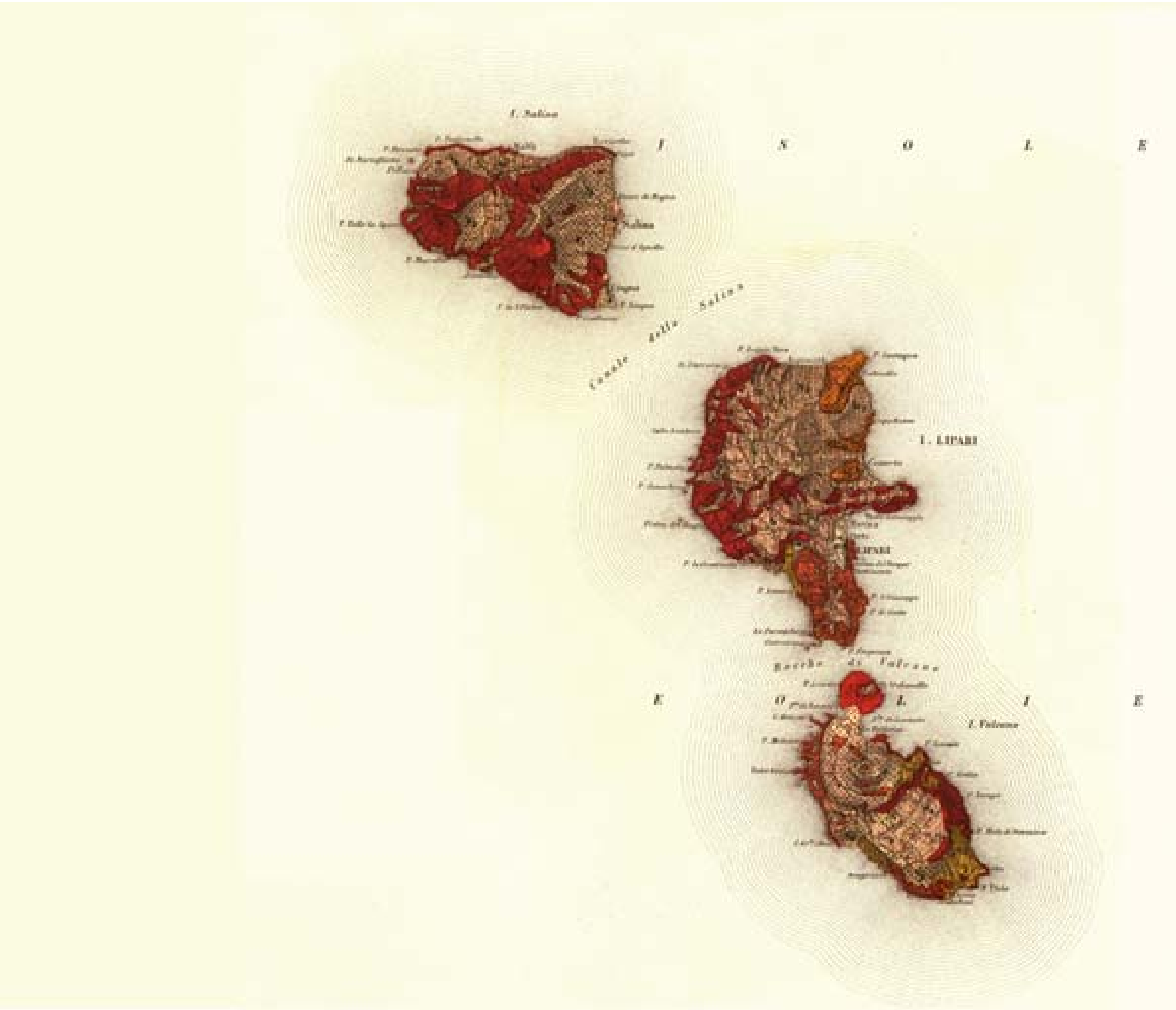
OTHER CONTRIBUTIONS



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Distortion in sdt shape as depicted in high-resolution profiles and the re-establishment of correct geometies (seismic migration)

CHIOCCI F.L.*

DESCRIPTION OF THE PHENOMENON.

The reflections generated by the single-channel seismic prospection can be seen as the response of the sea floor to a sound wave. Given that in these types of prospection the energizing source is very near to the receiving sensors, only the rays having normal incidence to the reflective surfaces are registered in the seismic sections and the arrival time is proportional to their depth, according to the waves speed in the media where they travel (water and sediment). Therefore, this type of survey gives a rather correct and detailed image of the sea floor (in function of the vertical and horizontal resolution of the prospection), especially in the case of horizontal or weakly inclined surfaces. On the contrary, in the case of complex geometries, the acoustic image undergoes a distortion because every single reflection is tought to came (and represented) directly below the seismic receivers, independently of the point in which the reflection actually originated. In the case of reflections coming from an inclined layer, this procedure creates an apparent slope with a less-than-actual dip.

The phenomenon increases with depth, with the speed of the medium where the wave travels and with the dip of the reflector.

Fig. 1 - *Geometric distortion of the seismic image of an inclined reflector. The real reflector* A-B *produces the seismic image* A'-B'*, with an underestimation of the actual depth increasing with depth and, therefore, with a reduction of the apparent dip.*

With digitally acquired exploration seismics data, the actual dip is re-established through the migration processing that, through complex algorithms, reports the reflections in their "correct" positions within the profile (YILMAZ, 1987). It is not, however, possible to correct the effects due to reflections caming from points that are external to the profile plan.

In the case of single-channel, high-resolution seismic profiles, such correction is not usually applied, because the data are usually acquired in analogic form, and because the reflectors of the very recent deposits are sub-horizontal enough and the depths investigated are not excessive.

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Nevertheless, the submerged depositional terraces have in some cases been depicted as having an apparent slope of the internal foresets and of the frontal slope up to 20°, suggesting that it is possible to have some distortion of the geometry of the reflectors.

This hypothesis is strengthened by the following circumstances: a) the base of the frontal slope is always connected in an extremely abrupt manner to the sea floor in front of it; b) sometimes it is possible to observe the intersection between the reflection of the lower part of the frontal slope and the reflection of the strata on which the SDT rests (for such an example, see the seismic profile of Fig. 2 or Fig. 30 of CHIOCCI & ROMAGNOLI, this volume); c) the reflections inside of the SDT, when they are not dipping too much, show a sigmoidal geometry with a tangential termination of the bottomsets on the basal surface. On the contrary, the external surface of the SDT often shows a convex form; d) as a result of the greater horizontal displacement of the reflections, the distortion of the seismic image is greater for the deeper terraces respect to the shallower ones, as it can be observed in the two terraces of Fig. 5 in CHIOCCI & ORLANDO (same volume).

MIGRATION OF THE DATA

In order to quantify the distortion of the external surface of the terrace, the migration is applied to a seismic profile choosing, for example, the submerged depositional terrace of Fig. 2. Given that the data were acquired in analog form, the external geometry of the terrace was manually resampled.

Then, the profile was replotted with the vertical axis expressed in depth, using the speed of 1500 m/s (the sound speed in water) for time/distance conversion. Vertical exaggeration was eliminated from the profile in such a way as to be able to apply the migration with the semi-circumference method (BADLEY, 1985). The result is the synthetic model reported in the figure below.

Fig. 2 - *Sismic profile on the eastern flank of Palmarola Isl.* (CHIOCCI & ORLANDO, *this volume*).

Fig. 3 - *Migration of the profile in fig. 4 of the article of* CHIOCCI & ORLANDO *(this volume). In the upper left the line drawing of the original seismic profile is reported for only the bathymetric surface, sedimentary substrate and some internal reflections. One can observe how the tail of the reflection of the frontal slope of the SDT intersects the sea floor. Below, the same profile is represented in depth sections (values in parentheses). The profile was represented without vertical exaggeration, which normally notably affects high-resolution seismic profiles.*

A semi-circumference was traced, centered on sea level at regular intervals (points in color) on the vertical of each point. Every semi-circumference represents the location of all possible points of origin of the wave received by the sensors. The enveloping of the semi-circumferences so traced represents the migrated bathymetric surface. There every point shows up as slanting rightward and upward along its own semi-circumference, with this effect increasing with the depth and with the slope of the reflection surface. At top center, the same procedure is reproduced on the profile affected by vertical exaggeration (in this case, the semi-circumferences look like semi-ellipses). At top right the migration procedure is reported.

One can observe: 1) an increase in the slope of the frontal slope (from around 20° to around 25°) and of internal reflectors; 2) the disappearance on the intersection between the foot of the slope and the sea floor in front of it; 3) the lack of reflection from the lowest part of the same slope that could therefore have had a tangential geometry (hypothesized in red in the blow-up); thus it can be very different from the apparent geometry in the seismic section; 4) a substantial lack of effect of the migration with respect to the nearly flat top of the terrace.

Fig. 4 - *Relationship between apparent and actual slopes in seismic profiles reported in depth sections and without vertical exaggeration.*

Making reference to the scheme in Fig. 1, one can observe that the LM segment represents a cathetus of the triangle A'LM but also the hypotenuse of ALM. Consequently, the sine of the actual angle (Qr) is equal to the tangent of the apparent angle (Qa).

One can observe how the difference between the actual slope and the apparent slope would be very low for slightly inclined reflectors and instead, would become very high for reflectors sloping some 10-20 degrees. Reflectors dipping more than 45° are not seismically depictable. The right half of the quadrant at the top right refers to reflectors sloping more than 90°, for which the reflection is obviously not detectable. The bottom left quadrant refers to reflections that originate above the water's surface.

It is important to observe how the migration procedure is thought to be effective only in the case of a seismic profile whose direction roughly coincides with the dip of the strata; in strike over sloping strata, the migration cannot work in that reflections originate from points outside the profile plan. Obviously, the migration has a slight effect for all the profiles between strike and dip direction.

CONSIDERATION ON THE EFFECTS OF THE GEOMETRIC DISTORTION ON THE INTERPRETATION OF THE SUBMERGED DEPOSITIONAL TERRACES

Even if in high-resolution seismic profiles the geometric distortion is usually very light, in the case of the SDTs one must consider that the seismic sections are "acoustic" images of the sea floor and sub-sea floor. Given that the SDTs are often characterized by slopes of up to more than 20°, the distortion can even be relevant. The knowledge of such phenomenon is important for the depositional interpretation based on the seismic features.

In general, it is possible to state that the abrupt contact often observed between the foot of the frontal slope and the sea floor in front of it is very likely to be an artifact; thus it is quite possible that the contact is far more gradual and even tangential. This fact is particularly relevant when comparing the SDT of relatively shallow depth with the deeper SDT (the distortions, in fact, lessen with diminishing depth).

For further information, see Fig. 5 of CHIOCCI & ORLANDO (this volume). Submerged depositional terraces with very sloping reflectors can even show an apparent acoustical transparency thta is not tied to the physical characteristics of the geological body but rather to the inability of the surveying methodology in detecting very inclined reflectors. The actual dip of the prograding foresets and of the frontal slope can also be slightly greater than those depicted (even 10-20%). This phenomenon, together with the fact that the seismic profiles don't always coincide exactly with the dip direction of the strata (either sea floor or the internal reflectors), must make one consider the slopes shown in the seismic profiles as underestimated with respect to the actual slopes.

This fact assumes a particular relevance when one wishes to compare the slopes with the mechanical characteristics of the sediment (for example, the angle of friction) in order to verify hypotheses on depositional mechanisms tied to gravitational flows. For this aspects, see caption of Fig. 30 of CHIOCCI & ROMAGNOLI (this volume).

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Coastal terraces in sub-aerial environment: state of the art

SPOSATO A.*

Since the beginning of the last century, several authors recorded Quaternary marine deposits uplifted with respect to the present sea level (DEPÈRET , 1906, 1918; ISSEL, 1914; GIGNOUX, 1911; ROVERETO, 1923, 1939). SELLI (1962) studied the relation between the Quaternary eustatic level variation and the vertical tectonic movements trying to understand the relation between the Quaternary marine deposits and the terraced morphologies. He pointed out the importance of relative stability, even if temporary, between sea level changes and tectonic movements. His hypothesis evidenced, for instance, a possible relative tectonic stability between a rising phase of the eustatic level and the tectonic uplifting of the area.

Studies about Quaternary climatic changes and the consequent eustatic variation (TOOLEY, 1993; SHACKLETON, 1987; MORNER, 1978; GORNITZ, 1993; AHARON& CHAPPELL, 1986; VESTAPPEN, 1980) evidenced that the latter generally show high rising rates. This fact makes possible a relative standing phase in moments approaching or corresponding to the reversal trend of the eustatic curve.

Chappell (1974, 1983) and other authors (BLOOM *et alii*, 1974; OTA, 1994) put the formation of terraces in direct relation to interglacial periods or, better, to the high standing phases of the eustatic level. They used the curve of climatic variations represented by $\delta^{18}O$ record (EMILIANI, 1955; SHAKLETON & OPDYKE, 1973) and radiocarbon age measurements on marine terraced deposits at Huon Peninsula (Papua New Guinea). In Fig. 1a the climatic curve of BASSINOT *et alii*, (1994) is shown.

Moreover, in 1986 CHAPPELL & SHACKLETON (Fig. 16) presented the first reference eustatic sea level curve for the Middle-Upper Quaternary reconstructing the elevation of the sea level high standings on the basis of the continuity of the uplift movement in the Huon peninsula.

Fig. 2 - Schematic diagrams representing the relations among the main factors concurring to eustatic sea-level variations.

The coastal geological evolution is connected:

- directly, with the relative variations of the sea level
- directly or indirectly, with the factors concurring to the rate of the sedimentary input along the coasts
- with the environmental parameters related to the continental, coastal and marine environments.

Marine terraces are the direct consequence of the coastal geologic evolution and of its periodical changes, particularly marked during Quaternary due to climatic fluctuations.

The morphological definition of marine coastal terrace can be borrowed from the one describing fluvial or lacustrine terraces: 'terraces are flat surfaces with slopes as boundary; fluvial terraces represent old surfaces of fluvial genesis and the slopes result from a subsequent cut…..in a terrace the

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remains of an alluvial plain or of a lateral erosion are preserved….;" (*"si dicono terrazzi, o terrazze, le superfici pianeggianti delimitate da scarpate; i T fluviali rappresentano vecchie superfici di origine fluviale e le scarpate risultano da successivo intaglio …....in un terrazzo si conserva un resto di piano alluvionale, oppure di un piano di erosione laterale...; La cronologia relativa delle forme terrestri si basa spesso sulla presunta successione cronologica dei sistemi di terrazzi posti a livelli diversi. Salvo casi particolari, i terrazzi più elevati sono considerati più antichi; i più bassi, come più recenti"*).

The relative chronology of continental morphologies is often based on the presumed chronological succession of the terraces system located at different elevations. Except for particular cases, the higher terraces are older, the lower ones younger. While the genesis of continental terraces is mainly linked to the rapid succession of Quaternary climatic phases, the genesis of the coastal marine terraces is directly connected with the variations of the eustatic sea level (CASTIGLIONI, 1979).

Fig. 3 - From a morphological point of view a terrace is defined by a gently sloping flat surface called terraced surface (a) and by a downstream convex slope called terrace edge or outer margin which divide the terraced surface from outer slope (c). Moreover the terrace may show a concave slope upstream that define its inner margin (d) and divide the terraced surface from the inner slope (e).

The terrace represents a remnant morphology related to a relative higher base level and the outer slope results from the following cut due to the fall of the base level.

Marine coastal terraces are morphologies extending with a longitudinal development parallel to the coast and are characterised by inner margins that, on the basis of morphological marks of ancient coastline (like corrosion notch, palaeocliffs etc.) are referable to relative high standing of the sea level.

Fig. 4 - A sedimentary terraced body (a) delimited by a basal surface (b) and by an upper surface (coincident with the terraced surface) (c) are "geologic" elements normally associated to the general morphology of the terrace. According to BOSI *et alii* (1990a) a necessary condition to define a marine terrace in absence of marine morphological indicators is at least one geological element indicating the coastal marine environment.

The sedimentary body of the terrace is cut toward the sea by an erosional surface cutting the upper surface and part of the terraced deposit (terraced slope) and it coincides with the outer slope.

The basal surface of the terraced deposit is an erosive surface, characterised by a direction subparallel to the present coastline and sloping toward the sea. Frequently this surface can represent, close to the upper edge, a marine abrasive form linked to the wave effects along the coast. Locally this surface shows linear incisions relative to drainage paleolines (d) eventually with associated deposits. Marine terrace deposits are mostly constituted by coastal marine sediments (a1) locally followed by coastal plain sediments, fluvial deposits, dunes and lagoonal deposits with important evidences of pedogenesis. A transgressive/regressive facies succession can be found, often incomplete.

The terraced sedimentary body is cut toward the sea by coastal and / or continental erosive morphologies following its formation; in the succession of terraces, such surfaces constitute the inner slope of the next terrace. Transversally to the coastline, the terrace can be interrupted by linear incisions related to the fluvial pattern.

Fig. 5 - Normally, marine terraces develop in succession sub-parallel to the coast. In these successions the upper terraces are the older and the younger ones are more and more lower, with a relation of reciprocal embedding. Fig. 5 shows a succession of terraces where t2, t3 and t5 are terraced sedimentary bodies (cs2, cs3 and cs5) with different reciprocal relations, while t1 and t4 are erosional terraces where sedimentary bodies are not present.

Marine terraces show variable shapes and dimensions. Erosional surfaces, infact, can show slopes deeping from some fractions of degree to some degrees. The upper surface, where it is conserved in its portions more far off the inner slope, shows low gradient, locally zero. Even the terraced surface show gradients varying from few degrees to vertical depending on the local environmental parameters.

The thickness of the terraced sedimentary body, where it is not eroded by the following transgressive or regressive phases and where it is preserved from the activity of the superficial pedogenetic factors, show increasing thickness toward the sea depending on the gradient of its basal surface; thickness varies from few cm of remnants of erosion to some tens of metres in the more conservative cases and where more sedimentary input took place.

Fig. 6 - The area along which coastal terraces are present is the coastal belt, where the sea level fluctuated during Quaternary with relative short standing. The interval of elevation is comprised between the eustatic maximum, occurred at elevation close to the present level (maximum elevation reached around 6 m during isotopic stage 5e) and the eustatic minimum at depth deeper than -100 m relative to the present sea level (minimum elevation reached at about -120m during stage 2). If the coastal belt involved by these fluctuations is located in areas characterised by Quaternary vertical mobility, its altimetric limits are defined by the same elevations of maximum and minimum eustatic level to which the altimetric variations induced by the tectonic velocity rate must be added.

In the lower part of a) the hypothetic terraced morphology can be observed, related to the eustatic curve of the last 350.000 years. In the upper part of a) it is shown the succession of terraced morphologies related to the same eustatic curve, deformed by the effect of a constant uplifting rate of 0,5 mm/y. As previously stated, it is evident that the main factor responsible for the formation of subaerial marine terraces is the curve of the variations of the local sea level resulting from the deformation of the glacio-eustatic curve with the interaction of the tectonic uplifting. In cases of strong tectonic activity, as illustrated in b), examples of Holocene coastal terraces exist. The formation of these terraces is linked to important discontinuous uplifting tectonic episodes (LAJOIE, 1986 mod) that, causing variations in the local eustatic curve (relative lowering of the eustatic level), create a succession of terraces where the embedding forms are linked to rapid uplifting. Since the present position of the sea level is close to the Quaternary high standing elevations, the occurrence of marine terraces esclusively happens in stable areas or characterised by tectonic uplifting during Quaternary.

Fig. 7 - Coastal erosion morphologies such as abrasion surfaces, corrosion notches are widely described; in a) a basic model of the evolution of a rocky cliff (SUNAMURA, 1992) is illustrated; in b) the characteristics of coastal erosion due to relative movements of the local eustatic curve (CINQUE *et alii*, 1995) are evidenced through the study of simulated models.

Fig. 8 - The geological conformation of a single terrace and of a succession of terraces is function of different parameters, variable in time. Beside the coastal physiography and the local marine parameters, the sedimentary input is very important. It can strongly influence the geological evolution until the extreme case of sedimentary regression during the rise of the eustatic level. In Fig. 8 coastal dynamic is schematically shown as a function of the eustatic variation and of the sedimentary input (CURRAY, 1964).

Conditions of prevailing depositional or erosive regression are differentiated from conditions of transgression by different colours.

Fig. 9 - Main steps in the formation of a generic marine terrace.

This reconstruction is based on several studies carried along the Northern coast of Latium where, due to the strong sedimentary input from the volcanic activity of the near Vico and Bolsena volcanic complexes, the depositional bodies are well developed (BOSI *et alii*, 1990b).

Moreover, the interaction between the terraced coastal body and the deposits of a paleo river-bed nearby the coast (MESSINA *et alii*, 1990) is shown. The curve illustrating the sea level variations is extremely simplified and represents a period of time related to the formation of all the elements of the terrace referred to the isotopic stage 7 (i.s.7).

Marine or coastal deposits are represented by yellow colour; continental deposits (alluvial and colluvial) are represented by green colour and the red surfaces indicate prevailing erosion.

9.1 - *fast eustatic fall (A of Fig. 8)/ climatic cooling*

Retreat of the sea due to eustatic lowering. Starting of subaerial evolution along a more or less steep slope and partial or total rielaboration in subaerial environment of forms or of deposits belonging to the previous cycle.

9.2 - *emersion/ cold climate*
The eustatic level falls and rises again (stage 8) attaining at elevations lower then those of the analysed terrace. The slope undergoes an evolution in subaerial environment with widespread areal erosion and deep incisions of the fluvial pattern. Local detritic or colluvial deposits develop. Locally soils formation occurs.

9.3 - *fast eustatic raising (B of Fig. 8)/ climatic improving.*
On the recently formed terrace the fast rising of the sea level causes time transgressive morphologies of coastal erosion and possible aggrading coastal deposits. The deepening of the coastal erosion due to the eustatic transgression velocity is reduced; the availability of space along the coast and inside the river-beds allows the deposition of sediments coming from inland.

9.4 - *slow eustatic raising (C of Fig. 8)/ climatic improving*
The deepening of the coastal erosion is possible, due to the slower raising rate of the eustatic level. In the meanwhile the abundant sedimentary input locally form thick depositional bodies passing from time-transgressive to time-regressive with the formation of a well developed coastal plain and local deposits of coastal swamp. The filling of the valleys are locally transgressed by marine deposits.

9.5 - *high eustatic standing (D of Fig. 8)/ climatic optimum*
The stability of the eustatic level (stage 7) locally causes the deepening of the coastal erosion or the depositional regression due to strong sedimentary inputs. The lacking in depositional space again causes fast sediment progradation with the formation of wide coastal plains and local coastal lagoons.

9.6 - *slow eustatic fall (E of Fig. 8)/ climatic deterioring*
The beginning of the sea-level fall causes forced regression with the abandonment of the emerged areas and the consequent evolution in sub-aerial environment with deepening of the fluvial pattern, pedogenesis and eolian dunes.

9.7 - *fast eustatic fall, emersion (stage 6), eustatic raising, high standing (stage 5)*
The new eustatic cycle reaches lower elevations due to the combination of the eustatic curve and the uplifting of the area, eroding most of the sedimentary body and forming the terraced surface. It leaves only the upper part of the former described cycle as outcropping remnants. (Some of the lower deposits can be locally preserved underground, at the base of the new basal surfaces of the deposit related to stage 5).
During this moment and the following period of time, the evolution of the terrace occurs only in sub-aerial environment with prevailing erosion both linear and areal and with soils formation.

9.8 - *It is important to remember that in the areas next to that described in the figure, marine terraces referred to the same eustatic cycle are represented by erosional terraces, because of different physiographic situations where the environmental parameters or the sedimentary input strongly vary. These terraces are esclusively represented by erosion forms often difficult to distinguish from each other. Locally, the outcrop of few dm of marine-coastal sediments allows the correlation with the geological evolution described.*
When the erosional activity of the following cycles prevails, both the form and the deposit of the marine terrace can be completely erased.

In conclusion a marine terrace represents, even not completely, a transgressive/regressive cycle of short period. Its formation is due to the characteristic variations of the Quaternary glacio-eustatic curve in particular if deformed by vertical tectonic movements. The preservation of a marine terrace is caused by the tectonic uplifting following its evolution. In the meanwhile, the uplifting causes its partial, often deep, erosion.

In the example illustrated in Figs. 9, 1-7, the terrace is well represented due to the abundance of sediments related to the activity of the volcanic complexes. Beside that, marine terraces are often incomplete or characterised esclusively by very thin deposits, since they are the result of a short period linked to intervals of warm climate in the climatic curve. In such periods the continental environment is characterised by biostasy, with a consequent low sedimentary input toward the coast characterised by a prevailing silico-clastic deposition.

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Pleistocene coastal prograding bodies outcropping in some uplifted basin fills of Southern Italy : field equivalent of submerged marine terraces ?

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Aim of this contribution is to illustrate the characteristics of some coastal prograding bodies which can be observed and studied in land outcrops, as part of recently uplifted sedimentary infills of some Plio-Pleistocene basins of Southern Italy. These bodies could represent the field equivalent of the submerged sea-marginal terraces which are the main subject of this atlas.

The prograding bodies of which some examples will be presented here, commonly appear vertically stacked within thick stratigraphic successions which originated in basins subject to high subsidence rate and commonly intense intrabasinal tectonics. As a result, a relatively continuous record was preserved, although punctuated by unconformities due to synsedimentary tectonics and high-amplitude glacio-eustatic fluctuations.

Shelf to nearshore depositional settings are usually very sensitive with respect to relative sea-level fluctuations. However, on one hand a chronostratigraphic interpretation of related deposits is often severely hindered by the scarcity and poor significance of age-constraining biostratigraphic data ; on the other hand, the identification of causative mechanisms may be complicated by the potential importance of autogenic processes linked to the intrinsic sedimentary dynamics of nearshore depositional systems. In this respect the analysis of the middle Pleistocene succession of S. Mauro Marchesato (Crotone basin, Fig. 1) has been surprisingly successful, since an integration of magnetostratigraphic data with biostratigraphic data obtained by the analysis of calcareous nannofossil assemblages allowed to recognize and document the succession of cycles in the interval from stage 33 to stage 19 and to prove their link with glacioeustatic fluctuations (Fig. 2; RIO *et alii*, 1996).

Fig. 1 - *Location of the study area.*

Fig. 2 - *(a) schematic stratigraphy of the succession of S.Mauro Basin, showing the correlations with the oxygen isotopic record (from* MASSARI *et alii, under submission). A and B: composite bodies (b) section of a prograding unit near Marcedusa (Crotone basin), with indication of the sedimentary structures and stratal geometries.*

As shown in Fig. 2a, the succession of S.Mauro Basin is of middle Pleistocene age and is characterized by marked cyclicity, expressed by an alternance of sandy prograding bodies, locally highly bioclastic, up to 45 m thick, forming the bulk of the sedimentary volume, and transgressive intervals.

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A slowing down of the subsidence rate in the upper part of the succession is documented by the increasing proximality and progradational stacking pattern of the cycles, which include increasingly important volumes of marine-marginal and nonmarine deposits, and are increasingly affected by unconformities and stratigraphic truncation.

Fig. 3 - *It is here depicted a section of the composite body A in Fig. 2(a); it is composed by minor units, two of which are divided by an unconformity surface covered by coarse-grained, fossiliferous deposits, interpreted as a ravinement surface (see the next figure for the description of the architecture of the composite bodies).*

The shoreface prograding bodies of the S. Mauro succession are simple or composite, the latter showing a polycyclic internal organization, being made up of a number of shingled, juxtaposed higher-order cycles. These composite bodies are particularly interesting, as they offer the opportunity of investigating the sedimentary response to two different scales of relative sea-level fluctuations. The shingled units are separated by sigmoid unconformity surfaces, which are erosional updip and become conformable downdip. These surfaces are draped by coarse shoreface blankets grading downdip into muddy offshore deposits and are interpreted as ravinement surfaces merging downdip into marine flooding surfaces. Therefore the surfaces and associated deposits document minor events of relative sea-level rise. At the resumption of the progradation, a thin package of sigmoid clinoforms first develops, marking a brief and short-way stage of "climbing progradation", then followed by a much thicker and farther prograding package of oblique clinoforms.

Two particularly prominent composite bodies occur in the lower part of S. Mauro succession (A and B in Fig. 2 a).

The older of them coincides with a drastic change from an essentially mud-dominated to sand-dominated sedimentation. The presence and local abundance of "cold guests" like Arctica islandica, the dominantly oblique pattern of clinoforms and local abundance of a residual fraction in the macrobenthic fauna, derived from cannibalization of former deposits, are all features indicating that the overall progradation took place as a result of a forced regression during a glacio-eustatic fall in sea level. Bio- and magnetostratigraphic age-constraining data allow an attribution of this body to the falling stage developing between stage 25 and stages 24-22. The sharp lithologic change is interpreted as the expression of the onset of the climatic crisis marking the beginning of the so-called glacial Pleistocene, characterized by high amplitude of sea-level oscillations.

The age of younger composite body is less constrained. Stratigraphic relationships suggest a correlation with the transition from stage 18.3 to stage 18.2. Although a precise chronostratigraphic framework is lacking, this body is regarded as genetically equivalent to the older one.

The internal composite architecture of the bodies is thought to reflect overall long-lasting sea-level falls punctuated by minor sea-level rises, an interpretation consistent with the typical sawtooth pattern of the falling limb of the middle Pleistocene sea-level fluctuations, as shown by the oxygen isotopic record, which is a proxy of sea level changes (Fig. 2 a).

The sedimentary structures and stratal geometries provide a lot of informations on the processes in play and characteristics of the depositional environment (Fig. 2 b).

Fig. 4 - *Stratigraphic sketch of the S. Mauro succession.*

Fig. 5 - *Detail of the S. Mauro succession, with ravinement surface represented by shoreface deposits resting on shelf pelitic sediments.*

Fig. 6 - *Dip angles of clinoforms range from a few degrees up to 10° in the case of sandy bodies and up to 16° in the case of highly bioclastic bodies wich are significantly coarser in grain size.*

Fig 7 - *Detail of the S. Mauro succession, with swaley cross-stratification.*

Informations of critical importance about the accretion mechanisms are provided by the topset beds, which are obviously preserved only at the top of sigmoid clinoform packages. The topset units most commonly show lower shoreface sedimentary structures, with ubiquitous swaley cross-stratification ; this facies locally grades upwards into a rarely preserved upper shoreface interval characterized by trough cross-bedding, planar lamination and wave megaripples, with palaeocurrents indicating both alongshore and downdip transport directions (see Fig. 2b). The facies association denotes a wave-dominated environment recording the activity of recurrent storm-driven flows. A mechanical reworking of the bioclastic debris above the wave base, prior to eventual deposition, is indicated by the common presence of broken to rounded bio-debris. Foreshore deposits have never been recognized at the top, probably due to erosion associated with ravinement surfaces.

DISCUSSION AND CONCLUSIONS

On the base of their main characteristics, the coastal prograding bodies studied in land outcrops in the S.Mauro basin could well represent, from a genetical point of view, the field equivalent of the submerged depositional terraces observed along wide coastal tracts along the Italian coasts and represented in this atlas.

The possible mechanism of progradation for some of them has been recently described in a careful way by CHIOCCI & ORLANDO (1996) and CHIOCCI & ROMAGNOLI (this volume), who assume a recurrent activity of storm-driven flows capable of putting in suspension and transporting offshore a large amount of sand within the topset platform, to redeposit it on the foreset slope of the prograding body by sediment gravity flows. The rhythmic growth of the front is clearly indicated by alternation of event beds and bioturbated intervals.

In the S. Mauro Basin the intrabasinal tectonics exerted an important control on stratal geometries, particularly influencing the dip angle of clinoforms, progradation directions, and location of gravity detachments and of cannibalization at the expense of previous deposits. All these features, as well as stratigraphic anomalies such as stratal attenuation, suppression or expansion, are particularly concentrated near the boundary faults and on the growth folds, where abnormal shelf gradients could be generated. However, at least for the lower part of S. Mauro succession for which bio- and magneto-stratigraphic age-constraining data are available, it has been demonstrated that the main control of cyclicity is of glacio-eustatic nature, and that the intrabasinal tectonics did not obscure the glacio-eustatic signature (RIO *et alii*, 1996).

Sand bodies with similar organization, commonly richly bioclastic, are relatively common in the Plio-Pleistocene successions of southern Italy. A well-known example is that of the Upper Pliocene succession of Capodarso in the Caltanissetta basin of Sicily (CATALANO *et alii,* 1992 ; VITALE, 1996 ; LIKORISH & BUTLER, 1996), characterized by a suite of bioclastic bodies recording, together with the interbedded mudstones, high-frequency fluctuations correlated with 40 ky tilt cycles within a lowstand of a third-order sequence. The internal organization of these bodies is wholly similar to that of the above described Pleistocene units of the Crotone area, with similar geometries and "reactivation surfaces", indicating minor relative sea-level fluctuations punctuating the building out of falling-stage prograding bodies.

Fig. 8 - *Detail of prograding bodies in the S. Mauro succession, cutted at thin top by ravinement surfaces*