MEMORIE DI SCIENZE GEOLOGICHE
già *Memorie degli Istituti di Geologia e Mineralogia dell'Università di Padova*

Allegato al Vol. XLIII, pagg. 297-337, 11 figg., 3 tabb. e 3 tavv.
Padova, maggio 1992

ETTA PATACCA *, PAOLO SCANDONE *, MASSIMO BELLATALLA *,
NICOLA PERILLI *, UBALDO SANTINI *

THE NUMIDIAN-SAND EVENT IN THE SOUTHERN APENNINES

CONTENTS

Key words: Numidian-sandstones, Southern-Apennines, paleogeography, Langhian.

ABSTRACT

The stratigraphic position of the Apennine Numidian quartzarenites has been revised from Eastern Abruzzi to Northern Calabria. Micropaleontological investigations based on nannofossil and planktonic-foram analises allowed us to recognize that in the Southern Apennines the Numidian quartzarenites were deposited in a short time-interval corresponding to the upper part of the NN4 zone and possibly to the lower part of the NN5 zone (N8 foraminiferal zone). The Numidian-sand input was preceded and accompanied by the deposition of calc-alkaline tuffites which recorded in far field an important volcanic activity. In the Apenninic depositional realms, the Numidian-sand accumulation represented a sedimentary event independent from the time-space evolution of the thrust belt-foredeep system. The latter was controlled, in Early/Middle Miocene times, by the Europe-Africa convergence and by the counterclockwise rotation of the Corsica-Sardinia block. The term "flysch" usually reported in the current geological literature to define the Apennine Numidian quartzarenites should be definitively abandoned, since these quartz-rich sandstones were mostly accumulated over foreland basinal areas not yet reached by compression fronts.

RIASSUNTO

È stata riesaminata la posizione stratigrafica delle quarzareniti "numidiche" nelle diverse unità tettoniche dell'Appennino Meridionale, dall'Abruzzo orientale alla Calabria settentrionale. Attraverso l'analisi incrociata dei nannofossili e dei foraminiferi planctonici è stato possibile delimitare un intervallo di tempo relativamente ristretto, corrispondente alla parte alta della zona NN4 e forse alla parte più bassa della zona NN5 (zona a foraminiferi N8), nel quale è avvenuta la sedimentazione delle quarzareniti. Questa sedimentazione è stata preceduta e accompagnata dalla deposizione di tufiti calc-alcaline che testimoniano un'importante attività eruttiva in aree relativamente lontane. L'accumulo delle arenarie numidiche nei domini sud-appenninici ha costituito un ben preciso evento deposizionale ad alimentazione africana, indipendente dall'evoluzione spazio-temporale del sistema catena-avanfossa la quale era strettamente controllata, nel Miocene inferiore e medio *p.p.*, dalla convergenza tra Europa ed Africa e soprattutto dalla rotazione antioraria del blocco sardo-corso. Il termine "flysch" comunemente usato nella letteratura geologica per le quarzareniti numidiche dell'Appennino meridionale dovrebbe essere definitivamente abbandonato, dal

* Dipartimento di Scienze della Terra dell'Università di Pisa - Via S. Maria, 53, I-56100 PISA (Italia).
Università di Pisa, Dipartimento di Scienze della Terra, Grants M.U.R.S.T. 40% 1987-89 (Resp. P. SCANDONE).

momento che queste ultime si sono depositate prevalentemente in bacini di avampaese non ancora raggiunti dal fronte della compressione.

INTRODUCTION

The Numidian Flysch (see FLANDRIN 1948) — a gravity flow deposit characterized by yellowish quartzarenites with interbedded grey-brownish argillites — is a peculiar lithosome widespread over 2000 kilometres from Gibraltar to the Southern Apennines (DURAND DELGA 1980; OGNIBEN 1963; WEZEL 1970 a, b). As regards the petrographic facies, the Numidian sandstones are typified by rounded quartz grains with frosted surfaces and by stable heavy minerals (zircon, tourmaline and subordinate rutile, sphene and garnet). The age currently attributed to the Numidian sandstones in Western Spain, North Africa, Sicily and Southern Apennines ranges from the middle/late Oligocene to the Early Miocene, up to the Langhian (see, among many Authors, BOENZI *et al.* 1968; BOUILLIN and RAOULT 1971; CARBONE *et al.* 1987; CENTAMORE *et al.* 1970, 1971; CHIOCCHINI *et al.* 1978; CIARANFI *et al.* 1973; COURME and MASCLE 1988; CRESCENTI 1966a; DIDON *et al.* 1973; DURAND DELGA 1969, 1980; FEINBERG *et al.* 1981; GIUNTA 1985; GLAÇON and ROUVIER 1967; GUERRERA and WEZEL 1974; HIEKE MERLIN *et al.* 1971; LAHONDÈRE *et al.* 1979; MAGNÉ and RAYMOND 1972; OGNIBEN 1960, 1963, 1969; ORTOLANI *et al.* 1975; PALMENTOLA 1967; WEZEL 1966, 1970b, 1974). WEZEL (1973) underlined a significant diachronism of the onset of the Numidian-sand sedimentation from west to east, that is from Algeria to the Southern Apennines, as well as from the internal (northern) to the external (southern) depositional realms in Sicily.

The supply of the Numidian quartzarenites has been matter of debate among geologists for a long time (see discussion in DURAND DELGA 1980, pp. 216-217). According to WEZEL (1970a) "... this extensive clastic wedge of grain flow, slump, bottom current deposits and turbidites represents former continental rise sediments at the foot of the cratonal slope of the African Platform". We think that this picture satisfactorily fits the present-day available data, including the radiometric ages (1800±100 Ma) of the detrital zircons (see LANCELOT *et al.* 1977 and references therein), in good accordance with the regional geological constraints.

The aim of this paper is to provide new data on the stratigraphic position and the age of the Apennine Numidian quartzarenites, as well as of some peculiar quartziferous calcarenites which recorded the Numidian-sand supply in sunken-platform areas. The age assignment is based on calcareous nannofossils and planktonic foraminifers recovered from the shaly interlayers of the quartzarenites (or quartziferous calcarenites), as well as from the immediately underlying and overlying quartz-free deposits. Our biostratigraphic results (some hundreds of samples collected over an area of about 15.000 square kilometres) indicate that the Numidian-sand supply was a nearly isochronous event which occurred in a very short time-interval within the Langhian. We would like to underline that the Numidian quartzarenites were accumulated in morphological depressions which occupied distinct palinspastic positions along the Adria margin; most of these depressions persisted as stable-foreland basins over a long period of time after the Numidian input. Therefore, the accumulation of the quartz-rich sands in the Southern Apennines seems to have been controlled only by the sea-bottom physiography (bathymetric gradients and elongation of the deep-water seaways) and by the distance from the source area (northward pinch-out of the quartzarenites), while the Apennine orogenic activity related to the Corsica-Sardinia/Apulia convergence did not influence it at all. In such a context, the term "flysch" currently adopted to define the Numidian quartzarenites is thus incorrect, or at least ambiguous, since "flysch" is a facies term frequently used to describe thick successions of redeposited deep-sea clastics accumulated in tectonically-active foredeep troughs (see *e.g.* HSÜ 1972, as well as BATES and JACKSON 1987).

THE NUMIDIAN QUARTZARENITES IN THE SOUTHERN APENNINES

The investigated region corresponds to the northern portion of the Southern Apenninic Arc, a complex bended structure convex towards the Ionian Sea which extends from the Maiella-Gaeta lineament to Sicily, through the Calabrian Arc. Figure 1 is an oversimplified geological sketch of the Southern Apennines which shows the principal structural features of the area and the regional distribution of the tectonic units making up the mountain chain. The latter consists of a huge duplex system piled up with Adriatic vergence during Neogene times and transported over the present-day Apulia foreland in the Early Pleistocene. The area is mostly occupied by rootless thrust sheets which tectonically overlie a buried antiform stack of carbonate horses cropping out only in the northeastern part of the region (Scontrone-Porrara, Maiella and Casoli units).

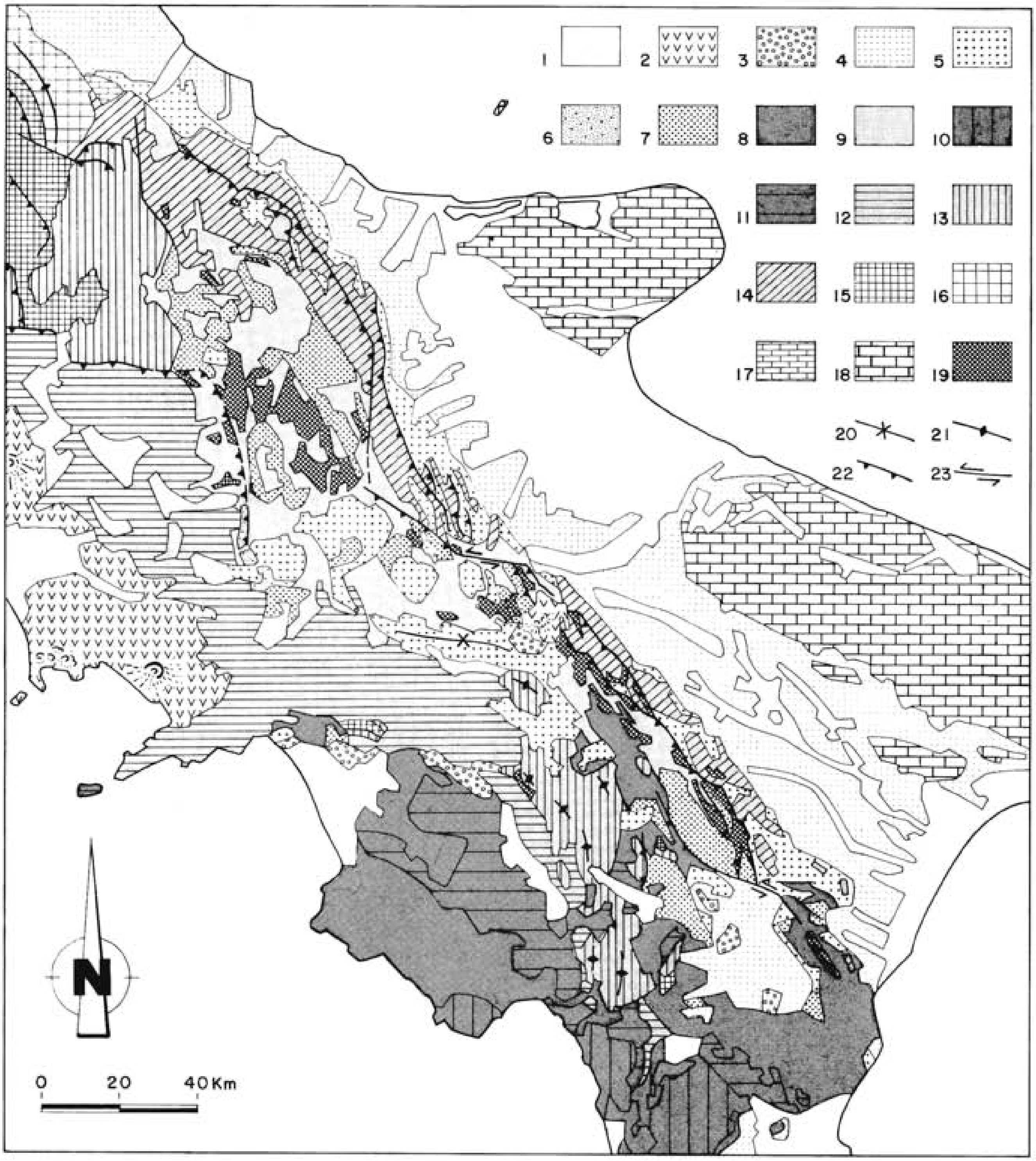


FIG. 1 - Structural sketch of the Southern Apennines and major outcrops of Numidian quartzarenites. 1) continental and subordinate shallow marine deposits (*Holocene-Middle Pleistocene*); 2) volcanites and volcanoclastites (*Holocene-Pleistocene*); 3) lacustrine and fluviolacustrine deposits (*Upper Villafranchian*); 4) Bradano (and Sant' Arcangelo?) sedimentary cycle: shelf-to-continental clastic deposits post-dating the last orogenic transport of the Apennines over the Apulia foreland (*Lower Pleistocene*); 5) Atessa (*Lower Pleistocene p.p.* and *upper-middle Pliocene*) and Ariano (*middle Pliocene p.p.-lower Pliocene p.p.*) sedimentary cycles: terrigenous shelf deposits unconformably overlying the Apenninic nappes, post-dating the lower Pliocene and the middle Pliocene compression; 6) Braneta sedimentary cycle: terrigenous shelf deposits (*lower Pliocene p.p. - Messinian p.p.*) unconformably covering the Apenninic nappes, post-dating the upper Messinian compression; 7) Altavilla, Anzano, Celenza and Gorgoglione sedimentary cycles (*Messinian p.p. - uppermost Tortonian*): siliciclastic deposits, including evaporites and diatomites, post-dating the upper Tortonian compression; 8) internal Apenninic units (Cilento, Sicilide and Calabrian nappes) and Albidona sedimentary cycle; 9) Sannio Nappe; 10) Verbicaro and San Donato units; 11) Alburno-Cervati and Monte Foraporta units; 12) Monti della Maddalena and Matese units, including the Castelvetere and Caiazzo formations; 13) Lagonegro, Frosolone and Agnone units; 14) Tufillo and Daunia units; 15) Scontrone-Porrara Unit; 16) Maiella Unit; 17) Casoli Unit; 18) Mesozoic-Tertiary carbonates of the Apulia foreland; 19) Numidian quartzarenites (*Langhian*); 20) synclines; 21) anticlines; 22) main Pliocene and Pleistocene overthrusts; 23) strike-slip faults.

Middle Pliocene or younger out-of-sequence thrust surfaces cut across the whole orogenic edifice slantwise, causing the development of second-order arcs.

The complexity of the present-day structure, together with too many persisting uncertainties about the regional geology, make the construction of reliable balanced sections across the Apennines very difficult, in spite of the rich subsurface information. Therefore, large disagreements still exist among geologists with regard to the possible palinspastic restorations of the tectonic units, as well as the timing of the deformation and the amount of the shortening. Figure 2 is an attempt to restore the Apennine paleogeographic domains at the time of the Numidian sand supply. The

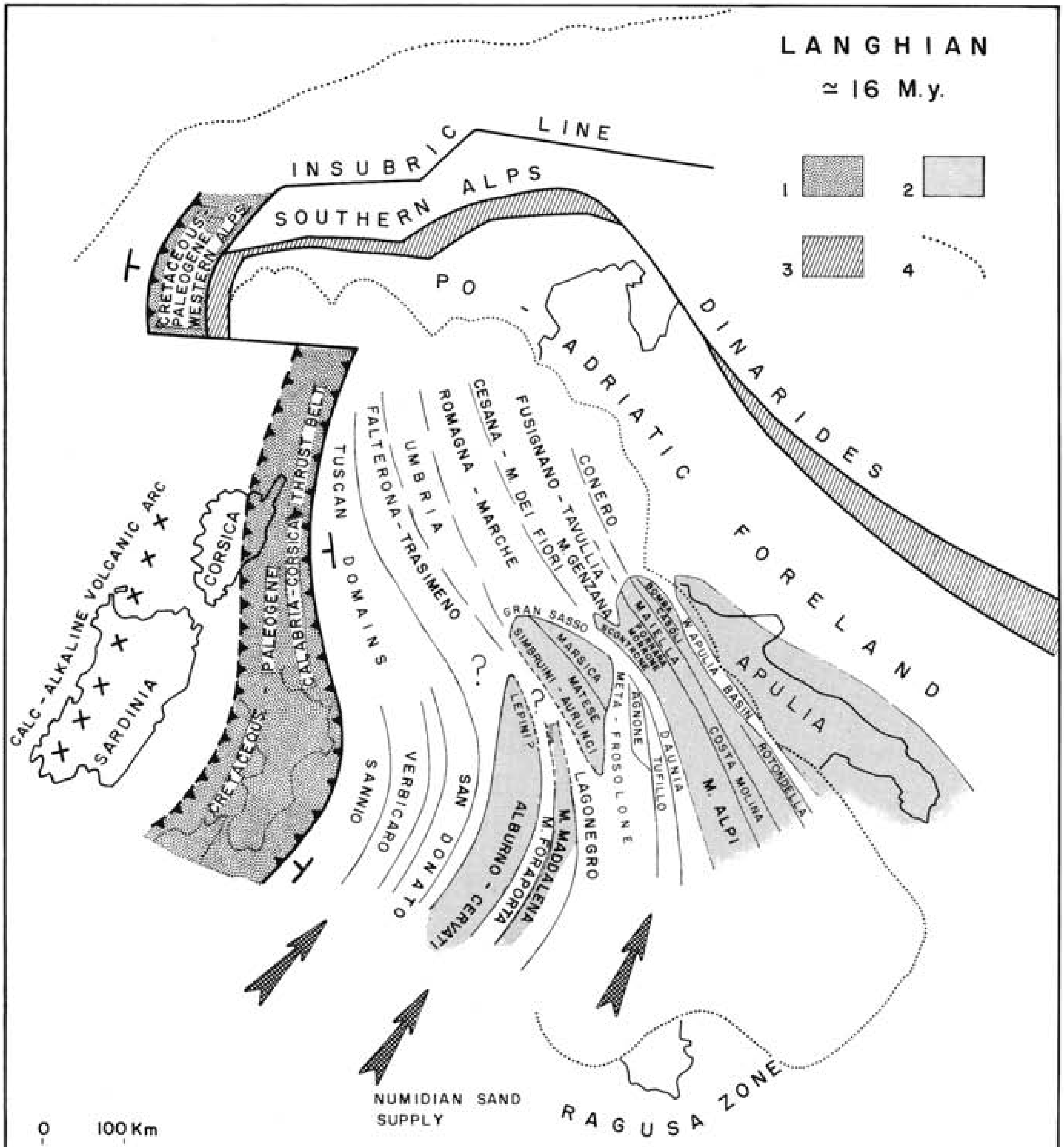


FIG. 2 - Palinspastic restoration of the Apenninic domains during Langhian times. 1) Cretaceous-Paleogene Corsica-Calabria thrust belt; 2) Mesozoic-Tertiary shallow-water carbonate platforms; 3) sink-areas along the Apulia outer margin related to the Europe-Africa convergence and to the independent counterclockwise rotation of the Adriatic Promontory; 4) outer front of the Pliocene-Quaternary compression in the Apenninic arcs.

boundary conditions, as well as the structural and stratigraphical criteria which led us to this kind of picture are discussed in PATACCA and SCANDONE (1989).

In the following pages, a brief outline of the tectonic units making up the investigated segment of the mountain chain (the most internal ones excepted) will be provided; the stratigraphic position of the Numidian quartzarenites, where they are present, will be concisely described. Figure 3 provides some toponymy references and the location of the sampling sites cited in the text and in Figures 4-11. Table 1 supplies the geographic coordinates of the selected analyzed samples and specifies the tectonic units and the stratigraphic intervals. The fossil contents of the quartz-rich Numidian interval, as well as those of the immediately underlying and overlying deposits are summarized in Table 3 ([1]). The reworked forms and the benthonic foraminifers, usually present in all examined samples, have been systematically omitted.

SANNIO UNIT

The sedimentary sequence of the Sannio Unit comprises from the bottom:
— varicoloured (hemi)pelagic clays with intercalated redeposited calcilutites and biocalcarenites, as well as subordinate manganese-bearing chert beds deposited from dilute tails of turbidity currents;
— hemipelagic to pelagic limestones and coarse-clastic lime resediments with red and green marly interlayers;
— gravity-flow deposited quartzarenites grading upwards to turbiditic calcarenites and arkosic sandstones.

The age of the sequence and the palinspastic position of the Sannio depositional domain are controversial. According to some Authors (see, *e.g.* LENTINI 1979; ORTOLANI *et al.* 1975) the Sannio Unit represents the Upper Cretaceous-Lower Miocene part of the basinal Lagonegro sequence detached from its Triassic-Lower Cretaceous portion and transported over more external domains during the Neogene compression. According to SELLI (1962) the Sannio Nappe consists of chaotic terranes including huge blocks of Miocene redeposited limestones and sandstones, orogenically transported into the Apenninic foredeep from an internal "Tyrrhenian" basin during late Tortonian time. Finally, according to other Authors (see, *e.g.*, CENTAMORE *et al.* 1970, 1971) the whole sequence is basically autochthonous and ranges in age from the upper Oligocene to the Lower Miocene. We agree with these last Authors on the age of the sedimentary sequence ([2]), but we conceive the Sannio Unit as a rootless thrust-sheet whose depositional realm had to be located west of the Monti della Maddalena paleogeographic domain (see Fig. 2). In fact, south of the Pliocene Ofanto basin, the Sannio Nappe overlies tectonically the Monti della Maddalena Unit, and the regional structural pattern indicates that no significant backthrusts may be invoked in the area in order to justify the observed geometrical relationships. Consequently, there are three possibilities about the provenance of the Sannio Unit: a) from a basinal area located between the Alburno-Cervati and the Monti della Maddalena paleogeographic domains (see, *e.g.*, the Monte Foraporta basin where the post-Jurassic portion of the sequence is unknown), b) from a basinal area located between the San Donato and the Alburno-

([1]) In the text, as well as in Tables 1 and 3, we shall concisely call "Numidian interval" the Numidian quartzarenites and the coeval quartziferous calcarenites whose composition has been influenced by the Numidian-sand supply. Consequently, we shall call "pre-Numidian interval" and "post-Numidian interval" the immediately underlying and overlying deposits lacking in Numidian quartz-grains.

([2]) It is possible that still undistiguished portions of the Lagonegro units have been included in the Sannio Nappe. We are still in doubt, for example, whether the basinal sequences cropping out in the Monte Moschiaturo area east of Matese actually belong to the Sannio Nappe or to the Lagonegro units. These sequences, tectonically sandwiched between the terrigenous deposits of the Matese Unit and varicoloured clays certainly belonging to the Sannio Nappe, have been attributed in the literature to the Upper Cretaceous-Lower Miocene (CRESCENTI 1966b; MANFREDINI 1963; ORTOLANI *et al.* 1975; PESCATORE 1965b). Here, Numidian quartzarenites are developed in the upper part of the sequence, stratigraphically overlying spicular calcarenites with associated thin pyroclastic beds and greenish marly interlayers. Clayey marls collected just below the quartz-rich sandstones yielded the following calcareous nannofossils: *Cyclicargolithus abisectus, Coronocyclus nitescens, Helicosphaera euphratis, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Discoaster deflandrei, Reticulofenestra* spp., *Coccolithus pelagicus, Helicosphaera carteri, Sphenolithus compactus, Sphenolithus conicus, Helicosphaera ampliaperta, Geminilithella rotula, Sphenolithus abies, Discoaster deflandrei-variabilis, Reticulofenestra pseudoumbilicus*. The planktonic foraminifers are here represented by *Globorotalia siakensis, Globigerina praebulloides, Globorotalia continuosa-pseudocontinuosa, Globigerinoides trilobus*. The fossil assemblage suggests an upper Burdigalian-Langhian age.

FIG. 3 - Location map of the sample stations (asterisks), supplying some toponymy references. 1) Carpineto di Sinello; 2) Castiglione Messer Marino; 3) San Felice; 4) Salcito; 5) Lupara; 6) Casone Cardillo; 7) Jelsi; 8) Riccia; 9) Monte Moschiaturo; 10) Ponte; 11) Laviano; 12) La Rotonda di Monte Marmo; 13) Sant'Angelo Le Fratte; 14) Monte Castelluccio; 15) Serra del Corno; 16) Capaccio Vecchio quarry; 17) San Michele; 18) Atena Lucana; 19) Capaccio; 20) Felitto: 21) La Raja del Pedale; 22) Monte Raparello; 23) Serra Cortina; 24) Brefaro; 25) Torno; 26) Campotenese; 27) Civita; 28) Cerchiara di Calabria; 29) Verbicaro.

Cervati domains (where an important shear zone responsible for the San Donato metamorphism may have obliterated intermediate depositional realms) and finally, c) from a basinal area located west of the Verbicaro domain [1]. We prefer this last possibility because of several facies affinities between the Sicilide and the Sannio stratigraphic sequences.

---

[1] It is unlikely that the Sannio Unit derived from a depositional domain intervening between the Verbicaro and the San Donato domains, since both Verbicaro and San Donato units underwent synkinematic low-grade metamorphism (see DIETRICH *et al.* 1976; PIERATTINI *et al.* 1975) whilst no metamorphic overprint is present in the Sannio Unit.

TABLE 1 - Geographic coordinates of the sample stations asterisked in Figure 3. The corresponding tectonic units and the stratigraphic intervals are also indicated

SAMPLE STATIONS	TECTONIC UNITS	INTERVALS	SAMPLES	LATITUDE	LONGITUDE
1. CARPINETO DI SINELLO	DAUNIA	NUMIDIAN INTERVAL	EP 1109-12	40°00'31'N	14°30'03"E
2. CASTIGLIONE MESSER MARINO	TUFILLO	PRE-NUMIDIAN INTERVAL	EP 1283-85; NP 1499-500	41°52'13"N	14°27'27"E
			NP 1888	41°52'00"N	14°27'16"E
		NUMIDIAN INTERVAL	EP 1286-88; NP 1501-03	41°52'13"N	14°27'27"E
			NP 1549-51	41°52'00"N	14°27'16"E
3. SAN FELICE	TUFILLO	NUMIDIAN INTERVAL	EP 1089	41°54'43"N	14°41'08"E
		POST-NUMIDIAN INTERVAL	EP 1090-1092	41°54'43"N	14°41'08"E
4. SALCITO	SANNIO	PRE-NUMIDIAN INTERVAL	NP 1465	41°43'56"N	14°31'08"E
			NP 1466	41°44'37"N	14°30'36"E
5. LUPARA	SANNIO	NUMIDIAN INTERVAL	NP 1318-20	41°45'25"N	14°43'08"E
6. CASONE CARDILLO	SANNIO	POST-NUMIDIAN INTERVAL	EP 1342-44; NP 1640-42	41°29'11"N	14°32'25"E
7. JELSI	SANNIO	PRE-NUMIDIAN INTERVAL	NP 1653	41°30'50"N	14°47'36"E
8. RICCIA	SANNIO	NUMIDIAN INTERVAL	EP 1348; NP 1654-55	41°10'25"N	14°50'24"E
		POST-NUMIDIAN INTERVAL	EP 1349-50bis; NP 1656-57	41°10'33"N	14°50'28"E
9. MONTE MOSCHIATURO	SANNIO ?	PRE-NUMIDIAN INTERVAL	NP 1606-08	41°21'30"N	14°36'04"E
			NP 1139	41°21'16"N	14°35'34"E
		NUMIDIAN INTERVAL	EP 1333	41°21'30"N	14°36'04"E
10. PONTE	SANNIO	NUMIDIAN INTERVAL	EP 1458-60; NP 2182-84	41°13'33"N	14°43'25"E
		POST-NUMIDIAN INTERVAL	EP 1461-62; NP 2185-87	41°14'33"N	14°43'38"E
11. LAVIANO	MONTI DELLA MADDALENA	PRE-NUMIDIAN INTERVAL	NP 2522-23	40°46'43"N	15°20'38"E
			NP 2524-27	40°46'50"N	15°18'12"E
		NUMIDIAN INTERVAL	EP 1621	40°46'50"N	15°18'12"E
12. LA ROTONDA DI MONTE MARMO	LAGONEGRO	PRE-NUMIDIAN INTERVAL	NP 2366-67	40°37'34"N	15°33'16"E
13. SANT'ANGELO LE FRATTE	LAGONEGRO	PRE-NUMIDIAN INTERVAL	NP 2357-58	40°33'03"N	15°33'29"E
14. MONTE CASTELLUCCIO	MONTI DELLA MADDALENA	PRE-NUMIDIAN INTERVAL	NP 2348-50	40°31'23"N	15°33'25"E
			EP 1563; NP 2351-55	40°11'50"N	15°33'25"E
15. SERRA DEL CORNO	MONTI DELLA MADDALENA	PRE-NUMIDIAN INTERVAL	NP 2331-41; NP 2344-45	40°10'25"N	15°32'29"E
		NUMIDIAN INTERVAL	NP 2342-43; NP 2346-47	40°10'25"N	15°32'29"E
16. CAPACCIO VECCHIO QUARRY	ALBURNO-CERVATI	PRE-NUMIDIAN INTERVAL	EP 1491; EP 1527-29; NP 2298-301	40°27'06"N	15°02'42"E
17. SAN MICHELE	ALBURNO-CERVATI	NUMIDIAN INTERVAL (●)	EP 1531; NP 2306	40°27'15"N	15°05'51"E
18. ATENA LUCANA	MONTI DELLA MADDALENA	PRE-NUMIDIAN INTERVAL	NP 2265-66	40°27'19"N	15°32'42"E
19. CAPACCIO	ALBURNO-CERVATI	NUMIDIAN INTERVAL	EP 1525-26	40°24'44"N	15°05'23"E
20. FELITTO	ALBURNO-CERVATI	PRE-NUMIDIAN INTERVAL	NP 2275-79	40°22'18"N	15°44'50"E
21. LA RAJA DEL PEDALE	ALBURNO-CERVATI	PRE-NUMIDIAN INTERVAL	EP 1495-96; NP 2247	40°13'35"N	15°26'08"E
			EP 1497; NP 2248	40°13'15"N	15°25'59"E
		NUMIDIAN INTERVAL (●●)	EP 1494; NP 2249-50	40°14'10"N	15°24'59"E
22. MONTE RAPARELLO	ALBURNO-CERVATI	PRE-NUMIDIAN INTERVAL	NP 2328	40°13'06"N	15°58'42"E
		NUMIDIAN INTERVAL	EP 1548-54; NP 2329-30	40°13'06"N	15°58'42"E
23. SERRA CORTINA	SANNIO	POST-NUMIDIAN INTERVAL	NP 2630-33	40°12'03"N	16°25'12"E
			NP 2634-35	40°12'13"N	16°24'50"E
			NP 2636-37	40°12'43"N	16°24'42"E
			NP 2638-49	40°11'26"N	16°25'03"E
24. BREFARO	VERBICARO	PRE-NUMIDIAN INTERVAL	EP 1585-91; NP 2456-67	39°59'15"N	15°45'42"E
25. TORNO	ALBURNO-CERVATI	PRE-NUMIDIAN INTERVAL	EP 1614; NP 2510-16	39°58'40"N	16°01'48"E
		NUMIDIAN INTERVAL	EP 1615-16	39°58'40"N	16°01'48"E
26. CAMPOTENESE PASS	SAN DONATO	NUMIDIAN INTERVAL	EP 1609-13	39°52'15"N	16°07'03"E
27. CIVITA	ALBURNO-CERVATI	POST-NUMIDIAN INTERVAL	EP 1603-07; NP 2504-09	39°50'21"N	16°18'29"E
28. CERCHIARA DI CALABRIA	ALBURNO-CERVATI	NUMIDIAN INTERVAL	EP 1596-601; NP 2497-503	39°50'50"N	16°23'46"E
29. VERBICARO	VERBICARO	PRE-NUMIDIAN INTERVAL	NP 2475-80	39°46'10"N	15°54'55"E

(●) Soft clast in slide conglomerates from the Numidian interval.

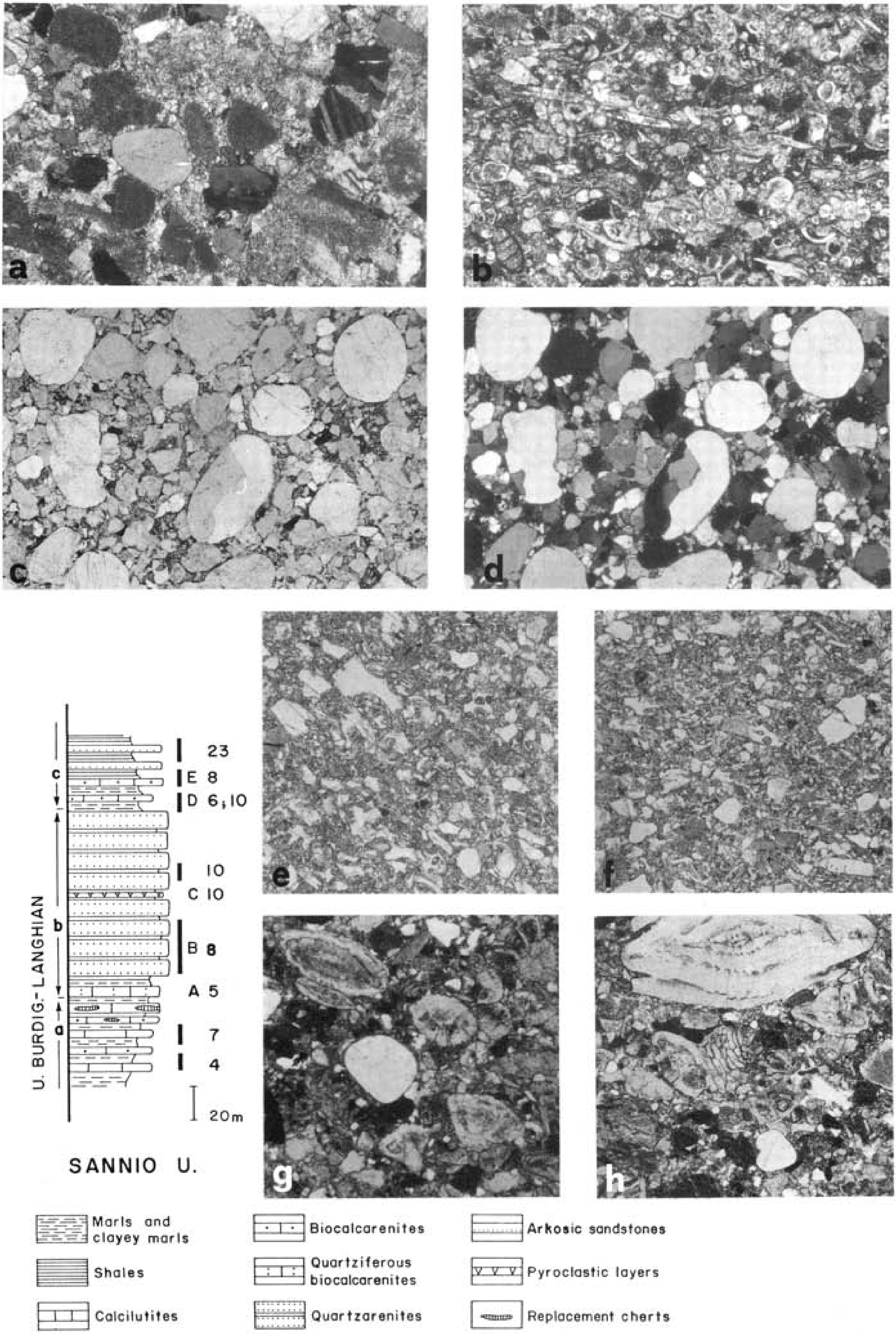
(●●) Blocks in Serravallian chaotic boulder clays.

In Figure 4 a schematic columnar section shows the position of the Numidian sandstones (interval *b*) in the upper part of the Sannio sequence. In this portion, three lithological intervals have been distinguished.

The interval *a* (pre-Numidian interval) is represented by light-coloured calcilutites and subordinate medium-sand-sized calciturbidites interlayered with green (hemi)pelagic marls. The fine-grained limestone beds frequently display somewhat nodular structures caused by a pervasive bioturbation which led to a complete destruction of the primary sedimentary structures. The microfauna is dominated here by unevenly distributed planktonic forams. A significant admixture of neritic materials (thick ostracode valves, rotaliids, miliolids, alveolinids, *Lepidocyclina* and fragments of coralline algae) appears in the sandy fraction of the associated gravity-flow deposits. Samples collected in different stations from the green marl interlayers yielded the same fossil assemblages. The nannofossils include *Reticulofenestra daviesii, Cyclicargolithus abisectus, Helicosphaera euphratis, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolitus moriformis, Helicosphaera, intermedia, Discoaster deflandrei, Reticulofenestra spp., Coccolithus pelagicus, Coronocyclus nitescens, Helicosphaera carteri, Sphenolithus compactus, S. conicus, Helicosphaera ampliaperta, Geminilithella rotula, Sphenolithus abies, Reticulofenestra pseudoumbilicus*. The planktonic foraminiferal assemblage includes *Globigerina praebulloides, Globorotalia pseudocontinuosa, Globoquadrina dehiscens, Globorotalia continuosa* and *Globigerinoides trilobus*. Up-section, the pre-Numidian interval is characterized by thin spongolite beds with diagenetic lenses or nodules of light-coloured vitreous chert and barren shaly interlayers.

The interval *a* grades to the overlying Numidian quartzarenites (interval *b*) through some metres of slightly quartziferous biocalcarenites emplaced by quite dilute turbidite currents. The arenitic fraction is represented by shelf-derived materials, such as fragments of calcareous algae, neritic lithoclasts, benthonic foraminifers (*Lepidocyclina, Amphistegina, Miogypsinoides, Elphidium,* etc.), admixed with variable amounts of pelagic biodetritus. A few rounded quartz-grains of fine to medium sand grade are sparsely scattered through the predominant allochemical sediment (see Figs. 4 *g, h*). The quartziferous calcarenites are followed by yellowish quartz-sandstone beds (Numidian quartzarenites) displaying shaly partings and sporadic pyroclastic interlayers. The thickness ranges from about one hundred (north) to several hundred metres (south). Texturally, the Numidian quartz-sandstones are medium to very-coarse-sized arenites containing more than 95% quartz framework grains (detrital chert excluded) frequently bonded by calcite cement and, in some cases, by an insignificant amount of interstitial clay minerals and silica. Semicomposite and single-crystal quartz grains displaying straight to strongly ondulose extinction prevail over the polycrystalline quartz-grains. Minor constituents include chert granules and medium to fine-sand-sized tourmaline, zircon, rutile and sphene (often concentrated in streaks), as well as a few scattered microcline feldspars. Petrographic microscope in-

FIG. 4 - Schematic columnar section and microfacies of the upper part of the Sannio sequence. The section shows the position of the Numidian sandstones, as it has been reconstructed by different outcrops. Small letters a, b, c, respectively indicate the pre-Numidian, the Numidian and the post-Numidian intervals.
The heavy bars indicate the portions of the sequence which have been sampled for paleontological analysis. Capital letters refer to the stratigraphic position of the microfacies illustrated in the photographs. Finally, the Arabic numerals correspond to sample stations (see Fig. 3 and Table 1). The same symbols have been used in Figg. 7, 10 and 11. 4 *a:* terrigenous calcarenite showing allochems commixed with a high percentage (≈ 50%) of siliciclastic extrabasinal grains. The latter are represented by well rounded, broken quartz grains, single-crystal and polycrystalline quartz with angular shape, plagioclase. Riccia, interval c (E position in the columnar section), EP 1349, x63, XPL. 4 *b*: slightly quartziferous (fine-sandy grains) foraminiferal packstone with sponge spicules. Casone Cardillo, interval c (D position), EP 1343, x25, PPL. 4 *c*: poorly sorted quartzarenite with well rounded larger grains (medium to coarse sand sized) set in subangular to subrounded fine-sand-sized, comminuted quartz clasts. The surfaces of the coarser grains are picked out by a thin and discontinuous red-brown rim of iron oxides. The quartz grains are bonded by calcite cement, usually fairly coarse-grained. Occasionally, a poikilitic texture may develop, when a single cement crystal envelops many finer detrital grains. Riccia, interval b, (B position), EP 1348, x25, PPL. 4 *d*: *id.id.*, XPL. The view cleary shows that most of the clasts consist of monocrystalline quartz-grains. 4 *e* and 4 *f*: coarse-grained vitric tuff with pumice fragments of various size and shape, rare feldspars and small, subrounded single-crystal quartz grains enclosed in a fine-grained ash matrix. Ponte, interval b (C position), EP 1458, x25, PPL. 4 *g* and 4 *h*: bioclastic packstone with scattered and well rounded quartz grains (medium to coarse sand sized) and subangular to subrounded finer quartz fragments. Lupara, interval a (A position), EP 1320, x25, PPL.

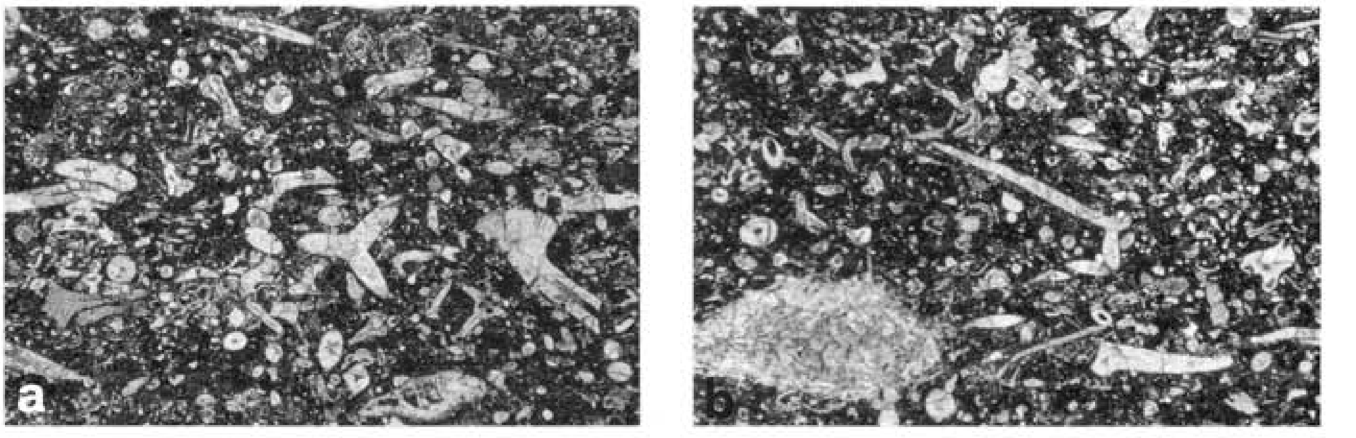

a
b
c
d
e
f
g
h
23
E 8
D 6,10
10
C 10
B 8
A 5
7
4
20m
c
b
a
U. BURDIG.-LANGHIAN
SANNIO U.
Marls and clayey marls
Shales
Calcilutites
Biocalcarenites
Quartziferous biocalcarenites
Quartzarenites
Arkosic sandstones
Pyroclastic layers
Replacement cherts

vestigation reveals that the sediment is characterized by a textural inversion (poorly sorted but well rounded to subrounded grains), in sharp contrast with the high mineralogic maturity (Figs. 4 *c, d*). The presence of abraded overgrowths, particularly evident on isolated dust-rimmed quartz-grains, points to a multicycle origin of the quartz granules likely derived from the erosion of former quartzarenites. The overall texture and structure of the quartzarenite beds imply that the deposition occurred through highly concentrated gravity flows. The occasional pyroclastic layers consist of fine to coarse-grained vitric tuffs characterized by dominant glass shards, frequently devitrified, and subordinate phenocrysts of volcanic plagioclases, volcanic rock fragments and quartz grains set in a cryptocrystalline or finely crystalline groundmass. The volcanic rock fragments include porphyrites with plagioclase phenocrysts, felted masses of very small, lath-like plagioclase crystals and pumice (Figs. *4* e, *f*). The pelitic interlayers of the quartzarenites are usually barren, and only in a few cases quite well preserved calcareous nannofossils and planktonic foraminifers have been found. In the fossiliferous samples the nannofossils include *Reticulofenestra daviesii, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Discoaster deflandrei, Reticulofenestra spp., Coccolithus pelagicus, Helicosphaera carteri, Sphenolithus abies* and *Reticulofenestra pseudoumbilicus*. The foraminiferal assemblage is usually represented by *Globorotalia siakensis, Gb. obesa* and *Globoquadrina dehiscens*.

The interval *c* (post-Numidian interval) consists of light-grey biocalcarenites with marly interlayers gradually replaced, up-section, by well bedded arkosic sandstones with shaly partings. These deposits, emplaced by turbidity currents, usually display lower-flow-regime sedimentary structures (C-E intervals); more complete BOUMA sequences have been rarely observed. The biocalcarenites are texturally defined as fine to medium sand-sized and poorly sorted packstones; the components include variable amounts of pelagic material (mostly planktonic forams) and penecontemporaneously-displaced shallow-water grains such as benthonic forams (*Elphidium, Amphistegina*), fragments of red algae, ramose bryozoan fronds, mollusk and brachiopod shell debris, echinoid spines and peloids. In addition, the lowermost part of the calcarenites is characterized by a considerable amount of sponge spicules merely preserved as microquartz-filled moulds, rare volcanic plagioclases and scattered rounded quartz-grains, the latter representing the last remainders of the Numidian input (Fig. 4 *b*). In a few metres, the biocalcarenites grade upwards into calcarenites with arcosic terrigenous admixture (Fig. 4 *a*) and finally into turbiditic arkosic sandstones. The nannofossil assemblage recovered in the lower part of the post-Numidian interval includes *Reticulofenestra daviesii, Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Discoaster deflandrei, Reticulofenestra spp., Coccolithus pelagicus, Coronocyclus nitescens, Helicosphaera carteri, Sphenolithus compactus, Helicosphaera mediterranea, Sphenolithus conicus, Helicosphaera ampliaperta, Geminilithella rotula, Sphenolithus abies, Sphenolithus belemnos, Discoaster variabilis, Sphenolithus heteromorphus* and *Reticulofenestra pseudoumbilicus* (some forms $> 7\ \mu$ m). The foraminiferal assemblage mostly consists of *Globorotalia acrostoma, Globorotalia siakensis, Globigerina praebulloides, Globorotalia obesa, Globoquadrina dehiscens, Globorotalia continuosa, Globigerinoides subquadratus, Gd. trilobus, Globorotalia praescitula, Globigerinoides bisphericus, Praeorbulina glomerosa, Globoquadrina langhiana* and *Globorotalia mayeri*.

VERBICARO UNIT

This unit (BOUSQUET and GRANDJACQUET 1969), cropping out only in the southern part of the investigated region, occupies the highest position in a thick pile of carbonate thrust sheets. The sedimentary sequence consists of Triassic-Liassic shallow-water carbonates followed by coarse to fine-grained basinal limestones and associated marls ranging in age from the Jurassic to the Lower Miocene (CIVITA 1965; DAMIANI 1970; GRANDJACQUET and GRANDJACQUET 1962; SCANDONE *et al.* 1963; SELLI 1957; VALLARIO and DE MEDICI 1967). According to the geological literature, the uppermost part of the sequence is represented by siliciclastic deposits consisting of quartz-sandstones with shaly interbeds. Actually, small outcrops of quartzarenites displaying typical Numidian characteristics are locally present on top of the Verbicaro carbonates, but the stratigraphic nature of the contact has not been proved. The youngest sediments certainly belonging to the Verbicaro Unit consist of dark-grey turbiditic biocalcarenites and calcisiltites regularly interbedded with (hemi)pelagic marls. On the microscope scale, the biogenic constituents making up the bulk of these lime resediments include planktonic forams and prevailing microquartz-filled moulds of sponge spicules (Figs. 5 *a, b*).



FIGS. 5 *a* and 5 *b* - Mixture of monoaxoned and multiaxoned spicules, mainly preserved as interlocking crystals of calcite, in a spicule-rich bioclastic packstone. Brefaro, uppermost part of the Verbicaro carbonate sequence; EP 1591, x25, PPL.

Limeclasts, benthonic forams (*Lepidocyclina, Miogypsina*, etc.) and fragments of coralline algae, associated with a variable amount of unidentified micritized bioclasts, are the dominant components of the coarser clastic fraction of the turbidite layers. The volumetric importance of the originally opaline sponge spicules accounts for the diagenetic patches of granular chert frequently observed in these deposits. In the Sannio, Monti della Maddalena, Lagonegro, Tufillo and Daunia units similar spicular deposits, often associated with volcaniclastic products, immediately underlie the Numidian quartzarenites.

Nannofossils yielded by yellowish marly interbeds sampled near Brefaro and Verbicaro villages (see Table 2) include *Reticulofenestra daviesii, Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Reticulofenestra spp., Coccolithus pelagicus, Sphenolithus compactus, S. conicus, S. abies, S. heteromorphus*. The planktonic foraminifers are here represented by *Catapsidrax dissimilis, Globigerina praebulloides, Globorotalia pseudocontinuosa* and *Globigerinoides trilobus*.

SAN DONATO UNIT

The San Donato Unit (AMODIO MORELLI *et al.* 1976), cropping out only in the Northern Calabria Coastal Chain, has not been distinguished from the Verbicaro Unit in the geological-structural sketch of Figure 1. The sequence comprises Middle Triassic metapsammites and metapelites followed by Upper Triassic crystalline

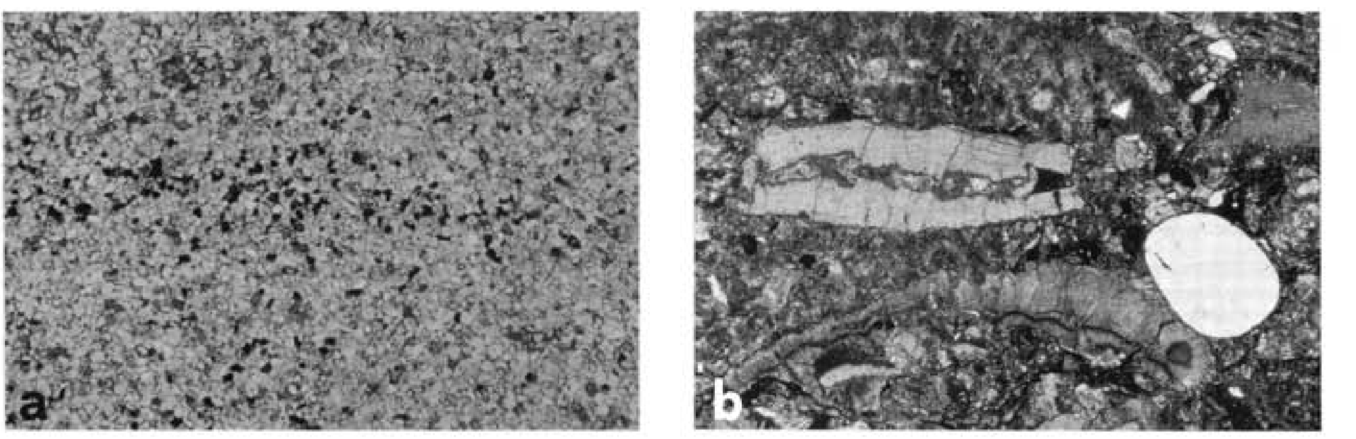


FIG. 6 - Microfacies from the upper part of the metamorphosed San Donato sequence. 6 *a*: very fine sand sized quartzarenite with heavy minerals (zircons and tourmalines) and iron oxides concentrated in thin bands. The quartzarenite is cemented by authigenic quartz in the form of overgrowth on originally rounded detrital grains. Campotenese Pass, uppermost part of the San Donato sequence; EP 1612, x25, PPL. 6 *b*: Bioclastic packstone showing a well rounded quartz grain together with smaller, subangular to subrounded grains of fine arenite-sized quartz. The view shows a well preserved portion of a metacalcarenite from the uppermost part of the San Donato sequence. Campotenese Pass, EP 1609, x25, PPL.

dolomites and by Jurassic-Lower Miocene metalimestones. In a few cases, very fine-grained metawackes, still revealing distal turbidite structures, are preserved in the uppermost part of the sequence. These immature siliciclastic deposits stratigraphically overlie redeposited *Miogypsina*-bearing metacalcarenites associated with subordinate fine-grained quartzites characterized by rounded single-crystal quartz grains of very fine sand size (Fig. 6 *a*). A close examination of the metacalcarenites (Fig. 6 *b*) reveals that the redeposited coarser materials include a moderate amount (5-10%) of Numidian-type quartz-grains scattered through the dominant shelf-derived biodetritus (*Miogypsina, Miogypsinoides, Amphistegina*, and reworked Cretaceous and Paleogene macroforaminifers). Due to the greenschist metamorphism, no microfossils are preserved, except for the still identifiable macroforams which indicate a vague Lower Miocene age of the Numidian input.

Alburno-Cervati unit

This unit (Scandone 1972), widespread in the south-western part of the Campania-Basilicata arc, is derived from an Upper Triassic-Lower Miocene persisting carbonate platform (see Sartoni and Crescenti 1961; Selli 1957, 1962) which began to sink below the photic zone by the end of the Burdigalian. Subsequently, it was turned into a foredeep basin which became a site of a considerable siliciclastic accumulation after the Langhian. The shallow-water portion of the Alburno-Cervati sequence consists of a thick pile of carbonates displaying characteristics which point to a quite uniform paleotectonic evolution. The most important depositional steps include:

— subtidal to supratidal carbonate sedimentation mostly indicative of lagoon restricted environments on a strongly subsiding platform (Upper Triassic-Upper Cretaceous);

— low-energy shallow-water sedimentation on a scarcely subsiding or stillstanding platform (Paleocene-Lower Eocene). The corresponding deposits are represented by some tens of metres of muddy limestones with green marly intercalations (Trentinara Formation, Selli 1962) usually displaying nodular and flaser structures. These structures, referable to intensive bioturbation and burrowing, are outlined by thin discontinuous layers of red-stained residual clays and are frequently associated with hardground horizons;

— subaerial exposure, and local accumulation of lateritic clays (Eocene-Oligocene) marking quite a prolonged break of the tectonic subsidence of the platform. The duration and the intensity of these weathering processes were likely enhanced by the Oligocene sea-level fall which corresponded to the level of minimum lowstand according to the global cycle charts of Vail *et al.* (1977) and of Haq *et al.* (1987);

— transgression on a shallow-water carbonate ramp with more or less open-marine circulation (Lower Miocene). The corresponding transgressive sediments are represented by light to dark-grey *Miogypsina*-rich biocalcarenites (Roccadaspide *p.p.* and Cerchiara formations, Selli 1957).

The Roccadaspide calcarenites display up-section uniform shallow-water features (massive to irregular, ill-defined bedding resulting from thorough burrowing through muddy-textured sediments). Only near the top of the sedimentary sequence a more regular bedding enhanced by continuous shaly partings suggests a gradual depth increase of the sea floor. On the contrary, in the Cerchiara Formation deeper-water conditions were already reached near the base of the formation, as it is testified by the considerable amount of planktonic forams admixed with benthonic forams and algal fragments. These broad and subtle facies variations of the *Miogypsina* calcarenites indicate that during the Early Miocene the Alburno-Cervati domain was a gently sloped carbonate ramp-like profile. Towards the end of the Late Burdigalian, a progressive submergence of the carbonate ramp not compensated by sedimentation led to a generalized drowning of the earlier neritic belt. As a consequence, deeper-water sedimentation and transgressive lags became widespread. In this stage, the Numidian-sand supply came to reach the Alburno-Cervati depositional domain.

The columnar sections of Figure 7 describe the spectrum of the depositional facies before and during the Numidian-sand supply. In these type-successions, a widespread horizon of chaotic boulder clays recording an important synsedimentary tectonic event forms a useful key level for regional correlations.

The Miocene deposits immediately underlying the Numidian interval (interval *a* in Fig. 7) show some significant lateral variations of facies which indicate a certain complexity of the sea-floor physiography of the Alburno-Cervati platform before its incorporation into the Apennine foredeep.

In the Monte Soprano-Monte Chianello area the pre-Numidian interval (upper portion of the Roccadaspide Formation) is represented by regularly bedded grey-greenish glauconitic packstones and wackestones indicative of sub-wave-base sedimentation on an incipiently-drowned carbonate

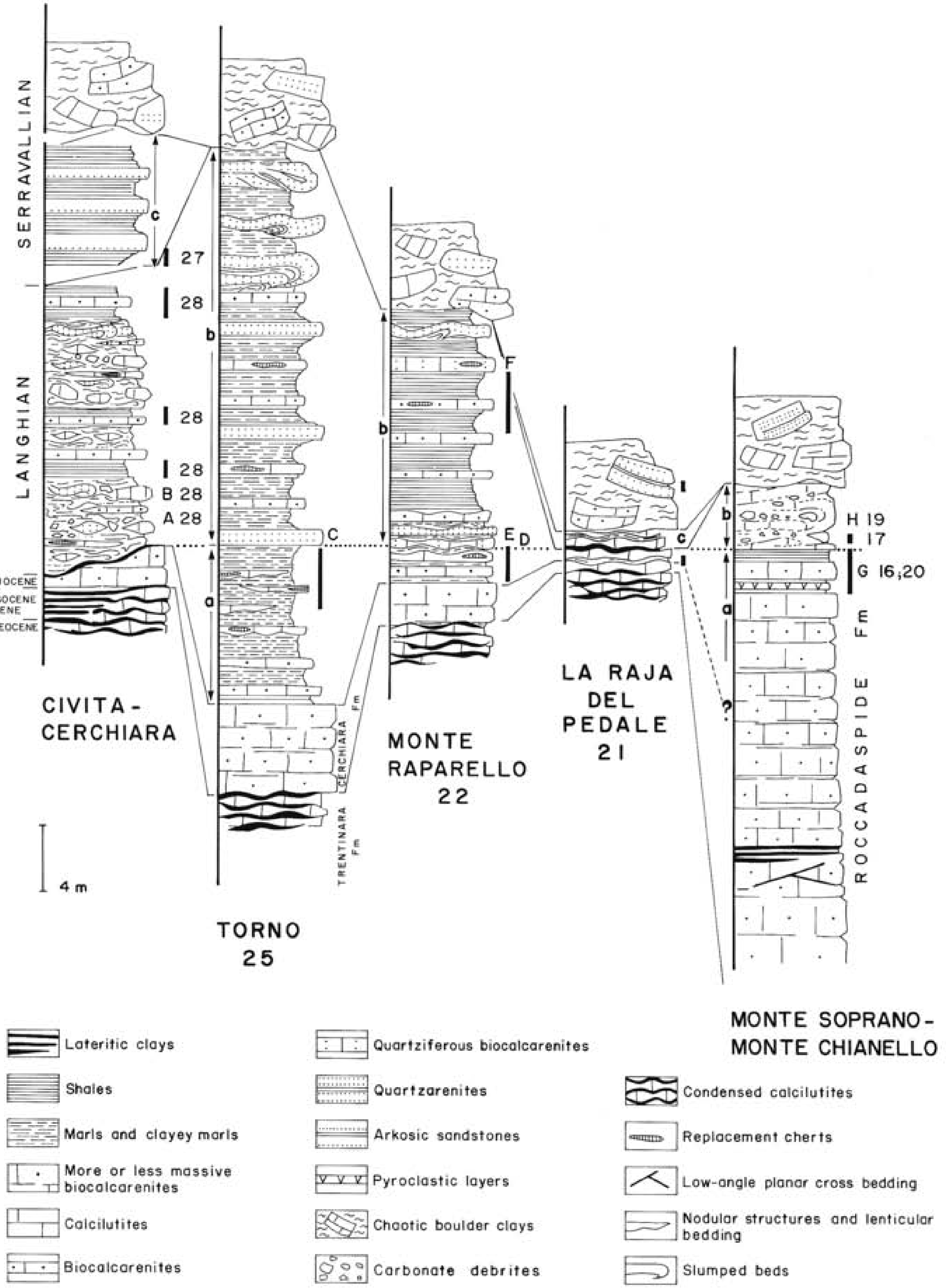


FIG. 7 - Schematic columnar sections representative of the upper part of the Alburno-Cervati carbonate sequence. Symbols (small letters, heavy bars, capital letters and Arabic numerals) have been explained in Fig. 4.

ramp near the photic zone. The corresponding microfacies are dominated by coarse to medium-sand-sized intraclasts with scattered open marine biota including planktonic forams, rounded and abraded algal fragments, *Miogypsina* shell debris and echinoid spines. In addition, a consistent amount of microquartz-preserved sponge spicules is disseminated through the sediment, in concomitance with a significant dilution of the allochems by admixture of pyroclastic materials such as glass shards, fine-grained crystal or vitric tuffs, plagioclases and pyroxenes (Figs. 8 *c* - *f*). This penecontemporaneous volcanic activity (see PERRONE 1987) is also recorded by the sporadic occurrence of thin tuffite layers (*e.g.* Capaccio Vecchio quarry in the Monte Soprano area).

In the La Raja del Pedale area, the pre-Numidian interval consists of pervasively burrowed and nodular, slightly tuffaceous lime-packstones mostly containing planktonic forams and echinoid spines associated with very rare and fragmented *Miogypsina*. The overall small thickness, the pervasive burrowing and the textural inhomogeneity of the sediment without any diagnostic physical sedimentary-structure indicate a very slow and discontinuous accumulation on morphological reliefs in correspondence of completely drowned portions of the Alburno-Cervati platform.

In the Monte Raparello and Torno sections the pre-Numidian interval consists of hemipelagic marls irregularly interbedded with thin redeposited calcilutites and skeletal calcarenites, some of which displaying distinctive features of rapid deposition by turbidity currents. Occasional bands and nodules of replacement chert associated with a somewhat faint lenticularity due to bioturbation have been observed. These facies indicate that the sinking of the platform below the photic zone allowed here the establishment of a basinal sedimentation.

In the Civita-Cerchiara area, the interval *a* is lacking. The absence is justified by the occurrence of submarine erosional features which mark the uppermost part of the Cerchiara Formation.

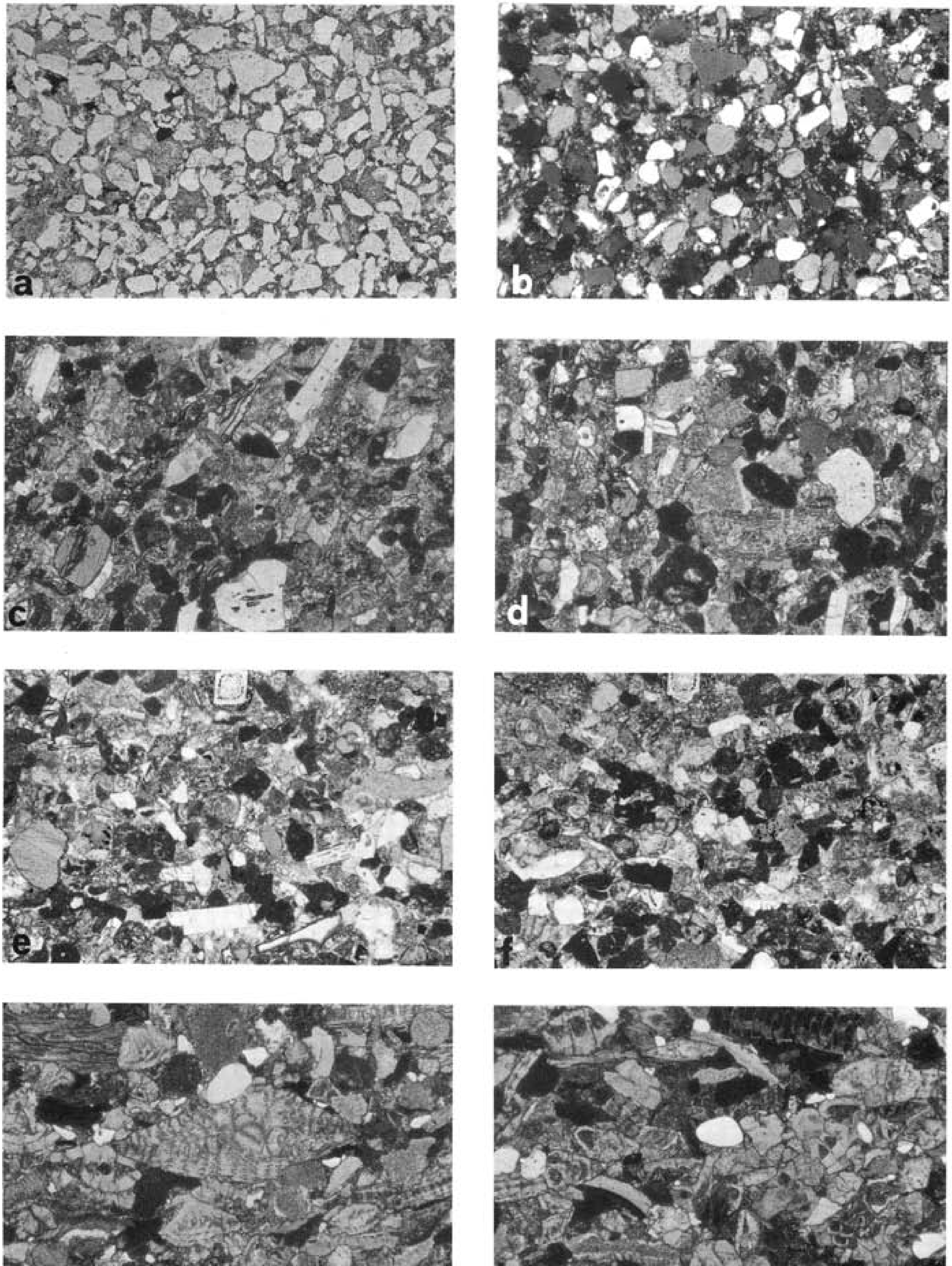
In conclusion, the pre-Numidian interval in the Alburno-Cervati succession represents everywhere a deepening sequence, in spite of the different sedimentary features. Where moderate sinking occurred, the early shallow platform became submerged to depths of several tens of metres and sub-wave-base carbonate deposition took place as the sedimentary upbuilding did not compensate the tectonic subsidence (*e.g.* Monte Soprano-Monte Chianello area). On more downwarped portions of the platform the drowning was complete and basinal deposits overlapped deep-ramp carbonates (see Torno and Monte Raparello areas).

Samples from marly interlayers in the uppermost part of the interval *a* yielded everywhere the same fossil assemblages. Calcareous nannofossils are represented by *Reticulofenestra daviesii, Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Reticulofenestra* spp., *Coccolithus pelagicus, Sphenolithus compactus, S. conicus, S. abies, S. heteromorphus*. The foraminiferal contents, usually very poor, mostly consist of few and badly preserved specimens of *Globigerinoides trilobus*.

The interval influenced by the Numidian-sand supply (interval *b* of Fig. 7) is represented everywhere by basinal deposits.

In the Monte Soprano-Monte Chianello area (*e.g.* near San Michele chapel and near Capaccio village) the interval *b* is represented by some tens of metres of quartz-bearing massive biocalcarenites with dispersed pebble-sized carbonate clasts and large shell debris of bivalves. Features of internal organization are usually lacking. The floating lithoclasts include soft clasts derived from unlithified calcarenites of the Roccadaspide Formation and bored clasts of the underlying Trentinara limestones. Occasionally, soft clasts of greenish marls have been observed, scattered within the largely remobilized sediment mass. Samples collected from these marls revealed the same fossil contents as those yielded by underlying marls of the interval *a*. The arenitic fraction of this poorly sorted sediment is dominated by displaced shallow-water materials consisting of large foraminifers (*Lepidocyclina, Amphistegina, Miogyp-*

FIG. 8 - Microfacies of lithologies representative of the pre-Numidian and Numidian intervals of the Alburno-Cervati Unit, as well as of the quartzarenites included as blocks in the chaotic boulder clay horizon. 8 *a*: fine sand-sized quartzarenite with quartz grains and a few feldspars in a carbonate cement. Block in the chaotic boulder clay horizon at La Raja del Pedale, EP 1494, x63, PPL. 8 *b*: *id.id.*, XPL. 8 *c* - 8 *f*: lime packstone rich in volcaniclastic materials (phenocrysts of plagioclase and pyroxenes, glass shards). In addition, Figures 8 *d* and 8 *f* show some sections of microquartz-filled moulds of sponge spicules. Capaccio Vecchio quarry, Roccadaspide Formation, interval a (G position in Fig. 7), EP 1527, x25, PPL. 8 *g* and 8 *h*: bioclastic packstone with fine to medium sand sized quartz-grains, some of them very well rounded in shape. Capaccio, interval b (H position in Fig. 7), EP 1525, x25, PPL.



sina, Miogypsinoides, etc.), echinoid spines, fragments of calcareous algae, bryozoan debris, mollusk shells (*Pecten*, oysters), broken portions of barnacles, crushed worm tubes, ooids and neritic lithoclasts. Variable amounts of pelagic bioclasts, rounded quartz-grains (single-crystal or semi-composite grains), volcanic plagioclases and subordinate glass-shards are also present (see Figs. 8

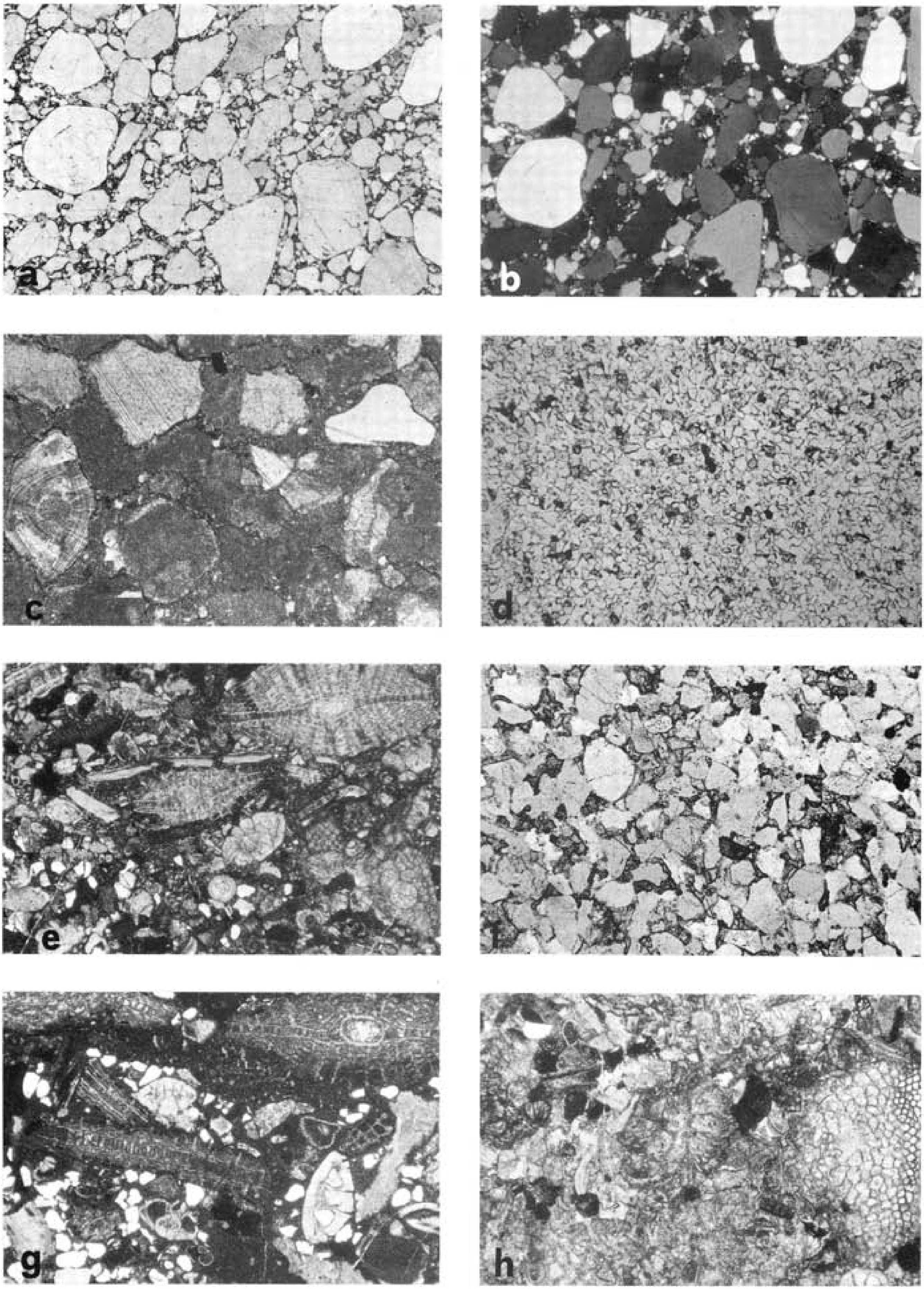
g, h). Overall structural and textural characteristics point to a highly-concentrated mass-flow deposit on a gently inclined depositional slope, probably emplaced by debris-flow mechanisms.

In the La Raia del Pedale succession, the interval *b* is lacking, owing to a hiatus in the depositional record testified by the occurrence of hard-ground surfaces on top of the interval *a*. These lag deposits display a highly irregular convolute sculpture and are often strewn with angular intraclasts.

In the Monte Raparello and Torno sections, the Numidian-sand supply is recorded both by fine-grained quartzarenite beds and by scattered rounded quartz-grains which form the minor detrital component of lime turbidites in a basinal sequence known as Bifurto Formation in the geological literature (SELLI 1957). A close examination of these sequences reveals that the interval *b* may be subdivided into two portions. The lower portion consists of redeposited calcilutites and slightly quartzose turbiditic biocalcarenites both displaying replacement chert nodules (Figs. 9 *e, g*), as well as of subordinate fine-grained quartzarenites (Figs. 9 *d, f*) interbedded with massive marls and shales. These more or less thick pelitic layers were partly accumulated by a slow pelagic settling, but in the greatest part were deposited from dilute tails of turbidity currents (E Bouma interval). In addition, the lower part of the interval *b* in the Monte Raparello section shows slightly ondulose and irregular bed surfaces which account for a bioturbation activity which modified the primary structures of the slowly-accumulated current-laid layers. In addition to the discontinuous and variable amount of quartz-sand supply, the redeposited materials include platform-derived detritus supplied from shallow-water areas not yet submerged below the photic zone (benthonic forams, oolites, lime clasts, bryozoan fronds, worm tubes, coralline algae etc.), as well as abundant pelagic material (essentially planktonic forams) of intrabasinal origin. The upper portion of the interval *b* is characterized by slumped quartzarenite layers deposited on a steeper slope. We believe that this part of the sequence marks the beginning of the incorporation of the Alburno-Cervati domain into the Apenninic foredeep.

In the Civita-Cerchiara section, the interval *b* is represented by slump deposits up to some metres thick, intercalated (Cerchiara) by undisturbed bioclastic calciturbidites displaying parallel thin bedding and normal grading. In thin section, the calciturbidites appear as a densely packed biomicrite with planktonic and benthonic foraminifers associated with fragments of *Briozoa* and coralline algae. The slump sheets reveal an highly penetrative plastic deformation, the sedimentary layering having been completely obliterated and the original sediment having been remobilized into a poorly-sorted lime-breccia. The latter consists of angular to subangular pebbles with subparallel orientation and granules floating in a structure-

FIG. 9 - Microfacies of lithologies representative of the Numidian interval of the Alburno-Cervati sequence as well as of the chaotic boulder clay horizon. 9 *a*: coarse to very fine grained quartzarenite with badly sorted and relatively well rounded quartz grains set in a brownish clay matrix stained by opaque iron oxides. The grains almost entirely consist of monocrystalline quartz often with uniform extinction. Cerchiara di Calabria, interval b (B position in Fig. 7), EP 1589A, x25, PPL. 9 *b*: *id.id.*, XPL. 9 *c*: lime packstone with a medium sand-sized monocrystalline grain having rounded shape and uniform extinction. The packstone shows a pervasive grain to grain pressure-solution. Most of the carbonate grain boundaries have been modified and the rock is pervaded by thin dark seams with fine saw-tooth appearence. The twinned calcite crystal in the upper left-hand side of the picture is a speckled echinoderm plate which underwent selective dissolution together with the syntaxial overgrowth. Cerchiara di Calabria, interval b (A position in Fig. 7), EP 1600, x63, PPL. 9 *d*: very fine grained quartzarenite with randomly scattered heavy minerals (high relief in the picture) and opaque minerals. The detrital grains are lined by clay minerals which evidence the relatively rounded shape of the original detrital particles. The original shape of the grains is often not recognizable because of pervasive overgrowth. Torno, interval b (C position in Fig. 7), EP 1615, x25, PPL. 9 *e*: bioclastic packstone with dispersed detrital monocrystalline quartz-grains of fine arenitic size and subangular to subrounded shape. The bioclasts include planktonic and benthonic forams and coralline algae. Monte Raparello, interval b (D position in Fig. 7), EP 1548, x25, PPL. 9 *f*: very fine grained quartzarenite with a carbonate cement (high relief in the photograph). This wiew shows some well rounded quartz grains admixed with other grains whose original shape has been largely obscured by effects of compaction and cementation. Monte Raparello, interval b (E position in Fig. 7), EP 1550, x 63, PPL. 9 *g*: slightly quartzose bioclastic packstone with planktonic forams, *Lepidocyclina* and other benthonic forams. The terrigenous input is merely represented by fine sand-sized quartz-grains with subangular to subrounded shape. Monte Raparello, interval b (F position in Fig. 7), EP 1554, x25, PPL. 9 *h*: *Miogypsina*-rich bioclastic packstone. In the upper left-hand side of the picture a broken and well rounded fine sand-sized quartz-grain is present. Block in the chaotic boulder clay horizon at La Raja del Pedale, EP 1493, x25, PPL.


a
b
c
d
e
g
h

less marly and slightly quartzose biocalcarenite matrix (Fig. 9 *c*). In addition, originally continuous quartzarenite beds (Figs. 9 *a, b*) appear tipically disrupted into phacoids or into elongate lenticular bodies displaying tight recumbent folds with axial planes parallel to the bedding. All lithic clasts of the lime breccia are derived from the immediately underlying carbonate lithologies. The dominant materials are derived from the Cerchiara Formation and clearly appear to have been sheared and merged with the matrix during the mass flow, revealing their incomplete lithification before the remobilization. In contrast, the early lithified shallow-platform clasts (mostly derived from the Trentinara Formation) still retain their primary depositional texture. The above described interval of the Civita-Cerchiara section likely corresponds to the lower portion of the interval *b* of Monte Raparello and Torno sections. This correlation is also supported by the occurrence of slumped Numidian quartzarenites in the Civita-Cerchiara area just above the quartz-bearing lime breccias, even though the contacts are not well exposed. The absence of more continuous quartzarenite beds, as well as the occurrence of rock fragments derived from the Trentinara and Cerchiara formations may be justified by admitting the existence of slopes where lower Miocene and pre-Miocene carbonates were exposed.

Samples from hemipelagic marls interbedded with the resediments of the interval *b* in the Monte Raparello and Cerchiara sections revealed the same fossil assemblages. The calcareous nannoplankton is represented by *Reticulofenestra daviesii, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Reticulofenestra* spp., *Coccolithus pelagicus, Sphenolithus compactus, S. conicus, S. abies, Reticulofenestra pseudoumbilicus*. The foraminiferal association includes *Globorotalia acrostoma, Globigerina praebulloides, Globorotalia continuosa* and *Globigerinoides trilobus*.

After the Numidian-sand supply the sedimentary features of the Alburno-Cervati domain were entirely controlled by the eastward migration of the thrust belt-foredeep system with the consequent incorporation of the Alburno-Cervati foreland domain into a foredeep basin. The foredeep siliciclastic accumulation is well recorded in the Civita section by a succession of immature arkosic sandstones (interval *c* in Fig. 7) which overlie the quartz-rich interval (1). On the contrary, the La Raja del Pedale section shows that this area persisted as a foreland structural high at least up to the late Serravallian (2) before its definitive incorporation into the orogenic system.

In all investigated sections, the interval *c* is followed by a thick horizon of chaotic boulder clays which more often disconformably overlies the Numidian interval (see Fig. 7). This chaotic horizon includes huge blocks and slides of Numidian sandstones (Figs. 8 *a, b*) often associated with resedimented biocalcarenites (Fig. 8 *b*), angular pebbles and blocks of Cretaceous and Tertiary shallow-water carbonates, olistostromes and slides of lithologies referable to the Sicilide Unit. The chaotic boulder clays, stratigraphically overlain by a thick pile of turbiditic litharenites, mark a significant tectonic event well recorded in the whole Alburno-Cervati depositional domain when it was definitively playing the role of a foredeep basin. Samples from the shaly partings of the Numidian quartzarenites included as slides in the chaotic horizon revealed the same age of the other investigated Numidian sandstones. The calcareous nannofossil contents comprise *Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Helicosphera intermedia, Discoaster deflandrei, Reticulofenestra* spp., *Coccolithus pelagicus, Sphenolithus compactus, S. conicus, Geminilithella rotula, Sphenolithus abies, Discoaster variabilis, Sphenolithus heteromorphus, Discoaster* cfr. *exilis, Reticulofenestra pseudoumbilicus*. The planktonic forams, here very rare, are represented by *Globoquadrina dehiscens* and *Globorotalia continuosa*.

According to the current literature (see, *e.g.*, IPPOLITO *et al.* 1975; SCANDONE 1972; SGROSSO 1981) the Alburno-Cervati Unit was involved in

(1) Several samples collected from this interval resulted barren.

(2) In the La Raja del Pedale and in the Sanza-Caselle in Pittari areas, hemipelagic condensed deposits underlying the chaotic-boulder-clay horizon yielded the following calcareous-nannofossil contents: *Reticulofenestra daviesii, Sphenolithus conicus, Cyclicargolithus abisectus, Helicosphaera* aff. *obliqua, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Discoaster deflandrei, Coccolithus pelagicus, Sphenolithus compactus, Helicosphaera mediterranea, H. carteri, Sphenolithus abies, Discoaster variabilis, D. exilis, Helicosphaera* cfr. *waltrans, Calcidiscus* cfr. *premacintyrei, Reticulofenestra pseudoumbilicus, Discoaster intercalaris, D. brouweri, D. pseudovariabilis, Sphenolithus neoabies, Discoaster* aff. *kugleri, D.* aff. *subsurculus*. The presence of *Discoaster brouweri, D. pseudovariabilis* and *Sphenolithus neoabies* points to an age not older than the late Serravallian.

the orogenic transport and overthrust the western flank of the Lagonegro basin during a Burdigalian/Langhian tectonic phase. Following this picture, SANTO and SGROSSO (1988) attributed the chaotic boulder clays and the arkosic sandstones to an upper Burdigalian-(?)Langhian sedimentary cycle ([1]) unconformably deposited over the Alburno-Cervati Unit after the sedimentation of the Numidian quartzarenites and after a Burdigalian compression. The change of sedimentation from the Numidian quartzarenites to the arkosic sandstones of the Civita section certainly corresponds to an important orogenic input, but our biostratigraphical results show that this change of petrographic composition did not occur before late Langhian times and probably took place near the Langhian-Serravallian boundary. Furthermore, we can exclude that the Alburno-Cervati Unit underwent severe compression and orogenic transport in Burdigalian or Langhian times (as it is usually reported in the geological literature) since upper Serravallian pre-orogenic deposits conformably overlie still-standing portion of the sinking carbonate platform not yet incorporated in the Apenninic foredeep. In conclusion, it seems us more likely that the abrupt compositional change from the Numidian quartzarenites to the arkosic sandstones represents the sedimentary record, in far field, of the tectonic event responsible for the metamorphism and the first orogenic transport of the Verbicaro and San Donato units.

MONTE FORAPORTA UNIT

This unit (SCANDONE 1972), tectonically sandwiched between the Monti della Maddalena and the Alburno-Cervati units, has not been cartographically distinguished in Figure 1 from the Alburno-Cervati carbonates because of the scantiness of its outcrops. No Numidian quartzarenites are referable to the Monte Foraporta Unit, the preserved part of the original sedimentary sequence (BONARDI 1966; BONI *et al.* 1974; DE ALFIERI *et al.* 1986; PAPPONE *et al.* 1988) being merely represented by Rhaetian (?)-Middle Jurassic basinal carbonates and marls.

MONTI DELLA MADDALENA UNIT

The Monti della Maddalena Unit (SCANDONE 1972) is clearly defined in the southern part of the Campania-Basilicata arc (see BONI *et al.* 1974; SCANDONE and BONARDI 1968). North of the Vallo di Diano area, the real extent of this unit is uncertain. Therefore, the attribution of the Marzano, Picentini, Lattari and Caserta mountains to the Monti della Maddalena Unit is still hypothetical.

In the Monti della Maddalena region and along the northern foot of Monte Marzano ([2]), the sedimentary sequence is represented by Upper Triassic-Lower Jurassic shallow-water carbonates followed by slope and basin resediments of Middle Jurassic-Middle *p.p.* Miocene age (COCCO *et al.* 1974; MARINI 1968; MARSELLA and PAPPONE 1986; PAPPONE 1988; SCANDONE and BONARDI 1968; SELLI 1957; SGROSSO 1966), and finally by Upper Miocene siliciclastic flysch deposits. The slope sedimentation, recorded by periplatform talus breccias, debrites and graded calcarenites, was repeatedly interrupted by sedimentary gaps marked by hard-ground horizons and more frequently by intraformational truncation-surfaces. In addition, an important discontinuity at the base of the Lower Miocene deposits is manifested by a generalized absence of Oligocene sediments. In a few places of the Monti della Maddalena region (*e.g.* western slope of Serra del Corno) and along the northern foot of Monte Marzano (*e.g.* Laviano) more complete sequences are exposed, revealing the occurrence of real Numidian quartzarenites or the presence of quartz-bearing limestones. In these cases, a marly interval some tens of metres thick usually precedes the quartz-rich interval.

Figure 10 describes two stratigraphic sections. The first one is represented by slope deposits cropping out along the western margin of Serra del Corno; the second one is a composite column reconstructed from several outcrops exposed near Laviano village which show base-of-slope to basin deposits.

In the Serra del Corno section, the lower part of the pre-Numidian interval (interval *a*) consists of some metres of light-coloured marls felted by

---

([1]) SANTO and SGROSSO (1988) recognized *Discoaster aulakos, D. deflandrei, D. druggii, D. nephados, D. variabilis,* as well as *Globigerina druryi, G. tripartita, Globigerinoides bisphericus, Gd. trilobus, Globoquadrina altispira, Gq. dehiscens* in deposits ("Raganello Formation") attributed to the chaotic boulder clays, but actually corresponding to the quartz-bearing lime breccias of the interval *b* in the present paper.

([2]) The Monte Marzano region is located north of the area where the Monti della Maddalena Unit has been carefully mapped. Nevertheless, the attribution of the Monte Marzano carbonate masses to the Monti della Maddalena Unit is supported by several geological evidences (see MARINI 1967; PESCATORE 1965a).

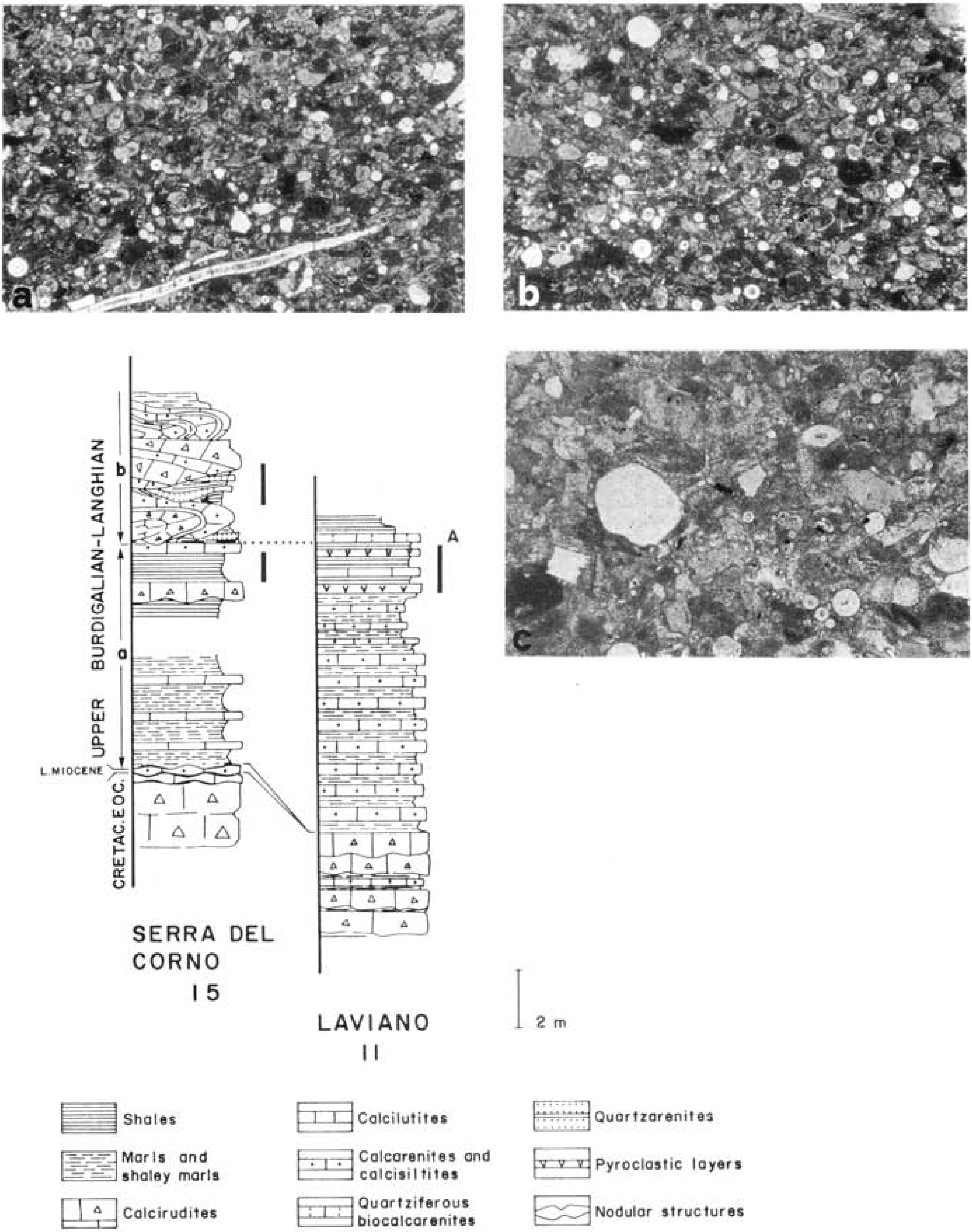


FIG. 10 - Schematic columnar sections of the upper part of the Monti della Maddalena carbonate sequence and examples of microfacies. 10 *a* - 10 *c*: spicule-rich packstone with dispersed very fine to fine sand-sized plagioclase (*e.g.* above the axial section of the spicule in Fig. 10 *a*) and quartz grains some of them (*e.g.* Fig. 10 *c*) well rounded. Laviano, interval b (A position in the columnar section), EP 1621, 10 *a* and 10 *b* x 25, 10 c x63, PPL.

siliceous sponge spicules, interlayered with thin-bedded foraminiferal lime wackestones. Up-section, a few metres of early-lithified debrites displaying mud-filled tensional fissures and fine-grained detrital limestones follow, both interlayered with greenish marls and clays. In the Laviano section, the pre-Numidian interval overlies disconformably Upper Cretaceous-Eocene slope carbonates and is represented by thin-bedded calcarenite and calcisiltite turbidites interlayered with (hemi)pelagic marls. The calcarenites, texturally grain-supported packstones, contain a comminuted shelf-derived carbonate detritus (intraclasts, micritized bioclasts, coralline algae, benthonic forams) admixed with abundant planktonic foraminifers, some of which reworked from Cretaceous and Eocene sediments. The upper part of the pre-Numidian interval is characterized by green shaly marls with intervening thin-bedded pyroclastic layers and slightly siliceous redeposited calcisiltites rich in sponge spicules. The inter-turbidite marls of the Laviano section and the shaly-marly interbeds of the Serra del Corno section revealed the same micro and nannofossil contents. The calcareous nannofossils comprise *Reticulofenestra daviesii, Cyclicargolithus abisectus, Helicosphaera euphratis, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Discoaster deflandrei, Reticulofenestra* spp., *Coccolithus pelagicus, Helicosphaera carteri, Sphenolithus compactus, S. conicus, Geminilithella rotula, Sphenolithus abies, Discoaster variabilis, Sphenolithus heteromorphus, Reticulofenestra pseudoumbilicus*. The foraminiferal assemblages include *Catapsidrax dissimilis, Globorotalia siakensis, Globigerina praebulloides, Globorotalia pseudocontinuosa* and *Globigerinoides trilobus*. The same paleontological association was found in equivalent marls collected at Monte Castelluccio and near Atena Lucana village (see Table 2).

The Numidian-sand input is recorded both in slope and basinal sequences. In slope deposits, like the Serra del Corno section, the Numidian interval (interval *b*) is represented by disrupted quartzarenite beds confined within huge sheets of remobilized carbonate masses. In this contorted and discordant chaotic interval, large-scale translational slides and thick slumped bodies have been observed. The slump bodies consist of lime breccias and marly calcisiltites affected by severe internal deformation and often remobilized into conglomerate-textured debrites with clasts set in a pervasive muddy matrix rich in sponge spicules. On the contrary, the translational slides show clear basal shear-surfaces and still preserved original bedding. The major lithologies comprise platform and slope-derived lime-breccias and graded biocalcarenites. Samples collected from clayey interbeds of the discontinuously intervening quartzarenites yielded *Cyclicargolithus abisectus, C. floridanus, Sphenolithus moriformis, Discoaster deflandrei, Coccolithus pelagicus, Sphenolithus abies, Discoaster variabilis*, as well as *Catapsidrax dissimilis, Globigerina praebulloides* and *Globorotalia pseudocontinuosa*. In basinal sequences, like the Laviano section, the Numidian-sand supply is recorded either by the presence of massive quartzarenite beds, or by the occurrence of rounded quartz-grains dispersed among the lime constituents of thin-bedded calciturbidites. The latter consist of lime packstones with abundant biogenic components (dominant sponge spicules, radiolarians and planktonic forams) admixed with shelf-derived fines (Figs. 10 *a* - *c*). Minor amounts of volcanic plagioclases are also present.

LAGONEGRO UNITS

The Lagonegro units (SCANDONE 1967, 1972) are widespread over the south-eastern part of the Campania-Basilicata arc. In the northern portion of the arc, they crop out near Salerno in a few tectonic windows (IETTO 1963a, 1963b; SCANDONE *et al.* 1967, TURCO 1976). The existence of the Lagonegro units in the Sannio-Molise region is still questionable. We think that most of the sediments attributed to the Lagonegro units in this area (see ORTOLANI *et al.* 1975) actually belong to the Sannio Nappe. In the type-area, the sequence (see, among many Authors, CIARAPICA *et al.* 1988; DE CAPOA BONARDI 1969; MARSELLA 1988; MICONNET 1983, 1987, 1988; SCANDONE 1967, 1972; WOOD 1981) consists of Middle Triassic to Lower Miocene basinal deposits generally indicating deep-sea sedimentation, sometimes (Upper Jurassic-Lower Cretaceous) exceeding the CCD, followed by Numidian quartzarenites. It is interesting to point out that the Tertiary deposits belonging to the Lagonegro units are usually lacking and only in a few outcrops the stratigraphic sequence includes the Numidian quartzarenites. The generalized absence of Tertiary deposits in the Lagonegro units has been justified (see CARBONE *et al.* 1988) by admitting a regional detachment of the upper part of the sequence from the Triassic-Cretaceous portion and a consequent eastward tectonic transport. We investigated sedimentary sections certainly belonging to the Lagonegro Upper Unit, where the latter appears tectonically overlain by the Monti della Maddalena carbonates. In these sections, the Numidian quartzarenites are systematically preceded by basinal deposits made up of even-bedded spicule rich calcarenites with marl interlayers. All samples collected from the clayey interbeds of the Numidian quartzarenites resulted barren or scarcely significant. Conversely, the underlying green marls, collected near Sant'Angelo Le Fratte village and at La Rotonda di Monte Marmo (see Table 2) provided *Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Discoaster deflandrei, Reticulofenestra* spp,. *Coccolithus pelagicus, Sphenolithus compactus, S. conicus, S. abies* and *Calcidiscus leptoporus* among the calcareous nannofossils, as well as *Globigerinoides trilobus* among the planktonic foraminifers.

Matese Unit

The Matese Unit (D'Argenio *et al.* 1972; Ippolito *et al.* 1975), widely exposed in the Latium-Campania region, is represented by a thick pile of Upper Triassic to Upper Cretaceous restricted-platform carbonates (see, among many Authors, Catenacci *et al.* 1963; D'Argenio and Pescatore 1962; Pescatore and Vallario 1963; Sartoni and Crescenti 1961) with an Albian-Cenomanian regional gap marked by widespread bauxite deposits. The Mesozoic carbonate sequence is disconformably overlain (Ciampo *et al.* 1987; Ogniben 1956; Selli 1957) by Lower-Middle Miocene limestones and marly limestones grading upwards to Upper Miocene siliciclastic flysch deposits. Numidian sands did not reach the Matese paleogeographic realm, since here the shallow-water carbonate platform began to undergo flexural sinking only in Serravallian times.

Frosolone and Agnone units

These units (see D'Argenio *et al.* 1972; Ippolito *et al.* 1975), widespread in the Molise region, are constituted of Jurassic to Miocene slope and basin lime resediments (Clermonté 1977; Clermonté and Pironon 1979; Manfredini 1963; Pescatore 1965b; Pieri 1966; Signorini 1961; Signorini and Devoto 1962) followed (Sgrosso *et al.* 1988) by a thick sequence of Messinian flysch deposits. No Numidian quartzarenites have been found in these units up to now. This absence may probably be due to the existence of morphological barriers which prevented the quartz-sand supply from the south.

Tufillo and Daunia units

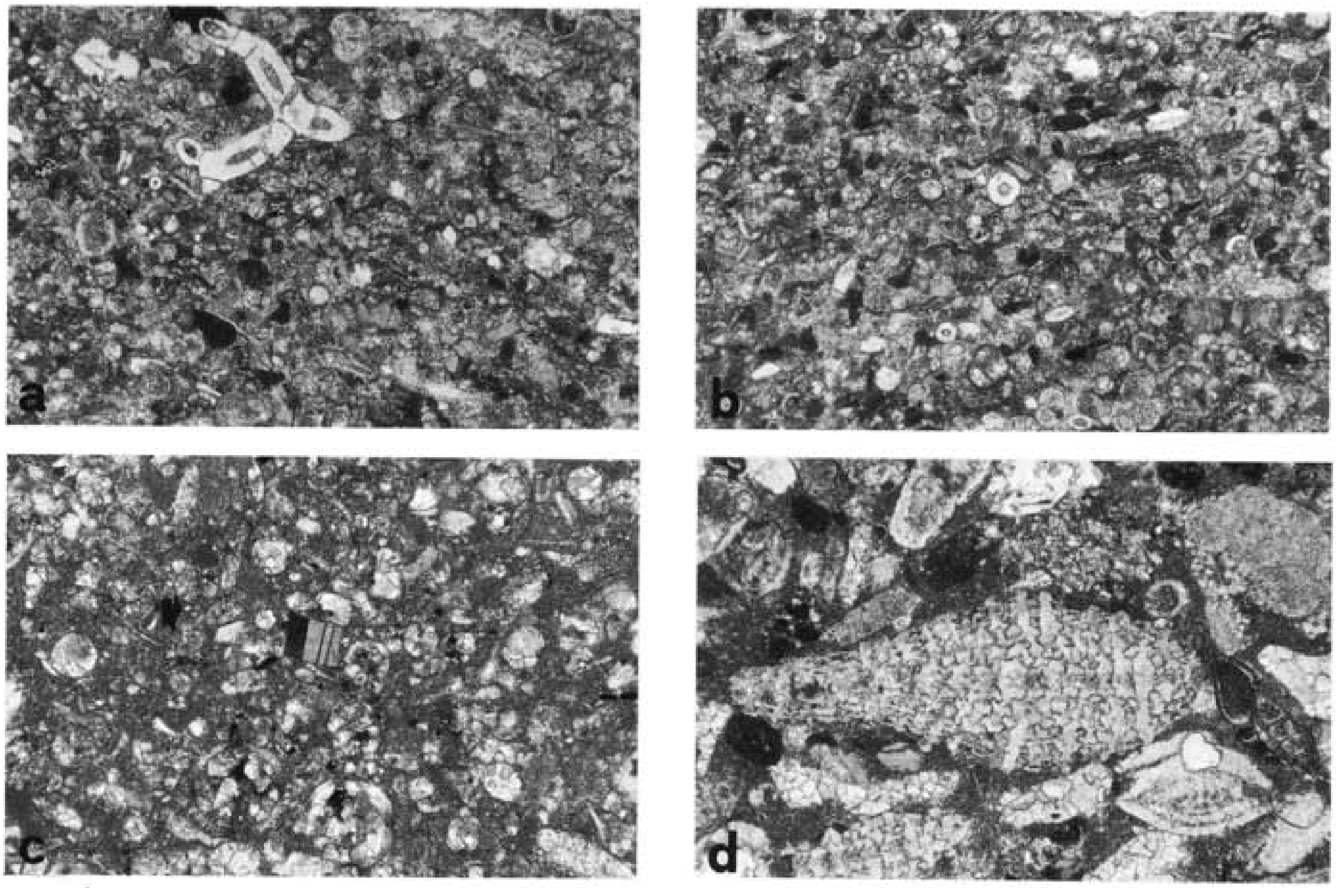
The Tufillo and Daunia thrust sheets form the most external Molise tectonic units; they extend from Abruzzi to the Taranto Gulf all along the outer margin of the Apennines.

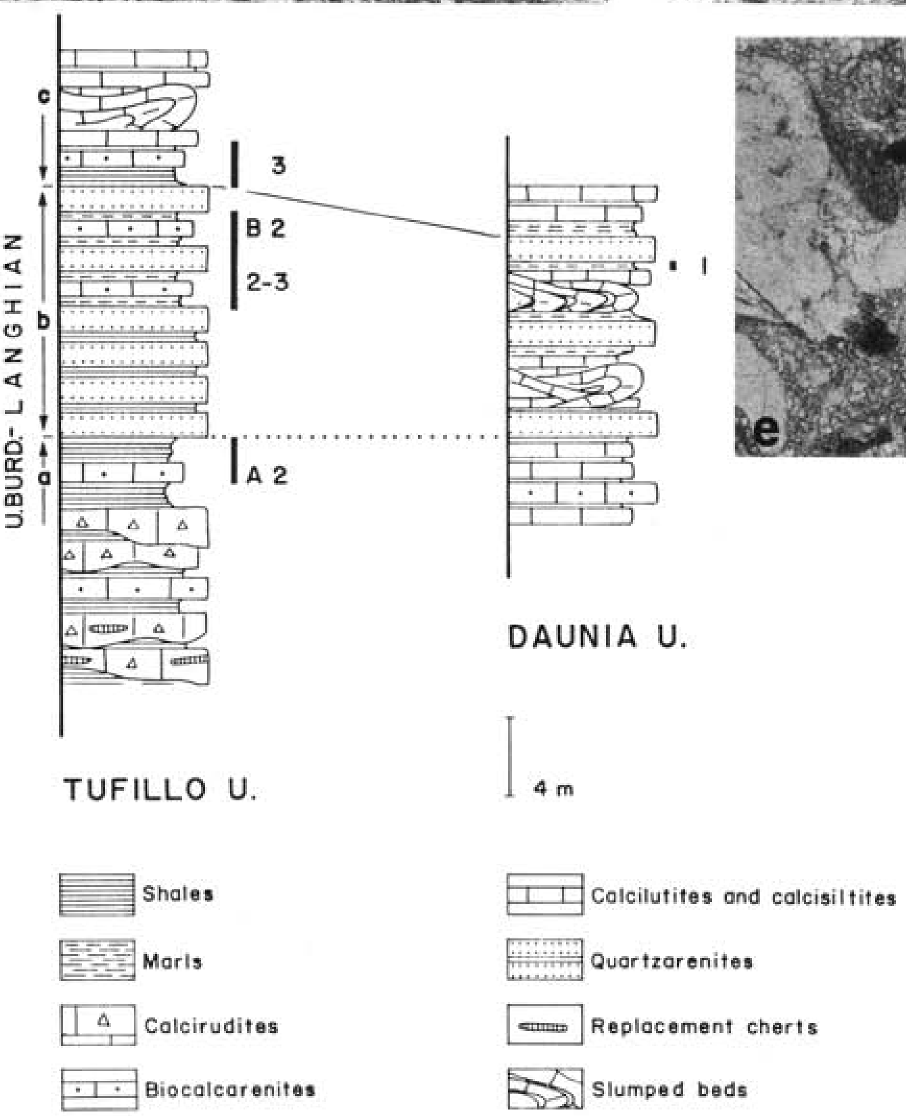
The Tufillo sequence (see Molise Nappe *p.p.* and Tufillo Formation, as well as Serra Palazzo Formation in Selli 1962) consists of Oligocene(?)-Lower Miocene varicoloured clays and lime debrites followed by Middle-Upper Miocene hemipelagic marly limestones frequently displaced by slumping. The latter grade upwards to Messinian siliciclastic flysch deposits. More or less thick intercalations of Numidian quartzarenite beds and of arkosic litharenites characterize respectively the lower and the middle/upper parts of the hemipelagic limestones. The thickness of the Numidian quartzarenites decreases from south to north, that is from Basilicata to the Abruzzi-Molise region. Several sections representative of the lower-middle part of the sequence have been described by Boenzi *et al.* (1968); Centamore *et al.* (1970, 1971); Ciaranfi *et al.* (1973); Crescenti (1967); Del Prete (1979); Palmentola (1967, 1970); Wezel (1966).

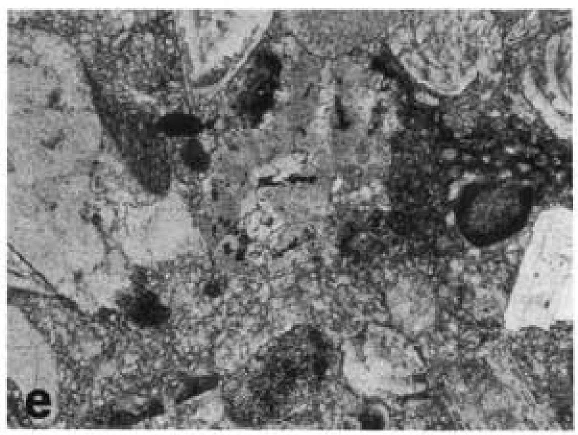
The Daunia sequence (Centamore *et al.* 1970, 1971; Centamore and Valletta 1968; Ciaranfi *et al.* 1973; Crostella and Vezzani 1964; Dazzaro *et al.* 1988; Dazzaro and Rapisardi 1984; Di Nocera and Torre 1987; Santo and Senatore 1988) broadly displays lithologies and depositional features very similar to those which characterize the Tufillo Unit. The principal differences are expressed by the absence of the arkosic litharenites, by the distal features of the siliciclastic flysch deposits and by the occurrence of Messinian evaporites.

Figure 11 shows two columnar sections repre-

Fig. 11 - Schematic columnar sections showing the position of the Numidian quartzarenites in the Tufillo and Daunia sequences and examples of microfacies. Symbols (small letters, heavy bars, capital letters and Arabic numerals) have been explained in Fig. 4. 11 *a* and 11 *b*: bioclastic packstone rich in spicules preserved as moulds filled by microquartz. Castiglione Messer Marino, interval b (B position in the Tufillo columnar section), EP 1286, x25, PPL. 11 *c* foraminiferal packstone with small plagioclase crystals. Castiglione Messer Marino, interval b (B position in the Tufillo columnar section), EP 1288, x63, XPL. 11 *d* and 11 *e*: bioclastic packstones with plagioclase phenocrysts (extreme right-hand side of photograph *e*). Castiglione Messer Marino, interval a (A position in the Tufillo columnar section), 11 *d* EP 1285, 11 *e* EP 1284, x25, PPL.


a
b
c
d


c
U.BURD.- LANGHIAN
b
a
3
B 2
2-3
A 2
I
TUFILLO U.
DAUNIA U.
4 m
Shales
Marls
Calcirudites
Biocalcarenites
Calcilutites and calcisiltites
Quartzarenites
Replacement cherts
Slumped beds


e

sentative of the lower portions of the Tufillo (Castiglione Messer Marino and San Felice areas) and Daunia units (Carpineto di Sinello area).

Near Castiglione Messer Marino village, the pre-Numidian interval (interval *a*) consists of thick-bedded lime breccias and coarse-grained biocalcarenites regularly interlayered with varicoloured clays. The redeposited lime beds immediately underlying the quartzarenites are very rich in bioclastic material such as echinoid spines, broken *Dentalium* tubes, mollusk shell- fragments, coralline algae and benthonic forams (*Miogypsina, Amphistegina, Lepidocyclina, Elphidium*. The coarser, granule sized components are essentially represented by platform-derived lithoclasts and chert fragments (Fig. 11 *a*). Minor amounts of sand-sized volcanic debris (mostly volcanic rock-fragments and plagioclase) are also present. Samples from clayey interlayers immediately below the Numidian quartzarenites (interval *a* in Fig. 11) revealed *Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Reticulofenestra* spp., *Coccolithus pelagicus, Helicosphaera carteri, Sphenolithus compactus, S. conicus, Helicosphaera ampliaperta, Discoaster exilis, Calcidiscus premacintyrei, Reticulofenestra pseudoumbilicus*. The foraminiferal contents are merely represented by *Globigerinoides trilobus*.

In the San Felice and Castiglione Messer Marino sections the Numidian interval (interval *b*) is represented by some metres of yellowish quartzarenites containing in the upper part thicker marly interlayers and slightly quartzose biocalcarenites rich in sponge spicules (Fig. 11 *b*). The calcareous nannofossils from the marly interlayers comprise *Reticulofenestra daviesii, Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Discoaster deflandrei, Reticulofenestra* spp., *Coccolithus pelagicus, Coronocyclus nitescens, Helicosphaera carteri, Triquetrorhabdulus milowii, Sphenolithus compactus, Helicosphaera mediterranea, Sphenolithus conicus, Discoaster druggii, Helicosphaera ampliaperta, Geminilithella rotula, Sphenolithus abies, Discoaster variabilis, Sphenolithus heteromorphus, Discoaster exilis, Calcidiscus leptoporus, Helicosphaera waltrans, Reticulofenestra pseudoumbilicus*. The planktonic forams are in turn represented by *Globorotalia acrostoma, Gb. siakensis, Globigerina praebulloides, Globoquadrina dehiscens, Globorotalia continuosa, Globigerina falconensis, Globigerinoides subquadratus, Globorotalia praescitula, Globigerinoides helicinus, Gd. bisphericus, Globoquadrina langhiana, Globorotalia mayeri.*

The Numidian quartzarenites are stratigraphically overlain by whitish foraminiferal limestones with intercalations of black (hemi)pelagic clays (interval *c* in Fig. 11). The clayey interlayers yielded *Reticulofenestra daviesii, Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Helicosphaera intermedia, Discoaster deflandrei, Reticulofenestra* spp., *Coccolithus pelagicus, Coronocyclus nitescens, Helicosphaera carteri, Triquetrorhabdulus milowii, Helicosphaera mediterranea, Sphenolithus conicus, Helicosphaera ampliaperta, Geminilithella rotula, Discoaster variabilis, Sphenolithus heteromorphus, Helicosphaera waltrans, Reticulofenestra pseudoumbilicus*. In the same interlayers, the planktonic-foram contents are represented by *Catapsidrax dissimilis, Globorotalia acrostoma, Gb. siakensis, Globigerina praebulloides, Globorotalia pseudocontinuosa, Globoquadrina dehiscens, Globorotalia continuosa, Globigerina falconensis, Globigerinoides trilobus, Globoquadrina altispira, Globigerinoides bisphericus, Globoquadrina langhiana* and *Globorotalia mayeri*.

In the Carpineto di Sinello section, the Numidian interval (interval *b* in Fig. 11) is represented by thick-bedded quartzarenites deposited by gravity-flow mechanisms, intercalated with slumped masses of graded biocalcarenites, spicule-rich calcisiltites and whitish marls. Samples collected from the upper part of the quartz-rich interval yielded *Cyclicargolithus abisectus, Coccolithus miopelagicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Discoaster deflandrei, Reticulofenestra* spp., *Coccolithus pelagicus, Coronocyclus nitescens, Helicosphaera carteri, Sphenolithus compactus, S. conicus, Helicosphaera ampliaperta, Discoaster variabilis, Sphenolithus heteromorphus, Calcidiscus leptoporus, C. macintyrei, Reticulofenestra pseudoumbilicus*. The planktonic-foram assemblage includes *Globorotalia acrostoma, Gb. siakensis, Globigerina praebulloides, Globorotalia obesa, Gb. continuosa, Globigerina falconensis, Globigerinoides subquadratus, Gd. trilobus, Gd. bisphericus*.

Scontrone-Porrara and Maiella units

This group of units, well exposed in the northwestern part of the area shown in Figure 1, includes Mesozoic-Tertiary carbonates (see Accordi *et al.* 1988 and references therein) conformably overlain by Upper Miocene and Lower Pliocene terrigenous flysch-deposits. Southwards, these units crop out only in the Monte Alpi area and, dubiously, in the Campagna tectonic window east of Salerno. Nevertheless, this carbonate thrust-system has been recognized on seismic lines and has been reached by commercial boreholes as far as the Taranto Gulf (see "Inner Apulia Platform" *p.p.*, in MOSTARDINI and MERLINI 1986). No Numidian quartzarenites are recorded in these units, since the sinking of the corresponding shallow platform areas took place only in late Miocene times.

CASOLI AND BOMBA UNITS

These units, identified by subsurface exploration, are known to extend from the Abruzzi region to the Taranto Gulf. The sedimentary sequences consist of Mesozoic-Tertiary carbonates overlain by Messinian evaporites and subsequently by Lower-Middle Pliocene terrigenous deposits ([1]). The absence of Numidian sandstones in these units is ascribed to persisting morphological-high conditions of the Casoli and Bomba platform-domains up to the Early Pliocene.

INNER APULIA BASIN

The existence of a narrow and elongate basin between the Casoli-Bomba and the Apulia platform-domains is documented by seismic information and by drilling results (see MOSTARDINI and MERLINI 1986). No Numidian quartzarenites have been noticed in the drilled sequences up to now.

MICROPALEONTOLOGICAL RESULTS AND BIOSTRATIGRAPHIC CONSIDERATIONS

The reference time scale we have adopted in order to date the Numidian-sand event in the Southern Apennines follows, with slight modifications, the BERGGREN *et al.* (1985) calibration of the BLOW (1969) foraminiferal zonation and of the MARTINI (1971) and OKADA and BUKRY (1980) nannofossil zonation. The modifications concern the position of the chronostratigraphic boundaries which define the Burdigalian and the Langhian stages, which have been fixed according to the zonal scheme of IACCARINO (1985). The nannofossil ranges (see Table 2) follow PERCH-NIELSEN (1985) and THEODORIDIS (1984), integrated by data coming from AUBRY (1984, 1988), FORNACIARI *et al.* (1990), GALLANGER (1987) JANG and GARTNER (1984), NEGRI (1988), PARKER *et al.* (1985), PUJOS (1985), RIO *et al.* (1990). The distribution of the planktonic foraminifers closely follows IACCARINO (1985).

Our micropaleontological data have been assembled into three groups (see Table 3):

— data concerning the sediments immediately underlying the Numidian quartzarenites. Where no Numidian quartzarenite beds are developed, the data refer to the sediments immediately underlying lime deposits including well-rounded quartz grains which appear, in any case, influenced by the Numidian sedimentary input (pre-Numidian interval in Tables 1 and 3 and interval *a* in Figs. 4, 7, 10, 11);

— data concerning the lithologic interval corresponding to the Numidian-sand supply (Numidian interval in Tables 1 and 3 and interval *b* in Figs. 4, 7, 10, 11);

— data concerning the sediments immediately overlying the Numidian quartzarenites or the quartz-bearing lime deposits (post-Numidian interval in Tables 1 and 3 and interval *c* in Figs. 4, 7, 11).

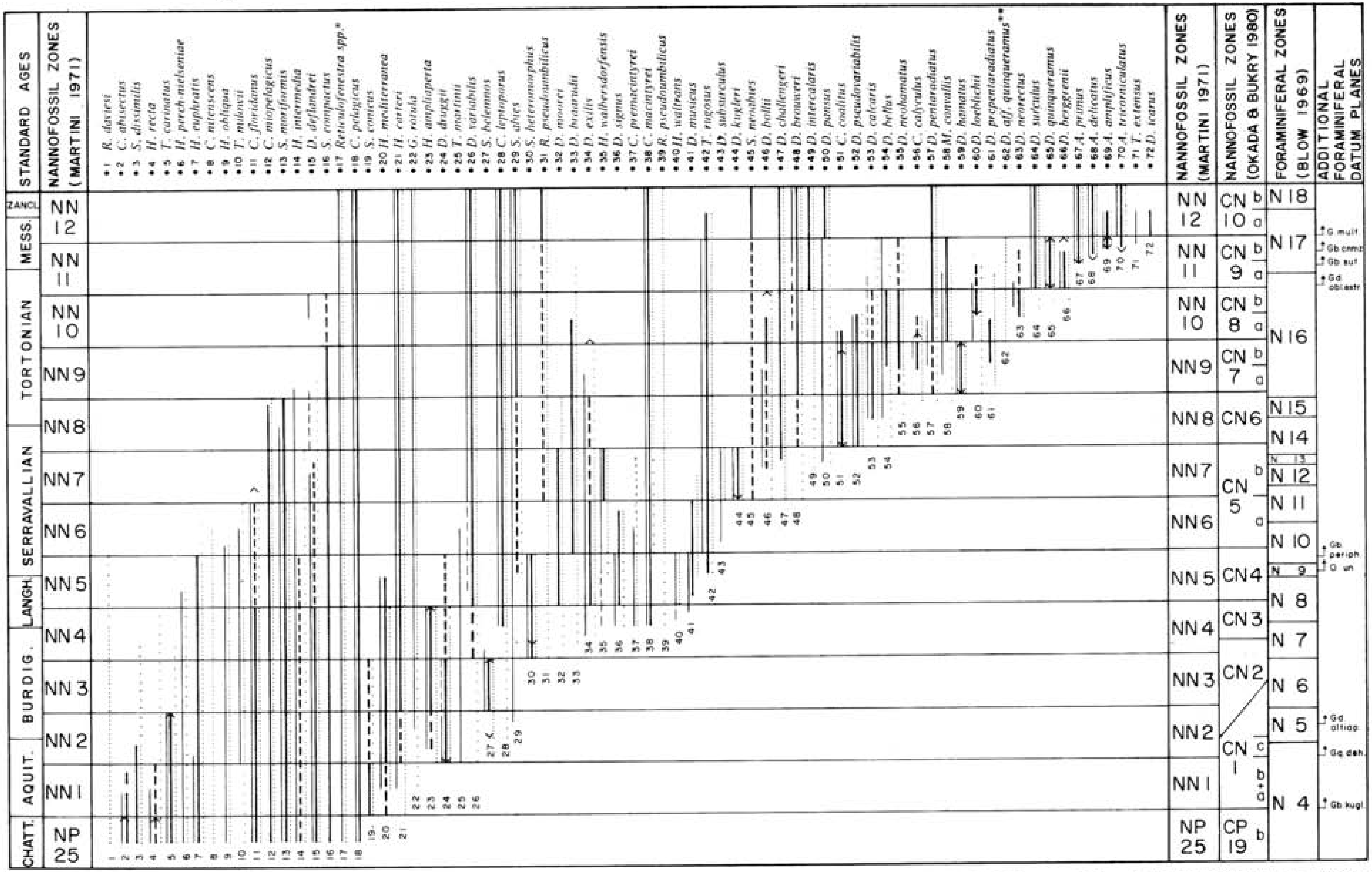
A summary of the micropaleontological data is given as a synoptical assemblage in Table 3. The incompleteness of the information is due to several factors. The lack of information about deposits corresponding to the Numidian and post-Numidian intervals in the Verbicaro Unit, as well as on post-Numidian deposits in the Monti della Maddalena and Lagonegro units is ascribed to the absence of outcrops certainly belonging to these units. The absence of micropaleontological data about the pre-Numidian and post-Numidian deposits of the Daunia Unit, as well as the lack of information about the Numidian interval of the Lagonegro units, is due to the incompleteness of our sampling related to non-continuous or non-exposed sections which prevented detailed investigations. Finally, researches in the post-Numidian deposits of the Alburno-Cervati Unit were fruitless since the interval resulted barren (see *e.g.* Civita-Cerchiara section of Fig. 8) or it was actually lacking. This lack seems to be due to sedimentary gaps caused either by erosional features at the base of the overlying chaotic boulder clays (see Torno, Monte Raparello and Monte Soprano-Monte Chianello sections of Fig. 7) or by winnowing and consequent non-deposition (see La Raja del Pedale section of Fig. 7).

PRE-NUMIDIAN INTERVAL

The planktonic foraminifer assemblage is relatively poor in all the investigated units. The wide-

([1]) The upper part of the Casoli Unit, represented by Lower-Middle Pliocene clays and siltstones, crops out in Eastern Abruzzi near the Casoli village.

TABLE 2 - Miocene nannofossil range chart adopted in this paper. The species distributions basically come from PERCH-NIELSEN (1985) and from THEODORIDIS (1984). Dotted lines refer to distributions derived from more recent literature (AUBRY 1988; FORNACIARI *et al.* 1990; GALLANGER 1987; JANG and GARTNER 1984; NEGRI 1988; PARKER *et al.* 1985; PUJOS 1985; RIO *et al.* 1990). The nannofossil and foraminiferal zone correlation closely follows BERGGREN *et al.* 1985. The chronostratigraphic boundaries derive from BERGGREN *et al.* 1985, except for the lower and upper boundaries of the Burdigalian and Langhian stages which have been fixed according to the zonal scheme of IACCARINO (1985)



———— - - - - - THEODORIDIS (1984) ———— - - - - - PERCH-NIELSEN (1985) .... VARIOUS AUTHORS ∨ FAD ∧ LAD BERGGREN et al. (1985)

* Forms < 5 μm ** Intergrade forms between D. bellus and D. quinqueramus with poorly pronounced central knob

TABLE 3 - Synoptic table showing the fossil contents of the pre-Numidian, Numidian and post-Numidian intervals in the Apenninic units

CALCAREOUS NANNOFOSSILS

Interval	TECTONICS UNITS	R. daviesi	C. abisectus	H. euphratis	C. nitescens	T. milowii	C. floridanus	C. miopelagicus	S. moriformis	H. intermedia	D. deflandrei	S. compactus	Reticulofenestra spp.*	C. pelagicus	S. conicus	H. mediterranea	H. carteri	G. rotula	H. ampliaperta	D. druggii	D. variabilis	S. belemnos	C. leptoporus	S. abies	S. heteromorphus	R. pseudoumbilicus **	D. exilis	C. premacintyrei	C. macintyrei	R. pseudoumbilicus >7 µm	H. waltrans
POST-NUMIDIAN INTERVAL	SANNIO U.	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	•		•	•	•				•	
	VERBICARO U.																														
	ALBURNO-CERVATI U.																														
	MONTI DELLA MADDALENA U.																														
	LAGONEGRO U.																														
	TUFILLO U.	•	•		•	•	•	•	•	•	•		•	•	•	•	•	•	•		•				•	•					•
	DAUNIA U.																														
NUMIDIAN INTERVAL	SANNIO U.	•					•	•	•		•	•	•	•	•		•		•					•		•					
	VERBICARO U.																														
	ALBURNO-CERVATI U.	•					•	•	•			•	•	•	•									•		•					
	MONTI DELLA MADDALENA U.		•				•		•		•			•							•			•							
	LAGONEGRO U.																														
	TUFILLO U.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•				•
	DAUNIA U.		•		•		•	•	•		•	•	•	•	•		•		•		•		•		•	•			•		
PRE-NUMIDIAN INTERVAL	SANNIO U.	•	•	•	•		•	•	•	•	•	•	•	•	•		•	•	•					•		•					
	VERBICARO U.	•	•				•	•	•	•		•	•	•	•									•	•						
	ALBURNO-CERVATI U.	•	•				•	•	•			•	•	•	•									•	•						
	MONTI DELLA MADDALENA U.	•	•	•			•	•	•	•	•	•	•	•	•		•	•			•			•	•	•					
	LAGONEGRO U.		•				•	•	•		•	•	•	•	•								•	•	•						
	TUFILLO U.						•	•	•	•		•	•	•	•		•		•							•	•	•			
	DAUNIA U.																														

PLANKTONIC FORAMINIFERS

Interval	TECTONICS UNITS	Ctx. dissimilis	Gb. acrostoma	Gb. siakensis ***	G. praebulloides	Gb. obesa	Gb. pseudocontinuosa	Gq. dehiscens	Gb. continuosa	G. falconensis	Gd. subquadratus	Gd. trilobus	Gb. praescitula	Gq. altispira	Gd. bisphericus	P. glomerosa sicana	Gq. langhiana	Gb. mayeri ***
POST-NUMIDIAN INTERVAL	SANNIO U.		•	•	•	•		•	•		•	•	•		•	•	•	•
	VERBICARO U.																	
	ALBURNO-CERVATI U.																	
	MONTI DELLA MADDALENA U.																	
	LAGONEGRO U.																	
	TUFILLO U.	•	•	•	•		•	•	•	•		•		•	•		•	•
	DAUNIA U.																	
NUMIDIAN INTERVAL	SANNIO U.			•		•		•										
	VERBICARO U.																	
	ALBURNO-CERVATI U.		•		•				•			•						
	MONTI DELLA MADDALENA U.	•			•		•											
	LAGONEGRO U.																	
	TUFILLO U.		•	•	•			•	•	•	•	•	•		•		•	
	DAUNIA U.		•	•	•	•			•	•	•	•			•			
PRE-NUMIDIAN INTERVAL	SANNIO U.				•			•	•			•						
	VERBICARO U.	•			•		•					•						
	ALBURNO-CERVATI U.											•						
	MONTI DELLA MADDALENA U.	•		•	•		•					•						
	LAGONEGRO U.											•						
	TUFILLO U.											•						
	DAUNIA U.																	

★ Forms with an overall placolith size smaller than 5 µm

★★ Forms with an overall placolith size between 5 and 7 µm

★★★ Sensu IACCARINO (1985)

spread occurrence of *Globigerinoides trilobus* and the absence of Langhian forms suggest that the deposits immediately underlying the Numidian quartzarenites may be reasonably attributed to the N7 foraminiferal zone (Late Burdigalian).

The nannofossil assemblages, characterized by the systematic presence of small sphenoliths and of *Reticulofenestra* spp. forming a homogeneous population with overall placolithe size smaller than 5 µm, appears quite uniform over all the investigated units. The occurrences of *Discoaster exilis* and *Calcidiscus premacintyrei* in the Tufillo Unit and of *Calcidiscus leptoporus* in the Lagonegro Upper Unit led us to attribute the pre-Numidian deposits of these successions to the upper part of the NN4 nannofossil zone. It is very likely that the same age may be assigned to the Verbicaro and Alburno-Cervati pre-Numidian intervals which yielded *Sphenolithus heteromorphus* associated with few forms of *Sphenolithus abies* whose first appearance took place after the NN4 zone according to many Authors. Integrating the results derived from the nannofossil analysis with those obtained from the planktonic-foram analysis, the upper boundary of the pre-Numidian deposits may be reasonably confined within the upper part of the NN4 zone (Late Burdigalian), just below the N7/N8 foraminifer zonal boundary.

NUMIDIAN INTERVAL

The foraminiferal contents in the Numidian interval are usually very poor and scarcely significant. Nevertheless, the sporadic presence of *Globoquadrina langhiana* in the Tufillo Unit and of *Globigerinoides bisphericus* in the Tufillo and Daunia units, as well as the recovery, according to the geological literature (see CARBONE *et al.* 1987) of *Praeorbulina sicana* in Numidian quartzarenites belonging, in our opinion, to the Sannio Unit, led us to consider as Langhian (N8 foraminiferal zone) the quartz-sand supply in the corresponding depositional realms. Furthermore, the systematic absence of *Orbulina* in the Numidian quartzarenites and in the immediately overlying post-Numidian deposits suggests that the quartz-sand input did not span over the N8/N9 zonal boundary.

The nannofossil assemblage of the Numidian interval does not show strong variations compared with those of the previously described pre-Numidian interval. The most significant differences include the abundance of larger forms of *Reticulofenestra pseudoumbilicus* (values ranging from 6.0 to 6.5 µm in this interval; values ranging from 5.5 to 6.5 µm in the Pre-Numidian interval) and the presence of forms like *Calcidiscus macintyrei* (Daunia Unit) and *Helicosphaera waltrans* (Tufillo Unit) whose first appearance has been noticed in the upper part of the NN4 zone. The concomitant absence of forms which had their first appearance in the NN5 zone suggests that the Numidian-sand supply wholly occurred in the upper part of the NN4 nannofossil zone. In conclusion, the nannofossil results do not allow an age discrimination between the pre-Numidian and the Numidian intervals. Nevertheless, when we integrate foraminifer and nannofossil data we can see that the Numidian-quartz supply took place everyhere, from the Sannio to the Daunia depositional domains, in the uppermost part of the NN4 nannofossil zone, and perhaps in the lowermost part of the NN5 zone, but in any case within the N8 foraminiferal zone.

POST-NUMIDIAN INTERVAL

The nannofossil assemblage from the deposits immediately overlying the Numidian interval does not markedly differ from that already described for the quartz-rich interval. Only the presence of *Reticulofenestra pseudoumbilicus* with increased overall size (mean values between 6.5 and 7 µm, with rare forms exceeding 7 µm) may imply a slightly younger age. The presence of *Praeorbulina glomerosa* (Sannio Unit), and of *Globigerinoides bisphericus* and *Globoquadrina langhiana* (Sannio and Tufillo units), as well as the virtual absence of *Orbulina* sp. still indicates the N8 foraminiferal zone. Furthermore, the occurrence of a few specimens of *Globorotalia mayeri sensu* IACCARINO (1985), which appears at the base of the N9 zone, suggests at least the uppermost part of the N8 foraminiferal zone for the upper boundary of the Numidian-sand depositional event.

REGIONAL REMARKS

In spite of several persisting uncertainties about the palinspastic restoration of the Apulian-margin paleogeographic domains in Early Miocene times, the available geological data and the new stratigraphic results discussed in this paper allow us to formulate some regional considerations on the Apennine Numidian quartzarenites which may be summarized in the following points:

— the Numidian quartzarenites were deposited over different depositional realms in a very short time interval corresponding to the N8 foraminiferal zone (upper part of the NN4 zone and possibly lower part of the NN5 zone);

— over the different Apenninic domains, the deposition of the Numidian quartzarenites was preceded and accompanied by an important input of calc-alkaline volcaniclastic products, probably derived from the Corsica-Sardinia volcanic arc. Spicular deposits, mainly developed at the base of the Numidian quarzarenites, characterize all investigated sections, associated with a major supply of volcaniclastic material. It seems to be very likely that the sudden and exceptional sponge proliferation over different depositional realms was related to the chemical modifications of the seawater induced by the abundance of volcanogenic material;

— in agreement with Wezel (1970a), the stable African Platform must be identified as the source-area of the quartz-sand supply (see also discussion in Durand Delga 1980). In the Apenninic domains, the Numidian sand distribution was mostly controlled by the sea-bottom physiography inherited from the Mesozoic paleotectonic activity, as well as by the distance from the source area. As already evidenced by Channel and Mareschal (1989), the existence of an oceanic sea-way between the Apennine and the Sicily paleogeographic realms during Early/Middle Miocene times (see, *e.g.* Malinverno and Ryan 1986) is unlikely, since an intervening ocean basin would have inhibited the Numidian quartz transport over the Apulia continental margin;

— during the Numidian-sand supply, no influence was exerted by compressional tectonics related to the Corsica-Sardinia/Apulia convergence, except for the Alburno-Cervati paleogeographic domain whose internal margin (Monte Pollino area) underwent high-rate subsidence at the beginning of the Numidian-sand input. The sinking of the carbonate platform was probably related to the retreat of the flexure-zone of the Apulia lithosphere which accompanied the counterclockwise Corsica-Sardinia rotation and the simultaneous eastward migration of the thrust belt-foredeep system. It is interesting to point out that according to Bellon *et al.* (1977) the NW magnetic declinations of the Upper Oligocene-Lower Miocene Sardinia volcanites should record a strong and fast counterclockwise rotation of the Sardinia block related to the opening of the younger portions of the Western Mediterranean basin between 17 and 15 Ma ago. Our stratigraphical results fit quite well these conclusions, since the tectonic event recorded in the Sannio and Alburno-Cervati depositional realms by a sudden change of sedimentation from highly mature (Numidian quartzarenites) to immature/submature sands (arkosic sandstones) took place around the Langhian-Serravallian boundary;

— if we label as "flysch" a sedimentary body deposited within a tectonically-active foredeep basin in front of advancing nappes or rising cordilleras (see Hsü 1972 and discussion therein), then the term "flysch" for the Apennine Numidian quartzarenites should be definitively abandoned, since the Numidian sands were mostly deposited in foreland basinal realms. Only by chance, in the Alburno-Cervati domain the beginning of the quartz-sand sedimentation coincided with the starting of the flexural subsidence responsible for the incorporation of this foreland platform in a foredeep basin.

REFERENCES

Accordi G., Carbone F., Civitelli G., Corda L., De Rita D., Esu D., Funicello R., Kotsakis T., Mariotti G., Sposato A., 1988 - *Note illustrative alla carta delle litofacies del Lazio-Abruzzo ed aree limitrofe.* C.N.R., Quaderni de "La Ricerca Scientifica", v. 114 (P.F. Geodinamica, Monografie Finali v. 5), 223 pp., Roma.

Amodio-Morelli L., Bonardi G., Colonna V., Dietrich D., Giunta G., Ippolito F., Liguori V., Lorenzoni S., Paglionico A., Perrone V., Piccarreta G., Russo M., Scandone P., Zanettin-Lorenzoni E., Zuppetta A., 1976 - *L'Arco Calabro nell'orogene appenninico-maghrebide.* Mem. Soc. geol. ital., v. 17, pp. 1-60, Roma.

Aubry M.P., 1984 - *Handbook of Cenozoic Calcareous Nannoplankton — Book 1: Ortholithae (Discoasters).* Micropaleontology Press - The American Museum of Natural History, pp. 1-265, New York.

Aubry M.P., 1988 - *Phylogeny of the Cenozoic Calcareous nannoplankton genus Helicosphaera.* Paleobiology, v. 14(1), pp. 64-80, Lawrence Kansas.

Bates R.L., Jackson J.A., 1987 - *Glossary of geology.* Am. Geol. Inst., third Edition, Boulder.

Bellon H., Coulon C., Edel J.B., 1977 - *Le déplacement de la Sardaigne. Synthèse des données géochronologiques, magmatiques et paléomagnétiques.* Bull. Soc. géol. France, s. 7, v. 19(4), pp. 825-831, Paris.

Berggren W.A., Kent D.V., Van Couvering J.A., 1985 - *Neogene geochronology and chronostratigraphy.* In N.J. Snelling (ed.), The Chronology of the Geological Record, Geol. Soc. Mem., v. 10, pp. 211-260, London.

Blow W., 1969 - *Late-middle Eocene to Recent planktonic foraminiferal biostratigraphy.* Proceedings of the First International Conference on planktonic microfossils, Geneve 1967, v. 1, pp. 199-421, Leiden.

BOENZI F., CIARANFI N., PIERI P., 1968 - *Osservazioni geologiche nei dintorni di Accettura e di Oliveto Lucano (Tav. 200 III NE, IV SE e IV NE).* Mem. Soc. geol. ital., v. 7, pp. 379-392, Roma.

BONARDI G., 1966 - *Osservazioni geologiche sui monti di Lauria.* Boll. Soc. natur. Napoli, v. 75, pp. 181-200, Napoli.

BONI M., IPPOLITO F., SCANDONE P., ZAMPARELLI-TORRE V., 1974 - *L'unità del Monte Foraporta nel Lagonegrese (Appennino Meridionale).* Boll. Soc. geol. ital., v. 93, pp. 469-512, Roma.

BOUILLIN J.P., RAOULT J.F., 1971 - *Présence sur le socle kabyle du Constantinois d'un olistostrome lié au charriage des flyschs; le Numidien peut-il être un néoautochtone?* Bull. Soc. géol. Fr., s. 7, v. 13(3-4), pp. 338-362, Paris.

BOUSQUET J.C., GRANDJACQUET C., 1969 - *Structure de l'Apennin Calabro-Lucanien (Italie Méridionale).* C.R. Acad. Sci. Paris, s. D, v. 268, pp. 13-16, Paris.

CARBONE S., CATALANO S., LENTINI F., MONACO C., 1988 -*Sistemi deformativi ed età dei ricoprimenti nella Val d'Agri (Appennino Lucano).* Atti 74° Congr. Naz. Soc. geol. ital. (Sorrento 13-17 sett. 1988), Extended Abstracts v. B, pp. 73-79, Napoli.

CARBONE S., LENTINI F., SONNIO M., DE ROSA R., 1987 -*Il flysch numidico di Valsinni (Appennino Lucano).* Boll. Soc. geol. ital., v. 106, pp. 331-345, Roma.

CATENACCI E., DE CASTRO P., SGROSSO I., 1963 - *Complessi guida del mesozoico calcareo-dolomitico nella zona orientale del Massiccio del Matese.* Mem. Soc. geol. ital., v. 4(2), pp. 1-20, Roma.

CENTAMORE E., CHIOCCHINI U., JACOBACCI A., LANARI G., SANTAGATI G., 1970 - *Geologia della zona nord-occidentale del F° 187 "Melfi".* Boll. Serv. geol. It., v. 91, pp. 113-148, Roma.

CENTAMORE E., CHIOCCHINI U., MORETTI A., 1971 - *Geologia della zona tra Acerenza e Avigliano (prov. di Potenza).* Studi Geol. Camerti, v. 1, pp. 97-122, Camerino.

CENTAMORE E., VALLETTA M., 1968 - *Contributo alla conoscenza geologica dell'Appennino Molisano.* Boll. Serv. geol. It., v. 89, pp. 53-64, Roma.

CHANNEL J.E.T., MARESCHAL J.C., 1989 - *Development of the Tyrrhenian rift.* In M.P. COWARD, D. DIETRICH and R.G. PARK (eds.), Alpine Tectonics. Geol. Soc. Special Pubblication 45, pp. 285-302, London.

CHIOCCHINI U., FRANCHI R., GUERRERA F., RYAN W.B.F., VANNUCCI S., 1978 - *Geologia di alcune successioni torbiditiche cretaceo-terziarie appartenenti ai "Flysch Mauretaniens" e alla "Nappe Numidienne" del Rif settentrionale (Marocco).* Stud. geol. Camerti, v. 4, pp. 37-65, Camerino.

CIAMPO G., SGROSSO I., RUGGIERO TADDEI E., 1987 - *L'inizio della sedimentazione terrigena nel Matese, nei monti del Casertano e nei monti di Suio.*Boll. Soc. geol. ital., v. 106, pp. 323-330, Roma.

CIARANFI N., DAZZARO L., PIERI P., RAPISARDI L., SARDELLA A., 1973 - *Geologia della zona compresa fra Bisaccia (Avellino) ed il T. Olivento, presso Lavello (Potenza).* Mem. Soc. geol. ital., v. 12, pp. 279-315, Roma.

CIARAPICA G., CIRILLI S., PANZANELLI-FRANTONI R., PASSERI L., ZANINETTI L., 1988 - *La formazione di Monte Facito (Appennino meridionale).* Atti 74° Congr. Naz. Soc. geol. ital. (Sorrento 13-17 sett. 1988), Extended Abstracts v. B, pp. 132-135, Napoli.

CIVITA M., 1965 - *Osservazioni geologiche nei Monti di Maratea (Lucania Meridionale).* Mem. Note Ist. Geol. appl. Univ. Napoli, v. 9, 1963-65, pp. 5-24, Napoli.

CLERMONTÉ J., 1977 - *La bordure abruzzaise sud-orientale et le haut Molise: histoire sédimentaire et tectonique comparée.* Riv. ital. Paleont. (Stratigr.), v. 83(1), pp. 21-102, Milano.

CLERMONTÉ J., PIRONON B., 1979 - *La plate forme campano-abruzzaise de la Meta au Matese (Italie méridionale): différenciations au Paléogène et au Miocène, structures, relations avec les formations molisanes.* Bull. Soc. geol. France, s. 7, v. 21(6), pp. 737-743, Paris.

COCCO E., CRAVERO E., ORTOLANI F., PESCATORE T., RUSSO M., TORRE M., COPPOLA L., 1974 - *Le Unità Irpine nell'area a nord di Monte Marzano; Appennino Meridionale.* Mem. Soc. geol. ital., v. 18, pp. 607-654, Roma.

COURME M.D., MASCLE J., 1988 - *Nouvelles données stratigraphiques sur les séries oligo-miocènes des unités siciliennes: conséquences paléogéographiques.* Bull Soc. géol. Fr., v. 4(1), pp. 105-118, Paris.

CRESCENTI U., 1966a - *Sulla biostratigrafia del Miocene affiorante al confine marchigiano-abruzzese.* Geologica rom., v. 5, pp. 1-54, Roma.

CRESCENTI U., 1966b - *Osservazioni sulla stratigrafia dell'Appennino meridionale alla luce delle recenti ricerche micropaleontologiche.* Boll. Soc. geol. ital., v. 85, pp. 541-579, Roma.

CRESCENTI U., 1967 - *Sulla biostratigrafia del Miocene medio del Molise occidentale.* Boll. Soc. geol. ital., v. 86, pp. 345-366, Roma.

CROSTELLA A., VEZZANI L., 1964 - *La geologia dell'Appennino foggiano.* Boll. Soc. geol. ital., v. 83(1), pp. 121-141, Roma.

DAMIANI A.V., 1970 - *Osservazioni geologiche in alcune tavolette del F° 220 nella Calabria nord-occidentale. Parte I - Stratigrafia. Parte II - Tettonica e probabile quadro evolutivo.* Boll. Soc. geol. ital., v. 89, pp. 65-96, Roma.

D'ARGENIO B., PESCATORE T., 1962 - *Stratigrafia del mesozoico nel gruppo del Monte Maggiore (Caserta).* Boll. Soc. natur. Napoli, v. 71, pp. 55-61, Napoli.

D'Argenio B., Pescatore T., Scandone P., 1972 - *Schema geologico dell'Appennino meridionale (Campania e Lucania).* Atti del Convegno Accad. Naz. Lincei sul tema : «Moderne vedute sulla geologia dell'Appennino», Quad. n. 183, pp. 49-72, Roma.

Dazzaro L., Di Nocera S., Pescatore T., Rapisardi L., Romeo M., Russo B., Senatore M.R., Torre M., 1988 - *Geologia del margine della catena appenninica tra il F. Fortore ed il T. Calaggio (Appennino Meridionale).* Atti 74° Congr. Naz. Soc. geol. ital. (Sorrento 13-17 sett. 1988), Extended Abstracts v. B, pp. 194-200, Napoli.

Dazzaro L., Rapisardi L., 1984 - *Nuovi dati stratigrafici, tettonici e paleogeografici della parte settentrionale dell'Appennino Dauno.* Boll. Soc. geol. ital., v. 103, pp. 51-58, Roma.

De Alfieri A., Guzzi R., Sacchi M., D'Argenio B., Perrone V., Zamparelli V., 1986 - *Monte Foraporta unit: a minor element of southern Apennine nappe pile. Stratigraphic and tectonic study.* Rend. Soc. geol. ital., v. 9, pp. 171-178, Roma.

De Capoa Bonardi P., 1969 - *Le Daonelle e le Halobie della serie calcareo-silico-marnosa della Lucania (Appennino Meridionale). Studio paleontologico e biostratigrafico.* Mem. Soc. natur. Napoli, suppl. Boll. v. 78, pp. 1-130, Napoli.

Del Prete M., 1979 - *Rilievo geologico e geomorfologico delle sponde del Lago di Bomba (Abruzzo) con particolare riferimento al rischio di frana.* Geol. Appl. Idrogeol., v. 14(2), pp. 255-297, Bari.

Didon J., Durand Delga M., Kornprobst J., 1973 - *Homologies géologiques entre le deux rives du détroit de Gibraltar.* Bull. Soc. géol. Fr., v. 15(7), pp. 77-105, Paris.

Dietrich D., Lorenzoni S., Scandone P., Zanettin-Lorenzoni E., Di Pierro M., 1976 - *Contribution to the knowledge of the tectonic units of Calabria. Relationships between composition of K-white micas and metamorphic evolution.* Boll. Soc. geol. ital., v. 95, pp. 193-217, Roma.

Di Nocera S., Torre M., 1987 - *Geologia dell'area compresa tra Deliceto e Scampitella (Appennino foggiano).* Boll. Soc. geol. ital., v. 106, pp. 351-364, Roma.

Durand Delga M., 1969 - *Mise au point sur la structure du nord-est de la Berberie.*Publ. Serv. Carte géol. Algér., n.s., v. 39, pp. 89-131, Algér.

Durand Delga M., 1980 - *La Méditerranée occidentale: étapes de sa genèse et problèmes structuraux liés à celle-ci.* Mem. h. sér. Soc. géol. Fr., v. 10, pp. 203-224, Paris.

Feinberg H., Hoyez B., Lahondère J.C., 1981 - *Nouvelles données biostratigraphiques sur le Numidien de l'Algérie et du Maroc.*Cahiers de Micropal., v. 3, pp. 93-99, Paris.

Flandrin J., 1948 - *Contribution à l'étude stratigraphique du Nummulitique algérien.* Bull. Serv. Carte Géol. Algérie, v. 19, pp. 1-346, Algér.

Fornaciari E., Raffi I., Rio D., Villa G., Backman J., Olafsson G., 1990 - *Quantitative distribution patterns of Oligocene and Miocene calcareous nannofossils from the western equatorial Indian ocean.* In R. Duncan, J. Backman *et al.*, Proc. Ocean Drill. Progr. v. 115, Scient. Res., pp. 237-254, College Station.

Gallanger L., 1987 - *Reticulofenestra: a critical review of taxonomy, structure and evolution.* In J.A. Crux and S. Van Heck (eds.), Nannofossil and their applications. Proceedings of the Intern. Nannofossil Association Conference, London 1987, pp. 41-75, London.

Giunta G., 1985 - *Problematiche ed ipotesi sul bacino numidico nelle Maghrebidi siciliane.* Boll. Soc. geol. ital., v. 104(2), pp. 239-256, Roma.

Glaçon G., Rouvier H., 1967 - *Précisions lithologiques et stratigraphiques sur le "Numidien" de Kroumirie (Tunisie septentrionale).* Bull. Soc. géol. Fr., v. 9(7), pp. 410-417, Paris.

Grandjacquet C., Grandjacquet M.J., 1962 - *Géologie de la zone de Diamante-Verbicaro (Calabre).* Geologica rom., v. 1, pp. 297-312, Roma.

Guerrera F., Wezel F.C., 1974 - *Nuovi dati stratigrafici sui flysch oligo-miocenici siciliani e considerazioni tettoniche relative.*Riv. min. sicil., anno 25, pp. 27-51, Palermo.

Haq B.U., Hardenbol J., Vail P.R., 1987 - *Chronology of fluctuating sea levels since the Triassic.* Science, v. 235, pp. 1156-1167, Washington.

Heike Merlin O., La Volpe L., Nappi G., Piccarreta G., Redini R., Santagati G., 1971 - *Note illustrative alla Carta geologica d'Italia alla scala 1:100.000. Fogli 186 e 187 S. Angelo de' Lombardi e Melfi.* Servizio Geologico d'Italia, 188 pp., Roma.

Hsü K.J., 1972 - *Alpine Flysch in a Mediterranean setting.* 24th IGC, Section 6, pp. 67-73, Montréal.

Iaccarino S., 1985 - *Mediterranean Miocene and Pliocene planktic foraminifera.* In H.M. Bolli, J.B. Saunders and K. Perch-Nielsen (eds.), Plankton Stratigraphy, Cambridge Earth Science Series, Cambridge Univ. Press, pp. 281-314, Cambridge.

Ietto A., 1963a - *Nuovi aspetti della tettonica della serie calcareo-dolomitica mesozoica nel salernitano.* Boll. Soc. natur. Napoli, v. 62, pp. 31-44, Napoli.

Ietto A., 1963b - *I rapporti tettonici fra "Scisti silicei" e Dolomia nei dintorni di Giffoni Valle Piana (Salerno).* Mem. Soc. geol. ital., v. 4, 15 pp., Roma.

Ippolito F., D'Argenio B., Pescatore T., Scandone P., 1975 - *Structural-Stratigraphic Units and tectonic framework of Southern Apennines.* In C. Squires (ed.), Geology of Italy, Earth Sci. Soc. Lybian Arab Republ., pp. 317-328, Castelfranco Veneto.

JANG M.J., GARTNER S., 1984 - *Neogene and Quaternary calcareous nannofossils biostratigraphy of the Walvis Ridge*. In T.C. MOORE jr., P.D. RABINOWITZ, *et al.*, Init. Rep. Deep Sea Drill. Proj., (U.S. Government Printing Office), v. 74, pp. 561-595, Washington.

LAHONDÈRE J.C., FIENBERG H., HAQ B., 1979 - *Datation de grès Numidiens d'Algérie orientale. Consequences structurales*. C.R. Acad. Sci. Paris, v. 289, pp. 383-386, Paris.

LANCELOT J.R., REILLE J.L., WEZEL F.C., 1977 - *Étude morphologique et radiochronologique des zircons détritiques des flysch "numidien" et "gréso-micacé". Conséquences paléogéographiques à l'échelle de la Méditerranée occidentale*. Bull. Soc. géol. France, s. 7, v. 19(4), pp. 733-780, Paris.

LENTINI F., 1979 - *Le Unità Sicilidi della Valle d'Agri (Appennino lucano)*. Geologica rom., v. 18, pp. 215-224, Roma.

MAGNÉ J., RAYMOND D., 1972 - *Dans le Nord de la Grande Kabilie (Algérie), le Numidien a un âge compris entre l'Oligocène Moyen et le Burdigalian inférieur*. C.R. Acad. Sc. Paris, v. 274, pp. 3052-3055, Paris.

MALINVERNO A., RYAN W.B.F., 1986 - *Extension in the Tyrrhenian Sea and shortening in the Apennines as a result of arc migration driven by sinking of the lithosphere*. Tectonics, v. 5(2), pp. 227-246, Washington.

MANFREDINI M., 1963 - *Osservazioni sul bordo interno della depressione molisano-sannitica (Italia meridionale)*. Mem. Soc. geol. ital., v. 4(2), 15 pp., Roma.

MARINI M., 1967 - *Affioramenti paleocenici ed eocenici a nord del Monte Marzano*. Atti Ist. Geol. Univ. Genova, v. 5 (1), 19 pp., Genova.

MARINI M., 1968 - *Osservazioni sul flysch dell'Appennino campano-lucano fra Laviano (Salerno) e Sant'Ilario di Atella (Potenza)*. Atti Ist. Geol. Univ. Genova, v. 5(1), pp. 37-63, Genova.

MARSELLA E., 1988 - *I terreni lagonegresi tra S. Fele e la Val d'Agri - Evoluzione tettonico-sedimentaria (Trias superiore-giurassico)*. Tesi di Dottorato di Ricerca in Geologia del Sedimentario - Consorzio Università di Napoli e Palermo, 159 pp.

MARSELLA E., PAPPONE G., 1986 - *Sediment gravity flows on a Mesozoic carbonate slope. Monti della Maddalena (Southern Apennines)*. Rend. Soc. geol. ital., v. 9, pp. 219-224, Roma.

MARTINI E., 1971 - *Standard Tertiary and Quaternary calcareous nannoplankton zonation*. In A. FARINACCI (ed.), Proceedings of the I Planktonic Conference (Roma, 1970), Ed. Tecnoscienza, v. 2, pp. 739-777, Roma.

MICONNET P., 1983 - *La region de Lagonegro (Italie méridionale): évolution géologique d'un bassin dans son cadre alpin*. Thèse 3^e^ cycle, Univ. Science et Techniques de Lille, n. 1083, 185 pp., Lille.

MICONNET P., 1987 - *Stratigraphie et évolution antetectonique de la région de Lagonegro (Bassin Lucanien, Italie méridionale)*. Ann. Soc. Géol. Nord, v. 105, pp. 221-231, Villeneuve d'Ascq.

MICONNET P., 1988 - *Evolution mesozoïque du secteur de Lagonegro*. Atti 74° Congr. Naz. Soc. geol. ital. (Sorrento 13-17 sett. 1988), Extended Abstracts v. B, pp. 318-324, Napoli.

MOSTARDINI F., MERLINI S., 1986 - *Appennino centromeridionale. Sezioni geologiche e proposta di modello strutturale*. Mem. Soc. geol. ital., v. 35, pp. 177-202, Roma.

NEGRI A., 1988 - *Biostratigrafia a nannofossili calcarei del Miocene inferiore-medio italiano e mediterraneo*. Tesi di Dottorato di Ricerca in Paleontologia, Univv. consorz. Modena, Bologna, Firenze e Roma, 289 pp.

OGNIBEN L., 1956 - *Flysch miocenico autoctono e parautoctono ed argille scagliose alloctone nella zona di Caiazzo (Caserta)*. Boll. Soc. geol. ital., v. 75 (3), pp. 169-179, Roma.

OGNIBEN L., 1960 - *Nota illustrativa allo schema geologico della Sicilia nord-occidentale*. Riv. min. sicil., v. 11(64-65), pp. 183-212, Palermo.

OGNIBEN L., 1963 - *Il Flysch Numidico nel quadro della Geologia della Sicilia*. Mem. Soc. geol. ital., v. 4(2), 18 pp., Roma.

OGNIBEN L., 1969 - *Schema introduttivo alla geologia del confine calabro-lucano*. Mem. Soc. geol. ital., v. 8, pp. 453-763, Roma.

OKADA H., BUKRY D., 1980 - *Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975)*. Marine Micropaleont,. v. 5, pp. 321-325, Amsterdam.

ORTOLANI F., NARCISO G., SANZÒ A., 1975 - *Prime considerazioni sulla presenza del flysch numidico nell'Appennino sannita*. Boll. Soc. natur. Napoli, v. 84, pp. 31-44, Napoli.

PALMENTOLA G., 1967 - *Sui rapporti tra la "formazione di Stigliano" e la "formazione di Serra Palazzo" nei dintorni di Tolve (Potenza)*. Boll. Soc. natur. Napoli, v. 76, pp. 291-297, Napoli.

PALMENTOLA G., 1970 - *Nuovi dati e considerazioni sulla Formazione di Serra Palazzo in Lucania*. Mem. Soc. geol. ital., v. 9, pp. 81-90, Roma.

PAPPONE G., 1988 - *Facies mesozoiche di margine di piattaforma carbonatica nel settore settentrionale del Vallo di Diano (Appennino campano)*. Atti 74° Congr. Naz. Soc. geol. ital. (Sorrento 13-17 sett. 1988), Extended Abstracts v. A, pp. 433-440, Napoli.

PAPPONE G., SACCHI M., ZAMPARELLI V., 1988 - *Studio comparato di alcune successioni di scarpata carbonatica dell'Appennino campano-lucano*. Atti 74° Congr. Naz. Soc. geol. ital. (Sorrento 13-17 sett. 1988), Extended Abstracts v. A, pp. 441-444, Napoli.

Parker M.E., Clarck M., Wise S.W. jr., 1985 - *Calcareous nannofossils of Deep Sea Drilling Project sites 558 and 563, North Atlantic Ocean: biostratigraphy and distribution of Oligocene Braarudosphaerids*. In H. Bougault, S.C. Canda *et al.* (eds.), Init. Rep. Deep Sea Drill. Proj. (U.S. Government Printing Office), v. 82, pp. 559-589, Washington.

Patacca E., Scandone P., 1989 - *Post-Tortonian mountain building in the Apennines. The role of the passive sinking of a relic lithospheric slab*. In A. Boriani, M. Bonafede, G.B. Piccardo and G.B. Vai (eds.), The lithosphere in Italy. Advances in Earth Science Research. I. Nat. Comm. Int. Lith. Progr., Mid-term Conf. (Rome, 5-6 May 1987), Atti Conv. Lincei, v. 80, pp. 157-176, Roma.

Perch-Nielsen K., 1985 - *Cenozoic calcareous nannoplankton*. In H.M. Bolli, J.B. Saunders and K. Perch-Nielsen (eds.), Plankton Stratigraphy, Cambridge Univ. Press, pp. 427-553, Cambridge.

Perrone V., 1987 - *I depositi miocenici della dorsale di Monte Soprano (Appennino Campano): segnalazione di vulcanismo andesitico e nuova interpretazione*. Boll. Soc. geol. ital., v. 106, pp. 3-12, Roma.

Pescatore T., 1965a - *La facies di transizione nel gruppo di Monte Marzano*. Boll. Soc. natur. Napoli, v. 64, pp. 149-158, Napoli.

Pescatore T., 1965b - *Ricerche geologiche sulla depressione molisano-sannitica*. Atti Accad. Sci. Fis. Mat. Napoli, s. 3, v. 5(4), pp. 101-145, Napoli.

Pescatore T., Vallario A., 1963 - *La serie mesozoica nel gruppo del Monte Maggiore (Caserta)*. Mem. Soc. geol. ital., v. 4(2), 11 pp., Roma.

Pierattini D., Scandone P., Cortini M., 1975 - *Età di messa in posto ed età di metamorfismo delle "limburgiti" nord calabresi*. Boll. Soc. geol. ital., v. 94, pp. 367-376, Roma.

Pieri M., 1966. *Tentativo di ricostruzione paleografico-strutturale dell'Italia centro-meridionale*. Geologica rom., v. 5, pp. 407-424, Roma.

Pujos A., 1985 - *Cenozoic nannofossils, central equatorial Pacific, Deep Sea Drilling Project Leg 85*. In L. Mayer, F. Theyer *et al.* (eds.), Init. Rep. Deep Sea Drill. Proj. (U.S. Government Printing Office), v. 85, pp. 581-607, Washington.

Rio D., Fornaciari E., Raffi I., 1990 - *Late Oligocene through early Pleistocene calcareous nannofossils from western equatorial Indian Ocean*. In R. Duncan, J. Backman *et al.*, Proc. Ocean Drill. Progr., v. 115, Scient. Res., pp. 175-236, College Station.

Santo A., Senatore M.R., 1988 - *La successione stratigrafica dell'Unità Dauna a Monte Sidone (Castelluccio Valmaggiore-Foggia)*. Atti 74° Congr. Naz. Soc. geol. ital. (Sorrento 13-17 sett. 1988), Extended Abstracts, v. A, pp. 486-400, Napoli.

Santo A., Sgrosso I., 1988 - *La formazione del Torrente Raganello: secondo ciclo sedimentario miocenico nel gruppo del Pollino (Calabria)*. Boll. Soc. geol. ital., v. 107(2), pp. 413-424, Roma.

Sartoni S., Crescenti U., 1961 - *Ricerche biostratigrafiche nel Mesozoico dell'Appennino meridionale*. Giorn. Geol. s. 2a, v. 29, pp. 161-302, Bologna.

Scandone P., 1967 - *Studi di geologia lucana: la serie calcareo-silico-marnosa e i suoi rapporti con l'Appennino Calcareo*. Boll. Soc. natur. Napoli, v. 76, pp. 301-469, Napoli.

Scandone P., 1972 - *Studi di geologia lucana: carta dei terreni della serie calcareo-silico-marnosa e note illustrative*. Boll. Soc. natur. Napoli, v. 81, pp. 225-300, Napoli.

Scandone P., Bonardi G., 1968 - *Synsedimentary tectonics controlling deposition of Mesozoic and Tertiary carbonatic sequences of areas surrounding Vallo di Diano (Southern Apennines)*. Mem. Soc. geol. ital., v. 7, pp. 1-10, Roma.

Scandone P., Sgrosso I., Bruno F., 1963 - *Appunti di geologia sul Monte Bulgheria (Salerno)*. Boll. Soc. natur. Napoli, v. 72, pp. 19-27, Napoli.

Scandone P., Sgrosso I., Vallario A., 1967 - *Finestra tettonica nella serie calcareo-silico-marnosa lucana presso Campagna (Monti Picentini, Salerno)*. Boll. Soc. natur. Napoli, v. 76, pp. 247-254, Napoli.

Selli R., 1957 - *Sulla trasgressione del Miocene nell'Italia meridionale*. Giorn. Geol., v. 26, pp. 1-54, Bologna.

Selli R., 1962 - *Il Paleogene nel quadro della Geologia dell'Italia Meridionale*. Mem. Soc. geol. ital., v. 3, pp. 733-789, Roma.

Sgrosso I., 1966 - *Tentativo di ricostruzione paleogeografica nella zona di Vietri di Potenza con particolare riguardo alla trasgressione miocenica*. Boll. Soc. natur. Napoli, v. 75, pp. 463-495, Napoli.

Sgrosso I., 1981 - *Il significato delle calciruditi di Piaggine nell'ambito degli eventi del Miocene inferiore nell'Appennino campano-lucano*. Boll. Soc. geol. ital., v. 100, pp. 129-137, Roma.

Sgrosso I., Amore F.O., Ruggiero Taddei E., 1988 - *L'inizio della sedimentazione terrigena nel bacino molisano*. Boll. Soc. geol. ital., v. 107, pp. 73-79, Roma.

Signorini R., 1961 - *Osservazioni geologiche nell'alto Molise*. Boll. Soc. geol. ital., v. 80(3), pp. 215-224, Roma.

Signorini R., Devoto G., 1962 - *Il Paleogene nell'Alto Molise*. Mem. Soc. geol. ital., v. 3, pp. 461-522, Roma.

Theodoridis S., 1984 - *Calcareous nannofossils biozonation of the Miocene and revision of the Helicoliths and Discoasters*. Utrecht Micropaleont. Bull., v. 32, pp. 1-271, Utrecht.

Turco E., 1976 - *La finestra tettonica di Campagna (M. Picentini, Salerno)*. Boll. Soc. natur. Napoli, v. 85, pp. 639-651, Napoli.

VAIL P.R., MITCHUM R.M. jr., THOMPSON S. III, 1977 -*Seismic stratigraphy and global changes of sea level, Part 4: Global cycles and relative changes of sea level*. In C.E. PAYTON (ed.), Seismic stratigraphy. Application to hydrocarbon exploration, Mem. Am. Ass. Petr. Geol., v. 26, pp. 83-97, Tulsa.

VALLARIO A., DE' MEDICI G.B., 1967 - *Contributo alla conoscenza stratigrafica della Calabria Settentrionale. I: La serie del Colle Trodo*. Boll. Soc. geol. ital., v. 86, pp. 233-252, Roma.

WEZEL F.C., 1966 - *La "Cenozona a Globorotalia fohsi" nel flysch esterno della Lucania*. Riv. ital. Paleont. (Stratigr.), v. 72(4), pp. 1269-1296, Milano.

WEZEL F.C., 1970a - *Numidian Flysch: an Oligocene-early Miocene continental rise deposit off the African Platform*. Nature, v. 228(5268), pp. 275-276, London.

WENZEL F.C., 1970b - *Geologia del Flysch Numidico della Sicilia nord-orientale*. Mem. Soc. geol. ital., v. 9, pp. 225-280, Roma.

WEZEL F.C., 1973 - *Diacronismo degli eventi geologici oligo-miocenici nelle Maghrebidi*. Riv. min. sicil., n. 142-144, pp. 219-232, Palermo.

WEZEL F.C., 1974 - *Flysch succession and the tectonic evolution of Sicily during the Oligocene and Early Miocene*. In C. SQUIRES (ed.), Geology of Italy, Petroleum Explor. Soc. of Libya, pp. 105,127, Castelfranco Veneto.

WOOD A.W., 1981 - *Extensional tectonics and the birth of the Lagonegro Basin (Southern Italian Apennines)*. N. Jb. Geol. Paläont. Abh., v. 161(1), pp. 93-131, Stuttgart.

PLATES I-III

EXPLANATION OF PLATE I

Examples of planktonic foraminifers listed in Table 3.

Taxa recovered in the pre-Numidian, Numidian and post-Numidian intervals. Magnification x100

FIG. 1 - *Globigerina praebulloides* BLOW. Umbilical view. Tufillo Unit, San Felice, post-Numidian interval, EP 1091.

FIG. 2 - *Globigerinoides trilobus* (REUSS). Umbilical view. Daunia Unit, Carpineto di Sinello, Numidian interval, EP 1110.

FIGS. 3-4 - *Globoquadrina dehiscens* (CHAPMANN, PARR and COLLINS). 3 spiral view; 4 umbilical view. Tufillo Unit, San Felice, post-Numidian interval, EP 1091.

FIGS. 5-7 - *Globorotalia continuosa* BLOW. 5 spiral view; 6 lateral view; 7 umbilical view. Tufillo Unit, San Felice, post-Numidian interval, EP 1091.

FIG. 8 - *Globorotalia pseudocontinuosa* JENKINS. Lateral view. Tufillo Unit, San Felice, post-Numidian interval, EP 1090.

FIGS. 9-11 - *Globorotalia siakensis* LE ROY. 9 spiral view; 10 lateral view; 11 umbilical view. Tufillo Unit, San Felice, post-Numidian interval, EP 1091.

Taxa recovered in the Numidian and in the post-Numidian intervals. Magnification x100.

FIG. 12 - *Globigerina falconensis* BLOW. Umbilical view. Tufillo Unit, San Felice, post-Numidian interval, EP 1092.

FIG. 13 - *Globigerinoides bisphericus* TODD. Umbilical view. Daunia Unit, Carpineto di Sinello, Numidian interval, EP 1110.

FIG. 14 - *Globigerinoides subquadratus* BRÖNNIMANN. Umbilical view. Daunia Unit, Carpineto di Sinello, Numidian interval, EP 1110.

FIGS. 15-16 - *Globoquadrina langhiana* CITA and GELATI. 15 umbilical view; 16 lateral view. Tufillo Unit, San Felice, Numidian interval, EP 1089.

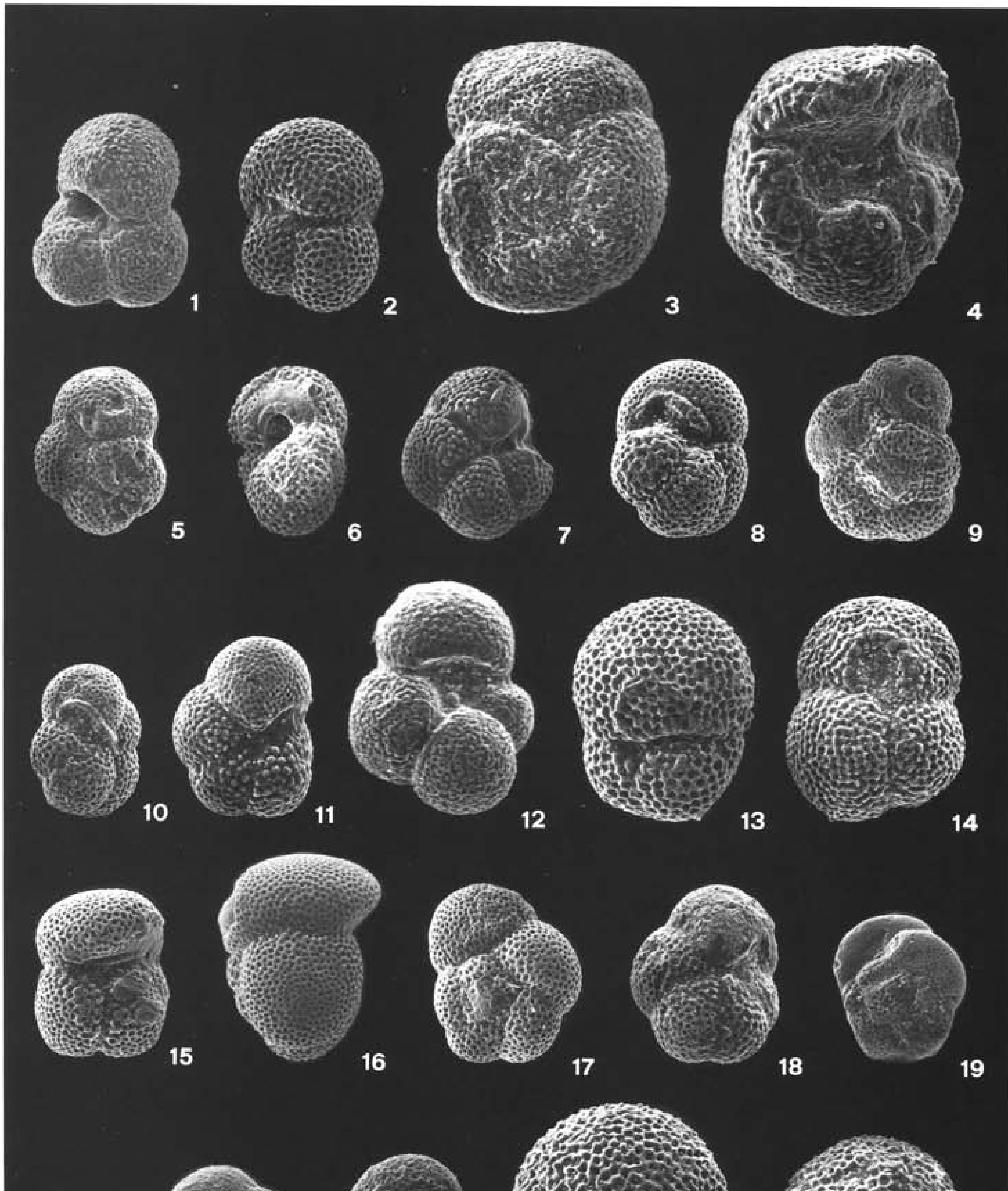
FIGS. 17-18 - *Globorotalia acrostoma* WEZEL. 17 spiral view. Tufillo Unit, San Felice, post-Numidian interval, EP 1092. 18 umbilical view. Tufillo Unit, San Felice, post-Numidian interval, EP 1091.

FIGS. 19-20 - *Globorotalia praescitula* BLOW. 19 spiral view; 20 lateral view. Tufillo Unit, San Felice, Numidian interval, EP 1089.

Taxa recovered in the post-Numidian interval. Magnification x 100.

FIGS. 21-22 - *Globorotalia mayeri* CUSHMAN and ELLISOR. 21 spiral view; 22 lateral view. Sannio Unit, Serra Cortina, post-Numidian interval, NP 2648.

FIGS. 23-24 - *Praeorbulina glomerosa sicana* (DE STEFANI). Lateral views. Sannio Unit, Serra Cortina, post-Numidian interval, NP 2649.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

EXPLANATION OF PLATE II

Examples of calcareous nannofossils listed in Table 3. Magnification x2200 ca.

FIGS. 1-4 - *Coronocyclus nitescens* (KAMPTNER, 1963) BRAMLETTE and WILCOXON, 1967
1, 2: same specimen, Tufillo Unit, San Felice, pre-Numidian interval, EP 1089; 1: crossed nicols, 2: parallel nicols.
3, 4: same specimen, Sannio Unit, Serra Cortina, post-Numidian interval, NP 2632; 3: crossed nicols, 4: parallel nicols.

FIGS. 5, 10, 15 - *Sphenolithus abies* DEFLANDRE in DEFLANDRE and FERT, 1954
5: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; crossed nicols.
10, 15: same specimen, Sannio Unit, Serra Cortina, post-Numidian interval, NP 2632; 10: crossed nicols, 15: parallel nicols.

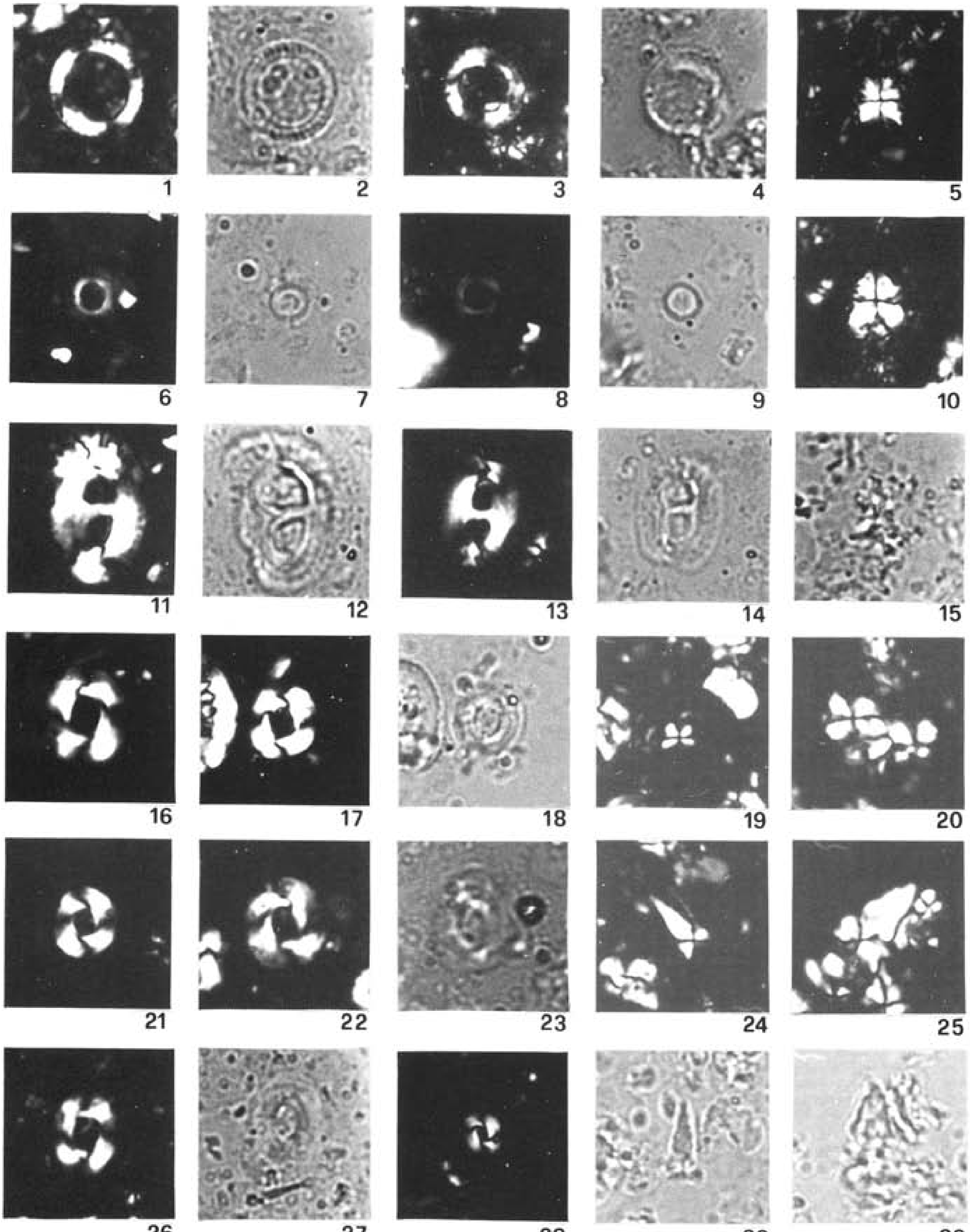
FIGS. 6-9 - *Geminilithella rotula* (KAMPTNER, 1956) BACKMAN 1980
6, 7: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; 6: crossed nicols, 7: parallel nicols.
8, 9: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; 8: crossed nicols, 9: parallel nicols.

FIGS. 11-14 - *Helicosphaera mediterranea* MÜLLER, 1981
11, 12: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; 11: crossed nicols, 12: parallel nicols.
13, 14: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; 13: crossed nicols, 14: parallel nicols.

FIGS. 16-18, 21-23, 26 - 27 - *Reticulofenestra pseudoumbilicus* (GARTNER, 1967) GARTNER, 1969
16: Sannio Unit, Ponte, post-Numidian interval, NP 2187; crossed nicols; lenght > 7 mμ
17, 18: same specimen, Sannio Unit, Ponte, post-Numidian interval, NP 2187; 17: crossed nicols; 18: parallel nicols; lenght 5-7 mμ
21: Sannio Unit, Ponte, post-Numidian interval, NP 2187; crossed nicols; lenght 5-7 mμ
22, 23: same specimen, Sannio Unit, Casone Cardillo, post-Numidian interval, NP 1640; 22: crossed nicols; 23: parallel nicols; lenght > 7 mμ
26, 27: same specimen, Tufillo Unit, Castiglione Messer Marino, Numidian interval, NP 1502; 26: crossed nicols; 27: parallel nicols; lenght 5-7 mμ.

FIG. 28 - *Reticulofenestra minutula* (GARTNER, 1967) HAQ and BERGGREN, 1978
Tufillo Unit, San Felice, Numidian interval, EP 1089; crossed nicols.

FIGS. 19, 24, 29, 20, 25, 30 - *Sphenolithus heteromorphus* DEFLANDRE, 1953
19, 24, 29: same specimen, Tufillo Unit, Castiglione Messer Marino, Numidian interval, NP 1502; 19: long axis O° to crossed nicols, 24: long axis 45° to crossed nicols, 29: parallel nicols.
20, 25, 30: same specimen, Alburno-Cervati Unit, La Raja del Pedale, Numidian interval, NP 2249; 20: long axis O° to crossed nicols, 25: long axis 45° to crossed nicols, 30: parallel nicols.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

EXPLANATION OF PLATE III

Examples of calcareous nannofossils listed in Table 3. Magnification x2200 ca.

FIGS. 1-8 - *Sphenolithus heteromorphus* DEFLANDRE, 1953
1-3: same specimen, Sannio Unit, Ponte, post-Numidian interval, NP 2187; 1: long axis 0° to crossed nicols, 2: long axis 45° to crossed nicols, 3: parallel nicols.
4, 5: same specimen, Lagonegro Unit, Sant'Angelo Le Fratte, pre-Numidian interval, NP 2357; 4: long axis 0° to crossed nicols, 5: long axis 45° to crossed nicols.
6-8: same specimen, Sannio Unit, Ponte, post-Numidian interval, NP 2187; 6: long axis 0° to crossed nicols, 7: long axis 45° to crossed nicols, 8: parallel nicols.

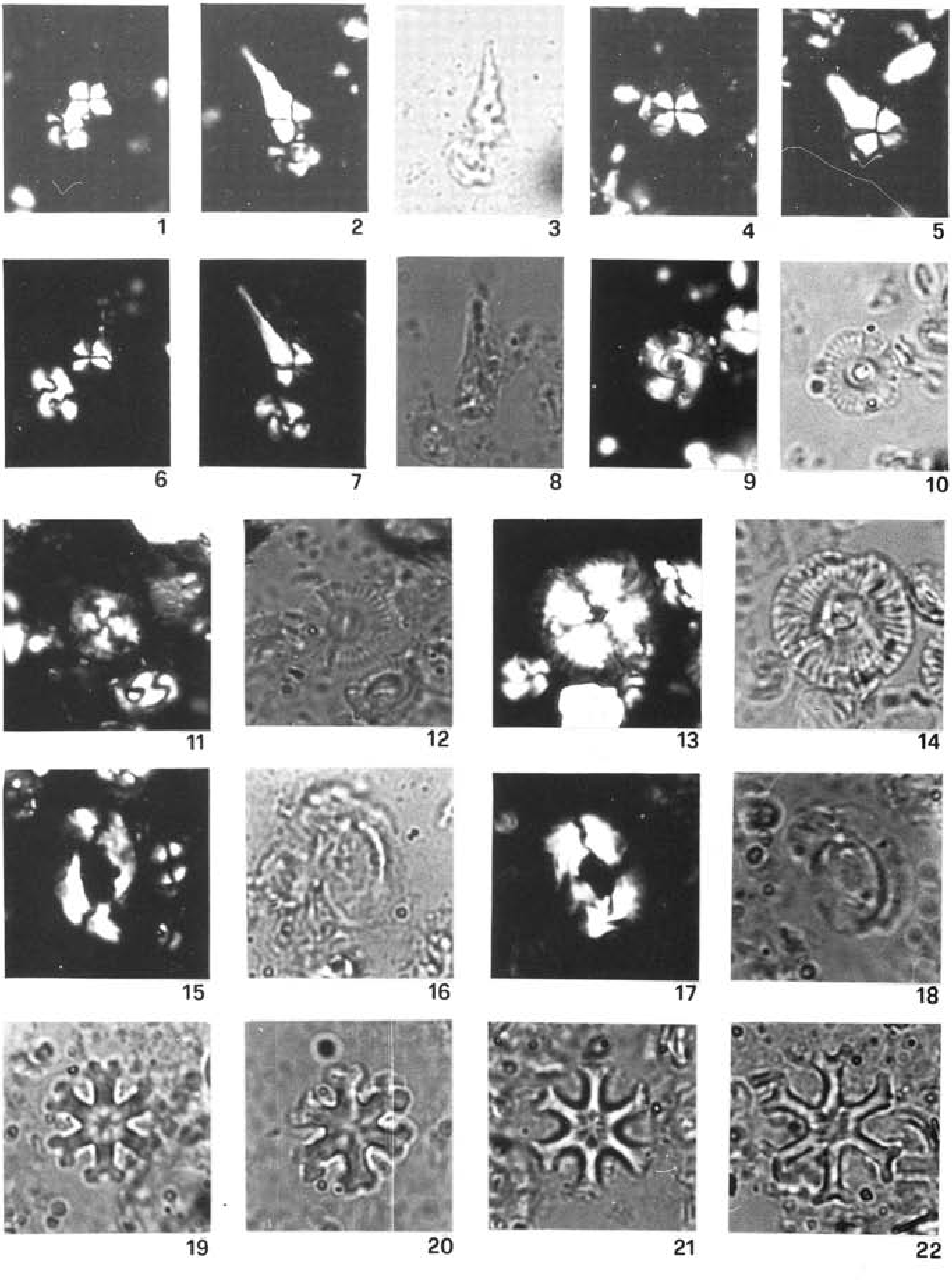
FIGS. 9-12 - *Calcidiscus leptoporus* (MURRY and BLACKMAN, 1898) LOEBLICH and TAPPAN, 1978
9-10: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; 9: crossed nicols, 10: parallel nicols.
11, 12: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; 11: crossed nicols, 12: parallel nicols.

FIGS. 13-14 - *Calcidiscus macintyrei* (BUKRY and BRAMLETTE, 1969) LOEBLICH and TAPPAN, 1978
13, 14: same specimen, Daunia Unit, Carpineto di Sinello, Numidian interval, EP 1110; 13: crossed nicols, 14: parallel nicols.

FIGS. 15-18 - *Helicosphaera ampliaperta* BRAMLETTE and WILCOXON, 1967
15, 16: same specimen, Tufillo Unit, Castiglione Messer Marino, Numidian interval, EP 1502; 15: crossed nicols, 16: parallel nicols.
17, 18: same specimen, Tufillo Unit, San Felice, Numidian interval, EP 1089; 17: crossed nicols, 18: parallel nicols.

FIGS. 19-20 - *Discoster deflandrei* BRAMLETTE and RIEDEL, 1954
19: Tufillo Unit, San Felice, Numidian interval, EP 1089; parallel nicols.
20: Sannio Unit, Casone Cardillo, post-Numidian interval, EP 1642; parallel nicols.

FIGS. 21-22 - *Discoaster variabilis* MARTINI and BRAMLETTE 1963
21: Tufillo Unit, San Felice, Numidian interval, EP 1089; parallel nicols.
22: Tufillo Unit, San Felice, Numidian interval, EP 1089; parallel nicols.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22