FACIES	25	147-186	Taf. 36-48	9 Abb.	5 Tab.	ERLANGEN 1991

Microfacies and Depositional Structure of Allochthonous Carbonate Base-of-Slope Deposits: The Late Permian Pietra di Salomone Megablock, Sosio Valley (Western Sicily)

Mikrofazies und Ablagerungsmuster allochthoner Hangfußkarbonate: Der Pietra di Salomone Megablock (Perm), Sosio-Tal (Westsizilien)

Erik **Flügel**, Erlangen, Pietro **Di Stefano**, Palermo and Baba **Senowbari-Daryan**, Erlangen

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SUMMARY

The carbonate breccias and calcarenites of the extremely fossiliferous Pietra di Salomone megablock southwest of Palazzo Adriano, Sosio Valley (Monti Sicani, Western Sicily) represent debris-flow and turbidite sediments deposited in a base-of-slope position.

Microfacies criteria (22 localities, 240 samples) and paleontological data (especially sphinctozoan and inozoan sponges, *Tubiphytes*, *Archaeolithoporella*, fusulinids, conodonts) provide evidence of long- and short-lasting erosion of Middle to Upper Permian carbonate platform marginal reefs formed by binder/encruster and baffler guilds, probably on the uppermost slope. Subsequent to repeated reworking, lithified material (rudstones, boundstones) was transported downslope by sedimentary gravity flow processes and deposited, possibly, as fillings in channels incised in the deep-water basinal marly sediments of the Torrente San Calogero section adjacent to the Pietra di Salomone outcrop.

The coincidence in the biostratigraphical age of the pebbles and the marly matrix of the breccias and of the basinal sediments indicates that the destruction of the platform margins and the platform lasted at least from the Murghabian to the Dzhulfian.

The comparison of the reef biota preserved in the Pietra di Salomone limestone with reef biota occurring in Lower Permian allochthonous blocks within the Lercara 'Formation' (Cozzo Intronata, River San Filippo) points to a turnover in the composition of algal and sphinctozoan sponge associations after the Artinskian, probably during the lower Middle Permian (Kubergandian).

RIASSUNTO

La Pietra di Salomone è il maggiore fra i famosi blocchi calcarei permiani della Valle del Sosio, ubicato a sudovest di

Addresses: Prof. Dr. E. Flügel, Dr. B. Senowbari-Daryan, Institut für Paläontologie, Universität, Loewenichstraße, D-8520 Erlangen; Dr. P. Di Stefano, Dipartimento di Geologia e Geodesia, Corso Tuköry 131, I-90134, Palermo, Italia

Palazzo Adriano (Monti Sicani, Sicilia occidentale) e noto fin dal secolo scorso per la straordinaria ricchezza di fossili. Questo blocco calcareo risulta costituito da carbonati clastici risedimentati, prevalentemente da debris-flow, alla base di una scarpata.

L'analisi delle microfacies e i dati paleontoloigici basati principalmente sulle spugne calcaree, *Tubiphytes, Archaeolithoporella,* fusulinidi e conodonti, indicano che le aree di alimentazione del materiale clastico erano costituite da complessi di scogliera ubicati al margine di piattaforme carbonatiche del Permiano medio e superiore.

Il materiale clastico (per lo più elementi già litificati di rudstones e boundstones) prodottosi in seguito a ripetuti eventi erosivi, è stato trasportato lungo la scarpata mediante flussi gravitativi e potrebbe aver costituito il riempimento di canali incisi nei depositi permiani di bacino rappresentati nella sezione del Torrente San Calogero, contigua alla Pietra di Salomone.

I dati biostratigrafici ricavati dagli elementi e dalla matrice marnosa delle brecce e quelli provenienti dai depositi di bacino, indicano che lo smantellamento dei margini della piattaforma si è protratto almeno dal Murgabiano allo Giulfiano.

Il confronto fra le faune di scogliera presenti nella Pietra di Salomone con quelle del Permiano inferiore presenti nei carbonati clastici della 'Formazione' Lercara (Cozzo Intronata, Fiume San Filippo) evidenzia una variazione nella composizione delle associazioni algali e delle spugne calcaree, variazione registrata dopo l'Artinskiano, probabilmente alla base del Permiano medio (Kubergandiniano).

1 AIM OF THE STUDY

The Permian of western Sicily is famous for the abundance and sometimes excellent preservation of its fossils, which have been studied since the middle of the last century. These fossils occur within large- and small-scaled allochthonous blocks whose deposition was originally regarded as being Mesozoic in age (CATALANO & D'ARGENIO 1978, MASCLE 1979).

The largest of the megablocks is the 'Pietra di Salomone' southwest of the village of Palazzo Adriano in the Sosio valley. Its dimensions are about 200 m in length, up to 100 m in width and 30 m in height. This outcrop exhibits limestone breccias whose microfacies, paleontological criteria and depositional features are the subject of our study.

The stratigraphic interpretation of the Permian megablock must consider the recent recognition of a Permian deep-water facies in western Sicily (CATALANO et al. 1988).

1.1 Major topics

Sedimentological and paleontological criteria of the Pietra di Salomone outcrop are used to discuss topics of major interest:

- the microfacies approach in the reconstruction of totally reworked carbonate platform margins
- the depositional interpretation of carbonate slope deposits based predominantly on the compositional data of limestone breccias
- the evaluation of changes in the evolution and diversity of reef biota during the Permian.

1.2 Previous investigations

The Pietra di Salomone (Pl. 36) is the largest Permian megablock in the Palazzo Adriano region. Other blocks (Pl. 37), differing somewhat in facies and biota, are the Rupe di San Calogero, the Rupe del Passo di Burgio and the Pietra dei Saracini (identical with the Rocca di San Benedetto), see Fig. 1. The Pietra di Salomone is situated adjacent to the Torrente San Calogero section, which represents the basinal facies of the Permian (CATALANO et al. 1988).

The allochthonous position of the limestones of the Pietra di Salomone and the Pietra dei Saracini were evidenced by two boreholes (SOLIGNAC 1933).

Fossils from the Pietra di Salomone have been studied from the very beginning of the paleontological investigations of the isolated limestone blocks occurring near Palazzo Adriano, starting with the work of GEMMELLARO, then professor of geology at the Palermo university, who recognized the Permian age and published extensive reports on the fauna between 1887 and 1898.

The fauna comprises:
Fusulinid foraminifera (STAFF 1909, DE GREGORIO 1930, SILVESTRI 1932a, b, 1933, WHEELER 1933, THOMPSON 1935, PASINI 1964, SKINNER & WILDE 1966, SARTORIO & VENTURINI 1988), sponges (DE GREGORIO 1930, PARONA 1929, 1933a, ALEOTTI et al. 1986, SENOWBARI-DARYAN 1990), corals (MONTANARO-GALLITELLI 1953, 1956), bryozoans (CIPOLLA 1952), brachiopods (GEMMELLARO 1893a, b, 1894, 1898,

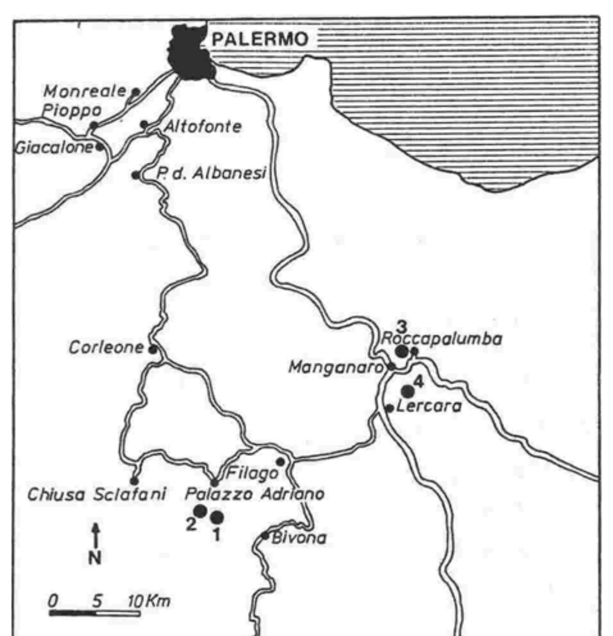


Fig. 1. Location of Sosio megablocks. 1 Pietra di Salomone, 2 Pietra dei Saracini (identical with Rocca di San Benedetto). The Rupe del Passo Burgio and the nearby Rupe di San Calogero are situated northwest of the Pietra di Salomone (see Fig. 3). Other localities with allochthonous Permian limestones occur in the Roccapalumba-Lercara area: 3 River San Filippo, 4 Cozzo Intronata.

1898/99, Di Stefano 1914, De Gregorio 1915, 1930, Merla 1928, Ruiz 1930, 1931, Greco 1937/1938 b, 1940/1941 and 1942/1946, Rudwick & Cowen 1968), gastropods (Gemmellaro 1889, Greco 1937/1938 a), pelecypods (Gemmellaro 1892a, b, 1895, Greco 1937/1938 a), ammonites (Gemmellaro 1887, 1888, Greco 1934/1935, Miller 1933, Miller & Furnish 1940), nautilid cephalopods (Gemmellaro 1889, Greco 1934/1935, Miller 1933), trilobites (Gemmellaro 1890, Greco 1934/1935, Gheyselinck 1937, Ruggieri 1959), crustaceans (Gemmellaro 1890, Bergeron 1890, Greco 1934/1935), ostracods (Gemmellaro 1890), crinoids (Yakovlev 1933, 1938, Yakovlev & Faas 1938, Nicosia 1954), blastoids (De Gregorio 1915, 1930, Yakovlev & Faas 1938), as well as fossils of uncertain taxonomic assignment (Greco 1934/1935, Parona 1929, 1933b, Montanaro-Gallitelli 1953, 1954, 1956, H.W. Flügel 1980).

Many fossil groups are in urgent need of thorough taxonomic revision (e.g., sponges) because of the too generalized descriptions. In addition, some of the original material has been lost (e.g. the collection of De Gregorio).

The numerical diversity appears to be quite high. Mascle (1979) listed more than 300 species from the Pietra di Salomone locality and more than 520 species from all the blocks, but the true diversity is difficult to estimate. Current studies of the sponges by Senowbari-Daryan, however, point to the existence of a high taxonomic diversity.

A paleoenvironmental interpretation of the described fauna is very difficult, because nearly all of the taxa (except for the fusulinids described by Skinner & Wilde 1966) were published without exact indications of the sampling localities. Paleontological descriptions generally refer only to 'Pietra di Salomone'.

Starting with the papers by Gemmellaro the limestone of this outcrop has been regarded by most authors as 'reef limestone' or 'reef-like limestone' (Skinner & Wilde 1966), usually because of the occurrence of organisms believed to be characteristic reef-builders (e.g., Aleotti et al. 1986) although no sedimentological studies have been done up to now. Furnish & Glenister (in Skinner & Wilde 1966) regarded the Pietra di Salomone as '... a reef core composed of sponges and algae to a large extent. At one spot the limestone is definitely stratified and composed of coarse detritus such as in a flank, just a short distance from the massive portion'.

Di Stefano (1990) interpreted the Sosio limestone blocks as slope deposits recognizing the composition of the blocks by limestone breccia consisting of carbonate platform material and resedimented limestone clasts.

Gemmellaro called the limestones 'calcari con *Fusulina*'. This term was later changed to 'Sosio beds' (e.g., Miller 1933). Some authors, refering to a 'Sosio stage', have argued for a chronostratigraphical definition (e.g. Gerth 1950, Montanaro-Gallitelli 1954) which, however, is of no value because of missing stratigraphic control of the fauna derived from allochthonous sediments (Kahler 1974, Mascle 1979). The same criteria argue against the use of the term 'Sosio Formation' introduced by Schmidt di Friedberg (1965).

1.3 Specific questions

The study should help to answer the following questions:

– Were the limestone clasts forming the limestone of the Pietra di Salomone reworked from coeval or non-coeval carbonates ?

The answer to this question is of crucial importance to the environmental interpretation of the carbonates which acted as source material for the components of the limestone breccia. Biostratigraphical data (fusulinids, algae) as well as the comparison of microfacies types and diagenetic criteria are used to answer this question.

– Which facies belts have been reworked ?

The interpretation of microfacies types and their spatial distribution, paleontological data as well as the attribution of the microfacies types to well-established facies models are the basis for answering this question.

– Which depositional pattern is reliable for the allochthonous carbonates now forming the Pietra di Salomone limestone ?

Answers are inferred from the depositional structures recognized in the field and from the microfacies data .

– Which stratigraphical relationships exist between the allochthonous carbonates and the surrounding and adjacent sediments represented by the Torrente San Calogero section (Catalano et al. 1988) southwest of the Pietra di Salomone?

These answers require a discussion of the geological situation and the age of the basinal section.

– The Pietra di Salomone limestone contains a wealth of paleontological information. This data should be used to answer questions dealing with Permian reef evolution.

2 GEOLOGICAL FRAMEWORK

The Sosio limestone blocks occur in the Monti Sicani region (western Sicily). This area belongs to the Sicilian segment of the Apenninic-Maghrebid chain and is characterized by several south-verging tectonic units mostly composed of Triassic to Miocene pelagic carbonates, radiolarites and siliciclastic deposits. In some places Permian siliciclastic and allochthonous carbonate rocks occur at the base of these units.

These units are regarded as being derived during the Neogene deformation of the Sicanian Basin (Catalano & d'Argenio 1978, 1982), partly corresponding to the 'Campofiorito-Cammarata Zone' defined by Broquet et al. (1966).

The Sicanian Basin was a basinal paleogeographic domain of the southwestern Tethys starting with the Permian and continuing to the Cenozoic (Di Stefano 1990, Catalano et al. 1991b).

A typical Sicanian succession is characterized by early to late Permian deposits consisting of deeper-water siliciclastic sediments and allochthonous carbonates followed by Ladinian to early Carnian pelagic bedded cherts, tuffites, red nodular limestones and marls, middle Carnian platy limestones and marls, overlain by late Carnian to Rhaetian cherty limestones.

The overlying rocks are represented by marls, carbonates, basalts and radiolarites (Jurassic) followed by *Calpionella* limestones and by marls and calcilutites of Cretaceous to Oligocene age. These beds are unconformably overlain by Miocene glauconitic sandy calcarenites and marls.

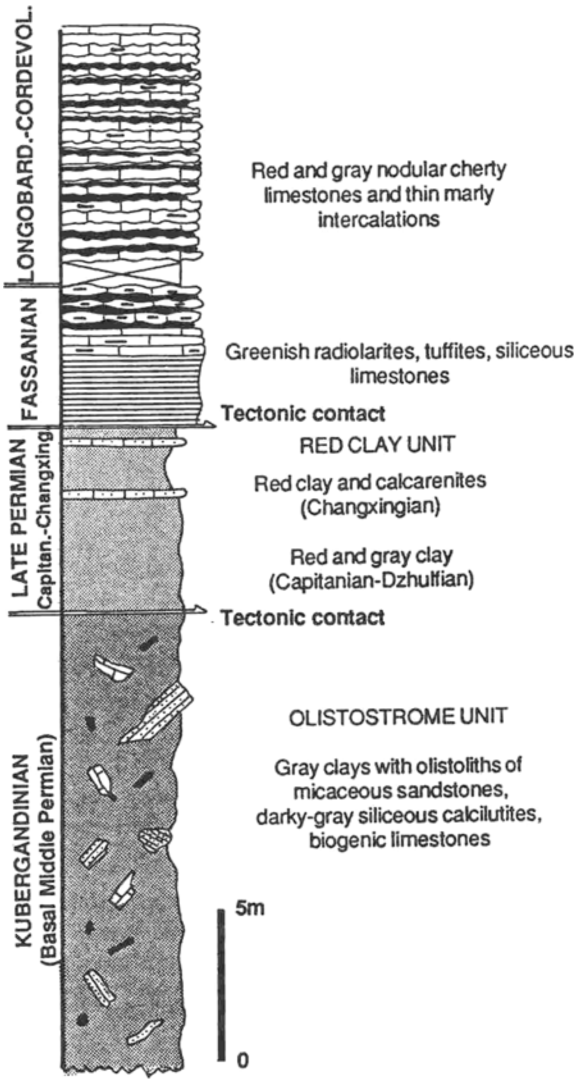


Fig. 2. The Torrente San Calogero section (see Fig. 1) representing the basinal facies. Early to late Permian siliciclastic sediments with allochthonous carbonates are overlain by Ladinian to Upper Triassic deposits.

2.1 Permian sediments in western Sicily

The base of the Sicanian-type sequence is formed by sandstones and shales with carbonate breccias and magmatic mafic rocks (Fabiani & Trevisan 1937). These rocks, including the Lercara 'Formation' (Schmidt Di Friedberg 1965), occur in a wide area between Roccapalumba, Lercara Friddi and Vicari. According to Broquet (1968) similar rocks are also present in the western Madonie (Cozzo Rasolocollo).

In contrast to former interpretations which debated a Permian, Triassic or Tertiary age of the Lercara Formation rocks (cf. Montanari & Panzanelli Fratoni 1990), recent field studies and new biostratigraphic data from the Lercara-Roccapalumba outcrops and from a locality in the Sosio valley adjacent to the Pietra Salomone (Torrente San Calogero section), proved that the former Lercara 'Formation' consists of at least three lithostratigraphic units of Permian age (Catalano et al. 1988, Di Stefano 1990; see Fig. 2):

– (1) Flysch Unit, consisting of siltstones and sandstones with reworked calcarenites and calcirudites

– (2) Olistostrome Unit characterized by grey clays with olistoliths reworked from the underlaying rocks and composed of flyschoid sediments, deep-water marls and limestones of different facies and different age

– (3) Red Clay Unit, composed of gray and red clays with deeper-water radiolarians, conodonts and pychrospheric ostracods, followed upwards by red clays and resedimented bioclastic calcarenites.

These units as well as the Triassic and Miocene rocks of the Roccapalumba-Lercara and Torrente San Calogero area are strongly deformed, as indicated by wells and seismic data (Fabiani 1929, Solignac 1933, Caflisch & Schmidt Di Friedberg 1967) and by field data.

2.2 Age of the Permian sediments

The age determination of these units is predominantly based on conodonts and radiolarians (Catalano et al. 1988, 1989, 1991 a, 1991 b). The age of the Flysch Unit is regarded as late Lower Permian (Kungurian). The matrix of the Olistostrome Unit yields fossils of Kubergandian age, the allochthonous sediments within the matrix are of latest Artinskian to basal Kubergandian age. The Red Clay Unit has been dated with radiolarians as Capitanian to Changxingian (Catalano et al. 1991a).

The presence of diverse pelagic circumpacific faunas in these deposits points to the existence of an early to late Permian deep-water sedimentation and indicates that the Permian Tethys extended to the west as far as at least to the Sicilian area (Catalano et al. 1988, 1991a, b).

2.3 Setting of the Pietra di Salomone

The Pietra di Salomone and the other Sosio limestone blocks are located along the Torrente San Calogero, a small tributary creek of the River Sosio, south of the village of Palazzo Adriano. The Permian limestone blocks crop out from a mostly clayey substrate composed of Permian and Triassic rocks (Fig. 3) and are surrounded by cliffs of late Triassic cherty limestones (Pls. 36 and 37/7).

All these rocks are affected by a very complex deformation pattern and belong in total to a major thrust sheet ('Upper Tectonic Unit') emplaced on late Miocene clays of the underlying 'Lower Tectonic Unit' (Fig. 2) The tectonic contact is exposed about a hundred meters east of the Pietra di Salomone and is evidenced by the well crossing the Permian block (Fabiani 1929; Fig. 4).

The clayey substrate in which the Pietra di Salomone occurs was formerly considered as Carnian (Fabiani 1926, Mascle 1979) and the Sosio megablocks were believed therefore to have been resedimented within Carnian beds (Fabiani 1951, Schmidt Di Friedberg 1964/1965, Mascle 1979). Later, flyschoid deposits, doubtfully assigned to the Permian, were described as 'Flysch infracarnien' from a zone near the Rupe del Passo di Burgio (Mascle 1979).

Recent stratigraphic investigations (Catalano et al. 1988) distinguished within the predominantly clayey rock body adjacent to the Pietra di Salomone several lithostratigraphic units of Permian and Triassic age arranged in complex strucures of stacked tectonic slices. Fig. 2 shows the units

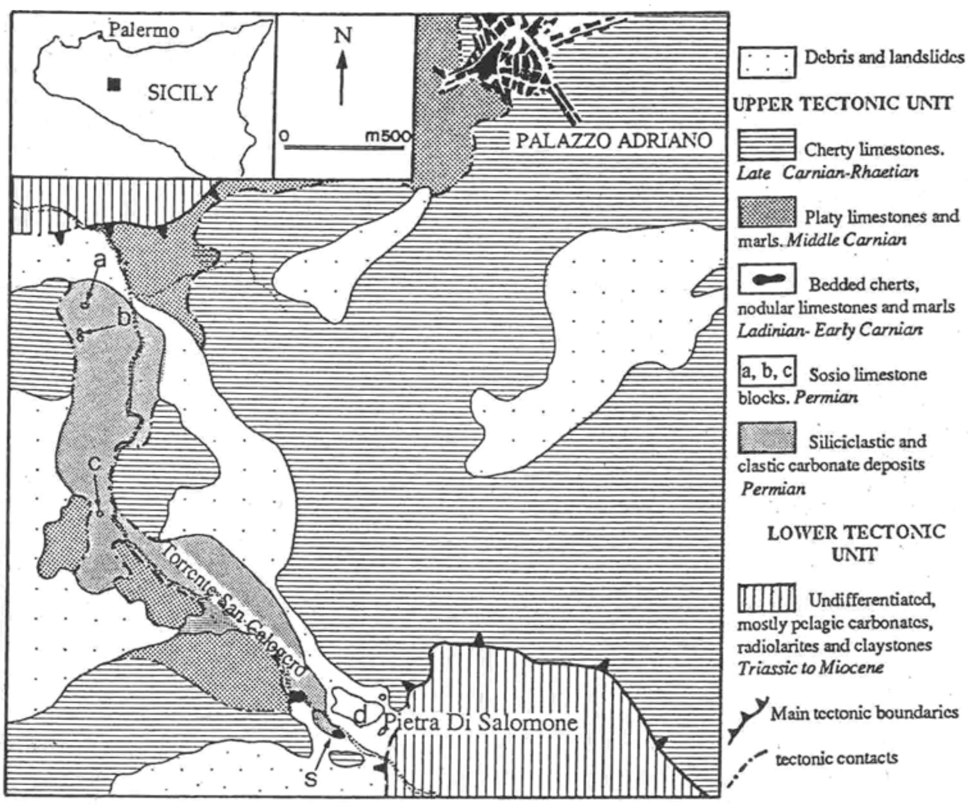


Fig. 3. Geological map of the Pietra di Salomone area. Permian megablocks are indicated by letters: a – Rupe di San Calogero, b – Pietra dei Saracini, c – Rupe del Passo di Burgio, d – Pietra di Salomone, S - location of the Torrente San Calogero section (predominantly marly deep-water sediments of the Middle and Late Permian age).

recognized in the Torrente San Calogero section until now.

These deposits also occur along the Torrente San Calogero valley but they are generally poorly exposed. In this area, several Triassic outcrops occur, too, exhibiting platy limestones and marls (middle Carnian), cherty limestones with *Halobia* (late Carnian to Rhaetian) as well as basic volcanites (Fig. 3).

Some yellowish weathered clays with Wordian conodonts have been found about 500 m southeast of the Rupe del Passo di Burgio (Catalano et al. 1991b). Flyschoid deposits represented by reddish to greenish micaceous sandstones, bioclastic calcarenites (with *Reichelina simplex* Sheng, Pl. 37/3) and red shales occur also in the area between the Rupe del Passo di Burgio and the Pietra dei Saracini megablock (Di Stefano & Gullo, in prep.). A latest Permian age of these sediments is proved by a highly diverse conodont fauna. An early Triassic age can not be excluded for the youngest beds of the unit.

In detail, the Pietra di Salomone is formed by an asymmetric anticline with a NW-SE striking axis (Fig. 4). The eastern limb dips about 15° NE, while the western block is strongly inclined to the SW. The bulk of the limestone block is composed of generally poorly defined thick and in places graded beds of coarse calcareous breccias. Fine-grained bioclastic packstones and grainstones, up to 9 m thick, in the southwestern limb are the stratigraphically highest beds. Geopetal structures suggest that these beds are in a normal position.

The total thickness of the Pietra di Salomone limestone is about 70 meters.

The relationships of the Pietra di Salomone to the adjacent rocks is shown in a cross-section (Fig. 4) based on field data and on the re-interpretation of subsurface data from the well drilled on top of the Pietra di Salomone (Fabiani 1929, Solignac 1933, Di Napoli-Alliata 1953). The cross-section indicates that the Pietra di Salomone megablock overthrusts tectonic slices composed of Permian and Ladinian-Cordevolian rocks and is overlain by latest Permian red clays and resedimented calcarenites outcropping near its western margin. The Pietra di Salomone, therefore, was not resedimented within Carnian deposits but is one of the several tectonic slices occurring in this area.

2.4 Stratigraphic evaluation

To restore the original stratigraphic relationships between the Pietra di Salomone and the Permian deep-water deposits of the Torrente San Calogero area, we must determine the age of the matrix of the megablock.

Previous age determinations for the 'Sosio beds' were based on fossils collected in different blocks or from different clasts of one and the same block.

Miller (1933) restudied the ammonoids described by Gemmelaro; he recognized 22 genera, indicating a Wordian age of the Sosio beds (cf. Pl. 37/9).

Fusulinids from samples from the Pietra di Salomone, the Rupe del Passo Burgio and the Rocca di San Benedetto (Pasini 1965, Skinner & Wilde 1966) point to the existence of two fusulinid assemblages. The first one, characterized by *Kahlerina, Chusenella, Rugososchwagerina, Yangchienia*

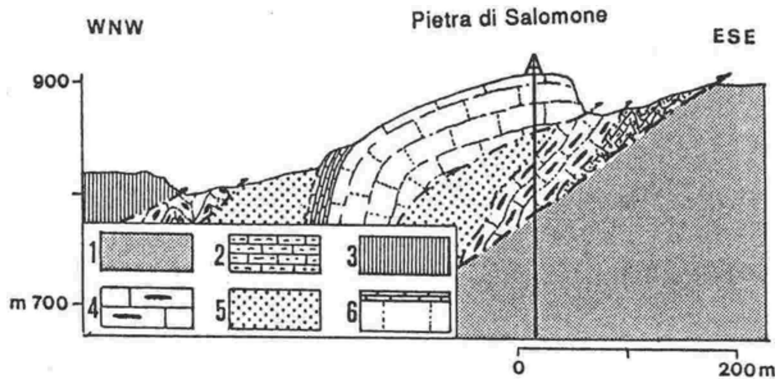


Fig. 4. Cross-section, based on field data and a re-interpretation of the well drilled on top of the Pietra di Salomone. The Pietra di Salomone megablock overthrusts tectonic slices composed of Permian and Triassic rocks. The block is tectonically overlain by fossiliferous late Permian red clays of the basinal facies, exposed in the Torrente San Calogero section westnorthwest of the Pietra di San Salomone. Legend: 1 – platy limestones and marls (Middle Carnian), 2 – cherty limestones (Late Carnian to Rhaetian), 3 – undifferentiated pelagic carbonates of the Lower Tectonic Unit (Triassic to Miocene), 4 – bedded cherts, nolular limestones and marls (Ladinian to early Carnian), 5 – Permian siliciclastic and detrital carbonate deposits, 6 – Pietra di Salomone limestone, differentiated into a lower more massive unit and in an upper bedded unit.

and *Rauserella* indicates the *Cancellina* zone (Kubergandian), the second one with *Neoschwagerina* and *Verbeekina* provides evidence for the *Neoschwagerina craticulifera* subzone of Murghabian age (KAHLER 1974) which is roughly time-equivalent to the Wordian. Both fusulinid zones are represented within the limestone of the Pietra di Salomone.

New fusulinid data from the Pietra di Salomone limestone (see 5.1.2) provide evidence for the existence of the *Neoschwagerina craticulifera* and the *Neoschwagerina margaritae* subzones of the Murghabian, the *Yabeina* zone of the Midinian and also the *Reichelina* zone of Dzhulfian age. Moreover, preliminary conodont data point to the presence of several early to late Permian conodont zones (DISTEFANO & KOZUR, in prep.).

The presence of *Reichelina* in some fine-grained grainstones interpreted as distal turbidites, and the absence of Triassic or younger fossils suggest a Dzhulfian (or a somewhat younger, Changxingian) age of the Pietra di Salomone clastic wedge. Conodonts from the eastern part of the Pietra di Salomone, sample 728, det. KOZUR) confirm the late Permian age.

Time-equivalent late Permian deposits occurring in the Torrente San Calogero section are deep-water radiolarian-bearing gray clays followed upwards by red clays and resedimented calcarenites of Capitanian to Changxingian age.

Table 1 summarizes the biostratigraphic data relevant for the discussion of the age of the Sicilian Permian megablocks.

Biostratigraphic and geological evidence, therefore, suggest that the Pietra di Salomone respresents a heteropic marginal sequence of the deep-water clays deposited in a base-of-slope location situated at the margins of or within (seamount ?) the late Permian basin of western Sicily.

3 DATA BASE AND LOCALITIES

Stratigraphically older deposits are exposed in the eastern part of the Pietra di Salomone, stratigraphically younger deposits in the western parts of the outcrop. A pass (Pl. 36/2) separates the western part with the localities 1-12 from the eastern part with the localities 13-22. The limestone breccias exposed in these localities have been studied with regard to the depositional structures (bedding; texture, size and rounding of the limestone pebbles).

About 240 samples were investigated with respect to microfacies variation (polymict or monomict composition of the breccias), age of the limestone clasts (long- or short-lasting reworking) and possible source area of the material. Paleontological work was concentrated on calcisponges, smaller foraminifera and fusulinids as well as on calcareous algae and microproblematica.

Localities and sections are indicated in Figs. 5 and 7 and in Pl. 36. The localities have been numbered in order to facilitate the discussion of our results, starting in the western part of the Pietra di Salomone.

4 FACIES OF THE PIETRA DI SALOMONE LIMESTONE

4.1 Review of facies criteria

(1) The pebbles of the limestone breccia of the Pietra di Salomone consist (in decreasing order) of rudstones, boundstones, floatstones and grainstones.

(2) Rudstones (Pl. 39/1) are generally poorly sorted. They exhibit different amounts of fossils, bioclasts and lithoclasts. Lithoclasts (Pl. 41) are angular and rounded. Most lithoclasts are smaller than 5 mm. The matrix between larger components is poorly-sorted grainstone and packstone. When reworked also matrix occurs as lithoclasts. Other lithoclasts are broken boundstones and wackestone. Intergranular voids are filled with carbonate cement. Common fossils are sponges (sphinctozoans, sclerosponges, inozoans), '*Tubiphytes*', *Archaeolithoporella*, bryozoans as well as smaller foraminifera.

(3) Boundstones (Pl. 39/3,4) are represented by sponge/*Tubiphytes* bafflestones and phylloid algae bafflestones as well as by sponge/*Archaeolithoporella* bindstones (Pl. 48/7). Biogenic encrustations are of major importance.

(4) Floatstones may differ in the rock color. Phylloid algae and epimastoporid algae are common. They are poorly sorted.

(5) Grainstones: (a) Fine-grained grainstones composed of poorly sorted micrite clasts and pellets; (b) fine-grained, graded and laminated grainstone with micrite clasts (Pl. 39/5); (c) medium-grained, partly graded grainstone with micrite clasts, arranged in layers (Pl. 39/6); (d) fine-grained grain- to packstone with abundant sparry clasts. Smaller foraminifera are common in all the types. Type (d) differs in the occurrence of *Reichelina*, the lack of micrite clasts and the occurrence of sparry clasts (Pl. 44/5).

(6) Grainstones of the types (a) to (c) occur intercalated within calcareous breccias at the top of turbidite layers but also within individualized beds in the stratigraphically higher

	STRATIGRAPHIC SUBDIVISION 1	Middle Asia	North America	Russia	T. San Calogero	Sosio Blocks: AMMONOIDS	FUSULINIDS	CONODONTS	KOZUR 1988
Upper	Palaeofusulina	Changxingian (Dorashamian)	Dzhulfian	Tatarian					Changxingian
Upper	Reichelina	Dzhulfian	Dzhulfian	Tatarian	Red Clay Unit				Dzhulfian
Upper	Codonofusiella	Dzhulfian	Capitanian (Guadalupian)	Tatarian	Red Clay Unit				Dzhulfian
Middle Permian	Yabeina	Midinian	Capitanian (Guadalupian)	Kazanian	Red Clay Unit				Abadehian / Capitanian
Middle Permian	Neoschwagerina	Murghabian	Wordian (Guadalupian)	Kazanian / Ufimian	Wordian Clays				Wordian
Middle Permian	Cancellina	Kubergandian	Roadian	Kungurian	Olistostrome Unit				Kubergandian / Chihsian / Jachtashian
Lower	Parafusulina	Artinskian	Leonardian	Artinskian					Artinskian
Lower	Pseudofusulina	Sakmarian	Wolfcampian	Sakmarian					Sakmarian
Lower	Pseudo-schwagerina	Asselian	Wolfcampian	Asselian					Asselian

Tab. 1. Age of limestone clasts composing the Permian megablocks in the Sosio Valley, Western Sicily.
Stratigraphic subdivisions: 1 –Fusulinid zonation, 2 – Middle Asia, 3 – Northern America (Delaware Basin), 4 – USSR (Uralian). The Torrente San Calogero comprises the basinal facies of the Permian. Allochthonous carbonates occur within the Olistostrome Unit and the Red Clay Unit (see Fig. 2). The age of the Pietra di Salomone limestone (black) and of other limestone blocks (white) is based on ammonoids, fusulinids and conodonts. Squares: Age of limestone boulders within the Olistostrome Unit. The correlation of the Tethyan scales (KOZUR 1988 and 'Middle Asia') with other Permian standards is difficult.

parts representing distal turbidites.

(7) The breccias are mono- and polymict with regard to the microfacies types of the breccia clasts (Pl. 38/2-5). Microfacially monomict pebbles exhibit some differences with regard to the frequency of various fossils.

(8) The degree of induration of lithoclasts is variable. Well cemented lithoclasts (Pl. 41/6) of intrapelsparite grainstone and biolastic-peloid packstone with clearly defined grain boundaries occur together with partly rounded lithoclasts (Pl. 42/2), indicating only moderate lithification prior to the deposition adjacent to the boundstone area.

(9) Larger bioclasts and lithoclasts may be surrounded by thick rims of fibrous and radiaxial calcite cement (Pl. 42/5, 6). These cement rims are partly reworked, together with bio- and lithoclasts. The crystals of the cement rims have been eroded and deposited within the micritic matrix. A similar situation has been recently described by SCHOLLE et al. (1991).

(10) Carbonate silt occurs within small-scaled fissures, within leached fossils (especially phylloid algae), in enlarged intergranular voids and in the center of interparticle pores. Carbonate silt and cement rims are particularly common in the chalky types of the Pietra di Salomone limestone (e.g., localities 4 and 13).

(11) Many samples exhibit a characteristic void filling sequence (Pl. 42/1-4) starting with grey internal sediments with intraclasts, followed by grey bedded internal sediment, micrite, crystal silt (partly dolomitized) and blocky calcite at the top. Geopetals within these pore-fillings differ from the primary sedimentary geopetal fabric.

(12) The background sedimentation ('matrix') during the time of the deposition of the pebbles forming the breccias is characterized by yellowish, partly dolomitized marls (e.g., locality 19).

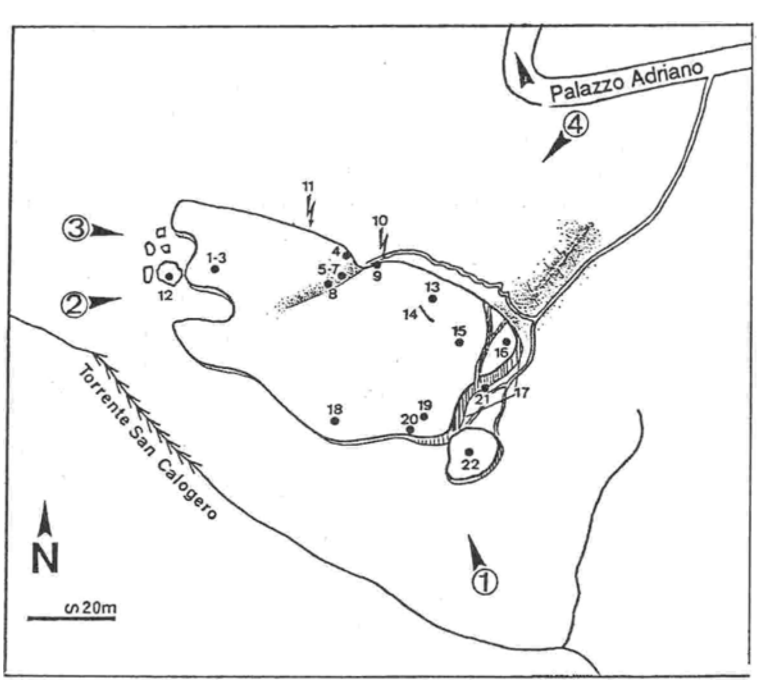


Fig. 5. Sampling localities 1-22. Outline of the Pietra di Salomone. Encircled numbers refer to different views of the Pietra di Salomone shown on Plate 36.

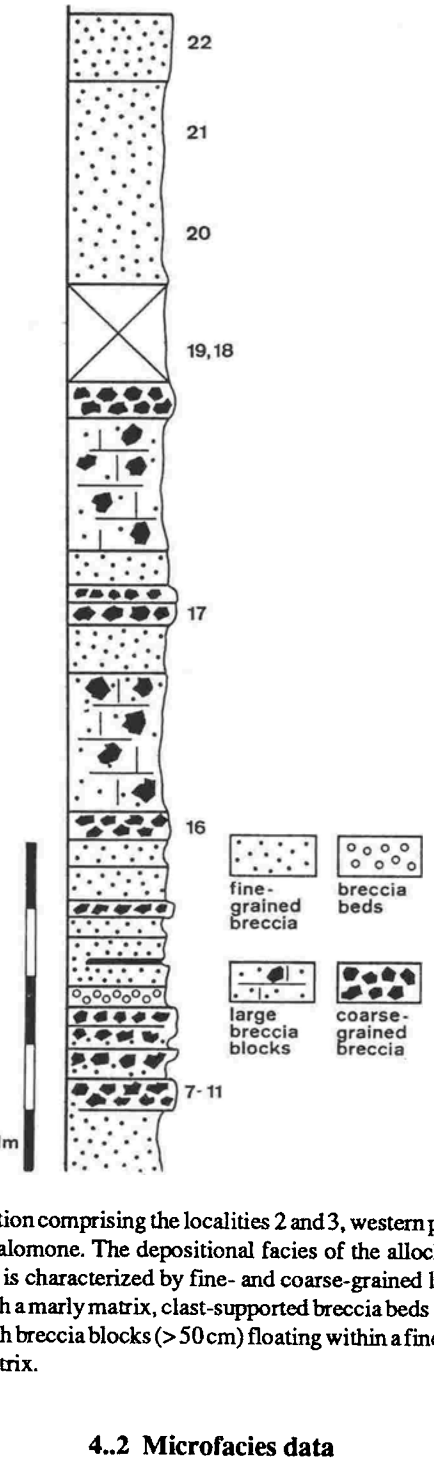


Fig. 6. Section comprising the localities 2 and 3, western part of the Pietra di Salomone. The depositional facies of the allochthonous limestones is characterized by fine- and coarse-grained limestone breccia with a marly matrix, clast-supported breccia beds as well as by beds with breccia blocks (> 50 cm) floating within a fine-grained breccia matrix.

4..2 Microfacies data

4.2.1 Western part of the Pietra di Salomone

The outcrops in the western part of the study area comprise the stratigraphically lower (localities 1-3) and higher units (localities 4-7) as well as the highest part of the Pietra di Salomone limestone (locality 12).

Northwestern margin of the Pietra di Salomone: Localities 1 (A), 2 (C) and 3 (B), Pl. 36/2, Fig. 7b

These outcrops can be used as examples for the depositional features of the allochthonous carbonates.

Locality 1 (A): Samples 1-6. Locality 2 (C): Samples 13-15, probably overlying A and B. Limestone breccias. Locality 3 (B): Samples 7-11 and the section shown in Fig. 6 representing the stratigraphically higher parts of the southsouthwest dipping slope. The section (samples 16-22) starts within the locality B and includes about 20 m of allochthonous carbonates.

Locality 1: An isolated block with a thickness of 130 cm is exposed, composed of a limestone breccia at the base and fine-grained laminated packstone within the upper third of the block.

The poorly sorted breccia consists of bioclastic/lithoclastic rudstones (sample 1)) and bioclastic/lithoclastic floatstones (sample 2). Rotated geopetals indicate reworking of lithified limestone clasts. Diagenetic geopetals (horizontal dissolution features within bioclasts) are orientated parallel to bedding planes. Bioclasts are more common than lithoclasts (pelsparite). Fossils are represented by *Archaeolithoporella* and *Tubiphytes* (common), phylloid algae, sphinctozoid sponges (*Sollasia*) and a few bryozoans and smaller foraminifera (*Pachyphloira* sp., Pl. 43/4).

Sample 3 is a very fine-grained graded intrapelsparite consisting of micritic peloids and small intraclasts occurring together with smaller foraminifera (*Pachyphloia, Hemigordius, Tuberitina*), bryozoan fragments, echinoderms and some ostracods as well as common *Epimastopora* and thin shells, both exhibiting current-induced orientation.

The laminated upper part (samples 4 and 6) consists of a fine-grained intrabioclastic packstone with abundant micritic intraclasts and echinoderms. Additional elements are smaller foraminifera (*Pachyphloia, Tuberitina, Globivalvulina* sp.), ostracods, thin shells and small tubes as well as broken *Archaeolithoporella*. Dolomite crystals occur scattered within the matrix. Vertical fissures are bordered by calcite rims and infilled by gray internal sediment.

The sequence corresponds to a distal limestone turbidite as indicated by the gradation of the basal detrital zone into finer sediments and by the pronounced lamination of the upper part.

Locality 2 probably represents breccia beds equivalent to those overlying the suboutcrop B (locality 3) at the base of the section.

The breccia consists of layers of reworked fossils and various lithoclasts (intrapelsparitic grainstones, micritic packstones with thin-shelled ostracods). Fossils are sponges, various bryozoans, *Tubiphytes*, *Archaeolithoporella*, echinoderms, smaller foraminifera (*Pachyphloia, Hemigordius, Tuberitina*), a few phylloid algae, dasycladaceans, porostromate algae and a few gastropods. Of special interest are fusulinids (*Sumatrina gemmellaroi* Silvestri and *Yabeina* sp. Pl. 44/4). Selectively dissoved fossils are filled with dolomitized reddish silt (sample 15).

The section (Fig. 6) outcropping in the localities 2 and 3 (Pl. 36/2) comprises

- fine-grained limestone breccia (average clast size < 2 cm) and coarse-grained breccia (clast size up to several centimeters) forming beds of different thickness,
- clast-supported breccias forming beds generally thinner than 50 cm (clast sizes between several centimeters and tens of centimeters) and
- very coarse-grained resedimented breccias (pebble size up to more than 50 cm) forming massive beds

The pebbles of the basal part of the section (locality 3) consist of bioclastic floatstones and packstones with sponges, bryozoans, *Tubiphytes* and *Archaeolithoporella* occurring as thin crusts around various fossils, and fine-grained laminated grainstones with (sample 8)) very small peloids and some encrusted gastropods. The upper part (samples 10 and 11) is characterized by fine-grained graded grainstone with micritic intraclasts and very small intraclasts and peloids, smaller foraminifera (*Pachyphloia, Lasiodiscus, Tuberitina*), small tubes and broken *Archaeolithoporella*. Bryozoans, *Tubiphytes* and sponge fragments (*Sollasia*) are rare. Grainstones and floatstones alternate within a scale of several centimeters.

Samples taken from the various breccia types of the section (samples 16 to 22) distinguished in the field by the size and rounding of the pebbles exhibit no marked differences in microfacies:

The breccia consists of broken fossils, and variously sized and rounded limestone clasts. Fossils are represented by sponges (*Polytubispongia*), *Tubiphytes*, bryozoans, rare solitary corals, rare dasycladaceans and solenoporaceans as well as some smaller foraminifera (*Pachyphloia, Hemigordiopsis Lasiotrochus*) and fusulinids (*Rugososchwagerina yabei* (Staff), Pl. 44/10). Most larger fossil fragments are covered by thin *Archaeolithoporella* crusts. *Archaeolithoporella* occurs also in reworked fragments. Limestone clasts (predominantly fine-grained graded intrapelsparite, rarely micrite) are angular, subrounded or rounded. Oncolitic boundstones reworked within the clast-supported breccia are rare (sample 18). The matrix is fine-crystalline blocky cement, in some samples (partly winnowed) micrite. Many limestone clasts but also isolated fossils are surrounded by a rim of coarse calcite crystals. A late brecciation took place after the deposition of the fossils and limestones clasts, as indicated by thin fractures cutting the clasts and filled with partly graded silt. Most of the sediments of the section can be interpreted as clast-supported debris flows.

Western margin of the pass: Locality 4 (Pl. 36/2, Fig. 7b)

The section (Fig. 6) is overlain by a coarse-grained debris flow breccia consisting of several beds. Samples 23-34.

Locality 4 (D) is a poorly sorted clast-supported limestone breccia forming the top of the section described above, with a thickness of about 1 m whose clasts have been studied with regard to microfacies variation. The samples 23 to 26 were collected from various parts of this unit, the samples 27-33 came from one bed of the breccia unit near the base.

The pebbles represent different microfacies types:

– (1) Medium-grained laminated intraclastic grainstone: Most particles are angular and subrounded very small micrite lithoclasts. Larger clasts comprise rounded pelsparite clasts and biomicrite clasts with thin ostracod shells and spicula. Fossils occurring together with the smaller intraclasts are echinoderm fragments, smaller foraminifera (*Tetrataxis, Pachyphloia, Hemigordius*), small tubes and a few reworked bryozoans and solitary corals. Sample 27.

– (2) Poorly sorted bioclastic grain/rudstone: This type is characterized by broken and reworked fossils (sponges and bryozoans coated by thin *Archaeolithoporella* crusts, also occurring as clasts, *Tubiphytes, Lercaritubus*, rare echinoderms) occurring together with fine-grained graded pelsparite and intrasparite. Foraminifera are represented by *Neoendothyra, Eolasiodiscus* and *Textularia*, algae by *Permocalculus kanmerai* Konishi (Pl. 47/8). Interparticles pores are filled with calcite cement, remaining voids with silt. Samples 24, 26, 28, PS28, 29, 30, 32, 33.

– (3) Poorly sorted bioclastic floatstone/boundstone with phylloid algae and solenoporecan algae (Pl. 47/11, 12)): As in type 2, broken and reworked fossils occur together with fine-grained pelsparite and intrasparite but phylloid algae (*Ivanovia* sp.) are of major quantitative importance. Reworked fossils include sponges (*Coedocladia, Peronidella*), *Lercaritubus* (or dasycladaceans ?), broken bryozoans, echinoderms, *Tubiphytes*, brachiopods and ammonites. In the samples 23 and 34 the phylloid algae are encrusted by thin layers of *Archaeolithoporella* which originally probably formed an organic framework. Samples 23, 31, 34 and 34A. Sample 34 yields *Sumatrina gemmellaroi* Silvestri.

– (4) Poorly sorted floatstone/wackestone: Fine-grained micritic matrix, sometimes containing reworked calcite crystals, and reworked intraclasts with calcite rims. A genetic sequence may be inferred for this rock type, starting with (a) the deposition of fine-grained packstone followed by (b) some stabilisation of the sediment (probably by binding organisms). (c) Slight reworking of parts of the sediment and the formation of intraclasts is indicated by rotated geopetals. (d) Growth of calcite cement took place on the surface of these intraclasts. (e) The intraclasts with the calcite rims were mechanically reworked, causing (f) a deposition of broken calcite crystals within the micritic matrix. Reworked fossils include sponges and bryozoans coated by *Archaeolithoporella* as well as *Tubiphytes* and smaller foraminifera. Sample 25.

Except for type 1, which might represent the fine-grained part of a turbidite, all the other microfacies types of the pebbles reflect the original sedimentation patterns characterized by simple and multiple reworking within marginal shelf environments of moderate and changing water energy.

Western side of the pass

Locality 5 (Pl. 36/2, Fig. 7b)

Bedded, silicified micrite, probably representing the background sedimentation.

Sample 36 (E) comes from a laminated dolomitized micrite occurring about 1 m below beds rich in *Richthofenia* (locality 7). The samples yields abundant conodonts (*Hindeodella, Mesogondolella*), pointing to a Wordian age.

Locality 6 (Pl. 36/2, Fig. 7b)

Fusulinid limestones. Samples 35 A to 35H (with 15 thin-sections).

This outcrop, adjacent to locality 5, exhibits boundstones and rudstones significantly rich in fusulinids (Pl. 44/11-15), see Chapter 5.1.2. Other fossils are diverse sponges (*Colospongia, Sollasia*), *Permosoma*, smaller foraminifera (*Climacammina, Hemigordius, Howchinia, Tetrataxis, Tuberitina*), echinoderms, brachiopods, bryozoans, gastropods and algae (dasycladaceans: *Mizzia velebitana* Schubert, Pl. 47/3), abundant solenoporaceans acting as bafflers (*Parachaetetes lamellatus* Konishi, Pl.47/12), some phylloid algae, and *Pseudovermiporella*).

Locality 7 (Pl. 36/2, Fig. 7b)

Limestone with *Richthofenia*., characterized by reworked large *Richthofenia* occurring in bioclastic floatstones with echinoderms, bryozoans, sponges, *Tubiphytes* and dasycladaceans (sample 36, G).

Locality 8 (Pl. 36/2, 37/4, 5, 7; Fig. 7b)

Tabular limestone block (R), differing in the dark rock color, microfacies, fossils (predominantly phylloid algae, *Tubiphytes* and sponges) and age (Lower Permian) from other blocks of the Pietra di Salomone. Samples 90/28-90/81.

The block consists of very coarse rounded and angular limestone pebbles embedded in a rare very fine-grained matrix (Pl. 37/4). Most of the samples 90/28-90/81 represent dark boundstones and floatstones with phylloid algae (Pl. 47/13), *Tubiphytes, Archaeolithoporella* and sponges (predominantly inozoans, sometimes forming bafflestones, sample 90/78). Additional biota are smaller foraminifera (*Langella, Lasiodiscus, Pachyphloia*), bryozoans, epimastoporids (*Epimastopora piae* Bilgütay, Pl. 47/6), *Lercaritubus* and agglutinated fecal pellets (Pl. 43/11); see Chapter 5.1.6). Rare lithofacies types are medium- to fine-grained graded lithobioclastic grainstones with slope-derived clasts;samples 90/57, 90/59, Pls. 37/5, 40/6,7) with some very small fusulinids (*Schubertella* sp., Pl. 44/3).

The microfacies types and the sphinctozoan species are identical with those of (late) Lower Permian allochthonous limestones from the river San Filippo near Roccapalumba (SENOWBARI-DARYAN & DI STEFANO 1988). A Lower Permian age is also indicated by the occurrence of *Schubertella* and by a sample taken just below the outcrop from fine-bedded packstones yielding Lower Permian conodonts.

Northern cliff: Locality 9 (Pl. 36/3, Pl. 37/7; Fig. 7c)

Section N (samples 90/15 to 90/27) with a thickness of approximately 25 meters represents the stratigraphically higher part of the Pietra di Salomone limestone.

Most pebbles are poorly sorted lithobioclastic rudstones. A few samples are lithobioclastic floatstones. Common microfacies types of the lithoclasts are pelsparite and intrapelsparite, pelmicrite and various boundstones (with *Archaeolithoporella* (Pl. 48/6, 7, 9), *Tubiphytes* Pl. 48/6), phylloid algae and sponges as well as with pelsparite, Pl. 40/3,4, Pl. 41/6, 8, 9). Intrapelsparite and pelmicrite also form the fine-grained grainstone and packstone matrix between the lithoclasts and fossils. These matrix types were reworked and deposited as angular and rounded lithoclasts together with boundstone lithoclasts and broken or well-preserved fossils (calcisponges, *Tubiphytes* and *Archaeolithoporella*, bryozoans, echinoderms) occurring as free components. The size of the lithoclasts varies between < 1 mm and > 50 mm, most lithoclasts are smaller than 5 mm.

Most interparticle pores of the lithobioclastic rudstones are totally filled with carbonate cements forming fringes of fibrous crystals and granular cement. Crystal silt occupies the center of some pores.

Sample 90/20 yields *Sumatrina gemmellaroi* SILVESTRI, indicating the

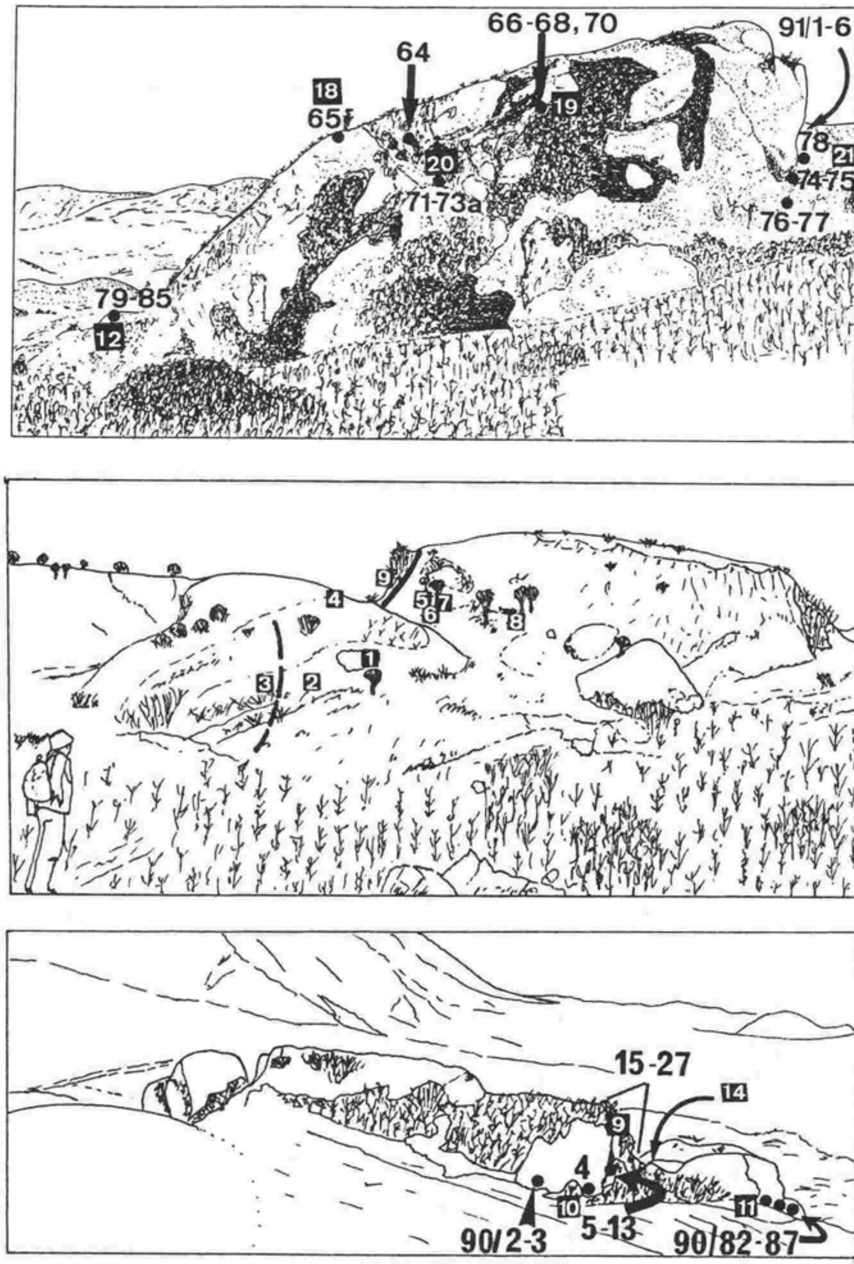


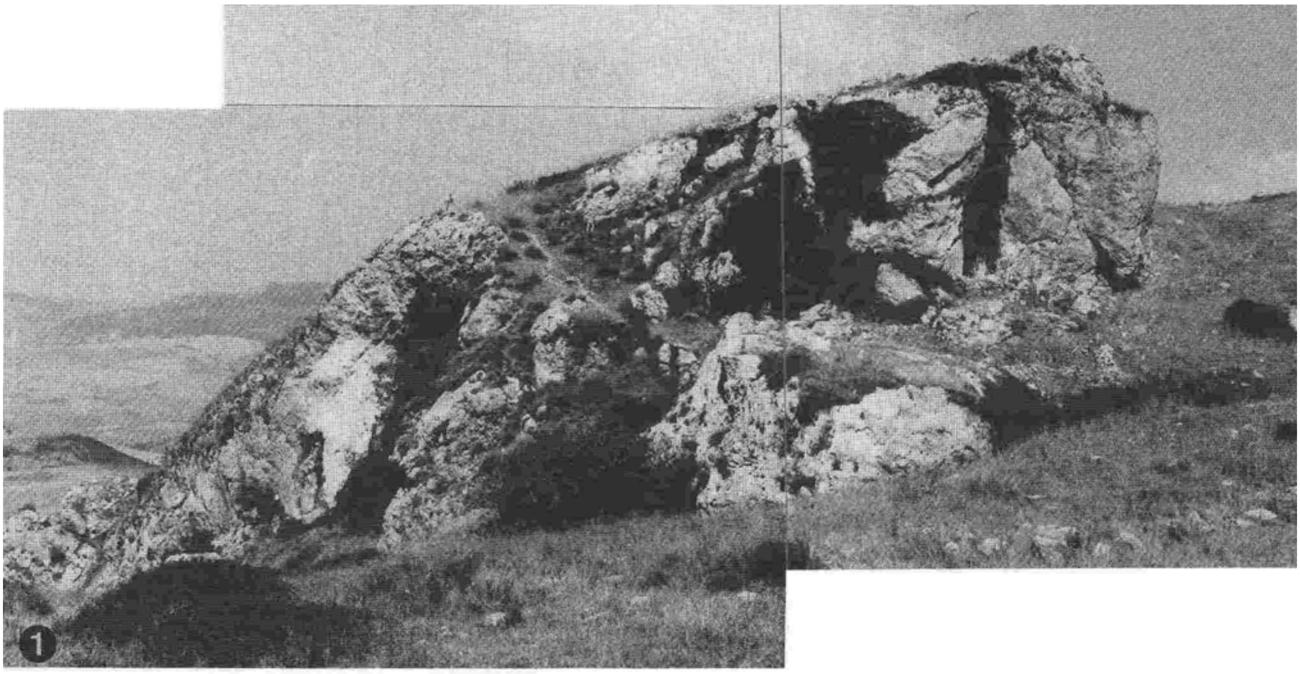
Fig. 7. Sampling localities. 7a – southwestern corner and southern cliff, 7b – western slope, 7c – northwestern cliff. The drawings correspond to the three photographs of Plate 36. Numbers in squares refer to sampling locality numbers (cf. Fig. 5). All the other numbers are sample numbers. Some localities situated at the northern cliff are not shown in the sketches.

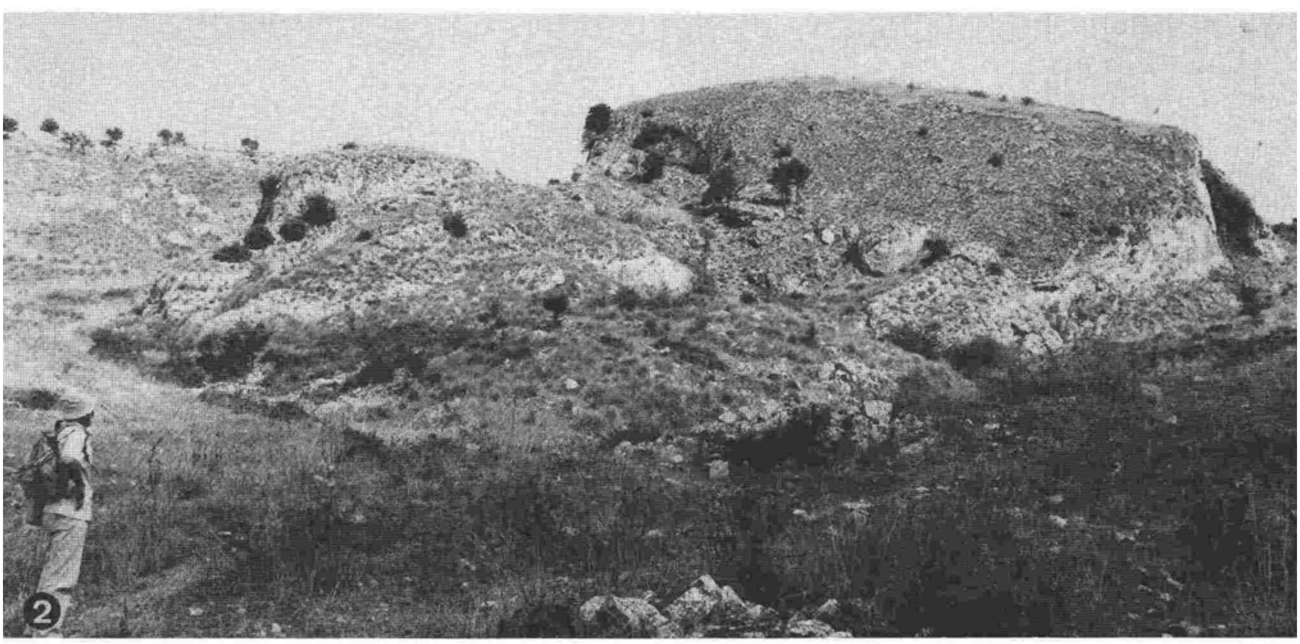
Plate 36 — The Pietra di Salomone, Sosio Valley, Western Sicily: An allochthonous Late Permian base-of-slope deposit. Different views and sampling localities. Compare Text-Fig. 7 (white ciphers) for sampling localities.

Fig. 1. Southeastern corner and southern cliff. Compare Fig. 5, view 1. The rock body consists of massive and coarsely bedded carbonate breccias (cliff at the right side) overlain by bedded calcarenites (top and far left). The height of the rock body is about 60 meters. Note geologist for scale.

Fig. 2. Western slope of the Pietra di Salomone. Compare Fig. 5, view 2. Note the pass which separates western and eastern sampling localities. The western block is strongly inclined to the southwest, the eastern limb of the anticline structure dips to the northeast. Geologist as scale.

Fig. 3. Northern cliff. Compare Fig. 5, view 3. The mountain slope in the background is formed by Triassic carbonates.





Middle Permian age of breccia pebbles of locality 9.

Northern cliff wall: Locality 10 (Pl. 36/3, Pl. 37/8; Fig. 7c)

Eastern side of the cave in the central part of the northern cliff wall of the Pietra di Salomone. Clast-supported coarse-grained breccias consisting of variously sized angular and rounded pebbles within a matrix of greenish gray marl. Samples M/90/5-90/13.

The microfacies is comparable to those from locality 9 with regard to the predominance of cement-rich poorly sorted lithobioclastic rudstones, but differs in the occurrence of voids rimmed by conspicuously thick fringes of yellowish acicular cements, and rare botroyidal cements (Pl. 42/9), and filled with internal sediments and crystal silts. These voids correspond to intraskeletal pores, enlarged interparticle pores and dissolution pores.

A generalized sequence of the pore filling sediment (Pl. 42/1, 2, 4, 7; samples 90/5, 90/6) comprises gray internal sediment with intraclasts, gray bedded internal sediment without intraclasts, micrite layers, overlain by calcite crystal silt and/or dolomite silt. The remaining void space may be filled with white blocky carbonate cement. The bedded internal sediment exhibits a geopetal fabric differing distinctly from that of the primary sediment of the packstone and grainstone matrix of the rudstones and floatstones. This indicates reworking of the primary sediment subsequent to a weak lithification by the formation of acicular cement rims.

Northern cliff: Locality 11 (Pl. 36/3, Fig. 37c)

Base of the northern cliff. Poorly-sorted clast-supported coarse-grained breccias. Samples 90/82-90/87. The pebbles of the breccia contain variously sized limestone clasts (10-50 cm) exhibiting different microfacies types:

(a) Grainstone: Very fine-grained intrasparite consisting of angular and rounded micrite clasts (< 100 μm), some lumps and few smaller foraminifera, echinoderms and very rare bryozoan fragments. Sample 90/82.

(b) Poorly sorted rudstone: Boundstone clasts (with sponges and dendroid *Tubiphytes* as well as *Archaeolithoporella* and phylloid algae)), pelsparite and pelmicrite clasts, together with smaller foraminifera (*Climacammina*), algae (*Salopekiella* sp., *Connexia* sp., Pl. 47/3,4) a few fusulinids (*Kahlerina siciliana* SKINNER & WILDE), bryozoans and agglutinated fecal pellets. Samples 90/84, 90/85, 90/87.

(c) Alternating layers of lithobioclastic rudstone; wackestone with debris of very small and thin shells, nodosariid foraminifera and abundant ostracods; lithobioclastic grainstone; wackestone, overlain by lithobioclastic rudstone. Sample 80/86.

(d) Boundstone: The framework is formed by dendroid *Tubiphytes* (Pl. 48/5), calcisponges and *Archaeolithoporella* crusts. The matrix between and around the framebuilders consists of biolithoclastic pack- and grainstone. Sample 90/83.

Westernmost part of the Pietra di Salomone : Locality 12 (Pl. 36/1, Fig. 7a)

Well-bedded allochthonous carbonates, representing the stratigraphically uppermost part of the Pietra di Salomone limestones have been studied in a section comprising 9 m of medium-grained breccias (grainstones). Samples V/79-85.

All the samples are medium-grained lithoclastic grainstones (Pl. 39/6), composed of angular and subangular micrite clasts which in some samples are arranged in layers differentiated by fine- and medium grained particles. Smaller foraminifera, especially *Hemigordius* and *Climacammina*, are abundant. Other fossils are rare dasyclads as well as broken fusulinids, bryozoans and *Archaeolithoporella* fragments. Sponge fragments are rare. Larger

Plate 37 Permian megablocks in the Sosio Valley, Western Sicily

Fig. 1. Pietra di Saraceni (right) and Rupe di San Calogero (arrow) which has been almost completely destroyed by fossil hunters. Samples from the Rupe di San Calogero yield *Codonofusiella* pointing to an early Upper Permian age.

Fig. 2. Rupe di Passo di Burgio. Most of the Wordian ammonites described from the Permian of the Sosio beds were collected from this block. See Fig. 9.

Fig. 3. Bioclastic beds intercalated in red clays near the Passo di Burgio yield the fusulinid *Reichelina simplex* SHENG, an index fossil of the uppermost Permian (Changxiangian).

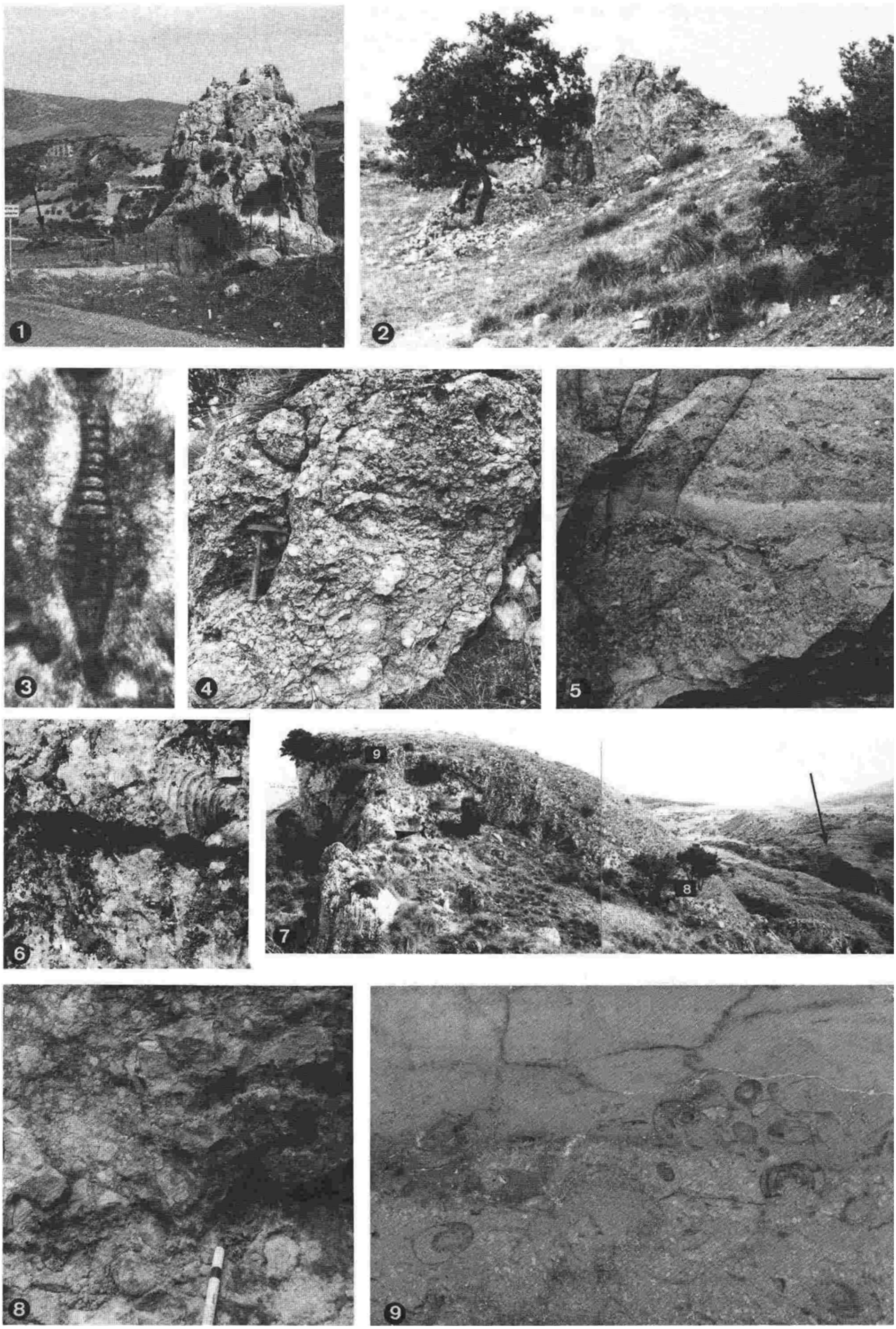
Fig. 4.-5. The megablocks consist of allochthonous carbonates, often exhibiting disorganized breccia-conglomerates, representing debris flow deposits (Fig. 4) and alternating with calciturbidites (Fig. 5). Note the very poor sorting of the limestone pebbles and the differences in shape and rounding. Pietra di Salomone, Locality 8 (see Fig. 5 and Plate 36). The breccia pebbles occurring in this locality differ in biota, microfacies and probably also in age (Lower Permian) from most of the breccia pebbles investigated, which have a proven Murghabian (Wordian) or younger age.

Fig. 6. Reworked *Richthofenia*. Maximum height 40 cm. Pietra di Salomone. Locality 7 (see this Plate, Fig. 5).

Fig. 7. Pietra di Salomone, the Permian megablock and the adjacent Torrente San Calogero section (arrow) exposing Middle to Upper Permian basinal sediments. View from the north. Numbers refer to study localities.

Fig. 8. Pietra di Salomone. Typical rock exposure (locality 10, M). The limestone breccia consists of pebbles which differ in shape, size and rounding, sometimes also in microfacies and - as indicated by fusulinids and conodonts - in age as well. Most data provide evidence of a Middle Permian (Murghabian and Midianian) age, but Lower Permian and Upper Permian (Dzhulfanian) fossils have also been found.

Fig. 9. Ammonites occur in carbonate turbidites together with platform and reef-derived limestone clasts. Rupe del Passo di Burgio. Width of the photo about 15 cm.



fossils and larger intraclasts (packstones and pelsparitic grainstones) mark current orientation. The sediment type somewhat resembles sample 78 found which is in the eastern part of the Pietra di Salomone and yields *Reichelina* but differs in the predominance of micrite clasts and the occurrence of reworked framebuilding organisms. Sample 85 (1709) from the topmost bed of the section yields the Middle Permian conodont *Mesogondolella*.

The depositional structure corresponds to that of distal turbidites.

4.2.2 Eastern part of the Pietra di Salomone

Samples from the localities 13, 14 and 15 represent the chalky part of the limestones occurring in the upper strata of the eastern part of the Pietra di Salomone. These limestones are very fossiliferous and the fossils can easily be collected from the soft chalky rocks.

Northern cliff: Locality 13

Northern cliff of the Pietra di Salomone. Sample I/55 is from the base of the cliff.

It is a porous poorly sorted lithobioclastic floatstone with reworked sponges, broken phylloid algae, *Archaeolithoporella* and pelmicrite clasts. The rounded or angular lithoclasts and bioclasts are totally or partly surrounded by thick yellowish calcite cement rims. These crusts occur also isolated within the matrix, indicating a reworking of clasts with cement crusts.

Plateau of the Pietra di Salomone: Locality 14

Northern cliff of the Pietra di Salomone. The samples 56 to 58 represent the chalky upper part of the limestone at the plateau near the place where the well was drilled. The samples 56-58 and 63-64 from the plateau of the Pietra di Salomone exhibit the same characteristics as sample 55.

Most of the samples are poorly sorted lithobioclastic rudstones with sponges encrusted by *Archaeolithoporella*, broken phylloid algae and different forms of *Tubiphytes*. Other fossils are bryozoans occurring within boundstone clasts together with *Archaeolithoporella* and sponges, rare fusulinids (*Sumatrina gemmellaroi* Silvestri, sample 57, Pl. 44/16), brachiopods and a few dasycladacean algae. Sample 64 yields *Chusenella (Sosioella) glenisteri* Skinner & Wilde (Pl. 44/9). Angular and subrounded intrapelsparitic grainstone clasts are common. Rotated geopetals indicate strong reworking.

Interparticle pores are partly filled by fibrous and blocky cements. In places reworked fossils as well as boundstone and grainstone clasts are coated by conspicuous yellowish cement rims which are partly reworked. These cement rims also border solution voids filled with graded internal sediment and crystal silt (e.g., sample 63). The samples are characterized by strong leaching. Leaching is especially conspicuous within micritic crusts coating fossils and clasts.

Pietra di Salomone peak: Locality 15

Sample 59 is from the uppermost bed. Sample 63 and 64 (locality 14) are stratigraphically below sample 59.The sample represents poorly sorted chalky lithobioclastic rudstones with cement crusts.

Northeastern Pietra di Salomone: Locality 16

Northeastern plateau of the Pietra di Salomone Samples II/60 to 62. Locality II is separated from I by a deep cut. The samples 76 A and 76 B were collected in the area between the localities 6 and 5.

This locality is characterized by chalky poorly sorted biolithoclastic rudstones with rounded pelsparite clasts.as well as boundstone clasts yielding phylloid algae, sponges, *Archaeolithoporella* and bryozoans. The clasts have been reworked together with yellowish cement crusts. Fossils are common in these (partly brecciated) chalky limestones. Sponges are highly-diverse.

Northeastern cliff wall: Locality 17

The samples 91/1-91/6 from the northeastern cliff wall exhibit boundstones with calcisponges and with slender dendroid *Tubiphytes*, as well as poorly sorted bioclastic rudstones.

Top of the southern cliff: Locality 18

Sample III/65 at the footh path exhibits an alternation of graded pelmicritic layers and layers with abundant cm-sized bio- and

Plate 38 Permian carbonate debris flows (Pietra di Salomone, Western Sicily): Facies variation of the breccia-conglomerate (Figs. 1-5). Common bryozoans (Figs. 6-9)

Fig. 1. Clast-supported, poorly sorted carbonate breccia-conglomerate composed of variously sized angular, subrounded and rounded limestone pebbles. The marly matrix is only locally preserved as thin films surrounding the pebbles. The pebbles 68A to 68G have been studied with regard to microfacies variation. Locality 19, eastern part of the Pietra di Salomone. Scale is about 70 cm.

Fig. 2. Poorly sorted rudstone with fine-grained pelsparite clasts, reworked fossils and *Tubiphytes*. Sample 68A (large angular pebble, maximum size 35 cm). x 4.5.

Fig. 3. Grainstone/Rudstone with small micrite lithoclasts, shell debris, *Lercaritubus* (bottom, center) and broken phylloid alga (center). Sample 68B (angular pebble, maximum size 13 cm). x 6.5.

Fig. 4. Boundstone with '*Tubiphytes*' forming a mat-like structure. Sample 68D (small rounded pebble, maximum size 4 cm). x 6.5

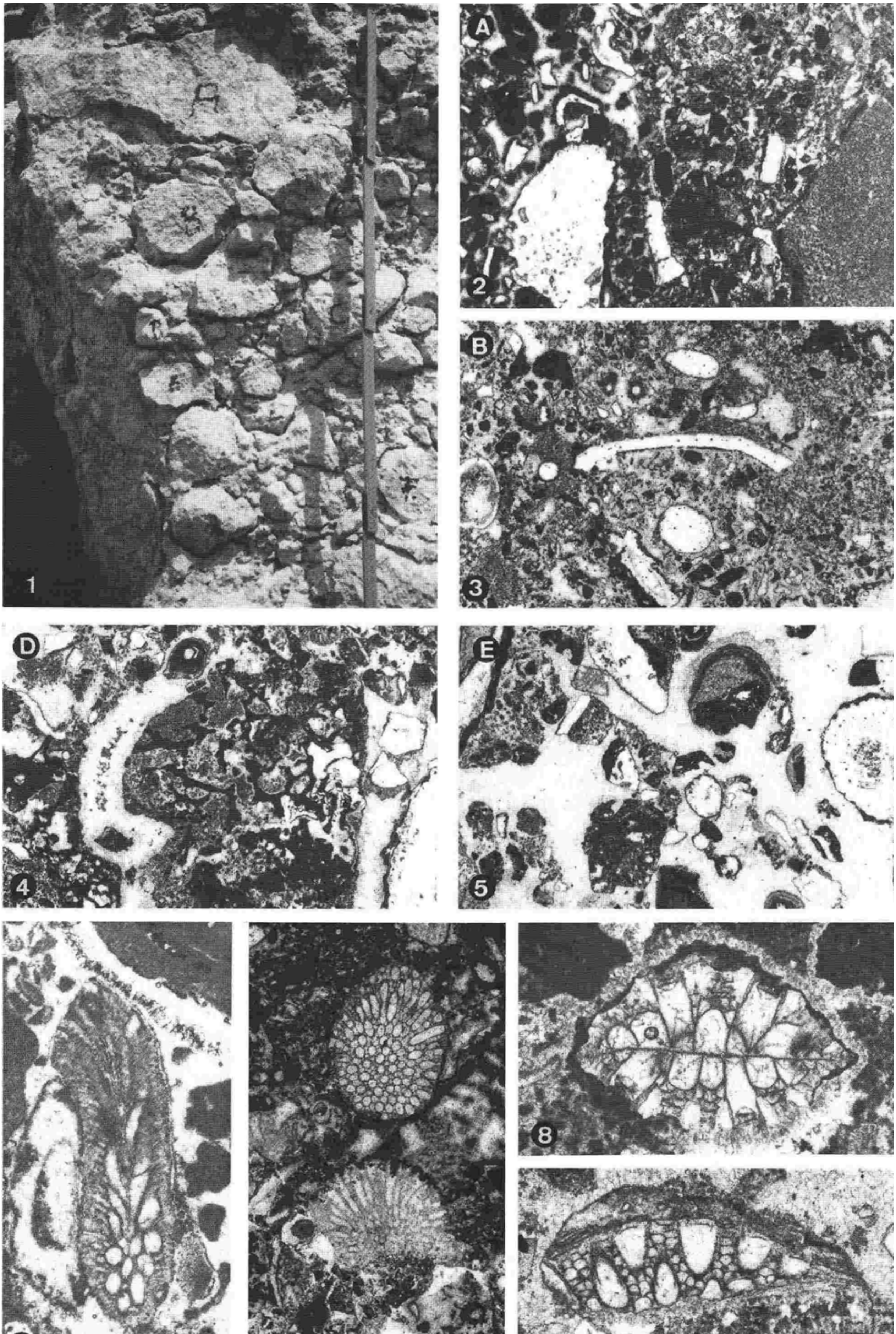
Fig. 5. Lithobioclastic rudstone. Fine-grained pelsparite and pelmicrite clasts, reworked fossils. Sample 68E (subangular pebble, maximum size 8 cm). x 7.5

Fig. 6. Cystoporid bryozoan: *Streblascopora* sp. Sample PS 21, eastern part of the Pietra di Salomone. x 26

Fig. 7. Trepostomid and rhabdomesid bryozoans: *Pseudobatostomella* sp. (bottom) and *Tabulipora* sp. (top). Sample 90/21/2, locality 9. x 5

Fig. 8. Cystoporid bryozoan: *Rhombopora* sp. Sample PS 3, western part of the Pietra di Salomone. x 27

Fig. 9. Cystoporid bryozoan: *Fistulipora* sp. Sample 90/15a, locality 9. x 22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intraclasts Fossils are sponges, bryozoans, *Tubiphytes*, solitary corals and dasycladaceans.

Southeastern part of the Pietra di Salomone: Locality 19 (Pl. 36/1, Fig. 7a)

Prominent cliff with caves. This locality was sampled in some detail because of the striking variations in the size and rounding of the limestone clasts. Samples 66 to 68 (with subsamples 68A to 68 G). Samples 70/1 to 70/3 are from a small cave (width 35 cm, height 20 cm) within the breccia horizon. The cave is filled with limestone pebbles embedded within a yellowish fine-grained dolomite silt.

This outcrop (Pl. 38/1) exhibits a clast-supported, poorly sorted limestone breccia consisting of angular and rounded clasts of different size. Maximum size ranges between about 3 cm and 35 cm. Most smaller clasts are broken and rounded.

The clasts 68/A to 68/G figured in Pl. 38/1-5 have been studied in more detail with respect to a possible variation in the microfacies types:

Size	Rounding	Texture	Composition
A 35 x15 cm	angular	poorly sorted	fossils; fine-grained pelsparite clast rudstone
B 12 x 9 cm	angular	rudstone	fossils; *Tubiphytes* boundstone-clasts,
C 13 x 10 cm	subrounded	poorly sorted rudstone	fossils; fine-grained pelmicrite clast; *Tubiphytes* boundstone
D 4 x 3 cm	rounded	poorly sorted	fossils; *Tubiphytes* boundstone rudstone
E 8 x 5 cm	subangular	rudstone	fossils; fine-grained pelsparite clast
F 8 x 8 cm	rounded	rudstone	fossils
G 18 x 13 cm	angular	poorly	fossils sorted floatstone

Tab. 2. Microfacial composition in limestone pebbles of the Pietra di Salomone limestone, locality 19. See Pl. 38/2-5.

Pebbles of different size and rounding exhibit no distinct textural differences. The texture of most pebbles corresponds to poorly sorted rudstones which may be classified as monomict or, not as common, polymict, with regard to the microfacies of larger lithoclasts. Fossils are free or encrusted sponges, phylloid algae, bryozoans, *Tubiphytes* and *Archaeolithoporella*. These fossils may form compound structures resulting from the binding activity of *Archaeolithoporella* and carbonate cements. Some of these compound structures occur as broken and reworked fragments. These commonly poorly sorted fragments have been embedded together with smaller bioclasts. Angular or subrounded intraclasts, characterized by differing microfacies types (pelsparite; micrite; pelmicrite) are rare.

Some differences in the original sediment are indicated by the occurrence and frequency of fossil types, e.g., phylloid algae, *Archaeolithoporella* and inozoan sponges, and by the diagenetic history following the total or partial primary submarine intergranular cementation as well as by the differing rock color. Some samples show cementation within later fissures crossing submarine cements. Late diagenetic features are represented by the infill of crystal silt in leached phylloid algae and in remaining voids (Pl. 38/4).

The microfacies of the pebbles point to multiple reworking of fossils, compound fossils and intraclasts from different parts of a platform margin or slope. This presupposes a rather rapid submarine cementation followed by submarine reworking, which produced the lithoclasts. Fragmentation of the lithified carbonate sediment and transport resulted in the deposition of angular to variously rounded limestone pebbles now occurring within the debris flow breccias.

Sample 70/1 from a cave at the southeastern cliff is a lithobioclastic rudstone with encrusted fossils (*Tubiphytes*, sponges), fossils compounded by *Archaeolithoporella* crusts as well as larger intraclasts whose surfaces have been partly covered by biogenic crusts (e.g., bryozoan/*Archaeolithoporella* crusts). Interparticle pores are marginally filled by

Plate 39 Facies of the breccia pebbles of the Permian Pietra di Salomone limestone, Western Sicily: Cement-rich skeletal rudstones, calcisponge/*Tubiphytes*/*Archaeolithoporella* boundstones and fine-grained grainstones

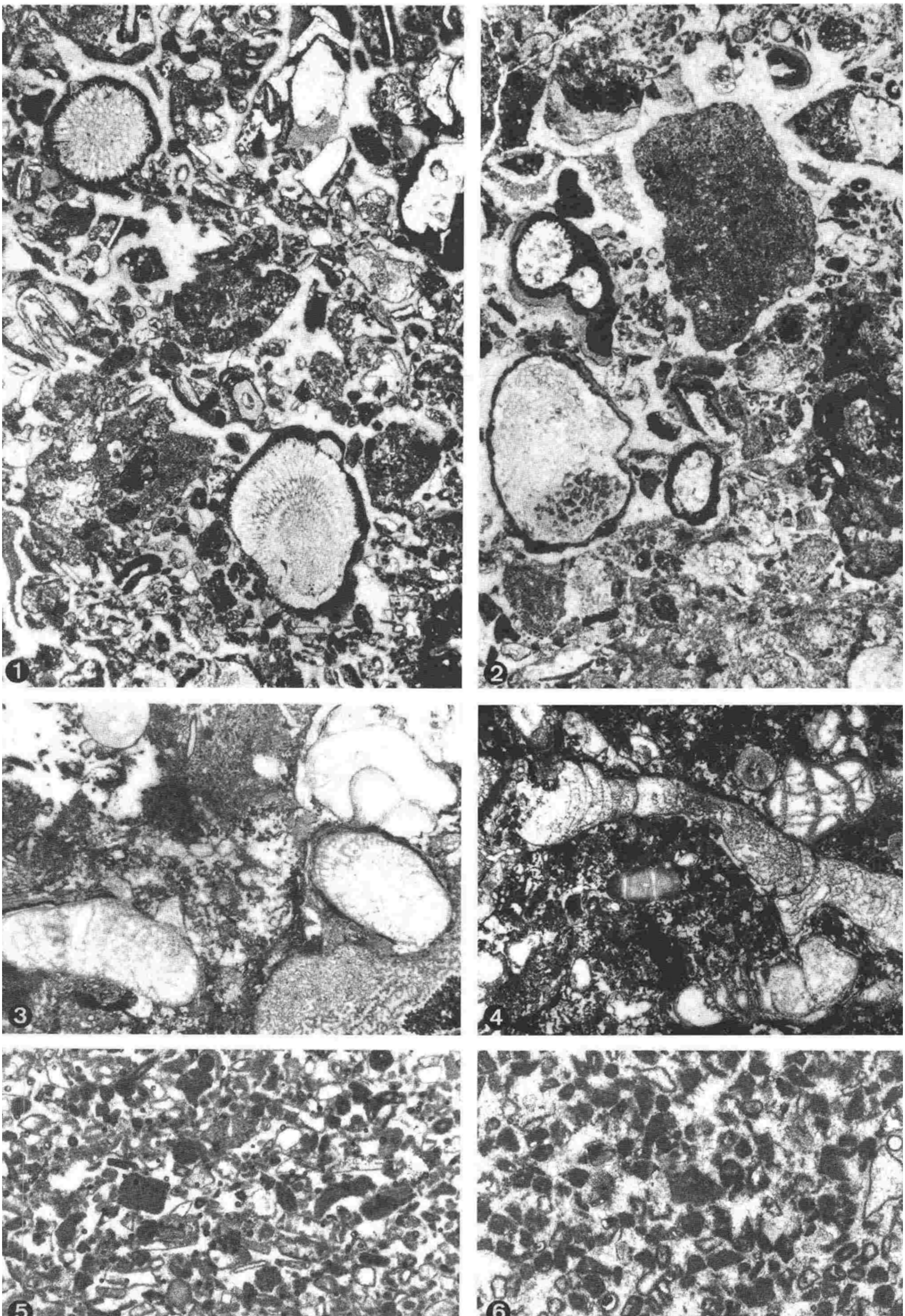
Fig. 1-2. Characteristic rudstone fabric of pebbles forming the limestone breccia of the Pietra di Salomone. Note the differences in size, rounding and microfacies of the lithoclasts which occur together with loose fossils. Many lithoclasts are reworked parts of the boundstone matrix or reworked boundstones.The clasts are cemented by by early submarine fibrous and radiaxial carbonate cements. Fig. 1. Boundstone clats, encrusted sclerosponges (top left and bottom right), pelmicrite clasts (reworked matrix within the boundstones). Sample 90/17, locality 9, northern cliff. x 4. Fig. 2: Subrounded packstone lithoclast (center), boundstone clasts (right), sponges lower left). angular lithoclasts (top). Sample 67, locality 18, top of the southern cliff. x 4

Fig. 3. Calcisponge boundstone with *Stylothalamia permica* SENOWBARI-DARYAN. Baffling by the sponges resulted in the accummulation of packstone type sediment between and around the sponges. Eastern part of the Pietra di Salomone. Sample S/1/7/1. x 4

Fig. 4. Calcisponge boundstone with *Stylothalamia permica* SENOWBARI-DARYAN and *Colospongia* sp. (top right). Eastern part of the Pietra di Salomone. Sample S/1. x 4

Fig. 5. Fine-grained grainstone with shallow-water debris (epimastoporid algae) and micrite clasts. The grainstone forms the top of a turbidite unit. Sample 3, locality 1. x 13

Fig. 6. Fine-grained grainstone composed of angular micrite clasts (< 100 µm) and calcitizedbioclasts. The grainstoneoccurs together with carbonate debris flow layers. Sample 80, locality 12. x 22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thick yellowish fibrous calcite crusts and silt which yields broken crystal tips. Some voids are filled with crystal silt followed by sparry calcite at the top.

This pebble occurs within a yellowish fine-grained marly dolomite (?) matrix, which appears to be thin-bedded (samples 70/2, 70/3). No fossils have been observed in thin-sections but the Permian conodont *Mesogondolella* (Kubergandian to Wordian) occurs in acid residues (sample 1710).

The samples 74 and 75 from beds west of the locality 19 are cement-rich biolithoclastic rudstones predominantly composed of boundstone clasts, encrusted sponges, *Tubiphytes*, some bryozoans and *Archaeolithoporella*. These samples indicate reworking of a boundstone facies.

Southeastern part: Locality 20 (Pl. 36/1, Fig. 7a)

Footpath between the localities 17 and 21. Samples 71 to 73. The samples 74 and 75 come from beds west of locality 8. Samples exhibit different microfacies types:

Biolithoclastic rudstone (sample 71), bioclastic floatstone (sample 73) and fine-grained lithobioclastic grainstone (sample 72 characterized by well-sorted micrite clasts (100-300 µm), smaller foraminifera and oriented echinoderm fragments).

Sample 73A (1711) yields a rich conodont fauna with *Pseudohindeodus*, *Mesogondolella* and *Hindeodus* pointing to a Wordian age.

Eastern cliff: Locality 21

Isolated block between the 'cave' at the southeastern foot of the cliff wall and locality 11. Sample 78.

The sample is of special interest because this bioclastic packstone yields Late Permian fusulinids (*Reichelina* sp. and *Parareichelina* sp., Pl. 44/2, 5) in addition to diverse smaller foraminifera (*Globivalvulina*, *Nodosaria*), reworked *Pseudovermiporella*, very small dasycladaceans and micrite clasts. The bulk of the grains is formed by small rounded sparry bioclasts of unknown origin. A very fine-grained micritic matrix occurs between the particles.

Southeastern margin of the Pietra di Salomone: Locality 22

Isolated block at the southeastern corner of the Pietra di Salomone. Samples IV/91/7-91/9. The chalky limestone is characterized by a strongly leached floatstone fabric with a few inozoan sponge clasts surrounded by thick cement rims.

5 PALEONTOLOGY

Nearly all the groups mentioned in Chapter 1.2 can also be recognized in thin-sections, but some fossils are extremely rare, e.g., trilobites, ammonoids and porostromate algae. Very small solitary corals probably belonging to *Lophocarinophyllum* cf. *acanthiseptum* (Grabau) were observed in less than 3 % of the total of the samples. In the coral fauna described by Montanaro-Gallitelli (1954) only the species mentioned above, *Pleramplexus* cf. *similis* Schindewolf and *Wentzelella salinaria sicula* Montanaro-Gallitelli are real corals whereas the systematic position of *Khmeria* and *Trachypsammia* (as well as that of the fossils compared with the stromatoporoid *Stachyodes*) remains still a matter of debate. The fossils classified as '*Alveolites*' and '*Chaetetes* cf. *thompsoni*' are sclerosponges (cf. Pl. 39/1).

5.1 Discussion of the main groups

5.1.1 Smaller Foraminifera (Pl. 43)

Smaller foraminifera occur in most of the samples but are more obvious in fine-grained grainstones forming the higher part of the Pietra di Salomone limestone (e.g., localities 12 and 21).

The fauna is composed of: Textulariina including Ammodiscidae (*Glomospira* Rzehak); Lituolacea including Hormosinidae (*Reophax* Montfort); Fusulinina including Nodosinellidae (*Tuberitina* Galloway & Harlton, *Geinitzina* Spandel, *Pachyphloia* Lange, Pl. 43/4), Palaeo-

Plate 40 — Rudstone and grainstone facies of Permian carbonate debris flows and turbidites: Pietra di Salomone, Western Sicily

Fig. 1. Poorly sorted lithobioclastic rudstone. Note the differences in size, rounding and microfacies of the clasts. Sample 75, west of locality 8. x 6.5

Fig. 2. Angular lithoclasts. Note different microfacies types of the lithoclasts (pelmicrite, pelbiosparite) as well as reworked *Archaeolithoporella/Tubipihytes* crusts (bottom). These microfacies also occurs as fine-grained packstone and grainstone matrix between the clasts. Sample 90/26, locality 9. x 5

Fig. 3. *Archaeolithoporella/Tubiphytes* oncoid together with angular lithoclasts and shell debris. Sample 90/23, locality 9. x 14

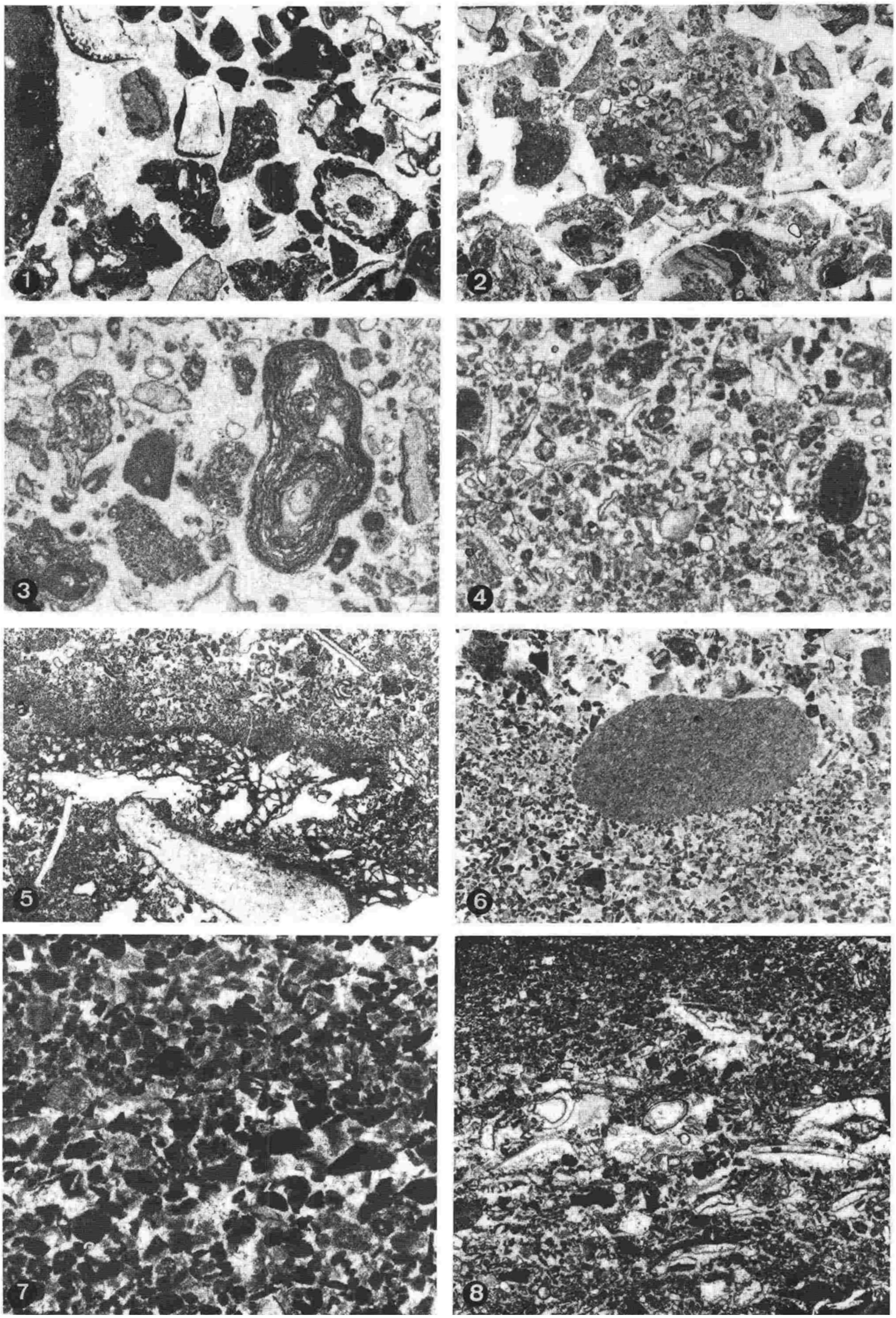
Fig. 4. Fine-grained bioclastic grainstone forming the matrix between larger litho- and bioclasts. Same sample as Fig. 3. x 15

Fig. 5. Boundary between grainstone and boundstone texture (bottom, characterized by '*Tubiphytes*' forming a net-like structure). Sample 90/6, locality 10. x 5

Fig. 6. Fine-grained and medium-grained lithobioclastic grainstone of a turbidite layer intercalated in poorly sorted rudstones. Note the well-rounded lithoclast (center) exhibiting a strikingly different microfacies (biomicrite packstone with radiolarians and sponge spicula), indicating reworking of slope or deep-water sediments. Sample 90/59, locality 8. x 5

Fig. 7 Fine-grained graded intrasparite grainstone. Note the current-aligned orientation of echinoderm elements. Turbidite. Same sample as Fig. 6. x 13

Fig. 8. Alternation of fine- and medium-grained packstone and grainstone layers. Note imbrication texture of larger bioclasts. Sample 90/54. x 3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textulariidae (*Climacammina* BRADY, Pl. 43/8, *Cribrogenerina* SCHUBERT, Pl. 43/7, *Deckerella* CUSHMAN & WATERS), Tetrataxidae (*Baisalina* REITLINGER, Pl. 43/3,*Tetrataxis* EHRENBERG), Biseriamminidae (*Globivalvulina* SCHUBERT), Neoendothyridae (*Neoendothyra* REITLINGER), Archaeodiscidae (*Permodiscus* DUTKEVICH), Lasiodiscidae REITLINGER (*Lasiodiscus* REICHEL, *Lasiotrochus* REICHEL); Miliolina including Fischerinidae (*Agathammina* NEUMAYR, Hemigordiopsidae NIKITINA (*Hemigordiopsis* REICHEL (Pl. 43/9),*Kamurana* ALTINER & ZANINETTI) and Rotaliina including Nodosariidae EHRENBERG (*Nodosaria* LAMARCK).

Similar to other smaller foraminifera occurring in Permian limestones, most species can not be readily identified in random thin-sections, except for *Lasiotrochus tatoensis* REICHEL (Pl. 43/3) and *Lasiodiscus minor* REICHEL (Pl. 43/2).

The association is significantly similar to that occurring in the Middle Permian reef and platform limestones of Slovenia (FLÜGEL et al. 1984, KOCHANSKY-DEVIDÉ & RAMOVS 1955) and to the Permian conglomerates occurring in the Monte Facito Formation of the Southern Apennines (PANZANELLI-FRATONI et al. 1987). The 'Conglomerates with Smaller Foraminifera' occurring in the Monte Facito Formation seem to be comparable to the fine-grained grainstones of the localities 3, 12 and 20 of the Pietra di Salomone with regard to lithofacies and the absence of fusulinids. The conglomerates of the Monte Facito Formation, however, yield typical Upper Permian foraminifera which we did not find in our samples.

5.1.2 Fusulinids (Pl. 44)

Fusulinids occur only in < 5 % of the samples, which is rather surprising since older publications have referred to these limestones as 'Calcari con *Fusulina*". SKINNER & WILDE (1966) drew attention to the patchy distribution of the fusulinids, which should have been in accordance with the presumed reef-like character of the Pietra di Salomone limestone. They recognized a definite association of certain species with certain lithofacies types which we could not recognize in our samples.

Several of the fusulinid species described by SKINNER & WILDE (1966), SILVESTRI (1932) and PASINI (1964) were found again in our material. Surprisingly, *Verbeekina* is missing in our samples. By contrast, *Sumatrina* , which is common in our samples, is absent in the material studied by SKINNER & WILDE. Table 3 summarizes the fusulinid fauna of the Pietra di Salomone limestone:

Some species can be used as time markers: Following the fusulinid zonations proposed by KAHLER (1974) and LEVEN (1981) the *Neoschwagerina* zone, the *Yabeina* zone and the *Reichelina* zone are represented. The *Codonofusiella* zone (which may be below or partly synchronous to the *Reichelina* zone) has not been proved in the Pietra di Salomone limestone but in a sample from the San Calogero block (90/108; Pl. 44/17).

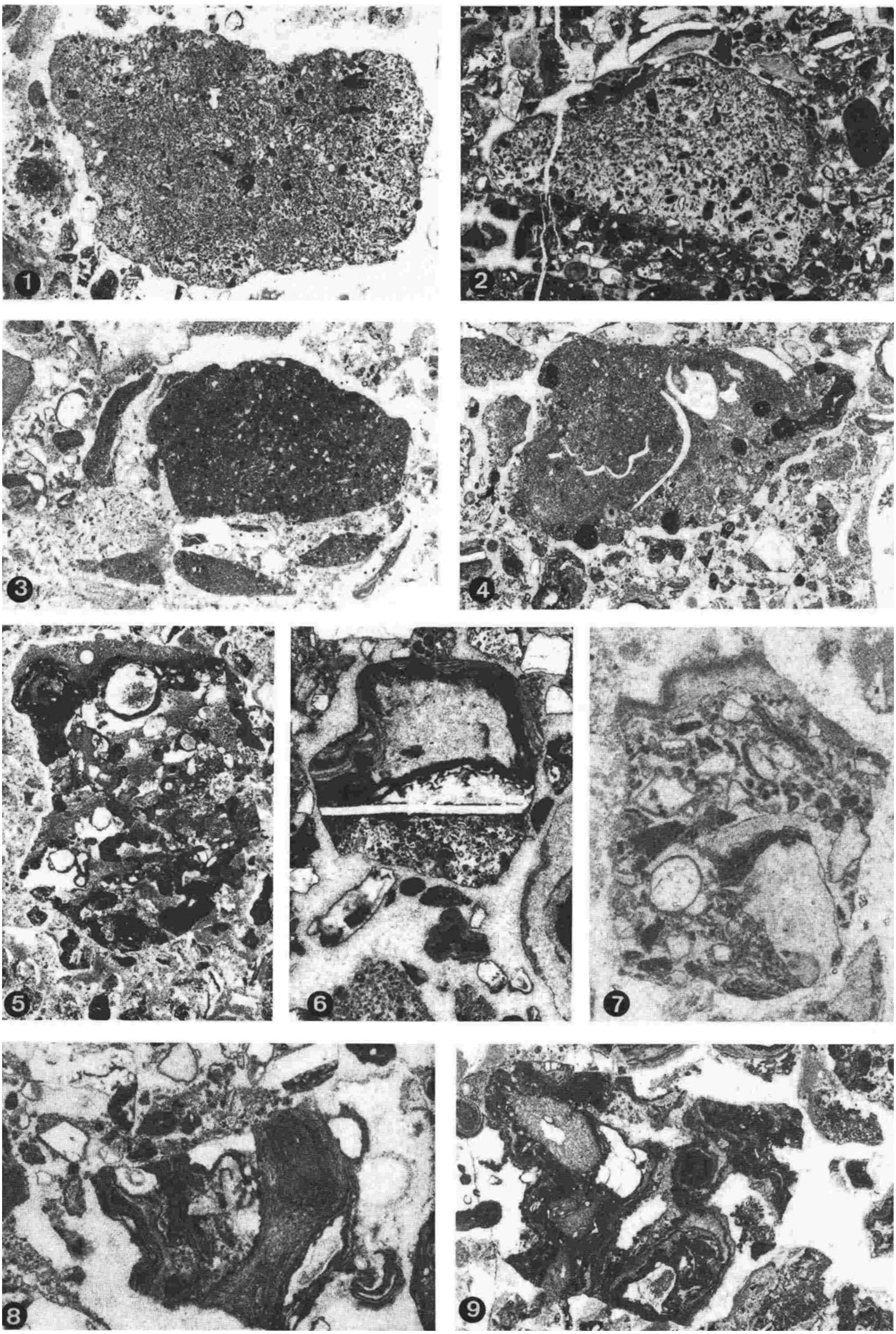
The species of *Neoschwagerina* occurring in the Pietra di Salomone point to the existence of the middle *Neoschwagerina craticulifera* subzone and the upper *N. margaritae* subzone, whereas the lower *N. simplex* subzone is missing. The *N. craticulifera* subzone is indicated by the occurrence of *N. sosiosensis*, which probably represents an evolved, stratigraphically younger species of the *N. craticulifera* species group. The *N. margaritae* subzone is indicated by *N. margaritae*, *N.* cf. *haydeni* and *Verbeekina verbeeki* as well as by *N.* cf. *tebagensis* and *N.* cf. *glintzboekeli* whose species seem to be slightly more highly evolved than *N. margaritae*.

Sumatrina gemmellaroi can be morphologically compared with *S. longissima* which occurs together with *Yabeina* at the base of the *Yabeina* zone in eastern Asia. Scarce fragments of *Yabeina* itself are known from locality 2.

Plate 41 — Permian carbonate debris flow deposits (Pietra di Salomone, Western Sicily): Lithoclast types of lithobioclastic rudstones

The lithoclasts were derived from various sources: Some clasts were eroded in areas with active reef growth (Figs. 5, 6, 8 and 9), other lithoclasts were derived from reef debris areas (Fig. 7). The clasts shown on Figs. 1 and 2 might have been eroded from sediments between active reef growth or from sediments adjacent to these sites. Fig. 3 could be an example of a slope- or basinal-derived lithoclast. Fig. 4 shows that some lithoclasts acted as substrates for encrusting organisms (*Tubiphytes*).

Fig.1 Packstone (partly winnowed intrapelmicrite). Sample 67, locality 19. x 6.5
Fig. 2. Grainstone (intrapelsparite). Sample 90/18, locality 9. x 5
Fig. 3. Wackestone (biomicrite with sponge spicula). Sample 90/26, locality 9. x 7
Fig. 4. Packstone (densely packed bionicrite with mollusk shells). Sample 90/16, locality 9. x 5
Fig. 5. Boundstone with *Tubiphytes* (black) and calcisponges (white), circumcrusted by *Archaeolithoporella*. Sample 90/4, locality 10. x 13
Fig. 6. Boundstone. The lithoclast exhibits organisms as well as the primary 'grainstone matrix' of reef debris sediment. Sample 90/18, locality 9. x 12
Fig. 7. Coarse-grained grainestone (biosparite), composed of reworked shells, calcisponges and broken *Archaeolithoporella*. Sample 90/14, locality 9. x 16
Fig. 8. Boundstone. Eroded and broken *Tubiphytes*/*Archaeolithoporella* association. Sample 90/18, locality 9. x 14



Verbeekinidae Staff & Wedekind, 1910
- Verbeekininae Staff & Wedekind, 1910
  - *Verbeekina* Staff, 1909
    - *Verbeekina furnishi* Skinner & Wilde, 1966
- Kahlerininae Leven, 1963
  - *Kahlerina* Kochansky-Devide & Ramovs, 1955
    - *Kahlerina siciliana* Skinner & Wilde, 1966 (*) – Pl.44/1

Ozawainellidae Thompson & Foster, 1937
- Ozawainellinae Thompson & Foster, 1937
  - *Rauserella* Dunbar, 1944
    - *Rauserella staffi* Skinner & Wilde, 1966
  - *Reichelina* Erk, 1941
    - *Reichelina* sp. (*) – Pl. 44/5
  - *Parareichelina* Miklucho-Maclay, 1958
    - *Parareichelina* sp. (*) – Pl. 44/2

Schubertellidae Skinner, 1931
- Schubertellinae Skinner, 1931
  - *Schubertella* Staff & Wedekind, 1910
    - *Schubertella silvestri* Skinner & Wilde, 1966
    - *Schubertella* sp. (*) – Pl. 44/3

Boultoniidae Skinner & Wilde, 1954
- Boultoniinae Skinner & Wilde, 1954
  - *Boultonia* Lee, 1927
    - *Boultonia* sp.
  - *Dunbarula* Ciry, 1948
    - *Dunbarula matthieui* Ciry (*) – Pl. 44/6
  - *Minojapanella* Fujimoto & Kanuma, 1953
    - *Minojapanella* sp. (*) - Pl. 44/7

Fusulinidae Möller, 1878
- Fusulinellinae Staff & Wedekind, 1910
  - *Yangchienia* Lee 1933
    - *Yangchenienia thompsoni* Skinner & Wilde, 1966
    - *Yangchienia* sp. (*) – Pl. 44/8

Schwagerinidae Dunbar & Henbest, 1930
- Chusenellinae Kahler & Kahler, 1966
  - *Chusenella* Hsu, 1942
  - *Chusenella (Sosioella* Skinner & Wilde, 1966*)*
    - *Chusenella (Sosioella) glenisteri* Skinner & Wilde, 1966 (*)
    - *Chusenella (Sosioella) intermedia* Skinner & Wilde, 1966
    - *Chusenella (Sosioella) sosiosensis* Pasini, 1964 (*) – Pl. 44/9
- Pseudoschwagerininae Chang, 1963
  - *Rugososchwagerina* Miklucho-Maclay, 1956
    - *Rugososchwagerina yabei* (Staff, 1909) (*) – Pl. 44/10
- Pseudofusulininae Dutkevich, 1934
  - *Pseudofusulina* Dunbar & Skinner, 1931
    - *Pseudofusulina anachrona* Skinner & Wilde, 1966
    - *Pseudofusulina dainelli* (Skinner & Wilde, 1966)

Neoschwagerinidae Dunbar, 1948
- Neoschwagerininae Staff, 1912
  - *Neoschwagerina* Yabe, 1903
    - *Neoschwagerina* cf. *glintzboekeli* Skinner & Wilde, 1967 (*) – Pl. 44/11
    - *Neoschwagerina* cf. *haydeni* Dutkevich & Chabakov, 1934 (*)– Pl. 44/12
    - *Neochwagerina margaritae* Deprat, 1913 (*)
    - *Neoschwagerina sosioensis* Skinner & Wilde,1966 (*) – Pl. 44/13-15
    - *Neoschwagerina tebeganensis* Skinner & Wilde, 1967 (*) – Pl. 44/15
  - *Yabeina* Deprat, 1914
    - *Yabeina.* sp (*) – Pl. 44/4
- Sumatrininae Silvestri, 1933
  - *Sumatrina* Volz, 1904
    - *Sumatrina gemmellaroi* Silvestri, 1932 (*) – Pl. 44/16, 17

Tab. 3. Fusulinids from the Pietra di Salomone limestone (det. F. Kahler). The list combines our data with those of previous authors. Species occurring in our material are marked by (*). Classification after Kahler & Kahler (1966) and Loeblich & Tappan (1988).

Plate 42 — Marine carbonate cements and transported meteoric diagenesis criteria in Permian debris flow pebbles: Pietra di Salomone, Western Sicily

Fig. 1. The geopetal fabric within intergranular voids (white arrow) is distinctly different from the sedimentary geopetal fabric (black arrows), pointing to resedimentation of the sediment subsequent to submarine cementation. The pore filling sequence consists of light gray internal sediments with intraclasts at the base, overlain by micrite and (dark) dolomitized crystal silt. The remaining pore space is filled with granular calcite. Sample 90/6, locality 10. x 3.5

Fig. 2. Detail of Fig. 1 exhibiting internal sediment with small (dark) intraclasts, crystal silt and recrystallized granular calcite cement. Note broken crystal tips within the crystal silt area. Same sample as Fig. 2. x 9.5

Fig. 3. Crystal silt. Leached and broken calcite crystals and crystal aggregates. Sample 90/4, locality 10. x 40

Fig. 4. The void filling sequence consists of cross-bedded internal sediment with intraclasts, internal sediment without intraclasts, dark micrite and dolomite crystal silt. Note the rotated geopetals (black and white arrows). Sample 90/5, locality 10. x 4.5

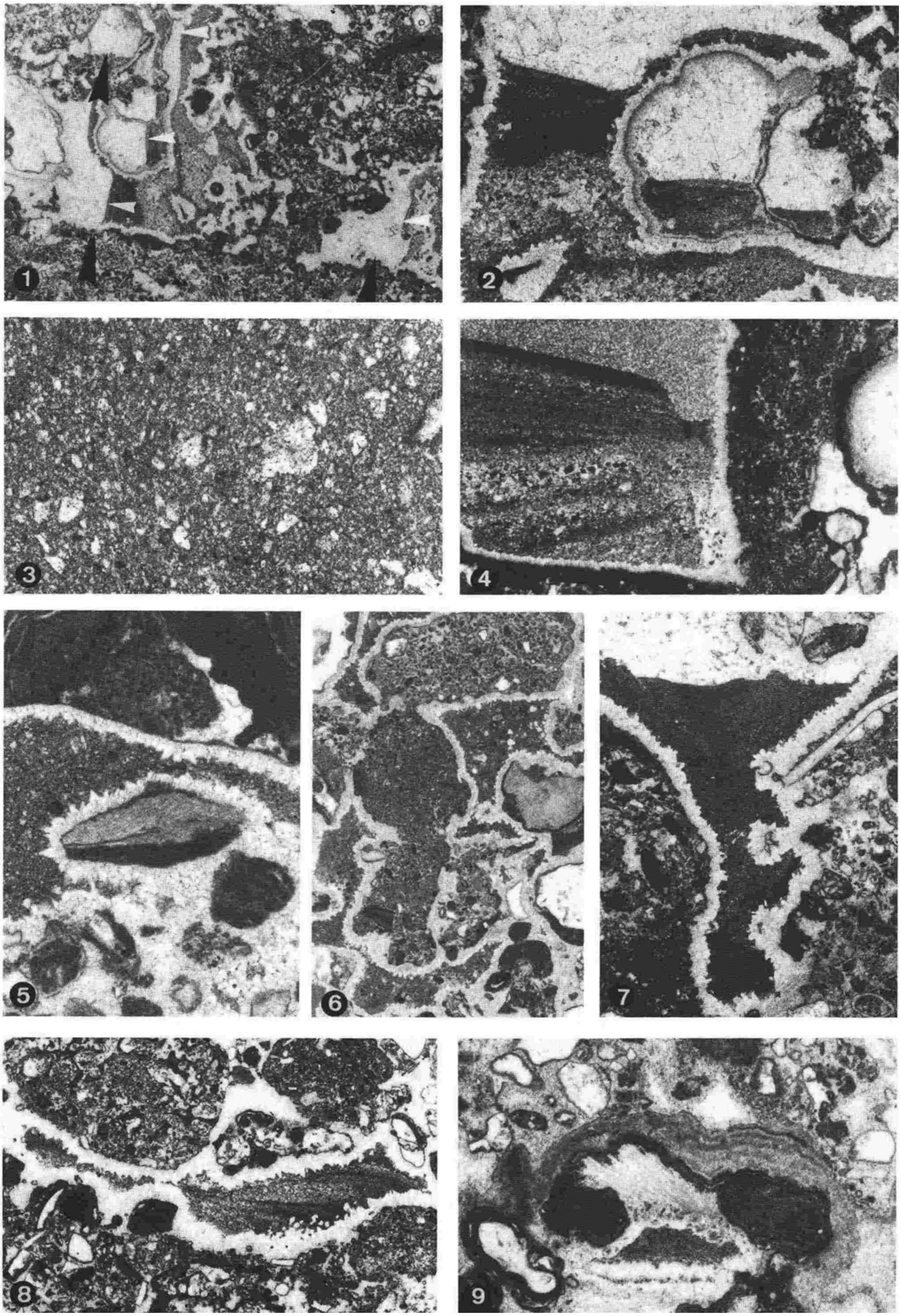
Fig. 5. Scalenohedral calcite spar cement (possibly a recrystallized marine cement) boundaring voids filled with meteoric calcite crystal silt. Sample 90/52, locality 8. x 22

Fig. 6. Marine cement rims surrounding densely packed lithoclasts. Early reworking of lithoclasts and cements resulted partly in the sedimentation of broken cement rims and isolated crystals. Sample 90/40/1, locality 8. x 6.5

Fig. 7. Intergranular void. Scalenohedral calcite spar cement (marine), fine-grained calcite crystal silt (meteoric). Sample 90/5, locality 10. x 6.5

Fig. 8. Lithobioclastic rudstone. Lithoclasts are boundstones (with net-like '*Tubiphytes*", top left) and pelmicrites. Intergranular voids are filled with thick marine cement rims, internal sediment and crystal silt indicating leaching of marine cement during meteoric exposure. Sample 90/12, locality 10. x 6.5

Fig. 9. Botryoidal cement between encrusting organisms. Botryoidal cements are rare in the samples and generally restricted to boundstone fabrics. Note the laminated marine cement overgrowing *Archaeolithoporella*. Sample 90/6, locality 10. x 3.5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Reichenella sp. and *Parareichenella* sp. point to the occurrence of the *Reichelina* zone not only in the Pietra di Salomone limestone but alsoin calcarenites near the Passo Rupe del Burgio locality where *Reichelina simplex* SHENG has been found (Pl. 37/3), known from the lower Changxiangian of southern and northwestern China. *Parareichelina* should indicate approximately the same age because this species has been described from the upper Lopingian which correlates to parts of the Changxiangian.

The fusulinid zones recognized within the pebbles of the Pietra di Salomone limestone breccia represent parts of the Murgabian, the Midinian, Dzhulfian and also the Dorashamian respectively the Changxiangian stages.

The fusulinid fauna as well as the association of the smaller foraminifera are similar to those found in the reworked Permian within the Monte Facito Formation of the Southern Apennines described by PANZANELLI-FRATONI et al. 1987 and CIARAPICA et al. (1990). Within the Permian conglomerates the authors distinguished the '*Chusenella* conglomerates' (yielding foraminifera of the *Neoschwagerina craticulifera* subzone of Middle Murghabian age), the '*Neoschwagerina* conglomerates' or '*Yabeina* conglomerates' (yielding species of the *Neoschwagerina margaritae* subzone of Upper Murghabian age), and the 'smaller foraminifera conglomerates' (characterized by diverse smaller foraminifera of Midinian to Dorashamian age, and the lack of fusulinids).

5.1.3 Sponges (Pls. 45, 46)

Sponges, *Tubiphytes* and 'algal crusts' (cf. *Archaeolithoporella*) are the most common fossils recognizable in thin-sections from the Pietra di Salomone limestone. Sponges occur isolated, locally also in concentrations.

The sponges from the Pietra di Salomone limestone belong to segmented sphinctozoans as well as to non-segmented 'inozoans'. Previous descriptions by DE GREGORIO (1930) and PARONA (1929, 1930a) have been somewhat revised by ALEOTTI et al. (1986) and by SENOWBARI-DARYAN (1990). Table 4 summarizes the results of these revisions. The inozoan sponges still need a thorough study. Preliminary results, based on the re-study of PARONA's type material in Palermo, are shown in Table 5. This list includes many species which have been erroneously regarded by PARONA as siliceous sponges.

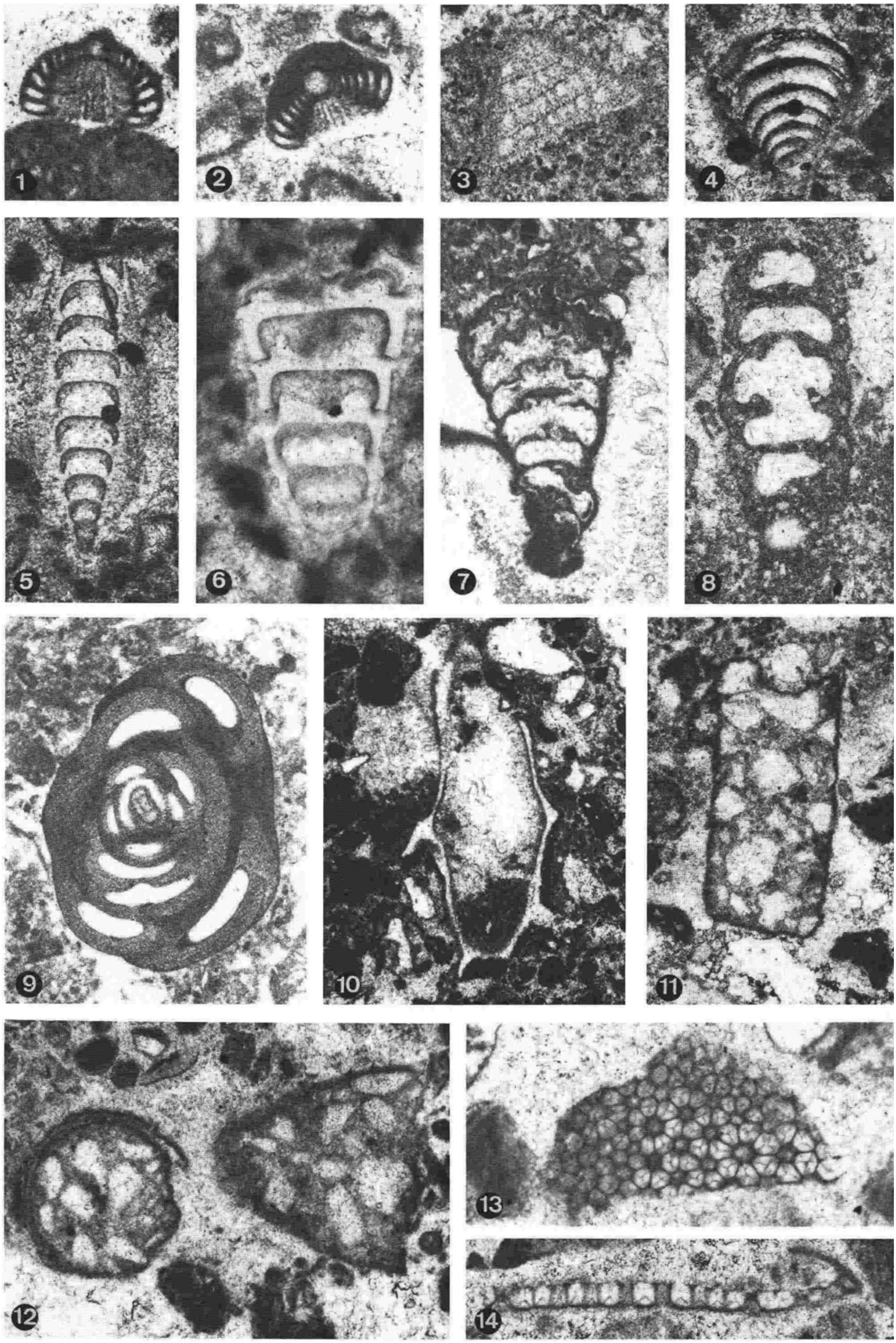
In addition to the taxa listed in Table 4 the following demospongid species have been determined from samples from the Pietra di Salomone (classification after SENOWBARI-DARYAN 1990):

Subclass Ceractinomorpha
- Order Verticillitida
  - Verticillitidae
    - *Stylothalamia permica* SENOWBARI-DARYAN (Pl. 39/2-3)
- Order Permosphincta TERMIER & TERMIER
  - Sebargisiidae
    - *Cystothalamia adrianensis* SENOWBARI-DARYAN
    - *Cystothalamia distefanoi* SENOWBARI-DARYAN
    - *Cystothalamia nodulifera* GIRTY
    - *Discosiphonella mammilosa* KING
    - *Amblysiphonella clathrata* PARONA
    - *Amblysiphonella merlai* PARONA – Pl. 46/6
    - *Ambylsiphonella ? permosicula* (PARONA)
    - *Ambysiphonella vesiculosa* (KONINCK)
  - Colospongiidae
    - *Colospongia cortexifera* SENOWBARI-DARYAN & RIGBY – Pl.45/2
    - *Colospongia paronae* ALEOTTI, DIECI & RUSSO
    - *Uvothalamia planiinvoluta* SENOWBARI-DARYAN
    - *Imbricatocoelia* cf. *elongata* RIGBY, FAN & ZHANG – Pl. 46/2, 5
  - Tebagathalamiidae
    - *Graminospongia girtyi* (PARONA) – Pl. 45/1
  - Solenomiidae
    - *Solenolmia permica* SENOWBARI-DARYAN & RIGBY
    - *Preverticillites columnella* PARONA – Pl. 46/5
  - Intrasporeocoeliidae
    - *Intrasporeocoelia hubeieinsis* FAN & ZHANG
  - Thaumastocoeliidae
    - *Sollasia ostiolata* STEINMANN
  - Polyedridae
    - *Pseudoguadalpupia alveolaris* (PARONA) – Pl. 46/3

Subclass Sclerospongea
- Order Guadalupiida
  - Guadalupiidae
    - *Lemonea ? cidarites* (PARONA)
    - *Lemonea cylindrica* (GIRTY) — Pl. 45/6

Plate 43 Smaller foraminifera (Fig. 1-9) and microproblematica (Fig. 10-14) from the Pietra di Salomone Limestone, Permian of Western Sicily

Fig. 1. *Lasiotrochus tatoensis* REICHEL. Sample 27, locality 4. x 70
Fig. 2. *Lasiodiscus minor* REICHEL. Sample PS 14, western part of the Pietra di Salomone. x 70
Fig. 3. *Baisalina* cf. *pulchra* REITLINGER. Sample 90/27a, locality 9. x 70
Fig. 4. *Pachyphloia* sp. Sample 2, locality 1. x 70
Fig. 5. *Langella* sp. Sample 90/41, locality 8. x 45
Fig. 6. *Langella*sp. Sample 90/41, locality 8. x 50
Fig. 7. *Cribrogenerina* sp. Sample PS 5, western part of the Pietra di Salomone. x 27
Fig. 8. *Climacammina* sp. Sample 90/27b, locality 9. x 35
Fig. 9. *Hemigordiopsis* sp. Sample PS 111, western part of the Pietra di Salomone. x 42
Fig. 10. Microproblematicum, somewhat similar to *Lercaritubus*. Sample 90/41/2, locality 8. x 20
Figs. 11.-12. Microproblematicum, probably an echinoid fecal pellet. Fig. 10: Sample 90/5, locality 19. x 27. Fig. 11: Sample 90/41/2, locality 8. x 45
Figs. 13.-14. Microproblematicum. Fig. 12: Sample 90/100, Rupe di San Calogero. x 75. Fig. 13: Sample 90/64, locality 8. x 90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Amblysiphonella clathrata PARONA	*A. clathrata* PARONA
Amblysiphonella merlai PARONA	*A. merlai* PARONA
Amblysiphonella nodosa PARONA	no *Amblysiphonella*
Amblysiphonella vesiculosa (KONINCK)	*A. vesiculosa* (KONINCK)
Cystothalamia nodulifera GIRTY	*C. nodulifera* GIRTY
Enoplocoelia cantabulata PARONA	coral
Guadalupia alveolaris PARONA	*Pseudoguadalupia alveolaris* (PARONA)
Guadalupia cidarites PARONA	*Lemonea ? cidarites* (PARONA)
Guadalupia cylindrica GIRTY	*Lemonea cylindrica* (GIRTY)
Guadalupia girtyi PARONA	*Graminospongia girtyi* (PARONA)
Guadalupia minima PARONA	dasyclad algae
Heterocoelia beedei GIRTY	*Sollasia ostiolata* (STEINMANN)
Imperatoria marcinii DE GREGORIO	no sphinctozoan sponge
Preverticillites columnella PARONA	*Preverticillites columnella* PARONA
Sollasia ostiolata permica PARONA	not recognizable
Steinmanni cf. gemina (WAAGEN & WENTZEL)	*Colospongia cortexifera* SENOWABARI-DARYAN & RIGBY
Steinmannia salinaria WAAGEN & WENTZEL	*Colospongia salinaria* (WAAGEN & WENTZEL)
Thaumastocoelia permosicula PARONA	*Amblysiphonella ? permosicula* (PARONA)

Tab. 4. Revised generic assignment (right column) of segmented sponges described by PARONA (1933) from the Pietra di Salomone limestone.

Amblysiphonella with catenulate growth forms and *Colospongia* with moniliform growth forms dominate within the sphinctozoan fauna, followed by *Lemonea* with cylindrical growth forms. The apparently high numerical diversity should not be overrated because several species have been found with only a few specimens and because the differentiation of species within the genus *Amblysiphonella* is highly artificial.

Most non-segmented sponges belong to *Polytubospongia* RIGBY, FAN & ZHANG and to *Precorynella* DIECI, ANTONACCI & ZARDINI (Pl. 45/4). In addition, species of *Peronidella* HINDE (Pl. 46/1) and some new inozoan sponges occur.

5.1.4 Bryozoans (Pl. 38/6-8)

Cystoporida, Trepostomida, Rhabdomesonida, and Fenestrida occur together with calcisponges, *Archaeolithoporella*, *Tubiphytes* and phylloid algae. Similar to the bryozoans of the Middle Permian Bled reef limestone, ramose zoaria are well-preserved showing no signs of stronger transport (and perhaps representing biota of the upper slope). Cystoporid and rhabdomesonid genera are more common than trepostomid and fenestrid bryozoans.

The bryozoans from the Sosio blocks have not yet been studied in detail. The only reference is given by CIPOLLA (1952) who distinguished about 20 species. The random sections available allow only a preliminary generic assignment of our material.

5.1.5 Calcareous Algae (Pl. 47)

Algae represented by green algae (dasycladaceans), red algae (solenoporaceans), very rare filamentous algae as well as phylloid algae are not common in the Pietra di Salomone limestone but the last mentioned group includes important frame-building elements.

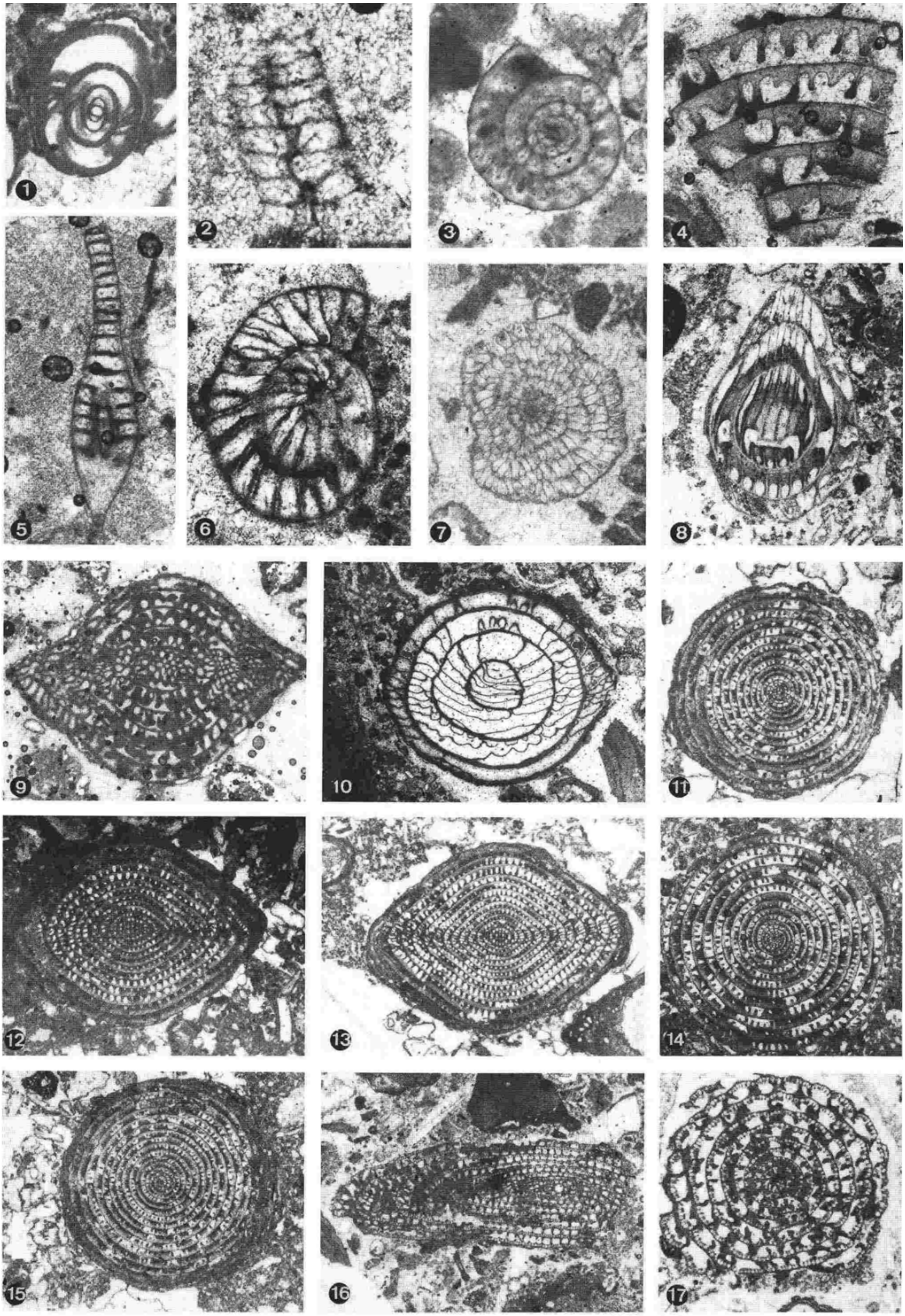
Dasycladaceae are rare. *Mizzia cornuta* KOCHANSKY & HERAK (Pl. 47/1), characterized by a garland-shaped outline of the thallus caused by horn-like projections of the pores, and *Mizzia velebitana* SCHUBERT (Pl. 47/2) have been found together in biolithoclastic rudstones, together with fusulinids. *Gyroporella*, probably *Gyroporella igoi* ENDO, occurs together with *Mizzia*. Additional elements are *Salopekiella* sp. (Pl. 47/3), *Macroporella* sp. and *Connexia* sp. (Pl. 47/4).

Epimastoporid algae (which probably do not belong to the dasycladadaceans; see FLÜGEL & FLÜGEL-KAHLER 1980) are represented by *Epimastopora densipora* ENDO, *Epimastopora piae* BILGÜTAY (Pl. 47/6), *Epimastopora hunzaensis* ZANIN BURI, *Pseudoepimastopora* cf. *ampullacea* ELLIOTT

Plate 44 — Middle and Upper Permian fusulinids from the Pietra di Salomone limestone, Western Sicily

Fig.. 1. *Kahlerina siciliana* SKINNER & WILDE. Sagittal to axial section. Sample PS 11, western part of the Pietra di Salomone. x 22
Fig. 2. *Parareichelina* sp. Sample 78, locality 21. Upper Permian. x 16
Fig. 3. *Schubertella* sp. Sagittal section. Sample 90/57, locality 8. x 82
Fig. 4. *Yabeina* sp. Sample 13, locality 2. x 34
Fig. 5. *Reichelina* sp. Sample 78, locality 21. Upper Permian. x 57
Fig. 6. *Dunbarula matthieui* CIRY. Sample PS 3, western part of the Pietra di Salomone. x 57
Fig. 7. *Minojapanella* (*Wutuella*) sp. Sample 90/17, locality 9. x 30
Fig. 8. *Yangchenia* sp. Sample PS 111, western part of the Pietra di Salomone. x 18
Fig. 9. *Chusenella* (*Sosioella*) *sosioensis* PASINI. Sagittal section. Sample 64, locality 14. x 8
Fig. 10. *Rugososchwagerina yabei* (STAFF). Sample 18, locality 2. x 4
Fig. 11. *Neoschwagerina* cf. *glintzboekeli* SKINNER & WILDE. Sample 35g, locality 6. x 8
Fig. 12. *Neoschwagerina* cf. *haydeni* DUTKEVICH & CHABAKOV. Sample 35h/2., locality 6. x 10
Fig. 13. *Neoschwagerina sosioensis* SKINNER & WILDE. Sample 35D/2, locality 6. x 8
FIG. 14. *Neoschwagerina sosioensis* SKINNER & WILDE. Sagittal section. Sample 35e, locality 6. x 10
Fig. 15. *Neoschwagerina* cf. *tebagensis* SKINNER & WILDE. Sample 35f, locality 6. x 8
Fig. 16. *Sumatrina gemmellaroi* SILVESTRI. Sample 57, locality 14. x 8
Fig. 17. *Sumatrina gemmellaroi* SILVESTRI. Sample Cal 1, boulder within the Torrente San Calogero section. x 1

Plate 44



Adrianella craterica PARONA	?
Adrianella distafanoi PARONA	?
Arbuscula contortiplicata PARONA	*Arbuscula contortiplicata* PARONA
Aulacospongia calogerii PARONA	*Paronaespongia calogerii* (PARONA)
Aulacospongia carota PARONA	?
Caryospongia ? dydacica GERTH	?
Corynella crysanthemum PARONA	*Precorynella crysanthemum* (PARONA)
Corynella fabiani PARONA	*Precorynella crysanthemum* (PARONA)
Corynella ovoidalis PARONA	*Corynella ovoidalis* PARONA
Corynella turbo PARONA	*Corynella turbo* PARONA
Gemmerellaroella permica PARONA	?
cf. *Heliospongia ramosa* GIRTY	cf. *Heliospongia ramosa* GIRTY
Himatella pauciforata PARONA	no *Himatella*, new genus
Hindia lacunosa PARONA	?
Hindia wanneri GERTH	?
Leiofungia benedettina PARONA	?
cf. *Palaeojarea molegraaffi* GERTH	*Palaeojarea molengraafi* GERTH
Pattersonia genista (DE GREGORIO)	*Pattersonia genista* (DE GREGORIO)
Pattersonia permosicula PARONA	*Pattersonia permosicula* PARONA
Pemmatites mediterraneus PARONA	*Pemmatites mediterraneus* PARONA ?
Pemmatites osculiferus PARONA	*Pemmatites osculiferus* PARONA
Permosoma tuberculatum GRECO	*Permosoma tuberculatum* GRECO
Permosoma tunicatum GRECO	*Permosoma tunicatum* GRECO
Puppispongia postrema DE GREGORIO	?
Sphaerospongia permotesselata PARONA	*Permosoma tunicatum* JAEKEL
Stellispongia lobata PARONA	*Stellispongia lobata* PARONA
Stellispongia permica PARONA	*Stellispongia permica* PARONA
Stuckenbergia adrianensis PARONA	*Paronaespongia adrianensis* (PARONA)
Trinacriella retusa PARONA	?
Virgula bifida PARONA	*Intratubospongia osiensis* (DEGREGORIO)
Virgula osiensis (DEGREGORIO)	*Intratubospngia osiensis* (DEGREGORIO)

Tab. 5. Revised generic assignment (right column) of the non-segmented sponges described by PARONA (1933) from the Permian of the Sosio valley. Most species were believed to be siliceous sponges but lack spicula.

(Pl. 47/5) and *Pseudoepimastopora iwaizakensis* (ENDO), Pl. 47/7. The last mentioned species, characterized by very thin but extended thalli, is of some importance in the binder guild, together with phylloid algae and *Archaeolithoporella*.

Most phylloid algae acted as binders and bafflers (Pl. 48/10). The internal structure of these algae is often lost during diagenesis. Some of the better preserved material can be attributed to *Ivanovia* sp. (Pl. 47/13), others to *Eugonophyllum* sp. Very large phylloid algae with a width of several centimetres are more common in micritic boundstones and floatstones.

Red algae are rare and represented by gymnocodiaceans and solenoporaceans:

Gymnocodiaceans occur as rare isolated fragments which can be attributed to *Permocalculus fragilis* (PIA), Pl. 47/9, and *Permocalculus kanmerai* KONISHI (Pl. 47/8).

Solenoporaceans are represented by *Parachaetetes lamellatus* KONISHI (Pl. 47/11, 12), *Solenopora* sp., similar to *Solenopora texana* JOHNSON and *Pycnoporidium* sp. (47/10). These red algae acted as baffling and binding elements (Pl. 47/12). They are often strongly bored.

The composition of the algal flora as well as the frequency of the groups in the main lithofacies types (boundstones and lithobioclastic rudstones and floatstones) exhibit striking similarities with those from the *Neoschwagerina* limestone of Bled, Slovenia (FLÜGEL et al. 1984). Most of the algal species of the Pietra di Salomone limestone are known from Murghabian and Midinian strata of the Tethyan region (FLÜGEL 1990).

5.1.6 Microproblematica (Pl. 43/9-13)

The taxonomic affinities of the most common and significant biogenic structures within the Pietra di Salomone limestone – generally attributed to *Archaeolithoporella* ENDO and *Tubiphytes* MASLOV – are still controversial (BABCOCK 1986, RIDING 1990, RAZGALLAH & VACHARD 1991; SENOWBARI-DARYAN & FLÜGEL, in press).

Archaeolithoporella (Pl. 48/6, 7, 9) is an abundant encrusting Permian reef organism, often associated with '*Tubiphytes*' and with submarine laminar cement crusts. It is characterized by alternating couplets of dark, often crinkled micritic layers and light sparry layers overgrowing various

Plate 45 — Sponges from the Permian Pietra di Salomone limestone, Western Sicily: Sphinctozoans (Figs. 1, 2, 5, 7), inozoans (Fig. 4) and sclerosponges (Fig. 3)

Fig. 1. *Graminospongia girtyi* (PARONA). Longitudinal section. Sample S/265/7. x 5

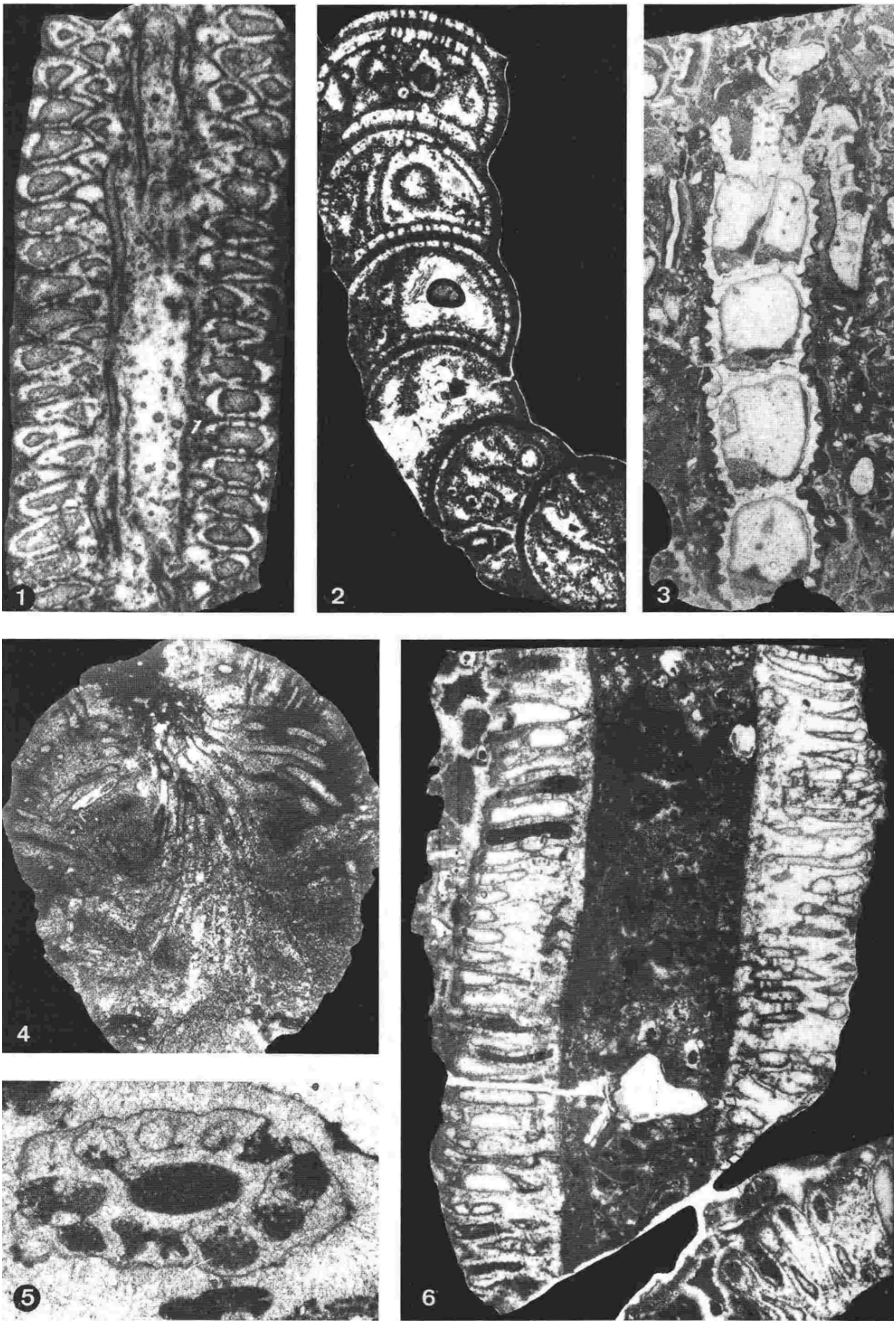
Fig. 2. *Colospongia cortexifera* SENOWBARI-DARYAN & RIGBY. Longitudinal section. Note the vesicular structures in the chambers. Sample B/2. x 2.7

Fig. 3. *Pseudoguadalupia alveolaris* (PARONA). Tangential latitudinal section. Sample 90/41. x 2.5

Fig. 4. *Precorynella crysanthemum* (PARONA). Longitudinal section. This species represents the most common inozoan sponge recognized in the Pietra di Salomone limestone. Sample S/238. x 3.5

Fig. 5. *Discosiphonella* sp. Oblique section exhibiting the glomerate chambers. Sample 90/84. x 22

Fig. 6. *Lemonea cylindrica* (GIRTY), a frequent sponge in the Pietra di Salomone limestone. Longitudinal section. The tube-like segments are arranged around a wide spongocoel. Sample B/8. x 3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sessile organisms (sponges, bryozoans, phylloid algae, *Tubiphytes*). The growth forms correspond to laterally extended crusts, irregular nodular masses and to oncoids. An early and rapid lithification is indicated by the frequent occurrence of bioclasts with broken elements of *Archaeolithoporella*.

Archaeolithoporella has been regarded as red alga, cyanobacteria and as being of inorganic (cement) origin. The material from the Pietra di Salomone limestone exhibits distinct variations with regard to the spacing and regularity of the dark layers, the filling of the interspaces with grey microsparitic or fibrous cement or with micritic sediment as well as the number of layers involved in the formation of the crusts.

Archaeolithoporella is one of the dominant members of the binder guild within Permian reefs. It seems to have been concentrated on the reef crest but was probably also a quantitatively important encruster of the reef slope, as indicated by the occurrence on the walls of seaward slope fissures (FAGERSTROM 1987). The organisms responsible for these biogenic crusts were probably not light-dependent because the basal layers are completely adapted to irregularities of the substrate extended deeply downwards (i.g., cavities of sponges). In most interpretative facies models a shelf-margin to foreslope paleoenvironment of Permian reefs with abundant *Archaeolithopora/Tubiphytes* crusts is postulated (e.g., TOOMEY 1991).

The generic name *Tubiphytes* MASLOV has been frequently applied to enigmatic variously shaped, mm to cm-sized encrusting organisms characterized by a dark flocculent structure enclosing 'tubes', and being a major element of Late Paleozoic and Mesozoic reefs. These structures are also common in the boundstone and rudstone lithofacies types of the Pietra di Salomone limestone.

Distinct differences in the nature of the 'tubes' and in the segmentation of Paleozoic '*Tubiphytes*' have led to the conclusion that the fossils called '*Tubiphytes*' up to now should be re-classified on a generic level (SENOWBARI-DARYAN & FLÜGEL, in press).

The most common types occurring in the Pietra di Salomone limestone are shown in Plate 48/1-5, 10.

Tubiphytes is an important member of the binder, baffler and and also of the constructor guild. The species occur in close association with *Archaeolithoporella*, bryozoans, calcisponges and phylloid algae.

Other common fossils of problematic affinities include *Lercaritubus problematicus* FLÜGEL, SENOWBARI-DARYAN & DI STEFANO, tubes with microgranular or agglutinated walls, comparable to those described from the Middle Permian Bled reef (FLÜGEL et al. 1984) and a tabular microproblematicum consisting of very densely packed hexagonal 'cells' exhibiting a flower-like structure in horizontal sections. A 'trilete' mark occurs within the cells (Pl. 43/13-14).

The most frequent microproblematicum (Pl. 43/11-12), however, are cylindrical grains with a well-defined micritic boundary. The grains consist of aggregates of densely packed angular and rarely subrounded sparry clasts up to 0.4 mm.in size The clasts are embedded within micrite. The diameter of the grains varies between 0.75 and 1.2 mm, the maximum length of broken grains is about 3 mm. These grains can be compared with fecal coprolites of grazing echinoids (cf. SCOFFIN 1987).

5.2 Guild structure

In Holocene reefs the combined activities of the constructor, baffler and binder guilds produce the organic framework. In late Paleozoic reefs the baffler and binder guilds are generally more important as the constructor guild.

Most sponges and bryozoans acted as bafflers. Microproblematica (*Archaeolithoporella, Tubiphytes*) and various calcareous algae represent the binder guild. Impressive examples of the formation of an organic framework by densely packed bafflers and binders in connection with abundant early cementation are known from Permian reefs of the Southwestern United States, Tunisia, Slovenia, the Southern Alps and China.

The guild structure of the reefs, documented in the microfacies and paleontological criteria of the pebbles of the Pietra di Salomone limestone breccia, is another example of the predominance of the baffler and binder/encruster guilds in Middle and Upper Permian reefs. Similar to the Capitan reefs, the species diversity of the dweller guild is very high. The destroyer guild is represented by rare macro-

Plate 46 Calcisponges from the Permian Pietra di Salomone limestone, Western Sicily: Sphinctozoans (Figs. 2-6), inozoans (Figs. 1, 7)

Fig. 1. *Corynella ovoidalis* PARONA, an abundant inozoan sponge in the Pietra di Salomone limestone. Longitudinal and cross section. Sample S/263. x 2

Fig. 2. *Imbricatocoelia elongata* RIGBY, FAN & ZHANG. Longitudinal section. Sample S/58/8. x 3

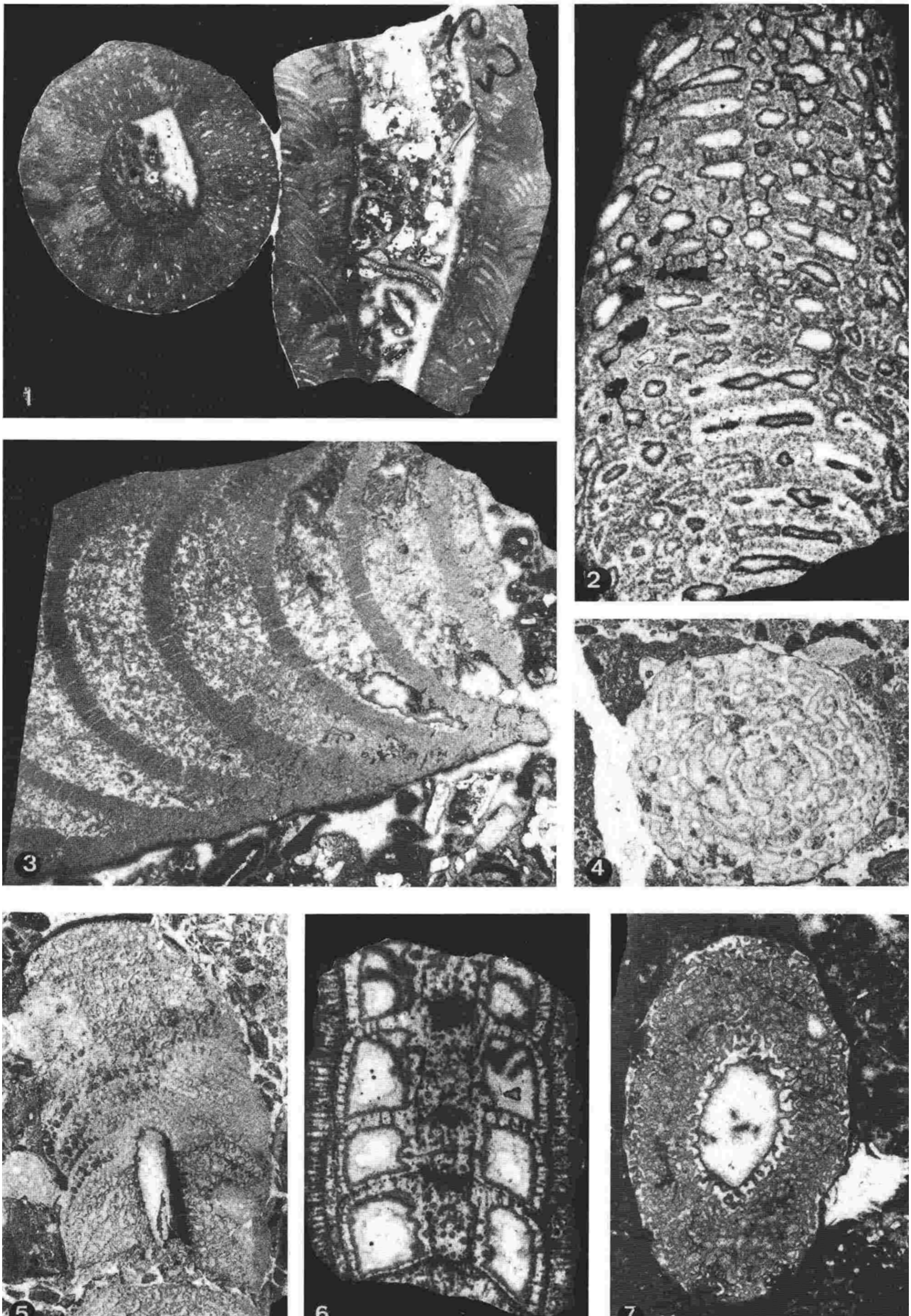
Fig. 3. *Preverticillites columnella* PARONA. Longitudinal section. This abundant sponge is characterized by very low chambers filled with reticular filling structures. Sample 90/26. x 2.5

Fig. 4. *Imbricatocoelia elongata* RIGBY, FAN & ZHANG. Cross section. Sample 90/14. x 9.5

Fig. 5. *Preverticillites columnella* PARONA, characterized by very low chambers with reticular filling structures. Sample 90/36. x 2.5

Fig. 6. *Amblysiphonlla merlai* PARONA., a common species in the Pietra di Salomone limestone. Sample 259. x 4

Fig. 7. *Peronidella* sp., an inozoan sponge. Sample 90/41/2. x 6.5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borers and common raspers (echinoids ?, Pl. 43/10-11) which have not yet been recognized in other Permian reefs until now.

6 DEPOSITIONAL HISTORY OF THE PIETRA DI SALOMONE LIMESTONE

The limestone of the Pietra di Salomone consists of sedimentary carbonate breccia-conglomerates and calcarenites. In this chapter we discuss the evidence of sedimentological, paleontological and geological data in unravelling the history of the breccias and the calcarenites.

Source area

The paleoenvironment of the area acting as a source region for the material represented in the pebbles of the breccia can be inferred from microfacies and paleontological data.

Boundstones with sponges, *Archaeolithoporella*, *Tubiphytes*, phylloid algae and bryozoans point to the existence of reefs predominantly formed by encrusting and baffling organisms and inhabited by a wealth of organisms. These reefs produced a high amount of reef detritus, as documented by the common bio- and lithoclastic rudstones and framestones. Bioerosion was a major destructive factor as indicated by abundant echinoid fecal pellets.

Permian reefs comparable in biota, microfacies types and in the abundance of submarine carbonate cements are known from rimmed platform-margins, often located in a slightly downslope position (Babcock 1977, Flügel 1981, Toomey 1991). That location corresponds to somewhat deeper stable areas with low sedimentation rates, favouring growth of encrusting organisms and an intensive early cementation.

Carbonate sands with common smaller foraminifera, documented in the fine- and medium-grained lithoclastic grainstones of the calcarenites, might have been derived from the platform.

Early submarine lithification

Differences in microfacies, size, shape and rounding of the lithoclasts occurring in the rudstone facies point to pervasive cementation, prior to breakage and movement of the reef-derived material. An early submarine lithification is indicated by common fibrous and, in places, botryoidal carbonate cements filling the intergranular pores.

Strong synsedimentary redeposition is indicated by reworked and disintegrated carbonate cement rims.

Sediment gravity flows

Pieces of lithified reef framework but probably also loose skeletal debris deposited on the 'forereef' slope were subject to downslope mass transport.

Recurring subaerial erosion during relative sea-level lowering would have structurally weakened the reef margins and promoted fracturing of cemented reef rock. A change between subaerial exposure and renewed transgression might be indicated by the crystal silt, internal sediments and selective leaching of fossils (especially in the chalky limestones).

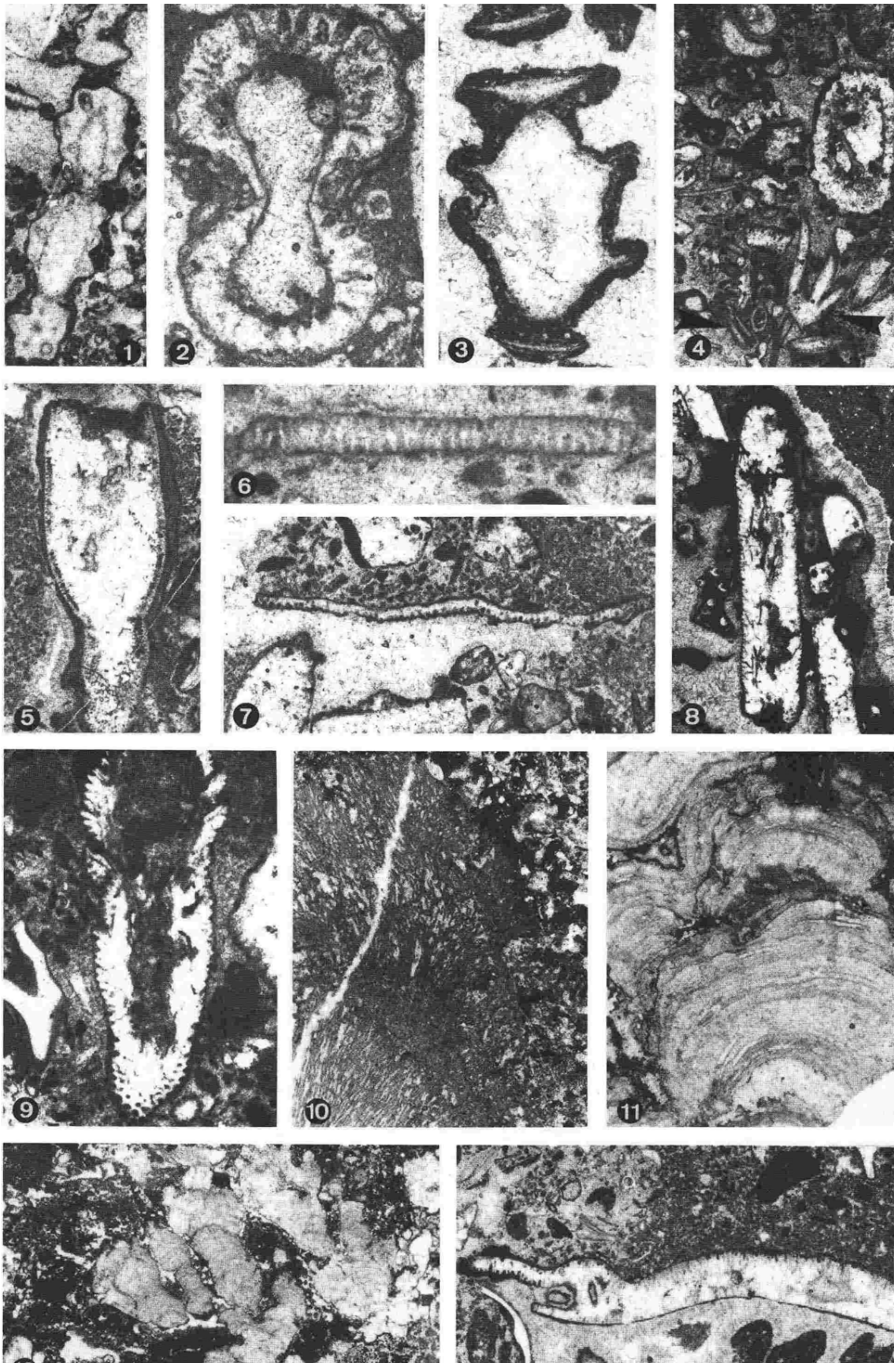
Individual skeletal grains of bryozoans and brachiopods in the debris flow deposits suggest active bioclastic sediment production on the upper slope during the time of the development of the debris flows.

Both debris flows and turbidity currents were responsible for the downslope mass transport resulting in the deposition of the breccia pebbles:

The limestone breccias of the Pietra di Salomone display many of of the distinctive attributes of carbonate debris flow deposits (Loucks et al. 1985), such as 1) large range in grain size, varying between pebbles and cobbles, 2) poor sorting, disorganized structure, 3) clasts and pebbles lithified before transport, 4) subangular and rounded lithoclasts and pebbles, 5) disoriented pebbles, as indicated by tilted geopetal fabrics and internal stratification, 6) pebbles surrounded by marly matrix.

Plate 47 — Calcareous algae from the Permian Pietra di Salomone limestone, Western Sicily: Dasycladaceans (Fig. 1-4), epimastoporids (Fig. 5-7), gymnocodiaceans (Fig. 8-9), solenoporaceans (Fig. 10-12) and phylloid algae (Fig. 13)

Fig. 1. *Mizzia cornuta* Kochansky & Herak. Sample 90/3, eastern part of the Pietra di Salomone. x 15
Fig. 2. *Mizzia velebitana* Schubert. Sample 35A, locality 6. Limestone with *Neoschwagerina*, Murghabian. x 25
Fig. 3. *Salopekiella* sp. Sample 90/87, locality 11. x 25
Fig. 4. *Connexia* sp. (arrows) and *Mizzia* sp. Sample 90/87, locality 11. x 25
Fig. 5. *Pseudoepimastopora* cf. *ampullacea* Elliott. Sample PS5, western part of the Pietra di Salomone. x 12
Fig. 6. *Epimastopora piae* Bilgütay. Sample 90/52, locality 8. x 4.5
Fig. 7. *Pseudoepimastopora iwaizakiensis* (Endo). Sample PS 111, western part of the Pietra di Salomone. x 15
Fig. 8. *Permocalculus kanmerai* Konishi. Sample 32, locality 4. x 3.5
Fig. 9. *Permocalculus fragilis* (Pia). Sample PS 14, western part of the Pietra di Salomone. x 12
Fig. 10. *Pycnoporidium* sp. Sample PS 11, western part of the Pietra di Salomone. x 20
Fig. 11. *Parachaetetes lamellatus* Konishi. Sample 32, locality 4. x 5
Fig. 12. Solenoporacean bafflestone with *Parachaetetes lamellatus* Konishi. Sample 31, locality 4. x 2.5
Fig. 13. *Ivanovia* sp. Sample 90/41, locality 8. x 13



Turbidites are represented by normally graded breccia with pebble- and cobble-sized clasts and by graded and finely laminated calcarenites. The common occurrence of carbonate breccias capped by graded calcarenites reflect a repeated change of debris flow and turbidity current deposition.

Depositional environment of the allochthonous carbonates

The matrix occurring between the pebbles of the breccia corresponds to the sediment of the basinal deposits adjacent to the Pietra di Salomone outcrop. These basinal deposits are deep-water sediments as shown by paleontological criteria. The deposition of the components of the allochtonous carbonates, therefore, must have taken place in a deep-water setting which would be reliable considering the base-of-slope apron model (MULLINS 1983).

In this model, shallow-water debris is shed into the basin from a line source and much of the material bypasses the upper slope. The carbonate breccia spectrum of the Pietra di Salomone limestone corresponds well to the lower-slope and base-of-slope facies of other ancient resedimented carbonates (TUCKER & WRIGHT 1990).

A line source might explain the abundance of the Sosio megablocks within a relatively small area. The Pietra di Salomone block seems to have a concave-up base and an almost flat top. Similar 'knobs' were interpreted by COOK & MULLINS (1983) as debris flow deposits filling large gullies or channels incised in the basinal facies. A similar origin might by inferred for some of the Sosio blocks.

Timing

The age of a few samples of the matrix of the breccia has been datet by conodonts as Middle Permian (Kubergandian-Wordian, sample 1713, a fine-grained laminated limestone) and Middle to Upper Permian (Capitanian-Dzhulfian, sample 1713, locality 5, Fig. 7/2). For some limestone pebbles a Lower Permian (probably Artinskian), Middle Permian (Murghabian and Midinian) as well as an Upper Permian (Dzhulfian, perhaps also Changxingian) age was recognized using fusulinids and conodonts. The age of the Red Clay Unit of the basinal sediments is Capitanian to Changxingian based on conodonts.

These coincidences in the age of matrix and the pebbles of the breccias and of the basinal sediments point to a prolonged existence of platform-margin reefs which acted as a source for carbonate debris flows, at least from the Murghabian up to the Dzhulfian. Most fusulind data indicate a Murghabian age (*Neoschwagerina* zone). There is no difference in the microfacies of boundstone and rudstone samples yielding fusulinids of the *Neoschwagerina* zone and of the *Yabeina* zone. This would support the assumption of a prolonged, more or less stationary rimmed carbonate platform margin which was not strongly affected by sea-level fluctuations.

The change of predominant debris flows with subordinate turbidites to predominant turbidites in the stratigraphically younger beds of the Pietra di Salomone is paralleled by a change in the composition of the sediment (reef-derived material to platform-derived sediment grains with only minor amounts of reef material). The change might indicate a backstepping of the margin and a drowning of the calcisponge/*Archaeolithoporella* reefs or the deposition of shelf carbonates which bypassed the shelf edge.

7 FACIES MODEL

Our observations clearly indicate that the Pietra di Salomone megablock exhibits differences with regard to the composition and the age of the clasts of the breccias and with regard to the facies of the fine-grained calcarenites and the marly matrix. Fig. 8 summarizes the information concerning the biostratigraphical age of the allochthonous carbonates

Plate 48 — '*Tubiphytes*' and '*Archaeolithoporella*' of the Permian Pietra di Salomone limestone, Western Sicily: Enigmatic in their systematic position but most successful in carbonate production

Fig. 1.-2. *Tubiphytes obscurus* MASLOV, characterized by hollow tubes in each segment. Fig. 1: Sample 90/20, locality 9. x 13. Fig. 2: Sample 90/151, locality 9. x 27

Fig. 3. *Tubiphytes carinthiacus* (FLÜGEL), characterized by the same criteria as *T. obscurus* but differentiated by an open spider-like network. Sample 90/18, locality 9. x 24

Fig. 4 '*Tubiphytes*'. The tube corresponds to a foraminifera. Sample 90/20, locality 9. x 24

Fig. 5. '*Tubiphytes*', characterized by a net-like aggregates. Sample 90/83, eastern part of the Pietra di Salomone. x 20

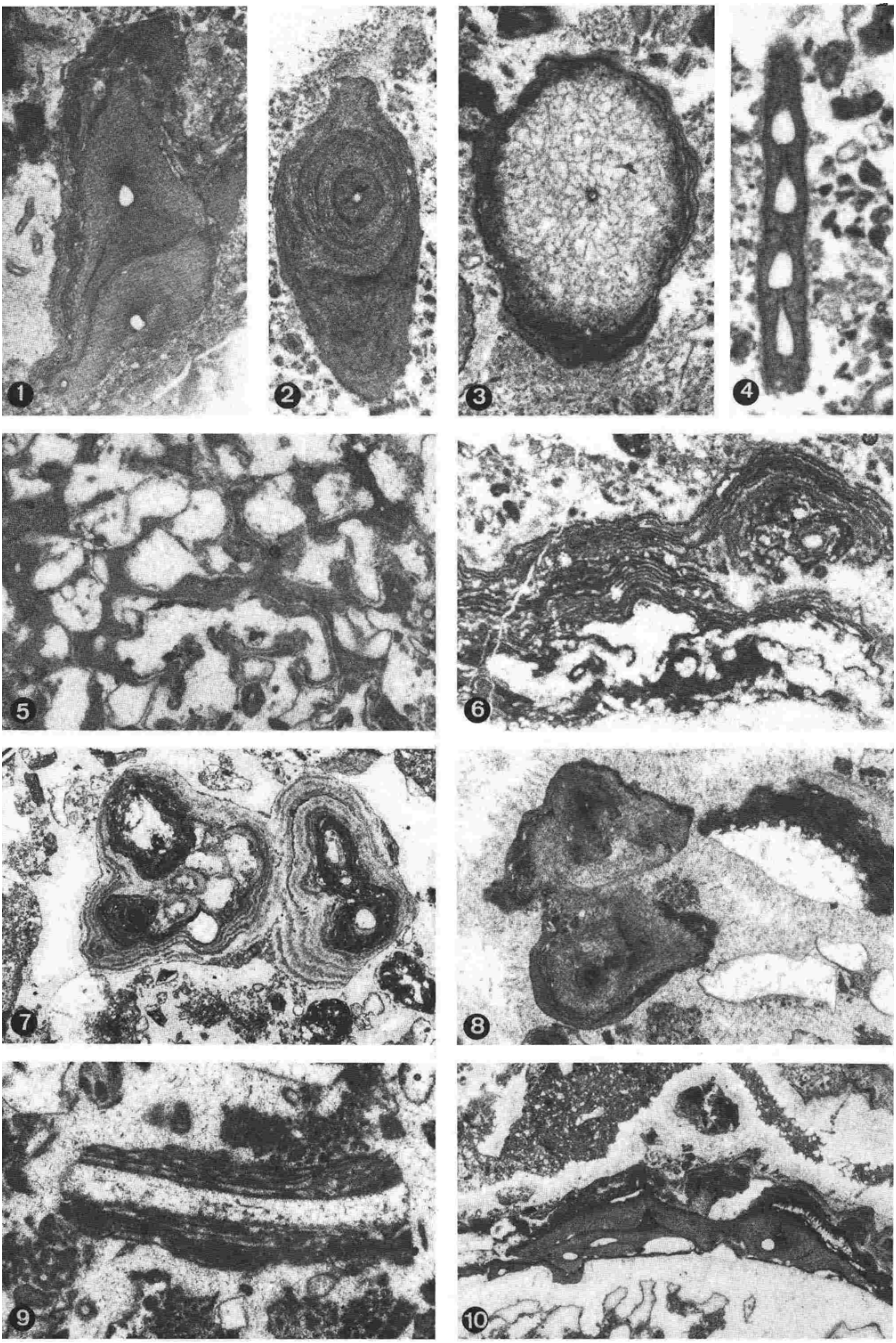
Fig. 6. *Archaeolithoporella*, characterized by crinkled couplets of micritic and sparitic laminae. Sample 90/19, locality 9. x 27

Fig. 7. Nodules formed by *Archaeolithoporella* circumcrusting sponge fragments and by cement layers encrusting *Archaeolithoporella*. Sample 90/16, locality 9. x 7.5

Fig. 8. *Tubiphytes* and *Archaeolithoporella* are common encrusters within cement-rich rudstones. Sample 90/70, locality 8. x 16

Fig. 9. *Archaeolithoporella* is a common encruster on phylloid algal thalli. Bioclasts of these associations are abundant components of the rudstones. Sample 90/27a, locality 9. x 23

Fig. 10. Biogenic encrustation sequence from bottom to top: calcisponge, *Tubiphytes obscurus* MASLOV, bryozoans, *Archaeolithoporella* and sediment. The biogenic crusts and the sediment have been overgrown by marine carbonate cement. Voids are filled with crystal silt. Sample 90/72/7, locality 8. x 7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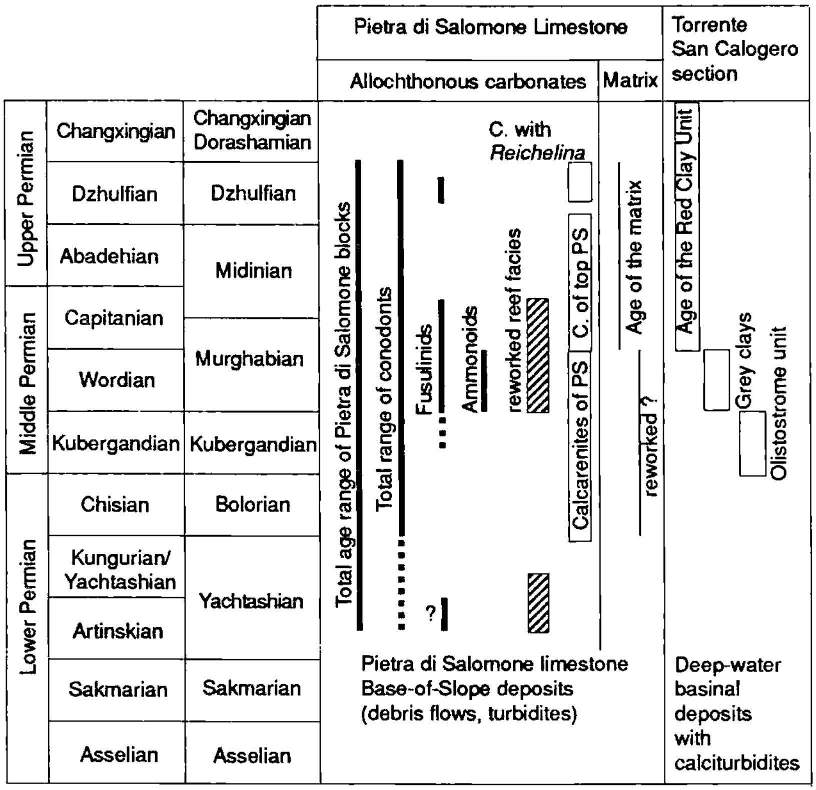

Fig. 8. Age of the allochthonous carbonates and the 'matrix' of the Pietra di Salomone megablock based on conodonts, fusulinids and ammonoids. Note the differences in the time range of the reef facies and the calcarenites. The calcarenites occur interbedded with the coarse-grained debris flows consisting of reef-derived and platform-derived material as well as in beds deposited during times without organically rimmed margins (late Middle to Upper Permian). Calcarenites within the basinal units of the Torrente San Calogero section indicate the strong imput of platform-derived sediment porobably until the end of the Permian. Stratigraphical standards after KOZUR (1988 and LEVEN (1981), correlation after CATALANO et al. (1991).

and the matrix of the Pietra di Salomone limestone and of the basinal sediments exposed in the Torrente San Calogero section. The data provide evidence for a change between long-term erosional processes resulting in the destruction of Middle Permian platforms and depositional rims and short-term processes during the late Permian characterized by the destruction of slope sediments and the redeposition of periplatform carbonates (allochthonous slope breccias) within a base-of-slope environment.

Fig. 9 illustrates the changes in the depositional patterns during time:

(A) Wordian (Murghabian) carbonate platform margins were characterized by downslope reefs formed by encrusting and baffling organisms and pervasive submarine cementation. The reefs produced reef debris. Reef material as well platform sediment were deposited in a downslope position. These platform rims were subjects to short-lasting subaerial exposure (documented by solution cavities filled with crystal silt).

(B) A stop in reef growth during the Wordian or early Capitanian (Murghabian) resulted in a change from a more stationary mode of the platform margin to a progradation of platform sediments.

(C) Rapid flooding and drowning of the platform caused oversteepening of some areas of the slope resulting in the redeposition of the periplatform breccia at the toe of the slope (probably during the late Middle or late Permian). Parts of the megablock were formed by debris flows and turbidity flows.

(D) The significant change of predominant debris flows to predominant turbidites in the stratigraphically younger beds of the megablock points to the existence of an offlap margin with an oversupply of platform sands deposited on the slope and in the basin, perhaps during a lowstand phase.

(E) During the Dzhulfian and Changxiangian the relative rate of sea level flucatuations might have been exceeded by the amount of biogenic shallow-marine carbonate production as indicated by the common fine-grained calciturbidites within the Red Clay Unit.

8 LOWER TO MIDDLE PERMIAN: COMPOSITIONAL TURNOVER OF REEF BIOTA

Based on the biotic composition, five major reef types have been differentiated in the Permian (FLÜGEL & REINHARDT 1989). Two of them are predominantly confined to the lower part of the Permian (*Palaeoaplysina* reefs and phylloid algal reefs). Middle and Upper Permian reef types are represented by stromatolite reefs, *Tubiphytes*/algal crust reefs (including reefs with abundant *Archaeolithoporella* and synsedimentary carbonate cement) and calcisponge reefs. This change in the reef types might correspond to a change in the composition of reef-associated biota (calcareous algae, sponges).

The turnover in the biotic composition is not yet fully understood because of the rareness of a thorough taxonomic data base which allows the comparison of early and late Permian reef biota. The Permian of Sicily offers a possibility for reducing the gap in our knowledge by comparing Lower Permian and Middle to Upper Permian reef biota using the data from Lower Permian reef limestone blocks of the 'Lercara Formation' (SENOWBARI-DARYAN & DISTEFANO 1988) and the results of the study of the Pietra di Salomone limestone.

Age of the compared reef limestones

The age of the Lower Permian reef limestones occurring within the 'Lercara Formation' in the Cozzo Intronata area near Lercara and along the River San Filippo near the Roccapalumba railway station (see Fig. 1) is upper Lower Permian. The fusulinids (det. F. KAHLER) *Pseudofusulina* (*Leeina*) *kraffti* SCHELLWIEN and *Pseudofusulina vulgaris*

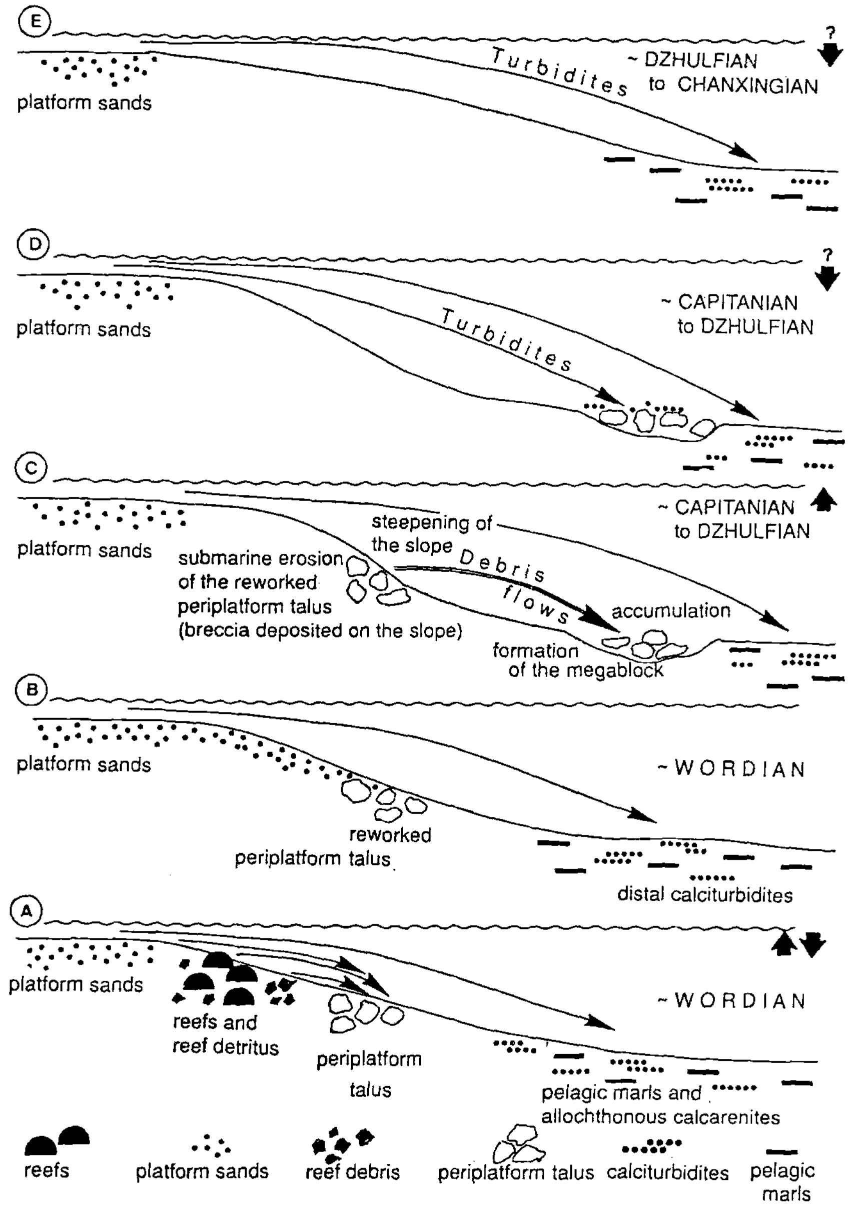

Fig. 9. Facies model summarizing the factors which might have controlled the formation of the Pietra di Salomone megablock. The megablock is interpreted as the result of a reworking and toe-of-slope deposition of periplatform carbonates.

SCHELLWIEN, document an Artinskian (Yatashian) age.

The age of most samples from the Pietra di Salomone, which could be dated paleontologically, is Murghabian, but the reef facies from which the material of the pebbles was derived continued during the Midinian and probably also in the Dzhulfian.

The age difference between Artinskian and Murghabian is within a range of about 10 m.y. (HARLAND et al. 1989).

Calcareous algae

The composition of the algal flora known from the Lower Permian blocks corresponds to that of other algal floras described from the Artinskian and Kubergandian (cf. FLÜGEL 1990). Algae are represented by phylloid algae (*Anchicodium, Eugonophyllum, Neoanchicodium*), epimastoporids, rare dasycladaceans (*Mizzia*), ungdarellids and some porostromate algae. Most of these algae are restricted to a skeletal grainstone. *Archaeolithoporella* and *Tubiphytes* are more common in calcisponge boundstones.

The algal flora from the Pietra di Salomone limestone (Chapter 5.1.5) differs from that of the Cozzo Intronata and San Filippo blocks by more diverse dasycladaceans, the occurrence of gymnocodiaceans, less diverse epimastoporids and the occurrence of the phylloid alga *Ivanovia*. *Archaeolithopora* and *Tubiphytes* are again important frame-building elements. The composition of the florula is similar to other Murghabian associations.

Sphinctozoan sponges

A comparison of the sphinctozoan faunas from the Lower Permian blocks (8 species) and from the Pietra di Salomone (20 species) limestone exhibits marked differences on species and genus level:

Most of the species known from the Pietra di Salomone limestone have not been found in the Lower Permian blocks. Only two species occur in both localities (*Sollasia ostiolata* and *Lemonea cylindrica*). The most common species of the Lower Permian limestones are *Girtyocoelia beedei* and *Sollasia ordinata*. The most frequent species of the Pietra di Salomone limestone belong to *Amblysiphonella*, *Colospongia* and *Lemonea*.

The fauna of the Pietra di Salomone can be considered as a significant sample for Murghabian and Midinian sphinctozoans. This is underlined by the comparison of the Sicilian fauna with Middle Permian sphinctozoan associations from other parts of the Tethys (SENOWBARI-DARYAN 1990).

Conclusion

From both groups, calcareous algae and sphinctozoan sponges (as well as from the different types of '*Tubiphytes*") it can be inferred that a distinct turnover in the taxonomic composition of baffling and binding reef organisms took place prior to the Murghabian, probably during the Kubergandian.

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