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FOSSIL NON-CALCAREOUS ALGAE FROM INSOLUBLE RESIDUES OF ALGAL LIMESTONES

BY

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ABSTRACT

Dissolution of algal limestones in a 1–10% HCL solution delivers flocks of well preserved non-calcareous algae and sometimes some other plant remains as well. Non-calcareous algae of Cambrian, Carboniferous, Jurassic and Paleogene age were obtained in this manner. Slides of these fossils together with thin sections of the limestones are shown. Various algal divisions are represented: Cyanophycophyta, Chlorophycophyta, Xanthophycophyta and Rhodophycophyta.

INTRODUCTION

Until now no fossil non-calcareous algae are known to a great extent, not even from sediments with clear organo-sedimentary structures caused by algal precipitation of calcium-carbonate. There is a big gap between paleontologists and sedimentologists studying the fossil organo-sedimentary structures without knowing by which algae these are built, and the phycologists studying the algae without being much concerned about the sedimentary structures these build. This is also the reason why there is difference in opinion between geologists studying recent blue-green algal communities and their sedimentary structures (Monty, 1965 a and b, 1967) and geologists describing fossil algal structures (Logan, Ginsburg & Rezak, 1964). Monty pointed out that differences in shape of the structures is caused, not only by differences of environment, but also by differences of the algal communities. In his opinion Logan *et al.* related, too one-sided, variations in shape to differences of environment. The discovery of well preserved fossil non-calcareous algae might lead to more exact environment determinations as now, in fossil structures too, the algal communities can be defined. Moreover the fossil non-calcareous algae appear to be more or less comparable with recent ones although one always should keep in mind the possibility that in the geological past the algae might have been adapted to environments different from those of comparable recent ones. Anyway one thing is definitely established, the fossil record of non-calcareous algae now can be extended and may be helpful in elucidating the major pathways of their evolution.

PREVIOUS WORK AND METHOD

The method described below is a result of studies on the genesis of Carboniferous limestones of the Lois-Ciguera Formation in the province of León, northwestern Spain (figs. 1 and 2). It appears that more than 90% of these limestones must have been formed by algae. They show excellent preserved algal textures and structures such as pseudostromata (Wolf, 1965), algal pellets and grains, colonial and stemfragments, algal filaments and cells, algal envelopes and algal crusts, stromatactis and birdseyes. The frequency of pseudostromata, masses of algal bound mudstone or algal bound wackestone (terminology see section Material and Description) is striking. Although the formation of these structures by algae is generally accepted, only vague algal molds are to be seen occasionally. The pseudostromata, although showing a variety of textures (dense, grumous, cellular, pelletoid and granuloid) always can be recognized easily. Therefore the author presumed a common element in the pseudostromata, perhaps an organic framework, which could not be seen materially at magnifications of the dissection microscope, but which one should be able to make visible in one way or another.

Study of acetate-peels of the limestone at magnifications of 100 to 400 times revealed certain phenomena which fortified that opinion.

Remains of brachiopods and molluscs with an algal envelope show a microstructure corroded by little tubes and aggregates of these tubes (Plate A, figs. 1 and 2). The same elements were found to form the framework of the limestone. Examination of thin sections, colored in a mixture of Alizarine Red-S and $K_3Fe(CN)_6$ (Friedman, 1959) proved that these phenomena were no artefacts or optical illusions. By this solution, which colors calcite red, ferroan calcite purple, ferroan dolomite blue and which does not color the dolomite, a similar framework of tubes and aggregates of tubes became visible at a 400 times magnification. They often form a dark blue or black network around or within the crystals. This resembles the picture given by Monty (1967, pl. 11–2) of recrystallization in crusty flakes: 'Algal filaments that were pervading the fine-grained matrix and binding detrital particles are reduced to small black streaks within or between the crystals of the new mosaic'.

By the somewhat acid reaction of the solution the border of the thin section had been etched away. In this dissolved part some isolated elements of the framework were visible: minute cylindrical tubes and their aggregates (Plate A, fig. 3). They have not been

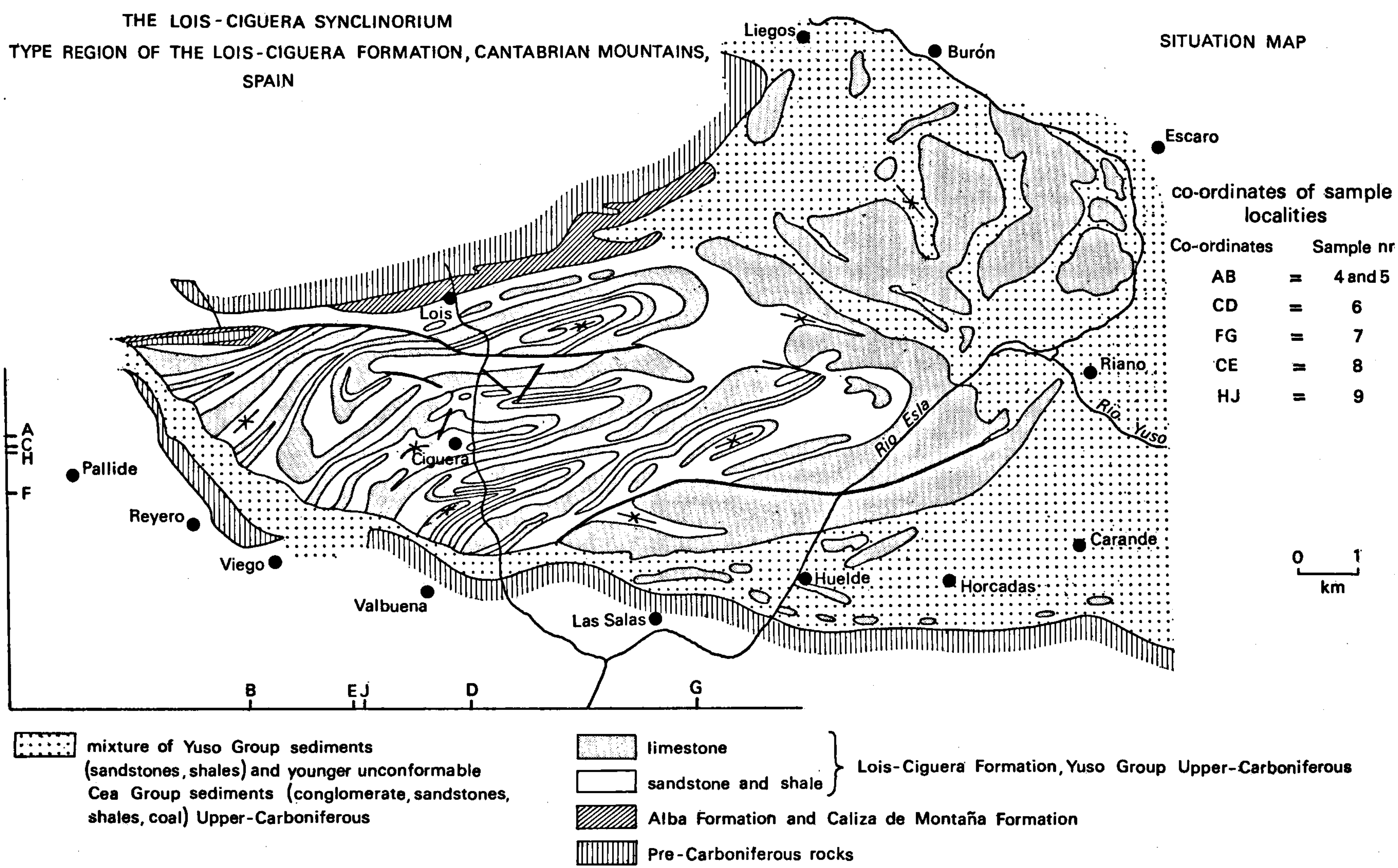
THE LOIS-CIGUERA SYNCLINORIUM
TYPE REGION OF THE LOIS-CIGUERA FORMATION, CANTABRIAN MOUNTAINS, SPAIN
SITUATION MAP
Liegos
Burón
Escaro
Riano
Rio Yuso
Rio Esla
Lois
Ciguera
Pallide
Reyero
Viego
Valbuena
Las Salas
Huelde
Horcadas
Carande
A
C
H
F
B
EJ
D
G
co-ordinates of sample localities
Co-ordinates Sample nr
AB = 4 and 5
CD = 6
FG = 7
CE = 8
HJ = 9
0 1
km
mixture of Yuso Group sediments (sandstones, shales) and younger unconformable Cea Group sediments (conglomerate, sandstones, shales, coal) Upper-Carboniferous
limestone
sandstone and shale
Lois-Ciguera Formation, Yuso Group Upper-Carboniferous
Alba Formation and Caliza de Montaña Formation
Pre-Carboniferous rocks

Fig. 1.

dissolved as they are silicified or constituted by another compound not soluble in HCL. Besides, in some borders a number of plankton-like forms were found. To extract this 'plankton' from the limestones, the method used on preparation of pollen samples could not be used because with this procedure manipulations are carried out, which should be avoided in this case (centrifuge, HF-treatment, acetolyse), the organisms being very fragile and often composed of SiO_2. The only method therefore was to dissolve the limestone in HCL and to investigate the insoluble residue. To be quite on the safe side small pieces of limestone were dissolved in a 1% HCL solution. Every time the solvent had lost its force some drops of 10% HCL were added in order to obtain complete dissolution. One of the samples gave a residue showing strong coherence. On moving the solution it did not fall apart but moved along as a yelly-like mass. A piece of this tough residue was cut apart and put on an object-glass in a drop of water, covered with a cover-glass and examined at a 400 times magnification. Beautiful algal filaments and colonies of unicellular algae were visible. They were held together in a coherent mass by the same elements of the framework, seen in the dissolved borders of the thin sections. These elements frequently stick to the algal filaments as to cover them totally.

Other limestone samples did not show similar coherent residues but on more thorough examination flocculent substances were found in the residue or still connected with the half dissolved piece of limestone. The flocks normally appear only locally on the limestone pieces. This makes clear why in the dissolved borders of the thin sections no algae had been observed.

The flocks are easily sucked up with a dropper (Plate C) and put on an object-glass. The excess of fluid can be sucked away with the same dropper. To prevent desiccation, which causes desintegration to powder of the flock, one can add a drop of glycerol. The slide is now ready to be covered with a cover-glass. To preserve the slide for longer time the borders of the cover-glass can be sealed off with colorless nail polish.

To make sure that no recent lithophyllic algae had been prepared in this manner, fresh, unweathered samples were prepared by sawing the centers out of large hand specimens. Some of these samples were dissolved in a 10% HCL solution in order to see if the same results could be obtained more rapidly. The other samples were dissolved in a 1% HCL solution. Both processes resulted in the desired flocks, containing non-calcareous algae.

The Rijksherbarium in Leiden was informed and the slides were studied there. Although the identification is still provisional, one can say that non-calcareous algae belonging to the divisions Cyanophycophyta, Chlorophycophyta, Xanthophycophyta and Rhodophycophyta, are present.

CHEMICAL COMPOSITION

Examination of the non-calcareous algae under the polarizing microscope reveals sometimes a local silicification, but generally there can be said that they consist of organic material. Under the UV-microscope a fluorescence typical for organic material was recognized.

More detailed chemical analyses are in progress, the results of which will be published in a separate paper.

MATERIAL AND DESCRIPTION

As already mentioned above the algae were discovered in Spanish Carboniferous limestones. Older and younger algal limestones were dissolved also to see whether the conservation in the Spanish Carboniferous samples is unique. Evidently this is not the case and probably algal limestones of the whole world and all ages likewise will deliver these fossil non-calcareous algae. The Cambrian, Jurassic and Paleogene samples described below form a rather haphazard collection of algal limestones, being casually available in the department and not the successful remainders of a large systematically dissolved series.

The geographic position of the samples is given in figs. 1, 2 and 3. A detailed description of the samples, locality, stratigraphic position, age, rock description and their non-calcareous algae, is given with the plates.

The description of the limestones is according to the classification of carbonate rocks of Dunham (in Ham, 1962, p. 108–122).

The textural aspects of many algal limestones, classified by the present writer as boundstones, do not entirely fit the three signs of binding during deposition, recognized by Dunham (p. 117). Therefore an additional description is given in terms such as algal bound mudstone, algal bound wackestone or algal bound packstone.

The identification of the algae is a provisional one. A more definitive classification and description will be given in forthcoming papers. In all the samples the algae are found in a coherent granulate or vermiculate mass of earlier mentioned framework elements. Dispersed in this mass euhedral quartz and dolomite crystals are commonly found. Still unidentified planktonic forms, similar to the ones seen in the dissolved borders of the thin sections, were encountered in nearly all samples.

In a number of samples other plant remains are found.

CONCLUSIONS

1. Many algal boundstones classified as such on observation of phenomena ascribed to algae, which themselves however are not visible, possess an algal framework which can be made visible. So in cases of doubt whether to classify a limestone as algal bound or not, dissolution of the limestone may give the answer.

2. Many phenomena in limestone-petrography and in the classification of the calcareous algae, such as algal envelopes and crusts, algal grains and lumps, oncolites,

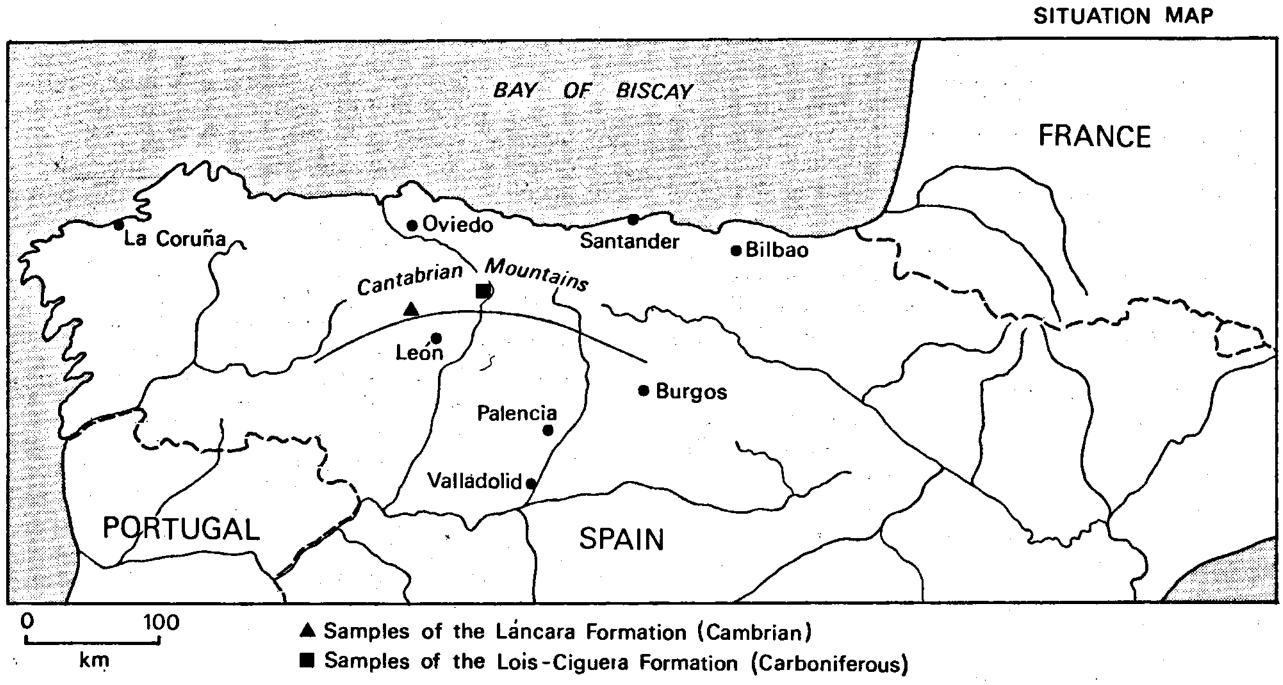
SITUATION MAP
BAY OF BISCAY
FRANCE
La Coruña
Oviedo
Santander
Bilbao
Cantabrian Mountains
León
Burgos
Palencia
Valladolid
PORTUGAL
SPAIN
0 100
km
▲ Samples of the Láncara Formation (Cambrian)
■ Samples of the Lois-Ciguera Formation (Carboniferous)

Fig. 2.

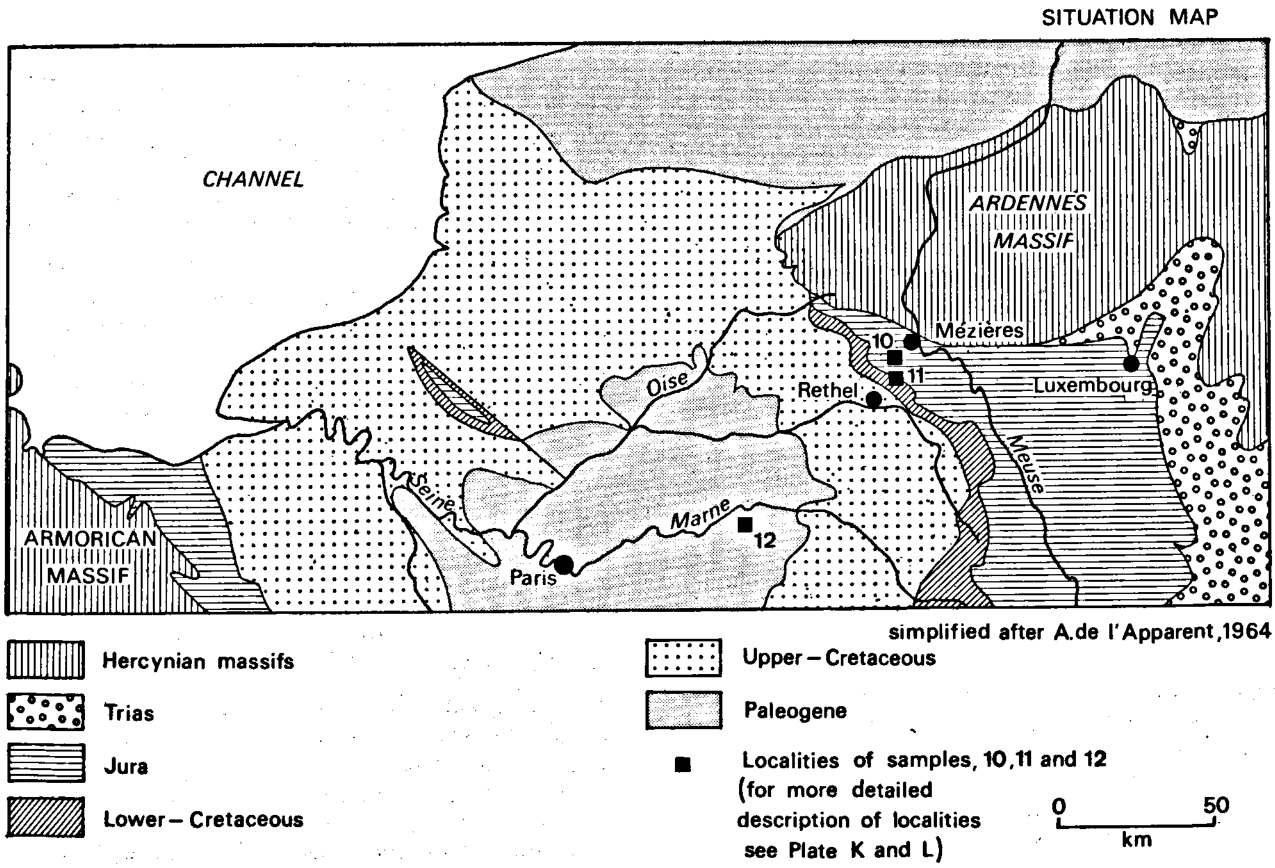
SITUATION MAP
CHANNEL
ARDENNES MASSIF
Mézières
10
11
Rethel
Luxembourg
Oise
Meuse
Seine
Marne
12
Paris
ARMORICAN MASSIF
simplified after A.de l'Apparent,1964
Hercynian massifs
Trias
Jura
Lower – Cretaceous
Upper – Cretaceous
Paleogene
Localities of samples, 10,11 and 12 (for more detailed description of localities see Plate K and L)
0 50
km

Fig. 3.

pseudostromata and stromatolites, frequently are ascribed to the activity of blue-green algae which left no trace or only vague molds. It now appears that algae belonging to various divisions may have been active.

3. The framework seen in peels, colored thin sections and dissolved thin sections of algal boundstones, consists of minute tube-like elements also encountered in the algal flocks. They constitute the coherent mass of the flocks and frequently stick to the filaments in such quantities as to cover them totally. May be they are comparable to the felts of *Schizothrix* overgrowing larger algal filaments as observed by Monty (1967, Plate 6–2 and 6–3). Sometimes a mosaic of somewhat larger tubes is visible (Plate A, fig. 4), which indeed might be a mosaic of minute algal filaments or, as is observed in some cases, a mosaic of cell- or filament-walls, due to diminution of original large filaments.

4. Plankton frequently accompanies the algal filaments and unicells in the slides.

5. The excellent conservation of the non-calcareous algae might be due to rather rapid enclosure in an environment of active carbonate precipitation. The fine-grained precipitates with low initial porosity provide good conservation material for the soft algal bodies.

6. Up to now the calcareous algae, visible in the thin sections of the Carboniferous samples, have not been seen in decalcified form in the algal flocks.

ACKNOWLEDGEMENTS

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I am grateful to Dr. P. van Gijzel, who kindly studied some of the algal slides under the UV-microscope.

Mr. W. C. Laurijssen and Mr. W. A. M. Devilée prepared the photographs and Mr. B. G. Henning the drawings.

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PLATES

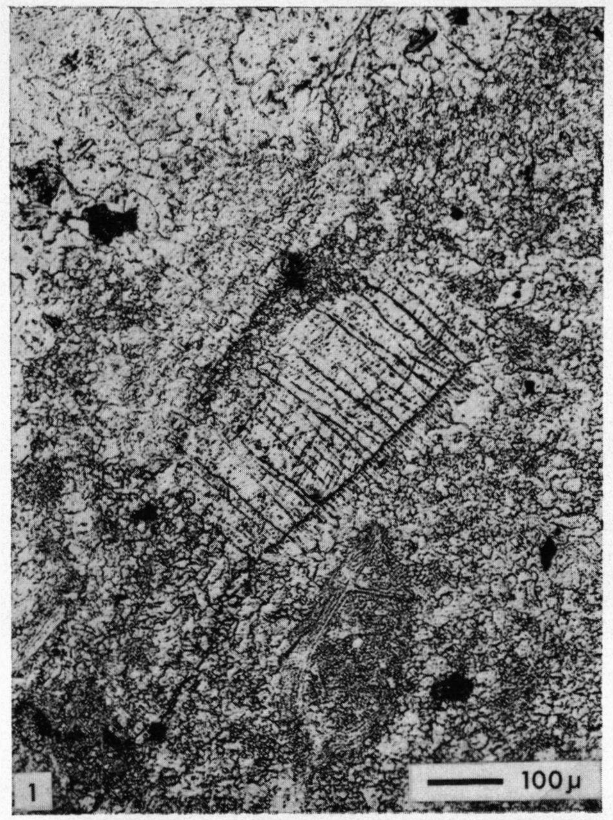
PLATE A

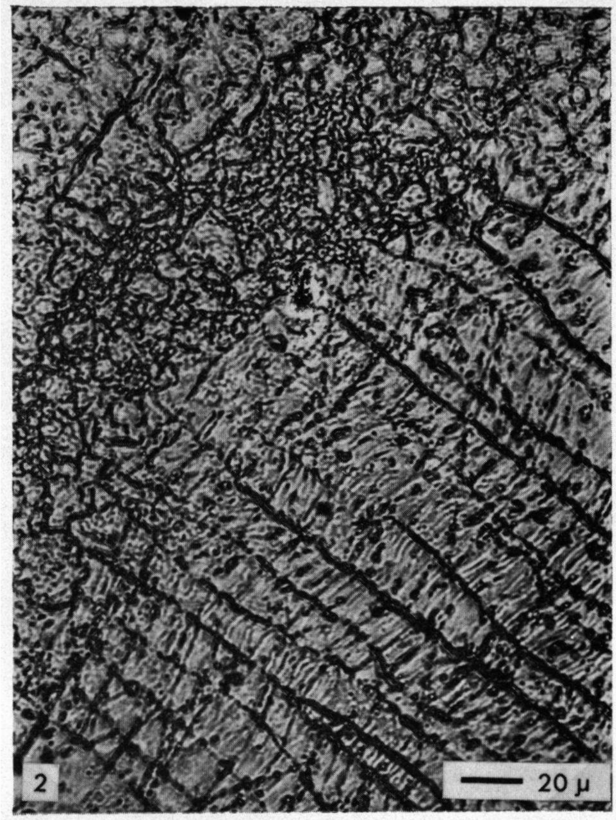
Fig. 1. Peel of a Lois-Ciguera Formation limestone, showing in the centre a mollusc remain with an algal envelope.

Fig. 2. Detail of fig. 1 showing the normal prismatic microstructure with growth-lines and the dark 'tube' mosaic of the algal envelope. Isolated small tube-like perforations are scattered over the whole length of the prisms.

Fig. 3. Dissolved thin section of sample 5 (description see Plate F), showing the same tube-like elements of fig. 2, isolated in the dissolved calcitic parts and lining and within the dolomite rhombs.

Fig. 4. Algal flock of sample 7 (description see Plate G), containing a mosaic of small algal tubes comparable with the tube-like elements of figs. 2 and 3. Out of focus in the lower half of the photo a larger algal filament. phase-contrast


1
100 µ


2
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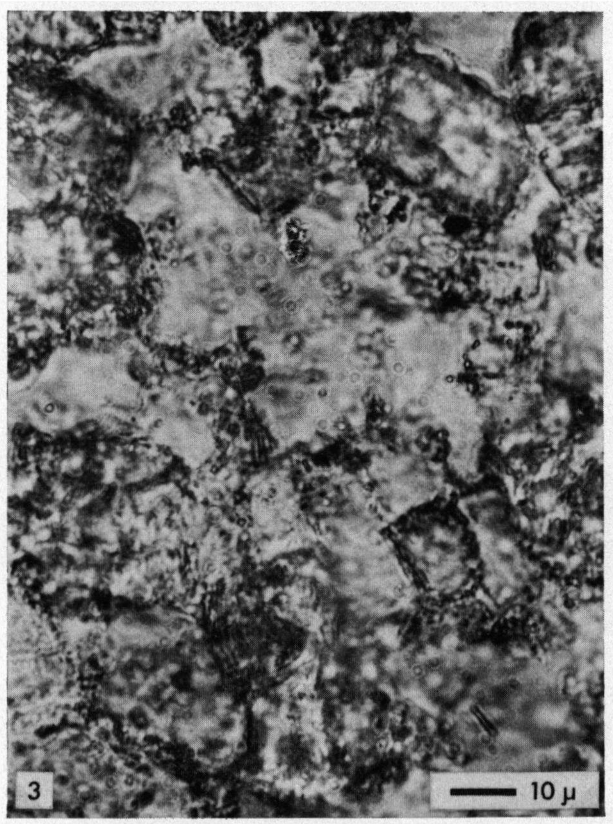

3
10 µ

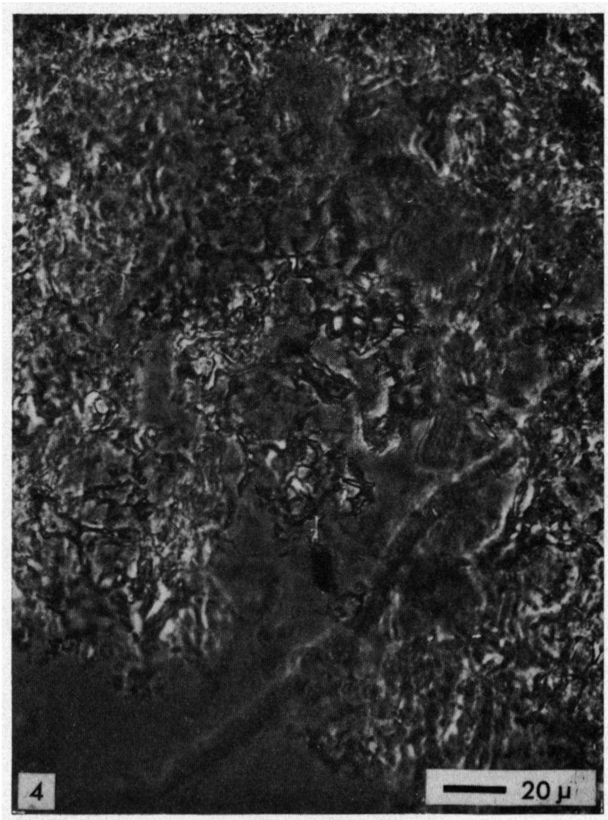
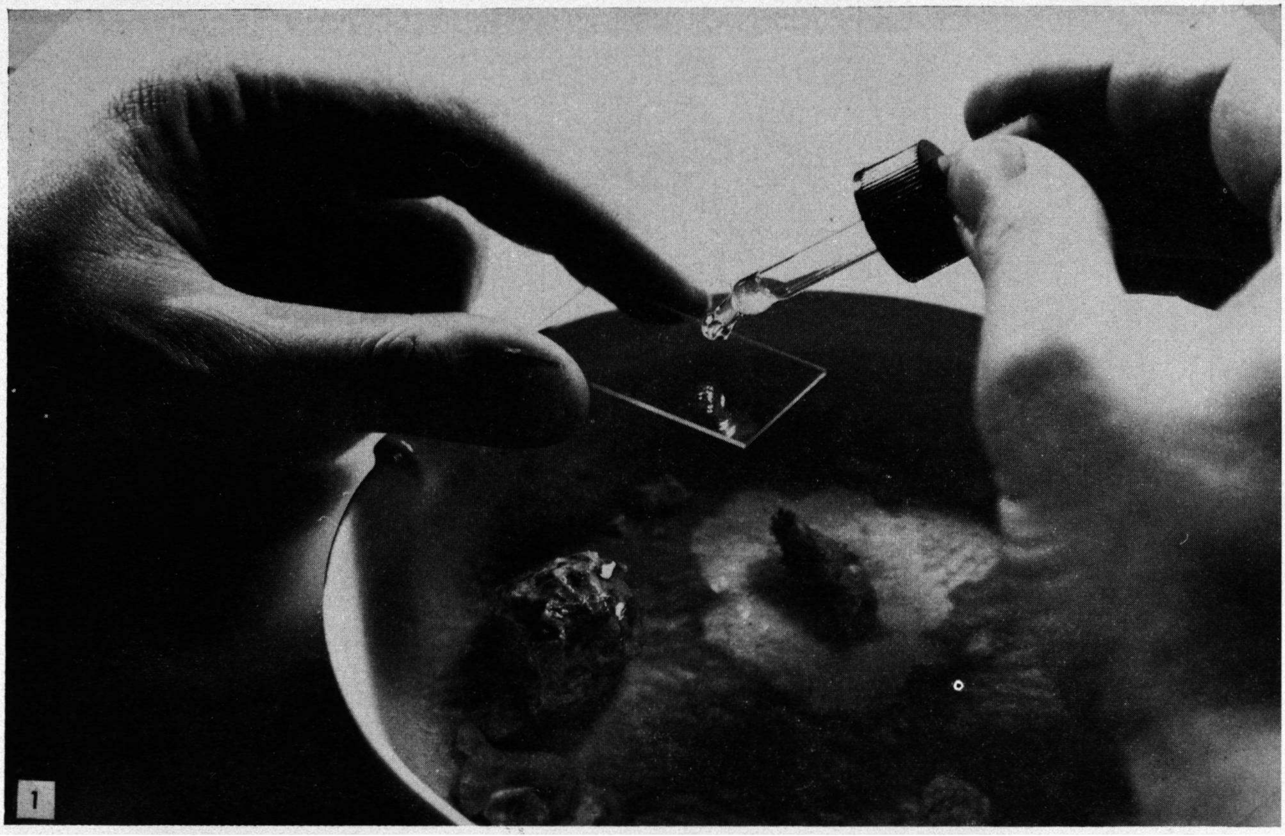

4
20 µ

PLATE B

Fig. 1. The tools for the preparation of the non-calcareous algae.

Fig. 2. Pieces of sample 10 (description see Plate K), in a 10% HCL solution. The surroundings of the oncolite in the upper centre have been cleaned from insoluble residue to show up the hairy algal flocks, appearing after two or three hours of dissolving.



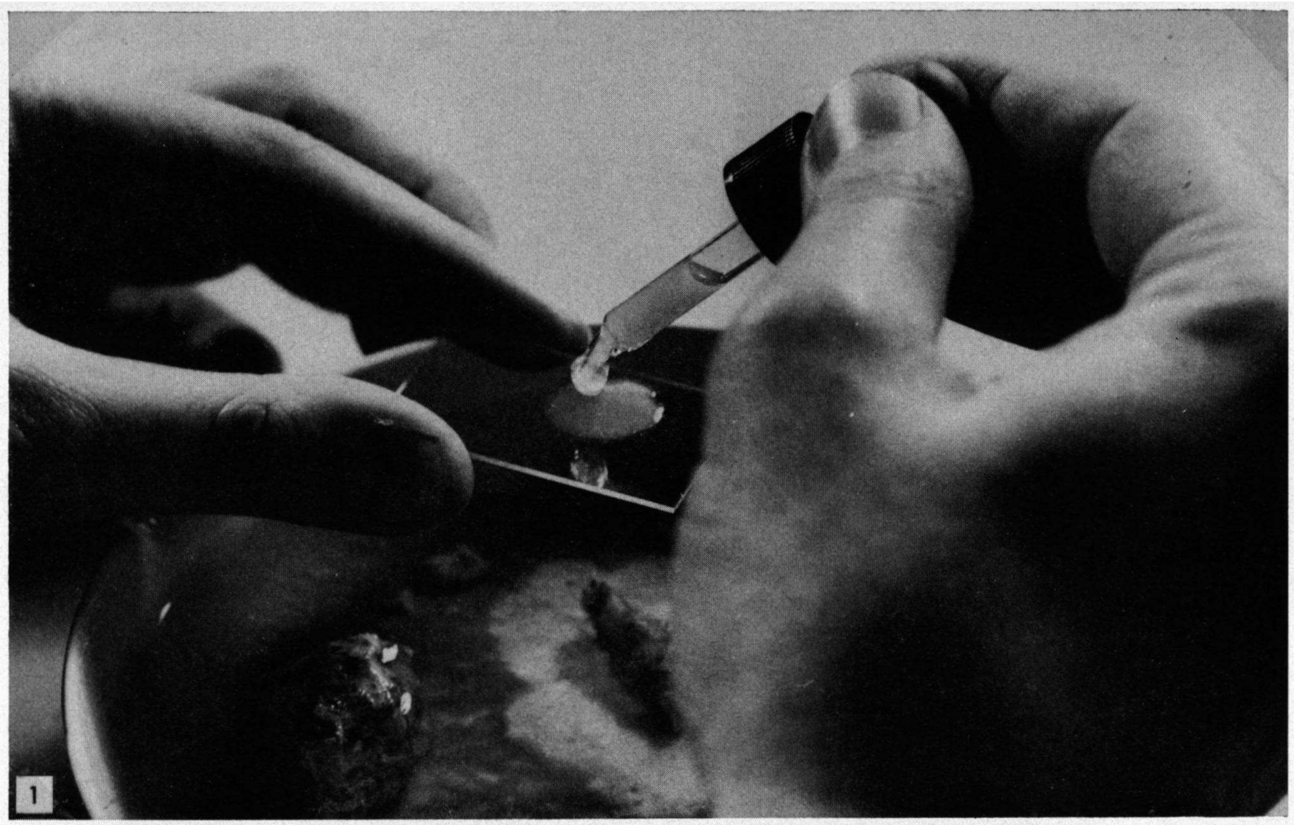
1

2

PLATE C

Fig. 1. Flocks of non-calcareous algae are sucked up with a dropper.

Fig. 2. After deposition of the flock on an object-glass the surplus of liquid is removed by sucking with the dropper and holding the glass vertical. After adding a drop of glycerol, the slide is ready to be examined.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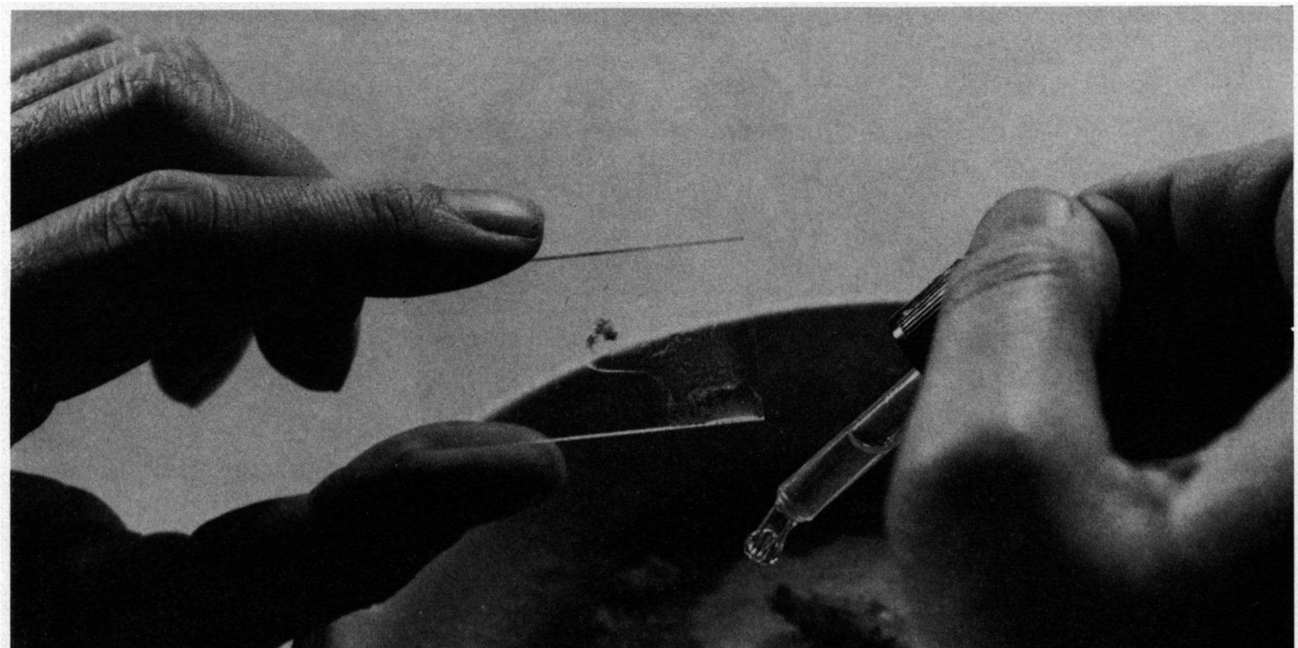
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PLATE D

Samples 1 and 2: from the Stromatolite Marker Bed of the Dolomite Member, the lowest member of the Lancara Formation, Spain (fig. 2).
Age: middle Lower Cambrian, ca. 560–550 x 10^6 years.
Rock description: stromatolitic boundstone.
Noncalcareous algae: cyanophyceans, unicells (cf. *Gloeocapsa*) and filaments (cf. *Microcoleus*); a primitive rhodophycean (cf. *Conchocelis*).

Sample 3: from the Limestone Member, the middle member of the Lancara Formation, Spain (fig. 2).
Age: Lower-Middle Cambrian, ca. 540 x 10^6 years.
Rock description: stromatolitic boundstone.
Noncalcareous algae: cyanophyceans, unicells (cf. *Gloeocapsa*) and two filamentous types; a primitive rhodophycean (cf. *Conchocelis*).

Fig. 1. Thin section of sample 3. Photo is a negative of the thin section. (sample LSF 42, loose debris, section LSF, see appendix II, v. d. Meer Mohr, 1969).

Fig. 2. Sample 3. A primitive rhodophycean (cf. *Conchocelis*). (sample LSF 42, loose debris, section LSF, see appendix II, v. d. Meer Mohr, 1969).
polarized light, gypsum plate

Fig. 3. Sample 2. Colonies of unicells (cf. *Gloeocapsa*). (sample LSM 21, section LSM, see appendix II, v. d. Meer Mohr, 1969).

Fig. 4. Sample 1. A primitive rhodophycean (cf. *Conchocelis*). (sample LSF 8, section LSF, see appendix II, v.d. Meer Mohr, 1969). phase-contrast

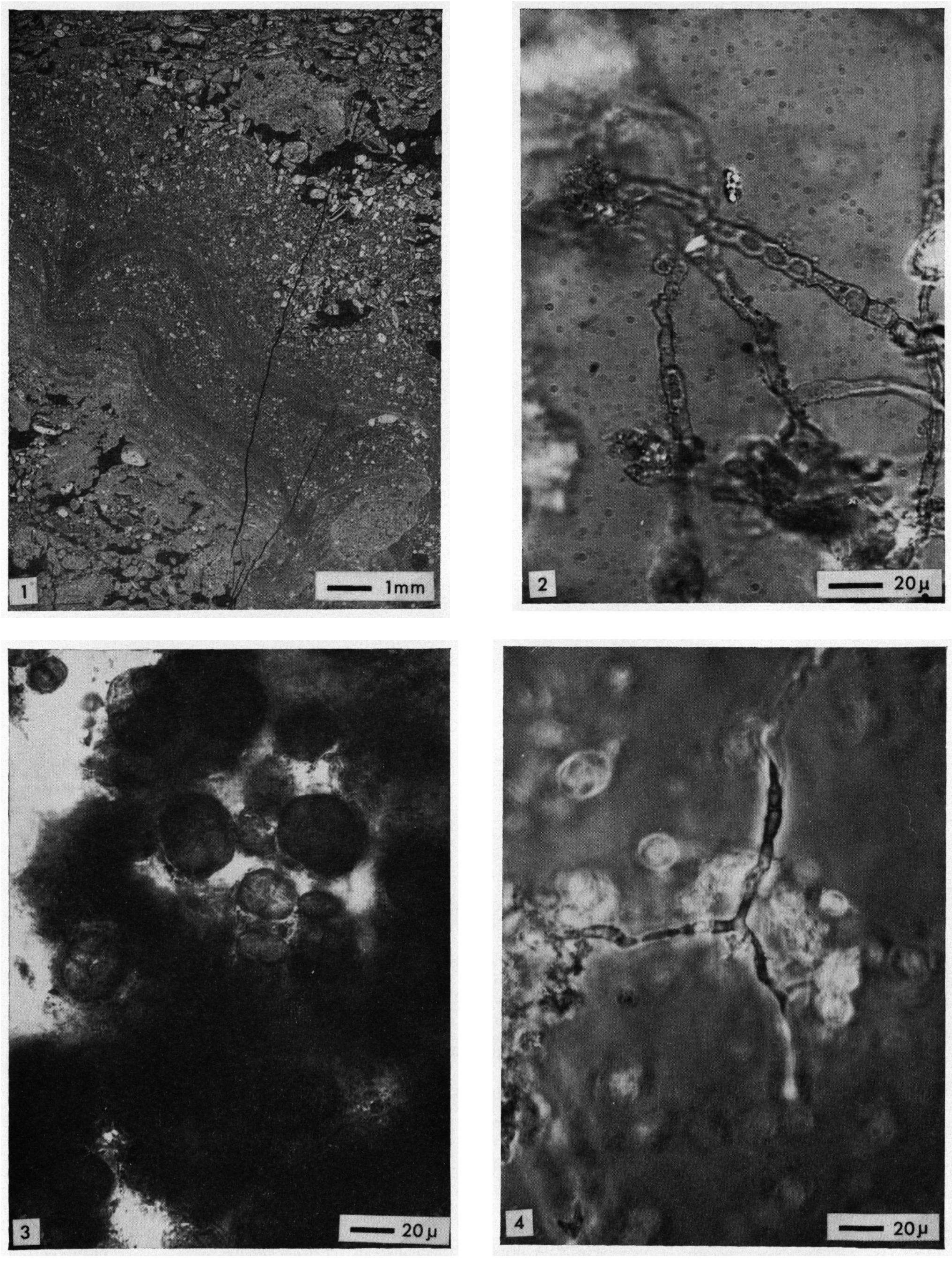

1
1mm
2
20µ
3
20µ
4
20µ

PLATE E

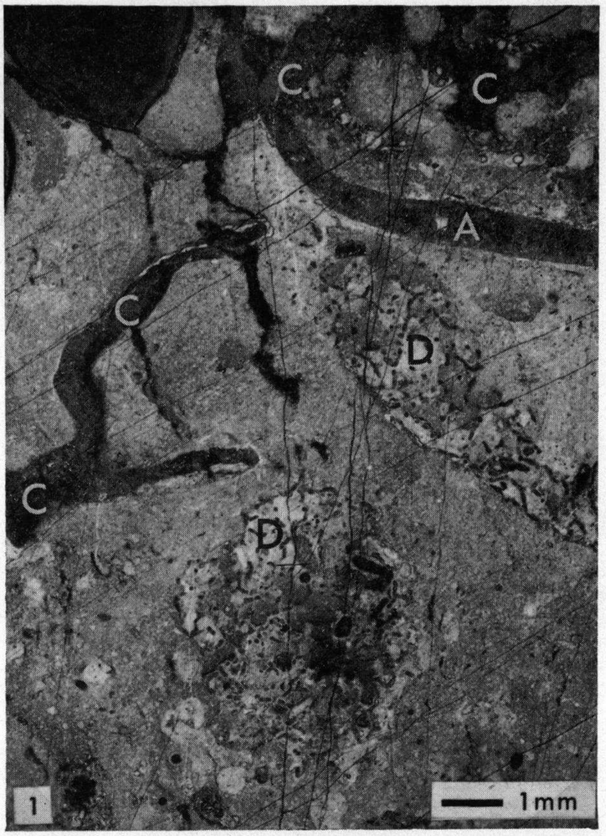
Sample 4: intersection of co-ordinates A and B, fig. 1, from the top of the Lois-Ciguera Formation, Spain.
Age: Westfalian (Moscovian, Pennsylvanian), ca. 300 x 10^6 years.
Rock description: boundstone (algal bound, algal fragment wackestone) containing calcareous algae (*Archeolihophyllum missouriensum* Johnson and *Donezella lugutini* Maslov), brachiopods, bryozoans, foraminifera and some mollusc-fragments.
Non-calcareous algae: cyanophyceans, unicells (cf. *Gloeocapsa*) and two filamentous types; a chlorohpycean or rhodophycean and a primitive rhodophycean (cf. *Conchocelis*).
Other plant remains: spore of an ascomycetean (Fungi).

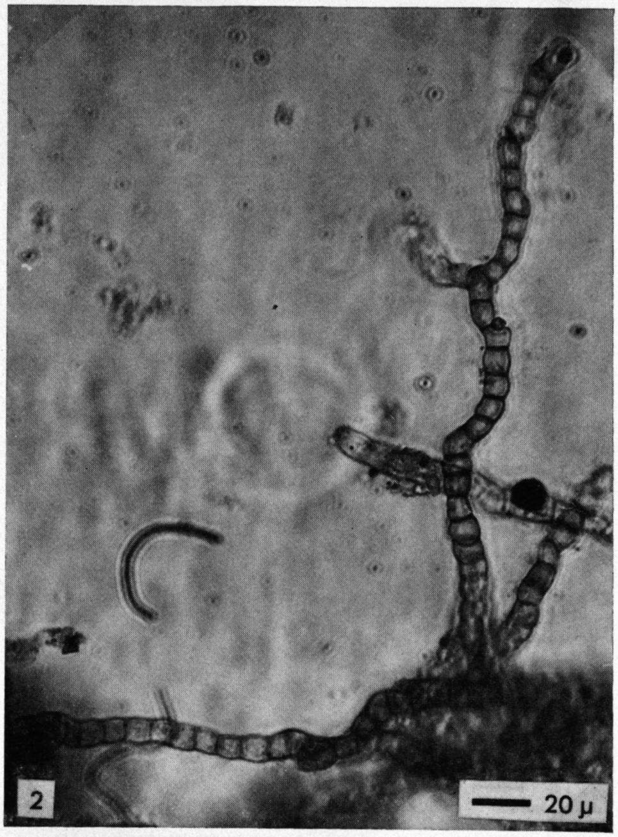
Fig. 1. Thin section of sample 4. Two colonies of *Donezella lugutini* Maslov (D), *Archeolithophyllum missouriensum* Johnson (A), cavities (C). Photo is a negative of the thin section.

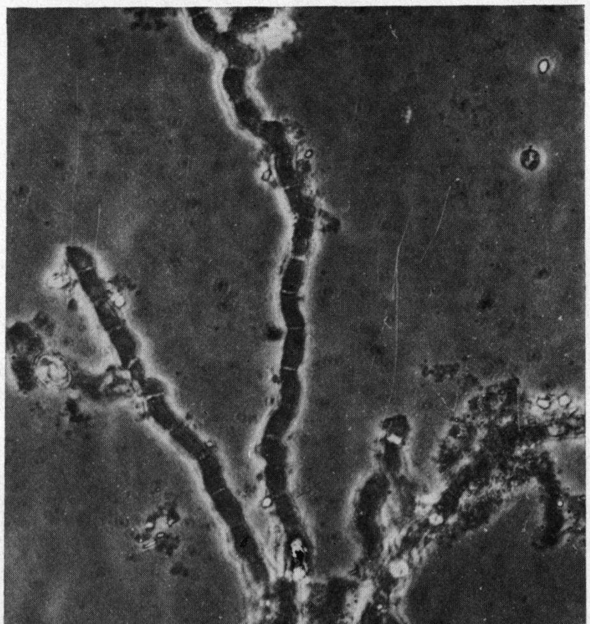
Fig. 2. A chlorophycean or rhodophycean. phase-contrast

Fig. 3. A cyanophycean. phase-contrast

Fig. 4. A primitive rhodophycean (cf. *Conchocelis*). phase-contrast


C
C
A
C
D
C
D
1
1 mm


2
20 μ


3
20 μ

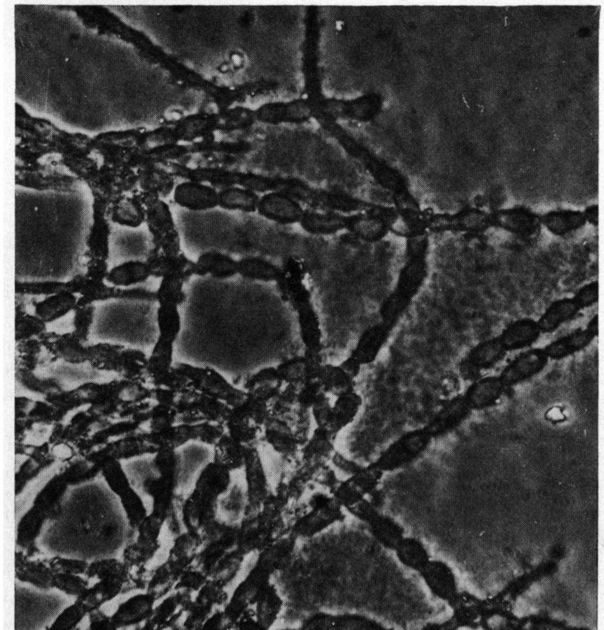

4
20 μ

PLATE F

Sample 5: intersection of co-ordinates A and B, fig. 1, from the top of the Lois-Ciguera Formation, Spain.
Age: Westfalian (Moscovian, Pennsylvanian), ca. 300 x 10^6 years.
Rock description: dolomitic boundstone (dolomitic, algal bound wackestone) containing the fusulinid ***Fusiella,*** fragments of brachiopods, bryozoa and echinoderms and calcispheres.
Non-calcareous algae: cyanophyceans (unicells and filamentous types), a primitive rhodophycean (cf. *Conchocelis*) and a large quantity of still unknown filaments.

Fig. 1. Thin section of sample 5. The lower right part of the photo shows pseudostromata (Ps). Photo is a negative of the thin section.

Fig. 2. Filaments of still unknown relationship. phase-contrast

Sample 6: intersection of co-ordinates C and D, fig. 1, from the Ciguera Limestone Member of the Lois-Ciguera Formation, Spain, the second limestone member down from the top of the formation.
Age: Westfalian (Moscovian, Pennsylvanian), ca. 300 x 10^6 years.
Rock description: boundstone (algal bound mudstone) with fibrous sparite cavity-filling, indicating subaerial exposure of the bioherm.
Non-calcareous algae: filamentous cyanophyceans (cf. *Scytonema*).

Fig. 3. Thin section of sample 6. The lower right part of the photo shows cavities with fibrous sparite-filling (F). Photo is a negative of the thin section.

Fig. 4. Filamentous cyanophyceans (cf. *Scytonema*).

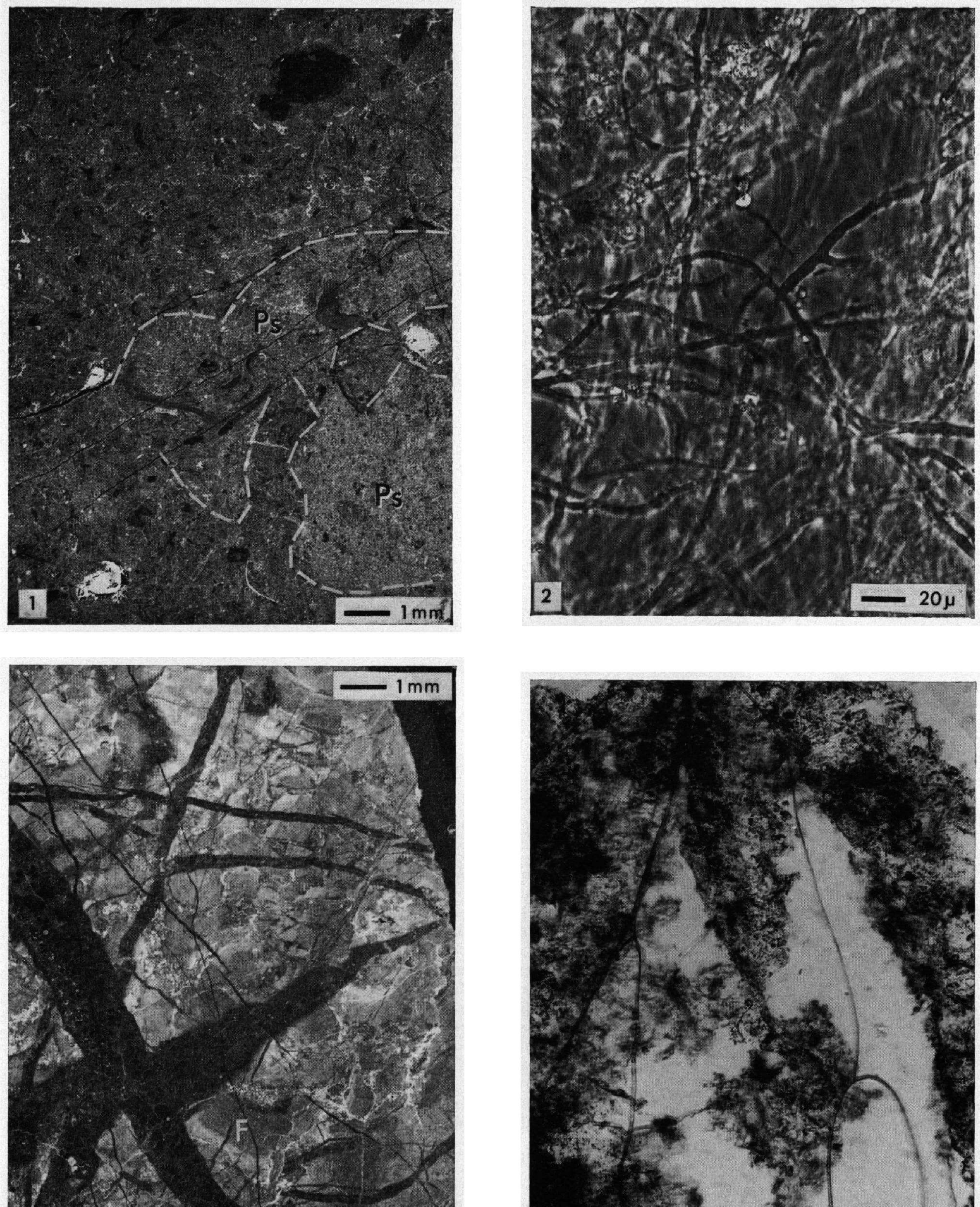

1
Ps
Ps
1mm
2
20µ
3
1mm
F
F
4
100µ

PLATE G

Sample 7: intersection of co-ordinates F and G, fig. 1, from the summit of the Peñas Pintas, a narrowly folded mountain-ridge. The limestone, the sample was taken from, lies somewhat above the base of the Lois-Ciguera Formation, Spain. Age: Westfalian (Moscovian, Pennsylvanian), ca. 300 x 10^6 years.
Rock description: boundstone (algal bound, algal grain, foraminifera and echinoderm packstone) containing the fusulinid *Beedeina* and a mud filled desiccation crack, indicating a subaerial exposure of the bioherm.
Noncalcareous algae: various cyanophyceans, somewhat resembling the recent *Ostreobium* and *Microcystis*; a primitive rhodophycean having *Conchocelis*-like filaments with very long cells.

Fig. 1. Thin section of sample 7. Mud filled desiccation crack. In upper right part of the photo a tangential sectioned fragment of *Beedeina* is visible. Photo is a negative of the thin section.

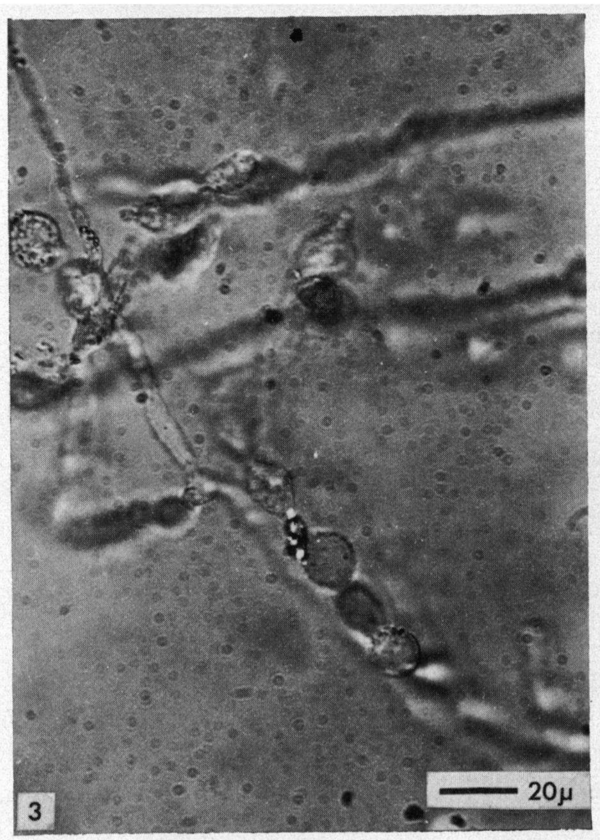
Fig. 2. A primitive rhodophycean (cf. *Conchocelis*) with very long cells. phase-contrast

Fig. 3. Sample 8 (description see Plate H). A primitive rhodophycean (cf. *Conchocelis*) with typical inflated cells. polarized light, gypsum plate

Fig. 4. Sample 8 (description see Plate H). A primitive rhodophycean (cf. *Conchocelis*) with typical inflated cells. phase-contrast


1mm
1


20µ
2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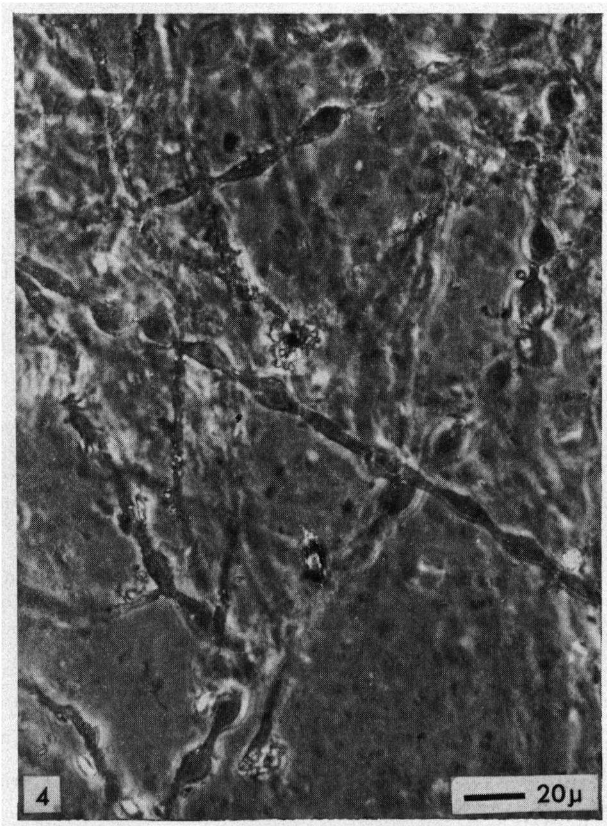

20µ
4

PLATE H

Sample 8: intersection of co-ordinates C and E, fig. 1, from the Terrionda Limestone Member of the Lois-Ciguera Formation, Spain, the third limestone member down from the top of the formation.
Age: Westfalian (Moscovian, Pennsylvanian), ca. 300 x 10^6 years.
Rock description: boundstone (algal bound, algal grain, algal fragment and foraminifera wackestone) containg calcareous algae (*Komia abundans* Korde and an *Eugonophyllum*-like codiacean), the fusulinids *Fusulina* and *Fusiella, Pseudostaffella* and *Ozawainella.*
Non-calcareous algae: cyanophyceans, unicells (cf. *Gloeocapsa*) and filamentous types, a xanthophycean (cf. *Vaucheria*) and a primitive rhodophycean (cf. *Conchocelis*).

Fig. 1. Thin section of sample 8. A codiacean stem-fragment (C), two *Komia abundans* Korde (K) and two oblique sections of *Fusulina* (F).
Photo is a negative of the thin section.

Fig. 2. Unicells (cf. *Gloeocapsa*) and a primitive rhodophycean (cf. *Conchocelis*). polarized light, gypsum plate

Fig. 3. A primitive rhodophycean (cf. *Conchocelis*). polarized light, gypsum plate

Fig. 4. A primitive rhodophycean (cf. *Conchocelis*) with fossil protoplasm still in the cells. phase-contrast

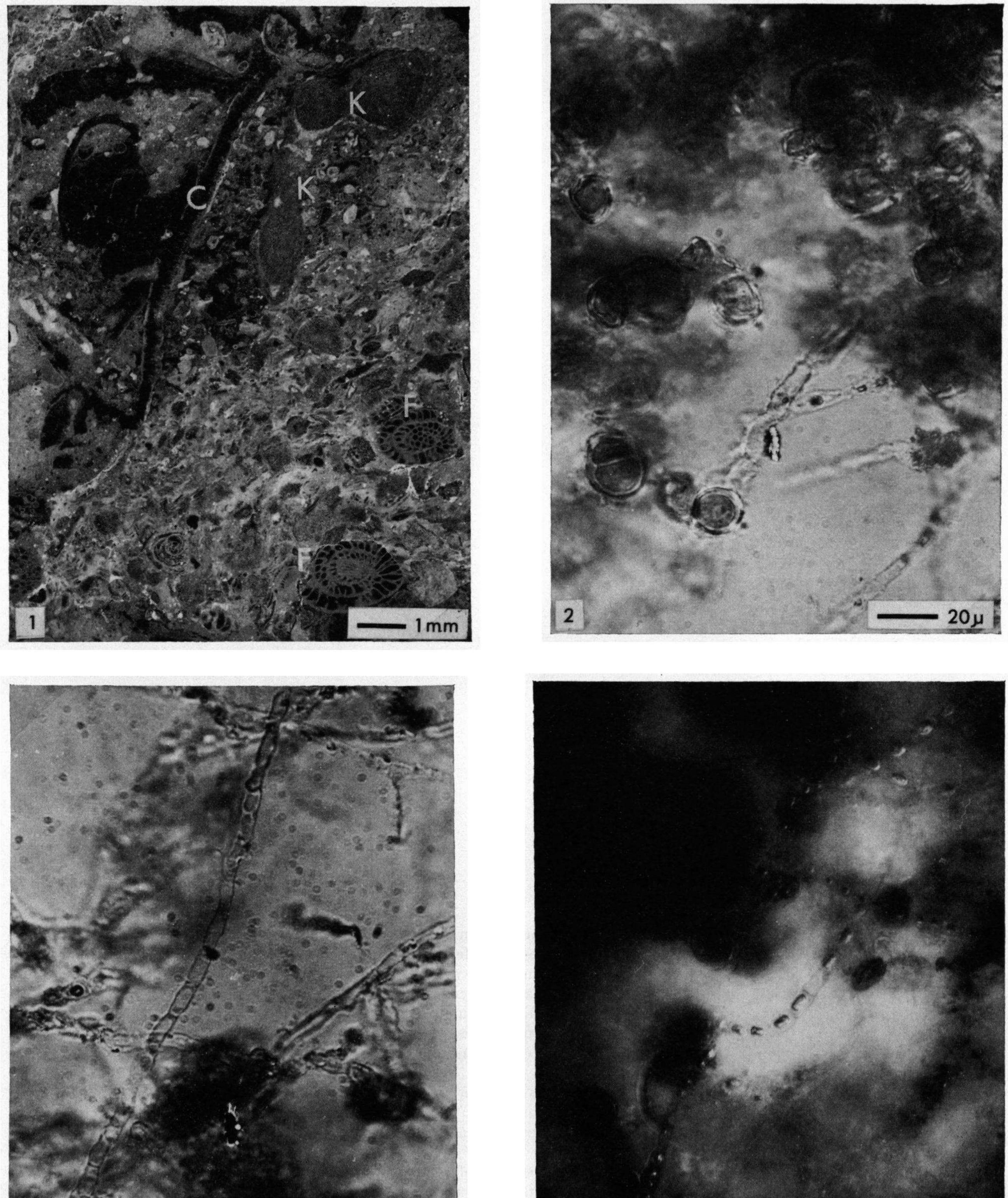

K
K
C
F
F
1
1 mm
2
20 μ
3
20 μ
4
20 μ

PLATE J

Sample 9: intersection of co-ordinates H and J, fig. 1, from the base of the Ciguera Limestone Member of the Lois-Ciguera Formation, Spain, the second limestone member down from the top of the formation.
Age: Westfalian (Moscovian, Pennsylvanian), ca. 300 x 10^6 years.
Rock description: boundstone (algal bound, algal grain, algal fragment and foraminifera packstone) containing badly preserved calcareous algae (*Archeolithophyllum*, codiaceans and dasycladaceans) and the fusulinids *Staffella, Fusulina* and *Fusiella.*
Noncalcareous algae: a xanthophycean (cf. *Vaucheria*) and a chlorophycean (cf. *Cladophoropsis*).
Other plant remains: a piece of a leaf, probably of a fern.

Fig. 1. Thin section of sample 9. *Staffella* (S) and other foraminifera, together with fragments of calcareous algae.
Photo is a negative of the thin section.

Fig. 2. A xanthophycean (cf. *Vaucheria).* polarized light, gypsum plate

Fig. 3. A piece of a leaf, probably of a fern.

Fig. 4. Detail of fig. 3.

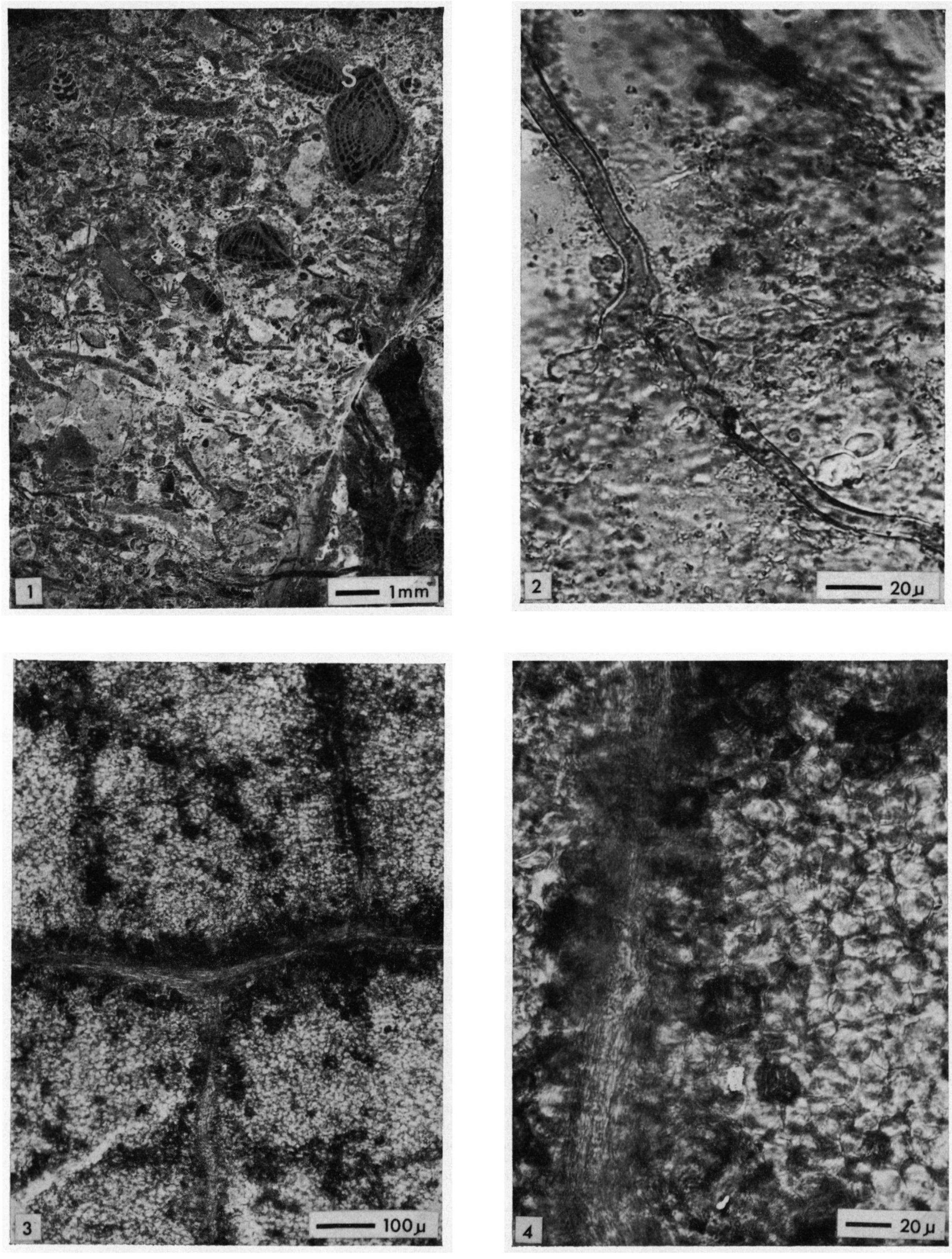

S
1
1mm
2
20µ
3
100µ
4
20µ

PLATE K

Sample 10: NE border of the Paris Basin, France, geological map 1:80.000, 24, Mézières. Along road D 3, 2–2½ kms. N of the crossing to Hocmont, on right and left hand of the road abandoned limestone quarries (fig. 3).
Age: Middle Bathonian (J^{II} symbol of the geological map), ca. 170 x 10^6 years.
Rock description: algal grain, algal lump, oncolite and fossil fragment grainstone containing echinoderms, sponges, corals, molluscs and hydrozoans.
Noncalcareous algae: cyanophyceans (unicells and various types of filaments), a chlorophycean (belonging to the Cladophorales) and a xanthophycean (cf. *Vaucheria*).
Other plant remains: a sporangium of a fern, pollen-grains (*Pinus*) and spores.

Fig. 1. Thin section of an oncolite of sample 10. In the lower right part of the photo a section through a gasteropod is vaguely visible. This gasteropod apparently served as a nucleus for the oncolite.
Photo is a negative of the thin section.

Fig. 2. Colony of unicells. polarized light, gypsum plate

Fig. 3. Sporangium of a fern, surrounded by algal filaments.

Fig. 4. Detail of fig. 3.

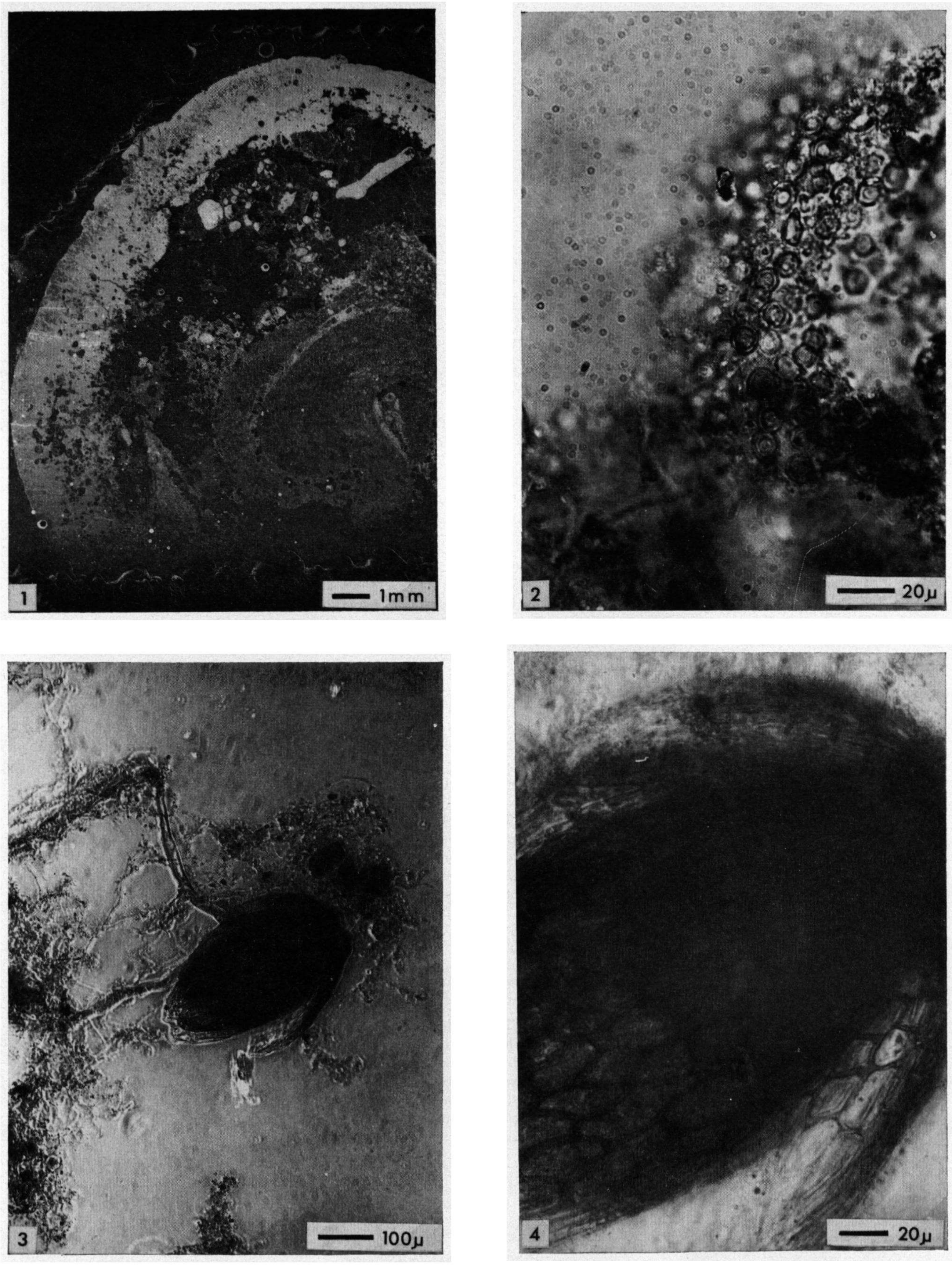

1
1mm
2
20μ
3
100μ
4
20μ

PLATE L

Sample 11: NE border of the Paris Basin, France, geological map 1:80.000, 23, Rethel. NE of Rethel, E of road N 51 one finds the village Saulces Monclin on road D 8. Less than 1 km north of this village there is the hamlet Saulces aux Tournelles with a quarry in reef limestones of the Upper-Jurassic (Argovian-facies).
Age: Oxfordian, ca. 160 x 10^6 years.
Rock description: boundstone (algal bound, algal grain, oöids and foraminifera wackestone) containing the lituolide *Choffatella.*
Non-calcareous algae: cyanophyceans (badly preserved filaments and two types of colonies of unicells).

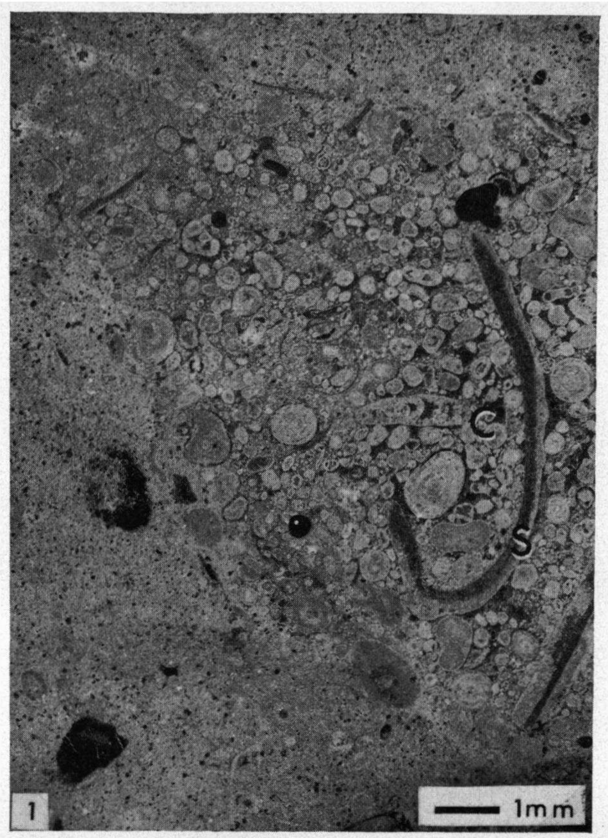
Fig. 1. Thin section of sample 11. Shell remain (S) with algal envelope, oöids and *Choffatella* (C). Photo is a negative of the thin section.

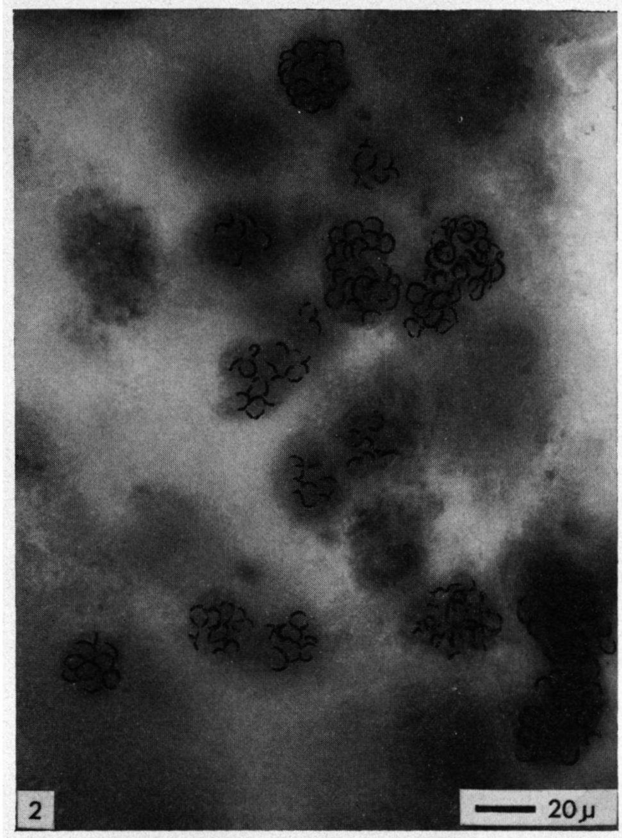
Fig. 2. Colonies of unicells.

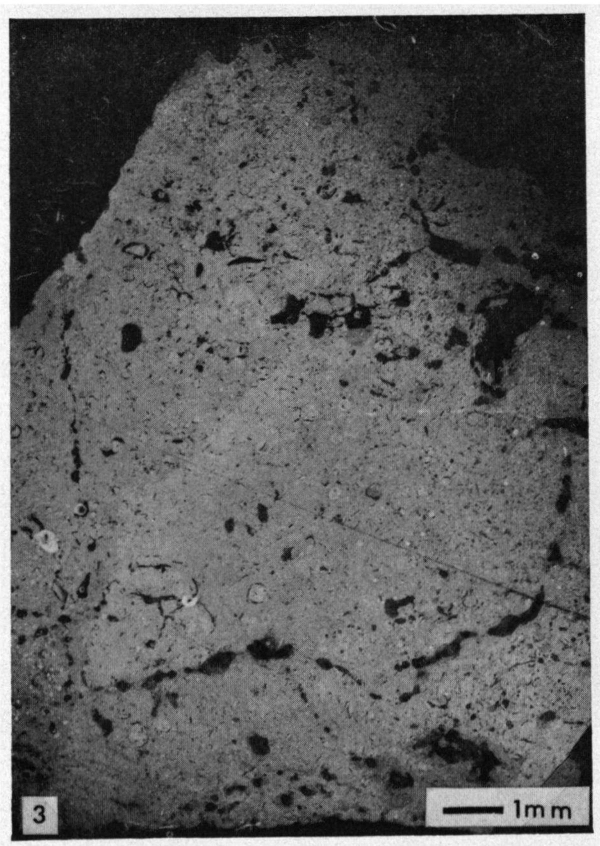
Sample 12: NE border of the Paris Basin, France, geological map 1:80.000, 34, Reims. South of road N 3 in the valley of the Marne river between Château Thierry and Dormans, road D 4 along the tributary Surmelin river. E of the Surmelin river between Connigis and Monthurel, high in the valley-side slope, two quarries, abandoned since 1905. The southern one has delivered sample 12.
Rock description: boundstone (bound mudstone).
Non-calcareous algae: a few badly preserved algal filaments.
Other plant remains: a good many remains of moss.

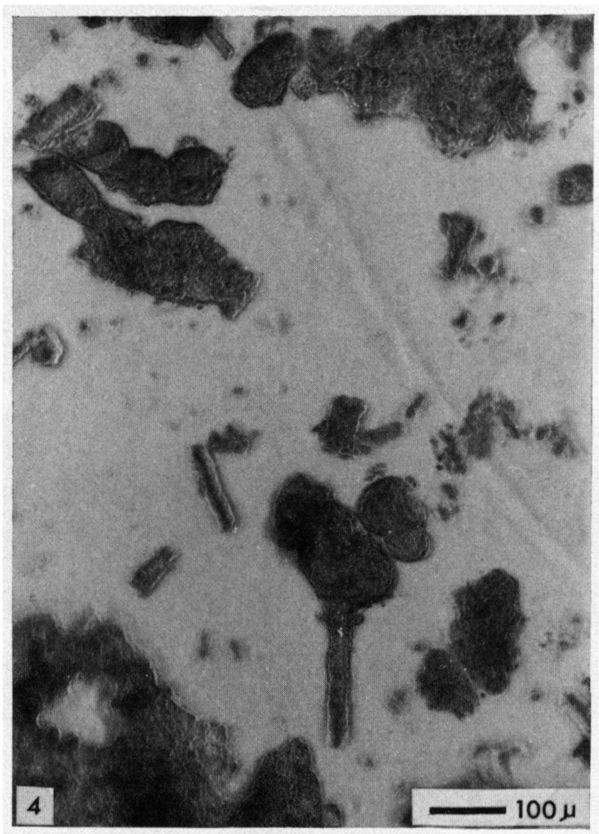
Fig. 3. Thin section of sample 12, showing birdseyes and cavities. Photo is a negative of the thin section.

Fig. 4. Moss.


C
S
1
1mm


2
20 µ


3
1mm


4
100 µ