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THE INFLUENCE OF HURRICANES UPON THE QUIET DEPOSITIONAL CONDITIONS IN THE LOWER EMSIAN LAVID SHALES OF COLLE (NW SPAIN)

BY

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ABSTRACT

The author supposes that the fossil content of thin carbonate units in the Upper La Vid shales (Lower Devonian) of Colle was influenced by heavy storms like hurricanes.
Apart from microplankton (Cramer, 1964) no fossils are found in the shales. Together with the very well developed fissility of the shales this points to abiotic conditions, probably caused by the lack of oxygen in the deposition area. Alterations, e.g. by storms, of the water circulation pattern in the basin destroyed this situation, and a pioneer fauna was able to develop. Sometimes storm debris, probably deposited by hurricanes, served as a substrate for larvae which settled in the area. Little by little the former situation of lack of oxygen returned and the communities died.

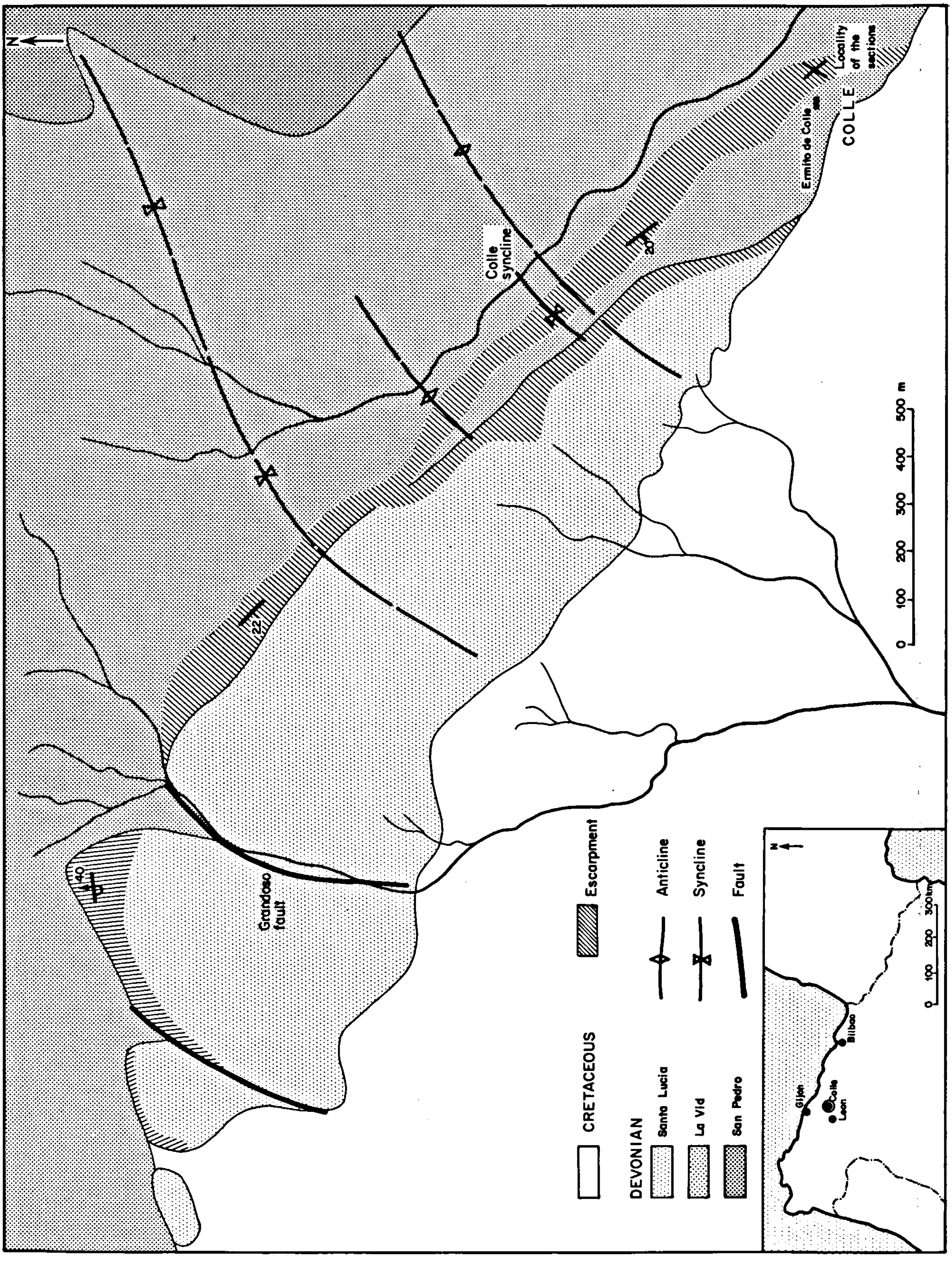
CONTENTS

Introduction 475
Palaeogeography 477
Field and Laboratory technique 477
Description of unit A 477
Description of unit C 479
Analysis of the data 480
Quantitative comparison of the units A and C 481
Carbonate rock types 483
Interpretation 484
Acknowledgements 485
References 486

INTRODUCTION

This paper deals with some thin carbonate units in the Upper La Vid shales of Colle in the Cantabrian Mountains of NW Spain. The Upper La Vid is well exposed in an escarpment (Fig. 1) NW of Colle. As early as 1882 De Verneuil mentioned the extremely fossiliferous strata near Sabero. Comte (1938) described the fossils of this area in detail. Breimer (1962) studied the crinoids of Colle, and Sleumer (1965) the stromatoporoids. Rupke (1965) studied the tectonics of the Esla nappe, on part of which the localities near Colle are situated.

In the summer of 1972 the author investigated the palaeoecology of the Upper La Vid exposed near Colle (Fig. 1). The only known coral biostrome of the La Vid Formation (Brouwer, 1964) is found here in a sequence of brown, splintery unfossiliferous shales and dark-grey to red limestones (Fig. 2).


N
Colle syncline
Grandoso fault
Ermita de Colle
COLLE
Locality of the sections
20
22
40
CRETACEOUS
DEVONIAN
Santa Lucia
La Vid
San Pedro
Escarpment
Anticline
Syncline
Fault
0 100 200 300 400 500 m
Gijon
Leon
Colle
Bilbao
0 100 200 300km

← Fig. 1. Generalized geological map of the area NW of Colle.

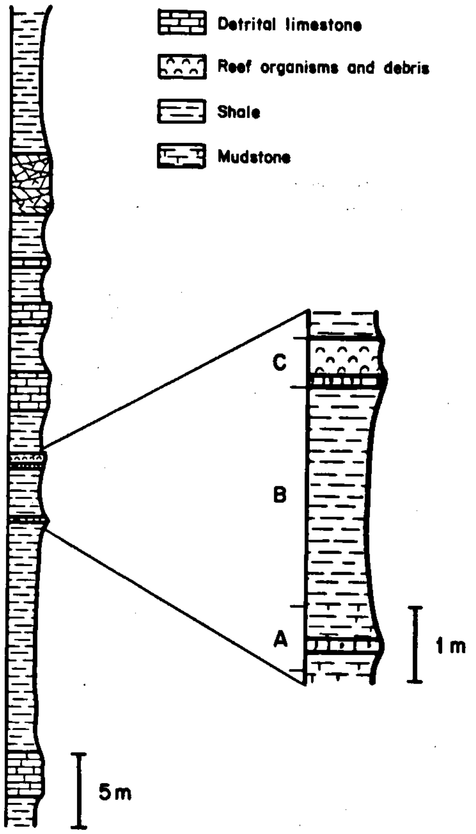


Fig. 2. Lithology of the Upper La Vid near Colle.

PALAEOGEOGRAPHY

Brouwer (1967) distinguished two main facies types in the Devonian of the Cantabrian Mountains: the Asturo-Leonese facies and the Palencian facies.

The Palencian facies is characterized by an irregular alternation of fine-grained carbonates, siltstones and shales. This facies type occurs in the northern part of Palencia. To the north and west it is bounded by the Asturian Geanticline. In the south-west and south it is separated from the Asturo-Leonese facies type by the Santibañez Ridge (van Adrichem Boogaert, 1967).

The Asturo-Leonese facies crops out in a belt along the west and south sides of the Asturian Geanticline. In this facies an alternation of clastic and carbonate rocks is found with a predominant benthonic fauna.

De Coo (1974) points out that the Asturo-Leonese facies could be the miogeosynclinal development of the Cantabrian Basin. This miogeosyncline was separated from the eugeosyncline by the Narcea Miogeanticline (= Narcea High).

FIELD AND LABORATORY TECHNIQUE

In the units A and C of the Upper La Vid (Fig. 2) some exposures were selected where sections could be measured. The exact position of each sample was figured in a situation sketch (scale 1 to 7). The shale samples were treated with hydrogen peroxide in order to extract the fossils. Instead of identifying the fossils at the species level, a collection of 214 types was made, which served as a reference collection to the different types of fossils in each sample.

The IBM 370/158 computer of the 'Centraal Reken Instituut' (CRI) of the University of Leiden was used for assorting the data. A similarity coefficient matrix was calculated between the objects, using mean square distances, expressing the degree of similarity as a distance in an n-dimensional space (Davis, 1973). The similarity matrices were calculated with the computer program SIMMAT (Library program at the CRI, Leiden) and the dendrograms were plotted by means of DENDRO (CRI, Leiden). As the types of crinoids did not influence the composition of the clusters they were left out. The fossil lists of the detrital limestone banks (Fig. 2) were not included because these banks are interpreted as storm deposits. Therefore they do not reflect the general environmental conditions.

Thin sections and peelings were made of the limestone samples. Twenty-eight thin sections were used for point countings. Dunham's classification of carbonate rocks (Dunham, 1962) was applied to the limestones.

DESCRIPTION OF UNIT A

This unit can be split into three sub-units (Fig. 3 and Enclosure I):

Sub-unit A1 consists of a blue-grey mudstone. The lower limit of this sub-unit is characterized by thin limestone banks. Locally, the mudstone gradually passes into the underlying dark-brown shales in which early diagenetic, marly, ferruginous yellow-brown concretions are often found (Fig. 3). Only a few fossils occur in the mudstone, e.g. *Euryspirifer paradoxus, Devonochonetes* sp., *Uncinulus pila, Platyceras* sp.

Sub-unit A2 consists of nodular dark-grey limestone which has both an abrupt basal and an abrupt upper limit (Enclosure I). This limestone layer has been teared up under the influence of the compaction of the clays (Stel, in prep.). Fossils found in the sub-unit are mainly crinoid debris and fragments of brachiopods. Deformations such as overthrusts and pull-apart structures are well exposed. The structures fade in the other sub-units (Fig. 3).

Sub-unit A3 consists of a blue-grey mudstone with the same lithology as sub-unit A1. This mudstone has an abrupt contact with sub-unit A2 and gradually

Fig. 3. View of unit A, which can be subdivided into the sub-units A1, A2 and A3 (SU A1, A2, A3). The top of the underlying dark-brown shales is characterized by small, early diagenetical concretions(c).

Fig. 4. View of unit C. The storm debris of sub-unit C1 (SU C1) has an abrupt contact with sub-unit C2 (SU C2). Just above the pencil, which has a length of 23 cm, a thin clay bed of sub-unit C3 (SU C3) is seen. The colonies of *Favosites* sp. (F) are in life position (↑).

passes into the overlying dark-brown shales of unit B (Fig. 2). The fossils in this sub-unit are similar to those found in sub-unit A1, but more individuals occur. Of frequent occurrence are *Uncinulus pila*, a trochoid solitary rugose coral and bryozoa. In some places thin dark-grey, marly limestone banks occur, in which the same fossils are found as in the surrounding mudstone. These banks probably developed diagenetically.

It appears that the unit has only a very limited horizontal range. Some hundreds of meters NW of Colle only the sub-units A1 and A2 are found.

DESCRIPTION OF UNIT C

On account of the lithology, unit C is divided into four sub-units (Fig. 4 and Enclosure I):

S u b - u n i t C 1 consists of a dark-grey limestone stratum (appr. 7 cm thick) which is similar to sub-unit A2. The sub-unit has an abrupt contact with the underlying dark-brown shales of unit B (Fig. 4) in which, apart from acritarchs and chitinozoans (Cramer, 1964) no fossils are found. The upper part of the sub-unit gradually passes into the cemented debris of sub-unit C2. In the lower part of the sub-unit occasionally some, about 3 cm thick banks occur in which *Uncinulus pila* is abundant. Their position in the sub-unit is explained by their dimensions. The scatheless state and orientation (Westbroek, Stel, Neyendorf, 1975) point to a transport over a short distance. In the sub-unit, faults are seen which are very well traceable into the overlying sub-unit. At the base of the sub-unit load- and flame-structures developed (Fig. 4).

S u b - u n i t C 2 mainly consists of fragments of *Disphyllum* sp. in a shaly matrix. The basal and upper limits are characterized by the appearance of *Disphyllum* sp. On some places the *Disphyllum* fragments show a distinct growth orientation (Fig. 5). It seems plausible that the *Disphyllum* colonies are autochthonous, but small displacements after the colonies died are present. Tabulate corals are represented by massive favositids (Fig. 6), alveolitids and encrusting auloporoids. Stromatoporoids, sometimes with a diameter of appr. 75 cm, occur. A counting of about 200 specimens of tabulates and stromatoporoids (Fig. 7) showed that a majority has been preserved in life position. Brachiopods are rare except *Atrypa reticularis*, which occurs abundantly together with *Disphyllum* sp. *Atrypa reticularis* is sometimes bent around *Disphyllum* sp. in very peculiar ways. Limestone banks occasionally developed diagenetically.

S u b - u n i t C 3 consists of thin dark-brown shale beds in and upon (Enclosure I) sub-unit C2. The shale is very similar to unit B and no fossils are found here either.

Fig. 5. Growth orientation of the basal part of a *Disphyllum* sp. colony in sub-unit C2.

Fig. 6. *Favosites* sp. (F) in the uppermost part of sub-unit C2. The colony is in life position. Stromatoporoids (S) equally in life position.

Sub-unit C4 consists of a nodular, light-grey, limy mudstone which is mostly about 5 cm thick. In the field this sub-unit is hardly conspicuous. The fauna consists especially of very small brachiopods which show the characteristics of adult specimens (dwarfing). Therefore it is interpreted as a community which developed under high stress conditions.

To the NW of Colle, unit C is exposed over a distance of appr. 2 km until it is cut off by the Grandoso fault (Fig. 1). About 1 km NW of Colle, fragments of *Thamnopora* sp., with a diameter of either 1 cm or about 1/2 cm, are found instead of fragments of *Disphyllum* sp. The other elements of the fauna in the sub-unit C2 are the same.

During the compaction of the clays a self-generating clay diapirism (Stel, in prep.) occurred which destroyed the coherence of the unit. Within the unit all deformation states between flame-structures and overthrusts are exposed. In the Colle syncline the unit was also disturbed by tectonical deformation.

To the south the unit is traceable over a distance of 100 m. It forms the marginal part of the NE limb of the Felechas syncline (Rupke, 1965).

ANALYSIS OF THE DATA

Unit A

In the 59 samples from the unit A, 77 types of fossils are found of which 23 types belong to the tabulate corals, 42 to the brachiopods and 5 to the rugose corals. The dendrogram of Fig. 8 shows that two clusters are present in the sub-units. These clusters agree with the lithologically distinguished sub-units A1 (lower cluster)

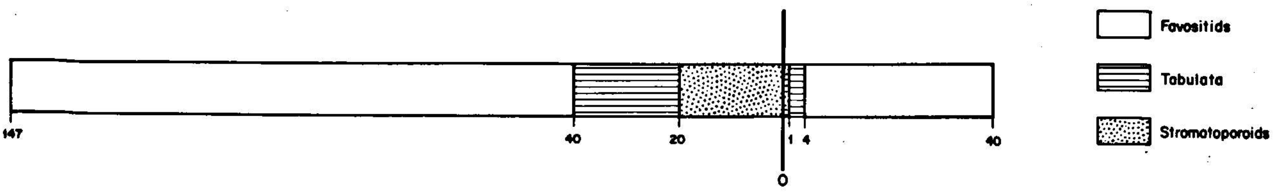


Fig. 7. Diagram of a counting of 200 colonies of tabulate corals and stromatoporoids in unit C. The colonies in the left part of the diagram are in life position; those in the right part are overturned.

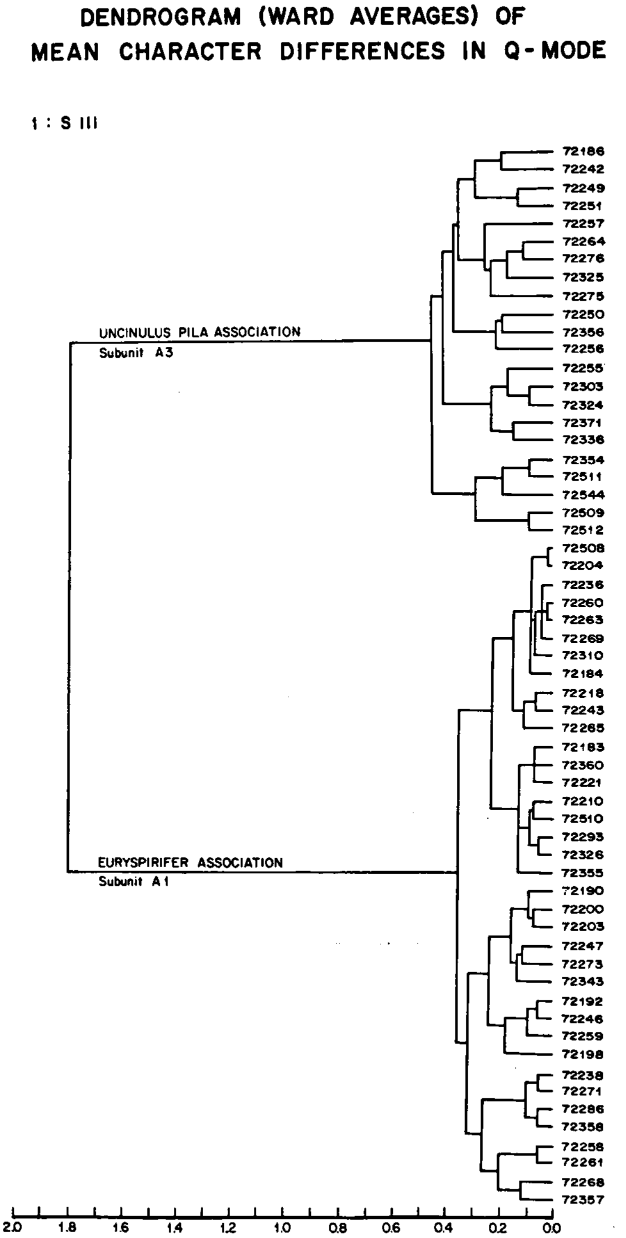


Fig. 8. Hierarchical dendrogram of 59 samples out of unit A. The numbers in the right part of the drawing are the sample numbers.

and A3 (upper cluster). Fifty percent, and sometimes even more, of the types is found in both clusters. This explains why some limestone banks from the sub-unit A3 are found in the cluster of sub-unit A1, 41 % is especially found in sub-unit A3 and 9 % in sub-unit A1. The difference between the sub-units A1 and A3 is mainly caused by a greater number of types of brachiopods in the latter (Figs. 9a and 10). Sub-unit Al is characterized by *Euryspirifer paradoxus*, *Devonochonetes* sp., more individuals of *Thamnopora* sp. than *Disphyllum* sp. This is called the *Euryspirifer* association. Sub-unit A3 is characterized by *Uncinulus pila*, *Athyris* sp. and trochoid solitary rugose corals. This is called the *Uncinulus pila* association.

Unit C

The dendrogram (Fig. 11) of the data of unit C is based on 70 types of which 24 belong to the tabulate corals, 31 to the brachiopods and 10 to the rugose corals. The clusters coincide again with the lithologically distinguished sub-units C2 (upper cluster) and C4 (lower cluster). Of the 70 types 26 % is found in both sub-units, 48 % is only found in sub-unit C4 while 21 % exclusively occurs in sub-unit C2 (four types had to be left out because of a sampling error). The difference of the two clusters is caused on the one hand by a lower number of types of tabulate and rugose corals, and on the other hand by a greater number of types of brachiopods (Figs. 9b and 10) in sub-unit C4. Sub-unit C2 is characterized by branching corals like *Disphyllum* sp. and *Thamnopora* sp., massive tabulate corals and *Atrypa reticularis*. For that reason this association is called the *Disphyllum-Atrypa* association. It probably developed during muddy environmental conditions because of:

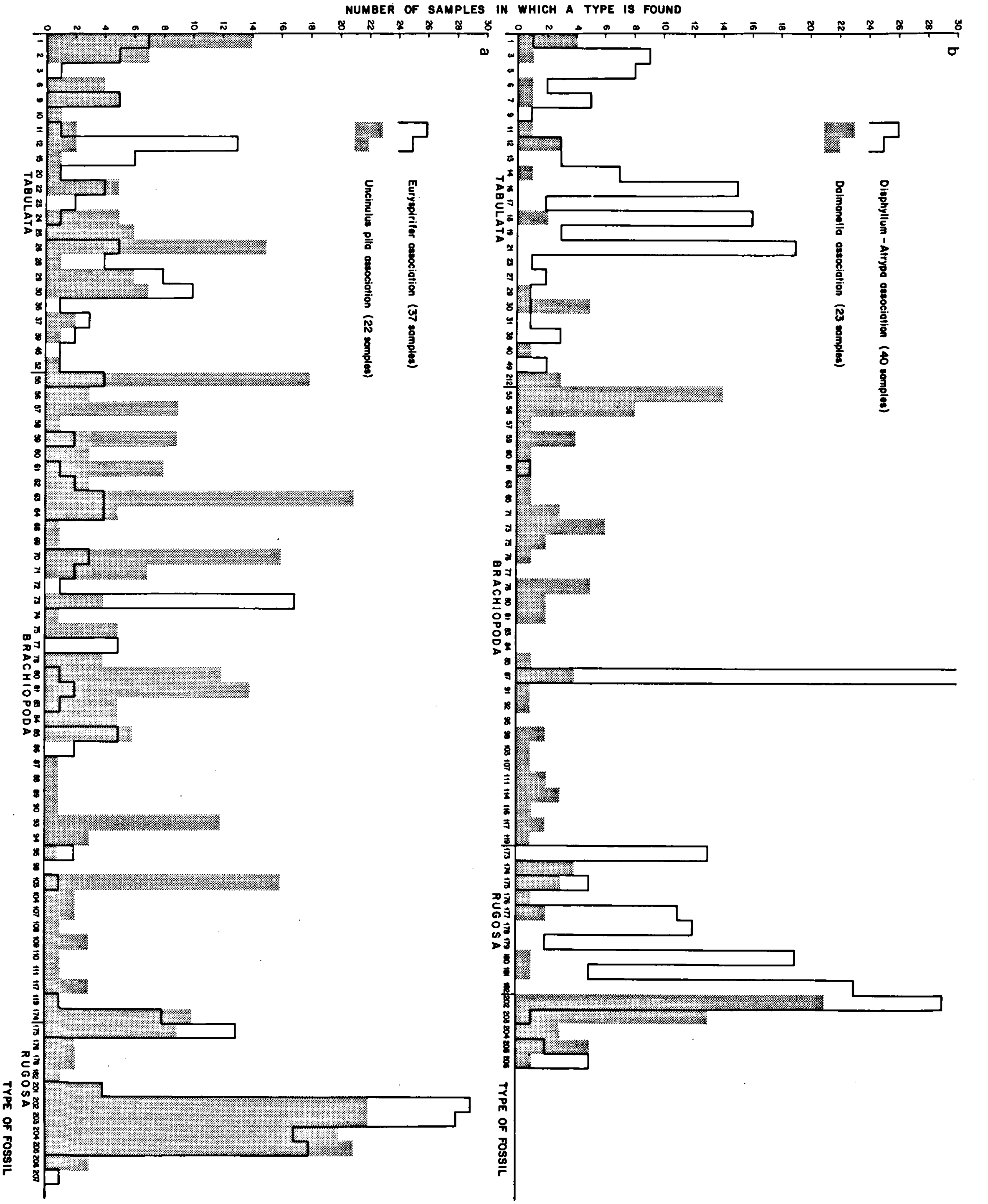
– the shaly matrix of the sub-unit
– a small number of types in the community but a large number of individuals
– the manifold appearance of *Atrypa reticularis*, a brachiopod which could live in muddy environments (Lowenstam, 1957)
– the dominating position of *Disphyllum* sp. These branching corals could probably live in muddy water too (Squires, 1964)
– the manifold appearance of massive tabulates which probably were able to live in muddy water (Ginsburg & James, 1973).

The fauna in sub-unit C4 is considered as a stunted fauna which developed in a high stress environment. This fauna is called the *Dalmanella* association because *Dalmanella* sp. is repeatedly found.

QUANTITATIVE COMPARISON OF THE UNITS A AND C

In order to compare the associations of the units A and C, the number of types found in two associations is added while the number of common types is subtracted. The percentages plotted in Fig. 12 show the mutual similarity between the associations.

It appeared that in all cases the *Dalmanella* association has only few types in common with the other associations. Although the *Euryspirifer* association and the *Uncinulus pila* association show a certain degree of similarity with the *Disphyllum-Atrypa* association, they can be considered as separate associations. The *Euryspirifer* association and the *Uncinulus pila* association are similar to a high degree. Fig. 12 also shows the striking difference between the *Disphyllum-Atrypa* association and the *Dalmanella* association.



NUMBER OF SAMPLES IN WHICH A TYPE IS FOUND
a
Eurypspirifer association (37 samples)
Uncinulus pila association (22 samples)
b
Disphyllum - Atrypa association (40 samples)
Dalmanella association (23 samples)
TABULATA
BRACHIOPODA
RUGOSA
TYPE OF FOSSIL

Fig. 9. a. Frequency histogram of the different types of fossils of the sub-units A1 and A3. b. Frequency histogram of the different types of fossils of the sub-units C2 and C4.
←

CARBONATE ROCK TYPES

Three different rock types of Dunham's classification can be perceived in the units A and C of the Upper La Vid of Colle:

– Bioclastic grainstones: Grainstones are uncommon in the units. They are more frequently found in sub-unit C1 than in sub-unit A2. The bioclasts are crinoids, brachiopods, trilobites, ostracods, molluscs, thamnoporoids and bryozoans (Fig. 13a). Dolomitic rhombs and hematitized crinoid stems are found.
– Bioclastic packstones: This type of carbonate rock is frequently found in the sub-units A2 and C1. The packstones are closely to very closely packed. The bioclasts are mostly fragments of crinoids and brachiopods (Figs. 13b and 14). Bryozoans, trilobites and ostracods are also found. In general the bioclasts are embedded in clay, but sometimes some sparite is found too.
– Bioclastic wackestones: The thin limestone banks in the muddy sub-units (A1 and A3) of unit A mainly consist of wackestones. Fragments of crinoids and bryozoans are the dominating bioclasts (Fig. 13c), and trilobites, ostracods, brachiopods, gastropods, tentaculites, tabulate and rugose corals are also found. The matrix consists of clay and micrite.

1.	*Pachypora* sp.	64.	*Schizophoria vulvaria*
2.	*Pachypora* sp.	65.	*Trigorhynchia pareti*
3.	*Favosites*	70.	*Chonetes* sp.
5.	*Pachypora* sp.	71.	*Stropheodonta* sp.
6.	*Pachypora* sp.	72.	*Athyris subconcentrica*
7.	*Aulopora* sp.	73.	*Euryspirifer paradoxus*
9.	*Pachypora* sp.	74.	*Trigeria adrieni*
11.	*Pachypora* sp.	76.	*Cyrtina* sp.
12.	*Pachypora* sp.	77.	*Schizophoria* sp.
13.	*Pachypora* sp.	78.	*Rhetzia* sp.
14.	*Alveolites* sp.	80.	*Athyris concentrica*
16.	*Pachypora* sp.	81.	*Athyris compomaresi*
17.	*Pachypora* sp.	83.	*Triathyris bordia*
18.	*Favosites*	84.	*Devonochonetes* sp.
19.	*Pachypora* sp.	85.	*Cyrtina* sp.
20.	*Pachypora* sp.	86.	*Anathyris* sp.
21.	*Alveolites* sp.	87.	*Atrypa reticularis*
22.	*Pachypora* sp.	90.	*Strophodonta*
23.	*Pachypora* sp.	91.	*Anathyris* sp.
24.	*Pachypora* sp.	92.	*Leptocoelia* sp.
25.	*Favosites* sp.	93.	*Athyris pelapeyensis*
26.	*Pachypora* sp.	103.	*Glossinotoechia* sp.
27.	*Aulopora* sp.	107.	*Coelospira* sp.
28.	*Pachypora* sp.	108.	*Coelospira* sp.
29.	*Pachypora* sp.	109.	*Leptocoelia* sp.
30.	*Pachypora* sp.	110.	*Coelospira* sp.
38.	*Pachypora* sp.	111.	*Plathyorthis* sp.
39.	*Alveolites* sp.	114.	*Camarotoechia* sp.
40.	*Pachypora* sp.	116.	*Atrypa* sp.
45.	*Pachypora* sp.	117.	*Atrypa* sp.
48.	*Favosites* sp.	119.	*Strophodonta* sp.
49.	*Aulopora* sp.	173.	*Phillipsastrea* sp.
52.	*Pachypora* sp.	174.	*Combophyllum* sp.
55.	*Dalmanella* sp.	177.	*Disphyllum* sp.
56.	*Xana bubo*	178.	*Disphyllum* sp.
58.	*Platyorthis* sp.	179.	*Disphyllum* sp.
60.	*Atrypa* sp.	180.	*Disphyllum* sp.
61.	*Leptaena* sp.	181.	*Disphyllum* sp.
63.	*Uncinulus pila*	182.	*Disphyllum* sp.

Fig. 10. Determinations at the genus level of the types of fossils of units A and C.

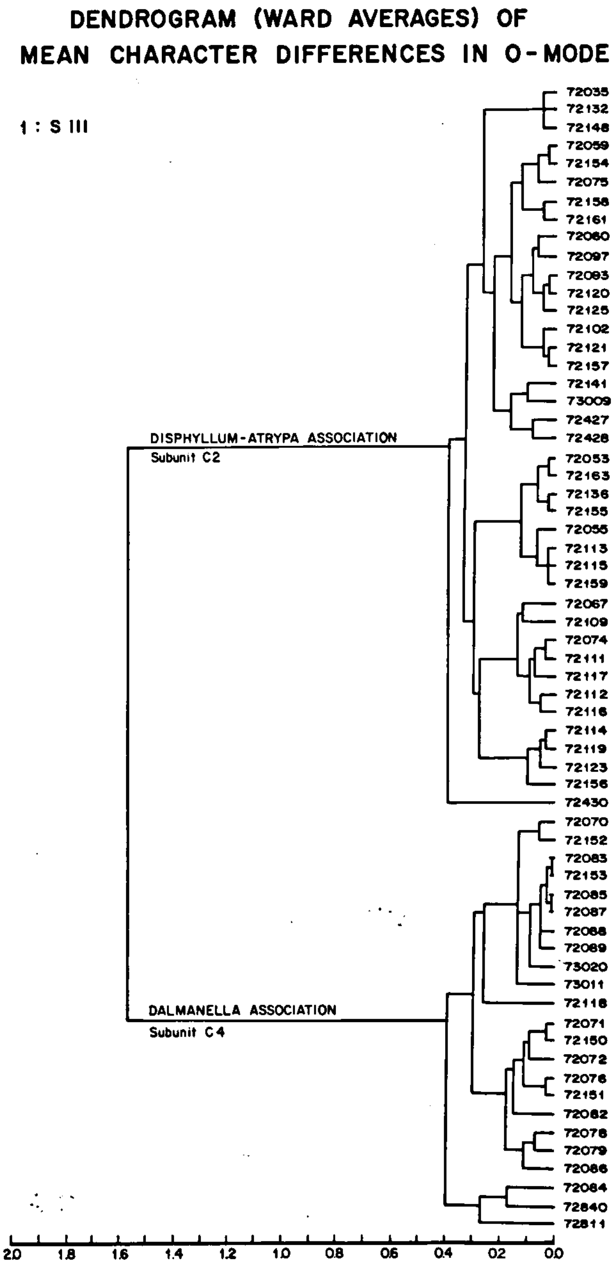


Fig. 11. Hierarchical dendrogram of 63 samples out of unit C. The numbers in the right part of the drawing are the sample numbers.

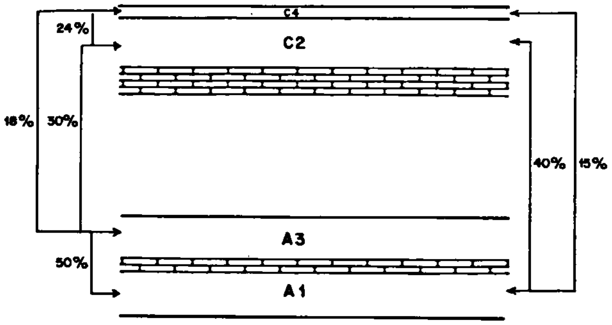


Fig. 12. Quantitative comparison of the associations found in the units A and C.

Similar deposits are known from Florida where they were described by Ball, Shinn and Stockman (1967) as hurricane deposits. The sub-units A2 and C1 are interpreted as storm deposits because of:

– the uniform character of the limestone banks in the whole area
– the clay matrix of the packstones
– the abrupt limits of the banks
– the appearance of load- and flame-structures, especially below the basal limestone bank of unit C, points at rapid deposition
– no fining upwards sequences are found in the banks
– no sole markings are found.

INTERPRETATION

Apart from microplankton no fossils are found in the dark brown shales in which the units A and C are embedded. Together with the very well developed fissility of the shale this fact points to abiotic conditions in the environment (Byers, 1974). The abiotic conditions might be caused by the lack of oxygen (van Straaten, 1973) in the lowermost water layer of the sea.

Alteration of the water circulation pattern in the basin (e.g. by storms) temporarily destroyed the former situation, and a pioneer fauna as the *Euryspirifer* association of sub-unit A1 was able to develop. During this development a Lower Devonian hurricane passed the Narcea High (situated more to the S), which probably was a reef zone. Debris was picked up from this area and, depending upon the specific gravity, deposited in different areas in the northern epicontinental sea. In this way fragments of especially crinoids and brachiopods (Fig. 13b) were deposited in the neighbourhood of Colle which was situated about 15 km N of the Narcea High. This storm debris served as a solid substratum for organisms. An indication of this is the increased number of types of brachiopods in the *Uncinulus pila* association of sub-unit A3 (Fig. 9a). Little by little the former situation with lack of oxygen returned and the *Uncinulus pila* association died. Subsequently the dark-brown clays of unit B were deposited.

Unit C clearly shows the influence of a hurricane. The storm deposit, which is similar to the storm debris of unit A lies with an abrupt contact upon the shales of unit B (Fig. 2 and Enclosure I). Load- and flame-structures point to a rapid deposition of the debris. The hurricane did away with oxygen deficiency in the deposition area. By means of the substrate function of the storm debris a pioneer fauna, resulting in the *Disphyllum-Atrypa* association, was able to settle. Taking into consideration the thickness of the coral debris in the lower part of sub-unit C2, it is reasonable to suppose

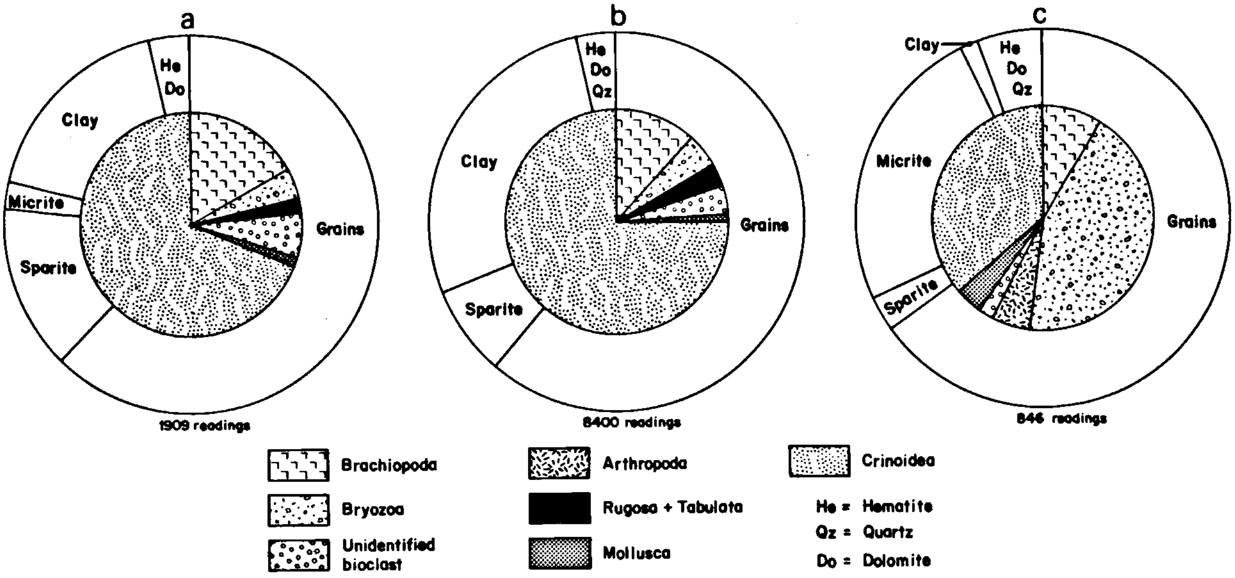


Fig. 13. Point-count results of selected samples from units A and C. a. Bioclastic grainstones. b. Bioclastic packstones. c. Bioclastic wackestones.

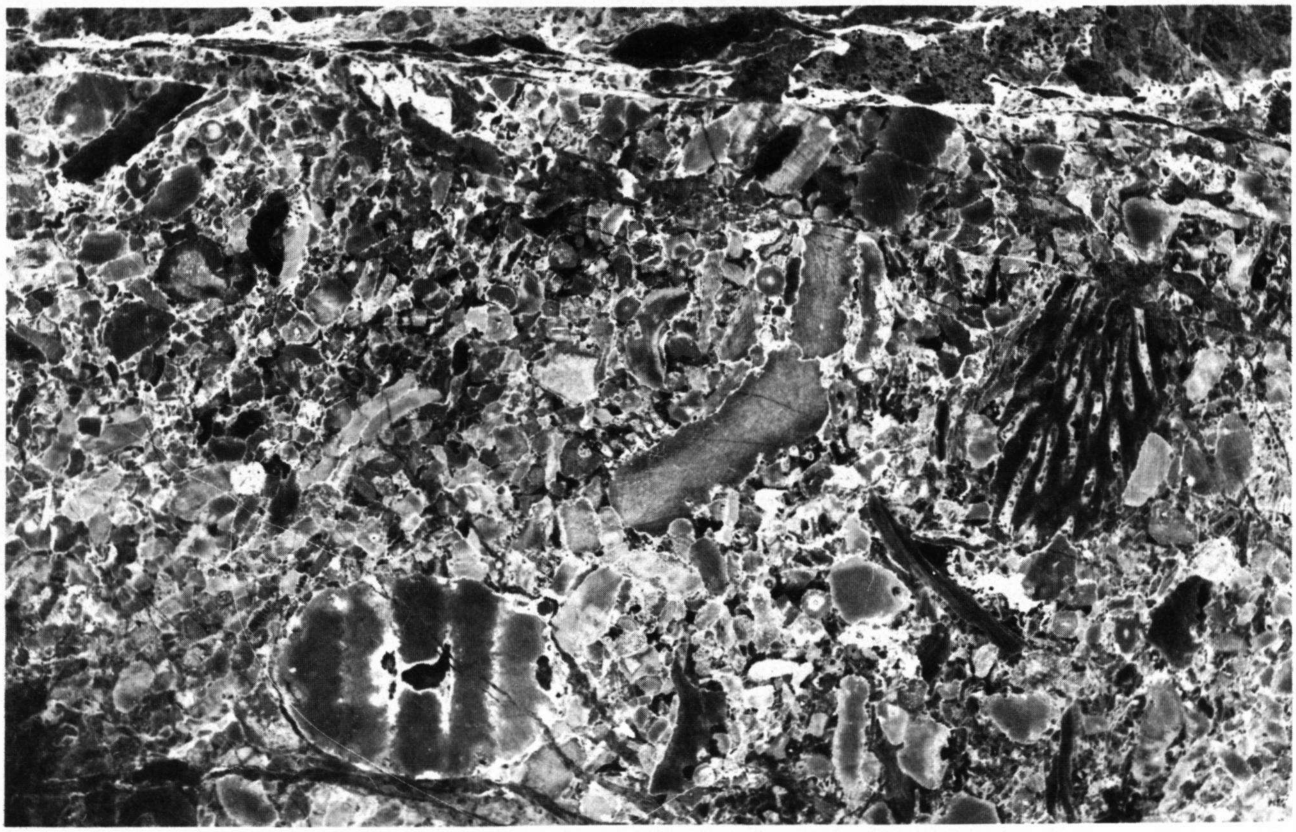


Fig. 14. Bioclastic packstone, with especially crinoids and brachiopods.

that this community was able to persist very well. In the uppermost part of this sub-unit thin clay beds without fossils are found (Enclosure I). This situation was probably caused by the decreasing amount of oxygen in the seawater, which caused dying of some coral colonies. Finally the oxygen deficiency caused extermination of the whole *Disphyllum-Atrypa* association, and dark-brown clays (like those of unit B) were deposited again. Notable in this high stress environment is the appearance of massive favositids and stromatoporoids in the uppermost part of sub-unit C2 (Fig. 6).

A temporary inflow of oxygenated water probably caused the development of the stunted fauna of sub-unit C4.

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