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Geologia. — *Sediment injection in the pit of the Urania Anoxic brine lake (Eastern Mediterranean)*. Nota di Giovanni Aloisi, Maria Bianca Cita e Davide Castradori, presentata (*) dal Socio M.B. Cita Sironi.

Abstract. — The Urania brine-filled, anoxic basin shows physical and geological characteristics which set it aside from the previously studied anoxic basins of the Eastern Mediterranean. The detailed study of a core raised from the western horn of the horseshoe-shaped basin provides evidence for the upward injection of old sediments into more recent, surficial anoxic mud. The oldest intruded sediments identified are Zanclean in age, and pelagic in facies (MPl3 and MPl4a biozones). Debris-flow or flow-in mechanisms are discussed, but discarded. The sediment injection agrees with the very high bottom water temperatures measured in the pit, the very high heat flow and a concave downwards pore water dissolved chlorosity gradient, all indicative of upward fluid migration. Mud expulsion features were recorded close to the location of the core. Movement along a fault plane could be responsible for the upward injection of old sediments and for their expulsion on the sea-floor.

Key words: Urania Anoxic Basin; Sediment Injection; Mediterranean Ridge.

Riassunto. — *Iniezione di sedimenti nel bacino anossico ipersalino Urania* (*Mediterraneo orientale*). Si presentano i risultati dello studio dettagliato di una carota prelevata in un bacino contenente salamoie anossiche ad alta densità, scoperto nella Dorsale Mediterranea occidentale. Il bacino ha una forma a ferro di cavallo e la sua estremità occidentale contiene una specie di buco profondo circa 80 m, dove la temperatura misurata cresce fino a 45°C. La carota contiene brandelli di sedimenti pelagici di età diversa, del Pleistocene e Pliocene inferiore, che sono interpretati come iniettati verso l'alto da fluidi in pressione lungo un piano di faglia entro i sedimenti anossici superficiali di età più recente. Questa interpretazione è in accordo con l'anomalia geochimica riscontrata (gradiente di clorinità inverso misurato nelle acque interstiziali della stessa carota) e con la forte anomalia termica registrata *in situ* e mediante misure del flusso di calore. Questi dati suggeriscono una provenienza dei fluidi da almeno 500 m di profondità.

Introduction

Three brine filled deep collapsed basins were discovered in a small area of the Mediterranean Ridge, close to the Inner Deformation Front and the Levantine Backstop (MEDRIFF Consortium, 1995; Fusi *et al.*, 1996; Westbrook and Reston, 2002; Cita, 2006) where Messinian evaporites are thin and offset by normal faults.

The basins were named Urania, Atalante and Discovery after the names of the oceanographic ships that first discovered and investigated them in 1993-94 (see fig. 1). A strong mid-water reflector separates the high density anoxic brines from normal sea-water. The seismic reflection profile illustrated in fig. 2, that crosses the Atalante Basin and the two horns of the horseshoe shaped Urania Basin, shows that the mid-water reflector or lake surface lies at different sub-sea depth in these two basins very close to one another. The sparker line allows to identify the M-reflector (calibrated by deep drilling

(*) Nella seduta del 10 marzo 2006.

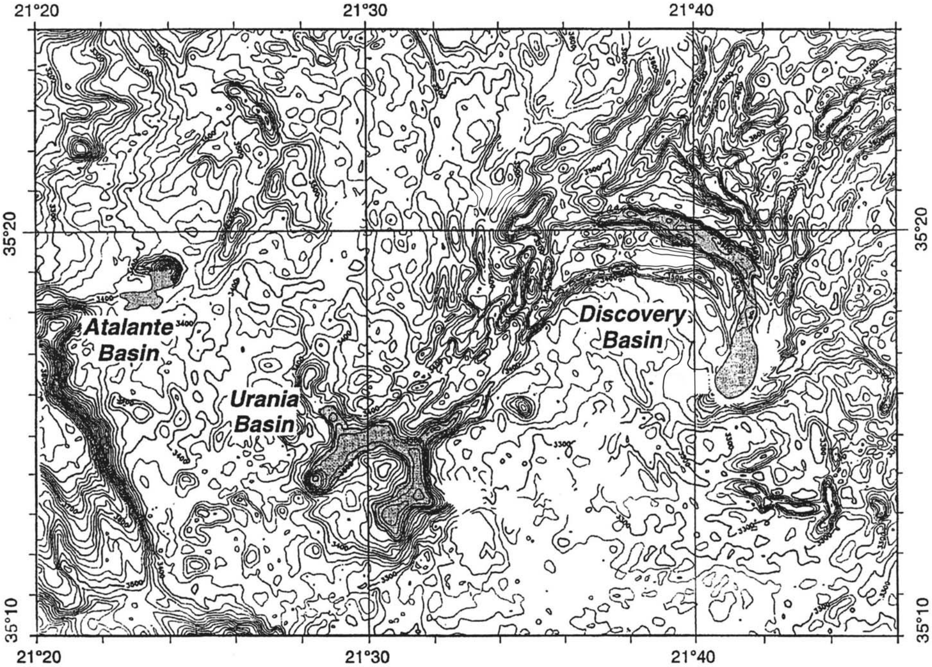

Fig. 1. – Bathymetric map of the MEDRIFF Corridor where three brine lakes were discovered in 1993-94 (after MEDRIFF Consortium, 1995).

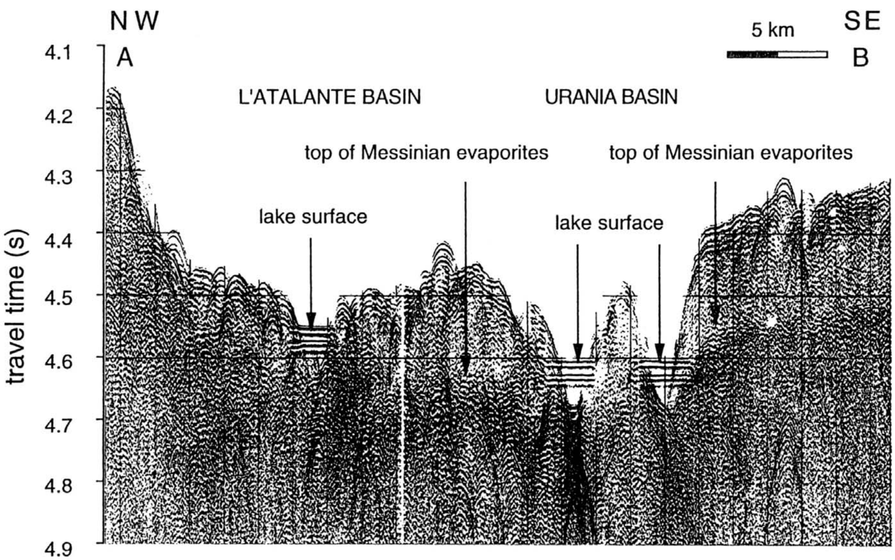

Fig. 2. – Seismic reflection profile across a portion of the western Mediterranean Ridge showing the interface separating the normal sea water from the high density anoxic brines that occupy the deepest portions of the Atalante and Urania Basins (after Camerlenghi *et al.*, 1993; MEDRIFF Consortium, 1995).

with the top of Messinian Evaporites), which lies at different levels and is offset by faults. The two adjacent brine lakes behave as two different and independent hydrologic systems and have a different chemical composition. Atalante is strongly enriched in K, suggesting a derivation from the potassium chlorides that characterise the uppermost levels of the evaporitic suite, whereas the Discovery Basin brines are enriched in magnesium chlorides and have the highest salinity ever found in the marine environment (Wallman *et al.*, 1997). Vengosh *et al.* (1998) suggest that the brines derive from the migration towards the sea floor of relic brines formed by evaporation during the Messinian salinity crisis.

Figure 3 (after MEDRIFF Consortium, 1995) shows the thermal structure recorded in the Atalante and Urania Basins. The mid-water reflector lies at approximately – 3460 m in Urania, where a very strong thermal anomaly is recorded in the «deep hole» or «pit», a depression localised in the western horn. A much smaller anomaly with an inverse trend near the surface of the brines is recorded in the Atalante Basin, where the interface lies at – 3344 m.

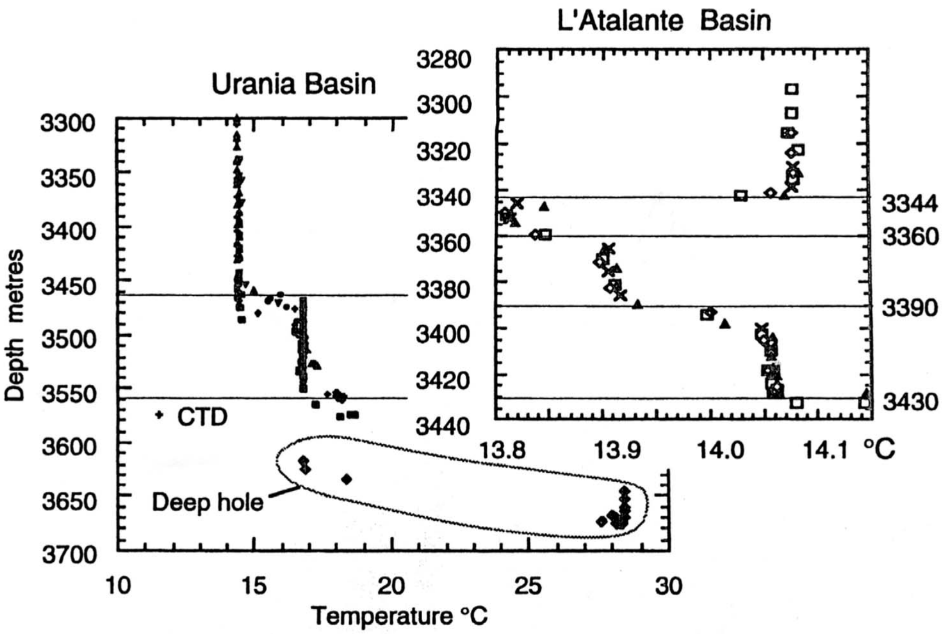

Fig. 3. – Thermal stratification observed in CTD measurements run in Urania Basin and with thermistor on heat flow probes in Urania and Atalante Basins (after MEDRIFF Consortium, 1995).

Background and motivation

The purpose of the present paper is to present and discuss the results of a detailed study of a piston core raised by the R/V Discovery in the Urania Basin, first explored by the R/V Urania (Camerlenghi *et al.*, 1993).

The western horn of the horseshoe shaped basin is some 80 m deeper than the rest of the brine-filled basin, and is characterised by anomalous, very high temperatures (up to 45°C) (Corselli *et al.*, 1996; Della Vedova *et al.*, 1998), exceptional temperature gradient in the sediments (190°C/km) (Westbrook *et al.*, 1995), very high methane content (Charlou *et al.*, 2003), and a concave downwards pore water chlorosity gradient (MEDRIFF Consortium, 1995). Evidence of mud expulsion structures has been imaged by the SCAMPI camera equipment during the Le Suroit '94 cruise part of the MEDRIFF project (Foucher, pers. comm. to G. Aloisi, 2000).

Core D206 07PC located on the lower slope of the pit at a depth of about 3385 m, was raised during the Discovery D206 cruise (Dec. '93 - Jan. '94) and contains an admixture of sediments originally interpreted as due to coring disturbance (Fusi *et al.*, 1996). This sediment core strongly differs from others raised from the same Urania Basin (see location in fig. 4 and characterisation in table I) and has been investigated in detail with multiple techniques in order to clarify nature, age, facies and mutual relationships of the various lithologies identified and to eventually propose a depositional model. We point out that the water depth for Core D206 07PC as indicated above and in table I is inconsistent with the location of the core in the bathymetric map (fig. 4) and with the water depth of the mid-water reflector (see fig. 3). It is maintained with reference to the original shipboard reports and with the first publication, although it is considered incorrect (too shallow). Indeed, we consider by far more important the precise location obtained with the same GPS positioning system by all the research vessels involved in the MEDRIFF, PALEOFLUX and JASON projects (*i.e.* l'Atalante, Urania, Discovery and Le Suroit).

VISUAL DESCRIPTION OF THE CORE

Overall, six distinct lithologies (A to E) were recognised in core D206 07PC. The general aspect of this core is that of a series of non layered, non laminated, disorganised lithologies which occur in discrete portions of different size and shape throughout the core (fig. 5).

Lithology A, a grey mud rich in small gypsum crystals and conspicuously devoid of any kind of layering (no bedding planes, no graded layers, no laminations are present) is the dominant lithology and appears as the «host sediment» that contains the other lithologies (B through E). Generally speaking, lithology A is similar to the sediments deposited in the brine-filled anoxic basins (see Montagnana and Sala, 1993; Fusi *et al.*, 1996), but appears disorganised, and shows evidence of faunal and floral mixing (see below). Lithologies B to E have nothing to share with the minor, basin-wide isochronous lithologies of the eastern Mediterranean deep-sea record, represented by sapropels and tephras, although two of these isochronous lithologies are present in another piston core raised from the eastern horn of the horseshoe shaped Urania basin (see Fusi *et al.*, 1996; Rimoldi, 1995; Rimoldi *et al.*, in preparation).

In the lower part of the core, lithology E occurs in two parallel and vertical strips up to 1 m in length and less than 1 cm in thickness. These elongated sediment portions are somewhat discontinuous and occasionally form subrounded lumps and folded structures

TABLE I. – *Location and characterisation of the cores from the Urania Basin. The marked differences in lithologic make up, sedimentation rates, and the evidence of upward sediment injection in the western core of the transect suggest a strong tectonic control.*

		D206 07PC	MD81 LC17	UR93 PC 02	UM94 PC33
Positioning	Lat. N	35°13.87'	35°13.85'	35°12.58'	35°13.27'
	Long. E	21°28.31'	21°28.61'	21°30.41'	21°31.25'
	Water depth (m)	3385 ??? (see text)	3511	3384	3442
	Core length (cm)	744	1888	519	618
Sediments	**Dominant lithology**	dark grey mud	homogeneous dark grey mud	dark mud	dark mud
	Minor lithologies	injected marls	mud turbidites (not a minor lithology)	sapropel tephra turbidites	sapropel tephra turbidites
	Marker horizons	none	none	S1, Y5	Y5, S5 (resedimented)
Structures	**Laminae**	none	yes	yes	yes
	Organic pellicles	none	yes	yes	none
	Degassing pipes	none	yes	none	yes
Post depositional processes	Gypsum crystals	yes	yes	none	none
	Sulphur	none	yes	yes	yes
	Carbonate crusts	none	none	none	yes
	Diagenesis	none	yes	none	none
	Oldest age *in situ* sediment	?	*Emiliania huxleyi* acme zone (<53.000 yBP)	Y5 (35.000 yBP)	S5 (125.000 yBP)

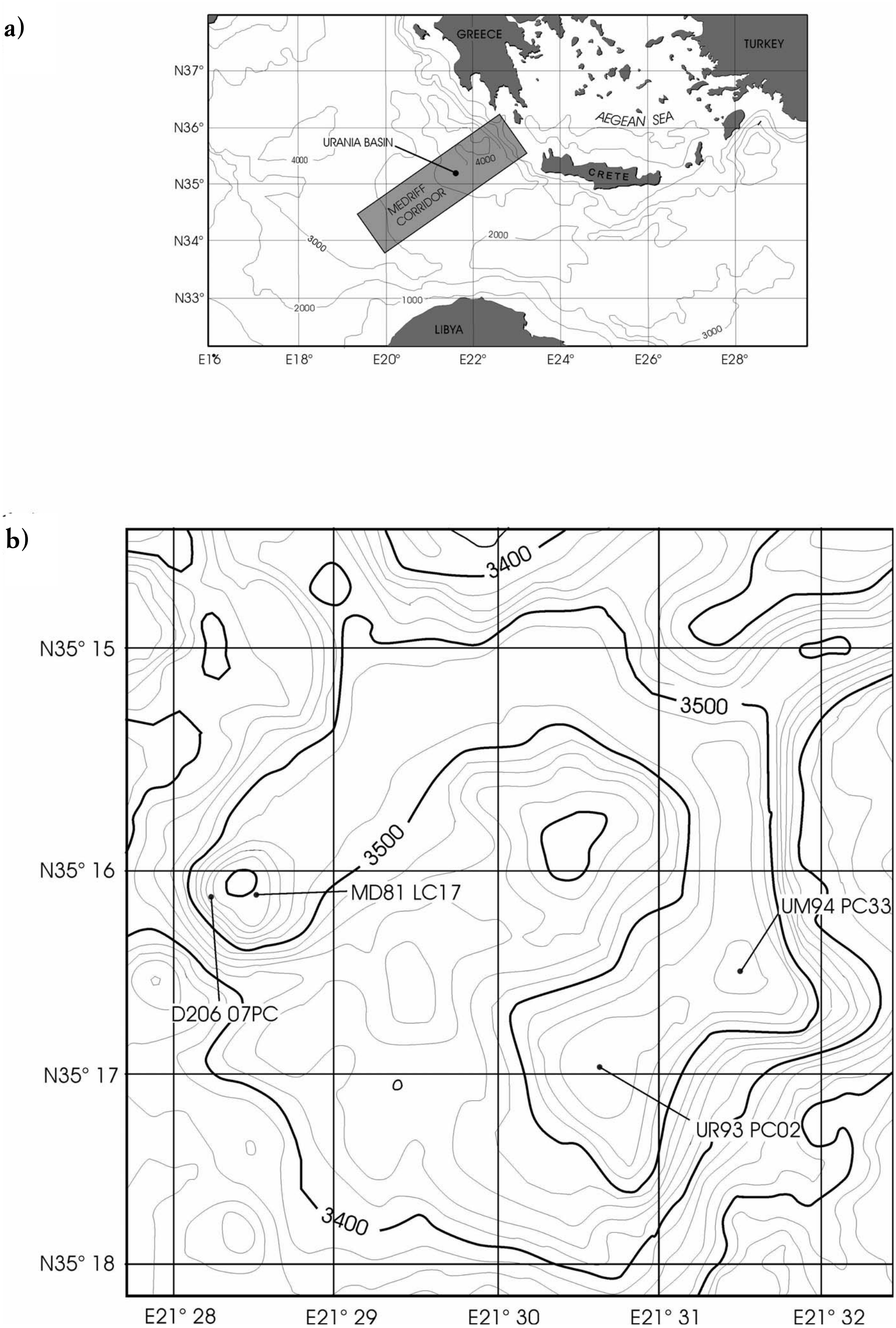

Fig. 4. – Location of the MEDRIFF study area within the Eastern Mediterranean (*a*) and bathymetry of the Urania basin with location of the four cores discussed in this paper (*b*).

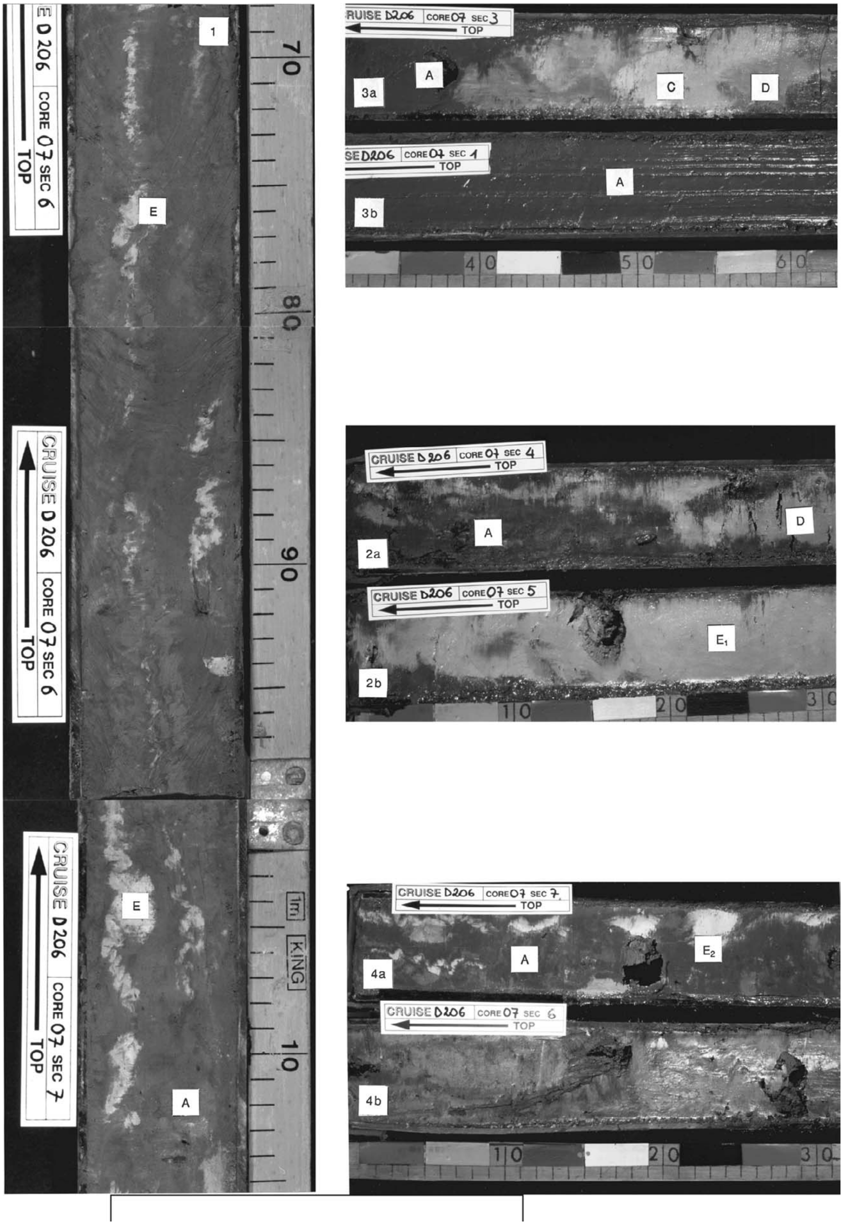

Fig. 5. – Detailed photographs of the six lithologies present in core D206 07PC and of the structures associated to upward injection of sediment. Centimetric voids are due to sampling for geochemical analysis. 1, discontinuous strips of lithology E into the host sediment, lithology A. Note the folded structures (0 to 10 cm in section 7); 2*a*, lithology D in contact with lithology A in section 4; 2*b*, lithology E (E_1) occupying the whole core section (406 to 436 cm from core top); 3*a*, lithologies C and D in contact with lithology A (section 3); 3*b*, in the topmost part of the core only lithology A is present; 4*a*, irregular lumps formed by lithology E in the lower part of the core (section 7), having two distinct ages (E_2 and E_3); 4*b*, lithology A in contact with the injected sediments of lithology E (right hand side of photograph).

(fig. 5.1). In the lower part of the core (from 573 to 673 cm from core top) lithology E is in lateral contact with lithology A, whilst between 406 cm and 436 cm from core top it occupies the whole diameter of the core (fig. 5.2*b*). Lithologies C and D occur in large portions in the upper part of the core (195 to 309 cm from core top) where they are in direct contact with lithology A (fig. 5.3*a*). Lithology B (fig. 5.2*a*, 420 cm from core top) and lithology F (683 cm from core top) are unique in this core and occupy small areas on the core. Throughout the whole core the lithologies show sharp contacts with the neighbour lithologies and a marked internal homogeneity.

Methods

The 6 recognised lithologies were photographed and sampled for further analyses. Calcimetric and grain-size analysis were carried out on samples of sufficient size. SEM and EDAX analysis of the sand fraction were conducted in order to investigate the composition of single grains. Detailed micropaleontological analysis of different samples of lithology E enabled us to distinguish three different ages (E_1, E_2 and E_3). A summary of the data obtained is presented alongside the sketch of the core in fig. 6.

Results

Calcimetric Analysis.

The amount of carbonates in the sediment was determined on nine 1g samples by means of reaction with dilute HCL (18%) and measurement of the amount of CO_2 produced. Of the 4 lithologies examined (samples of B and F were too small to be analysed), C, D and E showed high values of carbonate content (61-78% in weight) compared to the lower values (circa 40%) typical of the Quaternary pelagic sediments of the Mediterranean Ridge (Blechschmidt *et al.*, 1982; Cita *et al.*, 1982). Lithology A has lower values of carbonate content (20-34%) which seem unusual in this part of the Eastern Mediterranean.

Grain-size Analysis.

The sand fraction (> 63 microns) was separated from the fine fraction of the sediment by means of wet sieving and was examined with an optical microscope at 40 × magnification. When the samples where large enough (circa 4 g) the sand fraction was weighed in order to compare its abundance with that of the fine fraction. Values of 6% to 11% for lithologies A, C, D and E confirm their fine nature.

The sand fraction of lithologies B, C, D and E is mainly composed of planktonic foraminifers (figs. 2-4 and 6-7) which accounts for the unusually high values of carbonate content. Lithology C contains sparse benthic foraminifers while lithology B also contains pyrite and Fe oxides. Lithologies A and F, instead, are very different: the sand-size fraction of the former is composed mainly by authigenic gypsum crystals (figs. 1, 7),

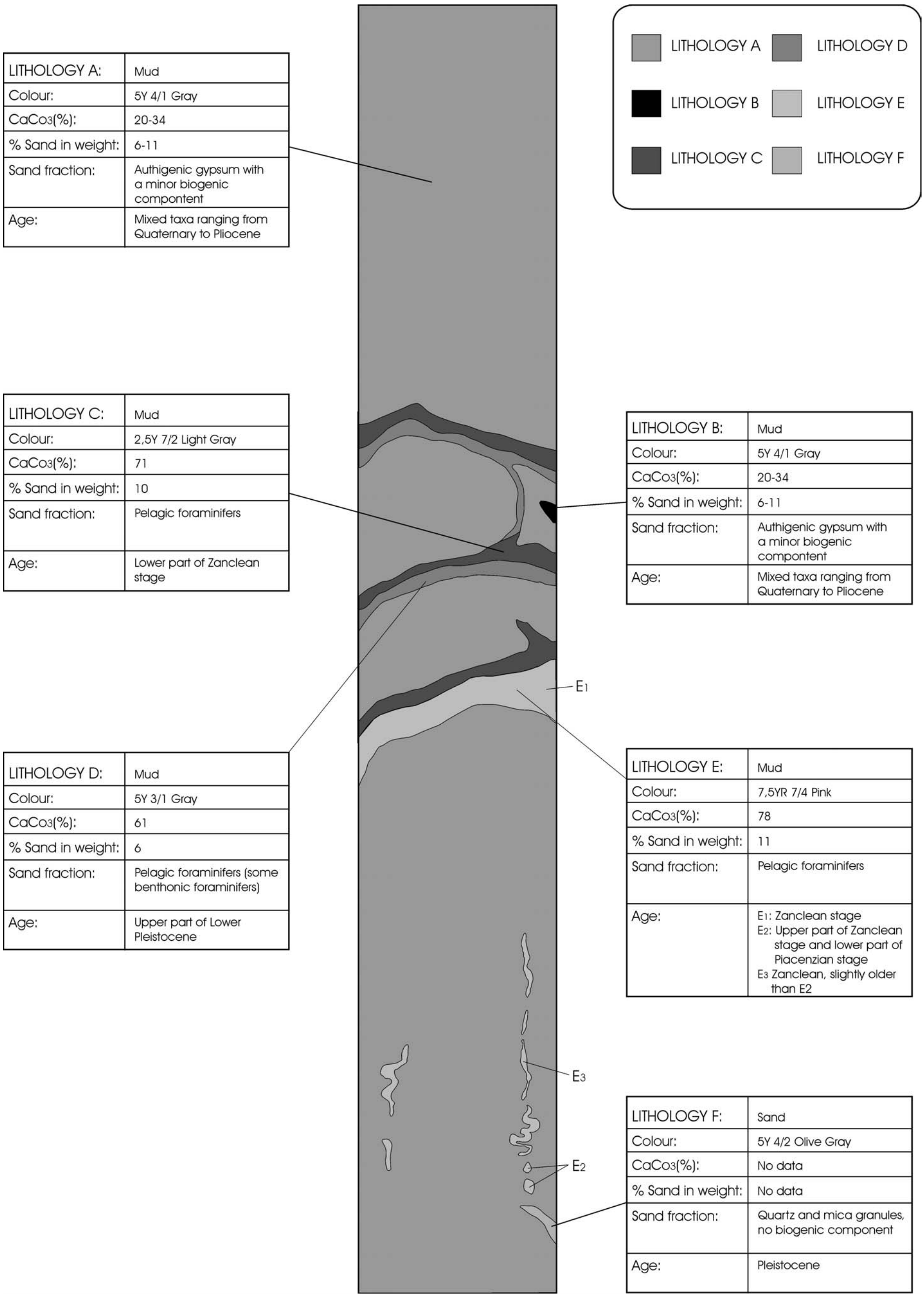

Fig. 6. – Sketch of core D206 07PC with a summary of the results obtained with the analysis carried out for this work.

sparse black minerals and a minor biogenic component. The black minerals proved to be microcrystalline gypsum agglomerates after EDAX analysis. The overall abundance of gypsum explains the relatively low carbonate content. Lithology F is entirely composed of quartz and mica granules, whilst the biogenic component is missing (figs. 7, 8).

Micropaleontological Analysis.

Both calcareous nannofossil and foraminiferal assemblages were investigated in order to obtain the most detailed age-dating of the different lithologies recovered. The nannofossil and foraminiferal biostratigraphic assignment was accomplished according to Rio *et al.*'s (1990) and Cita's (1973, 1975) zonal schemes, respectively. A correlation between the calcareous nannofossil and planktonic foraminiferal biozones is presented in figure 6 where the age of lithologies A to F are also plotted.

Lithology A.

The nannofossil assemblage appears as a «mixture» of: (*a*) a Pliocene source (probably pre-last appearance datum (LAD) of *Reticulofenestra pseudoumbilicus*), witnessed by the discoasterids, *R. pseudoumbilicus* and the small specimens of *Pseudoemiliania lacunosa*, (*b*) a lower-middle Pleistocene component, mainly represented by very large specimens of *P. lacunosa* and normal-sized *Gephyrocapsa*, and (*c*) a middle Pleistocene to Holocene sediment, with *Emiliania huxleyi*, whose confident recognition is hampered by the poor preservation and the small size of the specimens. The foraminiferal assemblage is mainly composed of sparse, not age-diagnostic species (*Globigerina bulloides, Globorotalia inflata, Orbulina universa, Globigerinoides ruber*). Some reworked specimens and some biogenic silica (radiolaria) were observed.

Lithology B.

This dark mud contains pyrite, iron oxides, and abundant organic matter. Calcareous nannofossils are highly diversified and rather well preserved. The abundance of *Amaurolithus delicatus* in the absence of *Helicosphaera sellii* allows a confident assignment to the MNN12 Zone (*Amaurolithus* spp. Zone). The presence of abundant organic matter, abundant specimens of *Florisphaera profunda* and *Discoaster pentaradiatus* is clearly indicative of a sapropel layer (Castradori, 1996). The foraminifers *O. universa, Globigerinoides quadrilobatus, G. bulloides* and other not age-diagnostic planktonic forms were observed (fig. 7.2). Chronostratigraphic synthesis: Nannofossil biostratigraphy clearly indicates the lower part of the Zanclean Stage (Lower Pliocene).

Lithology C.

The calcareous nannofossil assemblage is very similar to that of lithology B (see above). Therefore, it can be assigned to MNN12 Zone. The only difference is the non-

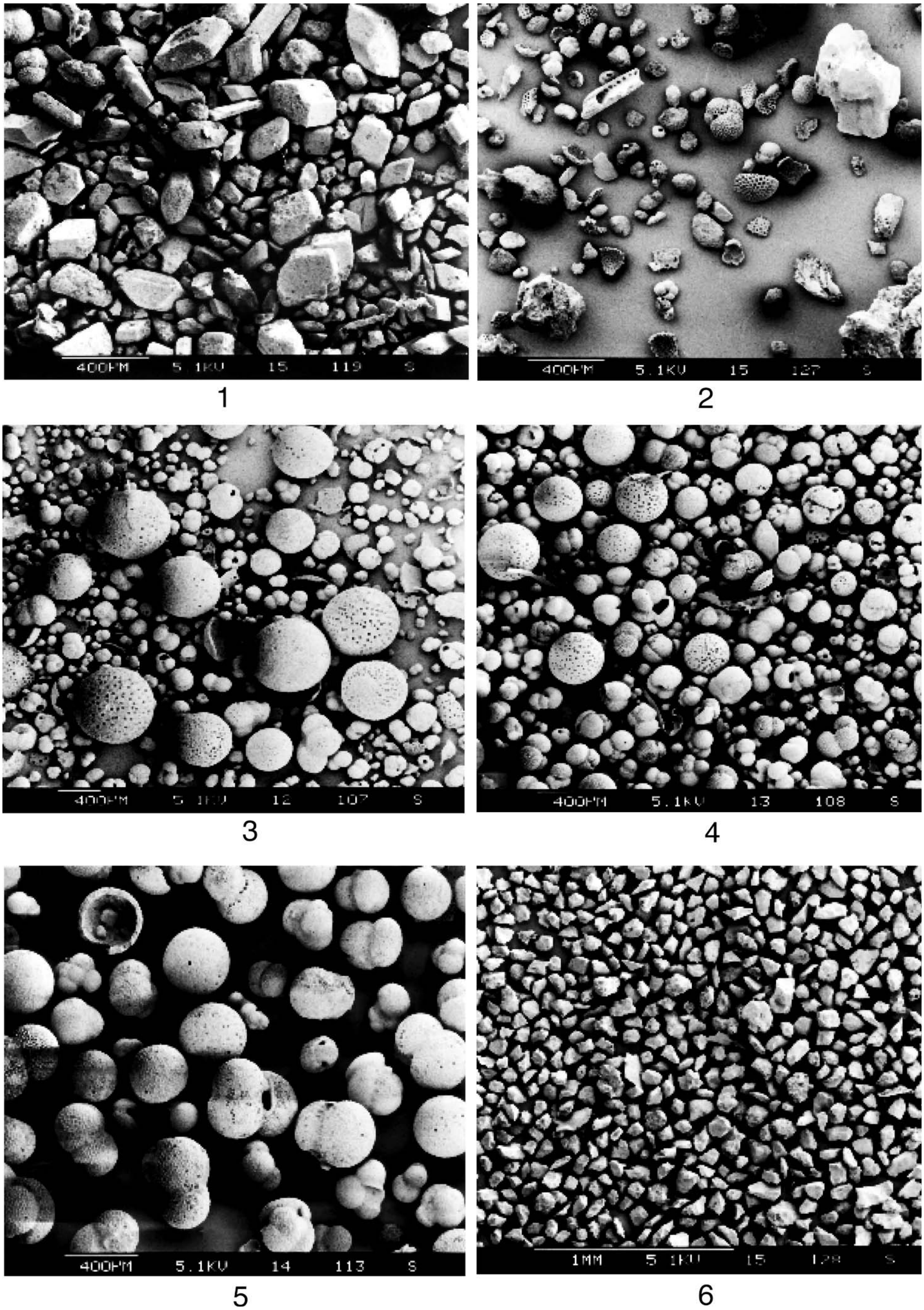

Fig. 7. – SEM photographs of the sand-size fraction of the six lithologies in the studied core. 1, lithology A; 2, lithology B; 3, lithology C; 4, lithology D; 5, lithology E; 6, lithology F.

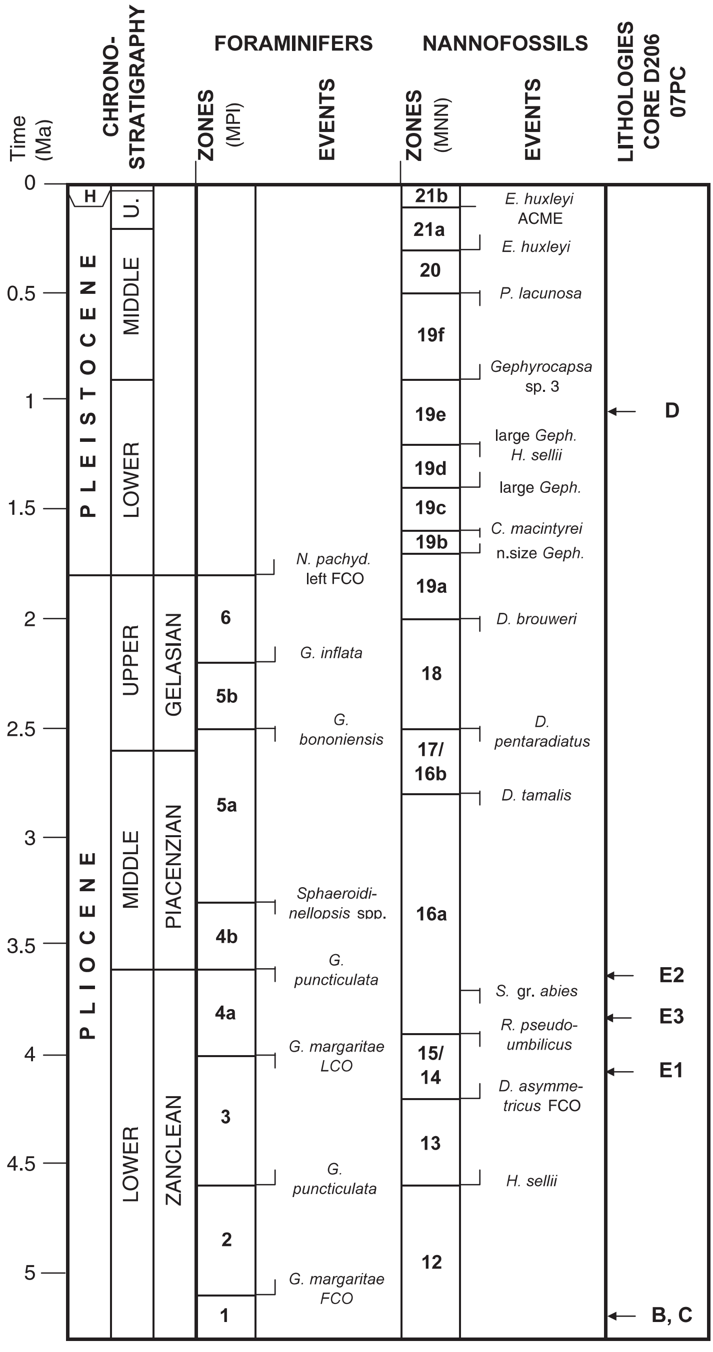

Fig. 8. – Position of lithologies B, C, D, E_1, E_2 and E_3 with respect to calcareous plankton biostratigraphies and chronostratigraphy. Calcareous nannofossil zonal scheme is after Rio *et al.* (1990); foraminiferal zonal scheme is after Cita (1973, 1975) (modified by Sprovieri, 1993). Lithologies A and F cannot be confidently plotted within these scheme (see text).

sapropelitic nature of this sample highlighted by the absence of organic matter and the scarcity of *F. profunda*. Foraminiferal assemblages are dominated by planktonic forms, including *Globigerinoides obliquus extremus, G. ruber, G. bulloides, Globorotalia scitula, Globorotalia menardii*, of a generic Pliocene age (fig. 7.3). Chronostratigraphic synthesis: Nannofossil biostratigraphy clearly indicates the lower part of the Zanclean Stage (Lower Pliocene).

Lithology D.

Calcareous nannofossils are very abundant and well preserved. The assemblage is characterised by the abundance of small *Gephyrocapsa*, the presence of *P. lacunosa* (very large specimens) and *Reticulofenestra asanoi* and by the absence of normal-sized *Gephyrocapsa*, large *Gephyrocapsa* (only 1 specimen detected) and *H. sellii*. This findings clearly indicate the MNN19e Zone (small *Gephyrocapsa* Zone). Planktonic foraminifers are abundant and indicative of a Quaternary age, with *Truncorotalia truncatulinoides*. The assemblage is very rich in large-sized *O. universa* and *Globigerinoides* spp., suggesting warm-water (pre-glacial) conditions (see fig. 7.4). Chronostratigraphic synthesis: Nannofossil biostratigraphy clearly indicates the upper part of the lower Pleistocene.

Lithology $E_{1.}$

Calcareous nannofossils are abundant and moderately well preserved. The presence of *H. sellii, R. pseudoumbilicus* and the *Sphenolithus abies* group (gr.) in the absence of *Amaurolithus* spp., *Discoaster asymmetricus* and *P. lacunosa* clearly indicate MNN13 Zone (*Ceratolithus rugosus* Zone). The sand-size fraction is entirely biogenic, of pelagic facies (fig. 7.5). Planktonic foraminifers are abundant and include *Globorotalia margaritae* and *Globorotalia puncticulata*, whose concurrent range defines the MPl3 Zone of Cita (1975). The fauna is very well preserved, contains a few benthic species and ostracods and does not show any evidence of reworking or contamination. Chronostratigraphic synthesis: Nannofossil and foraminiferal biostratigraphic results are in very good agreement and identify the middle part of the Zanclean Stage (Lower Pliocene).

Lithology E_2.

The absence of *R. pseudoumbilicus* together with the presence of *D. asymmetricus*, *Discoaster tamalis* and rather large specimens of *P. lacunosa* clearly indicate MNN16a Zone (*D. tamalis* Zone). In addition, the absence of the *S. abies* gr. and the rather low abundance of small *Gephyrocapsa* allow us to exclude the lower part of this zone. Foraminiferal assemblages are rich, highly diversified and characterised by the co-occurrence of *Globorotalia puncticulata* and *Sphaeroidinellopsis* spp. in the absence of

G. margaritae. This indicates MPl4a Zone. A limited number of benthic bathyal species (*Eggerella bradyi, Eponides tumidulus, Siphonina reticulata*) was also observed. Chronostratigraphic synthesis: Nannofossil and foraminiferal analytical results are in good agreement and indicate the upper part of the Zanclean Stage.

Lithology E_3.

Calcareous nannofossils are abundant and rather well preserved. The abundance of small *Gephyrocapsa*, together with the presence of *P. lacunosa* (rather large specimens), *D. tamalis* and *D. asymmetricus* in the absence of the *S. abies* gr. would indicate the lower (not basal) part of MNN16a Zone (upper part of the Zanclean Stage). However, the common specimens of *R. pseudoumbilicus* would imply a position below its LAD, particularly at the very top of Zone MNN14/15 (Zanclean Stage), where small *Gephyrocapsa* may also be abundant. Concerning the latter attribution, the absence of the *S. abies* gr. would be somewhat enigmatic. The foraminiferal assemblage is very similar to that of lithology E_2 (see above) and is, therefore, indicative of MPl4a Zone. Chronostratigraphic synthesis: Comparing nannofossil and foraminiferal evidences, this lithology may be assigned to the lower part of nannofossil MNN16a Zone and to foraminiferal MPl4a Zone, with an age most probably (slightly) older than that of lithologies E_2 and E_3.

Lithology F.

Calcareous nannofossils are less abundant than in the previously described lithologies and preservation is moderate to poor (moderate etching). The presence of normal-sized *Gephyrocapsa* indicate a generic Pleistocene age for this sediment. Common discoasterids witness a rather strong Pliocene reworking. Of interest is the presence of abundant and large crystals of dolomite. The sand-size fraction is entirely silicoclastic and unfossiliferous (see fig. 7.6).

Discussion

The occurrence of highly disturbed lithologies in piston cores generally indicates the presence of a debris flow deposit or it can be the result of coring disturbance (flow-in). In core D206 07PC, however, there is strong evidence that none of these two processes is responsible for the formation of this sediment admixture.

Debris flow deposits occur when unstable material forming part of the slope in a basin moves downslope in response to the pull of gravity. These deposits typically show a number of clasts of various dimensions embedded in a supporting matrix. The presence of the two parallel and vertical strips of lithology E, having a length of up to 1.5 m, clearly excludes the possibility of this being a debris flow deposit.

The effect of coring disturbance (flow-in) in a core containing unconsolidated pelagic sediments is that of displacing the sediments upwards in the core, the pull being stronger in the axial part of the core barrel due to sediment-liner friction along its circumference. The resulting deposit appears to be stretched upwards in the axial part while the lateral portions seem to lag behind. The folded structures and the thin, vertical strips formed by lithology E can not be attributed to coring disturbance and therefore another process has to be responsible for their formation.

We propose that the sediment in this core has been injected upwards and that this sub-bottom phenomenon is related to the mud escape structures viewed in the SCAMPI profiles on the bottom of the Urania Basin pit. Expulsion of brine-charged muds has already been described from the Mediterranean Ridge (MEDINAUT and MEDINETH Shipboard Scientific Parties, 2000) and might be more common than previously thought. Finally, mud expulsion in Urania Basin was tentatively identified in a METEOR core as causative mechanism of the geochemistry of an exotic sediment layer (Hubner *et al.*, 2003).

The previously known Bannock and Tyro brine-filled Basins (both in the Eastern Mediterranean Sea) were formed when the Messinian Evaporites deposited during the «Messinian salinity crisis» were exhumed by tectonic processes (Scientific Staff of Cruise BAN-84, 1986; Camerlenghi and Cita, 1987; Camerlenghi and Mc Coy, 1990; Cita, 2006), enabling the seawater to dissolve the evaporites and create the basins (Camerlenghi, 1990; De Lange *et al.*, 1990).

The high bottom water temperatures measured in correspondence to the pit (45.3°C) of the Urania Basin (see fig. 3), associated with the exceptionally high heat flow (~ 200 mW/m^2 considering a thermal gradient of 190°C/km and assuming a thermal conductivity of 1 W/(m × K)) indicate that their source must lie at a depth of more than 500 m (MEDRIFF Consortium, 1995). A concave downwards chlorosity gradient in the porewaters of core 07PC (fig. 9) is in favour of the upward migration of fluids (MEDRIFF Consortium, 1995). Thus, a mechanism involving a tectonic connection to a deeper source must be active in the Urania Basin in order to explain the temperature and chlorosity data. We speculate that the tectonic connection lies within the deep pit of the basin and that upward injection of mud is associated with the upward migration of hot fluids.

Acquisition of SAR deep-towed side scan sonar and deep-towed seismic streamer in 1994 (Le Suroit, MEDRIFF program) alongside with multichannel seismic lines collected in 1994 (OGS Explora, IMERSE program), helps to understand the structure of this part of the Mediterranean Ridge. The Urania Basin is interpreted as an extensional feature controlled by near vertical, ENE-WSW trending normal faults, although it cannot be excluded that the Urania basin is a ring-shaped collapse feature. Furthermore, a number of small active faults cutting the Messinian Evaporites are hypothesized in correspondence to the pit. We propose these to be the locus of the upward migration of fluids and mud which gives rise to the high bottom water temperatures and to the sea floor mud expulsion features visible on the SCAMPI record (fig. 10).

In addition, the very accurate micropaleontological analysis suggests that lithology A may represent erupted sediment, emplaced during an older phase of mud expulsion, through which lithologies B to E were later injected. Three sediment sources having three distinct ages (from Pleistocene to Pliocene) have in fact been recognised within lithology A (see micropaleontology Section). The absence of any evidence indicating that this may be a resedimented lithology (no layering, no grading) supports the mud eruption hypothesis.

The great quantity of gypsum crystals in lithology A (see fig. 7.1) may also represent a clue to the understanding of its provenance. The upward migrating, hot brines have a certain amount of salts, including gypsum, in solution. When they reach the sea floor they can be involved in mud expulsion processes. Eventually, after the erupted sediment has

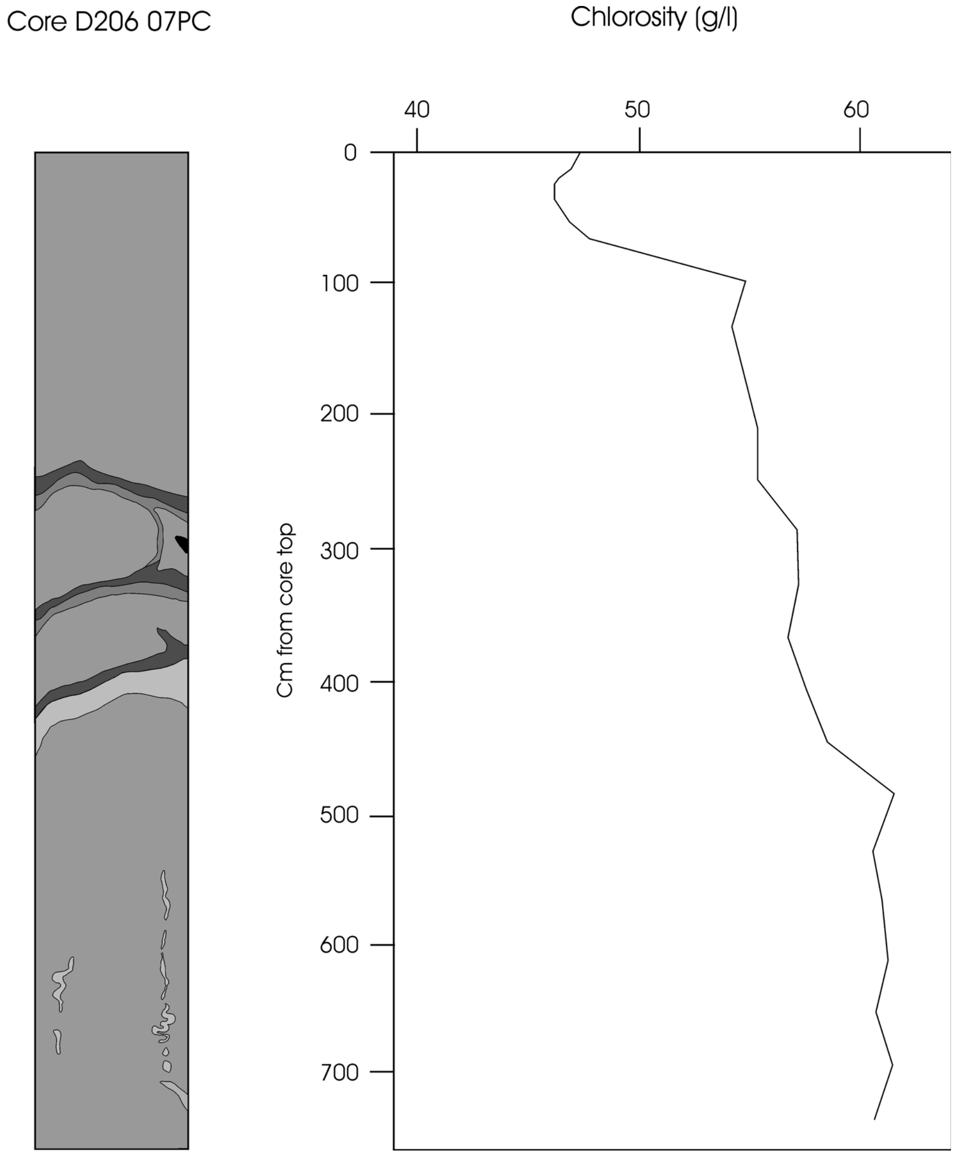

Fig. 9. – Chlorosity/depth relationship for the interstitial fluids contained in the sediments of the studied core. The inverse chlorosity gradient (1g/L/m) may be indicative of upward fluid migration.

settled on the sea floor, the brines involved in the mud expulsion processes will form its interstitial fluid. As the temperature in the sediment decreases with time the solubility of gypsum in water also decreases and its saturation point may be reached, inducing a mass precipitation of gypsum within the sediment. The direct solubility/temperature relationship for gypsum is true for temperatures of less than 50ºC (Sonnenfeld, 1984). Temperature oscillations in this range may occur with a certain frequency in the pit of the Urania Basin since during cruise D206 (Dec '93 - Jan '94) a temperature of 28ºC was recorded in the bottom water of the pit (MEDRIFF Consortium, 1995).

Moreover a wide diversity of prokaryotes was observed in these deep seated hypersaline anoxic brines (see papers published in Science, 2005 and Nature 2006).

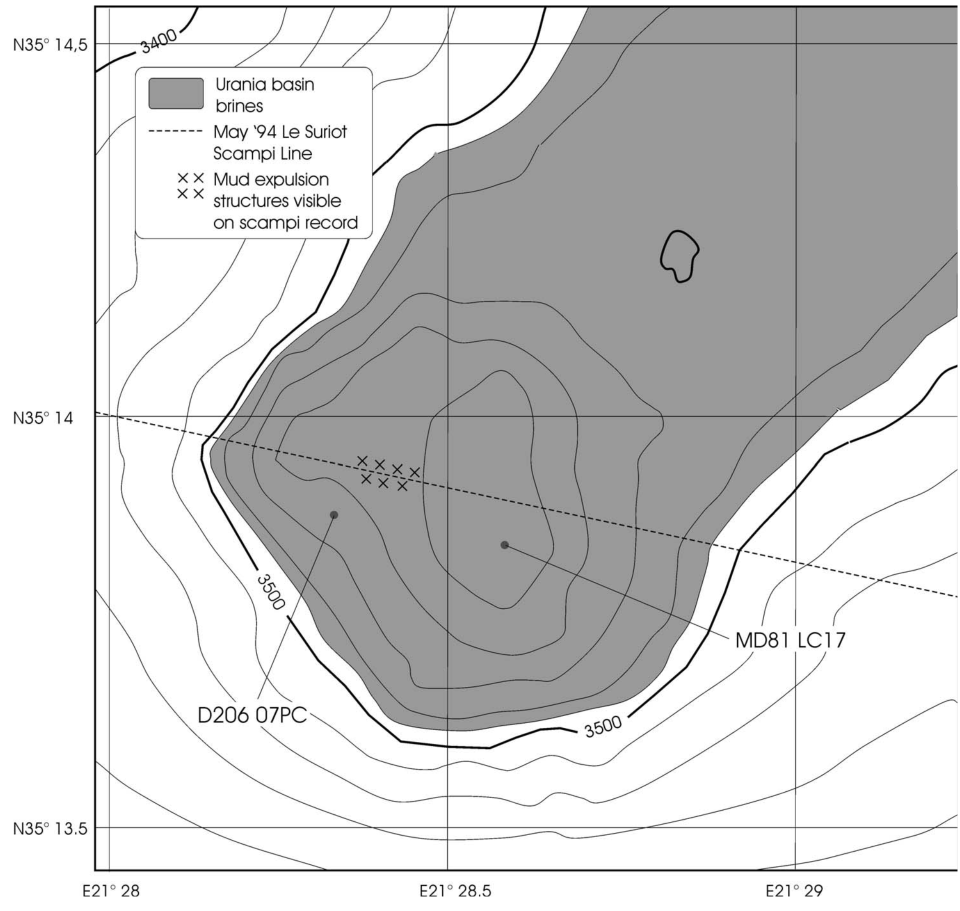

Fig. 10. – Detailed bathymetry of the western horn of the Urania brine lake. The shaded area indicates the interface separating the high density brines from normal sea water. The location of core D206 07PC and of a very long piston core MD81 LC17 investigated by Rimoldi (1995) is also shown. The latter is located in the central, deepest part of the pit and is completely different from the present one: no injection features are recorded, but a series of thin and thick turbidites with fining upwards sandy bases. The core also shows a very high sedimentation rate, very high methane content and very strong evidence of early diagenesis.

These studies demonstrate that these deep anoxic basins are not biogeochemical dead ends, but support in situ sulfate reduction, methanogenesis and heterotrophic activity (van der Wielen *et al.*, 2005; Daffonchio *et al.*, 2006).

Conclusions

The Urania brine-filled Basin shows physical and geological characteristics which set it aside from the previously studied anoxic basins of the Eastern Mediterranean. Anomalously high bottom water temperatures, very high heat flow and an inverse chlorosity gradient in the interstitial fluids of the bottom sediments are clearly indicative of upward fluid migration from considerable depths. The detailed study of a core coming from the pit of the basin showed that upward injection of sediments is associated to upward fluid migration. The sea floor expression of the mud injection is thought to be represented by the mud expulsion features viewed on the SCAMPI record. Movement along a fault plane is proposed for the upward migration of mud. This hypothesis is supported by detailed geophysical data collected by other research groups that locate near vertical faults intersecting the Messinian Evaporites in correspondence to the pit.

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