG GROUP	MOUNT ALBERT GROUP	BULLITA GROUP	TOLMER GROUP	YENEENA GROUP	WALTHA WOORA GROUP	BANGEMALL GROUP
unnamed form A																	■
Acaciella cf. *australica*																	■
Baicalia capricornia																	■
Conophyton garganicum australe																	■
unnamed form B															■	■	
"*Inzeria tjomusi*"?=unnamed form B														■			
"*Inzeria tjomusi*"														■			
unnamed forms C													■				
Eucapsiphora paradisa												■					
"*Inzeria* cf. *tjomusi*"											■						
Conophyton form indet A											■						
unnamed forms D										■							
Conophyton garganicum garganicum										■							
"*Collenia frequens*"									■								
Conophyton cylindricus									■								
Conophyton cf. *inclinatum*								■									
unnamed form E							■										
Conophyton f. indet B							■										
unnamed forms F						■											
Conophyton f. indet C						■											
Carnegia wongawolensis					■												
Earaheedia kuleliensis					■												
Ephyaltes f. indet					■												
Externia yilgarnia					■												
cf. ? *Kulparia*					■												
Murgurra nabberuensis					■												
Nabberubia toolooensis					■												
Omachtenia teagiana					■												
Pilbaria deverella					■												
Windidda granulosa					■												
Yandilla meekatharrensis					■												
Yelma digitata					■												
unnamed form G				■													
Kussoidella f. indet			■														
unnamed form H		■															
unnamed form I	■																
Asperia cf. *aspera*	■																
Patomia f. indet	■																
Pilbaria perplexa	■																

GSWA 19940

Figure 7. Distibution of stromatolite taxa in early and middle Proterozoic stratigraphic units in Australia. The time constraints are based on the most recently available geochronological and stratigraphic data available.


KUSSOIDELLA
⑭ f. indet.
⑬ f. indet.
⑬ limata
EPHYALTES
⑫ "Conophyton cf. garganicus"
⑤ f indet.
⑪ gorgonotus
⑪ myriocranus
EXTERNIA
⑤ yilgarnia
⑩ sp. indet
⑨ externa
SMALL DIGITATE TAXA
⑧ Pseudogymnosolen
⑤ Yelma digitata
⑦ Asperia aspera
⑥ Asperia aspera
④ Asperia cf. aspera
③ Asperia aspera
② ? Katernia perlina
① Katernia perlina
PILBARIA
⑤ deverella
④ perplexa
③ perplexa
② cf. perplexa
① inzeriaformis
① boetsapia
AGE b.y.
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
GSWA 19941

between Australian material and these other occurrences has only been attempted where actual specimens have been examined.

Examination of the Earaheedy and Bangemall assemblages suggests that stromatolite forms were numerous at approximately 1.7 b.y., but suffered a major decrease in diversity at about 1.1 b.y., before increasing in numbers again in the late Proterozoic and declining in the early Cambrian. The decline at 1.1 b.y. could reflect local environmental conditions, or could be the result of a significant evolutionary event such as the development of eukaryotes. More data are required from sequences of similar ages to determine the cause of the fluctuations in diversity.

The theoretical basis for stromatolite biostratigraphy is still not firmly established, but there is increasing evidence to suggest a strong empirical base. This study of the Earaheedy Group is a further step in the empirical approach, the ultimate aim of which is to test whether stromatolite biostratigraphy is possible. The evidence so far obtained from the Earaheedy Group, and elsewhere in Western Australia, points towards the suitability of stromatolites as biostratigraphic indicators.

SYSTEMATIC DESCRIPTIONS

Group CARNEGIA new group

TYPE FORM: *Carnegia wongawolensis* new form.

DERIVATION OF NAME: (noun, fem.) after Lake Carnegie, a few kilometres east of the type locality.

DIAGNOSIS: A stromatolite forming small nodules and consisting of closely spaced, widely divergent, sinuous branches, arising from cumulate structures which encrust clasts or topographical highs, and which terminate with a series of laminae completely encrusting the nodule. Columns have numerous peaks and bridges and are frequently coalescing. Laminae are irregular, gently to steeply convex, with wavy, lenticular profiles and a patchy development of a multilaminate wall.

CONTENT: *Carnegia wongawolensis* only.

REMARKS: The widely divergent pattern of branching with irregular tuberous columns is similar to that of *Tungussia* Semikhatov, but in the diagnosis of this group Semikhatov states that "only infrequently do laminae at the edge of a column bend down and cover short segments of its lateral surface", that "the lateral surfaces of the constructions have a few small peaks or are smooth; connecting bridges are rare" and that "laminae are gently convex" (translation in Walter and others, 1979, p. 299). In these features *Carnegia* differs from *Tungussia*, having a frequently developed, although patchy, multilaminate wall, very irregular column margins with numerous peaks and bridges and coalescing columns, and laminae which are frequently steeply convex. Additional criteria for the distinction of the two groups is provided by the terminal overgrowth of the fascicle which gives *Carnegia* a very distinctive appearance, particularly in plan view.

The group *Tesca* Walter (*in* Walter and others, 1979) has laminae with similar characteristics to those of *Carnegia*, and there are some similarities in the mode of occurrence and branching

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◄ Figure 8. Stratigraphic distribution of selected stromatolite groups and forms. The ranges shown indicate the time constraints on the stratigraphic units containing the stromatolites and do not indicate the actual ranges of the stromatolites themselves. The constraints are as follows:

(1) Schmidtsdrift Formation, northern Cape Province, South Africa, dated relative to younger lavas at greater than 2 224 ± 21 m.y. (D. Crampton, pers. comm., 1972, *in* Bertrand-Sarfati and Eriksson, 1977, p. 2).

(2) Koolpin Formation, Pine Creek Geosyncline, Northern Territory, Australia. Between 2 000 and 2 300 m.y. old (Crick and others, 1980).

(3) Rocknest Formation, Epworth Group, northwestern Canadian Shield. Age between 1 865 and 2 200 m.y. (Hoffman, 1976, p. 600). Stromatolites described by Semikhatov (1978a).

(4) Wyloo Group, Ashburton Trough, Western Australia. The Wyloo Group is younger than the Woongarra Volcanics (Trendall, 1979) which were dated by Arriens (1975) at about 2 000 m.y., and older than the Boolaloo Granodiorite, for which an age determination of 1 720 m.y. was obtained by Leggo and others (1965). Stromatolites described by Walter (1972).

(5) Earaheedy Group, Nabberu Basin, Western Australia. Hall and others (1977) and Bunting and others (1977) favoured an age of 1.6 to 1.7 b.y. based on regional considerations and available K-Ar and Rb-Sr isotopic dates. Stromatolites described by Preiss (1976a), and in this paper.

(6) Denault Formation, Kaniapiskau Supergroup, Labrador Trough, Canada. Dates of 1 800 m.y. to 2 060 m.y. occur in the Kaniapiskau Supergroup (Dimroth, 1970). Stromatolites recorded by Donaldson (1963).

(7) McLeary Formation, Belcher Supergroup, Hudson Bay, Canada, Hofmann (1977). The McLeary Formation is older than 1.8 b.y. and younger than 2.5 b.y. (Hofmann, 1976b).

(8) Basal part of the Wumishan Formation, Jixian System, North China, slightly younger than 1 400 m.y. (T.I.G.M.R. and others, 1979; Zhu and others, 1978).

(9) Et-then Group, northwestern Canadian Shield. Hoffman (1976, p. 600) suggests an age of between 1 300 and 1 865 m.y. for the Murky Formation, which is one of the units in the Et-then Group. The stromatolites were described by Semikhatov (1978a).

(10) Precambrian II^2 in "supra-quartzitic limestones and supra-andesites of Tirsal (Taliwine region) Antiatlasides orogenic belt, Morocco. The age is not clear and is partly based on biostratigraphic evidence but is older than 1 440-1 460 m.y. and younger than 1 950-2 000 m.y. (Choubert and Faure-Muret, 1980). The stromatolites are described by Raaben (1980).

(11) Satkin Suite, Southern Urals, USSR. Age between 1.6 and 1.7 to 1.9 b.y. (Semikhatov, 1976, Fig. 1). Stromatolites described by Vlasov (1977).

(12) Sibley Group, Ontario, Canada. The Sibley Group is poorly dated, but is older than 900 to 1100 m.y. and younger than 1650 to 1800 m.y. (Stockwell and others, 1970, p.119). Stromatolites described by Hofmann (1969b) and identified by Vlasov (1977).

(13) Taltheilei Formation, Pethei Group, Great Slave Supergroup, northwestern Canadian Shield. Hoffman (1976, p.600) suggests an age of between 1795 and 1865 m.y. The stromatolites were described by Semikhatov (1978a).

(14) Elgee Siltstone, Kimberley Group, Kimberley Basin, Western Australia. Older than 1800 + 25 m.y. (Compston and Arriens, 1968). Stromatolites described by Cloud and Semikhatov (1969) and Semikhatov (1978a).

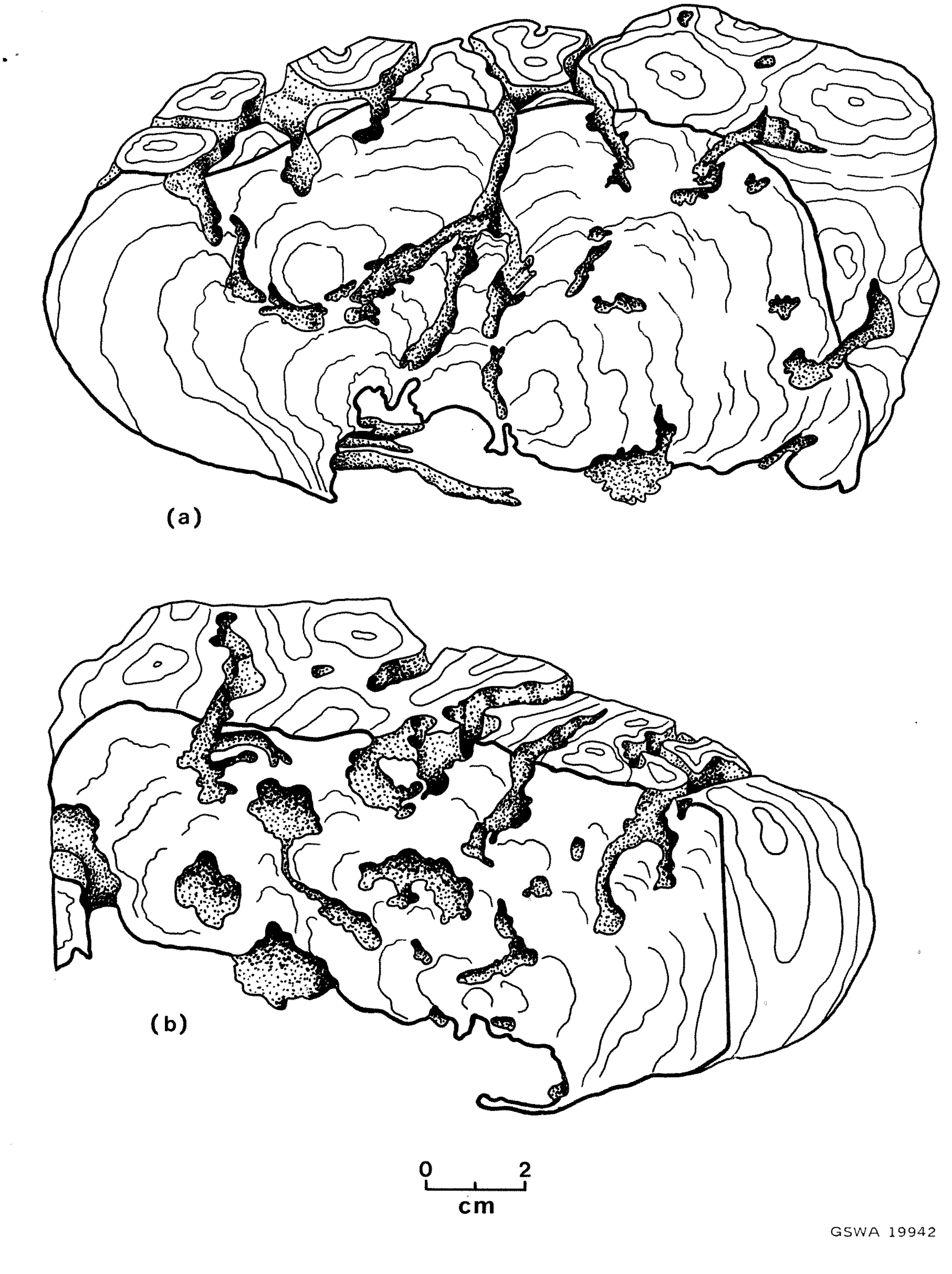


Figure 9. ***Carnegia wongawolensis*****, Windidda Formation. F12347 Holotype (b) is a reverse view of (a). Note the partial enveloping of the laminae at the side of the specimen.**

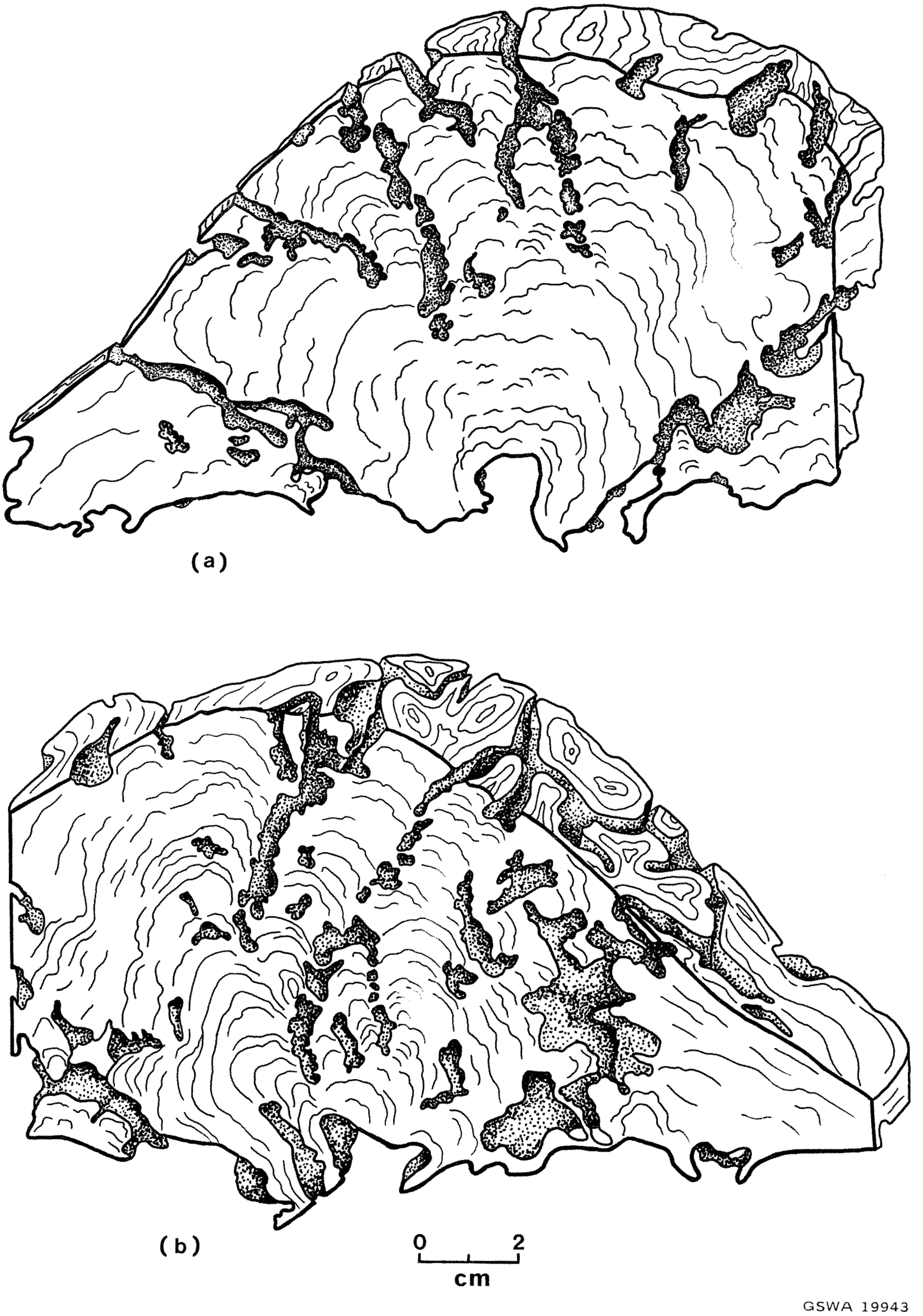


Figure 10. ***Carnegia wongawolensis*****, Windidda Formation. F12337, serial reconstruction. (b) is a reverse view of (a). Views show column development and numerous bridges.**

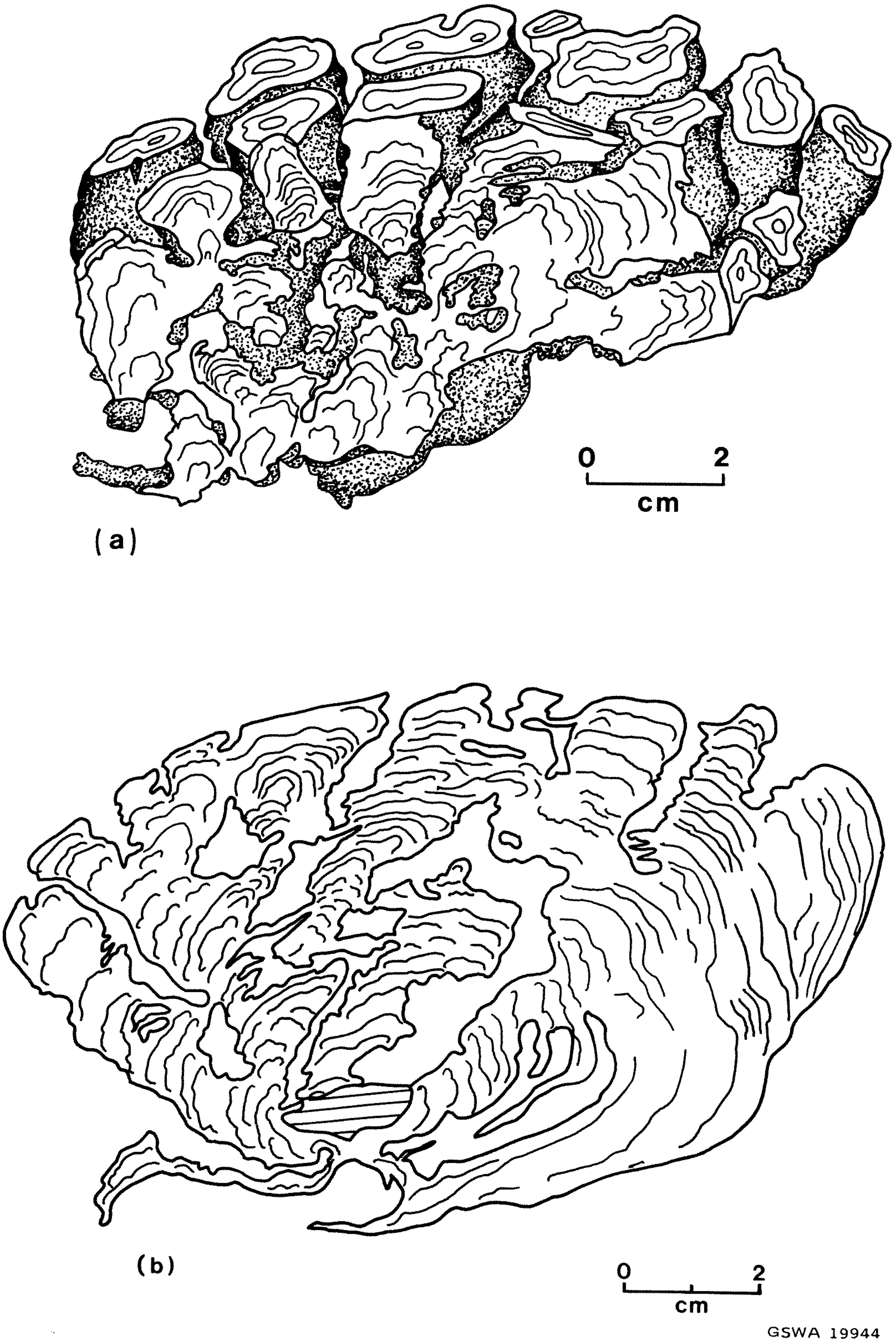


Figure 11. ***Carnegia wongawolensis,*** **Windidda Formation. F12348, (a) serial reconstruction showing column development. (b) Lamina profiles from a polished face in another part of the same sample.**

patterns, but *Carnegia* has more complex bushy branching with bridging, anastomosing and terminal overgrowth and has no cornices. The multilaminate wall of *Tesca* is more persistent than that of *Carnegia*.

DISTRIBUTION AND AGE: Windidda Formation Earaheedy Group, Nabberu Basin, Western Australia. Age approximately 1.7 b.y. old.

Carnegia wongawolensis new form

(Plates 2-6; Figs 9-11)

MATERIAL

Holotype—F12347 from KGS4.

Paratypes—F12348 from the type locality; F12334, F12335, F12336 and F12337 from KGS1; F12338, F12339, F12340, F12341, F12342, F12343, F12344, F12345 from KGS2; F12346 from KGS3, F12349, F12350 from KGS5; and F12351 and F12352 from KGS6.

DERIVATION OF NAME

Wongawolensis is derived from the name of the type locality, Wongawol Creek.

DIAGNOSIS

As for the group.

DESCRIPTION

OUTCROP: *Carnegia wongawolensis* is the commonest form in a 10 m thick, pinkish-grey limestone approximately 520 m below the top of the Windidda Formation. This unit is exposed along a fence line, 4.5 km southeast of Windidda homestead, and also in the vicinity of Wongawol Creek. The unit is composed of pinkish-grey limestone, interbedded with grey-green or maroon micaceous-mudstone, which may be massive or thinly laminated with weak shaley fissility. Individual limestone beds vary in thickness from 20 to 300 mm, and may be either lensoid, or continuous for several hundred metres. At the Wongawol Creek localities the bedrock is poorly exposed and the stromatolites occur as weathered-out nodules in the creek bed (Pl. 2B). At the locality southeast of Windidda homestead, the overlying mudstone horizons have been eroded to expose successive limestone bedding planes, which are studded with nodular fascicles which have a relief of several centimetres above the surface of the bedding plane (Pl. 2A).

More massive ferruginous-limestone nodules of *Carnegia wongawolensis* occur with interbedded cherts in a gorge near Tooloo Bluff.

MODE OF OCCURRENCE: Fascicles have a fairly regular spacing of between 5 and 10 cm. The terminal encrusting laminae in some cases overlap several adjacent fascicles to form larger structures from 50 to 100 cm in diameter.

FASCICLE MORPHOLOGY: Fascicles are small hemispherical nodules with a bushy, tungussiform, branching habit. They develop by encrustation on small topographic highs, or around disk-shaped clasts. The fascicle is usually a compact structure, with complex, closely spaced branches which develop from a few millimetres of encrusting laminae. The upper part of the fascicle is not always present because of weathering, but in most cases the whole structure is enveloped by a layer of stratiform or domed laminae. Fascicles usually have a maximum height of 15 to 20 cm and are 20 to 30 cm in diameter. In some cases the upper part of the fascicle protrudes up to 60 mm into the overlying shale horizon.

BRANCHING HABIT: Column branching is of the lateral-bifurcating type and is moderately frequent. Near the base the laminae are domed and unbranched, encrusting around non-biogenic material, but they rapidly develop widely-divergent branches with random orientation. Branching is moderately frequent and some branches may coalesce within a few millimetres of branching. The basal parts of branches are usually vertical near the centre of the fascicle, becoming steeply inclined to horizontal at fascicle margins. Such branches eventually curve upwards and become vertical and subparallel. In the final stage, the fascicle is completely encrusted by continuous laminae several millimetres thick. The microstructure of the terminal laminae is the same as that in the columns and the enveloping by these laminae seems to be an integral part of fascicle development.

COLUMN SHAPE AND MARGIN STRUCTURE: Columns are irregular, subcylindrical and tuberous with bumpy margins. Transverse sections are rounded-polygonol to lobate. Bumps are up to 5 mm high and approximately 5 mm in diameter. There are numerous small peaks and thin bridges. In the central part of the fascicle branches may be from 3 to 4 cm in width, and the outer branches are between 1 and 2 cm in width.

LAMINA SHAPE: The lamina profile varies from gently to steeply convex and many laminae are irregularly curved, multicrested and wavy. Laminae forming the terminal overgrowth have a similar wavy structure to those forming the column. The light laminae are frequently lensoid; the dark laminae are more regular in thickness and are more continuous across the column. Flexures have a wave length of 4 to 10 mm and a wave height of 1 to 3 mm. Most laminae curve downwards near the lateral margins, and some may be subparallel to the margins for at least 10 mm, although many are present for much shorter distances. Such laminae taper gradually and form a patchy wall, which may become a more persistent multilaminate wall for short stretches of column where several laminae become closely spaced and parallel to each other. Such walls rarely reach a thickness of 1 mm and are usually between 0.25 and 0.5 mm thick. Other laminae cluster together to form small peaks, or terminate abruptly. In such areas a wall is lacking.

MICROSTRUCTURE AND TEXTURE: The laminae occur in light and dark pairs in which the light laminae are thick and lensoid and the dark laminae are thin and tabular, producing a filmy microstructure. Light laminae sometimes lens out completely. They usually range in thickness from 10 to 200 μm, but exceptionally thick lenses may be 600 μm or more. At the column margins the light laminae forming the walls are very thin. Dark laminae contain a dark-brown to black pigment, are from 10 to 70 μm thick and have well defined boundaries. Many are wispy in appearance, but some continue across the full width of the column.

Both light and dark laminae consist of fine-grained hypidiotopic carbonate with a grain size of 5 to 25 μm. In patches there are some perpendicular disruptions to the laminae which may be former filament moulds, but preservation of these areas is poor.

INTERSPACE FILLING: Interspaces between columns are usually very narrow, and contain a mixture of clasts and small peloids. The grain size of the matrix is slightly coarser than that of the columns and patches of opaque mineral (magnetite) up to 3 cm in diameter are also present.

SECONDARY ALTERATION: Very little secondary alteration has occurred and the stromatolites are preserved in calcitic mudstone and siltstone which has undergone very little recrystallization.

COMPARISONS

Carnegia wongawolensis is distinguished from other Nabberu stromatolites by its tungussiform branching and enveloping laminae. The closest resemblance is to *Windidda granulosa* which has tungussiform branching near the base, but which is distinguished from *C. wongawolensis* by the very straight upper parts of the columns with a smooth, thick, multilaminate wall and a more granular microstructure in which the dark laminae are less distinct and not as continous as they are in *C. wongawolensis*.

DISTRIBUTION

Windidda Formation at Wongawol Creek, in the gorge north of Tooloo Bluff and southeast of Windidda homestead.

Group EARAHEEDIA new group

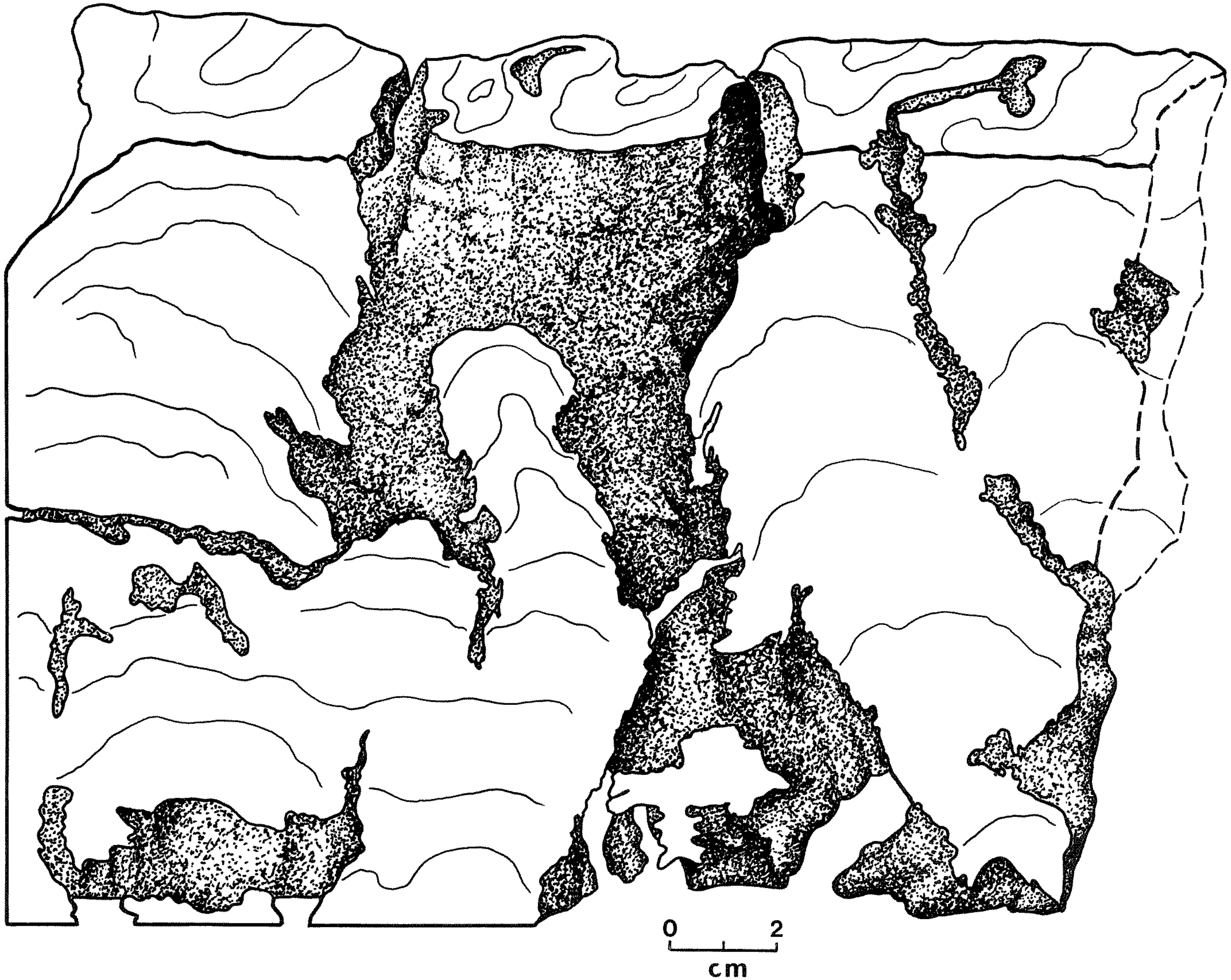
TYPE FORM: *Earaheedia kuleliensis* new form.

DERIVATION OF NAME: (noun, fem.) after the Earaheedy Group in which the form occurs.

DIAGNOSIS: A large, domed stromatolite formed by broad columns with flat to gently convex laminae which are distinctly banded and wavy, and with a multilaminate wall. Columns are cylindrical, or widen or taper upwards, usually from a stratiform base, although some columns develop from convex laminae draped around clasts.

CONTENT: *Earaheedia kuleliensis* only.

REMARKS: This group differs from *Omachtenia* Nuzhnov because it has a multilaminate wall and lacks cornices. Although some bridging and coalescing of columns occurs, this is not as frequent as in *Omachtenia*. The wavy-banded laminae also differ from the broad, smooth laminae, usually found in *Omachtenia*. *Earaheedia* resembles *Schancharia* Korolyuk in having flat laminae with sharply downturned edges in the lower parts of columns, and in the cyclic banding of the laminae. It differs from *Schancharia* in having a multilaminate wall, rather than a wall formed by a single lamina; in the increasing convexity of the laminae in the upper parts of the columns; and in the presence of wavy laminae.



GSWA 19945

Figure 12. ***Earaheedia kuleliensis*, Windidda Formation. F12354, Holotype. Serial reconstruction.**

DISTRIBUTION AND AGE: Kulele Limestone, Earaheedy Group, Nabberu Basin, Western Australia. Age Approximately 1.7 b.y. old.

Earaheedia kuleliensis new form

(Plates 7 to 9; Fig. 12)

MATERIAL

Holotype—F12354 from SNL1.

Paratypes—F12353, F12355, F12356, F12357 all from SNL1.

DERIVATION OF NAME

Kuleliensis is derived from nearby Kulele Creek, and is also the name of the formation in which the stromatolite occurs.

DIAGNOSIS

As for the group.

DESCRIPTION

OUTCROP: The samples were collected from several points at an extensive stromatolitic outcrop described by Bunting (in prep.). The stromatolites occur in pink, thickly bedded, laminated limestones which form part of a crudely cyclic sequence. The stromatolites range from small flat domes a few centimetres across, to large bioherms over 30 m in length (Pl. 1C and D). Bunting (in prep.) discusses the significance of the elongation and asymmetry of the stromatolites. Columns are developed in some of the smaller domes, and the name *Earaheedia kuleliensis* is restricted to those stromatolites showing columnar development. Systematic description of the large domes has not been attempted because of the problem of obtaining representative samples. It should be noted, however, that the microstructure and lamination is very similar in both the columns and large, domed forms.

MODE OF OCCURRENCE: The outcrop consists of successive biostromes, composed of numberous tabular bioherms. Some of the bioherms are formed by columnar fascicles, particularly in the lowest stromatolite horizon recognized by Bunting (in prep.).

FASCICLE MORPHOLOGY: Fascicles arise from stratiform bases and may consist of a single column, or a cluster of uniform, erect columns arising by multifurcate branching. Fascicle bases are often contiguous, or columns may develop from encrustation of clasts. Fascicles are usually up to 15 cm in diameter and over 20 cm in height.

BRANCHING HABIT: Branching is infrequent and usually of multifurcate type, with several columns arising from a single base. Rare dichotomous branching may occur. Columns are usually parallel or slightly inclined, and have rounded terminations.

COLUMN SHAPE AND MARGIN STRUCTURE: Columns are usually cylindrical, although the smaller columns may taper, and large single columns may increase in width. In plan they are circular to slightly elongate. The columns are usually short and erect and may reach over 20 cm in height. Where a fascicle is formed by a single column, the column width may be 15 cm or more. Columns forming multifurcate fascicles are much narrower, with diameters of 3 to 4 cm.

The column margins are not always well defined, and in several columns have been eroded, or affected by stylolitization. In many columns a wall area approximately 1 cm wide can be distinguished. Laminae can be recognized in this wall area, but they are not as clearly differentiated into light and dark laminae as they are in the centre of the column. The regular waviness recognizable in the column centre becomes erratic towards the column margins and the laminae taper towards the lateral margins. Several laminae may overlap to form a thick wall often reaching 10 mm in thickness or, more rarely, several tapered laminae may form small bumps, or short, wispy peaks. Bridging-over of the columns to form pseudocolumnar or stratiform bands occurs near the top of some columns.

LAMINA SHAPE: Laminae range from flatly to gently convex, with the greatest convexity occurring in the upper parts of narrower columns. The laminae remain flat or gently curved except near the column margins where they are sharply deflexed. Laminae in narrow columns may become double crested.

Laminae are regularly wavy with wave lengths of approximately 5 mm. Wave height is somewhat variable, usually about 1 mm, and waves may be in phase throughout several laminae. A series of larger undulations are probably the result of soft-sediment deformation (see secondary alteration). Boundaries of laminae are irregular and lamina thickness is usually quite variable, and convex laminae in narrow branches sometimes become lensoid.

MICROSTRUCTURE AND TEXTURE: The microstructure is irregularly banded with lateral variations in lamina thickness. Most laminae persist for the full width of the column. Laminae are broad and boundaries are well defined. Light and dark laminae can be recognized, ranging in thickness from 0.5 to 3.0 mm. These macrolaminae are composed of finer microlaminae, of variable thickness. Both light and dark microlaminae may range from 100 to 500 μm in thickness and show variations along their length. Boundaries between light and dark laminae are frequently diffuse. Both light and dark microlaminae are composed of xenotopic carbonate with a grain size of 3-5 μm. Rare ooliths occur between the laminae. Many laminae are interrupted by brown-pigmented iron-rich structures arranged vertically to the laminae and which show some branching in rare instances (Pl. 9D). Preservation of these structures is poor and their origin cannot be determined. They may be dewatering channels which have formed in tubes left by filament moulds. One well-preserved specimen branches and is 4 mm in length.

INTERSPACE FILLING: The interspaces between many columns are filled with fine micritic mudstone containing large intraclasts. Elongate clasts may reach 5 cm in length. Rare laminae occur in the interspaces. Erosion of the interstitial filling has occurred in many areas and the interspaces are now filled with large ooliths.

SECONDARY ALTERATION: Both columns and interspace fillings are composed of pink calcite, and show a complex history of soft-sediment deformation. Large undulations are developed in the laminae in the lateral parts of many columns and on weathered surfaces they form a series of parallel ridges. These structures are probably the result of soft-sediment slumping. This interpretation indicates that even very large domes (sometimes several metres in length) remained unlithified during the growth of the stromatolites. Some stylolitization has occurred at column margins and parallel to the laminae.

COMPARISONS

In gross morphology there is some resemblance to *Omachtenia kvartsimaa* Krylov and Perttunen but the wavy banded laminations of *Earaheedia kuleliensis* are quite distinctive. An undescribed stromatolite from the Trezona Formation in the Flinders Ranges of South Australia has similar marginal slumping (W. V. Preiss, pers. comm., 1980) but the microstructure does not have the distinctive wavy banding of *E. kuleliensis*.

DISTRIBUTION

Kulele Limestone near Thurraguddy Bore.

Group EPHYALTES Vlasov, 1977

1969: *Conophyton* Hofmann (Not *Conophyton* Maslov 1937)

TYPE FORM: *Ephyaltes myriocranus* Vlasov 1977, from the Satkin Suite, western slope of the Southern Urals.

DIAGNOSIS: "Colonies in the course of the entire ontogenesis are multimembered [polymemnaya], successively or alternatively multimembered or monomembered, or monomembered only, whereupon monomembered colonies form associations and, like polymembered colonies, form biostromes. Basic element of relief—cone (with diameter basically from 5 to 50 cm) which may be complicated by crests; concaves are not obligatory.

Besides polystigma, axial polygrams are often encountered; grains and stigmata of various orders may be [present] in large quantity on the surface of the relief; ornamentation of the lowest order is often observed with distance between elements of 0.1-0.5 mm." (Translated from Vlasov, 1977, p. 114).

From Vlasov's description and illustrations, *Ephylates* consists of a series of successive sheets, or of single layers of laterally-linked, or sometimes unliked, cones with a basal diameter of 5 to 50 cm. The cones have axial crests, radial ridges and small spines of varying size.

CONTENT: *Ephyaltes myriocranus* Vlasov 1977 and *Ephyaltes gorgonotus* Vlasov 1977. Vlasov (p. 115) also considered Hofmann's specimens (Hofmann, 1969b, Pl. 16-22) of *Conophyton* cf. *garganicum* from the Canadian Sibley Formation to be *Ephyaltes*.

REMARKS: Vlasov (1977) erected several groups for a series of laterally linked stromatolitic structures which he placed in the Family Thyssagetaceae. One of the more important features of these groups is the presence of a 'concave element' or lateral linkage, and it is this feature which distinguishes *Ephyaltes* and similar groups from *Conophyton* Maslov (1937). In other respects, such as the presence of an axial zone, *Ephyaltes* resembles *Conophyton.*

DISTRIBUTION AND AGE: *Ephyaltes myriocranus* and *Ephyaltes gorgonotus* occur in the Satkin Suite of the Southern Urals and are Lower Riphean in age.

The specimens of *Conophyton* and *Conophyton* cf. *garganicus* described by Hofmann (1969b) occur in the Sibley Group (north west of Lake Superior), which is Helikian and older than 900 to 1100 m.y. and younger than 1650 to 1800 m.y. (Stockwell and others, 1970, p. 119).

Ephyaltes form indet.

(Plates 10 and 11)

MATERIAL

A single specimen and a few fragments, F12359, from PKH4.

REMARKS

The material available at present is inadequate for systematic studies. The single sample contains several cones with a minimum height of 20 cm and a maximum observed diameter of at least 16 cm. The cones have a well-developed crestal zone and a crestal angle of 35° to 40°.

DISTRIBUTION

Yelma Formation near Edgingunna Well.

Group EXTERNIA Semikhatov 1978

TYPE FORM: *Externia externa* Semikhatov 1978 from the Et-then Group, Canada.

DIAGNOSIS: "The structure consists of more or less subcylindrical columns of varying diameter, without covering, passively branching, partially coalescing, often united by extended, rather thick bundles of joined laminae and transitional bridges. Because of partial branching and interlocking of the columns in the structure, rather numerous slit-like cavities arise in the structure. Curvature [of the laminae] from depressed to strongly convex; inheritance of laminations is high." (Translated from Semikhatov, 1978, p. 122.)

The diagnosis is here emended to include the presence of a tussocky microstructure, with low, elongate tussocks fairly regularly spaced and aligned along laminae. Tussocks in successive laminae may overlie each other and form small poorly defined microcolumns. Thick walls may be present in the upper parts of columns.

CONTENT: *Externia externa* Semikhatov 1978, *Externia* sp. indet. Raaben 1980, and *Externia yilgarnia* (Preiss 1976).

REMARKS: *Externia* was erected by Semikhatov (1978a) for a stromatolite showing partial branching of the columns and with numerous bridges and slit-like cavities in the structure. He also described a stratiform stromatolite, *Stratifera tenica*, which has a microstructure 'extremely close' to that of *Externia externa*, and stated that both forms sometimes comprise single bioherms. From Semikhatov's description it would seem that these two forms differ principally in their gross morphology and that *Stratifera tenica* develops upwards into *Externia externa*, constituting the basal and middle part of a single fascicle. The upper part of the fascicle has not been described.

If this interpretation is correct, then the fascicle as envisaged in this paper should be named *Externia externa* with *Stratifera tenica* becoming a junior synonym. This step is not taken here pending re-examination of the types.

Although Semikhatov commented on the nature of the microstructure, he did not use it as a diagnostic characteristic, nor did he discuss its similarity to the tussocky microstructure of *Tarioufetia* Bertrand-Sarfati 1972. The diagnosis of *Externia* is here emended by including details of the microstructure to place it on a comparative basis with *Tarioufetia*. Bertrand-Sarfati (1972a, 1972b and 1976) considered the presence of a tussocky microstructure in *Tarioufetia* to be of diagnostic significance at group level and Preiss (1976a) assigned his species *yilgarnia* to *Tarioufetia* principally because of the presence of tussocky microstructure.

This type of microstructure has now been described in several taxa (Bertrand-Sarfati, 1976, p. 253): *Tungussia globulosa* Bertrand-Sarfati 1970, *Serizia radians* Bertrand-Sarfati 1970, *Alternella hyperboreica* Raaben (*in* Raaben and Zabrodin, 1972), *Tarioufetia hemispherica* Bertrand-Sarfati 1972. *T. yilgarnia* Preiss 1976, *Externia externa* Semikhatov 1978 and *Stratifera tenica* Semikhatov 1978. Several types of tussocky microstructure have been recognized (Bertrand-Sarfati, 1976). The features which seem to be of significance in distinguishing the different kinds of tussocky microstructure comprise the shapes of the individual tussocks, the nature of any overgrowths, and the arrangement of the tussocks relative to the laminae.

In *Tungussia globulosa* the tussocks are randomly oriented, form high domes with a constant radius, are overgrown by a sparite cement, and have a very distinctive hemispherical appearance. The tussocks in *Serizia* (Bertrand-Sarfati, 1972b, Fig. 62) have variable dimensions and are embedded in carbonate cement and detrital quartz.

The size distribution of the tussocks in *Tarioufetia hemispherica* is also quite variable (Bertrand-Sarfati, 1972b, Fig. 62), but in this case the tussocks are overgrown by a dark film. In *Externia* (Fig. 13a and b) the tussocks are also overgrown by a dark film, but the arrangement of the tussocks is different from that in *Tarioufetia.* In *Tarioufetia* (Fig. 13c) the tussocks show a fairly random orientation. Several tussocks may be aligned for short distances along laminae but the alignment rarely persists across the width of the column. Tussocks in successive laminae may develop in the troughs of the underlying laminae, may overlie a preceding tussock or may develop on the sides of the preceding tussock. By contrast the tussocks in *Externia* are usually aligned across the whole width of the column, and individual tussocks in successive laminae overlie the crests of preceding tussocks, sometimes giving rise to microcolumns. In addition, the shapes of the tussocks also vary, as indicated by calculating the ratio of the height of the tussocks to their length (Fig. 14). For *Tarioufetia* the ratio varies from 1.20 to 6.73 with a mean of 2.85 (50 measurements), while for *Externia* the ratio ranges from 0.77 to 3.88 with a mean of 1.90 (25 measurements). Student's t-test indicates that the difference between the two means is highly significant ($t = 3.11$, 73 degrees of freedom, $0.1 \geq p > 0.001$).

A comparison of gross morphology suggests that *Tarioufetia* has abundant branches at an early stage of development and that the branches show wider spacing than in *Externia.* The column margins appear more irregular in *Tarioufetia* than in *Externia.* A wall develops in the upper parts of *Tarioufetia.* No wall is known for *Externia externa*, but the upper parts of the columns have not been described. A wall is present in the upper parts of the columns of the form described as *Tarioufetia yilgarnia* by Preiss, 1976a. This form is here transferred to *Externia* for the reasons discussed below.

DISTRIBUTION AND AGE: *Externia externa* Semikhatov 1978 occurs in the Et-then Group, Athapuscow Aulacogen, Canada, between 1300 and 1865 m.y. (Hoffman, 1976). *Externia* sp. indet. Raaben 1980 occurs in the Precambrian II^2 (Antiatlasides), Tirsal, Morocco, Early Riphean (Choubert and Faure-Muret, 1980) *Externia yilgarnia* (Preiss) occurs in the Yelma Formation, Earaheedy Group, Naberu Basin, Western Australia, approximately 1.7 b.y. old.

Externia yilgarnia (Preiss 1976)

(Plates 12 and 13; Figs. 13 and 14)

1976a *Tarioufetia yilgarnia* Preiss p. 18, Figs. 7, 9, 10, 16a-e, 18 (part), 31-33, 50-52.

MATERIAL

Holotype—CPC 16532 (field no. S.10) from DKN1, collected from NE Duketon by M. J. Jackson, Bureau of Mineral Resources (Preiss, 1976a).

Paratypes—CPC 16529 (field no. S.7), CPC 16531 (field no. S.9) from the type locality, collected by M. J. Jackson.

Other material—F12360, F12361 and F12399 from the type locality; collected by J. Bunting. As far as can be determined these samples are from the same locality as those collected by Jackson (J. Bunting, pers. comm., 1979).

REMARKS

F12360, F12361 and F12399 are samples from the vicinity of the type locality (Bunting, pers. comm., 1979). F12361 and F12399 consist of the lower parts of several columns and are very similar to the material described by Preiss (1976a). F12360 consists of numerous parallel columns with a fairly uniform diameter of 2.5 to 3 cm. The columns possess a multilaminate wall, up to 3 cm thick, which is absent or only patchily present in Preiss' specimens. However, because the new material resembles the holotype in all other respects it is placed in *yilgarnia*, the diagnosis of which is here emended to include a multilaminate wall in the upper part of the columns.

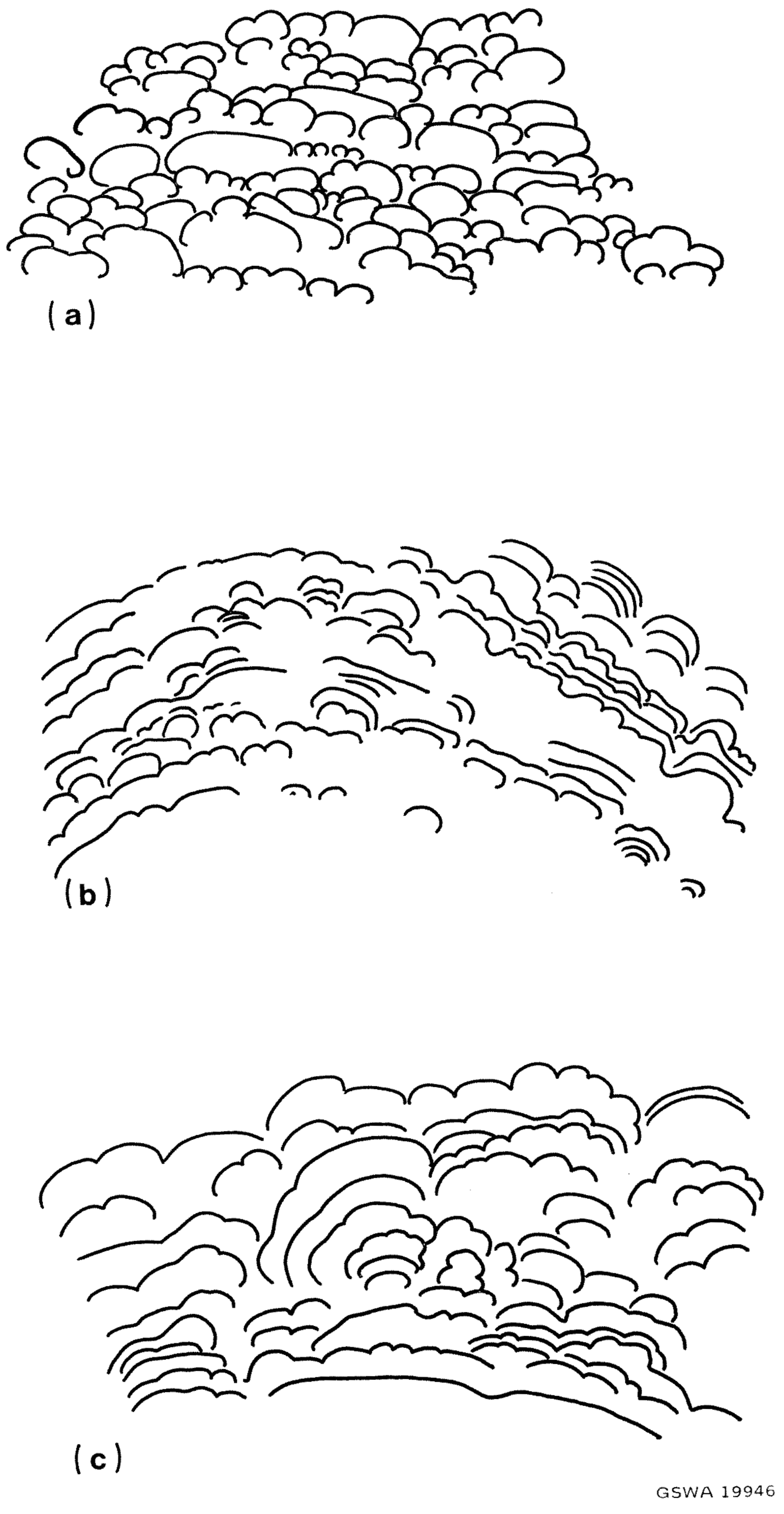


Figure 13. Comparative profiles of tussocky microstructure in (a) *Tarioufetia hemispherica* (traced from a photograph supplied by J. Bertrand-Sarfati) , (b) *Externia externa* (traced from Semikhatov, 1979, Pl. XIV, Fig. 3) and (c) *Externia yilgarnia* from the Yelma Formation (traced from a photograph of sample no. CPC 16531). Figures are not drawn to scale. Tussocks are between 1 and 2 mm.

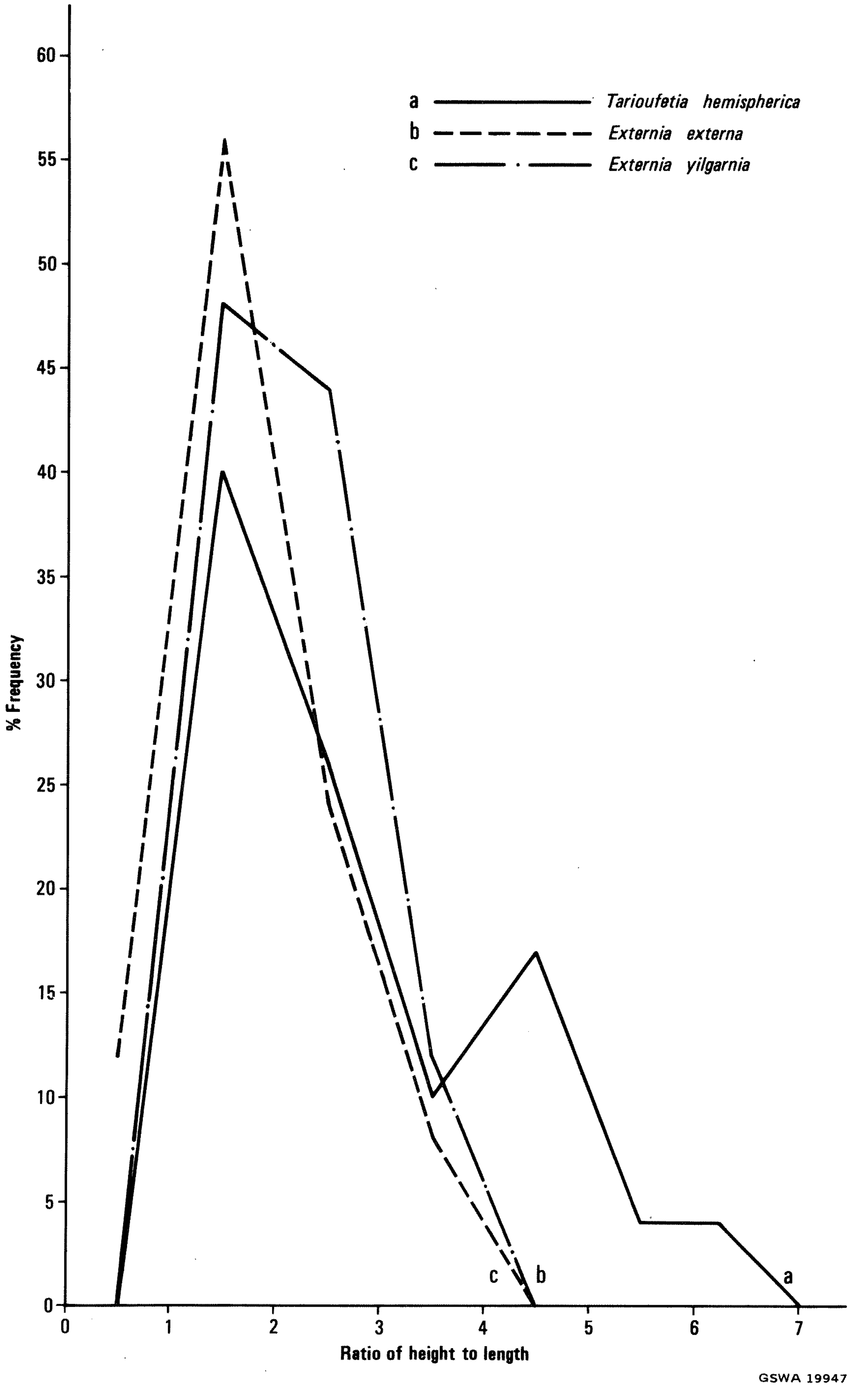


Figure 14. Comparison of relative frequency distribution plotted as a percentage of ratios of height to length of tussocks in (a) *Tarioufetia hemispherica* (50 measurements), (b) *Externia externa* (25 measurements) and (c) *Externia yilgarnia* (25 measurements).

Preiss (1976a) assigned *yilgarnia* to *Tarioufetia* because of a similarity in both miscrostructure and in gross morphology, but it has a much closer resemblance to *Externia* (see the previous discussion on microstructure). The ratio of the height of the tussocks to their length (Figs. 13, 14) ranges from 1.13 to 3.48 with a mean of 2.11 for 25 measurements. A comparison of the mean of *yilgarnia* (2.11) with that of *Tarioufetia hemispherica* (2.85, 50 measurements) using Student's t-test indicates that the difference between the two means is significant ($t = 2.52$, 73 degrees of freedom, $0.05 > p > 0.01$). By contrast the difference between the means of *yilgarnia* (2.1) and *Externia externa* (1.90, 25 measurements) is not significant ($t = 0.96$, 48 degrees of freedom, $p > 0.05$).

On the basis of microstructure alone, it is difficult to distinguish between *externa* and *yilgarnia*. There are possibly some differences in gross morphology, but their exact nature is difficult to determine because *externa* is known only from the lower part of a fascicle and *yilgarnia* from the upper part. It is possible that *externa* develops upwards into parallel-sided columns with thick walls in the upper parts; certainly numerous bridges and some slit-like cavities occur in the lower part of *yilgarnia* (see Preiss, 1976a, Fig. 16d, e and in particular Fig. f). Peaks are developed in both forms. There is a strong possibility that these forms are identical, but a detailed comparison of material is required to determine the exact extent of similarities of gross morphology before they are combined in a single form. (The valid name of such a combination would be *Externia yilgarnia* (Preiss) with junior subjective synonyms *Externia externa* and *Stratifer tenica).* *Externia* form indet. Raaben 1980 is poorly known, but appears similar to *Externia yilgarnia* in general column shape. It differs in that it lacks walls and is too poorly preserved for the nature of the microstructure to be determined.

DISTRIBUTION

The type locality in the northeast Duketon area is now placed in the Yelma Formation (Bunting, pers. comm.).

Group KULPARIA Preiss 1973

1972 *Kulparia* Preiss and Walter *in* Walter (1972, p. 151 nomen nudum)
1973 *Kulparia* Preiss, p. 113

TYPE FORM: *Kulparia kulparensis* Preiss 1973, from the Etina Formation equivalent, Umberatana Group, Yorke Peninsula, South Australia.

DIAGNOSIS: see Preiss (1973, p. 113).

CONTENT: *Kulparia kulparensis* Preiss 1973, *Kulparia alicia* (Cloud and Semikhatov, 1969), cf. ?*Kulparia* form indet. Preiss 1976.

REMARKS: A description of the new group *Kulparia* was published by Preiss and Walter, *in* Walter (1972), and *Kulparia kulparensis* was designated the type form. At this time the form had been illustrated, but not described, as *Patomia* sp. nov. Glaessner, Preiss and Walter (1969, p. 1057) and the name *kulparensis* existed only in manuscript form (Walter, 1972, p. 151). Neither reference constitutes a valid publication according to the International Code of Botanical Nomenclature (Articles 32, 38). *Kulparia* Preiss and Walter, *in* Walter (1972) is therefore a nomen nudum (Articles 34 (2), 37) and the description by Preiss (1973, p. 113) constitutes the first valid publication (Article 45).

DISTRIBUTION AND AGE: *Kulparia kulparensis* occurs in the Umberatana Group, South Australia, age younger then 750 ± 53 m.y. (Preiss and Forbes, 1981). *Kulparia alicia* (Cloud and Semikhatov 1969) Walter 1972 is from the Loves Creek Member of the Bitter Springs Formation, Amadeus Basin, Central Australia, and is between 700-800 to 1 050 m.y. old (Preiss and Forbes, 1981) and cf. ?*Kulparia* form indet. Preiss occurs in the Windidda Formation, Eeraheedy Group, Nabberu Basin, Western Australia.

cf. ?**Kulparia** form indet. Preiss 1976

REMARKS

Preiss (1976a) described only a small specimen from Mount Elisabeth. I have examined his material and can add nothing to the published description. No additional material of cf. ?*Kulparia* has been collected.

DISTRIBUTION

Windidda Formation at Mount Elisabeth.

Group MURGURRA new group

TYPE FORM: *Murgurra nabberuensis* new form.

DERIVATION OF NAME: (noun, fem.) after Murgurra Pool, a few kilometres north of the type locality.

DIAGNOSIS: A compact, bushy fascicle with widely divergent, complex branching, in which the diameter of the fascicle usually exceeds its height. Development is initially by multifurcate branching from an oncolite or a small cumulate structure. A multilaminate wall is present and the fabric is a combination of filmy and granular microstructure with wavy, lensoid laminae.

CONTENT: *Murgurra nabberuensis* only. On the basis of microstructure and laminae shape, it may be possible that small digitate stromatolites from the Gunflint Chert (Form F of Hofmann, 1969b, Pl. 12) also belong in the group *Murgurra*, but three-dimensional reconstruction of the fascicle shape is necessary to confirm this.

REMARKS: The widely divergent complex branching and sub-horizontal columns distinguish the new group *Murgurra* from most other stromatolite groups. The closest resemblance is to *Kotuikania* Komar (for translation of diagnosis see Walter and others, 1979, p. 294), which has a smooth lateral surface, numerous bulges and outgrowths, wavy and lensoid laminae and a multilaminate wall. The most important difference between *Murgurra* and *Kotuikania* is the shape of the fascicle and the branching habit. In *Murgurra* the fascicles are low and bushy and arise by widely-divergent, multifurcate branching from an oncolite or a small cumulate form. In *Kotuikania* the branches are less divergent and the fascicle does not have a low bushy relief, but is taller, with lateral branching usually developing from a single, wide, parent column. In addition the columns of *Murgurra* tend to be tuberous rather than having reniform swellings.

The group *Anabaria* Komar (1964) has a bushy, branching habit but the fascicle is fan shaped, rather than hemispherical; the branching occurs at acute angles, and branches are more or less straight. In *Murgurra* the branching is widely divergent, with angles of up to 90°. Many branches are initially horizontal and branches are bent and twisted. *Anabaria* lacks the well-developed, multilaminate wall which is present in *Murgurra*.

Komar (1966) claimed that *Kotuikania* could be distinguished from *Tungussia* Semikhatov (1962) by the presence of a multilaminate wall and the 'fluting' of the laminae. These features also serve to distinguish *Murgurra* from *Tungussia*; however, at present some forms included in *Tungussia* have multilaminate walls and perhaps would be more correctly placed in *Kotuikania* or *Murgurra*.

DISTRIBUTION AND AGE: Yelma Formation, Earaheedy Group, Nabberu Basin, Western Australia. Age approximately1.7 b.y. old.

Murgurra nabberuensis new form
(Plates 14 to 16; Figs. 15, 16)

MATERIAL

Holotype—F12365 from NBR1.
Paratypes—F12362, F12363 and F12364. All from NBR1.

DERIVATION OF NAME

Nabberuensis is derived from Lake Nabberu.

DIAGNOSIS

As for group.

DESCRIPTION

OUTCROP: Samples are from two small outcrops exposed in the lake bed at the southern end of the Sweetwaters Well locality, and from the same stratigraphic horizon approximately 300 m to the northwest on the lake shore. Another locality occurs several hundred metres northeast of the first site, but its exact stratigraphic level is uncertain.

MODE OF OCCURRENCE: The two small outcrops in the lake bed consist of a carbonate unit 1 m thick, with a lateral extent of approximately 10 m. Several stromatolitic beds, about 10 cm in thickness, are present. The stromatolites are fairly uniform in appearance and size, except in one bed where they are slightly larger. The stromatolites occur as small, bushy fascicles which are spaced a few centimetres apart (Pl. 14A, B). Boundaries between the stromatolite beds are usually stylolitized. The upper and lower boundaries of this unit were not observed.

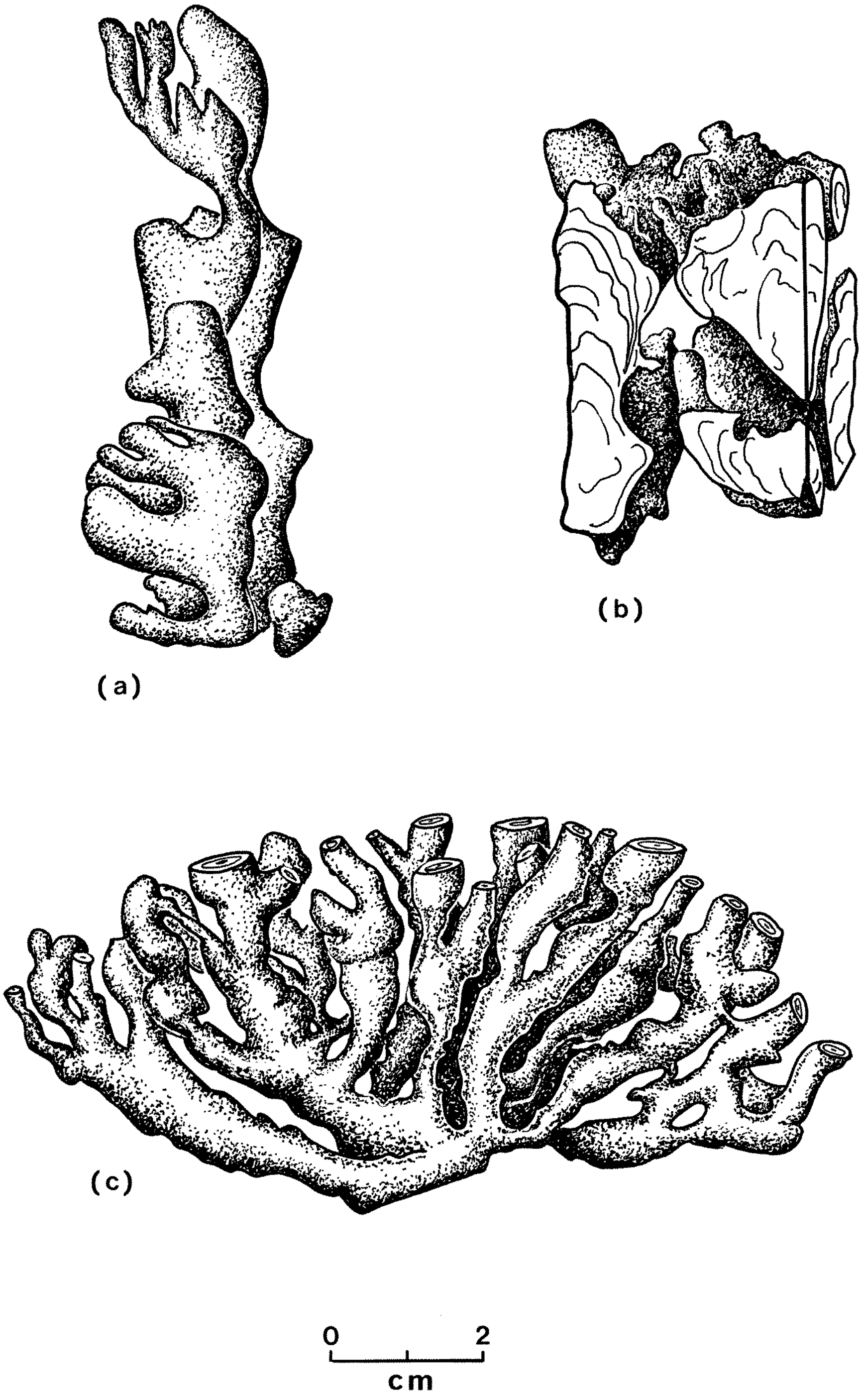


Figure 15. *Murgurra nabberuensis*, Yelma Formation. Serial Reconstructions of (a) and (b) fragments of F12362 showing the column bases and origin of branches and (c) an interpretive reconstruction of the Holotype F12365.

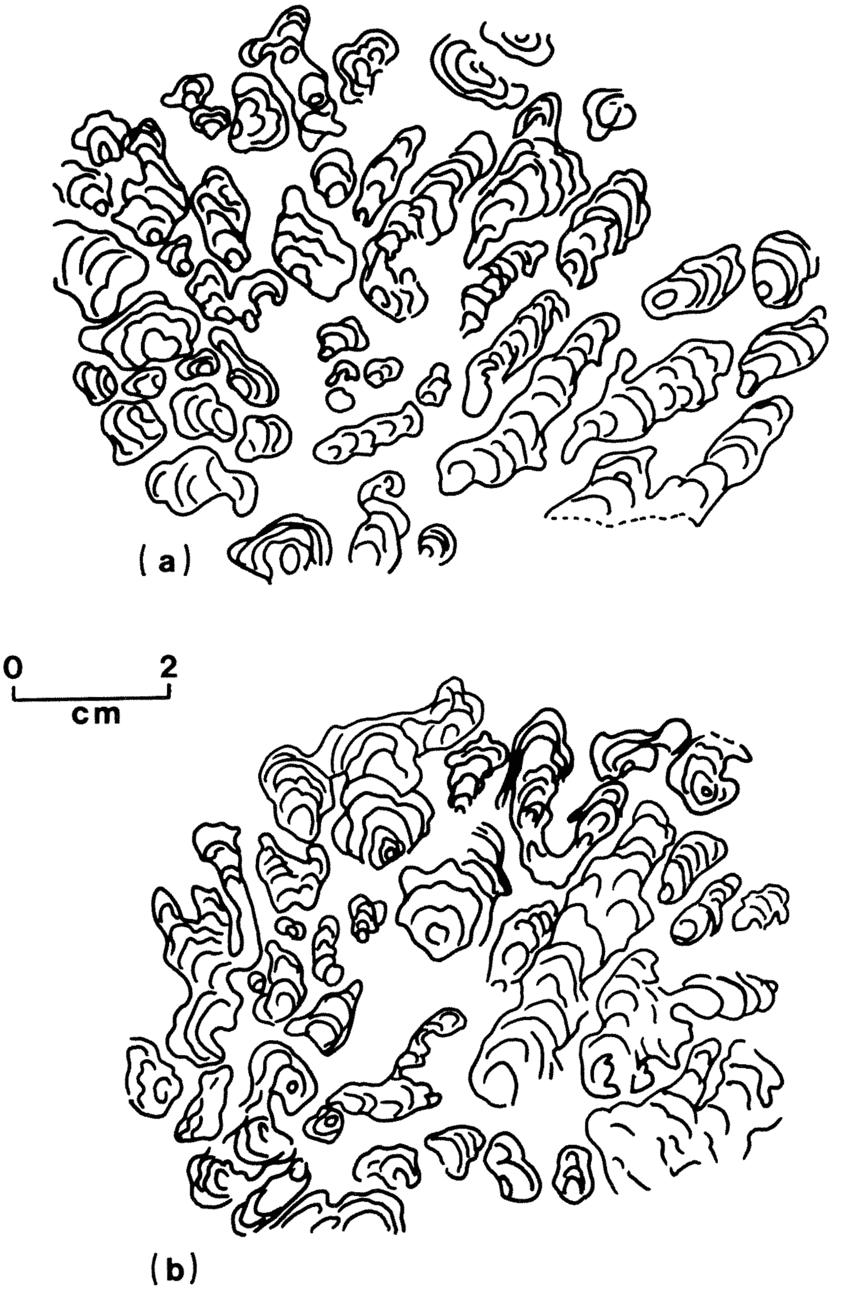


Figure 16. ***Murgurra nabberuensis*****, Yelma Formation. Lamina profiles from 2 polished faces of F12365, Holotype.**

The isolated outcrop to the northeast is patchily exposed in a scree slope. Its lateral and vertical extent are not known. It seems to be similar to the outcrop in the lake bed, in that it contains widely spaced fascicles, although at this locality the columns are narrower and straighter and oncolites are associated with the stromatolites.

The outcrop on the lake shore is more extensive than the other two localities and it can be traced for several metres along a low cliff. The unit is approximately 50 cm in thickness. Other details of the lateral and vertical extent of this unit are not known. The stromatolite fascicles at this point are closely packed and branches of adjacent fascicles may interlock. It is probable that *Murgurra nabberuensis* occurs as a lenticular bioherm.

FASCICLE MORPHOLOGY: The morpology of individual fascicles is difficult to determine near the centre of the buildup because of the close packing of the individuals and the extremely complex branching pattern. Three-dimensional reconstructions are very interpretative because of the bushy habit. Fascicles from the buildup margins and its centre appear to be very similar, and develop by complex branching from an oncolite or small cumulate structure. The diameter of the fascicle is usually greater than its height. Fascicles are approximately 15 cm in diameter, 5 to 10 cm in height and have a rounded cross-section. The synoptic relief of individual columns is of the order of 5 cm or greater, and laminae cannot be traced across the interspaces.

BRANCHING HABIT: Branching is complex and widely divergent. Columns arise initially from a small cumulate structure, and in the early stages branching is multifurcate, frequent and widely divergent. Later branching is of the lateral-bifurcating type. Gamma-style branching is common, although beta style also occurs. The outer branches may be nearly horizontal at the base of the fascicle, and then curve upwards. The central columns are nearly vertical and there is the tendency for all columns to become vertical and parallel in the later growth stages. Branches are closely spaced and may bridge or anastomose, particularly in the lower parts of the columns.

COLUMN SHAPE AND MARGIN STRUCTURE: The majority of the columns are subcylindrical in longitudinal section, although tapering and widening occurs occasionally. In plan, columns are rounded, oblong or brevilobate. Column attitude is variable; erect, inclined, recumbent, decumbent and sinous columns are all present.

Columns are bounded by multilaminate walls consisting of two to six laminae. The walls are coated with a selvage of light-brown, granular carbonate approximately 0.25 mm in thickness. Column margins are bumpy to tuberous. Bridging and anastomosing of the columns occurs relatively frequently near the base, but becomes less frequent in the upper parts of the columns. In some columns the margins have been eroded; in others they are occasionally stylolitic. Columns are relatively closely spaced and are usually 2 to 5 mm apart, occasionally reaching 10 mm. The columns themselves are 10 to 20 mm in diameter, but the width is not uniform. Columns tend to taper at the point of branching, and then increase rapidly in width after branching.

LAMINA SHAPE: Laminae are gently convex at the base of columns and become more steeply convex in the upper parts. The serial development of the columns shows only a moderate degree of inheritance. Laminae tend to be wavy and micro-unconformities are present, giving the laminae a lensoid appearance.

MICROSTRUCTURE AND TEXTURE: Laminae may be either light coloured, thick and coarsely granular; or dark brown, very thin and fine grained. The light laminae occur as thick lenses ranging from 15 to 220 µm in thickness. The dark laminae are much thinner and range from 15 to 100 µm, although the majority are 15 to 20 µm in thickness. They are frequently wavy, and may become wispy and merge into the light laminae, rarely continuing across the full width of the column. At the margins of the columns the dark laminae are deflected downwards and envelop the column for a considerable distance. Where only light laminae extend to the column margins, the downward deflection still occurs, but the laminae thin rapidly and do not persist for as great a distance as the dark laminae.

The dark laminae consist of a concentration of brown or black pigment occurring either as irregular and platy particles up to 10 µm in diameter, or as finely disseminated "dust". Much of this occurs as inclusions, or around grain boundaries. The grains in the dark laminae consist of equigranular, polygonal, xenotopic calcite, 12 to 15 µm in diameter. Laminae boundaries are poorly defined. The grains forming the light laminae are more irregular and slightly larger, being 15 to 20 µm in diameter. A selvage is also present around some columns. It is poorly preserved but appears to be composed of grains similar to those forming the light laminae.

INTERSPACE FILLING: The sedimentary filling is extremely varied and is considerably affected by recrystallization. It is usually layered and consists of bands of recrystallized, idiotopic, equigranular calcite 2 to 6 µm in diameter, and of granular limestone. The granular limestone consists of either oncolites, ooliths or intraclasts set in a matrix of hypidiotopic crystals approximately 3 µm in diameter. Grading may occur in some of these layers, and some small-scale channel filling can be recognized.

Oncolites tend to occur in layers below and around the bases of columns and a single oncolite may form the nucleus for fascicle development. The oncolites consist of alternating light and dark laminae, similar to those present in the columns. The centres of some oncolites are formed by coarse sparry calcite. Oncolites are spherical and may have diameters of up to 3 mm, although many are smaller than this. Ooliths are smaller than the oncolite and occur above the oncolite layers. Oolitic layers are usually poorly bedded and poorly sorted. They may be rounded, oval or crescentic in shape and are usually from 10 to 25 µm in diameter. Fragmented clasts of stromatolitic origin occur in the centre of some ooliths and many have a rim of dark-brown, fine carbonate. All have been considerably recrystallized and some have coarse-grained calcitic rims. Non-oolitic clasts have been similarly altered and their original nature is difficult to determine, although some are of stromatolitic origin. They may be oval, crescentic or more commonly elongate with rounded margins.

SECONDARY ALTERATION: Much of the fine detail has been lost through secondary alteration. The selvages on the column margins are probably of secondary origin, and recrystallization of parts of the columns has obliterated the structure of the laminae. Vertical calcite veins are present in some samples, and these cut across all other structures.

COMPARISONS

The widely divergent branching and subhorizontal columns distinguish *Murgurra nabberuensis* from most other stromatolites. The branches are more irregular and wider than in Stromatolite Form F from the Gunflint Chert (Hofmann, 1969b), although the fabric is very similar. The fabric is also similar to that of *Kotuikania juvensis* (Cloud and Semikhatov) Walter, Krylov and Preiss 1979, but in this form the columns are straighter and diverge at an acute angle rather than having some subhorizontal columns as occurs in *M. nabberuensis*.

The hemispherical shape of the fascicle and the filmy microstructure distinguish *M. nabberuensis* from *Yelma digitata*, a small bushy form with a banded microstructure and straight, slender columns, which occurs at the same locality.

DISTRIBUTION

Upper part of the Yelma Formation near Sweetwaters Well.

Group NABBERUBIA new group

TYPE FORM: *Naberubia toolooensis* new form

DERIVATION OF NAME: (noun fem.) from the Nabberu Basin in which the form occurs.

DIAGNOSIS: A small encrusting stromatolite which usually occurs as nodular columns, but may develop into small, slender, elongate columns by the successive superpositioning of nodules. Laminae are fine, evenly banded, thin and smooth, and of uniform thickness and separation.

CONTENT: *Nabberubia toolooensis* only

REMARKS: In their nodular encrusting habit and banded microstructure these small stromatolites show some resemblance to *Alcheringa* Walter 1972, but do not show the widening-upwards development of this group and lack the clavate, loaf and heart shapes commonly found in *Alcheringa*. An encrusting habit is typical of *Eucapsiphora* Cloud and Semikhatov 1969, and the column shape and development of bridges in *Nabberubia* is also similar to that of *Eucapsiphora*. Differences occur in the frequency of branching, which is more common in *Eucapsiphora*, and in the shape of the laminae, which are very roundly convex to hemispherical in *Nabberubia* and form a multilaminate wall, but are weakly convex to flat in *Eucapsiphora* and form only a discontinuous wall.

DISTRIBUTION AND AGE: Windidda Formation, Earaheedy Group, Nabberu Basin, Western Australia. Age approximately 1.7 b.y.

Nabberubia toolooensis new form
Plates 17 and 18, Figs 17 and 18

1976a *Tungussia heterostroma* Preiss (in part) p. 22, 24, 26, Figs 15a, b, e (parts), Fig. 18, S2 (part), Fig. 34 (part), Fig. 55, Fig. 57.

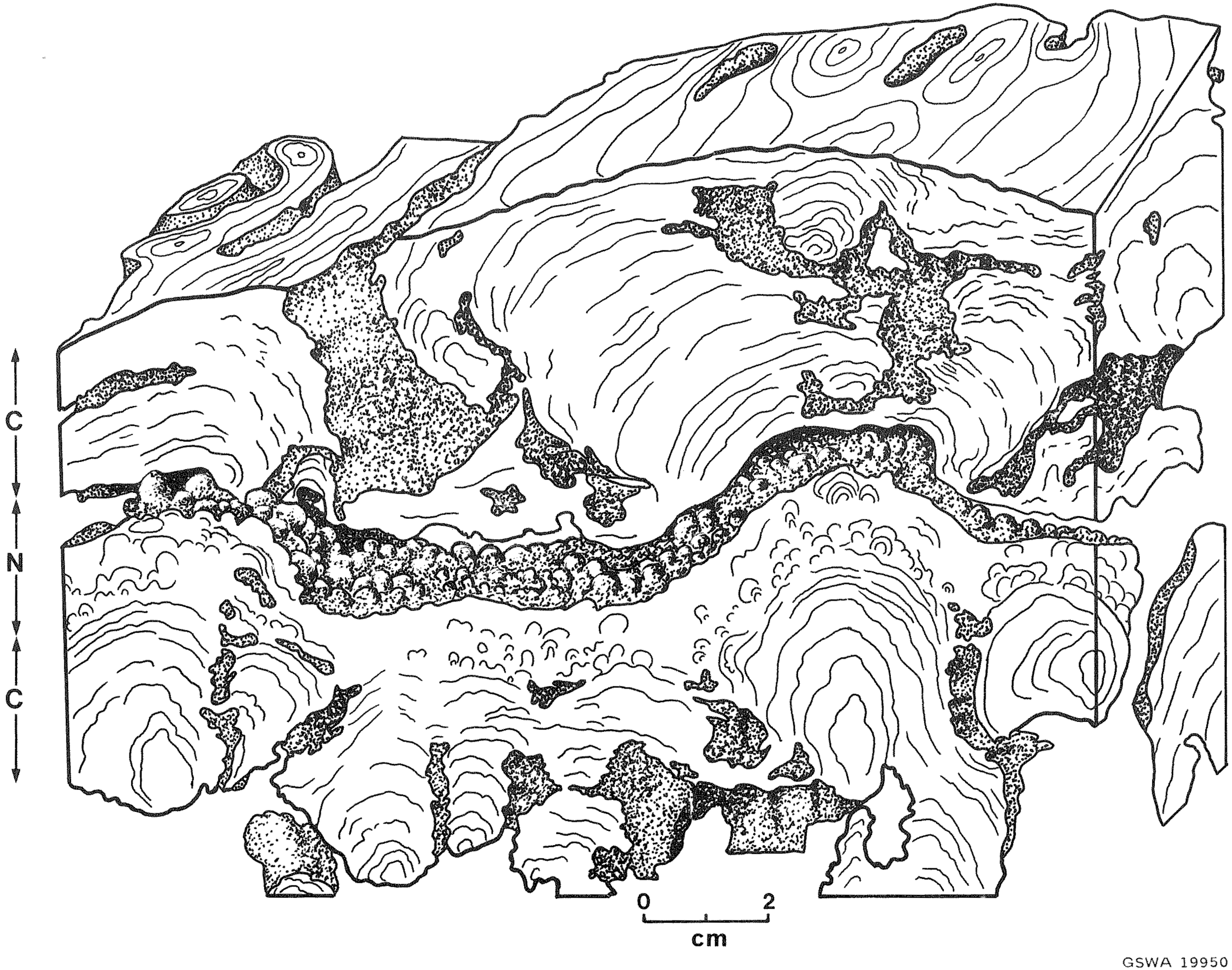


Figure 17. ***Nabberubia toolooensis,*** **Windidda Formation. Serial reconstruction of the Holotype F12366, showing the development of *N. toolooensis* (N) as an encrusting layer between two horizons of *Carnegia wongawolensis* (C).**

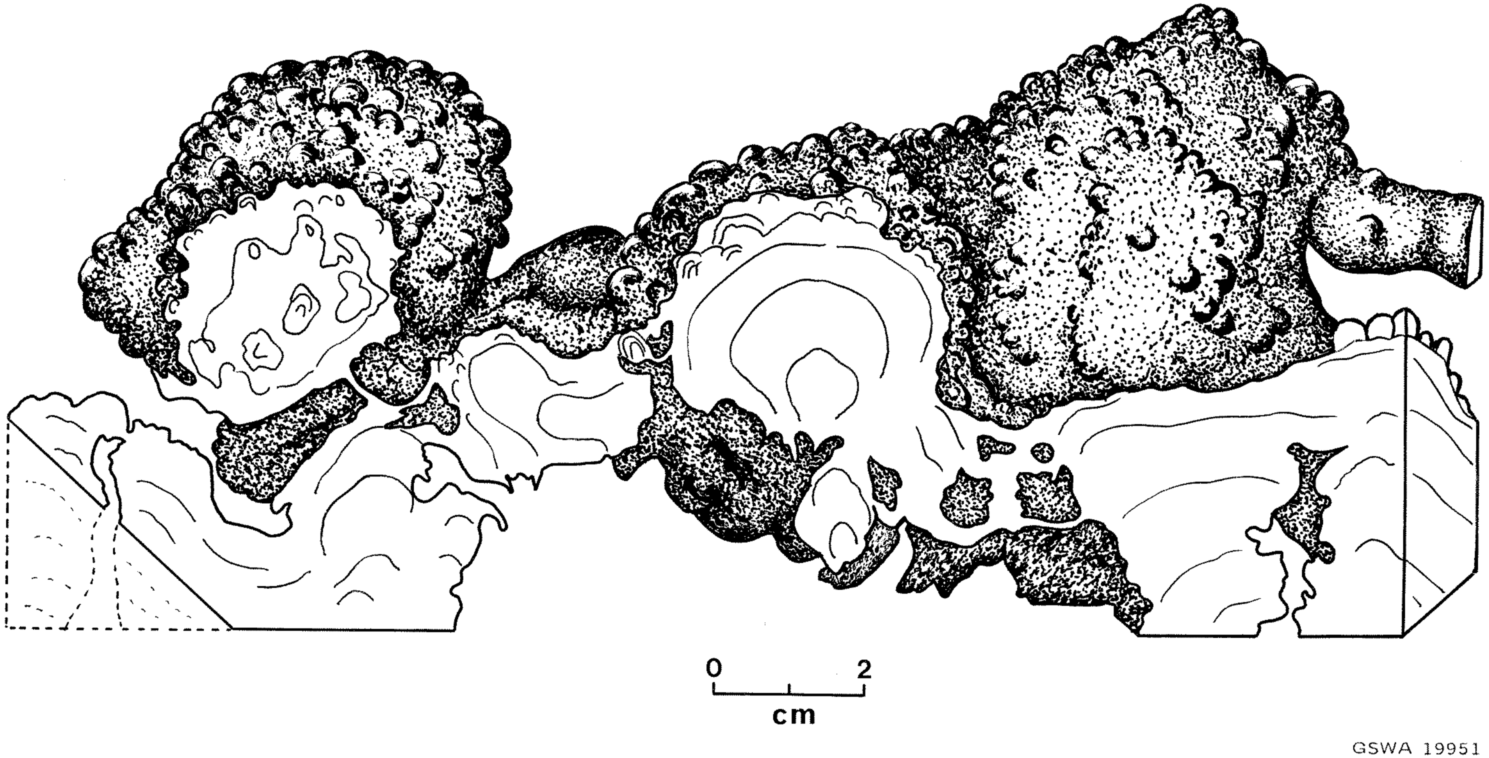


Figure 18. ***Nabberubia toolooensis,*** **Windidda Formation. Serial reconstruction of a slightly different part of the Holotype F12366 showing only the bottom horizon of *Carnegia wongawolensis* and emphasizing the encrusting development of *N. toolooensis.***

MATERIAL

Holotype—F12366 from KGS2

Paratype—CPC 16524 from RBR1, Mount Elisabeth. This specimen is the holotype of *Windidda granulosa* (Preiss) which is encrusted with small columns of *Nabberubia toolooensis.*

DERIVATION OF NAME

Toolooensis is derived from Tooloo Bluff, near which the type locality occurs.

DIAGNOSIS

As for the group.

DESCRIPTION

OUTCROP: Only two samples are known. At the type locality pinkish-grey limestone is interbedded with grey-green or maroon, micaceous mudstone. Individual limestone beds usually contain a stromatolitic horizon and vary in thickness from 20 to 200 mm. They may be lensoid or continue for several hundred metres.

Preiss (1976a) illustrated and briefly described the Mount Elisabeth locality (RBR1), where outcrop is poor, and where the stromatolites occur in flat to slightly raised, rocky mounds amongst the sand and colluvium plain (M. J. Jackson, pers. comm, 1980).

MODE OF OCCURRENCE: At the type locality, where the stromatolites occur in a sequence of interbedded shales and limestones, the type specimen was collected from one of the thicker limestone bands containing two stromatolite layers (J. Bunting, pers. comm., 1979). Both layers consist of nodules of *Carnegia wongawolensis.* The lower of the two layers is encrusted with 10 to 15 mm of *Nabberubia toolooensis* which occurs as a coating either around individual branches, or surrounding complete nodules of *C. wongawolensis.* The boundary between the two forms is not clearly defined, but shows interfingering. Even in areas where *Nabberubia toolooensis* is the dominant form, small patches of *Carnegia wongawolensis* recur. Growth of the encrusting form was interrupted by the deposition of a mudstone layer, and only rudimentary branching occurs.

In the sample from Mount Elisabeth, a column of *Windidda granulosa* (Preiss) is encrusted by a layer of *Nabberubia toolooensis.* The initial layers of the encrusting form follow the column contours. Small nodules develop on these layers and are succeeded by branching columns with a vertical orientation. Interfingering of the two forms occurs (Preiss, 1976a, p. 24). The principal mode of occurrence of *N. toolooensis* is as laminated sheets, and it does not form a branching fascicle which is the usual mode of occurrence for many of the other Nabberu stromatolites.

BRANCHING HABIT: Branching is infrequent and most columns develop directly from the first few millimetres of encrusting laminae. Where branching does occur it is by lateral bifurcation, giving rise to sub-parallel columns.

COLUMN SHAPE AND MARGIN STRUCTURE: The base of *Nabberubia toolooensis* is formed by 2 to 3 mm of stratiform laminae which encrust and interfinger with the laminae of another stromatolite form. Small discreet nodules develop from the sheet laminae with their axis of growth perpendicular to the encrusted surface, and may develop on the lower surfaces of branches of the 'host' form as well as on the upper surfaces. Several layers of nodules may be present, overlying each other disharmonically. In other areas the nodules may be stacked to form columns. This development is clearly shown by one of the columns at the left side of Figure 34 in Preiss (1976a). The later laminae tend to develop on the upper surface of the nodules giving rise to "short, narrow, projection-like columns with numerous bridges" (Preiss, 1976a, p. 22) and the columns may be tuberous or club shaped (see Preiss, Fig. 15a, b, e). The swellings usually coincide with the centre of one of the stacked nodules. A wall-like structure is developed around each nodule by successive laminae, and these may occasionally overlap lower nodules. In places bridges form between the columns.

LAMINA SHAPE: Laminae are regular and hemispherical throughout most of the column. They may become double crested before branching, and the basal laminae are irregular where they follow the contours of the underlying structure.

MICROSTRUCTURE: The microstructure of both specimens is similar. Preiss (1976a, p. 24) described this as being "very finely, evenly banded with thin smooth laminae of uniform thickness and separation. They contain no coarse trapped detritus. Light and dark laminae vary in thickness from 30 to 150 mm, the dark being generally somewhat thinner than adjacent light laminae."

INTERSPACE FILLING: Interspaces are rare in the holotype because the nodules are contiguous or overgrow each other. Interspaces between the branches of *Carnegia wongawolensis* and surrounding the encrustations of *Nabberubia toolooensis* are filled with maroon and green mudstone containing a mixture of clasts and small peloids. In CPC 16524 the interspaces are filled with "?oncolite grainstone or packstone .... cemented by sparry, xenotopic calcite cement of grain size 50 to 100 μm . . ." (Preiss, 1976a, p. 24).

SECONDARY ALTERATION: In the holotype the shape of the nodules is followed by a vein infilled with calcite. Patchy recrystallization of the nodules and small columns has occurred and the laminae are partially replaced by an opaque mineral, probably magnetite. This sometimes occurs as small branching structures (Pl. 18C), in which a faint acicular texture is emphasized by the opaque mineral. The primary depositional texture of the laminae of the Mount Elisabeth sample has been largely destroyed and an incipient acicular texture has developed (Preiss, 1976a, p. 24).

COMPARISONS

The resemblance to *Alcheringa narrina* and *Eucapsiphora paradisa* has already been commented upon in the discussion of the group. *Nabberubia toolooensis* can be distinguished from other Earaheedy Group stromatolites, including *Yelma digitata* new form, which it resembles to some extent in lamina shape, by its very distinctive growth pattern.

REMARKS

Preiss (1976a) included the small columns of *Nabberubia toolooensis* in the form *Tungussia heterostroma*, although he recognized that these columns were probably formed by a different microbial mat-community (p. 24) from the one which formed the columns of *T. heterostroma.* The association of the same type of small columns with a different form, in this case with *Carnegia wongawolensis,* confirms the conclusions drawn by Preiss and indicates that the encrusting structure represents a new form, which has both a different microstructure and different gross morphology from each of the two forms which act as 'host'.

DISTRIBUTION

Windidda Formation, near Windidda homestead and at Mount Elisabeth.

Group OMACHTENIA Nuzhnov 1967

TYPE FORM: *Collenia omachtensis* Nuzhnov 1960 from the Omakhtin Suite of the Uchur Basin, Uchuro-Maya region, S.E. Siberian Platform, USSR.

DIAGNOSIS: "Cylindrical and subcylindrical columns in parts with numerous cornices and semi-annular projections on the lateral surfaces. Columns are arranged fairly near each other and are joined by a large number of crossing laminae, and they are usually layered for several (two or more columns). During branching one column dissociates into two or more independent columns of lesser diameter. The columns and their outbranchings in a bioherm usually have a common orientation (in the majority of cases it is vertically upwards, rarely it is fanning from the common base), however sometimes small surface outgrowths and bent columns are observed. In bioherms it is possible to observe that one column widens upwards and overshadows others, which gradually narrow upwards, discontinuing their development. Transverse sections of the columns are rounded, rarely irregular, and are often connected with each other by connecting laminae. The construction is composed of clear lamellar laminations, which sometimes lie discordantly on one another. The character of the laminae is commonly inherited. There are constructions composed of bedding with a different form and degree of convexity of the arches." (Translated from Nuzhnov, 1967).

CONTENT: *Omachtenia omachtensis* (Nuzhnov 1960), *O. utschurica* Nuzhnov 1967, *O. givunensis* Nuzhnov 1967, *O. kvartsimaa* Krylov and Perttunen 1978, *O. teagiana* new form.

REMARKS: The group *Omachtenia* Nuzhnov is very similar to the group *Schancharia* Korolyuk, but *Schancharia* has a thin, one-layered wall, banded laminae, slightly non-parallel branching and flattened laminae.

DISTRIBUTION AND AGE: *Omachtenia omachtensis, O. givunensis* and *O. utschurica* occur in the Uchur Group, in the Uchur-Maya region, approximate age 1.4 b.y. Preiss (1974) described a specimen of *O. utschurica* from the Tapley Hill Formation (Late Adelaidean), but this identification is now doubtful (W. V. Preiss,

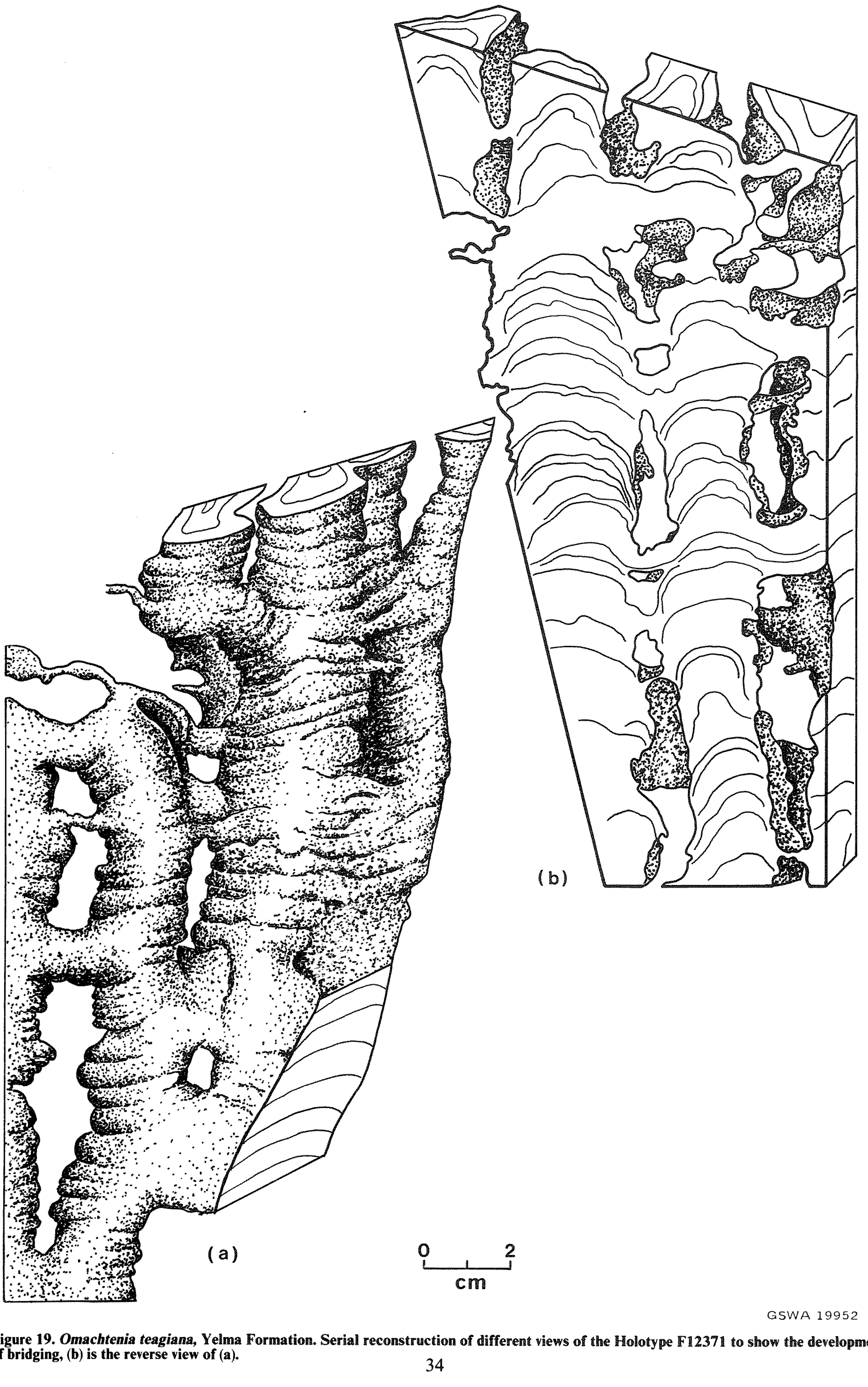


Figure 19. ***Omachtenia teagiana*****, Yelma Formation. Serial reconstruction of different views of the Holotype F12371 to show the development of bridging, (b) is the reverse view of (a).**

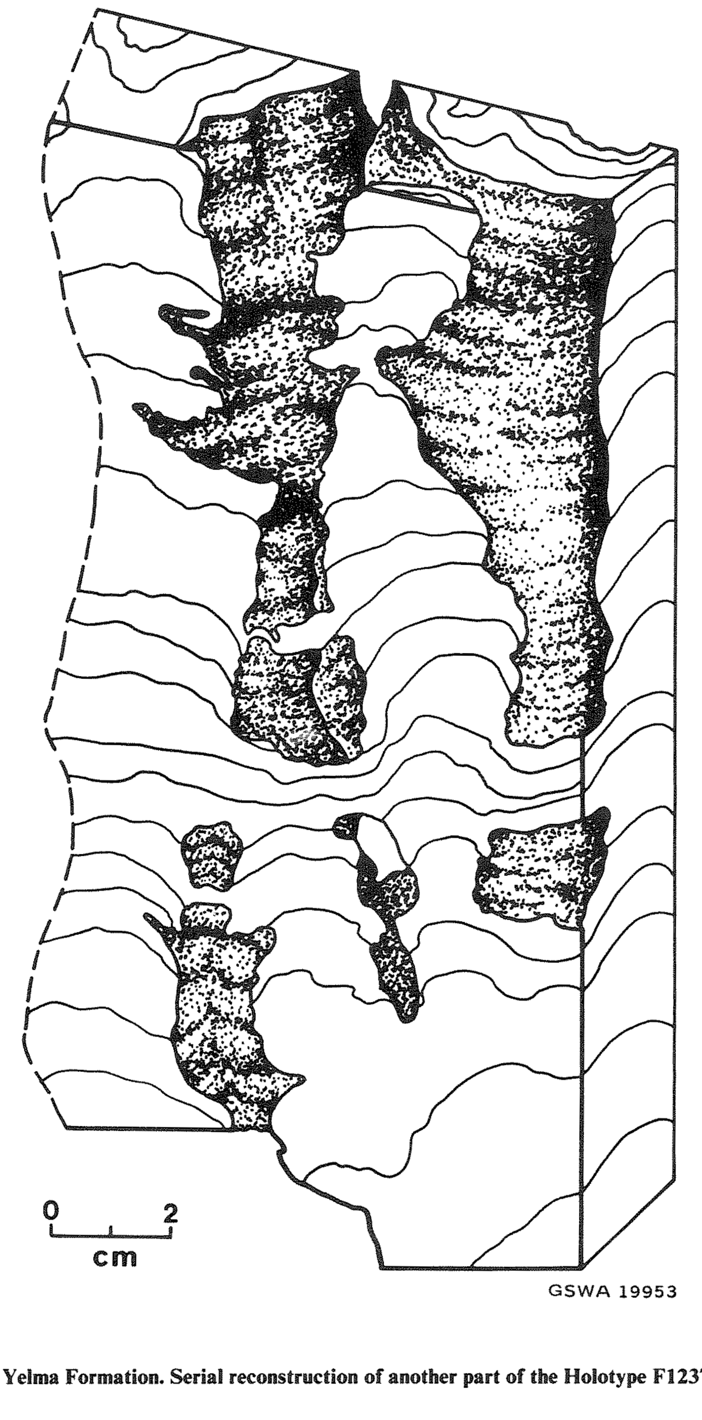


Figure 20. ***Omachtenia teagiana,*** **Yelma Formation. Serial reconstruction of another part of the Holotype F12371, shown in Fig. 19, showing column shape and bridging.**

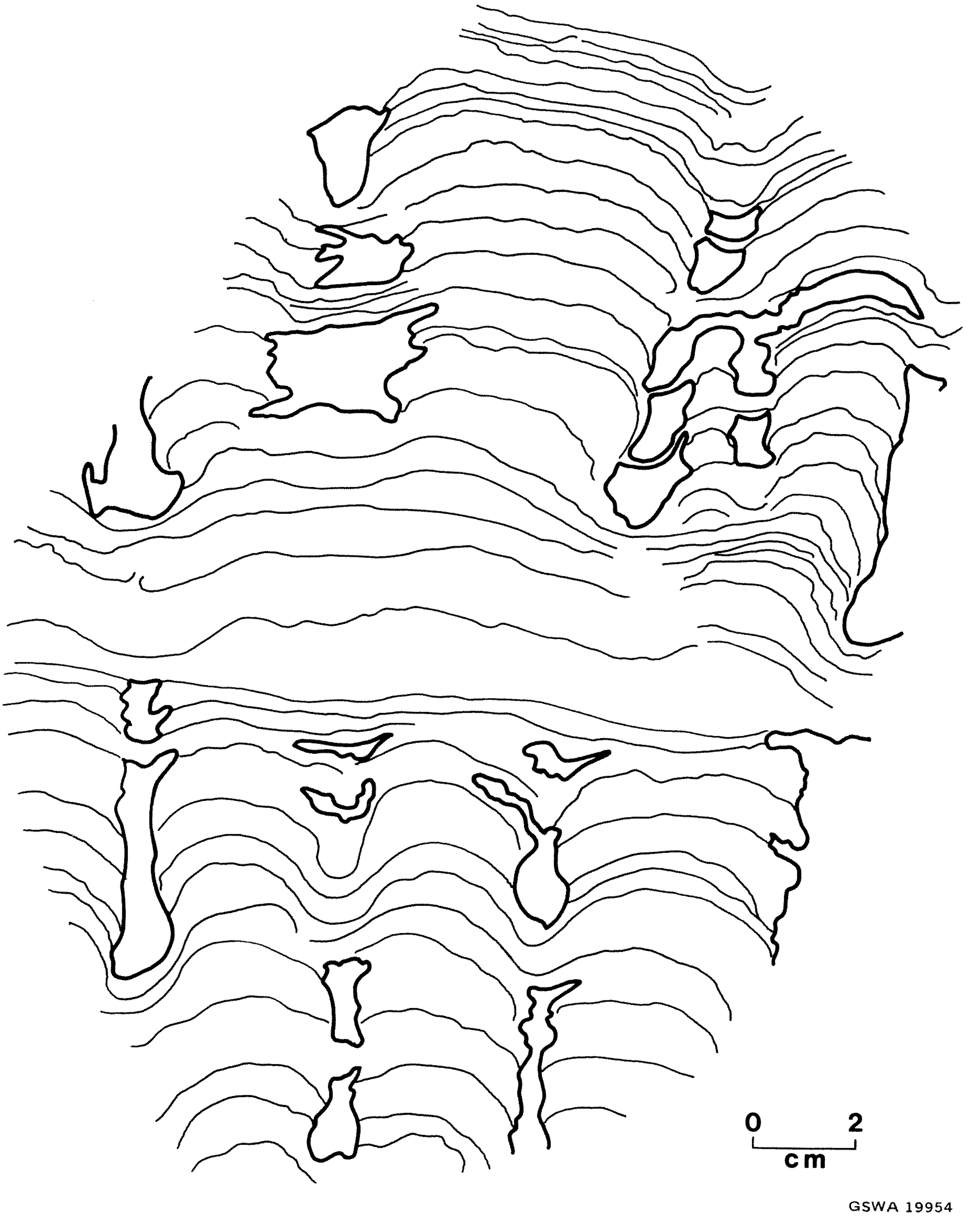


Figure 21. *Omachtenia teagiana*, Yelma Formation. F12369. Lamina profiles.

pers. comm., 1979). *Omachtenia kvartsimaa* Krylov and Perttunen 1978 occurs in an unnamed dolomite horizon in nothwestern Finland and is probably Yatulian (Early Riphean) in age (approximately 2.0 b.y. old). The new form *Omachtenia teagiana* occurs in the Yelma Formation of the Earaheedy Group, Nabberu Basin, Western Australia, approximately 1.7 b.y. old.

Omachtenia teagiana new form

(Plates 19 and 20, Figs 19 to 21)

MATERIAL

Holotype—F12371 from NBR2

Paratypes—F12367, F12368, F12369, F12370 all from NBR2.

Other material—A poorly preserved specimen ?*Omachtenia teagiana*, F12372, is from TSL1.

DERIVATION OF NAME

Teagiana after Mount Teague which lies to the north of the type locality.

DIAGNOSIS

Omachtenia with straight, erect, parallel columns arising from a stratiform base, initially as pseudocolumns and eventually developing into true columns. Coalescing and bridging occur in the lower parts of the columns, but become less frequent higher up. Transverse ribs or cornices are present, but not well developed. A short wall, usually consisting of a single lamination, is present throughout most of the column. Laminae are moderately convex, and smooth and distinctively banded in the lower part of the fascicle, but are less well-defined in the upper parts.

DESCRIPTION

OUTCROP: A fairly extensive outcrop occurs near the top of a low hill, in dark grey and brown stromatolitic carbonate which shows silcretization (Pl. 1B). The underlying and overlying units were not observed.

MODE OF OCCURRENCE: The outcrop consists of an extensive tabular bioherm, with columnar stromatolites occurring near the centre, grading laterally into small domes and stratiform stromatolites.

FASCICLE MORPHOLOGY: Each fascicle consists of a bulbous dome formed by a stratiform or slightly domed base from which numerous erect, parallel branches are developed. The stratiform base is usually poorly exposed. It passes upwards into pseudocolumns, which usually form short lengths of true columns (Pl. 19A) and then coalesce again to form pseudocolumns (Pl. 19B). In places stratiform layers of variable thicknesses develop across several columns or pseudocolumns. The height of the columnar and pseudocolumnar sections may be at least 10 cm, while that of intervening stratiform layers is approximately 5 cm. This pattern of interlayered columnar/pseudocolumnar and stratiform sections may be repeated several times.

Branching is infrequent and branches are closely spaced. Connecting bridges are common, particularly in the lower sections. The synoptic relief is low and the lamina shapes show a high degree of inheritance.

BRANCHING HABIT: Column branching is of the dichotomous-bifurcating type, and is infrequent. New columns are parallel and of beta or gamma style. The terminations of branches are rounded.

COLUMN SHAPE AND MARGIN STRUCTURE: Columns are cylindrical to slightly turbinate in longitudinal section, and are circular, oblong or completely irregular in plan outline. Columns and pseudocolumns are stubby to slender, show some variability of growth, and are erect. Lateral variation may occur ranging from wide to narrow columns, to pseudocolumns and, rarely, to stratiform layers at a single level. Such variation is quite random, although usually the narrower columns occur near the top of the fascicle. Columns vary from 1 to 5 cm in diameter, and may reach at least 15 cm in height.

The margins have been considerably affected by silcretization, particularly in the upper narrower parts of the columns.

In the lower part of the fascicle the laminae are distinctly banded. Certain bands, usually dark grey, extend down the sides of the column margin, overlapping several preceding laminae, and form a short wall which terminates by tapering against the preceding overlapping lamina. This is the most common form of wall structure, but variations occur, for example several successive laminae may form overlapping structures. These structures usually do not taper against the preceding overlap, but terminate abruptly to form cornices or small cornice-like projections, or are deflected outwards to form a bridge. The thickness of the bridges is variable. They may be less than 5 mm or up to 20 mm or more in thickness.

Details of the margins in the upper parts of the columns have been completely lost by stylolitization, although an occasional overlapping lamina can be observed. Bridges and cornices are not common in this area of the column; however, they may have been present originally, and destroyed by later silicification.

LAMINA SHAPE: Laminae range from flatly to steeply convex, with the greatest convexity in the lower to middle parts of the columns. The steeply convex laminae have smooth curves, whereas the flatter laminae are sharply deflexed downwards near the margins of the column.

MICROSTRUCTURE AND TEXTURE: The microstructure is distinctly streaky to broadly banded. Laminae continue across the full width of the column. Boundaries of the laminae are well defined but may be irregular. The laminae are best preserved in the lower parts of the columns, and here complex groupings occur, consisting of alternating broad bands of light-brown, dark-brown and dark-grey laminae each between 1 and 3 mm in thickness. Each band, or macrolamina, consists of finer, alternating light and dark laminae. the relative thicknesses of the constituent laminae determine the colour of the band. In light bands the light laminae are thicker, ranging from 70 to 170 µm. Darker laminae predominate in the dark-brown bands and are 170 to 230 µm thick, while the interlayered light laminae are 30 to 50 µm. Both the light-brown and dark-brown laminae have pelletal to granular microstructure and consist of hypidiotopic or rounded carbonate grains with a diameter of 30 to 70 µm. The dark-grey laminae are more sharply defined than the other types and are usually thicker, between 320 and 500 µm. They consist of micritic carbonate grains 10 to 40 µm in diameter and contain finely dispersed specks of dark pigment. It is these dark laminae which overlap the column margins to form the wall structure.

INTERSPACE FILLING: Interspaces in the lower parts of the columns are filled with finely granular carbonate, which may occasionally be laminated and in some parts of the interspace may be pelletal, or contain intraclasts up to 3 mm in length and 1 mm wide. Patches of homogenous micrite also occur. The interspaces in the upper parts of the columns are filled with homogenous micritic mudstone which has been recrystallized and lacks structural details.

SECONDARY ALTERATION: A complex history of secondary alteration can be traced, particularly in the interspaces and upper parts of the columns. Patchy dolomitization was probably an early feature, but silcretization and calcretization are more recent. The basal parts of the fascicles show relatively little alteration and details of the column margins and microstructure are well preserved, and formed of dark-grey and brown limestone. Preservation in the interspaces is poorer, but near the bases of the columns details of the structure can still be seen. In a transitional area the interspaces have patches showing structural details, but areas of recrystallization also occur. In the columns the banded laminae have a more uniform colouration, although individual bands can still be distinguished. Column margins are usually stylolitized, and have a stained rim of 4 to 10 mm of yellow-brown dolomite. In this transitional area individual laminae cannot be distinguished and patches of amorphous dolomite may replace parts of the columns. Small veins and stars of ?magnetite also occur.

The stained rims are more noticeable in the upper parts of the columns and a thin selvage of silcrete is present on columns which have weathered out at the surface. Some laminae and stylolites have also been replaced by similar material. The columns and interspaces are composed of yellow-brown limestone, possibly iron-stained. Individual fine laminae can be recognized in parts of the columns and some evidence of the original pigmented banding remains, but on the whole the present colouration of the column, consisting of irregular pink, white and yellow patches, is not related to the lamination. The columns are occasionally disrupted by patches of silcrete and calcrete.

COMPARISONS

The variations from stratiform, through pseudocolumnar to columnar shown by this new form are typical of *Omachtenia*. In the presence of banded, cyclic laminae and the formation of a patchy wall it resembles *Schancharia tenuiseptatum* Korolyuk 1960. However this latter form has flattened laminae with an abruptly down-turned margin, and sub-parallel branching, features typical of the group *Schancharia*. *Omachtenia omachtensis* Nuzhnov 1967 is very similar in gross morphology, but has finer laminae and more frequent bridges and cornices. The distinctive banding of the laminae in *O. teagiana* distinguishes it from other forms in the group. *O. kvartsimaa* Krylov and Perttunen 1978, seems to have a fairly similar gross morphology to *O. teagiana*, but in the latter the columns are narrower, the laminae thicker, more convex and are not wrinkled like those of *O. kvartsimaa*. The presence of a patchy wall is not mentioned in the text; but can be seen in the illustration (Fig. 28) of *O. kvartsimaa*.

DISTRIBUTION

Yelma Formation near Sweeney Creek.

Group PILBARIA Walter 1972

TYPE FORM: *Pilbaria perplexa* Walter 1972 from the Duck Creek Dolomite, Wyloo Group, Duck Creek area, Hamerlsey Ranges, Western Australia.

DIAGNOSIS: see Walter (1972, p. 167).

CONTENT: *Pilbaria perplexa* Walter 1972, *Pilbaria boetsapia* Bertrand-Sarfati and Eriksson 1977. *Pilbaria inzeriaformis* Bertrand-Sarfati and Eriksson 1977, *Pilbaria deverella* new form.

REMARKS: Three groups, *Inzeria* Krylov 1963, *Pilbaria* Walter 1972 and *Nordia* Krylov and Perttunen 1978 have well developed niches and projections. Walter (1972, p. 170) distinguishes *Pilbaria* from *Inzeria* by the smooth walls and poorly developed ribbing of the former. He also comments on the presence of "proportionately small, transversely elongate niches and niche-enclosed projections" which he claims provide a further distinction between *Pilbaria* and *Inzeria;* however, the sizes of the niches and projections illustrated by Krylov (1963, Fig. 22) for the type form *Inzeria tjomusi* are of approximately the same size relative to the diameter of the column as those figured by Walter (1972, Fig. 52b, p. 129, Fig. 5) for *Pilbaria perplexa*. The niches in the type forms of both *Inzeria* and *Pilbaria* form narrow, deep pockets and deeply dissect the columns. In the type forms of both groups the projections tend to remain within the general width of the column, and the overall width of the column is usually two or three times the width of the projection. This is not always the case in some of the other forms which have been placed in the group *Inzeria*; for example in the specimen of *I. tjomusi* described by Cloud and Semikhatov (1969, Fig. 11 and Plate 6, but not Fig. 10, from the Hinde Dolomite), in *I.* cf. *tjomusi* from the Wundowie Limestone Member (Preiss, 1973, this stromatolite is no longer considered to be *tjomusi*, Preiss, pers. comm., 1982) and in *I. intia* stage II Walter (1972, especially Fig. 41F and Plate 22, Figs 4 and 5), the columns are not as straight and erect as in *I. tjomusi*, the projections frequently diverge from the main column at an angle of approximately 30° or more and usually extend beyond the general column width, and the column diameter tends to be at least five times that of the projections. These features require careful evaluation to determine whether they are of sufficient significance to warrant the erection of a new group. *Inzeria* would then be restricted to forms with narrow, deep niches and relatively large projections which tend to be parallel to the main column. The presence of ribbing would be the main criterion distinguishing *Inzeria* from *Pilbaria*.

Krylov and Perttunen (1978) did not compare their new group *Nordia* with *Pilbaria*. Both groups have relatively smooth walls with small bumps and only occasional short ribs, and in both groups lateral branches develop from lateral projections separated from the main column by narrow niches. The main difference appears to be the greater irregularity of the columns of *Nordia*, but this may not be sufficient basis for a separate group and *Nordia* may be a junior synonym of *Pilbaria*.

DISTRIBUTION AND AGE: *Pilbara perplexa* Walter 1972, occurs in the Wyloo Group, Ashburton Trough, Western Australia, age 1.7 to 2.0 b.y. and in the Rocknest Formation, Epworth Group, Coronation Geosyncline, Canada (Semikhatov, 1978); age 1 865 to 2 200 million years. *Pilbaria* cf. *perplexa* has been reported from the Koolpin Formation, Pine Creek Geosyncline (Crick and others, 1980, p. 275); age 2 000 to 2 300 million years.

Pilbaria boetsapia Bertrand-Sarfati and Eriksson 1977 and *Pilbaria inzeriaformis* Bertrand-Sarfati and Eriksson 1977 occur in the Schmidtsdrift Formation of the Northern Cape Province of South Africa. Age approximately 2.2 b.y.

Pilbaria deverella new form occurs in the Yelma and Frere Formations in the Eeraheedy Group, Nabberu Basin, Western Australia. Age about 1.7 b.y.

Pilbaria deverella new form

(Plates 21 to 23, Figs 22 to 24)

MATERIAL

Holotype—F12374 from NBR1.

Paratypes—F12373, F12375, F12376 and F12377. All from NBR1. F12378 from NBR4.

Other material—A poorly preserved specimen ?*Pilbaria deverella*, F12379, from PKH3.

DERIVATION OF NAME

Deverella is from Mount Deverell near the type locality at Sweetwaters Well.

DIAGNOSIS

Pilbaria, with straight, erect columns, deeply dissected by narrow, complex niches. Branching is either infrequent and parallel, or develops laterally from projections. The wall is poorly defined and patchily developed. Small pseudocolumns, inclined to the axis of the main column, are sometimes present. Column margins are relatively smooth with small bumps and occasional weak ribbing. Laminae wavy, lensoid and steeply convex to slightly conical.

DESCRIPTION

OUTCROP: Samples are from an horizon a few metres above the lake-bed near the outcrop of large domed stromatolites. The outcrop is rubbly in this area, and the precise relationships to other stromatolite horizons are difficult to determine, but a patch of *Pilbaria deverella* occurs immediately above the lower *Yelma digitata* horizon. Several other horizons of *Pilbaria deverella* occur for about 20 m above the first, and form part of a cyclic sequence in which the *Pilbaria deverella* horizon overlies *Yelma digitata*, and underlies dolomite with flat-laminated stromatolites. Outcrop is poor in the upper horizons and precise relationships between the cyclic units cannot be determined.

MODE OF OCCURRENCE: The large, branching columnar stromatolites are visible mainly in cross section, and the collection of complete samples is difficult. The nature of the upper and lower boundaries of the unit have not been determined. Columns are composed of dark-grey carbonate, with pink patches in some areas, and the interstitial material is pale-pink to white carbonate. Calcrete occurs along some joint planes, and the columns are partially brecciated. The rubbly nature of the outcrop makes determination of the mode of occurrence difficult, although the columns are probably part of a relatively small stromatolite buildup, possibly a bioherm.

FASCICLE MORPHOLOGY: Details of the fascicle morphology cannot be determined because neither the base nor the tops of the column are exposed. The central parts of the columns are infrequently branching, unlinked and closely spaced. Synoptic relief is low and the laminae show a moderate degree of inheritance.

BRANCHING HABIT: Branching is infrequent and laterally bifurcating, and occasional coalescing of the columns occurs. New columns are slightly divergent with the parent column increasing slightly in width before branching occurs (gamma style). Branches may also develop from the elongation of projections. Such branches are usually short with rounded terminations, are frequently associated with the larger niches and diverge slightly from the direction of the main column, extending beyond the column width. A pseudocolumnar structure is present in some columns with pseudocolumns of up to 20 mm in width developing at an inclination to the axis of the main column (Pl. 21A and B).

COLUMN SHAPE AND MARGIN STRUCTURE: Columns are cylindrical in longitudinal section, and are circular, oblong or crescentic in plan outline. Crescentic shapes are usually formed by projections, and partially surround circular columns. At the base of projections columns are lobate. Columns are stubby to slender and are usually erect, up to 5 to 10 cm or more in diameter, and have a minimum height of 25 cm. Some columns show lateral elongation but the direction of elongation is random. Laminae turn downwards at column margins to form a poorly defined patchily developed wall. Some laminae have ragged terminations in areas where the wall is lacking, and give rise to short, transverse ribs, although generally column margins are smooth. The columns are characterized by the development of pronounced niches and short projections. Projections occur fairly frequently and tend to be broad with rounded terminations. They are set into niches at the side of the main column and rarely project beyond the width of the column, except where they develop into branches. The main column generally resumes its former width after the termination of a projection. Niches may be very deep and are of irregular shape. They cut into the columns at a variety of angles from nearly vertical to nearly horizontal. They may divide into several pockets. Some niches are so extensive that they almost bisect the column (Pl. 21A).

LAMINA SHAPE: Laminae are steeply convex to parabolic in profile and some are slightly conical. They are wavy and frequently lensoid. The margins are deflexed and the laminae then continue parallel to the margin for a short distance before becoming so diffuse that they cannot be distinguished. In the centre of the columns laminae are diffuse and lensoid and cannot usually be traced for the full width of the column. Laminae may become double crested before branching occurs or in areas of pseudocolumn development. There is a tendency for laminae to be asymmetrical, at least in parts of most columns.

MICROSTRUCTURE AND TEXTURE: The microstructure is irregularly streaky, with wavy laminae and the development of lenses. The columns have been considerably recrystallized, but some indication of the original lamination can be observed in places. Boundaries between light and dark laminae are moderately well defined. The thickness of the laminae is quite variable and the light laminae in particular tend to wedge out.

Dark laminae are 30 to 500 µm in thickness and stained with pale-brown pigment. They consist of a mosaic of sparry, hypidiotopic, equigranular calcite grains, 1.0 to 4.5 µm across which are probably of secondary origin. Rhombic crystals up to 75 µm in diameter occur infrequently. Light laminae are usually more lensoid than the dark laminae and range from 40 to 400 µm in thickness. The grain mosaic is similar to that forming the dark laminae. Rounded, detrital quartz grains are common in both types of laminae and measure between 30 and 40 µm. Rare cherty lenses, probably of recrystallized detrital quartz, also occur.

INTERSPACE FILLING: Interspaces were probably filled originally with homogenous micritic mudstone which has been extensively recrystallized. The degree of recrystallization varies, although the original infilling was probably fairly uniform in character.

SECONDARY ALTERATION: Secondary recrystallization has been extensive in both the columns and the interspaces. Much of this recrystallization probably occurred during early diagenesis, allowing preservation of some details of the laminae. It is difficult to determine the sequence of events, but one of the earliest phases was probably the development of bladed, radiating crystals, which occur at right angles to the laminae. The crystals reach up to 3 mm in length and are up to 0.25 mm wide. Bundles of crystals form a series of fan-shaped structures, with some bundles cross-cutting adjacent bundles. Individual crystals cut across several laminae, suggesting that the crystals formed after deposition, but before the sediment became lithified. The margins of these bladed crystals tend to be irregular, being disrupted by the calcite mosaic.

The crystals forming the calcite mosaic are very granular in appearance and grain boundaries are poorly defined. The granular appearance may reflect the original nature of the sediment. Large patches of mosaic grains are in optical continuity, suggesting that a further phase of recrystallization has occurred.

Calcite veins cross-cut some columns and occur frequently in the interspaces. Patches of calcrete disrupt and replace some columns. Stylolites occur along some column margins.

COMPARISONS

This form is placed in *Pilbaria* Walter 1972 because of the distinctive development of niches and projections associated with columns that have smooth walls. *Pilbaria perplexa* has more distinctly defined laminae which are more continuous than those in *P. deverella* and the development of branching from projections occurs more frequently in *P. deverella*. *Pilbaria boetsapia* Bertrand-Sarfati and Eriksson 1977 is much larger than *P. deverella* and is characterized by lateral discontinuities within the columns, which are crossed by numerous laminations. *Pilbaria inzeriaformis* Bertrand-Sarfati and Eriksson 1977 has straighter and more regular columns, and has more bridges. Niches are not as deep or as complex as those in *P. deverella* and projections sometimes extend beyond the main column width.

Nordia laplandica Krylov and Perttunen 1978 shows some similarity to *P. deverella* in the structure of the columns and in the manner of branching, but the columns are more tuberous, and show a well-developed widening before branching or developing projections. The microstructure appears to be more granulose than in *P. deverella*.

REMARKS

The radiating crystal fabric frequently observed in specimens of *Pilbaria perplexa* from Sweetwaters Well (NBR1), (also present in other forms from this and other localities), may well be pseudomorphs after gypsum crystals formed after the deposition of the laminae, but before lithification. The presence of such structures suggests a shallow water, evaporitic environment.

DISTRIBUTION

Upper part of the Yelma Formation near Sweetwaters Well; and a dolomite unit in the Frere Formation near Simpson Well.

Group WINDIDDA new group

1976 *Minjaria* Preiss p. 17 not *Minjaria* Krylov 1962

1976 *Tungussia* Preiss p. 22 not *Tungussia* Semikhatov 1962

TYPE FORM: *Minjaria granulosa* (Preiss 1976)

DERIVATION OF NAME: (noun, fem.) after the Windidda Formation in which the form occurs.

DIAGNOSIS: A fairly large stromatolite with tungussiform branching near the base, developing into smooth straight columns with a thick multilaminate wall. The microstructure is granular, particularly in the centre of the column, with wispy, very thin, dark laminae occurring only near column margins.

CONTENT: *Windidda granulosa* only.

REMARKS: The new group *Windidda* is proposed to include stromatolites previously described by Preiss (1976a) as *Minjaria granulosa* and *Tungussia heterostroma*. Preiss (1976a, p. 17) mentioned the similarity in microstructure between these two forms and commented "that this could indicate that they are parts of composite bioherms." After examination of type material and of new material from the type locality, it is concluded that all the specimens belong to a single form, to which the name *granulosa* Preiss (which has page priority over *heterostroma* Preiss) should be given. This form combines features of both *Tungussia* and *Minjaria*, and has some features not commonly observed in either.

The group *Minjaria* was erected by Krylov (1962) in an unpublished thesis, although a description was not published by him until a year later (Krylov, 1963). In the meantime the description, with minor variations, together with a description of the type form had been published by Semikhatov (1962) and this constitutes the first valid publication under the rules of the Botanical Code of Nomenclature. Krylov (1976) in a footnote refers to *Minjaria* and several other groups affected by this problem of priority, stating that:

"Inasmuch as references to these groups had appeared in publications before this paper (Krylov, 1963) came into print (Semikhatov, 1962), it has been accepted in the Soviet literature that the data were published in 1962, when the summary of Krylov's dissertation was published."

Although adoption of this procedure is contrary to the Botanical Code, it has been followed by other authors (Walter, 1972; Preiss, 1976a). It is probably necessary to seek a ruling to clarify the matter, as the status of the holotype is not clear.

The specimens illustrated by Preiss (1976a, Figs 15a-d and j-o) all have bumpy walls and rare peaks. Bumpy walls, peaks and bridges are also present in the new GSWA material. Semikhatov (1962) desribes rare peaks and bridges for *Minjaria*, but this is refuted by Krylov (1963), who claims that the walls of *Minjaria* are smooth and have no peaks or cornices. A multilaminate wall is present in the type form (Semikhatov, 1962; Krylov, 1963) but it is not clear how many laminae are involved in its formation. The very distinctive wall in *Windidda granulosa* may be up to 5 mm in thickness. This wall is apparently thicker and more persistent than in *Minjaria*. The new group *Windidda* is therefore distinguished from *Minjaria* by having widely divergent branching at the base, by the presence of a very thick multilaminate wall and by the presence of peaks.

The basal part of *Windidda* resembles *Tungussia* Semikhatov (1962), in its manner of branching and in having bumpy and tuberous column margins, but a thick, multilaminate wall is not characteristic of *Tungussia*, where only a few laminae form an impersistent wall. The very distinctive microstructure is also different from the streaky microstructure of *Tungussia*.

Windidda resembles *Tesca* Walter (*in* Walter and others, 1979) in having a rather variable branching pattern and a multilaminate wall. The wall in *Tesca* is less continuous and the wavy, banded laminae and filamentous microstructure of *Tesca* are quite different from the differentiated microstructure of *Windidda*.

DISTRIBUTION AND AGE: Windidda Formation, Earaheedy Group, Nabberu Basin, Western Australia. Age approximately 1.7 b.y. old.

Windidda granulosa (Preiss 1976) new combination
(Plates 24 and 25, Fig. 25)

1976a *Minjaria granulosa* Preiss p. 17, 18, Figs 15j-o, 18, 29, 30, 47, 49.

1976a *Tungussia heterostroma* Preiss p. 22, 24, 26, Figs 11, 15a-e, 18, 34, 35, 53-57 (in part).

MATERIAL

Holotype—*Minjaria granulosa* Preiss 1976, CPC 16527 (field no. S.5) collected from RBR1 (Mount Elisabeth) by M. J. Jackson, Bureau of Mineral Resources (Preiss, 1976a).

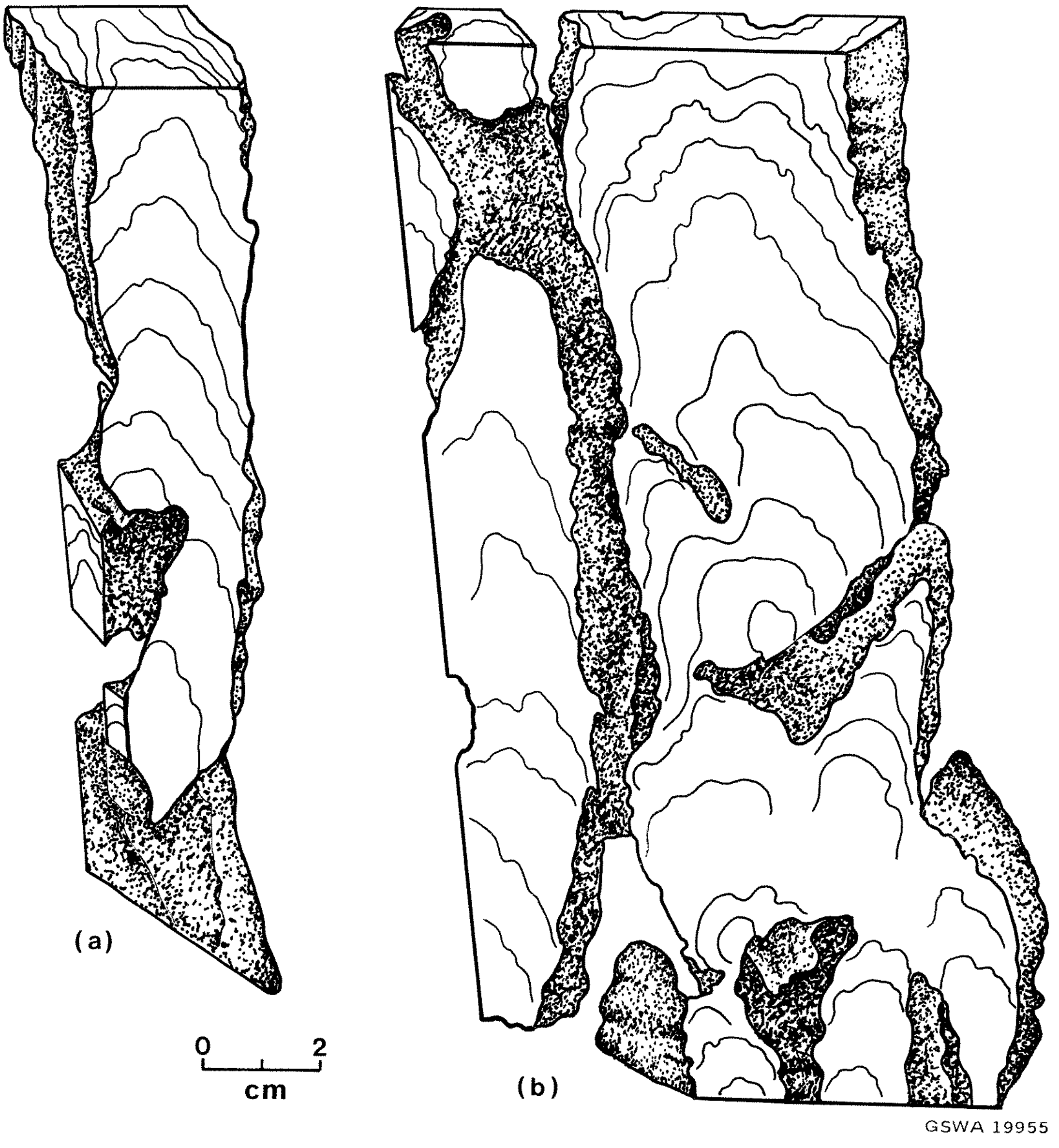
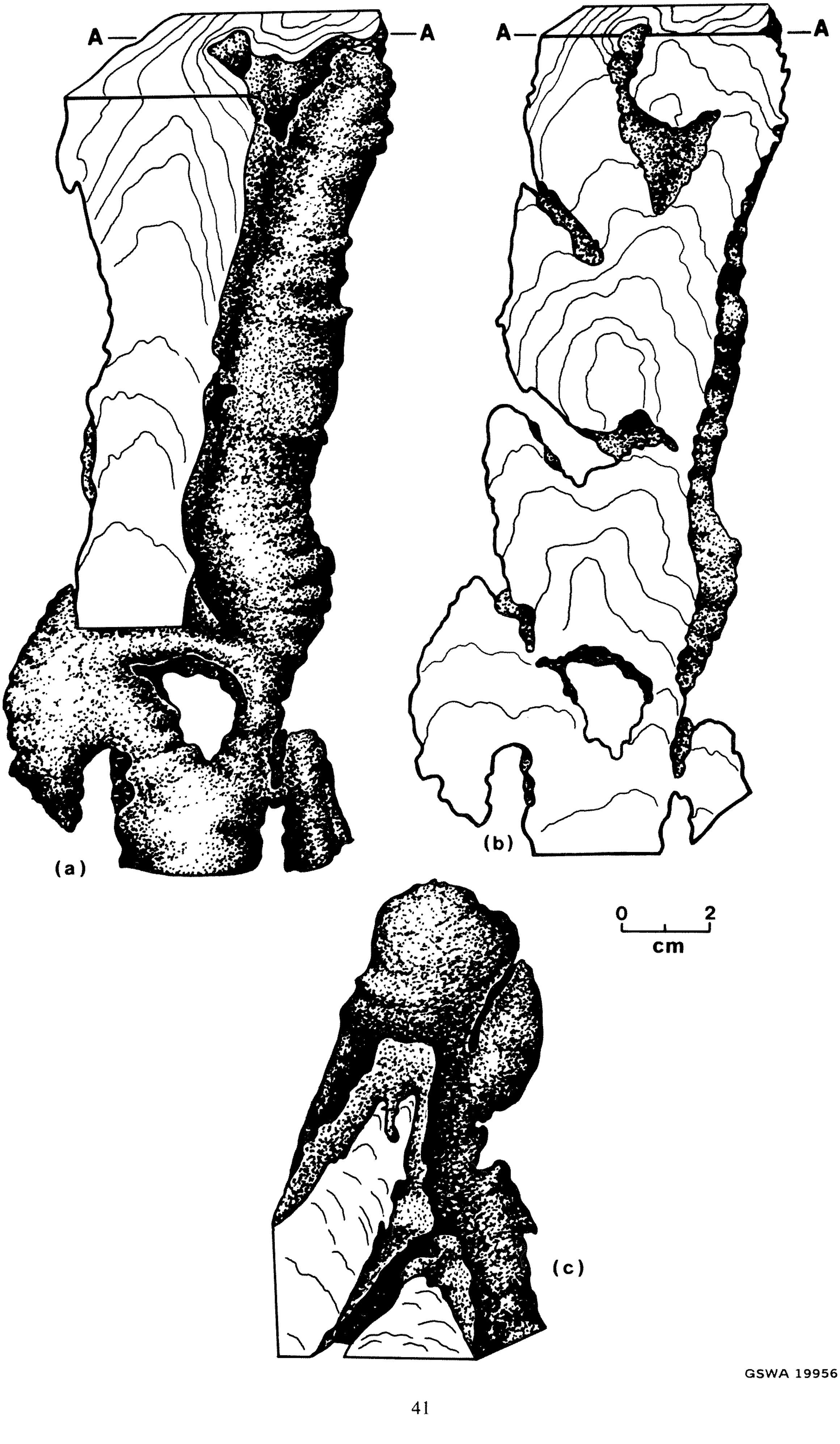


Figure 22. ***Pilbaria deverella*****, Yelma Formation. Serial reconstructions of the Holotype, F12374. (a) Single column showing lamina profiles, (b) different part of same specimen showing niches.**

Figure 23. ***Pilbaria deverella*****, Yelma Formation. Serial reconstructions and a) and b) the Holotype F12374, the same specimen shown in Fig. 22, viewed from different angles to show niche-development and c) F12376, showing development of projections.** ►



A — —A
A— —A
(a)
(b)
0 2
cm
(c)
GSWA 19956

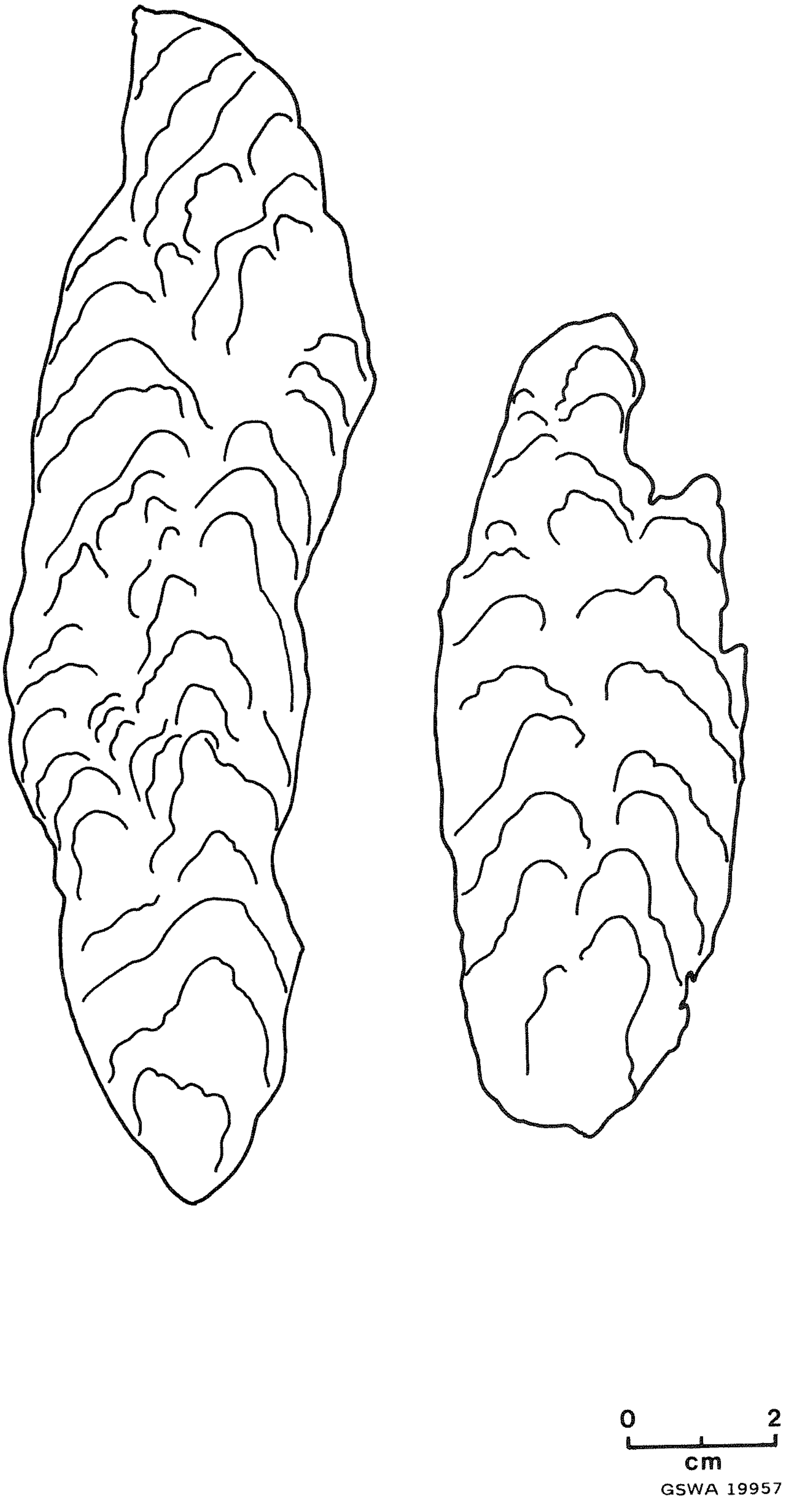


Figure 24. ***Pilbaria deverella*****, Yelma Formation. Lamina profiles drawn from two polished slabs of F12378.**

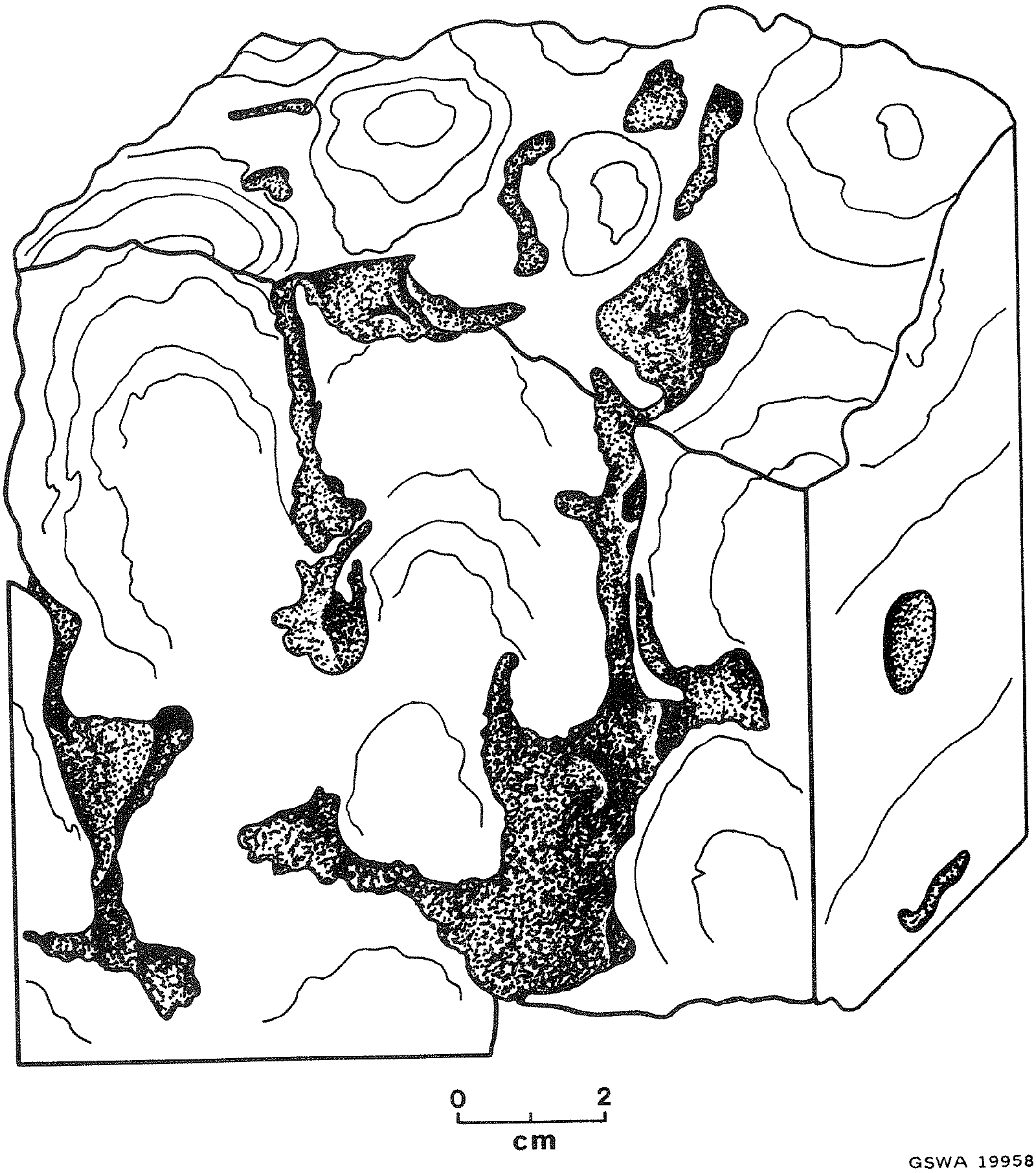


Figure 25. ***Windidda granulosa*****, Windidda Formation. Serial reconstruction of F46598 showing development of "*****Tungussia heterostroma*****" (Preiss) at the right hand side and two columns of "*****Minjaria granulosa*****" (Preiss) on the left front face.**

Paratypes—*Tungussia heterostroma* Preiss 1976, CPC 16524 and CPC 16525 (field nos S.2 and S.3) collected by M. J. Jackson from the same locality (RBR1) as the specimen of *Minjaria granulosa* (see Preiss, 1976a, p. 9, 17, 22).

Other Material—F12380 and F12381 collected from RBR1 by J. Bunting. As far as can be determined these samples are from the same locality as those collected by Jackson (J. Bunting, pers. comm., 1979).

DIAGNOSIS:

As for the group. The diagnosis of Preiss (1976a, p. 16) defines the form *granulosa* on the basis of its laterally differentiated microstructure. The diagnosis is here emended to include the branching pattern which consists of widely divergent branches near the base of the fascicle that develop into straight vertical columns.

DESCRIPTION

OUTCROP: Few details of the outcrop are available. Preiss (1976a) mentions that the stromatolites occur at only one stratigraphic level in a bed that can be traced for about 1 km and is composed of glauconitic sandstone, siltstone, shale and stromatolitic carbonate. A pale grey to blue, vaguely laminated limestone with fluted weathering surfaces overlies darker-coloured stromatolitic dolomites.

The following additional information was supplied by J. Bunting (pers. comm., 1979). "The stromatolites occur in domed structures 5 to 20 m across, which have an east-west elongation. Individual columns are poorly exposed. The columns are branching and are circular in plan section and measure 3 to 10 cm in diameter. Some larger columns are merged and may be 10 to 20 cm across. Sample F12380 is from the centre of a dome. Sample F12381 is from 1 km to the west at the same horizon".

MODE OF OCCURRENCE: Information about the field relationships of the various samples is sparse, but sample F12380, from the centre of a dome, contains a large column which shows similarities to *Tungussia heterostroma* and smaller columns which are smooth and straight like *Minjaria granulosa*. Serial reconstruction reveals that all these columns are part of a single fascicle. The spatial relationships of such fascicles are not known, and further field work is required to determine whether the domed bioherms are composed of more than one fascicle. Preiss (1976a, Figs 3 and 11) illustrated *Tungussia heterostroma* in the outcrop at Mount Elisabeth. Narrow, straight, parallel columns near the top of the stromatolitic bed can be clearly seen. In Figure 11 the narrower columns develop from broader, slightly more divergent columns. The angles of radiation of the columns in Figure 11 suggest that at least two fascicles, and possibly three, are present.

FASCICLE MORPHOLOGY: No direct evidence of the shape of individual fascicles is available, but from the descriptions and illustrations of Preiss (1976a), the field notes of J. Bunting and the two new samples, the following reconstruction can be made.

The fascicles begin as broad domes with pseudocolumnar structures, which rapidly develop into "broad bulbous, markedly tuberous and bumpy ... [columns which] are variously oriented relative to the bedding .... Branching [of the columns] is multiple, varying from parallel to markedly divergent, frequently giving rise to inclined and almost horizontal columns, but parallelism of the columns is attained in the upper parts of the bed." (Preiss, 1976a, p. 22). These columns become "even, vertical, parallel, subcylindrical and of rather uniform diameter." (Preiss, 1976a, p. 17). Branches show relatively wide spacing. Synoptic relief is in the order of two or three centimetres and the serial development shows a high degree of inheritance.

BRANCHING HABIT: Column branching is multifurcate, and widely divergent in the basal part of the fascicle, and dichotomous and parallel in the uppert part of the fascicle. Branching is only moderately frequent and is largely of alpha type or more rarely of beta type.

COLUMN SHAPE AND MARGIN STRUCTURE: The column shape and margin structures have been adequately described by Preiss (1976a, p. 17 and p. 22). The bumpy margin is particularly well developed in sample F12380 where the multilaminate wall forms a scalloped margin to the column.

LAMINA SHAPE: as described by Preiss (1976a, p. 17 and p. 22).

MICROSTRUCTURE AND TEXTURE: Preiss (1976a, p. 17) commented on the similarity of microstructure in *Minjaria granulosa* and *Tungussia heterostroma*. The two samples examined in this study are both of ferroan dolomite. Little can be added to the detailed descriptions already given (Preiss, 1976a, p. 17, 18 and p. 22, 24).

INTERSPACE FILLING: The interspaces are filled, as in the holotype, with dolomitic packstone or grainstone (see Preiss, 1976a, p. 18 and 24).

SECONDARY ALTERATION: For details see Preiss (1976a, p. 18 and p. 24)

REMARKS:

Preiss (1976a) described two forms from the locality at Mount Elisabeth, *Minjaria granulosa* and *Tungussia heterostroma* based on their different gross morphology and uncertain spatial relationship, although he remarked on the similarity of their microstructure. One of the features which Preiss considered to be a part of *Tungussia heterostroma* is that "At certain levels, short, narrow, projection-like columns with numerous bridges, are developed overlying the basal columns." [In these] "upper small columns, the laminae are finely banded," and the detailed microstructure (Preiss, 1976a, p. 24) is very different from that of the main part of the column. Preiss mentioned that "in certain places, an interfingering relationship may be observed" between the two types of column, and that "this suggests that they were formed by mats of different algal composition ... ." These small finely banded columns are here considered to be part of the new form *Nabberubia toolooensis*. When these columns are excluded from *Tungussia heterostroma*, the only difference between it and *Minjaria granulosa* is the inclination of the columns. As has already been discussed, new material from the type locality indicates that straight columns (*Minjaria granulosa*) develop from highly inclined, widely divergent columns (*Tungussia heterostroma*) and form one fascicle, here named *Windidda granulosa*.

DISTRIBUTION

Windidda Formation at Mount Elisabeth.

Group YANDILLA new group

TYPE FORM: *Yandilla meekatharrensis* new form.

DERIVATION OF NAME: (noun, fem.) from nearby Yandil station.

DIAGNOSIS: Fan-shaped fascicle with slightly bent, irregular columns with patchy development of walls. Branching is slightly divergent in lower parts of columns, becoming parallel upwards. Branching by division into two, possibly three daughter columns. Short lateral columns may also be present. Small, irregular peaks and bumps with bridges in lower parts of columns. Vermiform microstructure.

CONTENT: *Yandilla meekatharrensis* only.

REMARKS: *Yandilla* shows some resemblance to *Kussoidella* Semikhatov 1978, but the columns of *Yandilla* are much broader and have patchy walls. The peaks and bumps are more irregular and the bridges are thinner than in *Kussoidella* and lateral branches are less common.

DISTRIBUTION AND AGE: *Yandilla meekatharrensis* new form occurs in the Yelma Formation, Earaheedy Group, Nabberu Basin, Western Australia. Age approximately 1.7 b.y.

Yandilla meekatharrensis new form

(Plates 26 and 27 , Figs 26 to 29)

MATERIAL

Holotype F12383 from GLG1.

Paratypes F12381, F12384, F12385, F12386, F12387 all from the type locality.

DERIVATION OF NAME

Meekatharrensis, the locality occurs in the Meekatharra District of the Murchison Goldfield.

DIAGNOSIS

As for group.

DESCRIPTION

OUTCROP: The stromatolites occur in the middle of a 30 m thick band of buff to grey dolomite, with medium to thick bedding, which is occasionally sparry and has poorly developed stromatolitic layering, except in the middle section where the stromatolites are columnar. The buff dolomite overlies a grey carbonate unit containing thin, grey, medium-grained arenite bands, and this in turn overlies a white arenite. The stromatolitic unit is overlain by more than 10 m of silcreted and lateritized chert derived from the carbonate (J. Bunting, pers. comm., 1979).

MODE OF OCCURRENCE: The nature of the stromatolite buildup is not clear from the available field observations, but could be a tabular or domed biostrome.

FASCICLE MORPHOLOGY: Samples available do not comprise complete fascicles and the basal structure cannot be determined with certainty. However, from Bunting's field sketches it seems that the fascicle develops as a single vertical column from a stratiform layer and branches rapidly close to the column base. Fascicles are generally fan shaped with broad tops to the columns.

BRANCHING HABIT: Branching is by division into two, or occasionally three branches, which may be slightly divergent in the lower parts, but become parallel in the upper parts. Branching is infrequent and occurs most commonly near the base of the fascicle. In addition to branching by bifurcation, short lateral branches also occur.

COLUMN SHAPE AND MARGIN STRUCTURE: Columns show considerable variability in shape with pinch and swell structures. Near the base of the fascicle they widen upwards. After branching the columns have a more subcylindrical shape. The columns may be up to 10 cm in diameter before branching and usually range from 3 to 5 cm in diameter after branching. The columns may be at least 20 cm in height. Most columns are fairly slender and erect although some columns may be sinuous. Interspaces are from 1 to 3 cm wide between columns within a fascicle, but details of fascicle spacing could not be determined from the material available. In plan outline columns are irregular, elongate or lobate.

Column margins are ragged and uneven with numerous small bumps and peaks and some bridging. The margins have been considerably altered by recrystallization. Laminae are poorly defined towards the column margin, but those that can be distinguished are sharply deflected approximately 2 mm from the margin and extend for approximately 2 to 3 mm down the margins of the column to form a poorly defined and impersistent wall. Not all laminae are deflected in this manner, some terminate abruptly, or have rounded terminations and give rise to the peaks and nodules which comprise the wall ornament. These features protrude only 1 to 2 mm beyond the column margin and are usually only 1 mm in width. Bridges are 2-3 mm in thickness.

LAMINA SHAPE: The laminae show variability of convexity throughout the column, ranging from flat to gently convex. Frequently the convexity is more pronounced near the base of the column The laminae are irregular and wrinkled. Upper and lower boundaries of individual laminae are poorly defined and lamina thickness is variable, with light laminae approximately 1 mm in thickness and dark laminae 0.5 mm or less. Some dark laminae are stylolitized The pigmentation associated with the dark laminae is more noticeable towards the column margins.

MICROSTRUCTURE AND TEXTURE: The primary microstructure is difficult to determine because of secondary alteration, but is streaky to vermiform in the better preserved patches and consists of alternating light and dark types. The dark laminae range from 200 to 1 000 µm in thickness and the thickness may vary considerably along their length, often with diffuse boundaries. Light laminae vary in thickness from 400 to 1 000 µm and many are lenticular. Both light and dark laminae are composed of idiotopic carbonate with a grain size of between 30 and 90 µm.

INTERSPACE FILLING: This consists of recrystallized, unlaminated carbonate of idiotopic grains, with the size range of 10 to 40 µm.

SECONDARY ALTERATION: Dolomitization has been extensive and many of the primary features in both the columns and the interspaces have been destroyed. Stylolites occur along some column margins and are also commonly found parallel to the laminae.

COMPARISONS

Yandilla meekatharrensis differs from other forms in the Earaheedy Group in its branching pattern and presence of a vermiform microstructure.

DISTRIBUTION

Yandilla meekatharrensis occurs in the Yelma Formation near Crystal Well.

Group YELMA new group

TYPE FORM: *Yelma digitata* new form

DERIVATION OF NAME: (noun, fem.) after the Yelma Formation in which the form occurs.

DIAGNOSIS: Branching, columnar stromatolites forming small bushy fascicles with erect, slender, subparallel, closely spaced columns, and beta-style branching. Columns arise from a domed base. Branching into two or more columns of equal width is common, but small, tapering daughter-columns may arise laterally from the main columns. Wall structures are only patchily developed; column margins are scalloped or bumpy. Laminae can be almost flat, but are more commonly rounded convex and are often wavy. The microstructure is banded and shows a cyclic development of laminae.

CONTENT: *Yelma digitata* only

REMARKS: Small digitate stromatolites similar to *Yelma* have been illustrated by several authors (Donaldson, 1963, Pl. IVA, V; Hoffman, 1974, Fig. 9; 1975, Fig. 30.12; 1976, Fig. 5c; Hofmann, 1977, Fig. 11; Zhu and others, 1978, Fig. 5 and Semikhatov, 1978a, Pl. XIII). Systematic descriptions have not been published for the majority of the specimens illustrated, the main exceptions being *Asperia* Semikhatov 1978, *Parmites* Raaben 1964, *Kotuikania* Komar 1961 and *Anabaria* Komar 1964 which also have some characteristics in common with *Yelma*. Detailed comparison of the various groups presents some dificulties because information about such features as the microstructure and gross morphology is inadequate in some descriptions. Nevertheless there appear to be distinctions between *Yelma* and these other forms which are of sufficient significance to justify the erection of a new group.

Parmites resembles *Yelma* in having columns which develop from a domed base and laminae which can be traced across several columns. However, both the columns and the interspaces are wider and more irregular in *Parmites* and the columns are more divergent. No details of the microstructure have been illustrated, however specimens labelled '*Parmites aimica*' and '*Parmites concrescens*' in the collection of M. R. Walter and a specimen labelled '*Parmites*' in the collection of W. V. Preiss all have finer laminations than *Yelma digitata*.

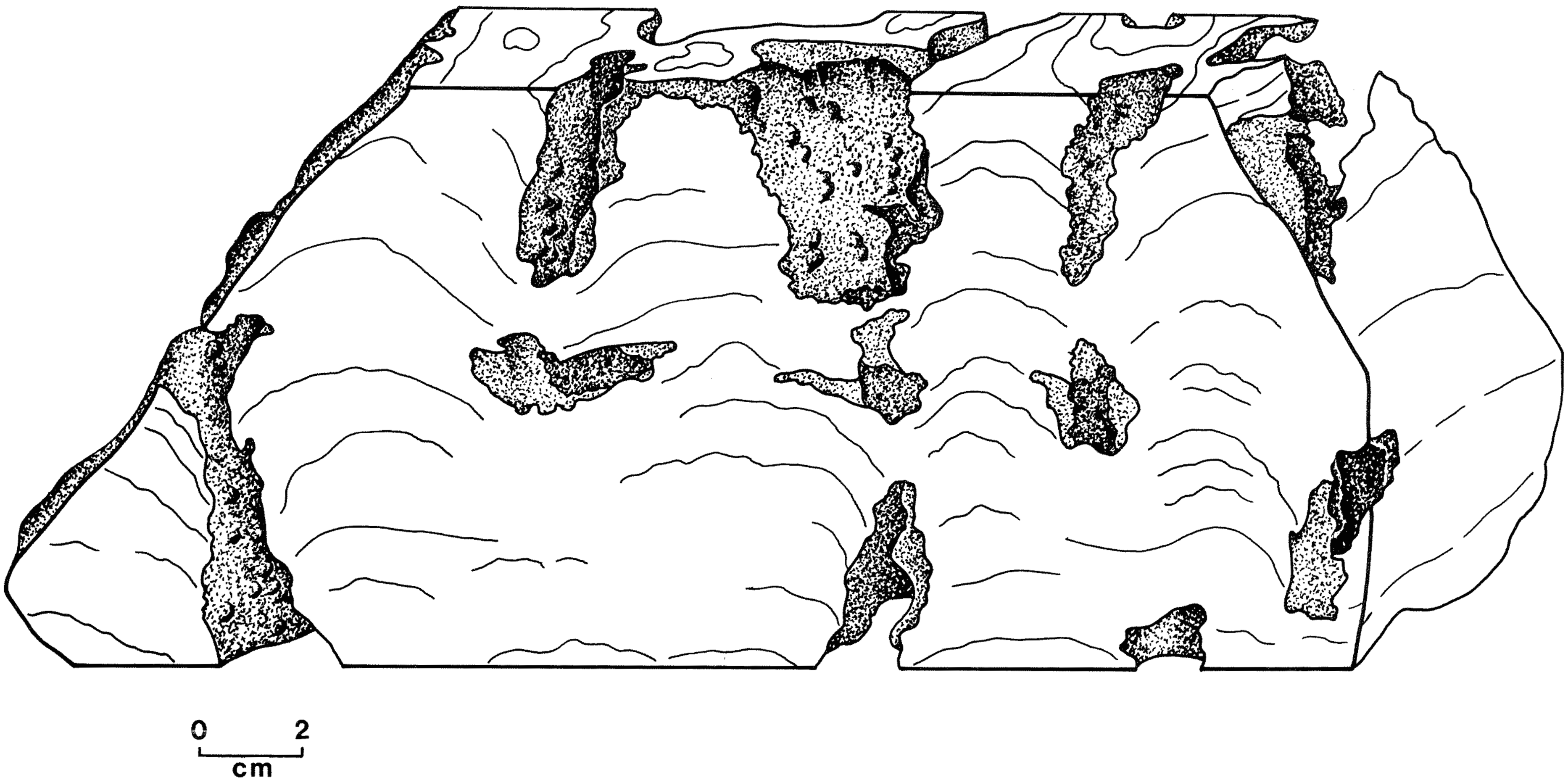
Both *Yelma* and *Kotuikania* show some similarities in branching pattern, however *Kotuikania* has a multilaminate wall, smooth lateral margins with reniform swellings and has markedly divergent branching in its basal parts, features not found in *Yelma*. In *Yelma* the microstructure is of a cyclic, banded type, whereas that of *Kotuikania* tends to be filmy.

Anabaria Komar occurs "in the shape of a compound branching bush with fan-shaped, divergent columns. The angle of divergence of the columns from the point of branching is acute . . ." (translated from Komar, 1966). The branching pattern of *Yelma* shows some similarity to that of *Anabaria*, but differs in that branches in *Anabaria* apparently develop by the division of a single column, rather than from a broad, bulbous base as in *Yelma*; the branching of *Anabaria* tends to be by bifurcation, whereas in *Yelma* the branches may be multifurcate as well as bifurcate and may also develop laterally. The width of the columns is much less and the columns are more crowded in *Yelma* than in *Anabaria*.

Lenia Dolnik (*in* Dolnik and Vorontsova, 1971) has daughter columns developing at the side of main branches, irregular column margins and a banded microstructure similar to that of *Yelma*. It differs from *Yelma* in having less-frequent branching, a distinctive selvage and in places a multilaminate wall, very distinctive canals and a microstructure containing oncolites. It may also have more sharply curved laminae than in *Yelma*, but this is difficult to determine from Dolnik's illustrations.

Several authors have illustrated (and in some cases informally named) but not described small digitate structures, including stromatolites from the Denault Formation, Marion Lake area of the Labrador Trough, Canada (Donaldson, 1963, Pl. IVa and V); from the Utsingi Formation of the Douglas Peninsula in the Slave Craton of Canada (Hoffman, 1974, Fig. 9); in the Rocknest Formation of the Coronation Geosyncline, Canada (Hoffman, 1975, Fig. 30.12, Hoffman, 1976, Fig. 5C; Hoffman informally named this stromatolite *Alenia*, presumably a misprint for *Lenia*); and in the McLeary Formation, Belcher Supergroup, Hudson Bay, Canada (Hofmann, 1977, Figs 11, 16. Hofmann informally named this stromatolite *Lenia* and suggested comparison with Donaldson's (1963, Pl. IV and V) 'digitate stromatolites', from the Denault Formation, but did not discuss its relationship to the other Canadian digitate forms).

Semikhatov (1978a, p. 120) erected the group *Asperia* for the digitate forms from the Rocknest Formation and placed the digitate forms from the Denault Formation into synonomy. He also considered specimens from the Belcher Group and from



GSWA 19959

Figure 26. ***Yandilla meekatharrensis*, Yelma Formation. Serial reconstruction of the Holotype F12383. Reconstruction of column margins is not precise because of recrystallization.**

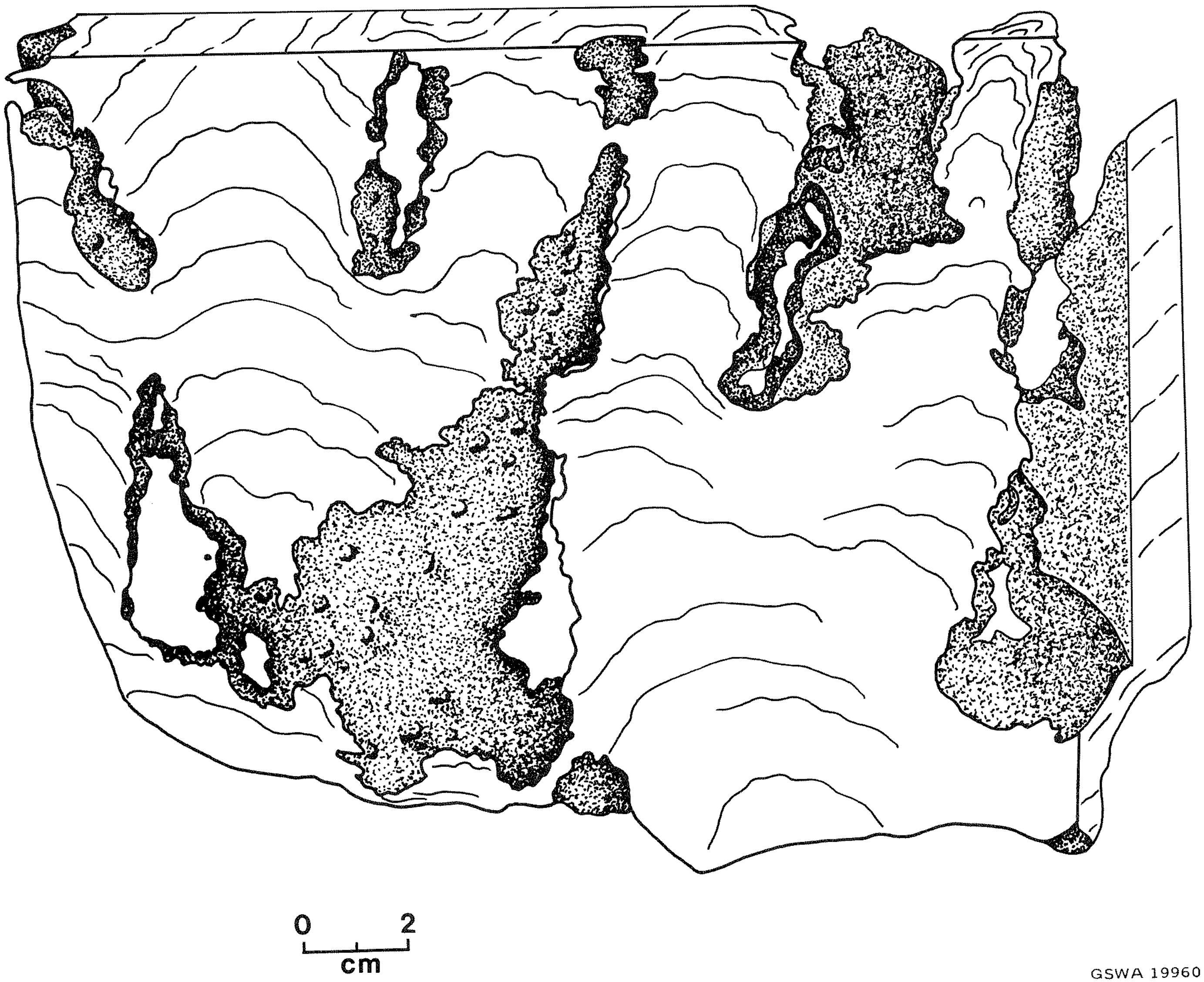


Figure 27. ***Yandilla meekatharrensis*****, Yelma Formation. Serial reconstruction of F12382. Reconstruction of column margins is not precise because of recrystallization.**

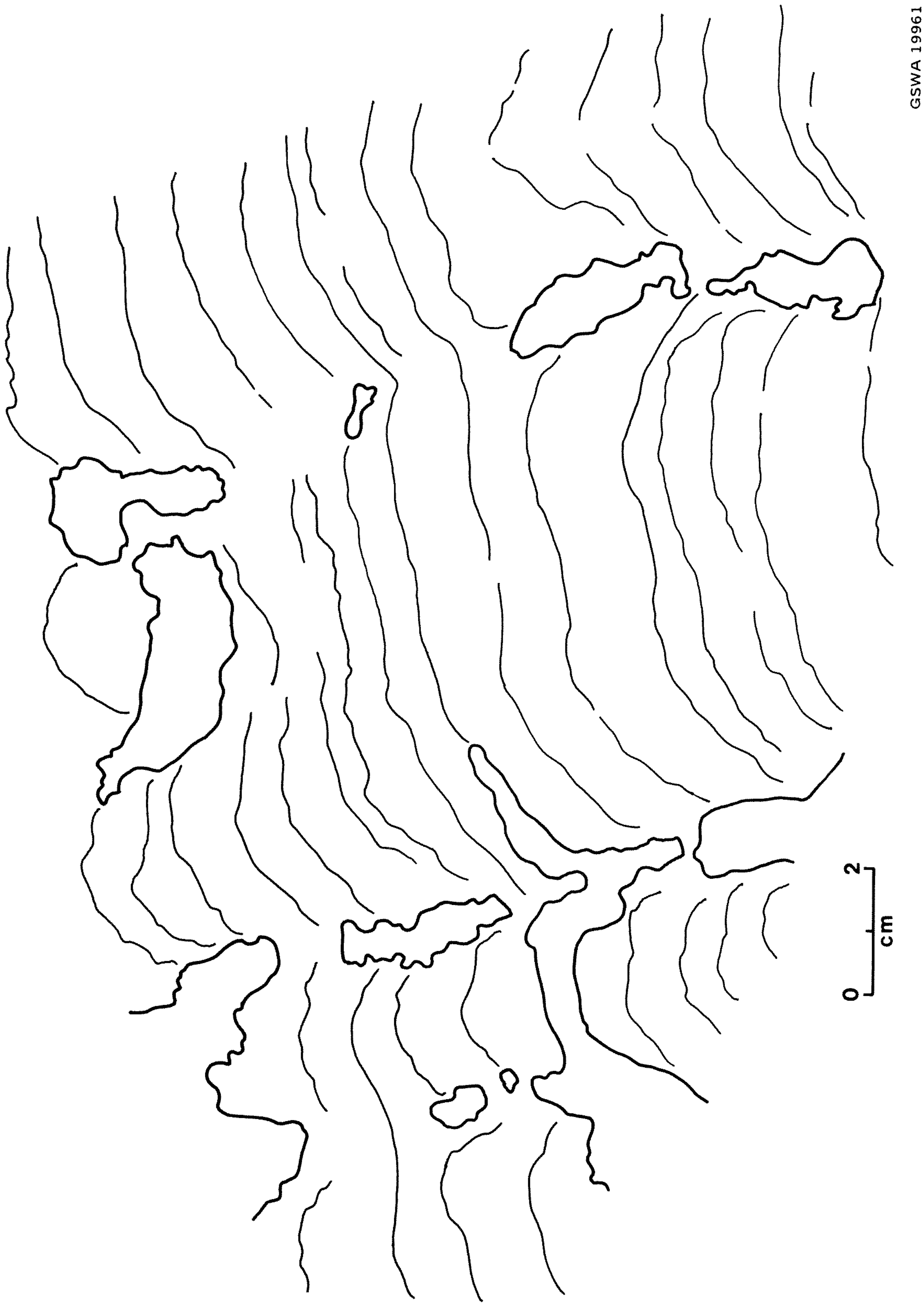


Figure 28. ***Yandilla meekatharrensis*, Yelma Formation. Lamina profiles of F12384.**

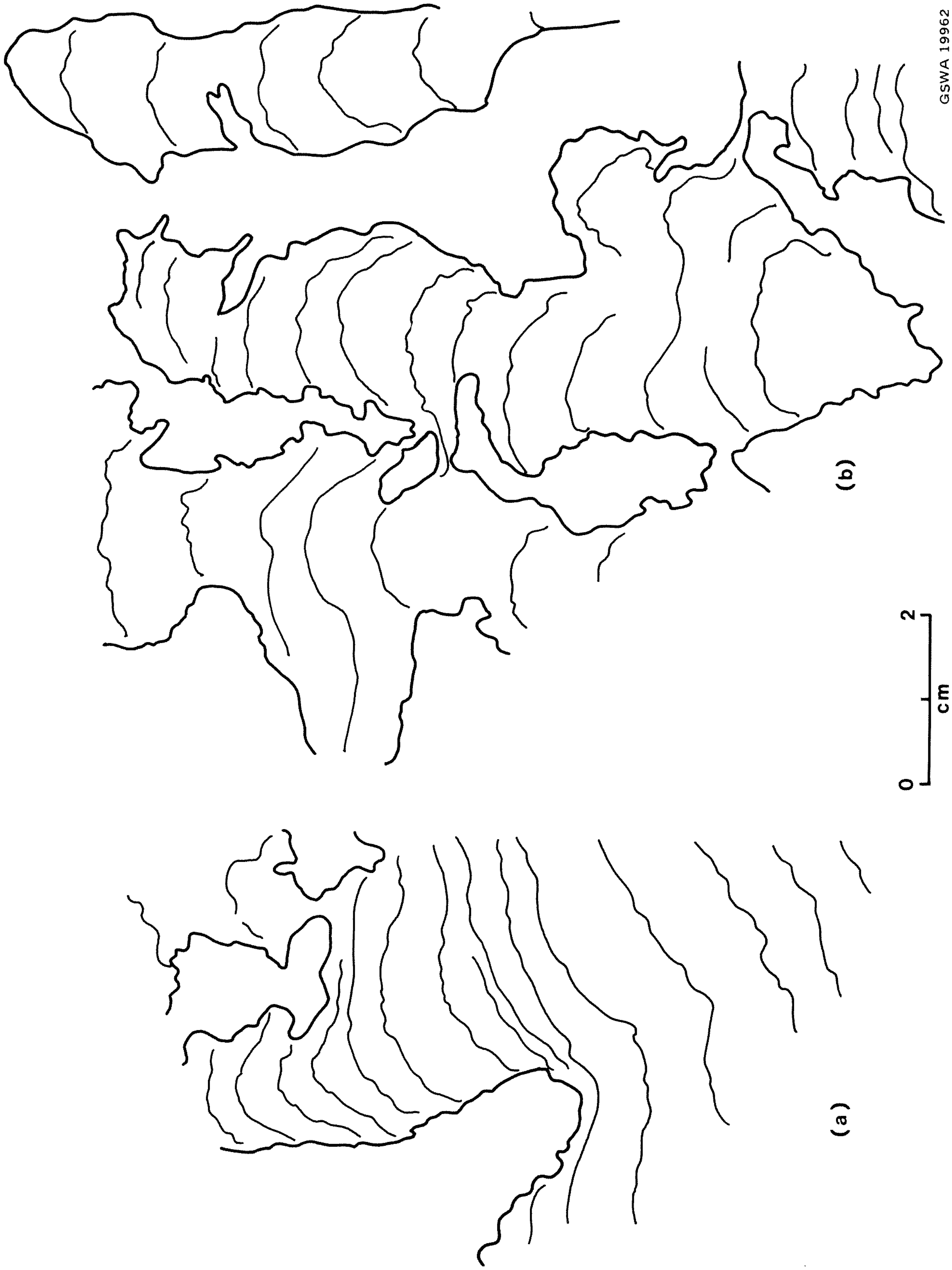


Figure 29. *Yandilla meekatharrensis,* Yelma Formation. Lamina profiles of (a) F12385 and (b) F12386.

Afghanistan to belong in *Asperia*. *Yelma* and *Asperia* have many features in common, but can be dinstinguished by the larger size of the columns of *Asperia* (3 to 8 mm in diameter, 10 to 30 mm in height, compared with 3 to 5 mm in diameter and 10 to 15 mm in height for *Yelma*). Semikhatov did not illustrate any serial reconstructions of *Asperia* but from the samples illustrated by Donaldson (1963) and Hofmann (1977), which I have examined, *Asperia* does not form the compact, fastigiate fascicles arising from a domical base, which are typical of *Yelma*, but has columns which arise directly from the substrate, or from a few millimetres of stratiform stromatolites. The branches in *Yelma* are slightly more divergent than in *Asperia*. In *Asperia* the laminations are much flatter than in *Yelma* and are not as wrinkled. Three types of laminae can be recognized in *Yelma*, whereas there are only two in *Asperia*, and they are only about half as thick as those in *Yelma*.

Semikhatov (1978, p. 122) comments on the similarity of the microstructure between *Asperia aspera* and *Stratifera laxa* Semikhatov 1978. He also states that they are both parts of " . . . . single biostromes and are connected vertically by inter-transitions." In my opinion it is unnecessary to give two binomials to such a structure which appears to consist only of growth variations. However, I would prefer to examine the type material before combining the two forms.

Another form showing some similarities to *Yelma* is the specimen of *Pseudogymnosolen epiphytum* Zhao and others (*in* T.I.G.M.R. and others, 1979) from Chihsien [Jixian] County, North China, illustrated by Zhu and others (1978, Pl. II, Fig. 5). I have been unable to obtain the diagnosis of this form, but from the illustration in Zhu and others, it differs from *Yelma* in having longer, straighter columns, and a finer microstructure with flatter laminations. According to Chen Jinbiao and others (1981) *Pseudogymnosolen* occurs in the basal part of the Wumishan Formation, Jixian System and is slightly younger than 1400 m.y.

A digitate specimen in the collection of the bureau of Mineral Resources (BMR F 24045) labelled as "stromatolite sp. 10" presented by Vlasov from the Satkin Suite of the USSR appears to be very similar to *Pseudogymnosolen*, having the same long, narrow columns and very fine laminations.

Katernia Cloud and Semikhatov 1969, consisting of two forms—*africana* Cloud and Semikhatov 1969 and *perlina* Bertrand-Sarfati and Eriksson 1977—has a more divergent and frequent branching pattern than that which occurs in *Yelma*. These differences are most noticeable in the type form *Katernia africana*, which is much larger than *Yelma digitata*, and in which the column width increases upwards, and which has a filmy microstructure rather than the banded microstructure of *Yelma*. *Katernia perlina* is more like *Yelma* in having relatively straight, elongate columns of fairly uniform width. These similarities suggest that *perlina* and *digitata* may belong in the same group, but differences occur in the shape of the laminae (which become steeply convex in *perlina* and do not show the overlapping which is characteristic of *digitata*). Examination of type material would be necessary to confirm the transfer of *perlina* to the group *Yelma*.

Small digitate stromatolites from the Koolpin Formation, Pine Creek Geosyncline, referred to by Walter (1972, p. 84) differ from *Yelma* in having a smaller-sized fascicle and widely divergent branching. These stromatolites were reported to be similar to *Katernia perlina* Bertrand-Sarfati and Ericksson 1977, by Crick and others (1980).

Distinctions between the various kinds of small digitate stromatolites are difficult to make, particularly in the case of those which have been only briefly described and poorly illustrated. The characteristics of probable significance are the dimensions of the columns, the shape of the laminae and the nature of the microstructure. As can be seen from Figure 8, the subtle variations between the various small digitate groups and forms may be of significance in biostratigraphy and a careful evaluation of the systematics and taxonomy of these forms is indicated.

DISTRIBUTION AND AGE: At several localities in the Yelma and Frere Formations, Earaheedy Group, Nabberu Basin, Western Australia. Age approximately 1.7 b.y. old.

Yelma digitata new form
(Plates 31 to 36, Fig. 30)

MATERIAL

Holotype F12390 from NBR1, lower horizon.

Paratypes F12388, F12389, F12391, F12392, F12393 all from the type locality. F12394, F12395 and F12396 from PKH2. F12397 from PKH4.

DERIVATION OF NAME

Digitata is from the latin word *digitatus*, which means "having fingers", a reference to the distinctive mode of branching of this form.

DIAGNOSIS

As for the group.

DESCRIPTION

OUTCROPS: *Yelma digitata* occurs near Sweetwaters Well at several horizons in a dolomite on the shore of Lake Nabberu. The lower horizon is the best exposed, and extends for approximately 400 m in length, although its full extent is not known. It is approximately 30 cm thick and lies about 1 m above a small rocky outcrop containing *Murgurra nabberuensis* which occurs in the lake bed.

Several other horizons containing *Yelma digitata* occur in a cyclic sequence for approximately 20 m above the first and each underlies a unit containing *Pilbaria deverella*. The precise extent of the units is not known, because of the rubbly nature of the outcrop, but each unit probably has a minimum thickness of 20 cm. In some of the higher horizons, the surface of the outcrop has been deeply weathered and individual columns protrude from the rock surface. At least three and probably more, cycles are present. Each cycle consists of stratiform dolomite, sometimes with large domes, overlain by *Pilbaria perplexa*, then *Yelma digitata* and finally a flat-laminated dolomite horizon, sometimes with mud cracks.

MODE OF OCCURRENCE: In the lower horizon, the stromatolites occur either as a mass of closely spaced, bushy, interlocking fascicles, or as smaller, widely spaced, individual fascicles. These isolated fascicles probably occur around the margins of a large stromatolite buildup, probably a lenticular bioherm. Within this lower horizon two growth phases of the fascicles can be recognized, although these phases are difficult to identify near the centre of the bioherm where the fascicles are closely packed. The base of the carbonate unit consists of 6 to 10 cm of yellow-brown dolomite with large pink patches. Some stratiform or gently undulating laminae are present but are poorly preserved and stylolites are common. Many fascicles begin as small bulbous structures within the lower part of the dolomitic layer. A yellow and grey, banded dolomite about 10 cm in thickness overlies the lower layer. In this horizon the greatest development of fascicles occurs. The bulbous structures develop into slightly domed laminae and then divide into thin, tapering columns. The interstitial material between individual fascicles consists of numerous, stratiform laminae. Approximately 10 cm above the base of this lower band of fascicles is a major stylolitized horizon. Many of the fascicles continue above this horizon, often for 5 cm or more. A second band of somewhat smaller fascicles occurs a few millimetres above the stylolitized horizon in the interspaces between the pre-existing ones. The carbonate unit containing the second growth-phase is similar in lithology to the main part of the unit and is approximately 5 to 10 cm thick.

In some of the upper horizons the columns are slightly larger than those from the lower horizon and are subparallel and gently inclined. The columns are very closely crowded. Only one growth-phase can be recognized. The closely spaced, inclined columns probably indicate the peripheral part of a large tabular or lenticular biostrome.

FASCICLE MORPHOLOGY: The morphology of the fascicles shows little variation other than an increase in column spacing with increasing distance from the centre of the stromatolite buildup. Individual fascicles have a rounded cross-section and may be from 20 to 25 cm in height. They widen fairly rapidly from the base, reaching a maximum diameter of 5 to 10 cm between 7 and 10 cm above the base before tapering gradually, usually by the thinning out of lateral branches (fastigiate). Only a few centre columns form the top of the fascicle. Each fascicle is composed of slightly diverging, contiguous or closely spaced columns formed by laminae with a low synoptic relief.

BRANCHING HABIT: Branching is multifurcate or occasionally bifurcate and may be by division of a column into daughter-columns of equal width, or by the development of slightly narrower, lateral daughter-columns. Branches are parallel near the centre of the fascicle, becoming slightly divergent towards the margins.

COLUMN SHAPE AND MARGIN STRUCTURE: Individual columns may be cylindrical, turbinate or terete. The outer branches are commonly terete and most branches have terete terminations. In plan most columns are rounded, although they may occasionally be crescentic or lobate. They are slender, erect and may show constringed growth towards the tops. Walls are patchily developed, one-lamina thick, and are formed by the downward growth of every

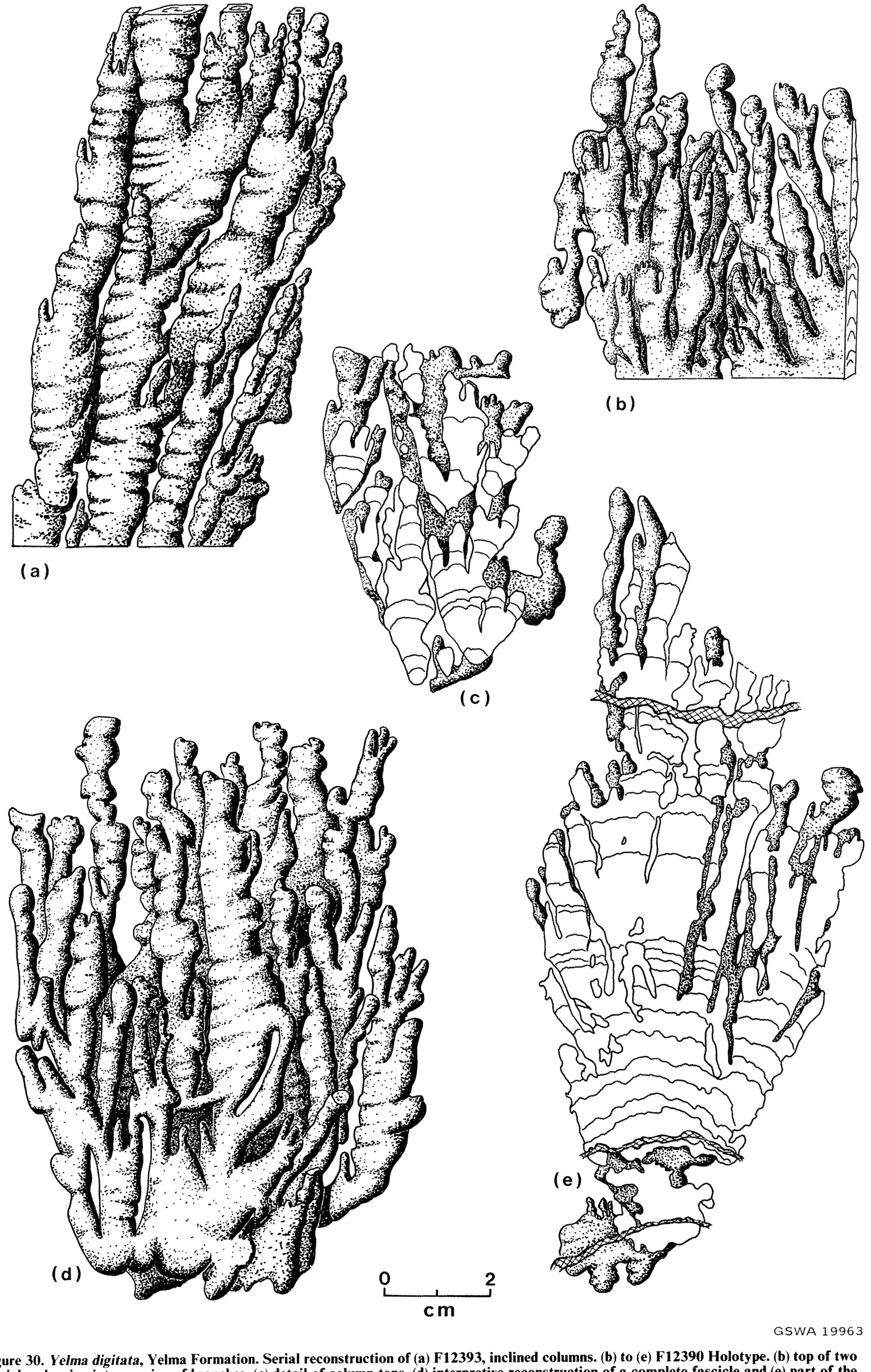


Figure 30. ***Yelma digitata*, Yelma Formation. Serial reconstruction of (a) F12393, inclined columns. (b) to (e) F12390 Holotype. (b) top of two fascicles showing interweaving of branches, (c) detail of column tops, (d) interpretive reconstruction of a complete fascicle and (e) part of the same fascicle showing lamina profiles.**

fourth or fifth dark lamina. The irregularities of the column margins appear more angular and resemble cornices or rugae in columns which have weathered out of the matrix. Columns are 10 to 15 cm in height and 3 to 5 mm in diameter.

LAMINA SHAPE: Lamina profiles range from almost flat to gently convex throughout most of the column. Those laminae involved in wall formation sometimes have a more steeply convex profile. The laminae are usually wavy, with wave lengths of up to 2 mm and wave height of approximately 0.5 mm. In the basal area of the fascicle large flexures occur for some distance before branching occurs. Individual laminae can be traced as a distinctive horizon across many adjacent columns. The serial development of the laminae shows a high degree of inheritance.

MICROSTRUCTURE AND TEXTURE: The microstructure is banded and three types of laminae (light, dark and very dark) can be recognized. Individual laminae are of fairly constant thickness and are continuous across the column, although they may thin slightly towards the margins. There is little difference between the three types of laminae except for the amount of pigment present. A relict texture at right angles to the laminae can be recognized in those parts of the columns which have not been severely affected by recrystallization.

Light laminae are generally thicker than the dark laminae and range in thickness from 70 to 230 μm with an average thickness of 150 μm.

Dark laminae have either diffuse boundaries or are bounded both at the top and bottom by thin, very dark laminae. The boundary between dark and very dark laminae is usually fairly distinct. The dark laminae are less variable in thickness than the light laminae and are usually thinner. They range in thickness from 60 to 150 μm with an average of 104 μm.

Very dark laminae are of two types: very thin, which form the top and bottom boundaries of dark laminae; and thicker laminae which usually occur between two light laminae, and frequently overlap the previous three or four laminae to form short walls. The margins of the very dark laminae are well defined, although somewhat irregular. The thin, marginal laminae are usually less than 100 μm, and are generally 30 to 70 μm in thickness. The wall-forming laminae are similar to the light laminae in thickness and range from 170 μm to 250 μm. Most laminae are between 170 and 190 μm in thickness.

Details of the original microstructure are difficult to determine because of extensive recrystallization, particularly in samples from the upper horizons. There is little variation in grain size between the various types of laminae. Most grains are probably of secondary origin but rare, rounded grains, 10 to 18 μm in diameter, which may be relicts of the primary texture, can occasionally be distinguished.

INTERSPACE FILLING: The interspaces are filled with banded dolomite consisting of micritic laminae less than 1 mm thick separated by sparry laminae. The interspace laminae frequently abut the column margins and in some cases are draped over column tops indicating accumulation after growth of that part of the column. Micritic laminae are yellow in colour and are separated by laminae composed of grains resembling those forming the laminae of the columns.

SECONDARY ALTERATION: Recrystallization has been extensive in the lowest horizon and these samples are formed by a coarse mosaic of inequigranular, polygonal, idiotopic carbonate grains which range from 14 to 40 μm in diameter. Many grains are rhombic and nearly all are probably of secondary origin. This mosaic may be an early diagenetic feature because details of the laminae are still relatively well preserved despite the recrystallization. Concordant and discordant patches of coarsely crystalline dolomite are also present both in the columns and the interspaces and are probably of later origin than the mosaic grains. Rare calcite veins cut across both of these textures. Stylolites are also present, although infrequent. They are parallel to the bedding and cut across columns or occasionally follow column margins. In the upper horizons large areas of the columns have been silicified and replaced with coarsely crystalline quartz.

COMPARISONS

Yelma digitata can be distinguished from other stromatolites in the Nabberu Basin by its small size and bushy habit. The upright branches distinguish it from *Murgurra nabberuensis*, in which the bushy columns have a spreading habit. The banded microstructure of *Yelma digitata* is a further distinguishing feature.

REMARKS

Several authors have commented on the unusual appearance of small digitate stromatolites of the *Yelma digitata* type. To some extent they resemble some chemically precipitated structures and this raises doubts about their biogenicity. Donaldson (1963) noted the correspondence of lamination thicknesses at co-incident levels. Hoffman (1975, p. 262) pointed out the resemblance between the "tiny arborescent stromatolites in the Rocknest Formation" and "structures in modern algal tufa." He interpreted the environment of formation as "brackish algal marshes, such as those in the Bahamas (Shin et al., 1969), in which crusts of calcareous tufa are precipitated." He considered that the climate was humid and that the "carbonate was precipitated directly in thick algal carpets." Hofmann (1977, p. 109) mentioned the "flared nature of the dark lamellae suggesting possible physiochemical origin of lamination."

Thrailkill (1976) has commented on the resemblance of some stromatolites to recent abiogenic speleothems, which frequently show continuous, contiguous banding and flared structures. Precipitated calcareous deposits associated with surface streams may form tufa deposits with similar structures (Braithwaite, 1979, Fig. 2D), as do aragonitic crusts formed in arid intertidal to supratidal zones and known as coniatolites (Purser and Loreau, 1973). All these structures are believed to have formed abiogenically. On the other hand, the formation of stromatolites by the precipitation of carbonate around algal filaments has been observed in calcareous stream deposits (Crowe and others, 1978).

Walter (1978) has outlined the problems of distinguishing between abiogenic structures and stromatolites in the fossil record. No satisfactory method has been discovered, except in those examples where algal filaments have been preserved as microfossils. No microfossils have been observed in the samples from the Nabberu Basin, which have been affected by recrystallization, and an abiogenic origin cannot be ruled out, although the presence of finely disseminated pigment in the dark and very dark laminae indicates that organic-rich layers were probably present originally. Hoffman (1975) observed filament moulds in the digitate structures in the Rocknest Formation, suggesting that micro-organisms played a role in their formation.

From the above evidence, and from the close association with other stromatolite groups, it seems reasonable to propose an organic origin for the Nabberu digitate structures, although precipitation around algal filaments may have been of greater significance than the trapping and binding of sediments.

DISTRIBUTION

Upper part of Yelma Formation, near Sweetwaters Well. Frere Formation near Simpson Well (poorly preserved) and possibly south of Lake Carnegie.

ACKNOWLEDGEMENTS

Numerous people have contributed to this study, but thanks are particularly due to S. M. Awramik, H. J. Hofmann, I. N. Krylov, W. V. Preiss, J. Sarfati, M. A. Semikhatov, and M. R. Walter who have at various times provided helpful discussion of problems relating to stromatolite biostratigraphy and in many cases have arranged for me to examine their extensive collections. I have also examined collections housed by the Bureau of Mineral Resources, South Australia Mines Department, University of Adelaide, University of Santa Barbara, University of Los Angeles, Geological Survey of Canada, the Royal Ontario Museum and Carleton University. I am grateful to the Directors of these various institutions and their staff who made these collections available to me.

W. D. M. Hall and other members of Broken Hill Pty Company Ltd provided valuable locality information and assistance with field work in the Nabberu Basin.

R. Livesay and C. Hoffmeister translated some sections of the Russian literature.

J. A. Bunting, M. R. Walter and W. V. Preiss have reviewed the manuscript and provided considerable constructive criticism.

APPENDIX

FOSSIL LOCALITIES REFERRED TO IN TEXT

Code	Sample No.	Identification	Locality description	1:250 000 Map Sheet	Latitude and Longitude
DKN1	CPC 16532 CPC 16531 F12360 F12361 F12399	*Externia yilgarnia* *Externia yilgarnia* *Externia yilgarnia* *Externia yilgarnia* *Externia yilgarnia*	17 km northeast of Mount Gerard (northeast Duketon locality of Preiss, 1976). Yelma Formation	Duketon	27°06′31″S 122°53′45″E
GLG1	F12382 F12383 F12384 F12385 F12386 F12387	*Yandilla meekatharrensis* *Yandilla meekatharrensis* *Yandilla meekatharrensis* *Yandilla meekatharrensis* *Yandilla meekatharrensis* *Yandilla meekatharrensis*	5 km east of Phar Lap Well. ?Yelma Formation	Glengarry	26°16′25″S 119°39′11″E
KGS1	F12334 F12335 F12336 F12337	*Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis*	Gorge 6 km south of Windidda Homestead. Windidda Formation	Kingston	26°25′39″S 122°12′25″E
KGS2	F12366 F12338 F12339 F12340 F12341 F12342 F12343 F12344 F12345	*Nabberubia toolooensis* *Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis* *Carnegia wongawolensis*	North of Tooloo Bluff 3 km south of Windidda Homestead. Windidda Formation	Kingston	26°24′42″S 122°14′23″E
KGS3	F12346	*Carnegia wongawolensis*	Tributary to Wongawol Creek. Windidda Formation	Kingston	26°13′54″S 121°45′59″E
KGS4	F12347 F12348	*Carnegia wongawolensis* *Carnegia wongawolensis*	Tributary to Wongawol Creek, approximately 1 km east of KGS3. Windidda Formation	Kingston	26°13′46″S 121°46′03″E
KGS5	F12349 F12350	*Carnegia wongawolensis* *Carnegia wongawolensis*	Wongawol Creek approximately 16 km southwest of Wongawol Homestead. Windidda Formation	Kingston	26°13′30″S 121°51′33″E
KGS6	F12351 F12352	*Carnegia wongawolensis* *Carnegia wongawolensis* Unnamed stromatolites —small domes	Approximately 12 km south of Wongawol Homestead. Top of Windidda Formation	Kingston	26°13′30″S 121°56′03″E
KGS7	—	Unnamed stromatolites —elongate domes	4 km north of Bulljah Pool, north of Lake Carnegie. Kulele Limestone	Kingston	26°07′00″S 122°40′00″E

APPENDIX
FOSSIL LOCALITIES REFERRED TO IN TEXT

Code	Sample No.	Identification	Locality description	1:250 000 Map Sheet	Latitude and Longitude
NBR1	F12362 F12363 F12364 F12365 F12373 F12374 F12375 F12376 F12377 F12378 F12389 F12390 F12391 F12392 F12393 —	*Murgurra nabberuensis* *Murgurra nabberuensis* *Murgurra nabberuensis* *Murgurra nabberuensis* *Pilbaria deverella* *Pilbaria deverella* *Pilbaria deverella* *Pilbaria deverella* *Pilbaria deverella* *Yelma digitata* *Yelma digitata* *Yelma digitata* *Yelma digitata* *Yelma digitata* *Yelma digitata* Unnamed stromatolites —rounded domes	3.5 km southeast of Sweetwaters Well, near Lake Nabberu. Yelma Formation	Nabberu	25°36'31"S 120°23'58"E
NBR2	F12367 F12368 F12369 F12370 F12371	*Omachtenia teagiana* *Omachtenia teagiana* *Omachtenia teagiana* *Omachtenia teagiana* *Omachtenia teagiana*	Approximately 4.5 km east of No. 5 Well, near Sweeney Creek. Yelma Formation	Nabberu	25°47'50"S 120°42'43"E
NBR4	F12378	*Pilbaria deverella*	Near Simpson Well. Frere Formation	Nabberu	25°22'05"S 120°06'29"E
PKH2	F12394 F12395 F12396	*Yelma digitata* *Yelma digitata* *Yelma digitata*	3 km west southwest of Combine Well. Yelma Formation	Peak Hill	25°41'08"S 119°57'53"E
PKH3	F12379	*?Pilbaria deverella*	North of Lake Gregory. Yelma Formation	Peak Hill	25°33'00"S 119°55'00"E
PKH4	F12359 F12397	*Ephyaltes* form indet. *?Yelma digitata*	4 km northwest of Edgingunna Well. Yelma Formation	Peak Hill	25°40'02"S 119°48'57"E
RBR1	CPC 16526 CPC 16524 CPC 16524 CPC 16525 CPC 16527 F12380 F12381	cf. *?Kulparia* form indet. *Nabberubia toolooensis* *Windidda granulosa* *Windidda granulosa* *Windidda granulosa* *Windidda granulosa* *Windidda granulosa*	Mount Elisabeth. Windidda Formation	Robert	26°33'07"S 123°01'12"E
RBR2	CPC 16528	Unnamed stromatolite	Southeast end of Ida Range: locality referred to by Preiss (1976). Windidda Formation	Robert	26°29'52"S 124°04'35"E
RBR3	—	Unnamed stromatolites —elongate domes	Near Mount Lancelot. Kulele Formation	Robert	26°13'59"S 123°07'51"E

APPENDIX

FOSSIL LOCALITIES REFERRED TO IN TEXT

Code	Sample No.	Identification	Locality description	1:250 000 Map Sheet	Latitude and Longitude
SNL1	F12353 F12354 F12355 F12356 F12357 F12358 — —	*Earaheedia kuleliensis* *Earaheedia kuleliensis* *Earaheedia kuleliensis* *Earaheedia kuleliensis* *Earaheedia kuleliensis* Unnamed stromatolites —columnar elongate domes— large spherical domes	Near Thurraguddy Bore. Kulele Limestone	Stanley	25°55′40″S 121°48′00″E
SNL2	—	Unnamed stromatolites —elongate domes	Mount Hosken. Kulele Limestone	Stanley	25°56′35″S 122°31′48″E
TSL1	F12372	?*Omachtenia teagiana*	20 km north of Buldya Soak. Frere Formation	Throssel	27°06′06″S 124°22′23″E
WLN1	—	Unnamed stromatolites —stratiform and bulbous, oncolites	2.5 km northeast of Camel Well. Frere Formation	Wiluna	26°08′51″S 121°48′29″E

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PLATES

PLATE 1

Field occurrences of stromatolites in the Earaheedy Group.

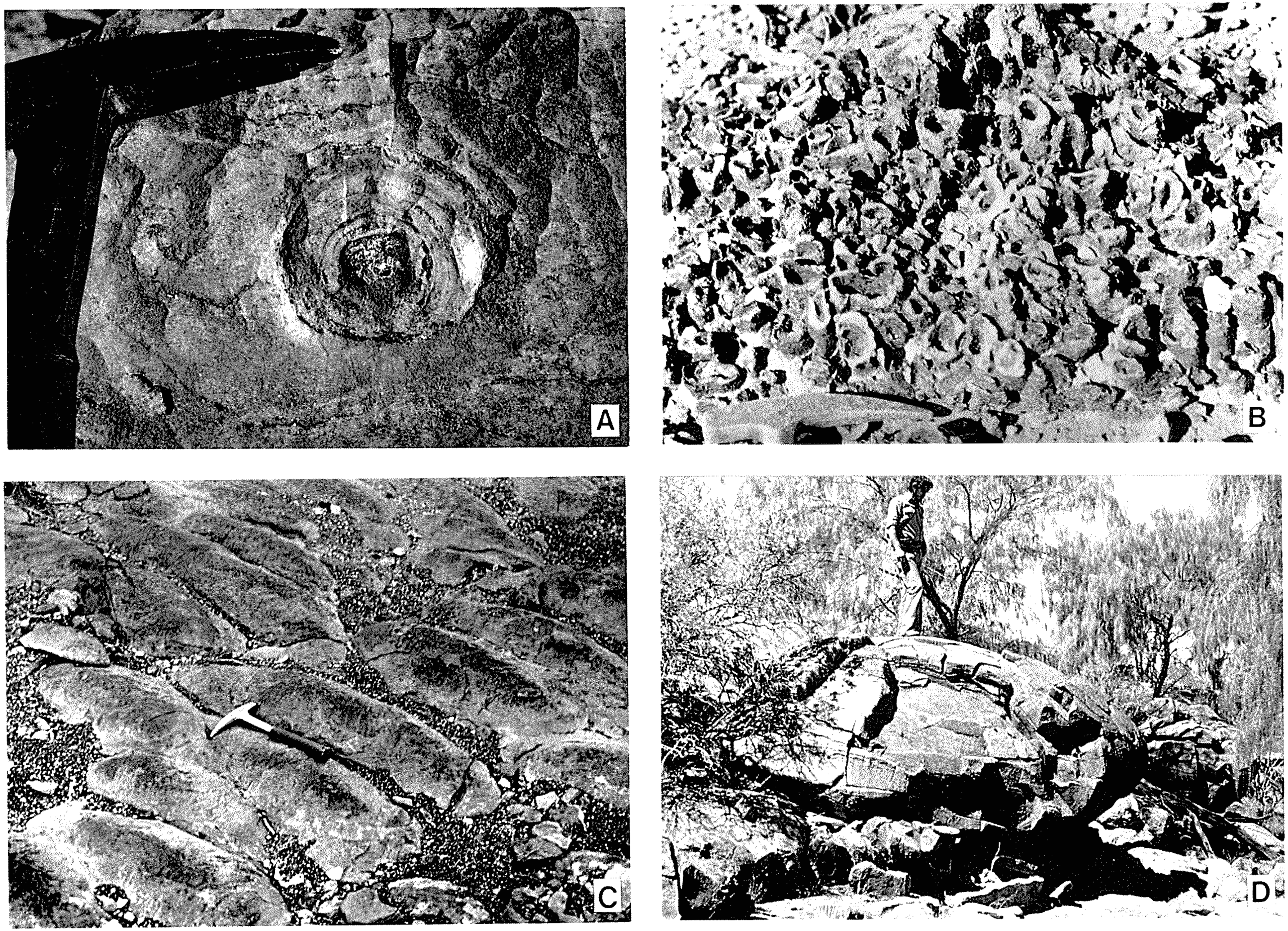
(A) Unnamed stromatolite from Yelma Formation (NBR1). Cross-section of dome with central laminae replaced by galena. Photo S. Rusyn.

(B) Differential silicification and weathering of stromatolite columns (probably *Omachtenia teagiana*), Yelma Formation, (NBR2). Photo J. A. Bunting.

(C) Elongate domes in Kulele Limestone (SNL1). Photo J. A. Bunting.

(D) Large domed stromatolite in Kulele Limestone (SNL1). Note the recurving of the laminae near the base of the dome. Photo I. R. Williams.

26784—6



GSWA 19964

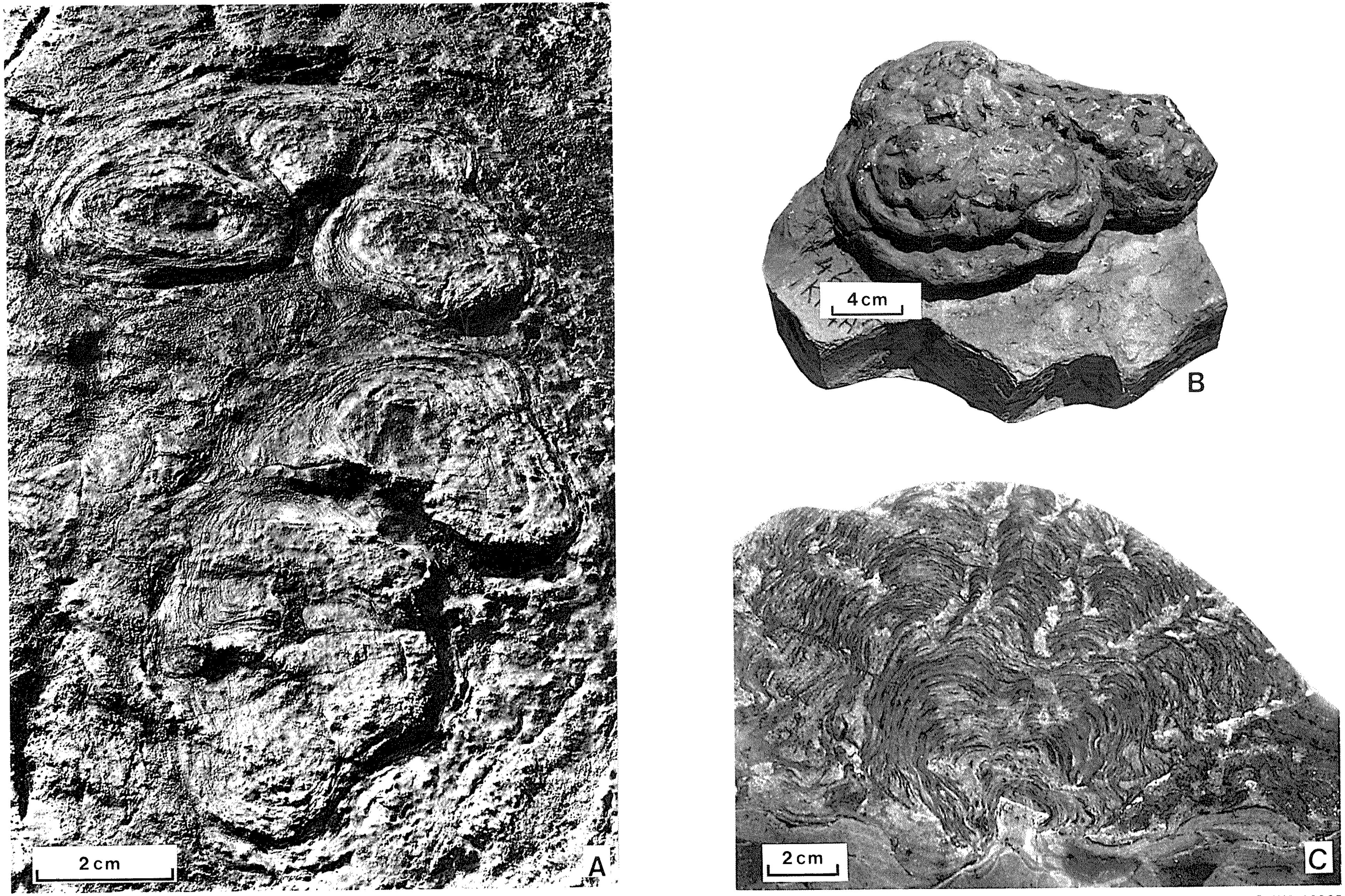
PLATE 2

Carnegia wongawolensis new group and form.
Windidda Formation.

(A) GSWA F12343 from KGS2. Weathered surface showing cross-sections of concentric laminae enveloping several columns.

(B) GSWA F12349 from KGS6. Typical development of a small dome of the type shown in (C).

(C) GSWA F12337 from KGS1. Polished face showing columns developed above a dome encrusting a topographic high.



GSWA 19965

PLATE 3

Carnegia wongawolensis new group and form.
Windidda Formation. Polished faces.

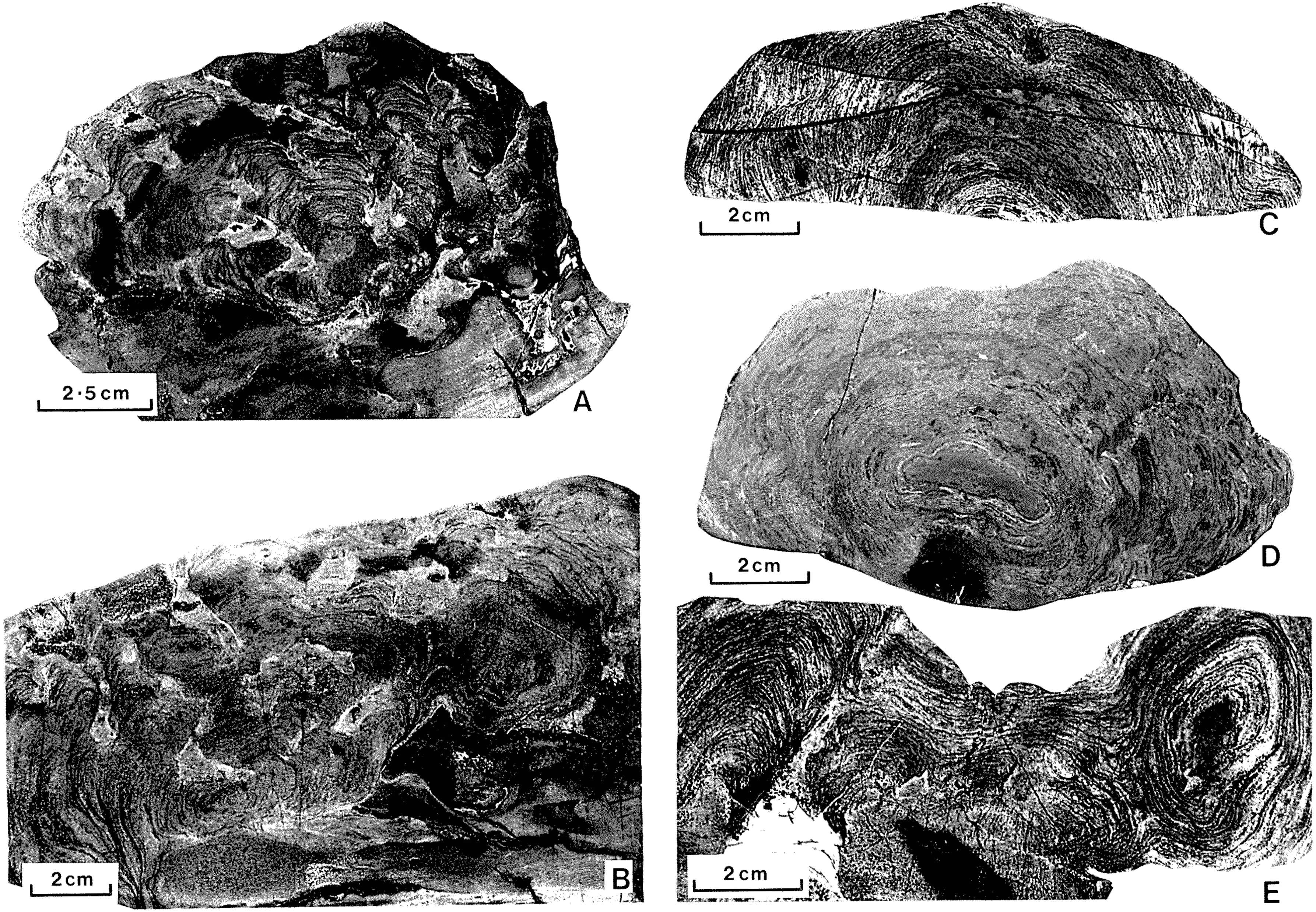
(A) GSWA F12347, Holotype, from KGS4, showing branching pattern.

(B) GSWA F12347, Holotype, from KGS4, showing branching pattern and development of some encrusting laminae.

(C) GSWA F12341, from KGS2, showing development of small dome.

(D) GSWA F12336, from KGS1, showing laminae encrusting a clast, limited development of branching and overgrowth by later laminae.

(E) GSWA F12344, from KGS2, showing encrusting laminae.



GSWA 19966

PLATE 4

Carnegia wongawolensis new group and form.
Windidda Formation (KGS5), thin sections.

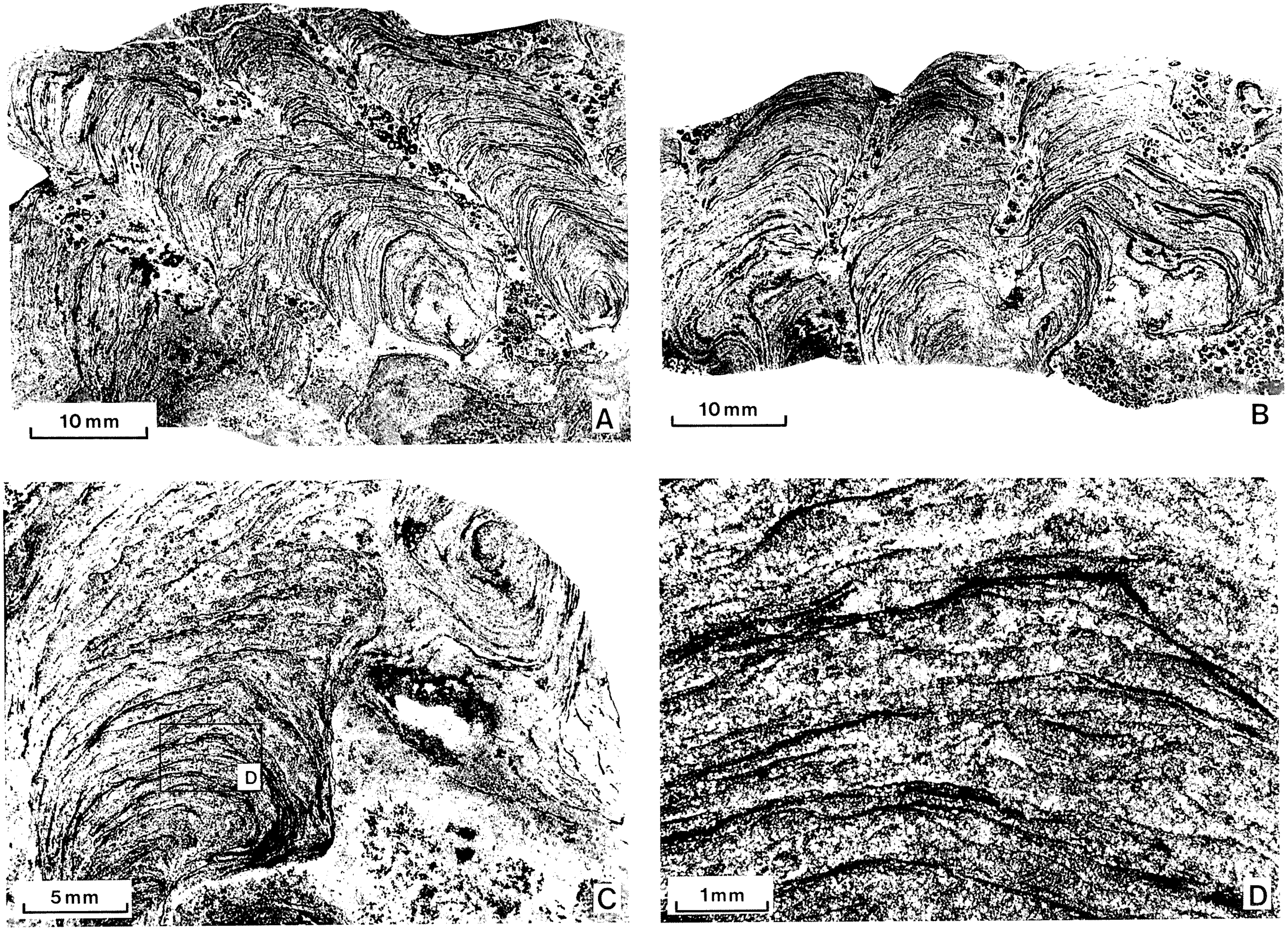
(A) GSWA F12350. Columns and laminae shapes.

(B) to (D) GSWA F12349.

(B) Branching style and laminae shapes.

(C) A different part of the same specimen showing detail of the laminae. Area shown in D is outlined.

(D) Detail of filmy microstructure.



GSWA 19967

PLATE 5

Carnegia wongawolensis new group and form.
Windidda Formation, thin sections.

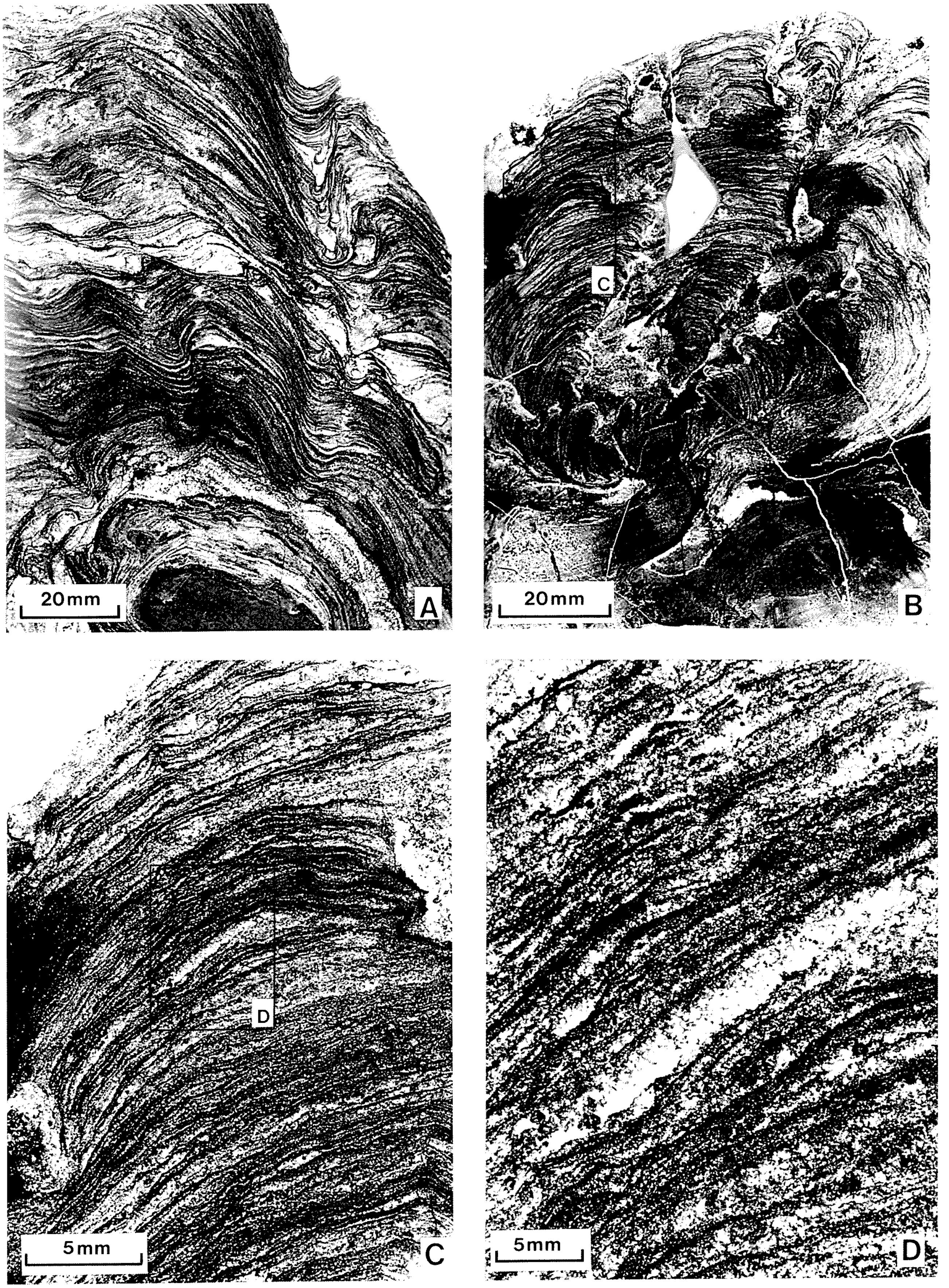
(A) GSWA F12336, from KGS1. Column developed above a clast.

(B) to (D) GSWA F12348, from KGS4.

(B) Columns developed above clasts. Area shown in C is outlined.

(C) Detail of column showing laminae shapes. Area shown in D is outlined.

(D) Microstructure.



GSWA 19968

PLATE 6

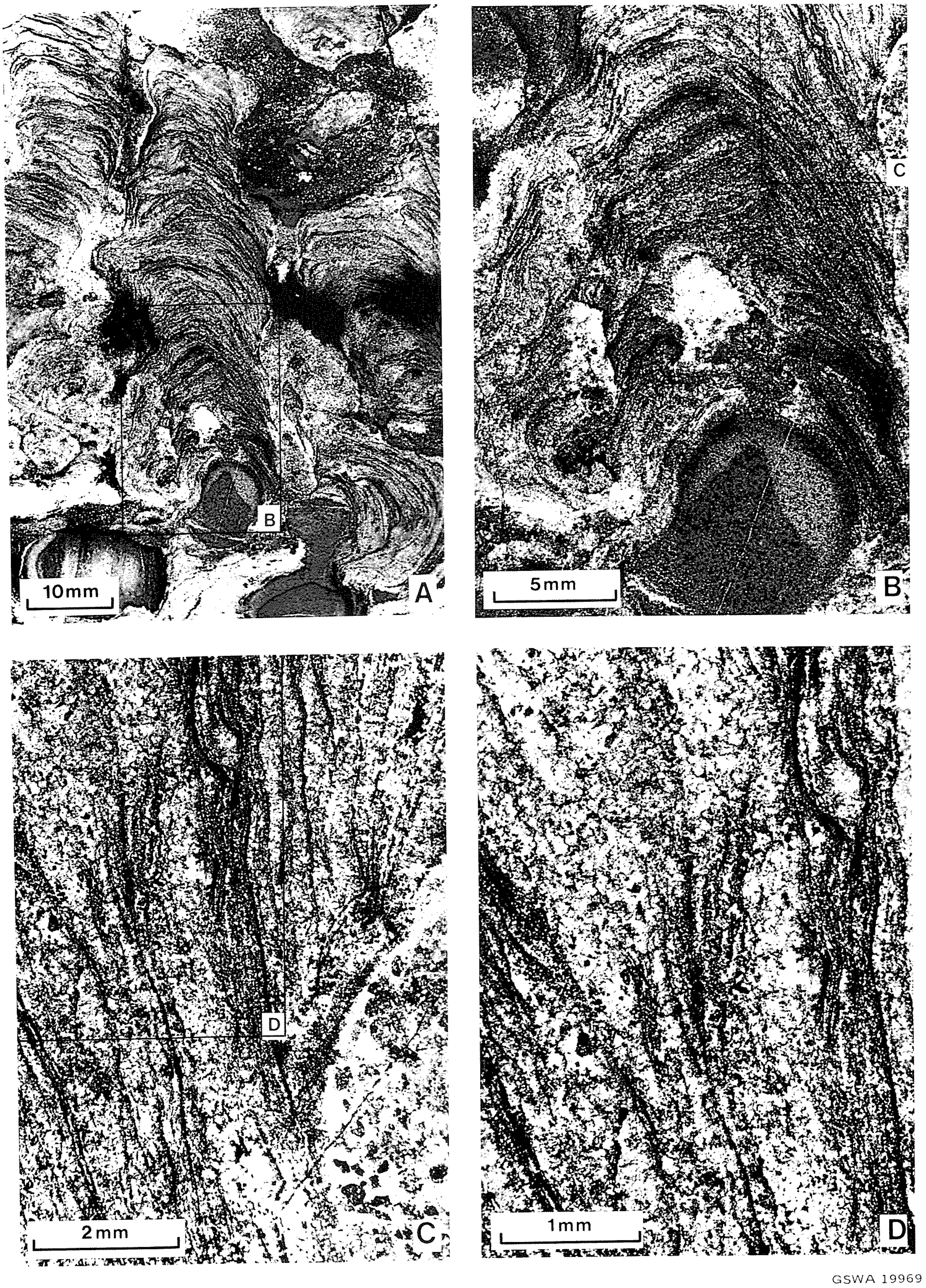
Carnegia wongawolensis new group and form.
GSWA F12347, Holotype, from Windidda Formation, KGS4, thin sections.

(A) Column developed above a clast. Area shown in B is outlined.

(B) Detail of laminae shapes. Area shown in C is outlined.

(C) Fabric and microstructure. Area shown in D is outlined.

(D) Detail of microstructure.



GSWA 19969

PLATE 7

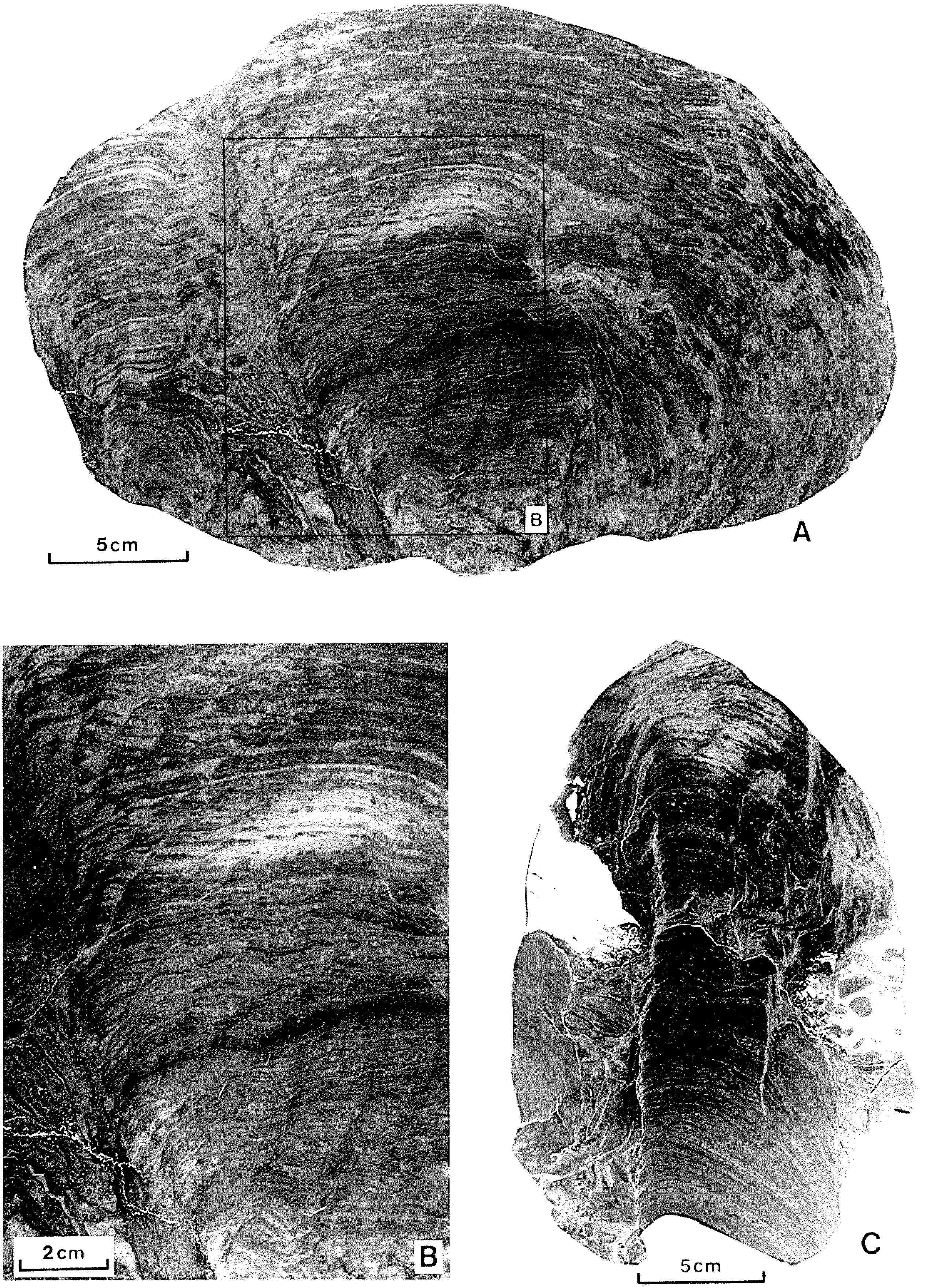
Earaheedia kuleliensis new group and form.
Kulele Limestone SNL1, polished faces.

(A) and (B) GSWA F12353.

(A) Dome showing wavy laminations.

(B) Detail showing disruption of laminae, probably a result of soft sediment deformation.

(C) GSWA F12355 showing column and clasts in interspaces.



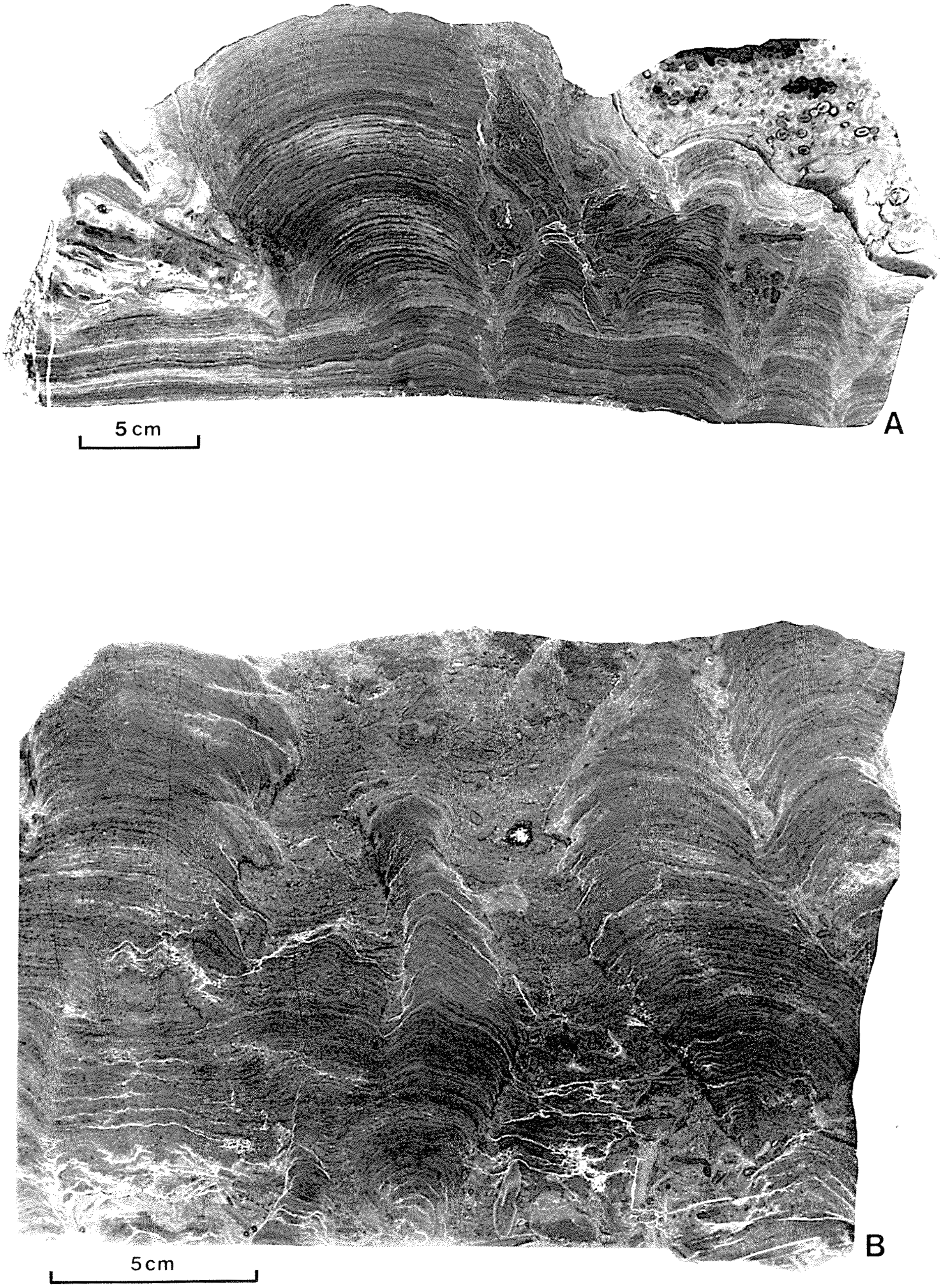
GSWA 19970

PLATE 8

Earaheedia kuleliensis new group and form.
Kulele Limestone, SNL1, polished faces.

(A) GSWA F12356 showing pseudocolumns and interspace clasts. Note the later infill with oolites.

(B) GSWA F12354 Holotype, showing column development.



GSWA 19971

PLATE 9

Earaheedia kuleliensis new group and form.
GSWA F12356, Kulele Limestone, SNL1, thin section.

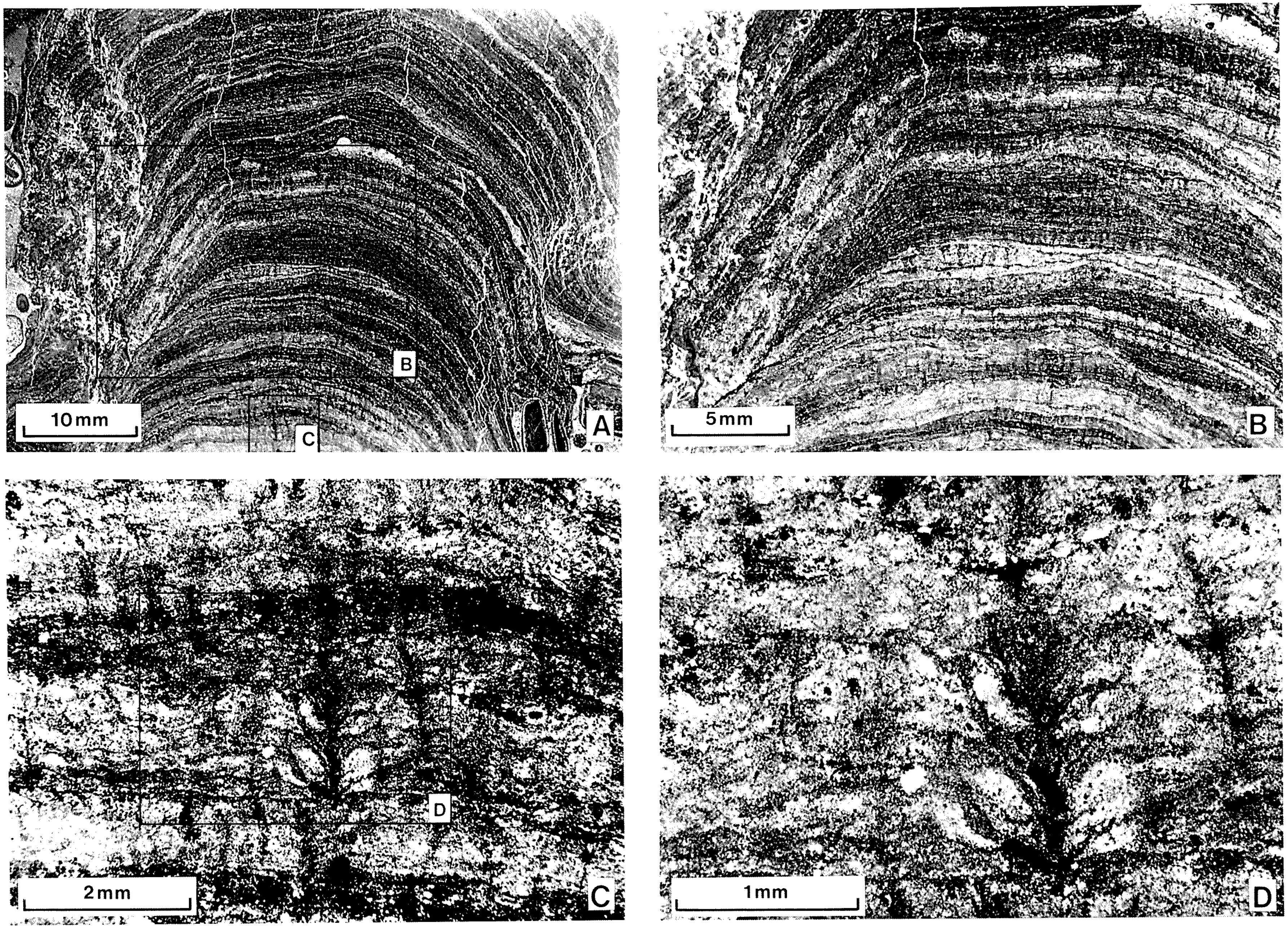
(A) Laminae shapes. Area shown in B is outlined by large frame; in C by small frame.

(B) Irregularly banded microstructure.

(C) Detail of fabric showing iron-pigmented, branching structures, possibly dewatering channels. Area shown in D outlined.

(D) Iron-pigmented, branching structure.

26784—7



GSWA 19972

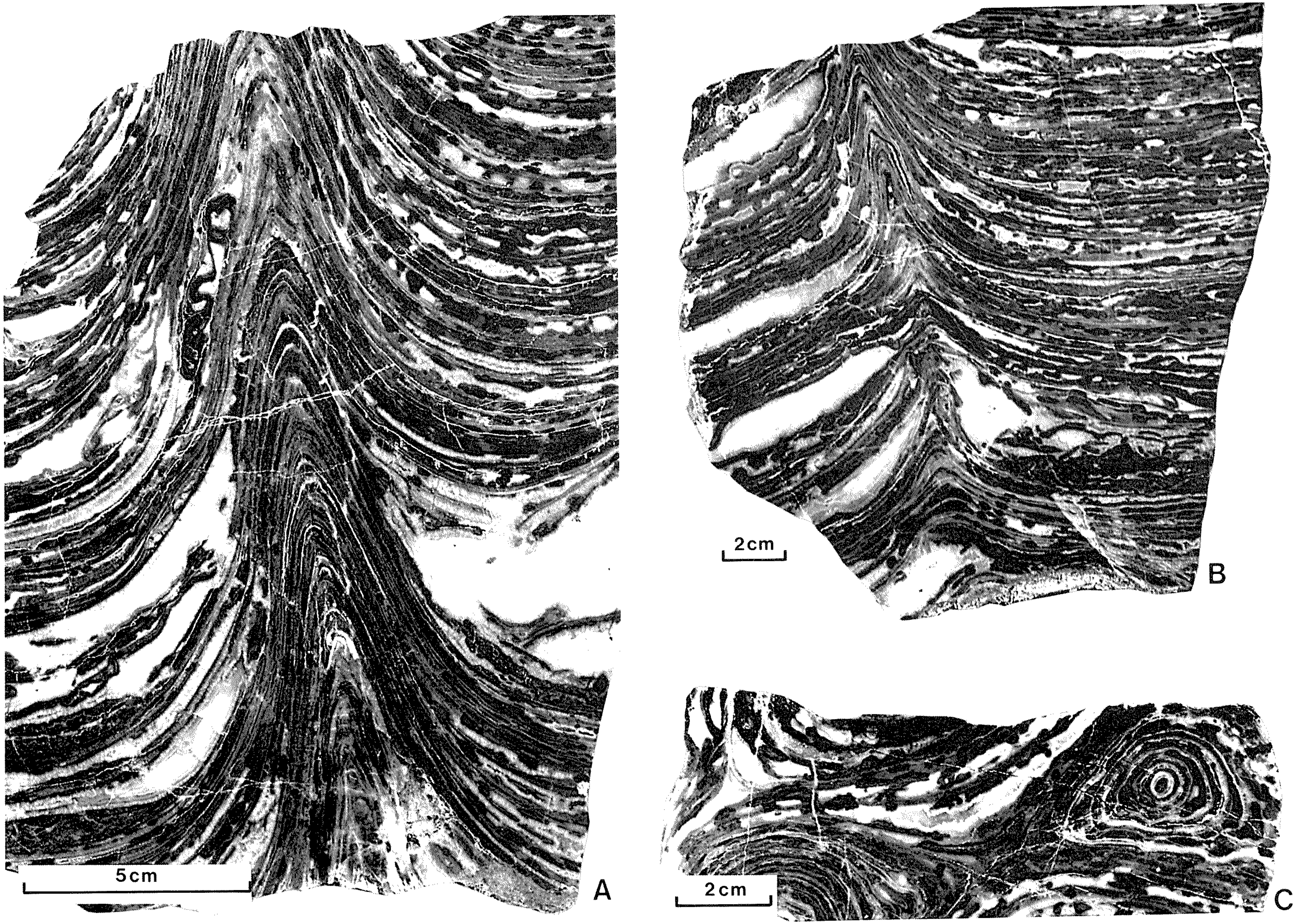
PLATE 10

Ephyaltes form indet.
GSWA F12359, Yelma Formation, PKH4, polished faces.

(A) Cone showing axial zone and laterally linked laminations.

(B) Second cone showing lateral linkage.

(C) Cross section of cones showing irregular shape.

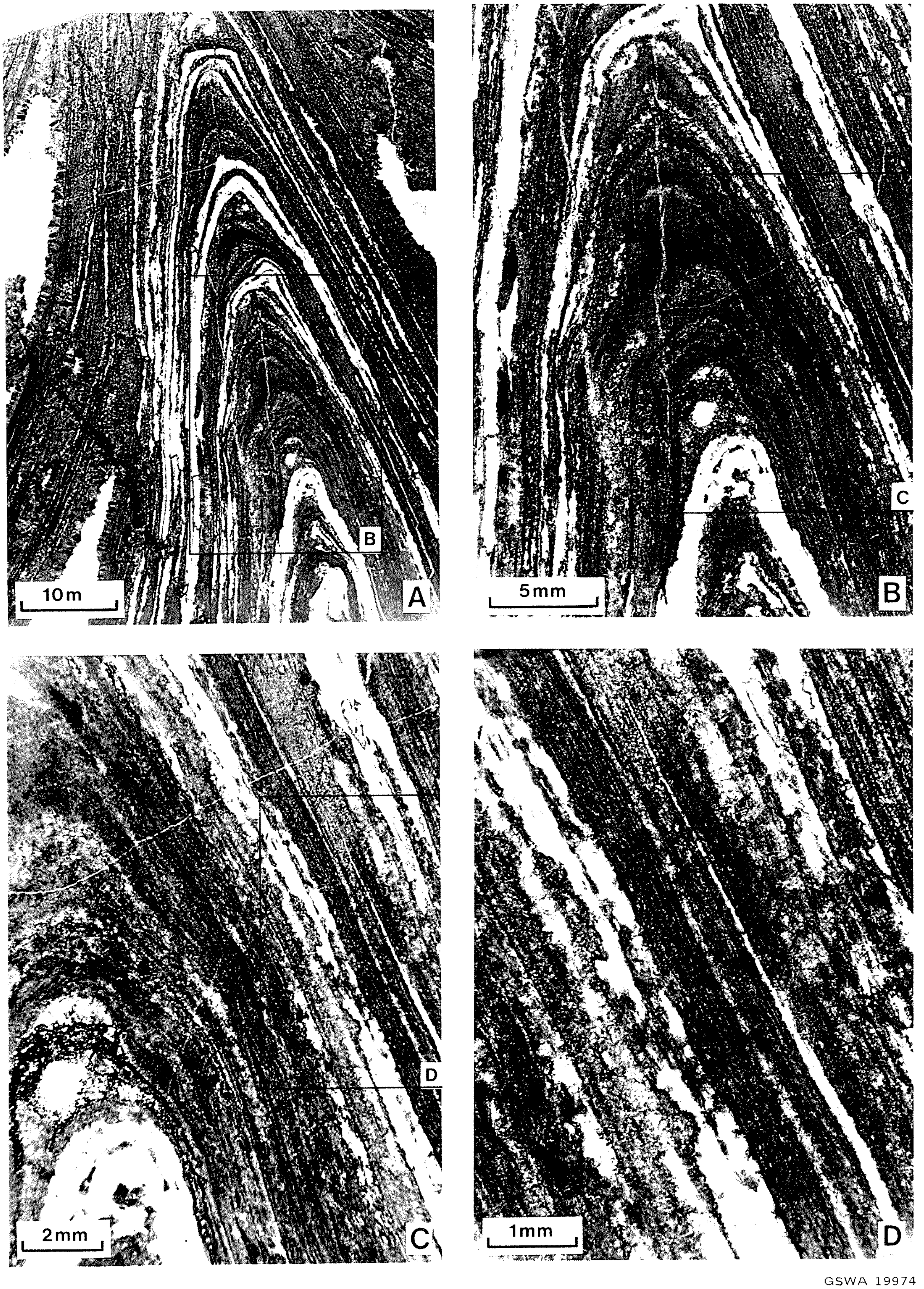


SWA 19973

PLATE 11

Ephyaltes form indet.

GSWA F12359, Yelma Formation, PKH4, thin section. Details of laminations and microstructure shown at increasing magnification. Areas outlined are shown in the next illustration in the sequence.



GSWA 19974

PLATE 12

Externia yilgarnia (Preiss 1976)
Yelma Formation, DKN1.

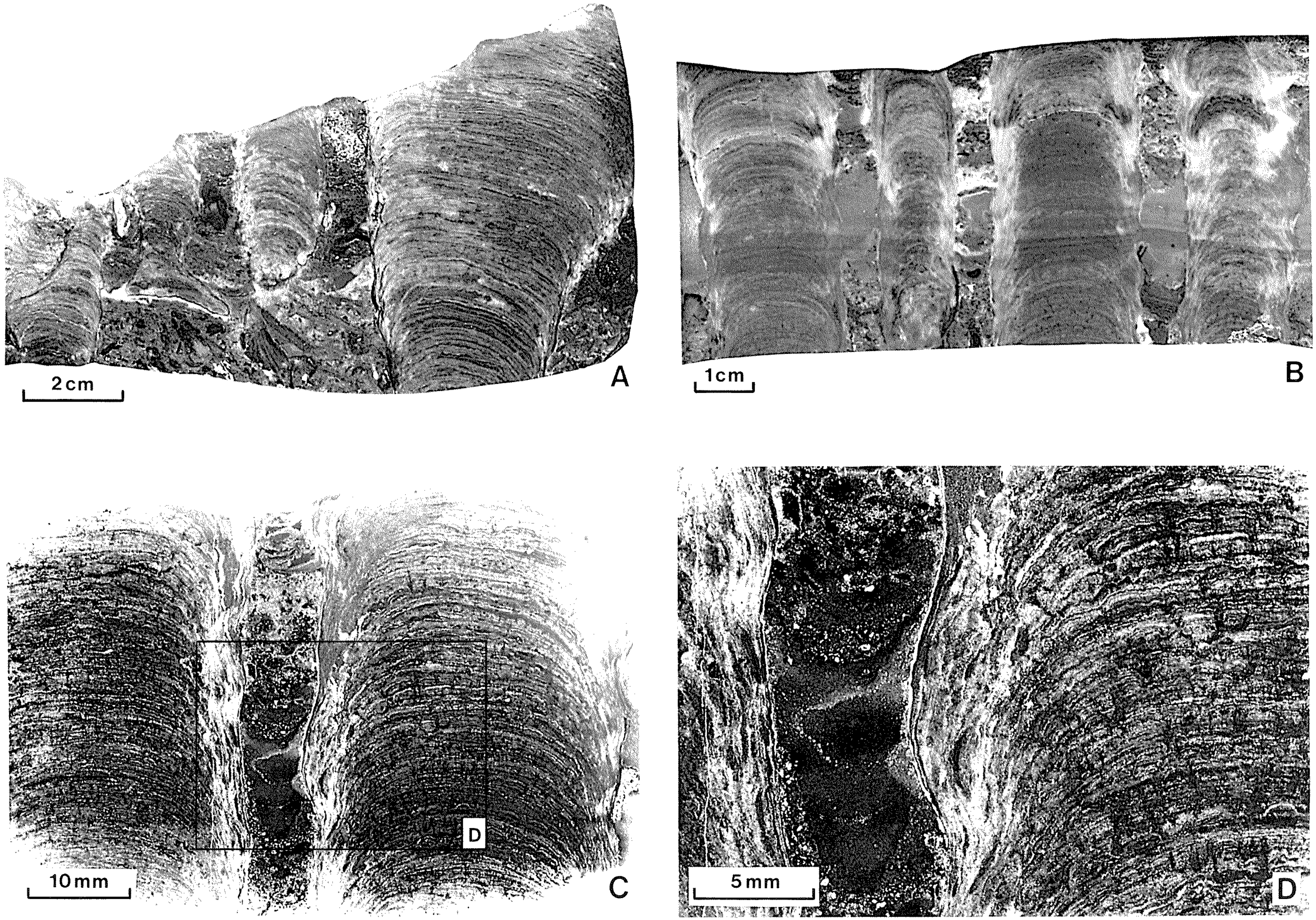
(A) GSWA F12399, polished face showing basal part of columns with poorly developed walls.

(B) to (D) GSWA F12360. Upper parts of columns with well-developed walls.

(B) Several parallel columns on a polished face.

(C) Thin section showing multilaminate wall and laminae shapes. Area shown in D is outlined.

(D) Detail of wall.



GSWA 19975

PLATE 13

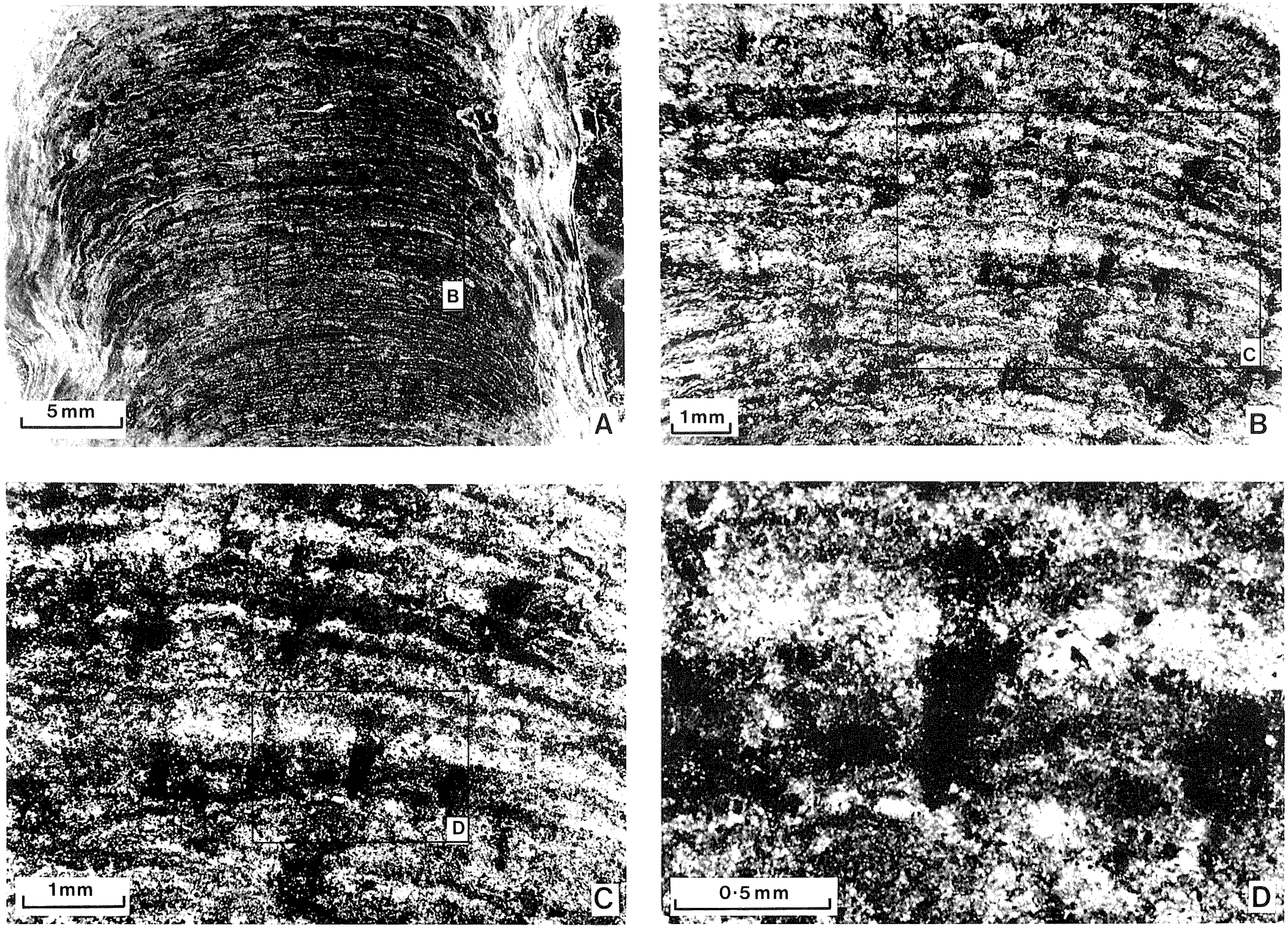
Externia yilgarnia (Preiss 1976).
GSWA F12360 (specimen in Plate 12C and D), from Yelma Formation, DKN1, thin sections.

(A) Shape of laminae. Area shown in B is outlined.

(B) Fabric. Note the linear and vertical distribution of tussocks. Area shown in C is outlined.

(C) Detail of fabric showing tussocks. Area shown in D is outlined.

(D) Two adjacent tussocks separated by an iron-stained structure, possibly a dewatering channel.



GSWA 19976

PLATE 14

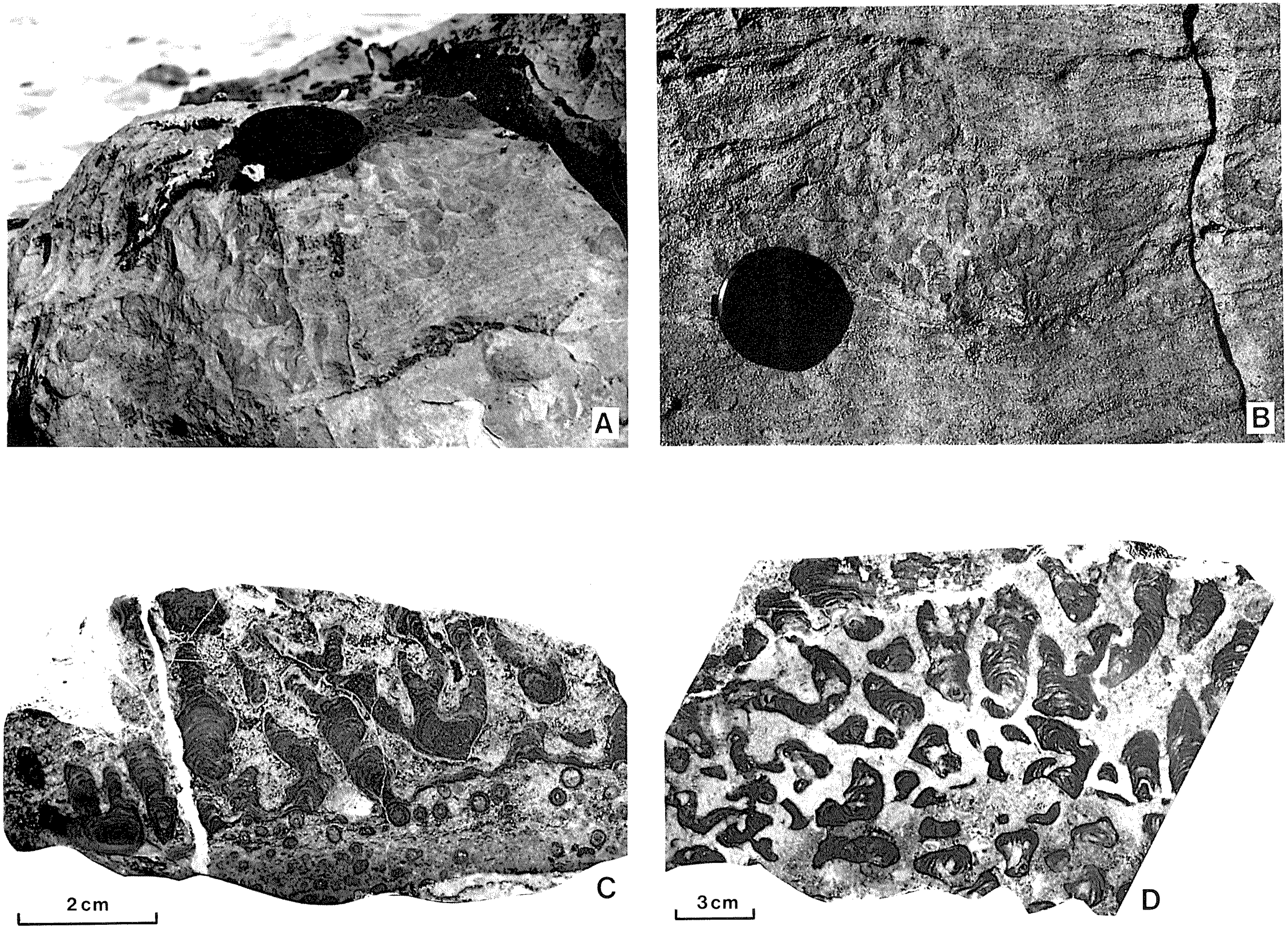
Murgurra nabberuensis new group and form.
Yelma Formation, NBR1.

(A) Field occurrence of *Murgurra nabberuensis*.

(B) Field occurrence of *Murgurra nabberuensis* showing bushy habit of fascicle. Photo S. Rusyn.

(C) GSWA F12363, polished face showing branching pattern near the centre of a fascicle, and associated oncolites which sometimes form a nucleus from which branching develops.

(D) GSWA F12365, Holotype, polished face showing distribution of branching in a single fascicle.



GSWA 19977

PLATE 15

Yelma Formation, NBR1, thin sections.
Murgurra nabberuensis new group and form.

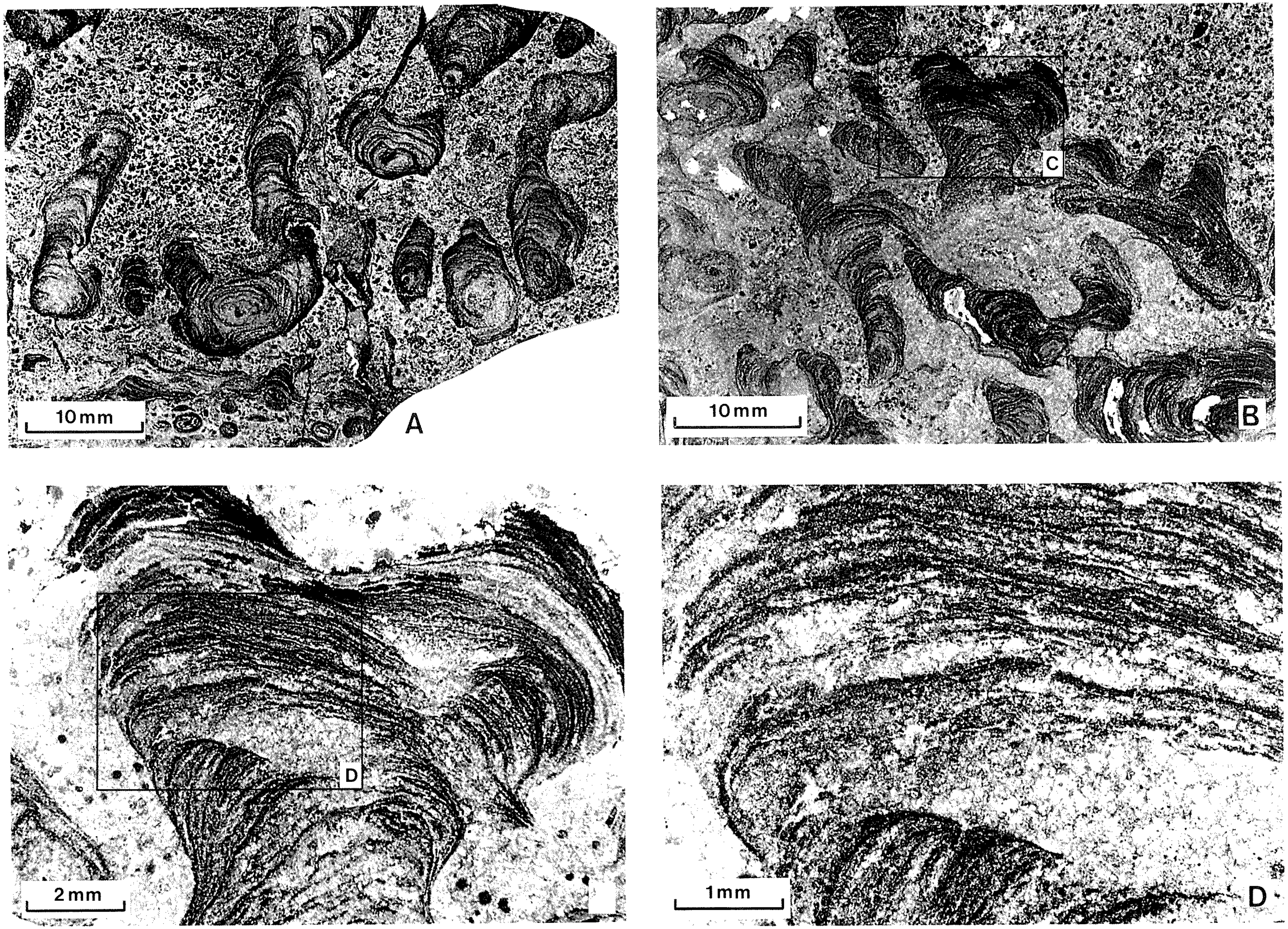
(A) GSWA F12363, showing irregular column shapes and filmy microstructure. Note the granular material in the interspaces, and the basal layer of oncolites.

(B) to (D) GSWA F12365, Holotype.

(B) Column shape and mode of branching. Area shown in (C) is outlined.

(C) Detail of column showing laminae shapes in an area of branching. Area shown in (D) is outlined.

(D) Filmy microstructure. Note the discontinuity across the column.



GSWA 19978

PLATE 16

Murgurra nabberuensis new group and form.
Yelma Formation, NBR1, thin sections.

(A) and (B) GSWA F12363.

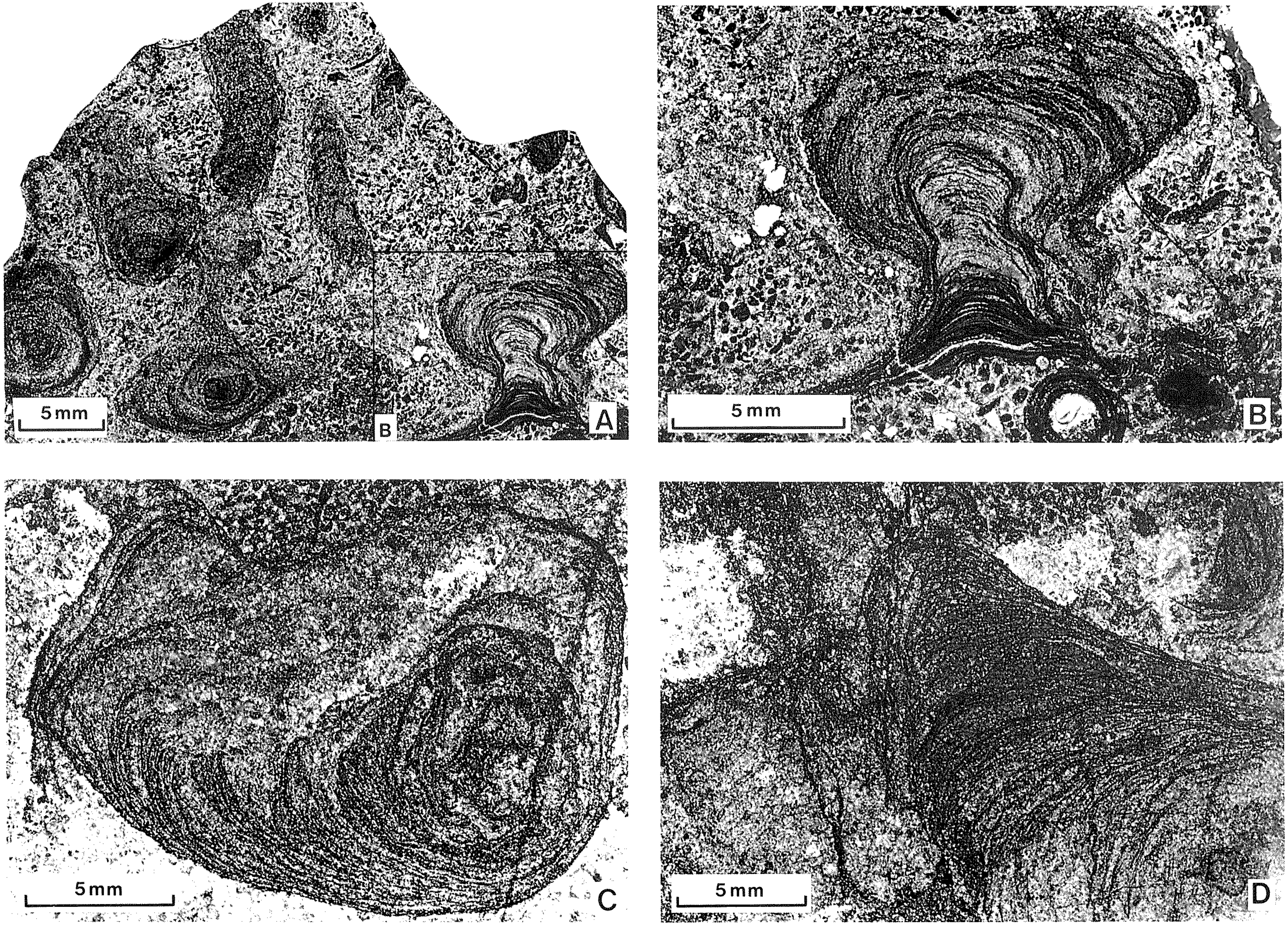
(A) Basal parts of columns. Area shown in (B) is outlined.

(B) Detail of laminae shapes in basal part of column.

(C) and (D) GSWA F12362.

(C) Basal part of column showing filmy microstructure and discontinuous nature of laminae.

(D) Different part of same thin section showing detail of microstructure.



GSWA 19979

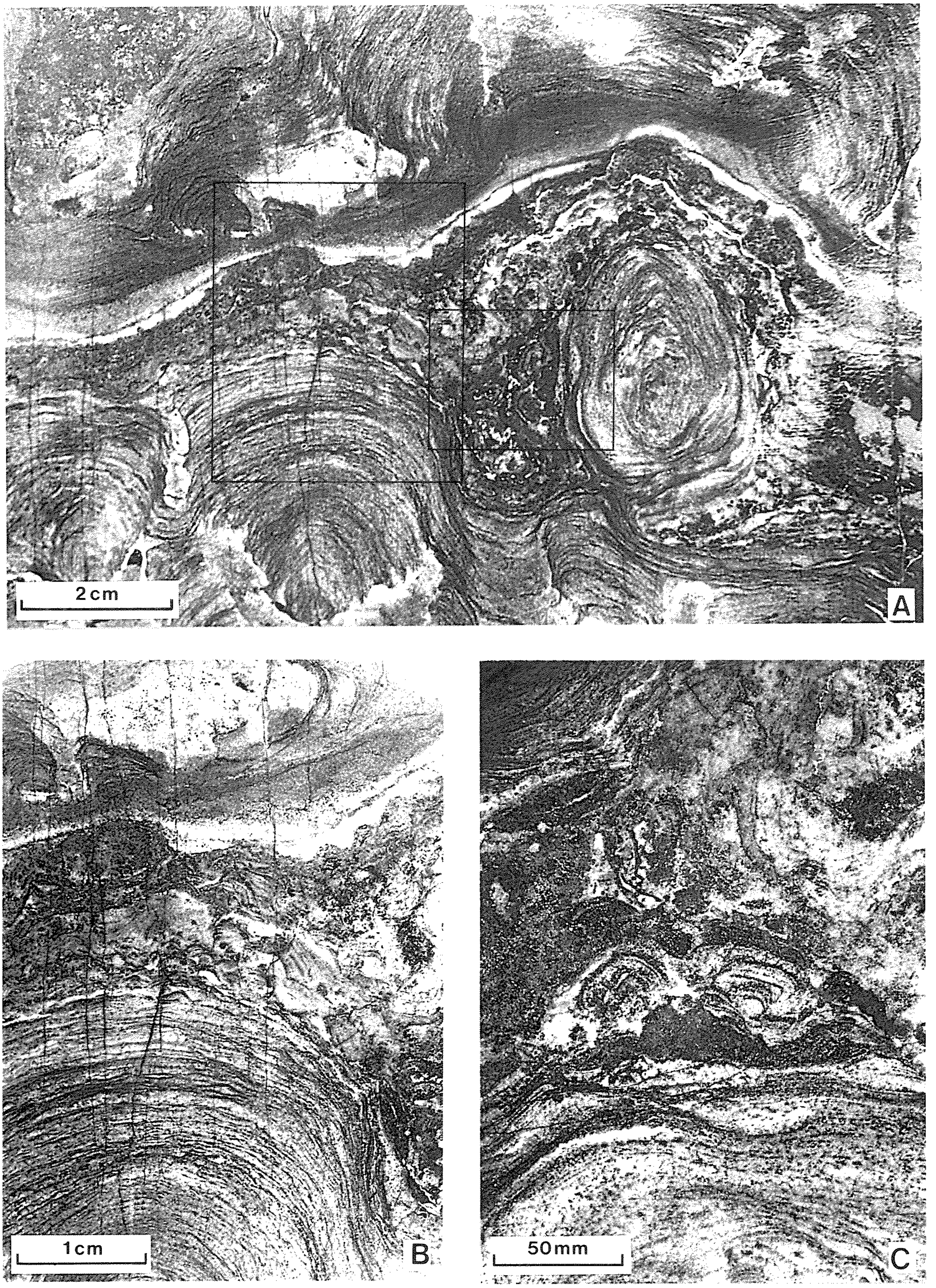
PLATE 17

Nabberubia toolooensis new group and form.
GSWA F12366, Windidda Formation, KGS2, polished faces.

(A) Encrusting layer of *Nabberubia toolooensis* between two layers of *Carnegia wongawolensis*. Area shown in (B) and (C) are outlined.

(B) Detail of transition from *Carnegia wongawolensis* (lower part of picture showing filmy microstructure) to *Nabberubia toolooensis* (central zone of microcolumnar structures). Note some occasional interfingering of the two forms.

(C) Detail of two microcolumns showing banded microstructure.



GSWA 19980

PLATE 18

Nabberubia toolooensis new group and form.
GSWA F12366, Windidda Formation, KGS2, thin sections.

(A) Typical development of microcolumns encrusting laminae of *Carnegia wongawolensis.*

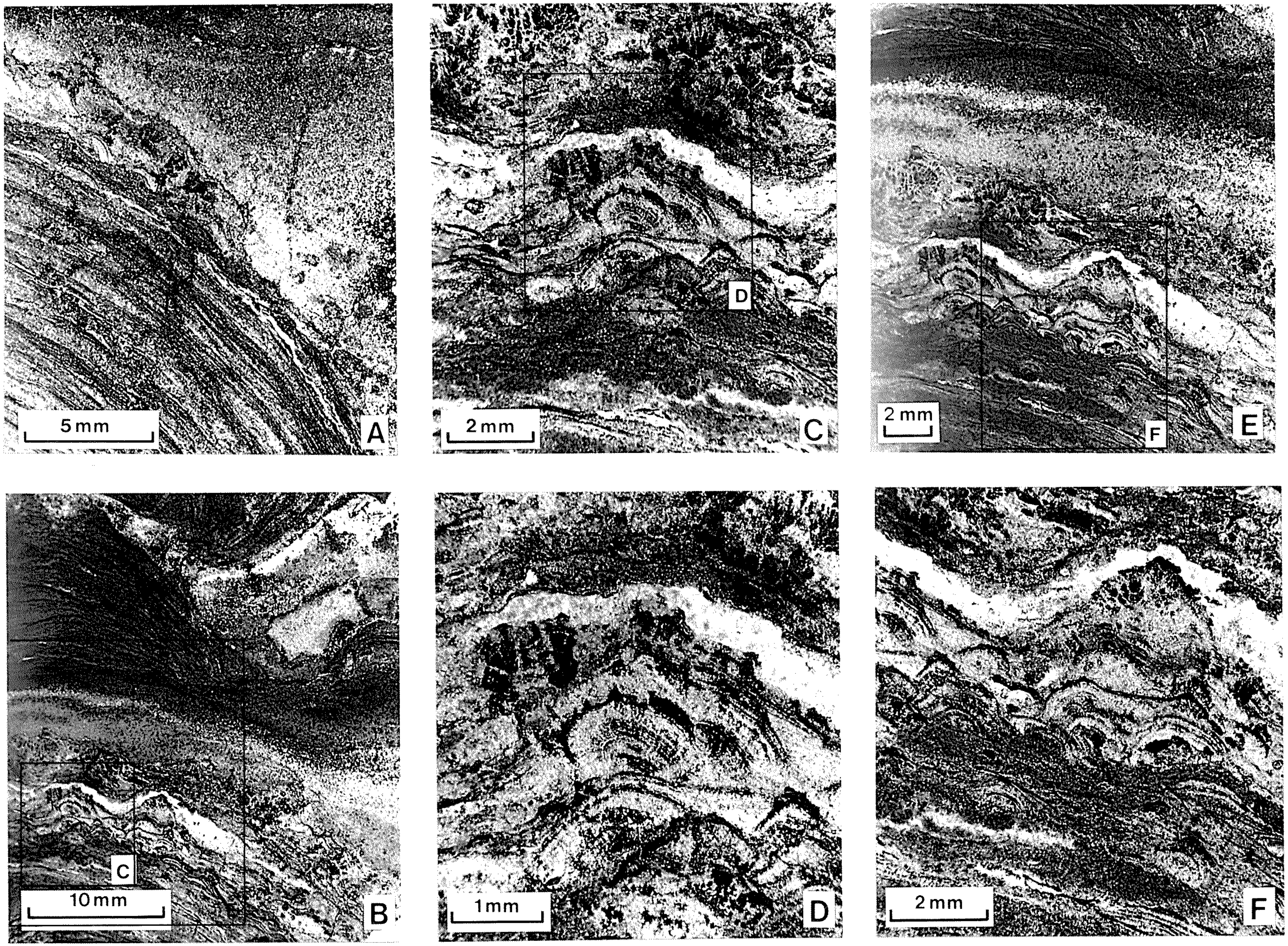
(B) Arrangement of columns of *Nabberubia toolooensis* between two layers of *Carnegia wongawolensis.* The areas outlined are shown in more detail in (C) to (F).

(C) Development of successive microcolumns. Area shown in (D) is outlined.

(D) Detail showing differential replacement by an opaque mineral, probably magnetite.

(E) Arrangement of microcolumns. Area shown in (F) is outlined.

(F) Detail of microcolumns. Note the interfingering of laminae of *Carnegia wongawolensis.*



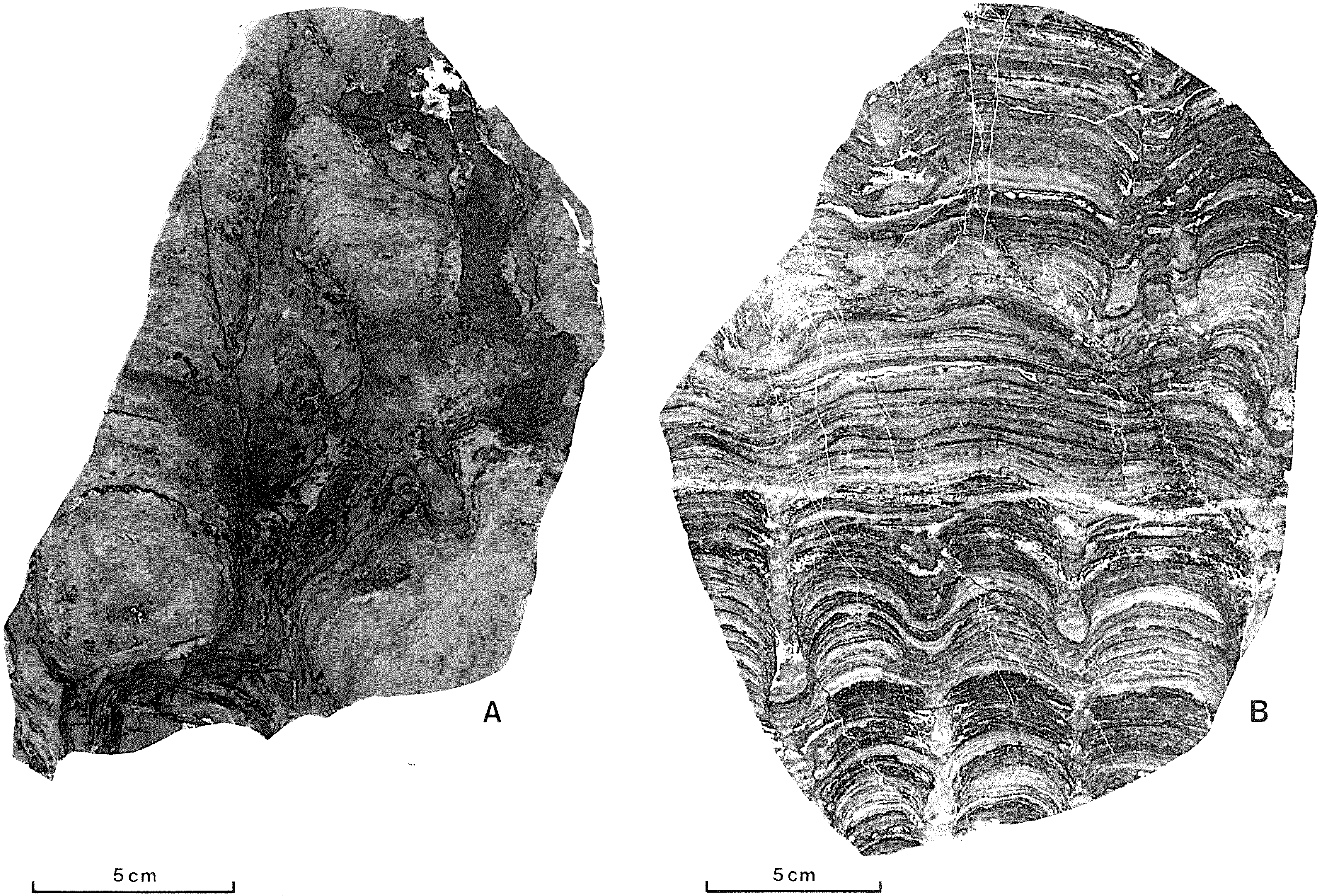
GSWA 19981

PLATE 19

Omachtenia teagiana new form.
Yelma Formation, NBR2, polished faces.

(A) GSWA F12368, showing poorly preserved, silicified upper parts of columns.

(B) GSWA F12369 lower part of stromatolite in non-silicified dolomite. Note presence of pseudocolumns and numerous bridges.



GSWA 19982

PLATE 20

Omachtenia teagiana new form.
Yelma Formation, NBR2, thin sections.

(A) and (B) GSWA F12368.

(A) Upper part of stromatolite showing silicified columns. Area shown is outlined in (B).

(B) Detail showing altered microstructure.

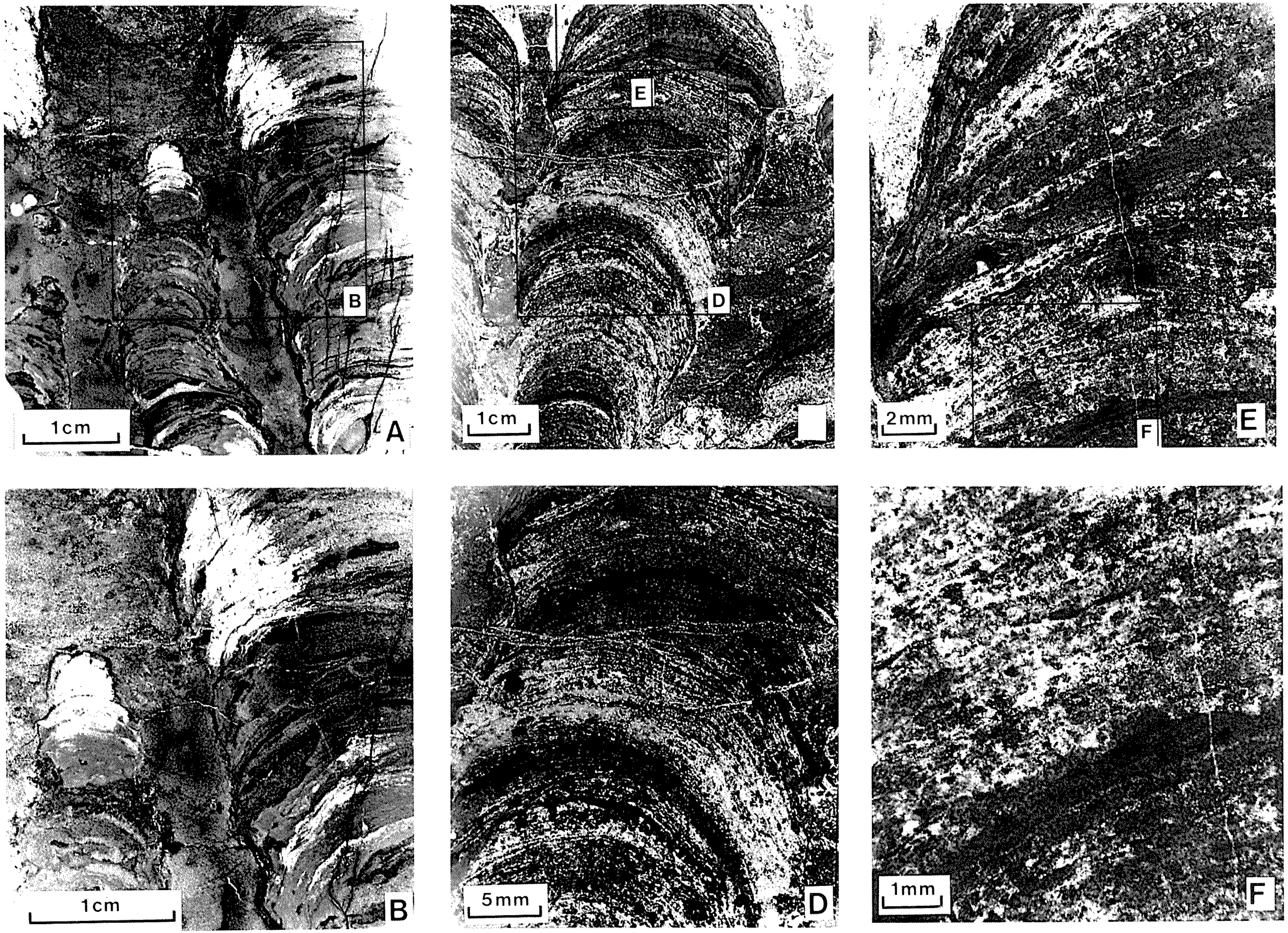
(C) to (F) GSWA F12371, Holotype.

(C) Column from lower part of stromatolite showing laminae shapes and better-preserved microstructure. Areas shown in (D) and (E) are outlined.

(D) Laminations.

(E) Laminae near column margin forming a short wall. Area shown in (F) is outlined.

(F) Microstructure.



GSWA 19983

PLATE 21

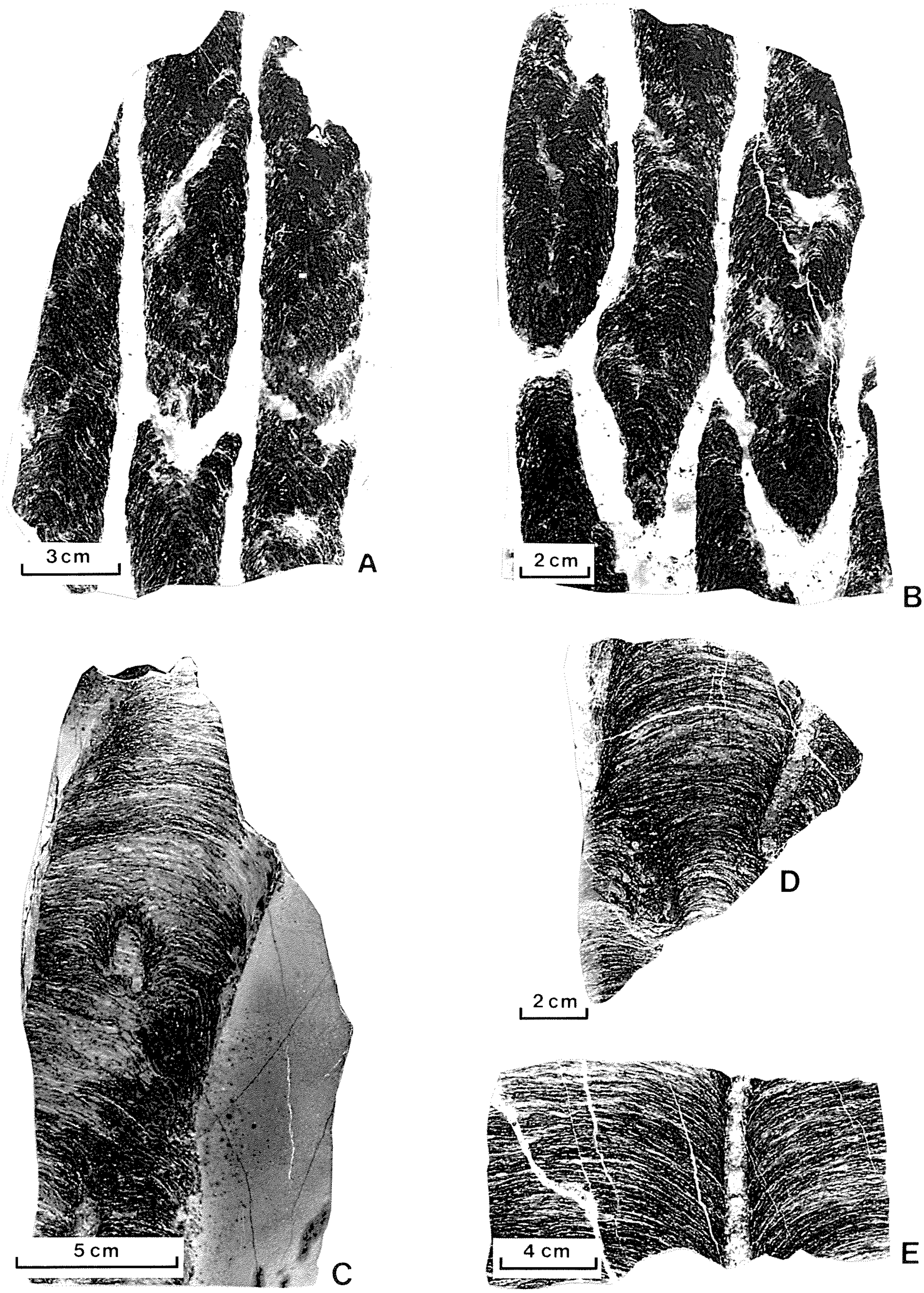
Pilbaria deverella new form.
Yelma or Frere Formations, polished faces.

(A) and (B) GSWA F12378 from Frere Formation, NBR4. Note the very deep niches and the development of pseudocolumns at an angle to the main direction of column growth.

(C) GSWA F12376 from Yelma Formation, NBR1. Part of column showing laminae shapes and cross section of a niche.

(D) GSWA F12373 from Yelma Formation, NBR1. Part of column showing laminae shapes.

(E) GSWA F12375 from Yelma Formation, NBR1. Part of two adjacent columns showing streaky, lensoid microstructure and patchily developed wall.



GSWA 19984

PLATE 22

Pilbaria deverella new form.
Yelma or Frere Formations, thin sections.

(A) GSWA F12378 from Frere Formation, NBR4, showing branching pattern.

(B) GSWA F12376 from Yelma Formation, NBR1. Microstructure.

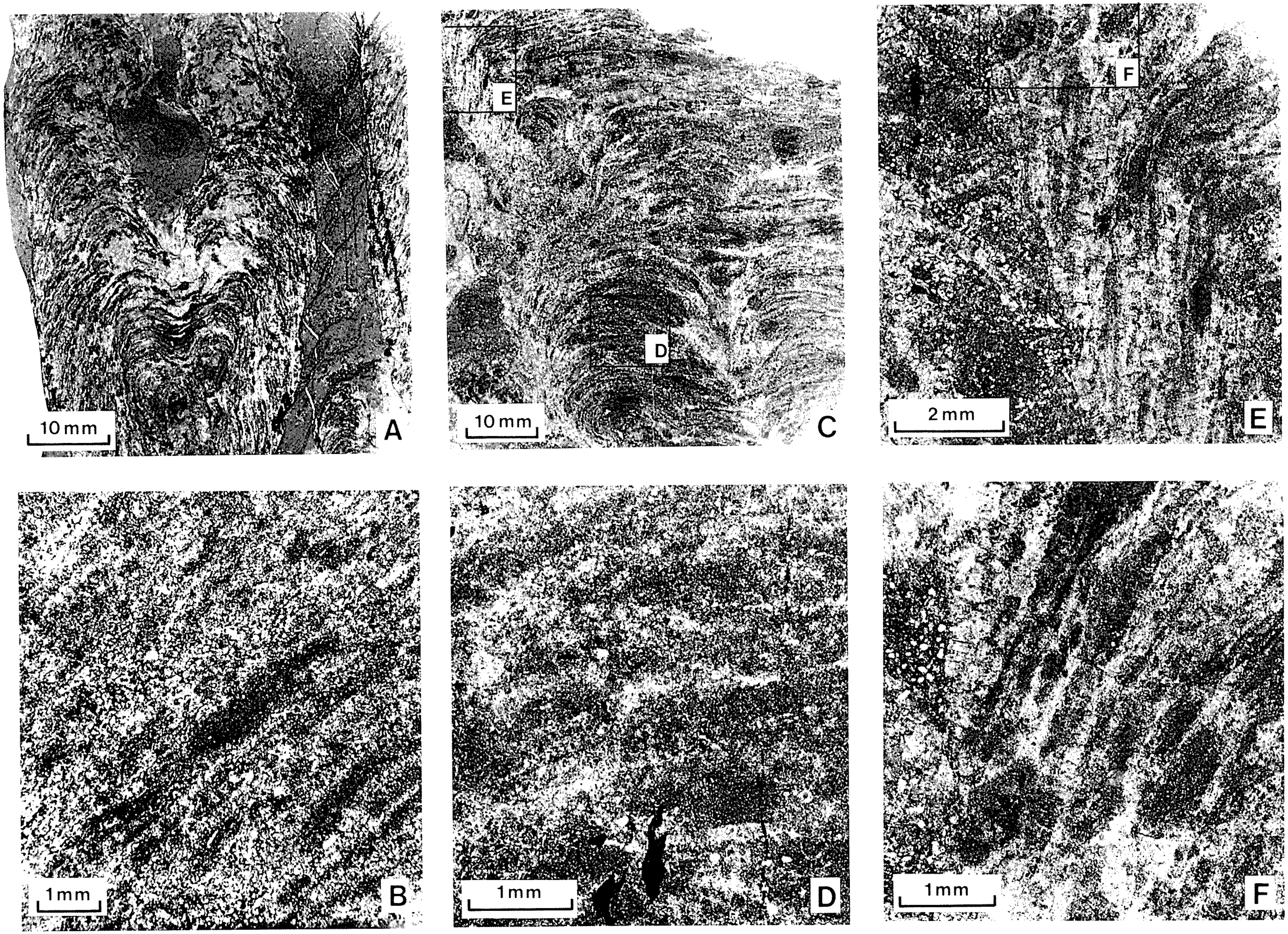
(C) to (F) GSWA F12377 from Yelma Formation, NBR1.

(C) Laminae shapes. (E) is outlined by upper frame, (D) by lower frame.

(D) Detail of microstructure.

(E) Laminae near column margin forming patchy wall. Area shown in (F) is outlined.

(F) Detail of laminae and microstructure near column margin.



GSWA 19985

PLATE 23

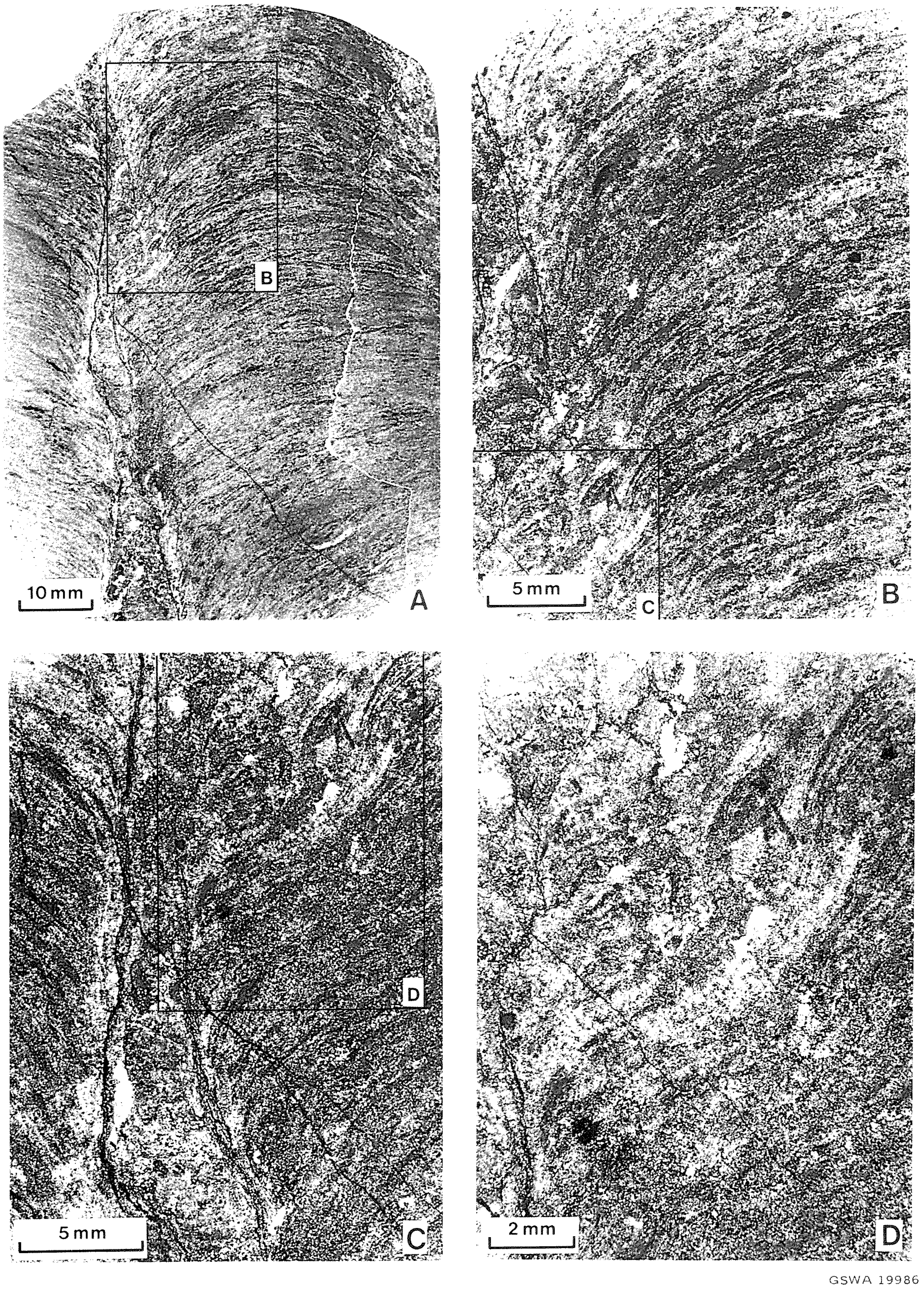
Pilbaria deverella new form.
GSWA F12376, Yelma Formation NBR1, thin sections.

(A) Laminae shapes. Area shown in (B) is outlined.

(B) Fabric showing lensoid laminae. Area shown in (C) is outlined.

(C) Column margins. Area shown in (D) is outlined.

(D) Microstructure.



GSWA 19986

PLATE 24

Windidda granulosa (Preiss 1976).
GSWA F12380, Windidda Formation, RBR1, polished faces.

(A) Adjacent straight columns of "*Minjaria*"-type.

(B) Column of "*Tungussia*"-type from face at right angles to (A), with a "*Minjaria*"-type column developing in the upper part of the specimen. Area shown in (C) is outlined.

(C) Detail of transition shown in (B). Note the multilaminate walls. Area shown in (D) is outlined.

(D) Detail of transition area showing similarity of microstructure in both parts of the column.

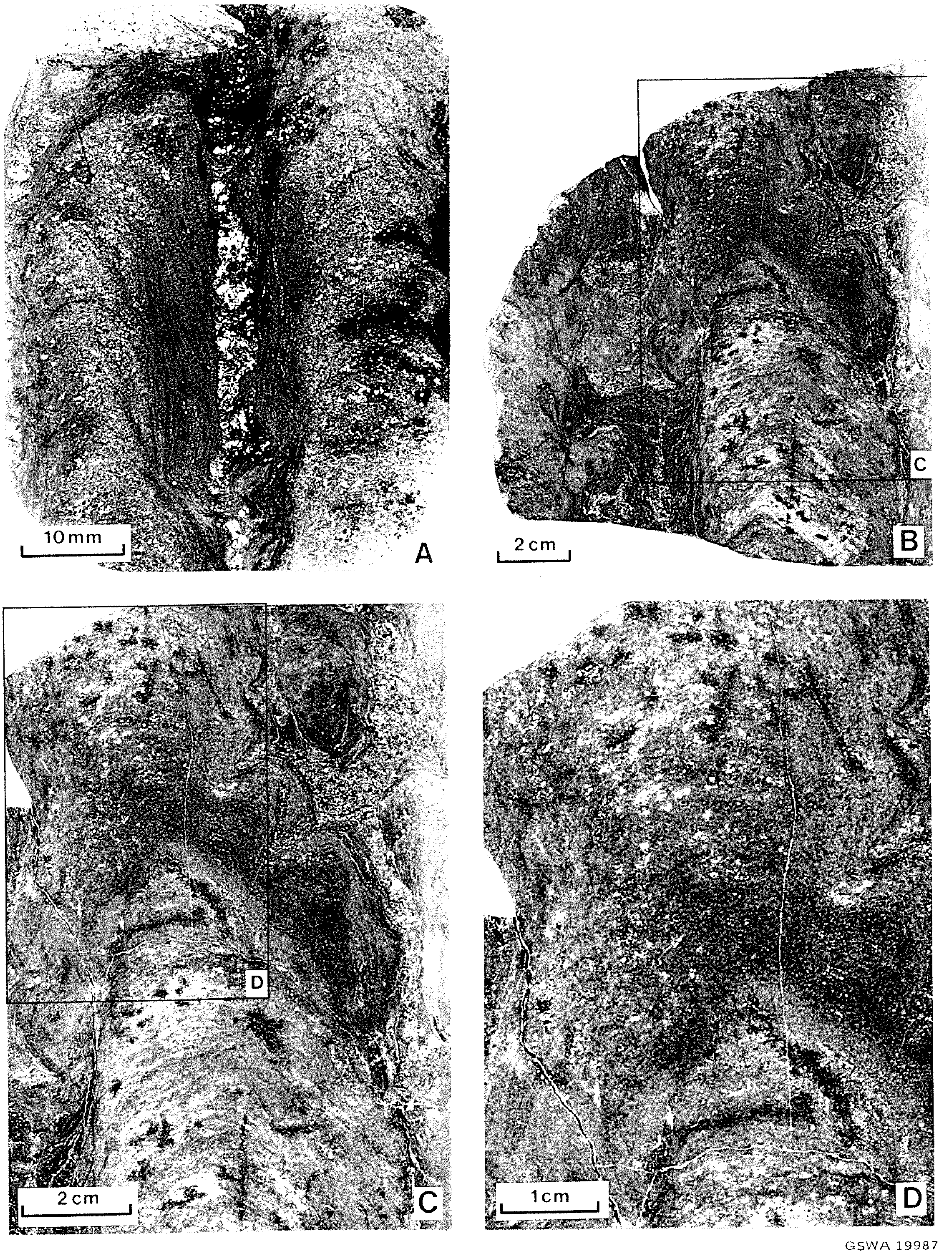

10 mm
A
2 cm
B
C
2 cm
C
D
1 cm
D
GSWA 19987

PLATE 25

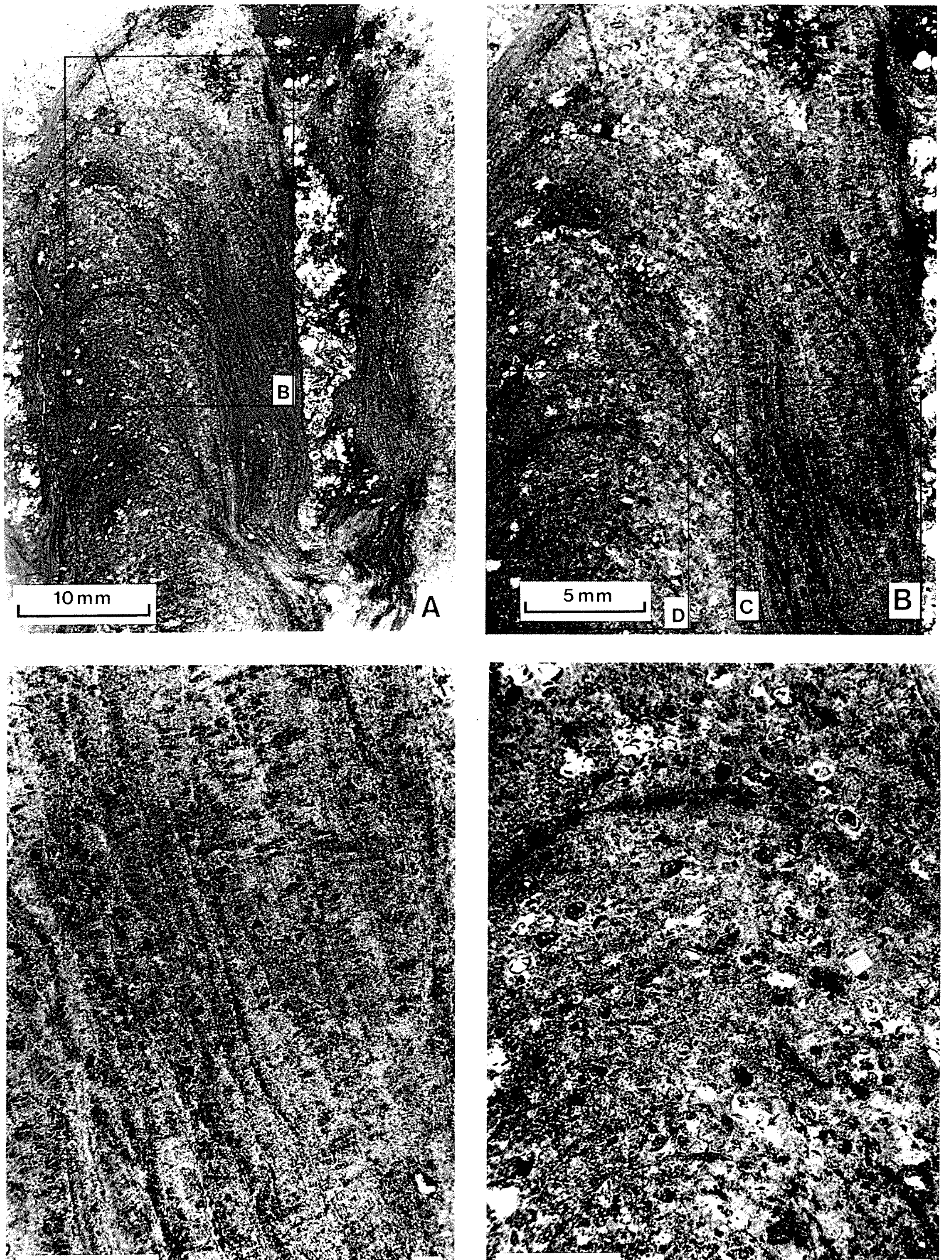
Windidda granulosa (Preiss 1976).
GSWA F12380, Windidda Formation, RBR1, thin sections.

(A) Part of straight-walled column *(Minjaria granulosa* of Preiss). Area shown in (B) is outlined.

(B) Detail of column showing granular microstructure in column centre and finely banded laminae forming thick walls. (C) is outlined by smaller frame, (D) by larger frame.

(C) Finely banded laminae forming multilaminate wall.

(D) Granular microstructure with occasional wispy laminae crossing the column centre.



GSWA 19988

PLATE 26

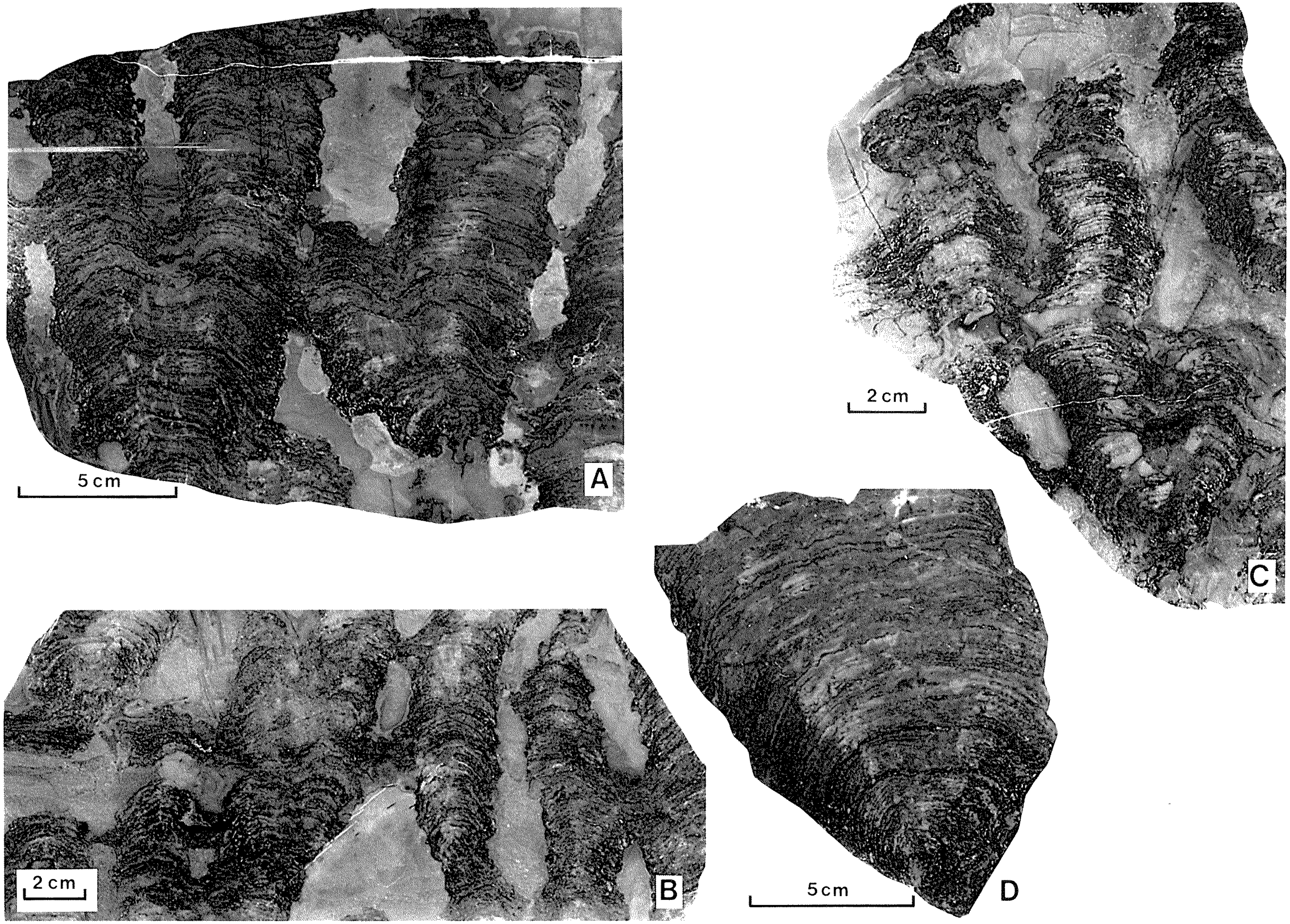
Yandilla meekatharrensis new group and form.
Yelma Formation, GLG1, polished faces.

(A) GSWA F12382. Column shape and branching pattern.

(B) GSWA F12383, Holotype. Column shape and branching pattern.

(C) GSWA F12386. Column shape and branching pattern.

(D) GSWA F12387. Laminae shapes.



GSWA 19989

PLATE 27

Yandilla meekatharrensis new group and form.
Yelma Formation, GLG1, thin sections.

(A) GSWA F12386. Column showing branching.

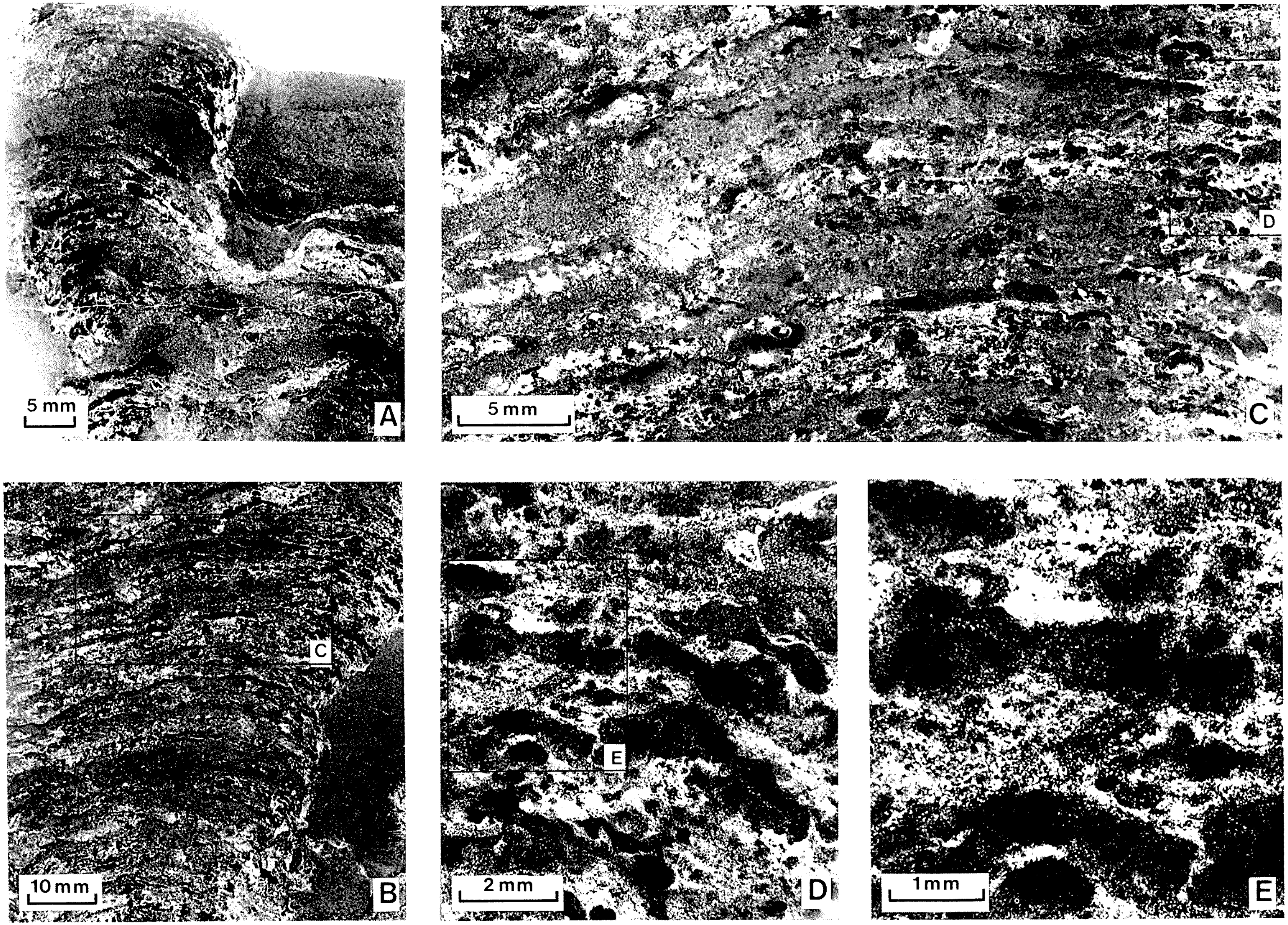
(B) to (E) GSWA F12385.

(B) Detail of column showing margin. Area shown in (C) is outlined.

(C) Streaky and vermiform laminae. Area shown in (D) is outlined.

(D) Vermiform microstructure. Area shown in (E) is outlined.

(E) Detail of microstructure. Note the considerable alteration as a result of recrystallization.



GSWA 19990

PLATE 28

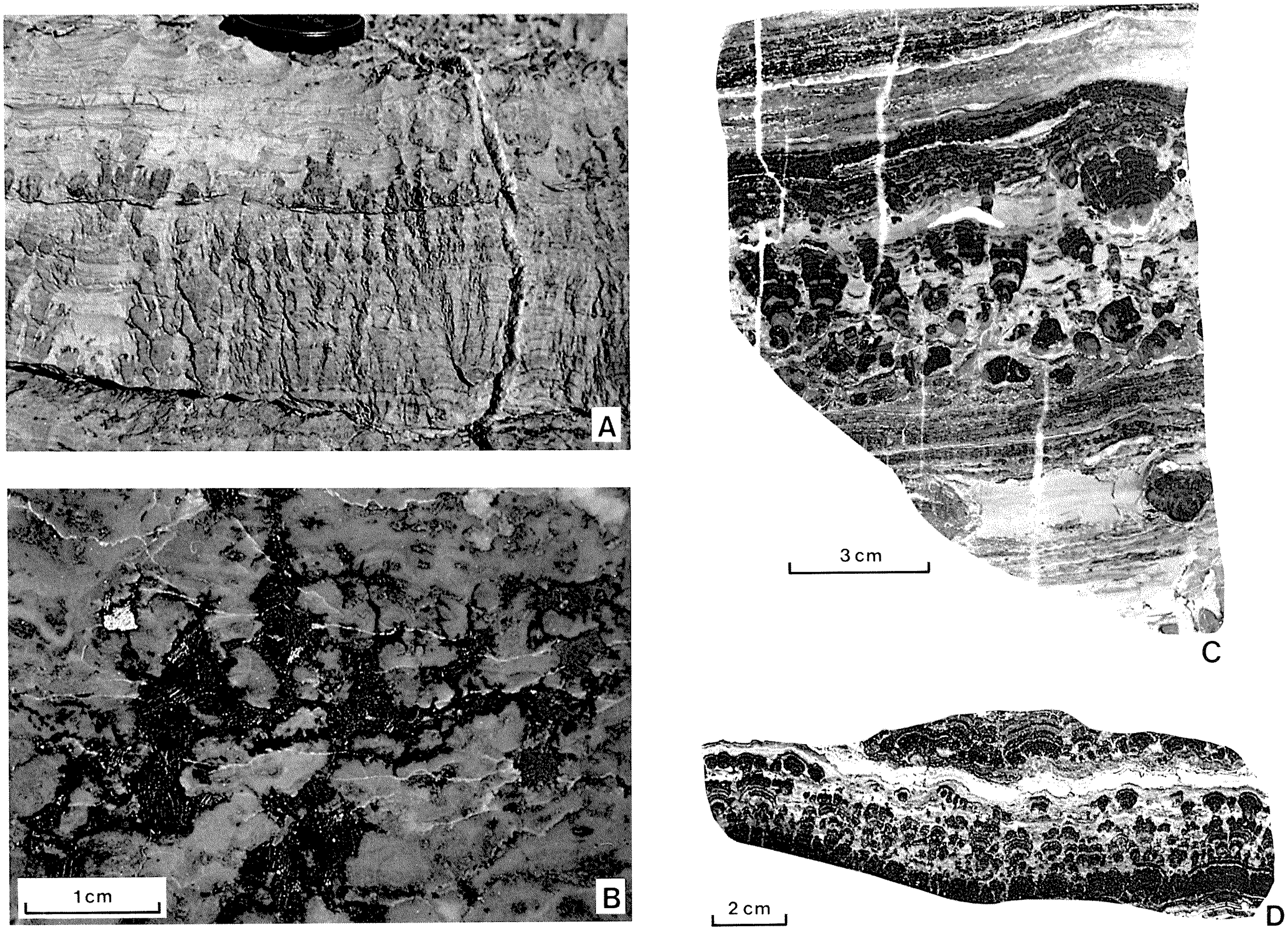
Yelma digitata new group and form.

(A) Field occurrence of *Yelma digitata*, Yelma Formation, NBR1. Lens cap for scale.

(B) GSWA sample number 59871 (R7044). Stromatolitic dolomite from Yelma Formation, NBR1, with poorly-preserved and recrystallized columns of *Yelma digitata* in which the column interspaces are infilled by galena.

(C) GSWA F12391 polished face from Yelma Formation, NBR1. Laminated stromatolitic dolomite with small fascicles of *Yelma digitata*.

(D) GSWA F12396 polished face from Yelma Formation, PKH2. Stratiform, small domical and small fascicular stromatolites of *Yelma digitata*.



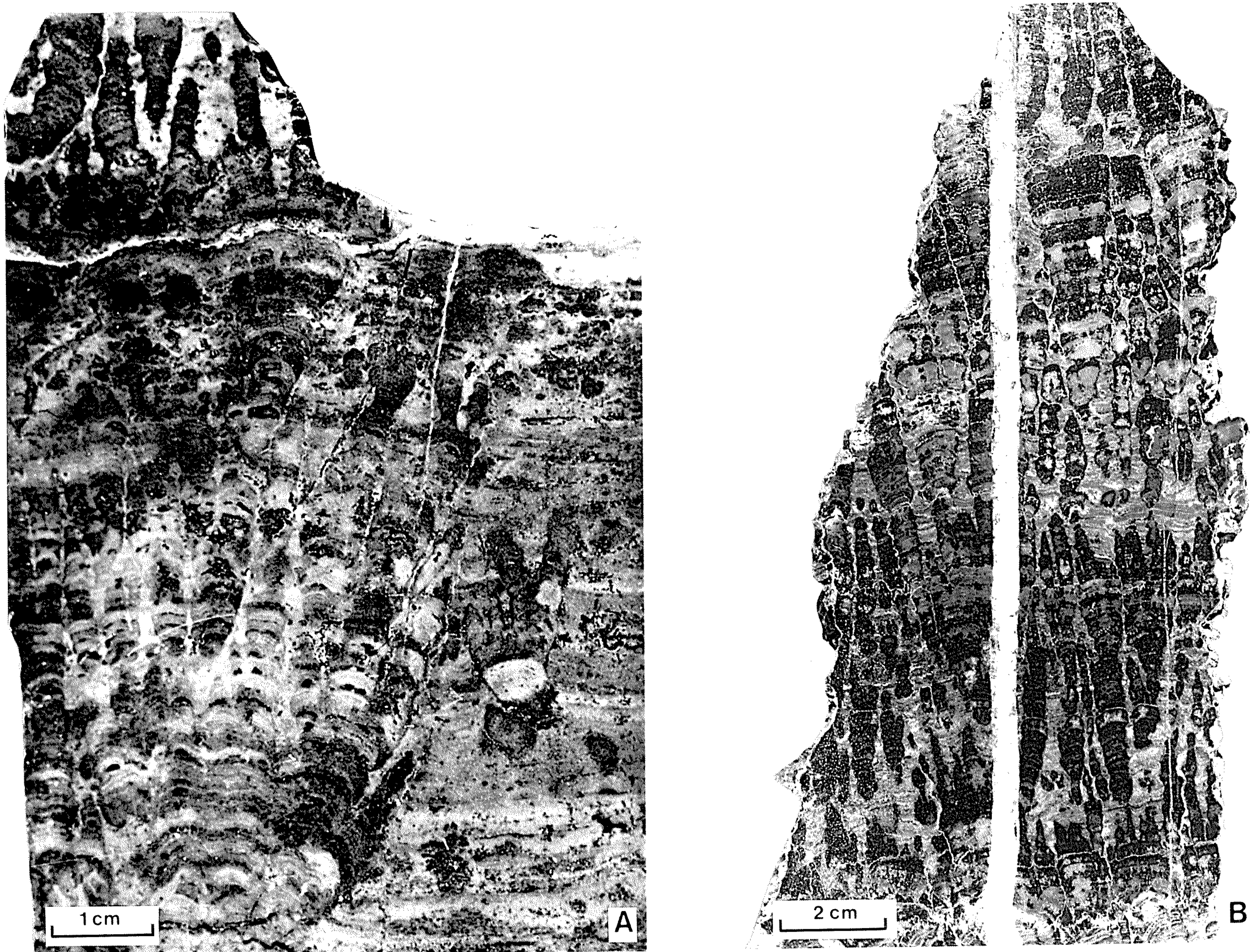
GSWA 19991

PLATE 29

Yelma digitata new group and form.
Yelma Formation, NBR1.

(A) GSWA F12390, Holotype. Branching pattern and fascicle development where individuals are relatively widely spaced.

(B) GSWA F12392. Specimen in which the columns are more crowded.



GSWA 19992

PLATE 30

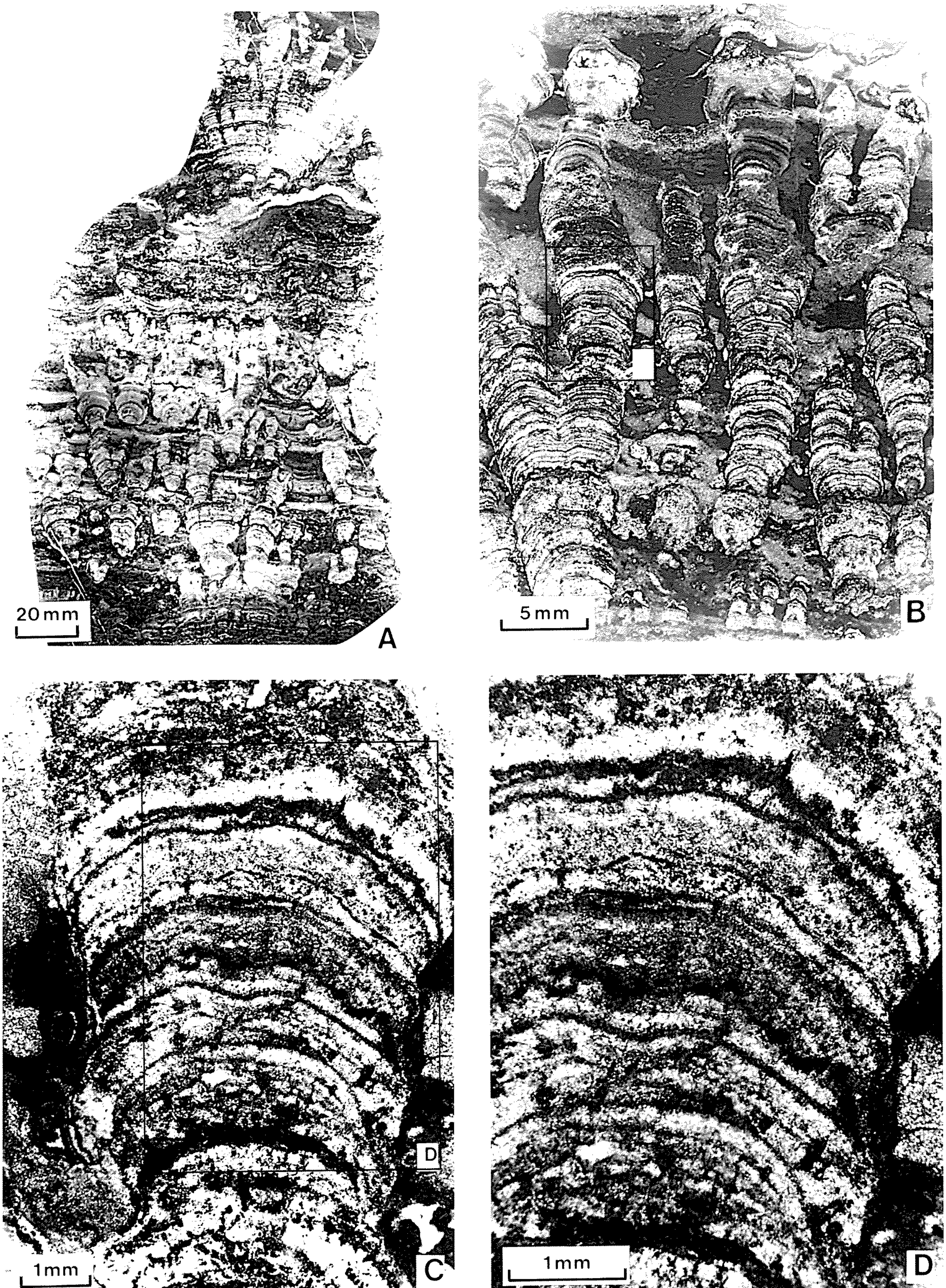
Yelma digitata new group and form.
GSWA F12390, Holotype, Yelma Formation, NBR1, thin sections.

(A) Fascicle shape of specimen illustrated in Plate 31.

(B) View of another thin section showing branching pattern. Area shown in (C) is outlined.

(C) Banded microstructure. Area shown in (D) is outlined.

(D) Banded microstructure.



GSWA 19993

PLATE 31

Yelma digitata new group and form.
GSWA F12390, Holotype, Yelma Formation, NBR1, thin sections.

(A) Branching pattern and column shape. Area shown in (B) is outlined.

(B) Laminae shapes. Area shown in (C) is outlined.

(C) Laminae shapes, banded microstructure and column margins. Area shown in (D) is outlined.

(D) Banded microstructure and column margins.

GSWA 19994

PLATE 32

Yelma digitata new group and form.
GSWA F12393, Yelma Formation, NBR1, thin section. White areas are replaced by secondary silica.

(A) General view of closely spaced columns. Area shown in (B) is outlined.

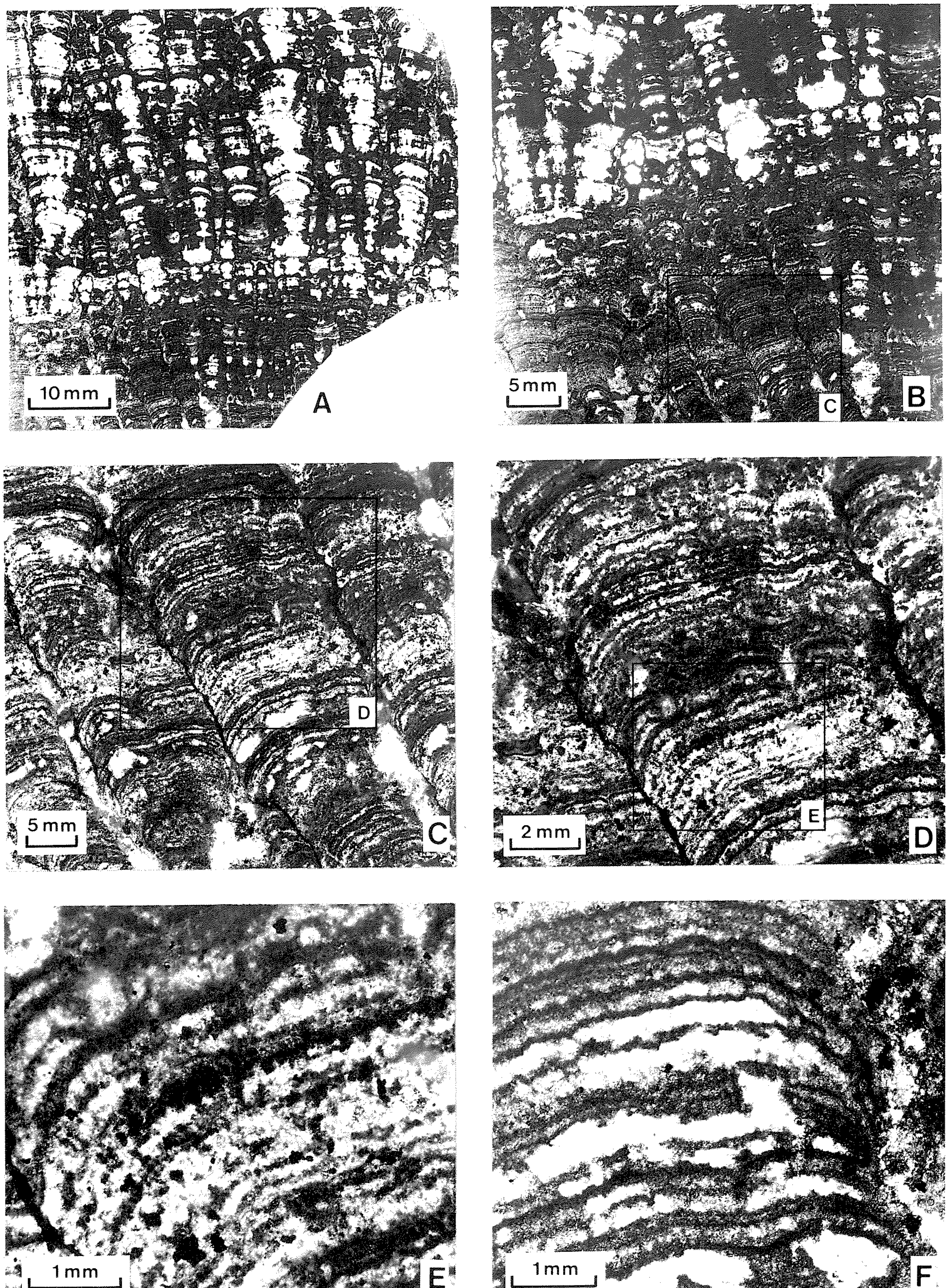
(B) Branching pattern and laminae shapes. Area shown in (C) is outlined.

(C) Laminae shapes. Area shown in (D) is outlined.

(D) Banded microstructure. Area shown in (E) is outlined.

(E) Banded microstructure and texture.

(F) Banded microstructure and texture is another part of the same thin section.



GSWA 19995