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Late Quaternary incised and infilled landforms in the shelf of the northern Adriatic Sea (Italy)

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ABSTRACT

The northern Adriatic shelf is punctuated by the presence of several incised and filled features that have been revealed by the offshore seismic and stratigraphic surveys carried out in the last decades. In this study we analyzed an area located in the northern Adriatic shelf, 30 km offshore of the Venice Lagoon and between 29 and 34 m below the mean sea level, where the most impressive examples were identified. By integrating the interpretation of about 3000 km of high-resolution seismic profiles (CHIRP) with sediment cores, paleontological analyses and radiocarbon dates, it was possible to distinguish between two generations of incised features. The older generation (Nadia) is represented by a fluvial incised valley that reaches a depth of up to 30 m and was formed and infilled during the LGM marine lowstand, probably between ca. 26 and 24 ka cal BP. The peculiar horizontal layering displayed by the infilling is characteristic of a low-energy environment. This suggest that, after its formation, the valley was first occupied by a swampy environment, which was then gradually filled-up with sediments received from nearby riverine systems. Differently, the younger generation (Attila) consists of a set of tidal inlets and channels with a maximum depth of 20 m, which are the legacy of a transgressive lagoon environment. The tidal nature of these features is confirmed by the geometry and paleontological content of their infilling and by their overall morphological and morphometric characteristics. The transgressive lagoon where these channels developed probably existed for just few centuries in the Early Holocene (ca. 10–9 ka cal BP). This period likely coincides with a temporary deceleration or stasis of the sea-level rise rate. This work presents new results for the paleogeographic and paleoenvironmental reconstruction of the northern Adriatic area, covering a period that spans from the middle LGM to the beginning of the Holocene.

1. Introduction

The marine fluctuations that occurred during the last glacial-eustatic cycle led the coastal zones and continental shelves to experience strong environmental variations. These changes are associated to the progressive subaerial exposure of vast areas during the marine forced regression and lowstand phases, while the subsequent transgression induced their drowning (Fairbanks, 1989; Fleming et al., 1998; Blum and Törnqvist, 2000; Cattaneo et al., 2003; Lambeck et al., 2014). As generally observed on a global scale, these dramatic changes mainly affected the continental shelves, while along the present coastal belt only the last phase of transgression and the marine highstand (i.e. last 8000 years), left traces within the incised valleys infillings (e.g. Allen and Posamentier, 1993; Vis and Kasse, 2009; Breda et al., 2016; Clement et al., 2017) and in the highstand stratigraphy and landforms (cf. Vacchi et al., 2016).

Apart from few areas, in the Mediterranean Basin the first steps of the postglacial transgression are generally almost completely lacking because of the absence of the continental shelf or its very steep gradient (Benjamin et al., 2017 and reference therein). A peculiar situation characterizes the northern Adriatic Sea, where the shelf has a very low gradient (~0.4‰) and the distance from the present coastline to the shelf edge reaches 300 km (Fig. 1). This setting allowed to record part of the environmental changes that occurred during the Late Pleistocene and Holocene in the sedimentary structures and in the depositional geometries preserved beneath the seafloor. These features can provide valuable information on the sea-level rise history (e.g. Storms et al., 2008; Trincardi et al., 2011; Vacchi et al., 2016) and on the morphological response of the alluvial and coastal systems to climate changes and marine transgression (Maselli et al., 2011; Fontana et al., 2014).

The presence in the northern Adriatic of subtle and elongated sandy ridge-like features (Fig. 2), is interpreted as the legacy of barrier-island

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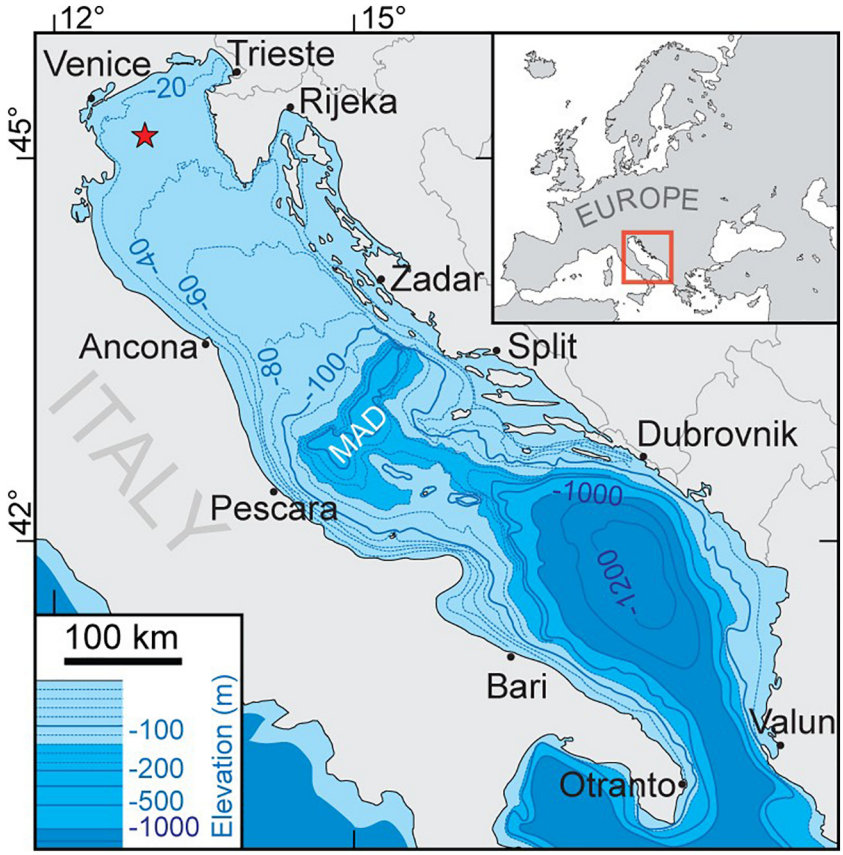

Fig. 1. Geographical location and bathymetry of the Adriatic Sea. The area analyzed in this study is indicated with a star.

systems formed during pulsations of the postglacial sea-level rise (Trincardi and Argnani, 2001; Cattaneo and Steel, 2003; Trincardi et al., 2011, 2014). These morphologies were strongly eroded and re-shaped after being drowned (Correggiari et al., 1996a; Storms et al., 2008; Trincardi et al., 2014).

Another group of important sea floor features located north of the Po Delta consists of infilled incised channels/valleys that currently have almost no bathymetric expression, but have been recognized through geophysical soundings and sediment cores since the early 90's (Trincardi et al., 1994, 2011; Correggiari et al., 1996b; Zecchin et al., 2008). These features have been generically described as “incised valleys” and their average characteristics (width: 150–500 m, maximum depth up to 25–30 m, fine-grain infill) make them rather similar to the late-Pleistocene fluvial incisions recognized in the distal sector of the Venetian-Friulian Plain (e.g. Carton et al., 2009; Mozzi et al., 2013; Fontana et al., 2014).

With the outbreak of the sequence stratigraphy the relation between incised valleys and relative sea-level change became a major research topic. The concepts related to the incised valleys formation, already described in the first seminal works (e.g. Van Wagoner et al., 1990; Hunt and Tucker, 1992; Dalrymple et al., 1994), have been revisited, refined and integrated during the last two decades (e.g. Blum and Törnqvist, 2000; Dalrymple et al., 2006; Boyd et al., 2006; Blum et al., 2013). Incised valleys constitute a major element in hydrocarbon exploration and paleoenvironmental reconstruction (Simms et al., 2010; Maselli and Trincardi, 2013; Bhattacharya et al., 2015). In particular, the fillings of Late Quaternary incised valleys often constitute the only available sedimentary records of the lowstand and transgressive phases on the shelf, which were generally erased by the marine transgression on the rest of the surface, especially on low-gradient shelves (Li et al., 2006; Nordfjord et al., 2006; Simms et al., 2010; Blum et al., 2013; Weschenfelder et al., 2014; Bogemans et al., 2016; De Clercq et al., 2018). We analyzed one of the most impressive group of these incised and filled features, that are currently located about 30 km offshore of the southern part of the Venice Lagoon (Fig. 2), in a sector where the depth of the present seafloor is about 30 m below present mean sea level (MSL). Through the analysis of a large dataset of seismic lines and cores retrieved during several oceanographic cruises, we reconstruct the planform and morphology of two different generations of channelized incisions and characterize their sediment infill, with the aim of understanding how the local and regional factors forced the evolution of these features. In particular, the stratigraphic sequence recorded by the infill of these incised landforms has been preserved from the erosive processes connected to the marine transgression. It therefore represents one of the few available archives that allow to investigate the processes and environmental changes occurred in the Adriatic shelf since the end of the last glaciation and to constrain the sea-level fluctuations that took place at the beginning of the Holocene, when the rate of transgression was high.

2. Settings

The Adriatic, a narrow and elongated epicontinental sea that separates the Italian Peninsula from the Dinaric-Balcanic mainland (Fig. 1), is located in the foreland basin existing between the Apennines, the Alps and the Dinarids. This structural setting is related to the convergence of Africa and Europe, which caused the subduction of the Adria microplate both under the Apennines and the Dinarids (Doglioni, 1993; Ghielmi et al., 2010). According to its structural, morphological and oceanographic characteristics, the Adriatic basin can be divided in three sectors from North to South. The northern Adriatic consists of a long shelf that is extending with a gentle slope (about 0.4‰) for > 300 km. A complex microrelief with metric undulations and local scours that can reach depths of 5 m characterizes the seafloor of this