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Dinoflagellate cysts from the Miocene of Sardinia (Italy)

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KEY WORDS — Dinoflagellates, Miocene, Sardinia.

ABSTRACT — Dinoflagellate cysts occur in Miocene sediments from Sardinia. Five sequences are examined and lists of dinocyst assemblages are given.

Biostratigraphic remarks tend to provide the basis for a cyst stratigraphy. The paleoecological significance of the dinoflagellate cyst assemblages is discussed with particular emphasis on the evolution of the oligo-miocenic sardinian rift.

RIASSUNTO — [Cisti di dinoflagellati del Miocene della Sardegna] — Viene qui dato l'elenco delle cisti di dinoflagellati provenienti da cinque sezioni del Miocene inferiore e medio della Sardegna centro-meridionale. Considerazioni biostratigrafiche preliminari tendono ad individuare taxa di possibile valore stratigrafico.

L'importanza paleoecologica delle associazioni a cisti di dinoflagellati viene messa in risalto dall'evoluzione geologica del bacino originato dalla frattura sarda oligo-miocenica.

Published papers dealing with Miocene dinoflagellate cysts are limited in number. If few of them concern with the Mediterranean Neogene, none regarde the Sardinia is Miocene dinocysts.

The present work wants to contribution these previously ignored Miocene dinocysts from Sardinia. The studied assemblages belong to five Miocene sequences, which samples are the same analyzed by others researchers in preparation of the 19th European Micropaleontological Colloquium (see this volume).

Additional lithological and biostratigraphical informations can be found in the guide-book of the Colloquium.

Sections considered in this investigation are four from the Marmilla region, Middle-southern Sardinia (Ales, Sardara-Villanovaforru, Gesturi-Giara, and Tuili-Giara), and one from the Campidano region (Cave N Sestu), South Sardinia. The location of the sections is shown in Text-fig. 1.

GEOLOGICAL REMARKS

The Marmilla sections consist of sediments deposited in a basin belonging to the Sardinian easternmost arm of the complex rift system that affected the western Mediterranean area during the Oligo-Miocene. The basin extends longitudinally N-S for about 220 km, from Asinara Gulf to Cagliari Gulf, and is 40-50 km large.

Most of the Oligo-Miocene Sardinian rift deposits were never involved in neotectonic movements, thus permitting accurate stratigraphic and structural studies. Biostratigraphic data on the Oligo-Miocene sediments of the rift margin allow to reconstruct the evolutionary history of the whole west Mediterranean area (Cherchi & Montadert, 1982, 1984).

The Sardinian rift system has been active from Middle Oligocene to Aquitanian and the phases of opening and evolution of the rift are testified by the

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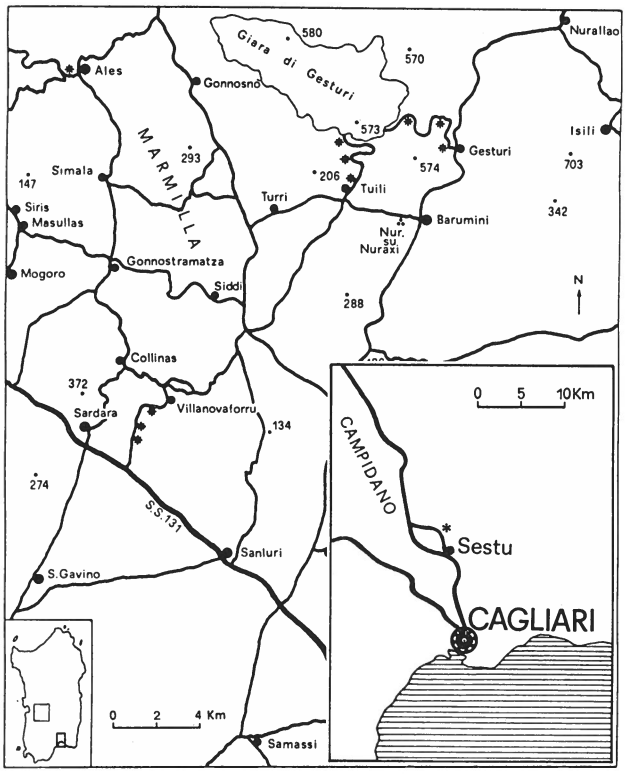

Text-fig. 1 - Location maps showing the outcrops (*) of the studied Sections.

pre-rift littoral and paralic-continental sediments, by the *sin-rift* marine sediments, and finally by the *post-rift* unfaulted marine sediments.

By the end of the tensive phase, in Burdigalian time, there is a general deepening of the basin, related either to eustatic changes of sea level or to increased subsidence caused by cooling after the rifting phase (Cherchi & Montadert, 1984). Sedimentation continues uninterrupted until the Late Miocene: sediments of other age outcrop in the Sinis peninsula (West Sardinia) where they are represented by shallow-water deposits (Cherchi & Montadert, 1982, 1984). The marine sediments of Oligo-Miocene age deposited in the basin are estimated to be about 1000 m thick.

The Campidano section examined in the present work becomes from an area of the Oligo-Miocene Sardinian rift which was involved later in the formation of the Campidano graben (eastern margin of the Paleozoic Massif in the Iglesiente-Sulcis area) in Plio- Pleistocene time.

THE STUDIED SECTIONS

ALES SECTION (AC). The section crops out near Ales village, along the road running from Ales to Gemma Spina. The sequence consists of marls, with interbedded coarser layers (slumping or debris flow) rich in macroforaminifera, especially in the lower part of the section.

Samples 7 and 6 belongs to the lower part of the Nannoplankton zone NN1, while Samples 5-4 belong to the NN1-NN2 zone. Dinocysts are present in Samples 7, 6, 5, 4 ter, and 4. The identified species are plotted in Tab. 1.

EXPLANATION OF PLATE 1

Fig. 1 - *Gonyaulacysta tenuitabulata* (Gerlach, 1961), Slide AC 15/28, Ales Section.
Fig. 2 - *Homothryblium* cf. *pallidum* Pais 1978. Slide AC 15/37, Ales Section.
Fig. 3 - *Lingulodinium machaerophorum* (Deflandre & Cookson 1955) = *Cleistosphaeridium disjunctum* Davey *et al.* Slide AC 16/6, Ales Section.
Fig. 4 - *Systematophora ancyrea* Cookson & Eisenack 1965. Slide AC 16/4, Ales Section.
Fig. 5 - *Apteodinium* sp. Slide SV 18/6, Sardara-Villanovaforru Section.
Fig. 6 - *Operculodinium pseudorecurvatum* (Morgenroth 1966) Stover & Evitt 1978. Slide SV 16/23, Sardara-Villanovaforru Section.
Fig. 7 - *Tuberculodinium* sp. Slide SV 18/19, Sardara-Villanovaforru Section.
Fig. 8 - *Pentadinium taeniagerum* Gerlach 1961. Slide TG 5/30, Tuili-Giara Section.
Fig. 9 - *Chiropteridium dispersum* Gocht 1960. Slide S 17/2, Cave N Sestu Section.
Fig. 10 - *Chiropteridium lobospinosum* (Gocht, in Weiler 1956). Slide S 1/5, Cave N Sestu Section.
Figs. 11a,b - *Hystrichokolpoma*? sp. a) Apical wiev. b) Antapical view. Slide S 2/5, Cave N Sestu Section.
Fig. 12 - *Hystrichokolpoma rigaudae* Deflandre & Cookson 1965. Slide S 2/19, Cave N Sestu Section.
Fig. 14 - *Operculodinium* sp. Slide S 1/1, Cave N Sestu Section.
Fig. 15 - *Spiniferites membranaceus* (Rossignol 1964). Slide S 1/18, Cave N Sestu Section.
All figures are x 400.

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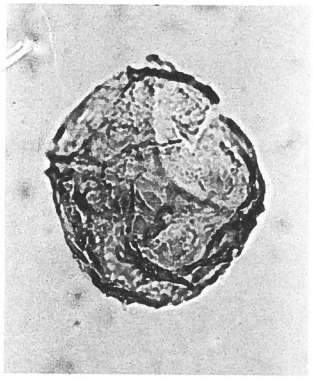

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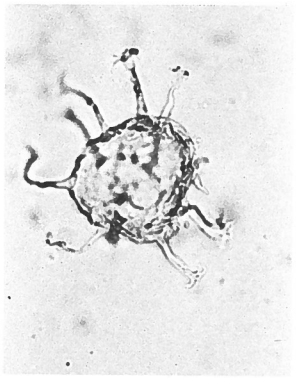

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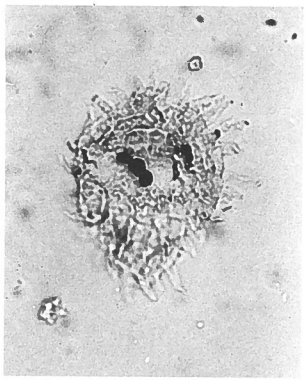

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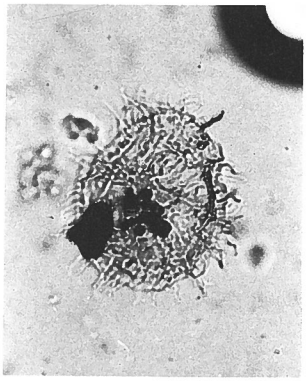

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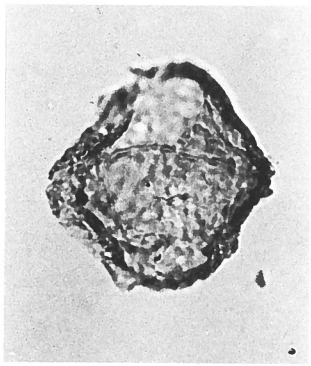

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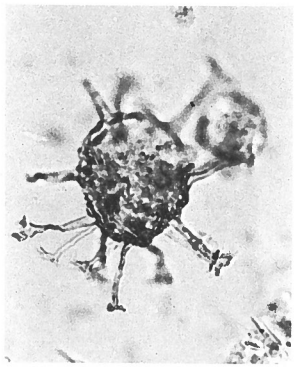

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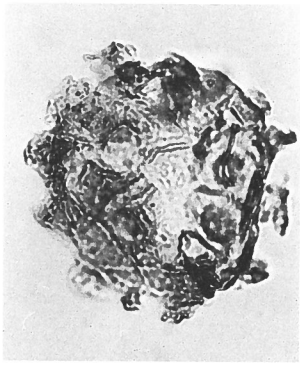

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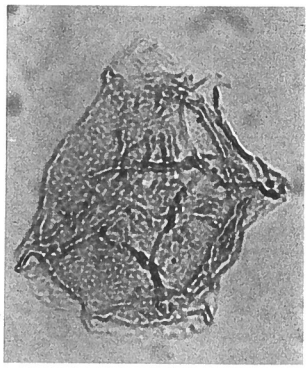

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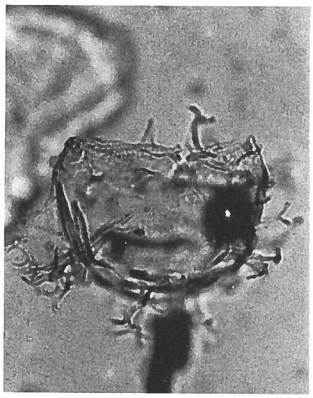

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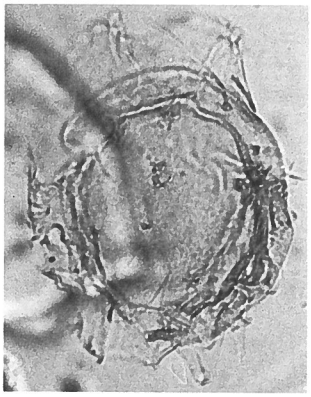

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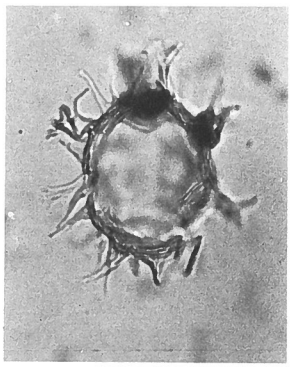

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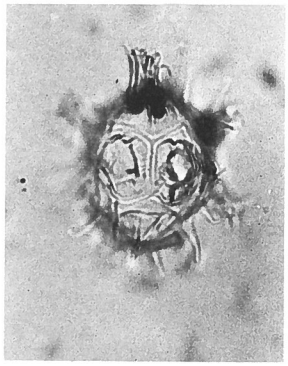

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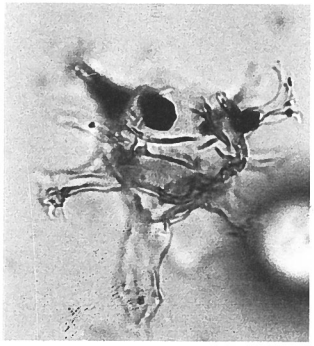

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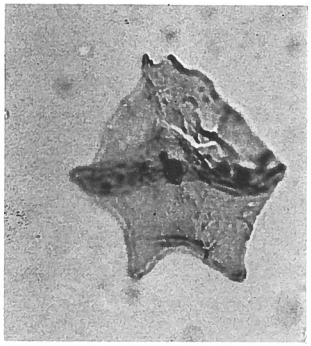

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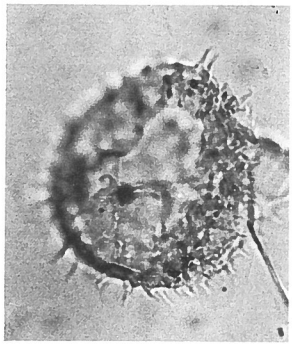

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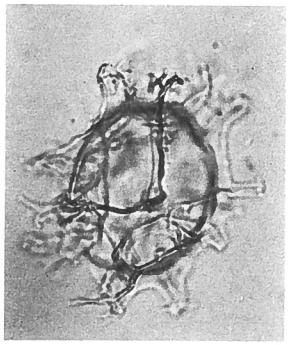

Nannoplankton Zone	NN1 low.		NN1-NN2		
Species / Samples	7	6	5	4ter	4
Gonyaulacysta tenuitabulata (Gerlach 1961)				x	
Gonyaulacysta sp.	x	x	x	x	x
Homothryblium cf. *pallidum* Pais 1978	x	x	x	x	
Hystrichokolpoma rigaudae Deflandre & Cookson 1955	x				
Hystrichokolpoma sp.	x	x		x	
Impagidinium sp.	x				
Lingulodinium machaerophorum (Deflandre & Cookson 1955)		x			
Operculodinium sp.1		x	x	x	
Operculodinium sp.	x			x	x
Pentadinium taeniagerum Gerlach 1961				x	
Spiniferites pseudofurcatus (Klumpp 1953)	x	x		x	
Spiniferites sp.	x	x		x	
Systematophora ancyrea Cookson & Eisenack 1965		x			
Systematophora placacantha (Deflandre & Cookson 1955)	x	x		x	x
Wetzeliella sp.	x	x			

Tab. 1 - Distribution of dinoflagellate cysts from Ales Section, Sardinia.

SARDARA - VILLANOVAFORRU SECTION (SV). The section crops out along the road running from Sardara to Villanovaforru.

The section consists, mainly, in the lower part of sandstones and conglomerates. Marls and marly sandstones prevail in the middle of the sequence. The upper 100 metres consist of marls also, interbedded with tuffs and tufaceous sandstones. Samples α and β belong to the lower part of Nannoplankton zone NN1; Samples 1 to 21 belong to the Nannoplankton zone NN1-NN2; Samples 22 to 29 belong to the Nannoplankton zones NN2-NN3. Dinoflagellate cysts are present in samples α, β, 2,2 bis, 6, 8, 9, 10, 19, 22, 25, 26, 29. The identified species are plotted in Tab. 2.

GESTURI-GIARA SECTION (GG). The section crops out along the road running from Gesturi village to Giara high plain (Giara is the regional name of the Quaternary basalt covering).

Marls prevail in the sequence but sandstones and tuffs are also present. Beds of « Calcari a Litotamni » indicate episodic low sea level conditions. The sequence is covered by basalts.

Samples 1-3 and GG ferrovia belong to Nannoplankton zone NN3, while Samples 4 to 18 are attributable to NN4 zone. Dinocysts are present in Samples 4, 5, 12, 15, 16 and 17. The identified species are plotted in Tab. 3.

Nannoplankton Zone	NN1 low.		NN1-NN2							NN2-NN3				
Species / Samples	α	β	2	2bis	6	8	9	10	19	20	22	25	26	29
Apteodinium sp.							x	x			x		x	
Chiropteridium aspinatum (Gerlach 1961)								x	x					
Gonyaulacysta tenuitabulata (Gerlach 1961)											x		x	
Gonyaulacysta sp.							x							
Hystrichokolpoma rigaudae Deflandre & Cookson 1955						x	x							
Hystrichokolpoma sp.						x	x	x			x	x		x
Hystrichosphaeridium? palmatum (White 1842)														x
Hystrichosphaeridium sp.									x				x	x
Lingulodinium sp.							x							
Operculodinium sp.B			x										x	
Operculodinium sp.	x		x			x		x		x	x	x	x	
Spiniferites pseudofurcatus (Klumpp 1953)			x				x	x			x		x	
Spiniferites sp.		x	x				x				x			
Systematophora ancyrea Cookson & Eisenack 1965					x		x		x		x	x		
Systematophora placacantha (Deflandre & Cookson 1955)							x							
Tectatodinium sp.													x	
Tuberculodinium vancampoae (Rossignol 1962)							x							
Wetzeliella sp.								x						
Wetzeliella (Dracodinium)? sp.				x										

Tab. 2 - Distribution of dinoflagellate cysts from Sardara-Villanovaforru Section, Sardinia.

Nannoplankton Zone	NN3	NN4					
Species / Samples	1	4	5	12	15	16	17
Achomosphaera sp.					x		
Areoligera sp.					x		
Chiropteridium sp.					x	x	
Gen. et sp. ind. A				x			
Gen. et sp. ind. B					x		
Hystrichokolpoma rigaudae Deflandre & Cookson 1955					x		
Leptodinium membranigerum Gerlach 1961					x		
Impagidinium sp.					x		
Lingulodinium machaerophorum (Deflandre & Cookson 1955)			x				x
Operculodinium spp.			x		x		x
Spiniferites pseudofurcatus (Klumpp 1953)					x	x	x
Spiniferites sp.B			x				
Spiniferites sp.		x	x				
Systematophora sp.			x		x		
Tuberculodinium vancampoae (Rossignol 1962)					x		

Tab. 3 - Distribution of dinoflagellate cysts from Gesturi-Giara Section, Sardinia.

TUILI-GIARA SECTION (TG). The section crops out along the road running from Tuili village to Giara high plain, on the opposite side of the same valley as the previous Gesturi-Giara Section.

The sequence of marls, silty marls and marly sandstones is interbedded by arenaceous and tufaceous layers. Limestones and calcarenites are present at the top of the sequence, some metres below the Quaternary basaltic cover. Samples 1-3 belong to the Nannoplankton zone NN3, while Samples 4 to 25 belong to NN4 zone. Dinocysts are present in samples 1, 2, 4, 5, 6, 8, 10, 12, 14, 15, 16, 17, 20, 21 and 22. The identified species are plotted in Tab. 4.

CAVE N SESTU SECTION (S). The section crops out in a quarry near Sestu (North of Cagliari) and is represented by a 30 metres marly sequence.

Samples belong to the Nannoplankton zone NN5. Dinocysts are present in Samples 5, 4, 3. The identified species are plotted in Tab. 5.

PREVIOUS WORKS ON DINOFLAGELLATES

A review of the few works on Miocene dinoflagellate cysts published in the last few years can start with the paper of Habib (1971) who described dinocysts from sediments across the Miocene/Pliocene boundary at the Tabiano type-section (Northern Italy). Williams & Brideaux (1975) erected an informal zonation based on dinoflagellate cyst assemblages from Mesozoic and Cenozoic sediments of the Nova Scotian Shelf and Grand Banks.

Nannoplankton Zone	NN3			NN4												
Species / Samples	1	2	3	4	5	6	8	10	12	14	15	16	17	20	21	22
Achomosphaera sp.							x						x			
Apteodinium sp.							x									
Areoligera sp.				x						x						
Chiropteridium spp.		x		x			x		x	x		x		x		x
Deflandrea phosphoritica Eisenack 1938													x			
Hystrichokolpoma? sp.	x									x	x	x	x	x		
Hystrichosphaeridium sp.	x										x	x				
Hystrichosphaeropsis ovum Deflandre 1935										x						
Impagidinium patulum (Wall 1967)												x				
Litosphaeridium siphoniphorum (Cookson & Eisenack 1958)									x							
Operculodinium sp.B									x	x	x					
Operculodinium sp.D										x						
Operculodinium sp.				x				x	x	x	x				x	
Pentadinium taeniagerum Gerlach 1961							x									
Spiniferites incertus (Klumpp 1953)						x										
Spiniferites pseudofurcatus (Klumpp 1953)							x				x					
Spiniferites? sp.A					x											
Spiniferites? sp.B														x		
Spiniferites spp.		x			x	x	x		x	x		x		x		
Systematophora sp.										x			x	x	x	x
"Thalassiphora delicata" Williams & Downie 1966										x	x					

Tab. 4 - Distribution of dinoflagellate cysts from Tuili-Giara Section, Sardinia.

Nannoplankton Zone	NN5		
Species \ Samples	5	4	3
Achomosphaera sp.	2	3	6
Areoligera sp.		1	
Chiropteridium dispersum Gocht 1960		1	2
Chiropteridium lobospinosum (Gocht,in Weiler,1956)		1	1
Deflandrea phosphoritica Eisenack 1938	1		
Gonyaulacysta? sp.		4	2
Hemicystodinium zohari (Rossignol 1962)		1	2
Hemicystodinium? sp.A		1	
Hystrichokolpoma rigaudae Deflandre & Cookson 1965		1	8
Hystrichokolpoma sp.A		4	
Hystrichokolpoma sp.		2	
Hystrichosphaeridium? palmatum (White 1842)		2	
Hystrichosphaeropsis ovum Deflandre 1935		1	
Impagidinium patulum (Wall 1967)		6	
Lejeuniecysta sp.	2		
Lingulodinium machaerophorum (Deflandre & Cookson 1955)		5	1
Litosphaeridium siphoniphorum (Cookson & Eisenack 1958)		2	2
Operculodinium sp.A	2	11	
Operculodinium sp.B			7
Operculodinium sp.C		3	23
Operculodinium sp.D	1	11	
Operculodinium sp.	2		13
Spiniferites membranaceus (Rossignol 1964)		8	2
Spiniferites mirabilis (Rossignol 1962)			2
Spiniferites pseudofurcatus (Klumpp 1953)	6	6	14
Spiniferites sp.A	10	13	21
Spiniferites sp.B		9	
Spiniferites sp.C		9	2
Spiniferites sp.D			5
Spiniferites spp.	9	32	45
Systematophora placacantha (Deflandre & Cookson 1955)		12	20
Tectatodinium sp.		2	
Tuberculodinium sp.	1	1	

Tab. 5 - Distribution of dinoflagellate cysts from Cave N Sestu Section, Sardinia.

Manum (1976) published on Miocene dinoflagellate cysts from the Norwegian-Greenland Sea, establishing a tentative zonation. Corradini (1978) published a short note on Miocene dinocysts from the Mediterranean DSDP Site 372.

Pais (1978) gave a first report on dinoflagellate cysts from lowermost Miocene beds of Portugal. Harland (1979) proposed a Neogene and Quaternary dinoflagellate biostratigraphy starting from the Middle Miocene (NN7 Nannoplankton zone) while Costa & Downie (1979) constructed a range chart based on the occurrence of Cenozoic Dinocysts from two sites drilled on the Rockall Plateau (DSDP Sites 403 to 406).

Piasecki (1980) finally proposed a dinocyst biostratigraphic scheme for the Hodde and Gram Formations of Denmark of Middle and Late Miocene age.

BIOSTRATIGRAPHIC REMARKS

Dinoflagellate cyst assemblages collected for the present investigation are in general poorly preserved, which state of preservation prevented some taxonomical investigations. Many morphotypes have been identified confidently as known species and named accordingly. Other morphotypes need more detailed morphological studies and are here informally named.

Species lists are arranged alphabetically because any biostratigraphic scheme based on dinoflagellate cyst distributions is considered premature.

Most of the species are present throghout the sequences but a few ones have a restricted occurrence. These restricted occurrence may provide a basis of a cyst stratigraphy for the area under study when more complete sequences and more detailed observations will be made.

At the moment, even if some species appear to be of stratigraphic utility in identifying Miocene strata, their appearance or disappearance may be caused by local environmental changes. Some remarks are here presented.

ALES SECTION. The dinocyst assemblage is charachterized by the occurrence of *Homothryblium* cf. *pallidum* Pais (1978), a form reported only from probably coeval sediments of Portugal. Limited to the interval corresponding to the NN1-NN2 Nannoplankton zone are *Systematophora ancyrea* and *Gonyaulacysta tenuitabulata*. The occurrence of dinoflagellate cysts from Ales Section is plotted in Tab. 1.

SARDARA-VILLANOVAFORRU SECTION. The assemblages of this sequence cannot be directly compared to the assemblages of Ales Section even forms such as *S. ancyrea, G. tenuitabulata* and *Hystrichokolpoma rigaudae* are common to both sections (Tab. 2).

Dinocysts are badly preserved and they do not seem to belong to stratigraphically interesting taxa. No meaningful differences are noted between NN1-NN2 and NN2-NN3 dinocyst assemblages.

No stratigraphical remarks may be made at the moment for the Gesturi- and Tuili-Giara Sections (Tabs. 3, 4). Cave N Sestu dinocyst assemblages instead request a more detailed study of some taxa, probably new (Tab. 5).

ENVIRONMENTAL INTERPRETATIONS

Paleoenvironmental interpretations based on dinoflagellate cysts suggest some interesting results. The relationships between dinocysts and paleoenvironment have been investigated since 1971 (Downie *et al.*).

Data of Wall *et al.* (1977) and Harland (1983) are particularly useful in interpreting the Quaternary and Recent dinoflagellate record. Because the Miocene dinoflagellate cyst assemblages have many species in common with recent sediments, their interpretations of Recent assemblages may be applied to the Miocene record.

Concerning the factors that affect and limit the occurrence of dinoflagellates, the reader can refer to Harland (1983, p. 374).

In Ales Section the dominating species (*Homothryblium* cf. *pallidum, Gonyaulacysta tenuitabulata, Hystrichokolpoma rigaudae* and *Lingulodinium machaerophorum*) also occur in the lowermost Miocene beds from Portugal (Pais, 1978).

These occurrences, associated with that of oceanic forms such as *Impagidinium* sp. and *Operculodinium* spp. suggest that at least during the depositional time of the lower part of the Ales Section, the western Mediterranean was under a possible Atlantic influence.

Representatives of the genus *Spiniferites* are known to have as a preferential habitat the neritic environment (Harland, 1983). Their scarcity in the Sardara-Villanovaforru assemblages would suggest that a possible influx of oceanic (?) current prevented the neritic conditions suitable to *Spiniferites* to establish during the opening of the Sardinian rift.

On the other hand, the great abundance of pollens and of terrestrial plant debris, and the more or less constant dinocyst/sporomorph ratios in the same samples from SV Section would suggest that the shoreline was quite proximal, implying that the rift at that time was poorly open.

The development of neritic and more open marine conditions in the Sardinian basin is, instead, testified in the Gesturi- and Tuili-Giara Sections by a decrease of the amount of pollen and by the presence of the *Operculodinium* and *Spiniferites* groups.

Finally the assemblages of Cave N Sestu display a great dinocyst species diversity. The increase in diversity concerns mainly the tropical and temperate neritic fossil groups. That may suggest a somewhat definite establishment of stable neritic conditions and a decreasing influence of Atlantic cooler currents. The abundance and large diversity of *Spiniferites* spp. in the Campidano sequence agree with such interpretation, this cosmopolitan group inhabiting preferentially the neritic environment.

More detailed observations on the Sardinian Oligo-Miocene rift Sections and a revision of Miocene dinoflagellate cysts from DSDP 372 are in progress in order to better correlate stratigraphically the eastern and western margins of the western mediterranean basin (v. fig. 4, Cherchi & Montadert, 1984).

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