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JEAN MARIE CORDY (*), SERGIO GINESU (**), ANDRE OZER (***) & STEFANIA SIAS (**)

GEOMORPHOLOGICAL AND PALAEOGEOGRAPHICAL CHARACTERISTICS OF THE OREOPITHECUS SITE OF FIUME SANTO (SASSARI, NORTHERN SARDINIA ITALY)

ABSTRACT: CORDY J.M., GINESU S., OZER A. & SIAS S., *Geomorphological and palaeogeographical characteristics of the Oreopithecus site of Fiume Santo (Sassari, Northern Sardinia, Italy).* (IT ISSN 0391-9838, 1995).

There is a summary of the first results obtained in the study of the area of Fiume Santo, where there has been the discovery of a site of Oreopithecus bambolii of the Upper Miocene. The investigation has identified a rich fossiliferous deposit of a fluvial delta environment, which has substantial faunistic analogies with the famous deposit of the Tuscan Maremma. However, among the 14 continental animal species identified so far, there are some which have never been found before either in Sardinia or in Tuscany. The palaeogeographical reconstruction has allowed identification in the Nurra of a hydrographic network far more important than that existing today, within a landscape of hilly dome-like relief linked by extensive plains in a morphoclimatic environment of sparse savannah.

KEY WORDS: Geomorphological evolution, Vertebrates, Late Tertiary, Fiume Santo, Sardinia (Italy).

RIASSUNTO: CORDY J.M., GINESU S., OZER A. & SIAS S., *Caratteri geomorfologici e paleogeografici del sito ad Oreopiteco di Fiume Santo (Sassari, Sardegna settentrionale).* (IT ISSN 0391-9838, 1995).

Vengono riassunti i primi risultati ottenuti nello studio dell'area di Fiume Santo dove è stato rinvenuto il sito ad *Oreopitheco bambolii* del Miocene superiore. L'indagine condotta ha permesso di identificare un ricco giacimento fossilifero di ambiente fluvio deltizio che presenta sostanziali analogie faunistiche con il celebre giacimento della Maremma toscana. Tuttavia fra le 14 specie di animali continentali finora individuate ve ne sono anche alcune mai segnalate prima oltre che in Sardegna anche in Toscana. La ricostruzione paleogeografica ha permesso di riconoscere nella Nurra una rete idrografica molto più importante rispetto a quella attuale inserita in un paesaggio di rilievi collinari cupoliformi raccordati da superfici pianeggianti in un ambiente morfoclimatico di rada savana.

TERMINI CHIAVE: Evoluzione geomorfologica, Vertebrati, Tardo Terziario, Fiume Santo, Sardegna.

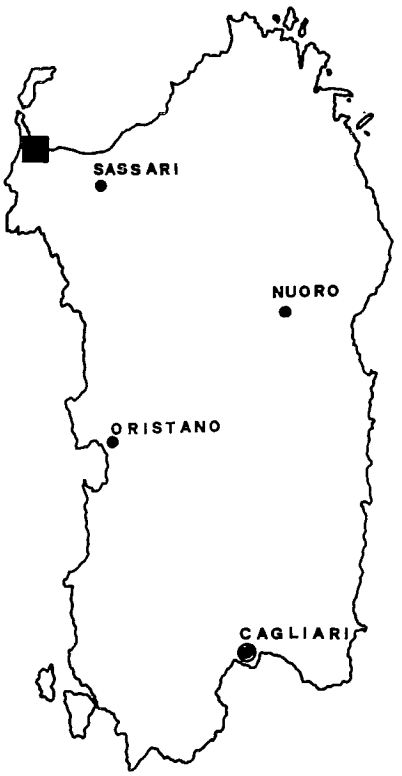

FIG. 1 - The study area

INTRODUCTION

During surveying in the industrial area of Fiume Santo, along the western coastline of Porto Torres, the remains of bones were found in a sandy-arenaceous forma-

(*) FNRS Unité de Recherche «Evolution des Vertébrés et Evolution Humaine». Universitè de Liège, Belgique.
(**) Istituto di Scienze Geologico Mineralogiche, Università di Sassari, Italia.
(***) Laboratoire de Gèomorphologie, Universite de Liège, Belgique.
Work carried out within the Murst Project 40% «Mountains and Plains: structural geomorphology and evolution in Italy and in Mediterranean areas». (Resp. P.R. Federici).

FIG. 2 - The landscape of this part of the Nurra di Porto Torres is characterised by inselbergs and pediment erosional surfaces initially produced by the intense karstic activity of the hot humid climate of the end of the Miocene.

tion. The discovery was made thanks to a deep excavation carried out for the construction of a depot for heavy vehicles in the area of the thermo-electric power station of the Italian State Electricity Board, *Ente Nazionale per L'Energia Elettrica* (ENEL). The building is known as the «Bulldozer building». These fossils were the object of particular attention because they were able to give, for the first time, a dating to the detrital cover present in the area of Nurra, known in the literature as Plio-quaternary deposits (CORDY & GINESU, 1993).

On the basis of this discovery a special group was formed with researchers from the Universities of Sassari and Liège, already collaborating on a long-term basis as regards some aspects of the recent evolution of Sardinia. The objective of this special research group was to better identify the episodes of environmental modification occurring in the Nurra area during the Late-Tertiary.

The most interesting result of the present research has been the identification of a particularly rich and well-conserved fauna, including remains attributed to a still enigmatic primate, *Oreopithecus*. This primate has so far only been found in the lignitic deposits of the Tuscan Maremma region. Due to these discoveries it has been possible to obtain a dating and an excellent opportunity for stratigraphic comparison between this area and the rest of North-West Sardinia. It also offers an important contribution to the evolutionary study of the fauna of the Tertiary period and of Primates in particular.

GEOGRAPHICAL BACKGROUND

The basin of the Fiume Santo is in the north-west of Sardinia, and is bordered by the highlands of the Argentiera and the hilly terrain of the region known as Alta Nurra di Porto Torres, near the mouth of the Rio of Fiume Santo in the Gulf of Asinara., The area essentially consists of a gently rolling hill morphology whose altitude is no greater than 300-450 m in the higher parts of the basin. Near the mouth of Fiume Santo altitudes are between 100 and 150 m (Mt. Elva 115 m), with hills modelled in the Mesozoic rocks (fig. 2). There is a great difference of landscape features across the area. In the west there is the outcrop of the gently rolling and modelled schist Palaeozoic bed. In the middle and coastal area there is low relief with rounded landforms, formed by Mesozoic outcrops.

These relief types suddenly join up with the gently sloping surface of a glaçis, which has a gradient of a few degrees as far as the hinterland of Nurra di Alghero and Porto Torres, and is already present in the cartography (OZER, 1976; GINESU, 1983). The surface also includes the Tertiary formations, which present a gently sloping landscape in continuity with the surface of the Mesozoic rocks.

It is interrupted by incisions of streams (rio of Fiume Santo, rio of San Nicola), best visible at the passage between the Tertiary and Mesozoic formations. Upriver the landscape is cut by wide gullies.

The short length of coastline of the Fiume Santo basin is today greatly modified by the impact of man, it being a densely industrialised area. In particular, in the area of the old Cuile di Fiume Santo there are two large plants for the production of electrical energy, an almost completed coal duct, and just to the east the industrial area of Porto Torres with the vast petrolchemical complex of Enichem.

GEOLOGICAL BACKGROUND

Sedimentary and metamorphic deposits predominate in the study area. The Palaeozoic is represented almost exclusively by metamorphic rocks. The Mesozoic consists of carbonate formations, whereas the Tertiary is made up of

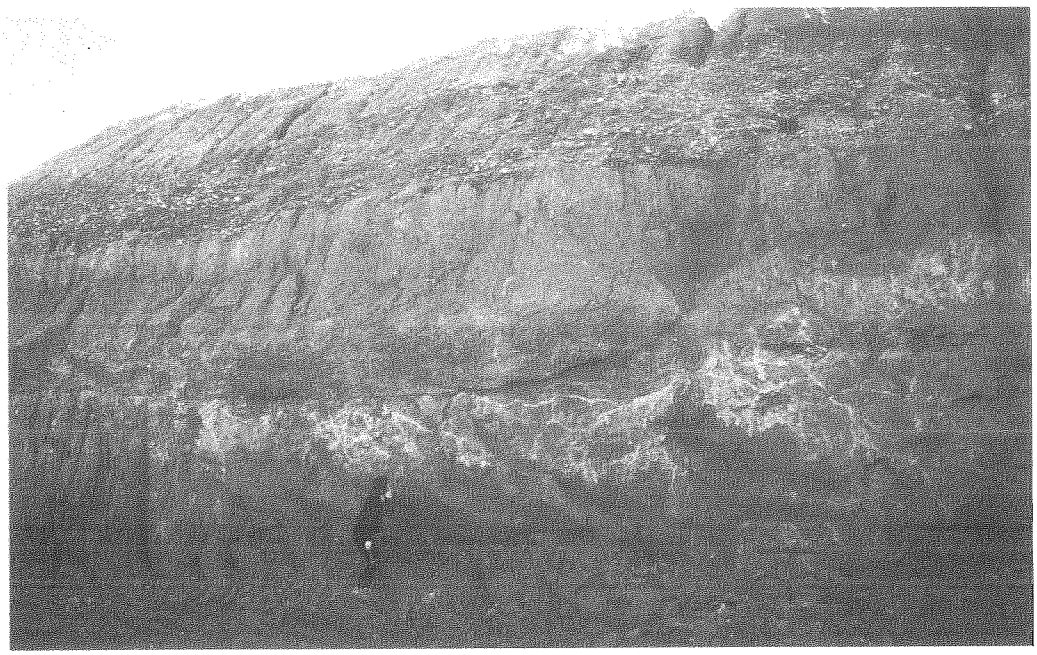

FIG. 3 - Scala Erre quarry. Clay - sand deposits with evident pedogenetic structures can be seen. The passage to the detrital deposit of the covering glacis is marked by a clear erosion surface.

only detrital sediments. The presence of the Quaternary is marginal, being mainly limited to deposits along the coast or along watercourses.

There is a total absence of the magmatic Palaeozoic or Tertiary rocks which outcrop in the immediately surrounding areas.

The presence of a thin bed of Tertiary effusive rocks has been identified in a survey near Cuile di Fiume Santo, but as the data cannot be examined there is uncertainty as regards its validity. However, some layers of montmorillonitic-type clays along the sections observed near the power station seem to indicate the local presence of a vulcanite at the passage with the Mesozoic bed.

The lithostratigraphic succession is the following:

Metamorphic complex (Palaeozoic)

This complex is represented by grey-green phyllites, rich in quartz veining with a relatively high degree of alteration, which produces a mature and not at all rocky landscape. It outcrops in discontinuous strips in the western sector of the area and represents the extreme continuity toward north-east of the metamorphic beds. This is present in the Nurra area with a metamorphic propagation from south to north, where it reaches its maximum in the island of Asinara. These rocks are probably of Silurian-Devonian age.

Near the Scala Erre quarries, along the incision of the Canale de Chirigu Cossu, near San Nicola, there are outcrops of plates of a limited extension and which are difficult to identify. Some of these could be attributable to the detrital complex of the Permo-Trias which outcrops a short distance away, near Mt. Santa Giusta. In fact, from the few samples analysed it appears to be a strongly reddened conglomerate containing mature elements originated exclusively from the phillyte metamorphic bed. The effect of alteration very similar to that of Tertiary alluvial deposits produces a strong reddening and clay production, which makes the outcrops very difficult to map.

Calcareous-dolomitic formation (Mesozoic)

This formation is mainly represented by carbonate rocks such as calcareous rocks, dolomitic calcareous rocks and dolomites, all gently sloping and with thicknesses of hundreds of metres. They constitute the lateral edges of the study area from where they outcrop continuously towards inland areas. Near the lateral edges, due east near Trobas, along the course of the Rio San Osanna in the area of Scala Erre and on the other side of the plain near Punghinosu, there are outcrops of strips of chalky clays attributed to the Keuper (CHERCHI & SCHROEDER, 1985; CHERCHI & MONTADERT, 1984). These suggest a modest dislocation in blocks of the Mesozoic complex generally ascribable here to the Trias and Jurassic. Furthermore, these rocks present high dissolution activity.

From the chalky levels identified and data obtained in numerous surveys carried out in the areas of Fiume Santo and Scala Erre, the amount of dislocation is on average 50 metres.

Detrital alluvial complex (Tertiary)

In the central sector an alluvial complex outcrops. It consists of gravel-conglomerate alternating with strips of sands and clays. The thickness is very variable from area to area and the sequence is not constant, often showing stratigraphic hiatus. The morphometry of the elements in the series and the sedimentological characteristics of the whole formation and its layering suggest a fan-delta environment in a humid sub-tropical climate. The thickness of the whole series, according to the data from some surveys near the Scala Erre quarries, is of around 50/55 meters.

FIG. 4 - Cuile of Fiume Santo. In the quarry near the watercourse the pebbly beach deposits of the Fiume Santo Formation can be seen. At the front of the quarry, where the base is not visible, show a thickness of 5 metres.

However, the contact with the basament, never visible, presumably varies with the geographical position of the complex. These coverings, till now attributed to the Pliocene (CHERCHI & *alii*, 1982), show continuity from the coastline as far as the area of Canaglia and beyond for various kilometres inland. Furthermore, their continuity below the sea has been documented by numerous surveys (GINESU & *alii*, 1994b).

In this complex, known for the industrial exploitation of refractory clays, there has been clear recognition of flow courses from west to north-north east (OZER, 1976, GINESU, 1983). As regards the fossil hydrography of the entire Nurra area, these deposits are very significant for the reconstruction of the landscape because a delta-type fluvial deposit of this extension cannot easily be justified by the present geographic structure of the area.

The recent discovery of a palaeontological level in the lower part of this complex has led, for the first time, to a precise date ascribable to the Upper Miocene (CORDY & GINESU, 1993) thus allowing possible correlation with the Formation of Macciadosa (BALDACCINI & *alii*, 1981; GINESU, 1990). This latter formation is also of a clearly continental origin and furrows the Tertiary deposits of the Miocenic palaeo-island of the Nurra di Porto Torres and Alghero. It outcrops near the Fiume Santo within the Enichem industrial complex.

A good number of surveys, carried out for the building of the ENEL power stations at Fiume Santo (PIETRACAPRINA, 1971), have been the object of a more complete stratigraphic reconstruction. They have shown the presence of some peat levels at the base of this formation.

The Tertiary alluvial detrital complex shows some variations which prompt a division into two different formations. The first, called «Scala Erre Formation», is made up entirely of a covering of coarse detritus and sandy-clay levels of continental origin. There are gravels with very mature, manganese-coated siliceous elements, and subordinate elements of the metamorphic bed which are both phillytic and quartzitic. The thickness of the clay levels, particularly near the Scala Erre quarries, where the formation has been studied the most due to its exposure (about 20-25 m in the excavation front), makes an interpretation of their nature complicated.

These levels, which could originate from the break-up of the Triassic chalky clays, are not found in the rest of the Nurra area, even though the landscape and evolutionary processes also involved this basament of the Trias (fig. 3). Their upper successions show them to be sub-tropical palaeosoils. It is likely that these layers were formed in a large watercourse with variable regime environment.

The second formation, termed «Fiume Santo Formation», shows precise characteristics of a coastal environment. There are strata of gravels and beach pebbles overlapping with and overlying eolian sandy levels and ofbeach deposits partly remained and pedogenized. These are still being studied by the present authors (fig. 4). There are also deposits of fine silt-clay sediments rich in ferrous and carbonate surfaces and pans, which show the existence of a swamp environment with a variation in water level.

These sediments, which outcrop in a quarry near the ENEL power station, are rich in vegetational remains which are attributable, on first examination, to aquatic plants similar to present-day mangroves (they are at present under study by palaeobotanists of the University of Sassari). A section of these sediments reveal a thickness of 2-2.5 metres (for an outcrop exposure of 50 m). The stratigraphic relationships place them in an upper position in the Fiume Santo series and lying on gravel deposits similar to those of Scala Erre (fig. 5).

The stratigraphic relationships between the two formations are for the moment based on the interpretation of some characteristics observed in the field and on survey results (GINESU & SIAS, 1993). From the surveys and from the existence of a palaeo-channel cut in the Fiume Santo Formation, unfortunately no longer existent due to quarrying and only photographically documented, it is possible to

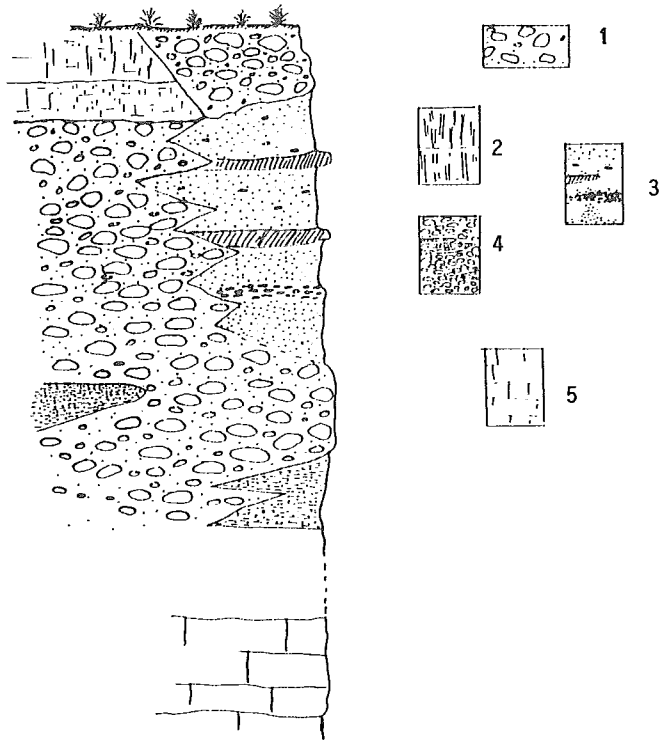

FIG. 5 - Scheme of the stratigraphic relationships in the area of Fiume Santo - Scala Erre. 1) Top conglomerates (Glacis), 2) Lacustrine deposits, 3) Coastal deposits (beach, eolianites), 4) Conglomerates with sand and clay lens, 5) Basement (Mesozoic limestones).

identify a lateral passage of the Scala Erre Formation to that of the Fiume Santo only in its upper part. This indicates the approach of the watercourse towards the coastline. The Scala Erre Formation could have begun its process of sedimentation before that of the Fiume Santo Formation, which appears to be, therefore, a coastal facies in transgression over the other formation.

Plio-Pleistocene deposits

Various deposits are marginal in the context of this area. They include all the deposits aboveall long the coastal edge and in the lower-lying area of depression that coincide with incisions of present watercourses, and also deposits around the depressions, such as the Stagno di Pilo. At the top of the Tertiary series there are coarse sands and gravels, sedimented by sheet flood processes. They have high maturity indexes and, if associated with modification of the Tertiary series terraces, can be attributed to the Pliocene. Also some kaolin-rich soils observed on the right bank of the Rio Fiume Santo and the same red soils present on the Mesozoic carbonate outcrops could be of Pliocenic age.

A careful geomorphological reconstruction of the whole area has revealed, at the contact between the top part of the Scala Erre — Fiume Santo formations and the higher detrital coverings, an encrusted layer of calcium carbonate. This layer deeply penetrates the underlying sediments as if the product of a strong drying-out of stagnant surface waters. This episode, observed in various parts of the study area, suggests a strong climatic change at the passage between the two deposits and antecedent to the long episode of levelling responsible for the glacis which forms the extensive gently sloping surface of the Nurra di Porto Torres (fig. 6). The placing of this event is still uncertain within the context of the passage between Messinian and Pliocene.

The palaeosoils present are under study in order to obtain valid comparisons among them in order to define their age and forming factors. Some pedogenetic structures present also in the Scala Erre and Fiume Santo Formations, such as manganese nodules and ferrous pans, indicate a climate more typical of the Middle Miocene rather than a condition of greater aridity of the Messinian and lower Pliocene, which are better represented by processes of desiccation and erosion.

Some coastal fossiliferous deposits of the Tyrrhenian, together with Würm aeolian deposits with partially compacted siliceous elements overlying these fossiliferous deposits, can be attributed to the Pleistocene. They have already been described and are well-known (OZER, 1976). Clays and colluvial deposits are found along the perimeter of the Stagno di Pilo and along the main incisions.

TECTONIC MOVEMENT

The particular position of the Tertiary detrital deposits, the chalky layers at the edges of the carbonate horst and the presence of the carbonate bed at about 70 m of depth in the quarry area of Scala Erre, documented by the C.M.P. surveys (CASMEZ, 1978), gives credit to the theory of the existence of a small graben involving the Palaeozoic and Mesozoic beds.

Furthermore, the presence of the lateral faults is often documented by the intense fracturing of the Mesozoic carbonate rocks which can often be seen in the road cuttings in the tectonic horst. Examples are along the state highway near the bridge over the Fiume Santo and in the abandoned quarry of Case Nicoleddu. The tectonic lines follow the more or less north — south alignment of the graben and of the late-Tertiary exstensional movements. However, there is the evident presence of an east — west dislocation which determines the sudden interruption towards north of the Mesozoic carbonate basament, a structure probably provoked by regional dislocations along the northern coastal edge that follows the Turritana cliff,

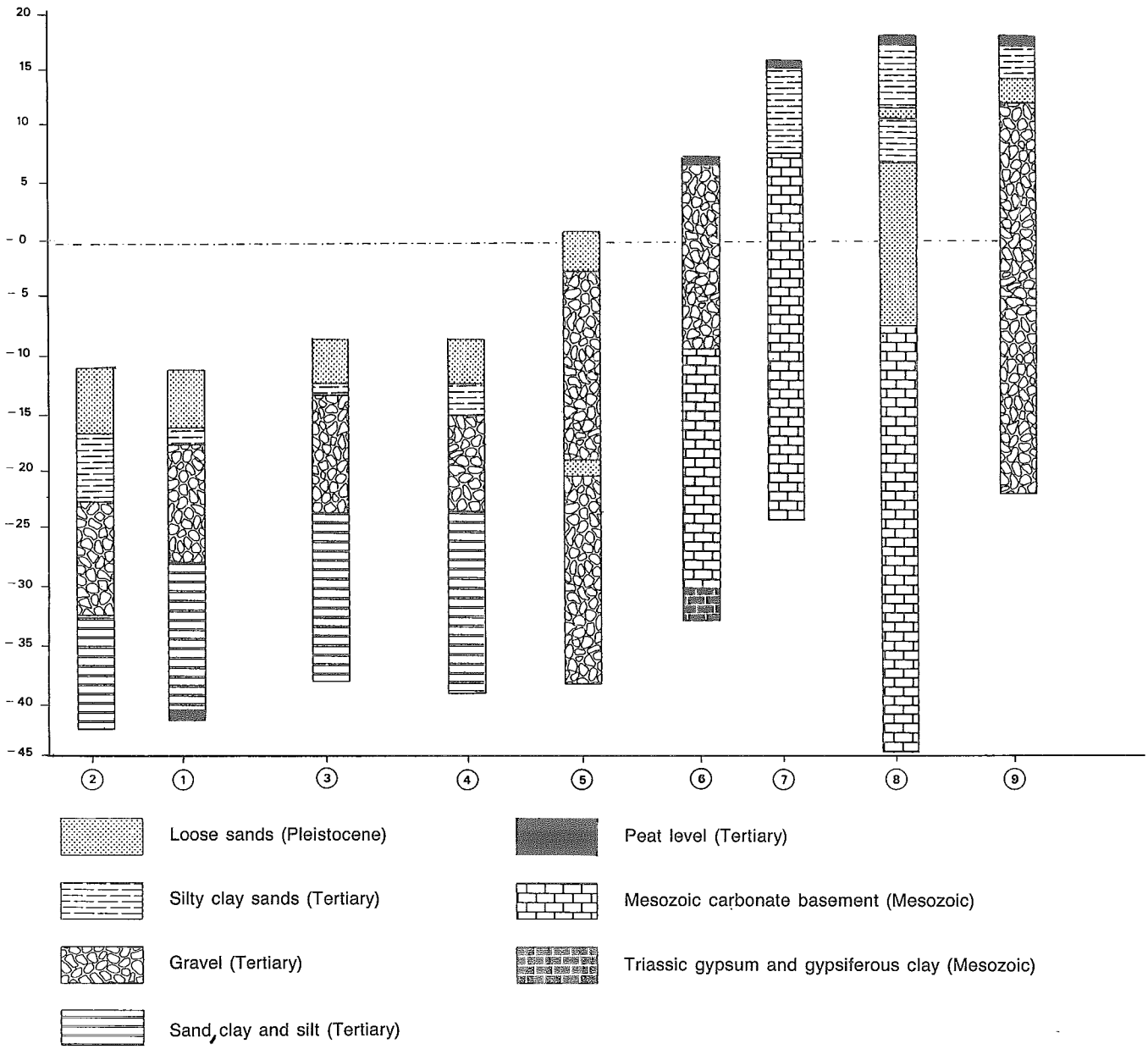

FIG. 6 - Correlations between the ENEL surveys carried out during the first phase of intervention in the creation of Groups 3 and 4 of the Fiume Santo power station.

that of the Anglona and Gallura regions (OZER, 1976; GINESU, 1990; FEDERICI & *alii*, 1987; CHERCHI & *alii*, 1982).

The presence of the Tortonian and the overlying late-Tertiary sequence, suggests a subsidence movement which was late with respect to the great rift of the Campidano (CHERCHI & *alii*, 1982) and a generalized uplifting movement referred to the Pliocene in accordance with the whole region (MARINI & MURRU, 1983). This tectonic activity is mainly shown by structural alignments with a S-N direction. The area of Porto Torres is a tectonic horst which separates the Sassari rift from this small graben. The ignimbritic rocks of the Tertiary calc-alkaline cycle make a lateral passage towards the graben, near Monte Rosé, where they mark the western edge of the Sardinian rift.

The carbonate bed of the Mesozoic which acts as the pavement of the graben, is however composed of blocks whose depth appears to progressively increase toward west and north. If the surveys in course confirm these conditions it is possible to speak of the existence of a semi-graben.

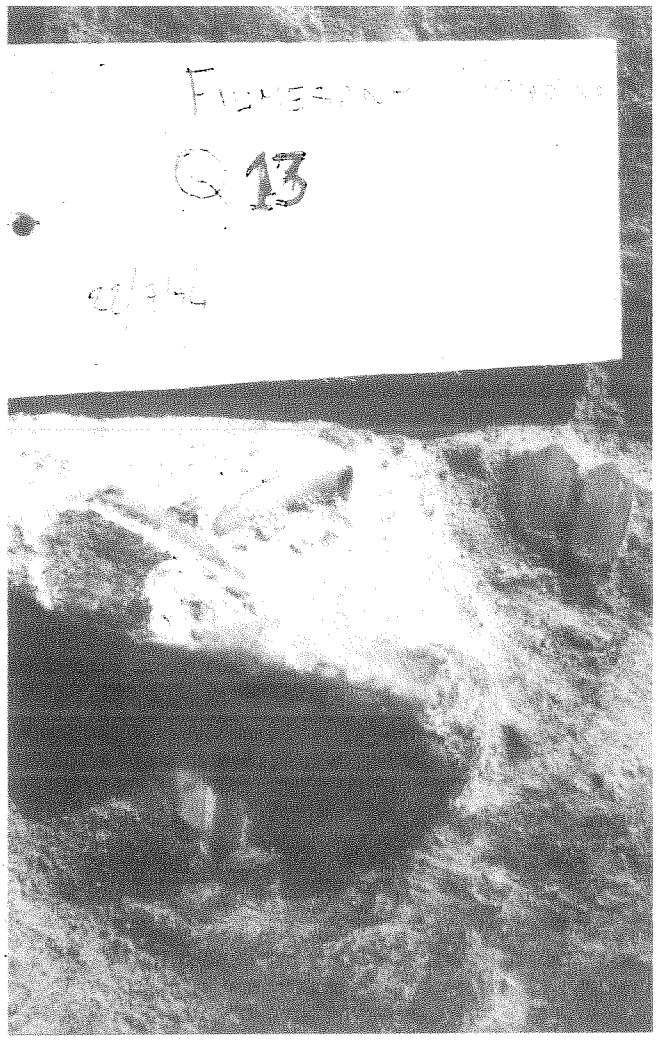

FIG. 7 - The layer of the fossiliferous deposit is characterised in the northern part by the presence of pockets of marine sand rich in bone remains with a chaotic distribution.

THE FOSSILIFEROUS DEPOSIT

The extensive quarrying activity carried out by the *Ente per l'Energia Elettrica (ENEL)* has brought to light a fossiliferous layer particularly rich in the remains of terrestrial fauna. It has been possible, thanks to collaboration with the *Soprintendenza Archeologica* for the provinces of Sassari and Nuoro, to carry out detailed surveys and to follow ENEL's quarrying activities in the area of the deposits in order to better understand the type of fossilization. In the light of the results obtained so far, it appears evident that the fossilized remains are in an extraordinarily well-preserved state.

It has been possible to identify three different conditions of fossilization of the remains, all allowing an excellent state of conservation but presenting complex problems of extraction due to the high degree of decarbonization of the bone remains.

A first element of conservation is represented by a layer of extremely fine littoral sands of a prevalently siliceous composition. The fossils are chaotically distributed within this layer and overlapping with layers of sand pockets richer in clay and with brightly-coloured coatings of oxidation. In fact, these sands do not constitute a uniform layer but form lenses and pockets within the underlying clay layer, or proper sandy wedges in the same clays, which represent particular forms of secondary circulation with the formation of characteristic pedogenetic structures.

One less frequent condition of fossilization is offered by the clays overlying the sands. Although with decidedly lower frequency, some remains consisting of teeth and occasionally bones, have been found in the clays and sandy clays, which illustrate a certain vertical movement within the same clay layer. Sometimes the fossil remains are chaotically arranged or grouped together intermingled both in the sands and in the underlying clays (fig. 7).

The last situation could be considered the most classic, it being determined by an ossiferous breccia in a sandy clay matrix. However, the enclosing rock, consisting of a stratum of strongly karstic travertine, does not show the classic features of a carbonate rock rich in karstic forms and structures. The fossils fill small funnel-shaped cavities in the carbonate layer which, slowly upwards, passes to the clay layer which digests remains of the travertine, as if marking an alteration surface.

Recently there has been trench excavation for a high voltage cable duct. The results of the analyses carried out on the layers encountered, followed for about 300 meters, are under study to in order to supply further interpretation of the modality of fossilization.

There is a particularly rich concentration of fossil remains belonging to numerous species (14 already recognised, tab. 1), some of which never before found in Sardinia, an excellent state of conservation and great extension of the deposit All these factors offer a great opportunity of both interpreting the palaeogeographical conditions of late-Tertiary Sardinia and of reconstructing very carefully the evolutionary stages of the island favouring the presence of so many species.

THE OREOPITHECUS DEPOSIT OF THE FIUME SANTO

The fossils so far found and collected in the layers of the deposits of Fiume Santo confirm the existence of a sub-tropical climate. The species determined and described are referred only to a few samples among the enormous amount of material archived and catalogued without having carried out a real palaeontological excavation. The species brought to light so far are listed in table 1.

The determination of *Oreopithecus* is based on the dis-

TABLE 1 - Faunistic list of the Fiume Santo deposit

Mammalia		
Primates		
Oreopithecidae	*Oreopithecus cf. bambolii*	Gervais, 1872
Carnivora		
Ursidae	*cf. Hyaenarctos anthracitis*	Weithofer, 1888
Rodentia		
Muridae	*aff. Valerymys turoliensis*	
Gliridae	one unrecognized taxon of large size	
Artiodactyla		
Suidae	one unrecognized taxon	
Giraffidae	one unrecognized taxon of medium size one unrecognized taxon (?) of small size	
Bovidae		
Alcelaphinae	*Maremmia lorenzi*	(Hurzeler, 1983)
Neotraginae	*Tyrrenotragus gracillimus*	(Weithofer, 1888)
Indet.	one unrecognized taxon of small size one unrecognized taxon of very small size	
Reptilia		
Crocodilia	two unrecognized taxa	
Chelonia	one unrecognized taxon	
Amphibia		
Anura	one unrecognized taxon	

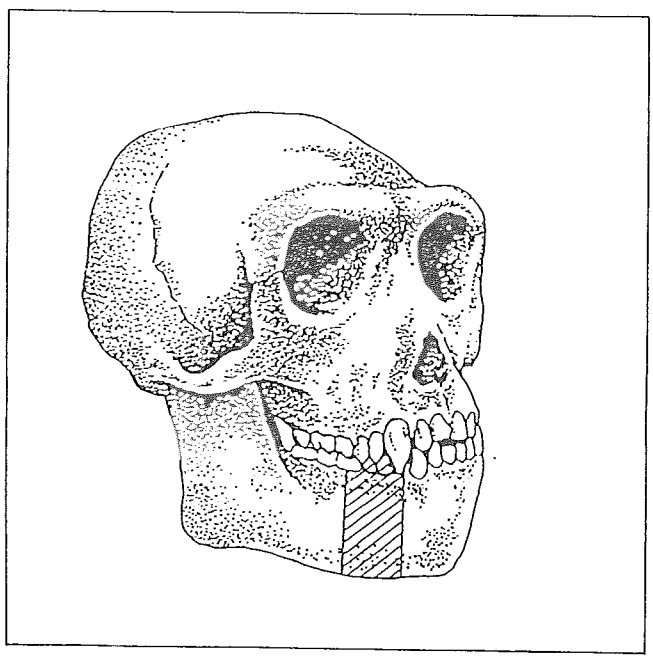

FIG. 8 - Reconstruction of the cranium of *Oreopithecus bambolii*, with indication of jaw fragment dx with premolars *in situ*.

covery of a fragment of the right mandible with the P3 and P4 *in situ* (fig 8) and of several isolated teeth, aboveall premolars and lower and upper molars. The sizes are very similar to those of *Oreopithecus bambolii* of Tuscany (HÜRZELER, 1949 and 1968; BUTLER & MILLS 1959; SZALAY & DELSON 1979). The bicuspid structure of the P3 and homomorphic appearance of the premolars are all typical features, together with other characteristics, which justify affinities of this fossil primate with the Hominidae (HÜRZELER, 1954 and 1968).

The presence of a particular *Bovidae Alcelaphinae* already described in the Miocenic basin of the Maremma in Tuscany (HÜRZELER, 1983; THOMAS, 1984), is documented by a series of mandibles and isolated teeth, with some bone horns and various bones. The very hypsodontic form and profile in lateral view of the M3, the structure of the molar and its size allow association of this fossil with the species *Maremmia lorenzi* (HÜRZELER, 1983), which could be the final form of an endemic evolution in Tuscany (HÜRZELER, 1983). According to Thomas (19849, this species could be conspecific with the species *Maremmia haupti* (WEITHOFFER, 1888). There is evident affinity of these species so far found in the Fiume Santo deposit with the Tuscan fauna.

At the same time the fauna of Fiume Santo presents endemic characteristics, in this case clearly a condition of insularity, just as other features are endemic for the Tuscan fauna (HÜRZELER & EUGESSER, 1976). As regards chronological correlation, the presence of an evolved *Alcelaphinae, Maremmia lorenzi* (HÜRZELER, 1983), allows us to correlate the site of Fiume Santo with the V2 horizon of the Miocenic basin of Bacinello described by Lorenz in the Maremma region (1968). The V2 horizon has been correlated by HÜRZELER & EUGESSER (1976) with the Late-

Tortonian (Turolian, zone 13 of the Mein, 1975) and dated with radiometric methods to 8.4 ± 0.4 m.a. by HUNZIKER (AZZAROLI & *alii*, 1987).

From a comparison of the teeth of the Sardinian *Oreopithecus*, from five different individuals, with those of the Tuscan *Oreopithecus* there are some minimal differences sufficient to induce some reserve as regards a specific determination.

Fiume Santo is the first terrestrial fossiliferous site in Sardinia belonging to the late Miocene. On the other hand, its discovery outside of mainland Italy supplies new data on the geographic extension of this enigmatic primate (DELSON, 1987; HARRISON, 1987). The presence of the *Oreopithecus* and of *Maremmia* in Sardinia and in Tuscany suggests a similar age for them, but also migrations into the two regions with origins in Africa in both cases (HÜRZELER, 1983, THOMAS, 1984; HARRISON, 1986). During the Miocene there were also exchanges of fauna between the two Italian regions, a reason for perfectly justifying the presence of a progenitor of *Tyrrhenoglis* (ENGESSER, 1976) in the Pliocene of Capo Figari in Sardinia, an endemic Gliridae of the Maremma (ENGESSER, 1976).

PALAEOGEOGRAPHICAL AND GEOMORPHOLOGICAL PROBLEMS

The recognition of two different formations such as those of Scala Erre and Fiume Santo, whose stratographic relationships show their partial contemporaneity, reveals a palaeogeographic situation of the area conditioned by a hydrographic network which has left clear signs of its activity.

The traces of a coastal environment are also equally significant, reflecting, more or less, the profile of the present coast, varying its appearance from sand and gravel beach to tracts of cliff coastline with relicts of erosion abandoned along the platform of external abrasion. The cliffline was positioned on the calcareous rocks of the Trias and Giura of which the present relief of Mt. Elva represents the old inland area. Cyclopic blocks of Triassic and Jurassic calcareous rocks, immersed in the Tertiary deposits, have been removed from the coastal excavation to give space for the positioning of the intake pump of the power station. Their presence can be attributed to the phases of retreat of the calcareous cliffline.

The deposits in one of the numerous quarries near the Fiume Santo site are of particular interest. Here there are sediment outcrops of a fluvial lacustrine environment whose sequence can be identified with an abandoned meander (LEEDER, 1988). At the base of these deposits there are widespread remains of root systems of mangrove-type vegetation. the general features of these deposits have been partially described in previous works and are still under study for the stratigraphic reconstruction of the various surveys carried out recently in the basin of the rio of Fiume Santo (GINESU & *alii*, 1994a; GINESU & SIAS, 1993; GINESU & *alii*, 1994b).

The particular fossilization of these vegetational remains that are ferretisized, has allowed their identification within the small cavities and fillings associated with the karstic activity of the late-Tertiary on the carbonate-travertine layers of the Fiume Santo deposit antecedent to the Tortonian. In these karst-type deposits the vegetational remains, like the other fossils present, show a high leaching activity which has emptied the internal conduit of these root systems, so differentiating them from those in the primary layering.

The configuration of the surrounding landscape, during the late Miocene, on the basis of the fauna and flora so far identified, also tracing the present orography characterised by hilly dome-like relief linked to extensive plains, was different particularly as regards its morphoclimatic features. These forms, well configured and modelled in a morphoclimatic system of the late Tertiary and clearly indicated by the palaeobotanic and palaeozoological data (a sparse savannah on the plain and woodland on the hills),have only been partially touched by the neotectonic movement which has caused a general uplifting of the northern sector of the Nurra by about 25/30 meters since the Upper Pleistocene.

The same deposits attributed to the Tyrrhenian, present along the strip next to the present shoreline, show the existence of a palaeocliff on the layers of the Fiume Santo Formation already uplifted by about 20 metres. The same planation surface observed on the summit of the accumulated gla,cis on the Tertiary deposits and on the erosional glacis on the Mesozoic carbonate rocks, shows a general process of post-Miocenic levelling which involved all the detrital deposits of the area.

It is specifically this succession of layers of deposition and erosion surfaces alternating in the top part with a thick horizon of desiccation and encrustation could suggest continuity with the Messinian and the Pliocene and give indications as to the continuity upriver of this great water course which was inevitable associated with an area much more extensive than the present one toward the west.

Precisely from the study and analysis of all the data being collected and from analysis of the evolutive state of the fauna and flora present in the various fossiliferous layers of Fiume Santo we can obtain new information in order to construct a more complete picture of the situation of Sardinia during its eastward drift and from its conditions of insularity. The work carried out in the first months after the discovery of the Oreopithecus layer has so far posed the first questions.

BIBLIOGRAPHY

AZZAROLI A., BOCCALETTI M., DELSON E., MORATTI G. & TORRE D. (1987) - *Chronological and paleogeographical background to the study of Oreopithecus bambolii.* Journ. Hum. Evol., 15, 533-540.

BALDACCINI P., DETTORI B., GINESU S., MANDRAU S., MARCHI M., PASSINO A.M., PIETRACAPRINA A. & PULINA M.A. (1981) - *Il rilievo integrale di Tottubella (Sardegna nord-occidentale).* Atti Ist. Min. Geol. Univ. Sassari, 1, 1-165.

BUTTLER P.M. & MILLS J.R.E. (1959) - *A conlribution to the odontology of Oreopithecus.* Bull. Br. Mus. nat. Hist. (Geol.), 4, 1-26.

CHERCHI A., MARCELLO A., MARINI A., MURRU M., PRETTI S. & SALVADORI I. (1982) - *Carta geologica della Sardegna. Scala 1:250.000.* SELCA, Firenze.

CHERCHI A. & MONTADERT L. (1984) - *Il sistema di rifting oligo-miocenico del Mediterraneo occidentale e sue conseguenze paleogeografiche sul Terziario sardo.* Mem. Soc. Geol. Ital., 24, 387-400.

CHERCHI A., SCHOEDER R. (1985) - *Mesozoic of nothwestern Sardinia. Stratigraphy.* 19th Int. Coll. Micropaleontology, 44-57.

CORDY J.M., GINESU S. (1993) - *Fiume Santo (Sassari, Sardaigne, Italie): a noveau gisement à Oréopithèque (Oreopithecidae, Primates, Mammalia).* C.R. Acad. Sci. Paris, 318, II, 697-704.

DELSON E. (1987) - *An antropoid enigma: historical introduction to the study of Oreophitecus bambolii.* Journ. Evol., 15, 523-531.

ENGESSER B. (1976) - *Tyrrenoglis majori ein neuer fossiler Gliride (Rodentia, Mammalia) aus Sardinien.* Eclog. Geol. Helv., 69 (3), 783-793.

GINESU S. (1983) - *Le alluvioni pedemontane del'Argentiera (Sardegna nord-occidentale).* St. Sassaresi, 30, 149-153.

GINESU S. (1990) - *Indagine geomorfologica dell'area di La Corte (Sardegna nord-occidentale).* Geogr. Fis. Dinam. Quat., 12, 2, 107-116.

GINESU S. & SIAS S. (1993) - *The quaternary evolution of Fiume Santo coast during Quaternary.* Reun. Sc. IGCP 274, Dakar, p. 27.

GINESU S., PREVITALI F. & SIAS S. (1994a) - *Lineamenti geologici e geomorfologici del bacino del rio Astemini-Fiume Santo.* Atti Conv. MEDALUS II, Sassari, pp.

GINESU S., MAROGNA A. & SIAS S. (1994b) - *Evoluzione quaternaria e dinamica attuale della fascia costiera di Fiume Santo (Sassari, Sardegna).* Il Quaternario, 7 (1), 317-324.

HARRISON T. (1986) - *New fossil anthropoid from the Middle Miocene of east Africa and their bearig on the origin of the Oreopithecidae.* Amer. Journ. Phys. Anthrop., 71, 265-284.

HARRISON T. (1987) - *A resasessment of the phylogenetic relanthionship of Oreopithecus bambolii Gervais.* Journ. Hum. Evol., 15, 541-585.

HURZELER J. (1949) - *Zur systematischen Stellung von Oreopithecus.* Verh. naturf. Ges. Basel, 65, 88-95.

HURZELER J. (1968) - *Oreopithecus bambolii Gervais: a preliminary report.* Verh. naturf. Ges. Basel, 69, 1-47.

HURZELER J. (1968) - *Question et réflexions sur l'histoire des Anthropomorphes.* Ann. Paléon. (Vert.), 54, 195-235.

HURZELER J. (1983) - *Un alcélaphiné aberrant (Bovidé, Mammalia) des «lignites de Grosseto» en Toscane.* C.R. Acad. Sc. Paris, II, 296, 497-503.

HURZELER J. & ENGESSER B. (1976) - *Les faunes de mammifères néogènes du bassin de Baccinello (Grosseto, Italie).* C.R. Acad. Sc. Paris, 283, D, 333-336.

LEEDER M.R. (1988) - *Sedimentology: process and product.* U. Hyman, London, 1/344.

LORENZ H.G. (1968) - *Stratigraphishe und micropalaentologische Untersuchungen des Braunkohlengebietes von Bacinello (Provinz Grosseto, Italien).* Riv. Ital. Paleont. Stratigr., 74, 147-270.

MARINI A. & MURRU M. (1983) - *Movimenti tettonici in Sardegna fra il Miocene superiore ed il Pleistocene.* Geogr. Fis. Dinam. Quat., 6, 39-43.

OZER A. (1976) - *Gèomorphologie du versant septentrional de la Sardaigne. Etude des fonds sous marin, de la morphologie cotiere et des terrasses fluviales.* Thése Doc. Sc. Geogr., Fac. Sc., Univ. Liège, 1-284.

PIETRACAPRINA A. (1971) - *Studio geoidrologico relativo all'approvvigionamento idrico del complesso industriale S.I.R. di Porto Torres (Sardegna).* Boll. Soc. Geol. It., 90, 183-201.

SZALAI F.S. & DELSON E. (1979) - *Evolutionary history of the Primates.* Acad. Press. N.Y., 79.

THOMAS H. (1984) - *Les origines africaines des Bovidae (Artiodactila, Mammalia) des lignites de Grosseto (Toscanae, Italie).* Bull. Mus. Nat. Hist. Nat., Paris, 4, 6, 81-101.

WEITHOFFER K.A. (1889) - *Alcune osservazioni sulla fauna della lignite di Casteani e di Monte Bamboli (Toscana).* Boll. Geol. Ital., II, 12-12, 361-368.