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Morpho-sedimentary setting and evolution of Marettimo Valley (Egadi Islands, Sicily) during middle-late Quaternary: interaction between sea level changes and oceanographic circulation

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Abstract **– We present morphological and stratigraphic results coming from surveys acquired in a NNW-SSE trending submarine depression (Marettimo Valley) located in the Egadi Islands (western Sicily offshore). In this area the seafloor is characterized by both depositional and erosional features generated under a variety of sedimentary processes.**

We identified two seismic facies units that are correlatable to: A) the progradation of shallow water (coastal to offshore) deposits during forced-regression sedimentary process, and B) contourite drifts emplaced by geostrophic currents through the Marettimo Valley. This unusual association of very shallow water contourites and shelf margin deposits originates, during middle-late Pleistocene glacio-eustatic cycles, from enhanced sedimentary dynamics establishing mutual interaction between progradational growth of the margin and bottom current deposition.

I. INTRODUCTION

Along the Mediterranean continental margins, insular sectors can display a very complex depositional pattern as result of the interaction between sea level changes, oceanographic processes and uneven sea floor morphology. We present morphological and stratigraphic results coming from integrated seismo-acoustic surveys acquired in a narrow (minimum width of 1.8 km, 30 km long) NNW-SSE trending submarine depression (Marettimo Valley) located in the Egadi Island Archipelago (western Sicily offshore; Fig. 1). This area is located along the pathway of the Levantine Intermediate Water current (LIW) which, coming from the eastern Mediterranean Sea, flows clockwise around the western Sicily margin. Moreover, in the archipelago, where a shelf-to-slope system can be identified, the sea floor shows a very irregular morphological setting. This peculiar setting offers good opportunity to investigate as sea level change and oceanographic regime combine each other to control the morpho-sedimentary evolution of the margin during the middle-late Quaternary interval.

II. DATA AND METHODS

We analyzed and interpreted a grid of middle-high resolution single-channel seismic reflection profiles recorded with different seismic sources: sub-bottom chirp, 1 kJ sparker, 4.5 kJ sparker. Seismostratigraphic techniques and sequence stratigraphy principles has been applied to the stratigraphic interpretation.

Morphological analysis has been performed using a 20x20 m sized cell digital elevation model acquired by means of multibeam swath batimetry survey. During all the surveys, the vessel's position was obtained by a DGPS system.

III. RESULTS

A. Seismostratigraphic analysis of the outer shelf progradational units

Along the eastern flank of the Marettimo Valley, the outer shelf consists of a stack of progradational units. The seismic profile of Fig 2 images two main progradational seismic units and a third one of smaller size interbedded between the main two. The following seismic facies attributes characterize these units: very thin oblique-tangential clinoforms (up to 45 m high) associated with reflection-free or sparse chaotic seismic signals; inside both the main wedges, well-developed bottom sets display higher amplitude and lateral continuity than the foresets. In the lowermost and oldest progradational unit (LPU) a small mound-shaped unit with chaotic seismic

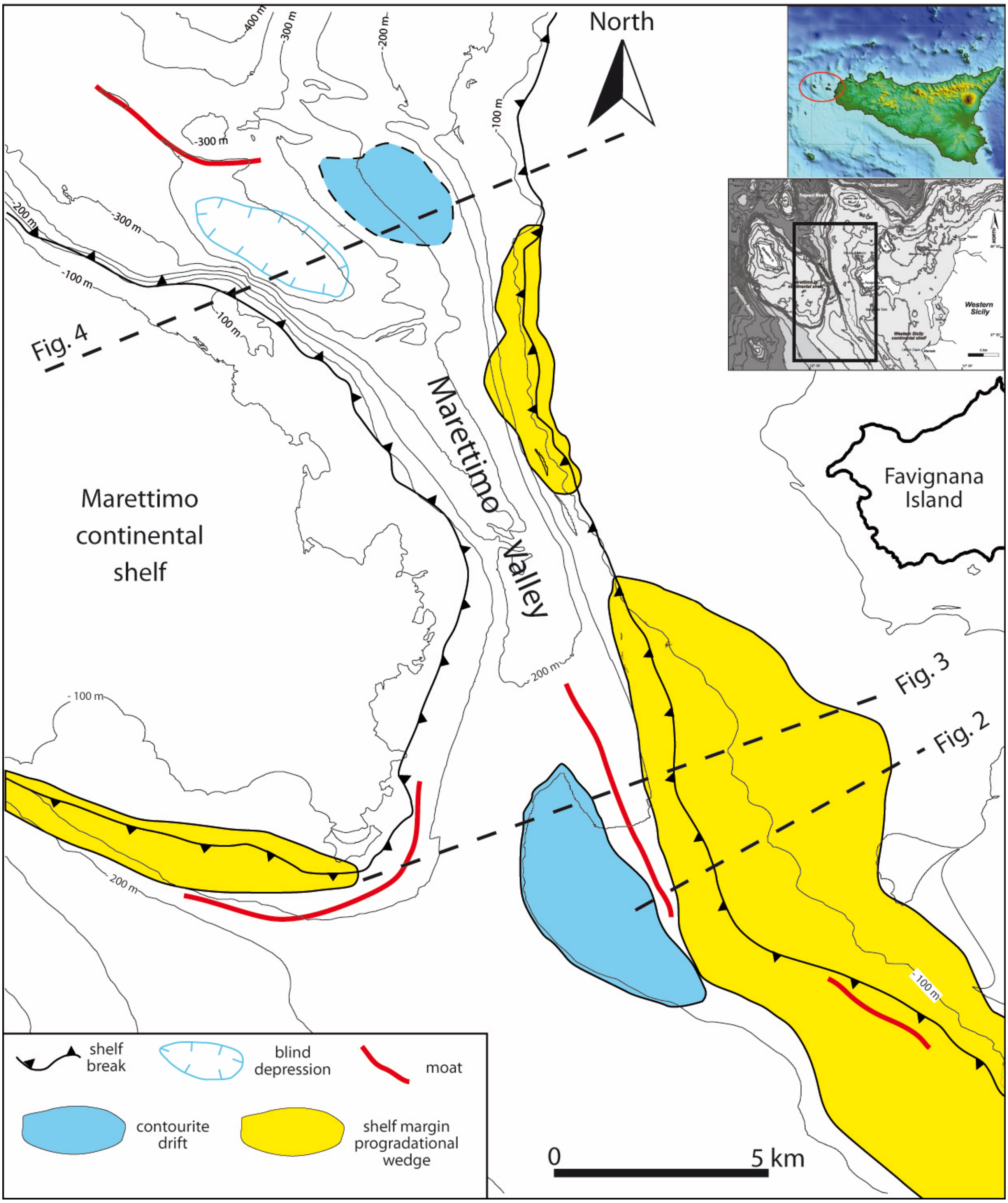


Fig. 1 – Bathyetry of the Marettio Valley and carthography of the main morpho-sedimentary features.

facies is interbedded between the bottom-set. The intermediate progradational unit (IPU) is the smallest one and displays very short oblique-parallel clinoforms with downlap lower termination. Inside the uppermost and

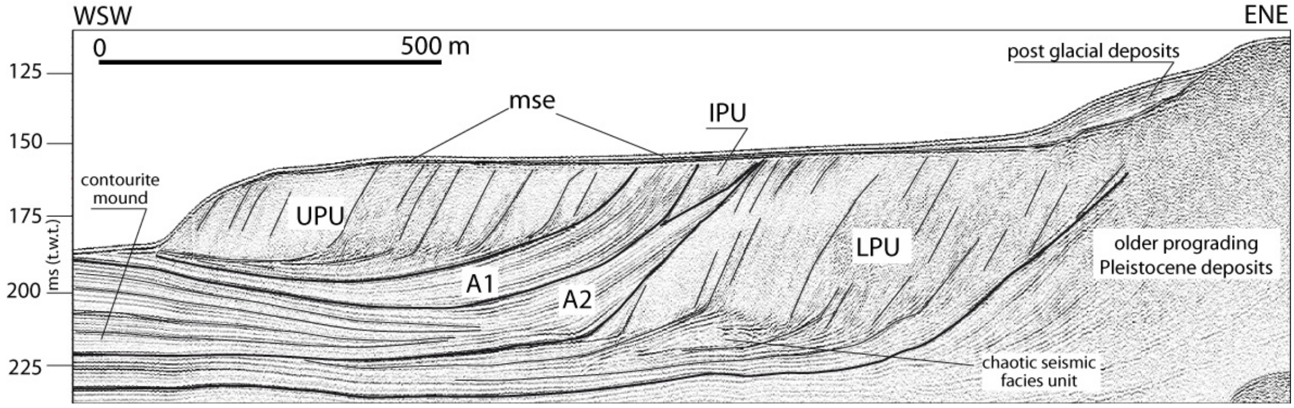


Fig. 2 – Single-channel (1 kJ Sparker source) seismic profile showing the stratigraphic setting of the eastern flank of the Marettimo Valley; seismic units and surfaces are illustrated in the text (see Fig. 1 for location).

younger one progradational unit (UPU), local erosional surface truncate the oldest bottom sets (Fig. 2).

The lower boundary of these progradational units is represented by a downlap surface seawards passing to a conformity surface where bottoms sets are concordant to underlying seismic reflectors. The upper boundary corresponds to a sharp erosional truncation surface.

Across the outer shelf, the three progradational units are separated by depositional units (A1 and A2) showing the following seismic facies: continuous, concave-upward reflectors with lens-shaped or mounded external geometry. These units display landward onlap termination on the outer boundary of the LPU and IPU. Moreover they display evident lateral variation of thickness: the lower one displays a gradual seaward increase of thickness, forming a mounded geometry beyond the shelf edge; the upper one displays a gradual seaward decrease of thickness.

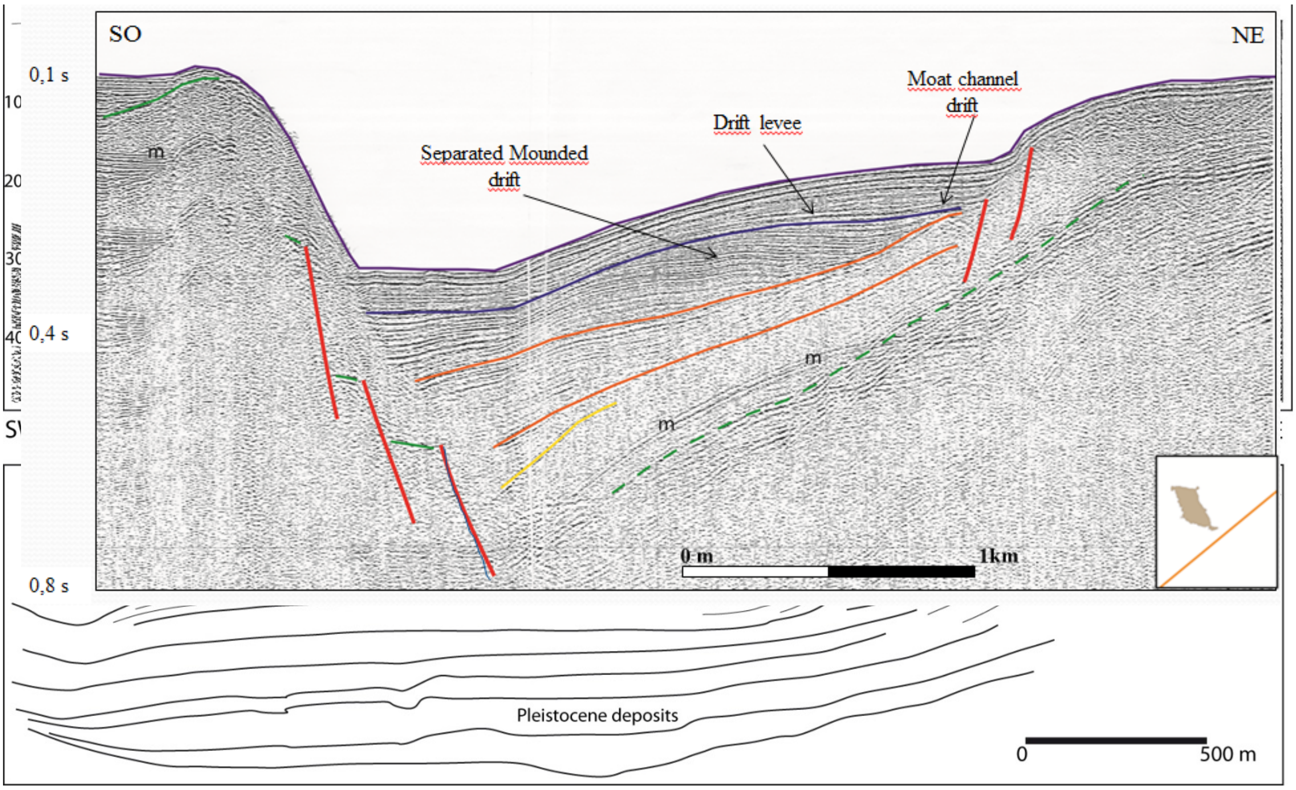
B. Morpho-stratigraphic analysis of upper slope depositional and erosional features

Along the Marettimo Valley a series of depositional and erosional features has been detected. At the southern mouth of the valley a depositional unit is located, which shows a mounded external geometry with a maximum thickness of about 50 m (using a sound velocity in sediments of 1600 m/s) and maximum amplitude of about 3000x6000 m (Fig. 3). The internal configuration is characterized by thin, continuous, convex-upward reflectors with an overall aggrading geometry. Besides an internal, faint, local erosional surface can be detected (Fig. 2), which separates two sub-units, with the lower one thicker.

This mounded unit corresponds to the uppermost portion of the Pleistocene succession along the central sector of the Marettimo Valley. The upper boundary of this unit outcrops at the sea floor where it reaches the shallowest water depth of 135 m; the lower boundary is a conformity surface in the slope, lying up to 190 m below the sea level. Toward the Favignana shelf this conformity surface passes to an onlap surface (Fig. 2). Upward, along the flanks of the mound, the sea floor is scoured by two narrow erosive channels (Fig. 1): that one close to the Marettimo Island shelf margin turns around the shelf edge and it is the most incised of the two ones (the western flank is up to 40 m high); the channel close to the Favignana Island shelf is less incised (both flanks are up to 10 m high), NNW-SSE trending and it ends southwards where the contourite drift is attached to the shelf margin and is partially buries underneath the UPU wedge.

In the central-northern sector of the Valley, some erosional features have been detected (Fig. 1): i) a blind depression with about NW-SE trending elliptical shape which is not completely filled by sediments; inside this depression the sea floor lies at about 375 m water depth; ii) northward of this depression a NW-SE trending erosive channel 400 - 600 m wide, about 4 km long, is located, with asymmetrical flanks up to 40 m high; iii) moreover, along the sea floor of this northern sector, sharp erosional surfaces of small extension have been detected.

Toward the North, another mounded depositional unit has been detected. It consists of thin, aggrading, convex upward horizons characterized by a slight upslope migration and a very small channel moat in the upper portion of the deposit. Towards the slope the horizons display onlap lateral termination highlighting an



unconformity surface, corresponding to the lower boundary of the mound, which overlay a growth sedimentary wedge that thickens toward the Marettimo Island slope, where a step of syn-sedimentary normal faults has been observed. The mound is buried beneath a 0.1 s thick package of parallel horizons.

IV. DISCUSSION

A. Forced regression deposits

Both seismic facies attributes and stratigraphic pattern suggest the sedimentary progradational wedges observed along the Marettimo valley flanks could be regressive depositional units formed in shallow water environments during sea level falling stage and lowstand. These attributes are: the prograding internal configuration, which is common for coastal-to-inner shelf deposits; the low amplitude up to reflection free seismic facies, due to the high slope of the horizons (up to 25°, probably because of the coarse sediment size); the stratigraphic setting along the outer shelf where the most recent sedimentary outward accretion originated the present day shelf margin.

Sedimentary successions with very similar features have been illustrated and also calibrated (see [1] and [2], among others), confirms this interpretation. In particular, our results document as the prograding wedges are coastal lithosomes (beaches or deltas) formed during subsequent erosive regression process forced by sea level fall and following lowstand stages, that can be correlated to middle-late Quaternary glacio-eustatic cycles.

Peculiar features that characterize the shelf margin prograding wedge of the Marettimo Valley are (Fig. 2): i) the progressive seaward decrease of the clinoforms height and wedge thickess, as consequence of deposition of former bottomsets; ii) the erosional truncation of older bottomsets (in the youngest wedge), probably due to landward dip of the basal downlap surface.

The two depositional units A1 and A2, interbedded between the three progradational wedges LPU, IPU and UPU, are interpreted as “healing phase” deposits accumulated during sea level rise stage, because of their stratigraphic setting and onlap landward terminations above the former, present day buried, shelf margin wedges (units LPU and IPU).

B. Bottom current related deposits

The overall morpho-stratigraphic characters of the sedimentary deposits detected along the upper slope inside the Marettimo Valley (external geometry, internal configuration, lateral terminations) and the close relationships with the related erosional features (moat channels and erosional surfaces), suggest that both the deposition of these units and the shaping of these features were controlled by bottom currents.

Indeed, the following seismic features are similar to that ones already extensively illustrated, during the past few decades, for oceanic, deep water contourites by many studies (see Rebesco et al. (2014) for a review): the upwardly convex geometry of internal horizons on dip section with some evidence of moat features; the presence of internal, minor erosional surfaces; the upslope migration of internal horizons (only for the northern contourite drift).

However, a main different feature of these shallow water contourites respect to that of deep oceanic basins is the size, since that they are much smaller and, moreover, they show a greater morphological variability even at short distances, as already illustrated by several Authors ([3], [4], [5]; among others) for other sectors of the Mediterranean Sea. In detail, very similar morpho-depositional features have been illustrated by [6] southward of the Egadi Islands, not far from the Marettimo valley.

As highlighted by [7], some seismic features shown by the contourite drift can be very similar to that of turbiditic deposits, but in the case of Marettimo valley we exclude a relationships with mass transport processes because of the absence of both a feeding system and the typical sedimentary features characterizing turbiditic deposits (as channel-levee complexes and depositional lobes).

According to the summary of the different types of contourite drifts proposed by [7], the overall morpho-stratigraphic features of the bottom current-controlled deposits, here illustrated, suggest the southern one can be classified as “confined mounded drift” and the northern one as “separated mounded drift”.

Therefore, we suppose the described Marettimo Valley deposits are contourite drifts originated by long-lasting bottom currents flowing along the Egadi Islands upper slope. Due to the recent age of these deposits, we can interpret them in the context of the present day physiographic setting and water depth and taking into account the oceanographic regime under which they formed. Notwithstanding no detailed oceanographic data coming from this area are available, we suggest that the LIW, flowing counterclockwise along the western Sicilian margin, could originated the observed sedimentary features, by means of a modification of the flow as consequence of the lateral confinement caused by the Marettimo Valley. The latter could determine an acceleration of the LIW current moving to the North through the Valley. Preliminary hydrological measures acquired at the southern mouth of the Marettimo valley (F. Placenti, per. com.) don’t exclude the possibility that a very shallow portion of the LIW (along the Mediterranean margin, the LIW flows in a depth range between – 200 and – 400 m) could penetrate inside the Marettimo Valley during the highstand stage. On the contrary, it is very unlikely that this penetration could occur during the lowstand stage when the shallowest point of the valley is only about - 60 m deep. Moreover, stratigraphic relationships imaged by seismic profile document that the contourite deposits laterally pass to etheropic and coheval outer shelf deposits (units A1 and A2) that are interbedded between depositional units IPU and LPU and that accumulated during sea level rise. This observation supports the hypothesis that, the southern, confined mounded drift didn’t deposited during the lowstand interval.

According to this hypothesis, we further suppose the uppermost portion of the LIW stream, as the current flows northward in the Marettimo Valley, undergoes a progressive acceleration as the Valley narrows, to a point in the central sector, where no more sediments can be accumulated, but only erosive or not depositional features are formed, such as the observed moat, erosional surface and blind depression. Following towards the northern mouth of the valley, the flow declines and favorable conditions for deposition of sediments transported by bottom current restore, giving rise to the northernmost drift.

V. CONCLUSIONS

The complex middle-late Quaternary depositional pattern highlighted along the shelf-to-slope system of the Marettimo Valley reflects mostly the interaction between sea level change and bottom currents and its variability during time. In fact bottom currents create a flow energy that control the maximum quantity of sediments that can be accumulated and, thus, the accommodation space along the valley. According to our morpho-stratigraphic interpretation, this energy barrier acted in the Marettimo Valley only during the highstand intervals, when both bottom current penetrated into the Valley and its variable width have generated different type of depositional and erosional structures. During the lowstand, the water depth inside the valley was too shallow to allow the flow of long-lasting bottom curren. In these stages, the eastern flank of the Valley accreted outward by means of forced regression with the deposition of inner shelf to coastal regressive sedimentary succession.

The close association of shelf margin regressive deposits with very shallow water contourite-like deposits must be taken into account in reconstruction of ancient deposits to highlight the possible existence of outer shelf-upper slope paleoenvironments characterized by peculiar morphological setting as insular archipelago and submarine valley. The finding of the correlated facies association could be relevant for what concern paleogeographic and paleooceanographic reconstructions as well as the hydrocarbon exploration, because these successions could be sandy prone and may constitute good reservoirs.

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