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Delta growth and river valleys: the influence of climate and sea level changes on the South Adriatic shelf (Mediterranean Sea)

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ABSTRACT

Incised valleys across continental margins represent the response of fluvial systems to changes in their equilibrium dynamics, mainly driven by base level fall forced by glacial–eustatic cycles. The Manfredonia Incised Valley formed during the last glacial sea level lowstand, when most of the southern Adriatic shelf was sub-aerially exposed but the outer shelf remained under water. The pronounced upstream deepening of the valley is ascribed to river incision of the MIS5e highstand coastal prism and related subaqueous clinoform under the influence of MIS5-4 sea level fluctuations, while the downstream shallowing and narrowing mainly reflects the impact of increased rates of sea level fall at the MIS3-2 transition on a flatter mid-outer shelf. Until 15 ka BP, the valley fed an asymmetric delta confined to the mid-outer shelf, testifying that continental and deep marine systems remained disconnected during the lowstand. Sea level rise reached the inner shelf during the Early Holocene, drowning the valley and leading to the formation of a sheltered embayment confined toward the land: at this time part of the incision remained underfilled with a marked bathymetric expression. This mini-basin was rapidly filled by sandy bayhead deltas, prograding from both the northern and southern sides of the valley. In this environment, protected by marine reworking and where sediment dispersal was less effective, the accommodation space was reduced and autogenic processes forced the formation of multiple and coalescing delta lobes. Bayhead delta progradations occurred in few centuries, between 8 and 7.2 ka cal BP, confirming the recent hypothesis that in this area the valley was filled during the formation of sapropel S1. This proximal valley fill, representing the very shallow-water equivalent of the cm-thick sapropel layers accumulated offshore in the deeper southern Adriatic basin, is of key importance in following the signature of the sapropel in a facies-tract ideally from the shoreline to the abyss.

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1. Introduction

The shape of modern continental shelves reflects the interaction between allogenic and autogenic processes that act on time scales ranging, virtually, from seconds to millions of years (Moutain et al., 2007) and display several orders of magnitude (Allen, 2008; Romans and Graham, 2013). The stacking pattern of depositional sequences, their internal architecture and facies association can be explained as a function of the ratio between sediment supply and accommodation space, together with autoretreat principles (see Muto and Steel, 1997; Allen et al., 2013 for reference). At Quaternary scale, under Milankovitch orbital forcing and especially during the Late Pleistocene to Holocene transition, four major interrelated factors appear to govern sediment production, accumulation and preservation in the marine realm: eustatic fluctuations, climate change, oceanographic circulation and tectonics (Pratson et al., 2007). In addition, during the last few millennia, anthropic pressure on the environment has been exponentially increasing, and the role of humans in shaping natural landscapes must be considered of paramount importance (Vitousek et al., 1997; Hooke, 2000; Wilkinson and McElroy, 2007; Maselli and Trincardi, 2013a).

All the natural and anthropic factors mentioned above affect sediment production, transport across the continents and dispersal in the marine realm in a source-to-sink view. Incised valleys are key feature of sedimentary systems (Blum et al., 2013), especially during periods of sea level lowstand when they act as *highways* across

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the shelves for the sediments produced in catchments on land. In the last few decades, the study of incised valleys has been the focus of many research papers, involving people interested in fluvial and coastal evolution, paleo-climate reconstructions, sequence-stratigraphic models and exploration geology (Posamentier and Vail, 1988; Van Wagoner et al., 1990; Blum and Aslan, 2006; Strong and Paola, 2008; Bauer et al., 2009; Rodriguez et al., 2010; Martin et al., 2011). In order to ease the dialog among several research communities, a suite of different nomenclatures has been introduced, depending on where the incision took place (Zaitlin et al., 1994), the nature of substrate (Blum et al., 2013), the size (Ashley and Sheridan, 1994) and the shape (Simms et al., 2006) of the valley, as well as the presence of single vs. multiple erosional surfaces (Zaitlin et al., 1994) and the nature of their sediment infill (Simms et al., 2006). In particular, the rate and amplitude of the relative base level change (governed by the combination of tectonics and eustasy) and the morphology of a newly-exposed subaerial shelf determine the shape and depth of the incision (Schumm, 1993; Talling, 1998; Törnqvist et al., 2006), whereas the climate accounts for sediment production and delivery from the catchments, and for the oceanographic regime that, in turn, controls long-shore vs. off-shore sediment redistribution. In principle, the suite of facies preserved within a valley incision may record the complete transition from fluvial to open marine environments (the latter best developed in the case of underfilled incised valleys *sensu* Simms et al., 2006), typically organized in a shoaling upward backstepping configuration. In the case of post-glacial sedimentary systems, moreover, a well-developed valley fill succession represents one of the best archives to investigate past environmental change since glacial times.

The Manfredonia Incised Valley (MIV) is an example of a simple-fill system (*sensu* Zaitlin et al., 1994) that extends throughout the Apulian shelf (southern Adriatic Sea) with a west-east orientation (Fig. 1). Based on seismic facies associations, reflector geometries and cross-shelf seismic correlations, Maselli and Trincardi (2013b) suggested the timing of valley incision and a first interpretation of its sedimentary infill and chronology: the MIV reached its maximum seaward extent at the peak of the Last Glacial Maximum (LGM), correlating with the regional-scale lowstand unconformity, and was filled during the post-glacial sea level rise and modern highstand with an upward succession from fluvial to distal marine environments.

Through newly acquired high-resolution seismic profiles and sediment cores, sampled in the most distal and most proximal sections of the valley, and following a multi-proxy approach (including the study of micro- and macro-fauna assemblages, grain-size analyses, sediment magnetic susceptibility and ^{14}C radiocarbon dates), the aim of this paper is to better constrain the depositional environments recorded in the valley fill, its chronostratigraphic framework and the impact of short-term climatic and base level changes on the valley-fill sedimentary facies. The study of the MIV has also important sequence stratigraphic implications: as the valley 1- narrows seaward, 2- does not cross the entire shelf and 3- is completely filled, its study will reveal new insights about 1- the processes controlling valley incision and lateral erosion, 2- the source to sink sediment flux since sea level lowstand, and 3- the temporal correlation between the timing of valley incision and its internal deposition.

2. Study area

2.1. Geological setting

The Gulf of Manfredonia in the inner Apulian shelf represents the seaward domain of the Bradanic Trough (Figs. 1 and 2), the Pliocene-Pleistocene foredeep of the southern Apennine chain (Tropeano et al., 2002). The high-subsidence rates of the Bradanic Trough characterizing the Lower Pliocene sedimentation favored the deposition of a deepening succession of shallow-marine carbonates to hemipelagic deposits (Tropeano et al., 2002). This trend was interrupted when the collision between the 110 km thick subducting Adria plate and the front of the accretionary prism led to the uplift of the foredeep/foreland domains (Doglioni et al., 1994), as recorded by the Middle Pleistocene–Holocene shoaling up trend of marine-alluvial sequences (Amorosi et al., 2009; De Santis et al., 2010), now partially exposed in the Tavoliere Plain (Tropeano et al., 2002).

2.2. Background

The MIV formed during the MIS5-2 sea level fall, when the three main rivers draining the modern Tavoliere (the Candelaro, the Cervaro and the Carapelle rivers) merged in a single valley incising the Apulian shelf for more than 60 km eastward (Maselli and Trincardi, 2013b). The MIV reaches its maximum depth and width (45 m and 7 km respectively) in the modern inner shelf, and could be even larger and deeper approaching the modern coastal plain (De Santis et al., 2010). The valley shrinks toward the outer shelf, reaching a minimum incision of about 5–8 m seaward, where the flanks of the valley are at ca 85 m bsl. Seaward of the valley mouth, a well-defined prograding deposit, confined at the base by a regionally-extensive unconformity that correlates with the floor of the incised valley, extends parallel to the isobaths on the outer shelf (less than 110 m depth) without reaching the shelf edge (presently at 160 m water depth). The post-LGM sea level rise forced the paleo-shoreline to migrate landward, as recorded by the backstepping fluvial to distal marine sedimentary infill of the valley (Maselli and Trincardi, 2013b), and by an up to 30-m-thick record of transgressive deposits along the Adriatic shelf (Cattaneo and Trincardi, 1999; Maselli et al., 2011).

3. Material and methods

This paper presents new results from seismic profiles coupled with sediment cores collected at the two opposite ends of the MIV system: the distal lowstand deposits (outer shelf) and the proximal deeply incised valley fill, presently lying in less than 20 m water depth (Fig. 2). The choice of these two targets was dictated by the impossibility to piston-core the valley-fill deposits in the mid-shelf region (between 20 m and 80 m water depths), where the extremely thick sequence of Late Holocene highstand muds prevents the possibility to penetrate valley-fill deposits with conventional coring systems (see Fig. 2; Cattaneo et al., 2003).

High-resolution chirp-sonar profiles were acquired with a Teledyne Benthos Chirp-III SBP system, composed by a 16 hull-mounted transducer array, using a 2–7 kHz sweep-modulated bandwidth, which allowed a vertical resolution on the order of 50 cm. Seismic profiles were post-processed and visualized with SeisPrho (Gasperini and Stanghellini, 2009). Track-line positioning was based on D-GPS navigation, assuring a position accuracy of ca 10 m, and converted to geographic coordinates referred to the WGS84 datum.

Sediment cores were extracted using Piston and gravity corer devices, with variable barrel length (up to 20 m), and stored at 6 °C. X-ray core scanning was performed using a Gilardoni® MPX160 as a source and an amorphous silicon (a-Si) flat panel sensor (LANMIT®, Canon) as a detector. Magnetic susceptibility logs, sampled every 2 cm, were measured with a Bartington Meter model MS2.

AMS ^{14}C radiocarbon dates on mollusk shells were performed at the Póznan Radiocarbon Laboratory while the only sample of

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