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The Messinian Salinity Crisis Revisited

Corte, July 19-25, 2004

Abstracts

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ENVIRONMENT AND IDENTITY IN THE MEDITERRANEAN

Università di Corsica Pasquale Paoli
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THE MESSINIAN SALINITY CRISIS REVISITED

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MESSINIAN EVENTS IN THE WESTERN MEDITERRANEAN: THE RECORD IN THE NEOGENE ALMERÍA BASINS AND ALBORÁN SEA

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The sedimentary record in the Neogene Vera, Sorbas, Almería-Nijar and Carboneras-Agua Amarga basins in Almería, SE Spain, and in deep-sea cores from the Alborán Sea suggests a sequence of major events in the palaeoenvironmental evolution of the western Mediterranean during the Messinian. Non-reefal carbonates formed at the basin margins during the latest Tortonian-earliest Messinian. Subsequent carbonate deposition during the early Messinian was dominated by coral reef and *Halimeda* accumulations. The regional extent of these deposits together with oxygen stable isotope signals indicates that surface-water temperatures were the main factor controlling the carbonate lithofacies. Shallow-water carbonates change basinwards into cyclic fine-grained basin deposits enclosing re-deposited material from the platforms. A major erosion surface cut into both the platform carbonates and the basin deposits records subaerial exposure of the basins, and was probably coeval with the desiccation of the Mediterranean Sea that led to evaporite deposition in the centre of the deep Mediterranean basin. Although geochemical data suggest a certain degree of isolation from the Atlantic Ocean, probably related to the closure of the Betic corridors, the palaeontological record in shallow and deep water deposits indicates that normal marine conditions prevailed in the western Mediterranean until desiccation. When the Mediterranean Sea recovered its normal level during the late Messinian, marginal basins were reflooded. Deposition of evaporites took place in those basins semi-isolated from the main Mediterranean body. Gypsum beds and pelitic interbeds onlap the major erosion surface and are gradually followed by marine sediments in the marginal basins. The occurrence of coral reefs on the platforms, and the widespread record of planktonic foraminifers and nannoplankton in deeper-water deposits, indicate re-establishment of normal marine conditions in the western Mediterranean before the end of the Messinian. Continued uplift of the Betic Cordillera promoted the emersion of the inner basins (most distant from the present-day coast line), such as the Sorbas Basin, during the latest Messinian. Red fluviatile and lacustrine deposits locally formed in these basins, whilst marine sedimentation continued to Pliocene times in the outer basins and in the Alborán Sea.

EVIDENCE FOR AFRICAN-IBERIAN MAMMAL EXCHANGES IN THE LATE MIOCENE-EARLY PLIOCENE CONTINENTAL BEDS OF THE GUADIX FORMATION (GUADIX-BAZA BASIN, SE SPAIN)

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In this paper, we present data from fossil mammal localities in the late Miocene-early Pliocene continental deposits of the Guadix Formation from the Guadix-Baza Basin. Since these deposits should be coeval with the Messinian Salinity Crisis of the Mediterranean (5.96-5.33 Myr), it can be investigated if this dramatic event in the marine realm had any impact on the terrestrial ecosystems. The various African immigrant species invading Iberia during the Messinian can now be studied in a high-resolution time frame, which may significantly help to understand the geodynamic and paleogeographic evolution of the marine and continental gateways in the western Mediterranean region.

One of the main events that have been related to the Messinian Salinity Crisis is the dispersal of gerbil rodents into Southern Spain. The gerbils are subdesertic rodents that today inhabit the dry landscapes of northern Africa and southwestern Asia. They appear as rare elements in a number of early Ruscinian localities from Southern Spain (Caravaca, Gorafe 1; Bruijn, 1974) and have been usually interpreted as African elements having entered Spain during the Messinian, at the same time that *Paraethomys* or *Paracamelus*. This hypothesis gained further support after the discovery in Spain of fissure infillings in which other north African rodents such as the Myocricetodontine hamsters appeared associated with gerbils. This is the case of Salobreña (Aguilar et al., 1983) and Almenara M (= Casablanca M, Agustí & Galobart, 1986). However, because of their karstic character the exact chronology of these localities remained uncertain for years. Therefore, the locality of Negratín has delivered a small mammalian fauna including *Parasorex ibericus,* Soricidae indet., *Apodemus gudrunae, Paraethomys meini, Stephanomys dubari, Occitanomys alcalai, Apocricetus alberti, Ruscinomys* sp., *Debruijnimys* sp., *Myocricetodon* sp., *Eliomys* sp., *Atlantoxerus* sp. Negratín 1 is the first fluvio-lacustrine locality in which African rodents other than the gerbils *Debruijnimys* or *Protatera* have been recovered. The recent advances in the chronostratigraphy of Guadix-Baza and other Betic basins enables one to shed light on the dating of the gerbil dispersal into Spain. The detailed mammal record allows us furthermore to study the zoogeographical changes that took place in southeastern Spain during the time interval from 7.6 to 4.8 Ma.

THE MESSINIAN OF TUSCANY: TECTONO-SEDIMENTARY EVOLUTION ALONG A TRANSECT FROM THE PERI-THYRRENIAN RIDGE TO THE CHIANTI MOUNTS

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Neogene Tuscan basins provide a valuable record of Messinian time in a variety of depositional systems whose evolution resulted from the complex interplay between regional tectonics, climate and sea-level changes related to the salinity crisis of Mediterranean Sea. Such basins resulted from the Late Miocene block-faulting which gave rise to NNE-SSW oriented tectonic depressions limited by emerging topographic highs. In this work a review of the Messinian deposits exposed along a transect from the Thyrrenian Sea to the Chianti Mounts is proposed. The main morphological features along this transect are, from west to east: the Pery-Thyrrenian Ridge, the Fine Basin, the Castellina Ridge, the Volterra-Radicondoli Basin, the Middle Tuscan Ridge, the Valdelsa Basin and the Chianti Mounts. The Middle Tuscan Ridge played a major role in governing the depositional evolution of these basins, separating the western ones, in which short-lived marine conditions developed, from the eastern ones, characterized by continental sedimentation.
WEST OF THE MIDDLE TUSCAN RIDGE - In the marginal highs of Fine Basin, Early Messinian deposits rest onto the allochthonous Ligurian Units (ophiolites, pelagic and flysch deposits) and are represented by the Rosignano Limestone. It records two main sedimentary cycles, each one consisting of basal conglomerates overlying by platform carbonate deposits (barrier reef and lagoonal carbonates in the lower one, patch reef carbonates in the upper one) which pass basinward to marine fines (*e.g.* laminated marine clayey marls and diatomitic marls).
In the Volterra-Radicondoli Basin, early Messinian deposits comprise brackish marls with a first horizon of laminated gypsum ("Balatino" Auct.) and laminated marls with serpulids. They rest unconformably onto the pre-neogene substratum or conformably onto upper Tortonian lacustrine fines ("Serie Lignitifera" Auct.). In the marginal part of the basin, the brackish lithofacies are separated from patch reef lithofacies (correlable with the upper part of the Rosignano Limestone exposed in the Fine Basin) by an angular unconformity marked by conglomerates. Such an unconformity passes basinward to a correlative conformity and the marginal carbonate lithofacies are replaced by marine fines (marine clays with *Neopycnodonte navicularis*).
Evaporitic Messinian deposition begins in the Fine Basin and in the Volterra Radicondoli Basin with gypsum horizons; a following erosional phase gave rise to an unconformity surface separating the marine deposits from the overlying, brackish to continental-lacustrine clays, marls, gypsum, sands and conglomerates, typically referred to the Lac-Mer succession.
EAST OF THE MIDDLE TUSCAN RIDGE - In the Valdelsa Basin, early Messinian deposits are represented by a few metres of brackish clays overlying the uppermost siliciclastic fines of the "Serie Lignitifera" succession. An intense erosional phase gave rise to an unconformity separating the brackish clays from the late Messinian fluvio-lacustrine sediments, which can be referred to the Lac Mer depositional phase recorded in the western basins, although devoid of gypsum lithofacies.
The Early Pliocene marine transgression overstepped the Middle Tuscan Ridge up to the Chianti Ridge, leading to the dominantly sedimentation of outer platform clayey sediments with subordinate sands and conglomerates. In the basin depocentres, these deposits typically overlies the Lac-Mer successions without intervening unconformities. This suggests that the transition from the Lac Mer continental-lacustrine sedimentation to the Early Pliocene sea took probably place within a submerged setting.

SEQUENTIAL SCHEME OF THE MESSINIAN SINIS PENINSULA SUCCESSION (SARDINIA)

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The unusual Messinian succession in the Sinis Peninsula raises several correlational questions (*André et al.,* 2004). On the basis of biostratigraphical and sedimentological data a new sequence stratigraphic interpretation is proposed.
Four lithostratigraphical units are distinguished: the Basal Marls, the Capo San Marco Formation, the Sinis Limestones and the Torre del Sevo Formation. The three lower formations developed during one and a half progradation-retrogradation cycle, the latter is composed of minor order stacked prograding sequences.
The Basal Marls and the Capo San Marco Formation display a marly facies at the base, followed by silty and sandy marls, and capped by organic buildups with vermetid gastropods and diverse shallow-water bivalves at the top. Fauna and microfauna indicate deep-waters at the bottom changing upward into shallower associations. The succession is an overall upward-shallowing sequence typical of a prograding prism comprising deposits from a Southwest gently dipping mixed carbonate-siliciclastic ramp.
The upper part of the Capo San Marco Formation and the whole Sinis Limestones compose a second prograding unit. This second unit rests upon a transgression surface merged with a maximum flooding surface at the top of the uppermost microbial-bryozoan-serpulid buildups. Facies and sedimentary structures are indicative carbonate platform of great extent, most of it being considered as a prograding prism terminated by bioclastic and oolitic facies. The top of the Sinis Limestones is capped by an aerial surface.
The Torre del Sevo Limestones Formation is made of stacked progradational subunits, each constituted of marine shallow water carbonate deposits (ooids, vermetids, stromatolites and subaerial exposures at the top). The Torre del Sevo Limestones was deposited in a regional shallow-water carbonate platform.
Compared with other Messinian Mediterranean carbonate platforms, the Sinis Peninsula exhibits several unusual features such as the notable absence of scleractinian coral reefs and the widespread occurrence of microbial-bryozoan-serpulid carbonate buildups. These features are regarded as related to upwelling currents.

MESSINIAN *PROLAGUS* (LAGOMORPHA, MAMMALIA) OF ITALY

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Since the Middle/Late Miocene boundary and during all Late Miocene, after a severe exctinction phenomenon (López Martínez, 2001), the distribution of the genus *Prolagus* in continental Europe consists in a succession of single species. During Messinian (corresponding to the second half of the Turolian Mammal Age and to the Late MN12-MN13 Units), *Prolagus* is quite widespread in continental Europe with a well-characterized species, *P. michauxi*.

In Italy, Messinian *Prolagus* remains have been reported from the following fossiliferous sites: Brisighella (Emilia-Romagna, latest MN13), *Prolagus* cf. *P. sorbinii* (Masini, 1989); Monte Castellaro (Marche, MN13), *Prolagus sorbinii* (Masini, 1989); Ciabòt Cagna (Piedmont, MN13), *Prolagus michauxi* (Cavallo *et al.,* 1996); Velona Basin (Tuscany, MN13), *Prolagus* ex gr. *P. sorbinii-P. michauxi* (Rook & Ghetti, 1997); Capo di Fiume (Abruzzi, earliest MN13), *Prolagus* cf. *P. apricenicus* (Mazza *et al.*, 1995). To this list it should be added *P. apricenicus* and *P. imperialis* from the Gargano fossil archipelago (Apulia) (Mazza, 1987), related to the Middle Miocene species *P. oeningensis*. Their age attribution probably ranges between late MN13(?) and early MN14.

Being *P. sorbinii* a species close to *P. michauxi,* italian Messinian *Prolagus* findings are ascribed or are closely related to *P. michauxi* or to *P. oeningensis* (*P. apricenicus, P. imperialis* and referable forms).

Such systematic considerations give some palaeobiogeographical and temporal hints, confirmed by the faunal assemblages associated to *Prolagus*:

- the above mentioned Italian fossiliferous sites belong to different palaeobioprovinces: a southern, insular domain (Abruzzi-Apulia PB) characterized by insular endemic species, and a northern domain (NI), representing a peripheral continental European appendix and populated by non-endemic faunal elements;
- different faunal affinities for the palaeobioprovinces and consequently different "source areas": a Balkan affinity for the Abruzzi-Apulia PB and a European affinity for the NI;
- distinct ages and modalities of colonization. The age of *Prolagus* colonization of Gargano is uncertain, since *P. oeningensis* does not survive in central Europe longer than earliest MN9 but no data are available for the Balkan area; moreover the nature of the connection is not clear. On the other hand for NI, a continuous interchange with continental Europe should be invoked, probably with minor geographical filters.

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MESSINIAN EVENTS IN A RAPIDLY SUBSIDING AND TECTONICALLY CONTROLLED FORELAND BASIN: THE SOUTERN LAGA BASIN (CENTRAL APENINES, ITALY)

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The Southern Laga Basin of Northern Abruzzo is considered to have been the largest and most rapidly subsiding turbiditic depocenter of the Apennine foredeep during the Messinian.

Taking a physical stratigraphic approach, a new stratigraphic scheme, consisting of four unconformity bounded stratigraphic units (U.B.S.U.), is proposed for the deepest portion of the Laga basin. The depositional events together with the palaeoenvironmental interpretation of the depositional units framed within the 4 U.B.S.U. reveal the vertical transition from deep marine to lacustrine and fluvio-deltaic environments, encouraging reconsideration of the real bathymetry of the Southern Laga Basin in Northern Abruzzo. The four Messinian units document also the transition from a foredeep to a wedge-top basin; a transition controlled by a progressive shortening and uplift of the thrust-related folds present in the Southern Laga Basin.

The Messinian sedimentary and tectonic events recorded in the Southern Laga Basin are strikingly similar to those recognised in less subsiding and marginal sectors of the Apennine foreland, which thus preserves a similar tectonic and sedimentary evolution over an area as wide as the whole Adriatic foredeep.

THE "SALINITY CRISIS" STRATIGRAPHIC AND STRONTIUM ISOTOPES RECORD IN THE MESSINIAN SOUTHERN APENNINES FORELAND BASIN, ITALY

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The Mediterranean region was involved during the Messinian in a pervasive salinity crisis, characterised by two major evaporitic sedimentary cycles, as the lower evaporites and upper evaporites in Sicily and Tyrrhenian Sea bottom. In Northern Apennines the upper evaporites are not present and are substituted by clastic post-evaporitic deposits, formed by two mainly terrigenous unconformity-bounded units.
Two Messinian evaporite-bearing units crop out in Irpinia-Daunia Mountains (southern Apennines, Italy). The Daunia and Vallone del Toro units record the tectonic and palaeogeographic evolution of the Messinian southern Apennine foreland basin system during the salinity crisis, and have never been studied with an integrated stratigraphic and Sr geochemical regional approach.
Detailed mapping, stratigraphic studies, facies analyses of gypsum lithologies, strontium content and $^{87}Sr/^{86}Sr$ isotopes ratio analytical determinations have been carried out in order to: (i) evaluate depositional conditions of the evaporites, (ii) discriminate between lower and upper type evaporite, (iii) discuss the palaeogeographic and tectonic controls on the evaporite sedimentation.
The Daunia unit comprises the Monte Castello Evaporites, formed by euxinic diatomitic marls, evaporitic limestones and shallow-water gypsum, characterised by a $^{87}Sr/^{86}Sr$ average value of 0.70898 ± 0.00005, very close to the Sr isotopic value of the coeval seawater. These marginal evaporites are capped by an erosional unconformity and continental clastic deposits. The Vallone del Toro unit is made up of thin-bedded marls, claystones, calcilutites and diatomite layers with small gypsum crystals, laminated gypsum and gypsarenite layers without desiccation traces, suggesting deposition in relatively deep-water settings. The Vallone del Toro unit gypsum presents variable Sr isotopic data, with the average value of 0.70899 ± 0.00005 for the "Argilliti policrome del Torrente Calaggio" formation and the average value of 0.70863 ± 0.00014 for the "Argilliti di Mezzana di Forte" formation, reflecting major riverine freshwater input.
The strontium content and $^{87}Sr/^{86}Sr$ isotopes ratios of primary gypsum lithofacies allowed us to discriminate between "lower" and "upper" type evaporites in the southern Apennines foreland basin. The different patterns of lithofacies and isotopic composition of gypsum characterizing the evaporites of the marginal and basinal deposits reflect the tectonic control and the palaeogeographic setting with respect to the Apennine thrust front and the Mediterranean Basin.
The southern Apennine foreland basin evaporites data confirms the presence of basins in the central and eastern Mediterranean Sea, which never desiccated during the entire salinity crisis and evolved to widespread Lago-Mare conditions in the latest Messinian.

MESSINIAN SEDIMENTARY EVOLUTION OF THE ROSSANO BASIN (CALABRIA, ITALY): PRELIMINARY INVESTIGATIONS

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Neogene sedimentary basins of eastern Calabria include abundant Messinian primary and resedimented evaporite sedimentation in the Crotone and Rossano basins. These basins are filled by Tortonian to Pleistocene dominantly clastic sedimentation interbedded with Messinian evaporite cycles. New geological, sedimentological and petrographic data are here used to describe the stratigraphic architecture of the Rossano Basin.
The Tortonian sequence unconformably covers the Paleozoic plutonic-metamorphic complex of the Sila Massif or the Late Oligocene to early Miocene clastics of the Paludi Formation. The Tortonian sequence, represents a characteristic transgressive system with an alluvial red conglomerate, passing into nearshore sediments and deep-marine turbidite strata probably deposited during a low-stand system tract. The latter strata are followed, throughout an angular unconformity, by marls and diatomaceous shales including sulphate nodules (Tripoli Fm.), carbonates with decimetric intercalation of varicolored marl-clays (Calcare di Base Fm.) and gypsumrudite-gypsumarenite deposits associated with clastic carbonates. This first evaporite deposits pass throughout a second angular unconformity to arenites, marls, halite, gypsarenites and olistostromes of variegated clays. In the eastern sector of the basin the euxinic shales of the Tripoli Fm. are truncated by an important erosional surface and followed by a chaotic complex including large gypsarenite and nodular gypsum blocks and by a succession of gypsum siltstone, gypsumarenite and breccia. The clastic evaporite sedimentation is capped by deep-marine hemipelagic marls and sandstone turbidites (Garicchi Fm.) and sandstones (Palopoli Fm.). The Rossano basin records the Messinian salinity crisis events in a complex basinal setting related to the foreland fold-thrust belt of southern Italy orogen.

STRATIGRAPHY AND DETRITAL MODES OF THE LATE MESSINIAN POST-EVAPORITIC SANDSTONES OF THE SOUTHERN APENNINES FORELAND BASIN SYSTEM, ITALY

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Post-evaporitic sandstones in the Irpinia-Daunia sector of the southern Apennines foreland basin system records both the effects of the foreland evolution and the Messinian salinity crisis occurred in vaste areas of the Mediterranean region.
During the Messinian salinity crisis, the southern Apennines experienced intense accretion and uplift. The Irpinian-Daunia ranges of the southern Apennines preserve remnants of the Messinian thrust-belt. The Messinian stratigraphy includes: **(a)** pre-evaporitic thin-bedded euxinic marly clay interbedded with diatomaceous marls. The environmental conditions are referred to a pelagic starved basin; **(b)** evaporitic limestone, crystalline shallow-water gypsum and reworked gypsum. The evaporitic and post-evaporitic sequences are separated by an erosive unconformity; **(c)** the post-evaporitic deposits are subdivided in three subunits. The Torrente Fiumarella unit, composed of lacustrine and alluvial conglomerate, sandstone, shale and reworked clastic gypsum; the Anzano Molasse, composed of thick bedded conglomerate and turbidite sandstone, passing upward to thin bedded turbidite sandstone and marly-clayey siltstones. Rare freshwater ostracods are present. Volcaniclastic layers are interbedded with turbidites in the upper part of the sequence. The "Lago-Mare" facies deposits are represented by arenite and silty-marly clay with abundant Ostracoda shells (*Ilyocypris gibba*, *Cyprideis torosa* and *Candona* sp.). The Torrente Fiumarella sandstones are quartzolithic and include abundant carbonate lithic fragments. Sandstones of the Anzano Molasse are quartzofeldspathic; aphanitic lithic fragments are dominantly sedimentary, both carbonate and siliciclastic particles. Total rock fragments include variable proportions of plutonic and sedimentary fragments. In particular, two populations are evident, one plutonic-rich, and a mixed plutonic and sedimentary. Anzano Molasse volcaniclastic strata are composed of dominantly vitric particles (shards and pumice). Arenites of the Lago-Mare facies are hybrid arenites, having abundant intrabasinal carbonate particles (ooids, peloids, and bioclast) and subordinate extrabasinal noncarbonate and carbonate particles.
The interplay of the accretionary tectonics of the Irpinian sector of the thrust belt and the evaporite sedimentation caused key perturbations in the sedimentary record of the basin fillings. The abrupt change from hemipelagic and turbidite sedimentation and the evaporite and clastic sedimentation is here explained by the interplay of accretionary tectonic and regional and local sea-level changes. Detrital modes testify complex provenance relations from the accreted terranes forming the late Messinian thrust-belt. All sandstones have abundant plutonic and sedimentary detritus. Sedimentary detritus consists of both carbonate and siliciclastic particles. Carbonate detritus includes both pelagic and shelfal microfacies suggesting provenance from deformed basinal and platform sequences assembled within the thrust-belt. The abundance of plutonic and metamorphic detritus may suggest a provenance from both the accreted Calabrian Arc terranes or recycling from older clastics as suggested by the presence of variable percentages of siliciclastic debris.

CLAY MINERALS STUDY OF THE TORTONIAN TO MESSINIAN PLATFORM TRANSECT ACROSS THE LORCA BASIN (SE SPAIN)

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The Lorca Basin is situated in the Murcia Province (SE Spain), it is one of several interconnected Neogene basins that formed within an extensive northeast trending shear zone of the Betic Cordillera. The Tortonian to Messinian deposits cropping out along the SW margin of the Lorca Basin are composed of five mixed siliciclastic/carbonate units. Each unit is composed of calcarenitic to marly sediments that grade upward into mostly carbonate deposits. Units contain several types of reefs that differ in size, geometry, coral diversity and abundance of coralline algae. The top of each unit is bounded by an erosive surface associated with subaerial exposure. The marls deposited before the first unit start, based on biostratigraphic constrains (planktonic foraminiferal and calcareous nannoplankton), after 10.55 Ma and before 10.02 Ma. The end of the carbonate platform development is uncertain, reef growth probably ceased when the first precursor evaporitic event occurred in the basin centre near the beginning of the Tripoli deposition.
This work is the first steep of a more global clay minerals study of the five mixed siliciclastic/carbonate units and their correlations with deposits of the central part of the basin. In this first steep we describe the clay minerals content of about 100 marls samples corresponding to off-reef deposits of each unit and interlayered reef deposits. The clay fraction of the marls deposited before the Unit 1 is composed of about 60% of smectite , 30% of illite and 10% of chlorite. This assemblage differs from the overlying off-reef marls of the Unit 1 which displays smectite (30-60%), illite (30-45%), chlorite (0-10%) and kaolinite (0-20%). The clay minerals patterns of marls between reef Units 1 and 2 are also different and display smectite (30-60%) illite (15-25) palygorskite (10-15%) chlorite (5-20%) and kaolinite (0-5%). Clay minerals content of marls which crop out between Units 2 and 3 are comparable to clay minerals content of the off-reef marls of the Unit 1 reef. The clay minerals assemblages of the off-reef marls of the Units 4 and 5 are similar and are composed of smectite (40-60%) illite (25-35%) chlorite (0-10%) kaolinite (0-10%) and palygorskite (0-15%).
Clay minerals assemblage changes through time and tree assemblages are recognized. The first corresponds to the assemblage of marls deposited before the Unit 1 (smectite, illite and chlorite). Second corresponds to the overlying off-reef marls of the Unit 1 with kaolinite occurrence (smectite, illite, chlorite and kaolinite), the third reflects the clay content of marls deposited after the Unit 1 with the occurence of palygorskite. Clay assemblage is similar for contemporaneous outcrops at different location in the basin. For example, two sections of marls between Unit 1 and 2 (first in NW second in SE) present the same assemblage. Clay minerals assemblages seem to be controlled by two main factors which are the source rocks and local sedimentary setting. The Lorca basin is enclosed within the mountain ranges to the south, to the east, to the north, and to the west. So, different terrigenous assemblage of smectite, illite, chlorite and kaolinite and enrichment can be interpreted as a response of several source rocks through the time. The palygorskite occurrence can be correlated with apparition of restricted local sedimentary setting in the platform (only after the Unit 1) which allow postdepositional processes of detrital aluminosilicates or a another eolian source.

EVOLUTION OF DEPOSITIONAL ENVIRONMENTS AFTER THE END OF MESSINIAN SALINITY CRISIS IN NIJAR BASIN (SE BETIC CORDILLERA)

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The Messinian succession is exceptionally well preserved in the intramontane sedimentary basin of Nijar in the Internal Betic Cordillera (SE Spain).
The early Messinian sedimentation in Nijar started with a transgressive sequence of coastal and shallow marine fossil-rich calcarenites (Azagador member) that unconformably overlies Paleozoic Basement. These deposits pass upwards and basinwards into open marine hemipelagic marls (Abad member), indicating rapid deepening of the environments. The sedimentary sequence continues with a large amount of gypsum deposits (Yesares Formation), corresponding to the Messinian Salinity Crisis of the Mediterranean.
Gypsum-olistostromes and large slabs of the Azagador member are unconformably overlain by the latest Messinian sediments of the Feos Formation.
These latest Messinian deposits are characterized by a marked sedimentary cyclicity and, from the bottom to the top, two units can be distinguished: the lower one that mainly consists of calcarenitic intervals with laminated pelites and limestone beds. The upper unit is made of cyclic alternation of fluvial fan deposits and lacustrine marls, that corresponds to the 'Lago-mare episode'.
The sedimentary succession records very precisely the strongly fluctuating environmental conditions during upper Messinian, as well as the paleomorphological and paleogeographical changes that are likely related to Late Miocene and Pliocene tectonic uplift of the Sierra Cabrera (Betic basement).
Detailed sedimentological and paleontological investigations have been carried out on the Feos Formation deposits and the dominant fauna, present throughout the upper unit in the lacustrine white marls of the Feos Formation, is represented by ostracod assemblages that are easily referable to *Loxocorniculina diaffarovi* FA, a residual assemblage of non-marine, aquatic communities which lived in brackish water bodies (Lago-mare fauna).
Grey-reddish continental silty-marls are interbedded with the whitish lacustrine sediments, showing pedogenetic features, roots burrowing and terrestrial gastropods, but a poor fauna *in situ*.
The re-establishment of marine conditions are marked by the presence of shallow-water sand deposits. Unfortunately, little can be said about the precise timing of the marine inundation in this context, although the presence of *Globorotalia margaritae* and the absence of *Globorotalia puncticulata* indicates a Lower Pliocene age. If we assume that the return of marine conditions coincide with the Zanclean flooding, we can assert:
- the Messinian post-evaporitic deposits record several events of base level oscillations in the Nijar basin likely influenced by both tectonic activity and regional climate variations, as suggested by strongly marked sedimentary cyclicity that would permit stratigraphic correlations at regional scale;
- the Lago-mare facies is very well developed in the upper unit of the Feos Formation and the transition to marine deposits does not imply a great change in paleodepth. This suggests that the refill of the Mediterranean was not a catastrophic event and that the base level of the Lago-mare was not much lower than that of the ocean.

PALYNOLOGICAL EVIDENCE AS AN INDICATOR OF PALAEOENVIRONMENTAL CHANGES DURING THE MESSINIAN OF ITALY

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The contribution of palynology in the understanding of causes and effects of the Messinian salinity crisis in the Mediterranean area is synthesised in the well known sentence: "climate was dry before, during and after the Messinian salinity crisis" (Suc & Bessais 1990). This idea, used to formulate the two-step model (Clauzon *et al.* 1996), was supported by later palynological studies, still carried out in southern Italian deposits (Bertini *et al.* 1998). The stratigraphic record of vegetational and climatic changes from the area of North and Central Italy completed the picture (Bertini 1994, in press). New sites, located on the Tyrrhenian side and central Apennines, have been studied and their record compared to that already well known from key localities such as the Po plain, the Vena del Gesso and Maccarone. The occurrence of a prevalent subtropical to warm temperate climate pointed out major differences (in both temperature and moisture values) with respect to the coeval sections from Southern Italy, confirming the existence of climatic gradients within the Mediterranean area, at least from the Messinian. In addition, palynological data allows the palaeoenvironmental characterization of the two main Messinian post-evaporitic depositional sequences of Northern Apennines: the lower post-evaporitic sequence (also named "di tetto"), and the upper post-evaporitic sequence (also named "Colombacci"). Both are characterized by peculiar pollen and dinocyst assemblages. Specifically the analysis of changes in the composition of dinocyst assemblages, linked to the progressive arrival and/or the dominance of taxa showing affinities with those of the Parathetys (e.g. *Impagidinium* sp. 1, *I.* sp. 2 and *Galeacysta etrusca*), contributes significantly to clarify the supposed connections between the Mediterranean and the Parathetyan realms as well as with the Atlantic ocean. Finally, the biochronological indications yielded from the palynological studies in North and Central Italian sites permit to propose a correlation with other Messinian peri-Mediterranean areas.

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POLLEN AND MACROFOSSILS OF TERRESTRIAL PLANTS INDICATE PREDOMINANTLY MOIST CLIMATE IN NORTHERN ITALY FROM MESSINIAN TO EARLY PLIOCENE

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The thick and well-exposed Messinian and Zanclean successions of northern Italy provided rich palaeofloral records, thanks to the abundance of both micro- and macroscopic remains of terrestrial plants. Fossil leaves, fruits and seeds, though restricted to a few layers and sites, have been the first source of information on the Messinian to Zanclean palaeoflora and vegetation, and are presently the object of extensive taxonomic revisions, which are aimed to verify the occurrence of problematic taxa, which were often reported in the old literature without a clear indication for reliable and diagnostic characters. In addition, fresh information on plant macrofossils has been recently provided by peculiar methods of preparation (palaeocarpology) and analysis (leaf physiognomy). Nowadays, however, palynology represents one of the most significant tools for the reconstruction of the Messinian-Zanclean flora, vegetation and environment both due to the well-known methodological advantages and because pollen grains can be retrieved in large quantity throughout thick successions of both continental and marine deposits. Thus, the available micro- and macropalaeobotanical information has seen a considerable increase in the last two decades, so that we decided to carry out a comparative analysis of micro- and macropalaeobotanical data from selected sites of the Po Basin and the Apennine foredeep, in order to obtain a more accurate interpretation of the palaeofloristic and vegetational setting. Furthermore, we compared and integrated the climatic reconstructions based either on pollen or macrofossil record.
The rich palynoflora provided by Messinian deposits of Piedmont and Emilia-Romagna, characterized by 135 taxa, indicates moist, subtropical to warm-temperate conditions. Cool-temperate taxa are scarcely represented, with the exception of some intervals characterized by the increase in *Picea* and *Cedrus* pollen (cooler episodes), especially during the post-evaporitic times. Herbs are rather scanty, indicating the absence of dry conditions. Scattered macrofloral data from the same successions confirm this picture, being characterised by the abundance of laurophyllous, entire-margined leaves, partly identified as Lauraceae. The mid-Messinian climatic reconstructions obtained by analysing the pollen data according the "Climatic Amplitude Method" (Fauquette *et al.,* in press) are in agreement with the ones based on the physiognomic analysis of leaf assemblages (Wiemann M.C. *et al.,* 1998). Minor discrepancies emerge concerning the estimate of precipitations, in fact leaf analysis provides significantly higher values, probably due to a local microclimatic signal. Fruits and seeds of the latest Messinian confirm the presence of taxa which require moist, subtropical to warm-temperate conditions (*Visnea, Cyclea, Toddalia,* ecc.). The Messinian to Early Pliocene plant communities, as reconstructed by means of this integrated approach, show the highest floristic affinity with the "Mixed Mesophytic" and "Evergreen Broad-Leaved" Forest, developed in warm temperate (MAT 17-14 °C) and moist (GSP> 800 mm) conditions on the relieves of central China.

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IMPACT OF THE MESSINIAN SALINITY CRISIS ON THE EVOLUTION OF THE LEVANT CONTINENTAL MARGIN (EASTERN MEDITERRANEAN): RESULTS FROM 3D SEISMIC ANALYSIS

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Recently acquired 3D seismic data from the Eastern Mediterranean reveal the complex depositional and structural setting of the Messinian evaporites in the Levant Basin. Since the first discovery in the early 1970s, the origin and evolution of the Messinian Salinity Crisis (MSC) and associated deposits beneath the Mediterranean seafloor has been subject of considerable debate, mainly focused on their depositional environment, age and correlation from the basinal to marginal series. One of the key problems concerns the lack of resolution and 3D geometrical control of this evaporitic system.
This research presents the first regional analysis of the Messinian evaporites in the Levant continental margin, based on 3D and 2D seismic data. The dataset covers a total area of 20,000km^2, depicting a comprehensive view of the evaporite-bearing basin. Seismic data are tied to key wells located on the continental margin, allowing stratigraphic and lithological correlation. The main aim of this study is to build a framework for the MSC and to highlight its impact on the outbuilding of the Levant continental margin and nearby basin.
The high spatial resolution and areal extent of this dataset makes it the ideal tool for analysing the MSC depositional system, through detailed mapping of bounding and internal Messinian horizons and seismic attribute analysis. The preliminary results show that:
The seismic character (seismic amplitude, thickness and reflection continuity) of the Messinian series is variable vertically and spatially. There is a lateral transition from an unconformity surface on the basin margin to an extensive evaporite unit 1.5km thick in the basinal area. Remarkably, the presence of a system of pre-Messinian canyons affected the distribution of evaporite facies, even in the deeper part of the basin.
The occurrence of the evaporites modified the structural style of the post-Messinian continental margin through evaporite dissolution, flowage, and acted as a detachment layer for gravity gliding-related shortening at the toe of the continental slope. The most relevant collapse and withdrawal features are located at the pinch-out of the evaporites towards the margin.
This study documents the importance of 3D seismic analysis in developing a depositional and structural model for the Messinian evaporites. Ultimately, this will allow for an evaluation of the role of local vs. regional factors in controlling their present distribution, linking forward to perspectives for future investigations e.g. ultradeep drilling of the Messinian evaporites.

IS THIS THE MESSINIAN SALINITY CRISIS?

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Ever since the mid-Miocene, the hydrological regime of the Mediterranean Sea has been a contest between the preservation of a normal level and a normal salinity : such objectives are contradictory for a basin with a negative budget.
The simple numerical model of the salt & water budgets developed since 1997 now makes it possible to re-assess some conceptual issues on the M.S.C.
The conceptual model intimately linked to our quantitative model borrows some features from most of the major concepts of the 70's :

- from the model of Van Couvering *et al.* (1976), we keep the idea that a long phase of rise in salinity took place in the Mediterranean deep basins, and that salt saturation was reached before drawdown could happen.
- from the model of Hsü *et al.* (1973), we keep the idea of the Deep Desiccated Basin, but evaporite deposition did not take place in an already desiccated basin: as also postulated by Rouchy (1982) the drawdown proceeded at the same path as evaporite deposition.
- from the model of Busson (1979), we have to keep the idea of a strong density stratification of the waters and brines, in full basins, but the basins do not remain at full level during the crisis, the occurrence of which does not require any significant climatic worsening with reference either to the average Miocene climate, nor to the present Quaternary interglacial climate, which appear to be similar under the latitudes of concern.
- from the model of Clauzon *et al.* (1996) we keep of course the idea that the MSC and drawdown proceeded in two steps - at least in the Western basin.

No other lithospheric process is implied in phasing the M.S.C. than the tectonic closure of the Miocene Atlantic straits, nor in its termination.
True marginal evaporites can only have been deposited when the Mediterranean level remained high; the marginal basins may not all be contemporaneous with each other, according to physiographic peculiarities.
The Mediterranean itself reached salt saturation when the Atlantic water supply only made up for the evaporative loss (the present regime requires a 22-fold higher supply).
The double erosion profiles of the valleys of the Western basin tributaries result from a stand of the western basin at an intermediate level, which took place when the restricted Rifian corridor only allowed for the inflow of an intermediate amount of water between the water deficit on the whole Mediterranean Sea and the deficit on the Western basin alone. This basin remained flush to the internal ("Sicily") sill, and only the amount in excess flowed to the Eastern basin : the late Miocene physiography was similar to present.
A debate on the Sicilian Messinian deposits being "an emergent deep basin series" against "a marginal series" now appears to be of no avail. The interrupted evaporitic deposition, between the Lower Evaporites and the Upper Evaporites, has the same meaning both in the Western Deep Basin and in the Sicilian Basin. It is caused by the partial de-salination caused by the transfer of a mixture of Atlantic surface waters and Western deep brines towards the Eastern Basin. The main difference between the Deep Western Basin and the Sicilian Basin must be that the true deep series are unlikely to be truncated and reworked at the summit, because they never were emergent.
However, it must not be forgotten, that the model essentially describes: - i.- the entry of the chemicals into the basins, - ii.- the possibility of deep-erosion phases. We cannot expect an oceanographic budget model to account for reworking of deposits or detritism.

THE ZANCLIAN CATACLYSM

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Beyond a logical description of the development of the crisis, quantitative modelling also makes it possible to integrate its own end to the salinity crisis.
At the end of the M.S.C, the widespread brackish or freshwater *Lago-mare* facies, coeval with the final deep canyons and detrital discharge, have now found a hydrological significance : they result from a supply limited to the rainfall, runoff and river discharge. Thus, the Plio-Quaternary Gibraltar strait cannot preserve any physiographic common feature with the fully continentalized Miocene portals.
A copy of our Mediterranean budget model has been modified to study the re-fill. We adopted a simple exponential law (in cubic meters) for the annual re-increase in Atlantic water influx to the Mediterranean. This increase law is too weak at the beginning, and the level of the basins is not significantly modified for the first 26 years, but the refill of the basins is completed within the 10 to 11 next years.
The extreme velocity of the Atlantic flow is reconfirmed both by hydraulic calculations, and by the structural morphology of the present strait itself :

- in the Mediterranean domain, it shows a simple corridor, but for a central crest which may originate from a collapsed panel from the northern bank.
- in the Atlantic domain, two unequal channels are found, separated by the "Majuan" or "Spartel" bank, which may be an outlier descending from the Trafalgar plateau, north of the northern channel.
- the Camarinal sill shows an intricate mosaic of submarine hills and closed basins, and is best explained as outliers slid from the Trafalgar-Tarifa coast towards a deeper channel, the course of the Atlantic stream itself.

In fact, the Zanclian deluge was a built-in feature of the M.S.C. : either a strait had to open somewhere, or the whole of the Mediterranean basins had to be filled up with detritals from the surrounding continents and folded belts.
The piracy of Atlantic waters by a Mediterranean stream put an end to the M.S.C.

PALEOENVIRONMENTAL CHANGES HERALDING THE MESSINIAN SALINITY CRISIS IN CENTRAL SICILY: THE TRIPOLI FORMATION OF THE FALCONARA-GIBLISCEMI COMPOSITE SECTION

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The Central Sicilian Basin is a key area to investigate the depositional changes that affected the Mediterranean prior to the beginning of the Messinian salinity crisis. The Tripoli Formation (6.96-5.98 Ma) in the Falconara-Gibliscemi composite section shows a general trend of increasing basin restriction from marine conditions at its base (previous middle Tortonian to early Messinian marls are deep marine sediments) to semi-closed settings in its uppermost part (in the overlying Calcare di Base, the presence of gypsum and halite pseudomorphs indicates incipient evaporitic conditions and a near emersion environment).
The Tripoli Formation includes 46 precession-controlled cycles resulting from the periodical increase in biosiliceous productivity (diatomites) that followed the deposition of marls and pinkish laminites. Higher scale environmental changes are superimposed to this precession forced-rhythmicity.
From 6.96 Ma until 6.71 Ma, open Atlantic-Mediterranean exchanges maintained relatively stable marine conditions.
At 6.71 Ma an important step in the basin restriction occurred with a wider range of salinity fluctuations and increased bottom stagnation; this event may have resulted from shallowing of the Mediterranean gateway under tectonic control. As a result of these reduced oceanic inputs there was an increased climatic constraint of the Mediterranean hydrology.
Around 6.29 Ma, stressful conditions for the marine microfauna were induced by an increase of the surface water salinity; this major step in the restriction may be correlated with the intensification of the glaciation recorded in the Atlantic, which could have enhanced the effects of the tectonic closure.
Around 6.03 Ma, there was a rapid transition to a semi-closed Mediterranean setting characterized by large variations of salinity from diluted to hypersaline conditions, under a dominant climatic control, and by the near complete disappearance of the marine organisms.
Long trend environmental changes recognised within the Tripoli Formation resulted from a complex set of interfering factors controlling the water fluxes exchanged between the Mediterranean and the Atlantic. The environmental changes identified in the Falconara/Gibliscemi sedimentary succession at 6.71 Ma, and 6.03 Ma, occurred simultaneously in western and eastern Mediterranean; they were mainly controlled by the stepwise tectonic closure of the Atlantic connections, although a glacio-eustatic overprint cannot be completely excluded.

EUSTATIC VS TECTONIC CYCLICITY OF MIDDLE MIOCENE (BADENIAN) EVAPORITE FROM FORE- AND INTRACARPATHIAN BASINS (SOUTHERN POLAND AND EAST SLOVAKIAN AREAS)

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The Middle Miocene (Badenian) evaporite-bearing formations from the East Slovakian Basin within the Inner Carpathians (Zbudza Fm, Slovakia) and from the Carpathian Foredeep (Wieliczka Fm, Poland) are characterized by a perfect cyclicity expressed by a succession of sulphates (gypsum to anhydrite), and pure up to clayey halite beds, separated by layers of siliciclastics. In both formations were registered 4 (Slovakia) to 5 (Poland) such cycles, hitherto being interpreted as an effect of sea-level fluctuations (possibly eustatic), enabling concentration or dilution/refreshing of salt brines, occupying both basins during the Middle Miocene salinity crisis. Chlorides of both formations represent several varieties: from structureless to laminated pure halites, interpreted as being precipitated from calm bottom brines in deep basin conditions, and pure to clayey halite-rudites and halite-arenites, chaotic or stratified (graded and cross-bedded), deposited by debris flows (subaqueous slumps) and currents. Occurrence of the last ones, registering intensive redeposition and mixture of salts and clastics, in each evaporite unit, as well as coarse material input in non-evaporitic interbeds may indicate episodes of intensive tectonic activity of basin margins. These periods were associated with volcanic phenomena, emitting a lot of pyroclastics, deposited as tuffite laminae and dispersed particles within salts and clastics.
Variations in environment dynamics (from calm basinal to dynamic slope settings with slumps), clastic inputs, brine salinity and evidence of volcanic activity suggest that the observed cyclicity could be tectonically determined rather than resulting from eustatic fluctuations. The episodes of intensive tectonic activity of the basin margins remobilize the sediments from marginal salt pans, flats and adjacent uplifts. Periods of "tectonic peace" were dominated by chlorides precipitation from bottom brines and accumulation of clastics in suspension within the density-salinity stratified brines. So the distinguished cycles could be nearly isochronous and correlatable in both studied regions/basins.

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PARATETHYAN - MEDITERRANEAN CONNECTIVITY IN THE MARMARA SEA REGION (NW TURKEY) DURING THE MESSINIAN

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Following a brief marine transgression from the Mediterranean in the Mid- Late Miocene (late Serravalian-early Tortonian), the Marmara region in NW Turkey became a transitional waterway between the Eastern Paratethys and the Mediterranean during the Neogene and Quaternary. The Pontian (Messinian) sequence in this region is represented by the Alçıtepe Formation, which is made up of oolitic and bioclastic limestones with basal clastic rocks. The Alçıtepe Formation conformably overlies the fluvio-lacustrine siliciclastic sediments of the Early to Middle Miocene Anafarta and Kirazlı formations and is overlain by fluvio-lacustrine sediments of the Kimmerian (5.5-3.2 Ma) Truva and Tevfikiye formations.

The bioclastic limestones of the Alçıtepe Formation contain a moluscan fauna that is endemic to Paratethys, and indicates deposition in a shallow, brackish water environment.

A detailed biolithostratigraphic study of a section of the Alçıtepe Formation in intepe (Çanakkale) confirms that the formation is of Pontian age and that during its deposition, salinity increased from brackish (<10 g/L) at its base to more marine-like salinities (>30 g/L) in its upper part. Paleomagnetic analysis indicates that the Alçıtepe Formation has a reverse polarity. Taken together with the biostratigraphic data, this reverse polarity interval probably represents chron C3r (6.04-5.24 Ma). Sr isotope analysis of ostracod valves show low $^{87}Sr/^{86}Sr$ values relative to Late Miocene ocean water. This indicates that exchange between the Sea of Marmara and the global ocean was restricted throughout this period. The increase in salinity in the upper part of the formation as shown by changes to the ostracod faunal assemblage is accompanied by a drop in $^{87}Sr/^{86}Sr$ to values low even with respect to the river-dominated signal preserved in Mediterranean Messinian evaporites. This suggests that inflow to the Sea of Marmara was dominated by non-marine sources with low $^{87}Sr/^{86}Sr$ and that the increase in salinity was generated either by increased evaporation, or by decreasing outflow, trapping salt within the basin, or by influx of saline hydrothermal fluids. Marmara - Paratethyan exchange with the Mediterranean was therefore restricted and possibly severed during the Messinian, and was not re-established until the late Aktchagylian (early Pliocene). This connection was the result of increased activity on the North Anatolian Fault and global sea level rise.

REVISED TIMING AND EVOLUTION OF THE MESSINIAN SALINITY CRISIS IN THE MEDITERRANEAN AREA

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A high resolution biostratigraphical and cyclostratigraphical study of various field sections of Sicily and the eastern Mediterranean, covering the entire Messinian Salinity Crisis interval, allows us to propose a revised timing for the major paleoenvironmental changes that affected the Mediterranean during this event. The new ages have been obtained using the astronomically calibrated timescale established by Hilgen and Krijgsman (1999) and with a re-calibration of the sedimentary cyclicities using Laskar $90_{(1,1)}$ solution. The study of the pre-evaporitic sedimentary successions of several field sections from Sicily shows that the evaporitic conditions recorded by the gypsum and halite pseudomorph-rich Calcare di Base deposits, associated to precursor gypsum beds, were formed 6.06 Ma in marginal sub-basins. These deposits correlate to an eccentricity minima 100 ky before those described at 5.96 Ma in the deepest part of Caltanissetta basin (Falconara section). However, a significant salinity increase is recognized locally in the Tripoli unit at around 6.25 Ma, coincident with increased glacial influence observed in the ocean record (Hodell et al., 2001; Vidal et al., 2002). The Lower Evaporites (Gypsum and Massive Halite Units) were formed during this long glacial period concomitant to tectonic closure of the Rifian corridor. The end of this cool period (5.57 Ma) corresponds to the last major glacial peak (TG12), correlated with the desiccation of the Caltanissetta basin at the end of the Lower Evaporites deposition. We propose to link the deposition of the potash salt, which requires increased basin restriction and aridity, to the major glacial event recorded by the peaks TG20 and TG22. The Upper Gypsum and Lago-Mare deposits were deposited during the post-glacial period; the abrupt restoration of normal marine conditions occurred synchronously at 5.33 Ma in relation to a geodynamical event in the Gibraltar area. These events were controlled by the complex interplay of regional (initial basin morphology and sedimentary tectonics) and global factors which regulated the influx of ocean water inputs (tectonically-driven closure of the marine gateways and glacio-eustatic variations). The precession-controlled fluctuations of the circum-Mediterranean climate also played an important role, especially during the Upper Evaporites and Lago-Mare deposition.

DISCOVERY OF ANOXIC BRINE-FILLED BASINS IN THE MEDITERRAEAN RIDGE DOCUMENT EXHUMATION AND DISSOLUTION OF THE MESINIAN EVAPORITES IN THE DEEP SEA

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One of the most striking consequences of the Messinian salinity crisis in the Mediterranean is the formation of deep-seated brines at the bottom of collapse basins due to the exhumation of subcropping Messinian evaporites. The Mediterranean Ridge (MR) is the accretionary prism developed above the Benioff plane of the African slab subducting underneath Eurasia. MR is a very special accretionary wedge both for its unusual width (250 km) and for being flat, with a tapering angle of 1.5° at the deformation front. Both peculiarities are accounted to the presence of evaporites within the accreted terrains, and of their variable thickness across the ridge. Hemipelagic Plio-Pleistocene sediments overlying the Messinian evaporites in the Ionian basin were deposited at a very low rate (less than 2 cm/1000 y) since the MR has always been turbidite-free, and the eastern Mediterranean is known for its low productivity. As a result, the total thickness of the post-Messinian succession may be as low as 100 m. Exhumation of underlying evaporites related to faulting, submarine dissolution and fluid migration or a combination of both resulted in the formation of deep-seated, high density brines.

Five such anoxic brine lakes have been discovered from 1983 to 1994 as follows

NAME	YEAR OF DISCOVERY	LOCATION OF BASIN
Tyro	1983	western Strabo Trench
Bannock	1984	close to the MR deformation front facing the Sirte A.P.
Urania	1993	close to the "cleft" big depression where no Messinian evaporites are present (DSDP Sites 126 and 377)
Atalante	1993	
Discovery	1994	

Each brine lake has its own chemistry: this finding is accounted to the dissolution of different levels of the evaporitic succession, which is locally unknown, but is interpreted from genetic models and in comparison with the well known sicilian succession. The best known is certainly Bannock Basin, investigated with multipole dedicated cruises in its geology, geomorphology, chemistry, sedimentology (by means of sediment traps), bacteriology (bacterial mats). Atalante Basin brine is strongly enriched in K, whereas brines from Discovery Basin are a concentrated solution of $MgCl_2$ and document that the last evaporative stage (close to total dryness) was reached at the end of the Messinian salinity crisis. It is pointed out that all the brine-filled basins created by exhumation of Messinian evaporites are located in areas of the MR where high precision, deep penetration seismic surveys suggest that the evaporites are thin, or even missing, whereas they are conspicuously absent in areas where large thicknesses of halite are geophysically detected.

In conclusion after over thirty years of active research and notwithstanding important advances in stratigraphy, the Messinian is still a (partly) open problem. No ending yet for Messinian research.

THE MESSINIAN – ZANCLEAN CYCLE IN THE NORTHERN AEGEAN SEA

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Several field trips have been realised in the northern Aegean Sea (Serres – Kavala region) in 1991. On these occasions, Gilbert delta fan deposits have been evidenced, for example in the area of Karyani. A recent field trip in 2002 offered the opportunity to observe outstanding Gilbert delta fan deposits along the new coastal highway Thessaloniki – Kavala (E90) in the area of Acto Nea Kerdylion. During this new field trip, it has also been possible to observe a clear erosional surface at the base of the Gilbert delta fan constructions. At Akropotamos, the erosional surface cuts evaporites (gypsum) and is obviously overlain by foreset beds of a Gilbert delta, the bottom set beds of which being nearby exposed southward.
An intensive work for dating these deposits has been recently done by Snel *et al.* (in press). According to their biostratigraphic results, evaporites from Akropotamos belong to the Messinian while deposits overlying the erosional surface belong to the earliest Zanclean.
The erosional surface which separates the Messinian deposits from the Zanclean Gilbert delta sediments in this area is an additional argument for the Clauzon *et al.'s* scenario (1996): evaporites from Akropotamos correspond to the first step of the salinity crisis (first fall in sea-level causing the coastal evaporites), the second step (intense sea-level drawdown and desiccation of the Mediterranean) is locally marked by the erosional surface. The erosional surface could be coeval with the deep basin evaporates well-known off-shore in the nearby Prinos Basin (Proedrou & Sidiropoulos, 1992).
Accordingly, the Messinian – Zanclean Mediterranean eustatic cycle is completely represented in the northern Aegean region.

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LATE MESSINIAN EROSION AND POST-CRISIS REFLOODING IN THE MEDITERRANEAN: CONSTRAINTS FROM MARGINAL BASINS OF NE MOROCCO, SARDINIA AND SICILY

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The late Messinian erosional surface and the subsequent reflooding deposits were investigated in three marginal basins of the Mediterranean, Melilla-Nador (NE Morocco), Sinis Peninsula (Western Sardinia, Italy) and Eraclea Minoa (SW Sicily, Italy), by using geometrical, sedimentological and biostratigraphical analysis. Results are:

- The surface was precisely located and characterized in Sardinia and Sicily. Karstic features are widely identified at the top of the underlying Messinian carbonates. In Sicily an erosional surface is identified at the top of the Lago Mare deposits;
- Gravity-induced erosional features are associated with subaerial erosion. They are recorded in Morocco (km wide landslides) and Sardinia (submarine chaotic deposits);
- The geometry of the surface is composed of wide-extent erosional plateaus, reaching 20km in length. The margins of the plateaus are indentated by steep cliffs and/or aerial paleovalleys reaching at most 80 metres depth (Morocco);
- The transgressive system tract of the post-Messinian Salinity Crisis deposits was identified in the three investigated basins; its age is in fact not definitely established and further investigations are necessary for a better precision. It could be late Messinian and/or earlymost Pliocene as only *Globorotalia cibaoensis* was found, above and under the erosional surface Sicily, above it in Morocco. This indicates that the *G. margaritae* group foraminifers occured earlier in the Mediterranean than previously accepted, under the Pliocene Trubi deposits. This situation is similar to the Atlantic one where the *G. margaritae* foraminifer group occured since late Messinian.The transgressive system tract upward passes into undoubtefully early Pliocene deposits (*G. puncticulata-G. margaritae*). Nevertheless, gaps or condensed deposits might exist during the reflooding.

These results allow a better understanding of the late Messinian erosional surface from subsurface data and lead to reinvestigate the Messinian-Zanclean transition for more precise dating and significance.

OCEANOGRAPHY AND THE MESSINIAN SALINITY CRISIS

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The Messinian Salinity Crisis constitutes an outstanding event with regards to amplitude of sea level changes and to its short duration (about 600 000 years). Since the discovery of the Messinian salt layer in the deep basins of the Mediterranean Sea in the 60's, a large amount of data has been collected on land and at sea, allowing for several scenarii of the Crisis to be proposed and discussed. Nevertheless, the relative chronology of the environmental changes before, during and after the Crisis, and the spatial relationships between both domains are still poorly understood. This can be partly explained by: (1) very different time and space resolutions of data collected onshore and offshore; (2) the tendency of the scientific Community to focus on their respective analyses without crossing independent approaches; and (3) the difficulty to link erosional and depositional processes acting on wide and contrasted domains, especially in a context of sea-level changes controlled both at regional (through climate, tectonics, global isostasy) and local (through evolution of sills and changes in sedimentary inputs) scales.

In this opening talk, we aim to illustrate the recent attempts of oceanographers to link these still poorly connected systems of the margins and deep basins, mostly led through an improvement of seismic imagery in vertical and horizontal resolutions. A first important step has been the high-resolution swath bathymetry obtained in several submarine areas, allowing for connecting canyon paths, at least partly inherited from the Crisis, from land to deep sea. After a period when oceanographers were more motivated by identifying deep structures of the basins and margins or by salt mobility and associated tectonics, a growing interest concerns nowadays the transition from the deep seismic facies of the margins to the salt and Upper Evaporites. Especially, the Gulf of Lions (the best documented area), the Liguria, Corsica and West Sardinia margins, and the Valencia trough offered recently new evidences for polygenic and contrasted erosional surfaces which are often covered by highly variable detrital deposits at the foot of margins, interpreted either as alluvial fans (aerial or submarine) or as slope deposits of various extents. Defining the complex geometrical relationships of these surfaces and seismic facies to the deep evaporites (from lower to upper deposits) is one of the main tasks performed since then. Various situations will be shown in the talk, mainly taken from the Gulf of Lions, the Provencal-Ligurian basin, and West Sardinia.

The new Project Eclipse 2 (INSU-CNRS, France) aims at improving our understanding of these relationships and at including them in a global scenario of the Crisis evolution. From comparisons between various margins, it is expected to: (1) precise which factors (evolution of drainage systems at sea, lithology of eroded areas, sedimentary inputs in volume and nature, including topographic, climatic and tectonic effects) have controlled the shaping and stratigraphy of the margins; (2) connect the various fossil markers updip and downdip, from the upper margins to the deep basins; and (3) deduce a more detailed evolution, especially at the beginning and end of the Crisis, taking into account the complexity of the Mediterranean paleogeography (particularly the control by morphological sills) in space and time. Deep drillings and high-resolution seismics will definitely help to propose detailed evolutionary models, hopefully in the near future.

MAGNETOBIOSTRATIGRAPHIC AGE CONSTRAINT OF POST-EVAPORITIC DEPOSITS: GAFARES, ALMERÍA-NÍJAR BASIN, SE SPAIN

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Messinian deposits are exceptionally well exposed in the Gafares area, NE Almería-Níjar basin (SE Spain). The uppermost Tortonian-Messinian sedimentary record can be divided into four units. The lower unit, the Azagador Member, lies unconformably both on top of the Betic basement of the Sierra Cabrera and on upper Tortonian marls. These sediments change basinwards and upwards into silts and marls of the Abad Member. Magneto-, cyclo- and bio-stratigraphic data locate the Tortonian/Messinian boundary (7.26 Ma) in silts at the base of the Abad Member, and suggest that the date of the top of the Abad is ~5.9 Ma. The third unit, the evaporitic Yesares Member, unconformably overlies an erosive surface affecting both the Abad basin centre marls and the laterally equivalent basin margin reef deposits. The Yesares is characterised by an alternation of gypsum and siliciclastic beds. It shows gradual upward transition to the post-evaporitic unit , which is up to 150 m thick. This consists of a variety of sediments formed in marine (Sorbas-like) and continental (Zorreras-like) facies. The marine sediments are characterised by foraminifer-bearing silty marls. Storm and turbidite sandstone beds are intercalated into the silty marls. A delta prograded SE towards the centre of the area. Additionally, fan-delta deposits were localised along the basin margins. The continental deposits are represented by fluvial channel conglomerates and alluvial-plain sands and silts where palaeosols developed. Lower Pliocene marine yellowish silts and fine-grained sands unconformably overlie a surface of intense erosion excavated in the top of the post-evaporitic unit.

Planktonic foraminifers of the *Globorotalia miotumida* group are present in the uppermost pelitic intercalation of the Yesares Member and throughout the silty marls of the post-evaporitic deposits up to the Messinian/Pliocene boundary. These foraminifers are abundant, continuously present, and generally well preserved. These assemblages are characterised by stratigraphically and temporally congruent species, indicating that reworking is unlikely. Moreover, size sorting, a typical feature of reworking, is not observed in the studied samples.

A magnetostratigraphic study of the post-evaporitic unit has been carried out. Samples at 16 sites were collected up to the Pliocene deposits. Some samples have a weak natural remanent magnetization that provide unreliable demagnetization (both thermal and alternating field) and polarity data. Nonetheless, those reliable samples with a clear magnetic signal show reverse polarity throughout the studied interval.

On the basis of their stratigraphic framework and biostratigraphic and paleomagnetic data, the post-evaporitic deposits cropping out in the Gafares area can be assigned to the upper Messinian, within the magnetic chron C3r. One of the implications of this age attribution is that the Miocene/Pliocene boundary is included in the erosional unconformity that overlies the post-evaporitic deposits, and not within the post-evaporitic unit, as has been postulated in the Sorbas basin. Another important implication is that marine recovery of the western Mediterranean was Messinian in age, and not Pliocene as traditionally claimed.

STRATIGRAPHY, SEDIMENTOLOGY AND PETROGRAPHY OF THE MESSINIAN CROTONE BASIN SEDIMENTS (CALABRIA, ITALY): PRELIMINARY RESULTS

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The Crotone Basin is filled by three main tectono-stratigraphic units bounded by regional unconformities: middle Miocene-middle Messinian unit (Unit a), middle Messinian-lower Pliocene unit (Unit b), and middle Pliocene-Pleistocene unit (Unit c). We investigated the north-western sector of the basin to focus on the relationships between lithostratigraphic units and the characteristics of the halite deposit.

Unit a is a trangressive system, consisting of alluvial and near-shore deposits (San Nicola Fm), that pass to a rhytmic alternance of marl and pelite (Ponda Fm.) passing upward to marl with interbedded diatomaceous shale (Tripoli Fm.). The Tripoli Fm. is overlain by a layer of bituminous shale followed by an up to 150 m-thick gypsumarenite body (Lower Evaporites) that underwent dehydration possibly by burial diagenesis.

Unit b consists of four formations: 1) mudstones interbedded with arenite strata and halite deposits (Detritico Salina Fm.), 2) marls interbedded with arenite strata having gypsum cement ("Upper Evaporites" corresponding to the Lago Mare facies), 3) conglomerates and sandstones (Carvane Fm.), and 4) mudstone and marl (Cavalieri Fm, Lower Pliocene).

The stratigraphic relationships of these formations are complex due to salt tectonics and complex architecture of the basin. From field data and preliminary biostratigraphic analyses, it appears that the "Upper Evaporite sequence" unconformably overlay the "Lower Evaporite sequence", whereas the rest of the succession represents a continuous stratigraphic record.

The halite rocks of the Detritico salina Fm. occur in diapiric structures with sulphate cap rock along a fault system trending N 60°-40°. In the Belvedere di Spinello area, the halite deposit is up to 300 m in thickness. The facies distribution and thickness of the post-Messinian sequences in these areas testify the close controls of the salt tectonics.

Four main types of halite rocks have been observed in the two areas:

- Banded facies can be interpreted, as the result of flow, disruption and recrystallization of former pairs of pure halite and halite/mudstone/siltstone laminites.
- White facies may represent the result of partial recrystallization of primary subacqueous halite to form larger crystals.
- Clear facies may be interpreted as a remnant of subacqueos primary crystals (cumulate?) in a rock consisting mostly of crystals grown displacively into the mud together with minor gypsum crystals.
- Breccia facies probably represent the result of dissolution collapse of the pairs halite/mudstone/siltstone layers.

E. MEDITERRANEAN SMALLER MAMMALS AT THE L. MIOCENE-E. PLIOCENE TRANSITION

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The late Turolian coincides with the Messinian Salinity Crisis in the marine sequences in the Mediterranean (de Bruijn, 1973).
The changes in composition of land mammals in the E. Mediterranean during this time interval (MN13) are the scope of this study.
Four Late Turolian rodent localities from Greece and Turkey are compared: the locality of Tomea Eksi in the Ptolemais basin, Maramena (Greece) and Suleimanli 2, and Kangal 2 (Turkey).
Of all the above localities, only Ptolemais basin (localities Komanos 1, 5.25 Ma and Tomea Eksi 5.34 Ma) has been calibrated by combining paleomagnetism, cyclostratigraphy and radiometric dating. Due to this, we have achieved an unprecedented high resolution time control for our rodent assemblages. We assume, based on the observed stage of evolution, that all four localities are coeval.
The rodent assemblages from the Late Turolian localities show an unusual patchiness, the presence of exotic fauna elements from different origins (*Calomyscus delicatus, Arvicanthis* n. sp. *Pseudomeriones* sp.) and differences in species content (Tbl. 1).
The composition of the Late Turolian assemblages does not suggest a dry environment. It is then safe to assume that during the Messinian the terrestrial environments in E. Mediterranean were not dry.
The great differences in diversity as well as in content are thought to be of local importance only due to local ecological factors around the localities.
Around the Mio/Pliocene boundary there is a change in rodent assemblages. They become more similar than before and lose their "exotic" elements. This is the time when arvicolines enter. The rodent assemblage from Komanos 1, in the Ptolemais basin over the Mio/Pliocene boundary has lost the "exotic" elements: *Arvicanthis* and *Pseudomeriones,* but includes the arvicoline *Promimomys.*

PALEOECOLOGICAL ASPECTS PRECEDING THE MESSINIAN SALINITY CRISIS: A CASE STUDY FROM GAVDOS ISLAND.

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The Messinian pre-evaporitic sedimentary succession of Gavdos island (Metochia section) is a nearly uninterrupted succession of marine sediments, dominated by finely laminated diatomaceous sediments, which are cyclically alternating with marlstone and white limestone beds. The purpose of this study is to analyze in detail the benthic and planktonic foraminiferal microfauna as well as the ichthyofauna preserved in the sediments of this section.
The qualitative and quantitative analysis of the planktonic foraminifera fauna allowed the recognition of six bioevents, which have been astronomically dated for the Mediterranean. The base of the diatomitic succession in Gavdos Island is dated at 6.696 Myr. The section ends at 6.0 Myr.
A species proportion matrix from benthic foraminifera was prepared from raw assemblage counts and a Principal Component Factor Analysis was implemented, yielding three principle axes which explain 83,031% of the variability contained in the matrix. The first axis which explains 57,221% of the variance is loaded negatively by *Bulimina aculeata* group indicating great tolerance for high salinities, oxygen deficiency and nutrient abundance (v.d. Zwaan, 1982; Kouwenhoven et al., 1999). The second axis which explains 13,341% of the variance is loaded negatively by *Bolivina plicatela,* which is a species highly tolerant to raised salinities and to oxygen deficiency, with probably an epiphytic mode of life (v.d. Zwaan, 1982).). The third axis which explains 12,47% of the total variance has a bipolar character indicating two assemblages. Species loading this axis positively is *Asterigerinata planorbis*, which is considered to have an epiphytic mode of life, pointing to a tolerance to increased salinities. Species loading the axis negatively *Bolivina spathulata* group which is known to survive in oxygen deficient environments and is often dominant in the oxygen-minimum zone or in the upwelling zones. The vertical distribution of the revealed scores indicate that throughout the deposition of the diatomaceous sequence of Metochia section extremely stagnant bottom water conditions interrupted by small scale stable marine conditions, prevailed.
An assemblage containing Myctophidae and Syngnathidae has been observed throughout the studied section. Such an association of fish having ways of life apparently incompatible can be explained only by the action of marine currents (Gaudant 2002). In particular, Myctophidae attest the existence of deep zones of at least several hundred meters deep, located along the margins of the circalittoral zone.

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LATEST MESSINIAN "LAGO-MARE" *LIMNOCARDIINAE* FROM ITALY: STRONG AFFINITY WITH THE PONTIAN FAUNA FROM THE DACIAN BASIN

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Sediments of hypo-oligohaline environment laid down during the post-evaporitic phase at the top of the Messinian evaporitic regime ("salinity crisis") within the Mediterranean basin are rich of mollusc assemblages characterising the "lago-mare" biofacies. Several oligo- mesohaline species of prosobranch gastropods belonging to Neritidae, Thiaridae, Melanopsidae, Hydrobiidae and bivalves of the families Cardiidae (subfamily *Limnocardiinae*) and Dreissenidae, colonised various districts of the Mediterranean area (Spain, France, Corse, Italian peninsula, Sicily). The occurrence of elements of the subfamily *Limnocardiinae* Stoliczka in the Mediterranean area is of special palaeobiogeographic interest because of their Paratethyan origin. *Limnocardiinae* were diffused in shallow water basins with low salinities (5-18‰) displaying repeatead events of adaptive radiation through Neogene in Paratethyan realm (Nevesskaya et al., 2001).

New records of significant species belonging to *Limnocardium, Euxinicardium, Tauricardium, Paradacna, Phyllocardium, Chartoconcha, Pontalmyra, Pseudocatillus, Eupatorina, Prosodacnomya, Prosodacna, Psilodon* from the uppermost Messinian sediments of Tuscany (Borro Strolla, Poggibonsi), Marche (Pietra La Croce, Ancona) and Sicily (NW margin of Hyblean Plateau) and the review of old literature following the new systematics *Limnocardiinae* arrangement by Nevesskaya *et al.* (2001) point out close relation of the Italian fauna with that from the lower and upper Pontian sediments of the Dacian basin (Papaianopol, 1989 cum refs.).

The ecology of *Limnocardiinae* is mainly tied to oligohaline water so that spreading of suitable habitats in depositional systems of marginal settings characterized by increasing freshwater influx at the top of the "salinity crisis" (Ricci Lucchi *et al.*, 2002) favoured their dispersal into the Mediterranean area from the Paratethys at the latest Messinian time, since these taxa are not recorded in the lower Messinian lacustrine/brackish episodes of Italy (Esu, 2003). The palaeobiogeographical data referred to *Limnocardiinae* (Popov & Nevesskaya, 2000) suggest that the Aegean basin could be an intermediate basin from whence the Paratethyan type fauna migrated into the Mediterranean area.

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LATE MIOCENE BRACKISH LOXOCONCHIDAE (CRUSTACEA, OSTRACODA) FROM ITALY

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The Family Loxoconchidae Sars 1925 includes over 800 fossil and extant species that mainly inhabit littoral and sublittoral marine environments. Only few living species (i.e. *Loxoconcha elliptica* Brady, *Elofsonia baltica* (Hirschmann), *Hirschmannia viridis* (Müller), *Sagmatocythere pennata* (Schornikov), *Loxoconchissa* (Loxocaspia) *immodulata* (Schornikov) can withstand brackish waters.

During Late Miocene, in the Paratethyan domain wide brackish basins developed and numerous Loxoconchidae adapted to the decreased salinity. Beside several species pertaining to the genus *Loxoconcha*, other species have been referred to the genera *Loxocorniculina, Loxoconchissa s.s.* and *Loxoconchissa* (*Loxocaspia*). In the Italian brackish basins developed during Late Miocene it is possible to recognise the presence of all these genera: *Loxoconcha* and *Loxocorniculina* are mainly documented in the latest Messinian *lago-mare* biofacies [i.e. *Loxoconcha eichwaldi* Livental, *Loxoconcha muelleri* (Mehés), *Loxoconcha rhombovalis* Pokorny and *Loxocorniculina djafarovi* (Sneider in Suzin)]; on the contrary *Loxoconchissa s.s.* and *Loxoconchissa* (*Loxocaspia*) seem to be confined to the Late Tortonian-early Messinian brackish basins of Tuscany (Volterra-Radicondoli, Cinigiano-Baccinello and Velona Basins) and are represented by new species.

A re-definition of the genus *Loxoconchissa s.* l. on the base of the hinge and of the sexual dimorphisms is presented in this paper and its geographic and stratigraphic distribution are discussed.

HOW MUCH DID CLIMATE FORCE THE MESSINIAN SALINITY CRISIS? QUANTIFIED CLIMATIC CONDITIONS FROM POLLEN RECORDS IN THE MEDITERRANEAN REGION

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Quantifying the climate of the Mediterranean region during the Messinian salinity crisis will help to better understand climate forcing on this event. The "Climatic Amplitude Method" was used for reconstructing climate from Neogene pollen data, conceived especially for periods devoid of modern vegetation analogue.
Twenty Messinian to Lower Zanclean pollen sequences areavailable in the Mediterranean region. Most of them do not cover the whole Messinian interval, particularly those along the Mediterranean shorelines where sedimentation was interrupted during the sea desiccation. In contrast, sedimentation was almost continuous in such areas as Morocco (Atlantic side), the Adriatic coast (Po Valley included), and momentarily the Black Sea.
Pollen diagrams reveal a high regional variability and a southward increase in herb frequency. Open and dry environments existed in the southern Mediterranean region prior to, during and after the salinity crisis. Trees developed in areas close to mountains such as in the Po Valley, Cerdanya and the Black Sea region. Most variations are constrained by fluctuations of *Pinus* pollen amounts, indicating eustatic variations. Climatic quantification from pollen data does not show obvious climatic changes due to the desiccation of the Mediterranean Sea, especially in the dry and warm southwestern Mediterranean area (Sicily, southern Spain and North Africa). At Maccarone, along the Adriatic Sea, a decrease in temperatures of the coldest month and, less importantly, a decrease in mean annual temperatures, correspond to a drastic vegetation change. These temperature variations are assumed to be controlled by regional environmental changes rather than to reflect cooling. Some migrations of plants probably occurred as a response to Mediterranean desiccation. But the climatic contrast that has probably existed at that time between the central Mediterranean and the peripheral areas might be amplified.
Climatic reconstruction from pollen data in the western Mediterranean area shows that climate is not the direct cause of the Mediterranean desiccation, as the Mediterranean region had experienced continuously high evaporation long before the crisis.

PALAEOVEGETATION MAPPING WITH INTERPOLATION METHODS OF POLLEN DATA

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Pollen records are an excellent tool for palaeovegetation and climate reconstructions. They have already been used to quantify the Pliocene climate (Fauquette *et al.*, 1998, 1999). In order to better understand continental environments as well as their evolution, palaeovegetation maps have to be established. Each site studied provides a picture of the local and regional vegetation according to the main biases (plant pollen productivity and pollen transport). After a selection of localities, based on their pollen richness, and a taxa grouping based on their climatic meaning (and incidentaly on their behaviour along the last 24 Myrs), we have selected the interpolation method suitable for our study. Among the different kinds of interpolations, it has been decided to use the Thin Plate Spline (TPS) allowing interpolations on shared random data (Charlet, 2002). When data have been described on two or three dimensions, the effects of natural variations and the measurement errors can lead the TPS to produce local artifacts for too high or too low values. We can unbias these situations by applying a TPS which will smooth the surface i.e. we replace the exaggerated values by an average of the closest values. This method presents two advantages: the minimum number of values necessary to interpolate is low ; furthermore, as it uses an exact interpolater, it will take into account the whole dataset by balancing local events. A study carried out with this method (Charlet, 2002) on the early Pliocene of the Northwestern Mediterranean area yielded good results for the various ecosystems with regards to their location on the resulting vegetation map. Similar processes are in progress for the time-window concerning the Messinian salinity crisis.

The interpolations processing and visualisation use different programs such as the geographic information system GRASS, the R language and the GMT program (Generic Mapping Tools).

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THE LATE MESSINIAN LAGO-MARE EPISODE IN THE CENTRAL MEDITERRANEAN BASIN: NEW DATA FROM THE ONSHORE MONDRAGONE 1 WELL (GARIGLIANO PLAIN, CENTRAL ITALY)

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The Mondragone 1 well, drilled in 1968 by Agip, for hydrocarbon exploration, is located in the plain of the Garigliano River, at about 3 km to the east of Cellole village (lat. 41° 12' 17", long. 13°48' 52"). The Mondragone 1 well cut across siliciclastic fine-to-coarse-grained upper Miocene-Quaternary deposits, for a total depth of 2002 m.
Drilling the Mondragone 1 well, fourteen sediments cores have been recovered from 495 m down to 2000 m; SP and resistivity logs have been also recorded. The Mondragone 1 sediment cores have been recently re-sampled and analysed.
This paper deals both with the results of the biostratigraphical analyses performed on the Mondragone 1 re-sampled sediment cores and with the significance of the Mondragone 1 well stratigraphy in the central Mediterranean scenario during the late Messinian *Lago-Mare* episode. Data from seismic lines have been used to reconstruct the geometry and the structural setting of the Garigliano Basin during the latest Messinian. Moreover, the analysis of the SP log allows us to suggest a possible sequence stratigraphy evolution of the Garigliano Basin during the late Messinian *Lago-Mare* episode.
Since the ostracod assemblages in sediment cores 2-14 contain species belonging to the *Loxoconcha djafarovi* Zone, as was defined byCarbonnel (1978) (e.g. *Loxoconcha (Loxocorniculina) djafarovi*, *Loxoconcha (L.) eichwaldi; Cyprideis anlavauxensis; Amnicythere palimpsesta; Zalanyiellavenusta*), it is reasonable to refer this portion of the Mondragone 1 drilled sediments (from -675 m down to –2002 m) to the late Messinian Lago-Mare biofacies.
The uppermost Messinian *Lago-Mare* deposits drilled by the Mondragone 1 well provided an apparent thickness of 1327 m and a true thickness of about 938 m considering a mean dip value of 45° in the strata measurements. Similar thickness (530 m) of pre-Pliocene sediments has been drilled at ODP Site 652, in the Tyrrhenian bathyal plain. The occurrence in the Unit 4 of the ODP Site 652 of scarce *Ammonia beccarii tepida* and *Cyprideis* sp. (Borsetti et al., 1990; Robertson et al., 1990) together with its magnetostratigraphy (Channell et al., 1990) point to time-correlate the ODP Site 652 pre-Pliocene deposits with those drilled at Mondragone 1.
Different behaviour between the northern and the southern Tyrrhenian Basin have been shown by differences in the total subsidence rates computed in the late Messinian *Lago-Mare* rifting areas of the Tyrrhenian Basin. North of the Tiber delta, the uppermost Messinian syn-rift clastic wedges recognized in the northern Latium and in the Tuscany Tyrrhenian margins show similar thickness (250 m and 230 m respectively), lower than that drilled in the Mondragone 1 well and inthe ODP Site 652.
Taking into account the duration of the late Messinian *Lago-Mare* episode (260 ka), a total subsidence rate of about 1 mm/a could be computed for the sedimentary basins north to the Tiber delta, whereas >4mm/a of subsidence rate affected the sedimentary basins developed SE of the R. Selli lineament. This lithosphere feature distinguishes two sectors with different amounts of horizontal stretching (Finetti and DelBen, 1986): 1) a northern Tyrrhenian area, characterized by a thinned continental crust and lower values of late Messinian total subsidence rates; 2) a southern Tyrrhenian area, characterized by an ocean-type crust and higher values of late Messinian total subsidence rates.

WHAT CAUSED THE TRANSITION FROM HYPERSALINE TO BRACKISH WATER CONDITIONS IN THE LATE MIOCENE? TESTING THE DILUTION HYPOTHESES FOR THE LAGO-MARE USING SR-SALINITY MODELLING

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Faunal and lithological data indicate large-scale fluctuations in the salinity of the Mediterranean in the Late Miocene. One of these, the transition from hypersaline conditions that produced widespread evaporite precipitation, to the brackish-water Lago-Mare facies, is attributed to dilution by fresh water. Modelling the hydrologic budget of the Late Miocene Mediterranean indicates that dilution by either river runoff or the fresh water lake system, Paratethys, is not consistent with Sr isotope and salinity constraints. We suggest an alternative hypothesis for this desalination event that depends on changes to outflow from the Mediterranean to the Atlantic Ocean.

MODELLING THE IMPACTS OF THE MESSINIAN SALINITY CRISIS ON CLIMATE AND VEGETATION

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The major event undergone by the Mediterranean Sea consists in its almost entire desiccation during the Late Miocene known as the Messinian Salinity Crisis (MSC). The Mediterranean Sea was isolated from the Atlantic ocean by sea level change and tectonic activity in the Betico-Rifian area. Because precipitation and continental runoff were not able to compensate evaporation, sea level in the Mediterranean basin dropped abruptly, leading to the deposition of evaporites in perched marginal basin in a first step and then in the abyssal plains and allowing the formation of deep subaerial canyons subsequently filled by Pliocene sediments. If climatic conditions have favoured the desiccation of the Mediterranean basin, what was in turn the influence of the MSC on the climate ? How can we explain that, despite the fact that a large area emerged, regions such as Sicily were not affected by any climate change before, during and after the MSC. What were the consequences for the vegetation in the Mediterranean area, as well as globally ?

To address these questions and quantify the impact of the MSC on climate and vegetation, we have performed a set of numerical simulations using the LMDz Atmospheric General Circulation model in combination with the CARAIB vegetation model. In a first experiment, we have forced the LMDz AGCM with pre-Messinian boundary conditions. Paleogeography and sea surface temperature were reconstructed for the Tortonian (Late Miocene). In a second experiment, we reduced the surface of the Mediterranean sea and Black sea keeping solely a few grid cells corresponding to the deeper part of the basin which remained flooded during the MSC. For both experiments, we used pre-industrial values for carbon dioxide and present day orbital parameters. The comparison between the two experiments should highlight the cause as well as the consequences of the MSC. The output climatic fields of both experiments have then been used as inputs to CARAIB, a dynamic global vegetation model. The impacts of the MSC on the vegetation distribution, as calculated by the CARAIB model, will be analysed and compared to information obtained from pollen data.

THE MESSINIAN SUCCESSION OF SINIS PENINSULA (SARDINIA, ITALY): MAIN ASPECTS

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Different investigations were realized in Sardinia (Sinis Peninsula) in the "Programme Eclipse messinien" : the general sequential scheme is treated by J.P. André *et al.* and several informations on the last Messinian erosonial surface are treated J.J. Cornée *et al.* (both this congress). We focalise here on the main aspects of the upper Miocene platform succession.

Lithologically, the Sinis Messinian consists of a forty meters mixed carbonate-siliciclastic deposits developed in a global shallowing-upward sequence from offshore *Amussium* marls to shoreface oolitic and bioclastic limestones.

The lower part of the platform is remarquable by the presence of decimetric to plurimetric carbonate buildups widespread in the whole peninsula. They are made of microbial and suspension-feeding invertebrates (mostly bryozoans and serpulids but also bivalves and vermetids) framework. These composite mud-mounds occured in different sedimentary facies (silty marls, sandy and oolitic limestones...) and growed in "normal" shallow marine environments under variable hydrodynamic conditions. Some of the best developed buildups (principaly in the North and South of the Sinis Peninsula) display several development phases and are clearly integrated into eustacy high frequency cycles. The absence of scleractinians, which are usually developed in Mediterranean Messinian littoral environments is related here to cooler seawater inputs.

Few meters above the last buildups, an unusual facies made of "azoic" laminated chalky limestones occured. Three to ten meters in thickness, it has a regional extension, and was considered by Cherchi *et al.* as hyperhaline chemical deposits from lagoonal environment. However, no real evidence of evaporitic features were observed. A marine environment is proposed, based on sedimentological structures and sedimentary continuity with surrounding facies. But the almost total absence (except rare sponge spicules, benthic foraminiferas, pisces? remains and extremely rare centimetric bivalve beds) of fauna is still unexplained.

The uppermost part of the Messinian sucession exhibits a wide extent breccia composed by micritic limestones, and parasequences of oolitic and bioclastic limestones with stromatolites. At the base, the breccia shows soft sediment deformations related to major seismic schocks that had affected the whole platform. In its upper part, karstic dissolutions are present and are related to subaerial exposures. This breccia ends with an erosonial surface onto Pliocene deposits had transgressed.

Despite the obvious facies dissimilarities with other Messinian marginal platforms, the global biosedimentological evolution, recurrent at this time, allow us to suggest a west Mediterrenean scale correlation.

THE SEDIMENTARY CONSEQUENCES OF THE MESSINIAN SALINITY CRISIS ON THE PROVENÇAL MARGIN, NORTHWESTERN MEDITERRANEAN: PRELIMINARY RESULTS FROM THE "MAURESC" CRUISE

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Between 5.95 and 5.32 My. B.P., the Messinian Salinity Crisis (MSC) is known to have deeply reshaped the Mediterranean Sea margins by huge erosional episodes, and to have led, in the deepest part of the basin, to the deposition of a thick sequence of evaporites, which are divided into three distinct units, the "Lower Evaporites", the "Salt", and the "Upper Evaporites". Although the main stages and timing of the MSC are nowadays broadly known, many aspects of this major event remain unresolved on the lower continental margins. In the deepest part of the margin, the age nature volume and extent of the messinian detritals accompanying the massive erosion of the continents during the second step of the MSC, described as the lower-stand stage (from ~5.60 to 5.32 My.) are badly constrained.

The geometrical and chronostratigraphic relationships between this detritic material, the mobile salt and the Upper Evaporites are still enigmatic because: (1) there is no deep drilling going through the entire messinian sedimentary sequence; (2) bad quality of Seismic imaging due to the presence of salt.

To better constrain the chronostratigraphic relationships between the Messinian detrital sequences and the evaporites, we recently started a new study at the the Provençal margin rise, offshore the Maures massif. This area is characterized by: (1) a small Plio-Quaternary sediment input (compared with the Gulf of Lion margin), (2) no major tectonic activity after the rifting stage of the Mediterranean except for the salt tectonics (compared to the other margins which were recently reactivated, such as the Ligurian margin) and all this lead to a better preservation and seismic imaging of the Messinian erosional surface and clastic deposits. All those elements should help to identify the sea-level lowering effects on the erosion and sedimentation processes. During the "MAURESC" cruise (R/V "TETHYS II") conducted on the Provençal Margin slope and rise, in September 2003, we have collected 530 km of high resolution seismic lines. These profiles complete an older data set acquired during the "MESEA I" cruise (1990), which has been reinterpreted. New seismic processing has been used to increase the accuracy of our subsurface interpretations. This work focuses on the identification, characterization and distribution of the MSC-related sedimentary units and on the relationships between the detrital sedimentary bodies and the evaporites in the deep Provençal Basin.

AN OVERVIEW ON THE MESSINIAN "LAGO-MARE" PALEONTOLOGICAL RECORD

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The «Lago-Mare» facies characterizes the latest Messinian of the Mediterranean area and is dominated by hypohaline deposits. It represents the period of time postdating the evaporitic phase and predating the re-establishment of open marine condition at the very base of the Pliocene. In fact, the most common faunal assemblage within this stratigraphic interval consists of molluscs (*Melanopsis* fauna of Ruggieri, 1958) and ostracods (Iaccarino & Papani, 1979; Bassetti et al 2003), indicating brackish-water environment. The foraminifers and calcareous nannofossils are at time abundant but because of their small and equidimensional sizes are considered by most of the researchers as rerworked. Among them Moruzzi & Follador (1973) described a foraminifer assemblage from the north-eastern Apennine, composed of «recrystallized Globigerinids rarely abundant in number, and frequently very small in size» (< 125 µm). Colalongo et al. (1976) reported the finding of an association of small or poorly preserved to broken planktonic and benthonic foraminifers. Iaccarino & Papani (1980) found a similar assemblage in the uppermost Messinian deposits of the north-western Apennine. All the authors agreed on the interpretation of these assemblages as resedimentation episodes. Iaccarino et al. (1998) documented at the very top of the Messinian "Lago-Mare" sequence at Site 975 (Leg 161, Balearic Basin) a paralic foraminifer assemblage which testifies the presence of marine waters before the Pliocene abrupt re-establishement of the open marine environment. Only very recently, on the basis of the calcareous nannofossil association , several authors (Snel et al. 2001, Popescu, 2003, Crescenti et al., 2002) suggested the presence of repetitive marine water incursions within the "Lago Mare" facies.

At present, on the basis of foraminifer assemblages, "Lago – Mare" deposits indicate typical brackish-water conditions. Even Cresenti et al. (2002) confirm that foraminifers are not clearly indicative of marine influxes because, as usual, they are very poor and badly preserved. Nonetheless the calcareous nannoplankton association is supposed to be authoctonous and therefore testifying marine influences prior to the base of the Pliocene. Recently, two ENI-AGIP survey were drilled in NE Apennine within the post-evaporitic unit; both recovered a continuous record, the former (Campea) recovered 170m from a volcanoclastic horizon (5.50 Ma, Odin et al., 1997) down to the top of resedimented evaporite; the latter (Scab) started from about 50 m below the M/P boundary and spanned 60 m downward in the "Lago – Mare" deposits. Therefore they cover almost completely the post-evaporitic unit of the NE Apennine Messinian basin (Roveri et al.,1998, Ricci Lucchi et al., 2002). The stratigraphic interval spanned by CAMPEA well is not considered an actual «Lago-Mare» environment. In samples from this well ostracods are very rare, while foraminifers range from rare to abundant; P/B ratio is often major than one, but specimens are often very small and not recognizable; a few sample are devoid of organic component.

In SCAB well foraminifers are very rare (can be abundant in <125 µm fraction) and badly preserved, while ostracods are more frequent. Ostracods are particularly well preserved, together with molluscs, in a thin horizon that overlies an organic-rich marsh deposit that, in turn, rest on a paleosoil.

WAS THE MESSINIAN EVENT RECORDED IN THE BLACK SEA? NEW INSIGHTS FROM BLASON HIGH RESOLUTION SEIMIC PROFILES

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In the 70's, the seismic reflection and DSDP drilling data revealed the presence of a thick layer of evaporites within the sediment pile of the deep Mediterranean basins. This discovery led to the famous hypothesis of the Messinian Salinity Crisis (MSC) (Ryan et al., 1973). In 1975, sediment cores from the DSDP program revealed in the Black Sea a thin evaporitic carbonates layer at the Miocene-Pliocene boundary (Ross et al, 1977). From this sampling and in the wake of the previous phenomenal Mediterranean discovery, Hsü suggested for the Black Sea, as for the Mediterranean Sea, a desiccation period at the end of the Messinian (Hsü and Giovanoli, 1979). As for the Mediterranean MSC hypothesis at the beginning, the Hsü's assumption was soon largely disapproved (Steininger and Papp, 1979; Kojumdgieva, 1983). Whereas the main topics of the MSC in Mediterranean Sea is now widely accepted, the debate about the Messinian desiccation of the Black Sea stayed until nowadays open.
The analysis of the new High Resolution (HR) multi-channel seismic data acquired recently (BLASON 1 and 2 French-Romanian surveys) bring new elements to the scientific debate about the possible Late Miocene Black Sea desiccation hypothesis. On the northwestern margin of the Black Sea, these data were calibrated with Romanian exploration boreholes. In the southwestern part of the basin, they were correlated with the DSDP drillings.
First, the correlation of the BLASON seismic data with the DSDP drillings at sites 380 and 381 on the Turkish slope, shows the top of the shallow water environment unit recognised in these drillings corresponding to an erosional surface on our seismic data. This is in agreement with the Hsü and Giovanoli proposition.
On the other hand, several incisions of restricted spatial extension, have been underlined under the Romanian shelf sea floor and are dated from the late Pontian period. Most of the authors consider the regional Pontian stage as the equivalent of the Messinian stage. Thus, these incisions may be related to a Messinian Black Sea sea-level drop. However, the restricted lateral and upstream extension of these incisions is in contrast with the complete desiccation of the Black Sea proposed by Hsü. These new observations should involve a review of the Hsü 's hypothesis. We propose that the Messinian event in the Black Sea may correspond to a sea level drop but with a weaker amplitude than the one recognised in the Mediterranean Sea.

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PARATETHYAN OSTRACODIMMIGRANTS IN ITALY DURING LATE MIOCENE

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During Serravallian, the emersion of the Carpathians and of the Alpine foreland domain closed the northern connection between the western and the eastern Tethys. In the late Miocene this latter became subdivided into several basins (Vienna Basin, Pannonian Basin, Dacic Basin, Ponto-Euxinic Basin and Caspian-Aral Basin) which, due to the freshwater input from several important rivers, were progressively characterised by brackish waters. The connection *via* the present Dardanelli straight was still open but the different salinity between western and eastern Tethys represented an ecological barrier, preventing the faunistic exchanges and causing the onset of two different Late Miocene bioprovinces: the Paleomediterranean bioprovince to the west and the Paratethyan bioprovince to the east.
Notwithstanding the Late Miocene isolation of Paleomediterranean from Paratethys, during Late Tortonian-early Messinian it is possible to recognise in Italy few brackish and freshwater ostracods with Paratethyan affinity. The palaeogeography of the area prevents to suppose a normal aquatic migration, and, indeed, the distribution of several Paratethyan genera seems disjuncted. In this case, only a passive dispersal by aquatic birds can be claimed. Paratethyan genera transported in Italy are *Camptocypria (Sirmiella), Bakunella, Propontoniella, Labiatocandona, Zalanyiella* (all included in the Subfamily Candoninae), *Loxoconchissa* s.s. and *Loxoconchissa* (*Loxocaspia*), included in Family Loxoconchidae and *Amnicythere* (and may be *Chartocythere* and *Mediocytherideis*) included in Family Leptocytheridae.
During the latest Messinian lago-mare event, the closure of the Atlantic-Mediterranean connection and the subsequent humid global climate phase caused a salinity lowering of the Paleomediterranean waters. The ecological barrier between Paleomediterranean and Paratethys was disrupted and an important contingent of Paratethyan ostracods migrated westwards colonising the Paleomediterranean, whose endemic fauna was severely impoverished by the Messinian salinity crisis and the following water dilution. The Italian (and Paleomediterranean) latest Messinian *lago-mare* deposits are characterised by Paratethyan species such as *Caspiocypris pontica, Lineocypris* cf. *L. fossulata, Lineocypris* cf. *L. hodonensis, Pontoniella pontica, Zalanyiella venusta, Amnicythere accicularia, Amnicythere anormalis, Amnicythere cellula, Amnicythere costata, Amnicythere idonea, Amnicythere pontica, Amnicythere lata, Amnicythere litica, Amnicythere multituberculata, Amnicythere palimpsesta, Amnicythere propinqua, Amnicythere* cf. *A. rosalinae, Amnicythere subcaspia, Euxinocythere (Maeotocythere) praebaquana, Euxinocythere (Maeotocythere) bosqueti, Loxoconcha (Loxoconcha) eichwaldi, Loxoconcha (Loxoconcha) muelleri, Loxoconcha rhombovalis, Loxoconcha* cf. *L. schweyeri, Loxocorniculina djafarovi, Pseudocythere limata, Cytherura pyrama, Tyrrhenocythere ruggierii, Tyrrhenocythere pontica.*

DRILLING IN THE NORTHERN PROVENCE BASIN THROUGH MESSINIAN EVAPORITES AND A THICK MIOCENE COVER: THE NORTHERN PROVENCE BASIN TRANSITIONAL CRUST

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The deep Northwestern Mediterranean (Provence) Basin lies between the Valencia Trough to the southwest, the Gulf of Lions to the north, the Catalan Margin to the west, and the Ligurian Sea to the northeast. This area is characterised by a Neogene extensional rift, within a context of regional compression between the European and African plates in the back-arc area of Calabrian subduction. Although the timing of this rifting event has been determined by indirect methods (cores from the edges of syn-rift Oligocene basins, kinematic reconstructions), the deep basin crust itself has never been sampled. Rifting came to an end during the Middle Aquitanian (23 Ma). The break-up unconformity is coeval with onset of the first oceanic crust in the Provence Basin, which opened during the Burdigalian (20.5 to 19 Ma) as a result of southeastward drifting of Corsica and Sardinia. The extent of oceanic crust is still the subject of debate due to an ambiguous magnetic pattern, which has led to the proposal of many different hypotheses.

From the northwest to the southwest, the transition between the slope and the central basin may be associated with a crustal discontinuity. A major change in crustal velocity occurs between ESP 203 (6.2 km/s, slope base,GLP2) and ESP 204 (6.6 km/s), coinciding with the T reflector high. This area corresponds to a zone of deformed, thinned, and presumably continental, basement. It also corresponds to a zone of listric faulting affecting the Late Messinian, as well as the Pliocene-Quaternary.

Southeast of ESP 205, the sedimentary layer between the Late Burdigalian marker and the acoustic basement is relatively thick, but the basement reflector here is flatter and smoother, and no syn-rift sediments are identified.

The crust has a homogeneous velocity structure, and is probably a highly extended crust or an intermediate crust, related to progressive lithospheric thinning from the end of rifting to the beginning of ocean spreading. The crustal nature in this area can be regarded as a fossil example of the transitional realm at the continent-ocean boundary. The salt layer is not disturbed and the Miocene succession is complete.

Drilling in this area will provide significant information concerning not only Mediterranean history (rifting and spreading constraints, Messinian event), but also thinning processes, lithospheric/asthenospheric interactions during continental break-up, thermal state of the lithosphere, etc.

Two longstanding and controversial geological issues relating to this area, namely the Messinian event in the Mediterranean Sea and the process of lithospheric extension, could be resolved by an ultra-deep drilling programme in this Mediterranean domain of the Provence Basin.

THE LATE MESSINIAN SALINITY CRISIS AND LATE MIOCENE TECTONISM: INTERACTION . CONSEQUENCES ON THE PHYSIOGRAPHY AND POST-RIFT EVOLUTION OF THE GULF OF LIONS MARGIN

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This study supports the interpretation of numerous industrial and high-resolution seismic profiles taken in the Gulf of Lions by the petroleum industry (RM96 LIGO et HR Total profiles) and by IFREMER (Marion and Calmar campaigns). Seismic profiles have revealed that in the Gulf of Lions, the Late Miocene platform is offset by normal faults associated with latest Miocene - earliest Pliocene extension. The origin of this extension has yet to be clearly identified, but it is thought to be associated with uplift in the east of the Pyrenees (Alberes and Canigou massifs).

The interpretation of the seismic profiles, the accurate mapping of all the structural features affecting the Miocene cover, and study of the Messinian river profiles on the platform made it possible for us to develop a structural model for the top of the eroded Miocene of the Gulf of Lions platform.

The latest Miocene extension could have been caused by gravity-driven destabilization of the platform associated with base-level lowering at the onset of the Messinian salinity crisis. Exposed during dessication, margin collapsed and was heavily eroded.

In the deep basin of the Gulf of Lions, salt is gradually replaced upsection by chaotic seismic units, which overlies the Messinian erosion surface, and which is interpreted as Messinian detritus (Lofi, 2001; Dos Reis, 2000).The geometries at the upper Miocene paleo slope show a thick prograding unit characterized by steep clinoforms (oblique progradation), whose upper limit is an erosive top lap. Its equivalent on the platform is a by-pass surface, associated with erosion. In the basin, its equivalent is a thick seismic unit, beneath the Messinian salt, characterized by high frequency reflectors and high seismic velocities, the signification of this unit is discussed.

MESSINIAN GEOLOGY AND STRUCTURE OF THE CORSICAN MARGINS: A REGIONAL SYNTHESIS

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The Corsican margins have been the subject of a lot of scientific studies within the framework of the collaboration between the University of Corsica, the BRGM and the IUEM (Brest) for many years. Several thousands kilometres of seismic profiles have been collected and interpreted on the basis of the new geological data, then digitised to build a Messinian map on a Corsican scale.

The Messinian geological map underlines the present dissymmetry of two Corsican margins: the western margin together with the North Ligurian margin bounds the oceanic saliferous ligurian area. The eastern margin edges the endoreic Messinian Corsican Basin.

The morphology of the Messinian western margin seems close to the present morphology. It is large and cut by some important canyons where the basement outcrops evenly. The sourthern part is characterised by an important volcanism dated from the Lower-Middle Miocene epochs extending those of Sardinian rift. The numerous volcanic structures attest all the post-rift evolution of the margin. Immediately in the North, very thick Miocene units cover the basement that deepens rapidly at the foot of the continental slope. The Miocene series of the continental rise are almost totally covered with a detritic sedimentary prism at the foot of the continental slope, dated from the Final Miocene to Lower Pliocene epochs. In the northern Corsica, the extension of numerous continental structures have been observed among which the large Miocene Saint-Florent basin in the West. The deep structures of the western margin are underlined by the presence of various volcanic systems which controlled the Messinian evaporitic deposition distribution.

On the contrary, the morphology of the Messinian eastern margin seems to be very different from the present morphology owing mainly to an important Plio-Quaternary sedimentation. The study of this margin (cf Thinon et al.) shows the influence of the tectonic heritage until the Messinian period and the absence of the Miocene shelf s.s. except for the Aleria zone in the centre area and the eastern Bofinacio margin in the South.

Along the Cap Corse Region, the Messinian continental slope is straight and the residual reliefs suggest that the morphology of the nowadays margin is little different to that of the Messinian margin. This steep margin reflects the likely structure of the south areas before the installation of the Plio-Quaternary sedimentary shelf.

The eastern Corsican margin is bounded by the shallow Messinian Corsican Basin. The nature of the Messinian deposition and the morphological context of this basin show its endoreic character of the Messinian epoch. The detailed study of the Messinian evidence - incision networks well drawn, uplifted and limited to the southern part of the basin where the connection has been obstructed by a magmatic structure - shows the active tectonic and magmatic context of the Pianosa Ridge of the Later Miocene epoch, the Plio-Quaternary periods and notably during the Messinian phase.

THE MESSINIAN PALEOMARGIN OF THE WESTERN BONIFACIO STRAITS: A WHITNESS OF A MULTIPLE RIFTING HISTORY BETWEEN CORSICA AND SARDINIA

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The margin of the Western Bonifacio Straits between Corsica and Sardinia is characterised by a large and wide outer margin and the absence of a continental hinterland. Previous studies have shown the presence of large magnetic anomalies in the outer part of the margin and deep Miocene basins in the inner part. Kinematic recontructions are still assuming some differential movements between Corsica and Sardinia that may explain some of these deep features. However, geological observations are arguing against any large movements between the two islands in the Straits of Bonifacio.

Despite various researches the history of this key section of the Corsican-Sardinian block was rather poorly known. Then, several recent studies have been conducted in order to decipher the Neogene history of the Western Bonifacio Straits margin.

On the outer part, geophysical studies and new geological observations made during Marco and Cylice cruises have demonstrated the importance of the Mid-Miocene (c.a. 17 - 16 Ma) volcanic stage on the South-western Corsican margin in the prolongation of the central Sardinian rift.

More recent studies have been focused on the Bonifacia platform itself during three cruises (Bocca 99, 2000, Geocorse 2003) and a dense grid of high resolution seismic profiles and some new geological sampling have been acquired.

These studies have demonstrated the complex structure of this platform area and as a major result, the discovery and detailed mapping of a Messinian paleoslope in the central part of the present shelf. Indeed, on the contrary to other adjacent margins, this Messinian paleoslope is located well inland of the present-day shelf edge. This paleoshelf displays a complex shape with large canyons and secondary canyons that may be controlled by deep structures.

This paleoslope sharply delimits the innermost area where a rather close relationship can be established between the Miocene series of the Bonifacio on land and the offshore Miocene seismic units that display a very low westward dipping. The offshore units are undeformed and only some minor flexures have been observed demonstrating the absence of significan brittle tectonics in that area since Mid-Miocene and confirming the observations made on land series. The Miocene cover is present over the whole inner shelf and very near to the land granitic basement areas along the whole coastline, which thus represents an erosional boundary.

The Messinian paleoslope is presently buried westwards under a thick sedimentary succession about 500 to 800 metres high. Although it has not been proved by sampling and dating, this infilling is Plio-Quaternary in age as a continuous sediment architecture can be seen in the southernmost part of the shelf offshore Northern Sardinia.

At the North-western edge of the present shelf the structure of the shelf edge is controlled by the presence of various magmatic structures (volcanic flows or sills, intrusive bodies...) that have uplifted and tilted the pre-existing lower Miocene series to the East.

These Mid-Miocene volcanic and tectonic events are linked to the "second" rifting stage of the Central Sardinia-SW Corsican margin and have controlled the Neogene evolution of the Western Bonifacio margin.

BIOSTRATIGRAPHY OF THE MESSINIAN: STATE OF THE ART

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The Messinian Stage represents the standard chronostratigraphic unit for the uppermost Miocene and is widely known because of the «salinity crisis» occurred in the Mediterranean at that time. The up-to-date biostratigraphic results related to the Messinian Stage from the base up to the early Pliocene Stage are presented. The base of the stage is well defined biochronologically (7,25 My) after the formal definition of the Global Stratigraphic Section and Point (GSSP) located at Oued Akrech (Rabat, Morocco). The Messinian sediments predating the deposition of the evaporites are biostratigraphically well documented in the Mediterranean area.
The paleontological record of the deposits overlying the evaporites is, on the contrary, poorly documented because of the poor microfossil content and therefore its meaning is still debated. Most of the researches carried out in the past led to the interpretation that these sediments were deposited in brackish paleoenvironments and therefore the only fossils occurring in these sediments are representative of this environment. Recent researches suggest the occurrence of "marine" intercalations within this brackish-water facies (Lago-Mare so-called event). We stress the occurrence of these levels and suggest a different interpretation of their source.

MEDITERRANEAN GEODYNAMICS IN THE CENOZOIC, FROM THE MANTLE TO POST-OROGENIC SEDIMENTARY BASINS

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The Cenozoic period in the Mediterranean region was characterized by a sharp change in the subduction dynamics some 30-35 Ma ago, from generalized compressional subduction, leading to the formation of Alpine mountain belts, to extensional subduction and the formation of backarc basins, from the Alboran Sea to the Aegean Sea. Backarc extension was thus associated with collapse of the mountain belts formed before this Oligocene revolution. Sedimentary basins evolved in connection with the reactivation of thrust faults as extensional detachments or the creation of new detachments. From the Aegean Sea to the Tyrrhenian Sea and the Alboran Sea we have analysed onshore the kinematic and P-T evolution of the deep crust exhumed by extension and the transition from ductile to brittle conditions and the relations between deep deformation and the formation of basins. We also have reconstructed the behaviour of the deep subducted slabs using kinematic reconstructions and tomographic models. We show two different types of evolution, in the eastern Mediterranean where subduction had been engaged in the Early Mesozoic, and in the Central and Western Mediterranean where it started only in the late Cretaceous or Early Cenozoic. We tentatively propose a scheme explaining how the interactions between the subducting slab and the mantle control the basal shear below the upper plate and the geometry and distribution of detachments and the associated sedimentary basins. The example of the Betic Cordillera and the Rif orogen, where the direction of stretching where different in the lower and the upper crust and changed through time, is discussed and we proposed a scenario of evolution from the Eocene to the Messinian salinity crisis.

UNRAVELLING THE PRE-MESSINIAN: INTEGRATED MICROFOSSIL DATA FROM THE LATE MIOCENE PISSOURI SECTION (CYPRUS)

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The 'Pissouri motorway' section on Cyprus covers the interval from ~7.6 Ma (Late Tortonian) to the start of the Messinian salinity crisis (MSC, 5.96 Ma). As such this section holds important information concerning the onset of the evaporative ("Messinian") phase at upper epibathyal depths. With the present accuracy of integrated dating methods (bio-, cyclo- and magnetostratigraphy) we have the opportunity to place important bio-events within a well-constrained time frame.
In this study integrated microfossil data (planktonic and benthic foraminifera, calcareous nannofossils) are compared in order to add more detail to the emerging picture of changes affecting the eastern Mediterranean Basin towards the MSC. These microfossil data reveal a stepwise development towards an increasingly restricted paleoenvironment.
The nannoflora shows a twofold distribution: starting from the bottom of the section to 6.6 Ma the surficial assemblage is typical of normal marine conditions whereas after this point it shows frequent, extreme fluctuations in abundance and in some cases oligotypic communities (e.g. consisting of 99% sphenoliths)
Benthic foraminifera indicate a rather well ventilated open marine bottom-water environment until ~7.2 Ma. Subsequently, increasing restriction becomes evident, with a time-step around ~6.7 Ma.
The planktonic foraminifera assemblage is well diversified until ~6.7 Ma, and mainly consists of *Globigerina decoraperta, Globigerinoides* spp. and *Globorotalia* genera. The simultaneous presence of surface-dwellers (*Globigerinoides* spp.) indicative of oligotrophic, stratified waters and deep dwellers as *Globorotalia* spp. indicative of mixing water, could indicate a strong seasonal contrast.
After ~6.4 Ma, rapid and repeated changes in both pelagic and benthic productivity are indicated by the foraminifera. The low-diversity benthic faunas are dominated by stress-tolerant taxa (buliminids, bolivinids). Samples barren of planktonic foraminifera alternate with samples with a low diversified planktonic assemblage where Neogloboquadrinids dominate. This taxon is supposed to flourish in spring when eutrophicated waters follow deep winter mixing, and their fluctuation in abundance suggests pulsing of the surficial productivity.
Although constriction of the portals towards the Atlantic (Betic and Rif corridors) is by now more or less accepted as a cause of the MSC, we suspect and find indications for a superimposed effect of astronomically driven climate cycles.

THE MESSINIAN SALINITY CRISIS OF THE MEDITERRANEAN: STATE OF THE ART

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The Messinian salinity crisis (MSC) is widely regarded as one of the most dramatic episodes of oceanic change of the past 20 or so million years. Earliest explanations were that extremely thick evaporites were deposited in a deep and desiccated Mediterranean basin that had been repeatedly isolated from the Atlantic Ocean, but elucidation of the causes of the isolation – whether driven largely by glacio-eustatic or tectonic processes – have been hampered by the absence of an accurate time frame. During the last decade significant progress has been made on the chronology of the Messinian deposits and accurate time scales have been developed for marine, lacustrine and continental realms. Here we will present the state of the art of the chronological data regarding the Messinian Stage. This will (hopefully) help us to solve, elucidate and discuss many of the long-standing problems and controversies related to the causes and consequences of the deposition of the so characteristic evaporite and Lago Mare facies of the Mediterranean Messinian.

EROSIONAL PROCESSES AND PALEO-ENVIRONMENTAL CHANGES IN THE GULF OF LION (SW FRANCE) DURING THE MESSINIAN SALINITY CRISIS (5.96-5.32 MY)

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The interpretation of the Messinian Salinity Crisis (MSC) currently involves the partial desiccation of the Mediterranean sea coupled with the deposition of thick evaporites in the deep basins. In the Gulf of Lions, new sets of seismic data (TotalFinaElf, IFREMER) confirm the basinward extent of the Messinian erosion and allow the mapping of distinctive Messinian seismic markers indicating the erosional surface, basin-margin detrital deposits and evaporite sequence. The geometrical relationship among these three elements and their relation to the paleogeography of the margin during the MSC provide information concerning the past evolution of this area
The Messinian erosional surface (MES), correlated with the "desiccation" phase (and deposition of deep evaporites), is commonly interpreted as a subaerial feature. In the Gulf of Lions, the MES is a complex diachronic polygenic erosional surface, whose morphology reflects a buried drainage pattern, supporting the interpretation of fluvial erosion driven by a substantial sea level drop. However, our results also suggest that large submarine gravity flows occurred prior to significant accumulation of salt and upper evaporites in the basin. As a result, interbedded clastic deposits may account for the conformable reflectors of the so-called deep "lower evaporites". Since erosion by rivers persisted all along the MSC, salt and upper evaporites may also contain a large part of detrital sediments.
Thanks to the improved quality of seismic data, fan-shaped Messinian accumulation are becoming evident in the downstream part of the main Messinian valleys (Nile, Var, Spanish rivers…). The depositional reconstructions generally involve a substantial sea-level fall coupled with deltaic/pro-deltaic accumulations. Over the study area, a chaotic seismic unit filling Messinian lows and extending beneath the salt is interpreted as a Messinian clastic unit. We propose a polyphased scenario of detrital fan edification, involving ante-, syn- and post-salt deposition in subaqueous/subaerial environments.
In the Gulf of Lions, an upper Miocene tectonic phase may have played an important role in the Messinian fluvial network organisation and in the maximum erosion and detrital fan depocenter location.
To progress in our understanding of the Messinian event, we need to compare the evolution of other margins presenting contrasting tectonic, morphologic and geologic settings. This should be initiated during the Eclipse II French program.

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THE MIOCENE/PLIOCENE TRANSITION IN THE GULF OF LION FROM EXPLORATORY BOREHOLE DATA AND SEISMIC PROFILE ANALYSIS

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Scant information exists about how rapid the sea-level rise was at the end of the Messinian Salinity Crisis (MSC). At the present day, studies of the Messinian peripheral successions led to varied interpretations regarding the duration of refilling (a few thousand years (Clauzon et al., 1996) vs. ≈ 200 000 years (Krijgsman et al., 1999)). In the Gulf of Lion, seismic profiles (TotalFinaElf and Ifremer) and data from nine exploratory boreholes allowed the investigation of the offshore Miocene/Pliocene transition.
The architecture of the western margin consists in a thick faulted Miocene sequence eroded at the top by a major discontinuity corresponding to the Messinian Erosional Surface (MES). This surface extends downslope beneath the upper evaporites and salt accumulated above the abyssal plain during the "desiccation" phase. The post-Messinian deposits consist in a thick Plio-Quaternary sequence, which deposited since the Early Pliocene and led to the progradation of the margin as much as 120 km seaward (Lofi et al., 2003).
The MES was tied to boreholes. Lithologic descriptions after drilling reports and biostratigraphic analysis carried out by Cravatte et al. (1974) on four of the wells confirm the presence of a major discordance at the base of the Plio-Quaternary sequence. Beneath the shelf, the Pliocene/Miocene transition mostly consists in a sharp contact between Lower Pliocene clays (occurrence of *Globorotalia margaritae* and/or *Sphaeridinellopsis subdehiscens*) and some deposits of varied ages and lithologies (ex. Jurassic dolomites in the Cicindèle borehole, Lower Langhian clays in Agde Maritime…). Downslope, the Lower Pliocene sediments drilled in GLP2 (MPL1 biozone, acme of *Sphaeroidinellopsis subd.*) overly a 300 m thick sequence composed of alternating salt, anhydrite and marls, corresponding to the upper Messinian evaporites. Over the shelf and slope, dip seismic profiles clearly evidence that the Lower Pliocene clinoforms downlap on the MES, showing that the new margin prograded directly over the eroded margin. Despite the seismic resolution scale (30-50 m), the absence on of any transgressive system tracts at the base of the Plio-Quaternary sequence is in agreement with the abundance of planctonic microfauna recovered in the deposits just above the MES. Transgressive sediments may nevertheless have deposited in the axis of the Messinian valleys as the river mouths retreated during the re-filling of the basin.
In the Gulf of Lion, as in the rest of the Mediterranean, the Miocene/Pliocene boundary corresponds to the reestablishment of open marine circulation after the MSC. At least in the offshore domain, seismic and borehole data support the idea of a rapid marine Lower Pliocene transgression at the achievement of the crisis.

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NUMERICAL MODELING OF THE MESSINIAN SEA-LEVEL FALL: SOME IMPLICATIONS ON EROSION DYNAMICS

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By using a surface process model (EROS) we investigate the consequences of the dramatic sea-level fall on erosion dynamics during the Messinian. The erosion law include in the model belongs to the classical power-law framework, where the erosion flux depends on local slope and water flow. The transfer model is completed by a transfer or deposition terms, allowing to simulate many kind of rivers. We first model the morphological evolution of the Rhone valley, which is one of the best documented Messinian canyons, in order to calibrate the parameters of the erosion law used in EROS. Starting from realistic pre-Messinian topography, we then simulate erosion dynamics at the scale of the Western Mediterranean, with particular attention to the Strait of Gibraltar and the Ebro River.

Until now, mechanisms proposed for both the initiation and the end of the Messinian Salinity Crisis (MSC) are related to external forcing, i.e. tectonics (Weijermars, 1988; Krijgsman et al., 1999; Duggen et al., 2003) combined in a more or less complex way with global eustasy (Kastens, 1992; Hodell et al., 1994; Clauzon et al., 1996; Krijgsman et al., 1999). Although a major effect of the Mediterranean sea-level drop was the dramatic increase of continental erosion, this "internal forcing" as a plausible cause for the end of the MSC has been poorly considered. Recently Blanc (2002) has argued by examining the morphological evolution of the Strait of Gibraltar that its opening was achieved through retrogressive erosion by an eastwards-flowing Messinian stream. Hsü et al. (1973) first suggested a similar interpretation but involving a westwards-flowing stream that might be turned into a tidal inlet. According to Blanc (2002), the retrogressive erosion might be able to attack in the rear the Atlantic continental slope but the difference in base-level on each side of the Gibraltar isthmus during the MSC (i.e. much lower base level on the Mediterranean side) rather suggests a piracy phenomenon by an eastwards-flowing stream. *The present modeling shows that using pertinent parameters, the "internal hypothesis" of a re-flooding of the Mediterranean by the capture of the Atlantic waters due to erosion of the Gibraltar threshold is viable.*

The Ebro Basin in NE Spain corresponds to the southern foreland basin of the Pyrenees with a Tertiary sedimentary fill. Until the end of the Eocene, the basin was open towards the Atlantic Ocean. Further tectonic shortening along the Pyrenees and the Iberian Range closed this western marine connection, resulting in endorheic drainage and lacustrine sedimentation during the Oligocene and the Miocene (e.g. Coney et al. 1996). At present the Ebro basin is drained through the Ebro River toward the Mediterranean Sea. When does the piracy of the endoreic Ebro basin exactly occur is still the subject of debate. For some authors the capture started during the Late Miocene (around 10 Ma) (Garcia-Castellanos et al., 2003), but for others it was induced by the Messinian Salinity Crisis (MSC) (e.g.Nelson and Maldonado, 1990). The present drainage area of the Ebro basin ($A=0.9.10^5$ Km^2) is similar to that of the Rhone ($A=1.10^5$ Km^2). *We first show that the main pre-Messinian drainage areas were of the same order as the present ones.* If the Ebro basin had been connected to the Mediterranean before or during the MSC, then deep canyons would have entered the Ebro Basin, but none has been identified at present. *We conclude that the Ebro basin as a whole was not connected to the Mediterranean before the Pliocene.*

SYNTHETIC MESSINIAN DINOFLAGELLATE CYST RECORD FROM SICILY

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Surficial hydrological conditions prevailing before, during and after the Messinian salinity crisis in Sicily have been approached using dinoflagellate cyst records. The synthetic sequence considered is based on 5 outcrops from the Caltanissetta Basin.

Following interpretations are supported by the use of newly enlarged modern dinocysts data base (e.g. Henry *et al.*, 2003; Londeix, 2004).

All along the Sicilian Messinian sequence, dinocyst taxa encountered are thermophylous and no important climatic change is expressed.

During the *Tripoli* deposition (Capodarso section), sea surface conditions are marine (neritic), with some slight discrepancies to normal salinities at the base of the sequence (abundance of *Homotryblium* spp.) in a context of cyclic sea level changes, as expressed by relays between neritic and oceanic taxa dominances.

Thin clayey layers interbeded in the salts of the *Lower Evaporitic Complex* (Realmonte and Racalmuto mines) provided numerous palynomorphs, but with several antagonist signals [concomitant variations of neritic and oceanic taxa percentages; concomitant variations of Messinian and reworked dinocyst concentrations; and concomitant abundance of confined environment taxa (*Homotryblium* spp.) and very high dinocyst diversity]. That evidences strong mixings of autochtonous, allochtonous and reworked dinocyst populations. Abundance of Prasynophyceae algae in such levels indicates a fluviatile influence. It is of note that taxa present in modern slightly sub-saline water (e.g. *Pyxidinopsis* spp.) show an increase of their percentages in these levels.

The river inputs appear weaker during the deposition of the clays of the *Upper Evaporites Complex* (Eraclea Minoa section), and dinocyst assemblages give evidence of a shallow marine context.

In the *Lago Mare* clays of Eraclea Minoa, the dinocyst assemblages are dominated by taxa, which tolerate confined environment with salinities aside from normal marine ones until more than 10‰ (*e.g. Homotryblium* spp., *Lingulodinium machaerophorum*). River inputs are still present.

These fluviatile inputs went on during the deposition of the *Arenazzolo* silts, and the very high concentration of cretaceous reworked dinocysts could give evidence of intensified terrestrial erosion. The dominance of confined environment dinocysts indicates brackish to marine water, but the more peculiar feature is the presence, at the base of this formation, of *Galeacysta etrusca,* a species though to become from Paratethys surficial sea waters.

The transition to the Pliocene calcareous marls of *Trubi* is extremely sharp and marked, as early as the lowest base of the formation, by the strong dominance of oceanic species (*e.g. Impagidinium patulum, Nematosphaeropsis labyrinthus*).

RADIATION OF LACUSTRINE COCKLES (LYMNOCARDIINAE; BIVALVIA) IN THE PARATETHYS AND ITS IMPLICATIONS FOR THE "LAGO MARE"

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The lacustrine (non-marine) cardiid bivalves (subfamily Lymnocardiinae) are perhaps the most characteristic members of the modern and ancient "caspi-brackish" faunas of southern and southeastern Europe. These faunas flourished primarily in the Paratethyan basins during intervals of restricted or closed marine connections, and also appeared in the Mediterranean "Lago Mare".

There were four major radiations of Lymnocardiinae since the Oligocene. In all four cases, marine *Cerastoderma* is proved or suspected to be the ancestral form; *Cerastoderma* itself is assigned to Lymnocardiinae. The first two events can be classified as "simple" radiations. They took place in the Early Oligocene and Early Miocene, respectively, and led to the appearance of a few endemic genera. These were relatively short-term events, affecting the entire Paratethys. With re-establishment of normal marine conditions, the endemic cardiid genera went extinct. The next two events, however, were more complex and long-lasting. Complexity was caused by apparently chance events; some representatives of a given endemic fauna survived the environmental change that exterminated the rest of the fauna, and continued to radiate under the new environmental conditions. Survival could be either in situ or associated with migration. The complex radiations generally involved individual basins rather than the entire Paratethys, and produced dozens of endemic genera. The first complex radiation commenced in the Middle Miocene and lasted until the Early Pleistocene. Temporally and geographically it consisted of three parts: started in the Middle Miocene in the entire Paratethys (Sarmatian "Sea"), continued in the Late Miocene in the Pannonian basin (Lake Pannon), and ended in the Late Miocene to Early Pleistocene in the Eastern Paratethys (Ponto-Caspian region). The second complex – twofold – radiation started in the Caspian basin in the Late Pliocene, and continued in the Pleistocene to present in the Caspian Lake and Black Sea.

Within the time frame of the Messinian, Lymnocardiinae inhabited two Paratethyan waterbodies: Lake Pannon and the Pontian ?lake of the Eastern Paratethys, the Aegean basin, and they also appeared in the Mediterranean "Lago Mare". Stratigraphic correlation between these basins is still far from being satisfactory, although now a consensus seems to emerge concerning the correlation of the Pontian Stage with the Upper Messinian. The base of the Pontian Stage of the Eastern Paratethys is characterized by a sudden appearance of a Lymnocardiinae association. The Russian school, which gave the best experts of non-marine cardiids ever, traditionally holds that the majority of these forms, namely *Euxinicardium, Pontalmyra, Pseudocatillus, Prosodacnomya, Eupatorina,* and *Paradacna* originated in the northern, freshened part of the Messinian Mediterranean Sea (?Aegean basin) from where they migrated into the Black Sea basin at the beginning of the Pontian. Stratigraphic and evolutionary study of Lake Pannon Lymncoardiinae, however, shows that with the exception of *Eupatorina,* these genera appeared in the Pannonian basin during the Tortonian. The stratigraphic data thus seem to support the following migration routes for Lymnocardiinae: Lake Pannon (Tortonian) - Euxinian basin (Early Pontian) - Aegean basin (Late Messinian) -Mediterranean (latest Messinian, "Lago Mare").

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EVIDENCES FOR EROSIONAL EPISODES AND "LAGO-MARE" TYPE ENVIRONMENT IN THE MESSINIAN UNITS OF THE VALENCIA TROUGH

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The Valencia Trough is an aborted Tertiary rift whose formation was associated with the opening of the Ligurian-Provençal oceanic basin. Because the Valencia Trough is located between the marginal Messinian basins and the deep Mediterranean oceanic basins, it is a key basin for investigating the Messinian Salinity Crisis.

We present new isobath and thickness maps of Messinian sequences in the Valencia Trough. Analysis of the seismic facies and geometries of the Messinian units, their chronologic and stratigraphic relationships at the transition between the shelf and the deep basin allows to better understand the impact of the margin's morphology on the distribution of Messinian depositional systems tracts.

The distribution of Messinian deposits in the Valencia Basin shows that they are sandwiched between **two major erosion surfaces:** (1) **An early basal erosion** affected the Pre-Messinian units in the entire Valencia Basin, with valleys incising the Miocene units on the margins. Except for the abyssal plain linking the Valencia basin to the Provencal basin in the NE, the entire area was subjected to aerial erosion resulting from the drastic sea-level drop at the beginning of the salinity crisis. During that first event, the salt was deposited in the Provençal basin and in the deep parts of the Valencia basin. The products of erosion were deposited first along what was then the Messinian nearshore (a distal area at present time), coevally with salt deposition offshore and erosion onshore. **The salt and early detritals are thus considered as early low-stand systems tract related to the first rapid sea-level drop.**

Deposition of the Upper Evaporites on the Basal Erosional Surface and on the first detritals supports their transgressive character. Although some amount of sea-level rise is necessary to explain the deposition of the Upper Evaporites sedimentation, the occurrence of fluctuations in sea level (recorded by alternating episodes of deposition and erosion in the Upper Evaporites Unit) indicates that the global sea level rise could not be important and that global sea level stayed low. As erosion of the margins persisted during all duration of the Crisis, detritals products filled the valleys by retrogression as sea level rise, coevally to deposition of the Upper Evaporites. **The Messinian deposits (Upper Evaporites and Detritals) can then be interpreted as late low-stand system tracts.**

(2) **A late Erosional episode** is the last event clearly recorded in the Valencia basin and affected both the top of the Upper Evaporites unit and detrital deposits. It is characterised by numerous incisions forming an intricate drainage network of Messinian valleys, later filled by marine Pliocene sequences. One last drop in sea level must therefore have occurred before the Pliocene marine reflooding. **This episode correlates with the « Lago Mare » episode** (Orszag et al., 2000; Rouchy et al., 2001), which represents a major environmental change at the end of Messinian times. The Lago Mare erosional episode described onshore is coeval with to freshwater dilution, paleosol formation, and karstification at the upper evaporitic sequence. It implies a decrease of oceanic inputs and increase of the run-off at the end of Messinian period, conditions responsible for the creation of small subbasins or shallow and episodically desiccated lakes, below word sea-level. Lacustrine muds have been found in Messinian interval at site DSDP 372 (Hsü et al., 1978) in the Valencia Basin, where a « Lago Mare » type environment with formation of lakes in the depressions or erosion is probable.

DEEP CLASTIC EVAPORITES DEPOSITION IN THE MESSINIAN ADRIATIC FOREDEEP (NORTHERN APENNINES, ITALY)

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The Messinian Salinity Crisis was accompanied by an intense phase of geodynamic re-organisation affecting the Mediterranean area that produced the fragmentation of the Miocene Apennine foredeep basin. During this event the deposition of primary evaporites occurred within growing semi-closed thrust-top basins whereas, in the adjacent deeper and more subsident parts of the foredeep, only organic-rich shales were deposited. The progressive tectonic uplift affecting the evaporitic basins, e.g. the Vena del Gesso basin, caused first the stop of the shallow-water evaporite deposition and then the development of a wide-spread phase of collapse leading to the resedimentation of the evaporites into the evolving deeper parts of the Apennine foredeep, that never underwent desiccation.

A detailed facies analysis on the products of the post-evaporitic dismantlement phase has been carried out during the last years in the northern Apennines in order to define: 1) their genetic relationship with the primary evaporites of the Vena del Gesso; 2) the sedimentary processes controlling their deposition; 3) the possible occurrence of a lithological cyclicity comparable to the well-developed one characterising the shallow-water primary evaporites.

Due to the burial-induced re-crystallisation affecting the resedimented evaporites of the Apennines, their study is not an easy task. The application of a siliciclastic-approach to field recognition, together with microscope analysis and geochemistry has been utilised to define a more accurate facies interpretation of the large variety of resedimented evaporites and led to the some important implications for the events that characterised the Messinian salinity crisis in this area.

A great variety of gravity-driven deposits, ranging from debris flow to low-density turbidites have been recognised within the Gessoso-solfifera Formation of the northern Apennines between the eastern edge of the Vena del Gesso, i.e., the Forlì Line, and the Laga basin. The deposition of such a wide variety of gravity-driven deposit was probably related to the formation of large submarine collapses and glides triggered by tectonic-induced gravitational instability, as witnessed by the diffuse presence of slides, slumps and gravity-driven deposits.

Two main depositional units of resedimented evaporites were recognised in the deeper "basinal" succession. Their formation can be related to different tectonic phases or, as here proposed, to the cannibalisation and resedimentation of two distinct primary evaporite members, producing different type of gravity flows. As an inversion of the stratigraphic succession, the upper gypsarenite-rich cycles were first resedimented as low-density gravity flows, then the lower selenite cycles dismantlement produced glides and higher density gravity flows, finally the fine-grained siliciclastic deposits of the S. Donato Formation, derived from the erosion of the pre-evaporitic units.

Although evaporites resedimentation occurred within a fragmented foredeep, their wide distribution and depositional character indicates the complete absence of desiccation. This important evidence ought to be taken into consideration even in the study of the other Mediterranean basins, especially in the interpretation of the deep-sea evaporitic deposits.

SUBTERRANEAN TESTIMONIES OF THE MESSINIAN SALINITY CRISIS: THE RHÔNE'S MIDDLE VALLEY ENDOKARSTIC RECORDS

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On shore, the Messinian salinity crisis resulted in unusual karstic base level fluctuations. First, this base level underwent a collapse down to the abyssal plains. This fall carved-out the margins with the famous sub-aerial Messinian canyons (such as the Rhône canyon in the studied area) by retrogressive erosion.

This huge fall was followed by a two step rise in Mediterranean sea level, constituting the delayed Pliocene impacts of the crisis. The first rise is consistent with the Mediterranean flooding at 5,32 Ma: the Messinian canyons are suddenly transformed into Pliocene rias. The second rise, slower than the first one, is due to the sedimentary aggradation of tributary rivers during their infill of the rias by *Gilbert type fan deltas.*

Our study of the karstic units located on the right bank of the middle Rhône valley (Saint-Remèze plateau in Ardèche region, Méjanne-le-Clap plateau in the Gard region) reveals a strange stepped endokarstic drainage pattern.

Obviously, this underground arrangement is linked to the Messinian-Pliocene external bench-mark levels:

- the pre-evaporitic abandonment surface of Saint-Restitut (5.95 Ma),
- the thalweg of the Rhône's Messinian canyon near Pierrelatte,
- the marine/non-marine transition at Trignan ,
- the Pliocene abandonment surface of Saint-Marcel d'Ardèche (2 Ma).

These four reference levels enable us to follow the karstic base level between 5,95 and 2 Ma, both in terms of their chronology and elevation. In totality, it appears that the endokarstic evolution is closely linked to the external Messinian-Pliocene mega-cycle.

This *per ascensum* structuring of the karst can be read in two ways:

- the first is geometric, by altitudinal concordance between the marker levels previously outlined and the different phases of the karst drainage pattern. Three relative levels have been identified: (1) the Messinian canyons, (2) the Pliocene high stand (indicated by the marine-continental transition), and finally (3) the high level aggradation (as revealed by the Pliocene abandonment surface).
- the second point is dynamic and corresponds to the karst's response to each of the base-level variations, during and posterior to the crisis. This dynamic is translated in the karst by the formation of vertical drainage channels, whose morphologies are downwards during the base-level fall and upwards during the successive rises.

The latter vertical drainage channels (relative to the base-level rises) reveal an exceptional hydrological dynamic, in that the three levels are interconnected. This characteristic suggests that a phase of base-level rise leads to a rising drainage channel. The channel develops at the contact of the new base level, between the submerged level and the level in genesis. Such a system is similar to current processes observed at the Fontaine de Vaucluse, the difference being that here the rising channel emerges in a superior level under formation. Consequently, throughout the Messinian-Pliocene cycle, each drainage phase is marked by the superposition and interconnection of the karst system.

Today we observe a polyphased karst, marked by three distinct and interconnected levels. Only the Messinian level is presently active in the Vauclusian system (a karst deep draining the massif, before following one or more ascending channels to emerge), because it is below the current base level.

SPECIES RICHNESS, COMMUNITIES AND CLIMATE: THE CASE OF MAMMALIAN FAUNAS

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The study of mammalian communities provides useful knowledge of palaeoenvironments and palaeoclimate. Palaeoecological reconstructions and quantification of climatic parameters are based on the analysis of species richness, body mass and new methods for quantifying climatic parameters (temperatures and precipitations).
Geographical distribution and species richness in mammals seem to be highly dependant on climate. Correlations between climatic parameters, as mean annual temperatures, and number of species in some rodent sub-families are high. Such relationships yielded to the construction of quantification models based on linear regression technique to estimate past temperatures.
Different models using arvicolines, murines, and sigmodontines (taken as analogues for Old World cricetines) have been proposed in order to quantify past climates and to analyse changes through time.
Based on rodents, temperatures are estimated here for Late Miocene-Early Pliocene (MN 9 to MN 15) European faunas at regional scale. Two kinds of continental patterns in temperatures are observed with homogenous temperatures for MN 9 up to MN 11 or contrasted temperatures at the end of the Miocene. The onset of a latitudinal effect is also supposed during MN 15.
Cenogram analysis (Calatayud-Daroca-Teruel Basin, Castillon-Valencia Basin, Languedoc-Roussillon Basin) has been made for the Messinian to understand the impact of the crisis on the continental mammalian faunas. No change has been observed between the Late Miocene and the Pliocene. The palaeoenvironments are similar inside the two regions before or after the Messinian event.

BIOCHRONOLOGY OF THE TORTONIAN-MESSINIAN PISSOURI SECTION (CYPRUS)

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The 'Pissouri motorway' section on Cyprus covers the interval from ~7.6 Ma (Late Tortonian) to the start of the Messinian salinity crisis (MSC, 5.96 Ma). This section is one of the most suitable sedimentary successions to study the onset of the Messinian Salinity Crisis in the Eastern Mediterranean. In this section previous biostratigraphic studies revealed several planktonic foraminifera events that have been astronomically dated in other Mediterranean sections, and as such provide an excellent first-order age control. In addition magnetostratigraphic results are in good agreement with the biostratigraphic data and show that all magnetic chrons between C4n.1n and C3An.1n are present.
The microfaunal and nannofloral assemblages are well preserved and abundant in the lower part of the section that predates the Tortonian - Messinian boundary. In particular the nannoflora shows a twofold distribution: starting from the bottom of the section to 6.6 Ma the superficial assemblage is typical of normal marine conditions whereas, after this point, it shows frequent and extreme fluctuations in abundance showing in some cases oligotypic communities (e.g. consisting of 99% sphenoliths). Also the planktonic foraminifera assemblage is well diversified in the first part of the section until ~6.7 Ma, and mainly consists of *Globigerina decoraperta, Globigerinoides* spp. and *Globorotalia* genera.
Our results confirm the isochrony and reliability of some calcareous nannofossil events (*Amaurolithus primus* FO, *A. delicatus* FO, *Reticulofenestra rotaria* FO and FCO) thus contributing to a better time constraint of the Tortonian - Messinian Boundary.

LAGO-MARE: WHAT DOES THAT MEAN?

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The Alpine orogeny (Cenozoic time) caused the partition of Tethys into several basins. During Late Neogene, the "Mediterranean" came into its definitive configuration existence, whereas, eastwards, the "Paratethys", isolated (temporarily?) from the World Ocean, disintegrated progressively into smaller basins. Thus an endemic fauna developed in these basins, mainly composed of low salinity faunas, with congeriids, cardiids, melanopsids and specific ostracods, indicating an environment subjected to changes in the water salinity. In the Mediterranean, at the end of the Neogene, sediments are characterized by similar fauna, leading Gignoux (1936) to carry the notion of "Sea-Lake" created previously by Andrussov, for the Paratethys, and translated into French by "Lac-Mer", and now largely known as "Lago-Mare" (after Ruggieri in 1967).
These last decades, numerous scientific investigations about the history of the Mediterranean during the Messinian were devoted to the understanding of the conditions prevailing after the deposition of evaporites. Brackish fauna are found in several outcrops and boreholes in the Mediterranean, already in the lastest beds of the Upper Evaporites and then, also present in coarse clastic sediments, just before the flooding of the marine Pliocene waters. Fresh water fauna are also found thus showing alternations of saline and fresh-water environments during this period. These fauna, because their similarities with the fauna described in the Paratethys, were named incorrectly "Paratethyan, or caspi-brackish" fauna leading some authors to consider a necessary migration of the fauna from Paratethys to Mediterranean, whereas others refute this hypothesis.

Such seems to have been the starting point of a drifting in the meaning of "Lago Mare", now often wrongly used as an "event", a transitory period before the Pliocene marine flooding, periods of connections between Paratethys and the Mediterranean, etc…

But also, this drift in meaning spurred, thanks to recent data about the Black Sea, the Dacic basin, the Pannonian basin, etc…, and the Mediterranean (Greece, Cyprus, Sicily) , researches of questionable connections between the Mediterranean and the Paratethys during and after the Messinian Salinity Crisis. Included in different models proposed so far by authors to explain the cause/effects relationships leading to the Messinian Salinity Crisis, the notion of "Lago Mare", is, here also subject to different vicissitudes.

After all these comments on the use of "Lago-Mare", the goal is now to look for evidences of potential connections Atlantic-Mediterranean-Paratethys during this Miocene-Pliocene boundary period. This requires more accurate controls to correlate the Messinian-Pliocene time with the stratigraphy of the Paratethys, more studies on the environmental specifications of these fauna (indicators of environmental changes or adaptation with regard to water evaporation and salinity ?, colonization ?), the significance of the coarse clastic unit ending the Messinian time, climatic and sea-levels changes with a better knowledge of the Messinian impact out of the Mediterranean.

THE MESSINIAN-ZANCLEAN TRANSITION IN CYPRUS

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The study of the late Messinian-Early Pliocene sediments in South Cyprus (Polemi and Pissouri basins) and the comparison with the offshore coeval deposits drilled in the ODP Leg 160 boreholes, illustrate the environmental changes which occurred in the Eastern Mediterranean at the end of the salinity crisis. The latest Messinian interval includes the so-called "Lago-Mare" environment.
In the Polemi Basin, at Kathikas, the brackish fauna appears into the marly-chalky beds intercalated between the two last gypsum beds. The uppermost gypsum beds consists of gypsified stromatolites. At Giolou (Yolou), the uppermost bed of gypsum which contains molluscs (*Abra alba*), is overlain by varved marls containing numerous *Melanopsis, Melania, Planorbis, Cyprideis* and fragments of *Chara*.. Pedogenetic carbonate concretions and roots imprints also indicate episodes of subaerial exposures.
In the Pissouri Basin, the last "Lago-Mare" sediments developed after an episode of erosion of the Upper Gypsum beds and consist of an alternation of conglomerates with paleosols and chalky marls. These latter contain at their base *Ammonia beccarri* and *Cyprideis,* followed by a fresh-water to brackish fauna (*Limnocardium, Melanopsis, Melanoides* and *Congeria*) The Pliocene marls (Trubi) belong to the MPL1 zone.
At ODP Hole 968 A, sediments contain a faunal association with *Cyprideis pannonica* and *Ammonia tepida* and include a gypsum-rich intercalation which indicates that the Lago-Mare environment began before the end of the gypsum deposits. A pulmonate gastropod also indicate an emersion.
A very sharp contrast in lithology, sedimentology, faunal assemblages and stable isotope composition of carbonates characterizes the Messinian-Pliocene boundary with an abrupt passage from oligo-mesohaline environments to deep marine conditions. In the land sections, horizons of paleosols intercalated with conglomerates indicate periods of subaerial exposure alternating with several discharges of detrital sediments resulting from the emerging Troodos. This detrital input of conglomerates is related to an important change in the hydrological balance (rainfall), leading to the dilution of basin waters. The processes of dilution started before the end of the Upper gypsum deposits the isotopic composition of which indicate an important contribution of freshwaters.

THE ONSET OF THE MESSINIAN SALINITY CRISIS IN THE EASTERN MEDITERRANEAN. A CASE STUDY: CYPRUS

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South of the Troodos mountain (Cyprus), a fragment of an ancient oceanic crust, three main basins formed during Neogene times, the Polemi, Pissouri and Psematismenos basins.

The Messinian sedimentary succession is characterized by pre-evaporite deposits, overlain by a massive Lower Gypsum Unit and an Upper Gypsum Unit comprising six levels of gypsum intercalated with marls and sandy marls. These two units are separated by a breccia. The so called "Lago-Mare" facies appears within the Upper Gypsum Unit and develops above the younger gypsum beds. It is made of conglomerates and marls with brackish fauna including several episodes of emersion (paleosols). These deposits are sharply overlain in the three basins by the Trubi marls of the Early Pliocene.

Very suitable sedimentary successions were measured, which allow, thanks to numerous investigations and recent data, to document the evolution of the depositional environments before the onset of evaporites and to evidence tectonic pulses.

- It is clearly shown that, during the deposition of the pre-evaporitic sediments, the environment progressively through the Upper Tortonian-Early Messinian, from a depth of about 500 m, up to very shallow conditions just before the onset of evaporitic conditions. Both shallowing and salinity increase are indicated by the decrease of the species diversity of planktonic foraminifera; this is confirmed by the abundance of miliolids and *Glabratella,* and the low diversity of the calcareous nannoplankton, dominated by *Reticulofenestra.* Diatoms microflora suggests a depth of 400-500 m. The malacofauna indicates an upper bathyal - deep circalittoral environment, evolving to an upper circalittoral environment just before the onset of the gypsum deposition. The disappearance of mollusks representative species also confirms the restriction of the environment. Also, the increasing number of Syngnathid remains and the disappearance of Myctophids are good indicative of a reduction of depth and an increasing isolation of the basin. In some sections, stromatolites developed below the gypsum.
- Several pulsations of tectonic instability are recognized before the evaporitic deposits, and documented by slumps, breccias, and sedimentary features like water escapes and hydroplastic structures.
- High resolution integrated studies performed in the Pissouri section show that the onset of the evaporites occurred around 5.96 Ma, in good agreement with the age proposed for other sections in the Mediterranean, thus allowing accurate correlations between different basins.

LATE MESSINIAN VALLEY FILL IN THE ASINARA GULF (NW SARDINIA, ITALY)

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The Asinara Gulf (North-West Sardinia) represents the offshore prosecution of the inland Porto Torres-Lugodoro basin. It is a half graben with the master fault located on the eastern border, and developed during the post-orogenic, post-collisional phase active in Sardinia from the Burdigalian to the late Tortonian. The sedimentary fill of the Gulf has been recently grouped into three Neogene-Quaternary depositional sequences.

Sequence 1 is characterized by continental, to deltaic, to marine deposits unconformably overlying the Aquitanian volcanic strata. Its age is Burdigalian-Langhian. **Sequence 2** is characterized by deltaic, to marine deposits onlapping onto sequence 1. Its age is Serravalian-late Tortonian (possibly early Messinian). **Sequence 3** is characterized by continental and possibly marine post-rift deposits resting unconformably on the older sequences. Its age ranges from the late Messinan to the Present. The basal deposits of Sequence 3 crop out only in a small area close to Stintino (SW border of the gulf), but can been followed offshore through the seismic lines covering the gulf. In outcrop the sequence is characterized by alternating of clays and conglomerates. Clays are reddish, massive, highly bioturbated and pedogenized. Paleosols are occasionally found in the clays. They have been interpreted to be alluvial plain deposits. Conglomerates are organized in clast- to matrix-supported amalgamated beds (10 m wide and 2-3 m high) showing cut-and-fill structures. Clasts dimension vary from cobble to pebble and reduce in size from west to east. Clasts composition (mainly Paleozoic metamorphic rocks and Permian sandstones) and paleoflow (clasts imbrication and channels orientation) indicate that the headwaters was to the SW; that is, close to the present western coast of North Sardinia (Cala Viola, Torre del Porticciolo areas). Most of the metamorphic clasts are highly weathered and show a reddish color. The conglomerates have been interpreted to be a braided stream deposit.

The basal part of Sequence 3 is interpreted to be a valley fill deposit. Inland, the valley was SW-NE oriented, 60 km long and 2 km wide. It can be also followed offshore where it cut through Sequence 2, and ends at the edge of the Sardinia. A deep canyon has developed in correspondence of the fossil valley. Canyons such as that of Castel Sardo are documented on the North Sardinia shelf and have been interpreted to have formed during the transgression associated with the Messinian salinity crisis. No fossils have been found in Sequence 3 strata leaving opened its age. However, on seismic profiles it has been interpreted as a low stand deposit. Moreover, the highly weathered clasts are indicative of tropical to sub-tropical conditions similar to those occurred of the late Messinian time. If these were true, the valley deposits of Sequence 3 can represent the pre early-Pliocene transgressive system tract.

THE BEGINNING AND THE TERMINATION OF THE MIDDLE MIOCENE BADENIAN SALINITY CRISIS IN CENTRAL PARATETHYS

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The age and correlation of evaporites occurring in different parts of the Badenian Carpathian Foredeep Basin, and hence the reconstruction of basin history during deposition of evaporites, are subject to controversies. Recent study of calcareous nannoplankton indicates that the Badenian sulfates of the Carpathian Foredeep represent the lower part of the NN6 zone.

Basin-marginal Badenian evaporites formed in a standing body of water, as well as in desiccated environments subject to floods. The lateral persistence of thin beds over large areas with only minor changes in thickness and facies indicates that they formed on broad, very low relief areas which were affected by rapid transgressions that led to major changes in brine chemistry.

Halite and associated deposits in the central part of the Badenian evaporite basin show the same facies successions and marker beds can be traced across and between individual basins. The Badenian evaporite basin was located in a depression in which the brine top level was located below the contemporaneous sea level. Accordingly, during sea-level rises new marine water could enter this depression and bring with it a temporary pulse of marine fauna.

Although the correlation of different Badenian evaporite facies is difficult (if possible et all), there are no such problems in the case of particular evaporite facies zones. The correlation between facies zones of the marginal sulfate platform was based on the occurrence of characteristic marker beds, as well as the observations made in areas transitional between the facies zones. The marker beds seem to reflect events that may be related to sudden and widespread changes in water chemistry, which in turn imply major changes in basin hydrology. However, physical stratigraphic relationships between sulfates occurring in the marginal sulfate platform and sulfates from sulfate basin and the relation of the areas of halite and sulfate deposition remain enigmatic

The scenario of events leading to the deposition of widespread evaporites, being a synchronous event, in the Badenian is not established in detail. Isotopic studies of Badenian foraminifers occurring below and above evaporites suggest that the interrupted communication of the Paratethys with the ocean was a consequence of eustatic sea-level fall, possibly related to climatic cooling. However, a tectonic closure of connection with the Tethys could also contribute to the origin of salinary crisis.

Sedimentological and geochemical data indicate "cannibalisation" of evaporites throughout the most time of evaporite deposition. The cannibalization at the end of gypsum deposition in the marginal sulfate platform was accompanied by the block-tectonics that resulted in the creation of bathymetric difference at least a few ten of meters as indicated by the occurrence of Ratyn Limestone on stratigraphically different parts of the gypsum section. It was accompanied by a change in the hydrology of the Central Paratethys that was tectonically-driven, and possibly related to the block tectonic phase manifested in the marginal part of the Carpathian Foredeep Basin. The change in hydrology implied the dilution of brines by inflowing marine water and this terminated the Badenian salinity crisis.

RECONSTRUCTION OF THE PALEOENVIRONMENTAL CHANGES AROUND THE MESSINIAN-PLIOCENE BOUNDARY ALONG A W-E TRANSECT ACROSS THE MEDITERRANEAN

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A multidisciplinary study has been carried out with a high sampling resolution of the upper Messinian-Lower Pliocene (biozone MPl 1) sediments along a West-East Mediterranean transect from southern Spain (Vera/Almanzora), Balearic Basin (ODP Site 975b), Sicily (Eraclea Minoa), Zakynthos (Kalamaki), Corfu (Aghios Stefanos), Crete (Aghios Vlasis), including previous data obtained in the Levantin Basin (Cyprus and ODP Sites 968 and 969). All the studied sections have been correlated using planktonic foraminifera assemblages, sedimentological and stable isotope variations, and compared to the lithological cyclicity defined in the Messinian/Pliocene boundary stratotype of Eraclea Minoa, Sicily. The Messinian/Pliocene transition displays strong variations of $CaCO_3$ content, stable isotopes ($\partial^{18}O$, $\partial^{13}C$) of carbonates and foraminiferal assemblages that can be correlated between the different studied sections.

The uppermost Messinian deposits are barren or characterized by only reworked planktonic foraminifera, except for the sporadic presence of *Ammonia beccarii tepida*, ostracods and brackish mollusks typical of the "Lago–Mare" conditions. The bulk carbonate oxygen and carbon isotopic compositions usually exhibit large variations with dominant low d values indicating freshwater dilution. The lowermost part of the Pliocene (MPl1 biozone, cycle 1) shows a rapid and progressive increase of the $\partial^{18}O$ values by up to 1 to 3‰ which characterises the restoration of marine conditions after the Lago-Mare event. Normal marine environments were definitely established and stabilized at the base of cycle 2 which corresponds to the base of *Sphaeroidinellopsis* spp. acme zone, at 5.31 Ma. These data confirm that the inflow of marine waters occurred contemporaneously within the whole Mediterranean at the base of the Pliocene, although the onset of stable marine conditions occurred about 20 ky later.

UPPER MESSINIAN *LAGO-MARE* DEPOSITS IN THE STRATIGRAPHY OF THE MESSARÀ BASIN (CENTRAL CRETE, GREECE)

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In the Crete Island, late Messinian "Lago-Mare" facies are not well known. At present, the occurrence in Crete of the uppermost Messinian post evaporitic deposits is matter of debate. According to several authors the well-known late Messinian "Lago-Mare" facies did not occur in Crete. There, lower Pliocene open-marine clays of the **Finikia Group** directly overlie the upper Messinian evaporites of the **Hellenikon Group** (Dermitzakis *et alii,* 1979; Frydas, 1998; Fassoulas, 2001).
Meulenkamp *et alii* (1977 and 1979) described continental coarse-grained deposits and lagoonal sediments with *Cyprideis pannonica agrigentina* Decima (= *C. agrigentina*) from eastern Crete (Ag. Nicolaos). Moreover, fine-grained deposits with *Cyprideis* sp. have been, also, detected in a few places of central Crete (Meulenkamp *et alii,* 1977). The stratigraphic positions of all these *Cyprideis-bearing* deposits, which occur above upper Messinian gypsum, allow us to consider them as deposited during the late Messinian "Lago-Mare" event.
The aim of this paper is to show the preliminary results obtained from the analyses of some stratigraphical sections sampled in the Messarà Plain. Nearby Faneromeni village, the Miocene/Pliocene boundary is well exposed. The uppermost lower Messinian deposits (pre-evaporitic stage) are characterized by brownish laminated tripolaceous marls with intercalations of marl horizons rich in benthic forams, ostracods and molluscs. Moreover, two organic-rich horizons have been found in the uppermost part of the tripolaceous marls. Up section, these marls pass to clays with gypsum, beds of laminate microcrystalline gypsum and gypsiferous breccias. Above these evaporitic deposits, fine-laminated polychrome clays with intercalations of sandstones and conglomerates (bedding attitude N 183°, 17°) have been found resting unconformable below Pliocene grey claysand conglomerates (bedding attitude N 164°, 24°).
In this preliminary phase, 12 samples have been collected across the Messinian/Pliocene boundary in the Faneromeni section. In the Kasteli-Ano Akria area, above gypsiferous breccias and laminated microcrystalline gypsum deposits, silty-clays with intercalations of sandstone and conglomerate horizons have been found. In this area, 2 samples from the post evaporitic fine-grained deposits have been collected. More recently, a 20 cm-spaced sampling has been performed in both the sections, for about 100 samples collected.
Micropaleontological analyses have been performed on the preliminary sampling of the post evaporitic deposits from both Faneromeni and Kasteli-Ano Akria sections.
The results of these analyses point to the presence of an ostracod assemblage containing: *Cyprideis* sp., *Amnicythere* spp., *Amnicythere* cf. *A. palimpsesta* (Livental), *Amnicythere* cf. *A. propinqua* (Livental), *Camptocypria* sp., and *Pseudocythere* sp. Reworked planktonic foraminifera and well-preserved charophyte gyrogonites have been also found.
The ostracod assemblage found in the Messarà Plain belongs to the *Loxoconcha djafarovi* Zone (*sensu* Carbonnel, 1978), which characterizes the uppermost Messinian deposits of the whole Mediterranean Basin. At that time, the well-known "Lago-Mare" biofacies was widespread on the Crete Island also. The presence of Paratethyan ostracods in the post-evaporitic Messinian deposits of both Faneromeni and Kasteli-Ano Akria sections suggests that in the latest Messinian Crete Island was affected by sedimentation processes in brackish water palaeoenvironments.

COEVAL VOLCANISM AND EVAPORITE DEPOSITION IN THE FORTUNA BASIN (NEOGENE, MURCIA, SPAIN): PETROGRAPHIC EVIDENCE OF SYNCHRONISM

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The Neogene basins of the Eastern Betic Moutains, located in a marginal position with respect to the deep Mediterranean basin during the Tortonian and to the Messinian, contain thick gypsum-anhydrite formations resulting from the salinity crisis; the occurrence of halite bodies is known in some basins (e.g., the Lorca basin). The evaporitic sedimentation reached its maximum extension and stratigraphic complexity in the Fortuna basin, which belongs to this geological setting. This work illustrates the presence of peperitic lithofacies in volcanic rocks and discusses their implications in terms of assesment of an age to the coeval evaporite sediments; this information allows us to date the evaporite units of the Fortuna-Lorca basins and to enlighten the controversy around its Tortonian or Messinian age.

Five stratigraphic units are distinguished in the Fortuna basin: 1) Lower Gypsum, 2) Chicamo Gypsum, 3) Chicamo Diatomitic-evaporitic cycles, 4) Ribera Gypsum and 5) Rambla Salada Gypsum units. Some of these units occur locally, whereas others can be laterally correlated with those of the Archena-Mula, Guadalentín corridor and Lorca basins. Most of the gypsum units consist of nodular-laminated lithofacies (secondary gypsum); however, primary selenitic, laminated (gypsarenites) and fine-grained ("balatino") gypsum lithofacies are present. The evaporite units can also be characterized by their geochemical composition: a) highly variable strontium contents, b) isotopic composition of sulphur ($\partial^{34}S$) ranging from those characteristic of the Tertiary marine water (+20.3 to +25.5‰) to those characteristic of the Triassic sulphates (+8.0 to +16.0‰), and c) strontium isotope ratios ($^{87}Sr/^{86}Sr$) comprised between 0.70804 to 0.70888. These sulphur-oxygen and strontium isotope compositions indicate precipitation from Tertiary marine brines, or from meteoric waters (recycled Triassic sulphate anion and additional non-marine contributions from country rocks and hydrothermal solutions); intermediate values are attributed to mixed seawater and non-marine mother brines.

The Fortuna basin contains several outcrops of separate lamproitic volcanic to subvolcanic igneous bodies (Cabezos Negros, El Tale, Derramadores); several absolute ages are known. The isotopic age of a volcanic rock provides a good chronostratigraphic marker in the case of lava or pyroclastic flows interbedded in a sedimentary sequence. Also, a sill gives some relative information (it is younger than the intruded rocks). However, the lamproitic rocks present in the Fortuna basin crop out without clear stratigraphic position in the sedimentary sequence: as individual domic volcanos without sedimentary cover (eroded; Cabezos Negros) or as intrusive subvertical dikes (El Tale, Derramadores), a fact that a priori excludes good chronological constraints. Nevertheless, there exists good evidence of several magma-sediment interactions that provided macroglobular peperitic lithofacies. A peperite is produced when two liquids (a hot magma and a fluidized, water-satured sediment) interact and no mixing is possible due to the sharp contrast of viscosity between them. This implies that at the moment of the eruption, the sediment is water-satured (in terms of time, they are nearby coeval).

THE DINOCYSTS NEW MARKERS OF MEDITERRANEAN - PARATETHYS CONNECTIONS BEFORE AND AFTER THE MESSINIAN SALINITY CRISIS

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Relationships between the Mediterranean Sea and the Paratethys realm are debated from a long time. Normal connections between these seas are generaly considered to have ended in the late Miocene.

Two successive Mediterranean nannoplankton influxes belonging to NN11 and NN12 zones have been evidenced in the Dacic and Euxinian basins. Nannoplankton is accompanied by typical marine dinocysts: *Spiniferites mirabilis, Spiniferites bentorii, Tectatodinium pellitum, Spiniferites hyperacanthus,* identified within the Dacic Basin. More recently, dinocysts such as *Galeacysta etrusca,* and morphotypes of *Spiniferites cruciformis* and *Pyxidiniopsis psilata* (= *Impagidinium* sp.; Corradini & Biffi, 1988) the usual endemic Paratethyan species have been regularly found in the Mediterranean area (Corradini & Biffi, 1988) and added to the "Lago Mare" biofacies (Bertini *et al.,* 1994, 1995). These data indicate the existence of high sea-level cross exchanges between the Mediterranean Sea and the Eastern Paratethys just before and after the Messinian salinity crisis. Moreover, dinocyst assemblages show a large number of marine species morphotypes in the western part of the Dacic Basin, which probably originate from adaptation to low salinity.

Palynological analysis from Site 380 A (Black Sea) shows a very poor assemblage of Paratethyan dinocysts in the late Miocene, a bloom of freshwaters acritarchs (between 5.33 Ma and 5.11 Ma) being followed by an assemblage grouping brackish and marine dinocysts.

The presence of typical marine taxa in the western part of the Dacic Basin, the development of marine taxa morphotypes in the eastern part of the basin and the presence of freshwaters acritarchs just after Messinian salinity crisis in the Euxinian Basin suggest that:

- the "proto-Bosphore" was closed at this time,
- the Dacic Basin should have been directly connected to the Mediterranean Sea, being itself episodically connected to the Black Sea.

Dinocysts are highly sensitive to environmental changes, especially to salinity changes. As a consequence, they can adapt to new conditions with some important morphological changes. The Paratethyan endemic species *Galeacysta etrusca* is a demonstrative example.

NEW DIATOM AND NANNOFOSSIL RECORDS FROM THE MAEOTIAN–LOWERMOST PONTIAN DEPOSITS OF THE TAMANSKII PENINSULA (BLACK AND AZOV SEA)

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Diatoms and nannofossils from the two Maeotian and Lower Pontian reference sections of the Tamanskii Peninsula (Zheleznyi Rog and Taman') were studied. Both sections are composed of marls, clays, and diatomites and represent more deep-water sediments than their stratotype analogues on the Kerchenskii Peninsula. The deposits were accumulated at different bathymetric levels (the Zheleznyi Rog section is more deep-water than that of Taman'), however, their lithology, cyclicity character and plankton distribution are similar.

The Maeotian and lowermost Pontian sediments are represented by three units bearing diatoms. The lower unit corresponds to the interval with the *Thalassiosira meotica* assemblage and represent the interbedding of carbonate and noncarbonate clays and clayey diatomites that form sedimentary cycles. Its total thickness is 40–80 m. The middle unit bears the *Cymatosira savchenkoe* assemblage. It is represented by alternation of clayey marls and diatom clays, and is 20–80 m thick. The upper unit with the *Actinocyclus ehrenbergii* assemblage is composed of laminated diatomite members interbedded with noncarbonate clays and is 20–60 m thick.

The diatom assemblages from both sections are characteristic of the Eastern Paratethys (Kozyrenko and Temnishkova-Topalova, 1990; Kozyrenko and Radionova, 2002). They are dominated by marine genera *Thalassiosira, Nitzschia,* and *Actinocyclus* (*Cestodiscus?*) commonly represented by endemic species. The number and abundance of brackish- and fresh-water forms is variable in the sections. The maximum freshening was recorded in the upper part of the unit bearing *Thalassiosira meotica* and in some horizons of that with *Actinocyclus ehrenbergii.* In the lower part of the unit with *Thalassiosira meotica* few nannofossils *Reticulofenestra* sp. and tropical diatoms *Thalassiosira brunii, Nitzschia fossilis,* and *N. praereinholdii* were encountered. According to Barron and Baldauf (1995), the LAD of *Thalassiosira brunii* is at 8.6 Ma, and the FAD of *Nitzschia fossilis,* at 8,5 Ma (after scale of Cande and Kent, 1992). The second interval with almost normal salinity is the unit bearing *Cymatosira savchenkoe.* It contains rare nannofossils *Reticulofenestra* sp. and *Coccolithus pelagicus* and the oceanic diatoms *Azpeitia komurae, Thalassiosira trifulta, Nitzschia miocenica, N. prolongata* and others. The range of *Azpeitia komurae* is about 7.5–7.1 Ma (Akiba, 1987); of *Nitzschia miocenica,* 7.4–6.4 Ma (Barron and Baldauf, 1995). The upper unit with *Actinocyclus ehrenbergii* contains microflora only in the thin-bedded diatomites, where the bedding results from the alternation of carbonate and siliceous layers. The siliceous layers are sharply dominated by *Actinocyclus ehrenbergii* and the carbonate, by *Braarudosphaera bigelowi.* In the upper part of this unit the Pontian mollusks *Paradacna abi_hi* appeared. The peculiar diatom composition (Jousé, 1947) and peculiar rhythmic structure of sediments permitted to refer this unit to the Pontian. The overlying sediments yield the typical Pontian mollusk fauna and lack marine plankton.

The correlation of the Maeotian and Pontian with the Mediterranean scale is up to now controversial. According to our records on planktonic groups, the Maeotian sediments are distinctly subdivided into two units: those bearing *Thalassiosira meotica* and *Cymatosira savchenkoe,* which age we have refined. The structure of the unit with *Actinocyclus ehrenbergii* sharply differs from the underlying sediments in the occurrence of laminated diatomites with monospecific plankton assemblages. The conditions of accumulation of these deposits were similar to those of the pre-evaporite Messinian.

THE MESSINIAN SALINITY CRISIS IN THE MEDITERRANEAN: AN INTEGRATED SCENARIO

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The knowledge of the Messinian salinity crisis (MSC) improved considerably during the past decade due to the availability of an accurate astronomically calibrated timescale and new studies that renewed both the debate. In this work, the updated re-examination of the most salient features along with consideration of hydrological requirements for evaporite deposition leads to propose an integrated scenario for the MSC. Two major stages of evaporite deposition affected the whole Mediterranean that was configured as an assemblage of deep basins including the Central Sicily, and more marginal basins distributed at shallower depths. This paleogeographical partitioning and the related threshold effects controlled both the diachronic deposition and the fractionation of the evaporite deposits between deep and marginal basins

The first stage (lower evaporites) which comprises the thicker halite deposits with K-Mg salt interbeds corresponds to the major phase of drawdown related to higher aridity of the circum-Mediterranean climate. It correlates with the interval marked, in the ocean record, by a strong glacial influence with episodes of global sea-level fall, including the major peaks TG 20 and 22, that lasted around 5.6 Ma.

The second stage (upper evaporites) involved a cyclic alternation of reflooding in highly restricted conditions with an intense freshwater contribution, and isolation ending, in some basins, by drying-up episodes. This matches logically the interval of warming recorded in the ocean since 5.6 Ma onwards.

Sea water inputs remained the major feedstock for evaporite deposition and, although considerably reduced, never ceased durably through the MSC. However, the freshwater contribution increased drastically during the second stage culminating in the latest Messinian lacustrine conditions (Lago-Mare event), as the result of the worsening of the tectonically induced closure of the marine gateways and wetter climate at least on the peripheral mountains. The restoration of stable open marine conditions took place abruptly at the Messinian-Zanclean boundary. A multistaged erosion (M Horizon), affected the whole Mediterranean margin with a major step coeval of the first evaporitic stage. The erosion was reactivated during the second stage whenever the basin dried-up, before a new important stage caused by the latest Messinian dilution, while an earlier event probably pre-dated the MSC.

Finally, although the restriction of the Mediterranean was predominantly under a global tectonic control, the hydrological changes that controlled the MSC implied the interplay of glacio-eustatic changes and fluctuations of the circum-Mediterranean climate.

PALEOENVIRONMENTAL CHANGES AT THE MESSINIAN /PLIOCENE BOUNDARY IN THE ALBORAN AREA: THE EXAMPLE OF THE MELILLA BASIN, NE MAROCCO

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The Melilla Basin, NE Morocco, located close to the outlet of the southern Mediterranean-Atlantic gateway, is a key area to investigate the depositional changes that affected the Mediterranean at the end of the Messinian Salinity Crisis (MSC). This basin did not experience the Messinian evaporite deposition although the classical succession of the marine preevaporitic deposits i.e., the carbonate platforms and the Tripoli unit, is represented.

Three major paleoenvironmental changes are recognized during the late Messinian to Early Pliocene and compared with the events that affected the Mediterranean hydrology at the same time. The first change was the definitive conversion, around 5.8 Ma, of the marine conditions that prevailed in the early Messinian (tripoli deposits and reef carbonate complex) into lacustrine environments. It occurred earlier than in the rest of the Mediterranean where the Lower Evaporites were still forming. Although the absence of typical Paratethyan organisms, these lacustrine settings display great similarities with the classical Lago-Mare event that started in the Mediterranean during the deposition of the Upper Evaporites and climaxed during the latest Messinian. The second change was a long period of subaerial exposure that caused a widespread erosional surface with a deep paleovalley that truncated the whole Messinian deposits in the deeper southwestern part of the basin. This event postdates a lava flow dated at 5.77 Ma and confirms the importance of the latest Messinian erosional event. The third change was the rapid, although progressive, drowning of this topography by the Early Pliocene marine transgression that started there by an intense boring activity, oyster encrusting and deposition of shallow water mollusk-rich deposits.

The absence of evaporites in the Melilla Basin may be due to later dissolution, drainage of the brines towards the deeper South Alboran Basin during the MSC or rather low salinity conditions caused by a local excess of continental water inputs. These data confirm that the Rifian gateway was completely closed during the MSC. Such an evolution fits well with the history of depositional environments in the central and southern Alboran area where evaporites are poorly developed and the Messinian mainly represented by an erosional surface.

WHAT CAN BE EXPECTED FROM CORING THE WHOLE MESSINIAN EVAPORITIC SUCCESSION IN THE DEEP BASINS OF THE MEDITERRANEAN?

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As it is one of the greatest evaporitic episodes of the stratigraphic record, the Messinian Salinity Crisis (MSC) of the Mediterranean has been the subject of active debates and various interpretative models that are still lively discussed. In spite of the unusual volume of high quality data gathered on land-basin and offshore deposits, our knowledge lies on a very small fraction of the evaporitic deposits only. Indeed, the greatest volume of evaporites is located in the huge deep basins where the sedimentary successions reach up to 1.5 km of thickness or much more, including in their lower part a thick massive salt unit whose thickness may exceed locally 1 km. The DSDP-ODP drill cores yielded information on the upper part of the Upper Evaporites only, but never reached the lower massive salt. "*The deep sea drilling holes failed to penetrate into the Main Salt Unit. The halite and potash salts encountered in Holes 134, 374 and 376 all belong to the Upper Evaporite*" (Hsü et al., 1978). Thus, less than 1% of the salt (halite with associated K-Mg potash deposits) that however represents the greater fraction of the Messinian evaporites has been studied both in land-basins (Sicily, Lorca in SE Spain, Calabria) and in the Sites 134, 374 and 376. Three holes (Sites 372, 375, 654) crossed a complete evaporitic succession, but this succession was similar in thickness and composition to marginal-type evaporites. Thus, most of the evaporite deposits that contain the information crucial for any suitable reconstruction of this event and its consequences still remain inaccessible to direct observation, except for their seismic record.

This huge gap in our knowledge should be filled by coring the deep evaporites that could be one of the objectives of an IODP cruise in the Mediterranean (Odysseus project). This would answer most of the crucial questions that are still arising about this unusual event. What is the age of the onset of the MSC in the deeper parts of the basin and the timing of the paleoenvironmental changes that occurred during this period? What do the infra-salt reflectors really represent? What is the magnitude of the evaporative drawdown and its timing? What is the importance of the K-Mg salt deposits trapped in the deeper areas? These deposits are of paramount importance as they record the highest brine concentrations and therefore the maximum evaporative drawdown and hyperarid climate conditions. Was the Mediterranean completely desiccated down to the bottom of the deep basins and if so, how many times did it dry up and how long lasted these episodes of subaerial exposure? Did the post-salt desiccation observed in Sicily affect the deeper basins as well? How deep were the residual brine ponds during salt precipitation? What is the real significance of the cycles in the upper evaporites?

To achieve these objectives, the future hole should be drilled in the central part of a deep basin to promote a continuous sedimentary record of the MSC since the pre-crisis paleoenvironmental changes. The area selected should be devoid of significant tectonic influence, as for instance the abyssal plain of the western Mediterranean south of the Gulf of Lion. Due to the mechanical behaviour of the salt, even a moderate deformation would have indeed destroyed the depositional structures. The cores should be submitted to a complete set of integrated studies (sedimentology, geochemistry, micropaleontology, bio-and cyclostratigraphy), with a focus on the salt that is the crucial sedimentary marker of the MSC. This project opens the perspective of a new intellectual adventure that we expect to be as rich and exciting than that which has been initiated by the discovery of this unusual event.

DIATOM ASSEMBLAGES FROM THE MESSINIAN DIATOMITES OF CASABIANDA (ALERIA FORMATION, EASTER CORSICA)

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The Neogene "Aleria formation", situated in the northeastern Corsica, consist of siliciclastic deposits from deltaic environment according to Magne et al (1975). In Casabianda section, this formation rests upon erosional surface affecting upper Tortonian sediments and comprises diatomitic lenses and marls with brackish water molluscs (Pilot et al., 1975).

Diatomitic deposit of Casabianda section appears white and very homogeneous without stratification and lamination. 15 successive samples were collected. Two of them were steril. Relative abundances (in percentages) of the species in each sample were calculated based on 600 individuals. Diatom microflora of Casabianda is reach and well preserved with 59 species. Pennate indicate a very large diversity with 17 genera and 54 species. Centrics are represented by 4 genera and 5 species. Diatom assemblages show a relative constant composition along the studied interval. The species *Aulacoseira granulata* is the dominant taxa having about 90% in all samples. All the taxa are represented in Modern diatom assemblages, which allows paleoecological indications for the paleoenvironemental reconstruction. Taxa are of different salinity classes and different mode of life (planktic, tychoplanctic, benthic, epiphytic...) suggesting multiple interactions. The co-occurrence of fresh to marine taxa can be regarded as a result of short term fluctuation in salinity and/or spatial juxtaposition of habitats (Gasse et al., 1987). In the same time, the permanent domination of the planktic freshwater species *Aulacoseira granulata* should indicate a stable environment. The environmental model suggested by sedimentological and biological data let as to assume a pond-like coastal receptacle common in deltaic system and slowly influenced by marine proximity. Permament freshwater supply is responsible both of nutrient concentration and of the development of a continue freshwater plume (Campeau et al., 1999). These facts can explain the *Aulacoseira granulata* continuous blooms. A stratified system permits the occurence of the benthic species having a wide salinity range. Among them the constant presence of euryhaline taxa is related to fluctuations in osmotic pressure due to the dispersion of freshwater plume.

The geological context suggests an upper Messinian age.

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THE MESSINIAN DETRITAL BODIES: CONFRONTATION OF SEISMIC AND DIVING DATA OFFSHORE MONACO AND CANNES, NW LIGURIAN SEA (NORTHWESTERN MEDITERRANEAN)

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The Var submarine fan is located in the Ligurian Sea off France and extends seaward of the Var delta to the base of the northern continental slope of Corsica. It has been deposited throughout the Pliocene and Quaternary in a basin whose shape and architecture were strongly influenced by the Messinian event. High resolution seismic reflection lines have been used to map the Messinian erosion surface and associated basin-margin deposits on the continental margin, off the french Riviera. A palaeovalley extends seaward from the incised Var palaeovalley mapped on land by Clauzon et al. (1995). The lower part of this valley is filled by an acoustically incoherent unit, interpreted as a coarse-grained pro-deltaic deposit that accumulated during Messinian. Along the base of the slope, conglomerates units had been recognized lying between two erosional surfaces below the base of the Pliocene.

Several submersible dives (Cyana, Nautile, ROV) investigated strategic outcrops in order to calibrate the interpretation of the seismic profiles. We examined and sampled outcrops of crossbedded sandstones and of a fining-up, predominantly conglomeratic sequence that fills Messinian channels on the continental slope. These conglomerates pass up into Early Pliocene marls and have turbidite sedimentary structures. These are prodeltaic deposits. Based on new seismic facies mapping, sampling and submersible observations, the palaeogeographic scheme is revisited. A basal erosion surface, including the Var palaeovalley, represents extreme dessication of the western Mediterranean and was followed by accumulation of the main Messinian salt. Cross bedded sandstones sampled within the Cirque Marcel are early Messinian in age. Following this, a lake was ponded in the Ligurian Basin, with accumulation of evaporites and shales. Simultaneously, conglomerates started to deposit on the adjacent slopes. They are organised in two successive fans. One profile clearly demonstrates that the upper and most recent one is correlated to upper evaporites showing a gradual transition towards basin. The new data help to understand the relationships between Messinian detrital and evaporite formation in west Mediterranean.

IMPACT OF THE MESSINIAN SALINITY CRISIS OFF THE WEST AFRICAN MARGIN SEDIMENTS / PRELIMINARY SEDIMENTARY AND ISOTOPIC RECORD OF THE ODP SITE 659

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The aim of this study is to investigate global climatic changes during the late Miocene in relation to the Messinian salinity crisis, through a high-resolution oxygen and carbon isotope and sedimentary record from Site 659 (ODP Leg 108, 18°05'N, 21°02'W, water depth 3070 m) located on top of the Cape Verde plateau off northwest Africa.

The age model of Site 659 is based on $\partial^{18}O$ stratigraphy, correlated to the astronomically dated $\partial^{18}O$ record from western equatorial Atlantic Site 926 (Shackleton and Hall 1997). Site 659 is characterised by a sedimentation rate on the order of 3 to 5 cm/ka induced by surface high carbonate productivity and by eolian dust input of Sahara and Sahel (Tiedemann et al., 1994). A preliminary $\partial^{18}O$ and $\partial^{13}C$ record in bulk fine carbonate fraction has been obtained for the Late Miocene (5-6,5 Ma) at 10 cm intervals corresponding to a time resolution of 4 to 10 ky. Long and short-term $\partial^{18}O$ and $\partial^{13}C$ fluctuations are observed in the climatic record and discussed in terms of eustatic, deep water temperature and ventilation changes.

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FIRST DATA ON MESSINIAN PORTUGUESE BIVALVE FAUNA FROM ALGARVE

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The Miocene sequence from the Atlantic frontage in Algarve is made up of two superimposed formations. The lower one, cropping out in the western Algarve, namely the Lagos-Portimão Formation consists mainly of carbonate facies while the upper one, exposed in the eastern Algarve is distinguished as the Cacela Formation. The latter formation represented by a fine to very fine grained, unstratified sand and sandstone occurs now as isolated patches due to post-Miocene erosion. The coastal cliff section within the Cacela Fm along the Algarve coast west of the Cacela village represents only portion of the whole upper Miocene sequence.

Until 2002, molluscan-dominated Late Miocene fossil assemblages of the eastern Algarve were known to occur only in the famous sequence of the Cacela River. This exposure has attracted attention of geologists since 150 years because of its assemblage of high species diversity and unique shell preservation. The geological age of this fauna is defined as the latest Tortonian (ca 8.6-7.2 Ma) on the basis of nannofossils, planktonic foraminifers and Sr-data as well.

The recent fieldwork, financially supported through the EU Marie Curie Fellowship, has resulted in the abundant and diversified bivalve material derived from three localities (Cabanas, Barroquinha and Lacem) which are accessible during the low-tide only.

These new findings give new insight into the Late Miocene history of the marine fauna in the western Atlantic region and allow to get more precise image of faunal exchanges before and/or during Messinian via the Betic Corridor connecting Atlantic and Mediterranean Seas. Crucial factor in these considerations is the geological age. On the basis of Sr-isotopic ratios (ranging from 0.708956 to 0.708980) in the newly collected pectinids from Cabanas and Barroquinha, the Messinian age of the bivalve fauna - about 6.8-6.3 (+/-0.4) Ma - has been defined for the first time in Portugal.

Apart from pectinids and oysters which are extremely well preserved, the remaining specimens derived in Cabanas needed some preparatory work. Sixty five species are recognized belonging to 20 families of which the family Veneridae is characterized by particularly high taxonomic diversity. Very high proportion of articulated shells, a wide range of modal size values of fossil species and many specimens preserved in their life position indicate minimum post-mortem alteration. Taxonomic composition of the newly collected bivalve material from these localities resembles more closely the latest Tortonian bivalve fauna from the Cacela River section than the Tortonian/Messinian fauna from the Guadalquivir Basin in Spain and than the Messinian fauna from the Sorbas Basin in Spain.

WHY THREE LAGO MARE EVENTS?

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Since the seventies (Hsü *et al.,* 1973, 1977), the Lago Mare has been understood as the infilling of the Mediterranean desiccated basin by Paratethian brackish waters, which corresponded to one event within the latest Messinian. As a consequence, this event had a chronostratigraphic sense. Then, Corradini & Biffi (1988) and Bertini *et al.* (1995) added an ecostratigraphic significance to Lago Mare, without attenuating its chronologic assumption. More recently, the evidence of Mediterranean marine water influxes in the Dacic Basin has considerably changed the concept of water exchanges between the Mediterranean Sea and Paratethys (Marunteanu & Papaionopol, 1998) that can only be interpreted as connections during high sea-level episodes (Snel *et al.,* in press; Clauzon *et al.,* in press). In this region, Mediterranean nannoplankton influxes have been recorded before and after the Messinian salinity crisis (Snel *et al.,* in press; Clauzon *et al.,* in press), the consequence of which being also specified in the area (Gillet *et al.,* 2003; Clauzon *et al.,* in press). In the frame of the two-step scenario for the Messinian salinity crisis (Clauzon *et al.,* 1996), it is not only obvious that the Lago Mare biofacies corresponds to a high sea-level crossed exchange between the Mediterranean and Paratethys (involving also dinocysts) but also that two similar events occurred just before and just after the Messinian salinity crisis. Some deposits from the deep Mediterranean basins have been related to "Lago Mare" because of the presence of specimens of the *Cyprideis pannonica* group: they could represent a freshwater inflow into the hypersaline lagoons of the deep desiccated Mediterranean basins at the extreme end of the crisis just before the Zanclean deluge (Iaccarino & Bossio, 1999). In addition, it cannot be excluded that some "Lago Mare" events correspond to local environmental changes (Cyprus?) (Rouchy *et al.,* 2001).

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CORING THE MESSINIAN EVAPORITES IN THE NORTHWESTERN MEDITERRANEAN REGION: WHAT A CHALLENGE FOR THE UNDERSTANDING OF THE SALINITY CRISIS!

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Since the discovery of the Messinian salinity crisis in 1970, several scenarios have been proposed and discussed a lot. The Clauzon *et al.'s* (1996) scenario derives from that of Hsü *et al.* (1973) but differs in considering two phases of lowering of sea-level: a moderate phase, of glacio-eustatism origin, which caused the marginal evaporites (including those of Sicily); then, a prominent phase, of tectonic origin (Clauzon *et al.,* 1996; Duggen *et al.,* 2003), which caused the almost complete desiccation of the Mediterranean Sea, and as a consequence, the deposition of the deep basin evaporites and the cutting of aerial canyons by rivers. This scenario is highly consistent with data on shore and benefits from a large support from oceanographic records (Vidal *et al.,* 2002; Lofi *et al.,* 2003; Warny *et al.,* 2003). Another scenario is now in discussion (Krijgsman *et al.,* 1999), which considers only one salinity crisis, i.e. that marginal and central evaporites are coeval. This means that (1) the first scenario considers an age of 5.7 Ma for the beginning of the central evaporites, in correspondence with Oxygen Isotope Stage TG 15 (Shackleton *et al.,* 1995), (2) the second scenario considers an age of 5.96 Ma for the beginning of all the evaporites, whatever marginal or central, i.e. a certain time before glacial Oxygen Isotope Stages TG 22 and TG 20 (Shackleton *et al.,* 1995).

Coring the Mediterranean central evaporites will provide, with respect to Oxygen Isotope Stratigraphy of the underlying sediments, the precise age of their beginning. This will solve the present-day discussion.

In addition, the Western Mediterranean appears more propitious for such a project because of the lesser complexity in the evaporitic process deposition than the Eastern Mediterranean. The proposed drilling site by C. Gorini in the Gulf of Lion is fully convenient.

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ORIGIN OF SOLUTES AND EVAPORITE DEPOSITION AT THE END OF THE MESSINIAN SALINITY CRISIS. THE ONSET OF "LAGO MARE" SEDIMENTATION

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There has been an historical debate about the type of environments (marine vs. continental) at the end of the 'Messinian Salinity Crisis'. The inflow of seawater has been claimed as a major source of solutes at the end of the Messinian evaporite precipitation. However, fresh water inflows have been also proposed as a source of solutes into the Messinian seawaters by some authors. A continuous or sporadic inflow of seawater, during the deposition of the Upper Evaporite is mainly supported by 1) the isotopic composition ($\partial^{34}S$, $\partial^{18}O$) of sulphate beds (e.g. Pierre, 1982; Ricchiuto and McKenzie, 1978) and 2) the sporadic occurrence of marine organisms in the marls interbedded within the Upper Evaporites or in the marginal carbonate units, stratigraphically equivalent to the evaporites (TCC). Nevertheless, a major inflow of freshwaters during the precipitation of the Upper Gypsiferous Unit may be interpreted from $\partial^{34}S$ values in some sulphate samples and $\partial^{18}O_{calcite}$ at various levels in the Eraclea Minoa - Sicily section (Longinelli, 1979/1980).

$\partial^{34}S$ and $\partial^{18}O$ of sulphates are powerful markers for the interpretation of evaporite precipitation from marine brines. However, when previously deposited marine sulphates are recycled, $\partial^{34}S$ and $\partial^{18}O$ may not distinguish between sulphates precipitated from SO_4^{2-} dissolved in seawater and sulphates recycled from previous marine evaporite sequences (Taberner et al., 2000). In these cases, the combined use of $\partial^{34}S$, $\partial^{18}O$ and $^{87}Sr/^{86}Sr$ becomes a powerful tool for the interpretation of the source of sulphates and fluids in continental settings (Carmona et al., 2000; Taberner et al., 2002).

This approach has been applied to the Messinian Upper Evaporite Unit outcropping in the Eraclea Minoa section (Sicily) and has provided the basis for new interpretations of its depositional environment. The $^{87}Sr/^{86}Sr$ ratios and $\partial^{34}S$ and $\partial^{18}O$ of sulphate beds from the Upper Gypsiferous Unit can be mostly explained as resulting from recycling, by continental waters, of different proportions of Triassic rocks and older Messinian evaporites (Lower Gypsiferous Unit). The contribution of seawater indicated by geochemical and biological markers will be adressed. Also, the palaeoenvironmental implications for the end of the "Messinian Salinity Crisis" (Hsü et al., 1973, 1978) and starting of the so-called "fresh-water crisis" (Longinelli, 1979) shall be discussed.

THE EFFECTS OF THE MESSINIAN SALINITY CRISIS IN THE LEVANTINE BASIN BETWEEN THE CYPRUS ARC AND THE SYRIAN MARGIN: PRELIMINARY RESULTS FROM THE BLAC CRUISE

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The recent "BLAC" cruise, onboard the R/V "Suroît", (October-November 2003) has surveyed the 300 km-long Eastern branch of the Cyprus Arc and recorded swath multibeam bathymetry, backscatter imagery, 3.5 kHz (Chirp) and 6-channels seismic profiling. As one of the scientific objectives, the impact of the Messinian Salinity Crisis detained a special and significant interest in the study area.

In the Eastern part of the Mediterranean Sea, the thickness of the sedimentary cover (including the Mesozoic series) is extremely important, up to 16.000 meters (Markis *et al.,* 1983), which includes a fairly thin layer of post-Messinian Plio-Quaternary sediments (200-300 meters thick that can reach 1.000-3.000 meters in limited areas of intense sedimentation in the deep basin (Vidal *et al.,* 2000). In the Western and the middle part of the study area, the "M" reflector (attributed to the top of the Messinian sequence) is identified above the 1.5 km thick Messinian evaporites. Eastward the "M" reflector displays erosional features nearby the Syrian margin and the adjacent Cyprus Arc range with a thinner to nonentity absent Messinian evaporites.

The strong "M" reflector identified on our new seismic profiles shows several unconformities related to both salt tectonics and compressional crustal-scale tectonics, especially in the Cyprus front area.

On the Hecataeus plateau, in the deformed area, the Messinian sequence is thinner and characterized by a "transparent" seismic facies where no distinguishing can be done between salt and Upper Evaporites. The "M"reflector is flat, onlapping the Miocene sediments to the West and then becomes folded, following deformations of the underlying series, to the East. Wavy structures at the top of the Messinian sequence form and grow as we approach the contractional front.

In the Levantine basin near the deformation front, a disturbed and high-energy reflector is identified in the thick Messinian sediments, which seems to mark the limit between the transparent mobile salt and the Upper Evaporites.

The seismic analysis, combined with the observation of the bathymetry and subsurface structures, reveals the presence of mud volcanoes in the axis of this regional anticline.

In the Northern Larnaca – Lattakia basin, Messinian sequences thicken and salt diapirs are well displayed.

The main important features revealed by the "BLAC" Survey are erosional surfaces well observed within and/or on top of the Messinian sequences, which must be interpreted in term of environmental and tectonic changes during Messinian Times.

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RECONSTITUTION OF THE MESSINIAN EVENTS ON THE EASTERN CORSICAN MARGIN AND IN THE CORSICA BASIN

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The Eastern Corsica margin and the Corsica Basin Messinian formations and structures have been recently resurveyed. From 1997 to 2003, we have gathered, processed and interpreted 7100 km of reflection seismic profiles through collaborations with the University of Corsica, the BRGM and the University of Brest. The compilation of this new seismic set with the previous oil industry and academic seismic profiles lead to a precise Messinian erosion surface on the whole "Corsica Basin" between East of the island and the Elba-Pianosa Ridge. From the seismic surveys of the Corsica Basin, the dense grid gave an accurate cartography of the incision Messinian river system. These incisions groove a layered formation interpreted as a thin endoreic deposit, coeval with the evaporitic series of the Ligurian or Tyrrhenian Seas: *i.e.* an homogeneous layer between a high amplitude reflector for base and a layered formation at the top looking like the succession carbonatic base, halite, upper evaporites. They affect the top of this unit and cut the whole unit up to the underlying Miocene series. This system is composed by a great N-S valley converging towards a large zone of meanders from the West in the southern central area. More discontinuous and small gullies-type incisions are assigned to the base reflector only, rests of a first sea level lowering. Northward, the main valley running along the foot of the Pianosa Ridge, is now clearly uplifted on his flank. Southward, this valley widens, deepens and bypasses the Pianosa Ridge eastward to run into the deeper Tyrrhenian basin. Nevertheless, this southern ending is "obstructed" by a magmatic intrusion and deformed by the continuous uplift of the Pianosa Ridge and East-Sardinia margin during the Mio-Pliocene epochs. This deep incision and widely eroded area emphasise an extremely short and active connection with the Tyrrhenian domain and illustrate the active tectonic context at the end of the Messinian period. It also suggests that the Corsican Basin was inclined southward in the direction of the Tyrrhenian sea at the Miocene periods.

On the eastern margin, the Messinian erosion traces on the shelf are used to reconstruct the Messinian slope along the whole margin. The configuration of this slope evidences the tectonic heritage linked to the deep structural pattern. The seismic data have revealed the presence of a residual Miocene shelf in line with the emerged Aleria Basin. Except for this area, the East-Corsica shelf was built almost everywhere by important progradation and aggradation processes at the Pliocene and Quaternary periods.

In the North, at the junction of the Pianosa Ridge and the north-eastern margin, a brittle tectonic has affected the pre-messinian units and the thick Plio-Quaternary sedimentary cover in the basin. On the continental shelf many Messinian residual reliefs are present in the topography. The present platform morphology is herited from the Messsinian times.

In the South, the east Bonifacio strait is characterised by the restricted Miocene shelf. The occurrence of some remnants of the base of the Messinian and the exhumation of the Lower Miocene formations, directly covered by the Plio-Quaternary depositions, suggest that the final Messinian erosion was wider in the south Corsica Basin than in the northern area.

The Messinian incision river system stopping in the South, as the South larger erosion, the uplift of the Pianosa Ridge and the associated magmatic events outline the active brittle tectonics during the Messinian period whereas the Plio-Quaternary deposition-centre migrates regularly northward.

ORGANIC CARBON COMPOSITION AND NEW ORGANIC LIPID PALEOTEMPERATURE PROXY APPLIED TO THE MESSINIAN TRIPOLI FORMATION, CALTANISETTA BASIN, SICILY

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Detailed biostratigraphy and cyclostratigraphy in the Messinian Tripoli Formation exposed in northern (Vaccarizzo) and southern (Serra Pirciata) marginal sub-basins correlate the transition from marine to hypersaline conditions across central Sicily. This allows organic matter properties and a new organic geochemical paleotemperature proxy to be interpreted within a robust stratigraphic framework. The paleotemperature proxy, termed Tetraether Index (TEX86), is based on a correlation between the distribution of membrane ether lipids from picoplankton (specifically *Archaea*) in core-top sediments and annual mean sea surface temperature in modern oceans. We have evaluated this proxy in extractable organic matter from the Serra Pirciata (Tallarita). Our results reveal fluctuating sea surface temperatures trending to an overall cooling from 33ºC to 19ºC prior to the deposition of the Calcare di Base. This could be a record of local water mass temperature fluctuations, or a more regional temperature decrease. However, high S content and a correlation (r^2=0.5) between S and C wt% in organic matter may indicate the presence of organic sulfur compounds. Organic sulfur compounds have been reported in similar Messinian material from the Lorca Basin (Spain) and the Vena del Gesso (N. Italy). Furthermore, isoprenoidal ether lipids similar to those used in the TEX86 proxy have been reported as bithiopenes in other Messinian sediments. In future work, we will determine the distribution of sulfur-linked biomarkers in extractable organic matter and their potential influence on paleotemperature calculations.

The northern Vaccarizzo section is composed of cycles of marls, laminated limestones, and diatomitic marls. Organic carbon content varies from 0.88 to > 4.0 wt %. In comparison, the Serra Pirciata section is composed of dolomitic marls and well-developed diatomites, with 2.0 to 10.0 wt % organic carbon. The organic carbon content therefore supports lithological evidence of enhanced diatom-driven productivity in the Serra Pirciata relative to the Vaccarizzo. The ∂^{13}Corg record in the two sections are similar during normal marine deposition (to cycle 48), with relatively constant composition from -23 ‰ to -20‰ PDB, considered a normal range for marine algae using the C_3 photosynthetic pathway. In the Serra Pirciata section, the ∂^{13}Corg increases to ~ -18‰ PDB. Previous work reports isotopically depleted inorganic carbon indicative of mineralization of isotopically depleted organic matter. Just prior to the deposition of evaporites in the Serra Pirciata section (cycle 52), the isotopic enrichment of ~5‰ may signal either increased productivity or increased carbon limitation with the onset of evaporitic conditions.

GEOMETRY AND SEQUENTIAL CORRELATIONS OF TORTONIAN TO MESSINIAN PLATFORM TRANSECT ACROSS THE LORCA BASIN (SE SPAIN)

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Coral reefs represent one of the main carbonate factories that contributed to the control of the stratigraphic architecture of carbonate platforms. This study presents a high resolution sequence stratigraphic model, that enables: (1) a geometrical reconstruction of the depositional system constrained by timelines, (2) a definition of lateral facies changes within depositional sequences, and (3) an evaluation of the role of coral reefs on the stratigraphic architecture of carbonate platforms.

The Tortonian to Messinian deposits crop out in the Lorca Basin, SE Spain, and are composed of five mixed siliciclastic/carbonate units. These excellent outcrop conditions allow surface and bedding planes to be physically traced, guaranteeing a robust stratigraphic correlation scheme. A preliminary biostratigraphical study, based on the planktonic foraminifera and calcareous nannoplankton, allowed us to correlate the basal marls, which record the onset of the sedimentary succession before the first carbonate unit with the MMi 11 biozone of Sprovieri *et al.* (2002). Consequently, on the basis of these biostratigraphic constraints and correlations with the timescale defined in the Sicilian sections, the deposition of the marls was interpreted to have started after 10.55 Ma and before 10.02 Ma. The age of the end of the carbonate platform development is uncertain as the base of the Tripoli unit that immediately postdates the carbonate deposits is dated around 7.7 Ma (Krijgsman et al., 2000) or 6.7 Ma (Rouchy et al., 1998). Reef development probably ceased when the first precursor evaporitic event occurred in the basin centre near the beginning of the Tripoli deposition.

At a platform scale, the carbonates are found intermixed with terrigenous deposits related to two main types of clastic systems: alluvial fans and deltaic to fluvial depositional systems. The amount of clastic input affected reef growth and coral morphologies. Twelve facies are distinguished, from distal to proximal, that correspond to shelf carbonate settings and siliciclastic coastal plain environments. The reef morphologies are variable throughout the mixed siliciclastic/carbonate units at the platform scale. The first unit is dominated by bioclasts, whereas units 2, 3 and 5 are sigmoidal carbonate complexes dominated by *Porites* sigmoid complexes. Unit 4 is a well-developed biohermal complex mainly composed of *Tarbellastraea.* Four fourth order sequences (tens of meters thick) can be recognised, each of these composed of higher frequency cycles. The geometry of deposits is described as a large scale sigmoidal wedge, prograding towards the basin, and the sedimentation is disturbed by local syn-sedimentary tectonic. The carbonate production changes, from grain-producing biota in the basal unit to a framework-producing biota in the overlying units, that agrees with an evolution from a distally steepened ramp to a reef-rimmed shelf.

COMPARATIVE ANALYSIS OF ECHINOID AND OYSTER PALAEOECOLOGICAL DISTRIBUTIONS BEFORE, DURING AND AFTER THE MESSINIAN EVAPORITIC EPISODE

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A comparative analysis between echinoid and oyster Neogene assemblages of the Sorbas basin (southeast Spain) has been realized to evaluate depth, oxygenation and salinity variations of this basin from the beginning of the Messinian to the Early Pliocene.

Both groups have already demonstrate their ability to palaeoenvironmental reconstructions, these reconstructions being facilitated by the survival of most of the Messinian species in the Pliocene and the Present-Day Mediterranean basin.

First, the distribution of Messinian echinoids assemblages follows an ecomorphological gradient strongly related to environmental depth, but always under normal conditions of salinity. Most of the taxa, such as *Clypeaster marginatus, Schizaster saheliensis, Spatangus purpureus* or *Schizechinus,* characterize normal marine silty and muddy substrates of the infralittoral zone. Other ones, like *Echinolampas, Psammechinus* and *Arbacina* mark reefal influences in the photic zone. A few species, such as *Brissopis atlantica,* both in the Mio-Pliocene and the Recent Mediterranean seas, are known to proliferate in deep poor oxygen substrates (circalittoral to bathial). Finally, other echinoids, like *Clypeaster altus,* are able to settle very high energy coastal environment, where faint variation in salinity can take place sometimes. In the Recent seas, it was demonstrated that salinity variations lead to monstrous « malformations » in the echinoid development.

The Messinian oysters are distributed all along the platform from the intertidal zone to the circalittoral zone. Several species of oysters, with their robust shell, are more able to live in high energy environments than echinoderms. Even if environmental distribution of oysters is broader than the one of echinoids, use of specific ratio of *Neopycnodonte cochlear* and *Ostrea lamellosa* allows to characterize bathymetric conditions, whatever be the type of sediment. Another species, *Hyotissa hyotis,* is more generally pledged to reefal conditions and is therefore associated to *Psammechinus* and *Arbacina* echinoids. Finally, a few species, like *Crassostrea gryphoides,* can settle brackish environments where echinoids are absolutely absent.

The combination of these two benthic macro-indices in the palaeoecological analysis of the Neogene series of the Sorbas basin allows to follow acurately the evolution of marine faunas and environments before, during and after the Messinian evaporitic crisis. Multivariate analyses have been realized to test the ways of association and distribution of echinoids and oysters in the different Messinian and Early Pliocene beds.

MESSINIAN FORAMINIFERAL ASSEMBLAGES FROM LAMINITES NEAR NIZZA MONFERRATO (PIEDMONT, NORTHERN ITALY)

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Rich assemblages of planktonic foraminifers have been recovered in laminated clayey marls, exposed by works along the Nizza Torrent, in the surroundings of Nizza Monferrato (Asti, Piedmont, Northern Italy). Messinian fillites outcrop in the nearby hillsides and are inferred to overlay the marls. Geological investigations suggest a tectonic evolution more complex than previously reported. In spite of the laminites small exposure, significant data have been collected, for the first time documenting Messinian pre-evaporitic sediments in this area (Violanti & Gallo, 2002). On the basis of foraminiferal assemblages, the laminated clayey marls have been referred to the Messinian *Globorotalia conomiozea* biozone. Quantitative foraminiferal analyses have been carried out for this study, and testify a deep marine paleoenvironment. Planktonic specimens are strongly dominant (P/(P+B)=95-100%). Warm water taxa, as *Orbulina universa, Globigerinoides seigliei, Globigerinoides sacculifer,* are frequent, followed by common *Globigerina apertura, Globigerinella obesa, Globorotalia conomiozea, Neogloboquadrina acostaensis* (sinistral) and T*urborotalita quinqueloba.* Benthic taxa are represented by rare specimens of *Chilostomella oolina, Globobulimina affinis,* frequently reported from disaerobic bottoms and sapropelitic layers. Pyrite and iron-oxides aggregates, as pyritized tests of planktonic taxa, are very abundant in some layers. Micropaleontological and sedimentological data provide signals of condensed sedimentation.

Moreover, rare specimens of *Hastigerinella digitata,* reported as fossil only from Messinian assemblages of Piedmont more than 25 years ago (Giannelli *et al.,* 1976; Colalongo *et al.*, 1979), have been collected. This finding allows a better correlation with the historical coeval sections of Piedmont, near Alba (Sturani, 1978) or in the Alto Monferrato (upper Rio Mazzapiedi-Castellania section, Rio *et al.,* 1997) and confirms tropical paleoenvironmental conditions in the Piedmont area during the Messinian.

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THE BIOTIC RESPONSE OF CALCAREOUS NANNOPLANKTON AT THE ONSET OF THE MESSINIAN SALINITY CRISIS

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The rapidly changing and extreme environmental conditions of the early Messinian Salinity Crisis are reflected in abrupt variations in nannofosssil assemblages within the Messinian units (Kalavasos Formation) from the Polemi Basin, Cyprus. During the Messinian, sedimentary and microfossil data indicate that the Polemi Basin was a semi-enclosed, neritic to littoral environment, subject to repeated influxes of marine and freshwater. This is supported by the absence of open marine nannoplankton (e.g. *Discoaster*) and the presence of neritic - littoral and freshwater diatoms (e.g. *Thalassionema nitzschioides, Coscinodiscus excentricus*). The rapidly changing and extreme environmental conditions of the early Messinian Salinity Crisis are reflected in the abrupt variations in nannofossil assemblages. Nannoplankton diversity (3 to 11 species) is greatly reduced in comparison to the open ocean and the assemblages are highly uneven, with high dominance. One of five species were observed to dominate any of the assemblages, these were *Reticulofenestra minuta, Dictyococcites antarcticus, Helicosphaera carteri, Umbilicosphaera jafari* and *Sphenolithus abies.* The associated diatom and sedimentological evidence from the Polemi Basin are used to indicate the palaeoecology of key nannofossil taxa. *D. antarcticus* predominated in normal salinity, mesotrophic, shallow water environments; *H. carteri* in shallow, brackish, hyper-eutrophic environments; *U. jafari* in hypersaline conditions; *R. minuta* in hyper-eutrophic conditions with an abnormal salinity from brackish to hypersaline; *S. abies* in mesotrophic, deeper and normal salinity environments. These species are indicated to be opportunistic, adapted to unstable environments. Fluctuations in nutrient levels and salinity are interpreted as the primary factors controlling the overall nature of the nannoplankton assemblages and the species which dominate at any one level.

AEGEAN BRACKISH MOLLUSKS AND MEDITERRANEAN - EUXINIAN CONNECTIONS DURING THE MESSINIAN

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Brackish Pontian-like mollusks are known in the Mediterranean domain since the 19 century from Barcelona area, North Italy, Sicily, and Aegean area. Many specialists found here species, which were common with the Paratethys, and proposed the Thracian - Aegean Gulf of the Paratethys existed during the Messinian, or in Paratethys scale, during the Pontian, Maeotian, and sometimes - late Sarmatian). Well-preserved Pontian-like mollusks were studied from the Serres basin, Northern Greece. 22 species of brackish and lagoon bivalves and one species of gastropods were determined from Choumnikon formation, from which 6 species and one subgenus of cardiids were described as a new (Popov, Nevesskaya, 2000). 8 species are common with the Eastern Paratethys Pontian, the most characteristic - *Lymnocardium (Euxinicardium) nobile, Eupatorina littoralis, Pseudocatillus pseudocatillus, Paradacna abichi.* From other side the association include 5-6 species and genera *Mactra* and *Cerastoderma* unknown in the Pontian but present in the Upper Messinian complexes of the Spain, North Italy and Sicily. On the base of high specific mollusk fauna, as well as paleomagnetic and astronomical cyclicity data (Snel et al., 2002) the Choumnicon formation is correlatable with the Pontian and the Upper Messinian. Overlying continental Spilia formation contains mammal remains, age of which was defined at the Turolian - Ruscinian transition (Schmidt-Kittler N. (ed), 1995).

From paleogeographic point of view the North Aegean basin was not a gulf of the Paratethys. It was more closely connected with the Mediterranean Messinian basin, based on marine polyhaline fauna of underlying Dafni formation (with colonial corals, *Pecten benedictus, Arca, Anadara, Chama, Cardita, Venus*) and overlying strata (with *Neopycnodonte*) and faunistic similarity of the Choumnicon mollusks with the Upper Messinian ones. Thick Messinian evaporites are known from this region. It is possible, the North Aegean Basin was the intermediate one, where the Maeotian and Pontian mollusk associations had been formed.

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