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An Upper Devonian Limestone Slide Block near Marbella (Betic Cordillera, Southern Spain) and the Palaeogeographic Relations between Malaguides and Menorca

Hans-Georg HERBIG

Freie Universität Berlin, Institut für Geologie, Altensteinstrasse 34A, D-1000 Berlin 33, Federal Rep. of Germany.

ABSTRACT

Allochthonous Devonian limestone slide blocks are common in the Viséan to probably basal Namurian Retamares Member (lower Almogia Formation) of the Malaguides. The only slide block known from the coastal Palaeozoic between Fuengirola and Estepona is described from the Arroyo de la Cruz W of Marbella. This block is approximately 50 m in diameter and 11 m thick. Four stages of internal deformation prove its allochthonous nature. Deformation features and tectonic setting indicate a S to SE derivation. The block is of late Frasnian to early Famennian age. In terms of conodont zonation, it represents the Upper *gigas* Zone and the Middle *Palmatolepis triangularis* to Lower *rhomboidea* Zones, with the Uppermost *gigas* and Lower *Pa. triangularis* Zones missing. Pelagic mudstones predominate in rocks of the Upper *gigas* Zone, whereas fine-grained limestone turbidites, derived from lower slope environments or from intrabasinal rises, predominate above the hiatus. Carbonate microfacies as well as conodont biofacies point to a deep-water deposition of all limestones. Concurrence of microfacies and biostratigraphy between the slide block and limestones pebbles from conglomerates of the Retamares Member prove a common source area. Microfacies and biostratigraphy of carbonate components known from Upper Devonian and post-lower-most Namurian conglomerates of Menorca show striking similarities to those of the Malaguides. Therefore, both limestone blocks and pebbles of the two realms are interpreted to have been reworked from different sectors of a single primary sedimentary basin. This interpretation points to closer palaeogeographic relations between the Malaguides and Menorca.

Key words: Devonian. Carbonate microfacies. Conodonts Gravitational sliding. Paleogeography. Betic Cordillera. Menorca.

RESUMEN

En los Malaguides los bloques deslizados de calizas Devónicas son abundantes en el Miembro de Retamares (Formación Almogia inferior) de posible edad Viséense - Namuriense muy bajo. En el Paleozoico costero entre Fuengirola y Estepona solamente se conoce la existencia de un bloque deslizado situado en el Arroyo de la Cruz, al oeste de Marbella. Tiene un diámetro de 50 m y un espesor de 11 m, aproximadamente. Las cuatro fases de la deformación interna demuestran la naturaleza alóctona del cuerpo calcáreo. Las características de la deformación y la posición tectónica indican una derivación del Sur o del Sureste. El bloque es de edad Frasniense superior - Famenniense inferior o, en términos de zonas de conodontos, contiene la Zona Superior de *gigas* hasta la Zona Inferior de *rhomboidea*. Un hiato comprende la Zona Superior más alta de *gigas* y la Zona Inferior de *Palmatolepis triangularis*. Los mudstones pelágicos (biomicritas de entomozoas y de styliolinas) predominan en las calizas de la Zona Superior de *gigas*. Por encima del hiato predominan las turbiditas calcáreas de grano fino procedentes de la parte inferior del talud continental o de una elevación intrabasinal. Las microfacies de carbonatos y biofacies de conodontos indican una sedimentación en aguas profundas, para las calizas. Las microfacies y bioestratigrafía del bloque deslizado son idénticas a los cantos de caliza de los conglomerados del Miembro de Retamares. Esto prueba que proceden de una misma fuente. Se discute la similitud en las microfacies y bioestratigrafía con los cantos calcáreos que provienen de los conglomerados de edad Devónico Superior y post-Namuriense bajo de Menorca. Se concluye, que todos los bloques deslizados y cantos de caliza en los Malaguides y en Menorca derivan de diferentes sectores de una misma cuenca sedimentaria. Esto indica unas relaciones paleogeográficas muy estrechas entre los Malaguides y Menorca.

INTRODUCTION

The internal zone of the Betic Cordillera is composed of three major superimposed tectonic units; these are from the bottom to the top the Nevado-Filabrides, the Alpujarrides and the Malaguides. As opposed to the mainly metamorphic underlying units, the Malaguides consist essentially of low-grade, phyllitic, to unmetamorphosed Palaeozoic rocks of Ordovician (?) to Late Carboniferous age. They are overlain by Permo-Triassic redbeds; a condensed sequence of younger Mesozoic and Cenozoic rocks is preserved only locally.

Palaeozoic rocks of the Malaguides are widely distributed in the Province of Málaga (Fig. 1). They also crop out in the Zone of Cogollos Vega northeast of Granada and in the Corridor of Vélez Rubio west of Lorca. Patchy outcrops are known south of the Sierra Nevada and in the coastal Sierras between Almería in the south and Mazarrón in the northeast (for references see Herbig, 1983).

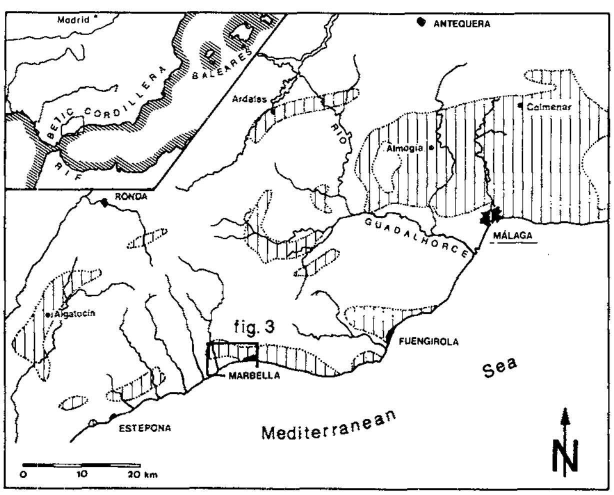
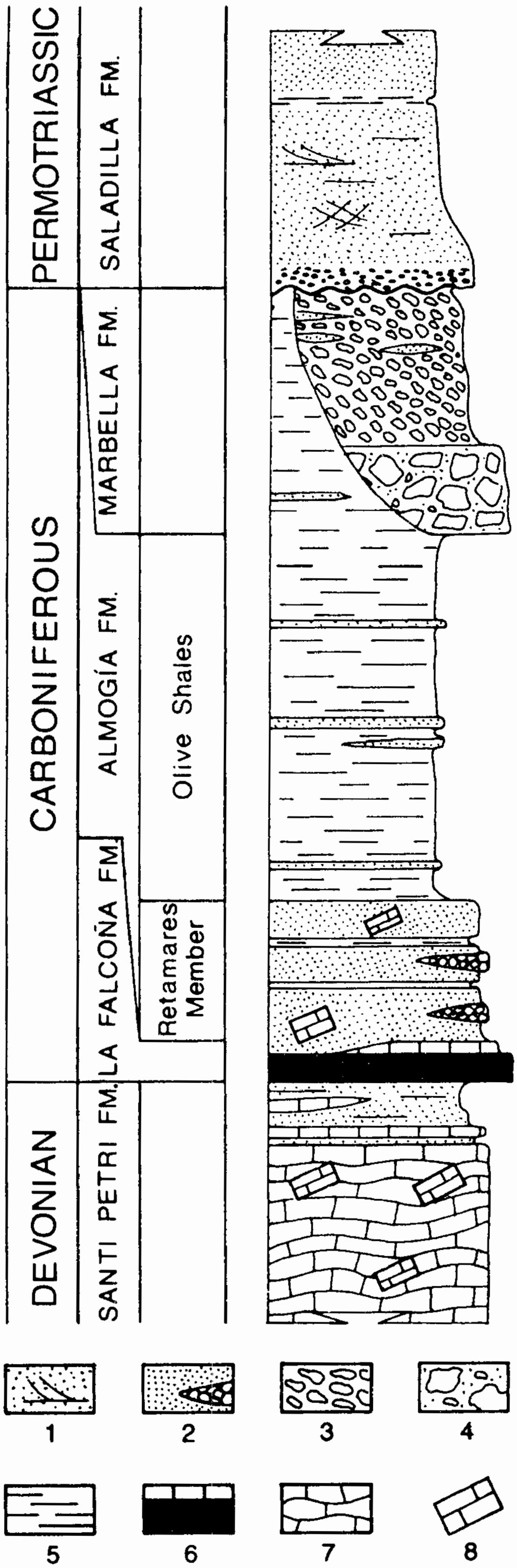


Figure 1. — Distribution of Malaguide rocks in the Western Betic Cordillera. Index map shows geographic location.

Essentially, the stratigraphic succession of the Palaeozoic is comparable in all areas (Fig. 2). It comprises typical deep-water sediments from basinal, base of slope, and slope environments (Herbig, 1983, 1984). According to Mon (1969, 1971) it starts with the Morales Formation of Ordovician (?) to Early Silurian age, consisting mainly of dark, bluish-grey phyllites and phyllitic shales. The Morales Formation is overlain by the 200-500 m thick Santi Petri Formation of unfossiliferous, quartz-bearing, platy limestones, which are intensely folded («calizas alabeadas»). Greywackes are intercalated. This formation contains allochthonous limestones slide blocks of Middle Silurian (Wenlockian) to Middle Devonian (Eifelian) age and is interpreted as a calcareous flysch unit. The Santi Petri Formation is assumed to range from the Lower Silurian up to the Devonian/Carboniferous boundary. It is overlain by black cherts, 5-15 m thick, locally with thin Upper Tournaisian pelagic limestones on top (Falcoña Formation). The overlying flysch succession of the Almogia Formation of basal Viséan to post-early Bashkirian age can be subdivided, at least locally, into the lower Retamares Member and the upper, not yet formally named «Olive Shales». The Retamares Member (basal Viséan to probably basal Namurian; Herbig, 1984: 81) consists of 40-60 m thick, massive greywackes with intercalated conglomerate lenses and allochthonous limestone slide blocks of Early Devonian (Gedinnian) to Late Devonian (Middle Famennian) age. It is interpreted as a braided suprafan deposit at the base of a continental slope. The overlying «Olive Shales» of probably basal Namurian to post-early Bashkirian age, as much as 150 m thick, represent a primarily pelitic slope facies. Locally the Almogia Formation is overlain by the post-lower Bashkirian, lens-shaped debris-flow deposits and associated conglomerates of the Marbella Formation. These sediments, as much as 100 m thick, were deposited in submarine canyons incised into the continental slope, or in main upper-fan channels. They represent the youngest sediments below the Variscan unconformity. A more detailed account of stratigraphy, including a complete list of references on earlier studies, is given in Herbig, 1983.

The existence of allochthonous limestone slide blocks in the Santi Petri Formation was theorized by several authors because of the different lithofacies and disharmonic emplacement of the blocks compared to the lithofacies and the bedding of the «calizas alabeadas» (Kockel & Stoppel, 1962: 151; Mollat, 1968:



479; see also the descriptions given by Blumenthal, 1930: 70-71). The same differences hold true for the limestone lenses included in the greywackes of the Retamares Member (Mauthe, 1971: 8; Bourgois, 1978: 263, see also the descriptions given by Blumenthal, 1930: 70-71). Until now, the location of some limestone slide blocks of the Santi Petri Formation was known only from conodont studies of Kockel (1958, 1959) for the region Casarabonela / Ardales (Prov. of Málaga) and for a single slide block W of Algatocin in the Palaeozoic of the Western Serrania de Ronda. Kockel & Stoppel (1962) described localities and conodont faunas of limestone slide blocks within the Retamares Member in the vicinity of Almogia. Wether these slide blocks might also be present in the overlying «Olive Shales» is not certain.

According to literature studies, Herbig (1984: 13) concluded the existence of limestone slide blocks also within the Santi Petri Formation of the Corridor of Vélez Rubio (E Betic Cordillera).

In the present study a detailed description of the only limestone slide block known from the coastal Palaeozoic between Fuengirola and Estepona, south of the Sierra Blanca, is given for the following reasons: First, to prove its allochthonous nature and to reconstruct the sense of its emplacement. Second, to study biostratigraphy and lithofacies to get further information of the development of the unknown source area. A first attempt at its reconstruction was based on limestone pebbles and boulders from the Retamares Member and the Marbella Formation (Herbig, 1984).

The investigated limestone slide block is situated at the Arroyo de la Cruz west of Marbella. It was first described by Blumenthal (1949), who regarded it to be the autochthonous

Figure 2. — Idealized lithostratigraphic section of the Malaguide Palaeozoic. Lowermost part (Morales Formation) not indicated. 1, red, continental sandstones; 2, greywackes, mostly massive, with intercalated conglomerate lenses; 3, polymict conglomerates and debrisflow sediments without limestone clasts; 4, coarse debrisflow sediments with abundant shallow-water limestone clasts; 5, shales and siltstones; 6, black cherts, locally radiolarian-bearing, micritic limestones on top of unit; 7, quartz-bearing, platy limestones, type «calizas alabeadas»; 8, allochthonous limestone slide blocks.

source of the limestone conglomerates of the Marbella Formation. A first account on its allochthonous nature, biostratigraphy, and carbonate microfacies is given by Herbig (1984).

The described samples are housed at the Institut of Palaeontology, University of Erlangen, together with the samples of Herbig (1984).

GEOLOGICAL SETTING

On the coastal plain near Marbella, the Palaeozoic rocks crop out in a one to two kilometers wide, E-W striking band, covered in the south, at the rim of the Mediterranean sea by unconsolidated Cenozoic sediments (Fig. 3 a). In the north, the Palaeozoic is bordered by the

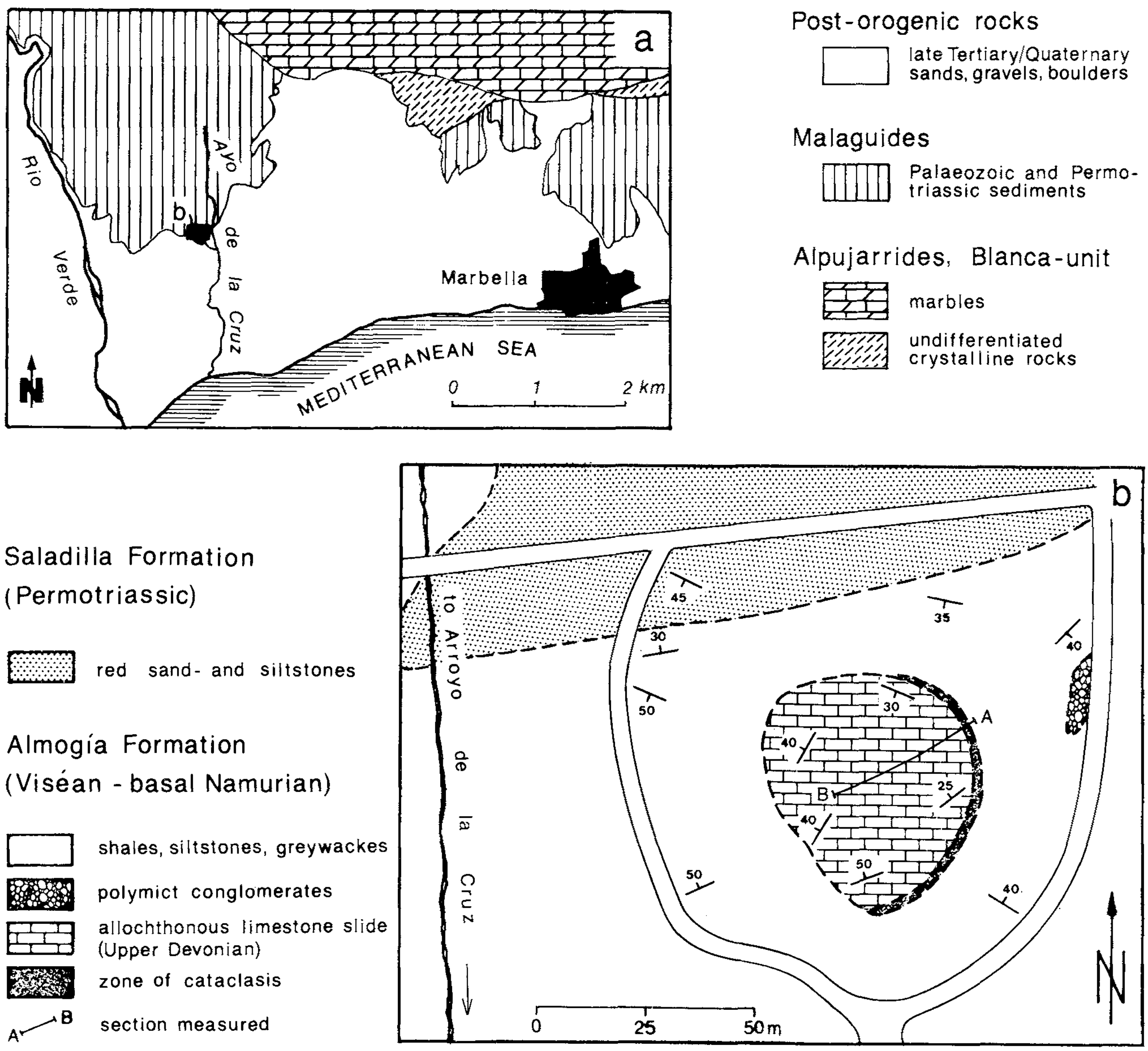


Figure 3. — a, Geological map of the coastal plain near Marbella, as indexed in Fig. 1; simplified after MOLLAT (1968); b, Geological sketch of the allochthonous limestone slide block at Arroyo de laCruz, as indexed in 3a.

marbles of the Sierra Blanca which belong to the Blanca unit of the Alpujarrides (Mollat, 1968). The Palaeozoic is characterized by south-dipping, imbricated units of small scale. In the vicinity of the Arroyo de la Cruz at least three such units are found between the Sierra Blanca in the north and the Cenozoic cover in the south. They are faulted further into a mosaic of small blocks (Mollat, 1968). The limestone slide block (Fig. 3 b; Plate 2/3) is situated in a small, E-W striking syncline (Blumenthal, 1949: 36). It is embedded in olive-weathering, dark- grey shales, siltstones and some greywacke beds of the Retamares Member. Typical conglomerates of the Retamares Member crop out in a small lens some tens of meters to the east of the slide block (Herbig, 1984: 19, this paper, Fig. 3 b). The limestone slide, approximately 11 m thick and 50 m in diameter is resistant to weathering compared to the surrounding siliclastic rocks and, therefore, forms the top of a small hill. This feature is observed in many other slide blocks of the Malaguide Palaeozoic and causes problems in studying the relations between slide masses and embedding rocks and, therefore, in confirming their allochthonous nature.

INTERNAL DEFORMATION

The most significant argument for the allochthonous nature of the slide block is the shear zone developed at its southern, eastern, and northeastern margins (Fig. 3 b; Plate 2/1-2). It lies subparallel to the bedding on top of olive-weathering, dark-grey shales with some minor intercalated greywacke beds. The shear zone consists of 50-70 cm thick, totally cataclasized shales without any remaining bedding structures. The shales may contain densely packed fragments of other sedimentary rocks with diameters smaller than 0.5 cm and rare, angular fragments of limestones, cherts, and greywackes as much as 10 cm in diameter. The fragments may be further broken in several, more or less fitting pieces. The shear zone weathers to a noticeable ochreous, earthy substance.

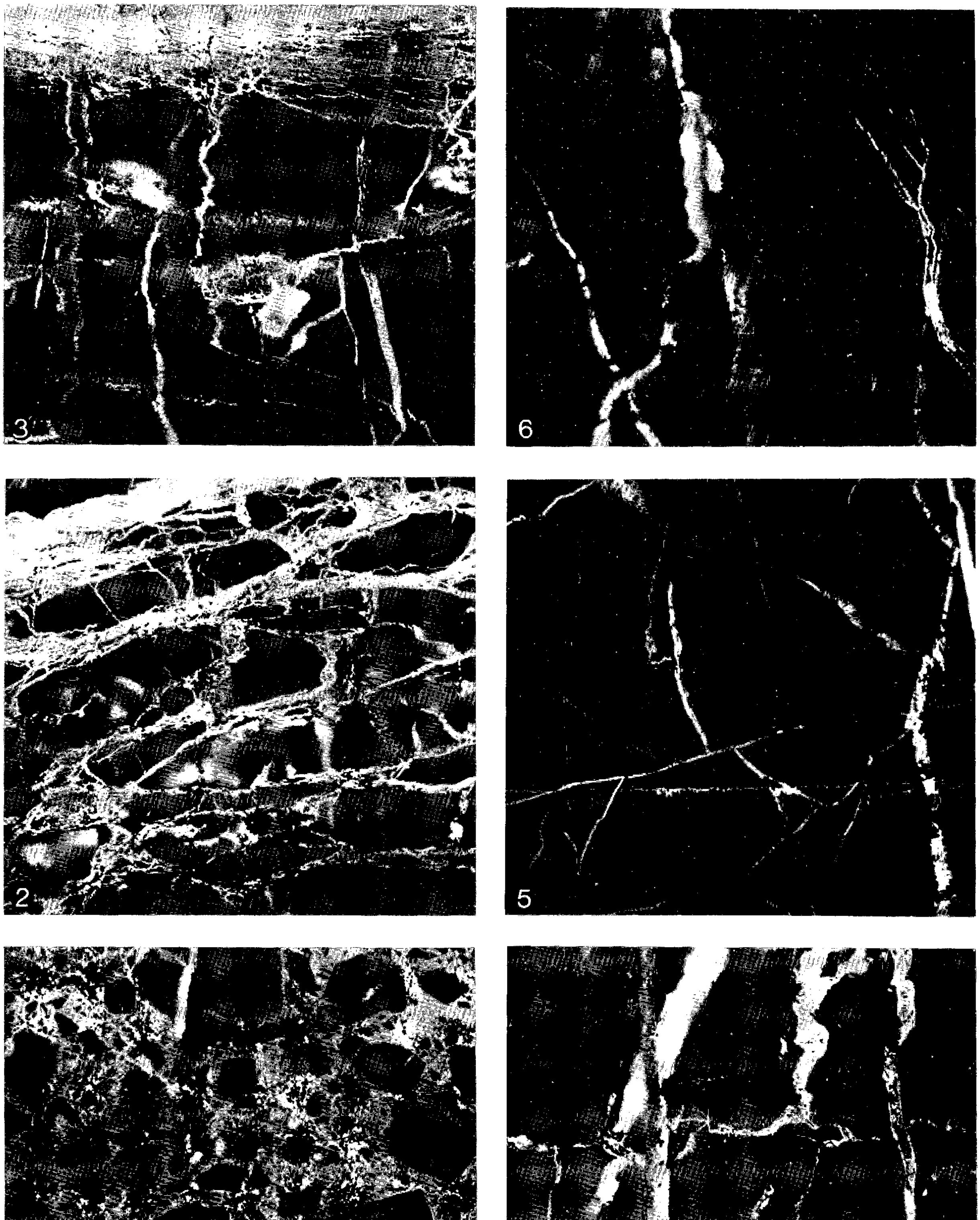
The base of the overlying slide block does not correspond to a single bedding-plane. At its eastern to northeastern margin, the stratigraphically oldest beds are exposed; obviously, in other parts of the slide block they were destroyed by cataclasis. The degree of cataclasis is most intense within the basal beds, then it diminishes rapidly, giving way to nearly unaffected limestones in the higher parts of the slide block (Plate 1). The uppermost beds again are intensely brecciated. Several brecciated limestone intervals with clasts as much as 10 cm in diameter are found at unpredictable positions within the slide block, pointing to internal movements, more or less parallel to bedding planes.

Comparable observations were made by Cook (1979), who additionally observed strong overfolding within slide blocks consisting of thin-bedded hemipelagic limestones. Such elastic deformations were not observed at Arroyo de la Cruz due to the predominance of thick-bedded turbiditic limestones. There, the deformation only allowed a ski-shovel-like upward warping of the slide's frontal part (see next chapter).

As noted, the degree of cataclasis diminishes sharply above the basal beds, and is also strikinly related to lithofacies: the basal 2.4 m of the slide block consists mainly of thin-bedded, 5-10 cm thick, brecciated beds of pelagic limestone. Three intervening, 15-20 cm thick beds of turbiditic limestone are only in an initial stage of brecciation (Plate 1/3), as are most beds of the turbiditic limestone succession following on top of the basal pelagic seliments. Such incompetent pelagic limestones may form preferentially the base of slide blocks, acting as lubricating layers beginning with the separation from an autochthonous rock succession.

Description of the deformation features: The breccias of the slide block are internal breccias («Internbreccien», Richter & Füchtbauer, 1981, «jigsaw-puzzle breccias» of American authors) characterized by a high percentage of fitting components, a small amount of matrix, and monomictic composition.

Sample 8-0 (Plates 1/1, 2/4), directly from the base of the slide block, shows 0.5-10 mm large, mostly angular limestone clasts in a dense, brownish, ferruginous matrix with some subhedral, authigenic pyrite crystals. Many of the limestone clasts have protruding edges, which permit matching of adjacent fragments; the fit is better among larger fragments. Smaller clasts float without orientation in the matrix, which comprises approximately 40 % of the rock volume. Therefore, the rock approaches the ap-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pearance of a mass-flow breccia (Richter & Füchtbauer, 1981: Fig. 3 and Plate 2). The generation of mass-flow breccias from the base and margins of slide blocks was also observed by Cook (1979).

Sample 8-1 (Plates 1/2, 2/5), 0.5 m above the base of the slide block, shows features typical of internal breccias: the fit is nearly 100 %, and the matrix is less than 5 % of the rock volume. It is present only in fissures as thick as 2 mm; the thicker ones contain tiny limestone clasts. The size of the clasts reaches 25 mm. Most are long-sided rectangular to phacoid-shaped with their long-axis parallel to the bedding plane. This shape and orientation point to strong horizontal shear movements.

Plate 1. — *Internal deformation features of the slide block.* Photographs stratigraphically arranged from bottom to top of the slide block from lower left to uper right. Polished slabs: all x 1.75.
Figure 1. — Base of slide block. The original structure of the rock is totally destroyed by strong shear movements. Fit of components is relatively low. Rock resembles mass-flow breccia as defined by RICHTER & FÜCHTBAUER (1981). Sample 8-0.
Figure 2. — 0.5 m above base of slide block. Internal breccia with a very high percentage of fitting components. Long-sided rectangular to phacoid-shaped clasts point to strong horizontal shear movements. Sample 8-1.
Figure 3. — 1.3 m above base of slide block. The relatively thick-bedded turbiditic limestone is only in an initial stage of brecciation compared to the underlying, thin-bedded pelagic limestones. Marly BOUMA interval t_d in the uppermost part of the photograph shows again stronger deformation features. Sample 8-3.
Figure 4. — 1.8 m above base of slide block. Internal breccia of pelagic limestone. Vertical joints are more prominent than horizontal fissures: pull-apart movements prevail over horizontal shear movements. Note three phases of deformation: 1, white, tapering calcite veins; 2, stylolites; 3, joints and fissures infilled with ferruginous matrix. They also can split older styloplanes (arrows). Sample 8-4.
Figure 5. — 3.9 m above base of slide blocks. Thick-bedded turbiditic limestone in an initial stage of brecciation. Sample 8-10.
Figure 6. — 7.8 m above base of slide block. Thick-bedded turbiditic limestone. Note evident lesser deformation compared to the underlying turbiditic limestones of Figs. 3 and 5. Irregular tapering, apophysis-like cracks infilled with ferruginous matrix are still present. Sample 8-17.

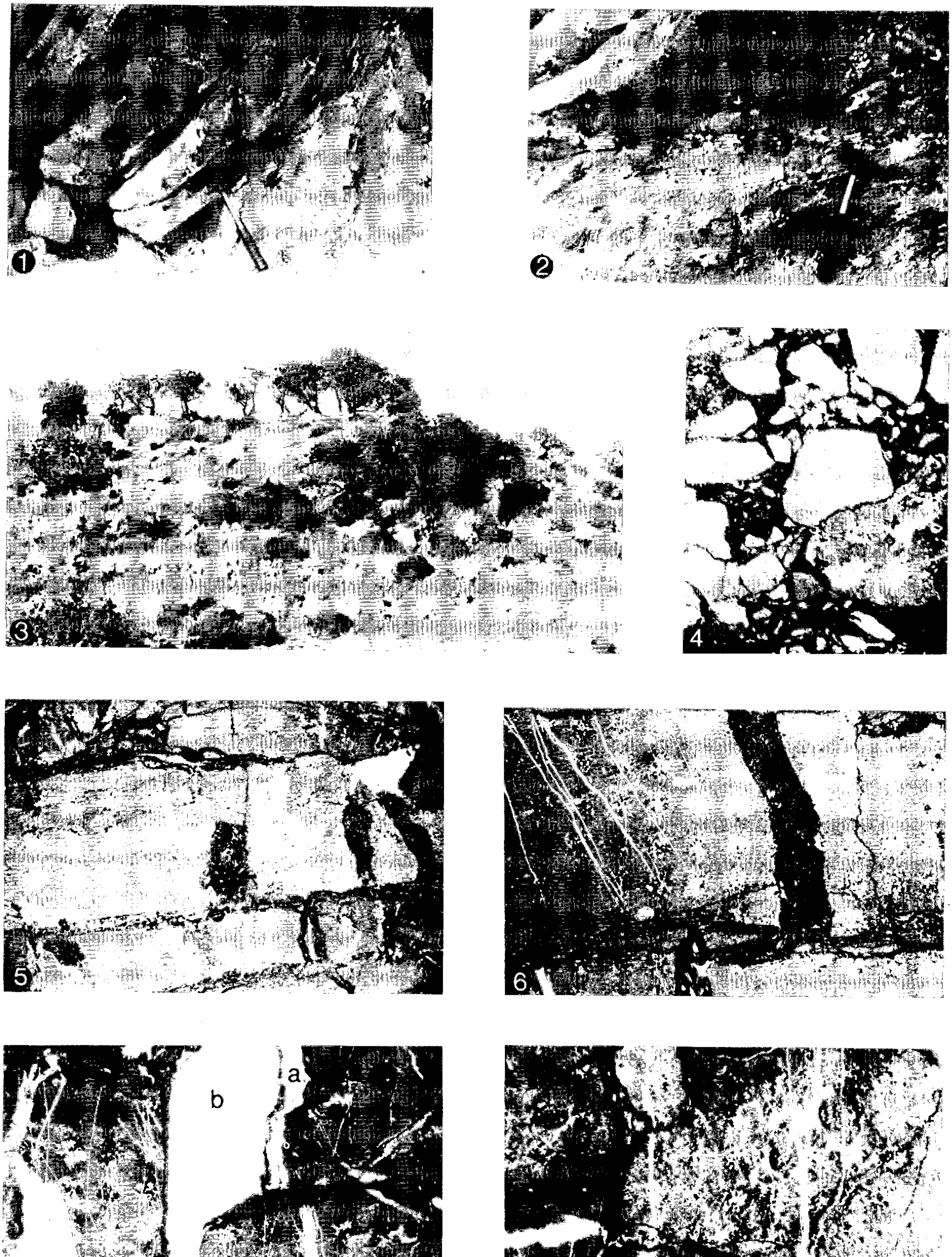
Sample 8-2, 1.0 m above the base of the slide block, from a 0.4 m thick recrystallized limestone bed shows only a stylobreccioid structure.

Two further samples of thin-bedded pelagic limestones (sample 8-4, Plate 1/4; sample 8-6), 1.8 m and 2.4 m above the base of the slide block are still well-developed internal breccias. Bedding-plane parallel shear movements in the scale of several millimeters are still recognized, but in these samples pull-apart of the clasts seems to be more important. Vertical joints are as thick as 10 mm, whereas horizontal fissures never exceed 2 mm (Plates 2/6, 3/2). Accordingly, the clasts tend to be more cubic. They reach sizes of 30 mm, but commonly they are internally broken at subtle fissures. All fissures are infilled with the ferruginous matrix described for sample 8-0.

In most of the overlying beds the sliding resulted only in fracturing of the rocks and the ferruginous matrix is present only in some apophysis-like fissures (Plate 1/5-6).

The development of the internal breccias is predated by two other features. The first stage of the block's movement, perhaps even its incipient separation from an autochthonous rock succession, resulted in fracturing. The resulting fractures are now present as calcite veins, as much as 15 mm thick. They intersect mainly in steep angles to the bedding planes, but low-angle intersections or irregular fractures are also present. The calcite veins are obviously not real joints, first, because of their irregular-spaced appearance and second, because they commonly taper and terminate apophysis-like at unpredictable spots (Plate 2/6).

Most of the calcite veins are transected by stylolites (Plates 2/8, 3/1, 3/7). The formation of stylolites, therefore, postdates the formation of most of the calcite veins and seems to be related to an early phase of sliding. The irregular to low-peaked stylolites may form stylobreccioid structures (Plate 2/8). The pressure-solution surfaces are commonly enlarged during shear movements. In many cases a brecciation and an infill of the ferruginous matrix (see description of sample 8-0) take place along these pressure-solution surfaces. Also the calcite veins as preexisting fracture zones were opened again in this last phase of brecciation and infilled with the ferrugious matrix (Plate 2/7). In a few cases rare remaining or new



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opened craks were filled with late calcite (Plates 2/7, 3/1).

In summary, four consecutive processes are interpreted to have led to the observed rock structure (Plate 1/4): (1) generation of calcite veins from fractures during the genesis of the slide block; (2) formation of stylolites and stylobreccioid structures in an early stage of sliding; (3) brecciation during continued movement; (4) filling of rare remaining or newly opened cracks with sparry calcite. Such multiple fracturing and brecciation is commonly observed in internal breccias and points to longlasting processes (Richter & Füchtbauer, 1981: 465).

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Plate 2. — *Internal deformation features of the slide block.* Figs. 1-3: outcrop photographs; Figs. 4-8: photomicrographs of thin-sections.
Figure 1. — Base of the slide block at its southern margin. Limestones of the slide block are underlain by a cataclastic shear zone. Length of hammer 32.5 m.
Figure 2. — Base of the slide block at its south-eastern margin. Note missing bedding structures but faint 'fluidal' structures in the cataclastic shear zone. Lower side of overlying limestone bed is totally brecciated. Length of hammer 32.5 m.
Figure 3. — The limestone slide block at Arroyo de la Cruz seen from the west.
Figure 4. — Base of the slide block. Degree of fitting is high between large components. Smaller clasts float without orientation in ferruginous matrix. Rock starts to resemble mass-flow breccia. Sample 8-0 x 5.0.
Figure 5. — 0.5 m above base of slide block. Typical internal breccia with degree of fitting nearly 100 %. Matrix only present in thin fissures. Long-sided rectangular clasts and well-developed horizontal fissures point to strong horizontal shear movements. Sample 8-1. x 5.0.
Figure 6. — 1.8 m above base of slide block. Internal breccia composed of ± cubic clasts. Horizontal shear movements still present, but pull-apart of clasts prevails, producing thick vertical joints. Note tapering calcite veins of the earliest phase of deformation. Ostracode(entomozoan)-biomicrite. Sample 8-4, lower part. x 5.2.
Figure 7. — Calcite vein (a) of the earliest phase of deformation reopened during last phase of brecciation, and rimmed with dark ferruginous matrix. Ferruginous matrix also intrudes into former stylo-planes. Large calcite-filled crack (b) in center still postdates brecciation! Sample 8-4. x 5.2.
Figure 8. — Detail of stylobreccioid structure. Stylo-planes with thick accumulation of stylocumulate transect calcite veins of earliest deformation. Recrystallisation results in typically clotted structure of former micritic sediment. Sample 8-2. x 6.6.

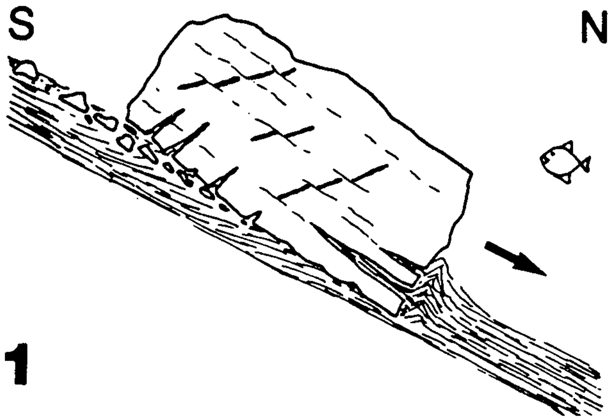
SENSE OF EMPLACEMENT

Generally the Palaeozoic of the Marbella coastal plain dips to the south; the slide block is situated in a small, E-W striking syncline. The dips of the slide block and of its encasing nonresistant rocks are of special interest and probably give hints on the direction of transport. Curiously, the dips of both are not fully consistent: most of the slide block dips to the NW; only a small northern part dips to the S (Fig. 3 b). This part is interpreted to be the front of the block, driven into the underlying unconsolidated sediments by its weight and bent up during movement. In this way, it could act like a ski-shovel during further sliding. The general NW dip of the slide block, therefore, approximately represents the sense of its emplacement, considering a rather synthetical, not antithethical, movement downslope.

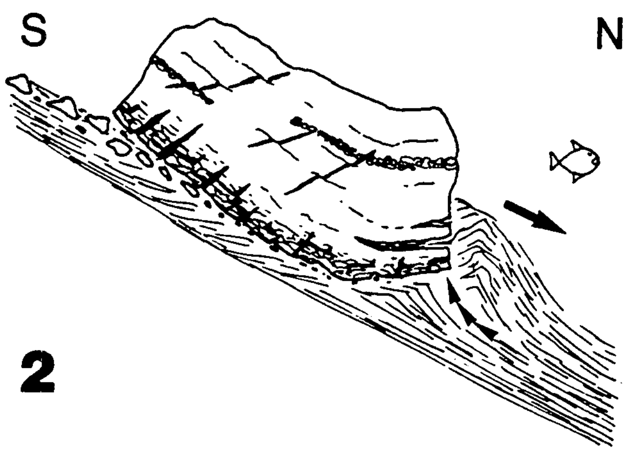
Bulldozing of the sediments in front of the slide block may have initiated the small syncline. Afterwards, the structure was accentuated by higher compaction of the underlying siliclastic muds and sands through the weight of the block. A final development of the syncline is envisaged during the movements causing the tectonic imbrication of the Palaeozoic rocks. The slide block behaved like a rigid mass and resisted installation of the predominant dip to the south.

Two further observations support the hypothesis of a NW to N emplacement of the slide block. First, at its NE edge, a several meters long shale injection wedging out to the S, is observed. Such a structure can only be generated at the frontal part of a slide block, intruding there between split bedding-planes. Second, the zone of cataclasis at the base of the block is developed only at its southern, eastern, and northeastern margins (Fig. 3 b). This zone is interpreted as a wake phenomena opposed to the direction of transport. Coincidentally, the oldest beds of the slide block are exposed at its eastern to northeastern margins. In its southern part they were destroyed by cataclasis.

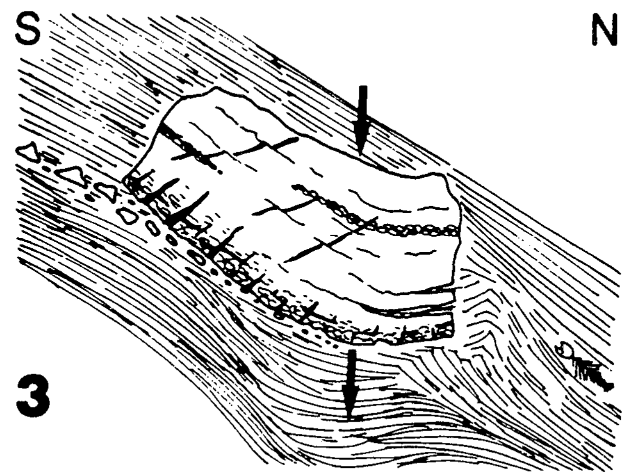
In summary, the slide block seems to have moved from a southern to southeastern direction. In Fig. 4 the envisaged movements of the block and the development of the syncline are sketched in several stages.



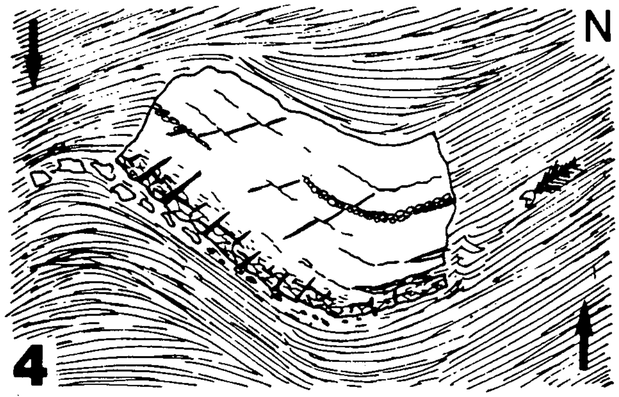
Sliding approximately parallel to bedding-planes; cataclasis as a wake phenomena; shale injections at the slide block's front between split bedding-planes; development of stylolites as response to internal shear-stress; stylolites transect older calcite veins.



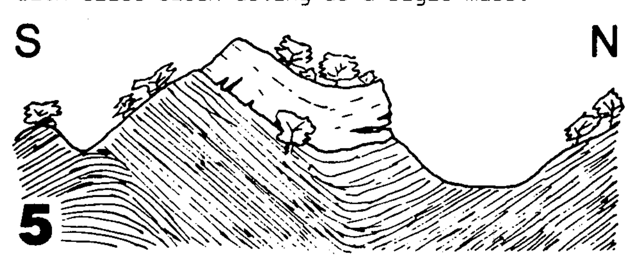
During further movement upward-warping of the slide block's frontal part as a ski-shovel effect; strong cataclasis at the base with development of internal breccias. Internal breccias in higher parts of the slide block point to internal shear movements.



Further sedimentation of siliclastic rocks; initiation of syncline by different loading and accentuation of ski-shovel form.

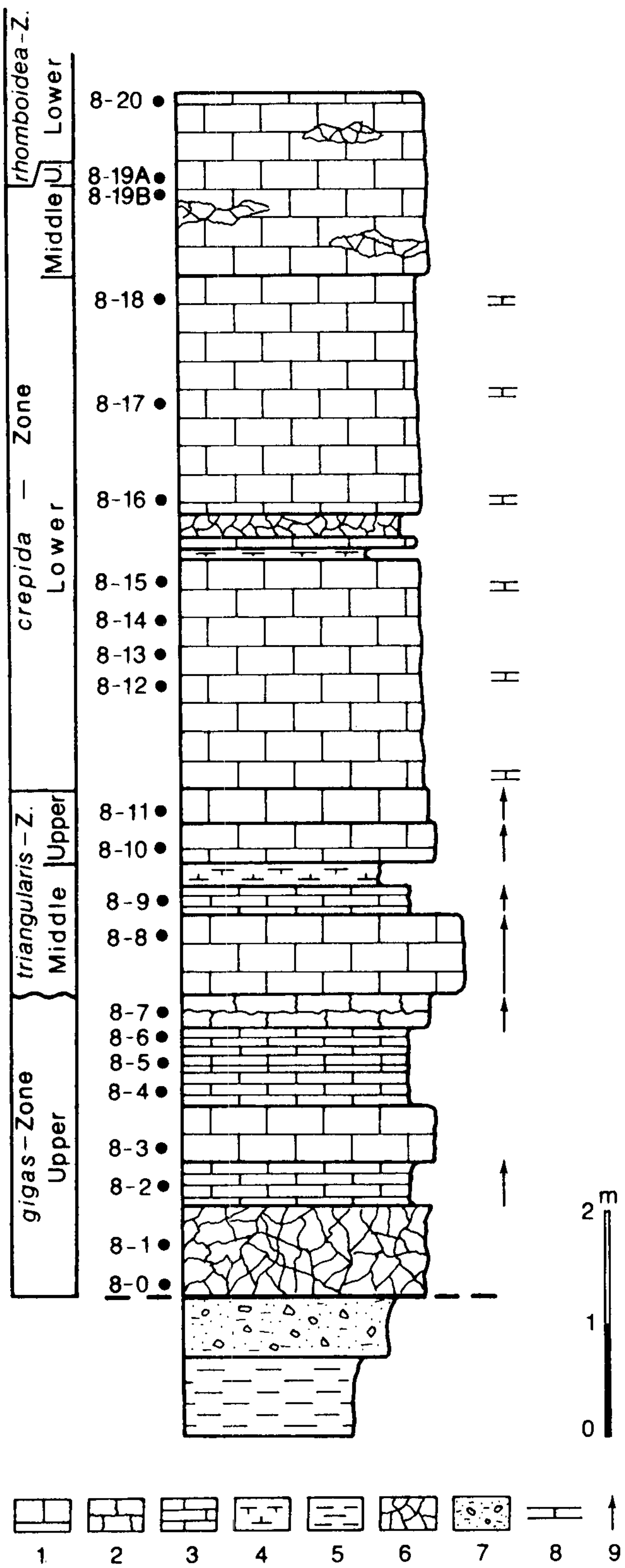


Late tectonic installation of a generally southern dip; full development of syncline with slide block acting as a rigid mass.



Present status after erosion.

Figure 4. — Different stages of movement and connected internal deformation of the slide block at Arroyo de la Cruz and development of synclinal structure.



LITHOFACIES

The slide block shows two genetically different types of limestones. Most of its lowermost 2.4. m consists of pelagic mudstones. The overlying part of the section, approximately 8 m thick, are predominantly limestone turbitides with some minor pelagic interbeds (Fig. 5).

a) *Pelagic mudstones:* Samples 8-0, 8-1, 8-2?, 8-4, 8-5, 8-6, 8-9, partly: 8-14, 8-15, 8-18.

Macroscopically, these are light-grey, micritic limestones, mostly in 5-10 cm thick beds, with scattered pelagic microfossils. Different degrees of recrystallisation affected the rock, in some places forming patches or bands of clotted structure and in other places resulting in totally recrystallized microsparites (sample 8-2, Table 2/8), in which the fossil content is obliterated. Three important microfacies types are discernible according to the predominance of different organisms, in spite of recrystallisation and strong tectonisation.

Radiolarian-bearing micrites (sample 8-14, upper part): Plate 3/3. The homogeneous micritic matrix contains scattered calcified radiolarians and undeterminable, silt-sized microbioclasts. Other fossils are absent. This type of sediment is found only as a pelagic interlude on top of a limestone turbidite (t_f of the BOUMA-sequence). In sample 8-18 radiolarians are present in the t_e interval of a turbiditic limestone, which grades into a heavily burrowed micrite containing silt-sized microbioclasts (Table 4/3). The horizontal and vertical burrows are 0,25 mm in diameter.

Ostracode(entomozoan) - biomicrite (sample 8-0?; 8-1; 8-4, lower part; 8-6?; 8-9?; 8-15, lowermost part): Plates 2/6, 3/5, 3/8. Ostracodes, frequently ornamented, spinose valves of the pelagic group Entomozoidae are the predominant organisms. Single valves occur as well as complete, sparite-infilled shells. Other fossils include rare sponge spicules, radiolarians, styliolinids, trilobites (Plate 3/6), small filamentous shells and undeterminable, silt-sized microbioclasts. Burrows with less compacted carbonate mud and geopetal fabrics - roof of sparry calcite and bottom filled with sediment - are common.

Styliolinid-biomicrite (samples 8-4, upper part; 8-5): Plates 3/4, 3/7. Styliolinids are the predominant organisms. Other fossils include ostracodes, some of them

Figure 5. — Litho- and biostratigraphic section of the slide block, as indicated in fig. 3b. 1, fine-grained limestone turbidites; 2, coarse-grained, stylobreccioid limestone turbidites; 3, pelagic limestones; 4, pelagic marls; 5, shales (underlaying the slide block); 6, internal limestone-breccias; 7, cataclasized shales with fragments of other sedimentary rocks; 8, marly interbeds separating limestone turbidites (schematically indicated); 9, single limestone beds of prominent thickness.

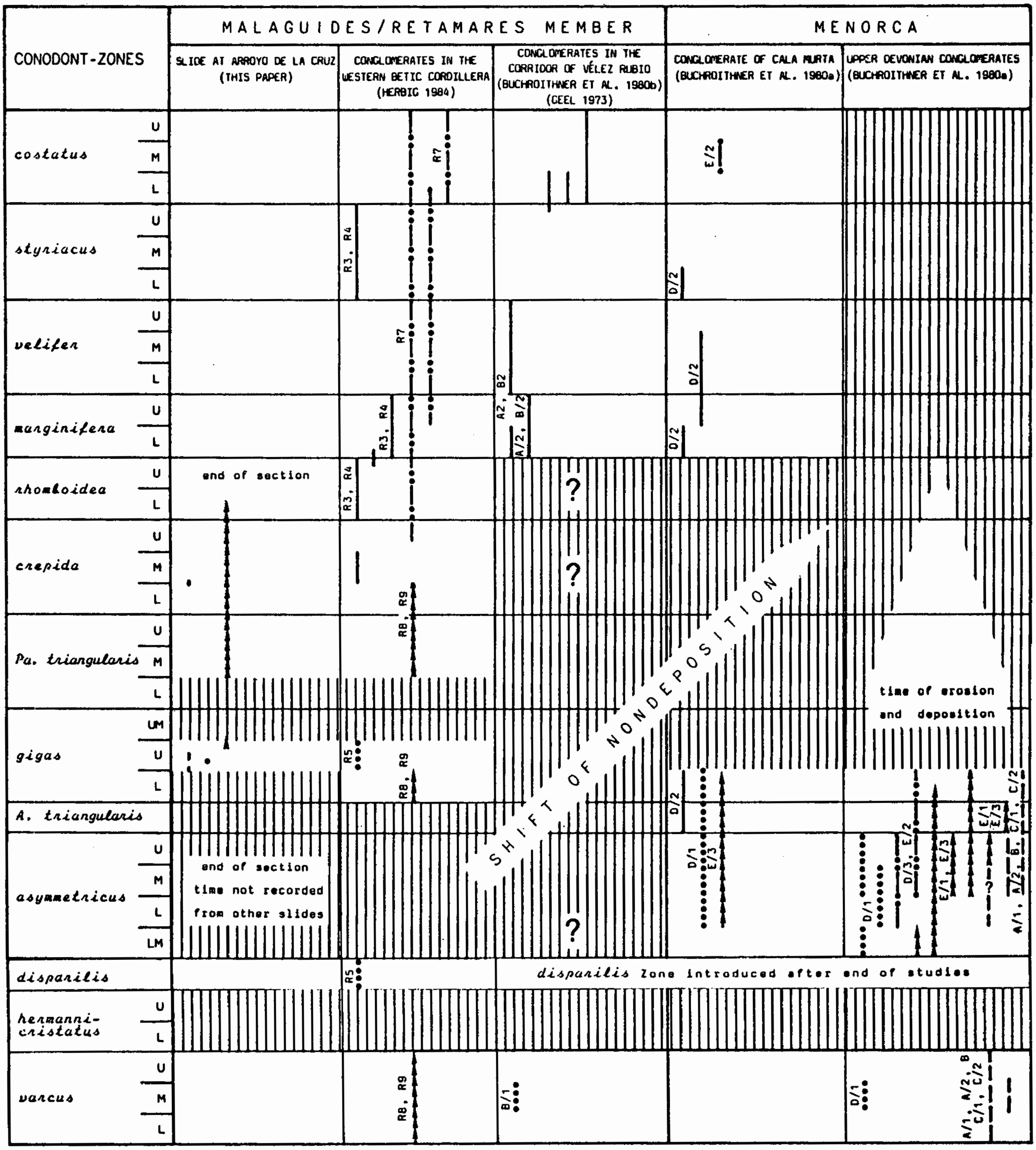


Figure 6. — Age and carbonate microfacies of isolated late Middle Devonian and Upper Devonian limestone pebbles from the Betic Cordillera (Malaguides) and Menorca. Concurrent age/microfacies determinations are indicated only once. Solid lines: ostracode (entomozoan) - biomicrite, including reworked monomictic breccias of the rock-type; dotted lines: styliolinid-biomicrites; broken lines with dots: pelagic biomicrites (in the Corridor of Vélez Rubio included into ostracode (entomozoan)-biomicrites); arrowed lines: allochthonous deeper water limestones; broken lines: shallow water limestones, including their reworked slope facies; vertically ruled: hiatuses. Code numbers refer to the microfacies types described by the cited authors.

entomozoans, and silt-sized microbioclasts. Radiolarians, trilobites, and small echinoderm fragments are rare, as are burrows. Layers with peloids exist. Geopetal fabrics as described for ostracode(entomozoan)-biomicrites occur in styliolinid and ostracode shells.

Interpretation and comparisons: All pelagic microfacies types described above are known from limestone pebbles of comparable age, found in conglomerates of the Retamares Member (Corridor of Velez Rubio/Eastern Betic Cordillera: Buchroithner *et al.*, 1980 b; Western Betic Cordillera: Herbig, 1984). Ostracode(entomozoan)-biomicrites and styliolinid-biomicrites are known from limestone-bearing conglomerates of Menorca as well (Buchroithner *et al.*, 1980 a). Figure 6 gives an overview of the different ages of the limestone-types in the various regions compared with the slide block at Arroyo de la Cruz.

In the Retamares Member, Herbig (1984) also observed the formation of clotted structure and microspar in the limestone pebbles formed by ostracode (entomozoan)-biomicrites. In all types of pelagic microfacies he observed stylolitization, which in several cases led to nodular structures. Thus, not only microfacies, but also recrystallisation and tectonisation are very similar and stress a common source area for the limestone pebbles in the Retamares Member and the slide block at Arroyo de la Cruz. Cook (1979) also showed the formation of different types of conglomerates by progressive brecciation of limestone slide blocks.

On the other hand, the limestones of the Arroyo de la Cruz slide block show no signs of fresh-water diagenesis encountered in the analogous limestone pebbles from the Retamares Member, such as dogtooth cements or typically twisted, fibrous calcite crystals in the shells of styliolinids.

Buchroithner *et al.* (1980 a, b) and Herbig (1984) assumed a pelagic, deep-subtidal to upper-bathyal rise within the basin as the site of deposition for ostracode (entomozoan)-and styliolinil-biomicrites. In the limestones at Arroyo de la Cruz faunal density and clear predominance or entomozoans of styliolinids are poorly developed features, compared with the bulk of the limestone pebbles from the Retamares conglomerates. The poor development points to relatively unfavorable environmental conditions. For this reason, and because of the intimate connection with limestone turbidites, a more basinal deposition is envisaged for the pelagic limestones of the slide block.

b) *Limestone turbidites*: (samples 8-3, 8-7, 8-8, 8-10 through 8-19, only partly 8-14, 8-15, and 8-18).

Macroscopically these are bluish-grey to dark-grey, fine-grained to massive limestones, which form beds mostly 20 to 30 cm thick with a few as thick as 70 cm. Often the limestone beds are separated by thin, yellowish weathering, marly interbeds, which can reach a maximum thickness of 10 cm. These interbeds represent the autochthonous pelagic sedimentation.

Microfacies studies revealed that most of the limestone turbidites are very fine grained. Only sample 8-7, a 30 cm thick bed, is a rudstone (Plates 3/8, 4/1). This stylobreccia probably corresponds to interval t_a of the BOUMA-sequence and consists of three different types of clasts, 0.5-15 mm in diameter. These are, first, ostracode(entomozoan)-biomicrites, which are strongly recrystallized in many cases, forming clotted structure and microspar; second, microbioclastic packstones, a facies type known especially from the t_a interval of the fine-grained turbidites described below, and third, isolated echinoderm fragments.

The fine-grained turbidites show various parts of BOUMA-intervals (t_a through t_e). Sometimes their differentiation is difficult, and complete sequences are rare. In an idealized limestone bed the following characteristics are observed from bottom to top.

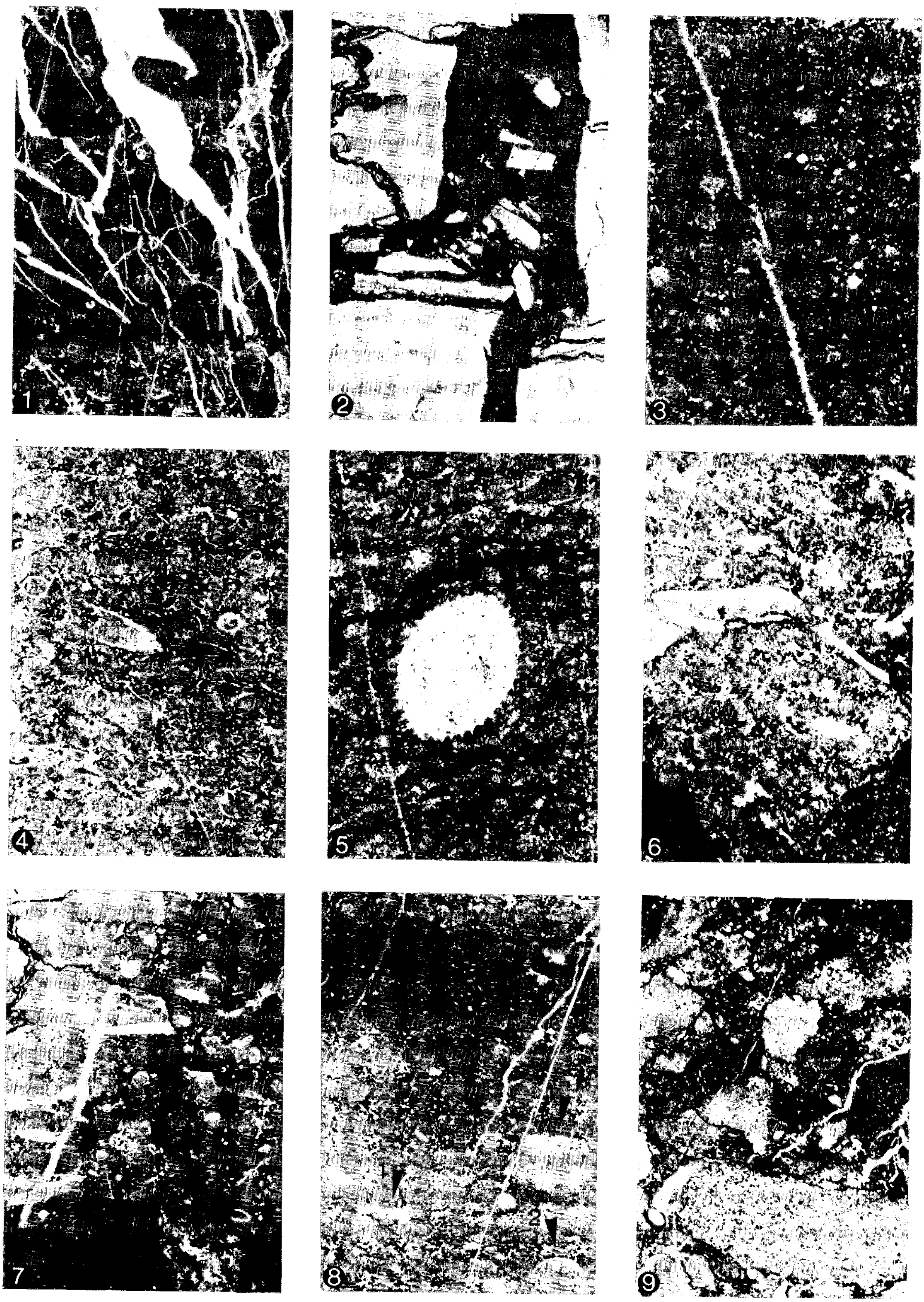
Divisi**ó**n t_a (Plate 4/2, 4/6): This basal division is in most samples poorly developed or missing. It consists of 1-3 cm of normally graded, in many cases densely packed, sparitic sediment. Grainsize never exceeds that of coarse sand, except for some shells and echinoderm fragments. Most components are small micritic intraclasts and pseudopeloids (Flügel, 1982: 133). Some structureless sparitic grains with micrite envelopes could be calcispheres, at least in part. Rare fossils include tiny shells and echinoderm fragments. The contact with the underlying pelagic sediment is often overprinted by stylolites (Plate 4/6). Reworked pelagic clasts, invariably smaller than 10 mm and a wavy, erosional base are observed only in sample 8-3 (Plate 4/2).

Division t_b (Plate 4/7-8): This is the best developed division in the investigated samples. It consists of 1-5 mm thick, parallel laminae of alternating pelsparite and pelmicrite. Also within the pelsparitic laminae a certain amount of micritic matrix is present. Very well sorted, densely packed pseudopeloids, 0.05-0.1 mm in size, are the almost unique components. Fossils are scarce, except for some tiny shells and echinoderm fragments. Commonly the components are orientated with their long-axis parallel to the bedding-plane. There is an overall tendency for normal grading and increasing micrite content towards the top of the division.

Division t_c (Plate 4/4): This is characterized by current ripple lamination of pelsparitic and pelmicritic laminae. It shows the same components as t_b with a continued trend of decreasing grain size and increasing micrite content.

Division t_d and t_e are difficult to discern; both are very fine grained pelmicrite (Plate 4/5). Calcite grains, probably microbioclasts and radiolarians (the first autochthonous component) are common. Planar lamination, characteristic of t_d, is often obscure or seems to be missing totally in the upper part, which, therefore, has to be division t_e. In sample 8-18, division t_e is overlain by an autochthonous, bioturbated mudstone (division t_f; Plate 4/3).

Interpretation and comparisons: According to the presence of BOUMA intervals and the predominance of medium to thick-bedded limestones, the sediments correspond to limestone turbidites and not to contourites, as might be thought because of their fine-grained appearance. They do not contain any shallow-water components and, therefore, are derived from lower-slope environments or from intrabasinal rises. The reworking of pelagic material, predominantly mudstones, explains the small grain size and the poor spectrum of components. The relatively thick beds,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which are atypical for such fine-grained turbidites, can be easily explained by the relatively proximal source within the deep basin or by ponding effects.

Limestone turbidites with very similar sedimentological criteria were described by Scholle (1971) from the Upper Cretaceous of the Northern Apennines (northern Italy). He also stressed the reworking of contemporaneous deep-water carbonate oozes from a continental slope-rise or from a ridge within the basin, producing very fine grained, but thick-bedded turbidites with missing shallow-water components. Scholle (loc. cit.) assumed a sedimentation below the carbonate-compensation depth because of the absence of carbonate material in the background sediment.

Plate 3. — *Internal deformation features of the slide block*: figs. 1-2. Microfacies of pelagic mudstones, figs. 3-8; Microfacies of limestone turbidite, fig. 9; Microphotographs of thin-sections.

Figure 1. — Typically irregular spaced calcite veins of early fracturing transected by irregular to low peaked stylolites which form a stylobreccioid structure. Apophysis-like, central calcite vein transects first generation of calcite veins as well as stylo-planes. It is related to filling of last cracks after brecciation ocurred (brecciation not documented in this microphotograph). Sample 8-4. x 5.2.

Figure 2. — Thick vertical joint in internal breccia filled with dark ferruginous matrix. It contains small clasts plunged in from above. Sample 8-4. x 5.0.

Figure 3. — Radiolarian-bearing micrite. Radiolarians appear in many cases as relatively coarsely recrystallized, calcitic ghost-structures (arrows). Sample 8-14. x 32.

Figure 4. — Styliolinid-biomicrite. Sample 8-4, upper part. x 16.5.

Figure 5. — Ostracode(entomozoan)-biomicrite. Complete, calcite filled spinose shell of pelagic living entomozoa. Matrix heavily affected by pressure solution. Sample 8-4, lower part. x 45.

Figure 6. — Trilobite fragment. Typical «shepherds-crock» pattern. Trilobites are very rare in the pelagic limestones. Sample 8-9. x 16.

Figure 7. — Styliolinid - biomicrite. Styliolinid - shells and burrows (arrows) contain less compacted pelmicritic carbonate mud and geopetal fabrics (roof of sparry calcite and bottom filled with sediment). Stylolites form stylobreccioid structure and transect calcite veins of first deformation. Sample 8-5. x 6.6

Figure 8. — Ostracode(enomozoan) - biomicrite. Burrows (arrows 1) contain less compacted pelmicritic sediment and geopetal fabrics as described under fig. 7. Shelter-struceure below small filamentous shell (arrow 2) causes same structures. Sample 8-1. x 0.5

Figure 9. — Stylobreccia, consistent to division t_a of the BOUMA-sequence. Large clast at lower margin is a reworked microbioclastic packstone from the t_a interval of fine-grained turbidites. Sample 8-7. x 5.2.

At Arroyo de la Cruz, autochthonous carbonate interbeds exist and the sedimentation was above the carbonate-compensation depth, therefore.

The microfacies of the limestone turbidites described, is comparable to the type R9 (microbioclastic packstone) of Herbig (1984), encountered in limestone pebbles of the conglomerates in the Retamares Member, Western Betic Cordillera. Herbig's type R1 (unfossiliferous, homogeneous or laminated micrites), also known from limestone pebbles of the Retamares Member, may be connected, at least in part, with the t_d or t_e intervals of the limestone turbidites.

CONODONT BIOSTRATIGRAPHY

The first to state the Devonian age of the slide block at Arroyo de la Cruz was Blumenthal (1949: 40), who discovered *Tentaculites* sp. and *Nautilus* sp. On the basis of four conodont samples, Herbig (1984: 30) proved the presence of the Lower *gigas* Zone, the interval Middle to Upper *Palmatolepis triangularis* Zone, and the *rhomboidea* Zone and, therefore, a late Frasnian to early Famennian age of the slide block. Seventeen additional samples were collected to test the assumption of a continuous sedimentation from the Lower *gigas* to the *rhomboidea* Zones with the *crepida* Zone not detected due to wide-spaced sampling.

Forty-three conodont form-species of platform genera, including subspecies and morphotypes (Tab. 1), and a detailed conodont zonation coul be unraveled from the now well- documented section at Arroyo de la Cruz (Fig. 5). Accompanying microfossils are rare. They include some agglutinated foraminifers, mainly of the genus *Hyperammina*, a hexactinellid sponge spicule, some pteriomorph lamellibranchs, ostracodes and conical fish teeth.

The applied conodont zonation follows Sandberg (1979), who refined ranges of Upper Devonian zonal index species based on sections in the Western United States. The results are fully applicable to the standard Upper Devonian conodont zonation (Sandberg, 1979: 88) and were not yet considered in Klapper & Ziegler (1979). Ranges of *Icriodus* are based on Sandberg & Dreesen (1984).

The succession of the slide block at Arroyo de la Cruz starts in the Upper *gigas* Zone. This is proved by the joint occurrence of *Icriodus alternatus alternatus*, first appearing at the base of the Upper *gigas* Zone, and *Ancyrodella ioides*,

● 1–3 specimen
╲ 4–10 specimen
╳ 11–20 specimen
◣ 21–30 specimen
▩ > 30 specimen

	gigas-ZONE							*triangularis*-Z.				*crepida*-ZONE									*rhomb.*-Z.
	UPPER							MIDDLE		UPPER		LOWER							M.	U.	L.
	8-1	8-2	8-3	8-4	8-5	8-6	8-7	8-8	8-9	8-10	8-11	8-12	8-13	8-14	8-15	8-16	8-17	8-18	8-19B	8-19A	8-20
Ancyrodella buckeyensis				╲	cf																
Ancyrodella curvata					●																
Ancyrodella ioides	●		●				●														
Ancyrodella lobata		●				cf	●														
Ancyrodella nodosa	●	●	●	●	╲		╲														
Ancyrognathus sp.				●																	
Palmatolepis gigas	●		●	╳	╲		●														
Palmatolepis hassi	╲	●																			
Palmatolepis subrecta	╲	●		╳	╳	●	╳														
Polygnathus decorosus			╲	▩	◣	●	╳														
Polygnathus webbi				●			●		?												
Icriodus ssp.	╲							●												◣	
Icriodus symmetricus							╲														
Icriodus alternatus alternatus	╲						╲	●	╲	╲	●	●	╲	╳	●		●	●	●		
Icriodus alternatus helmsi														●					●		
"*Icriodus*" *cornutus*								●	●							●			╲		
Palmatolepis delicatula delicatula								╲	◣	◣	╳		╲	╳	╲	╳	◣				
Palmatolepis delicatula clarki								●	◣	●				╲		╲	●				
Palmatolepis minuta minuta										╲	●				╲	╳	◣	╲	▩	╲	╲
Palmatolepis perlobata perlobata															●				╲		
Palmatolepis cf. *regularis*																			╳		
Palmatolepis subperlobata								╳	╳	╳	╲	╲	●	╳	╲	╲		╲	╲	╲	●
Palmatolepis tenuipunctata														cf	●	●	╲	●	▩		
Palmatolepis triangularis								╲	▩	●			●	▩	╲	╲	●				
P. triangularis → *quadrantinodosalobata*									╲		●		●				●				
Pelekysgnathus planus														●			●		●		
Polygnathellus ssp.							●		●					╲	●				●	●	
Polygnathus brevilaminus									╲								●				
Polygnathus procerus									╳	╲			●	●		●			╲		
Palmatolepis quadrantinodosalobata												●	●	╳	╲	╲			╳		
Palmatolepis delicatula protorhomboidea															●	●					
Palmatolepis crepida																			╳		
Palmatolepis termini																			◣		
Palmatolepis minuta loba																			╲		●
Palmatolepis minuta subgracilis																			●		
Palmatolepis perlobata schindewolfi																					▩
Polygnathus glaber glaber																			cf	●	▩
Polygnathus nodocostatus nodocostatus																			●		●
Polygnathus triphyllatus																					●
Palmatolepis glabra lepta																				╲	◣
Palmatolepis glabra pectinata																				╳	▩
Palmatolepis glabra prima																				╲	◣
Palmatolepis klapperi																					◣
Palmatolepis minuta wolskae																					●
P. quadrantinodosalobata morphotype 1																				●	
Palmatolepis rhomboidea																					╲

which becomes extinct within this zone. Other important species, frequently encountered, are *Ancyrodella buckeyensis, A. nodosa, Palmatolepis gigas, Pa. subrecta,* and *Polygnathus decorosus. Ancyrognathus asymmetricus,* whose first appearance defines the base of the Upper *gigas* Zone, is missing.

A hiatus comprises the Uppermost *gigas* and Lower *Palmatolepis triangularis* Zones: sample 8-7 still yields *Ancyrodella ioides,* which becomes extinct within the Upper *gigas* Zone; sample 8-8 contains *Palmatolepis delicatula clarki,* whose lowermost appearance defines the base of the Middle *Pa. triangularis* Zone. Additionally «*Icriodus*» *cornutus* is present, first appearing within that zone. Other commonly encountered species are *I. alternatus alternatus, Pa. delicatula delicatula, Pa. subperlobata,* and *Pa. triangularis.*

The existence of the Uppermost *gigas* Zone elsewhere is evidenced by a reworked specimen of the zonal index species *Pa. linguiformis,* together with a reworked specimen of *Tentaculites* sp., in sample 8-10 (Upper *Pa. triangularis* Zone).

The base of the *Upper Pa. triangularis* Zone (sample 8-10) is recognized by the first occurrence of *Pa. minuta minuta.* Other commonly encountered species are *I. alternatus alternatus, Pa. delicatula delicatula,* and *Pa. subperlobata.*

The Lower crepida Zone starts with sample 8-12 containing the lowermost specimens of *Pa. quadrantinodosalobata* s.s. Other species frequently encountered within the Lower *crepida* Zone at Arroyo de la Cruz are *I. alternatus alternatus, Pa. delicatula delicatula, Pa. delicatula clarki, Pa. minuta minuta, Pa. subperlobata, Pa. triangularis,* and *Polygnathus procerus. Palmatolepis delicatula protorhomboidea* (samples 8-15, 8-16) is present in the middle part of the zone, well below its first occurrence at the type locality in Nevada (upper part of Middle *crepida* Zone). There, limestones of the Middle *crepida* Zone rest disconformably on Middle and Upper Devonian quartzites interbedded with some very sandy dolomites. These

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Table 1. — Distribution of conodont form-species from the limestone slide block at Arroyo de la Cruz.

rocks are undated by conodonts (Sondberg & Ziegler, 1973: 98). Therefore, the exact first occurrence of *Pa. delicatula protorhomboidea* is not known (Sandberg, personal communication).

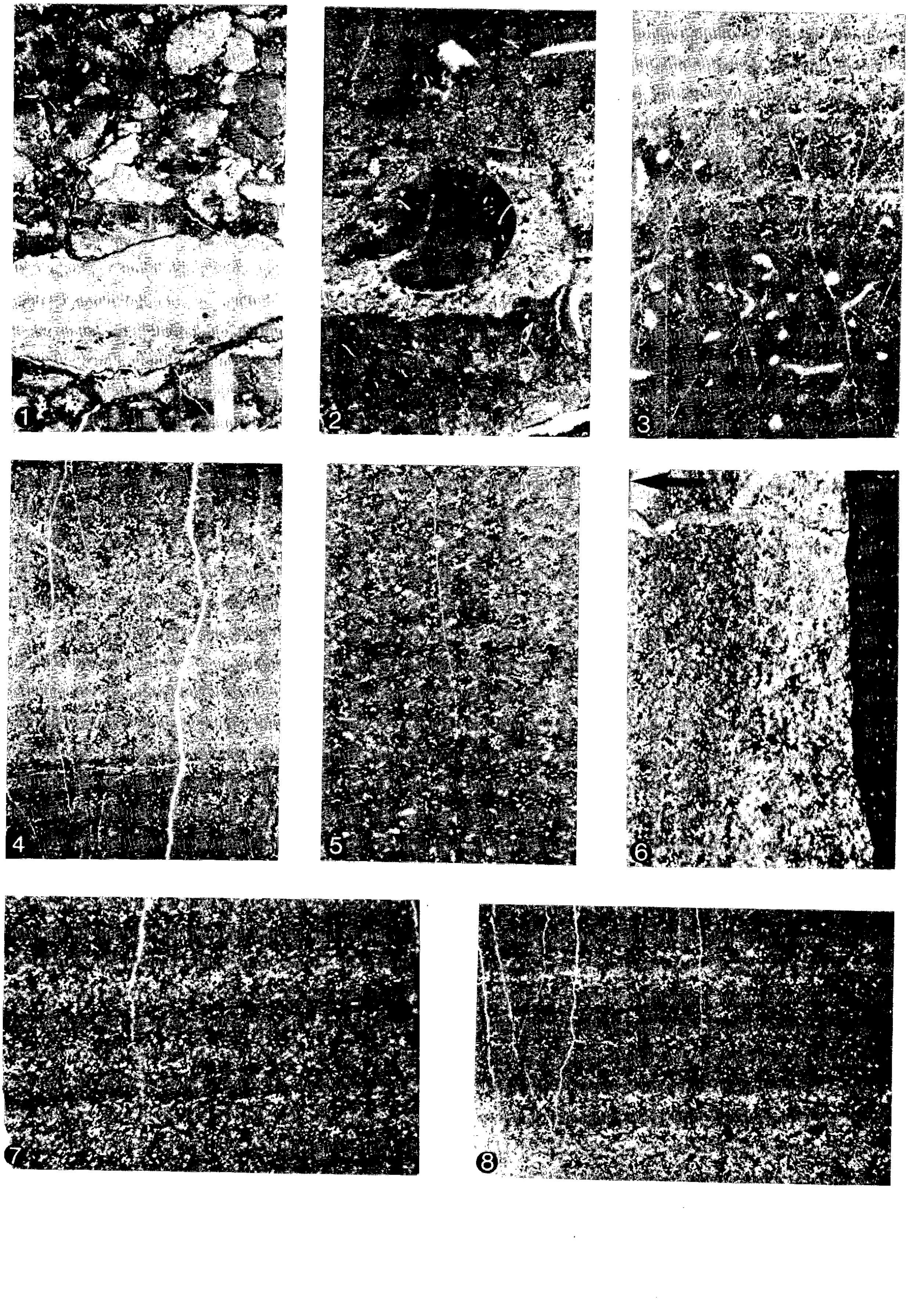
The Middle *crepida* Zone is recognized by the first occurrence of *Palmatolepis termini* (sample 8-19 B), which defines the base of the zone. Additionally, *Icriodus alternatus helmsi* is present, occurring latest at the top of the zone. Only sample 8-19 B yielded *Palmatolepis crepida.* Sandberg (1979: 94-95) interprets joint occurrences of abundant *Pa. termini* and *Pa. crepida* as facies-dependent, pointing to a more offshore pelagic setting (deep-water starved basin setting?) compared to the other species of *Palmatolepis* in that zone.

The upper part of the Upper *crepida* Zone is recognized in sample 8-19 A, taken only 15 cm above sample 8-19 B. The sample yielded *Palmatolepis glabra prima,* whose first occurrence defines the base of the Upper *crepida* Zone. The upper part of the zone is evidenced by the joint occurrence of *Pa. glabra prima* with *Pa. glabra lepta, Pa. glabra pectinata, Pa. quadrantinodosalobata* morphotype 1, and *Polygnathus glaber glaber.*

In the uppermost sample 8-20, the Lower *rhomboidea* Zone is recognized by the first appearance of *Pa. rhomboidea,* which defines the base of the zone. Additionally, *Pa. klapperi* is present, also first occurring at the base of the zone.

CONODONT BIOFACIES

Few conodonts were recovered from most samples belonging to the Upper *gigas* Zone. Adding the numbers of conodonts for all samples consisting of autochthonous pelagic mudstone, a percentage of *Palmatolepis* : *Polygnathus* : *Ancyrodella* : *Icriodus* resulted as 54 : 27 : 12,6 : 6,4. Therefore, the samples of the Upper *gigas* Zone can be placed into the palmatolepid-polygnathid biofacies of Sandberg (1976) and Dreesen & Thorez (1980) which indicates shallow to moderately deep water of an open-marine continental shelf. But relatively deep-water conditions are assumed for the investigated section according to the high percentage of *Palmatolepis.* The interpretation derived from microfacies studies, of a pelagic deep-subtidal to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upper-bathyal rise within the basin as depositional site is well compatible with the results obtained from conodont biofacies. Relatively deep-water conditions also explain the absence of the shallow-water and near-reef dweller *Ancyrognathus* (e.g. Klapper & Ziegler, 1979).

The samples from the Middle *triangularis* to the Lower *rhomboidea* Zones clearly belong to the palmatolepid biofacies of the basin proper (e.g. Seddon, 1970). Other genera than *Palmatolepis* yield only rare specimens. The genus *Icriodus* is mainly represented by the *Icriodus alternatus* group, which occupied relatively quiet offshore settings (Dreesen & Houlleberghs 1980; Sandberg & Dreesen, 1984: 155, 156). All samples are from limestone turbidites and, therefore, probably yield mixed thanatocoenoses.

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Plate 4. — *Microfacies of limestone turbidites.* Photomicrographs of thin-sections.
Figure 1. — Stylobreccia, consistent to division t_a of the BOUMA-sequence. Large clast is a reworked ostracode-(entomozoan)-biomicrite, strongly recrystallized and of predominantly clotted structure. Sample 8-7. x 5.2.
Figure 2. — Pelagic mudstone (lower third of photomicrograph) with irregular erosion surface is overlain by a limestone turbidite - division t_a of the BOUMA-sequence. Micrograding is well developed. Note reworked shell fragment (juvenile ammonoid?) infilled with pelagic sediment. Sample 8-3. x 5.2.
Figure 3. — Autochthonous bioturbated mudstone. Division t_f of the BOUMA-sequence. This unit is directly underlain by the pelmicrite shown in fig. 5, this plate. Sample 8-18. x 5.2.
Figure 4. — Current ripple lamination of pelsparitic and pelmicritic laminae. Division t_c of the BOUMA-sequence. Sample 8-16. x 4.2.
Figure 5. — Very fine grained pelmicrite with calcite grains, probably representing microbioclasts. Division t_d or t_e of the BOUMA-sequence. This unit is directly overlain by the bioturbated mudstone shown in fig. 3, this plate. Sample 8-18. x 8.0.
Figure 6. — Normally graded pelsparite, composed mainly of pseudopeloids. Division t_a of the BOUMA-sequence. Contact to the underlying pelagic mundstone containing filamentous shells and tiny sponge spicules is overprinted by stylolites. Top of photomicrograph is to the left. Sample 8-15. x 6.6.
Figure 7. — Horizontally laminated pelsparite/pelmicrite. Division t_b of the BOUMA-sequence. Sample 8-17. x 8.0.
Figure 8. — Horizontally laminated pelsparite/pelmicrite. Division t_b of the BOUMA-sequence. Note normal grading and increasing micrite content toward the top. Sample 8-11. x 8.0.

According to their palmatolepid biofacies, the turbidites have to be derived from lower-slope environments or from intrabasinal rises; this was also postulated by microfacies studies.

Many specimens from the limestone turbidides are small (juvenile) and smooth forms. Large, coarse sculptured forms are rare or absent in most samples. The small size of the conodonts might be a sorting effect, especially because of the fine grain-size of the turbidites. But, for example, the tiny *Palmatolepis delicatula delicatula* is interpreted as a basinal form (Dreesen & Thorez, 1980). Therefore, it cannot be ruled out that size of specimens and degree of ornamentation might be also environmentally controlled.

CONCLUSIONS AND COMPARISONS CONCERNING THE MALAGUIDES

A limestone lens north of Almogía, described by Kockel & Stoppel (1962: 146) is identical to the slide block at Arroyo de la Cruz in respect of lithofacies and age. The at least 10 m thick slide block shows in its lower part bluish-grey, thin-bedded limestones; towards the top the limestone beds get thicker, darker (blackish-blue) and more compact. This lithofacies is also present at Arroyo de la Cruz with pelagic limestones at the base of the slide block; they are overlain by thickbedded limestone turbidites. Kockel & Stoppel (1962) listed two mixed conodont faunas from the limestone block N of Almogía indicating a late Frasnian to earliest Famennian age (interval from the *Ancyrognathus triangularis* Zone (?) to the *Palmatolepis triangularis* Zone). Two conodont samples from another isolated limestone block N of Almogía (Kockel & Stoppel, 1962: 147) are of earliest Famennian age (Upper *Pa. triangularis* to Middle *crepida* Zones.

The assumption of Herbig (1984: 30) of a continuous sedimentation within the slide block at Arroyo de la Cruz has to be revised. A hiatus comprising the Uppermost *gigas* and Lower *Pa. triangularis* Zones is well documented. The existence of the Uppermost *gigas* Zone elsewhere is evidenced by a reworked specimen of *Palmatolepis linguiformis*. The hiatus is also evident in the lithostratigraphic succession. The time of the Upper *gigas* Zone corresponds mainly to an authochthonous sedimentation of pelagic mudstones with only one turbidite bed intercalated. The unconformity is directly underlain by a 30 cm thick stylobreccia (sample 8-7). Beginning in the Middle *Palmatolepis triangularis* Zone, on top of the hiatus, a nearly exclusively turbiditic sedimentation starts and continues at least into the Lower *rhomboidea* Zone. Turbiditic influx was most intense in the Lower *crepida* Zone, where a 4,5 m thick succession was deposited. The overlying sequence from the Middle *crepida* to the Lower *rhomboidea* Zone is only 1,5 m thick. This points to very occasional turbiditic influxes and to strong condensation.

With the knowledge of a hiatus in the section at Arroyo de la Cruz, it also can be verified in the isolated limestone pebbles from the Retamares Member. Herbig (1984: 27) determined only the Lower and Upper *gigas* Zones, and the interval Middle *Pa. triangularis* to Lower *crepida* Zones. The Uppermost *gigas* and Lower *Pa. triangularis* Zones are missing.

The presence of the hiatus in the limestone pebbles of the Retamares Member and in the slide block at Arroyo de la Cruz points to a relatively widespread unconformity. In fact, a hiatus comprising the Lower and Middle *Pa. triangularis* Zones is widespread on top of the Kellwasser Limestone in the Rhenohercynian Zone of the central European Variscides, in the Montagne Noire, and in North Africa (Buggisch 1972: 16, 45). Buggisch did not distinguish between Upper and Uppermost *gigas* Zones and, therefore, the hiatus might extend into the latter. Johnson *et al.* (1985: Fig. 12) show pronounced eustatic sea-level fluctuations, i.e. regression during the Uppermost *gigas* Zone, transgression during the Lower *Pa. triangularis* Zone, and regression during the Middle *Pa. triangularis* Zone. Also Engel *et al.* (1983: 24) think of a large-scale, probably global «Kellwasser event» causing a break-down in oxygenation of the sea-floor. These events encompass the previously mentioned sedimentary gap.

In the Malaguides two other hiatuses are assumed for late Givetian/early Frasnian times, with (1) the *hermanni-cristatus* Zone missing and (2) the *asymmetricus* and *Ancyrognathus triangularis* Zones missing in the limestone slide blocks described by Kockel & Stoppel (1962) as well as in the limestone pebbles from conglomerates of the Retamares Member (Herbig, 1984: 76).

Biostratigraphic and carbonate microfacies concurrence in limestone slide blocks and limestone pebbles of conglomerates, both within the Retamares Member, heavily stress a common source area. It is regarded to have been a deep-water, pelagic realm, divided into intrabasinal rises and basins. The source area shows a discontinuous sedimentation during late Givetian and Frasnian times. Beginning with the Famennian (Middle *Pa. triangularis* Zone) a continuous carbonate sedimentation ranging to the late Famennian *costatus* Zone still is assumed according to Herbig (1984: 72, 76).

The palaeogeographic position of the source area is unknown. Mesozoic-Cenozoic plate tectonics and the nappe character of the Malaguides allow a primary sedimentary realm in a geographic position differing totally from the Recent position of the Malaguides. As possible source areas the known Palaeozoic realms of the Western Mediterranean, including the Saharan basins, are excluded (Herbig, 1984). Instead, the source area seems to be subducted or totally eroded in our time. The well-documented southern to south-eastern derivation of the slide block at Arroyo de la Cruz and a strong N-S bipolarity of conglomerate components in the Marbella Formation (Herbig, 1984) strongly point to a southern position of the source area. Therefore, a continental slope has to border the Malaguide flysch trough to the south or south-east during Viséan and Namurian times i.e. the time of deposition of the Retamares Member and the younger Marbella Formation.

PALAEOGEOGRAPHIC RELATIONS TO MENORCA

Strong similarities are observed in biostratigraphy and microfacies of limestone pebbles and slide blocks of the Malaguide Retamares Member and limestone-bearing conglomerates from Menorca described by Buchroithner *et al.* (1980 a). Besides rare Lower Carboniferous limestone pebbles both regions yield limestone pebbles from the Givetian *varcus* Zone to the late Famennian *costatus* Zone. Slide blocks, also of older age, are known only from the Malaguides.

In Menorca the *hermanni-cristatus* Zone and the interval Upper *gigas* to Upper *rhomboidea* Zones are not proved from limestone pebbles.

This means that two similar, but different ranging hiatuses than in the Western Betic Cordillera characterize the source area of the Menorcan pebbles.

The post-lowermost Namurian conglomerate of Cala Murta/Menorca is nearly or totally time-equivalent to the conglomerates of the Retamares Member. The concurrence of carbonate microfacies in pebbles from both conglomerates, first noted by Buchroithner *et al.* (1980 b), is striking. Autochthonous pelagic deep-water limestones of Late Devonian age predominate in Cala Murta and in the Retamares Member (Fig. 6). An allochthonous deep-water sedimentation is represented at Cala Murta by moderately sorted microbreccias, which seem to be identical to those of sample 8-7 at Arroyo de la Cruz. Both conglomerates contain rare Upper Viséan shallow-water limestones of comparable microfacies. Some pelagic limestone pebbles from Cala Murta represent the time of the Lower *asymmetricus* to Lower *gigas* Zones, i.e. they are slightly older than those of the Western Betic Cordillera; most are from the Lower *marginifera* Zone and some from younger Famennian conodont zones (Buchroithner *et al.* 1980 a: Tab. 7).

Considering all similarities, the pebbles from Cala Murta/Menorca and the Malaguide Retamares Member seem to derive from a common sedimentary basin of Givetian to latest Viséan age. It was uplifted and eroded, probably already in the earliest Namurian (Herbig, 1984: 81). A relatively big size of the primary sedimentary basin and a later line source erosion explains the small differences in age between the Menorcan and the Western Malaguide pebbles: it is possible to imagine a shifting in time of the zone of nondeposition or erosion, in the primary carbonate basin, from the source area relevant to the Western Betic Cordillera to the source area relevant to Menorca, with a hiatus common to both primary realms during the *hermanni-cristatus* Zone and during the Uppermost *gigas* and lower *Pa. triangularis* Zones. The zone of deposition would shift vice-versa. Beginning with the Lower *marginifera* Zone, sedimentation took place again in both realms.

Upper Devonian conglomerates like those from Ferragut Vell and Escollo del Frances in Menorca are not known from the Malaguides. Their palaeogeographic relations to the conglomerates of Cala Murta and of the Retamares Member are difficult to assess. Due to their Late Devonian deposition different strata than in the post-earliest Namurian had been exposed and eroded.

As opposed to Cala Murta/Menorca and the Malaguide Retamares Member, the Upper Devonian conglomerates of Menorca yield differentiated shallow-water limestone pebbles from the time of the Lower *varcus* to the Lower *gigas* Zones. Ostracode(entomozoan)-biomicrites are missing. In latest Givetian and Frasnian time only quartz-bearing styliolinid-biomicrites and polymict, moderately sorted micro-breccias are common to the Upper Devonian conglomerates and the Cala Murta conglomerate. No limestone pebbles younger than of the Lower *gigas* Zone are reported from Ferragut Vell and Escollo del Frances; the sedimentation of these conglomerates is envisaged a following hiatus (Upper *gigas* to Upper *rhomboidea* Zones) in the original carbonate basin. Buchroithner *et al.* (1980 a: 187) think of an at least partly emergent carbonate shelf in the source area for that time. The hiatus is represented in the stratigraphic gap shown by limestone pebbles from Cala Murta. Such a connection between the Upper Devonian and post-lowermost Namurian conglomerates of Menorca suggests that they derive from a common primary sedimentary basin, but, according to the line source principle, from different sectors. Only in the two sectors, which later provided the pebbles for the post-lowermost Namurian conglomerates of Cala Murta/Menorca and the Malaguides, sedimentation continued through Famennian and Early Carboniferous time.

As for the Malaguides, the source area of the Menorcan pebbles is unknown. Because of similarities in facies and stratigraphic development, Buchroithner *et al.* (1980 a) think of the Moroccan Variscan belt. Such a provenance was disproved for the conglomerates of the Betic Cordillera by Herbig (1984). Sedimentological investigations of the Carboniferous clastic rocks of Menorca point to a northeastern derivation (Obrador *et al.* 1978). Henningsen (1982) mentions a northwestern derivation of the Devonian and a northern to northeastern derivation of the Carboniferous sediments. In both studies later plate-tectonic movements are not regarded.

Only some stratigraphic data are available from limestone pebbles of the Retamares Member in the the Corridor of Vélez Rubio, Eastern Betic Cordillera (Geel, 1973; Buchroithner *et al.* 1980 b; compare Fig. 6). Stratigraphy and lithofacies development is identical to the Western Betic Cordillera. Therefore, the limestone pebbles of both regions and of Menorca should derive from the same primary sedimentary basin. A certain hint is given by *Bispathodus multidenticulatus* Buchroithner 1980, which is only known from upper Famennian limestone pebbles of Cala Murta/Menorca and Vélez Rubio (Buchroithner *et al.* 1980 a: 10). No limestone pebbles are recorded from the Upper *varcus* to the Upper *rhomboidea* Zones. All the time between, therefore, could represent a hiatus. Thus, the source area of the Eastern Betic Cordillera might be a submarine rise, dividing the Menorcan from the Western Betic source area within a single big basin. This idea has to remain speculative, as not enough data are available.

CONCLUDING REMARKS

The Givetian to Uppermost Viséan limestone pebbles and slide blocks of the Malaguides and of Menorca originally constituted a large, common sedimentary basin. It was affected in different degrees by late Givetian and Frasnian tectonic movements or eustatic events, e.g. the «Kellwasser event», which caused stratigraphic gaps of different range. One sector of the basin was elevated in the late Frasnian and shed the limestone pebbles of the Upper Devonian conglomerates of Menorca. The other parts of the basin persisted and probably were elevated in the earliest Namurian. Again two different sectors shed the limestone components encountered in the Retamares Member of the Malaguides in the Western Betic Cordillera and in the Cala Murta conglomerate of Menorca.

These considerations point to a closer position of the Malaguides and of Menorca in late Palaeozoic times and to a Mesozoic-Cenozoic westward displacement of the Malaguides as already expressed by Bourrouilh (1976, 1978) and Bourrouilh & Gorsline (1979). The relative position of the two blocks to one another still is to discuss.

As shown, the source area of the allochthonous limestone components of the Malaguides and of Menorca can be reconstructed by detailed microfacies and biostratigraphic studies. Further studies of limestone slide blocks are necessary to complete this work. Also further data have to be sampled from the Corridor of Vélez Rubio in the Eastern Betic Cordillera. Not at last, other sedimentological and biostratigraphical data have to be gathered from the Malaguides, Menorca, and the other fragments of the Alboran block to solve the palaeogeographic relations amongst these isolated massifs.

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