Il Quaternario
Italian Journal of Quaternary Sciences
***15**(1), 2002, 121-130*

PEDOSTRATIGRAPHIC NOTES ON THE MIDDLE – LATE PLEISTOCENE OF CAPO SAN VITO PENINSULA (NW SICILY)

A. Cottignoli[1], G. Boschian[2], C. Di Maggio[1], F. Masini[1], D. Petruso[1]
[1]Dipartimento di Geologia e Geodesia, Università di Palermo, Corso Tukory, 131, I-90134
[2]Dipartimento di Scienze Archeologiche, Università di Pisa, Via Santa Maria, 53 I-56100 Pisa

This work is supported by grants MURST COFIN 1997, "Risposta dei processi geomorfologici alle variazioni ambientali" (Nat. Resp. A. Biancotti, Loc. Resp V. Agnesi) and by Athenaeum Grants of Palermo University (ex 60%) to F. Masini.

ABSTRACT
The available data about Quaternary pedostratigraphic of North-Western Sicily are mainly obtained when fossil vertebrate assemblages are studied. These are often found in caves or in other morphological "traps", where the products of the erosion of soils developed outside these features are redeposited.
Soils that may have originated these deposits were found on the marine terraces that are typical of the coast areas of Sicily.
Two sequences, called "K22" and "Isolidda", that crop out in the North-Western side of the San Vito lo Capo peninsula – to the West of Palermo - are examined in this work.
The first one is a karstic cave infilling, situated near the eastern rim of the old falaise that borders the Piana di Sopra plateau. Two phases were identified in this site. a) transitional environment deposits, with terrigenous input due to the occurrence of Alfisols and/or Ultisols in the neighbouring area. b) continental deposits, mainly made up of reworked terra rossa, that point to fluctuations of the erosive regime. The aeolian input can be observed throughout the sequence and is apparently stronger in the uppermost levels. This deposition ends at the end of the Pleistocene.
The second one is a thick sedimentary body that occupies a tectonic depression, near Torre Isolidda. This sequence is made up of alternating colluvia, éboulis ordonnés and palaeosols dating back to the Late Pleistocene.
The aim of this study is to ascertain which environmental condition affected the deposition of the lithological units of these two sequences and to correlate them to the climatic phases of the Middle-Late Pleistocene.
The study of the macroscopic characteristics of the sequences has been carried out in detail with the help of soil micromorphological observations.

RIASSUNTO
Le conoscenze pedostratigrafiche relative al Quaternario della Sicilia nord-occidentale sono legate essenzialmente allo studio delle associazioni fossili a vertebrati che sovente si rinvengono in grotte o in altre "trappole" morfologiche, all'interno delle quali sono stati trasportati e rideposti i prodotti dell'erosione dei suoli che si sviluppavano all'esterno.
Suoli che potrebbero aver dato origine a questi depositi sono stati segnalati sulle successioni di terrazzi marini che caratterizzano il settore costiero dell'isola.
In questo lavoro si esaminano due successioni, denominate K22 e Sezione 5 Isolidda, affioranti nel settore NO della penisola di San Vito lo Capo, ad ovest di Palermo.
La prima è costituita dal riempimento di un cavità carsica ubicata in prossimità del margine orientale della paleofalesia che borda il pianoro di Piana di Sopra; ivi sono state identificate due fasi: a) depositi di ambiente di transizione, con apporti terrigeni dovuti alla presenza di Alfisuoli/Ultisuoli nelle aree emerse circostanti. b) depositi continentali, costituiti prevalentemente da terre rosse risedimentate che indicano pulsazioni del regime erosivo; l'input eolico, presente in tutta questa fase, diviene più cospicuo nei livelli superiori. Questa sedimentazione si conclude con la fine del Pleistocene
La seconda è un potente corpo sedimentario alloggiato in una depressione di origine tettonica, in località Torre Isolidda. Qui si osserva una successione costituita da alternanze di depositi di colluvio, éboulis ordonnés e paleosuoli ascrivibile al Pleistocene superiore.
Lo scopo di questo lavoro è di individuare le condizioni ambientali che hanno presieduto alla formazione degli orizzonti delle due serie stratigrafiche e di mettere in relazione questi ultimi alle fasi climatiche del Pleistocene medio-superiore.
A tal fine lo studio delle caratteristiche macroscopiche e la ricostruzione di dettaglio delle serie è stata integrata con i dati derivanti dall'analisi micromorfologica in sezione sottile.

Parole chiave: Pedostratigrafia, Quaternario, Aree costiere
Key words: Pedostratigraphy, Quaternary, Coastal areas

1. INTRODUCTION

Several sedimentary sequences containing soils, palaeosols and their relicts were preserved in the Capo San Vito Peninsula, mainly in its Western sector, because of the relative tectonic stability of this area.

These sequences are mainly preserved within caves or in other morphological traps; they were shortly described by Di Maggio *et al.* (1999) in a previous work concerning the seven orders of marine terraces of the peninsula, and the fossil vertebrate assemblages which are frequently found within these sequences. (Fig. 1)

The aim of this note is to give further insight in the reconstruction of the Middle–Late Pleistocene environmental conditions by a pedostratigraphic approach, highlighting the role of the climatic fluctuations in the change of the sedimentary and soil-forming processes. Special emphasis is given to two of the outcropping sequences, which are reasonably thick and can be dated by their faunal content and/or through geomorphological evidences that can be correlated to the sequence of the marine eustatic fluctuations and to the oxygen stable isotope climatostratigraphy. (Fig. 1).

The lower part of the sequence testifies to a phase of deposition in transitional and shallow sea environment. This phase was correlated to some high stand of the isotopic stages 15-13, that in some places abraded the 2nd order terrace (Di Maggio *et al*. 1999).

The upper part was deposited in continental environment and the lithological units embed vertebrate remains that can be ascribed to two different faunal assemblages. The lower ones yielded a fauna that can be referred to the *Elephas mnaidriensis* Faunal Complex of Sicily, of late Middle Pleistocene to early Late Pleistocene age (8(?)/6 – 5a isotopic stages). The upper ones embed an assemblage documenting a younger dispersal phase of mammals from the Italian peninsula (Pianetti – Castello Faunal Complex of Sicily). This assemblage is dominated by the *savii* ground vole, a species with steppe - mediterranean affinities, that, in this context, testifies to a dry climate phase of the last glacial cycle (isotopic stage 4). The sedimentary sequence is closed by an anthropised level containing late Mesolithic to early Neolithic cultural remains (Tusa personal communication), which can be referred to the Pleistocene–Holocene transition.

The lithological units (*sensu* Orombelli, 1971) of the sequences are described according to the guidelines of Sanesi (1977) and Catt (1990), while the descriptive criteria adopted for the soil micromorphological features follow the standard proposed by Bullock *et al.* (1985). The c/f limit is set to 10 mm in the soil micromorphological descriptions.

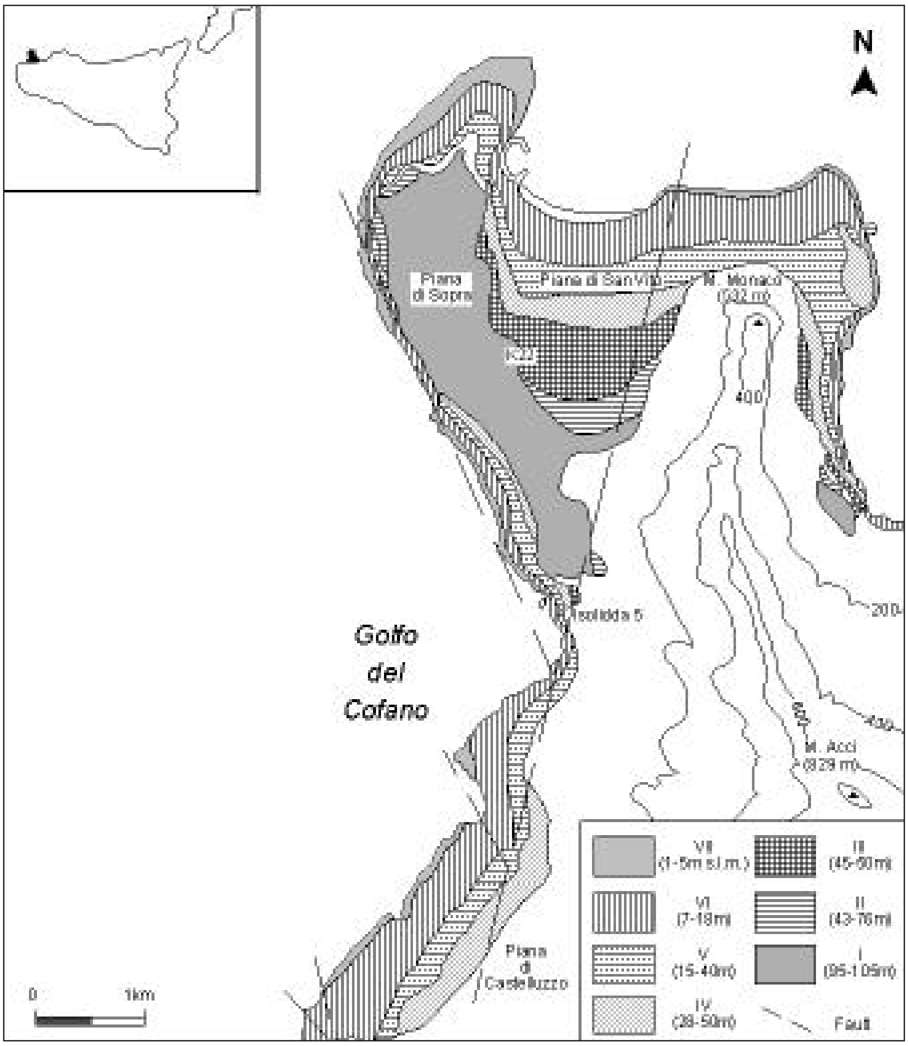

Fig. 1 - Capo San Vito Peninsula: location of the sites and distribution of the marine terraces. The heights of the terrace edges are reported in the legend.

Penisola di San Vito lo Capo: ubicazione dei siti e distribuzione dei terrazzi marini. Le altezze del margine interno dei terrazzi di vario ordine è riportata in legenda.

2. THE "K22" SEQUENCE

This 9 m thick sequence infills a karst cavity located on the eastern edge of an ancient wave – cut cliff contouring the wide abrasion surface of the 1st order terrace, called Piana di Sopra (Fig. 2).

A large part of the cavity, of its entrance and of its infilling, were destroyed by a quarry whose cut advanced parallel to the cliff, so that the original shape of the cave cannot be observed. Apparently, the original entrance of the cavity was situated on the top of the abrasion surface, very close to where the edge of the terrace is now. However, the present-day morphology of the cliff and the occurrence of lithodomous borings and marine deposits in the bottom of the cavity show that a large side aperture was opened when part of the cave was destroyed by the progressing wave-cut cliff.

2.1. Geometry of the sedimentary bodies.

The shape of the lithological units in the K22 succession is controlled by two main factors: a) the shape of the karstic dissolution cavity where the sediments were deposited and b) the strong erosion activity which took place throughout the depositional history of the site.

The lower units are sub-horizontal layers probably separated by paraconformities, that fill up the funnel – like bottom of the cave. The units of the upper half of the sequence (from the top of the '*Upper Conglomerate*' upwards) are limited by erosion surfaces apparently dipping towards the South; these erosion surfaces are often channel-shaped and sometimes marked by stone-lines. Therefore, these units are sometimes shaped as channels whose axes plunge from the overlying abrasion surface to the bottom of the cavity.

2.2. Profile description

The sequence is made up of the following units, from the bottom upwards.

a. '*Base*' unit.

Coarse rounded calcareous sandstone with some fine gravel (5-20 mm) and common remains of marine molluscs.

Few pinkish to light orange clayey matrix; strongly cemented.

Thickness 0 to 20-40 cm depending on the shape of the underlying limestone surface.

This units lies on the karstified limestone of the bottom of the cave and fills up part of the fractures.

b. '*Lower Conglomerate*' unit.

Polygenic conglomerate, with fine gravel to cobble-size subrounded elements with some rounded and subangular ones; unsorted; skeleton-supported structure. The conglomerate elements, mainly the less rounded ones, show sponge (*Clionia*) borings.

Light pinkish matrix, made up of few angular or subangular quartz elements and very few subrounded flint; common dark reddish clayey aggregates, silt- to medium sand-sized, impregnated of iron oxides; the skeleton of these aggregates is few, made up of coarse silt to very fine sand with quartz, few chert and sparse muscovite flakelets. Fine micritic cement, with common larger euedral crystals. A second phase of cementation, deposed coarse subedral sparite crystals within the largest pores.

Thickness 0-35 cm; sharp, subhorizontal, slightly undulating limit.

This unit lies within the funnel-like bottom of the cave and is shaped like a subhorizontal layer whose sides are limited by a roughly conical surface.

Common marine molluscs (*Spondylus, Jujubinus*) and few fish bone fragments

c. '*Pinkish Sandstone*' unit.

Light pinkish grainstone, strongly cemented, with common centimetre-size pores; few skeleton, made up of subrounded to subangular pebbles (maximum diameter 5 cm).

Most of the grains are apparently more or less fragmented bioclasts, possibly vegetal remains in which faint traces of cellular features can still be observed. Very few angular very fine silt-sized quartz elements. Common subrounded to rounded clayey aggregates, without skeleton, impregnated by amorphous Fe-oxides; their size varies from very fine to fine sand. Medium sorting.

Fine sandy matrix, made up of micrite elements.

Sparitic cement, made up of small size anhedral elements.

Thickness 15-20 cm; sharp, subhorizontal and slightly undulating limit. The unit is lens-shaped, convex downwards.

Common darker or lighter layer-like bands, caused by enrichments or depletions of iron oxides originated by movements of the water table.

Few fish bone fragments. (Fig. 6 e).

d. '*Upper Conglomerate*' unit.

Polygenic conglomerate (biomicrites, biosparites, micrites and "*scaglia*"), with fine gravel to boulder-size elements (0.2 to 70-80 cm), fining upwards, skeleton-supported structure, common simple packing voids. Strongly cemented. The elements are mainly prolate or oblate, subrounded, and their major axes usually lie horizontally, sometimes imbricated.

Very few matrix, made up of sparse very fine sand-size quartz elements and clayey aggregates as in c). These aggregates are common at the bottom and at

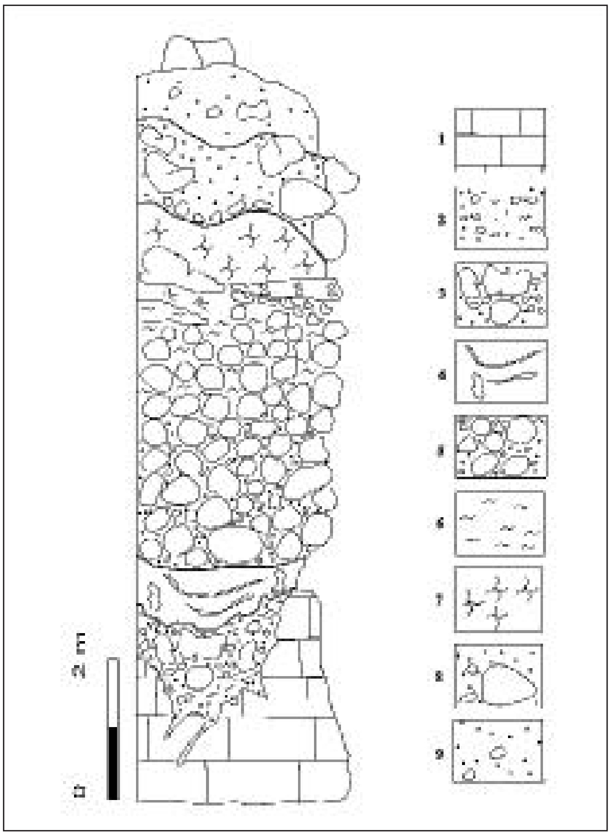

Fig. 2 - Stratigraphic profile of the K22 sequence. 1: Mesozoic coralgal limestone; 2: Base unit; 3: Lower Conglomerate unit; 4: Pinkish Sandstone unit, 5: Upper Conglomerate unit; 6: Orange unit; 7: Red unit and petrocalcic horizon; 8: Blocks unit; 9: Brown unit.

Colonna stratigrafica della successione K22. 1: Calcari coralgali mesozoici; 2: Unità Base; 3: Unità Conglomerato Inferiore; 4: Unità Arenaria Rosata; 5: Unità Conglomerato Superiore; 6: Unità Arancio; 7: Unità Rosso e livello petrocalcico, 8: Unità Blocchi; 9: Unità Bruno.

the top of the layer and give it a pinkish colour.

Cement made up of micrite, finely layered in the pores, sometimes alternating with Fe-oxides; a second phase of cementation deposed coarse subhedral sparite coatings within some pores.

Thickness 2-2.5 m; abrupt, subhorizontal, flat limit, gently dipping towards the centre of the cave.

This unit covers the underlying unit c) and partly lies on the limestone bedrock of the Northern side of the cave. Its thickness increases towards the South, as the limit dips towards this direction.

Common remains of small size *Hippopothamus* cf. *pentlandi*.

e. '*Orange*' unit.

Reddish (2.5YR 4/6 red) silty loam to silty clay loam; well developed fine granular structure, slightly cemented. Few skeleton, made up of sparse subrounded (dissolution) gravel-size elements (maximum diameter 3 cm).

The sand-size fraction is made up of angular to subrounded quartz (very fine to fine sand), subrounded chert (slightly coarser) few muscovite flakelets (silt), angular to subangular fragments of biomicrites ad sparites (medium sand to fine gravel).

Common clayey aggregates (pedorelicts, *sensu* Brewer, 1964) subrounded to rounded (fine to medium sand) stained by Fe-oxides, usually without skeleton, sometimes with evident traces of very fine convolute layering, low birefringence strial b-fabric. (Fig. 6 f). Another group of aggregates contain less clay and Fe-oxides and embed some fine skeleton with the same characteristics of that of the matrix.

Few clay coatings with iron oxides, some carbonate concretions. Stipple speckled and granostriated b-fabric.

Thickness 25-35 cm; sharp, flat limit, gently dipping towards the centre of the cave.

This lens-shaped unit may be the eroded remain of a layer partly interfingered with the upper part of d); nevertheless, it can be observed only in a small area at the centre of the excavation profile, so that its stratigraphic position is not perfectly defined.

Common pulmonate molluscs, vertebrates and small mammals (*Crocidura* aff. *esuae*, *Leithia* ex gr. *melitensis*, *Maltamys* aff. *wiedincitensis*).

f. '*Red*' unit.

Red clay loam to silty clay loam, colour 2.5YR 4/6 red to 2.5YR 3/4 dark reddish brown, well developed medium polyhedric (prismatic in the upper part) structure. Few subrounded (dissolution) skeleton.

The sandy fraction is fine to very fine, mainly made up of angular to subrounded quartz (very fine to fine sand), common chert (slightly coarser), common muscovite laminae, few feldspar (some plagioclases, one sanidine), pyroxenes and some fragment of microcrystalline lava.

Few pedorelicts, slightly different from the matrix, but somewhat richer in clay and Fe-oxides; rounded, fine to coarse sand-sized. Common carbonate nodular concretions, nodules of iron and manganese oxides. Few "dusty" clay coatings. Striated, granostriated and stipple speckled b-fabric. (Fig. 6 g - h).

Thickness 50-110 cm; clear, flat limit, shaped as a large and deep depression, possibly an erosion channel. As a consequence of this erosion surface, the horizon lies upon units d) and e).

In the Western part of the excavation profile, a strongly cemented, 30-40 cm thick lens-shaped sublevel can be observed; it partly overlies a stone line of angular elements that marks the base of the "*Red*" unit and embeds a large block, probably a cave ceiling or wall breakdown. The cementation is due to large anhedral sparite crystals, often organised in dendritic structures, rather dusty for Fe-oxides impurities.

Common remains of continental gastropods, amphibians, reptiles, birds, large and small mammals. The mammal assemblage belongs the *Elephas mnaidriensis* Faunal Complex of Sicily and includes the following taxa: *Crocidura* aff. *esuae*, Leithia ex gr. *melitensis*, *Maltamys* aff. *wiedincitensis*, *Hippopotamus* cf. *pentlandi* and *Sus* sp.

g. '*Blocks*' Unit.

Reddish silty loam, colour 2.5YR 4/6 red, medium developed polyhedric aggregation. Common limestone skeleton, poorly sorted to unsorted (elements from 1 to 60-70 cm), made up of angular, prolate to oblate elements whose surfaces are altered by dissolution. Skeleton supported or sometimes matrix supported structure.

The sandy fraction is made up of angular to subangular quartz (very fine to fine sand with frequent rounded coarse sand elements); common muscovite flakelets, few feldspar and sparse pyroxene. Common fragments of flint and of cherty rocks (scaglia), subangular to subrounded (medium to coarse sand); frequent slabs of sparitic limestone (very coarse sand to very fine gravel).

Common clayey pedorelicts, with very few fine skeleton, impregnated by Fe-oxides. Very common nodular concretions made up of sparite crystals, of various size. Clayey groundmass, with very low birefringence; stipple speckled to granostriated b-fabric.

Thickness 40-60 cm; abrupt limit, marked by a stone-line, gently dipping towards the East and shaped as a large and shallow erosion channel.

Common remains of pulmonate gastropods and of micromammals. The small mammal assemblage, dominated by the vole *Microtus* (*Terricola*) ex gr. *savii*, also includes *Apodemus* cf. *sylvaticus* and *Crocidura* cf. *sicula*, while *Sus scrofa* e *Cervus elaphus* cf. *siciliae* occur among large mammals. This faunal assemblage can be referred to the Pianetti–Castello Faunal Complex.

h. '*Brown'* unit.

Silty loam to sandy silt loam, colour 5YR 3/3 dark reddish brown, massive, rather loose. Few limestone skeleton, unsorted (elements up to 50-60 cm), slightly altered by dissolution and chaotically dispersed.

Sandy fraction mainly made up of angular to subrounded quartz (very fine to medium sand), with some larger rounded elements; common fine muscovite flakelets, frequent feldspar and sparse pyroxene. Common fragments of flint and cherty rocks (*scaglia*), subangular to subrounded (medium to coarse sand); few limestone slabs, sparse, very fine, rounded lava fragments.

Few clayey pedorelicts, embodying very few skeleton, impregnated by Fe-oxides; common sparite concretions of various size; very common fine fragments and flakes of amorphous organic matter, at various degrees of decay. Clayey groundmass, with low birefringence and stipple-speckled b-fabric.

Thickness 20-50 cm; clear, wavy limit, shaped as a shallow erosion channel.

Common more or less fragmented bone, charcoal, marine molluscs (*Patella*, *Trochus*) flint artefacts; remains of microvertebrates, (*Microtus* (*Terricola*) ex gr. *savii*, *Crocidura* cf. *sicula*) and macrovertebrates (*Sus scrofa*, *Vulpes vulpes* e *Cervus elaphus*). Skeletal remains of *Homo sapiens*. The typology of the lithic assemblage and the occurrence of obsidian artefacts show that these cultural remains can be ascribed to the Late Mesolithic-Early Neolithic (Pleistocene-Holocene boundary).

2.3. Discussion

The lowermost levels of the sequence, up to the top of the '*Pinkish Sandstone*' unit, were deposited in peculiar environmental niches connected to near-shore or reef environments, like pools at the base of the reef or conglomerate deposition areas on abrasion surfaces. A more or less substantial input of terrigenous sediments coming from the neighbouring emerged areas characterises these deposits of transitional environment.

The units '*Base*' and '*Lower Conglomerate*' testify to high energy depositional events in shallow sea environment (intertidal or submerged beach), as shown also by borings of Clyonid sponges occurring on pebbles of the '*Lower Conglomerate*'. Conversely, the sandy Unit '*Pinkish Sandstone*' represents a very low energy environment, where almost only biogenic clasts, possibly fragments of algae or marine vascular plants, were deposited. It is likely that this rather homogeneous sediment was originated by *in situ* growth and decay of biogenic concretions, while middle or low energy transport processes were very rare.

Some weak input of sediments from the emerged land into these near-shore sediments is suggested by the occurrence of pedorelicts probably originated from the colluvium of soils developed on the abrasion surface overlying the cave. As these pedorelicts are mainly made up of clay and iron oxides, it may be inferred that they came from medium to long evolution red soils (Alfisols or Ultisols), that develop in temperate to warm–temperate climates and that are present in the Capo S. Vito area.

The origin of Unit '*Upper Conglomerate*' is strongly questionable (Di Maggio *et al*., 1999). The large size of the cobbles and the low matrix content point to a high energy environment; conversely, the fossil remains of *Hippopotamus* cf. *pentlandi* found in this unit are rather well preserved, and suggest therefore a low energy depositional environment, or at least a short range transport. River deposition may possibly explain the removal of the fine grained matrix by low energy flow; however, this hypothesis looks rather unlikely because no hydrographic basins or river sediments were found in the surrounding area.

The general features of the deposit may also indicate a marine origin. The '*Upper Conglomerate*' could be considered as a beach or a storm deposit, implying that the shoreline was rather close to the site. The terrigenous fine-grained fraction and the pedorelicts would have infiltrated into the pores of the conglomerate after the deposition of the coarse fraction. In this case the conglomerate, with its mammal fossil content, would date back to one of the high stand phases related to the isotopic stages 15-11, according to Di Maggio *et al* (1999). However, this range of ages is in contrast with several data concerning the presence of the hippo in the Sicilian island, which is usually dated to the late Middle Pleistocene to Late Pleistocene (isotopic stages 8 or 6 ?).

Finally, an alternative explanation in accordance with all the available data, and based on the parsimony principle, would consider the '*Upper Conglomerate*' as derived from a pre-existing conglomerate, dismantled by gravitational processes and runoff water, which would also have caused the transport of the vertebrate remains into the cavity.

The upper part of the sequence, from the unit '*Orange*' upwards, was deposited in continental environment. The characteristics of the deposits follow the polycyclic nature of the "*terra rossa*" and result from the erosion of the soils and the accumulation of the products of their reworking into the cavity. The occurrence of pedorelicts in all these levels is sound evidence of erosion and transport (Cremaschi, 1990b; Boschian, 1998), and their concentration may be regarded as a rough estimate of the intensity of the reworking processes. The greater amount of pedorelicts in unit '*Orange*' documents a period when erosion was stronger than in the other phases.

Apparently, the pedorelicts found in the upper units are not so rich in clay and iron oxides as those in the underlying ones, and also embody some fine skeleton. It is likely that the older ones belonged to more evolved soils, while less developed soils overlied Piana di Sopra during the younger phase of the site formation process. As a consequence, it may be inferred that strong erosion processes had removed most of the soil cover of the area in some moment between isotopic stages 15-11 and 8-6. Nevertheless, the occurrence of several gaps in the sequence suggests caution in inferring this diachronic and evolutionary hypothesis.

Summing up, the evolution of the climate towards 'continental' conditions may have started some deforestation and the triggering of erosive processes that caused the accumulation of unit '*Orange*'. Unit '*Red*' may be related to a phase of weaker erosive processes, with climate not so strongly continental as before.

The occurrence of muscovite flakes all over the sequence shows that the aeolian input, still important nowadays, played always a consistent role in the formation of the "*terra rossa*" deposits.

However, it must be pointed out that the palaeoclimatic meaning of this aeolian input is certainly different from that postulated for the northern regions of the Italian peninsula (Cremaschi, 1990a), even if it points towards somewhat aridic conditions. Nevertheless, the occurrence of rounded coarse quartz grains within the upper units '*Blocks*' and '*Brown*' may testify to an increase of the aeolian transport, which probably corresponded to dune formation in the neighbours of the site and might suggest a shift of the climate towards dry conditions. Eventually, the '*Brown*' anthropic level is characterised by a high content in fine amorphous organic matter consequent to human presence.

3. THE "ISOLIDDA" SEQUENCE

This sequence (Fig. 3) is located in the northernmost part of a widely extended set of deposits that occupy a morphostructural depression shaped in "Scaglia"–like marly limestone of Upper Cretaceous to Eocene age. It is limited to the North by the Southern side of the calcareous plateau of Piana di Sopra, and to the South (at Seno del Bue Marino) by a morphological high originated by the denudation of a limestone olistolith embedded in the *Scaglia*.

The profile studied here is about 50m long and 11m high, with its bottom at the height of the present-day sea-level.

The base of the sequence is made up of Late Pleistocene shallow sea and intertidal deposits (Di Maggio *et al*., 1999), and lies on a marine abrasion surface located at 0.5-1m a. s. l., that partially cuts the Eutyrrhenian terrace (VI order); this terrace is here 3-5m a. s. l. high, and is covered by sediments containing a warm, "Senegal–like" marine invertebrate fauna including *Patella ferruginea* and *Strombus bubonius* (at Seno del Bue Marino; Ruggieri *et al*. 1968; Mauz *et al*., 1997) (Fig. 4, 5).

As a consequence, the formation of the Isolidda abrasion surface is younger than the Eutyrrhenian, and can be reasonably referred to high stands related to the isotopic substages 5c or 5a ("neotyrrhenian").

Six subhorizontal or slightly dipping units can be observed within the continental part of the sequence, and are hereafter described from the bottom upwards.

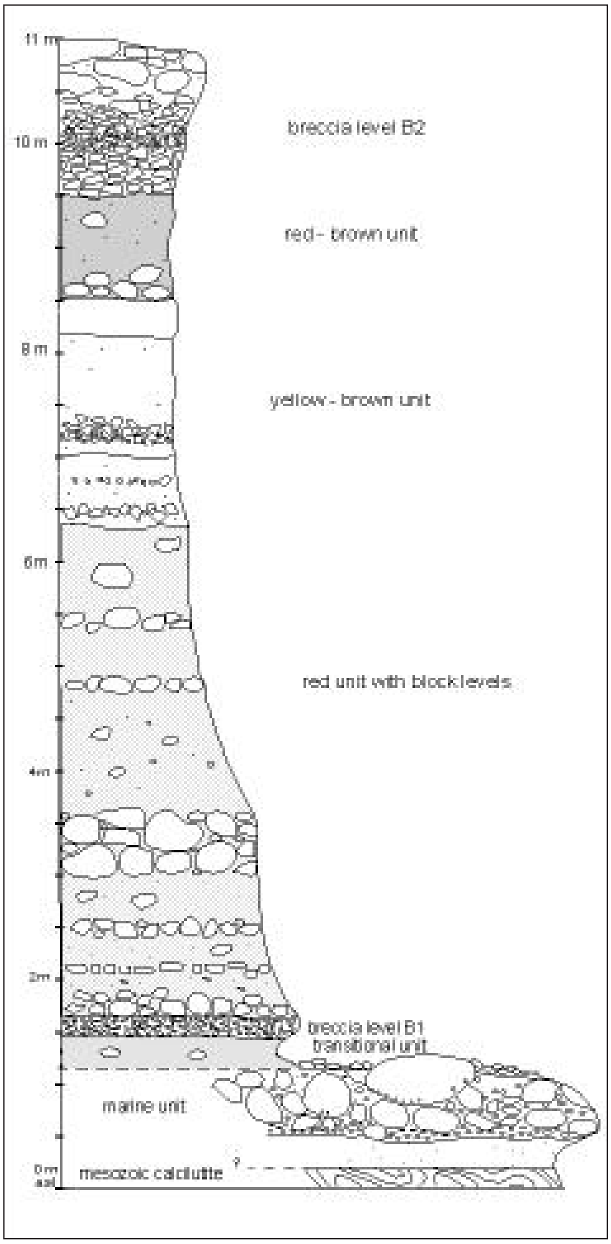

Fig. 3 - Schematic section of the Isolidda sequence.

Sezione schematica della successione Isolidda.

3.1. Profile description

a. '*Marine'* unit

It is made up of two sub-units. 1) biocalcarenite with some reddish sandy loam matrix. 2) conglomerate made up of coarse limestone and marly limestone blocks with lithodomous borings and cemented sandy matrix (sandstone) with pebbles; the pebbles are rather common in the lower part of this subunit and form a thin level at the very bottom.

Thickness about 1.3 m, sharp limit situated at about 0 m a. s. l.

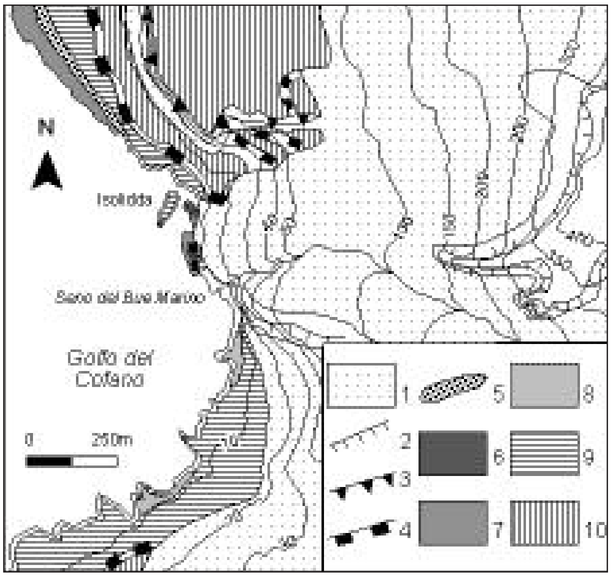

Fig. 4 - Geomorphological map of the Isolidda Area. 1: Slope deposits; 2: weathered and eroded scarp; 3: Inactive marine cliff (height > 10 m); 4: Inactive marine cliff (height < 5 m), 5: Active storm ridge; 6: Neotyrrhenian marine deposits; 7: Neotyrrhenian marine abrasion surface, 8: Eutyrrhenian marine deposits; 9: Eutyrrhenian marine abrasion surface, 10: Marine abrasion surfaces (late Early Pleistocene – Middle Pleistocene).

Carta geomorfologica dell'area di Isolidda. 1: Deposito di versante; 2: Scarpata di morfoselezione degradata; 3: Falesia inattiva; 4: Ripa di erosione marina inattiva; 5: Cordone di tempesta attuale; 6: Deposito marino neotirreniano; 7: Superficie di abrasione marina neotirreniana; 8: Deposito marino eutirreniano; 9: Superficie di abrasione marina eutirreniana; 10: Superfici di abrasione marina del tardo Pleistocene inferiore – Pleistocene medio.

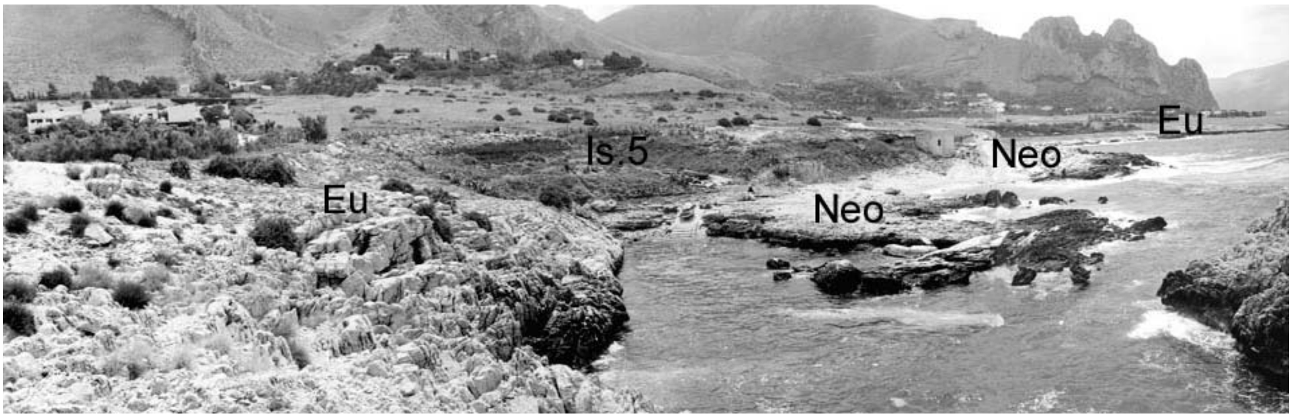

Fig. 5 - Panoramic view of the Isolidda area. Eu: Eutyrrhenian abrasion surface; Neo: Neotyrrhenian abrasion surface; Is.5: Isolidda sequence.

Panoramica dell'area di Isolidda. Eu: Superficie di abrasione eutirreniana; Neo: Superficie di abrasione neotirrreniana; Is.5: Successione Isolidda.

This unit was deposited in infralitoral environment and is at present partly covered by recent storm deposits.

Shells of *Spondylus* sp., Pectinidae and helicoidal Gastropoda are present.

b. '*Transitional'* unit

Sandy loam, 2,5YR 4/6 red with white carbonatic mottles, massive structure.

Sandy fraction made up of quartz and feldspar grains, muscovite and biotite laminae, common limestone and some flint slabs.

Channel and chamber microstructure. Common nodules of iron oxides, micrite hypocoatings and infillings, iron-stained clay coatings on the pedorelicts and on the coarse grains. Frequent pedorelicts, whose matrix is made up of subangular quartz, impregnated by Fe-oxides and with poro- and granostriated b-fabric. Frequent mollusc shells. (Fig. 6 c).

Stipple-speckled b-fabric.

Thickness 30 cm, sharp subhorizontal limit.

c. '*Fine breccia*' (B1) unit

Breccia, made up of fine (up to 3 cm) subangular elements and reddish sandy matrix.

Thickness 25 cm; sharp, slightly wavy subhorizontal limit.

d. '*Red with blocky levels*' unit

The bottom part of this unit is dark red (2.5YR 3/6) sandy loam; medium developed fine granular structure.

The sandy fraction is made up of quartz, flint and limestone (biomicrite and grainstone).

Common iron and manganese aggregates; frequent calcite concretions, mainly micrite infillings and hypocoatings covered by sparite coatings; coatings and hypocoatings made up of iron oxides. Stipple-speckled and sometimes poro- and granostriated b-fabric.

The middle and upper part is red clay loam, with poorly developed polyhedric structure.

Sandy fraction made up of quartz, glauconite, feldspar and muscovite flakelets.

Common and thick coatings made up of iron oxides. (Fig. 6 b).

Stipple-speckled and sometimes poro- and granostriated b-fabric. The most outstanding characteristics are the almost thorough decalcification and the rubefaction of the clay fraction of the groundmass.

Thichness 4.7 m; sharp subhorizontal limit.

Several subhorizontal levels of large blocks are interlayered within this unit.

Common bioclasts, mainly remains of continental molluscs, strongly altered.

e. '*Yellow–brown*' unit

Sandy loam, yellow 10YR 8/6, with medium gravel-size skeleton, poorly developed granular structure, common pores.

Sandy fraction made up of flint and quartz and some feldspar grains, muscovite laminae; limestone slabs are common.

Common diffuse and nodular calcite concretions; sequences of micrite coatings/hypocoatings, clay coatings and coatings of acicular calcite. (Fig. 6 a). Frequent typic and nucleic nodules of Fe-oxides. Few charcoal and vegetal remains. Abundant rounded to subrounded pedorelicts. Stipple-speckled b-fabric, sometimes crystallitic in the upper part, where the groundmass is impregnated by micrite.

Thickness 2.40 m; sharp, subhorizontal erosive limit.

Several thin breccia levels, with medium to fine gravel elements testify to phases of increase in detritic input; an erosion surface can be observed in the lower part. At the top of the unit there is a hard petrocalcic horizon, 20-30 cm thick, with common shells of continental molluscs.

Common fragments of continental mollusc shells.

f. '*Red–brown*' unit

Sandy loam with few subangular limestone and cherty slabs, reddish brown 2.5YR 4/4, poorly developed granular structure.

The sandy fraction is made up of rounded quartz grains, feldspar, muscovite laminae and some glauconite grains.

Micrite and sparite coatings, (Fig. 6 d), few coprolites; pedorelicts with quartz skeleton and few iron oxides; common nodules of Fe-oxides. Stipple speckled b-fabric, sometimes poro- or granostriated; in some areas the groundmass is impregnated by micrite.

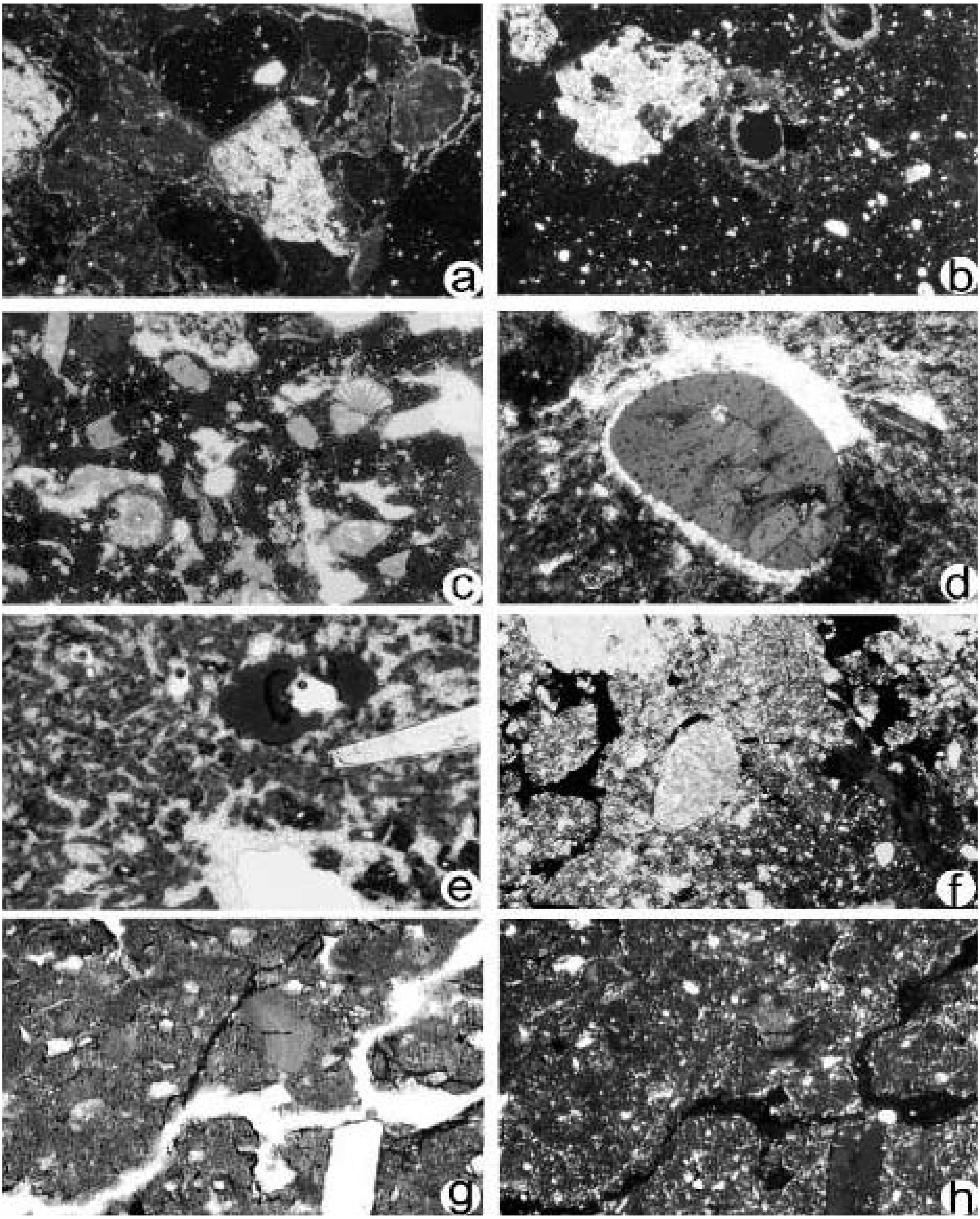

Fig. 6 - Microphotographs of the thin sections. a) Clay and micrite coatings on pedorelicts and limestone grains; XPL. b) Sparite coatings and iron oxide coatings and ipocoatings on grains and simple voids. XPL. c) Pedorelicts and marine mollusc shells. XPL. d) Sparite capping on rounded quartz grain. XPL. e) Calcareous bioclasts, embedded in microsparite/micrite groundmass; at left, an elongated fish bone remain. PPL, frame width 1100 mm. f) Rounded pedorelict made up of clay and iron oxides and, with stipple speckled b-fabric. Clayey groundmass, with fine sand to silt-size quartz grains. XPL, frame width 1100 mm. g) Fragments of layered dusty clay coatings, embedded in sandy silt loam groundmass with Fe-oxides. PPL, frame width 1100 mm. h) As before, XPL.

Microfotografie delle sezioni sottili. a) Pedorelitti e clasti carbonatici con rivestimenti argillosi e micritici; XPL. b) Rivestimenti di ossidi di ferro e sparite su clasti e pori; XPL. c) Pedoreliti e resti di molluschi marini; XPL. d) Rivestimento sparitico "a cappello" su clasto di quarzo arrotondato; XPL. e) Bioclasti calcarei in matrice microsparitica/micritica; a destra, un frammento allungato di osso di pesce; PPL, larghezza dell'immagine 1100 mm. f) Pedorelitto argilloso e con ossidi di ferro, b-fabric macchiettata. Pasta di fondo argillosa, con granuli di quarzo delle dimensioni delle sabbie fini-limo. PPL, larghezza dell'immagine 100 mm. g) Frammenti di rivestimenti argillosi impuri stratificati; pasta di fondo franco limosa con sabbia ed ossidi di ferro. PPL, larghezza dell'immagine 1100 mm. h) Come sopra, XPL.

Thichness 1 m, sharp, subhorizontal limit.

At the bottom, a thin blocky level can be observed. The top part of the unit is strongly cemented and covered by a pinkish calcite crust.

g. '*Breccia*' (B2)

Medium to fine breccia (3-5 cm), made up of limestone and cherty elements, well sorted; few sandy loam reddish brown matrix, poorly cemented.

Thickness 0.7-1.5 m, abrupted limit.

The top of the unit is reddish brown sandy loam with 12 to 15 cm cobbles, forming a continuous, about 50 cm thick horizon that covers the sequence.

Frequent fragments of shells of continental molluscs.

3.2. Discussion

As indicated by its field aspect and micromorphological characteristics, Isolidda can be interpreted as a cyclic sequence of palaeosols developed on scree-slope deposits located in a morphological trap; different pedo–climatic conditions affected the formation of the units.

The lowermost horizon of the sequence, i. e. the biocalcarenitic '*Marine*' unit, is covered by beach deposits representing the transition to fully emerged conditions ('*Transitional*' unit); soil forming processes affected the '*Transitional*' unit probably during a temperate climate phase, as shown by its colour, texture and pedofeatures that suggest the development of an illuviation horizon. The thin layer of angular pebbles (B1) overlying this unit may be interpreted as the effect of a cold climatic fluctuation, that caused the accumulation of coarse deposits and interrupted abruptly the soil forming processes.

The following unit ('*Red with block levels*') probably testifies to two climatic phases. During the first one, some climatic instability induced variously alternating deposition, soil-forming and erosion processes that built up a rhythmic interlayering of "stone lines" of cobbles and blocks with slightly pedogenised finer deposits. During the second phase, long lasting soil-forming processes acted on the stable surface of this deposit under temperate-wet pedoclimatic conditions. A red soil (now palaeosol) developed, affecting the whole unit.

The unit ('*Yellow–brown*') is divided from the underlying '*Red with block levels*' by a sharp erosional limit, and a secondary erosion surface can be observed within it. The overall aspect of this unit, in which some levels of chaotically arranged breccia are evident, points to a fast colluvium process that involved sediments coming from a landslide body located to the west of the outcrop. This hypothesis is corroborated by the occurrence of frequent pedorelicts and coarse coatings within this unit, as well as by the scanty evidence of soil forming processes. These processes are evidence of a renewed climatic instability phase, during which arid events characterised by high evapotranspiration rate caused the deposition of carbonatic concretions, culminating with the formation of a petrocalcic horizon at the top of the unit. This unit indicates a remarkable change in sedimentary and pedogenetic conditions with respect to the underlying units.

Within the third unit ('*Red–brown*'), the decalcification of detrital fraction and rubefaction of clays are weak, while a greater amount in rounded quartz grains indicates an increased aeolian input. Pedofeatures like iron concretions are well developed and pedorelicts are common, showing that some weak soil forming processes and colluvium acted under probably temperate-cold conditions.

The breccia levels, indicated as B1 and B2, located close to the bottom and to the top of the sequence, can be compared to the *éboulis ordonnés* resulting from strong physical weathering of rocks due to abrupt dry–cold climatic variations that have been reported in the Late Glacial sequences of North Western Sicily by Agnesi (1989) and Ulzega (1989).

4. CONCLUSIONS

In the North–Western sector of the Capo San Vito peninsula, the formation of sequences of continental deposits, soils and palaeosols has been controlled by several interacting factors during the Quaternary. The major role was played by the Quaternary climatic fluctuations and related eustatic sea-level changes; the tectonic movements modulated role and intensity of the morphogenesis, thus affecting the development of the marine terraces and of the soils. As a consequence, soil evolution is typically polycyclic in this context. The resulting sediments and soils are characterised either by features that indicate climatic (and tectonic?) stability, or by colluvial and detrital components and by erosion surfaces that point to a highly dynamical environment. Such an instability characterised mainly the climatic deterioration phases; in this Southern area, the most relevant aspect of the climate cannot have been a "strong" decrease in temperature, as it was at higher latitude, but probably some sort of shift to continental characteristics of the environment.

The Isolidda sequence is the record of this evolution through the last Ice Age. The '*Marine*' unit at the base of the sequence covers the abrasion surface of the VII order terrace, which is of neotyrrhenian age (stage 5c/5a?), and was deposited during the last marine transgression, before the beginning of the First Pleniglacial (stage 4). The beach deposit of the '*Transitional'* unit represents the ultimate emersion of the area; soil-forming processes acted on its top, apparently under temperate conditions, until a cool–dry event documented by the *éboulis ordonnés* (breccia level B1) interrupted the process.

The thick deposit '*Red with blocky levels*' is the result of probably fast accumulation of fine sediments with coarse debris events, in a landscape with scant vegetal cover. Strong pedogenesis acted on this deposit during a subsequent long-lasting temperate-humid climatic phase (stage 3?), favouring the formation of a poorly developed Alfisol.

A marked climatic deterioration originated the unit '*Yellow–brown*': fast erosive and depositional events alternated to weak soil-forming point to highly dynamic and unstable conditions, probably characterised by scant forest cover and contrasted seasons. Later, the climate evolved towards cold–temperate conditions that favoured a weak pedogenesis, as documented by the unit '*Red-brown*', which is somewhat rubefacted (stage 2?).

The gravelly levels (B2) at the top of the sequence may be representative of late Second Pleniglacial–Late Glacial "cold" climatic phases, when *éboulis ordonné*-like deposits accumulated (stage 2-1?).

Traces of older soils are preserved on a wide relict of the I order terrace, which has been an isolated relief since its emersion. These relicts are mainly preserved within sequences deposited in caves, depressions and notches, like the site K22. Here, they occur in the basal marine and transitional units of the sequence ('*Base*', '*Lower Conglomerate*', '*Pinkish Sandstone*'), and can be correlated to the isotopic stages 15-13.

A drift towards a "continental" climate, which is supposed to have caused deforestation and the onset of erosive processes, would be indicated by the unit '*Orange*'. The formation of this unit likely followed a long lasting phase of stable environmental conditions: the occurrence of abundant fragments of thick *clay coatings* (papulae *sensu* Brewer, 1964), indicates that evolved soils (Alfisols or Ultisols, typical of long "interglacial" phases of temperate conditions) originated these pedo-relicts. Tentative correlations can ascribe the soil-forming phase to stage 7, while the following erosive phase may be related to glacial stage 6.

The unit '*Red'* may have been formed during a period of climatic improvement, when the erosion was somewhat weaker; possibly an interglacial phase that can be tentatively correlated to the last interglacial (isotopic stage 5 *s. l.*).

The occurrence of muscovite flakes throughout the sequence shows that the aeolian input played a consistent role in the formation of the deposits. Nevertheless, the occurrence of rounded coarse-grained quartz within the upper units '*Blocks*' and '*Brown'* may point to an increase of the aeolian transport, which likely corresponded to dune formation in the neighbours of the site (Agnesi *et al*. 1998; Di Maggio *et al.* 1999). A climatic shift towards dry conditions during stadial phases of the last glacial cycle may explain this phenomenon. These units are here tentatively correlated to the stages 3 or 2 ('*Blocks*') and to the Pleistocene-Holocene transition ('*Brown*').

Finally, it must be pointed out that the sequences are located on morphological highs or in other areas of strong morphogenetic energy, where stratigraphic gaps can develop easily. This peculiarity explains the shortness of the sequences, but also infers some incertitude in the interpretation.

REFERENCES

Agnesi V., 1989. Levanzo. In "Guida alle escursioni", Gruppo nazionale geografia e geomorfologia, CNR, Trapani 27 – 30 Giugno 1989, 27 –32.

Agnesi V., Macaluso T., Masini F., 1998. *L'ambiente e il clima della Sicilia nell'ultimo milione di anni*, In S. Tusa (Ed.) "Prima Sicilia, alle origini della società siciliana", vol. I, 31-52, Ediprint, Palermo.

Boschian G. (1998). *Middle Pleistocene to early Holocene infilling deposits of the Trieste Karst caves (North-East Italy)*. XIII UISPP Congress, Forlì (Italy), September 8-14, 1996, Vol. 1, Section 3-Paleoecology, Subsection Geoarchaeology, 383-386.

Brewer R., 1964. *Fabric and Mineral Analysis of Soils*. John Wiley and Sons, New York.

Bullock P., Fedoroff N., Jongerius A., Stoops G., Tursina T., Babel U., 1985. *Handbook for Soil Thin Section Description*, Waine Research Publications, Wolvehampton.

Catt J. A., (Ed.), 1991. *Paleopedology Manual*. Quaternary International, 6, 1-95.

Cremaschi M., 1990a. T*he Loess in Central and Northern Italy: a Loess Basin Between the Alps and the Mediterranean Region*. In Cremaschi M. (Ed.) "The Loess in Central and Northern Italy: a Loess Basin Between the Alps and the Mediterranean Region", C.N.R., Centro di studio per la Stratigrafia e la Petrografia delle Alpi centrali. Quaderni di Geodinamica alpina e quaternaria, 1, 15-19.

Cremaschi M. (1990b). *Depositional and Post-depositional Processes in Rock Shelters of Northern Italy during the Late Pleistocene: their Paleoclimatic and Paleoenvironmental Significance*. Quaternaire, 1990 (1), 51-64.

Di Maggio C., Incandela A., Masini F., Petruso D., Renda P., Simonelli C., Boschian G., 1999. *Oscillazioni eustatiche, biocronologia dei depositi continentali quaternari e neotettonica della Sicilia nord-occidentale (penisola di San Vito lo Capo - Trapani)*. Il Quaternario, 12 (1), 25-49.

Mauz B., Buccheri G., Zöller L. & Greco A., 1997 - *Middle to Upper Pleistocene morphostructural evolution of the NW - coast of Sicily: thermoluminescence dating and palaentological-stratigraphical evaluations of littoral deposits*. Palaeogeography, Palaeoclimatology, Palaeoecology, 128, 269-285.

Orombelli G., 1971, *Concetti stratigrafici utilizzabili nello studio dei depositi quaternari continentali*, Riv. Ital. Paleontologia Stratigrafia, 77 (2), 265-291.

Ruggieri G., Buccheri G., Rendina M., 1968 – *Segnalazione di Tirreniano fossilifero a Trapani*. Riv. Min. Sic., 112 - 114, 1 - 4.

Sanesi G., 1977, *Guida alla descrizione del suolo*. C.N.R., P. F. Conservazione del Suolo, pubbl. n° 11, Firenze.

Ulzega A., 1989, *San Vito lo Capo – Piana di Sopra Macari*, in Guida alle escursioni, Gruppo nazionale geografia e geomorfologia, CNR, Trapani 27 – 30 Giugno, 18 – 23.

Ms. ricevuto marzo 2002

Ms. received: March 2002