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# LOWER PLEISTOCENE DEPOSITS IN EAST PART OF THE FAVIGNANA ISLAND, SICILY, ITALY

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ABSTRACT: Ślączka A. *et al.*, *Lower Pleistocene deposits in east part of the Favignana Island, Sicily, Italy*.
In the Favignana Island (Egadi Archipelago, Sicily, Central Mediterranean) Pleistocene shallow water marine deposits are widely well exposed to form a prograding beach/near foreshore complex system. A group of facies associations have been recognised, suggesting different depositional environments and processes, related both to currents dynamics, palaeoclimatic conditions, sea-level changes and syn-sedimentary tectonics. The sedimentological pattern of the facies allow to reconstruct the depositional history of the island, characterised by the interplay of long/oblique shore currents dynamics and storm events during the Lower Pleistocene, developed on a mobile Mesozoic bedrock just affected by strike-slip tectonics

*RIASSUNTO: Ślączka A. et al.*, I depositi del pleistocene inferiore nel settore orientale dell'Isola di Favignana, Sicilia, Italia.
*Nell'isola di Favignana (Arcipelago delle Egadi, Sicilia occidentale), affiorano estesamente calcareniti infrapleistoceniche, ben esposte soprattutto lungo le pareti delle numerose cave a pozzo, oggi dismesse, presenti nel settore orientale dell'isola.*
*Le calcareniti sono caratterizzate da un complesso sistema di associazioni di facies, che nel loro complesso indicano ambienti deposizionali di spiaggia/mare basso, e ricoprono in discordanza successioni carbonatiche mesozoiche deformate, che costituiscono le unità tettoniche esterne della Catena Siciliana, messe in posto nel Miocene superiore Depositi, di età pleistocenica inferiore, affiorano estesamente sia nel settore orientale che in quello occidentale dell'Isola e sono separati da una dorsale carbonatica mesozoica, affiorante nel settore centrale.*
*Le migliori esposizioni di questi depositi si rinvengono nel settore orientale, dove sono state riconosciute cinque associazioni di facies. L'analisi sedimentologica ha permesso di ricostruire gli ambienti ed i processi sedimentari, che sembrano essere il risultato dell'interazione sia di dinamiche di correnti, di condizioni paleoclimatiche e di oscillazioni eustatiche, oltre che di deformazioni tettoniche sin-sedimentarie.*
*Le geometrie stratali, le strutture sedimentarie e le ichnofacies hanno permesso di distinguere nel settore orientale di Favignana associazioni di facies caratteristiche di ambienti di spiaggia sommersa nei quali si è sviluppato un sistema di barre disposte obliquamente rispetto alla paleolinea di riva. La diffusa presenza di strutture erosive e di depositi canalizzati suggerisce che la deposizione sia avvenuta per lo più al di sopra del livello di base delle onde e che a luoghi sia anche stata condizionata da eventi di tempesta.*
*L'evoluzione verticale delle facies mostra inoltre che la sedimentazione è stata anche controllata sia da oscillazioni del livello del mare che da mobilità del substrato, soggetto a deformazioni tettoniche, come evidenziato da numerose faglie di crescita presenti a diverse scale entro i depositi calcarenitici*.

Keywords: depositional processes, sinsedimentary tectonics, Pleistocene, Egadi-Sicily.

*Parole chiave: Processi deposizionali, tettonica sin sedimentaria, Pleistocene, Isole Egadi, Sicilia.*

## 1. INTRODUCTION

The Lower Pleistocene (Calabrian; MALATESTA, 1955) sediments exposed along some cliffs and in the quarries in the eastern sector of the Favignana Island (Fig. 1), between Favignana town and Punta Marsala, are a good example of ancient shoreface deposits (ABATE *et al*., 1999): the main purpose of this study is to describe them for try to define their depositional environments. The sediments of the Favignana Basin show general similarity to the Upper Pliocene-Lower Pleistocene Calcarenite di Gravina Formation outcropping in Apulia region, whose paleographical and sedimentological features were discussed in several papers (e.g. D'ALESSANDRO & BROMLEY, 1986; D'ALESSANDRO *et al.*,1993; D'ALESSANDRO & MASSARI, 1997; IANNONE & PIERI, 1979; MASSARI & CHIOCCI, 2006; MATEU-VICENS *et al.*, 2008; POMAR & TROPEANO, 2001). The deposition of Favignana Pleistocene sediments was strongly influenced by the size and shape of the island. The paleo-Favignana Island probably was smaller than presently. The clastic sediments forming calcarentes mainly derive from redeposition of ancient shore material and from very common skeletal remains of bentic organisms (Fig. 2); a negligible part of clastics derive from the Mesozoic calcareous rocks.

The main controlling factor of the coastal sedimentation was the interplay of fair weather and storm periods, as already point out for similar Lower Pleistocene deposits, (MASSARI & PAREA, 1988, MATEU-VICENS *et al.*, 2008), also by prossible tsunamis (TINTI, 1993). Relative changes of sea level caused by local tectonic movements during Lower Pleistocene (ABATE *et al*., 1995) and by regional sea level fluctuations (TROPEANO & SABATO, 2000) have an important role for the Favignana area.

## 2. GEOLOGICAL SETTING

The Favignana Island belongs to the Egadi Archipelago (Fig. 1) that represents an emerged part of the Egadi Thrust Belt (ABATE *et al*., 1995-1997) of Sicilian-Maghrebian system (SULLI, 2000; NIGRO & RENDA, 2001). Favignana is mainly build-up of Mesozoic-Lower Tertiary carbonate deposits, unconformably capped by younger sediments which are represented by biocalcarenites and biorudites of Early-Middle Miocene and marly shales of Late Miocene (CATALANO *et al*., 1996; ABATE *et al*., 1997). Mesozoic-Lower Tertiary carbonate deposits are unconformably covered by Middle-Upper Pliocene bluish marls and shale followed by Lower Pleistocene calcareous deposits and by Tyrrhenian calcarenites and biorudites. The Lower Pleistocene depo sits are widespread along the eastern slope of the emerged paleo-Favignana Island in a pull-apart Basin, probably generated by transtensional faults activity.

Three faults systems, recognised in the Favignana Island, displace both the Mesozoic-Tertiary and Pleistocene deposits (Fig. 3). The first system, represented by N-S strike-slip faults, bounds the ridge of Favignana and somewhere it reactives/displaces the Miocene thrusts (ABATE *et al*., 1995). The other faults systems NE-SW and NNW-SSE oriented at low-angle pitches.

Minor positive flower structures 1-to-10 meters in scale have also been observed (INCANDELA, 1995; 1996; ABATE *et al*., 1995). In the eastern sector of the island, joints and minor strike-slip faults deform the deposits of Pleistocene age, as well as the more younger breccias and paleosoils with displacements ranging from 0.1 to 1 m. This faulting activity determined small-scale block tilting, as recognised at Cala Monaci. In the middle-southern sector of the island a N-S oriented morphostructure (so-called Promontorio Scindo Passo), is located and bounded by two strike-slip faults. The outcropping Pleistocene deposits are displaced by minor right-hand transtensional and normal faults oriented NNW-SSE. This grid of minor faults determined pull-apart like geometries In the north-western sector of the island (Punta Sottile) outcrop conglomerates and sandstones of Pleistocene age, that are displaced by strike-slip and normal faults oriented from NW-SE to W-E. The sandstones also fill the faults-related joints, suggesting soft-sediment deformation processes. Also, between the localities of Cala del Pozzo and Punta di Ferro, outcrop gravels and sandstones of Pleistocene age are deformad by NW-SE and W-E oriented strike-slip faults (INCANDELA, 1996; ABATE *et al*., 1995; 1997). In the northern sector of the island (Punta Faraglione), right-hand strike-slip faults oriented from NW-SE to W-E, formed a set of meters-in-scale graben-like structures, filled by marine deposits of Pleistocene age. This deposits are deformed by left-hand strike-slip faults NE-SW striking. Finally, the Pleistocene sandstones outcropping in the eastern sector of the island are folded to form a gentle anticline, interpreted as a drag-fold by INCANDELA (1996) and ABATE *et al*., (1995).

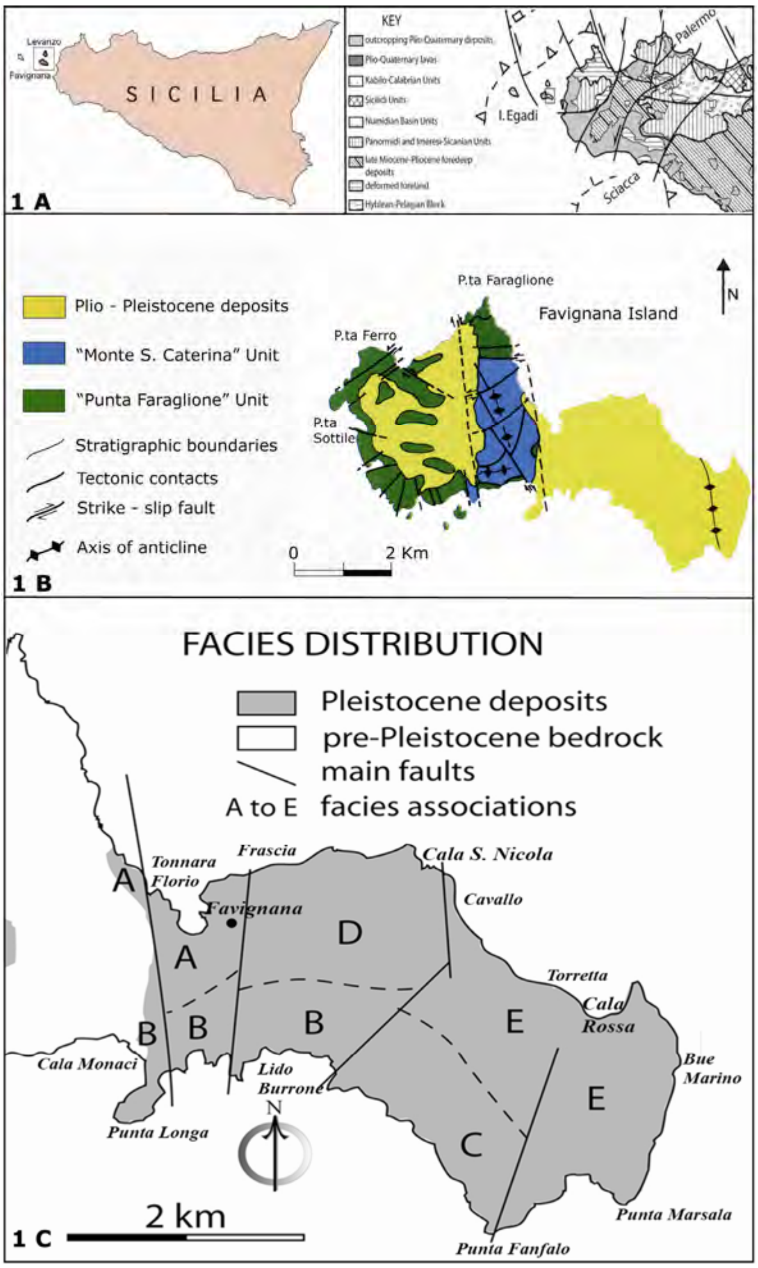


Fig. 1. - a) Schematic structural map of the Western Sicily; b) Schematic geological map of the Favignana; c) Pleistocene facies distribution in the eastern Favignana Island.

*a) Carta strutturale schematica della Sicilia Occidentale; b) Carta geologica schematica dell'Isola di Favignana; c) Distribuzione delle facies pleistoceniche nel settore orientale dell'Isola di Favignana.*

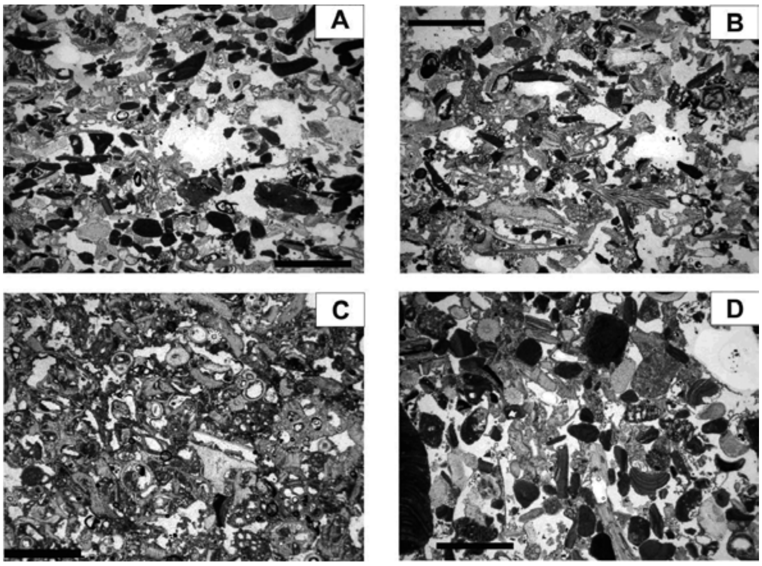


Fig. 2. - a) Bioclastic sandstone with red algal clast, foraminifera and sporadic bryozoan. Punta Burrone. Length of bar is 2 mm; b) Bioclastic sandstone with foraminifera, bivalve shell fragments, bryozoan, red algae. Punta Fanfalo. Length of bar is 2mm; c) Fine grained bioclastic sandstone with numerous foraminifera. Area of Frascia. Length of bar is 1 mm; d) Bioclastic sandstone with red algae, bivalve shell fragments, bryozoan and foraminifera. Madonna-Cortigliolo. Length of bar is 2 mm.

a) Arenaria bioclastica con clasti di alghe rosse, foraminiferi e sporadici briozoi. Punta Burrone. La lunghezza della barra è 2 mm; b) Arenaria bioclastica con foraminiferi, frammenti di gusci di bivalvi, briozoi ed alghe rosse. Punta Fanfalo. La lunghezza della barra è 2 mm; c) Arenaria bioclastica fine con numerosi foraminiferi. Località Frascia. La lunghezza della barra è 1 mm; d) Arenaria bioclastica con alghe rosse, frammenti di gusci di bivalvi, briozoi e foraminiferi. Madonna-Cortigliolo. La lunghezza della barra è 2 mm.

## 3. DESCRIPTION OF LITHOFACIES

Several facies associations can be locally described on the basis of coexistence of lithological features, sedimentological structures and trace fossil assemblages. Relationship between the facies associations are in some cases of hard interpretation because of lacking of several diagnostic elements: all the stratigraphic sections are incomplete, the basal Lower Pleistocene deposits are frequently unexposed and the erosion and/or faulting cut the topmost part of the successions.

### 3.1 Facies Association A

This Association, whose visible thickness is about 10 meters, is exposed in the western margin of the Favignana Basin between Cala Fumere and Tonnara Florio (north of the town of Favignana, Fig. 1c). It is generally represented by coarsening up sequence of calcarenites and conglomerates (Fig. 4). The bottom of the sequence is masked by strike-slip fault. In the lower part, fine-to-coarse grained calcarenites, up to several dozen cm thick, display a variety of laminations, from parallel to cross-bedded in lunate megaripples and to wave ripple lamination[1].

In the upper part of the sequence, whose thickness can reach 1.5 meters, predominate conglomerates (Fig. 4c) composed of rounded and subrounded pebbles derived from the erosion of the Mesozoic bedrock, as well as from other lower Pleistocene deposits. The size of sporadic boulders can reach dozen cm. Scattered fragments of bivalve shells, rhodolithes and serpulite limestones also occur. The matrix consists in abraded bioclastics. Conglomerates show crude parallel-bedding (PETTIJHON, POTTER & SIEVER, 1987) and low angle cross bedding seaward directed; somewhere they are massive, without distinct internal structures. Parallel-bedded conglomerates include small lenses of cross-laminated calcarenites. Inclination of lamination is generally parallel or oblique to the coastline. Conglomerate bodies present an erosional basal surface signed by broad shallow channels. Trace fossils, random distributed in the sediments, must be referred to three ichnogenera, *Thalassinoides, Planolithes* and *Thenidium*; somewhere vertical traces of *Skolithos*-like also occur (Fig. 4c). Few beds of calcarenites are pervasive bioturbated (Fig. 4d), locally limestone with borings can be observed in blocks up to tens cm in diameter.

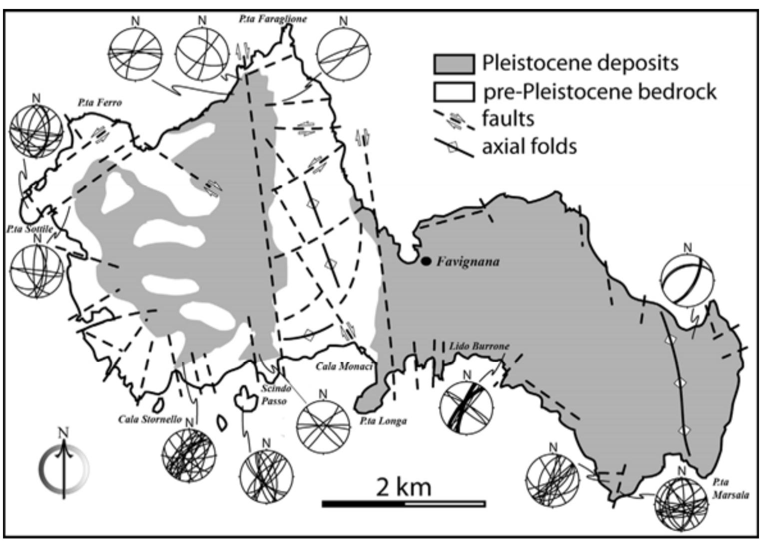


Fig. 3 - Schematic structural map of the Favignana Island showing the main faults that deform the Pleistocene deposits

*Carta strutturale schematica dell'Isola di Favignana che mostra le principali faglie che deformano i depositi del Pleistocene.*

1 Locally there are bi-directional set of lenses (Fig. 4a) and in places wave ripples follow upward megaripples. On some inclined laminae there are lags of gravels and shells (Fig. 4b). Also, between laminated bodies there are lags of flat limestone pebbles and thin (up to dozen cm) layers and/or lenses of conglomerates, formed by rounded pebbles of Mesozoic limestones, bioclasts and fragments of molluscs and echinoids shells (Fig. 4b). Some layers (up to 50 cm thick) display distinct gradation from matrix supported carbonate pebbles and fragment of shells in lower part to coarse and medium grained calcarenites topwards.

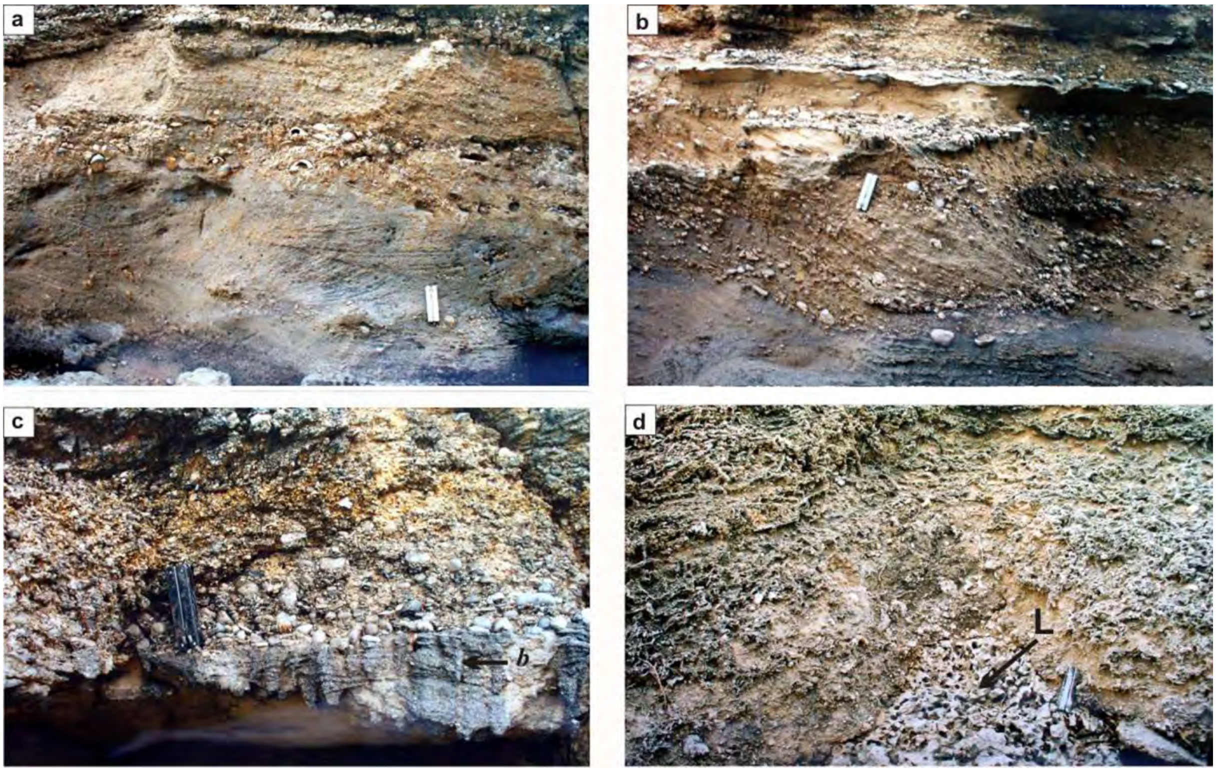


Fig. 4 - Facies Association A (beach/nearshore zone), area of Cala Fumere, north from the town of Favignana. a) Lower part of the sequences started with bi-directional bundled cross-bedded lenses covered by thin layer of conglomerate built up of fragments of moluscs and Echinoidea shells and unidirectional cross bedded calcarenites. Length of penknife is 11 cm; b) Cross-bedded calcarenites with lags of limestone pebbles along inclined laminae and covered by parallel laminated calcarenites with pebbly lags. Length of penknife is 11 cm; c) Layer of conglomerate showing crude gradation with well rounded limestone pebbles. Sporadic vertical burrows (*b*). Length of penknife is 11 cm; d) Pervasive bioturbated calcarenites. In lower part of the picture burrowed limestone boulder (L) with borings. Length of penknife is 11 cm

*Associazione di Facies A (zona beach/nearshore), area di Cala Fumere, a nord della città di Favignana. a) La base della sequenza inizia con lenti a stratificazione incrociata a festoni bidirezionali ricoperte da un sottile strato conglomeratico costituito da frammenti di molluschi ed echinidi e calcareniti a stratificazione incrociata unidirezionale. La lunghezza del temperino è 11 cm; b) Calcarenite a stratificazione incrociata con isolati ciottoli carbonatici disposti lungo lamine inclinate e ricoperti da calcareniti a laminazione piano-parallela con clasti isolati. La lunghezza del temperino è 11 cm; c) Orizzonte conglomeratico scarsamente gradato, con ciottoli di calcare ben arrotondati. Sporadici burrows verticali (b). La lunghezza del temperino è 11 cm; d) Calcareniti ampiamente bioturbate. Nella parte inferiore della foto si osserva un ciottolo carbonatico (L) perforato. La lunghezza del temperino è 11 cm.*

Predominance of coarse-grained sediments and sedimentary structures suggest that Facies Association A (Fig. 1c) represents high wave energy beach/upper foreshore zone (POMAR & TROPEANO, 2001; CLIFTON, 2006; BRIDGE & DEMICCO, 2008). In this zone storm sediments, represented by pebbly lags, passing upwards to finer laminated deposits, graded beds, lunate megaripples and pebbly layers, are interrupted by fair weather conditions when developed wave ripple lamination and burrowed interval (CLIFTON, 1976; JOHNSON & BALDWIN, 1986). Seaward deeping cross-bedding prevailed. Occasionally longshore southward currents appeared. Observed intricately interwoven cross-lamination are characteristic of wave origin and connected probably with fair-weather period.

Very thick conglomerates near the top of sequence can mark exceptional strong storms events. Due to storms cyclicity, deposits of previous periods were partly eroded and are only partially preserved. Increase of conglomerates in the upper part of the sequence is linked to the increase of storm magnitude in lapse of time. Periodically pervasive bioturbated horizons took place.

### 3.2 Facies Association B

Facies Association B, whose thickness not exceeds 10 meters, is located between Punta Lunga and Lido Burrone, southwards of Favignana town (Fig. 1c) and reaches Favignana harbour towards the north. It is characterized by the occurrence of calcirudites with several algae remains and rhodolithes and occurrence of horizons with *Thalassinoides*. Relationships to the previous Facies Association is not clear in the souther part (Cala Monaci) due to the lack of exposures. However data from the harbour of Favignana imply that Facies Association B is generally situated farther to east than the previous one. Relationship with older substratum is unknown. The outcrop of this Association starts near Punta Lunga with thick bedded/massive conglomerates (Fig. 5a) built-up mainly by rhodolithes, up to dozen cm in size, fragments of serpulite and, somewhere, by fragments of bivalve shells. Erosive surfaces bound base of some conglomerates, displaying broad but general shallow (several tens of cm) channels. Crude planar cross-bedding is visible in topmost part of the section. In the western sector the conglomerates can reach 3 meters thick. There are lenses, up to 1.5 meters thick, composed by calcarenites rich in mollusc shells that display in their lower part crude lamination, that becomes more chaotic upwards (Fig. 5b). The upper part of the sequence consists of thick-bedded conglomerates, displaying erosive base with planar westward cross-bedding, locally underlined by lag of single, ellipsoidal pebbles. Decreasing of size of clastics is visible (Fig. 5c) landwards. In some localities, homogenous medium-grained calcarenites, up to several tens cm thick, enriched in pelitic material, show a medium bedding. The sequence generally stops with coarsening-up strata, homogenous in their lower part, showing low-angled lamination near the top, covered by laminated bioturbated calcirudites (Fig. 5d) with eastward dipping and muddy drapes. Somewhere channelized conglomeratic beds with pebbles, rhodolihts and shell fragments, in which the size of clastics and thickness of layers is decreasing eastward, can be observed. Conglomerates show a cover of oblique cross-bedded layers, generally dipping toward ESE, pervasively bioturbated and topped or by a bundled part (Fig. 5e) and by horizontal laminated or wave laminated calcarenites. Calcirudites with rhodoliths crop out eastward, almost up to Lido Burone Locally. Broad and deeply incised erosional channels, NW-SE and N-S directed, filled up by stack of oblique and locally sinuosinoidal cross laminated material with very coarse grained material concentrated in the middle part of inclined layer (Fig. 5f), can be observed. Thin, pelitic horizons separate individual laminated set. The calcirudites in Punta Lunga are locally cut by *Scolithos*-type traces (Fig. 5d) and on the upper surface there is characteristic network of *Thalassinoides* (Fig. 5g) and sporadic *Ophiomorpha* (Fig. 5h). This can represent *Cruziana* and *Skolithos* ichnofacies (BROMLEY, 1996; SEILACHER, 1967) or *Thalassinoides Skolitus* Suite of D'ALESSANDRO *et al*. (1993).

Facies association B, mainly deposited by storm waves of high magnitudes, could represent a portion of the upper shoreface zone (ELLIOt, 1986; CLIFTON, 2006). Size of detrital material and seeward inclination of cross-bedding show that coarse detrital material, together with rhodoliths and Serpulids, was probably derived from shoreline, by back currents generated by exceptionally strong storms. Bodies of sediments rich in fragments of bivalve shells chaotically distributed represent storm deposits. Single coarse-grained body was probably formed during a very short time amount (about few hours?). Erosive channels, perpendicular or oblique to the shoreline, probably created by local rip currents can also be seen. Visible in exposures bodies and structures probably not represent all events which took place in this area as due to the strong erosion processes, which are suggested by preserved sedimentary structures, erosional surfaces specially, part of sediments was reworked by subsequent storms. Gravel containing dunes, generated by strong storm current migrated generally seawards, but sporadic occurrence of landward inclined cross-bedding implies occasionally shore-ward movements of dunes. Longshore currents played less important role than currents more and less perpendicular to the shoreline. Sediments of fair weather, represented by medium scale cross bedding, are preserved only locally. The lack of trace fossils in the lower part of sequence could be en efect of conditions existing during that period (strong current and wave actions), which was probably unfavorable for development and/or preservation of epi- and infauna (D'ALESSANDRO & BROMLEY 1996). Only at the end of the development of Facies Association B sequence, locally, in sheltered area, were formed favourable, calm habitats that allowed to develop and preserve extensive nets of *Thalassoinoides* and *Skolithos*. The coexistence of *Skolithos* and *Thalassoinoides* indicates moderate turbulence D'ALESSANDRO, LOIACONO & BROMLEY (1993). MCILROY (2004) sugessts that it can be an effect of partially isolation of that area by bars.

### 3.3 Facies Association C, coarser fraction

This Facies Association, that stretches eastward (seaward) from the previous one Facies in the area of Lido Burrone up to Punta Fanfalo[2] (Fig. 1c), is dominated by coarse and medium-grained calcarenites, whose thickness not exceed 20 meters. Generally the coarser fraction consists in shell fragments and the sediments typically present traces of Echinoidea. Direct relation to the Facies Association B is partly obliterated by faults (ABATE *et al.,* 1995). The visible part of the sequence starts with a layer of calcirudite with rhodolithes and shell fragments, similar to those of Facies Association B, covered by thin calcarenite strata with trough cross laminations or ripple cross-lamination. Inclination of cross-bedding structures is generally southwestwards and less common towards S-SSE (Punta Burrone, western outcrop) and WSW (Punta Fanfalo, eastern outcrop). The main part of Facies Association C is characterized by occurrence of thick beds (up to two m) of thick-bedded calcarenites, often sub-horizontal laminated, mostly well-sorted, coarse to medium-grained with channels filled up by cross-bedded calcarenites (Fig. 6a). There are also thick (up to 1 m) tabular cross-stratified calcarenites, covered by ripple cross-laminated ones. Locally, shallow (up to tens of centimeters deep) channels broad occur, filled-up by cross-laminated calcarenites (Fig. 6a). Several beds contain numerous dispersed shells of pectinids and Echinoidea (see the upper part of Fig. 6b) and, less commonly, of Brachiopods, *Dentalium* and *Cardium*. Molluscs in life position or forming layers of convex-up oriented bivalve shells (Fig. 6c), together with fragments of Echinoidea and – more rarely – rhodoliths, heve been observed in some oucrops (Lido Burrone, Punta Fanfalo). These organic remains may form lags above erosional lower surfaces (Fig. 6d). In Punta Burrone area planar bifurcated structure, similar to mangrove tye roots (Fig. 10h) have been discovered.

This generally low-energy Facies Association, locally with mollusc shells in life position, was developed in relatively deep, quiet environment within shoreface zone. Longshore currents from NNE dominate, favouring

2 Sediments similar to Facies Association C are also exposed in area of Punta Marsala.

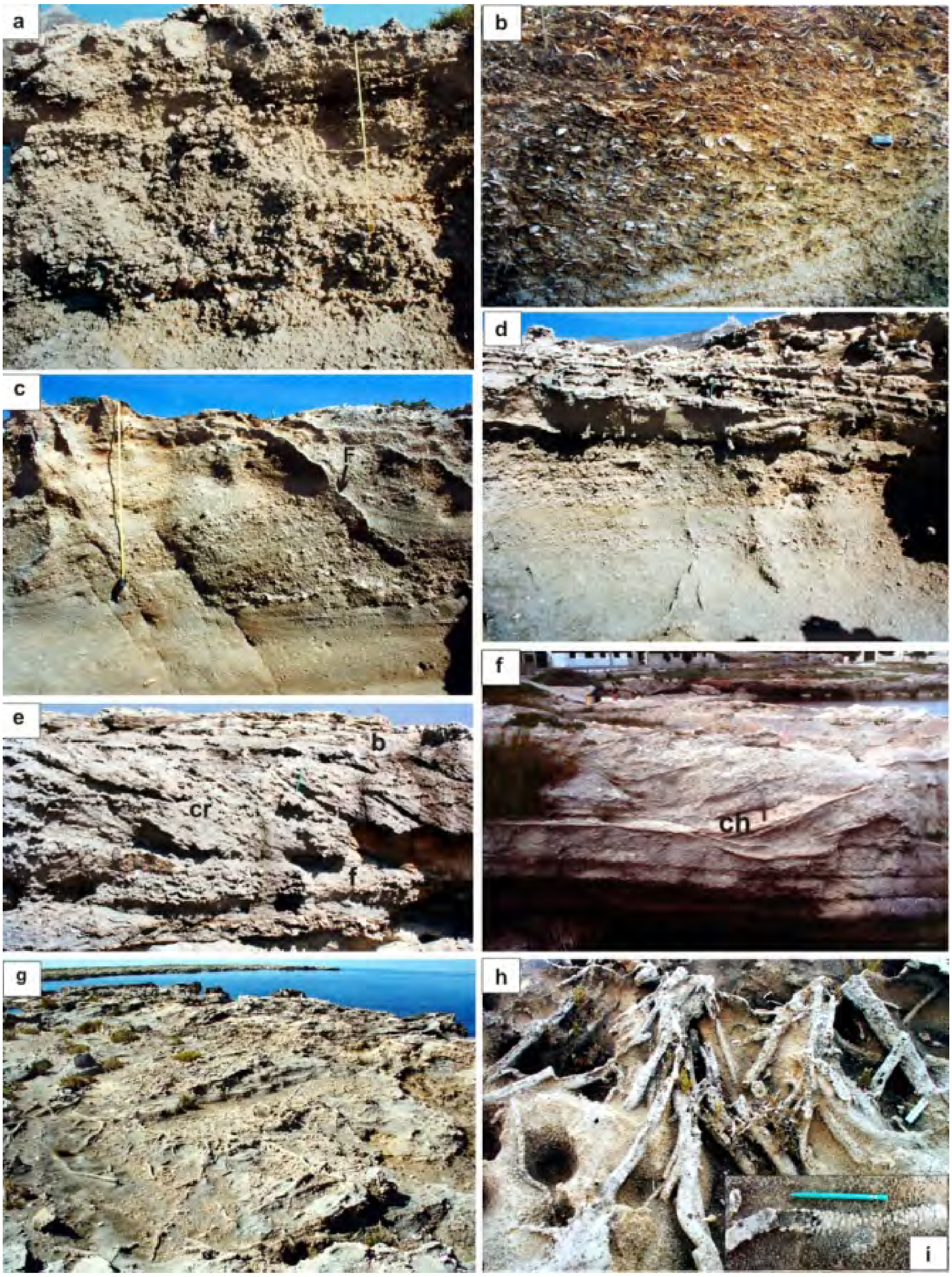


Fig. 5 - Facies Association B (uppershore zone), area di Punta Longa, south of town of Favignana. a) Conglomerate build up mainly of rhodolithes, cross-bedded in upper part. North towards the right. Length of measure 1 m; b) Local, concentration of shells of molluscs horizontally arranged. In lower part visible cross-bedding. Length of penknife is 6 cm; c) Massive calcarenite with poorly defined cross-lamination covered by cross-bedded calcirudites, which pass landward into coarsegrained calcarenites. Sharp bedding plane records storm period. Note a fault on the right side of picture (F). Length of measure 1 m; d) Sub-horizontal, coarsening upwards calcirudites with pebbly lags and erosional upper surface overlain by seaward dipping coarse-grained and conglomeratic calcarenites strongly bioturbated. Note vertical, Scolithos type traces fossils. Some of them penetrated the lower unit. Less visible are *Thalassinoides* developed on surface of the inclined layers – compare Fig. 3g. Pen for scale; e) Sequence which started with calcirudites that contain rhodolithes and fragments of shell, covered by horizontal layers (f), passing upwards into oblique cross-bedded bioturbated calcarenite (cr) and topped by hummocky like (b) calcarenite. Seaward inclination of laminae. Length of pencil is 15 cm; f) A local channel (Ch) in sub-horizontal coarse calcarenites with muddy matrix. This channel, 1,5 meters deep, is filled by stack of sinusoidal cross-bedded bodies incline landward. Note patchy concentration of pebbles (e.g. near hammer). Hammer for scale; g) Thalassinoides network at the top of the sequence shown on Fig.3d. Note the thin layers of mudstone that are very rare in the study area; h) detail of Thalassinoides network; i) *Ophiomorpha* occur only sporadically.

the deposition of thin, tabular cross-stratified or horizontally laminated calcarenites. Exceptionally, storm action reworked the sediments developing both massive calcarenites, with lags above erosive surfaces, or calcarenites with vertical sequence of tabular cross-stratified and ripple laminations or erosive channels filled up by cross-bedded calcarenites. During colonization windows (GOLDRING, 1991), planar trace fossils sets (*Cruziana* facies) took place. Facies Association C represents low energy environment connected with a bar trough (CLIFTON, 2006). Sporadic appearance of very coarse sediments could be rather an effect of strong storms (ELLIOT, 1986; CLIFTON, 2006) while evolution of beach/nearshore facies could be linked with change of sea level (MATEU-VICENS, 2008). Scattered occurrence of problematic mangrove type roots suggests shoal areas.

**3.4 Facies Association D**

This Facies Association, characterized by the occurrence of tabular laminated cross-bedded calcarenites (Figs 7, 9a), whose lower and upper surface of beds are erosive, with broad deep channels (Figs 8, 10b) and abundant trace fossil of *Skolithos* ichnofacies, is exposed, for a thickness that do not exceed 15 meters, along the northern island shore (Frascia area), between the town of Favignana and Cala S. Nicola (Fig. 1c).The main facies, mainly developed in western (landward) part of Association D (Fig. 9a), is represented by thick bedded (up to 2 m) and coarse-grained calcarenites, with subhorizontal and large-scale cross-bedding. Generally the lamination is emphasized by change of grain size and locally by lags of fragments of bivalve shells. Locally laminae are pervasive bioturbated. The main feature of some cross-bedded strata shows a laminated-to-bioturbated pattern, similar to described from Pleistocene deposits of Salento area by D'ALESSANDRO & MASSARI, (1977). In few cases, only the lower part of each set of inclined laminae is bioturbated; somewhere bioturbation is pervasive. In some thick calcarenite beds, a vertical facies succession can be observed: from the base subhorizontal laminated calcarenites crop out, capped by cross-bedded calcarenites, locally wedgelike, whose top consists of strongly bioturbated calcarenites (Fig. 10)[3].

Generally, cross-bedding is inclined towards SE, only locally toward W. The upper part of the Facies Association D shows typically the occurrence, particularly in more distal (seaward) part (Fig. 9b), of broad (dozen or so meters) erosional channels and washouts (usually up to 2 m) (Fig. 8): channels are filled-up or by massive calcirudites (Fig. 10a) or by calcarenites with trough cross-lamination, partly destroyed by bioturbation. Some calcarenites show crude concave or chaotic laminations and can pass into parallel laminated and cross-bedded calcarenites. Exceptional deep channels (up to 5 m) have been observed in Cala Calamoni, SE from the town of Favignana; channels are filled by laminated calcarenites and massive calcarenites with scattered bivalve shells. Direction of chan- nels are generally N-S, (NW-SE to NE-SW) and locally W-E[4].

Facies Association D is also characterized by the occurrence of *Scolithos* ichnofacies (Figs 10c-e, 11a), in some localities the *Scolithos*-type traces cross the earlier bioturbated zones (Fig. 10e); less common there are *Cruziana* (*Thalassinoides* and *Ophiomorpha*) ichnofacies linked with the colonization windows. Concentration of vertical burrows at the top of the bed is often observed (Fig. 10d). Mainly between Punta S. Nicola and Madonna traces of Echinoidea have been observed. In the central part of the Island, near the town of Favignana, in very thick cross-bedded and subhorizontal laminated calcarenites, several horizons with *Scolithos* are observed (Fig. 11a). Locally, there are cluster burrows represented by straight radial tubes (few millimeters thick) and tens of cm long (Fig. 10g), which resemble that traces which were made by colony of social insects (CURRAN, 1992). The planar, radial and bifurcated structures (Fig. 10h) can represent root system of plants. The presence of rooted plants in the Pleistocene sediments

3 Less common are thick-bedded calcarenites, with big scale through cross-bedding, Locally, there are sets of bi-directional cross bedded bodies, lenses of medium- and fine-grained structurless calcarenites and intercalations of calcirudite represented generally by matrix-supported conglomerates with rhodoliths (few cm in size), fragment of shells (mainly bivalves, locally Dentalium) and sporadic pebbles of Mesozoic limestones. Sporadically shells of bivalves (Fig. 10a) and Echinoidea are concentrated on surfaces of cross-bedding.

4 In some places, near the top of the beds, convolute laminations or single small conical forms are visible, the dimension of convolute raises several tens of cm (Fig. 10b). Locally, there are sets of small, rotated synsedimentary normal faults (Fig. 11b). In few places small parallel dunes, 30 cm of width, which upper surface can be covered by scattered shells and rhodolithes, are locally developed on the upper surface of calcarenites.

*Associazione di Facies B (zona uppershore), area di Punta Longa, a sud della città di Favignana. a) Conglomerato costituito principalmente da rodoliti, a stratificazione incrociata nella sua parte superiore. Il Nord è verso destra. L'unità di misura è di 1 m; b) Particolare, concentrazione di gusci di molluschi disposti orizzontalmente. Nella parte inferiore è visibile la stratificazione incrociata. La lunghezza del temperino è 6 cm; c) Calcarenite massiva con stratificazione incrociata mal definita ricoperta da calciruditi a stratificazione incrociata che passa verso terra a calcareniti grossolane. Le superfici di strato registrano eventi di tempesta. Si noti una faglia sul lato destro della foto (F). L'unità di misura è 1 m; d) calciruditi suborizzontali, a gradazione inversa con clasti maggiori isolati, troncati da una superficie di erosione sulla quale poggiano calcareniti grossolane e conglomerati, inclinati verso mare, fortemente bioturbati. Si notino le tracce fossili verticali tipo Scolithos. Alcune di queste attraversano l'unità più bassa. Meno visibili sono i Thalassinoides sviluppati sulle superfici di strato inclinate – confronta la Fig. 3g. Vedi la penna per la scala; e) Sequenza sedimentaria che inizia con calciruditi contenenti rodoliti e frammenti di gusci, seguiti da strati orizzontali (f), passanti verso l'alto a calcareniti a stratificazione obliqua, incrociata, bioturbate (cr) e ricoperte da calcareniti tipo hummocky (b). L'inclinazione delle lamine è verso il mare. La lunghezza della matita è 15 cm; f) Canale locale (Ch) nelle calcareniti suborizzontali grossolane con matrice pelitica. Questo canale, profondo 1,5 metri, è riempito da un gruppo di corpi sinusoidali a stratificazione incrociata inclinati verso terra. Nota la concentrazione di ciottoli (e.g. vicino il martello). Vedi il martello per la scala; g) griglia di Thalassinoides al tetto della sequenza mostrata in Fig. 3d. Nota gli strati sottili di peliti che sono molto rari nell'area di studio; h) dettaglio della griglia di Thalassinoides; i) a luoghi vi è anche la presenza sporadica di Ophiomorpha.*

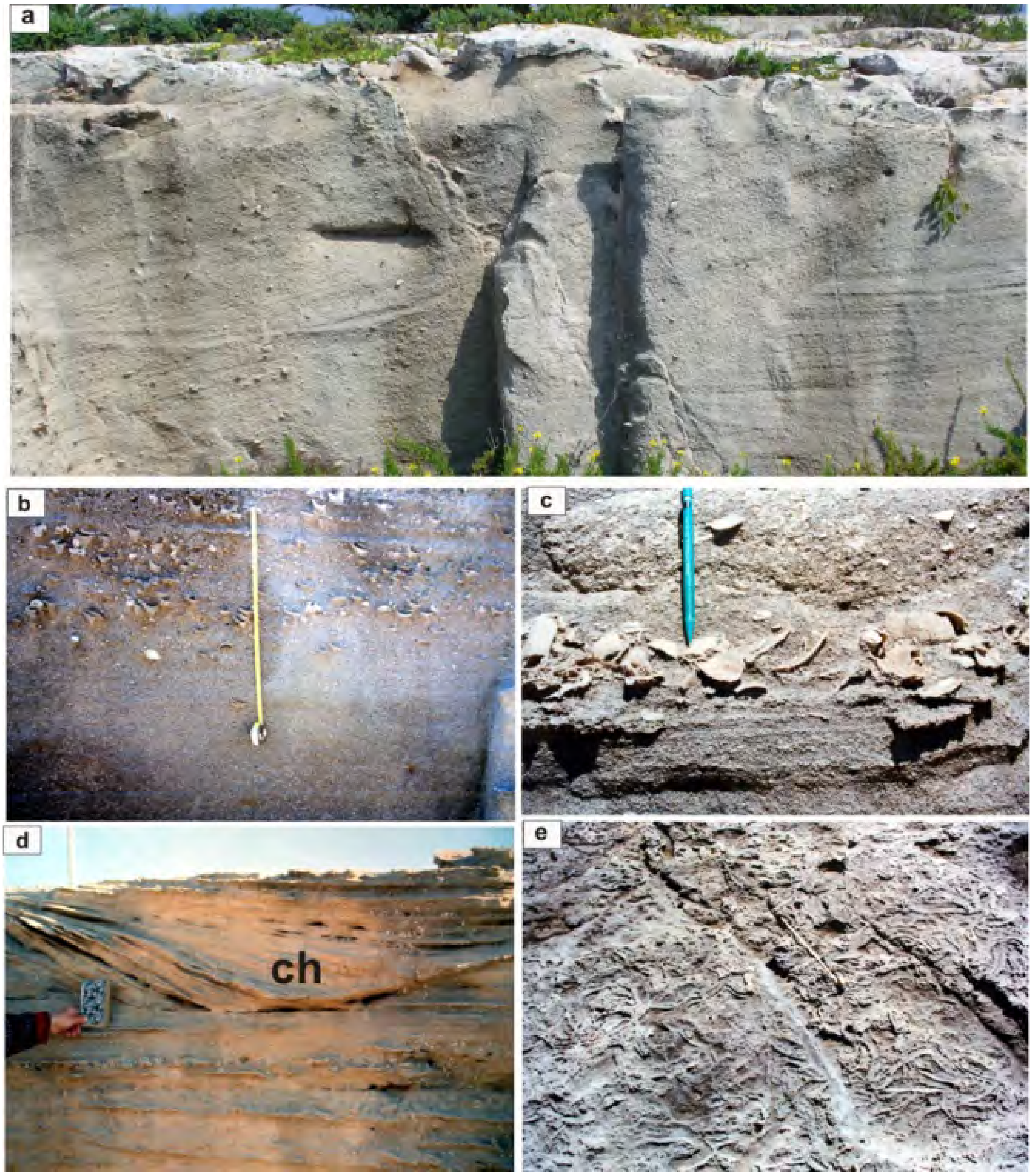


Fig. 6 - Facies Association C (shoreface zone), area east of Lido Burrone. a) Coarse grained, subhorizontal laminated calcarenite, partly eroded. Cross-bedding of calcarenite that fills eroded part is inclined towards SW (height of wall around 2 m); b) Horizontally laminated calcarenites with layers and patches of shells of moluscs in concave-upward position. Note their imbrications. Length of tape measure is 100 cm; c) Horizontally laminated calcarenites covered by horizon of imbricated fragments of Echinoidea shells and massive calcarenites with scattered fragments of shells. Pencil for scale; d) Upper surface of calcarenite covered by network of traces of Echinoidea. Length of tape-measure 100 cm; e) Small, longshore channel (Ch), 45 cm deep incised in medium bedded calcarenites that are cross-bedded in the lower part and horizontally laminated in the upper part. Length of note-book is 16 cm.

*Associazione di Facies C (zona di shoreface), settore orientale di Lido Burrone. a) Calcarenite grossolana, a laminazione suborizzontale, parzialmente erosa. La calcarenite a stratificazione incrociata che riempie i settori erosi è inclinata verso SO (l'altezza della parete è circa 2 m); b) Calcareniti a laminazione orizzontale con livelli di frammenti di gusci di molluschi con la concavità rivolta verso l'alto. Si noti la loro imbricazione. La lunghezza del nastro è 100 cm; c) Calcareniti a laminazione orizzontale ricoperte da orizzonti costituiti da frammenti embricati di gusci di echinoidi e calcareniti massive contenenti frammenti sparsi di gusci. Vedi la matita per la scala; d) superficie sommitale delle calcareniti coperta da una griglia di tracce di echinoidi. La lunghezza del nastro è 100 cm; e) Piccolo canale parallelo alla linea di riva (Ch), profondo 45 cm che incide gli strati calcarenitici caratterizzati da stratificazione incrociata nella porzione inferiore dell'affioramento e da laminazione orizzontale in quella superiore. La lunghezza del libretto è 16 cm.*

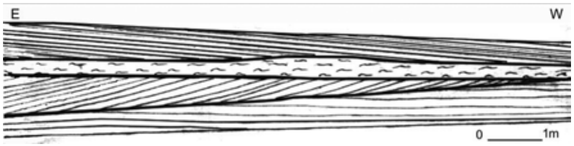


Fig. 7 - Facies Association D. Vertical facies succession started with subhorizontal laminated calcarenite with erosional top surface that is followed by wedge-like, seawards cross-bedded body and terminated by pervasive bioturbated part (colonization window). Probably an effect of one storm. Next succession starts with subhorizontal laminated calcarenite. Frascia, east from town of Favignana.

*Associazione di Facies D. Successione verticale di facies: in basso calcareniti a laminazione suborizzontale troncate al tetto da una superficie erosiva. Segue un corpo, con geometria cuneiforme, a stratificazione incrociata inclinata verso mare, ampiamente bioturbato nella parte terminale (colonizzazione a "finestra"), probabilmente per effetto di tempesta. La rimanente parte della successione inizia con calcareniti a laminazione suborizzontale. Località Frascia, ad est dell'abitato di Favignana.*

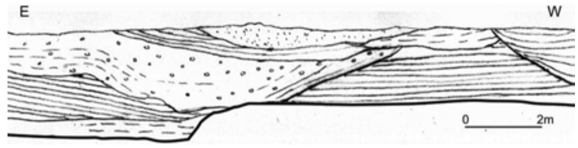


Fig. 8 - Facies Association D. Stack of several successive channels filled or by cross-laminated calcarenites or by, massive calcirudites with dispersed pebbles. Note that erosion removed practically all-preceding sediments. It clearly illustrates sediments of several exceptionally highenergy events. Frascia, east from town of Favignana.

*Associazione di Facies D. Sequenza verticale di diversi canali riempiti o da calcareniti a laminazione incrociata o da calciruditi massive con ciottoli sparsi. Nota che l'erosione ha praticamente rimosso tutti i sedimenti precedentemente deposti. Ciò mostra chiaramente che si tratta di eventi deposizionali ad energia molto elevata. Località Frascia, est dell'abitato di Favignana.*


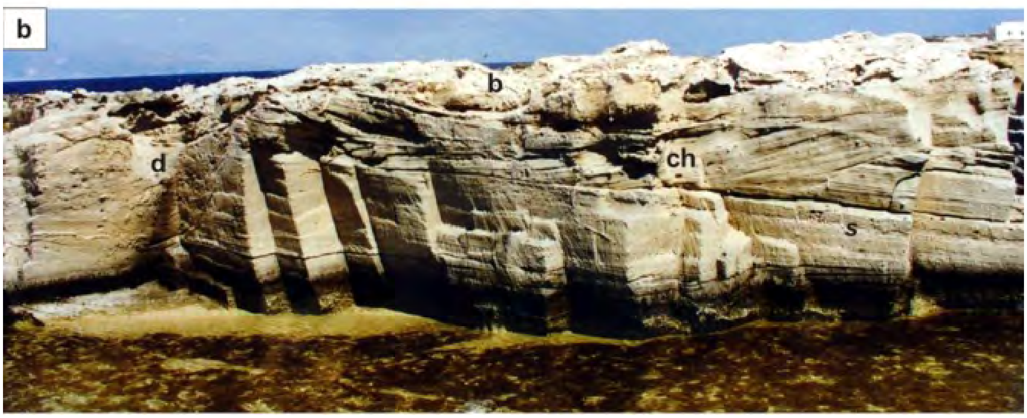


Fig. 9 - Facies Association D (shoreface zone), a) Large scale cross-bedded calcarenites and calcirudites dipping seaward. Note the seaward decrease on angle of cross-beds (pointed by arrow). Sparse sub-vertical burrows occur. Area of Frascia, near to town of Favignana, exposure along the shoreline; b) Laminated calcarenites inclined towards ESE cut by two channels, one a broad filled by laminated coarse grained calcarenites (ch) and other younger, deeper, with steep wall filed up by massive debrite (d) that represent sediments of cohesive flow. Direction of channels is generally W-E. Note several vertical burrows of *Scolithos* type (*s*). The uppermost part is strongly bioturbated (b). Wall is 4 meters high. More distal of shoreline exposure then on fig. a.

*Associazione di Facies D (zona di shoreface), a) calcareniti e calciruditi, con stratificazione incrociata a grande scala, immergenti verso mare. Da notare che l'inclinazione degli strati decresce verso mare (punta della freccia). A luoghi si rinvengono anche burrows subverticali. Affioramento lungo la costa nell'area di Frascia, vicino l'abitato di Favignana; b) Calcareniti laminate immergenti verso ESE, incise da due canali, il più grande dei quali è riempito da calcareniti grossolane laminate (ch) mentre l'altro più recente e più profondo, è riempito da detrito massivo (d) che rappresenta il prodotto di un flusso sedimentario coesivo. La direzione dei canali è generalmente O-E. Da notare anche la presenza di numerosi burrows verticali di tipo Scolithos (s). La porzione più elevata della sezione è fortemente bioturbata (b). La parete è alta 4 metri. L'affioramento è più distante dalla costa rispetto alla fig. 9a.*

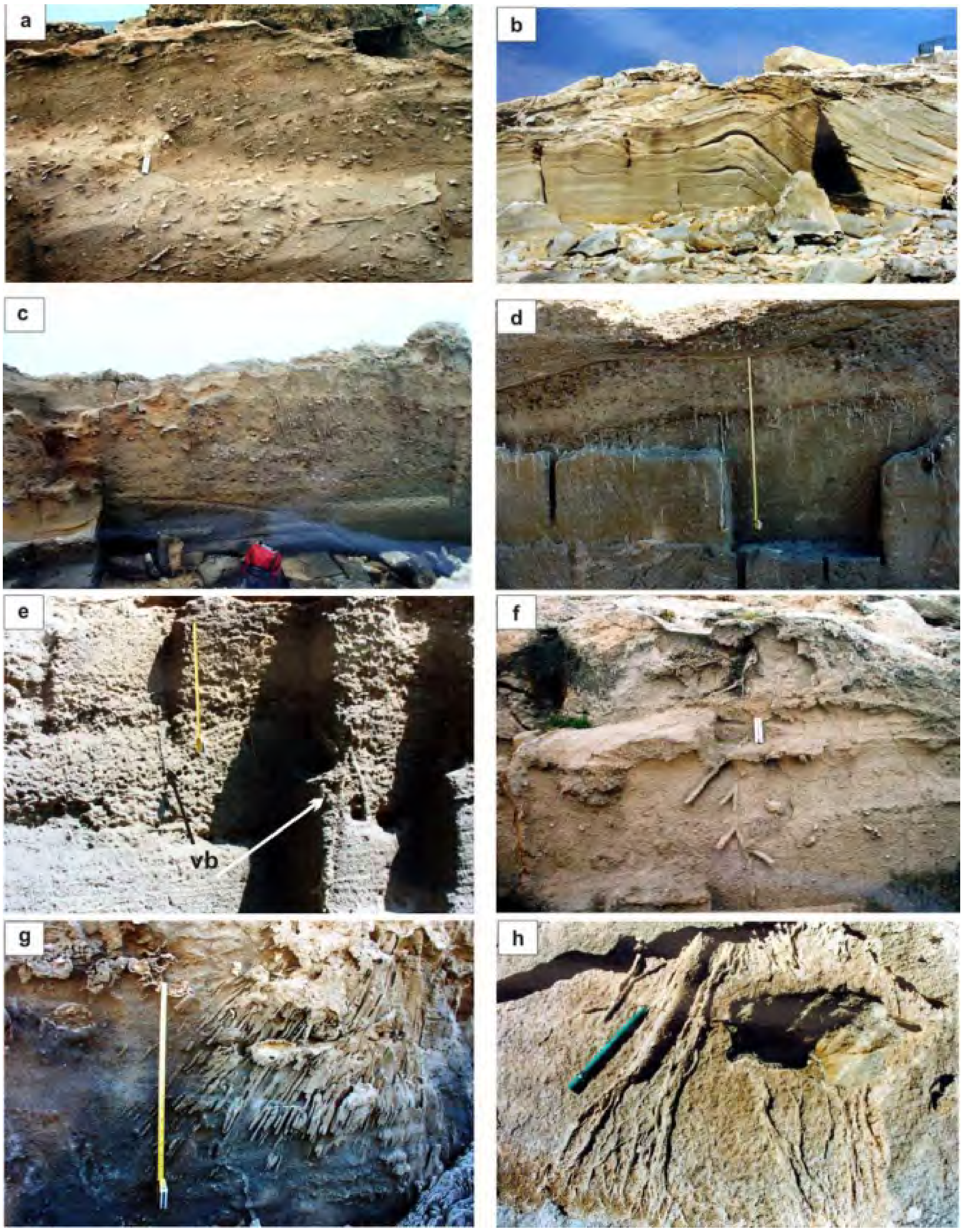


Fig. 10 - Facies Association D (shoreface zone) a) Calcirudite with scattered molluscs shells. Note increase of on angle of cross- bedding toward left (landward). Storm triggered sediments. Penknife is 6 cm long; b) Bending of laminated calcarenites due probably to synsedimentary folding connected with vertical movement of substratum. Wall aprox. two meters high; c) Set of vertical burrows of *Scolithos* type that cut massive calcirudite. Rucksack for scale; d) *Scolithos* ichnogulid. Note two sets of vertical trace fossils: older formed below upper erosional surface (colonization window) in calcarenite and younger in calcirudite that locally penetrated the lower calcarenite. Length of tape measure 100 cm; e) Totally bioturbated level cut by younger vertical burrows (vb). Length of tape measure 100 cm; f) detail of a branched vertical burrow in calcarenite. Penknife is 6 cm. long; g) Bundle of vertical tubes that resemble a colony of insects. Length of tape measure 50cm; h) Structure on upper surface of calcarenite that resemble root traces, probably mangrove type of plant. Pencil for scale.

*Associazione di Facies D (zona di shoreface) a) Calcirudite con gusci di molluschi sparsi. Si noti l'aumento dell'angolo di inclinazione verso sinistra (verso terra). Deposito di tempesta. Il temperino è lungo 6 cm; b) Calcareniti con geometria curviforme dovute a piegamenti sinsedimentari connessi con le deformazioni verticali del substrato. La parete è alta circa 2 m; c) Set di burrows verticali del tipo Scolithos dentro la calcirudite massiva. Per la scala vedi lo zaino; d) Ichnofacies di Scolithos. Si notino i due set di tracce fossili verticali: il più antico si è formato nella calcarenite sotto la superficie erosiva superiore (finestra di colonizzazione) il più giovane, invece, dentro la calcirudite e localmente ha penetrato le calcareniti. La lunghezza del nastro è 100 cm; e) Livello completamente bioturbato attraversato da burrows verticali più recenti (vb). La lunghezza del nastro è 100 cm; f) dettaglio di un burrow verticale e ramificato dentro la calcarenite. Il temperino è lungo 6 cm.; g) Fascio di burrows verticali che assomigliano ad una colonia di insetti. La lunghezza del nastro è 50 cm; h) Struttura sulla superficie superiore delle calcareniti che assomiglia a una traccia di radice, probabilmente tipo mangrovia. Vedi la matita per la scala.*

were already noted by D'ALESSANDRO *et al*,. (1993) in the Bradano Trough (South Apennines). In several places, calcarenites beds are cut by faults, some of which become extinct upwards within the sandbodies.

Depositional assemblages of sedimentary structures, existence of coarse lag of shell debris, lateral changes of facies, frequent channels, disorganized shell debrites sequences, similar to hummocky sequences of DOTT & BOURGEOIS (1982), are characteristic for high-energy shoreface environment (CLIFTON, 2006; ELLIOT, 1986; WYSOCKA, 2002). Planar laminated sets reflect highest current velocities and covering them cross-bedded lenses the decreasing of energy conditions (*cfr*. CLIFTON, 1976). The thick bedded, large-scale cross-beds of calcarenite and calcirudite, that developed in western part, near the town of Favignana, with bioturbated intervals (*Cruziana* ichnofacies), can represents remnants of shoreface zone with seaward prograding wedges (POMAR & TROPEANO, 2001; MATEU-VICENS *et al*., 2008). More seaward part, with differentiated facies, relatively abundant washouts and channels and common *Skolithos* ichnofacies probably represents inner bars system (BRIDGE & DEMICCO, 2008; CLIFTON, 2006; DAVDSON-ARNOTT & GREENWOOD, 1976). The prevailing ichnofacies, represented by *Skolithos* ichnofacies, in this area represents more shallow conditions than *Cruziana* ichnofacies (SEILACHER, 1967, PEMBERTON *et al.*, 1992). Also, big-scale planar cross-bedded bodies, observed east of the town of Favignana, with tiers of *Scolithos* ichnofacies, can represent a local inner bar system generated by longshore currents. Washouts and channels that cut the inner shoreface longshore bars were created by rip currents, generated from long shore ones (CLIFTON, 1976-2006; DAVDSON-ARNOTT & GREENWOOD, 1976). The channels size increased with magnitude of storm. Occurrence of stacks of storm surge channels, cut through calcarenite beds and filled commonly by storm sedimentary breccias (storm lag deposit), are indicative of periods of frequent storms occurrence. Very deep erosional channels, with sedimentary breccia that derived from the shoreline and transported seaward on distance almost 2 km, could be related to surges and debris flows (CLARK & PICKERING, 1996), generated by very high energy events (hurricanes and probably also tsunami TINTI, 1993). The latter could be the effect of submarine earthquakes, generated by local tectonic movements that existed during Late Pleistocene. Vertical changes of bioturbation characters (pervasive bioturbation and *Skolithos* type) can represent water depths changes, generated by synsedi-

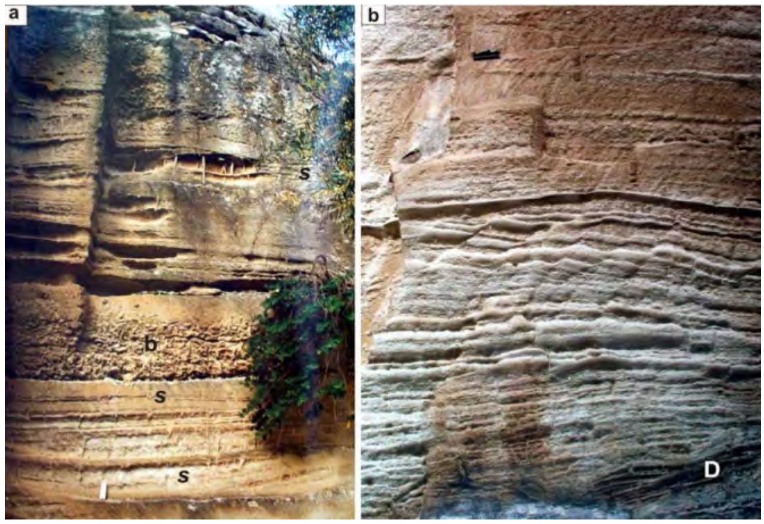


Fig. 11. continued - Facies Association D. a) Vertical stacking of subhorizontal and low-angle laminated calcarenites with abundant vertical burrows (s) and pervasive bioturbated horizons (b). Penknife (white) is 6 cm long. Cala Calamoni, abandoned quarry on west outskirts of the town of Favignana Town; b) Sequence of parallel laminated coarse grained calcarenites that rest on the flat symmetrical dune (D) around 30 cm high. Note normal synsedimentary fault system at the top of the lower layer. Penknife (black) is 6 cm long. Another part of the same quarry as on Fig.7a.

*continua - Associazione di Facies D. a) Sequenza verticale di calcareniti con laminazioni suborizzontali ed a basso-angolo, con abbondanti burrows verticali (s) ed orizzonti ampiamente bioturbati (b). Il temperino è lungo 6 cm. Cala Calamoni, cave abbandonate alla periferia ovest della città di Favignana; b) Sequenza di calcareniti grossolane a laminazione parallela, espressione di parte di una duna simmetrica e piatta (D) alta circa 30 cm. Da notare la presenza di un sistema di faglie dirette sinsedimentarie normali al tetto dello strato più profondo. Il temperino è lungo 6 cm. Altro settore della cava di Fig. 7a.*

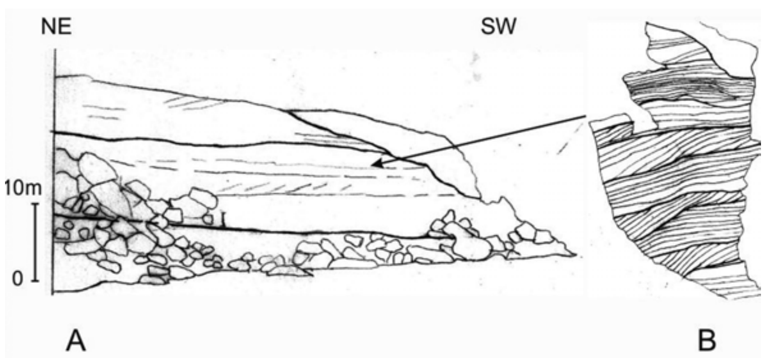


Fig. 12 - Facies Association E. a) Vertical stacking of several horizontal and cross-laminated calcarenites that continue over a length of tens of meters, separated by subhorizontal surfaces represented probably temporary wave base levels. Note a huge channel on the left side of the picture, deep more than 10 meters, it is filled up by massive calcirudites. Slope lithofacies. Cliff below Cala Torretta, NW from Calarossa; b) Detail of Fig. 12A. Note a vertical stacking of double sandbodies that are represented by horizontal and cross-laminated calcarenites. Cross-lamination dipping to SE (seaward), ch = channel.

*Associazione di Facies E. a) Successione verticale di calcareniti a stratificazione orizzontale e a laminazione incrociata continua per decine di metri, separata da superfici suborizzontali che probabilmente rappresentano temporanei livelli di base delle onde. Da notare un canale di notevoli dimensioni sul lato sinistro della figura, profondo più di 10 metri, riempito da calciruditi massive. Litofacies di scarpata. Cala Torretta, a NO di Calarossa; b) Dettaglio di Fig. 12A. Si noti la successione verticale dei corpi sabbiosi costituiti da calcareniti a stratificazione orizzontale e a laminazione incrociata, inclinata verso SE (mare), ch = canale.*

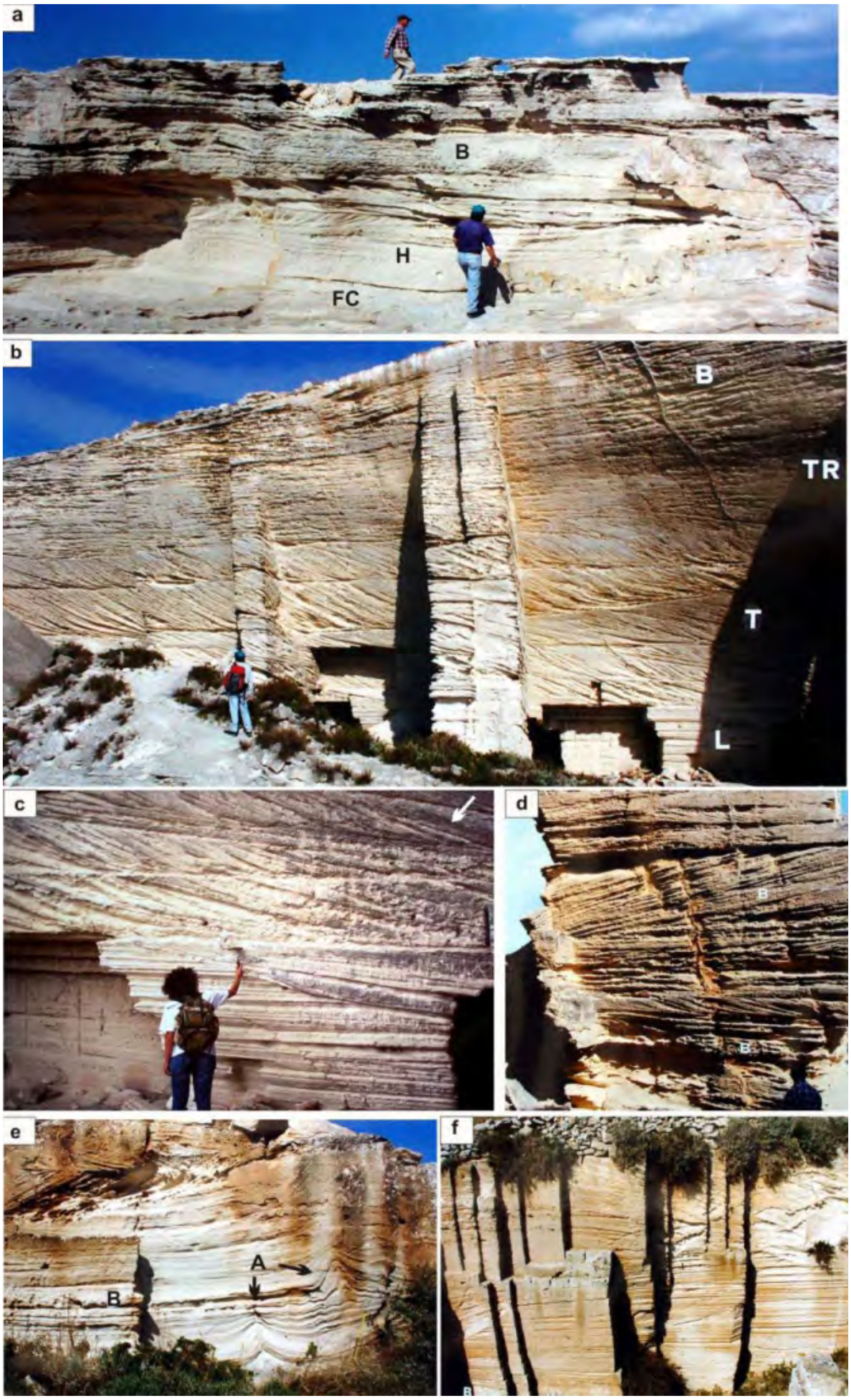


Fig. 13 - Facies Association E (lower shoreface zone with bar system). Area between Torretta and Bue Marino. a) Lower part of the Association E. Sequence started by fine-grained calcarenites (FC) followed by subhorizontal laminated calcarenites (H and set of bi-directional cross-bedded calcarenites covered by horizontal layers coarse grained calcarenites partly pervasive bioturbated (B). Cross lamination is inclined to S and NW. That sequence show resembles to Facies Association C. Punta Marsala; b) Lower part of Facies Association E. Sequence started with parallel laminated calcarenites (L) overlaid by cross-bedded zone (T) that have oblique to sigmoidal stratification facing SW (shoreward), and terminated by set of medium scale trough cross-bedding (B) resembling hummocky cross-bedding, with bioturbated horizons. Note flat dunes. Probably crest or landward slope part of an outer bar. Cliff in Calarossa; c) Detail of Fig. 12a that show internal architecture of cross-bedded facies. Note the diminishing inclination of cross-lamination on lee side of dunes (white arrow); d) sequence of medium to large-scale bi-directional tabular cross-bedding calcarenite bodies. Bue Marino; e) synsedimen-

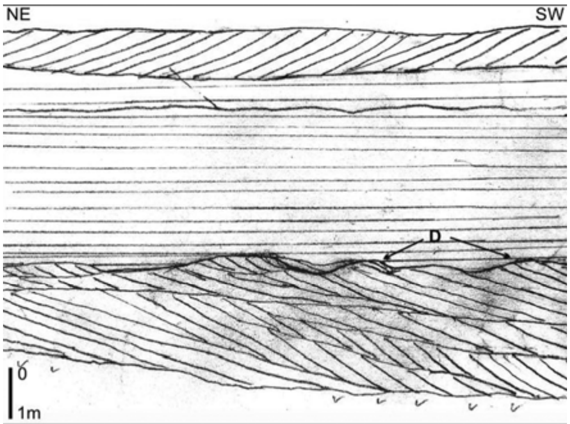


Fig. 14 - Top of a bar with medium-sized dunes at the top (D, arrows) with foreset inclination oblique to paleo-shore line. Lower part of Facies Association E. Calarossa.

*Top di una barra seguita da dune di medie dimensioni (D, frecce) con inclinazione dei foreset obliqua rispetto alla paleolinea di riva. Parte più bassa dell'Associazione di Facies E. Calarossa.*

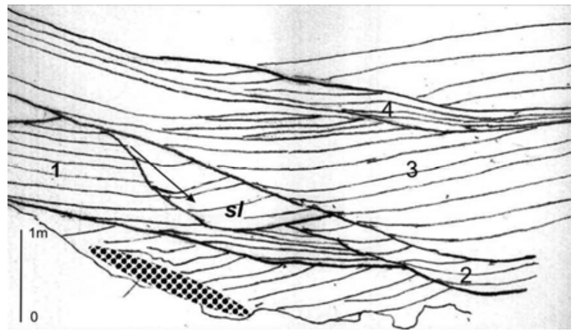


Fig. 15 - Stack of erosional channels (1-4) filled by laminated calcarenites. Arrow indicates slumped block (sl) of a normal synsedimentary fold. Note that sedimentary structures in slumped block are only partly disintegrated. Current directions generally perpendicular to the face of photograph. Facies Association E. Punta S. Vituzzo.

*Pila di canali erosivi (1-4) riempiti da calcareniti laminate. La freccia indica un blocco scivolato (sl) di una piega sinsedimentaria. Si noti che le strutture sedimentarie nel blocco scivolato sono disintegrate solamente in parte. Le direzioni delle correnti sono generalmente perpendicolari alla fotografia. Associazione di Facies E. Punta S. Vituzzo (Cala Rossa).*

mentary tectonic activity, as well as by sea level changes. They were also responsible for temporary appearance of very shallow environments, that are suggested by occurrence of traces of mangrove type root system and sub-aerial dunes with cluster burrows, which are regarded as insects burrows (CURRAN, 1992). Development of synsedimentary faults, escape of water structures was also triggered by tectonic activity, as suggested by synsedimentary, meters-in-scale, folds and convolutions (LOWE, 19751976). However, some of them, that developed within gently inclined foreset cross-lamination, could be also generated by local slumps (ŁAPTAS, 1992). The general lack of sediments with structures that represent fair-weather conditions (fine-grained sediments, oscillation small-scale cross bedding) may be an effect of bottom erosion during successive storm (CLIFTON, 1976). A more outer part of Facies Association D, observed near Capo S. Nicola, where traces of Echinoidea appear, can represents a local phenomenon or more deeper part of shoreface. It shows similarity to Facies Association C. Direction of inclination of cross laminations within Facies Association D document that calcareous sand was transported generally southeastwards, obliquely to the shoreline. Seaward transport was less common. Landward sand transport from reworked more distal bars is now visible only locally.

### 3.5 Facies Association E

The lowermost part of this Facies Association, whose contact with the underlying Facies Association D is sharp, starts or with a layer (tens of cm thick) of broken shells, covered by cross-bedded calcirudites seaward dipping (Cala Canaleddi), or with a thick, homogenous bed of calcarenite covered by a tabular cross-bedded interval that close with a pervasive bioturbated layer (Calarossa).The thick sequence of large-scale cross-bedded and subhorizontal laminated bedforms are the most characteristic feature of this Association (Fig. 12), outcropping in the easternmost part of the Favignana Island, between the localities of Cavallo and Bue Marino; the Facies thickness reaches more than

tary conical structures (A) of different size probably created by escape of water. Bioturbated horizon (B) pinching out towards one of these structures. At the top of subhorizontal there is a sequence of bi-directional foresets. Torretta, Calarossa; f) uppermost part of the bar sequence, parallel laminated in the lower part and large scale crossbedded in the upper part. Inclination of foresets is seaward. Note bioturbated horizon (B) in the lower part of the photograph. Cala Fossofelle.

*Associazione di Facies E (shoreface suddivisa da un sistema di barre). Area tra Torretta e Bue Marino: a) porzione più profonda dell'associazione E. Inizia con calcareniti molto fini (FC) seguite da calcareniti a laminazione suborizzontale (H) e da un set di calcareniti a stratificazione incrociata bi-direzionale ricoperto da strati orizzontali di calcareniti grossolane, a luoghi bioturbate in maniera pervasiva (B). La laminazione obliqua è inclinata verso S e NO. La sequenza è simile all'associazione di Facies C. Punta Marsala: b) parte più profonda dell'Associazione di Facies E. Inizia con calcareniti a laminazione parallela (L) ricoperte da un intervallo a stratificazione incrociata (T) che possiede una stratificazione da obliqua a sigmoidale verso SO (mare), e termina con un gruppo di corpi a stratificazione incrociata (B) simili a stratificazioni gibbose (hummocky), con orizzonti di bioturbazione. Si noti la presenza di dune piatte. Probabilmente la cresta o il lato interno costituivano parte di una barra esterna. Scogliera di Calarossa; c) Dettaglio di Fg. 12a che mostra l'architettura interna della facies a stratificazione incrociata. Si noti che l'inclinazione della stratificazione incrociata diminuisce sul lato di protezione delle dune (freccia bianca); d) sequenza di corpi calcarenitici tabulari a stratificazione incrociata bi-direzionale a media-grande scala. Bue Marino; e) strutture coniche sinsedimentarie (A) di diversa taglia, probabilmente effetto di fughe d'acqua verso l'alto per improvviso carico sedimentario. Orizzonte bioturbato (B) che si rastrema verso una di queste strutture. Al tetto del corpo sub-orizzontale vi è una sequenza di foresets bidirezionali. Torretta, Calarossa; f) parte più elevata della sequenza di barra, laminazione parallela nella parte più bassa e stratificazione incrociata a grande scala nella parte superiore. L'inclinazione dei foresets è verso mare. Si noti l'orizzonte di bioturbato (B) nella parte più bassa della fotografia. Cala Fossofelle.*

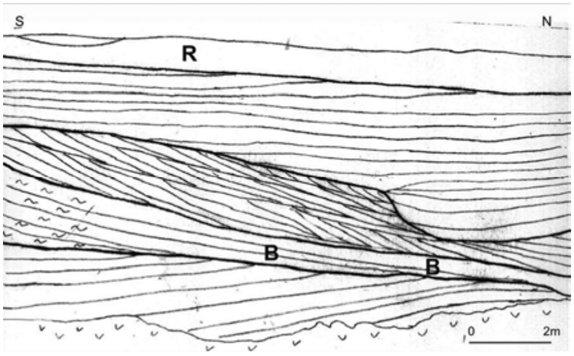


Fig. 16 - Higher part of the Lower Pleistocene sequence started with large cross-bedded calcarenites that dipping to NW (landward) covered by calcarenite with low angle seaward dipping lamination and by set of cross-bedded calcarenites with at least two orders of bounding surfaces. Upper surface of this set is erosional and covered by thick sand body with subhorizontal lamination that terminated by ripple laminated calcarenites (R). Note that bioturbation in cross-bedded calcarenite, on the right side of the picture, marked by letter B, disappears to the left, in more elevated part. Facies Association E, upper part of a bar system. Cala Fossofelle, Case Di Vita.

*Parte più elevata della sequenza del Pleistocene inferiore che inizia con calcareniti, a stratificazione incrociata a grande scala immergenti verso NO (verso terra), ricoperte da calcareniti laminate debolmente immergenti verso mare e da un gruppo di strati di calcareniti a stratificazione incrociata. La superficie superiore di questo gruppo di strati è erosiva ed è ricoperta da uno spesso corpo sabbioso con laminazione suborizzontale che termina con calcareniti laminate con strutture da ripple (R). Si noti che la bioturbazione nelle calcareniti a stratificazione incrociata, sul lato destro della figura marcato dalla lettera B, scompare verso sinistra nella parte più elevata. Associazione di Facies E, parte superiore di un sistema di barra. Cala Fossofelle, Case Di Vita.*

40 meters in Cavallo-Torretta area. This Facies in Calarossa and Cala Canalleddi area rest directly on the uplifted Lower Pliocene marls (ABATE *et al*., 1995-1997) or sediments similar to Facies Association C[5]. The main part of this Facies is built of thick- and very thick-bedded sequences of, coarse-grained calcarenites, with subhorizontal and/or low angled lamination, and of calcarenites with large-scale cross-bedding (Figs 12, 13b,f). Calcarenites with hummocky cross-lamination (Fig. 13b, uppermost part) also occur. Seaward- and landward-directed, as well as shore-parallel, sets of cross bedding are observed (Fig. 13 b, d, and e)[6].

The majority of calcarenite beds presents lower and upper sharp, erosional surfaces. However, locally higher horizontal laminated bedform rest on non-eroded rippled upper surface of the lower bed. Calcarenite beds form bodies long some of tens of meters, each gradually wedging out; lateral changes of facies have been observed. Locally, asymmetric, cross-bedded mega-ripples (few tens centimeters high and several meters long) are preserved (Fig. 14). Also, symmetrical sandwaves (up to 50 cm high and several meters of length), built-up of homogenous sand have been observed on the top of horizontal laminated calcarenites. In more western (landward) part (Torretta area), visible fragment of Facies Association sequence two, almost flat, erosional surfaces divide into three parts (Fig. 12a) each calcarenitic body. Each part shows complex internal structures; particularly the middle one consist in subhorizontal stack and in cross-bedded sandbodies (Fig. 12b). This organization is preserved on distance of tens of meters, with local landwards opposite direction of cross-bedding. At Calarossa and Bue Marino localities, the outer part of calcarenite body is characterized by cross-bedding dipping both landwards (Fig. 13b, c), as well seaward (Figs 13b-f, 14 and 16). Somewhere, single or sets of medium-sized conical or diapiric structures can be observed at the top of horizontal laminated body (Fig. 13e). Cross- and horizontal-bedded calcarenites are cut by several channels, generally filled up by cross-laminated bodies (Fig. 13e); locally, stacks of channels are visible (Fig. 15). A small synsedimentary slump was formed along the wall of channel (Fig. 15). In topmost part of the sequence there broad channels filled by cross stratified bodies have benn observed (left part of Fig. 13f and Fig. 16), locally the filling shows lags of pebbles and rhodolithes or of debrites at the bottom, graded in their lower portion and containing scattered rhodolithes and shell fragments. Along the western boundary of Cavallo locality exceptionally large and deep channels were developed: one of them, more than 10 meters deep, is infilled by homogenous calcarenites (fluxoturbidite type; ŚLACZKA & THOMPSON, 1981); another one, tens of meters broad and more than 15 meters deep, is visible along the northern cliff of the same locality (Fig 12a). Intercalation of layers of pervasively bioturbated calcarenites (from dozen centimeters to one meter thick) occurs locally (Fig. 13a, b, and f). A typical feature of some cross-bedded bodies consists in laminated-to-bioturbated pattern, similar to those described by D'ALESSANDRO & MASSARI, (1997): normal and bioturbated laminae are alternate (Fig. 13c). In some cases, only a lower part of inclined laminae shows bioturbations (Figs. 13e and 16). Sporadically, traces of Echinoidea occur in the lower part of the sequence. *Scolithos*-type of burrows is extremely rare and occurs in higher part of the sequence. Bioturbation disappear in the highest part of the sequence (Torretta).

Coarse-grained and conglomeratic sandbodies, occurring in the lowest part of Facies Association, more than two kilometers from the ancient shoreline, probably represent storm-reworked beds, redeposited from the shoreline and distributed on the shallow shelf, east from paleo-Favignana Island, by high energy currents. The main part of Facies Association E consists of mixed facies of thick and very thick bedded, planar or cross-laminated, sandbodies, showing often characteristic facies succession from planar and/or crossbedded to hummocky-like and/or medium trough cross-lamination, bounded by unconformity with local channels represents the outer part of shoreface zone, marked by offshore bars/ridges system related to storm high-energy epi-

5 In Punta Marsala where Facies Association E is underlayed by Facies Association C the profile starts with trough cross-bedded fine-grained calcarenite, horizontally laminated, fine-grained muddy calcarenites (Fig 13a), with traces of Echinoidea, covered by layer (up to 50 cm thick) built-up of shell fragments covered by several meters calcarenite, generally pervasive bioturbated.

6 Locally, in elongated lens-like bodies, laminae are sinusoidal, and cross-bedded sandbodies form tabular cossets. The ripple cross-laminated bodies (up to 1.5 m thick) locally rest on tabular cross-stratified or horizontal laminated sandbodies.

sodes (BRIDGE & DEMICCO, 2008; CLIFTON, 2006; ELLIOT, 1986; JOHNSON & BALDWIN, 1986). Long lasted, wind-induced currents deposited thick, seaward-dipping cross-bedded calcarenites, spreading out on distance of hundreds meters. A submarine bar system, probably developed along an uplifted block of the pre-Pleistocene platform and run generally from north towards south. Stacks of bedforms with subhorizontal lamination and through cross-bedding dipping seaward and landward, with decrease of bioturbation and occurrence of erosional channels, can be regarded as crest part of bar facies, similar to suggestion of DAVIDSON-ARNOTT & GREENWOOD (1971). Seaward slops of bars are probably represented by a sequence, where number of bioturbated bedforms and sets of small scale trough increase in number and where generally the planar bedding dips seawards.

This successions are exposed in Bue Marino area, in the easternmost part of the Favignana Island. Occurrence of layers, with offshore and onshore dipping sets of cross-bedding, shows on periodical migration of dunes sea- and shoreward by wave induced currents, but seaward movements predominated. The magnitude and direction of all of these currents was varying during weather and long-term sea-level changes, and was also connected with vertical tectonic movements. It can be suggested that the observed bedforms were generated by giant long periods waves and by related surges, such as those generated by propagation of hurricanes and/or tsunamis into shallow water areas (D'ALESSANDRO & MASSARI, 1997; TINTI, 1993). Periods of high wave energy were interrupted by fair weather periods, during these latter wave cross-ripple beds develop and the sea bottom was colonized by burrow animals of *Cruziana* ichnofacies while the upper part of deposited bedforms was intensively bioturbated. The occurrence of bioturbation suggests favorable conditions only in lower part of foreset laminae thus suggesting the persistence of a sea depth useful for a better concentration of food. On the contrary the uppermost part of sequence, totally devoid of trace fossils, can represents facies of short duration aeolian dune. Considerable thickness of Facies Association (over … m), the lacking of distinct changes of facies in vertical profile and of distinct progradation suggest a fault-induced lowering of this part of offshore area. Flat erosional surfaces near Cavallo area show similarities to shoreface erosion planes described by ELLIOT (1986): temporary tectonic uplift could be create an effect of sea-level changes of a part of the shelf, thus increasing the erosion by wave actions: it removed clastic material from higher part of the uplifted bar toward deeper sea.

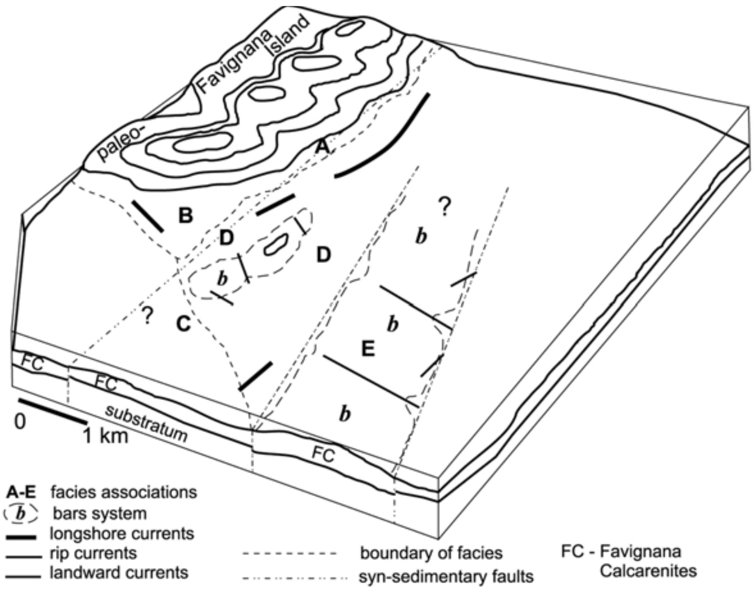


Fig. 17 - A model of currents distribution and Facies Associations, east from paleo-Favignana Island. Prevailed southward longshore currents. Scale bar dimension is approximate. Vertical scale is roughly estimated.

*Modello della distribuzione di correnti e delle associazioni di facies ricostruite per il settore orientale della paleo-isola di Favignana, caratterizzata dalla prevalenza di correnti dirette verso sud parallele alla riva. Le scale, orizzontale e verticale, sono approssimative.*

## 4. CONCLUSIONS

The distribution of bedforms, sedimentary structures and ichnofacies allow to distinguish eastwards from shoreline of paleo-Favignana Island several characteristic Facies Associations connected with foreshore/shoreface (F A **A**), upper shoreface (F A **B**), upper/middle shoreface (F A **D**) and lower shoreface (F A **E**) depositional zones with a system of inner bars (F A **D** *p.p.*) and outer bars (F A **E** *p.p.*) parallel or oblique to the shoreline separated by trough (F A **C**) (Fig. 17-18). Widely distribution washouts, rip channels and sediments of tractional currents in all Facies Associations suggest deposition above wave-base level. Temporary developed partly emerged dunes have been recognized. Only negligible part of clastic material was derived from erosion of uplifted part of paleo-Favignana Island that probably had greater northward extension, however bulk of the bioclastic material accumulated on Favignana inner shelf originated from shoreline material and is composed of debris from molluscs, calcareous red algae, bryozoan, foraminifera, etc. The main role in distribution of clastics was played by storms that induced strong and very strong longshore currents along the shoreline: These currents were shunted offshore and cut and filled channels across the bars. Landward movement of clastic

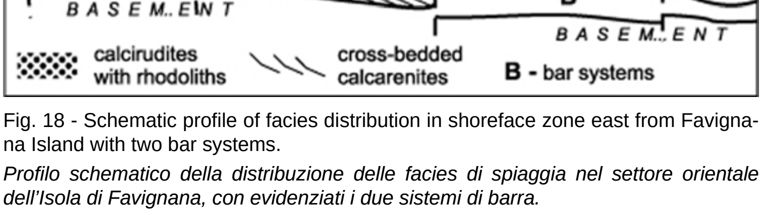


Fig. 18 - Schematic profile of facies distribution in shoreface zone east from Favignana Island with two bar systems.

*Profilo schematico della distribuzione delle facies di spiaggia nel settore orientale dell'Isola di Favignana, con evidenziati i due sistemi di barra.*

material and the development of megarippled dunes has been observed locally, due to high energy landwards waves. During tsunami-related high-energy events scattered large erosional structures were probably formed. Similar events triggered local debris flows. Storm-generated sedimentation units are underlined by the erosion surfaces on which some channels, up to tens meter wide and several meters deep took place. Besides storm wind-induced currents were active producing longshore and rip currents that deposited seaward dipping cross-bedded calcarenites which spread out on distance of hundreds of meters. The storm periods were separated by fair weather intervals: cross-ripple beds were colonized by population of burrowing organisms thus producing pervasive bioturbation. The bioturbated deposits were frequently eroded by series of storms. During intense storm the erosion cut deeper part of dunes and episodic, low angle dipping surfaces;. the development of such erosional surfaces was also controlled by uplifting of the substratum and by relative change of the sea level. Synsedimentary strike-slip tectonics were besides reported for Favignana area. The relevant thickness of the Facies Association E, more than 40 meters, also suggests a generalized fault-induced downward movements of the substratum[7]. Typical vertical and lateral sequences of sedimentary structures in storm deposits were represented by subhorizontal lamination succeeded by about-planar cross-bedding, hummocky type cross stratification or/and rarely wave ripple lamination. The top of sequence is often bioturbated, as an effect of recolonization by fauna during fair weather.

The recognized Facies Associations also differ in ichnofacies content: in FA **A** ichnofossils are rare and mainly represented by short vertical tubes; in FA **B** wide areas are colonized by *Thalassinoides* and, more rarely, by vertical burrows (*Cruziana* and *Skolithos* ichnofacies); in FA **C** traces produced by Echinoidea; in FA **D** *Skolithos* ichnofacies and horizons pervasively bioturbated are common, locally cluster of insects burrows have been oberved; in FA **E** trace fossils are rare and are limited to few traces of Echinoidea and some vertical burrows, while pervasive bioturbated horizons are common.

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7 Also locally observed sharp differences in thickness and facies between Facies Associations could be fault-induced, as proposed for similar phenomena in upper Cretaceous shelf sandstones in Sudetes by Wojewoda (1986).

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