# CARBONIFEROUS CALCAREOUS ALGAE AND THEIR ASSOCIATIONS IN THE SAN EMILIANO AND LOIS-CIGUERA FORMATIONS (PROV. LEÓN, NW SPAIN)

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## CONTENTS

| | | |
|---|---|---|
| | ABSTRACT | 5 |
| | INTRODUCTION | 7 |
| CHAPTER I. | GEOLOGICAL SETTING AND STRATIGRAPHY | 9 |
| | Structural geology | 9 |
| | Stratigraphy | 10 |
| | Getino Formation | 10 |
| | Sella Formation | 12 |
| | Escapa Formation | 13 |
| | San Emiliano Formation | 14 |
| | Lithostratigraphic aspects | 14 |
| | Biostratigraphic aspects | 16 |
| | Lois-Ciguera Formation | 19 |
| | Lithostratigraphic aspects | 19 |
| | Biostratigraphic aspects | 22 |
| CHAPTER II. | LIMESTONE FACIES | 26 |
| | Introduction | 26 |
| | Limestone facies type *A* | 26 |
| | Lithologic characteristics | 26 |
| | Biological characteristics | 26 |
| | Limestone facies type *B* | 27 |
| | Lithologic characteristics | 27 |
| | Biological characteristics | 27 |
| | Limestone facies type *AB* | 29 |
| | Summary | 30 |
| CHAPTER III. | PALEOECOLOGICAL CONSIDERATIONS | 31 |
| | Introduction and terminology | 31 |
| | Rhythmic stratification of the sediments | 31 |

Introduction . . . . . . . . . . . . . . . . . . . . . . . . . 31
Description of the layer types . . . . . . . . . . . . . . . . 31
Limestone facies type *A* . . . . . . . . . . . . . . . . . . . 36
Limestone facies type *B* . . . . . . . . . . . . . . . . . . . 36
Cyclical sedimentation . . . . . . . . . . . . . . . . . . . . . 36
Bathymetric considerations . . . . . . . . . . . . . . . . . . 38
Introduction . . . . . . . . . . . . . . . . . . . . . . . . . 38
Bathymetric consideration of flora and fauna . . . . . . . . . 40
The concept of "phase" and its bathymetric application . . . . . 43
The classification of the limestones, according to their origin and manner of organism accumulation . . . . . . . . . . . . . . . . 45
Fragmental limestones . . . . . . . . . . . . . . . . . . . . . 46
Skeletal limestones . . . . . . . . . . . . . . . . . . . . . . 46
The classification of the limestones, according to their origin and maturity . . . . . . . . . . . . . . . . . . . . . . . . . . 47
Qualitative and quantitative analysis of the rock building organisms 51
Introduction . . . . . . . . . . . . . . . . . . . . . . . . . 51
Method . . . . . . . . . . . . . . . . . . . . . . . . . . . . 51
Fossil associations of the most important rock building organisms 51
Calcareous algae . . . . . . . . . . . . . . . . . . . . . . 51
Gastropoda . . . . . . . . . . . . . . . . . . . . . . . . . 51
Brachiopoda . . . . . . . . . . . . . . . . . . . . . . . . . 52
Foraminifera . . . . . . . . . . . . . . . . . . . . . . . . 52
Coelenterata . . . . . . . . . . . . . . . . . . . . . . . . 52
Echinodermata . . . . . . . . . . . . . . . . . . . . . . . . 52
Summary . . . . . . . . . . . . . . . . . . . . . . . . . . . 53
Change of the biofraction within a member . . . . . . . . . . . 53
Analysis of the limestones, according to their composition and environnement . . . . . . . . . . . . . . . . . . . . . . . . . . . 57
Mixed beds . . . . . . . . . . . . . . . . . . . . . . . . . . 57
Beds of calcareous algae . . . . . . . . . . . . . . . . . . . 58
The position of the calcareous algae in a lithological unit . . . . 58
San Emiliano Formation . . . . . . . . . . . . . . . . . . . 58
Lois-Ciguera Formation . . . . . . . . . . . . . . . . . . . 60
Algal beds in a minor cycle . . . . . . . . . . . . . . . . . . 60
Algal beds in a limestone member . . . . . . . . . . . . . . . 62
Echinoderm beds . . . . . . . . . . . . . . . . . . . . . . . 65
Brachiopod beds . . . . . . . . . . . . . . . . . . . . . . . 67
Facies type *B* . . . . . . . . . . . . . . . . . . . . . . . 67
Facies type *A* . . . . . . . . . . . . . . . . . . . . . . . 67
Foraminifera beds . . . . . . . . . . . . . . . . . . . . . . 69
Bryozoan beds . . . . . . . . . . . . . . . . . . . . . . . . 70
Gastropod beds . . . . . . . . . . . . . . . . . . . . . . . . 70
The participation of various organisms in the composition of the biofraction . . . . . . . . . . . . . . . . . . . . . . . . . . 71
The adaptability and rapid multiplication of the organisms during

an environmental change . . . . . . . . . . . . . . . . . . . 72
The change is strength of wave action, reflected by the fossil associations within a bed . . . . . . . . . . . . . . . . . . . . 73
In a strong wave action environment . . . . . . . . . . . . 74
In a weak wave action environment . . . . . . . . . . . . . 74
The origin of the dwarf fauniflora in the mixed beds . . . . . . . 75
Paleogeographical distribution . . . . . . . . . . . . . . . . . 76
Concluding remarks . . . . . . . . . . . . . . . . . . . . . 77

CHAPTER IV. REMARKS ON THE STRATIGRAPHY OF THE CALCAREOUS ALGAE AND THEIR SYSTEMATIC DESCRIPTIONS 79
The stratigraphic value of the calcareous algae . . . . . . . . . 79
The biostratigraphic units of the calcareous algae . . . . . . . 79
Chronostratigraphic limits of the calcareous algal zones . . . . 84
Systematic descriptions . . . . . . . . . . . . . . . . . . . . 85
Phylum Rhodophycophyta Papenfuss, 1946
Red algae of uncertain affinities, Johnson, 1961 . . . . . . . 85
Genus *Amorfia* RÁCZ gen. nov. . . . . . . . . . . . . . . . . 85
*Amorfia jalinki* RÁCZ spec. nov. . . . . . . . . . . . . . 86
Genus *Archaeolithophyllum* JOHNSON, 1956
*Archaeolithophyllum missouriensum* JOHNSON. . . . . . . . . 86
*Archaeolithophyllum johnsoni* RÁCZ spec. nov. . . . . . . . 87
Genus *Cuneiphycus* JOHNSON, 1960
*Cuneiphycus aliquantulus* JOHNSON . . . . . . . . . . . . . 88
Genus *Komia* KORDE, 1951
*Komia abundans* KORDE . . . . . . . . . . . . . . . . . . 88
Genus *Petschoria* KORDE, 1951
*Petschoria elegans* KORDE . . . . . . . . . . . . . . . . . 90
Genus *Pseudokomia* RÁCZ gen. nov.. . . . . . . . . . . . . . . 90
*Pseudokomia cansecoensis* RÁCZ spec. nov. . . . . . . . . . 91
Genus *Ungdarella* MASLOV, 1950
*Ungdarella uralica* MASLOV . . . . . . . . . . . . . . . . 92
Phylum Chlorophycophyta Papenfuss, 1946
Family Dasycladaceae Kützing orth. mut. Stizenberger, 1860 . . 92
Genus *Anthracoporella* PIA, 1920
*Anthracoporella spectabilis* PIA . . . . . . . . . . . . . . . 92
Genus *Beresella* MACHAEV, 1937
*Beresella hermineae* RÁCZ spec. nov. . . . . . . . . . . . 93
Genus *Dvinella* CHVOROVA, 1949
*Dvinella comata* CHVOROVA . . . . . . . . . . . . . . . . 94
Genus *Epimastopora* PIA, 1922
*Epimastopora bodoniensis* RÁCZ spec. nov.. . . . . . . . . . 95
*Epimastopora rolloensis* RÁCZ spec. nov. . . . . . . . . . . 97
*Epimastopora* spec. . . . . . . . . . . . . . . . . . . . . 98

Genus *Macroporella* PIA, 1912
*Macroporella ginkeli* RÁCZ spec. nov. . . . . . . . . . . . 98
Genus *Mellporella* RÁCZ gen. nov. . . . . . . . . . . . . . . 99
*Mellporella anthracoporellaformis* RÁCZ spec. nov.. . . . . . . 100
*Mellporella beundermani* RÁCZ spec. nov. . . . . . . . . . . 101
Genus *Uraloporella* KORDE, 1950
*Uraloporella sieswerdai* RÁCZ spec. nov. . . . . . . . . . . 101
Genus *Zaporella* RÁCZ gen. nov. . . . . . . . . . . . . . . . . . 102
*Zaporella cantabriensis* RÁCZ spec. nov.. . . . . . . . . . . 103
Family Codiaceae (Trivisan) Zanardini, 1843 . . . . . . . . . . 103
Genus *Donezella* MASLOV, 1929 . . . . . . . . . . . . . . . . . 103
*Donezella lutugini* MASLOV. . . . . . . . . . . . . . . . . 104
*Donezella lunaensis* RÁCZ spec. nov. . . . . . . . . . . . . 105
Genus *Eugonophyllum* KONISHI & WRAY, 1961
*Eugonophyllum mulderi* RÁCZ spec. nov. . . . . . . . . . . 106
Genus *Ortonella* GARWOOD, 1914
*Ortonella myrae* RÁCZ spec. nov. . . . . . . . . . . . . . . 106
Phylum Schizophyta (Falkenberg) Engler, 1892
„Section" Porostromata PIA, 1927 . . . . . . . . . . . . . . 107
Genus *Girvanella* NICHOLSON & ETHERIDGE, 1880
*Girvanella* spec. . . . . . . . . . . . . . . . . . . . . . 107
Genus *Osagia* TWENHOFEL, 1919
*Osagia* spec. . . . . . . . . . . . . . . . . . . . . . . . 108
„Section" Spongiostromata PIA, 1927 . . . . . . . . . . . . . 108
Genus *Pycnostroma* GÜRICH, 1906
*Pycnostroma* spec. . . . . . . . . . . . . . . . . . . . . 108

REFERENCES . . . . . . . . . . . . . . . . . . . . . . . . . 109

PLATES

Geological and Locality Map . . . . . . . . . . . in back pocket.

# ABSTRACT

This study of the calcareous algae in the limestone deposits of the two formations (San Emiliano and Lois-Ciguera) in NW Spain is based on field observations and microscopical study. It was possible in the field to divide almost all the limestone members into smaller units on the basis of physical, chemical and biological composition of the rocks. After studying the organic content of the rocks, it appeared that there was a close connection between their lithological and biological composition. With these aspects known, it became a fact that units with a given composition alternated in a regular sequence. This offered the possibility of recognising a cyclical sedimentation within a single limestone member. Considering the special properties of the cyclical sedimentation, such as the fact that it is only found in $CaCO_3$ containing layers and the small size of the cycles, the name *minor cycle* has been suggested for such deposits.

Two facies types can be distinguished: (1) originating in a quiet milieu, and (2) facies originating in a disturbed milieu (these were called limestone facies type *A* and limestone facies type *B*, respectively).

It is typical of the limestones which were deposited in facies type *A*, that, amongst other properties, they have very little terrigenous material in their matrix, while those of facies type *B* contain large quantities in their matrix. A mixture between the two facies types was also observed and called facies type *AB*.

The microscopical study was aimed to investigate:

1. the characteristics of the limestone construction,
2. the quantitative composition of the fauna and flora over the whole area; in a member in a minor cycle, and in a bed,
3. certain environmental changes, which affected the composition of the organic material.

A detailed study has shown that two types of limestone are present, with respect to origin, manner of accumulation, and texture. These are *skeletal* and *fragmental* limestones. The skeletal limestones can occur as reefs and as banks. Proportionately, there are as many banks as fragmental limestones, and fewer reef limestones.

It became clear, from the quantitative analysis, that the algae were by far the most important rock builders. Brachiopods, Foraminifera, corals, and gastropods also form a considerable fraction. There are fewer bryozoans, trilobites and ostracods present in detectable numbers.

In the qualitative analysis, various associations of organisms were found, which must be considered as constant associations. It has thus been established that associations of, gastropods with red algae (mainly specimens of the genus *Archaeolithophyllum*), brachiopods with bryozoans and echinoderms, corals with blue green algae, Foraminifera with algae and echinoderms, are often found. On the other hand, gastropods are found with brachiopods and bryozoans, Foraminifera with brachiopods and bryozoans, and calcareous algae with brachiopods and bryozoans, can be considered as less frequent associations. An exception is the association of brachiopods with gastropods and red algae, in oolitic beds. These elements, however, lived in a special environment and this resulted in an exceptional composition of dwarf elements.

Sometimes, clear changes could be seen in the composition of the flora and fauna within a bed. These changes can be qualitative and quantitative. It is noticeable, in most echinoderm beds, that the percentage of brachiopod fragments increases from the bottom to the top. The composition of other beds also shows such changes with other types of organic remains. The algal beds can generally be divided into three parts, on the basis of their biofraction composition. This can be explained by changes in one or more of the environmental components.

Until now, no attention has been paid to a study of the rich algal flora in the Carboniferous deposits of NW Spain. 21 genera (4 new) and 26 species (15 new ones) have now been described. There are 8 species (7 genera) of red algae, 15 species (11 genera) of green algae, and 3 species of blue-green algae. The systematic position of the red algae, which are found in the area, has not yet been fully determined, thus two newly described genera *Amorfia* and *Pseudokomia* have been placed in the first group — according to Johnson's usage — the "Red algae of uncertain affinities", together with the genera *Cuneiphycus*, *Komia*, *Archaeolithophyllum*, *Petschoria*, and *Ungdarella*. Three new species of red algae are described: *Archaeolithophyllum johnsoni*, *Amorfia jalinki*, and *Pseudokomia cansecoensis*. The largest proportion of the green algae belong to the family Dasycladaceae, 11 species (8 genera) are described in the present work, nine of these being new. These are *Beresella hermineae*, *Epimastopora bodoniensis*, *Epimastopora rolloensis*, *Epimastopora sp.*, *Macroporella ginkeli*, *Mellporella beundermani*, *Mellporella anthracoporellaformis*, *Uraloporella sieswerdai*, and *Zaporella cantabriensis*. The new genera are *Mellporella* and *Zaporella*.

4 new species of the family Codiacea are described (3 genera), 3 of these species are new: *Donezella lunaensis*, *Eugonophyllum mulderi*, and *Ortonella myrae*.

Strong arguments, on the basis of algal body construction, were found for placing the new species, *Donezella lunaensis*, in the family Codiaceae.

The blue-green algae could not be specifically determined because of their generally poorly preserved structures. Of these, *Girvanella* sp., *Osagia* sp., and *Pycnostroma* sp., were described.

# INTRODUCTION

In the last few years, students of the "Geologisch- en Mineralogisch Instituut der Rijksuniversiteit te Leiden" have been studying the southern slope of the Cantabrian mountain chain, under the guidance of Professor Dr. L. U. de Sitter, to construct a geological map. The area, in which the present study was carried out, lies in the most northerly part of the province of León in NW Spain. The northern limit of the study was the watershed, at the same time the province border between León and Oviedo (Asturia). The upper reaches of the four following rivers: Río Bernesga, Torio, Curueño, and the Porma, cross the area in a N - S direction. The first and last form the western and eastern borders, respectively. The southern limit is taken from the line which goes through the villages Villamanín, Getino, and Campillo, from west to east.

The geological mapping work was carried out between the years 1960 and 1964. W. J. Jalink and H. J. Evers worked between the Río Bernesga and the Río Torio, from north to south; W. F. Beunderman, C. A. Mulder, L. Rácz, C. F. Winkler Prins between the Río Torio and the Río Curueño; J. H. Oosterbaan, P. J. Verwoerd, and A. J. Bijwaard between the Río Curueño and the Río Porma, at the time these were all students at the "Geologisch- en Mineralogisch Instituut der Rijksuniversiteit te Leiden". On the basis of the data which they gathered, the Geological Department of the Leiden University constructed the map which was used here. Recently a geological map has been published which covers a much larger area, with a 1 : 100,000 scale (de Sitter, 1962).

Under the leadership of Professor Dr. A. Brouwer, students and co-workers carried out a stratigraphic and paleontological investigation in different formations and various parts of the Cantabrian mountain chain. One of these studies is presented in the present work. As far as could be seen from the literature, no systematic description of the Carboniferous calcareous algae in NW Spain has yet been published. Thus the description of the microplant fossils in the present work can be described as the first step in their recognition as important rock builders. There is very little about the stratigraphic history of the area between the Río Bernesga and the Río Porma, in the literature. Only recently have a few publications appeared (Wagner, 1963; Brouwer and Van Ginkel, 1964).

Wagner's work was concerned with the rocks of Bashkirian age (= Namurian limestones, shales and sandstones of Wagner) in the southern part (nappe structures) of the area and is based on a small amount of data and described in general terms. Brouwer and Van Ginkel give a very good general lithostratigraphic description of all the Carboniferous deposits on the southern side of the mountains. On the basis of well considered arguments, they give a terminology pertaining to the formation classification of the Carboniferous deposits in NW Spain. Helped by the fusulinid fauna they constructed a biozone classification, which is synchronized with that of the Russian Carboniferous deposits. A detailed stratigraphy of these rocks has not yet been established.

I am indebted to W. J. Jalink, C. A. Mulder, W. F. Beunderman, C. F. Winkler Prins, and A. J. Bijwaard, who were kind enough to offer parts of their sample collections. I would like to thank Professor Dr. A. Födvári of the Mineralogical and Geological Institute of the "Kossuth" University of Debrecen (Hungary) for his willingness to send an excellent collection of calcareous algae, as comparative material. To Professor Dr. J. H. Johnson of the Colorado School of mines at Golden (U.S.A.) and Professor Dr. R. Endo of the Saitama University at Urawa (Japan) I express thankfulness for their help by sending a few of their publications and advice in connection with the determination of the calcareous algae. Dr. C. E. de Groot of the Museum of Mineralogy and Geology at Leiden and Dr. J. Kullmann (Geologisch-Paläontologische Institut at Tübingen) gave their help by identifying a few corals and goniatites, respectively. Mr. B. Leigh made a large contribution to the preparation of the English text.

For the careful typing of the manuscript I am indebted to Miss Th. H. Sieverts, and for drawing to Mr. I. Sánta. I would like to thank Mr. J. F. Hoogendoorn for the illustrations and Mr. J. Schipper for the preparation of more than a thousand thin sections.

CHAPTER I

# GEOLOGICAL SETTING AND STRATIGRAPHY

## STRUCTURAL GEOLOGY

The deposits of the area can be principally divided into two longitudinal units; a northern one, which mainly consists of Carboniferous deposits, of Moscovian age and younger, in smaller amounts there are also Devonian and Lower Paleozoic rocks; and a southern one where the Carboniferous deposits are older than Moscovian, with Devonian and Lower Paleozoic rocks. The two units were called the Leonides and Asturides (de Sitter, 1959). They differ in various aspects and are divided by an (imaginary) line, the León-line. The Leonides south of the line were divided into various zones (de Sitter, 1962), of which the area under present study formed the central and western regions of the Bernesga-Esla zone, named after the two limiting rivers. In the area there is an alternation between Lower Paleozoic and Devonian rocks with Lower- and Middle Carboniferous* (Bashkirian) deposits, which arose through nappe structures. From the most northerly nappes there fall two complete (Forcada and Bodón respectively) and one partial (Gayo) in the studied area (see map).

The structural history of the Leonides can be summarized as follows (Oele, 1964, p. 7): "After a Precambrian diastrophism, the first tectonic movement during the Paleozoic was a tilting and subsequent erosion of the northern part of the Leonides just before the Famennian. The main movement, however, took place just before or during early-Westphalian times (Sudetic phase), while later phases of the Hercynian folding resulted in a refolding of the previously-created structures. The Alpine orogeny placed the rocks in their final position".

The main orogenetic phase, in the Bernesga-Esla region, was very active. Its activity is expressed by the origin of many thrust sheets. In the stratigraphically most developed Bodón nappe there is a very well formed syncline (Cármenes syncline) of Carboniferous and Devonian rocks, which arose before or during the overthrusts.

In the Asturides, north of the León-line, there is a thick mass of Middle Carboniferous (Moscovian) rocks. In the NE of the area there are Lower Carboniferous, Devonian, and Lower Paleozoic deposits. At the southern edge of the area there are a few small units of Stefanian deposits. This structural unit was called the Pajares-Isidro area, (de Sitter, 1962), and the area under present study lies in the western and central regions of it.

The Middle Carboniferous rocks show a very complicated folding pattern. The Asturian phase was undoubtedly the main orogenetic phase causing this. Its effects are expressed in mainly isoclinally folded anticlines and synclines of varying size. Because of the irregularity of the limestone deposits, it is not always possible to follow the layers, which makes an interpretation more difficult.

In the NE part of the area, the Lower Paleozoic, Devonian, and Lower Carboniferous rocks as in the Leonides, show nappe structures. Between the Rio Torio

* According to the Russian system.

and Bernesga there are in a few regions, as on the west side of the Porma in a larger area, Stefanian deposits to be found. These are composed of conglomerates and shales. The latter often contain coal layers. The Stefanian deposits lie discordantly on the Middle Carboniferous rocks.

## STRATIGRAPHY

The Carboniferous deposits, of the area, belong to the following formations (see also fig. 1 and 2 and map):

Cea Formation,
Lois-Ciguera Formation,
San Emiliano Formation,
Escapa Formation,
Sella Formation,
Getino Formation.

Of the above named formations, the Lois-Ciguera and the Cea Formations are not found in the southern surface structures. It is the purpose of this study to consider the facies and stratigraphic value of the calcareous algae. Considering, that these microplants are usually associated with other organic remains, it was considered desirable to broaden the basis of the study. There has thus been a concentration on the paleoecological problems, a study of the numerical and typical associations of flora and fauna and a reconstruction of the environment in which they existed. Only two formations were suitable for such a study, the San Emiliano and the Lois-Ciguera Formation, which contain a fossil "paradise" and are, therefore, a stratigrapher's "eldorado". This is the reason why these two formations were thoroughly studied. Only the most characteristic properties of the other four formations are mentioned.

### *Getino Formation. Devonian - Carboniferous boundary*

The top of the Devonian deposits is generally called the Ermitage Formation. The Ermitage Formation consists of red, coarse grained decalcified sandstone, with fossil pockets of brachiopods and crinoid stems. Among others in the brachiopod fauna, there is *Spirifer verneuili,* * which is an indicator of Upper Devonian age. There are several localities found, in the area, where the sandstone is overlaid with a coarsegrained, grey, hard limestone bank, which is 2.50—3.00 meters thick. The passage, from sandstone to limestone, is gradual; first there is a calcareous sandstone, then a sandy-limestone, which progresses into a pure limestone. The intermediate zone is about 0.70—1.20 meters thick. Few well preserved fossils are found in the limestone. None of the examples of brachiopods can be identified as *Spirifer verneuili.*

A microscopical examination has shown that fossil composition of the limestone is identical to that of the sandstone; the calcified limestone matrix contains crinoid stem remains, and brachiopod shell fragments. Because the transformation is gradual, in each locality there is a good continuity between the limestones and the underlying sandstone, there can be no doubt that this limestone bank represents the highest Devonian deposits in the area and are of Famennian age. The entire thickness of the Ermitage Formation is 7 to 18 meters.

* T. F. Krans (personal communication) advises that the correct identification should be: *Cyrtospirifer verneuili* (MURCH). *Cyrtospirifer* cf. *almadenensis* PAECKELM. and *Cyrtospirifer* aff. *tenticulum* (DE VERNEUIL).

Above the limestone bank, there is usually a soft, black shale, 6 to 10 meters thick. There are phosphate nodules and chert nodules in the shale strata. The phosphate containing nodules enclose many Radiolaria.

Above the shale deposit, there is an approximately 3 meters thick nodular limestone, which is grey at the bottom and tinted red at the top. This is rich with the fossil remains of goniatites, brachiopods, trilobites, crinoids, and to a lesser extent Bryozoa are also present. In the sequence, above the nodular limestone, there is a brown-red tinted hard shale layer, with a thickness of 6 to 15 meters. No fossils are found in this layer.

Comte (1959) found the black shale near Vegamián, Bernesga valley and referred to it as Vegamián Formation. Because along with the black shale, there are two other types of sediments in the present area, it is desirable to avoid misunderstanding and give them another name. The mapped sequence was therefore called, after the most conveniently associated village, the Getino Formation.

The age of the Getino Formation has only recently been determined. Higgins described a rich conodont fauna in the black shales near Genicera, which valuded the following species (Higgins et al., 1964, p. 218 and 225):

*Angulodus walrathi* (HIBRARD)
*Bryantodus planus* BRANSON and MEHL
*Gnathodus* cf. *texanus* ROUNDY
*Gnathodus delicatus* BRANSON and MEHL
*Gnathodus* sp. B
*Hindeodella ibergensis* BISCHOFF
*Hindeodella segaformis* BISCHOFF
*Ozarkodina roundyi* (HASS)
*Polygnathus nodomarginata* E. R. BRANSON
*Pseudopolygnathus triangula pinnata* VOGES
*Roundya aurita* SANNEMAN
*Scaliognathus anchoralis* BRANSON and MEHL
*Spathognathodus aculeatus* (BRANSON and MEHL)
*Spathognathodus costatus costatus* (E. R. BRANSON)
*Spathognathodus costatus spinulicostatus* (E. R. BRANSON)
*Spathoganthodus inornatus* (BRANSON and MEHL)
*Spathognathodus stabilis* (BRANSON and MEHL)
*Spathognathodus strigosus* (BRANSON and MEHL)

According to Higgings, they are of Upper Tournaisian age. The Radiolaria, present in the phosphate nodules, can be of either Upper Devonian or Lower Carboniferous age.

In the red and grey nodular limestone various goniatites and brachiopods are found which belong to the Lower Viséan.

Kullmann (personal communication) determined the goniatites in the author's collection, and found several examples of *Muensteroceras sphaeroïdale* (M'COY) and *Merocanites applanatus* (FRENCH). These goniatites are characteristic in the Upper-Pericyclus zone.

Winkler Prins (personal communication) found in this collection several examples of *Chonetes* cf. *papilionaceae* PHILL., which are guide fossils for the $C_{\mathrm{I}}^{\mathrm{V}}$d zone, upper part of the Lower Visean, in the Donetz Basin. The goniatite and brachiopod fauna comes from the red part of the formation.

Wagner-Gentis (Wagner, 1963, p. 41) found, in the grey basal part of the section, *Pericyclus hauchecornei* Delépine which is also of Lower Viséan age. No fossils were found in the red-brown-black tinted chert-shale.

### *Sella Formation*

Above the chert containing shale part of the Getino Formation, there are, mainly red and grey coloured, nodular limestones which some geologists call "griotte limestone". This formation varies in thickness between 15 and 25 meters. The lowest part, about 1.50 meters, is very soft and is therefore often completely eroded away. The following 3 meters are more resistant, probably because of the flint nodules which are present.

The upper part, about 17 meters, has an intermediate hardness between the two above named types. The stratification is clearest in this region, because of the alternation between red and grey layers.

The basal part is much richer in fossils than the upper part. This does not, however, apply to the crinoids which are found in larger numbers at the top than at the bottom.

The rocks in the lower part have a bright red colour. After the soft, fossiliferous bank, there is a tendency towards the top for the red colour to become lighter and more grey beds appear towards the top. At the top of the formation the relationship between red and grey layers is approximately equal. Particularly in this part, the stratification is very distinct.

The Sella Formation is of Upper Visean age. This interpretation is supported by the age determination of the goniatites and the conodonts.

Kullmann (personal communication) has determined the goniatites, from the basal part of the Sella Formation in the author's collection as follows:

G 11, 12; *Goniatites stenumbilicatus stenumbilicatus* Kullmann
103A; *Prolecamites postapplamatus* Kullmann
104A; *Prolecanitid*, gen. et sp. intern.
G 16, 17; *Prionoceras* (Irinoceras) *romingeri* Winch.

The biostratigraphic unit of this assemblage is the Goniatite zone (Go β) in the Aguasalio syncline.

Higgins (1962) described a conodont fauna, which came from the eastern bank of the Torio river, near Getino (loc. 1071 Wagner, 1957) in "red nodular limestone above ferrugeineous sandstones".

*Gnathodus girtyi* Hass
*Hibbardella fragilis* Higgins
*Hindeodella ibergensis* Bischoff
*Ligonodina typa* (Gunnell)
*Lonchodina?* sp.
*Ozarkodina delicatula* (Stauffer & Plummer)
*Roundya subacoda* (Gunnell)
*Siphonodella?* sp.
*Synprioniodina forsenta* Stauffer

According to Higgins the association indicates an Upper Visean age.

### *Escapa Formation*

Synonimous names aıe: Caliza de Montaña, Calcaire des Cañons, Basal limestone, etc. The Escapa Formation is built of limestones and clastic material. The basal limestones are concordant with the Sella Formation. Broadly, the limestone part of the Escapa Formation can be divided as follows (from top to base):

c. fossiliferous part (10—40 meters)
b. massive limestone (50—250 meters)
a. very well stratified, bituminous layered limestones (ca. 20 meters)

The layered limestone contains much bitumen, is dirty grey, and shows excellent stratification. The thickness of the layers varies between 5 and 20 cm and is lateraly almost constant. The resistance of these limestones against erosion is much greater than that of the underlying "griotte". This portion of the Escapa Formation is generally poor in fossils, although a few brachiopods and goniatites were found. Wagner (1963), pp. 40 and 57) described a locality with yielded a rich goniatite fauna.

The middle part of the limestone deposits is so-called "massive limestone", with a light grey colour. There are locally large, or smaller, lens or irregular shaped dolomitized limestone bodies present. These dolomite bodies often contain considerable mineral concentrations.

In the non-dolomitized parts of this limestone formation, the stratification can scarcely be detected, and sometimes cannot be followed at all. This gives rise to the name massive. Where a vague stratification is present, the limestone consist of very thick beds. It is noticeable that in this part of the formation there are calcite veins, sometimes several centimeters thick, which lie in the stratification or traverse it.

G. E. de Groot identified the following corals (Wagner, 1963, p. 58):

*Rotiphyllum* sp.
*Plerophyllum* (*Ufimia*) sp. *A*, cf. *tachyblasta* (Hudson).

There are no age determinations of the massive limestone to be found in the literature. From the upper part of the Escapa Formation, Foraminifera, brachiopods, and calcareous algae were recovered. According to Brouwer and Van Ginkel (1964) the Foraminifera, which are found here, belong to the Profusulinella Zone, subzone A. Following the Russian zonal division based on Foraminifera, these deposits would be of Bashkirian age.

The calcareous algae which were found, such as the genera *Ortonella*, *Donezella*, and *Ungdarella*, do not allow an exact age determination. The genus *Ortonella* is generally typical of the Lower Carboniferous but a few species have been reported from younger deposits, so the occurence of the new species *Ortonella myrae* (see description in chapter IV) cannot be considered significant.

*Donezella* is found in large numbers in certain rocks. This genus is found throughout the Carboniferous deposits of NW Spain. *Ungdarella*, unlike the other two genera, provides good comparative material for an exact age determination. However, specimens of this genus are usually found, in large numbers, in the uppermost limestone section of the Escapa Formation. Thus a biostratigraphical positioning of the calcareous algae is possible, based on the zone-division of the Foraminifera, but no comparative material from other Carboniferous areas was found in the literature.

Based on the age determination of the goniatites and Foraminifera, the chronostratigraphic position of the Escapa Formation is Lower to Middle Bashkirian (Brouwer and Van Ginkel, 1964, p. 310 and fig. 2).

The uppermost part of the limestone deposits do contain fossils: crinoid stems, brachiopods, calcareous algae, and single corals are the most important of these.

The limestones are mostly well stratified. Often a clear lamination can be seen. These laminated bituminous limestones alternate with fossiliferous beds. In some localities, there are several centimeter thick fine chert layers present in the stratification.

Above the continuous limestone deposits, there is a monotonous alternation of sandstones and shales. For a depth of 40—60 meters, there are still irregularly formed clayey limestones, which are locally rich in macrofossils (brachiopods, gastropods, echinoderms, fucoids, etc.). The shales are black and occasionally well stratified slate layers are also found. At other places the shales contain carbonate material.

West of Getino, just on the west side of the Torio river, Wagner (locality 1069) found an locality, in the basal part of the Escapa Formation, with a goniatite fauna. Wagner-Gentis (Wagner, 1963, p. 57) identified the following assemblage:

*Delepinoceras thalassoide* (DELÉPINE)
*Proshumardites delepinei* SCHINDEWOLF
*Stenopronorites arkansensis* (SMITH)
*Tympanoceras getinoi* WAGNER-GENTIS
*Eoasianites cadiconifirmis* WAGNER-GENTIS

According to Wagner-Gentis this association is of Lower Namurian age. Higgins (1962) studied the conodonts from the same locality and found the following fauna:

*Cavusgnathus nodulifera* ELLISON & GRAVES
*Gnathodus bilineatus* (ROUNDY)
*Gnathodus commutatus commutatus* (BRANSON & MEHL)
*Gnathodus commutatus nodosus* BISCHOFF
*Hindeodella germana* HOLMES
*Lonchdipoua?* sp.
*Neoprioniodus singularis* (HASS)
*Roundya subacoda* (GUNNELL)
*Subbryantodus* sp.

### *San Emiliano Formation*

*Lithostratigraphic aspects*

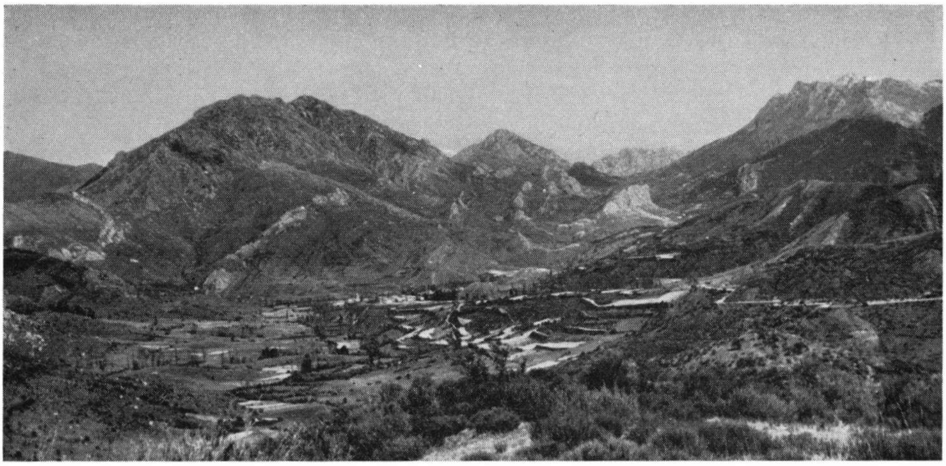
Above the Escapa Formation there is a sedimentary succession, which consists of an alternation of sandstones, shales, and limestones. The type-locality of the formation lies to the west of the area at present under study.

Brouwer and Van Ginkel (1964, p. 310) described the origin of the name, place, thickness, and composition of the rocks in the type locality as follows: "Le développement très caractéristique aux environs de San Emiliano (dans la vallée du Rio Luna supérieur) nous a conduit à choisir la section près de ce village comme localité-type de cette formation. Elle se trouve entre les villages de Villargusan et

Pinos, et se poursuit jusqu'à la vallée du Rio Luna. Cette succession, épaisse de 1750 m, est essentiellement formée de schistes, de grauwackes et subgrauwackes. En outre elle contient au moins dix bancs de calcaires et quelques minces couches de charbon."

The section of the San Emiliano Formation, which was studied by the writer, lies several tens of kilometers east of the type section. In this region the deposits of the San Emiliano Formation can be followed from the Rio Bernesga almost to the Rio Curueño. The thickness of the sediments is approximately 750 m.

The relatively broad syncline, in which Cármenes is situated, is called the Cármenes syncline (fig. 3). The north flank of the syncline shows a complete succession, but on the south flank there are several Upper Devonian formations (Ermitage, La Vid?) and the Escapa limestones are only found in isolated localities. The nucleus of the syncline is formed by shale deposits of the San Emiliano Formation. Most of the San Emiliano Formation limestones pinch out in the south flank of the



Fig, 3. Panorama of the Cármenes syncline, photographed from the west. The deposits of the San Emiliano Formation can be seen in the centre of the photograph, with the thick limestones of the Escapa Formation in the high scarp on the left.

syncline a few hundred meters after curving round the nose. Because all the limestones fail along a straight line, several geologists have sought to explain it by tectonic activity. For this, a fault will have to go through the villages Valverdin, Lavandera, and Valverde, in an E-W direction. The other possibility is a facies change, wherely the limestones are wedging out. This is certainly the case with the limestone members in the south flank near Valverdin, Pedrosa, and between Genicera and Valverde. Evidence of vigorous facies changes are found throughout the deposits of the San Emiliano Formation: some members disappear suddenly or wedge out, and on the other hand new ones appear; lenses of argilleceous limestone are found in varying sizes. At some localities, where a change takes place between shale and sandy rock, the sandstone banks can show a threefold increase in vertical thickness, within a few meters horizontally.

The general composition of the formation, in this area is the same as that of the type-section: a monotonous alternation of limestones, shales, and greywackes. Shales with a high content of carbonaceous material are present, but there are no pure coal layers. In one case, north of Genicera between layers no. III and IV (see fig. 1), there is a thin impure coal layer in the shale. The shale deposits do not form a homogeneous unit. In most cases there is an alternation between black and brown shale layers. Yellow shales are mainly found in the western part of the area. The black shales often contain inclusions of sandy mud balls. Indistinct plant impressions are regularly found in the shales.

The greywacke layers often form thick, hard banks which have a dirty grey or dark brown weathering colour. The sand banks, like the limestones, can stop suddenly. Some greywacke bands show well developed joints structures with usually two systems, which stand perpendicularly, or almost perpendicularly (80° to 85°) to each other.

The limestone members vary in thickness, from a few meters to 20 or 25 meters, and in a few cases particular limestone members are difficult to follow, although this can be done by careful mapping. Most of the limestone layers have shown more resistance to erosion than the shale and greywacke layers, although the largest differences are only a few meters. There is a great difference in topography between the Escapa and the San Emiliano Formation (fig. 3). The thickness of the limestone members increases from east to west. Almost all the members can be sub-divided, on the basis of their lithological properties, into smaller units. The units are usually sharply separated from each other.

The stratification of the members is different; all the intermediate sizes between a few centimeter to 40 to 50 cm thick banks were measured.

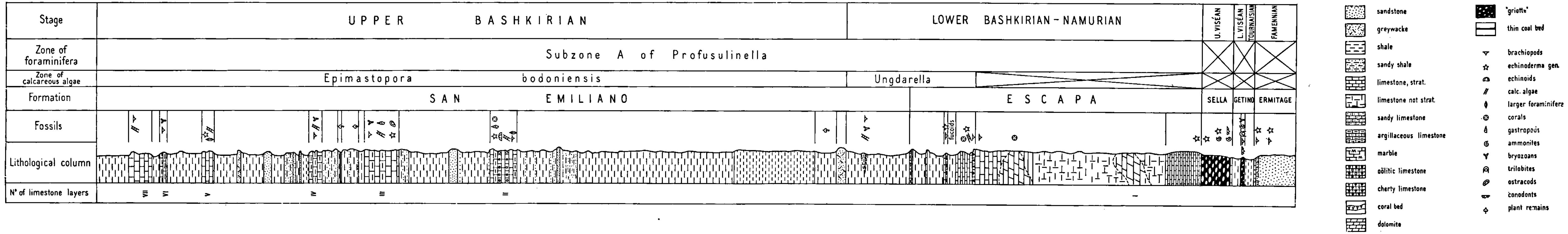
It can be directly seen that some limestone layers contain a lot of clay, while others do not. This differences in composition of the limestones are clearly reflected in differences in weathering colour and hardness. The clay-containing beds are naturally softer than those without. The limestones, containing the smallest amount of clay, have a light grey weathering colour. The fresh colour of the limestones varies from dark to light grey. The limestones, which contain a large amount of clay, have a brown weathering colour and a fine dark grey-black matrix. The grain size of the limestones varies, from very fine crystalline limestones to coarse crystalline limestones. All the intermediate forms are present. A considerable proportion of the limestones contain oolites. The oolitic layers are generally harder than the other small lithostratigraphic units.

There are no dolomitized parts in these limestones. In one case there are a few conglomerate pebbles in the strata of member no. III near Valverdin.

The limestone members also contain concretions. Chert concretions, in the form of nodules or bands parellel to the bedding, are found in small numbers in a few layers. Between Valverde and Genicera there is a chert layer present which is a few meters thick and a few tens of meters long. This layer is between shale material. The origin of this great accumulation of chert is still a problem.

### *Biostratigraphic aspects*

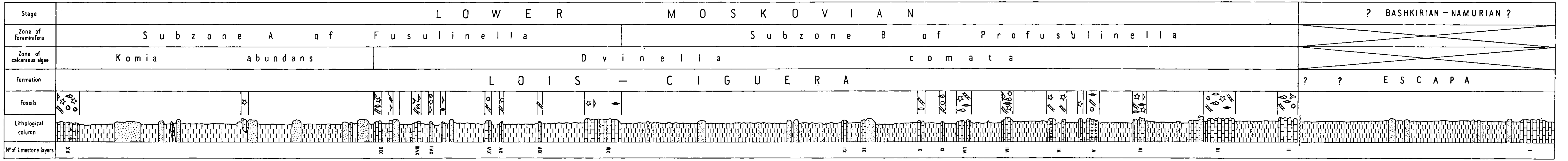
In general, the limestone members in the San Emiliano Formation contain many fossils, such as brachiopods, gastropods, echinoderms, corals, bryozoans, calcareous algae, trilobites, and ostracods. In some members, beds with abundant specimens of one of the above named groups are easily found. Only the Foraminifera and the calcareous algae have been systematically studied in the San Emiliano Formation. In a few cases the brachiopods and corals were also examined, but a detailed study of these groups has, not yet been completed.




STRATIGRAPHICAL SECTION OF THE CARMENES SYNCLINE

SCALE 0 10 20 30 40 50 m

Fig. 1




STRATIGRAPHICAL SECTION OF THE VEGARADA VALLEY

SCALE 0 10 20 30 40 50 m

Fig. 2

The oldest work concerned with the fauna in these deposits, is that of Barrois (1882, p. 577) who described the following brachiopods, gastropods, and echinoderms, of a locality S of Villanueva de la Tercia:

*Poteriocrinus* cf. *crassus* MILLER
*Rhabdomeson funicula* MICHELIN
*Archaeocidaris nerei* MÜNSTER
*Productus cora* D'ORBIGNY
*Chonetes variolata* D'ORBIGNY
*Aulacorhynchus davidsoni* BARROIS
*Streptorhynchus arachnoides* PHILLIPS
*Spirifer glaber* MARTIN
*Spirifer bisulcatus* SOWERBY
*Naticopsis collombi* BARROIS
*Loxonema scalarioideum?* PHILLIPS
*Pleurotomaria conica?* PHILLIPS
*Bellerophon hiulcus* MARTIN

More recently, Delépine (1943, p. 24—25) described the following brachiopods of a locality near Cármenes:

*Spirifer pavlovi* STUCKENBERG
*Spirifer fasciger* KEYSERLING
*Spirifer aff. asturicus* DELÉPINE
*Productus cora* D'ORBIGNY
*Reticularia lineata* MARTIN

De Groot (Wagner 1963, p. 64) identified the coral genera from several localities *:

East of Barrio de la Tercia (in limestone member no. I or II)
*Caninia* spec. div. (compound and solitary forms)

SW from Cármenes (probably near locality R. 476)
*Chaetetes* sp.
*Pseudozaphrentoides* sp. (= "*Caninia*" sp. ex gr. *juddi* THOMSON)
*Stuckenbergia* sp. (= "*Caninia*" sp., compound)
*Carcinophyllum* sp.

North of Pedrosa (probably in the neighbourhood of loc. 452) in limestone member no. VI
*Chaetetes* sp.
*Syringopora* sp.
*Carcinophyllum* sp.

NW from Lavandera (probably near loc. R. 24 in limestone member no. II)
*Claviphyllum?* sp.

South of Cármenes, in locality R. 24 Miss. G. E. de Groot (personal communication) identified the genera: *Chaetetes* and *Stuckenbergia*.

The Russian paleontologists consider the genus *Chaetetes* as typical Middle Carboniferous coral.

* (Because of the schematic nature of Wagner's map (1963), at the back of the book, it is impossible to determine the exact position of the localities.)

The calcareous algae are the most important rock builders (see chapter III).
The following species were found in the various limestones:

Loc. R. 471 NW of Barrio de la Tercia;
*Donezella lunaensis* sp. nov.
*Donezella lutugini* Maslov

Loc. R. 475 east of Barrio de la Tercia:
*Donezella lunaensis* sp. nov.
*Petschoria elegans* Korde

Loc. R. 476 east of Cármenes;
*Beresella hermineae* sp. nov.
*Donezella lutugini* Maslov
*Epimastopora bodoniensis* sp. nov.
*Osagia* sp.

Loc. R. 49 south west of Cármenes;
*Petschoria elegans* Korde
*Donezella lutugini* Maslov
*Archaeolithophyllum johnsoni* sp. nov.
*Epimastopora bodoniensis* sp. nov.

Loc. R. 42 sout of Cármenes;
*Epimastopora bodoniensis* sp. nov.
*Epimastopora* sp.
*Archaeolithophyllum johnsoni* sp. nov.
*Mellporella anthracoporellaformis* gen. et sp. nov.
*Anthracoporella spectabilis* Pia
*Donezella lutugini* Maslov

Loc. R. 43 south of Cármenes;
*Epimastopora bodoniensis* sp. nov.
*Epimastopora* sp.
*Archaeolithophyllum johnsoni* sp. nov.
*Mellporella anthracoporellaformis* gen. et sp. nov.
*Anthracoporella spectabilis* Pia
*Donezella lutugini* Maslov
*Petschoria elegans* Korde
*Beresella hermineae* sp. nov.
*Osagia* sp.
*Girvanella*? sp.

Loc. R. 34 south of Cármenes;
*Epimastopora bodoniensis* sp. nov.
*Beresella hermineae* sp. nov.
*Petschoria elegans* Korde

Loc. R. 401 north of Cármenes;
*Ungdarella uralica* Maslov
*Ortonella myrae* sp. nov.
*Donezella lutugini* Maslov

Loc. R. 449 north of Valverdin;
*Donezella lutugini* MASLOV
*Petschoria elegans* KORDE
*Osagia*? sp.
*Pycnostroma* sp.
*Beresella hermineae* sp. nov.
*Mellporella anthracoporellaformis* gen. et sp. nov.

Loc. W. 207 north of Valverde;
*Ungdarella uralica* MASLOV
*Donezella lutugini* MASLOV
*Ortonella myrae* sp. nov.

The Foraminifera are being studied by Van Ginkel. The characteristic features of the fusulinids and their vertical distribution were summarized by A. C. van Ginkel, as follows (personal communication): "The San Emiliano Formation yields abundant fusulinid faunas which may be compared with those found in the U.S.S.R. from strata of the Bashkirian stage".

## *Lois-Ciguera Formation*

### *Lithostratigraphic aspects*

West of the nappe structures there stretches, another rock complex consisting of limestones, greywackes, and shales, called the Lois-Ciguera Formation. The type section lies to the east of the area described in the present work. Brouwer and Van Ginkel (1964, p. 311) summarize the characteristic properties as follows:

"Le nombre des couches calcareuses, peu important dans la partie occidentale de la formation, augmente vers l'est, ainsi que l'épaisseur des bancs individuels. Ce développement culmine dans les synclinaux de Lois et de Ciguera, oú plus d'un tiers de l'épaisseur des totale est constituée par des calcaires. C'est là que nous avons choisi la section-type. Coupé par des failles, ni l'un, ni l'autre des deux synclinaux montre une succession complète. L'épaisseur totale est à peu près 1400 m, mais les corrélations entre les différentes successions sont difficiles à suivre, puisque les niveaux calcareux sont assez irréguliers. A plusieurs endroits, des bancs de calcaire se divisent en deux, séparés par des grauwackes ou des schistes."

The western stretch of the Lois-Ciguera Formation is also called the Piedrafita-Lillo strip, because these two villages were considered the most important positioning points in the area (see map).

In this part, the formation has a thickness of about 2,000 m. The larger part consists of clastic sediments. The total thickness of the limestone members is markedly less than in the type section, but still greater than the limestone members of the San Emiliano Formation in this area.

The contact between the Lois-Ciguera Formation and the sediments of the nappe structures is still a puzzle. At some places, as for example west of Campó and also at other places, there is a clear unconformity between the Precambrian sandstones and the Carboniferous limestones. At other places, signs of a fault contact are found.

The morphology of the area where the Lois-Ciguera Formation forms the surface shows more remarkable features than the deposits in the nappe structures south of the León-line: high peaks above 2,000 m are not seldom. Broad valleys and high ridges adorn the area. The Carboniferous deposits of the Lois-Ciguera Formation are ususally thickly covered with grass and heather, thus giving the landscape a monotonous rather appearance (fig. 4).

The formation consists mainly of clastic sediments, with shales predominating. Two types of shale are found: a laminated sand containing shale, and also a hard, black shale with a lower sand content (fig. 2). The sandy shales contain many plant impressions. There are sometimes also stem remains of *Calamites.* In contrast to the San Emiliano Formation, these sandy layers have decalcified brachiopod and crinoid stem holes. Cleavage folding is often found in the shale layers.

The hard, black shales often show a "pencil shale" appearance. The individual "pencil shale" pieces can be as long as 50 to 80 cm. These shales contain no fossils.

Sandstones are present as distinct banks. They are found as well stratified units. They are weathered brown and have a coarse grained matrix. The thinly layered sandstones often show a clear cross bedding (fig. 5).

In general, the western part of the region contains more sand material (greywackes, sub-greywackes, and sandy shales) than the eastern part.

Joints are less common than in the San Emiliano Formation. The sandstones contain more plant impressions than those of the San Emiliano Formation.

There are a few exploitable coal seams in the Lois-Ciguera Formation. Besides these, the formation also contains coal veins, which would not be exploitable economically. The exploitable coal layers are deposited in the stratigraphically higher parts, such as the Río Torio valley near Campó, and in the Curueño valley north of Lugueros there are several companies operating.

With the exception of a few of the thicker members, most of the limestones are thin eroded layers (fig. 4). The weathered colour of the limestones is light grey to dark grey, but in fresh state they appear to have a fine grained, black matrix.

Almost every limestone layer contains chert nodules, but it is mainly thick and thin chert layers, running parallel with the strata, which are present. An example of the latter case can be seen in figure no. 6. The limestone layers of this formation sometimes contain pyrite crystals, with clear stress-shadows. The limestone

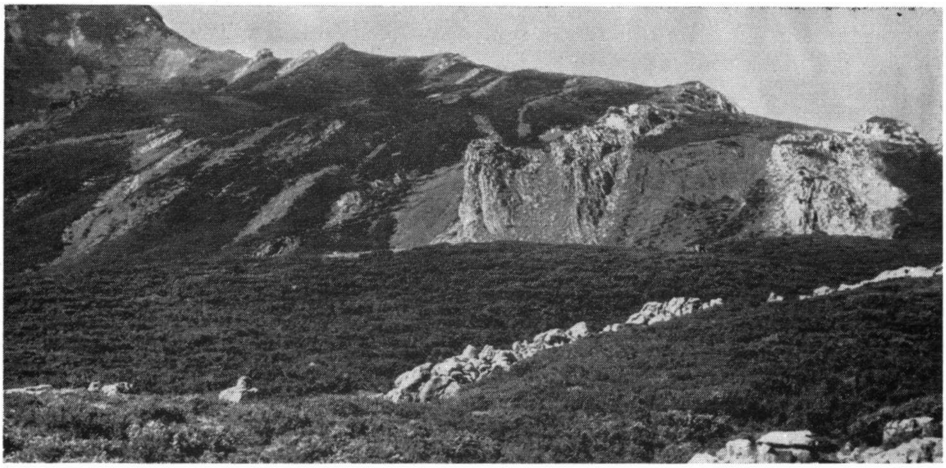


Fig. 4. Panorama of the development of the Lois-Ciguera Formation in the Vegarada valley, photographed from the east.

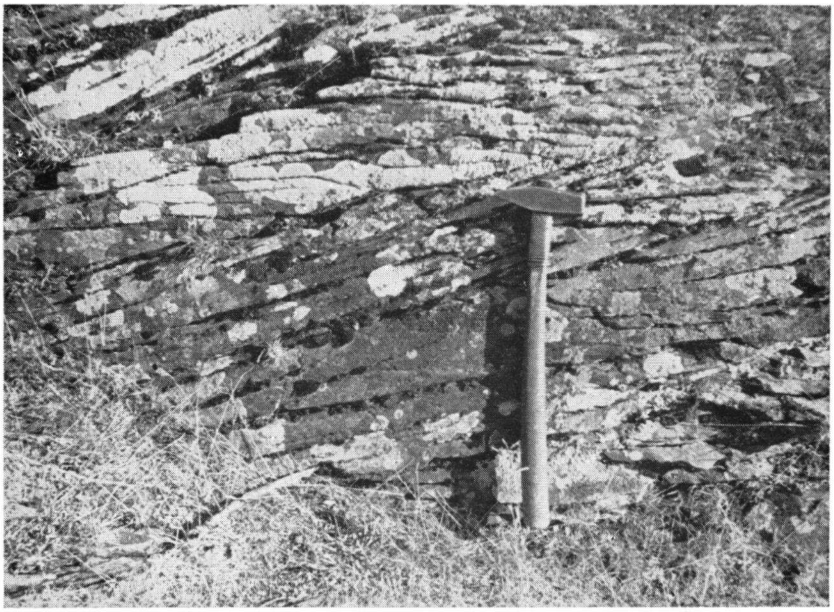


Fig. 5. Cross-bedding in the sandstones of the Lois-Ciguera Formation, to the north of Lugueros near the Rio Curueño.

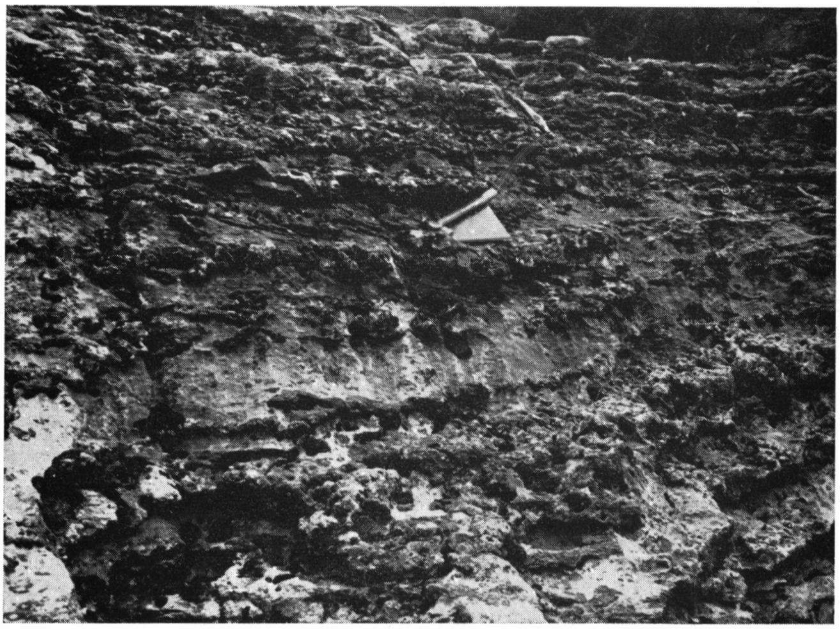


Fig. 6. Chert bands in the stratification of limestone member no. VI in the Vegarada valley of the Lois-Ciguera Formation.

members of the Lois-Ciguera Formation, like those of the San Emiliano Formation, can be divided into smaller units on the basis of their lithological and biological construction (fig. 9).

North of Piedrafita, in the valley of the river Torio near locality R. 1001, marble has been mined for a long time. The recovery of marble has also been started in the valley of the Rio Curueño, west of Cerudella, in member no. XIII. The number of limestone members increases towards the east and the amount of clastic material diminishes correspondingly.

The lithological properties, show that the limestones of the San Emiliano and Lois-Ciguera Formations differ in two aspects: the limestone matrix of the former is yellow-brown and that of the latter always black. The other difference between the two limestones is that in the limestones of the Lois-Ciguera Formation the fossils (fusulinids, calcareous algae, crinoid stems, ostracods, etc.) almost always show a marked deformation, while the organic remains in the San Emiliano Formation do not.

*Biostratigraphic aspects*

The sandy shales and all the limestones contain fossils. It is usually impressions of brachiopod shells and crinoid stems which have remained. The limestone members often have a great accumulation of both macro- and microfossils. As in the San Emiliano Formation, the limestones contain brachiopods, echinoderms, gastropods, corals, calcareous algae, bryozoans, trilobites, fusulinids, and ostracods.

Foraminifera are more abundant in the Lois-Ciguera Formation, than in the San Emiliano Formation. Fusulinid beds are often found at the lower part of a limestone member.

Brachiopods are less abundant than in the San Emiliano Formation but the numbers of gastropods are considerably greater. Both single and compound corals are present. Rugosa and Tabulata are often found together. Calcareous algae, as in the San Emiliano Formation, are represented by green, and blue-green algae, although red algae are in the majority. Bryozoa, ostracods, and trilobites are also found in the Lois-Ciguera Formation as less important organisms in the composition of the biofraction.

A. C. van Ginkel (personal communication) has the following to say about the occurrence of fusulinids in the Lois-Ciguera Formation:

"The Middle Carboniferous strata immediately north of the Leonide thrust-sheets, that is approximately the zone from Piedrafita (W) to Lois-Ciguera (E) (= Lois-Ciguera Fm.) contain a large number of relatively thin limestones. Although the fusulinid assemblages from these limestones are not yet studied in detail, some general remarks with regard to their age can be made. All samples handed to me for examinination are of Lower Moscovian age. This is especially true for the western part of the region (Torio-Curueño). It seems that to the east (Rio Porma) progressively younger strata take a place in the sequence. Here and still more convincingly in the Lois-Ciguera region presence of Upper Moscovian (Podolskian) strata could be demonstrated besides those of Lower Moscovian age.

It is almost certain that the time-equivalent of the thick column of strata of Bashkirian age deposited south of the Piedrafita-Lois Ciguera region in the Leonides San Emiliano Fm.) is either an hiatus or represented by a much thinner sequence, this seemingly indicating slower sedimentation or gaps north of the Leonide line in Bashkirian time."

A systematic stud y of the calcareous algae yielded the following species (for details see chapter IV):

Loc. R. 300 west of Piornedo;
*Dvinella comata* CHVOROVA
*Amorfia jalinki* gen. et sp. nov.
*Donezella lutugini* MASLOV

Loc. R. 303 west of Piedrafita;
*Dvinella comata* CHVOROVA
*Amorfia jalinki* gen. et sp. nov.

Loc. R. 304 east of loc. R. 303;
*Amorfia jalinki* gen. et sp. nov.
*Pseudokomia cansecoensis* gen. et sp. nov.

Loc. R. 313 east of loc. R. 304;
*Dvinella comata* CHVOROVA
*Epimastopora bodoniensis* sp. nov.

Loc. R. 1001 north of Piedrafita;
*Epimastopora bodoniensis* sp. nov.
*Dvinella comata* CHVOROVA
*Donezella lutugini* MASLOV
*Osagia* sp.

Loc. R. 1004 north-east of Piedrafita;
*Dvinella comata* CHVOROVA
*Amorfia jalinki* gen. et sp. nov.
*Pseudokomia cansecoensis* gen. et sp. nov.
*Osagia* sp.
*Girvanella*? sp.

Loc. R. 1006 south of Piornedo;
*Dvinella comata* CHVOROVA
*Archaeolithophyllum* sp.

Loc. 216 north of Canseco;
*Pseudokomia cansecoensis* gen. et sp. nov.
*Komia abundans* KORDE
*Donezella lutugini* MASLOV
*Mellporella beundermani* gen. et sp. nov.

Loc. C. 11 Slightly to the west of Peña de la Carva in the Vegarada valley;
*Dvinella comata* CHVOROVA
*Girvanella* sp.
*Cuneiphycus aliquantulus* JOHNSON

Loc. B. 42 south of locality C. 11;
*Dvinella comata* CHVOROVA
*Amorfia jalinki* gen. et sp. nov.

Loc. B. 29 south-west of locality B. 42;
*Dvinella comata* CHVOROVA
*Amorfia jalinki* gen. et sp. nov.
*Pseudokomia cansecoensis* gen. et sp. nov.
*Komia abundans* KORDE

Loc. 508 east of the Rio Curueño and NE of Cerulleda;
*Epimastopora rolloensis* sp. nov.
*Dvinella comata* CHVOROVA
*Donezella lutugini* MASLOV
*Amorfia jalinki* gen. et sp. nov.

Loc. 509 NE of Cerudella;
*Pseudokomia cansecoensis* gen. et sp. nov.
*Uraloporella sieswerdai* sp. nov.

Loc. 510 ōn the eastern side of the Rio Curueño, between Cerulleda and Lugueros;
*Cuneiphycus aliquantulus* JOHNSON
*Pseudokomia cansecoensis* gen. et sp. nov.
*Komia abundans* KORDE
*Donezella lutugini* MASLOV

Loc. 513 north of Tolibia de Arriba;
*Komia abundans* KORDE
*Pseudokomia cansecoensis* gen. et sp. nov.
*Uraloporella sieswerdai* sp. nov.

Loc. 514 south of Tolibia de Arriba;
*Komia abundans* KORDE
*Uraloporella? sieswerdai* sp. nov.
*Donezella lutugini* MASLOV

Loc. 515 east of Locality 514;
*Komia abundans* KORDE

Loc. 154 NE of Rucayo;
*Epimastopora bodoniensis* sp. nov.
*Pycnostroma* sp.

Loc. 161 NE of Quintanilla de Vegamián;
*Epimastopora bodoniensis* sp. nov.
*Epimastopora* sp.
*Donezella lunaensis* sp. nov.
*Pycnostroma* sp.

Loc. 156 and S. 19a north of Rucayo;
*Epimastopora bodoniensis* sp. nov.
*Dvinella comata?* CHVOROVA

Loc. 160 NE of Locality 156, in the centre of the syncline;
*Komia abundans* KORDE
*Macroporella ginkeli* sp. nov.
*Eugonophyllum mulderi* sp. nov.
*Archaeolithophyllum missouriensum* JOHNSON

Loc. 151 NW of Locality 160;
*Dvinella comata* CHVOROVA
*Uraloporella sieswerdai* sp. nov.

Loc. 506 north of Locality 151;
*Dvinella comata* CHVOROVA

Loc. S. 14 east of Locality 506 and west of Pueblo de Lillo;
*Dvinella comata* Chvorova
*Donezella lutugini* Maslov
*Epimastopora* sp.

Loc. S. 19 SW of Pueblo de Lillo;
*Dvinella comata* Chvorova
*Donezella lutugini* Maslov

Loc. S. 2 south of Pueblo de Lillo;
*Epimastopora bodoniensis* sp. nov.

Loc. S. 1 south of Locality S. 2;
*Epimastopora bodoniensis* sp. nov.
*Epimastopora* sp.
*Donezella lunaensis* sp. nov.

CHAPTER II

# LIMESTONE FACIES

## *Introduction*

The limestone deposits of the San Emiliano and of the Lois-Ciguera Formation belong to two large groups. These are completely different sedimentary types, both qualitatively and quantitatively they differ in content of organic remains. They will be referred to as facies type *A* and facies type *B*. A specific combination of the types will be called *AB*. The bathymetric problems will be considered, in detail, in the section on "Bathymetric studies" (chapt. III). The fossil associations and their sequence are discussed in the section "Rhythmic stratification" (chapt. III).

## LIMESTONE FACIES TYPE A

### *Lithologic characteristics*

The limestones of this facies type are generally hard and vary in colour from light to dark grey. Occasionally they are tinted light red. These limestones generally have a fine or relatively fine crystalline matrix. The thickness of the strata varies between 8 and 25 cm. The layers, especially of the red tinted limestone, are regular in thickness and composition along the direction of strike. The light grey layers usually have a wavy surface and sometimes the light and dark layers alternate along a wavy line. The weathering colour of the limestone varies from light grey, through light grey, to light brown. The strata often contain calcite veins and a lesser amount of cherty layers or nodules. Substantial quantities of oolitic limestone are also found in this facies type. The clay and sand content of the limestone is very low (fig. 7a).

### *Biological characteristics*

These limestones are generally rich in fossils, with a good assortment present. An important property is that many of the organic remains are broken.

*Brachiopoda* are mainly present in small forms. In 50—80 % of the cases the majority of the specimens have their brachial valve uppermost. Because of the breaking up and large amount of shells present, it is impossible to determine a particular orientation.

*Crinoid stem remains* are very short and generally thin. Most of the crinoid beds are found in association with brachiopod beds. Usually there is a distinct separation between the two beds and, as with the brachiopod shells, there is a good sorting of crinoid stems.

*Bryozoa* are found in far smaller numbers than either of the two foregoing groups. It is characteristic that the bryozoans have cylindrical bodies which may reach a few centimeters in length.

*Gastropoda* form extremely hard beds. Besides the small types, which predominate, large examples are occasional present. The gastropods are usually associated with limestone building algae, especially the red algae, but it is also common to find a blue-green algal crust round some of the smaller gastropods.

*Calcareous algae*, as mentioned above, are often found in association with gastropods. They also form separate banks, where some crinoid remains, a few brachiopods, and Foraminifera are also found. The limestone algal remains are usually crystallized. In this facies it is mainly red and blue-green algae are found.

*Corals* are found, only as compound forms. Usually rugose and tabulate corals form independent beds. Both types form biostromes, which are easy to follow in the direction of strike. In exceptional cases the two types, rugose and tabulate corals are found together. Other organisms are never or only very scarcely associated with the corals. The mode of growth of the corals results in the wavy strata and irregular thickness of layers.

*Foraminifera* are seldom found as independent rock builders. They are usually associated with limestone building algae, crinoid, and brachiopod remains. The fusulinids, which are present, consist of large and small individuals.

### *Environmental conditions*

From the above description of the organic remains it can be concluded that the environmental conditions were effected by moderate or strong wave action. Supporting this conclusion are the presence of relatively large amounts of compound corals and of red algae, belonging to the genus *Archaeolithophyllum*, the complete mixing of organic remains, the large amount of crystallized material, and the large amount of broken material. The absence of large brachiopods, gastropods, crinoids, plant remains, and the small amount of clay in the crystal matrix, indicate a moderate depth of water. All the organisms indicate that the water was clear and sunlight penetrated to the bottom. The small quantity of fine material indicated that the bottom was also free of mud.

## LIMESTONE FACIES TYPE B

### *Lithologic properties*

The limestones belonging to this facies usually contain a large amount of clay in the matrix. The strata are generally thin (5—10 cm). The limestones are also generally fine grained and vary in colour from dark grey to brown. Most layers are soft, because of the high clay content, and thus have little resistance to erosion. In certain beds decalcification has taken place and there are cavities of fossils, especially brachiopods and crinoids (fig. 7b).

### *Biological properties*

*Brachiopoda.* Large forms are found in this facies, associated with thick crinoid stems. There is a considerable concentration of these large brachiopods, and many specimens have well preserved spines and decoration. There is little orientation in the specimens and 50—70 % of the individuals have the brachial valve facing the bottom.

*Bryozoa* are often associated with brachiopods. They consist mainly of small colonies of fenestrate bryozoans.

*Crinoids* are usually well preserved, and both stems and crowns are found. It is not unusual to find stems which are 25—30 cm long, and the diameter varies between 0.8—1.2 cm. The stem remains show a better orientation than the brachiopods. A well developed east-west direction can often be recognized.

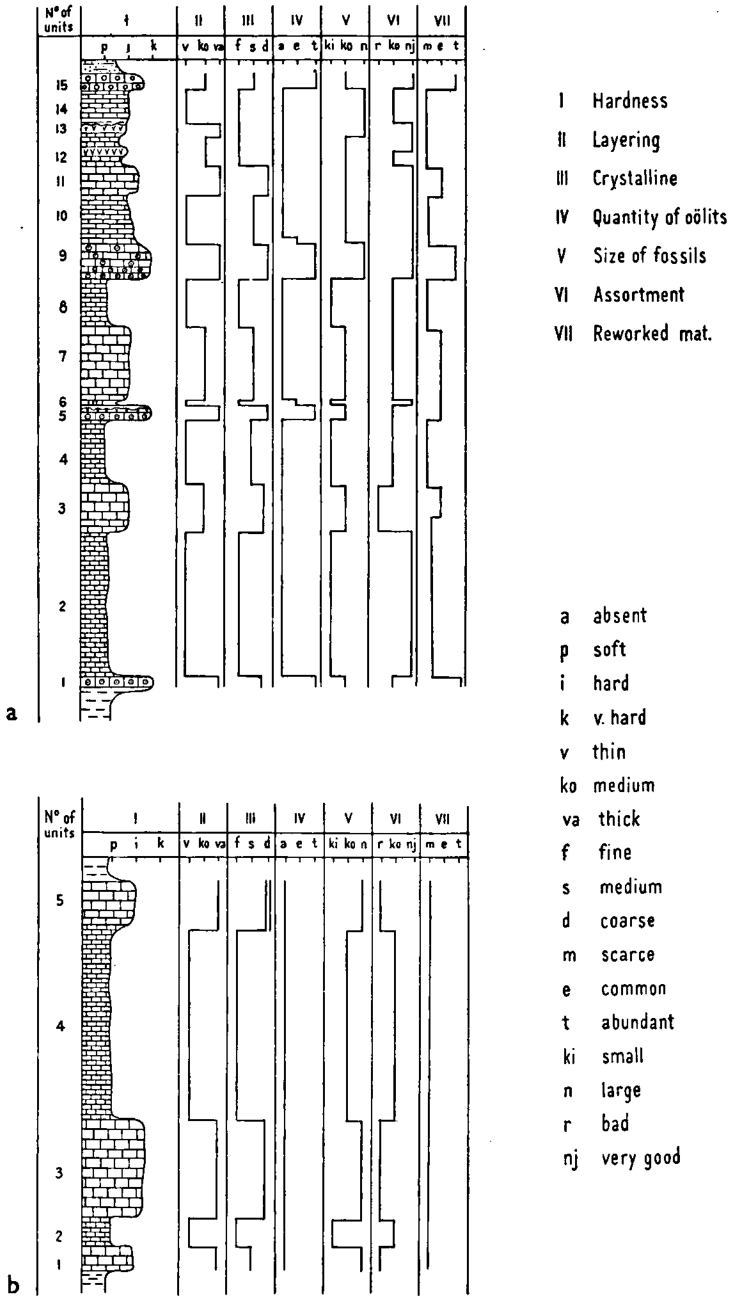



Fig. 7. Physical, chemical, and biological composition of the two limestone members, in vertical section. Scale 1 : 300.

*a.* Limestone facies type *A* — member no. II in the San Emiliano Formation.

*b.* Limestone facies type *B* — member no. VI in the San Emiliano Formation.

*Foraminifera* are represented by large and intermediate forms. They are present in soft deposits, which contain large amounts of clay. In some cases they form thick beds (0.50—1.50 m).

*Limestone building algae* are less abundant than in facies type *A*. Mostly green algae are found; occasionally red limestone building algae and blue-green algae are present. The strata, where the algae are found, are very thin and the limestone matrix varies in colour from dark grey to black.

*Corals* are present as large specimens often associated with brachiopods and crinoid stems; compound corals are never found in this type of sediment.

*Trilobites* usually occur in small numbers in the dark grey, streaky limestones, where they are associated with bryozoans, brachiopods and green algae.

*Ostracoda* are occasionally found in this facies type.

*Plant remains* are frequently found in this type of sediment, usually together with brachiopods. The fragmentary state of the plant material does not allow specific or even genetic determinations.

### *Environmental conditions*

The abundance of brachiopods and the long crinoid stems indicate that this fossil remains were autochthonous. The large size and the thick shells of the brachiopod, as well as the presence of plant remains, suggest that the sedimentation occurred in shallow water. The long fragments of crinoid stems, the wide range in size of organisms, and the scarcity of a distinct preferred orientation of fossil remains indicate a quiet environment, in a calm, undisturbed sea. The high clay content indicates a muddy bottom. The water was, despite the muddy bottom probably clear, because organisms such as corals, calcareous algae, and crinoids would not be present.

## LIMESTONE FACIES TYPE AB

It is difficult to group the limestones, which are found west of Cármenes, into either of the types described above. The sediments contain more clay than facies type *A*, and less than those of facies type *B*, in the eastern and western parts of the syncline.

The organic remains show a mixed picture, with large and small forms beside each other. It is also noticeable that the Bryozoa are represented by cylindrical branched forms as well as by fenestrate forms. There are solitary and compound corals in the same strata. A special relation is found between the compound tabulate corals and the large brachiopods. These two groups appear alternating in the succession, with brachiopods predominating. There are places where the corals have been broken from their biostrome construction, grown round one or more brachiopods, and then redeposited (fig. 8). It cannot be doubted that they were pulled off, because they are randomly orientated, while in their normal structure they grow upwards. There is a considerable amount of broken material in this facies type, but markedly less than in facies type *A*.

The substratum, in which these organisms were deposited, certainly contained clay. The large amount of broken material present, the peculiar association of organisms, the association of large and small forms, and the few cases of preferred orientation, all indicate that the conditions varied with disturbed and undisturbed periods.

All the limestones in the San Emiliano and the Lois-Ciguera Formations can be fitted into this scheme. It should be noted, however, that a limestone bed or limestone member, can be constructed from a combination of the facies types.

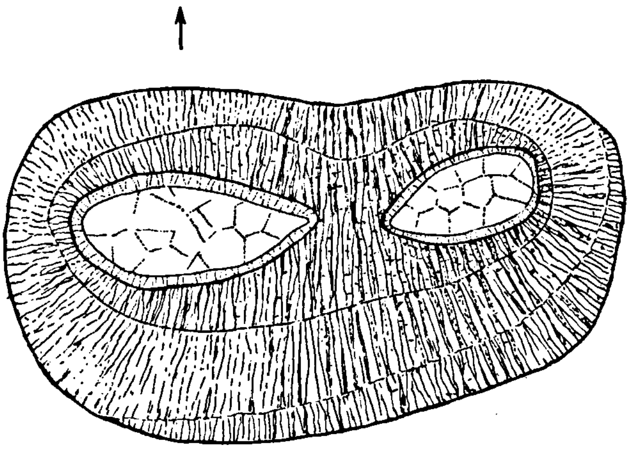


Fig. 8. Tabulate coral, which has coated two brachiopod shells, in facies type *AB*. Natural size, vertical section; arrow indicates top of bed.

*San Emiliano Formation* (Cármenes syncline):

a. east of Cármenes
The older limestone members (I and II) of the San Emiliano Formation are characterized mainly by facies *A*. The upper members (III, IV, V) are mainly characterized by limestone of facies type *B*.

b. west of Cármenes
In this area the two facies types are often found in combination and it is therefore more fitting to describe this area as containing facies type *AB*.

*Lois-Ciguera Formation* (Pajares - Isidro area)

The limestone deposits of the Lois-Ciguera Formation show an inverted picture, when compared to the eastern and central parts of the San Emiliano Formation; the lower layers contain mainly facies type *B*, and the upper layers contain mainly facies type *A*.

SUMMARY

| | Type *A* | Type *B* |
|---|---|---|
| Lithological characteristics | Hard, little clay, dark grey, red tint, sometimes cherts. Limestone with calcite veins | Soft, fine crystalline, dark grey, brown-yellow worn limestone, with high clay content |
| Biological characteristics | brachiopods – small forms<br>gastropods<br>calcareous algae – red, blue-green<br>crinoids – thin stems<br>compound corals<br>Foraminifera – range of varieties | brachiopods — large forms<br><br>calcareous algae – green<br>crinoids – thick stems<br>single corals<br>Foraminifera – large forms<br>Plant remains |

CHAPTER III

# PALEOECOLOGICAL CONSIDERATIONS

### *Introduction and terminology*

The large numbers of organic remains in the San Emiliano and Lois-Ciguera Formations offers an opportunity for a paleoecological study.

Although the object of paleoecology is a reconstruction of the biological milieu, on the basis of flora and fauna and their inter-relationship, some authors also apply the term to a reconstruction of the sedimentary milieu. When the meaning of the term "ecology" is considered, the latter usage cannot be considered valid.

Ager (1963) made a attempt to clarify some of the confusion, which still exists, in the terminology, by the introduction of the terms "paleoautecology" and "paleosynecology". According to Ager (1963, p. 19), paleoautecology is the paleological equivalent of the term autecology, where the latter defines the study of an individual organism or a small taxonomic group. According to the same author, paleosynecology is the fossil version of the term synecology, which is used in connection with communities as a whole. Because the fossils in an inorganic matrix are present in random milieu, a fruitful investigation to determine the causes, which contributed to the formation of the milieu, can only be carried out by analysing the organic and inorganic components together. On the other hand it is also valid that certain milieu changes have affected the organic as well as the inorganic components of the sediment. The two interpretations of the same object will now be analysed.

## RHYTHMIC STRATIFICATION OF THE SEDIMENTS

### *Introduction*

It is possible, with experience, to see from a distance that a limestone member can be divided into smaller units. This can be detected from the physical properties, such as thickness of layers, different weathering colours in the small units, and the resistance which these have against erosion. The character of the contact line, in the direction of strike, can also be regarded as a significant feature. The borders between the units are clear and often sharp (fig. 9). Closer inspection has shown that the small units have fossil associations where brachiopods, echinoderms, Foraminifera, calcareous algae, and corals predominate.

### *Description of the layer types*

As found in the facies study, the limestone deposits of the San Emiliano and the Lois-Ciguera Formation can be divided into two types: a limestone facies, a clay-containing facies, or a mixture of these two types.

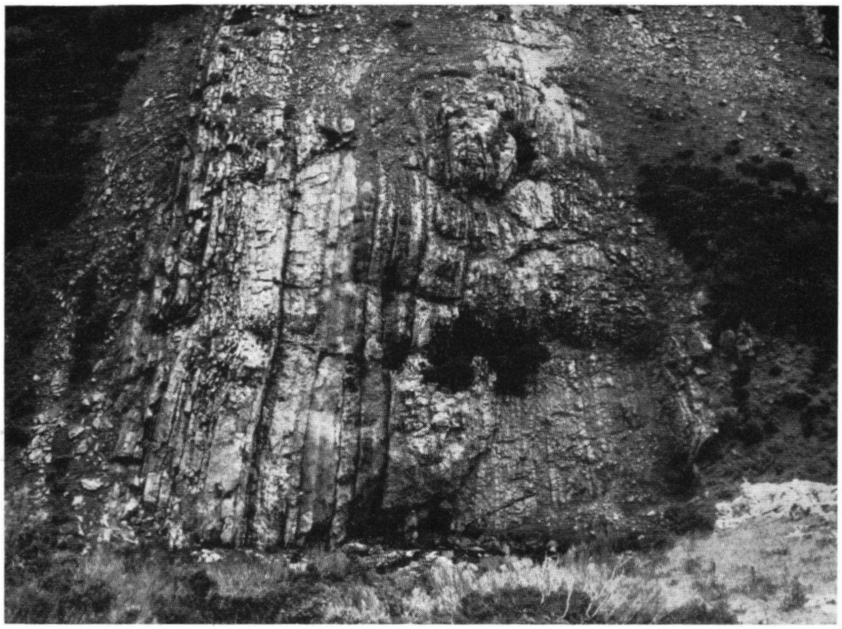


Fig. 9. Sub-division of a limestone member into smaller units, in the Pendilla valley to the north of Tonin, in the Lois-Ciguera Formation. Photo taken in the direction of strike.

The limestones of the San Emiliano Formation were studied in loc. R. 43. The vertical section of the limestone member is shown in fig. 10 and a description is given below.

*Description*

20. small sandstone layer; no fossils.
19. oolitic, thick layered, hard, dark brown weathered limestone, coarse grained; gastropods, and calcareous algae.
18. light grey limestone hard, calcite veins; no fossils.
17. fine crystalline, light grey limestone; brachiopods.
16. soft, fine grained limestone; with calcareous algae.
15. biostrome of tabulate corals grown on rugose corals.
14. soft, dark grey limestone, fine grained; calcareous algae.
13. biostrome of rugose coral.
12. thin bedded, dark grey limestone, fine grained; calcareous algae, echinoderms.
11. thick bed, light grey limestone; Foraminifera and gastropods.
10. very fine crystalline, black limestone, thin bedded; calcareous algae.
9. oolitic, thick bedded, brown weathered limestone; brachiopods, echinoderms, and gastropods.
8. very soft, fine crystalline, dark grey limestone; calcareous algae.
7. coarse grained, dark grey, thick bedded limestone; brachiopods.
6. slightly oolitic, medium grained limestone; calcareous algae.
5. upper part — compound Tabulata coral lower part — oolitic, thick bedded, coarse grained, brown weathered limestone; calcareous algae, gastropods, and brachiopods.
4. grey weathered, very thin bedded, dark grey limestone; calcareous algae, and gastropods.

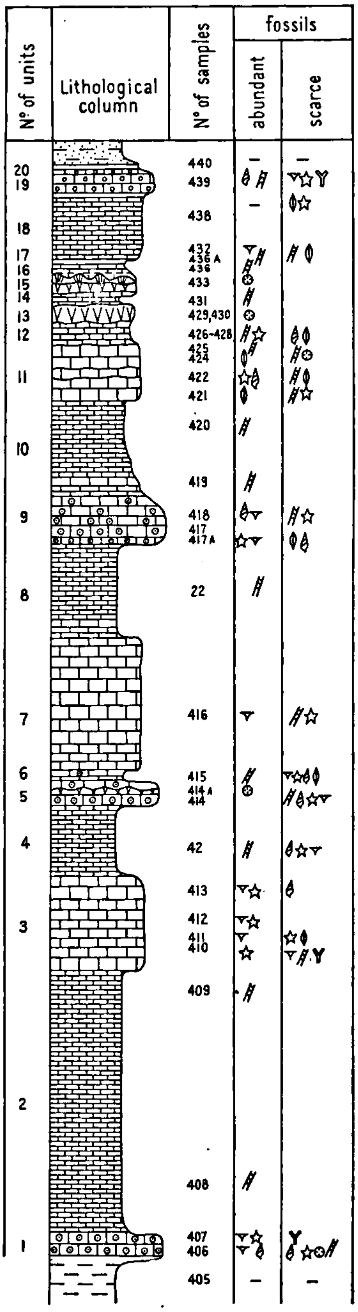



Fig. 10. Vertical section with the fossil content, in member no. II, at loc. R 42 in the San Emiliano Formation. Scale 1 : 150.

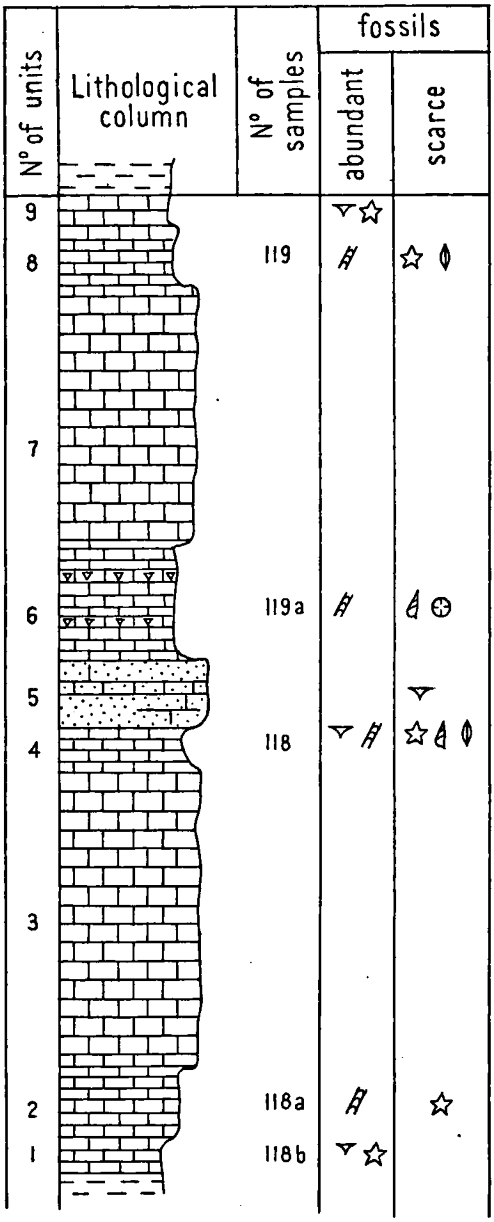



Fig. 11. Vertical section with the fossil content in member no. V, at locality B 42 in the Lois-Ciguera Formation. Scale 1 : 100.

3. brown-grey, weathered, thick bed, coarse grained, in some places red tinted; brachiopods, and echinoderms.
2. thin bed, soft, fine crystalline, limestone with calcareous algae.
1. dark grey to brown weathered, thick bed, dark grey oölitic limestone; brachiopods, and echinoderms.

Loc. no, B. 42, from the Vegarada valley in the Lois-Ciguera Formation.

*Description loc. B. 42* (see also fig. 11)

9. yellow-brown weathered limestone bed, 0.30 m thick; crinoid stems and brachiopods.
8. black, fine crystalline, thin bedded, soft limestone, 0.80 m thick; calcareous algae, Foraminifera, crinoid remains.
7. dark - light grey weathered limestone, thick bedded, 3.50 m thick, with calcite veins; no fossils.
6. dark grey weathered, black highly compacted limestone, with cherts bands, 1.50 m thick; calcareous algae, gastropods and solitary corals.
5. sandstone bank 0.75 m thick; brachiopods.
4. dark grey - black, limestone bed, coarse crystalline; brachiopods, gastropods, calcareous algae, Foraminifera and crinoids.
3. light grey limestone, with calcite veins, 4 m thick; no fossils.
2. black, fine crystalline, soft limestone, thin layer 1.0 m; calcareous algae, and crinoid stems.
1. muddy limestone, thick bedded, light brown-grey weathered; crinoid stems and brachiopods.

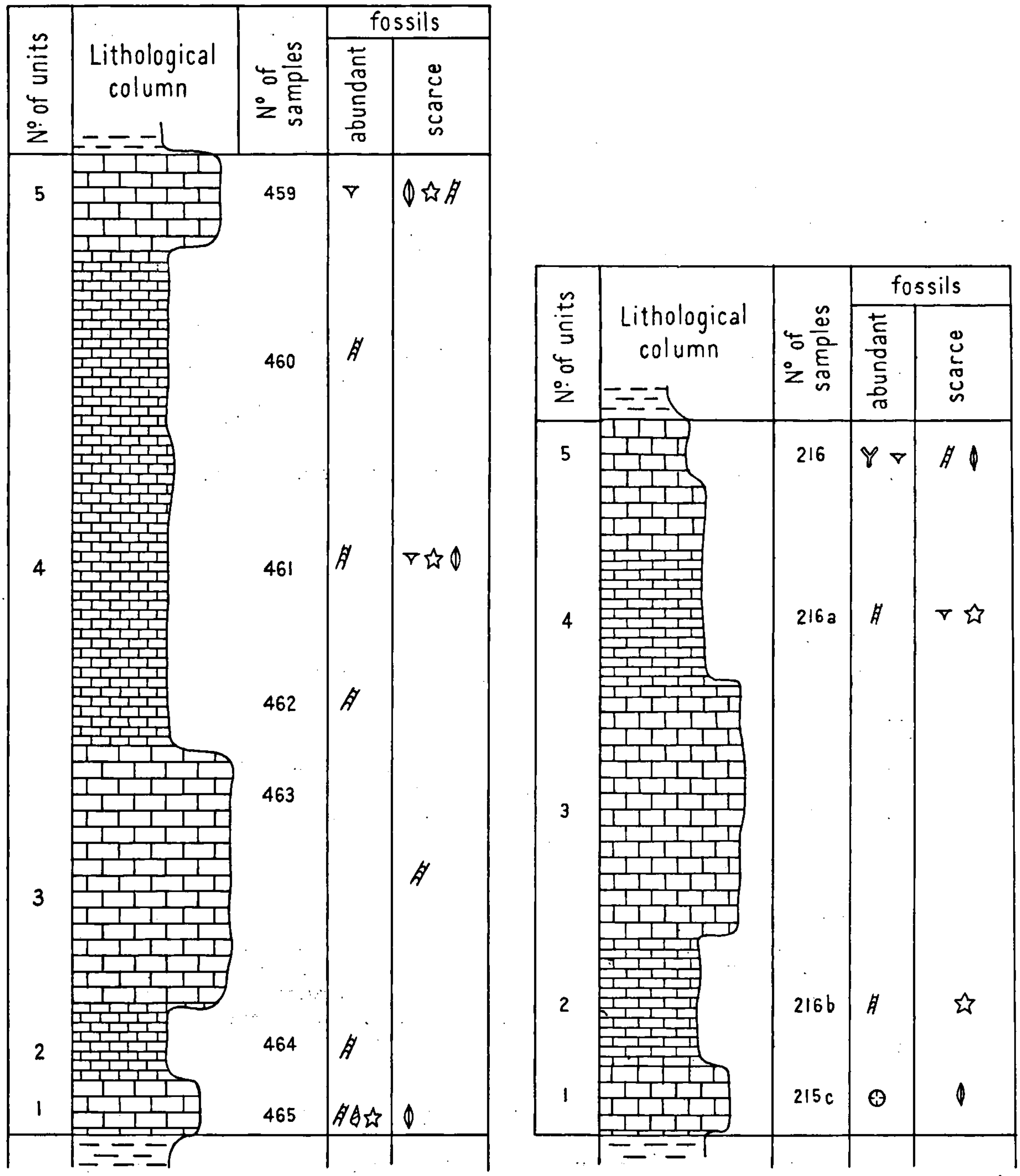
*Description* (see also fig. 12a),

1.5 m brown-yellow weathered, bituminous limestone, fine crystalline, thick layer, high clay content; large formed brachiopods, echinoderms and blue-green algae.
7.7 m dark grey-black, soft, thin layered, limestone, weathered light grey, high clay content; calcareous algae.
4.0 m hard, light grey limestone, thick layer, with calcite veins; no fossils.
1.20 m soft, fine crystalline, clayey, grey limestone, thin layer, weathered brown; calcareous algae.
0.80 m pseudo-oölitic, thick layered, coarse crystalline limestone; gastropods and calcareous algae.

Another example of the lithological and biological composition of the deposits is a vertical section, taken from locality 216 in the Lois-Ciguera Formation, north of Canseco (see fig. 12b).

*Description*

1.00 m weathered brown, soft, clay-containing grey limestone with a coarse crystalline matrix: calcareous algae, brachiopods, and bryozoans.
2.20 m black, very fine crystalline limestone, soft, thin bedded: calcareous algae, echinoderms, and bryozoans.
4.00 m dark grey, thick bedded limestone with thick calcite veins: no fossils.
2.00 m dark-grey - black, thin bedded, fine crystalline limestone: calcareous algae (green), and echinoderms.
1.00 m massive limestone layer, thick layered, dark grey, weathered light grey with a few calcite veins: single corals, and Foraminifera.




a b

Fig. 12. Vertical section with the fossil content in limestone layers of limestone facies type *B*. Scale 1 : 100.
*a.* Locality 216 in the Lois-Ciguera Formation.
*b.* Locality R 449 in the San Emiliano Formation.

It appears from this description and also from the investigation of several limestone beds that there is a definite connection between the physical-chemical properties of a sediment and its faunal and floral content. On the basis of this finding it is possible to summarize the results in table form, as shown below.

*Limestone facies type A*

| *lithology* | *fossil content* |
|---|---|
| 5. light grey, coarse crystalline limestone, calcite veins in and across, or at an angle to the layer. | no fossils. |
| 4. light grey limestone, with or without calcite veins. | compound corals (biostromes), single corals. |
| 3. dark grey-black, fine crystalline limestone, thin layered, soft. | calcareous algae, gastropods, echinoderms, Foraminifera. |
| 2. dark grey-black, fine crystalline, often cherts layers in strata. | single corals, Foraminifera, gastropods. |
| 1. hard, grey, coarse crystalline, limestone often tinted red, oolitic. | brachiopods, echinoderms. |

*Limestone facies type B*

| *lithology* | *fossil content* |
|---|---|
| 4. dark grey-black, light grey weathered, soft limestone. | calcareous algae (mainly green). |
| 3. dark grey limestone with light grey-brown streaks. | bryozoans, brachiopods, trilobites. |
| 2. fine crystalline, dark grey-black, light brown, weathered, limestone. | brachiopods, echinoderms, bryozoans, single corals. |
| 1. very soft, fine crystalline, brown yellow, weathered limestone, stratification with wavy surface. | Foraminifera. |

This connection between the lithological units and particular fossil content can be applied to most of the limestones, in the greater part of the area.

The fossil content is in most cases closely connected to the lithology. There are, of course, intermediate cases when the transition is gradual, without a clearly defined border. All the possibilities are shown in fig. 13. The problem is here slightly generalized and simplified, but it still remains of general value.

## CYCLICAL SEDIMENTATION, MINOR CYCLE

The small lithological units appear in a definite order, within a limestone member. They can be present once or several times and extend over the whole area. These facts provide the basis for assuming that a cyclical sequence of circumstances has occurred. Because the thickness of these beds is much smaller (1—8 meter) than is

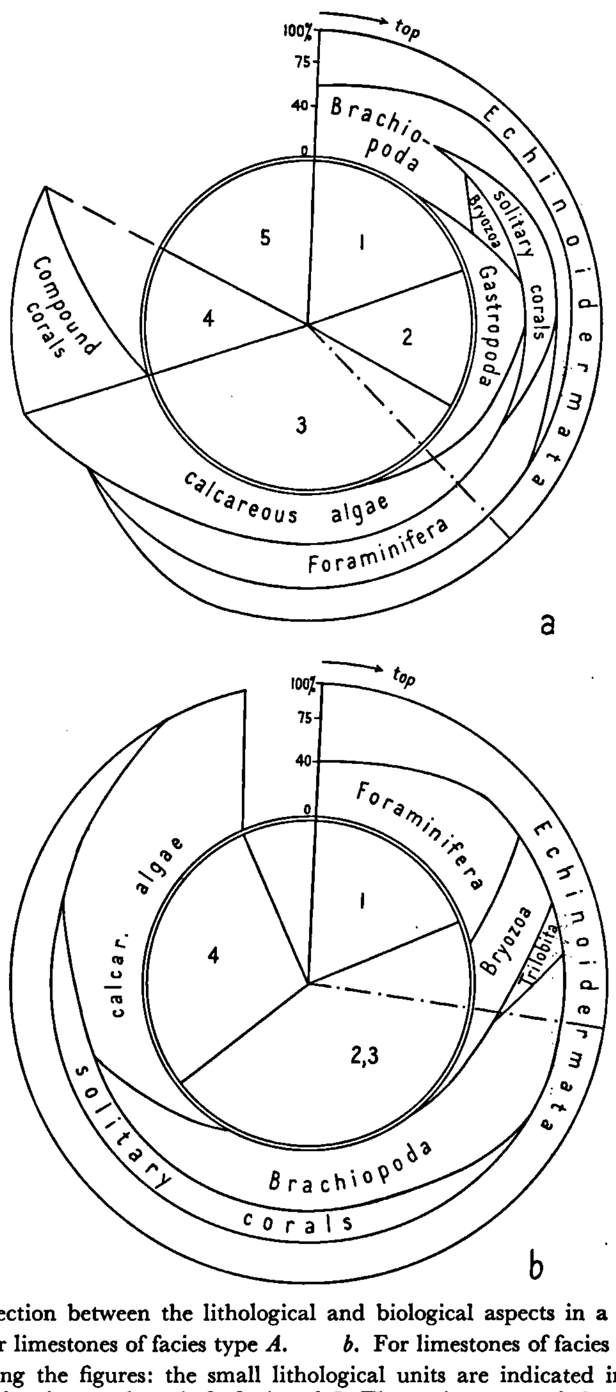



Fig. 13. Connection between the lithological and biological aspects in a limestone layer. *a.* For limestones of facies type *A*. *b.* For limestones of facies type *B*.
Reading the figures: the small lithological units are indicated in the innermost circle by the numbers 1, 2, 3, 4 and 5. The regions around the innermost circle represent the organic remains, which are present in particular units. The stippled lines drawn radially from the centre enclose the lithological unit with the approximate percentage composition of the associated fossils (see page 36).

normally found in cyclical sediments, they also have a special character, being always found in limestone, and because the units contain particular biotopes, the term *minor cycle* is used.

The heading minor cycle is thus understood to indicate: a regular succession of small, $CaCO_3$ containing, units within a limestone layer or member, differing in physical, chemical, and biological composition; and can repeat themselves in the same order.

The minor cycles are often complete, but incomplete cycles are also found. In some layers, where two facies types are present, there is a combination of the two types of cycle. In such cases neither cycle is complete.

In the illustrations the numbers of cycles are shown and also the small sub-units. The small units, of facies type *A*, are indicated with the letters *a*, *b* and *c*, while those of the small facies (facies type *B*, are indicated with the letters *x*, *y* and *z* figs. 14a and 14b).

Figure 14a shows an example of cyclical deposition in the limestone facies type *A*. The cycles are symmetrical in this layer. At the bottom of a cycle there is oolitic limestone, above this there is a soft, finely bedded limestone layer, and above this a hard, coarse crystalline, thick bedded unit (succession a — b — c, fig. 14a). This part of the cycle can be regarded as the transgressive phase of the substrate movement.

The regressive phase is represented by the units c — b — a. Most of the layers, as is shown in fig. 14a, contain more minor cycles, which show decreasing thickness from top to bottom. Another phenomenon which can be seen is that the transgressive phase of a cycle is thicker than the regressive phase. These two properties of the minor cycles are not found in every layer.

An example of a minor cycle, in a layer of limestone facies type *B*, is shown in fig. 14b. In this case, the sequence of units x — y — z can be considered the transgressive phase of the substrate movement and the z — y — x succession as the regressive phase. In this case it appears that the transgressive phase is much smaller than the regressive phase. Because there is only one cycle present, it is impossible to make an inter-cycle comparison.

When the two cycles, from the two limestone facies types, are compared, it can be immediately seen that there is no oolitic layer unit present in the limestones of facies type *B*. It would, otherwise, have been possible to find an analogy between the two types of cycle. Generally the units of the cycle in limestones of facies type *B* are more clearly limited than those of facies type *A*. This results from the more peaceful circumstances during sedimentation.

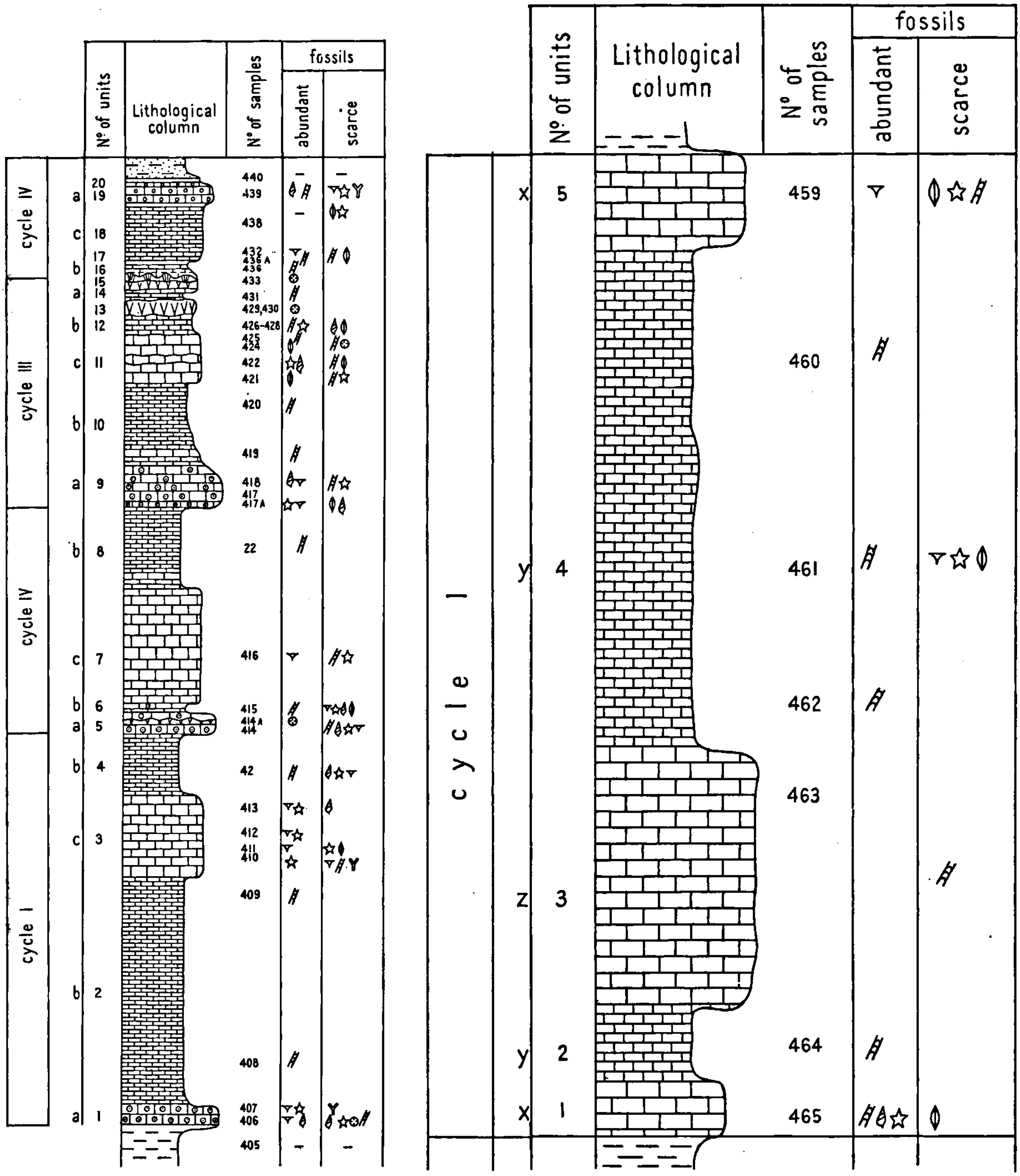
The author found it impossible to explain the difference between several physical and mechanical properties of the cycles in the two different facies types.

## BATHYMETRIC CONSIDERATIONS

### *Introduction*

Logically and in accordance with the original purpose, the marine environments can be classified as follows:

a. littoral zone;
b. sub-littoral zone,
c. oceanic zone.



a b

Fig. 14. Minor cycles in the limestone layers.
*a.* In limestone facies type *A*. *b.* In limestone facies type *B*.

In the San Emiliano Formation and in the Piedrafita-Lillo strip the indications are that all the Carboniferous sediments were deposited certainly not deeper than the lower edge of the sub-littoral zone. To be more precise, it is most probable that the greater part of these sediments were deposited in the littoral and middle sub-littoral zones. All the characteristics of shallow sedimentation are found in this area. The two facies:

sandstone and clay type, and
limestone and marl type,

are deposited here. The criteria for undisturbed sedimentation are less easy to apply to this area.

The conditions given here are typical of a sedimentation in the upper part of the sub-littoral zone (epineritic zone). Experience has shown that these criteria are valid for each of these deposits. It has been shown, in practice, that these conditions apply in depths varying from 10 to 40 meters. It is therefore necessary, in this case, to make a finer division of the sub-littoral zone. This is as follows:

a. littoral zone (depth 0—10 meters),
b. sub-littoral zone (depth 10—200 meters),
$b_1$. shallow sub-zone (depth 10—40 meters),
$b_2$. intermediate sub-zone (depth 40—100 meters),
$b_3$. deeper sub-zone (depth 100—200 meters),
c. oceanic zone.

The sandstones and greywackes contain plant remains, and large brachiopods, it is therefore to be assumed that they were deposited in a very shallow facies.

The shale layers also contain plant remains but fewer macrofossils are found than in the sandstones. Variations are found in the colour of the shale, from black or dark brown to light brown or yellow. This changing of colour indicates changes in the relationship between the oxidation and reduction processes. It is also probable that these shales were deposited at different depths. This is further indicated by the fact that the yellow shales contain no plant remains, and are found in the western part of the Cármenes syncline. On the basis of this argumentation it is possible to place the shales in the area between the littoral and sub-littoral zones, or possibly in the sub-littoral zone.

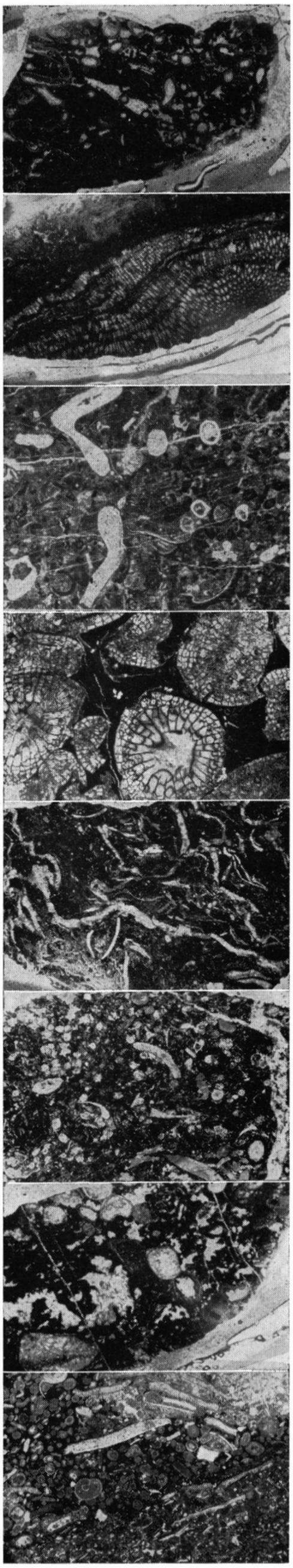
The calcareous layers present greater problems. As has been shown, the sedimentation and fossil content of the limestone layers are interrelated. Changes in the flora and fauna reflect changes in the environment. Because there are usually sharp boundaries between the lithological and faunal units within a minor cycle, the assumption can be made that sudden changes have occurred.

### *Bathymetric consideration of flora and fauna*

*Foraminifera* can be found at various bathymetric levels. As is known from the literature, members of the family Fusulinideae are usually found in the littoral and sub-littoral zones. This family is also found in the Carboniferous deposits in NW Spain.

The scarce, small Foraminifera, which are found in the Escapa limestone suggest that,

a. either they existed in the deepest part of the sub-littoral zone ($b_3$ sub-zone),
b. or the high rate of sedimentation did not permit a full development of the specimens.




A predominance of calcareous algae, which belong to the genus *Anthracoporella.* — Packed algal biomicrite with geopetal pore filling.

Tabulate corals and crust forming blue-green algae are present in the uppermost part of the unit. — Corals biolithe.

Calcareous algae, of the genus *Petschoria.* — Poorly washed algal biosparite with geopetal pore filling.

Rugose corals.

There are two calcareous algal genera: *Petschoria* and *Donezella.*

Foraminifera form the main part of the biofraction. — Unsorted Foraminifera-crinoid biosparite.

Calcareous algae of the genus *Petschoria.* — Sparse algal biomicrite.

Oolitic limestone with calcareous algae (*Archaeolithophyllum*), gastropods, brachiopods, and bryozoans. — Well sorted oosparite.

Fig. 15. Changes in the composition of the biofraction and the petrographic properties in a minor cycle. (Loc. R 43, cycle III, member no. II San Emiliano Formation). All slides enlarged 3×.

It is also possible that both the above factors resulted in the evolution of these small Foraminifera.

The large Foraminifera are found in large quantities, in the Lois-Ciguera Formation, and to a smaller extent in the San Emiliano Formation, in the lower part of the minor cycle, usually before the small brachiopods. It can thus be assumed the former populated the deepest part of the sea bed ($b_2$ sub-zone of the sub-littoral zone). Sometimes they are found in association with other fossil remains. Very occasionally they are found with blue-green algae, which are known to be shallow water organisms. Usually their highest level corresponds to that of the green algae, and this is the upper part of the sub-littoral zone ($b_1$ sub-zone).

*Brachiopods* are found in clay-containing limestone and also in limestone which contains no clay. Two types of brachiopod are found: small with a thin shell, and large with a thick shell. These have important differences when considered bathymetrically: the small forms in large numbers and few different sorts represent deeper regions ($b_2$ sub-zone of the sub-littoral zone), and the large forms with many examples and species represent the shallow littoral zone. It is noticeable, with the large brachiopods, that the shell decoration is well preserved. This indicates that the conditions were calm and there was little sand on the sea bottom, to wear off the decoration.

Sometimes the two forms are found mixed, or a region is found where the examples are intermediate between the large and small forms. These are always found in association with green algae, bryozoans, and trilobites. Therefore these areas are placed in the shallowest part of the sub-littoral zone.

Representatives of the three sorts of *calcareous algae*, red, green, and blue-green algae, are found in both regions. It is known that the algae are limited by sunlight and cannot exist below the level at which photosynthesis can take place. It appears, from other ecological data that the red algae can exist in the deeper part of the sea bottom, (until approximately 200 meters). In the San Emiliano and Lois-Ciguera Formations they have formed their banks in the vicinity of the small brachiopods. They probably existed between 40 and 100 meters, in the $b_2$ sub-zone of the sub-littoral zone.

The green algae are always found in shallow deposits. Investigation has shown that, where these algae are present, large and small brachiopods are found. It is therefore probable that the green algae existed at the bathymetric border between these two sorts. The green algae are therefore placed in the shallowest part of the sub-littoral zone ($b_1$ sub-zone).

The blue-green algae are typical plants of the littoral zone.

Fenestrate *bryozoans* are characteristically found in the vicinity of brachiopods, but they are never found with the small forms. Round cylindrical bryozoa are found together with small brachiopods and gastropods. Their bathymetric level is probably in the $b_1$ sub-zone, where the intermediate or mixed form brachiopods are found with green algae and trilobites. Fenestrate bryozoans are mainly found in sediment which is clay containing limestone, with pure clay streaks in it. Thus they probably preferred a muddy quiet environment, while the round forms preferred a deeper, more disturbed environment.

The bathymetric position of the gastropods cannot be precisely defined. In one case they are clearly between the green and the blue-green algae, and in another case they were found much deeper, in chert-containing limestone together with Foraminifera and small brachiopods. In the second case the specimens were much smaller than normal. It is thus possible that the gastropods, like the brachiopods, are divided into large and small forms. In this case the small forms are found with the small brachiopods ($b_2$ sub-zone) and the large forms appear with the green algae and the mixed brachiopod zone ($b_1$ sub-zone).

*Coelenterata* are found in two types: solitary corals and compound corals. The solitary corals are rugose, but the compound corals are both tabulate and rugose. There are definite bathymetric differences between these two types. The solitary corals can be found much deeper ($b_2$ sub-zone) than the compound corals. The compound rugose appear to have lived deeper than the tabulate, but they are also found together. The compound tabulate are often found together with blue-green algae and large brachiopods. On the basis of this data it appears that their bathymetric level has been very shallow.

The few specimens of *trilobites*, which have been found, belong to the genus *Phillipsia* and are found with bryozoans and the mixed zone brachiopods. We can therefore place them in the $b_1$ sub-zone. They probably preferred, as some brachiopods and bryozoans, to live in a muddy undisturbed substratum.

Considering the above discussed bathymetric conditions, the calcareous layers of the San Emiliano and the Lois-Ciguera Formation are summarized in figs. 16 and 17.

## THE CONCEPT OF "PHASE" AND ITS BATHYMETRIC APPLICATION

Elias (1937) in his study of the Permian deposits in Kansas, used the term "phase" as a bathymetric concept. By this he meant a certain depth, where one species of organism in association with other species lived under the most favourable conditions. Elias was able to distinguish 7 depth-phases. It has also been assumed, in the present study, that depth changes were the most responsible factor in changing flora and fauna. A detailed paleoecological study brought the conclusion, that with the changes in depth, other factors have also played an important role: of these the most important are strength of wave action, condition of the substrata, and changes in the chemical composition of the sea water, in the origin of a particular association at a bathymetric level. Thus in many cases special environments arose. Because of the presence of such situations, it was necessary to study a precise bathymetric picture of the deposits in NW Spain. In limestones of facies type *A* there are always "special" milieus present, while in limestone facies type *B* the "normal" milieus are found. Taking this into consideration, it becomes clear that the limestone deposits in facies type *B* are more suitable for bathymetric determination than those of facies type *A*.

In a limestone layer, with a normally developed minor cycle, 4 depth phases can be distinguished, on the basis of the biological and lithological composition, as is summarized below.

The difference between the depth phases 1 and 4 can be clearly seen in the fossil associations of both limestone facies types. They are immediately recognisable. It is not so simple in the cases of depth phases 2 and 3. This is especially true of limestones with equal numbers of red and green algae. In facies type *B* the recognition is simplified by the presence of brachiopods, where in most cases the size and thickness of their shells can give very valuable bathymetric data.

Figures 16 and 17 show a picture of the bathymetric conditions in the deposits of both facies types. It is likely that the oscilations occurred suddenly, which are expressed by the use of broken lines in place of continuous lines.

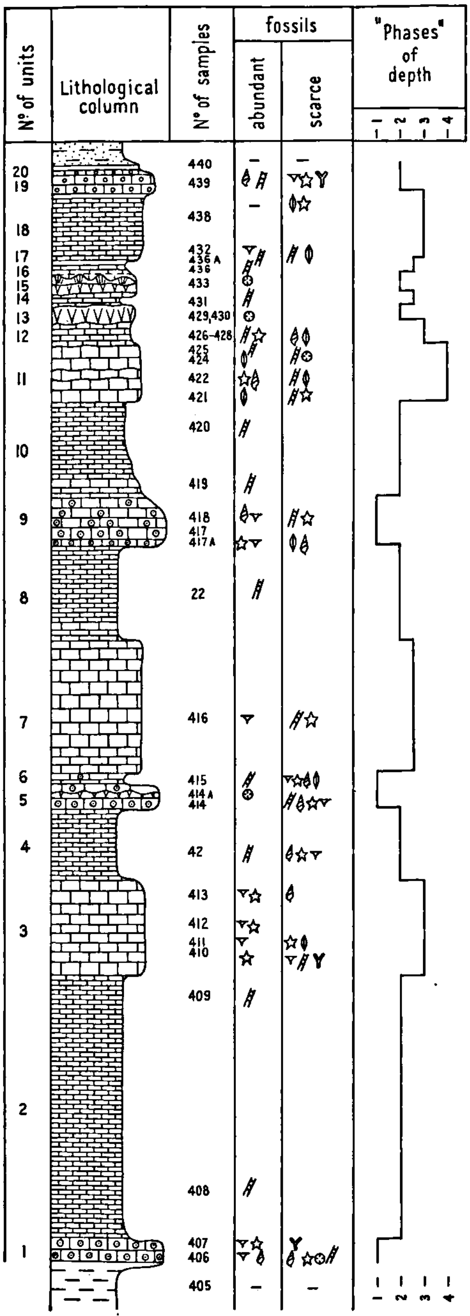



Fig. 16. Depth "phases" in a limestone member of facies type *A*.

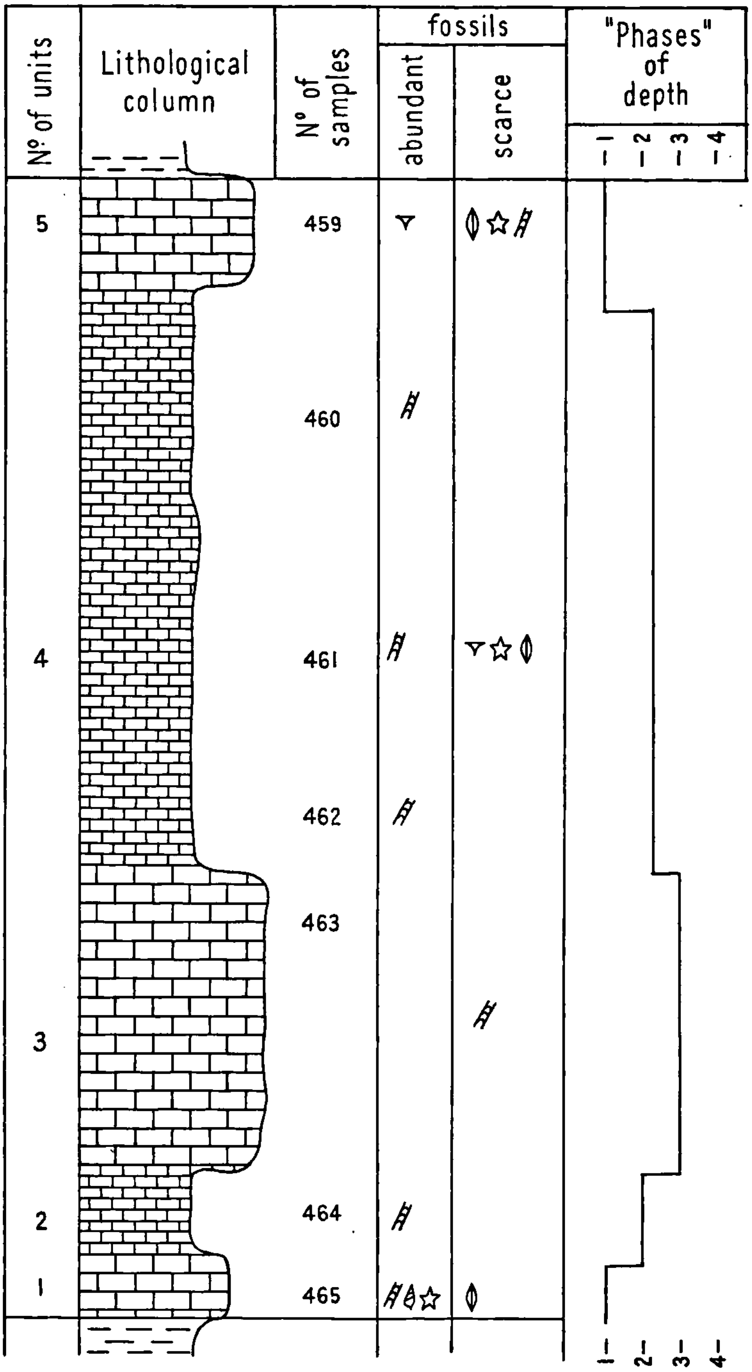



Fig. 17. Depth "phases" in a limestone member of facies type *B*.

| Depth phase | Association of organisms in facies type *A* | Association of organisms in facies type *B* |
|---|---|---|
| 1 | *Archaeolithophyllum*, dwarf elements in oolitic limest., compound corals, | brachiopods (large) bryozoa (fenestrate) crinoid stems (long and thick) |
| 2 | green algae (many) red algae (few) blue-green algae | green algae (many) red algae (few) brachiopods (medium) blue-green algae |
| 3 | red algae (many) green algae (few) single corals | red algae (many) green algae (few) single corals brachiopods (small) |
| 4 | Foraminifera | Foraminifera |

## THE CLASSIFICATION OF THE LIMESTONES, ACCORDING TO THEIR ORIGIN AND MANNER OF ORGANISM ACCUMULATION

In the previous section the physical and some of the petrographical properties of the two facies types of limestone, in the San Emiliano and the Lois-Ciguera Formation, were compared. Several of the conditions under which they were deposited were also mentioned.

Now the limestones of the two facies types will be considered from another angle. We shall now concern ourselves with:

1. a study of the rock texture,
2. the rock origin, and
3. the method of accumulation.

It has appeared that the greater part of the limestone deposits consist of clearly defined units, with typical physio-chemical and biological compositions. It appeared, from the microscopical study, that based on the texture, origin, and manner of accumulation of the San Emiliano and the Lois-Ciguera Formation they can be divided into two general types:

A. skeletal limestones,
B. fragmental limestones.

H. F. Nelson, C. W. Brown and J. H. Brineman (1962, p. 250) define the skeletal limestones as "rocks which consist of, or owe their characteristics to, the in-place accumulation of calcareous skeletal material". According to these same authors, a skeletal limestone is dependent on the organisms which are responsible for the sediment formation, according to their form, limestones can be designated *biohermal* or *biostromal*. On the other hand, "a skeletal limestone deposit is classified as a *reef* or *bank*, depending upon the ecologic potential of the organisms to build a topographic wave-resistant structure" (p. 224).

Cummings (1932, p. 333) defined a *bioherm* as "a reef, bank, or mound; for reef-like, mound-like, lens-like, or otherwise circumscribed structures of strictly organic origin, embedded in rocks of different lithology". Similarly Cummings (1932, p. 334) described the biostrome as "purely bedded structures, such as shell beds, crinoid beds, coral beds, etc., consisting of, and built mainly by sedentary organisms, and not swelling into mound-like or lens-like forms, ... which means a bed or layer".

Bioherm and biostrome structures can occur as *reefs* or *banks* — depending on the "structure to the structure building potential" (Lowenstam, 1950, p. 443). Continuing from Cummings and Lowenstam, a *reef* was defined by Nelson et al. (p. 234) as "a skeletal deposit formed by organisms posessing the ecologic potential to erect a rigid topographic structure". The process, which causes the formation of a reef, is called by Nelson et al. (p. 236) a "Primary process" and is expressed as a "dynamic growth upward and outward by frame building organisms such as certain forms of corals, algae, and rudistids".

A *bank* is defined by the same authors (p. 234) as "a skeletal deposit formed by organisms which do not have the ecologic potential to erect a rigid wave-resistant structure". Nelson et al. call the process which occurs also a "Primary process" and it is characterized by organisms which are make up *in situ* accumulations such as Lucina, Gryphaea, crinoids, and Foraminifera".

*Fragmental limestones*, according to Nelson et al. (p. 236), is the name given to limestones which arise through a wave and current action, where organic activity is also present. By such a process, which according to the authors is also a "Primary process", the shell debris (coquina), granular limestone (calcarenite), and limestone conglomerate (calcirudite) were formed, (p. 236).

A "Secondary process" is also possible here, and is found by the "sedimentary breccia" deposits. This type of limestone did not arise *in situ*, but was accumulated by a favourable wave movement.

It has been found that both skeletal and fragmental limestones are present in the San Emiliano and Lois-Ciguera Formations.

*Skeletal limestones*. Biostromes are present, in large numbers, in both formations, and were formed by corals, calcareous algae, Foraminifera, crinoids, and brachiopods. The bioherms and a proportion of the biostromes (corals and some of the calcareous algae) fulfil the qualifications for the designation "*reef*". The rest of the calcareous algae, with the brachiopods, crinoids, and some Foraminifera beds, have developed as "*banks*".

Bioherms are found as exceptions. In the San Emiliano Formation, between Cármenes and Villamanin, there are a few small coral bioherms. There is also an algal bioherm, several meters long and broad, in the eastern part of the area, in the Lois-Ciguera Formation, west of Pueblo de Lillo.

Fragmental limestones. There is a remarkably concentrated accumulation of organic remains, with or without oolites, in this type of limestone. The fossil fragments, which are mainly gastropods, brachiopods, red algae, and echinoderms, are generally well mixed and rounded. In most cases this limestone is composed of shell debris or calcarenite. It is only found in the limestone deposits of facies type *A*.

That reef development is found in the lower part of the San Emiliano Formation and the upper part of the Lois-Ciguera Formation is interesting. In other words, the limestones, in facies type *A*, have developed as reefs, alongside the fragmental limestones. In the limestones, of facies type *B*, it is mainly banks which are found. This does not contradict the original milieu determination of the two facies types. In limestones of facies type *A* there was a disturbed, strong wave movement, while in facies type *B* there must have been a restful environment.

The proportion of skeletal to fragmental limestones, in the two formations, is approximately 3 : 2.

The skeletal limestones consist of about 60 % banks, and about 40 % reefs. This means that about 1/5 of all the limestones are reefs, 2/5 are limestone banks, and 2/5 are fragmental limestones and other types of bedded limestone.

According to these results, it can be seen that care is needed in the drawing of conclusions from a small amount of data and how misleading generalisations can be, when based on insufficient data from the Carboniferous deposits. Wagner describes the limestones of the San Emiliano Formation (1963, p. 380) "the greater part of which seems to consist of reef limestones" and he continues constantly about "reef limestones" or "bands of reef limestones" referring to the above formation. In the present study it has become clear that Wagner's conclusions, concerning the characteristic structure of these limestones, are no longer tenable.

## THE CLASSIFICATION OF THE LIMESTONES, ACCORDING TO THEIR ORIGIN AND MATURITY

In recent years, several people — mainly in the United States — have tried to give the carbonate deposits a practical classification. (Folk, 1959 and 1961; Plumley et al., 1961; Dunham, 1961; Thomas, 1961, etc.) The results of studies, obtained from deposits of different ages and types of carbonates, led to the conclusion: physical factors, such as energy difference, are reflected by the spectrum of textural types and therefore make an important contribution to the reconstruction of the milieu during the deposition period.

Folk (1961) described the limestones according to their textural maturity, keeping in view the composition of the matrix, grain size, number of allochems, assortment and rounding, etc., and he was able to distinguish eight stages in the textural spectrum. So-called "immature" rocks, where the lime mud matrix forms a large part of the rock, are called "low energy" sediments, while depending on the assortment and rounding, rocks with sparry calcite cement or pore space, were called "submature", "mature", or "supermature" rocks. The last group of limestones are called "high-energy" sediments, with the energy succesively stronger from sub-mature to the super-mature stage. The end result of his classification is summarized by Folk (1961, p. 76) in a table, where he obtained the following series from "low energy" sediments to "high energy" sediments with the following "rock terms": micrite and dismicrite, fossiliferous micrite, sparse biomicrite, packed biomicrit and poorly washed biospraite, unsorted biospraite, sorted biospraite, and rounded biospraite, respectively.

Plumley et al. (1961) tried to reconstruct the sedimentary history of a basin by a genetic classification of the limestones, bases on "energy that existed in the depositional environment". After first studying the minerology (proportions of calcite, clay, and detrital quartz), texture (size, sorting, and roundness), the fossil abundance and complexity, also the characteristic fossils, their associations and preservation, they were able to distinguish five limestones types on the basis of "energy index". They were also able to distinguish three limestones subtypes within a single type. Plumley et al. made the following classification of the limestone types, according to their energy index:

I. Quiet — deposition in quiet water.
II. Intermittently agitated — deposition alternately in agitated water and in quiet water.
III. Slightly agitated — deposition in slightly agitated water.
IV. Moderately agitated — deposition in moderately agitated water.
V. Strongly agitated — deposition and growth in strongly agitated water.

Both studies are applicable for practical aims, such as classification of the limestones according to their physical properties. These two have therefore been mentioned, there are also the bed types, which have been discussed elsewhere in this work.

In the San Emiliano and the Lois-Ciguera Formation the limetones can be easily classified on the basis of these considerations, the rhythmic sedimentation being a great help. The main types of limestones are dealt with below:

Limestone type 1. Fine microcrystalline limestone with brachiopods.
Mineralogy: calcite,
clay: 40 %,
detrital quartz: approximately 7 %.
Petrography: brachipod biomicrite.
Size: large fossil fragments in fine microcrystalline matrix.
Sorting: matrix - good; fossils - poor.
Roundness: original fossil shapes.
Fossil abundance and complexity: moderately fossiliferous single assemblages.
Characteristic fossils: brachiopods, bryozoans.
Energy index: index $I_{2-3}$.
Textural spectrum: sparse biomicrite.
Type bed: brachiopods with fenestrate bryozoans.

Limestone type 2. Algae in microcrystalline carbonate matrix.
Mineralogy: calcite predominant,
clay: approximately 20 %.
Petrography: algal biomicrite.
Size: any fossil fragments in microcrystalline matrix.
Sorting: matrix - good; fossils - good.
Roundness: original fossil shapes.
Fossil abundance and complexity: moderately fossiliferous single assemblages.
Characteristic fossils: algae.
Fossil preservation: unbroken.
Fossil association: *Petschoria* - *Anthracoporella.*
Energy index: $I_3$.
Textural spectrum: sparse algal - biomicrite.
Type bed: algal bed - *Petschoria* - *Anthracoporella.*

Limestone type 3. Coarse-grained rock - fragments and brachiopods fossils in crystalline matrix.
Mineralogy: calcite predominant.
Petrography: biomicrite and biosparite together.
Size: coarse-grained rock fragments and fossils.

Sorting: middling to poor.
Roundness: subangular to rounded.
Fossil abundance and complexity: moderately fossiliferous, moderately simple assemblages.
Characteristics fossils: brachiopods and echinoderms.
Fossil preservation: a little broken material, a little rounding.
Energy index: $II_2$.
Textural spectrum stage: poorly washed brachiopod-crinoid biosparite.
Type bed: brachiopod bed.

Limestone type 4. Interlaminated algal debris.
Mineralogy: calcite predominant.
Petrography: algal biomicrite.
Size: fossil debris interlaminated.
Sorting: Sorting good within laminae.
Roundness: good for the very small amount of organisms other than algal fragments which are angular, cemented into irregular lenses.
Fossil abundance and complexity: abundantly fossiliferous, simple assemblages.
Characteristic fossils: algae.
Energy index: $II_3$.
Textural spectrum: packed algal - biomicrite.
Type bed: *Donezella* - containing algal bed.

Limestone type 5. Foraminifera in microcrystalline carbonate matrix.
Mineralogy: calcite predominant.
Petrography: Foraminifera - echinoderm biosparite.
Size: fine-grained clastic carbonate (0,10 to 0.20 mm).
Sorting: matrix poor; clastic material good.
Roundness: subangular to rounded.
Fossil abundance and complexity: moderately fossiliferous simple assemblages.
Fossil preservation: larger fossils abraded, small fossils not.
Fossil association: Foraminifera - echinoderms.
Energy index: $III_3$.
Textural spectrum: unsorted Foraminifera biosparite.
Type bed: Foraminifera bed.

Limestone type 6. Fossil containing oolitic limestone.
Mineralogy calcite predominant.
Petrography: intergranular sparry calcite cement.
Size: Medium-grained clastic carbonate (0,40 to 0,7 mm) predominates.
Sorting: good.
Roundness: good.
Fossil abundance and complexity: moderately fossiliferous, moderately complex assemblages.
Characteristic fossils: red algae (*Archaeolithophyllum*), brachiopod echinoderms, gastropods and some green-algae.
Fossil preservation: fossil material generally broken and coated with oolites.
Energy index: $IV_{1-2}$.
Textural spectrum stage: sorted oosparite.
Type bed: mixed bed.

Limestone type 7. Very coarse-grained clastic limestones (rock and fossil fragments) with crystalline matrix.
Mineralogy: calcite predominant.
Petrography: gastropods - algal - biosparite.
Size: more than 2,0 mm.
Sorting: matrix - poor.
Roundness: clastic material rounded, oolites are present.
Fossil abundance and complexity: abundantly fossiliferous, simple complexity.
Characteristic fossils: gastropods and algae.
Energy index: $IV_3$.
Textural spectrum stage: rounded gastropod - algal biosparite.
Type bed: gastropods bed.

As appeared from the study, the limestones in both formations were deposited under very variable physical conditions. There were, of course, among the presently described four types and three sub-types — sometimes very difficult to determine — intermediate stages.

According to the method of Folk, the two "lowest-energy" sediments were not present in the limestones, but the last stage of the "high energy" sediments was.

According to the theory of Plumley et al., some of the limestones belong to the quiet water sediments (energy index I), no limestones are present which were deposited in strongly agitated water. The succession according to the strength of wave action, with one exception, is in good agreement according to both methods, as the following table shows:

| no. limestone type: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Energy index (Plumley et al.) | $I_{2-3}$ | $I_3$ | $II_2$ | $II_3$ | $III_3$ | $IV_{1-2}$ | $IV_3$ |
| Textural spectrum stage. (Folk) | sparse brachiopod biomicrite | sparse algal biomicrite | poorly washed brachiopod crinoid biosparite | packed algal biomicrite | unsorted foramini- fera biosparite | sorted oösparite | rounded gastropod- algae biosparite |

In conclusion, we can say that the assumptions, which were made when the field work was carried out, have been well supported by the microscopiac study. The assumption was made that, the rhythmic alternation of the different lithological units was a direct result of changes in the physical-chemical and biological factors. One of the most important physical factors, changes in the strength of wave action, has already been mentioned. Figure 15 shows the units of a minor cycle, where a few of the above described limestone types can be immediately recognized.

## QUALITATIVE AND QUANTITATIVE ANALYSIS OF THE ROCK BUILDING ORGANISMS

### *Introduction*

This section of the study consists of a microscopical investigation, and is a continuation of the field study. The object is to obtain an over-all picture of the numerical quantities and the important characteristics of the relationships between the rock building organisms found in the San Emiliano and the Lois-Ciguera Formation. The strata of these two formations were carefully sampled and studied. The variation of organisms was also studied in its relation to the petrographic properties of the rocks. The results make it possible to estimate the paleoecological and paleogeographical changes.

### *Method*

Sampling was restricted to strata which consisted mainly of $CaCO_3$. Samples were taken from each lithological unit within a stratum, where possible several were taken from each vertical section. Samples were also taken at various distances along the direction of strike, the distances between localities varying from tens of meters to several kilometers. Depending on the fossil content and the state of preservation, 5 to 8 thin sections were made from each sample. The determination and counting of the rock building organisms and organic fragments was carried out under a microscope, and then set out diagrammatically.

### *Fossil associations of the most important rock building organisms*

*Calcareous algae*

It appears that these micro-plants have made the major contribution to the construction of the limestones in the San Emiliano and the Lois-Ciguera Formations. The red algae have been the most important, and examples are found where they form biostromes in a layer or member. Green and blue-green algae are also found in banks, but this is less common than in the case of the red algae. A combination of two algal types is common, but a combination of three types is exceptional.

It is notable, how often an association is found between red calcareous algae (usually of the genera *Archaeolithophyllum* and *Donezella*) and gastropods. Green and blue-green algae are almost never found with gastropods.

Besides gastropods, also Foraminifera, echinoderms, brachiopods and, to a smaller extent bryozoans, are found in association with calcareous algae.

Blue-green algae often form a crust over the coral bodies. It can sometimes be seen that a layer of these calcareous algae has penetrated between the cell structure of the tabulate corals.

*Gastropoda*

The field observations and the microscopical investigation over the importance of gastropods as rock builders are not in complete agreement. In most cases the percentage of other organisms in a "gastropod bank" is higher than that of the gastropods.

The most important "foreign organisms" in these banks are calcareous algae and echinoderms. Gastropods are thus never found alone as rock builders. An association of corals and gastropods is occasionally found. The association of corals and gastropods in these formations can be considered exceptional. Gastropods in these formations can be considered exceptional. The gastropod shells are usually crystallized, but the original structures and petrographical properties can still be deduced. All the examples appear to be of the same type.

*Brachiopoda*

Bryozoa and echinoderms are almost always found with large concentrations of brachiopods. Foraminifera and brachiopods are seldom found together as rock builders. This is also true, though less so, for the association of calcareous algae and gastropods with brachiopods. Brachiopods are usually found as fragments. It is not easy to make a stratigraphical or paleogeographical division of the brachiopods from the shell construction and the petrographic properties. Associations of punctate and inpunctate forms are commonly found. Punctate and pseudo-punctate forms are also found together. When the ecology is studied, it is always found that brachiopods from facies type *B* are inpunctate, while both punctate and inpunctate forms are found in facies type *A*.

*Foraminifera*

Foraminifera banks almost always include calcareous algae and echinoderms. There is no bias for any particular type of alga; red, green and blue-green algae are found in association with Foraminifera. In particular cases, mainly in the Lois-Ciguera Formation, Foraminifera are found alone as rock builders. Small quantities of brachiopods and bryozoa are also found with Foraminifera.

*Coelenterata*

Corals are found as solitary forms and as compound forms. With the exception of algae which formed crusts and are sometimes found as streaks between the cells, few other organic forms are found with the colonial corals.

*Echinodermata*

Occasionally echinoderms are found in both formations as definite bods. In these cases it is mainly large amounts of crinoid stem remains which are found. The crinoid stem remains can vary considerably, both in length and thickness.

They can be divided into two groups on the basis of their cross-sectional forms:

a. round specimens, with a smooth border,
b. non-round specimens, elliptical and polygonal, with a smooth border, and also elliptical with a polylobate border containing lumps of various size.

It is possible to classify them into three types on the basis of the cell structure in cross section:

1. regular cell size in the whole cross section,
2. two concentric rings, the cells in the core are similar to those of the first type, but the cells in the outer ring are radially orientated,
3. the cells are clearly orientated radially from the centre and increase in size towards the periphery.

In the basal part of the San Emiliano Formation, with few exceptions, the stalk remains are found in cross section, with cells of uniform size. In the intermediate and upper parts of the formation combinations of all the forms and cell types are found. This pattern is found in the entire Lois-Ciguera Formation.

Echinoderm spines are found in smaller quantities than the crinoid stem remains in both formations. They are present in larger numbers in the upper part of the San Emiliano Formation and the entire Lois-Ciguera Formation than in the basal part of the San Emiliano Formation.

Echinoderms are found in association with Foraminifera, brachiopods, bryozoans and calcareous algae.

### *Summary*

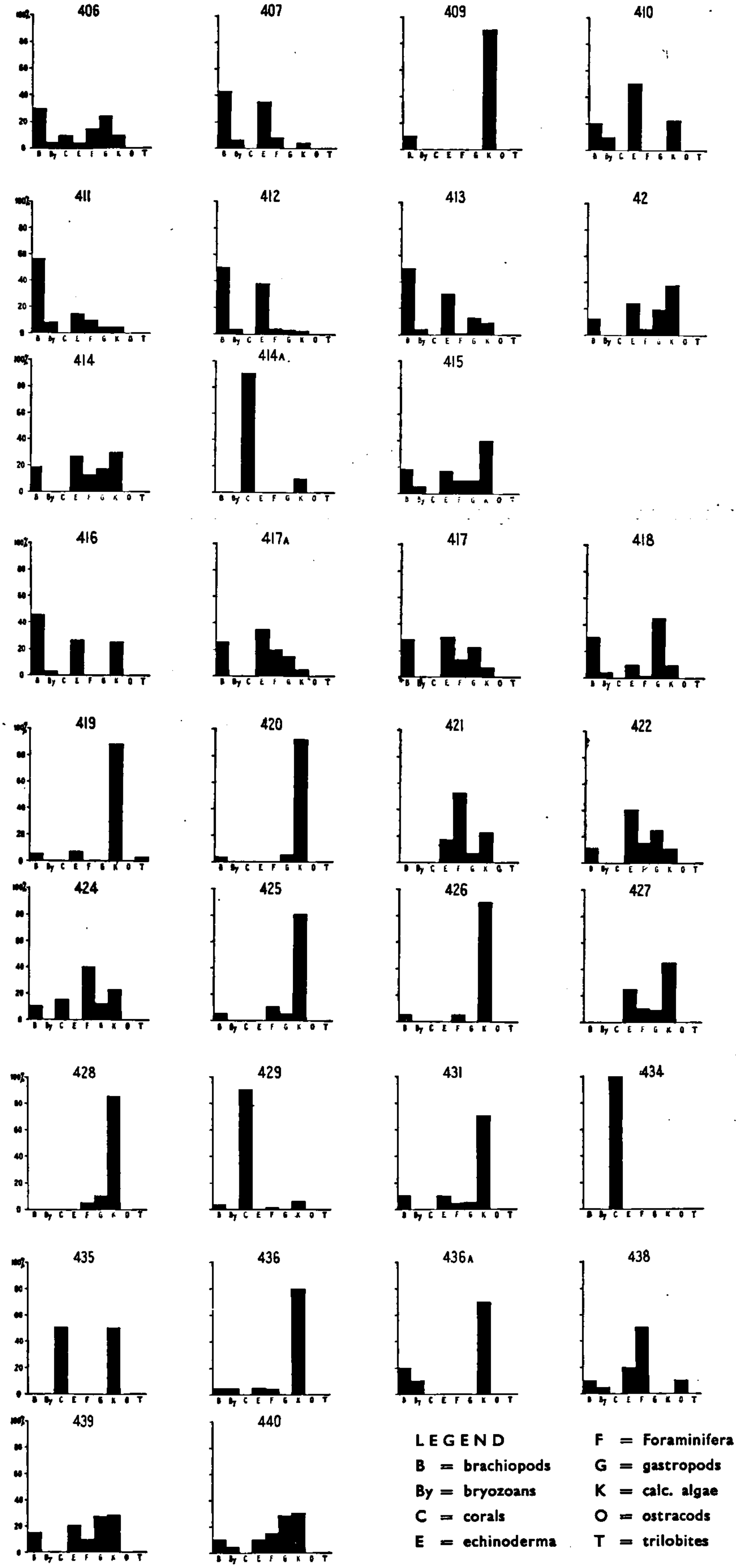
In conclusion the following associations can be expected:

| *common* | *rare* |
|---|---|
| gastropods - calcareous algae (mainly red) | gastropods - brachiopods |
| brachiopods - bryozoans - echinoderms | gastropods - bryozoans |
| corals - calcareous algae (blue-green) | brachiopods - Foraminifera |
| Foraminifera - calcareous algae (all) | Foraminifera - bryozoans |
| Foraminifera - echinoderms | calcareous algae - bryozoans |
| | brachiopods - calcareous algae |

## CHANGES OF THE BIOFRACTION WITHIN A MEMBER

In the section "Rhythmic sedimentation" the fact that various smaller units contain another type of fossil association, has already been discussed. The associations and their causes were also analysed. It is now the intention to show that sudden changes in the sequence can occur. This also has relevance to the qualitative and quantitative properties of the rocks. In fig. 18, member no. II of the San Emiliano Formation in locality 43 (S. of Cármenes) has been studied from this aspect (see also fig. 10).

| | |
|---|---|
| Unit no. 1<br>histogram<br>nos. 406, 407 | contains several types, with no dominant group. Certainly not in the lower portion of the unit, where brachiopods are in the majority and do not form more than 35 % of the biofraction. |
| Unit no. 2<br>histogram<br>no. 409 | A great concentration of calcareous algae (ca. 90 %) is found. Apart from some brachiopods, no other organic remains are present. |
| Unit no. 3<br>histograms<br>no. 410 and 413 | A large concentration of echinoderms on the lower part, (no. 410), then dominated by brachiopods. |
| Unit no. 4<br>histogram<br>no. 42 | Various organic types, but calcareous algae dominate (ca. 40 %). |




LEGEND

B = brachiopods
By = bryozoans
C = corals
E = echinoderma
F = Foraminifera
G = gastropods
K = calc. algae
O = ostracods
T = trilobites

| | |
|---|---|
| Unit no. 5<br>histogram<br>no. 414—414a | It is typical for the lower part of the unit that the composition consists of almost equal amouns of different types of organisms (histogram no. 414). In the upper part there is a large concentration of one type (corals) which contribute about 90 % to the composition of the bio-fraction. |
| Unit no. 6<br>histogram<br>no. 415 | Various types of organisms, with a predominance (40 %) of calcareous algae. |
| Unit no. 7<br>histogram<br>no. 416 | Three types of organic remains are present, with a clear brachiopod majority (46 %). |
| Unit no. 9<br>histogram<br>no. 417a—418 | In the lower and central parts of the unit there is not much fluctuation in the composition of at least four types. The greater part of the unit contains many gastropods (about 40%). |
| Unit no. 10<br>histogram<br>no. 419—420 | In the whole layer a considerably great accumulatio n of calcareous algae. |
| Unit no. 11<br>histogram<br>no. 421—424 | A very interesting unit. At the base, between two large concentrations of Foraminifera (histograms 421 and 424), there is an accumulation of echinoderms. |
| Unit no. 12<br>histogram<br>no. 425—428 | At the lower and upper sides of the unit there is very high percentage of calcareous algae (histograms nos. 425, 426 and 424). The central part of the unit contains fewer calcareous algae (about 45 %) and other organisms thus play a more important role than in the upper and lower parts of the unit. |
| Unit no. 13<br>histogram<br>no. 431 | Almost entirely corals (90 %) present, Rugosa. |
| Unit no. 14<br>histogram<br>no. 434 | Compound Tabulata corals (100 %). |
| Unit no. 16<br>histogram<br>nos. 435—436a | The bio-fraction in the lower part consists of two types, corals and calcareous algae (histogram 435). The corals disappear higher in the unit and it becomes characterized by a high concentration of calcareous algae. There is a small decrease in the numbers of calcareous algae at the top of the layer and parallel with this decrease there is an increase in the numbers of brachiopods and bryozoans (histogram 436a). |
| Unit no. 18<br>histogram<br>no. 438 | There is a relatively high percentage of Foraminifera (50 %) here. Smaller numbers echinoderms, calcareous algae, brachiopods and bryozoa occur in association with Foraminifera. |

Fig. 18. Histograms of the composition of the biofraction in several beds of limestone member no. II in the San Emiliano Formation at loc. R 43. (see also fig. 10). Black columns: many fossils.

| | |
|---|---|
| Unit no. 19 histogram nos. 439—440 | Various sorts of organism, in oolitic rock, with calcareous algae and gastropods dominant (both 30 %), but other organic remains, such as echinoderms, brachiopods, and Foraminifera are also present. |
| Unit no. 20 | A thin sandstone bed, with no organic remains. |

To give an impression of the composition and sudden changes of the bio-fraction, within a short distance, the units of limestone member no. II in the San Emiliano Formation (locality R. 42) from no. 9 to no. 16 of fig. no. 10, have been photographed. This can be seen in fig. no. 15, page 41.

*North of Canseco*

A vertical section, of the limestone member, in locality 216 of the Lois-Ciguera Formation (see fig. 2b and fig. 19).

| | |
|---|---|
| Unit no. 1 histogram nos. 216c—000 | The composition of the limestone is characterized by the presence of large amounts of coral (70 %), smaller quantities of Foraminifera (20 %) and brachiopods (10 %). No other organic remains are found here. |
| Unit no. 2 histogram no. 216b | There are very large quantities of calcareous algae present (ca. 65 %), while other organic remains of brachiopods, echinoderms, and Foraminifera form the rest of the bio-fraction. |
| Unit no. 4 histogram no. 216a | The composition is similar to that of unit 2. |
| Unit no. 5 histogram no. 216 | There are five groups of organic remains present. There is only a small percentage difference in the amounts of the Bryozoa (28 %), brachiopods and calcareous algae (each 25 %), and the remaining 22 % consists of equal amounts of echinoderms and Foraminifera. |

A study of the biofraction in locality R. 458, north of Valverdin in the San Emiliano Formation, gives the following picture, (see fig. 12b and fig. 19).

| | |
|---|---|
| Unit no. 5 histogram no. 459 | A large concentration (almost 60 %) of brachiopods is found. In smaller quantities echinoderms, Foraminifera, and calcareous algae are present. |
| Unit no. 4 histogram nos. 460—462 | Calcareous algae are present in great numbers. In histogram 461 small percentages of brachiopods, Bryozoa, echinoderms, and Foraminifera are present. |
| Unit no. 2 histogram no. 464 | Relatively few examples of organic remains are present in this rock. The bio-fraction consists, almost entirely, out of calcareous algae. |
| Unit no. 1 histogram | A mixed bio-fraction, where calcareous algae and echinoderms dominate gastropods and Foraminifera. |

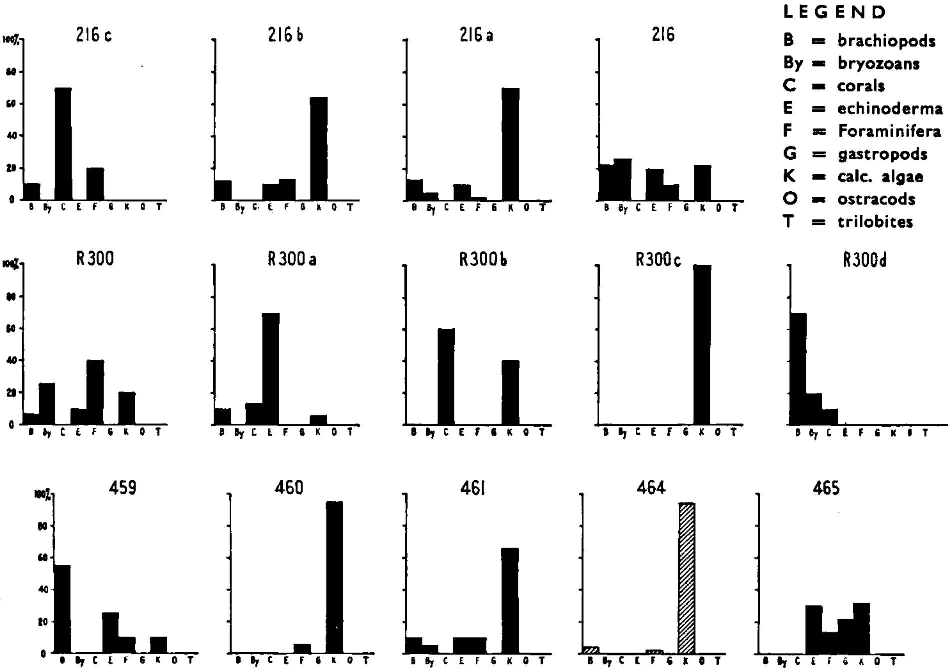



Fig. 19. Histograms of the composition of the biofraction in three different limestone units in the Lois Ciguera Formation.

*a.* In loc. 216
*b.* In loc. R 300 black columns: many fossils
*c.* In loc. R 449 shaded columns: moderate amount of fossils.

## ANALYSIS OF THE LIMESTONES, ACCORDING TO THEIR COMPOSITION AND MILIEU

### *Mixed beds*

Oolitic banks form about 13 % of all the limestone in facies type *A*. Limestone deposits of facies type *B* do not contain oolites. The oolitic banks, present in facies type *A*, are relatively hard, thick layered, and evenly bedded. The rock is weathered brown-yellow. When fresh, it is light brown to dark grey.

In thin section, the rock is full of oolitic bodies. These are round or egg-shaped. Sometimes they can have the form of the fragments which they enclose. This can be completely irregular, although the top surface of the oolite body has a less pronounced variation than the enclosed fragment. Found in the centre of the oolites are fragments of brachiopods, echinoderms, algae, bryozoans, Foraminifera, and on a smaller scale — other oolites. In most cases there is a well-developed radial, and a perfectly developed concentric structure. In most cases, two or three concentric bands can be distinguished. These are separated from each other either by a thin, usually dark coloured bank or a variation in colour. In the latter case there is an alternation between light and dark regions. It is sometimes found that in the formation of the envelope there is a variation in the density of the radial structure between the concentric rings. The large oolites vary between 180 and 400 $\mu$ in diameter. The thickness of the envelope is, on average, 50—180 $\mu$. This is approximately a third of the diameter.

The oolites are generally in association with well rounded fossil fragments, which are normally much larger than the chemical products. A typical relationship is, for example, that in the half-turn of a gastropod shell there are more than a 100 oolites. In these limestones there is little sign of secondary reworking in the oolites; only in such cases where old ones are coated by younger. Most of the properties of the oolites are similar in the two formations. There is, however, a marked difference in structure. As mentioned above, the oolites usually have a well developed radial and concentric structure. This, however, is only the case with those found in the San Emiliano Formation. Most of the oolites in the Lois-Cigurera Formation have no radial structures.

## *Beds of calcareous algae*

In this section of the investigation, the accent is on the study of the numbers and the relationships between the different types of calcareous algae and other organisms in a bed; the study of these statistics in different algal beds, in a cycle, and then in a limestone layer or member; the connection between the most important petrographic properties of the limestones and the algal floras present in the variously constructed limestones.

## *The position of the calcareous algae in a lithological unit*

### *San Emiliano Formation*

A small lithological unit, in which algae were the most important rock builders, will now be called an "algal bed".

As related previously, these beds form, like the others, evenly bedded and sharply defined units. No variations are seen in an algal bed during field observations, either lithologically or biologically. Under the microscope it can usually be seen that most algal beds are not homogeneous units.

Algae are seldom found in the oolitic limestone beds of facies type *A*. Even so, the genera *Archaeolithophyllum*, *Epimastopora* and *Mellporella* gen. nov. are found in most thin sections. Crossing the border between an oolite and an algal bed, the difference in lithological and biological composition can be immediately seen. In the algal bed, a few centimeters from the border with the oolitic bed, a rich algal flora can be found and no more oolites appear. The calcareous algae are of the genus *Donezella*. The stems of this alga are often shattered into small fragments, but in a few cases longer pieces are found with a definite branching. Occasionally larger or smaller fragments of this genus are found, in the strata, within a slightly crumbled or rounded limestone matrix. Large numbers of specimens can be found locally. In such a case, these algae are the only rock-builders in this part of the bed. The last part of the algal bed consists of a fine limestone matrix, formed by a crystalline calcite ooze. Representatives of the genus *Petschoria* are most commonly found in the rocks. Occasionally (e.g. in sample 436a, fig. 10) besides *Petschoria*, various specimens of *Anthracoporella* are found. The remains of *Petschoria* are almost always recrystallized in axial and transverse section. This applies most to the central portion (hypothallus) which, in almost every specimen, is filled with sparry calcite-cement. The outer region (perithallus) is still so well preserved that a structure, usually vague, can still be distinguished. In contrast, the examples of *Anthracoporella*, in cross section, often show an excellent geopetal structure (see plate V, no. 7). These geopetal structures have a clear orientation. The mainly calcite ooze matrix, the sparry calcite, and the geopetal structures conform with each other and suggest an extremely calm environment, free from great sedimentation and strong movement.

*Donezella* and *Petschoria* are also found together. This is regularly found in the centre of an algal bed. Besides this association, other organic remains, such as gastropods, Foraminifera, brachiopods, and echinoderms, are also present.

The double multiple increase in calcareous algae, within a bed, is evidence for their great adaptability and rapid multiplication of these primitive plants in a new environment. As examples of the above, illustrations from the samples (figs. 18, 20 and 21):

Sample 419 - lower edge of the bed - *Donezella*
Sample 420 - upper edge of the bed - *Petschoria*
Sample 431 - upper edge of the bed - *Petschoria*
Sample 425 - middle of the layer - *Petschoria* and *Donezella* together
Sample 438 - in the middle of the layer - with calcareous algae, also many echinoderms
Sample 42 - middle of the layer - with calcareous algae, also gastropods, echinoderms, and brachiopods

It cannot be excluded that *Donezella* do not fit into this scheme. For example, specimens of this genus are occasionally found in oolitic limestone. Their presence does not, however, necessarily indicate that these algae also lived in this environment but that they have been transported here.

In such a way it is possible that in a bed, described in the field as fossil-less, *Donezella* is present. In such cases no other algal types are found. In a very peaceful milieu, where calcite ooze was deposited *Donezella* is never found. It appears that the most favourable environment, for the growth of *Donezella*, had a reasonable wave movement and a relatively rapid sedimentation.

*Petschoria* alone, or in association with *Anthracoporella*, are limited to an orthochemically composed rock, where the matrix is mainly microcrystalline calcite ooze and the fossil fragments are filled with sparry calcite cement. Ooze was described by Folk (1959, p. 8) and is defined as "a micro-crystalline calcite, that appears dusty or imperfectly translucent in thin section because of its fine particle size", the coral size being 1—4 $\mu$ in diameter. Sparry calcite, in thin section, shows a clear mosaic structure with units larger than 10 $\mu$. Sparry calcite can occur as:

1. cement,
2. vein filling,
3. recrystallized or replaced fossil fragments, and
4. recrystallized ooze (Terriere, 1963, p. 88).

The relatively large algal fragments of *Petschoria* and *Anthracoporella* are found in this matrix. According to Folk (1959) where calcite ooze is present in the deposits, there has been little transport.

If it is thus found that, going from an oolitic bed with *Archeolithophyllum* and its associated green algae, through great concentrations of *Donezella* to a *Petschoria-Anthracoporella* association, it can be concluded there was first a disturbed environment, with strong wave movement, which suddenly changed to a progressively more restful environment. In such cases, we are in fact dealing with two facies types which follow each other.

The examples already discussed relate to both limestone facies types. The only difference is that in many clay-containing facies type B there is no oolitic bed. It is regularly found that, in place of the genera *Donezella* and *Petschoria*, there are blue-green and green algae in large concentrations. It is probable that bathymetric factors play an important role where the crust-forming blue-green algae replace the *Donezella*. While the circumstances, in which several of the green algal genera lived, resemble that of the *Petschoria-Anthracoporella* combination, they actually lived at a different depth. The fact, that *Donezella* and *Petschoria* are replaced by other algal genera, does not mean that they disappeared from the scene. Particularly here in facies type *B*, there are locally very large concentrations of *Petschoria*.

*Lois-Ciguera Formation*

In the limestone deposits of the Lois-Ciguera Formation, the same situations, concerning the position of the calcareous algae, are found as in the San Emiliano Formation. Here, resulting from the age difference between the two formations, we find other genera in the algal beds with *Petschoria* and *Donezella*. There is no *Archeolithophyllum* in the oolitic limestones beds of facies type *A* but *Epimastopora* and *Mellporella* are present. The species of these two genera are not the same as those found in the San Emiliano Formation. *Donezella* and *Petschoria* are also found in large numbers in the algal beds. Together with, or in place of, *Petschoria* there are *Uraloporella* and other dasyclades. In place of *Donezella* there are locally *Amorfia*, *Komia* and *Pseudokomia*. Because these last three genera are never found in association with *Petschoria* and its related genera, and also the matrix is similar to that of the *Donezella* in the middle portion of the algal bed, it can be concluded that these algae lived in similar conditions to *Donezella* but probably at another bathymetric level.

It is also possible that the genera *Amorfia* and *Pseudokomia*, which are almost always found in black, bituminous limestone, did not differ very much bathymetrically from *Donezella* but preferred a lime milieu with a high bitumen content. *Komia* is a rare plant in bituminous limestone. This genus is associated with other organisms, such as echinoderms, brachiopods, Foraminifera, and other (mainly green) calcareous algae. *Komia* is very seldom found with *Donezella*, but this is caused by the difference in bathymetric position.

The limestones of facies type *B* show the same picture, in the deposits, as in the San Emiliano Formation.

## *Algal beds in a minor cycle*

Almost without exception, each minor cycle contains two algal beds: one in transgressive and the other in regressive phase. In facies type *A* the transgressive algal bed is found above the oolitic bed and under the lithological unit, described as fossil-less in the field. The transgressive algal bed is found above the last named lithological unit and beneath the following oolitic bed, (see fig. 14a).

There is little superficial difference between the two algal beds. The only difference, in this facies type, is that the transgressive algal beds are usually thicker than those in the regressive phase. This can be clearly seen, e.g. in cycle I and III in fig. 14a, where the lower algal beds (units 2 and 10) are markedly thicker than the higher units (units 4 and 12).

The microfacies of the two types of algal bed have more profound differences. The most important of these is that the algal beds in transgressive phase are rich in *Donezella* and with a mixed composition, contain *Petschoria* or *Petschoria-Anthracoporella* floras. In the regressive phase, the mixed composition is more diverse. This can be easily seen in the histograms. Samples from locality no. 42 (see map), taken from the middle portion of four algal beds, were set out in the histograms, (see fig. 20, no. 42, 43, 44, 45), which can be considered examples of the algal beds deposited in the regressive phase. In three of the four cases, the algal content of the thanatocoenose is not higher than 50 %. Besides the calcareous algae, other organic remains such as gastropods, Foraminifera, echinoderms, corals, bryozoans, and brachiopods are present. The matrix thus consists of an accumulation of organic fragments, which can be considered coarse material. The calcareous algae, found here, belong to the genera *Donezella*, *Epimastopora* and *Mellporella*. *Petschoria*, *Anthracoporella*, or a combination of the two are not found here. This composition of the matrix and the calcareous algae suggests a relatively calm environment. At the lower side of the bed, in only one case was an abundance of *Petschoria* found. On the upper side of the beds, rocks with *Donezella* were found twice.

As already described, there is a clear tendency in the transgressive phase of a minor cycle (a — b — c to top, fig. 14a), from the oolitic bed, through the unfossiliferous bed, to the algal bed, to assume a more restful environment (see fig. 18, no. 419, 420, 425, 431, etc.).

The picture is different in the regressive phase (c — b — a to top, fig. 14a). It is dominated by a strongly mixed composition of organic remains and the importance of the *Petschoria-Anthracoporella* combination (calm environments), as well as the *Donezella* flora (less calm environments), is much reduced compared to the trans gressive phase. From this it can be concluded that the regressive phase of facies-type *A* was shorter than the transgressive, and the former had a stronger wave movement than the latter. In facies type *B* there is, with respect to the thickness of the beds, an inverse picture of what is found in facies type *A*. The algal beds in the regressive phase are usually thicker than those in the transgressive phase (fig. 12b). It is regularly found that the beds in the two phases are of equal thickness. The content of the beds is less diverse than in facies type *A*. This comes because it is usual to find here mainly *Donezella*, and *Petschoria*, or a mixture of the two. Beds in the transgressive phase generally have a *Petschoria-Donezella* combination, where *Petschoria* is dominant (unit 2 of fig. 12b), while in the regressive phase there is more *Donezella* than *Petschoria*. Where these two genera are replaced by blue-green algae and dasyclades respectively, green algae are found in the transgressive and blue-green algae in the regressive phase.

As in facies type *A* there is a calmer environment here in the transgressive phase and a more disturbed one in the regressive phase.

In conclusion it can be said that, on the basis of the algae present in the two beds of a minor cycle and the different conditions in which these have lived and been deposited, there was a tendency towards a calmer environment in the transgressive phase, while in the regressive phase there was a stronger wave movement. According to the observations there was less sedimentation in the transgressive than the regressive phase.

*The algal beds in a limestone member*

Most limestone members contain more than one minor cycle. Each cycle usually has two algal beds, it can thus be expected that in the presence of complete cycles there will be twice as many algal beds. In the members where several algal beds are found, valuable conclusions can be drawn concerning the relationship between different organic remains in the biofraction.

That the algal beds in the regressive and transgressive phases differ in thickness has already been discussed. When the position of the algal beds, within a member, is considered it can be concluded that the algal beds in the upper part of a member are relatively less thick than those in the lower part of a member. Algal beds, which occur in layers where only one cycle is present, can be considered exceptional.

Where several algal beds are found in one member, it has been found that the average percentage content of calcareous algae in the upper beds is higher than that in the lower beds. As an example of this we can consider the following example: shown in fig. 20 are vertical sections, from two localities, of the same limestone member

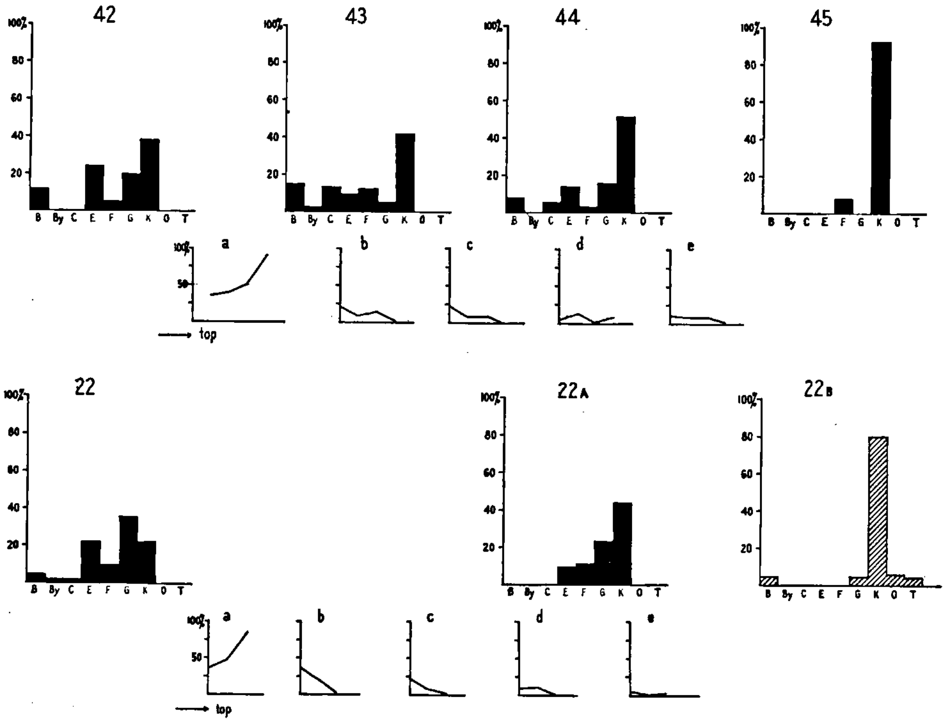



Fig. 20. Histograms of the composition of the biofraction in a calcareous algal bed at localities R 24 and R 42, of the San Emiliano Formation.

LEGEND

B = brachiopods
By = bryozoans
C = corals
E = echinoderma
F = Foraminifera
G = gastropods
K = calc. algae
O = ostracods
T = trilobites

a = calc. algae
b = gastropods
c = echinoderma
d = Foraminifera
e = brachiopods
f = bryozoans

(nr. II) in the San Emiliano Formation. In locality R. 42, which is South of Cármenes, the samples were taken from the middle of four algal beds, going from the base to the top. The amounts of organic remains are shown in histograms 42, 43, 44 and 45. While in histogram 42 the calcareous algae contribute less than 40 %, they represent more than 90 % in histogram 45. A general picture of the amounts of calcareous algae in the various algal beds can be seen in histogram *a*.

Histogram *b* shows the percentage of gastropods in the four algal beds. The amounts of these organic remains show a marked decrease from the lower to the higher beds in the same member. A similar effect is found with echinoderms (fig. 20*c*).

Foraminifera present a less regular picture than the previous two groups. The amounts of Foraminifera give a zigzag histogram (fig. 20*d*) and not a straight line.

There is a tendency for the amount of brachiopods to decrease, but this can only be clearly seen in the uppermost part of the member.

These same results are found in the bottom row of fig. 20, where the same limestone member has been sampled, about 6.5 km to the east of locality R. 42, between Lanvandera and Genicera (loc. R. 24).

The only difference between the two localities is that in locality R. 24 the second algal bed, from the base, is not found. Otherwise the results from a comparison between the components of the biofraction are the same.

The study of the algal beds from the two localities is also shown in fig. 21, but from another angle. In the histograms are shown the average percentages, from the whole depth, present in the biofraction of an algal bed. In other words, the average is taken of all the organic remains which, as found in the study of the separate algal beds, show a vertical variation in accumulation. There is an interesting agreement between the two methods. In the top row we find numbers 50, 49 and 51 from locality R. 49 in the San Emiliano Formation, which are not sample numbers, but represent the average of several samples. Usually the amounts shown under one number come from three or four samples, the biofraction thus found in 20—25 thin sections. Here we also find a definite increase in the amount of calcareous algae present, from the base to the top (summarized in histogram *a*). The increase is slight in the first two algal beds but is marked in the last. The amount of gastropods increases in the second bed but then quickly decreases (histogram *b*). Other organic remains such as echinoderms and Foraminifera (histograms *c* and *d* respectively) clearly decrease in amount towards the top. The small quantities of brachiopods do not affect the relationships in the biofraction. In the bottom row of fig. 21 samples were taken from loc. R. 27 of the San Emiliano Formation. The results are shown in histograms 23a and 24.

In general they show a similar picture to that found from locality R. 49. The only difference in the composition of organic remains, between loc. R. 27 and locality R. 49, is that in the lowest algal bed of the latter more brachiopods are found than gastropods while the opposite was found in locality R. 27.

Considering the above results, there can be no doubt that the relative amount of calcareous algae, present in the limestone members, shows a definite increase from the lower to the higher beds. All the other organic remains, with a few insignificant exceptions, show a decrease towards the top. The reason for this phenomenon can be explained by the following theory: it is probable that the epirogenetic movements were interrupted by minor oscillations of the sealevel. A new environment was produced after each oscillation which, after the sudden change, was less favourable for the bottom living organisms. These have all required a certain amount of time to adjust to the new conditions. Organisms, to which the new environment was favourable, have also required a longer amount of time to become established.

Only the calcareous algae were able, in a short period of time, to completely adjust to the new conditions and spread themselves.

Taking into consideration the fact that the thickness of the algal beds decreases towards the top, it can be supposed that in such cases there was no time for other organisms to multiply before the next rise of fall of the substratum.

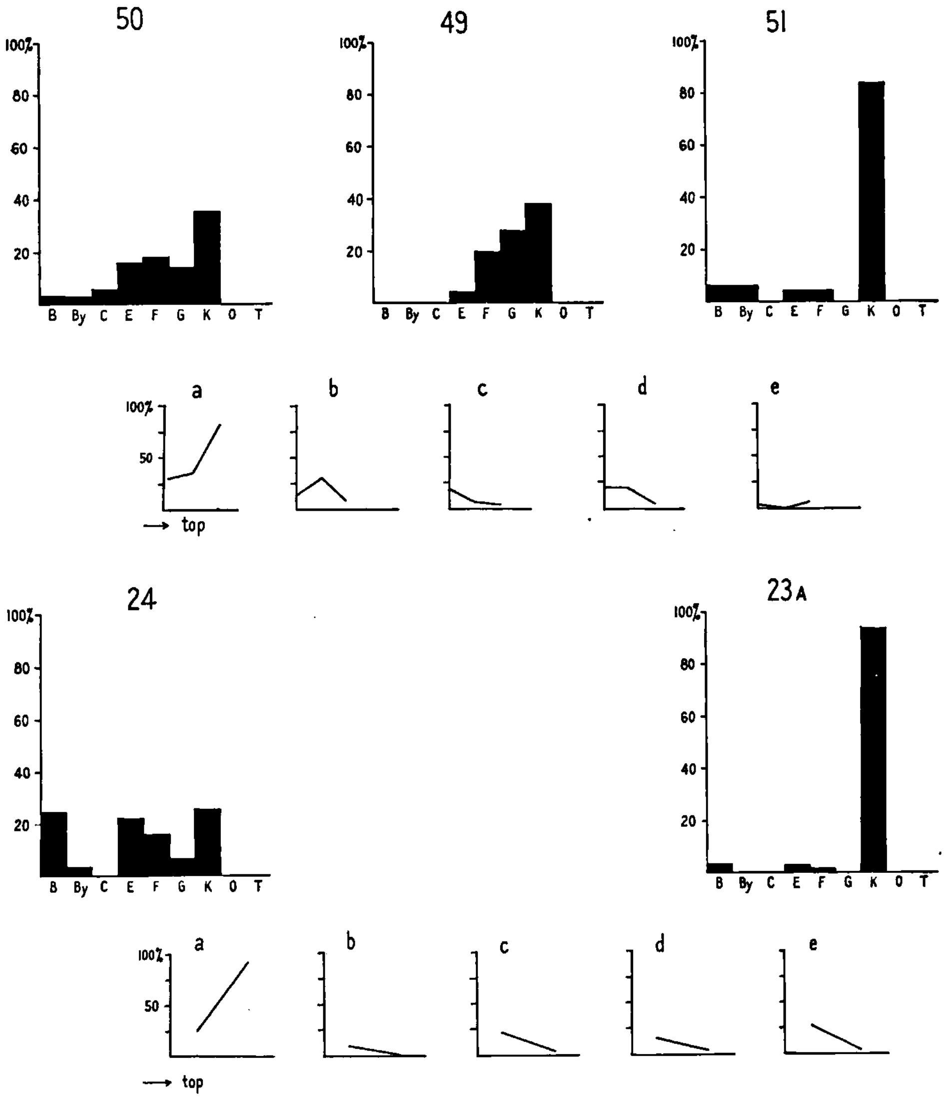



Fig. 21. Histogram of the composition of a calcareous algal bed in localities R 49 and R 27 in the San Emiliano Formation.

LEGEND

B = brachiopods
By = bryozoans
C = corals
E = echinoderma
F = Foraminifera
G = gastropods
K = calc. algae
O = ostracods
T = trilobites

a = calc. algae
b = gastropods
c = echinoderma
d = Foraminifera
e = brachiopods
f = bryozoans

### *Echinoderm beds*

It is only in the uppermost fossiliferous part of the Escapa Formation that definite echinoderm beds are found. In the San Emiliano and Lois-Ciguera Formations there are local concentrations of echinoderms but usually they are found with other organic remains, where they are in the minority.

Nevertheless there are cases where the crinoids form the major part of the biofraction. Such cases can be seen in fig. 18 at numbers 410, 417a, 417 and 422 in the San Emiliano Formation. The amount of echinoderm remains, in these members, is however not enough to justify calling them echinoderm beds. This can only be done with no. 410, where the echinoderms represent 50 % of the biofraction. The other cases contain 40 %, 32 % and 40 % of echinoderms in the biofraction. Because of the small quantitative difference between these and the other organisms they can only be regarded as slightly dominant. In contrast, the members of the Escapa Formation crinoid beds which can be followed extending over large distances. A stratigraphic section at locality R. 401 showed that there were four crinoid beds. The composition of organic remains can be seen in fig. 22. The numbers 401, 402, 403 and 404 again give the percentage amounts of organic remains, going from base to top.

The crinoid beds vary in thickness from 0.50 to 2.50 m. Between the beds there is usually a thin, 0.20—0.80 meter rock present. These rocks between the crinoid beds contain no fossils. The layers above the uppermost bed, to the top, are dolomitized.

As can be seen in the histograms there is a relatively high percentage content of crinoids in the four beds; about 60 %, with slight variation. The percentage content of crinoids in the four beds are shown in histogram *c*. Apart from bed 402, the other beds contain many types. There is little change in the echinoderm biofraction, going from base to top. This can be seen, however, in the organisms associated with the echinoderms, such as brachiopods and Bryozoa; Foraminifera and calcareous algae are less useful here for paleoecological evalutation.

*Brachiopods* are found in each bed and it is immediately evident that, going from base to top, their relative amount increases. Thus they represent 5 % of the biofraction in the lowest bed (histogram 401) and almost 20 % in the uppermost bed (histogram 404). This is summarized in histogram *e*.

*Bryozoans*. These show the reverse picture from the brachiopods. The amounts of bryozoan organic remains decreases from the base to the top. While the bryozoans in no. 401 represent about 18 % of the biofraction, this is reduced to 6 % in no. 404. This is a reduction to a third of the amount found in the first bed. These results are summarized in histogram *f*.

*Calcareous algae* are irregularly found in the crinoid beds. In two cases they constitute more than 15 % (nos. 402 and 404), in one case they are rare (about 3 % in no. 401), and in one case they are not to be found. Histogram *a* summarizes these results.

*Foraminifera*. These form a relatively small fraction of the biological content of these rocks and are mainly small Foraminifera. In the crinoid beds the Foraminifera show the same trend as the bryozoans, with respect to the numerical amount in the various beds. Their number also decreases from the base to the top, but this is not so marked as in the case of the bryozoans.

*Gastropods* play an almost negligible role in the composition of the biofraction.

No fragments of corals, ostracods, or trilobites were found. In locality R. 36, north of Pedrosa, the results are in complete agreement with those described for locality R. 401.

The paleoecological reason for this composition of the biofraction is a difficult problem, because:

1. The amount of crinoid remains is more or less constant in all four beds.
2. Brachiopods and bryozoans are often found together but there is no explanation for the fact that an increase in one type is always accompanied by a decrease in the other, as is the case here.
3. Nowhere is there another clear picture found where bryozoans and Foraminifera show the same conditions, with respect to quantitative change.
4. The facies-sensitive calcareous algae are scarce and irregularly found.

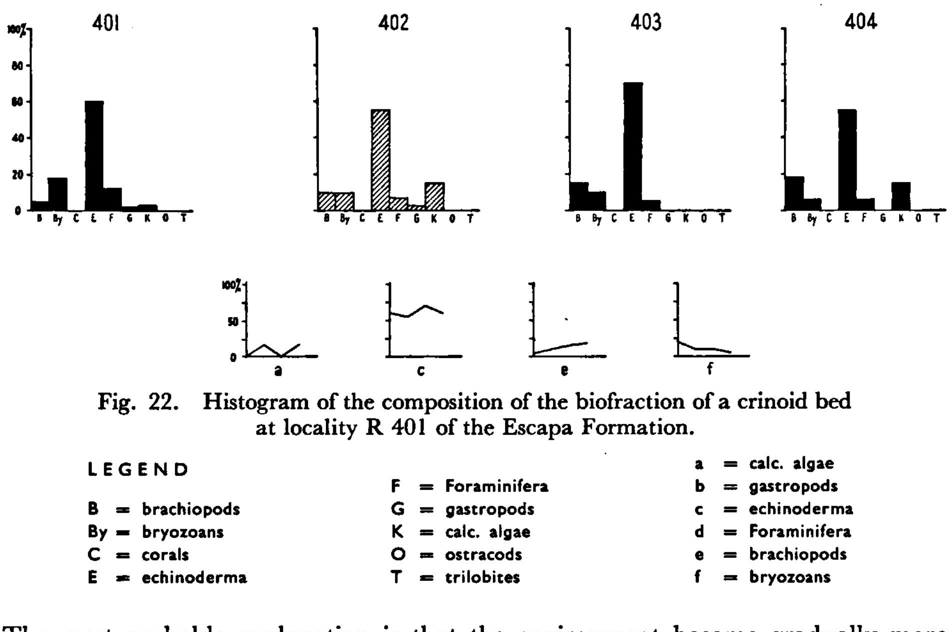



Fig. 22. Histogram of the composition of the biofraction of a crinoid bed at locality R 401 of the Escapa Formation.

LEGEND

| | | |
|---|---|---|
| | | a = calc. algae |
| | F = Foraminifera | b = gastropods |
| B = brachiopods | G = gastropods | c = echinoderma |
| By = bryozoans | K = calc. algae | d = Foraminifera |
| C = corals | O = ostracods | e = brachiopods |
| E = echinoderma | T = trilobites | f = bryozoans |

The most probable explanation is that the environment became gradually more disturbed, the fenestrate bryozoans, characteristic of a quiet environment, disappeared from the scene and only the cylindrical ones remained. In the lowest bed the two types are found together, but in the highest bed this is no longer the case. The change of environment has, however, not been sudden because the percentage of crinoids is almost unchanged. The increase in the relative number of brachiopods can be explained because it has often been noted that there is a regular alternation between echinoderm and brachiopod beds. In such a case the milieu would have become gradually more favourable for the spreading of the brachiopods. It is probable that, with the less restful change in the environment, the non-fenestrate bryozoans required a certain amount of time to establish themselves. According to this argument they were at their nadir in the uppermost crinoid bed. After this the amounts of brachiopods and bryozoans should have increased and the amount of crinoids decreased. Unfortunately there was no further limestone sedimentation and this remains a theoretical conception.

### *Brachiopod beds*

Brachiopods are found in both formations locally in large numbers. Depending on the facies type, punctate, inpunctate, or pseudopunctate brachiopods can be expected. In deposits, of facies type *B*, large numbers of inpunctate brachiopods are found. In limestones of facies type *A*, mainly punctate and pseudopunctate examples are found, either separately or together.

*In facies type B*

In member no. VI (see section in fig. 1) of the San Emiliano Formation brachiopods with a thick shell were found in a limestone layer of facies type *B*. In thin section the shells appear thick and imperforate. These brachiopods are found in association with fenestrate bryozoans and thick crinoid stem remains.

The limestone member no. IV of the San Emiliano Formation (see section in fig. 1 and fig. 12b) has a brachiopod bed which is approximately 1.50 meters thick (unit no. 5). Echinoderms, and to a lesser extent calcareous algae and Foraminifera, are found in association with brachiopods in this bed (see fig. 19, no. 459). No Bryozoa are found in this bed and the brachiopods are inpunctate.

In locality R. 300, west of Piornedo in the Lois-Ciguera Formation, another brachiopod bed was found (see fig. 19, no. R. 300d). In the top unit (R. 300d) fenestrate bryozoans and a few corals are found with the brachiopods.

Unfortunately no conclusions can be drawn concerning the variation of the biofraction within the cycles or a limestone member because in most cases there is only one brachiopod bed present.

*In facies type A*

From limestone member no. II of the San Emiliano Formation, four brachiopod beds were studied (see fig. 10 and fig. 23, no. 406—418). In the bottom row (unit 1, fig. 10) the brachiopod bed was sampled from the top (no. 407 of fig. 23) and the bottom (no. 406 of fig. 23).

Seven groups of organic remains are present at the base of the brachiopod bed, but only five types were found at the top. After brachiopods, gastropods are the most numerous, then Foraminifera, corals, calcareous algae, echinoderms and bryozoans which are far less numerous. At the top of the bed, the numbers of brachiopods and echinoderms have markedly increased, while corals and gastropods are not to be found. Thus, going from the base to the top, an increase can be seen in relative numbers of echinoderms (histogram *c*), brachiopods (histogram *e*), and to a lesser extent bryozoans. In contrast there is a marked decrease in the numbers of Foraminifera, gastropods, and calcareous algae.

In the middle row, samples (nos. 411, 412 and 413) were taken from the brachiopod bed (unit 3, fig. 10). At the base of this unit there is a great concentration of echinoderms. This bed has an approximate thickness of 0.50 meters. After this there is a sudden change in the biofraction and brachiopods become dominant. Sample number 411 was taken from this section. Slightly higher, almost in the middle of the brachiopod bed, sample number 412 was taken, and sample number 413 was taken from the top of the bed. It is remarkable that, in this case also, there is an increase in the numbers of echinoderms and a decrease in the numbers of gastropods and bryozoans. While, however, in the previous bed there was a decrease in the numbers of calcareous algae towards the top, there is no particularly marked increase here.

The relative numbers of brachiopods remain almost constant, from the base to the top, while there is a slight decrease in bryozoans.

In the lower row, the histograms have been made from two units: no. 416 from unit 7 and nos. 417a, 417 and 418 from unit 9. In lowest graphs *a*, *b*, *c*, *d*, and *e*, the same results are given. This has been done in order to show clearly that there are marked differences in the composition of the samples out the two beds. This can be easily seen in the histogram, because in four cases out of five, almost 1/4 part of the histogram going from left to right, a clear change of course is shown. This is expressed by the formation of a — mainly obtuse — angle between the indicated amounts of the biofraction of the two units.

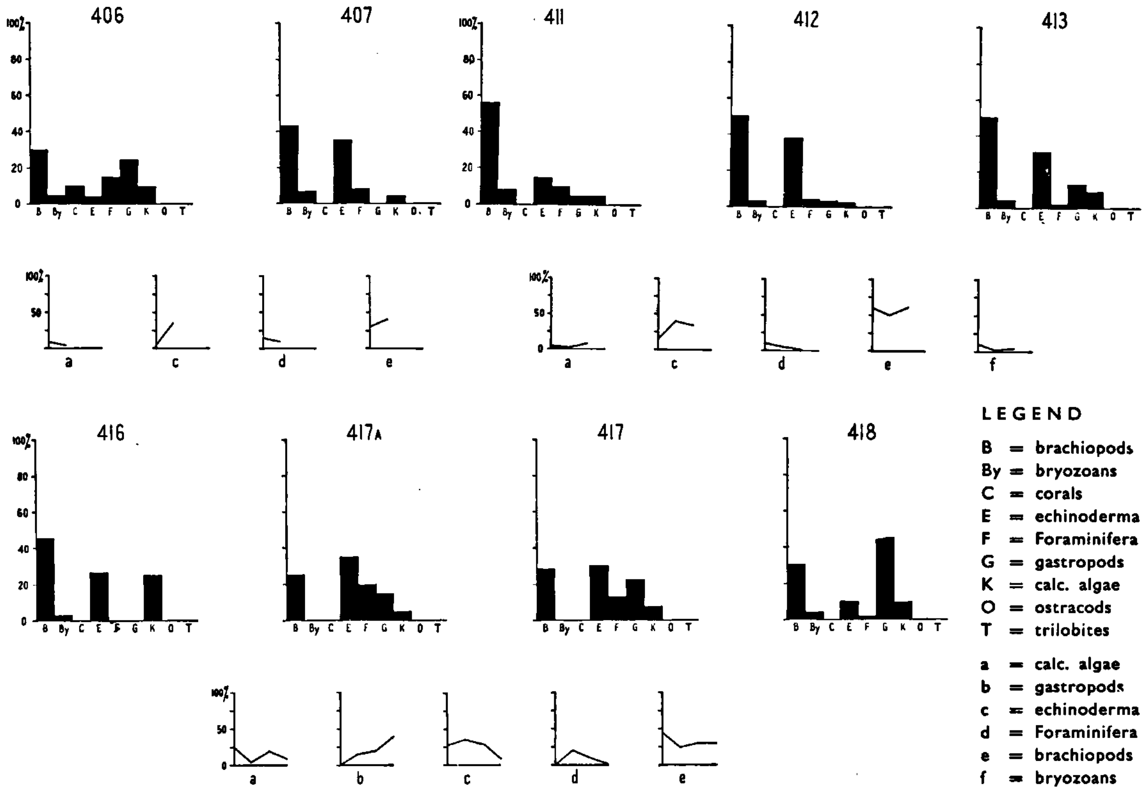



Fig. 23. Histograms of the composition of the biofraction in a brachiopod bed at locality R 43 in the San Emiliano Formation.

There was no material comparable with that which was taken from unit 7, in the same bed and therefore it will not be dealt with further.

In the samples from unit 9 there is about as much, or less, brachiopods as other organic remains. Therefore this cannot be called a brachiopod bed. Because, however, the biofraction contains a considerable proportion of brachiopods it was considered of interest to compare this mixed bed to definite brachiopod beds. It is remarkable that there is a definite increase in the numbers of gastropods. In no. 417a there is approximately 15 % gastropods, while in 418 there is more than 40 %.

Although fewer, there is a similar tendency with the calcareous algae. The numbers of echinoderm and Foraminifera remains show a marked decrease, from base to top.

Brachiopods are found in approximately uniform frequency. Particularly these last observations in facies type *A* are useful paleoecological data. In the first two discussed units (units 1 and 3, histograms 406, 407, 411, 412 and 413) there is an increase in echinoderms and a decrease in gastropods. In one case, the brachiopods increase (no. 406 and 407) and in another case they are more or less constant (no. 411, 412 and 413). The brachiopods behave in the same way in unit 9 as in unit 7. The amount which they contribute to the composition of the biofraction is almost as much in one section of the unit. There is here however an abrupt increase in the numbers of gastropods and an exactly corresponding decrease in the numbers of echinoderms. Foraminifera, like the echinoderms, are found in smaller numbers from the base to the top. In contrast there is, going towards the top, an increase in the calcareous algae of the genus *Archaeolithophyllum*. When it is kept in view that all these organic remains are found in oolitic limestone, these results appear to contradict each other. The problems encountered here can be answered by the following argument:

Resulting from the disturbed character of the Carboniferous period, it has already been supposed that the environment — influenced by various lithological factors — was able to change within a relatively short time period. This was probably also the case with these oolitic units. It can thus be assumed that there was a strong wave movement in the environment, the large amount of broken material and occurrence of oolites being the strongest argument for this. Slight changes in the strength of the wave movement are reflected by the small variations in the composition of the biofraction. It is thus proposed that, while the bottom two units (units 1 and 3) had a relatively more restful environment going from bottom to top, the opposite happened in unit 9.

### *Foraminifera beds*

Foraminifera beds occur at definite levels in the cyclic sequences of the San Emiliano and Lois-Ciguera Formations. In the former these members usually consist of a hard, dark-grey limestone whereas in the latter they are an argillaceous limestone. Foraminifera beds are not present everywhere in the cycles of the San Emiliano Formation.

In a few cases Foraminifera are associated with echinoderms and calcareous algae. Other organic remains are irregularly found in the Foraminifera beds. Corals and bryozoans are almost never found with them. Gastropods can, in a few cases, be found in considerable numbers in the Foraminifera beds.

Because there is only one bed of Foraminifera in each cycle, no judgement can be made over their behaviour within a cycle. This also applies to their position within a member. Because of this, only a few histograms from different localities are set out in figure 24.

Histogram R. 476 comes from the locality of the same number, west of Cármenes (San Emiliano Formation). The Foraminifera form about 60 % of the biofraction. There are no brachiopods, bryozoans, or corals present. There is a good variety of Foraminifera, but less so of the calcareous algae and crinoid stem remains present.

Number C. 22 is from the Lois-Ciguera Formation. The histogram (fig. 24) has the same number as the locality, north of Redilluera. There are few brachiopods and relatively many gastropods (25 %) with the echinoderms and a few calcareous algae and ostracods.

Histogram number R. 300, in figure 19, from locality R. 300 (Lois-Ciguera Formation), west of Piornedo, contains a notable number (about 30 %) of bryozoans.

Histogram number 438, in figure 18, is from locality R. 42, south of Cármenes (San Emiliano Formation). Next to the Foraminifera, echinoderms are the most important organisms of this association.

Histogram numbers 421 and 424, of figure 18 (locality R. 42) closely resemble the beds, which are mainly echinoderm and calcareous algae containing, besides the Foraminifera, but in histogram number 424 there is a small majority of corals.

### *Bryozoan beds*

Bryozoans, fenestrate and other types, are never found as single rock builders. They are, almost without exception, always accompanied by brachiopods. This relationship has been discussed under "brachiopod beds". Sometimes the bryozoans form a relatively high percentage of the biofraction, e.g. histogram number 216, R. 300, in figure 19, they are only present in the company as a xenocön. They are found in greater numbers in limestones of facies type *B*, than in those of facies type *A*.

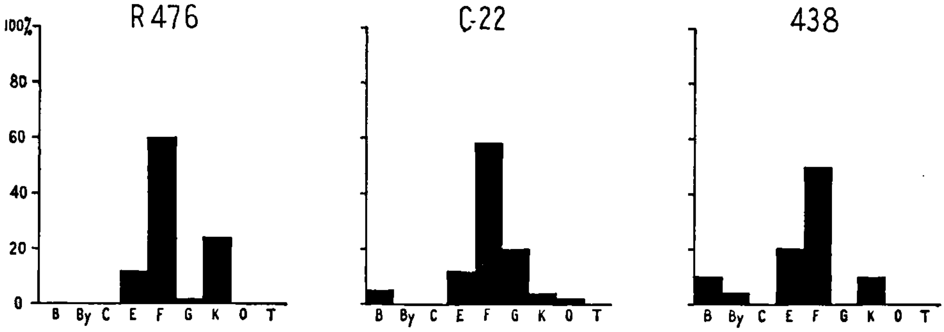



Fig. 24. Histograms of the composition of the biofraction of Foraminiferan beds at three localities, R 476, C 22 and 438, in the Lois-Ciguera and San Emiliano Formations.

LEGEND B = brachiopods, By = bryozoans, C = corals, E = echinoderma, F = Foraminifera, G = gastropods, K = calc. algae, O = ostracods, T = trilobites

### *Gastropod beds*

As the bryozoans, there are no proper gastropod beds, because the percentage of gastropod remains present is not high enough for the use of this term. These organic remains are typical components of a so-called mixed bed. Occasionally the gastropods have formed a considerable accumulation, but they never represent more than 50 % of the whole biofraction (histogram number 418, figure 18).

Gastropods are only found in fragmental limestones. Gastropods, in company with red algae (genus *Archaeolithophyllum*) appear to be indicators of strength of water movement.

## THE PARTICIPATION OF VARIOUS ORGANISMS IN THE COMPOSITION OF THE BIOFRACTION

A microfacies study has shown that the organisms made an important contribution to the deposition of the limestones in the San Emiliano and Lois-Ciguera Formations. The conditions of life were not always equally favourable for all organisms. The problems arising from this shall discussed in the section "The adaptability and rapid multiplication of the organisms during an environmental change". The causes which were discussed there, result in a large difference in the amount with which different organisms appear in the biofraction. To obtain an overall picture, a statistical examination was carried out and this showed that the algae were the most important limestone building organisms. Next important are the brachiopods, then the echinoderms and Foraminifera, and to a lesser extent gastropods. Bryozoa were present in a small region. Ostracods, trilobites, and other organisms participated only to a small extent in the construction of the biofraction. A summary of the percentages is given below:

| | |
|---|---|
| algae: | 39 % |
| brachiopods: | 15 % |
| echinoderms | 12 % |
| Foraminifera: | 12 % |
| corals: | 8 % |
| remainder: | 14 % |

E. A. Ivanova (1951, p. 99) gives the analysis of the composition of the biofraction in "a deeper sea with a normal salt content" (which corresponds to our depth phase 4, or Foraminifera "phase") in Carboniferous limestones with a high clay content from the southern part of the Moscow Basin. It is interesting to make a comparison between the compositions of the biofraction in the Russian and Spanish Carboniferous deposits. Samples, from our collection, which come from the so-called "Foraminifera beds" were examined. As is known, the sediments in the two facies types offered different conditions of life for the organisms and this resulted in different assemblages. For this reason the samples were examined separately and the average of the organic remains taken from:

a. limestone with a low clay content,
b. limestone with a high clay content.

A comparison of the compositions can be seen in the following table (page 72).

The main compositions of the biofraction in the Moscow Basin and the Cantabrian Mountains agree in so far that, in both areas crinoids, brachiopods, and corals are found with the Foraminifera. In the deposits of the Cantabrian Mountains, however, calcareous algae are important and bryozoans and ostracods form a minor part of the biofraction, while these organic remains are not found in the Moscow Basin. In the latter, fish remains were found and these have not yet been encountered in the Carboniferous deposits of NW Spain.

Composition of the biofraction

| Organic remains | Moscow basin * | Cantabrian mountains | |
|---|---|---|---|
| | | a | b |
| Foraminifera | 50 % | 45 % | 52 % |
| Crinoids | 20 % | 14 % | 17 % |
| Echinoderms | 10 % | 3 % | 4 % |
| Corals | 5 % | — | 3 % |
| Brachiopods | 7 % | 10 % | 5 % |
| Bryozoans | — | 2 % | — |
| Gastropods | — | 8 % | 3 % |
| Calcareous algae | — | 14 % | 13 % |
| Ostracods | — | 2 % | — |
| Fish remains | 4 % | — | — |
| Rest | 4 % | 2 % | 3 % |

## THE ADAPTABILITY AND RAPID MULTIPLICATION OF THE ORGANISMS DURING AN ENVIRONMENTAL CHANGE

The reason for the fact that the calcareous algae are the most important rock building organisms in the San Emiliano Formation and the Lois-Ciguera Formation has already been discussed during the consideration of the calcareous algal beds. The reason given, for the mass presence of algae was their ability to recover and multiply rapidly after a sudden change in the environment. Because there was an alternation of the environment between restful and disturbed periods, with all the possible intermediate conditions, it can be assumed that certain types of organism preferred certain conditions.

Helped by the study of the petrographic properties of the various limestone units within a limestone member it appeared that certain milieu changes could also be detected within a small unit. It became clear that certain algal genera thrived in a milieu which was quiet or had only a slight wave movement, while others only lived where there was a strong wave action. It is thus possible to classify some of the algal genera on the basis of their reaction to the wave-action-energy (see p. 75). Having given good consideration to this problem it is now easier to explain:

a. the rapid adaptation and multiplication after a milieu change, and
b. the divisibility of the algal genera according to various strengths of wave action and depth changes.

After the calcareous algae, the brachiopods show the greatest ability to adapt to a new milieu and multiply. This can possibly result, as is the case with the calcareous algae, from the divisibility of the brachiopods with respect to their preference for one or another environment. Thus particular types, such as rhynchonellid and like brachiopods, characteristic partners in the oolitic limestones which arose under special conditions.

* The percentage amount of the organisms is approximately correct, because these have been derived from a drawing.

The thick-shelled impunctate brachiopods are present in clay-containing limestone or in sandy shale. The arguments (see description of facies type *B*) indicate that there was a quiet environment during deposition.

It appears from the observations that echinoids and crinoids also adapted quickly to a new environment but they possessed to a lesser extent the ability to develop in enormous numbers. The echinoderms thus appear only in a few cases as the most important rock builders. The same can be said about the Foraminifera. They are present in almost every biofraction, but are the dominant element in only a few units.

There are two types of Bryozoa present, fenestrate bryozoans and cylindrical-branching bryozoans. These two types do not occur together, because the fenestrate bryozoans preferred a peaceful milieu while the cylindrical branched forms are found in the company of organisms which lived in an environment with strong wave action. Encrusting types of Bryozoa are very seldom found.

Gastropods were found in the company of organisms which are generally typical for a disturbed milieu. They were able to multiply rapidly under such conditions. There are a few lithological units in which the gastropods are the most important part of the biofraction. Because there are so few gastropod beds, it can be assumed that they lived in a special milieu.

Corals, like the gastropods, were only able to develop in very large numbers under special conditions. Under such conditions other organisms were not able to maintain themselves in the new milieu. In several cases, where the circumstances were favourable, the corals have multiplied rapidly. This is likely because coral biostromes are often found near mixed beds, and it is thus probable that certain conditions were the same for the origin of the two types of deposit. On the other hand there must have been some factors present which were favourable for one type and unfavourable for the other. The compound Tabulata and Rugosa corals are often found next to each other as elements of a biostrome, but usually in separate beds. It may be concluded from this that very slight milieu changes between the corals have produced this peculiar separation.

In summary, we can say that the rock builders, in the San Emiliano and the Lois-Ciguera Formations can be divided into two groups on the basis of their adaptability and reproductive potential in a new milieu:

I. Organisms which adapt to every environment, and, when the change of environment is not too drastic, have the ability to multiply rapidly. Specimens, which contain more than one type, have the advantage for rapid multiplication because in such cases the new milieu will be most favourable for the massive replication of one of the types.

II. Organisms which are only adaptable to a special environment, in which they can usually multiply rapidly.

In group I can be included: (1) the algae, (2) brachiopods, (3) echinoderms, (4) Foraminifera, and (5) bryozoans, in decreasing order of importance as rock builders.

The corals and gastropods can be placed in group II.

## THE CHANGE IN STRENGTH OF WAVE ACTION, REFLECTED BY THE FOSSIL ASSOCIATIONS WITHIN A BED

In the "Bathymetric considerations" and by the application of depth "phases" in the bathymetric study, the fauna and flora were analysed according to the relationship with depth changes. From this it appeared that various organisms and certain types of organism within a group can be very sensitive to changes in depth. Because of the sharp limits between two completely differently composed fauni-floras next to each other, it can be assumed that the changes were abrupt (see figs. 15, 16 and 17). It is thus possible to separate various depth phases.

Helped by the physical and petrographic behaviour of the rocks, it becomes clear that there is evidence of small changes within a bed and that these are caused by the strength of wave action. Two cases are found in such beds:

a. that the strength of wave action increases towards the top of the bed,
b. that the strength of wave action decreases towards the top of the bed.

### *In a strong wave action environment*

It appeared that in strong wave action environment, where the strength increased within a bed, an increase is found in the numbers of gastropods and red algae of the genus *Archaeolithophyllum.* The number of brachiopods is more or less constant, with a possible decreasing tendency (fig. 18, hist. 439 and 440). The echinoderms, Bryozoa, and green algae generally show a decrease in numbers.

Where the circumstances were reversed, the strength of wave action decreasing from base to top, it appeared from the observations that brachiopods, echinoderms, bryozoans, and green algae show a clear increase, while gastropods and the specimens of *Archaeolithophyllum* decreased. In many cases a decrease was also noted in the Foraminifera, but because these generally form only a small part of this organic population, this last observation is not particularly convincing.

### *In a weak wave action environment*

In beds where there was a relatively weak wave action there is a remarkably large number of algae of several genera. Where the wave action strength increased (case *a*) there is a sharp decrease of the algal genera *Anthrocoporella* and *Petschoria.* In contrast, an increase in the numbers of the genera *Donezella, Komia, Epimastopora* and *Mell-porella* of the blue-green algae. There is also an increase of some (mainly dwarfed?) brachiopods and gastropods and generally of echinoderms.

Where a decrease has been detected in the wave action (case *b*) there is a decrease of gastropods, red algae of the genera *Amorfia, Komia* and *Pseudokomia,* and also of *Donezella, Epimastopora* and the blue-green algae, while the genera *Petschoria* and *Anthracoporella* show a definite increase. Similarly the Foraminifera and large brachiopods increase here in great numbers.

It appears to be the case in both environment types, that where it was possible to detect a decrease in the strength of wave action some types of brachiopods, Bryozoa, and Foraminifera could be expected with the algal genera *Petschoria* and *Anthracoporella.*

On the other hand, where the tendency was from quiet wave action to disturbed, most of the red algal genera with the gastropods showed an increase.

It has thus been established that different algal genera react differently to wave action. Some genera are found together with oolitic limestone, others are found in rocks where calcite ooze is deposited. Intermediate forms are, of course, also present. An energy-index table, obtained from observations, for the typical algal genera in the two formations, gives the following picture:

| wave action | strong | medium | weak |
|---|---|---|---|
| specific genera | Archaeolithophyllum | Donezella | Petschoria |
| other algae | Epimastopora<br>Mellporella<br>Donezella? | Amorfia<br>Komia<br>Pseudokomia<br>Ungdarella and the red algae associated with it,<br>blue-green algae | Anthracoporella<br>Uraloporella<br>and the green algae associated with these genera |

It appears that the algal genera, which are good milieu indicators, have a long stratigraphic range. For example, the genera *Archaeolithophyllum*, *Donezella* and *Petschoria*, which are very sensitive for a given environment, are found with a very wide chronostratigraphic limit in the Carboniferous deposits of the San Emiliano and the Lois-Ciguera Formations.

## THE ORIGIN OF THE DWARF FAUNI-FLORA IN THE MIXED BEDS

It has appeared that the, so-called, mixed fossil beds originated in oolitic limestone. The fauna and flora present in this type of rock consists mainly of small specimens. Shimer (1908) called such faunas "dwarf faunas". Because, in this case, plant remains form part of the bio-fraction, we can follow the same line and call the fossil assemblies "dwarf fauni-floras". This term is certainly applicable when it is realized that the calcareous algae, present in the mixed beds, are miniature forms of particular genera. The thickness of the thallus, of the specimens of the genera *Archaeolithophyllum*, *Epimastopora* and *Mellprella*, is in most cases only a fraction of the thicknesses found in other types of sediment.

The mixed beds contain much larger amounts of other faunal elements, such as small, thin shelled brachiopods and gastropods.

Cloud, Jr. (1948, p. 57) named three causes for the origin of assemblages of miniature brachiopods:

1. actual dwarfing due to physiological retardation of growth, for whatever reason;
2. accumulation of immature specimens of normally larger species and adults of smaller species due to segregation by moving waters;
3. accumulation of immature specimens because of environmental factors tending to produce subnormal life span or exceptionally high mortality of the younger animals.

It is probable that all three factors have played a role in the origin of the mixed beds in the San Emiliano and the Lois-Ciguera Formations. The excellent sorting and the small grain size of the matrix suggest a very agitated milieu. The masses of oolites, which are also present, support this interpretation.

According to Moore (1948, p. 126), the association of various dwarf faunas with oolites suggests a special milieu. His experiences of this come from two sources:

the Pennsylvanian cyclothems in Kansas and the Lower Mississippian deposits in Iowa. His study of these led to the suppositions that:

a. the oolites had an algal origin and arose in the marginal regions of a retreating Pennsylvanian cyclothem, with saltier than normal seawater.
b. organisms which live in saturated seawater where oolites are deposited cannot continue to exist in hypersaline water, where dolomite is laid down.

The changes in the salt content of the seawater can thus be seen to have played an important role in the origin of dolomites, oolites, and in the alternation of fossils in the oolitic limestones. A consideration, of the previously described textures of the oolitic limest ones in the San Emiliano and Lois-Ciguera Formations, will allow immediate acceptance of the second point enumerated by Cloud, "segregation by moving waters".

On the other hand, the salinity changes in the seawater, proposed by Moore, would have caused the deposition of oolites and the special composition of the dwarf fauni-floras. That the sediment-binding algae have also played a role in the origin of oolites, in our case, is difficult to prove. It is, however, not an impossible supposition because the algae in these two formations, as shown in the quantitative study, are by far the most important sediment-building organisms. In the oolitic limestones, red and green algal fragments are the only ones found which have a relatively substantial thallus. The blue green algae are absent. It can thus be assumed that the blue-green algae formed cement during the origin of the oolite rings. Following this argument, it is necessary to seek the origin of dwarfing in the chemical factors, enumerated by Cloud as point no. 1.

There is no doubt that the sharp limiting between the various units within a member is caused by bathymetrical changes. Thus in a unit, where the conditions were already unfavourable for the existence of a biocoenose, a sudden change in depth will mean the death of all organisms, including the diminutive ones. This situation corresponds to the third factor enumerated by Cloud, generalizing on the entire dwarf fauniflora of the mixed beds. It now appears from the discussion above that several factors are responsible for the origin of the minute fossils in the mixed beds of the San Emiliano and Lois-Ciguera Formations.

## PALEOGEOGRAPHICAL DISTRIBUTION

The area under study is far too small to allow the drawing of paleogeographical conclusions.

Striking lithological units, such as the oolite beds in the limestones on the north flank of the Cármenes syncline and certain layers of the Lois-Ciguera Formation, can be followed horizontally over large distances. This is also the case with some coral biostromes.

There was also very little change of the fossil association, in particular parts of the layer in a lateral direction. This is shown in the two histograms (no. 104—104a) of figure 25. The two samples are taken from a very peculiarly weathered bank of the same layer, with the localities about 7.50 km apart, between the Río Torio and the Río Curueño (member no. XIII), to the east and west of the limits of locality B. 29. As can be seen from the histograms, the composition of the biofraction — apart from slight variations — is exactly the same. When the examination of several other samples revealed the same picture, work in this direction was discontinued.

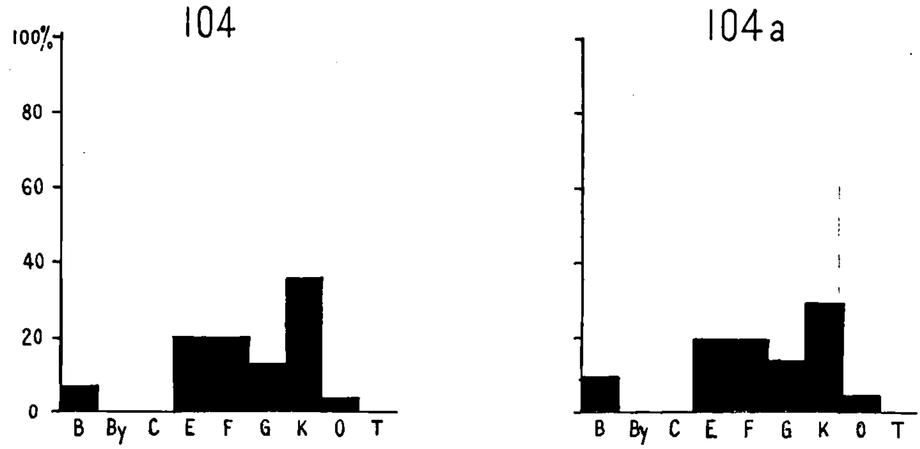



Fig. 25. Composition of the biofraction of layer no. XIII at points separated by 7.5 km, in the Lois-Ciguera Formation.

LEGEND B = brachiopods E = echinoderma K = calc. algae
By = bryozoans F = Foraminifera O = ostracods
C = corals G = gastropods T = trilobites

## CONCLUDING REMARKS

The situations under which the layers are found indicate that certain causes have been operative. Applied paleoecologically: the rock found in a particular layer, having its own lithological and biological composition, has a history. One or more phenomena occurred in the past which have resulted in the formation of the rock, as we now find it in the field. To find the exact origin of the rock is very difficult. The data, which are given here, mainly give an indirect answer. When, however, all possible factors are studied, important dat are obtained which help in the investigation. To find the reasons — at least approximately — for the origin of a rock, when there was a possibility of investigating its biological composition, two approaches were used:

1. by analysis of the composition and various properties of the *biofraction* and a search for the causes which created such a situation,
2. obtaining important data about the *environment* and studying the changes, which were caused by certain environmental changes, in the composition of the biofraction.

In the first case, the causes are sought which determine the environment, and in the second case, the already known reasons which are characteristic of the environment show their effect on the fauna and flora. It is clear, that from the above, the two points finally give the same result. The causes which resulted in the origin of the rock can be divided into two groups; physical and chemical causes; and biological causes.

These three causes are complexes of various factors which have contributed to the origin of an environment. The most important of these are temperature, light conditions, pressure, condition of the substrate etc., as physical factors, pH value, $CO_2$ content of the sea-water, chemical buffers etc., as chemical factors.

The most important physical phenomena, in our situations, were:

a. depth of water,
b. sudden movement of the substrate after a rest period,
c. wave action.

The chemical factor dealt with is:

a. the salinity of the water.

The biological factors are:

a. adaptability, and
b. rapid multiplication, which were found.

The character of the qualitative composition, of the organic component as a unit, in the area, suggests that there was *shallow water*. The most convincing proof of this is the presence of calcareous algae as the most important rock builders. Because the existence of these microplants is dependent on light; through photosynthesis, in deeper regions where the light-intensity decreases the calcareous algae can no longer survive. The benthonic existence of most of the other organisms does not contradict an assumption of shallow water.

The sudden changes, in floral and faunal composition, between two small lithological units can be best explained by *sudden oscillations* of the sea-water level or of the substratum. The mechanism proposed is that the epirogenetic movements were interrupted by relatively rapid vertical movements. A regular succession of oscillations with particular conditions are reflected as cyclical deposits in the sedimentation.

The relatively slow changes in the qualitative composition of the biofraction within a bed leads strongly to the conclusion that different organisms preferred different strengths of *wave action*. This is clearly shown by a few algal genera, from which it was possible to form a so-called *energy-index* with respect to these genera. Possession of such data also makes it possible to classify the other organic species which are found with them.

Some sediments are very useful subjects for a paleoecological study. One of these is the oolites. They often provide more data. It appeared, in both formations, that the oolites were formed during strong wave action and, following the argumentation of Moore they would have been deposited in *sea-water with a higher-than-normal salt content*. The first observation is of an important physical property and the second of an important chemical property.

Two points were studied, concerning the causes for the composition of the biofraction. These were *adaptability* of the different types of organism, and their *ability to multiply rapidly*. It appeared from this that, with the moving substratum of the Carboniferous system, it was not sufficient for the organism to be able to adapt itself in order to be able to multiply rapidly. The latter could only occur when all the factors were favourable for the organism to act as an important rock builder. To stress only a few factors is difficult and can be misleading, because the change of one factor can often lead to the modification of one or more organisms. A complete analysis of the paleoecological factors, however, would extend far beyond the scope of this work.

CHAPTER IV

# REMARKS ON THE STRATIGRAPHY OF THE CALCAREOUS ALGAE AND THEIR SYSTEMATIC DESCRIPTIONS

## THE STRATIGRAPHIC VALUE OF THE CALCAREOUS ALGAE

It has not yet been possible to say that the calcareous algae, found in the various systems, are not only of value as facies-indicators, but are also definitely connected to the stratigraphy. This is because, until now, a considerable percentage of the areas which contain calcareous algae have not been througly enough studied. The result has been serious gaps in the phylogeny of these micro-plants. A deficiency in the phylogeny automatically creates obstacles against building up their stratigraphy. A filling-in of their phylogenetic pattern will, without doubt, result in an improvement in their age determination. With the Carboniferous deposits of NW Spain, we are in the fortunate position that almost all the limestones contain different algae, thus offering the possibility of the micro-flora found in them.

Secondly, support is found in the Foraminifera fauna, which has also been studied in detail and provides excellent comparative material for age determinations. These data, fortunately, make possible a biostratigraphic classification of the calcareous algae.

It is unfortunate, that the area is the only one with this particular type of facies development, and in which such a composition can be established, which results in no possibility for comparison of the findings with those from other Carboniferous deposits. It is also unfortunate that the phylogenetic study must be restricted to the Carboniferous system. Calcareous algae are rare in the Devonian, Lower Paleozoic, and in the younger Mesozoic deposits. Where this is not the case, no study has yet been made. The phylogenetic and stratigraphic data are thus restricted to a relatively short time period and a relatively small geographical distribution. This does not mean that the results are not useful and useable for further study.

### *The biostratigraphic units of the calcareous algae*

The age determination is relative and indirect. The fact, that the results are not directly comparable with the calcareous algae found in other areas, means that only a relative age can be determined. Fortunately, however, there is the excellent possibility of correlating the calcareous algae with the similarly benthonic Foraminifera. The latter can be fitted into the structure of the other Carboniferous areas, and thus the results are of indirect help in this study.

Van Ginkel (1960, unpublished annual reports of the "Geologisch en Mineralogisch Instituut te Leiden", and personal communication) was able to distinguish three Foraminifera zones: These zones are divided into sub-zones as follows:

| | |
|---|---|
| *Protriticites* Zone | (not sub-divided) |
| *Fusulinella* Zone | sub-zone $B_3$ |
| | sub-zone $B_2$ |
| | sub-zone $B_1$ |
| | sub-zone A |
| *Profusulinella* Zone | sub-zone B |
| | sub-zone A |

Most of the Carboniferous limestone deposits in NW Spain belong to the *Profusulinella* and *Fusulinella* zones.

According to the biostratigraphic classification of the Foraminifera, the deposits of the San Emiliano Formation belong to the *Profusulinella* zone, sub-zone A.

The Foraminifera of the Lois-Ciguera Formation belong to sub-zone B of the *Profusulinella* zone and the lower part of the *Fusulinella* zone (sub-zones A and $B_1$: see table I).

### Zone I of the calcareous algae

Sub-zone A of the *Profusulinella* zone can be clearly divided into two algal-zones, an older (zone I) and a younger (zone II). Zone I is based on the regular occurrence of the species *Ungdarella uralica* Maslov and the genera *Ortonella* and *Donezella*, in the deposits. The presence of the genus *Donezella* gives little information, concerning the zone classification, because examples of these algae are also found in the youngest part of the Lois-Ciguera Formation. The lower edge of zone I is most probably between the massive limestone and the top fossil-containing beds in the Escapa Formation. In the top of this formation there are calcareous algae with other organic remains, sometimes in considerable concentrations, and specimens of the genus *Ungdarella* are certainly found here. The upper limit of the calcareous algae zone I is found in the lower part of the San Emiliano Formation. In a few limestone layers no. I and II (see fig. 1), representatives of zone I are still found.

### Zone II of the calcareous algae

The limestone layers of zone II are identified by the regular occurrence of the species *Epimastopora bodoniensis*, and the genera *Anthracoporella*, *Donezella*, *Petschoria*, *Archaeolithophyllum*, *Mellporella*, *Beresella*. *Epimastopora bodoniensis* sp. nov. with its striking form and numerical amount is an easily recognized guide fossil for zone II. The upper limit of zone II does not coincide with the border of the sub-zones A and B of *Profusulinella* but is slightly higher, in the lower part of sub-zone B (see table I).

### Zone III of the calcareous algae

This zone is characterized by the presence of the species *Dvinella comata* Chvorova and *Epimastopora rolloensis* sp. nov. in large numbers. There are also the genera *Amorfia*, *Cuneiphycus*, *Pseudokomia*, *Uraloporella*, *Donezella*, etc. This zone of the calcareous algae includes the uppermost and at the same time the largest part of sub-zone B of the *Profusulinella* zone and the largest part of sub-zone A of the *Fusulinella* zone (see table I).

### Zone IV of the calcareous algae

Identifying zone IV is the presence of the genus *Komia*. This alga is found in very large numbers in the Lois-Ciguera Formation. The genera *Macroporella*, *Pseudokomia*, *Eugonophyllum*, *Donezella*, *Zaporella*, and the species *Archaeolithophyllum missouriensum*

JOHNSON are found with *Komia*. It is most probable, that resulting from an interruption of the sedimentation, this zone is not complete. In any case, the calcareous algae present correspond to the Foraminifera from the uppermost part of sub-zone A, and of sub-zone $B_1$ of the *Fusulinella* zone.

| Foraminifera | | | Calcareous algae | | Chronostratigraphy | |
|---|---|---|---|---|---|---|
| Zone | Subzone | Characteristic fossils | Zone | Characteristic fossils | Stage | Substage |
| FUSULINELLA | $B_3$ | | V | | MOSKOVIAN | UPPER |
| | $B_2$ | | IV | | | |
| | $B_1$ | Fusulinella ex. gr. bocki<br>Fusulina spp. | | Komia abundans<br>Macroporella ginkeli<br>Archaeolithophyllum missouriensis<br>Eugonophyllum sp. | | |
| | A | Fusulinella ex. gr. schubertellinoïdes<br>Fusulinella delepinei<br>Eofusulina spp. | III | Dvinella comata<br>Amorfia jalinki<br>Pseudokomia cansecoensis<br>Epimastopora sp.<br>Uraloporella sieswerdai | | LOWER |
| PROFUSULINELLA | B | Profusulinella spp.<br>Eofusulina spp. | | | | |
| | A | Profusulinella spp.<br>Verella sp. | II | Donezella lunaensis<br>Epimastopora bodoniensis<br>Mellporella anthracoporellaformis | BASHKIRIAN | UPPER |
| | | | I | Ungdarella uralica<br>Ortonella myrae | | |
| | | | | | | LOWER |

TABLE I Correlation between the Carboniferous Formainifera and calcareous algae in the San Emiliano and Lois-Ciguera Formations.

| Species of calcareous algae | Loc. | R 471 | R 475 | R 476 | R 49 | R 42 | R 43 | R 34 | R 401 | R 449 | R 36 | R 24 | W 207 | R 300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amorfia jalinki gen. et spec. nov. | | | | | | | | | | | | | | + |
| Anthracoporella spectabilis PIA | | | | | + | + | | | | | | | | |
| Archaeolithophyllum johnsoni spec. nov. | | | | | + | + | + | | | | | | | |
| Archaeolithophyllum missouriensum JOHNSON | | | | | | | | | | | | | | |
| Beresella hermineae spec. nov. | | | | + | | | | + | | | | + | | |
| Cuneiphycus aliquantulus JOHNSON | | | | | | | | | | | | | | |
| Donezella lunaensis spec. nov. | | + | + | | | | | | | | | | | |
| Donezella lutugini MASLOV | | + | | + | + | + | + | | + | + | | + | + | + |
| Dvinella comata CHVOROVA | | | | | | | | | | | | | | + |
| Epimastopora bodoniensis spec. nov. | | | | + | + | + | + | + | | | | + | | |
| Epimastopora rolloensis spec. nov. | | | | | | | | | | | | | | |
| Epimastopora sp. | | | | | + | + | | | | | + | | | |
| Eugonophyllum mulderi spec. nov. | | | | | | | | | | | | | | |
| Girvanella sp. | | | | | | | | | | | | | | |
| Komia abundans KORDE | | | | | | | | | | | | | | |
| Macroporella ginkeli spec. nov. | | | | | | | | | | | | | | |
| Mellporella beundermani gen. et spec. nov. | | | | | | | | | | | | | | |
| Mellporella anthracoporellaformis gen. et spec. nov. | | | | | | + | + | | | | | + | | |
| Ortonella myreae spec. nov. | | | | | | | | | + | | + | | | |
| Osagia sp. | | | | | | | | | | + | | + | | |
| Petschoria elegans KORDE | | | + | | + | | + | + | | + | | + | | |
| Pseudokomia cansecoensis gen. et spec. nov. | | | | | | | | | | | | | | |
| Pycnostroma sp. | | | | | | | | | | | | + | | |
| Ungdarella uralica MASLOV | | | | | | | | | + | | + | | + | |
| Uraloporella sieswerdai spec. nov. | | | | | | | | | | | | | | |
| Zaporella cantabriensis gen. et spec. nov. | | | | | | | | | | | | | | |

TABLE II Distribution of the calcareous algae

| R 304 | R 313 | R 1001 | R 1004 | R 1006 | 216 | C 11 | B 42 | B 29 | C 21 | 508 | 509 | 510 | 513 | 514 | 515 | 154 | 161 | 156 | 160 | 151 | 506 | S 14 | S 19 | S 2 | S 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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the San Emiliano and Lois-Ciguera Formations (see map in back pocket)

*Chronostratigraphic limits of the calcareous algae zones*

Zone I and the largest part of zone II (the deposits in the San Emiliano Formation) belong to the Bashkirian stage. Whether the lower limit of zone I corresponds to the limit of the Lower or Upper Bashkirian cannot yet be established because of the lack of evidence. The same is true of the change from zone I to zone II. The upper limit of zone II comes in the lower part of the Lower Moscovian. Thus the change from zone II to zone III must have taken place in the Vereyian. The change from zone III to zone IV comes at about the border between the Lower and Upper Moscovian. According to the results, obtained with the help of the calcareous algae, the sedimentation in the Lois-Ciguera Formation between the rivers Bernesga and Porma stopped in the lowest part of the Upper Moscovian (see table I). The distribution of the calcareous algae in the several localities shown by table II.

Explanation of symbols used in the tables of systematic descriptions:

| | | |
|---|---|---|
| * D | = | outer diameter of calcareous body |
| d | = | inner diameter of calcareous body |
| w | = | thickness of calcareous wall |
| p | = | diameter of the pores (= branches) |
| t | = | thickness of the wall between contiguous pores |
| s | = | thickness of the calcite wall |
| l | = | length of the body (= fragment) |
| pf | = | thickness of the pores (thicker extreme-end) |
| pa | = | thickness of the pores (thinner extreme-end) |
| n | = | number of the branches in a whorl in cross section |

* All measurements in $\mu$.

## SYSTEMATIC DESCRIPTIONS

Phylum RHODOPHYCOPHYTA Papenfuss, 1946
RED ALGAE OF UNCERTAIN AFFINITIES, Johnson, 1961

Genus Amorfia Rácz gen. nov.
*Genotype. Amorfia jalinki* RÁCZ spec. nov.

*Diagnosis.* The thallus is elongated and flat, but can also have an irregular wavy ribbon form. The thallus often shows branching. The tissue is composed of a delicate wavy cell structure. There is a clear difference between the hypo- and the perithallus. Reproductive organs are present.

Hypothallus. In cross-section, the hypothallus consists of polygonal cells which are considerably larger than the elongated rectangular cells of the perithallus. No clear division can usually be observed between the hypo- and the perithallus. The hypothallus is generally much smaller in diameter, than the perithallus.

In transverse section the cells are rectangular, with the vertical sides of the cells longer than the horizontal ones. The few threads, built out of rectangular cells, form a bundle. When the thallus branches, the hypothallus also divides into two bundles. In a few cases it can be noted, that at the uppermost part of the thallus, the hypothallus-bundle splits into separate threads which spread over the whole breadth of the thallus. Cases are also found where the hypothallus no longer shows its original structure and the cells have dissappeared through an active recrystallization process.

Perithallus. In cross-section the tissue consists of slightly bent, close horizontal layers and perpendicularly, or almost perpendicularly, above this stand vertical cell walls, which in this way form a remarkable square cell-structure. In analogy to some of the stromatopore structures, the vertical sides of the cells do not form a continuous line, but are "interlaminar". The cell walls are usually of even thickness. The horizontal and vertical sides (wall structures) are not equal, but elongated, with the horizontal cells always slightly longer. In tangential section the cell threads are joined into curved bundles. Different bundles lie at angles to each other. In transverse section the cells appear as slightly curved rows, in brush form.

Reproductive organs. *Amorfia* sometimes has large circular conceptacles. The reproductive organs are present in the perithallus.

*Comparison.* On the basis of general form and main construction, *Amorfia* bears a great resemblance to the genera *Archaeolithophyllum*, *Komia* and *Ungdarella*. *Amorfia* and *Archaeolithophyllum* are similar in two ways: (1) both genera occur as small, irregular, platy, foliate or crustose masses, which grow loosely on the sea bottom and (2) in the arrangement of the cells, in both genera the layer-complexes are arched.

The differences between *Archaeolithophyllum* and *Amorfia* also consist of two points: (1) while the hypothallus of *Archaeolithophyllum* is usually thicker than the perithallus, the opposite is the case with Amorfia, and (2) the cells of *Archaeolithophyllum* are considerably larger than those of *Amorfia*.

*Amorfia* and *Komia* are similar in that: (1) the plants of both genera are strongly branched, (2) both are built of delicate cell structures with a thinner hypothallus of polygonal cells and a thicker perithallus of rectangular cells. The differences are: (1) the specimens of *Amorfia* are generally much smaller than those of *Komia*, (2) the fact that the hypothallus of *Amorfia* splits into single cell-threads, (3) the conceptacles of *Amorfia* are generally much larger than those of *Komia*, (4) the thread-like structures of *Komia* never unite into bundles, which lie at angles to each other, and this is a common phenomenon in *Amorfia*.

*Amorfia* and *Ungdarella* have one common property, the thread structures of both genera join in curved bundles, which lie at angles to each other. In contrast, there is the fact that (1) *Amorfia* is represented with many smaller specimens of *Ungdarella*, (2) the construction of the hypothallus (*Ungdarella* has only a single row of large cells) and (3) the presence of sporangia with *Amorfia*, which are not found with *Ungdarella.*

### *Amorfia jalinki* RÁCZ., spec. nov.

*Description.* The plant has developed in the form of a smal wavy and branched body on the one hand, and on the other in very irregular crumpled crustose masses. The thickness of the thallus is from 400 to 900 $\mu$ and the length from 500 $\mu$ to several mms.

The tissue of the thallus can be divided into a hypothallus, which is built out of polygonal cells and forms the smaller part of the thallus; a perithallus, which forms the larger part of the thallus and is constructed of delicate rectangular cells. In cross-section, the polygonal cells of the hypothallus vary between 45 and 55 $\mu$ in size. The tissue of the perithallus consists of cells which are 35 to 42 $\mu$ horizontally and 10 to 14 $\mu$ vertically: wall thickness 4 to 6 $\mu$.

The ratio of hypo- to perithallus is approximately 1 : 7.

The reproductive organs are relatively large (100 to 280 $\mu$). They are almost circular. There were only a small number of conceptacles present on the specimens.

*Locus typicus.* Lois-Ciguera Formation, West of Piedrafita in loc. R. 300.

*Biostratigraphic units.* Calcareous algal zone II.

Profusulinella zone, sub-zone B.

*Association. Dvinella comata* CHVOROVA, and *Donezella lutugini* MASLOV.

*Holotype.* Slide no. II-A-J-9 in the collection of the Department of Stratigraphy and Paleontology, Leiden University.

*Paratype.* Slides no. II-A-B-49 and II-A-B-50 in the same collection.

*Figured specimens.* Slides no. II-A-J-9 and II-A-B-50.

## Genus Archaeolithophyllum JOHNSON, 1956

*Genotype. A. missouriensum* JOHNSON

Plate X, figs. 4, 5 and 6

1956, *A. missouriensum* JOHNSON – J. Pal. 30, p. 54, p. 1—14, figs. 1—3, 5, 6.

*Description.* The plant is branched. On both sides of the lower part of the central part there are thin arched branches. The branchings do not occur on both sides at the same level. The branches of the thallus are irregular, flat, and show local thickenning. The central stem branches dichotomously at the top. At other times it is present as a crustaceous and crumpled mass.

The hypo- and perithallus can be clearly distinguished. The hypothallus is coaxial and consists of polygonal cells, of varying dimensions. The perithallal cells are rectangular. The sporangia are contained in conceptacles. In the branched parts of the plant, conceptacles are present where the thickennings occur. Their presence is probably the cause of the thickenning.

*Remarks.* As far as is known, (with the exception of Yugoslavia, Kochansky - Devidé *1963*) *Archaeolithophyllum* has been found nowhere else in Europe.

| | | |
|---|---|---|
| *Dimensions.* | Length of plant fragments: | a few millimeters |
| | Thickness of thallus: | from 425 to 1600 μ |
| | Thickness of hypothallus: | from 310 to 1000 μ |
| | Thickness of perithallus: | from 115 to 170 μ |
| | Hypothallic cell length: | from 40 to 64 μ |
| | Perithallic cell length: | from 8 to 14 μ |
| | Hypothallic cell breadth: | from 30 to 55 μ |
| | Perithallic cell breadth: | from 7 to 15 μ |

*Material.* In the collections of the Stratigr. & Paleont. Dept., Leiden University slide no. II-A-160 uit locality 160 in the Lois-Ciguera Formation.
*Biostratigraphic unit.* Calcareous algal zone IV,
Fusulinella zone, sub-zone $B_1$.
*Association. Macroporella ginkeli* and *Komia abundans.*
*Figured specimens.* Slide no. II-A-160.

### *Archaeolithophyllum johnsoni* RÁCZ, spec. nov.

Plate IX, fig. 1, 2, 3 and 4

*Description.* The plant is branched. The branches are arched and wavy, and vary in thickness. The basic part of the plant is thick and has no particular form. The distinction between hypo- and perithallus is indistinct, because the thallus is usually recrystallized at the perifery. The hypothallus consists of elongated polygonal cells. The cells can be slightly rounded. There is a definite variation in the size of the cells. In some cases the hypothallus is coaxial, in other cases the rows of cells are randomly arranged. In specimens which show weathering, the more resistant cell walls have remained well preserved. These are thin, but of uniform thickness.

The perithallus is usually indistinct. Sometimes there appears to be a gradual transition from the tissue of the hypothallus to that of the perithallus. In some cases a very vague, fine cell structure can be observed. The conceptacles are rodshaped or ellipsoid.

| | | |
|---|---|---|
| *Dimensions.* | Fragment length: | a few millimeters |
| | Thallus thickness: | from 315 to 780 μ |
| | Hypothallic cells: | from 55 to 80 length |
| | Hypothallic cells: | from 35 to 47 breadth |
| | Cell wall thickness: | from 8 to 12 μ |
| | Conceptacle diameter: | from 240 to 275 μ |

*Remarks.* Many examples show a great similarity to those which were illustrated by Johnson (1961, pl. 23, fig. 1—3 and 1963, pl. 4, fig. 1—37) but not described, *Archaeolithophyllum* species.

After an exchange of letters, about the problems concerning this genus, Professor Johnson gave the author a free hand to name and describe this species. It has been given the name *Archaeolithophyllum johnsoni.*

*Locus typicus.* San Emiliano Formation, to the south of Cármenes, at locality R. 43, in layer no. II.
*Biostratigraphic unit.* Calcareous algal zone II,
Profusulinella zone, sub-zone A (highest part).
*Association. Epimastopora bodoniensis, Epimastopora sp.*, and *Donezella lutugini.* Slide no. I-c-106 in the collection of the Department of Stratigraphy and Paleontology, Leiden University.
*Paratype.* Slides no. I-c-101, 102, I-b-145, 149, in the same collection.
*Figures specimens.* Slides no. I-c-106 and I-b-145.

Genus Cuneiphycus JOHNSON, 1960

*Cuneiphycus aliquantulus* JOHNSON

Plate VIII, fig. 6 and 7

*Description.* The thallus of these micro-plants is small and probably has a cylindrical form. No branching of the thallus was found. A segmented thallus, which is probably a characteristic of their construction, (according to Johnson, 1963) was not found. The tissue consists of wavy layers, which are filled with slightly elongated square or wedge shaped cells. It was not possible to separate hypo- and perithallus. Sporangia were also not found.

| | | |
|---|---|---|
| *Dimensions.* | Thallus size: | from 500 to 1500 $\mu$ |
| | Thallus thickness: | from 300 to 640 $\mu$ |
| | Cell size: | from 35 to 65 $\mu$ |

*Material.* Slides no. II-A-M-66 in the collection of the Department of Stratigraphy and Paleontology, Leiden University from the Lois-Ciguera Formation at locality C. 11.
*Biostratigraphic units.* Calcareous algal zone III,
Profusulinella zone, sub-zone B.
*Figured specimens.* Slide no. II-A-M-66.

Genus Komia KORDE, 1951

*Genotype. Komia abundans* KORDE

Plate XII, fig. 5, 6, 7 and plate XIII, fig. 1, 2, 4

1951, *Komia abundans* KORDE – Novye rody i vidy etc. Moskov. Obshch. Ispyt. Prir. Trans., Otd. Geol. t. 1, p. 182.

*Description.* The plant is usually branched. The thallus varies in length and thickness. The tissue of the thallus can be divided into a relatively thin hypothallus and a thick perithallus. Both parts of the thallus consist of cell structures.

The hypothallus consists, in cross-section, of polygonal cells (usually 5 or 6 sides). These cells are larger than those of the hypothallus. In axial section, the cells are oblong and 34 to 50 $\mu$ long.

The perithallus consists of a cell structure, with the cells formed into straight or branched filaments through recrystallization. The cell layers are concentrically arranged, in cross-section. Two types of cell were observed; (a) oblong shaped and (b) triangular. The latter are in the minority. The triangular cells, in a calcified thallus, appear as starting points for branchings and filaments.

The reproductive organs have an elongated-pear shape. They are found in the perthallus, but not in the hypothallus. The thicker partssof the organs point upwards, at an angle of about 70° to the vertical axis.

| | | |
|---|---|---|
| *Dimensions.* | Thallus length: | a few millimeters |
| | Thallus thickness: | from 300 to 1250 $\mu$ |
| | Hypothallus thickness: | from 80 to 135 $\mu$ |
| | Perithallic thickness: | from 200 to 900 $\mu$ |
| | Hypothallic cell size: | from 30 to 60 $\mu$ |
| | Perithallus cell size: | from 13 to 25 $\mu$ |
| | Cell wall thickness: | about 7 $\mu$ |
| | Conceptacle length: | from 250 to 480 $\mu$ |
| | Thick part of conceptacles: | from 75 to 155 $\mu$ |

*Discussions and Remarks.* Wilson, Waines and Cookes (1963) studied a considerable amount of material and concluded that *Komia* was a colentarete. They say: "Our study demonstrates that *Komia* is a stromatopotoid with a non-celluar coenonstome formed of (1) an outer region (perithallus of Korde) composed of trabeculate pillars and perforate, conical laminae and (2) an axial cylinder (hypothallus of Korde) composed of elongate abaxially walled grooves".

The result of the present study proves *Komia* to be a calcareous alga. Arguments for this conclusion are:

a. In hand specimens *Komia* fragments do not differ from the red algae; they appear as strings or branched, rounded on the ends, more or less cylindrical bodies.
b. The thallus is composed of a clear celluar structure.
c. The division of the thallus in hypo- and perithallus.
d. The presence of conceptacles.

An angle of 15° in the tranverse section cannot be considered a characteristic feature, as claimed by Wilson et al. (1963), because the rows of cells follow the outer rim of the thallus, which may be considerably bent. The author can also not accept their statement about the existence of a perforation at the walls of the cell. In their original article, they state that the cells clearly exhibit a continuous wall structure (figs. 2, 3). Their remark about the dichotomous branching of filaments of the perithallus is probably based on an artefact. These "filaments" are caused by a later calcification of a row of cells, and do not belong to the original structure. When no clear distinction is possible between hypo- and perithallus, this is also caused by calcification.

The present author emphasizes the necessity of a very cautious procedure is systematic description of *Komia* because, however well the specimens are preserved, they are usually calcified and possibly also in weathered material.

The statement of Drushits and Yakubowskaya (1961) that the thallus of *Komia* is less celluar, than in Korde's description, cannot be maintained after this study. Neither can this be done with Maslov's earlier (1956) supposition of *Komia's* relationship to echinoderms.

*Material.* In the collection of the Department of Stratigraphy and Paleontology,

Leiden University. Slides no. II-A-M-53, II-A-M-54, II-A-M-55, from loc. C. 21, Slides no. II-A-160, II-A-160A from loc. 160 in the Lois-Ciguera Formation.
*Association. Macroporella ginkeli* RÁCZ, sp. nov., *Eugonophyllum mulderi* RÁCZ sp. nov.
*Figured specimens.* Slides no. II-A-M-53, II-A-M-55 and II-A-160.

## Genus Petschoria KORDE, 1951

*Genotype. Petschoria elegans* KORDE

Plate XI, fig. 3, 4, 5 and 6

1951, *Petschoria elegans* KORDE – Obsch. Ispyt. Prirody. Trans, Otd. Geol. t. 1, p. 175—182, illus.

*Description.* The thallus is branched, not segmented, and longitudinally waved. In cross section, it has a round form and there is a great variation in diameter. The algal body can be divided into a hypo- and a perithallus, of which the hypothallus represents most of the tissue. The tissue structure of the hypothallus could not be determined, because of the strong recrystallization which has occurred. The perithallus, which forms a massive crust around the hypothallus, has an even thickness. It is constructed of very fine filaments, which often show branching. The filaments stand perpendicularly upon the hypothallus. No reproductive organs were found.

| | |
|---|---|
| *Dimensions.* Diameter of the thallus: | from 620 to 2200 $\mu$ |
| Thickness of perithallus: | from 65 to 175 $\mu$ |
| Thickness of perithallic filaments: | from 8 to 13 $\mu$ |

*Remarks.* According to the observations, *Petschoria* and *Pseudokomia* have several common properties, such as (a) The thick hypothallus and thin perithallus (b) in both genera the perithallus consists of filaments, which can be branched. In contrast, the branched thallus of *Petschoria* is often much thicker than that of *Pseudokomia*, which is not branched. Further, the hypothallus of *Pseudokomia*, in longitudinal section, consists, of a clearly discernable thread structure, with the threads running approximately parallel to the outer surface. The hypothallus structure of *Petschoria* could not be determined. Another difference is found between the morphology of the two genera, the perithallal filaments in *Pseudokomia* are noticeably thicker than those of *Petschoria.*
*Material.* Slides no. I-c-455 and I-c-31 from layer no. III to the north of Valverdin, Loc. R. 454 and slides no. I-b-88 and I-b-89 to the east of Barrio de la Tercía, loc. R. 475 in the San Emiliano Formation, in the collection of the Strat. and Pal. Dept., Leiden University.
*Association. Anthracoporella spectabilis, Donezella lutugini, Uraloporella sieswerdai.* It is often found as a rock builder in both formations.
*Figured specimens.* Slide no. I-c-455, I-b-88 and I-b-89.

## Genus Pseudokomia RÁCZ gen. nov.

*Genotype. Pseudokomia cansecoensis* RÁCZ spec. nov.

*Diagnosis.* The thallus is not branched. There is a definite separation between the central and the outer parts (hypothallus and perithallus, respectively. The thallus is round in cross section, but longitudinally one end is considerably thicker than the other. The thallus is not segmented, though the central portion is slightly constricted, in longitudinal section. The algal body consists of elongated cells, which can join into longer threads when in the recrystallized state. This phenomenon is present in most specimens.

The perithallus, in cross section, forms a stable outer layer, which has a more or less constant thickness. It consists of short, straight, or slightly curved "threads", which are perpendicular, or almost perpendicular, to the outer surface. The threads are relatively thick and can show dichotomy.

The hypothallus is less distinct, in the section, than the perithallus However, another type of cell structure can be established: the recrystallized cell structures of the hypo- and perithallus show a different orientation, and thus lie at angles to each other.

The different orientations of the hypo- and perithallus is clearly shown in longitudinal section, where — as has already been mentioned — the threads of the perithallus lie perpendicularly to the outer surface, while those of the hypothallus are horizontal in the central part of the algal body and lie at an angle — sometimes very small — with the perithallus threads at the end. The "threads" of the central part of the hypothallus are usually curved and can also show dichotomy.

There are indications of the presence organs in the central part of the alga, but this cannot be said with absolute certainty.

*Remarks.* The specimens of Pseudokomia bear the greatest resemblance to those of *Komia*. The genus can be distinguished from *Komia* because the thallus of *Pseudokomia* is not branched, has a thick hypothallus, and the cell structure of the inner and outer parts are otherwise orientated.

### *Pseudokomia cansecoensis* RÁCZ spec. nov.

Plate IX, figs. 5 and 6, and Plate X, figs. 1, 2 and 3

*Description.* The thickness of the thallus varies between 700 and 1750 $\mu$. The hypo- and perithallus consists of calcified threads, in which the original cells structure can often be seen. For example the perithallus usually consists of two rows of elongate cells, which have been joined, by recrystallization, to short threads.

The hypothallus is thick (50 to 75 % of the thickness of the thallus) and the threads are as thick, or even thicker (30—50$\mu$) than those of the perithallus. The central part of the body is filled with threads which lie parallel to the outer surface, the two systems being thus perpendicular to each other. At the two ends, the needles turn toward the outside and make an angle with the threads of the perithallus. This angle is accasionally very small (7—15°).

| | | |
|---|---|---|
| *Dimensions.* | Diameter of the thallus: | from 700 to 1760 $\mu$ |
| | Diameter of the hypothallus: | from 400 to 1170 $\mu$ |
| | Thickness of the perithallus: | from 110 to 300 $\mu$ |
| | Thickness of the threads: | from 18 to 30 $\mu$ |

*Locus typicus.* Lois-Ciguera Formation, to the north of Canseco, at loc. 216.
*Biostratigraphic unit.* Calcareous algal zone III and IV.
Fusulinella zone, sub-zone A.

*Association. Dvinella comata* CHVOROVA, *Komia abundans* KORDE.
*Holotype.* Slide no. II-A-B-92-1 in the collection of the Dept. Stratigr. en Paleont., Leiden University.
*Paratypes.* Slides no. II-A-B-18, II-A-B-83 and II-A-B-78, in the same collection.
*Figured specimens.* Slides no. II-A-B-92-1, II-A-B-18 and II-A-B-83.

Genus Ungdarella MASLOV, 1950

*Genotype. Ungdarella uralica* MASLOV

Plate XI, figs. 1 and 2

1956, *Ungdarella uralica* MASLOV – Iskopaemye izvestkovye vodorislí SSSR. Trudy Inst. Geol. Nauk SSSR, no. 160 16/s.
1962, *Ungdarella uralica* MASLOV – Trudy Geol. Inst. SSSR. no. 53 (Transl. Bureau Rech. Géol. Min. Paris, traduct no. 3811).

*Description.* The thallus is branched, varies in thickness, and is not articulated. The tissue shows little differentiation and it is therefore difficult to distinguish a hypo- and perithallus. The elongated and recrystallized cells form filaments, which are usually joined into groups. The various bundles of filaments lie at angles to each other. It can be seen by the marked twisting, in longitudinal section, that the tissue-units often grow upon each other.

Round conceptacles were found.

| | | |
|---|---|---|
| *Dimensions.* | Thallus length: | a few millimeters |
| | Thallus breadth: | from 600 to 3000 $\mu$ |
| | Filament thickness: | from 10 to 35 $\mu$ |
| | Conceptacle diam.: | from 85 to 110 $\mu$ |

*Material.* In the collection of the Department of the Stratigraphy and Paleontology, Leiden University. Slides nos. I-28 and I-29 of the limestones in the upper part of the Escapa Formation, to the NW of Cármenes at locality R. 401; Slide no. I-a-96 in the San Emiliano Formation, to the north of Valverde at locality W. 207.
*Biostratigraphic unit.* Calcareous algal zone I,
Profusulinella zone, sub-zone A.
*Association. Donezella lutugini* MASLOV.
*Figured specimens.* Slides no. I-28 and I-a-96.

Phylum CHLOROPHYCOPHYTA Papenfuss, 1946

Family DASYCLADACEAE Kützing orth. mut. Stizenberger, 1860

Genus Anthracoporella PIA, 1920

*Genotype. Anthracoporella spectabilis* PIA

Plate V, fig. 4, 5, 6, 7

1927, *Anthracoporella spectabilis* PIA – Handb. der Paleob., t. III, 3.
1928, *Anthracoporella spectabilis* PIA – Die Anpassungs. der Kalkalgen, Paleob., v. 1.
1930, *Anthracoporella spectabilis* JODOT – Bull. Soc. Géol. Fr., Sér. 4, v. 30.
1937, *Anthracoporella spectabilis* PIA – Die wicht. Kalkalg. ect., C.R. 2e Congr. d. études de Strat. Carb.
1940, *Anthracoporella spectabilis*? MACHAEV – Bull. MOIP, dept. geol. (t. 18, 15—16), tab. I, fig. 8, 9, 10, 12; tab. II, fig. 6.
1960, *Anthracoporella spectabilis* KOCHANSKY & HERAK – Geol. vjesnik. Zagreb. 13. pp. 66—69. pl. I. fig. 6; pl. II. figs. 1—6. — Cum synonymis.

*Remarks.* Well preserved specimens are found in member II of the San Emiliano Formation. The characteristic properties described by Pia are in accord with the Spanish specimens. It is peculiar that they are only found in one thin bed. Thes-species is found together with *Petschoria elegans* KORDE, *Donezella lutugini* MASLOV and *Epimastopora bodoniensis* sp. nov.

*Measurements.*

| No. | D | d | d/D in % | w | p | t | n |
|---|---|---|---|---|---|---|---|
| I-b-57 | 1500 | 900 | 60 | 300 | 35 | 8 | 80 |
| I-b-57 | 1850 | 1100 | 60 | 375 | 37 | 13 | 88 |
| I-b-58 | 1970 | 1150 | 63 | 410 | 35 | 10 | 80 |
| I-b-58 | 2000 | 1320 | 66 | 340 | 40 | 10 | 76 |
| 436a | 2100 | 1370 | 64 | 365 | 36 | 12 | 85 |
| 436a | 2250 | 1550 | 68 | 350 | 35 | 10 | 72 |
| 436a | 1250 | 880 | 70 | 185 | 38 | 25 | 68 |

*Material.* Slides no. I-b-57, I-b-58 and 436a in the collection of the Dept. of Stratigraphy and Paleontology, Leiden University from the San Emiliano Formation South of Cármenes in layer no. II, locality R. 42, upper part of the layer.
*Biostratigraphic units.* Calcareous algal zone II.
Profusulinella zone, subzone A.
*Remarks on the age.* Pia found these algae in the Carnic Alps together with fusulinids (Upper Carboniferous). The Spanish specimens are found in older rocks. This appearance in older rocks is not surprising when it is considered that the species is found in Lower Carboniferous as well as Permian deposits.
*Figured specimens.* Slides no. I-b-57 and 436a.

### Genus Beresella MACHAEV, 1937

### *Beresella hermineae* RÁCZ, spec. nov.

Plate I, fig. 1, 2 and 3

*Description.* The plant has a straight cylindrical body, which descreases in size towards the end. The thallus can be several mm long. It never shows bifurcation. A central and an outer protion can be clearly distinguished. The central part is filled with calcite cement. The outer part is composed of small pores which stand perpendicular to the vertical axis. The pores are usually straight, except at the outer end where they are slightly bent, making a sharp angle with the vertical axis. The outer end of the pores form a shell- (comb?) structure. The inner and outer side of the calcite part is limited by calcite walls, with the outer thinner (approx. 10 $\mu$) than the inner (15—20 $\mu$).

*Pores.* The pores are not branched. There are primary pores and also tufts of secondary pores. In most cases the primary pores have a raindrop form, with the thicker part towards the outside. A calcite shield has developed around the thickened pores. The primary pores are regularly arranged. When both sides are looked at, a spiral arrangement can be seen. The distance between the pores varies between 60 and 100 $\mu$.

In cross section the primary and secondary pores are radially arranged. The inner and outermost limestone wall are usually indistinct. No reproductive organs were found.

*Measurements.*

| No. | D | d | w | p | t | s | l |
|---|---|---|---|---|---|---|---|
| 1-b-476 | 315 | 190 | 62 | 25 | 100 | 5 | a few mm |
| 1-b-476 | 400 | 200 | 200 | 38 | 56 | 8 | — |
| 1-b-476a | 382 | 222 | 80 | 42 | 60 | 6 | — |
| 1-b-476A | 300 | 150 | 75 | 35 | 60 | — | 2300 |
| 1-b-476b | 435 | 218 | 100 | — | — | — | — |
| 1-b-476b | 375 | 175 | 100 | 34 | 75 | — | — |

*Remarks.* The basic construction of *Dvinella* and *Beresella* is almost the same. The only difference between the two is the form of the primary pores, which are often called channels.

*Beresella hermineae* sp. nov. differs in size in size from *Beresella erecta* MASLOV and KULIK. All the dimensions of the Spanish species are larger.

*Locus typicus.* San Emiliano Formation, layer no. II to the west of Cármenes, in locality R. 476.

*Biostratigraphic unit.* Calcareous algal zone II.

Profusulinella zone, subzone A (uppermost part).

*Association. Epimastopora bodoniensis, Epimastopora* sp., *Donezella lutugini, Oasagia sp.* of the other calcareous algae.

*Holotype.* Slide no. I-b-476 in the collection of the Dept. Stratigr. & Paleont., Leiden University.

*Paratypes.* Slides no. I-b-476a, I-b-476a in the same collection.

*Figured specimens.* Slide no. I-b-476, I-b-476a.

## Genus Dvinella CHVOROVA, 1949

*Genotype. Dvinella comata* CHVOROVA

Plate III, fig 1, 2

1949, Dvinella comata, CHVOROVA – Dokl. Akad. Nauk SSSR., no. 65, p. 769, fig. 1—3.

1956, Dvinella comata, MASLOV – Iskopaemye izvestkovye vodovosli SSSR., Trudy Inst. Geol. Nauk SSSR., no. 160, p. 59 – plate XIII, fig. 1—2, plate XIX, fig. 2.

*Description.* The thallus consists of a cylindrical body, which is not branched. The central stem is relatively thick and filled with calcite cement. The calcareous part consists of primary and secondary branches. The space between the branches is large (60—75 $\mu$). This space is filled with fine cylindrical pores, arranged perpendicularly to the vertical axis.

*Measurements.*

| No. | D | d | w | p | t |
|---|---|---|---|---|---|
| II-A-G-1 | 250 | 100 | 75 | 35 | 60 |
| II-A-G-2 | 265 | 125 | 50 | 27 | 75 |
| II-A-B-94 | 300 | 196 | 70 | 44 | — |
| II-A-M-58 | 320 | 198 | 66 | 36 | — |
| II-A-M-58 | 284 | 168 | 58 | 42 | — |

*Material.* Slides no. II-A-G-1, II-A-B-94, from locality C. 11, and II-A-M-58 from locality B. 29 in the Lois-Ciguera Formation. In the collection of the Department of Stratigraphy and Paleontology, Leiden University.
*Biostratigraphic unit.* Calcareous algal zone III,
Profusulinella zone, sub-zone B, and
Fusulinella zone, sub-zone A.
*Association. Uraloporella sieswerdai* and *Pseudokomia cansecoensis.*
*Figured specimens.* Slide no. II-A-G-1.

### Genus Epimastopora Pia, 1922
### *Epimastopora bodoniensis* Rácz spec. nov.

Plate III, fig. 3, 4, 5, 6

*Description.* The thallus of *Epinastopora bodoniensis* has a relatively thick (max. 2100 $\mu$) cylindrical body.

In transverse section it can be divided into a central portion, which is filled by secondary calcification, and an outer region composed of many branches, which can vary in length and thickness. The branches are not evenly long, there are two types:

a. longer branches which reach the outer surface;

b. shorter branches which are approximately half the length of the longer ones. In general the longer branches are also thicker than the shorter ones. The alternation of the two types of branch is irregular. They have a common charaster: they increase in thickness towards the perifery. The branches are arranged, not flatly, but in a spiral (see fig. 26).

In longitudinal section, only fragments of the thallus are present. Almost all the fragments are slightly wavy. The two sorts of branches, short and long, can also be distinguished here, also a broadening of the branches towards the outer surface.

There has been limestone deposition on the outer surface of the body. The branches have grown very close together and thus, in most cases, are only separated by a thin division.

*Measurements.*

| No. | D | d | w | pf | pa | t | n |
|---|---|---|---|---|---|---|---|
| I-C-5 | 1600 | 700 | 450 | 150 | 60 | 20 | 80 |
| I-c-6 | 1820 | 790 | 530 | 150 | 110 | 26 | 56 |
| I-c-A-11 | 2050 | 950 | 550 | 350 | 200 | 40 | 70 |
| I-c-A-11 | 2080 | 880 | 600 | 180 | 125 | 25 | 72 |

In tangential section, the branches appear as polygonal cells, with a variation from 5 to 7 sides. Six-sided cells are the normal. The cell walls are distinct and regular in thicknes (20 $\mu$—40 $\mu$). The longest side found was 280 $\mu$ and the shortest 60 $\mu$.

*Discussion on the form of the genus.* There is no agreement, between paleontologists, about the thallus form of the *Epimastopora.* Pia (1922) suggested a spherical thallus. Later investigators Wood (1943), Johnson (1946), Endo (1951) prefer an elongated cylindrical form. Maslov et al. in a recent publication (1963) agree with Pia's proposal and regard *Epimastopora,* phylogenetically, as directly derived from the genus *Mastopora.* The transverse sections of the Spanish examples of *Epimastopora bodoniensis* give additional evidence for the proposal of Wood and the others. The phylogenetic relationship, between the genera *Koninckopora* and *Epimastopora,* which was the origin of Wood's form determination, is also made more real by the above finding.

*Locus typicus.* About 1 km south of Cármenes village, in the San Emiliano Formation in loc. R. 42.

*Holotype.* The slide no. I-c-A-11 in the collection of the Department of Stratigraphy and Paleontology, Leiden University.

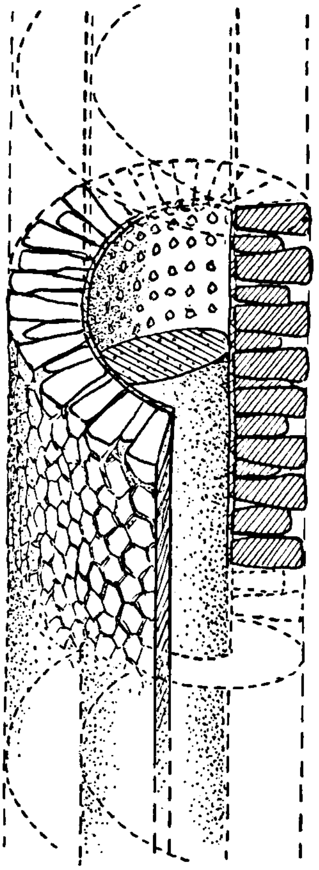

Fig. 26. Reconstruction of *Epimastopora.*

*Paratypes.* I-c-5, 6, II-A-V-32 and II-92 in the same collection.
*Association.* The species is found with other calcareous algae: *Donezella, Epimastopora sp., Archaeolithophyllum, Mellporella, Petschoria, Beresella* and *Girvanella.*
*Biostratigraphic units.*
a. The species is found in relatively large numbers, with a very small vertical spread. Therefore it has been chosen as a zone fossil (zone II).
b. The uppermost portion of sub-zone A of the Profusulinella and the lowest part of sub-zone B of the Profusulinella zone.

*Figured specimens.* Slides no. I-c-A-11 and I-c-5.

### *Epimastopora rolloensis* RÁCZ spec. nov.

Plate II, fig. 4, 5, 6

*Description.* T h a l l u s. The thallus form is not known. No examples were found which had been sectioned transversally. It is, however, possible to surmise that it has a cylindrical body. This is based on the fact that the examples found by the author were with specimens of *Epimastopora bodoniensis* in the Cármenes syncline.

The fragments found in axial section are constructed from large numbers of thick branches. These are not uniform on both sides but are gradually wider towards the exterior. This cannot always be clearly seen. A large number of the branches are rounded on the outside. There are no bifurcating branches. The thickness of the calcified portion varies between 500 $\mu$ and 700 $\mu$.

The partitions are not all straight, but wavy, and their thickness varies from 10 $\mu$ to 25 $\mu$.

B r a n c h e s. In tangential section, the branches form a cellular structure. The cells of *E. rolloensis* are polygonal (8 to 9 sides) or triangular in form. It is typical of the cells that their sides are rounded and not sharp. The largeness of the cells amounts to less than the clear honeycomb structure of *Epimastopora bodoniensis* n. sp. Many of the cells are tunnelled.

*Remarks.* This species has many properties which overlap those of *Epimastopora bodoniensis*. There are, however, definite differences between the two species. These are found in the difference in thickness of the calcified portion of the thallus, the difference in pore size, and the form and size of the cell structure.

*Measusements.*

| No. | w | $p_f$ | $p_a$ | t |
|---|---|---|---|---|
| II-S-13 | 600 | 130 | 60 | 12 |
| II-S-13 | 525 | 100 | 68 | 14 |
| II-S-15 | 500 | 142 | 76 | 16 |
| II-S-16 | 675 | 128 | 70 | 12 |
| II-S-18 | 575 | 140 | 78 | 15 |

*Locus typicus.* Prioro Formation?, 3 km. WSW of Siero de la Reina.
*Holotype.* Slide no. II-S-A-16 in the collection of the Department of Stratigraphy and Paleontology, Leiden University.
*Paratypes.* Slides no. II-A-13, 18 in the same collection.
*Association.* In the limestone layers together with *E. rolloensis* are found *Pseudokomia, Dvinella,* and also *Komia.*
*Biostratigraphic units.* Upper part zone III,
Profusulinella zone, subzone B.
*Figured specimens.* Slides no. II-A-S-13 and II-A-S-16.

### *Epimastopora spec.*

Plate IV, fig. 1, 2 and 3

*Remarks.* Short fragments (1 to 2 mm) of this species are present, and they are usually calcified. It is therefore not possible to give it a species name. The regularly arranged branches are, in relation to the inter-spaces, relatively thick and rounded at the ends.

This species closely resembles *Epimastopora* sp. A. Johnson (1946, p. 1097) found in the Kansas limestones, at Deer Creek.

| | |
|---|---|
| *Dimensions.* Diameter of branches: | from 40 to 75 $\mu$ |
| Space between branches: | from 18 to 35 $\mu$ |

*Locus typicus.* San Emiliano Formation, to the South of Cármenes at loc. R. 42, in member no. II.
*Biosrratigraphic unit.* Calcareous algal zone II,
Profusulinella zone, sub-zone A.
*Association. Epimastopora bodoniensis, Archaeolithophyllum johnsoni, Donezella lutugini* and *Beresella herminae.*
*Holotype.* Slide no. I-b-143 in the collection of Stratigraphy and Paleontology, Leiden University.
*Paratypes.* Slides no. I-c-465 and I-c-466.
*Figured specimens.* Slides no. I-b-143 and I-c-466.

### Genus Macroporella Pia, 1912
### *Macroporella ginkeli* Rácz spec. nov.

Plate VI, fig. 1, 2 and 3

*Description.* The thallus is cylindrical, slightly bent and waved. The central stem is of medium thickness. It is not branched. Clear, relatively thick primary branches show a very slight thickening towards the outer surface, in cross-section. The branches have no bifurcation. In transverse section there are also well preserved fragments. In this section the less regularly arranged primary branches show a clear increase in thickness from the central stem to the outer surface. It can also be seen here that the branches are directed slightly upwards and form an angle of 16—28° with the horizontal base surface. A clear and typical property of the *Macroporella* is that all the branches — only slightly — are bent.

*Measurements.*

| No. | D | d | w | pf | pa | t | α° | n |
|---|---|---|---|---|---|---|---|---|
| A-IV-V-32 | 1700 | 1100 | 300 | 125 | 100 | 35—40 | — | 32 |
| A-IV-V-32 | 1410 | 700 | 355 | 100 | 76 | 30—36 | — | 30 |
| A-IV-V-33 | 1375 | 600 | 352 | 125 | 108 | 39—50 | 18—26 | — |
| A-IV-V-37 | 1535 | 891 | 322 | 128 | 87 | 34—46 | 21—28 | — |
| A-IV-V-44 | 1750 | 1160 | 295 | 112 | 96 | 34—38 | — | 33 |

*Comparison. Macroporella ginkeli* RÁCZ sp. nov. bears a great similarity to the species found in the Apache Mountains (Texas) *Macroporella apachena* JOHNSON. From the Permian. The Spanish species differs from *Macroporella apachena* in two aspects: (1) the central stem of *Macroporella ginkeli* RÁCZ sp. nov. is relatively smaller than that of *Macroporella apachena* JOHNSON, (2) the thallus and the pores of the newly described species are comparatively much larger than those of the Permian alga from Texas. Other known species of *Macroporella* differ clearly from *Macroporella ginkeli* RÁCZ in both form and dimensions.
*Remarks.* These extremely well preserved calcareous algae are found locally in large numbers. Their striking form and very good preservability are easy to recognise.
*Locus typicus.* In the Lois-Ciguera Formation at locality 160.
*Biostratigraphic units.* Calcareous algal zone IV,
Fusulinella zone, sub-zone B 1.
*Holotype.* Slide no. A-IV-V-32 in the collection of the Department of Stratigraphy and Paleontology, Leiden University.
*Paratypes.* Slides no. A-IV-V-33, A-IV-V-37, A-IV-V-44 in the same collection.
*Figured specimens.* A-IV-V-32, A-IV-V-33, A-IV-V-44.

Genus Mellporella RÁCZ, gen. nov.

*Genotype. Mellporella anthracoporellaformis* RÁCZ, spec. nov.

*Diagnosis.* The thallus is cylindrical, not branched, and contains many small pores. In transverse section, the fragments of the algal body show a straight or waved surface and a slightly varying thickness. The central stem, which is relatively thick, has been filled with calcite cement. The outer part is perforated by many small pores. Sporangia are probably in the central stem.

The pores, which are present in large numbers, are dichotomously branched. In transverse section they are slightly expanded towards the outer surface. In tangential section, the pores are round and show an regular arrangement.
*Remarks.* Until now, only one paleozoic genus is known, *Anthracoporella,* in which the pores show a bifurcation. Because the thallus of *Anthracoporella,* as well as the pores, are branched, it can be concluded that the algae being described belong to a new genus. Two species of this genus were found: *Mellporella anthracoporellaformis* and

*Mellporella beundermani.* The former is found in the San Emiliano Formation and the latter in the Lois-Ciguera Formation.
*Occurrence.* These calcareous algae are mainly found in oolitic rocks, together with the genera *Archaeolithophyllum* and *Epimastopora.*

*Mellporella anthracoporellaformis* RÁCZ, sp. nov.

Plate IV, fig. 4, 5 and 6

*Description.* The thallus is cylindrical and not branched. The central part of the thallus, which is relatively thick, has been filled with crystalline calcite. The pores are short and present in large numbers (between 100 and 150). The pores show a small widening towards the outer surface, at the same time they bifurcate. The thickness of the pores varies slightly, 50 to 62 $\mu$ in diameter. In cross section the pores are fairly regularly arranged. No reproductive organs were found.

*Measurements*

| No. | D | d | w | p | n |
|---|---|---|---|---|---|
| I-b-90 | 2250 | 1800 | 200 | 62 | 144 |
| I-c-163 | 1130 | 870 | 130 | — | — |
| I-c-163 | 2020 | 1620 | 200 | 52 | 104 |
| I-b-91 | 2370 | 1870 | 250 | 62 | 112 |
| I-b-84 | 2280 | 1880 | 200 | 50 | 150 |
| I-b-84 | 2430 | 1980 | 225 | 56 | 148 |

*Remarks.* Because the vertical part of the thallus shows no dichotomy and the pore length is small, the species cannot be included with the already known genera of the *Dasycladaceae.*
*Locus typicus.* The San Emiliano Formation, SW of Cármenes in member no. II, locality R. 49.
*Biostratigraphic units.* Calcareous algal zone II,
Profusulinella zone, sub-zone A.
*Association. Mellporella anthracoporellaformis* is most commonly found together with the species *Epimastopora bodoniensis* sp. nov. and *Archaeolithophyllum johnsoni* sp. nov. usually in oolitic limestones.
*Holotype.* Slide no. I-b-90 in the collection of the Department of Stratigraphy and Paleontology, Leiden University.
*Paratypes.* Slides no. I-b-84, I-b-91 and I-c-163, in the same collection.
*Figured specimens.* Slides no. I-c-163 and I-b-90.

*Mellporella beundermani* RÁCZ, spec. nov.

Plate II, fig. 1, 2 and 3

*Description.* The thallus is cylindrical and not branched. The central part is relatively thick. The pores short and thin, but slightly thicker towards the outer surface. A bifurcation of the pores was seen. The pores are present in large numbers (60—80).

*Measurements.*

| No. | D | d | w | p | n |
|---|---|---|---|---|---|
| II-A-B-91 | 1050 | 870 | 90 | 25 | 65 |
| II-A-B-84 | 1280 | 1000 | 150 | 30 | 78 |
| II-A-B-91 | 1350 | 1074 | 138 | 28 | 79 |
| II-A-B-81 | 1146 | 954 | 96 | 32 | 76 |

*Locus typicus.* Lois-Ciguera Formation, to the north of Canseco, in loc. 216.
*Biostratigraphic unit.* Calcareous algal zone III,
Profusulinella zone, sub-zone B,
Fusulinella zone, subzone A.
*Association. Pseudokomia cansecoensis, Dvinella comata, Epimastopora rolloensis* and *Zaporella cantabriensis.*
*Holotype.* Slide no. II-A-B-91 in the collection of the Dept. Stratigr. & Pal., Leiden University.
*Paratypes.* Slides no. II-A-B-81 and II-A-B-84 in the same collection.
*Figured specimens.* Slides no. II-A-B-91 and II-A-B-81.

Genus Uraloporella KORDE, 1950

*Uraloporella sieswerdai* RÁCZ, spec. nov.

Plate IV, fig. 8 and plate V, fig. 1, 2 and 3

*Description.* The thallus consists of a segmented, usually arched, cylindrical body. It is not branched. The size of the segments varies between 300 and 400 $\mu$. The central stem is relatively thick and filled with calcite. Geopetal pore filling can often be seen. The outer surface of the central stem is not flat, but shell-formed. This structure is formes by the rounded inner ends of the pores. The very fine, regularly arranged, and needle-like pores stand perpendicular to the outer surface. These secondary pores are present in large numbers. In axial section the pores are cylindrical, or slightly expanded towards the outer surface. No dichotomy of the needle-like structures was seen. The pores are usually straight, slightly bent at the extremity towards the outer surface. This gives rise to a fan-like structure.

The presence of all the needle pores gives the thallus its brush form. Above the "pore layer" there is a thin (8 to 17 $\mu$) calcite layer which formes the outermost part of the body. Occasionally, in axial section, there are usually vague pores, lying far apart. No reproductive organs were found.

*Measurements.*

| No. | D | d | w | l | n |
|---|---|---|---|---|---|
| III-IV-S-79 | 550 | 425 | 62 | 7200 | — |
| III-IV-S-79 | 500 | 375 | 62 | 6100 | — |
| III-IV-S-80 | 520 | 450 | 35 | 3400 | — |
| III-IV-S-80 | 435 | 325 | 55 | — | 146 |
| III-IV-S-78 | 650 | 490 | 80 | — | 134 |

*Remarks.* The principal construction resembles that of *Dvinella.* There are differences expressed in the size of the thallus in cross section, the cross section of the central portion, the way in which the thickness of the wall originated, and the arrangement and form of the primary pores, which all show that we are dealing with another genus.

*Uraloporella variabilis* KORDE is smaller in every respect than the presently described species *Uraloporella sieswerdai.*

*Locus typicus.* The Lois-Ciguera Formation at locality 513.

*Biostratigraphic unit.* Calcareous algal zone II (upper part),
Fusulinella zone, subzone A.

*Association. Dvinella comata,* CHVOROVA and *Zaporella cantabriensis,* spec. nov.

*Holotype.* Slide no. IIII-V-S-79 in the collection of the Dept. Stratigr. & Paleont., Leiden University.

*Figures specimens.* Slides no. III-IV-S-79, III-IV-S-80.

## Genus Zaporella RÁCZ, gen. nov.

*Genotype. Zaporella cantabriensis* RÁCZ, spec. nov.

*Description.* The thallus is club-shaped. The central stem is relatively thin. In a few cases the outer part of the plant forms two concentric rings. There are primary, secondary and tertiary branches in the outer part. The primary branches are cylindrical or shield-shaped, and regularly arranged.

In cross-section, the primary and secondary branches are of equal thickness. The secondary branches arose through dichotomous branching of the primary branches. The tertiary branches arise in groups (usually 3 or 4) at the end of the secondary branches.

The three types of branch can be more clearly distinguished in axial section. Where two layers are present, it can be seen in some specimens that the tertiary branches arise at the partition line between the two layers. At other times the impression is given that the branches in the outer "layer" are randomly arranged until

the inner "layer". The thallus is subspherical at the uppermost end. In tangential section it can be seen that the pores are regularly arranged. In this section a slightly deformed honeycomb-structure can also be seen.
*Remarks.* The three types of branches are not found in every specimen. Even less common is the division of the outer part of the thallus. These are probably dependent on the position, where they are present on the plant.

### *Zaporella cantabriensis* RÁCZ, spec. nov.

*Description.* The thick thallus is club-shaped. The central stem is relatively thin and filled with calcite cement. Primary, secondary and tertiary branches are present. The primary branches are well preserved cylindrical elements. Double secondary branches grow out of the ends of the primary branches. Two or more tertiary branches can develop at the ends of the secondary branches.
*Measurements.* D = 1550—4600 $\mu$; d = 1200—3500 $\mu$; w = 275—550 $\mu$; p = 50—75 $\mu$; t = 25—40 $\mu$; n = 64—100.
*Locus typicus.* Lois-Ciguera Formation, to north of Canseco, at loc. 216.
*Biostratigraphic unit.* Calcareous algal zone III,
Profusulinella zone, sub-zone B; Fusulinella zone, sub-zone A.
*Association. Epimastopora rolloensis, Dvinella comata* and *Mellporella beundermani.*
*Holotype.* Slide no. II-A-B-43 in the collection of the Department of Stratigraphy and Paleontology. Leiden University.
*Paratypes.* Slides no. II-A-M-53, II-A-B-42 and II-A-G-5 in the same coll.
*Figured specimens.* Slide no. II-A-B-43, II-A-M-53 and II-A-G-5.

### Family CODIACEAE (Trevisan) Zanardini, 1843
### Genus Donezella MASLOV, 1929
*Genotype. Donezella lutugini* MASLOV

*Remarks on the construction.* The thallus can be round, egg-shaped, or heart-shaped, with a vaulted edge. It consists of a ramification of small and very branched tubes, which lie in a dark matrix. The tube are segmented with partitions which are usually perpendicular to the walls of the tubes. The tubes can be divided into two parts, a central part which is filled with calcite cement, and an outer wall structure. Where partitions are present, the tubes are slightly constricted. The partitions, which separate the elongated cells, can be perforated in one place, but in many cases this does not occur. Where a perforation is present, the partitions do not lie horizontally through the whole breadth of the tube, but approximately in the middle part of the central region where they end. These "half" partitions do not originate at the same horizontal level, and a small vertical interval can be seen between them. The tubes may — not in every case — narrow towards the upper end, seen in axial section. The uppermost end of the segmented tube is rounded, with the uppermost cell lump-formed.

The branching between two tubes can be random, but many cases are found where the two tubes are perpendicular to each other. Where the tubes have branched there is a thickening of both branches (or only of one) at contact points. The wall structure of the tubes consists of two parts: a thick inner-, and a thin outer part. The inner part, which is darker in the fossil state, shows indications that at some places it is constructed from very fine needle structures. This is not certain. The outer part of the tube wall consists of a thin calcite layer. Generally the partitions of the barrel-shaped cells can be followed to the outer edge of the calcite shell, thus to the outer surface of the tube.

In cross section, the tubes are more or less round and in well preserved specimens the main construction of the tubes can be clearly seen. The genus Donezella is represented is NW Spain by the species *Donezella lutugini* MASLOV and *Donezella lunaensis* spec. nov. These two species can be separated by the different origins of the partitions, and the form and dimensions of the cells.

*Systematic position of the genus.* Maslov (1929 and 1963) considered the genus *Donezella* as a red alga of uncertain affinity. The presence of a thallus constructed of fine branched tubes is found in the Chlorophyta (for example in the genera *Bevocastria, Garwoodia, Ortonella,* etc.).

The fine pores of the calcite portion which stand perpendicularly to the wall — which are indistinct in *Donezella* — are most typical of the green algae. Segmented types are also more commonly found in the Chlorophyta than in the Rhodophyta, and there is also the possibility of dividing the wall structure, into two parts. It has therefore been concluded that the systematic position of *Donezella* is more appropriate to the Chlorophyta than to the Rhodophyta.

*Donezella lutugini* MASLOV, 1929

Plate VII, fig. 2 and 3

1929, Donezella lutuginii MASLOV – Izv. Geol. Kom. t. 48, no. 10, p. 125—128, fig. 8 à 21, pl. XXI, fig. 5—9.
1949, Donezella lutuginii MACHAEV – Bull MOIP. otd. geol. 18, p. 67—68, pl. II, fig. 3.
1956, Donezella lutuginii MASLOV – Calcareous fossil algae of the SSSR Akad. Nauk, p. 76, pl. XXIV, fig. 1—3.
1962, Donezella lutuginii MASLOV – Algues rouges fossiles d'U.R.S.S. etc. Trudy Geol. Inst. SSSR, no. 53, 222 p., 128 fig.

*Description.* The thallus is usually round, egg-shaped, or heart-shaped. The edge of the thallus is wavy. The thallus is built of many arched tubes. The tubes are almost always branched. The tubes are cylindrical, but constricted. These constrictions occur where partitions separate the barrel-shaped cells of the tube.

The central cavity of *Donozella lutigini* is narrow, it is often only a few $\mu$. The partitions, which are usually 20 to 40 $\mu$ apart, are perforated because the two half partitions do not meet. There is a calcite shell on the outside of the tube. The angle of branching of the varies, but smaller angles than 45° are rare. The branches which stand perpendicularly to each other, or slightly less than 90°, are the most commonly found. The thickness of the tubes is small, 30 to 50 $\mu$ in most cases.

*Remarks.* It has appeared from the study that the great variation in the size and breadth of the tubes is not as dependent on their age or their position in the thallus, as MASLOV (1963) suggests, but probably to the environment in which the algae lived. It has often been noted that under various conditions all the tubes in the thallus have changed. It has also been noted that in a few cases, the tubes are larger near the perifery of the thallus.

| | | |
|---|---|---|
| *Dimensions.* | Tube length: | from 150 to 600 $\mu$ |
| | Tube diameter: | from 25 to 55 $\mu$ |
| | Diameter of inner part: | from 16 to 45 $\mu$ |
| | Wall thickness: | from 8 to 13 $\mu$ |
| | Partition thickness: | from 5 to 15 $\mu$ |
| | Partition distance: | from 20 to 60 $\mu$ |

*Material.* In the collection of the Dept. Stratigr. & Paleont., Leiden University from the San Emiliano Formation, member no. II, to the south of Cármenes, at locality R. 43 (slides no. 8-409, I-c-124, I-c-125 and I-c-126).
*Biostratigraphic position.* Calcareous algal zone I, II, III and IV,
Profusinella and Fusulinella zones.
*Association.* Examples of *Donezella lutugini* MASLOV are found together with almost all the algal genera. There are local plazes where they are present in enormous accumulations, thus playing an important role as rock builders.
*Figured specimens.* Slides no. 8-409 and I-c-124.

### *Donezella lunaensis* RÁCZ, spec. nov.

Plate VI, fig. 4, 5 and 6 and Plate VII, fig. 1

*Description.* The thallus is large, but less distinct than that of *Donezella lutugini* MASLOV. The loosely arranged branched tubes, with a clearly discernable wall structure, are usually segmented by small partitions. This gives a cell structure to the tubes. At the points, where the partitions are present, there is a definite constriction of the tubes. The uppermost sement is rounded and has a lump shapes cell. The partitions are usually perpendicular to the walls. The central part of the tubes is filled with calcite cement. The wall structure consists of two parts:

a. an inner, thick, in fossilized condition darker coloured, with apparent perforations,
b. a thin outer calcite shell.

In the inner part of the wall, the perforations can arise through the presence of small pores or canals, which are arranged perpendicularly to the wall. This is very indistinct in the wall structures.

The branching is variable, but examples are often found where two tubes stand perpendicularly to each other. The branches are thickened at the branching points.

| | | |
|---|---|---|
| *Dimensions.* | Tube length: | from 1000 to 2200 μ |
| | Tube diameter: | from 160 to 225 μ |
| | Diameter of inner region: | from 100 to 120 μ |
| | Wall thickness: | from 33 to 40 μ |
| | Perforated wall thickness: | from 23 to 28 μ |
| | Thickness of calcite layer: | from 10 to 15 μ |
| | Partition thickness: | from 12 to 20 μ |
| | Distance between partitions: | from 100 to 225 μ |

*Locus typicus.* In the San Emiliano Formations, member no. IV to the NW of Barrio de la Tercia, in locality R. 471.
*Biostratigraphic unit.* Calcareous algal zone II,
Profusulinella zone, sub-zone A.
*Association. Donezella lutugini* MASLOV and *Petschoria elegans* KORDE.
*Holotype.* Slide no. I-c-471 in the collection of the Dept. Stratigr. & Pal., Leiden University.
*Paratype.* Slide no. I-c-471a in the same collection.
*Figures specimens.* Slide no. I-c-471 and I-c-471a.

Genus Eugonophyllum Konishi & Wray, 1961
*Eugonophyllum mulderi* Rácz, spec. nov.

Plate XII, fig. 1, 2, 3 and 4

*Description.* The thallus has a leafy form, which is sporadically perforated. The leaves show an undulation and vary in length and thickness. The wall structure is divided into two parts: a central part, called medulla, which is filled with crystallized calcite cement, and an outer part, called the cortex. The cortex can also be divided into an outer-cortex and an inner-cortex (sub-cortex) where the outer-cortex is crystallized. The thickness of the thallus varies between 180 and 870 $\mu$, that of the medulla between 50 and 520 $\mu$. The sub-cortex, which is at the outer surface, has a thickness of 40 to 50 $\mu$. The length of the cortex varies between 65 and 125 $\mu$, that of the outer-cortex is 30 to 62 $\mu$. In some examples, indistinct circle forms can be seen on the exterior upper surface.
*Remarks.* Concerning the form of the alga, in certain cross-sections the examples of the thallus have a circular form (see fig. 3). It is assumed that the leafy structures of the thallus, without abrupt differentiation, have gradually formed a cylindrical "stem", which held the plant fast. The circular form would thus be found in the cross-section of such a "stem" fragment. In these cross-sections the examples show the same structure as is present in the walls of the leaves.
*Comparison. Eugonophyllum mulderi* Rácz spec. nov. resembles *Eugonophyllum johnsoni* Konishi & Wray, but the diameter of *Eugonophyllum mulderi* Rácz is greater than that of the latter. Another difference is that the thickness of the medulla, of the presently described species, is very variable. In some extreme cases, it is so thin that the cortex, which is present on both sides, almost meets.
*Locus typicus.* In the Lois-Ciguera Formation, north of Rucayo, in loc. 160.
*Biostratigraphic units.* Calcareous algal zone IV,
Fusulinella zone, sub-zone $B_1$.
*Association.* The genera *Komia* and *Macroporella* are found together with *Eugonophyllum mulderi* Rácz spec. nov.
*Holotype.* Slide no. II-A-V-160 in the collection of the Dept. Stratigr. & Paleont., Leiden University.
*Paratypes.* Slides no. II-A-V-160a, 160b, 160c, in the same collection.
*Figured specimens.* Slides no. II-A-V-160, 160a.

Genus Ortonella Garwood, 1914
*Ortonella myrae* Rácz spec. nov.

Plate VII, fig. 4, 5 and 6

*Description.* The thallus has the form of a slightly deformed lamp bulb. It is filled with small branched tubes. The branching resembles that of blood veins, which are straight or slightly bent. There is a main branch from which the smaller branches spread out. At the uppermost extremity the main branch has dichotomous branching. All the tubes are bent, but not wavy, and have a round form in cross-section. The angle of branching is variable, but a division can be made of two types:

a. 16—21° (about 60 % of all branches, of which most lie between 16—18°)
b. 34—42° (about 40 % of the branches).

These forms cannot be divided into a particular system. The diameter (d) of the tubes varies between 40 and 50 $\mu$. No conceptacles were found.
*Comparison.* On the basis of form and characteristics, *Ortonella myrae* RÁCZ spec. nov. is close to the species *Ortonella furcata* GARWOOD, *Ortonella moscovica* MASLOV and *Ortonella kershopensis* GARWOOD. This is based on the size of the tubes and the angle of branching.

| | d | $\alpha^{\circ}$ |
|---|---|---|
| Ortonella kershopensis | 10—12 | 45—50 |
| Ortonella furcata | 32 | 40 |
| Ortonella moscovica | 40 | 65 |
| Ortonella myrae | 40—50 | 16—21 and 34—42 |

The best positioning of *Ortonella myrea* is most probably between *Ortonella furcata* GARWOOD and *Ortonella moscovica* MASLOV.
*Association. Ortonella myrea* spec. nov. is found together with *Ungdarella uralica* MASLOV and *Donezella lutugini* MASLOV.
*Locus typicus.* The uppermost part of the Escapa Formation (locality R. 36), North of Pedrosa.

*Biostratigraphic units.* Calcareous algal zone I,
Profusulinella zone, sub-zone A.
*Holotype.* Slide no. I-a-46 in the collection of the Department of Stratigraphy and Paleontology, Leiden University.
*Paratypes.* Slides no. I-a-47 and I-a-48 in the same collection.
*Figured specimens.* Slides no. I-a-46 and I-a-48.

Phylum SCHIZOPHYTA (Falkenberg) Engler, 1892
"Section" POROSTROMATA Pia, 1927
Genus Girvanella NICHOLSON & ETHERIDGE, 1880
*Girvanella* spec.

Plate XIII, fig. 6

*Description.* The species is characterized by a rather indistinct tabular filaments, which are separated by a — sometimes thick — wall. In most cases it is present around hard fossil fragments (brachiopod shell fragments, corals, bryozoans, etc.) forming an elliptical or egg-formed mass. No branching of the tubes was seen.
*Remarks.* The specimens are very dark, which made measurement impossible. It was thus only possible to determine the genus.

*Material.* In the collection of the Department of the Stratigr. and Paleont., Leiden University. Slides no. I-b-476, I-b-476a, I-b-77 from the San Emiliano Formation; slide no. II-A-M-66 from the Lois-Ciguera Formation.
*Locus typicus.* San Emiliano Formation, locality R. 476.

*Biostratigraphic unit.* Found in every calcareous algal zone,
Every Fusulinella zone contains specimens.
*Association. Beresella herminae, Epimastopora bodoniensis, Epimastopora, Donezella lutugini, Mellporella beundermani*, etc.
*Figured specimens.* Slide I-b-476.

Genus Osagia TWENHOFEL, 1919
*Osagia* spec.

Plate XIII, fig. 3

*Description.* The species only occurs as a colony of varing sized cylindrical or arched and wavy tubes. Very often they are present as encrusting material over other types of fragment. This results in a considerable variation in the length and thickness of the colonies.
*Remarks.* It is Johnson's opinion (1946, p. 1104) that there is so little variation in the genus, from formation to formation, that no sub-division can be attempted.
*Material.* In the collection of the Strat. and Pal. Dept., Leiden University. Slides no. I-b-605 from loc. R. 476 in the San Emiliano Formation; slides no. II-A-O-48, II-A-V-18, from locality 151 in the Lois-Ciguera Formation.
*Biostratigraphic unit.* Calcareous algal zones I, II, III and IV,
Profusulinella and Fusulinella zones.
*Figured specimens.* Slide no. I-b-604.

"Section" SPONGIOSTROMATA PIA, 1927
Genus Pycnostroma GÜRICH, 1906
*Pycnostroma* spec.

Plate XIII, fig. 5

*Description.* Concentrically developed crust forming algae. The relatively thick crust is formed by parallel layers, which are generally laminated. There is an alternation of colour from light to dak layers or groups of layers.
*Material.* In the collection of the Strat. and Pal. Dept., Leiden University. Slides no. I-b-51, 52 and I-c-24 from the San Emiliano Formation.
*Biostratigraphic unit.* Calcareous algal zones I, II, III and IV,
Profusulinella and Fusulinella zones.
*Figured specimens.* Slide no. I-b-51.

# REFERENCES


AGER, D. V., 1963. Principles of Paleoecology. McGraw-Hill Book Comp. Inc. New York, San Francisco, Toronto, London, p. 371.

AISENVERG, D. E. et al., 1960. Carboniferous stratigraphy of the Donetz Basin. C.R., 4e Congr. Strat. Géol. Carb., t. I, pp. 1–12.

BARROIS, CH., 1882. Recherches sur les terrains anciens des Asturies et de la Galice. Mém. Soc. géol. Nord, II, 1, pp. 1–630, pls. I–XX.

BOUCOT, A. J., 1953. Life and death assemblages among fossils, Am. Jour. Sci., Vol. 251, pp. 25–40.

BROUWER, A., 1959. Algemene paleontologie. W. de Haan N.V., Zeist, 200 p.

—— 1962. Enkele beschouwingen over de geologische geschiedenis van rifbbouwers en organische riffen. E. J. Brill, Leiden, pp. 5–37.

BROUWER, A. & A. C. VAN GINKEL, 1964. La succession Carbonifère dans la partie méridionale des montagnes Cantabriques (Espagne du Nord-Ouest). C.R. 5e Congr. de Strat. et de Géol. du Carbonifère, v. 1, pp. 307–319.

BUCHER, W. H., 1920. Observations on Organisms and Sedimentations on Shallow Sea-bottoms. Am. Midland Naturalist, v. 11, pp. 236–242.

CHURAKOV, A. N., 1945. The significance of algae for the age determination of earliest formations; Osagia Twenhofel. Akad. Sci. U.S.S.R. Bull., ser. geol., no. 3, pp. 135–148 (in Russian, English summary, pp. 149).

CHVOROVA, L. V., 1946. On a new genus of algae from the Middle Carboniferous deposits of the Moscow basin. Akad. Sci. U.S.S.R., C.R. (Doklady), v. 53, no. 8, pp. 737–739, 2 figs.

CLIFTON, R. L., 1944. Paleoecology and environments interferred for some marginal Middle Permian strata. Am. Assoc. Petrol. Geol. Bull., v. 28, pp. 1012–1031.

CLOUD, P. E., Jr., 1948. Assemblages of diminutive Brachiopods and their Paleoecological significance. Jour. Sed. Petrol., v. 18, pp. 56–60.

COLOM, G., 1953. Las "alguas perforantes". Est. Geol. España, no. 19, pp. 353–368, 2 figs., 8 pls.

COMTE, P., 1959. Recherches sur les terrains anciens de la Cordillère cantabrique. Mem. Inst. Geol. Min. Esp., 60.

CRAIG, G. Y., 1953. Fossil Communities and Assemblages. (Discussion of Boucot, 1953). Am. Jour. Sci., v. 251, pp. 547–548.

CUMMINGS, E. R., 1932. Reefs or Bioherms? Geol. Soc. Amer. Bull., v. 43, pp. 331–52.

DELÉPINE, C., 1943. Les faunes marines du Carbonifère des Asturies (Espagne). Mém. Akad. Sci. Inst. France, 66, pp. 1–122, pls. I–VI. (Trad. extr. P. H. Sampelayo, 1946: Faunas marinas del Carbonífero de Asturias. Bol. Inst. Geol. Min. España, LIX, pp. 21–127, láms. I–VI).

DUNHAM, R. J., 1962. Classification of carbonate rocks according to depositional texture; in classification of carbonate rocks; a symposium; mem. 1: Am. Ass. Petrol. Geol., pp. 108–121.

ELIAS, M. K., 1937. Depth of deposition of the Big Blue sediments in Kansas. Geol. Soc. America Bull., v. 48, pp. 403–432.

—— 1946. Fossil symbiotic algae in comparison with other fossil and living algae, *in* Symposium on Paleobotanical Taxonomy. Am. Midland Naturalist, v. 36, no. 2, pp. 282–290, 20 figs.

ENDO, R., 1954A. Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan; IX, Interesting species from the Yayamadake limestone subgroup, Kyushus and new species from Sakamotomura, Taga-gun, Ibaraki-ken. Saitama Univ. Sci. Rept., ser. B, v. 1, no. 3, pp. 217–220, illus.

—— 1958. Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan. XIII: A restudy of the genus Physoporella. Trans. Proc. Palaeont. Soc. Japan, N.S., no. 31, pp. 265–269, pls. 39.

—— 1960. Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan. XV: A restudy of the genus Epimastopora. Sci. Rep. Saitama Univ., ser. B, v. 3, no. 3, pp. 267–270, pl. 44.

ENDO, R. & M. KANUMA, 1954. Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan; VII: Geology of the Nino mountain land and southern part of Hido plateau, with descriptions of the algal remains found in those districts. Saitama Univ. Sci. Rept., ser. B, v. 1, no. 3, pp. 177–205, illus.

ENDO, R. & M. HORIGUCHI, 1957. Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan; XII: Fossil algae from the Dept. of Earth Sciences Saitama University, Urawa, Japan. Japan. Jour. Geol. & Geograph., v. 28, pp. 169–179.

FENTON, C. L., 1935. Viewpoints and Objects of Paleoecology. Jour. Paleont., v. 9, pp. 63–78.

FENTON, C. L. & M. A. FENTON, 1933. Algal reefs or bioherms in the Belt series of Montana. Geol. Soc. Amer. Bull., v. 44, no. 6, pp. 1135–1142.

FLÜGEL, H., 1963. Algen und Problematica aus dem Süd-Anatonliens und Irans. Osterr. Akad. Wiss. Mathem.-naturw. Kl., Abt. I, 172, Bd., 1. und 2. Heft, pp. 86–95.

FÖLDVÁRI, A., 1952. A szabadbattyáni ólomérc — és Kövületes Karbonelőfordulás. Magy. Tud. Akad. Müsz. Oszt. Közl. V., no. 3, pp. 25–53.

FOLK, R. L., 1959. Practical petrographic classification of limestones. Am. Ass. Petrol. Geol. Bull., v. 43, no. 1, pp. 1–38.

—— 1962. Spectral subdivision of limestone types; *in*: Classification of carbonate rocks; a symposium. Mem. 1, Am. Ass. Petrol. Geol., p. 62–84.

GINKEL, A. C. VAN, 1960. The Casavegas section and its fusulinid fauna. Leidse Geol. Med., v. 24/2, pp. 705–720.

GINSBURG, R. N., 1956. Environmental relationships of grain size and constituent particles in some South Florida carbonate sediments. Am. Ass. Petrol. Geol. Bull., v. 40, no. 10, pp. 2384–2427.

GRABAU, A. W., 1904. On the classification of sedimentary rocks. Am. Geologist, v. 33, pp. 228–247.

HERAK, M., 1960. Calcareous algae of the young Paleozoic and Mesozoic of Yugoslavia and their application in the stratigraphy. Report of the 21-Session (Norden) of the Int. Geol. Congr., 1960, part VI, Proc. of Sec. 6, pp. 90–97, 2 text-figs.

HERITSCH, F., 1934. Die Stratigraphie von Ober-Karbon und Perm in den Karnischen Alpen. Geol. Gesell. Wien, Mitt. 26, 162 p.

HIGGINS, A. C., 1962. Conodonts from the "Griotte" limestone of Northwest Spain. Not. Comun. Inst. Geol. Min. España, 65, pp. 5–22, 1–3 pls.

HIGGINS, A. C. et al., 1964. Basal Carboniferous strata in part of northern León, NW Spain. Stratigraphy of conodont and goniatite fauna. Bull. Soc. belge. Geol., Pal., Hydrol., t. LXXII, fasc. 2, pp. 205–248.

IVANOVA, E. A., 1953. A detailed comparison of the marine deposits, based on their fauna (in Russian). Pal. Inst. Geol. Nauk SSSR., pp. 92–110.

IVANOVA, E. A. & KHVOROVA, 1955. Stratigraphy of the Middle and Upper Carboniferous in the Eastern part of the Moscow Syncline. Trud. Paleont. Inst. Akad. Nauk SSSR., v. 53, pp. 1–282 (in Russian).

JABLONSZKY, E., 1919. Die Karbonalgen Ungarns. Földtani Közlöny, v. 48, 449 p.

JACKSON, J. W., 1941. Description of a Carboniferous limestone section *Girvanella* in North Derbyshire. Manchester Geol. Ass. Jour., v. 1, pp. 230–246.

JOHNSON, G. A. L., 1958. Biostromes in the Namurian great limestone of northern England. Paleontology, v. 1, part 2, pp. 147–157, pls. 30–31.

JOHNSON, J. H., 1938. Algal limestones from the Pennsylvanian of Central Colorado (abs.). Geol. Soc. Am. Proc., 1937, pp. 89–90.

—— 1938A. *Nubecularia* and *Girvanella* from the Pennsylvanian near La Luz, N. Mex. (abs.). Geol. Soc. Am. Bull., v. 49, no. 12, pt. 2, p. 1889.

—— 1944. Paleozoic stratigraphy of the Sawatch Range, Colorado. Bull. Geol. Soc. Am., v. 55, pp. 303–378, 7 figs.

—— 1945. Calcareous algae as useful microfossils. Jour. Paleontology, v. 19, no. 4, pp. 350–354, 2 pls.

—— 1946A. Lime-secreting algae from the Pennsylvanian and Permian of Kansas. Geol. Soc. Am. Bull., v. 57, no. 12, pp. 1087–1120, 10 pls., 5 figs.

—— 1951. Permian calcareous algae from the Apache Mountains, Texas. Jour. Paleontology, v. 25, no. 1, pp. 21–30, 5 pls.

—— 1954. An introduction to the study of rock building algae and algal limestones. Colorado School Mines Quart., v. 49, no. 2, pp. 1–116.

—— 1956. *Archaeolithophyllum*, a new genus of Paleozoic coralline algae. Jour. Paleontology, v. 30, no. 1, pp. 53–55, 1 pl.

—— 1961. Limestone-building algae and algal limestones. Colorado School Mines, 297 p.

—— 1963. Pennsylvanian and Permian algae. Colorado School Mines Quart., v. 58, no. 3, 211 p.

JOHNSON, J. H. & K. KONISHI, 1956. Studies of Mississippian algae. Colorado School Mines Quart., v. 51, no. 4, 133 p.

JOHNSON, R. G., 1960a. Models and Methods for Analysis of the Mode of Formation of Fossil Assemblages. Geol. Soc. Am. Bull., v. 21, no. 455, pp. 1075–1086.

—— 1960b. Pennsylvanian Life Assemblages, Western Illinois. (Abstract only). Progr. Geol. Soc. Am. Ann. Mtg., pp. 130–131.

—— 1962a. Interspecific Associations in Pennsylvanian Fossil Assemblages. Jour. Geol., v. 70, pp. 32–55.

KOCHANSKY, V. & M. HERAK, 1960. On the Carboniferous and Permian Dasycladaceae of Yugoslavia. Geol. Vjesnik, Zagreb, v. 13, pp. 65–94, 9 pls., 7 text-figs.

KOCHANSKY-DEVIDÉ, V., 1964. Die Fusuliniden und Kalkalgen des Jugoslavischen Karbons. C.R. 5e Congr. Strat. Géol. Carb., t. II, pp. 513–518.

KONISHI, K. & J. L. WRAY, 1961. *Eugonophyllum*, a new Pennsylvanian and Permian algal genus. Jour. Paleontology, v. 35, no. 4, p. 659.

KORDE, K. B., 1950B. On the morphology of the Dasycladaceae of the Carboniferous strata of the Northern Ural. Akad. Nauk USSR Doklady, v. 73, no. 3, pp. 569–571 (in Russian).

—— 1951. Novye rody i vidy izvestkovyh vodorosli iz kamennougolnykh otlozhenii severnogo Urala. Moskov. Obshch. Ispyt. Prirody, Trans., Otdel Geol., t. 1, pp. 175–182, illus.

LADD, H. S., 1944. Reefs and other bioherms. Natl. Res. Council, Div. Geol. Geog. Ann. Rept. 4, app. K, pp. 26–29.

LLADO, LLOPIS, 1955. Estudio geologico del Reborde meridional de la cuenca Carbonifera de Asturias. Monogr. Geol. III Oviedo.

LOWENSTAM, H. A., 1950. Niagaran reefs of the Great Lakes area. Jour. Geol., v. 58, no. 4, pp. 430–487.

MAKHAEV, B. N., 1937. Les algues comme fossiles caracteristiques. Akad. Sci. U.R.S.S. Comtes rendus (Doklady), new ser., v. 15, no. 8, pp. 483–486.

MASLOV, V. P., 1939. Contributions to the knowledge of the fossil algae of the U.S.S.R. VIII. A new microonkolite from the Lower Paleozoic of the Yenisei Taiga IX. A discovery of green algae in the Paleozoic of Kazakhstan. Problems of Paleontology, v. 5, pp. 28–297 (in Russian with English summary), 4 figs., 2 pls.

—— 1956. "Algues calcaires fossiles de l'URSS": Trudy Inst. Geol. Nauk SSSR, no. 160, 301 p., 86 tbls.

—— 1962. Algues rouges fossiles d'U.R.S.S. et leur rapport avec les faciès. Trudy Geol. Inst., SSSR, no. 53, (Bur. Rech. géol. min. Paris, trad. 3811).

MOORE, R. C., 1936. Stratigraphic classification of the Pennsylvanian rocks of Kansas. Geol. Surv. Bull., v. 22.

—— 1948. Remarks on environmental significance of dwarfed faunas at S.E.P.M. symposium. Jour. Sed. Petrol., v. 18, no. 3, pp. 126.

—— 1957. Modern methods of Paleoecology. Am. Ass. Petrol. Geologist Bull., v. 41, no. 8, pp. 1775–1801.

MUDGE, M. R. & E. L. YOCHELSON, 1962. Stratigraphy and Paleontology of the uppermost Pennsylvanian and Lowermost Permian rocks in Kansas. Geol. Surv. Prof. Paper 323.

NELSON, H. F., et al., 1962. Skeletal limestone classification, in: Classification of carbonate rocks; a symposium, memoir 1: Am. Ass. Petrol. Geol., pp. 224–252.

NEWELL, N. D., et al., 1953. The Permian Reef Complex of the Guadalupe Mountains Region, Texas and New Mexico — a study in Paleoecology. W. H. Freeman & Comp., San Francisco, 233 p.

OELE, E., 1964. Sedimentological aspects of four Lower-Paleozoic formations in the Northern part of the province of León (Spain). Thesis, Leiden, 99 p.

PARKER, R. H., 1955. Changes in the Invertebrata Fauna, Apparently Attributable to Salinity Changes in the Bays of Central Texas. Jour. Paleont., v. 29, no. 2, pp. 193–211.

—— 1956. Macro-Invertebrata Assemblages as Indicators of Sedimentary Environments in East Mississippi Delta Region. Am. Ass. Petroleum Geologist Bull., v. 40, no. 2, pp. 295–376.

PIA, J., 1912. Neue Studien über die triadischen Siphoneae verticillatae. Beitr. Paläontologie Österr.-Ungarns u. des Orients 25, 25 pls.

—— 1920. Die Siphoneae vericillatae vom Karbon bis zur Kreide. Zool.-bot. Gesell. Wien, Abh., v. 11, no. 2.

—— 1926b. Pflanzen als Gesteinsbildner, Berlin, 355 p.

—— 1927. Neue Beobachtungen über die geologische Verbreitung fossiler Kalkalgen. Akad. Wiss. Wien. Math.-naturw. Kl., Anz., v. 64, 92 p.

—— 1927. "Thallophyta", in: Hirmer, Handbuch der Paläobotanik, v. 1, Berlin.

—— 1937. Die wichtigsten Kalkalgen des Jungpaläozoikums und ihre geologische Bedeutung. 2d Congr. av. etudes stratig. Carbon., C.R. no. 2, pp. 765–856, 2 figs., 13 pls.

PLUMLEY, G. A., et al., 1962. Energy index for limestone interpretation and classification, in: Classification of carbonate rocks; a symposium; mem. 1, Am. Ass. Petroleum Geol., pp. 85–107.

RAKUSZ, GY., 1928. Die stratigraphische Stellung des karpathischen marinen Oberkarbons. Congr. stratigr. carbon., 1927, C.R., 561 p.

—— 1932. Dobsínai és nagyvisnyói felsökarbon kövületek. Geol. Hung. Ser. Paleont., no. 8, pp. 1–223, tbl. I–XI.

SITTER, L. U. DE, 1956. Structural geology. New York, McGraw-Hill, 552 p.

—— 1962. The structure of the southern slope of the Cantabrian Mountains: explanation of a geological map with sections, scale 1 : 100.000: Leidse Geol. Meded., 26, pp. 255–264.

TERRIERE, R. T., 1963. Petrography and Environmental Analysis of some Pennsylvanian limestones from Central Texas. Geol. Surv. Prof. Paper 315-E.

TURNER, J. S., 1948. New records of Carboniferous algae and rugose coral. Leeds Geol. Ass., Trans., v. 6, pt. 2, pp. 72–74.

WAGNER, R. H., 1962e. An upper Westfalian flora from the mine "Inés", near the Pass of Pajares, on the Leonese-Asturian boundary (NW Spain). Not. Com. Inst. Geol. Min. España, 68, pp. 79–102, pls. 1–5.

—— 1963. A general account of the Paleozoic rocks between the rivers Porma and Bernesga (León, NW Spain). Bol. Inst. Geol. Min. España, t. 74, 163 p.

WELLER, I. M., 1960. Stratigraphic principles and practice. Harper and Brothers, publishers, New York.

WILSON, E. C., et al., 1963. A new species of *Komia* KORDE and the systematic position of the genus. Paleontology, v. 6, pt. 2, pp. 246–253.

WOOD, A., 1940. Two new calcareous algae of the family Dasycladaceae from the Carboniferous limestone. Geol. Soc. Liverpool Proc., v. 18, pt. 1, pp. 14–18, 1 fig., 1 pl.

—— 1941B. The algae nature of the genus *Koninckopora* Lee in Canada and Western Europe (abs.): Geol. Soc. London Proc. 1940—41, no. 1380, p. 77—78, discussion by author, H. P. Lewis, W. N. Edwards, M. A. Arber, A. G. Davis, and K. P. Oakley, pp. 78—80.

—— 1943. The algal nature of the genus *Koninckopora* Lee, its occurrence in Canada and Western Europe. Geol. Soc. London Quart. Jour., v. 98, pts. 3–4, nos. 391–392, pp. 205–221 (discussion, pp. 221–222), 3 pls, 3 figs.