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Research paper

# Genesis of the Northern Adriatic Sea (Northern Italy) since early Pliocene

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ABSTRACT

The Northern Adriatic Sea is a shallow and very flat shelf area located between the northern Apennines, the southern Alps and the Dinarides; its present day physiography is the result of the filling of a relatively deep Quaternary foredeep basin, developed due to the northeastward migration of the Apennine chain. Multichannel seismic profiles and well data have allowed documenting the stratigraphic architecture, the depositional systems and the physiographic evolution of the Northern Adriatic sea since early Pliocene time. In particular, three main depositional sequences bounded by regional unconformities were recognized. The Zanclean Sequence 1 documents first the drowning of late Messinian incised valleys and then the southward progradation of a shelf-slope system, which is inferred to be related to a tectonic phase of the Apenninic front. The Piacenzian-Gelasian Sequence 2 records a relatively rapid transgressive episode followed by minor southward progradation; the top of the sequence is associated with a major late Gelasian drowning event, linked to the NE-ward migration of the Apennine foredeep. The Calabrian to upper Pleistocene Sequence 3 testifies the infilling of accommodation previously created by the late Gelasian drowning event, and it initially accumulated in deep-water settings and then in shallow-water to continental settings. The upper part of Sequence 3, consisting of the paleo-Po deltaic system, is composed of seven high-frequency sequences inferred to record late Quaternary glacio-eustatic changes. These high-frequency sequences document the stepwise filling of the remaining accommodation, resulting in the development of the modern shelf.



## 1. Introduction

The Northern Adriatic Sea is a key area to study the environmental and physiographic evolution related to regional-scale tectonics, as it is located between three thrust-and-fold belts: the northern Apennines, the southern Alps and the Dinarides (Fig. 1). To perform such an analysis, we have used the sequence stratigraphic approach, mainly based on the recognition of main stratal surfaces, depositional systems and geometry of the sedimentary bodies. This approach is essential to reconstruct physiographic changes and the accommodation history of this region. Sequence stratigraphy represents a powerful tool to reconstruct past relative sea-level changes of different hierarchy related to eustasy, tectonics or the interplay of both, as documented by several examples (e.g., Posamentier and Allen, 1999; Jackson et al., 2005; Catuneanu, 2006; Neal and Abreu, 2009; Zecchin et al., 2011, 2012, 2013; Zecchin and Tosi, 2014). The study of the architectural variability of sequences may be useful to infer the possible control on accommodation development (Csato and Catuneanu, 2012). Systems tracts composing sequences are stratigraphic units bounded by sequence stratigraphic surfaces and formed by contemporaneous depositional systems (Brown and Fisher, 1977; Catuneanu et al., 2009); their study, requiring both sedimentological and stratigraphic approaches, is very useful to reconstruct the evolution of both depositional environments and physiography of sedimentary basins through time (e.g., Massari et al., 2004; Csato et al., 2013, 2015; Zecchin et al., 2012, 2013; Zecchin and Tosi, 2014). This is particularly relevant in those contexts where tectonic deformation leads to large transformation of the physiography, such as in thrust-and-fold belts, forearc and thrust-top basins, foredeeps, forelands, as well as in rift contexts (e.g., Leckie and Smith, 1992; Embry, 1993; Marzo et al., 1998; Ravnås and Steel, 1998; Jackson et al., 2005; Ghielmi et al., 2010, 2013; Zecchin et al., 2012; Csato et al., 2013, 2015; Zecchin and Tosi, 2014; Rossi et al., 2015).

Previous studies performed in the study area and in the adjacent

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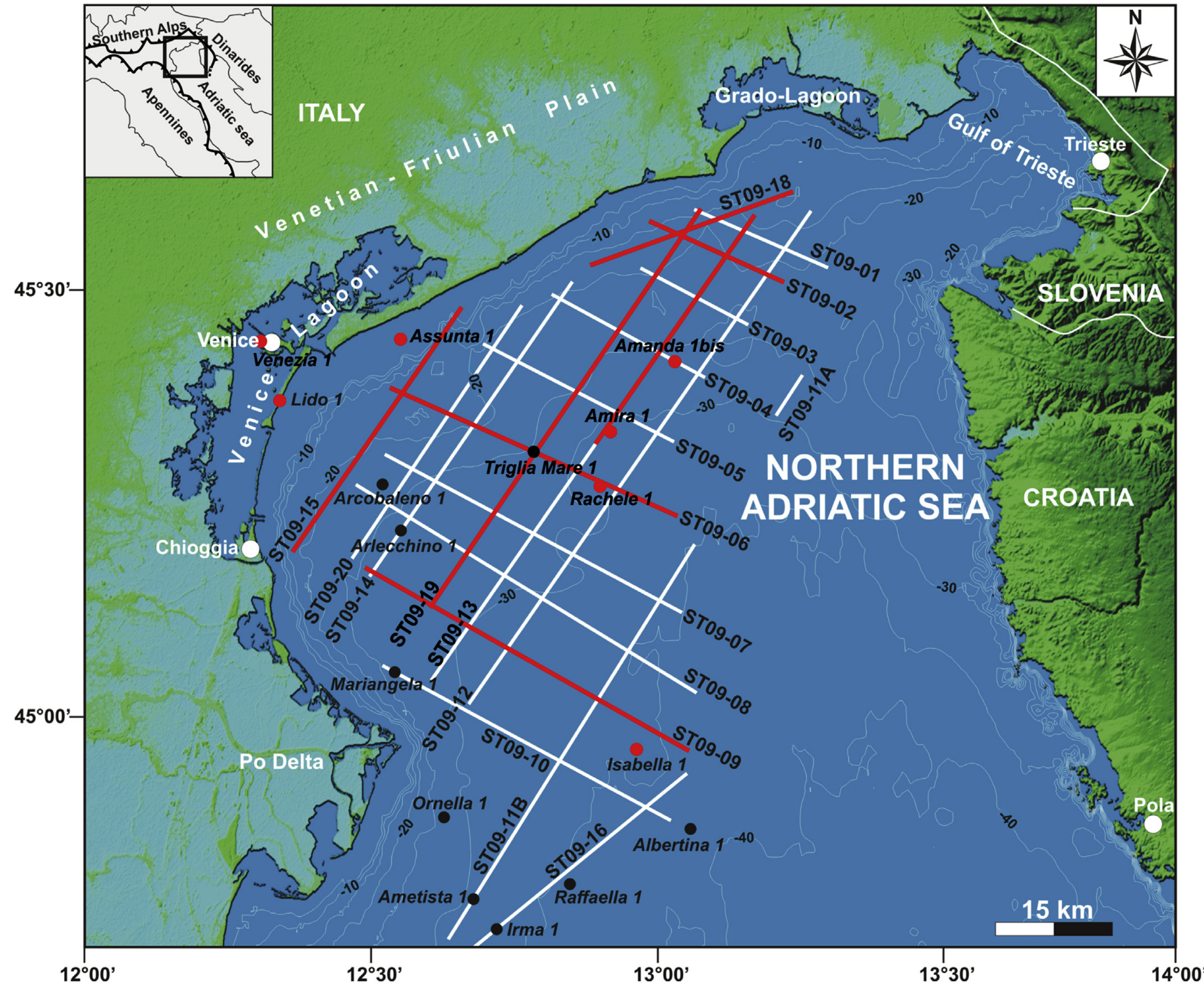


**Fig. 1.** Location of the Northern Adriatic Sea, of the seismic profiles collected in the framework of the OGS/STENAP geophysical survey and of the wells made available through the ViDEPI project. The seismic profiles and wells analyzed in this study are highlighted in red. A simplified structural sketch of the study area is shown in the inset map. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Po plain have documented a complex late Miocene to Pleistocene depositional and structural evolution due to the outbuilding of the Apennine chain and the onset of the late Quaternary glaciations (Kent et al., 2002; Muttoni et al., 2003; Massari et al., 2004; Barbieri et al., 2007; Ghielmi et al., 2010, 2013; Tosi et al., 2012; Turrini et al., 2014; Zecchin and Tosi, 2014; Rossi et al., 2015). In particular, a foredeep basin, linked to the NE-ward migration of the northern Apennine thrust-and-fold belt, developed in the Northern Adriatic Sea during early Pleistocene time. It was filled first by turbidites and then by the prograding paleo-Po deltaic system (Massari et al., 2004; Ghielmi et al., 2010, 2013; Tosi et al., 2012; Zecchin and Tosi, 2014). This study, based on sequence stratigraphic analysis of multichannel seismic profiles and well data, provides a reconstruction of the Plio-Pleistocene environmental and physiographic evolution of the Northern Adriatic Sea (Fig. 1). Present results also demonstrate the effectiveness of the sequence stratigraphic approach in the study of the large-scale stratigraphic architecture of sedimentary basins to document the main controls (eustatic and/or tectonic) on sedimentation and basin evolution (e.g., Zecchin et al., 2012).

## 2. Geological setting

The study area lies at the northern boundary of the Adria microplate, which represents the foreland of South Alpine, Apennine and Dinaric thrust-and-fold belts (Fig. 1). The Cenozoic compressional regime is overprinted on the polyphasic framework produced by the mid-late Jurassic and Early Cretaceous extensional phases (Fantoni and Franciosi, 2010; Ghielmi et al., 2013; Rossi et al., 2015).

The Cenozoic compressional regime appears to be very complex and characterized by both different timing and changing directions of tectonic movement. The E-W compression in the Dinaric system took place from Paleocene to Pleistocene, the N-S compression in the Southern Alps system was active during the Middle Eocene to Miocene Meso and Neoalpine Phases, whereas the NNE-SSW compression in the Apennines is the most recent and occurred from Oligocene to Plio-Pleistocene (Ghielmi et al., 2010). In particular, the depositional and paleogeographic evolution of study area reflects the key role played by the structural setting of the northern Apennines, which is dominated by a step-wise, eastward