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NOTA BREVE

MIDDLE PLIOCENE CETACEANS FROM MONTE VOLTRAIO (TUSCANY, ITALY). BIOSTRATIGRAPHICAL, PALEOECOLOGICAL AND PALEOCLIMATIC OBSERVATIONS

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Riassunto. Viene esaminata la collezione storica di odontoceti (Cetacea) fossili del Monte Voltraio vicino a Volterra (Toscana) e viene condotta un'indagine litostratigrafica e biostratigrafica nella località di ritrovamento. L'affioramento di Monte Voltraio è attribuito al Pliocene medio, in particolare alle zone a *Globorotalia aemiliana* e *Discoaster tamalis*. I resti di odontoceti vengono riferiti alle famiglie Kogiidae (*Kogia pusilla*) e Delphinidae (*Globicephala? etruriae* e due reperti indeterminati che potrebbero appartenere a *Hemisyntrachelus* e a *Stenella giulii*). La fauna a cetacei del Pliocene medio del bacino Mediterraneo (associazioni di Monte Voltraio e di Rio Stramonte) include taxa estinti o attualmente assenti in questo bacino. La loro scomparsa potrebbe essere messa in relazione ai deterioramenti climatici pliocenici e/o quaternari (per esempio, la crisi climatica intorno a 2.6-2.4 MA).

Abstract. The historic collection of fossil odontocetes (Cetacea) from Monte Voltraio, near Volterra (Tuscany, Italy) has been examined and lithostratigraphical and biostratigraphical investigations on the find locality have been carried out. The Monte Voltraio outcrop is referred to the Middle Pliocene, in particular to *Globorotalia aemiliana* and *Discoaster tamalis* zones. The odontocete remains are assigned to the families Kogiidae (*Kogia pusilla*) and Delphinidae (*Globicephala? etruriae* and two indeterminate specimens which might belong to *Hemisyntrachelus* and *Stenella giulii*). The Middle Pliocene cetacean fauna from the Mediterranean basin (Monte Voltraio and Rio Stramonte associations) includes extinct taxa or extant taxa no longer represented in this basin. The disappearance of these taxa may be linked with the Pliocene and/or Quaternary climatic deteriorations (e.g. the climatic crisis at about 2.6-2.4 MA).

Introduction.

Some historic collections and new finds of fossil cetaceans from Italian Pliocene sediments have recently been examined (Bianucci, 1996a-b, 1997a-c).

The new systematic interpretation of these records confirmed a basic renewal of the Mediterranean fauna during the Pliocene with respect to the archaic Miocene cetacean association, already pointed out by Bianucci & Landini (1991, 1992).

These studies also documented the presence during the Pliocene of some extinct taxa or extant taxa no longer represented in the Mediterranean sea. These taxa disappeared from the Mediterranean basin in the course of the Pliocene and/or of the Quaternary. The evolution of these Mediterranean representatives during the last 5 MA is unknown and possible events of extinction and/or renewal events, at present, are not recognized. This is due to the fact that most of these fossils were collected in the second half of nineteenth century without reliable stratigraphic reference.

This paper is a biostratigraphical study aimed to shed new light on the evolution of the Pliocene cetaceans of Mediterranean basin.

Materials and methods.

The four cetacean fossils examined make part of the Lawley Collection, which includes many other cetacean remains collected from Pliocene sediments of Tuscany (Pilleri, 1987). These specimens are preserved in the Museum of Geology and Palaeontology of the University of Florence (IGF). Although incomplete and fragmentary, these specimens are relatively significant from both a systematic (two of them are the holotypes and the only known records of fossil species) and from a stratigraphical point of view (the fossils are very close in age). These specimens had been collected in the nineteenth century from Pliocene sediments outcropping at "La Rocca", locality on Monte Voltraio, a hill 458 m above sea level about 2 km east of Volterra (province of Pisa) (Fig. 1).

The systematic analysis of cetacean fossils was completed by a geological and biostratigraphical study of the Monte Voltraio outcrop. A section representative of the whole depositional sequence of this area was examined and sampled. Twenty-nine samples were collected for micropaleontological analysis (foraminifera and calca-

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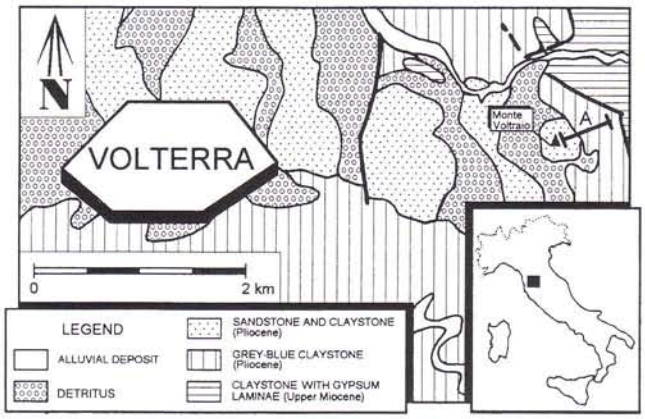


Fig. 1 - Location of Monte Voltraio cetacean assemblage. A = studied section.

reous nannofossils). The small amount of matrix still preserved on the fossil specimens was also sampled for nannofossils.

The abundance of the species of *Discoaster* was noted in the samples in which 10 or more specimens of this genus were counted. At the latest 100 specimens were counted in the samples with very abundant *Discoaster* (Backmann & Schakleton, 1983; Rio et al., 1990).

The planktonic foraminiferal zonal scheme of Iaccarino & Salvatorini (1982) followed in other papers concerning the Pliocene sediments of Tuscany (Bossio et al., 1995) was also followed here. The calcareous nannofossil zonation is by Rio et al. (1990).

Geological and biostratigraphical setting.

The extensional basin of Volterra is filled by upper Miocene-Quaternary sequences (Sarti & Testa, 1994; Bossio et al., 1995). Pliocene deposits outcrop at Monte Voltraio. They consist of grey claystones (called "Pag" on the *Foglio 12* of the 1/100,000 National Geological Cartography) at the bottom, and by yellow sandstones at the top. The studied section is exposed to SE of Monte Voltraio; here the succession has an average thickness of 150 m (Fig. 2). The first 100 m at the base of the section are grey massive silty claystone. Moving upward the sand content increases rapidly, and after few alternating sand and clay layers yellow medium-fine sands outcrop at the top of the sequence. Three decimetric levels of well cemented grey bioclastic (bivalves and gastropods mainly) calcarenites are present in the uppermost part of the section. The foraminiferal assemblage is suggestive of a transition from an outer-inner neritic zone (basal-medium part of the section) to a littoral zone (upper part of the section). In particular the associations are diversified and abundant in the samples collected from the lowest part of the section (P\B ratio 1\10-1\5). In the samples from the middle and upper part there is a progressive replacement of planktonic foraminifers and of benthic taxa from the deepest environments by littoral benthic assemblages. Therefore the section represents a coarsening and shallowing upward sequence. The genera *Scyphosphaera* and *Pontosphaera*, both belonging to the family Pontosphaeracae, are particularly well represented in the nannofossil assemblage. These taxa indicate neritic and emipelagic environments (Perch-Nielsen, 1985), which is consistent with the foraminiferal datum.

From a biostratigraphical point of view, the presence in the studied section of *Globorotalia crassaformis crassaformis* associated with *Globorotalia bononiensis* and *Globorotalia aemiliana* in the claystone part of the sequence suggests a reference to the lower part of *Globorotalia crassaformis crassaformis* subzone (upper part of *Globorotalia aemiliana* zone) and therefore this part of sequence is dated Middle Pliocene.

The calcareous nannofossil association is referable to the *Discoaster tamalis* zone. In fact, in the samples where the *Discoaster* is relatively frequent, the identified species of this genus (*D. surculus*, *D. tamalis*, *D. asymmetricus*, *D. brouweri*, *D. intercalaris*, *D. pentaradiatus*, *D. triradiatus*) show abundance comparable to those of *Discoaster tamalis* zone of the western Mediterranean basin reported by Rio et al. (1990).

Zonal markers are lacking in the upper part of section where littoral conditions are reached. Detailed regional biostratigraphical studies carried out in Tuscany (Bossio et al., 1995) show that the regressive upper part of the Pliocene deposits can be entirely included in *Globorotalia aemiliana* zone. The Upper Pliocene deposits (*Globorotalia inflata* zone) are indeed lacking in Tuscany because of a general uplift of the whole area.

The calcareous nannofossil assemblage contained in a sample collected from the sediment preserved on the fossil delphinid IGF 1562V is referable to the same zone (*Discoaster tamalis*) identified in the studied section of Monte Voltraio. The samples collected from the sediment on the others fossil cetaceans either are sterile or bear biostratigraphicaly insignificant calcareous nannofossil associations.

Systematic palaeontology.

Class Mammalia Linnaeus, 1758

Order Cetacea Brisson, 1762

Suborder Odontoceti Flower, 1867

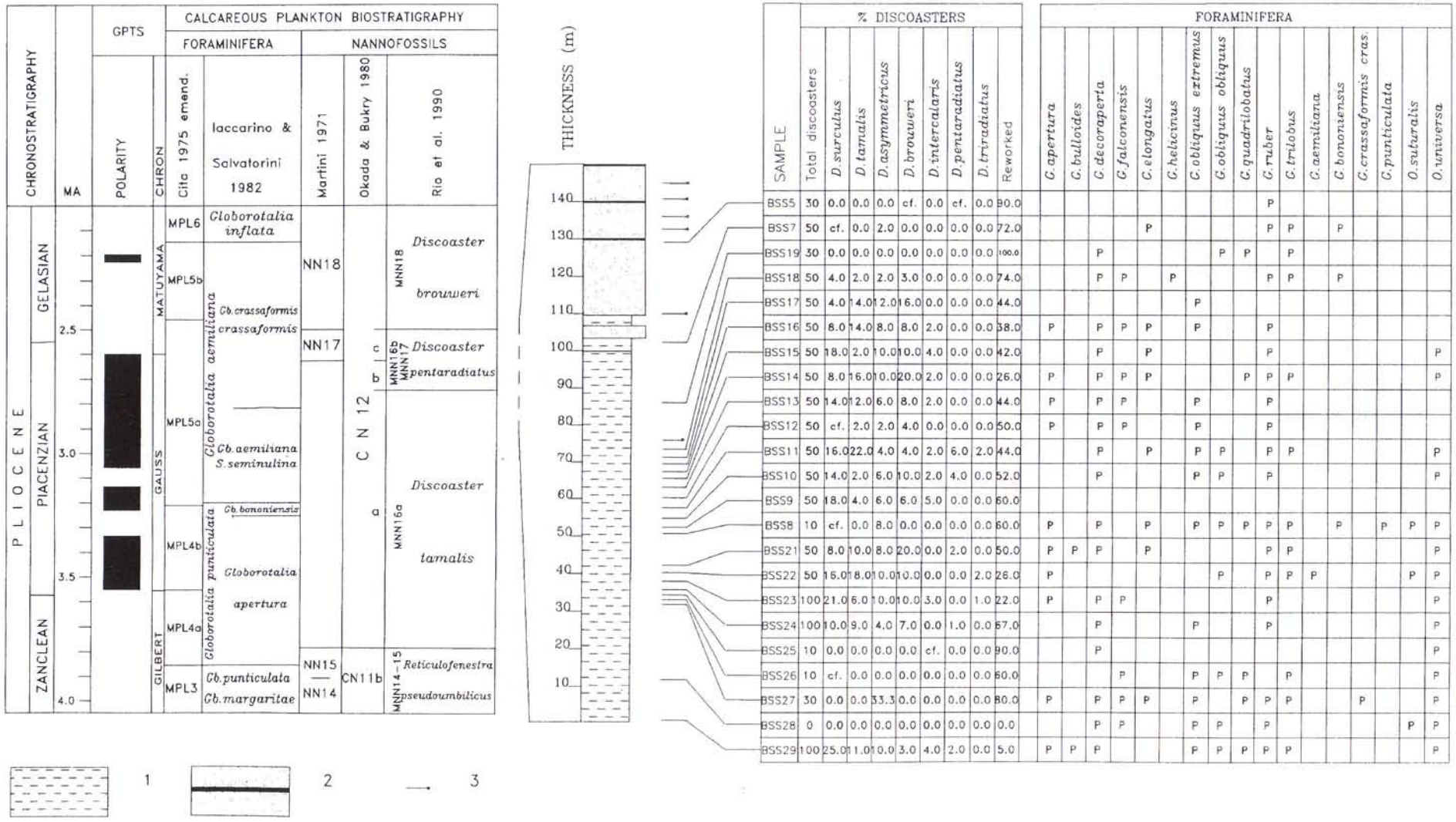
Family *Kogiidae* (Gill, 1871) Miller, 1923

Genus *Kogia* Gray, 1846

Kogia pusilla (Pilleri, 1987)

(Fig. 3a1-a2)

1893 *Placoziphius*, V. Beneden - Capellini, pp. 287-288.
1987 *Hyperoodon pusillus* Pilleri, pp. 35-36, fig. 11, pl. 13.
1997c *Kogia pusilla* (Pilleri) - Bianucci, pp. 172-173, fig. 6.



SAMPLE	% DISCOASTERS: Total discoasters	D. surculus	D. tamalis	D. asymmetricus	D. brouweri	D. intercalaris	D. pentaradiatus	D. tridradiatus	Reworked	FORAMINIFERA: G. apertura	G. bulloides	G. decoraperta	G. falconensis	G. elongatus	G. helicinus	G. obliquus extremus	G. obliquus obliquus	G. quadrilobatus	G. ruber	G. trilobus	G. aemiliana	G. bononiensis	G. crassaformis cras.	G. punticulata	O. suturalis	O. universa
BSS5	30	0.0	0.0	0.0	cf.	0.0	cf.	0.0	90.0										P							
BSS7	50	cf.	0.0	2.0	0.0	0.0	0.0	0.0	72.0					P					P	P		P				
BSS19	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0			P					P	P		P						
BSS18	50	4.0	2.0	2.0	3.0	0.0	0.0	0.0	74.0			P	P		P				P	P		P				
BSS17	50	4.0	14.0	12.0	16.0	0.0	0.0	0.0	44.0							P										
BSS16	50	8.0	14.0	8.0	8.0	2.0	0.0	0.0	38.0	P		P	P	P		P			P							
BSS15	50	18.0	2.0	10.0	10.0	4.0	0.0	0.0	42.0			P		P					P							P
BSS14	50	8.0	16.0	10.0	20.0	2.0	0.0	0.0	26.0	P		P	P	P				P	P	P						P
BSS13	50	14.0	12.0	6.0	8.0	2.0	0.0	0.0	44.0	P		P	P			P			P							
BSS12	50	cf.	2.0	2.0	4.0	0.0	0.0	0.0	50.0	P		P	P			P			P							
BSS11	50	16.0	22.0	4.0	4.0	2.0	6.0	2.0	44.0			P		P		P	P		P	P						P
BSS10	50	14.0	2.0	6.0	10.0	2.0	4.0	0.0	52.0			P				P	P		P							P
BSS9	50	18.0	4.0	6.0	6.0	5.0	0.0	0.0	60.0																	
BSS8	10	cf.	0.0	8.0	0.0	0.0	0.0	0.0	60.0	P		P		P		P	P	P	P	P		P		P	P	P
BSS21	50	8.0	10.0	8.0	20.0	0.0	2.0	0.0	50.0	P	P	P		P					P	P						P
BSS22	50	16.0	18.0	10.0	10.0	0.0	0.0	2.0	26.0	P							P		P	P	P				P	P
BSS23	100	21.0	6.0	10.0	10.0	3.0	0.0	1.0	22.0	P		P	P						P							P
BSS24	100	10.0	9.0	4.0	7.0	0.0	1.0	0.0	67.0			P				P			P							P
BSS25	10	0.0	0.0	0.0	0.0	cf.	0.0	0.0	90.0			P														P
BSS26	10	cf.	0.0	0.0	0.0	0.0	0.0	0.0	60.0				P			P	P	P		P						P
BSS27	30	0.0	0.0	33.3	0.0	0.0	0.0	0.0	80.0	P		P	P	P		P		P	P	P			P			P
BSS28	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			P	P			P	P		P						P	P
BSS29	100	25.0	11.0	10.0	3.0	4.0	2.0	0.0	5.0	P	P	P				P	P	P	P	P						P

Fig. 2 - Chronostratigraphy, biostratigraphy and lithology for the Monte Voltraio section. The most significant species of genus *Discoaster* and their percentage abundance for calcareous nannofossils and the recognized species for planktonic foraminifera are reported. 1 = silty claystone, 2, sandstone with decimetric levels of well cement grey bioclastic (black); 3 = sample sterile or with biostratigaraphically insignificant fauna. Geomagnetic Polarity Time Scale after Cande & Kent (1992).

The skull (IGF1540V) is slightly deformed and lacks of part of the right side and of ventral portion of braincase. This specimen was originally referred to a ziphiid by Capellini (1893) and Pilleri (1987), but actually belongs to the Kogiidae (Bianucci, 1997c). It represents the only preserved fossil skull of pigmy sperm whale of the genus *Kogia*. It is the holotype and the only known record of the extinct species *Kogia pusilla* (Pilleri, 1987). *Kogia pusilla* differs from living *K. simus* and *K. breviceps* in having a more elongated rostrum, a smaller antorbital process, and an apparently more marked dorsal asymmetry. The posterior portion of the cranium is also slightly more uplifted. A detailed description of this species will appear in a future paper (Bianucci, in preparation).

Family *Delphinidae* Gray, 1825
Genus *Globicephala* Lesson, 1828

Globicephala ? etruriae (Pilleri, 1987)
(Fig. 3b1-b3)

1987 *Globicephala etruriae* Pilleri, pp. 28-30, pl. 6.
1996b *Globicephala? etruriae* (Pilleri) - Bianucci, pp. 98-99, fig. 33, pl. 9, fig. 3-5.

The incomplete mandible lacks the posterior parts of the rami but still bearing 30 teeth in place (IGF 1675V). Pilleri (1987) choose this specimen as holotype of the extinct delphinid species *Globicephala etruriae*. This mandible (the only known record of *G. etruriae*) differs from the mandible of living pilot whales (*Globicephala melas* and *G. macrorhynchus*) in its smaller size and in larger number of teeth. The Monte Voltraio fossil may belong, however, to a different genus from that of the two living species (Bianucci, 1996b).

Delphinidae indet.

1987 *Tursiops* sp. - Pilleri, p. 44.

Fourteen complete teeth and seventeen fragments of teeth (IGF 1562V) were referred to *Tursiops* sp. by Pilleri (1987), but are morphologically and dimensionally similar to the teeth of *Hemisyntrachelus*, a delphinid which lived in the Mediterranean sea during the Pliocene (Bianucci, 1996b, 1997a, 1997b). Isolated teeth are however inadequate for generic determination.

Delphinidae indet.

1987 Odontoceti *Gen. et sp. indet.* - Pilleri, pp. 47-48, fig. 13.

Seven cervical and the first two thoracic vertebrae, belonging to of the same animal (IGF 1548V), all lack the neural and transverse processes. Pilleri (1987, pp. 47-48) referred this find to "Odontoceti *Gen. et sp. indet*" (*sic*). The atlas and the axis are fused and the other cervical vertebrae have small and very flatten corpora; the thickness of the corpora increase in the first two thoracic vertebrae. These vertebrae are illustrated by Pilleri (1987, fig. 13) although he misinterpreted the fused atlas and axis as the first cervical vertebra (and consequently in Pilleri's illustration there is only one thoracic vertebra). The atlas is similar to but larger than that of *Stenella* sp. from the Pliocene of Tuscany (Bianucci, 1996b). These vertebrae might belong to the relatively large-size dolphin *Stenella giulii*, an extinct species represented by only four finds from Pliocene sediments of Orciano (Tuscany). The calcareous nannofossil content of the sediment preserved on three of these fossil specimens of *Stenella giulii* (one, the holotype, has been lost) was analysed. The sediment on one of these specimens (IGF 1541V) contained a biostratigraphically insignificant nannofossil assemblage, while the assemblages of the samples from the other two specimens (MC CF1, IGF 1545V) are attributable to the same nannofossil zone (*Discoaster tamalis*) found in the Monte Voltraio outcrop. These biostratigraphical data support the hypothesis of the presence of *Stenella giulii* in the Monte Voltraio sediments.

Discussion and conclusion.

The bathymetric analysis of foraminiferal and nannofossil associations indicate the transition from the inner-outer neritic to the littoral zone. There is an apparent discrepancy between the environmental conditions documented by the plankton and the pelagic habitat indicate by *Kogia* and the delphinid near *Globicephala*. The Recent species of these cetaceans live on the continental slope and feed in the bathyal environment. Long drifting of the carcasses from pelagic water to near coast environment may have occurred after death. Prolonged carcass transportation has actually been observed in present-day cetaceans (Shäfer, 1972); such an explanation has already been advocated to explain the odd presence of a fossil pelagic whale in a shallow water environment (Bianucci, 1996a).

The odontocete cetacean assemblage from Monte Voltraio can be referred to a restricted time span in biostratigraphical terms, ranging from approximately 3 to 2.6 MA. This is the same interval in which the clayed marls of Rio Stramonte in Piacenza province were deposited (Monegatti & Ranieri, 1987; Monegatti, pers. com.). These clays yielded fossil remains of cetaceans in the past (Bianucci, 1997b; Cigala Fulgosi, 1990; Del Prato, 1897, 1900). The two associations together shed new light on the Middle Pliocene cetacean fauna of the Mediterranean basin (Tab. 1).

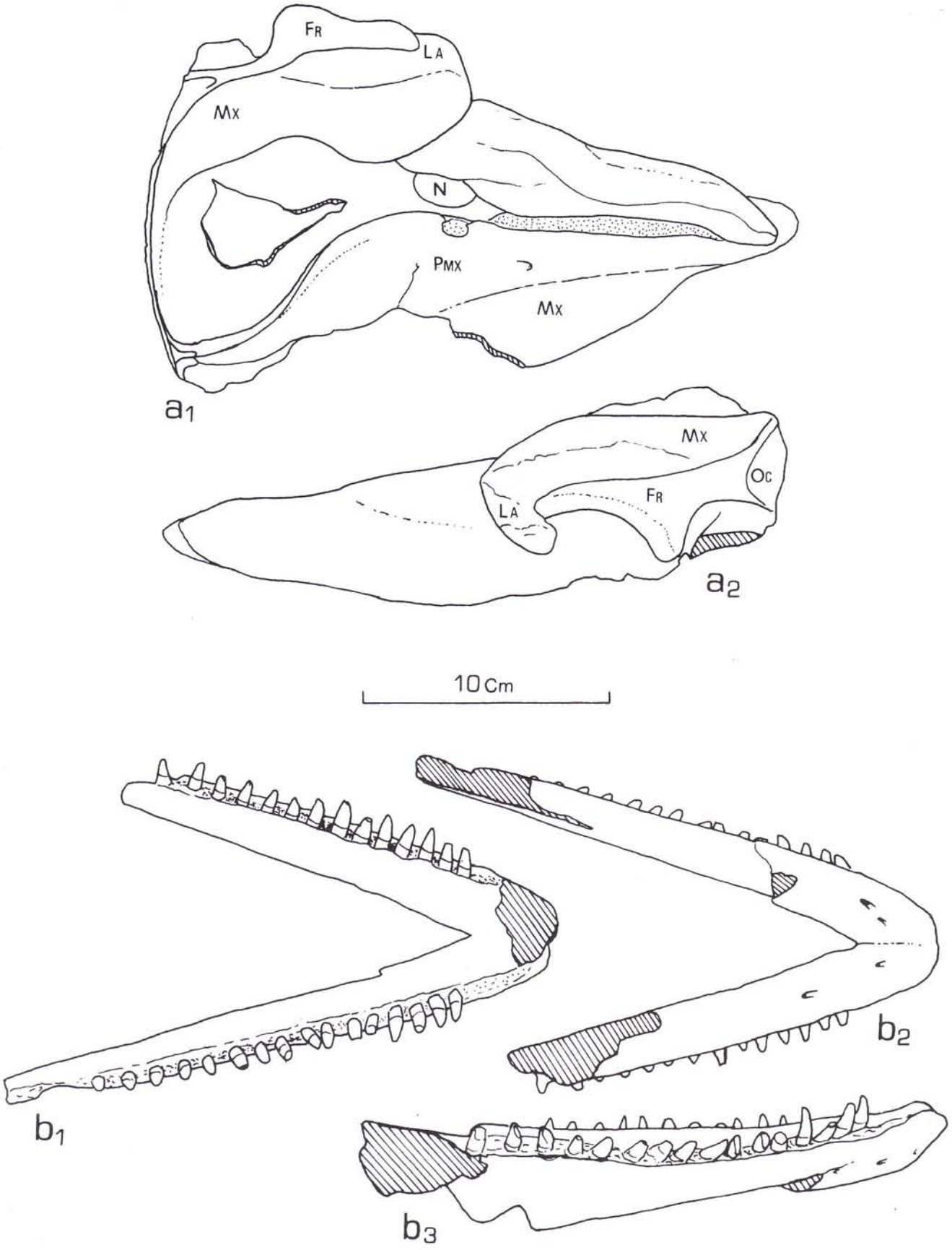


Fig. 3 - Odontocete remains from Middle Pliocene sediments of Monte Voltraio (Tuscany). a_1, *Kogia pusilla* (Pilleri, 1987), incomplete skull in dorsal view; a_2, the same in lateral view; b_1, *Globicephala? etruriae* (Pilleri, 1987), incomplete mandible in dorsal view; b_2, the same in ventral view; b_3, the same in lateral view. Fr = frontal, La = lacrimal; Mx = Maxilla; N = external nares, Pmx = premaxilla.

	Monte Voltraio	Rio Stramonte
Suborder Odontoceti		
Family Delphinida		
Globicephala? etruriae	X	
Hemisyntrachelus cortesii		X
Hemisyntrachelus sp.	?	X
Stenella giulii	?	
Family Kogiidae		
Kogia pusilla	X	
Suborder Mysticeti		
Family Balaenidae		
Balaena paronai		X

Tab. 1 - Middle Pliocene cetaceans from Monte Voltraio (Tuscany) and Rio Stramonte (Emilia Romagna).

The three families recognized are still living, although two (Kogiidae and Balaenidae) are no longer represented in the Mediterranean sea.

The listed taxa include both living (*Kogia*, *Balaena* and probably *Stenella*) and extinct genera (*Hemisyntrachelus* and a delphinid near *Globicephala*). *Kogia* and *Balaena*, as are their families, are missing today from the Mediterranean sea. All of these taxa are extinct at the specific level.

These data indicate that the Mediterranean cetacean association of Middle Pliocene differed from the extant one in composition and structure.

Pliocene and/or Quaternary phases of climatic deterioration (and consequently changes in water circulation, in the water productivity and in the food availability) might have caused the extinction of some Middle Pliocene cetaceans. The effects of climatic changes and of other correlated factors are already associated with variations in cetacean distribution (Barnes, 1974; Davies, 1963; Fordyce, 1980, 1984; Fordyce & Barnes, 1994; Gaskin, 1976; Whitmore, 1994). In particular, food availability seems to have an important control on the structure and composition of cetacean communities (Fordyce, 1996; Lipps & Mitchell, 1976). As regards, the co-occurrence of a delphinid near *Globicephala* and of *Kogia* (both fed on squids in the bathyal environment) in the Middle Pliocene Monte Voltraio association, indicate that the teutophag trophic resource was probably larger than that existing today. The analysis of isolated periotics from Lower-Middle Pliocene sediments of Tuscany confirms the presence of kogiids and teuthophag delphinids (probably *Globicephala* and *Grampus*, see Bianucci, 1996b) in the Mediterranean earlier than the Late Pliocene. *Kogia* today shows an almost cosmopolitan distribution (Caldwell & Caldwell, 1989) and its absence from the Mediterranean might be due to the scarce food supply and to the competition with teuthophag delphinids (*Grampus*, *Globicephala* and *Pseudorca*).

The climatic deteriorations in the Mediterranean basin have been dated and calibrated on the basis of extinction events of molluscs (Raffi & Monegatti, 1992; Raffi et al., 1985) and benthic foraminifera (Sprovieri, 1986). A possible change in the Mediterranean cetacean communities may have occurred at the time of the intense climatic crisis which is detected at about 2.6-2.4 MA (approximately correlatable with the upper deposition boundary of Monte Voltraio and Rio Stramonte outcrops). According to Landini & Menesini (1988), this climatic deterioration caused the extinction of *Bregmaceros* (teleost, fish) from the Mediterranean Basin. This extinction episode of molluscs, foraminifera and fishes has been correlated with the first major glacial event of the northern hemisphere (Thunell & Williams, 1983).

A better calibration of cetacean extinction events with and climatic changes will be possible when systematic and biostratigraphical studies of other Mediterranean cetacean assemblages (particularly from the Late Pliocene and Quaternary) are carried out.

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