



The northernmost Adriatic Sea: A potential location for CO₂ geological storage?

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ABSTRACT

In 2009, the National Institute of Oceanography and Experimental Geophysics (OGS, Italy) has performed a geophysical survey in the northernmost sector of the Northern Adriatic Sea, between the Tagliamento and Po river deltas, with R/V OGS Explora. About 820 km of 2D multichannel seismic and Chirp profiles, together with multibeam data along the ship tracks, have been acquired, with the aim to reconstructing the Plio-Quaternary stratigraphic and tectonic setting of the study area. Data have been also analyzed to verify whether this region is suitable for CO₂ geological storage. Sites eligible for the application of Carbon Capture and Storage (CCS) techniques have been already identified in the Adriatic Sea, except in the northernmost sector, due to the scarcity of available data. The analyses of the new OGS seismic dataset highlighted the occurrence of peculiar seismic anomalies, represented by sub-vertical wipe-out zones, that have been interpreted as due to gas leakages affecting the Plio-Quaternary sequence. They could be possibly related to the formation of rock outcrops interpreted as methane-derived carbonates. It is suggested that gas migrates along sub-vertical chimneys throughout the Plio-Quaternary sequence. The correlation of these sub-vertical features among the seismic profiles reveals that two main alignments could be recognized: a NW–SE trend offshore the Venice Lagoon and a NE–SW in the northernmost part of the investigated area. It leads to hypothesize that the preferential conduits for gas migration are associated to tectonic lineaments. The analysis of the tectonic setting has been then addressed at defining the role of fault/fracture zones, which can affect the integrity of a CO₂ storage complex in this area. Tectonic features have been identified in the Mesozoic–Paleogene succession, but their relationship with the shallow faults/fractures representing the paths for gas leakages still need further work and additional data in order to be clearly constrained.

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1. Introduction

The Northern Adriatic Sea has been recently studied in the framework of National and European projects aimed at evaluating its suitability for CO₂ geological storage, as part of the Carbon Capture and Storage (CCS) techniques, widely recognized as a key instrument for the reduction of the CO₂ emissions in the atmosphere. CCS involves capturing the carbon dioxide produced by large industrial plants, that would otherwise be emitted into the atmosphere, compressing and transporting it to a suitable site. CO₂ is then injected into deep geological formations where it will be trapped for thousands or millions of years. Our study was focused on saline aquifers; they have, among all the storage options, the greatest potential for the CO₂ storage (Benson and Cook, 2005). By definition, saline aquifers, are porous and permeable rocks

containing saline fluids within pores spaces. They can be represented by sands, sandstones and limestones but to be potentially suitable for CO₂ storage they must be sealed by an impermeable formation (caprock) not affected by faults, in order to avoid CO₂ leakages to the surface. The formations which have generally good characteristics of caprock are clays, marls, mudstones and evaporites. Potential sites suitable for CO₂ geological storage have been identified in the Adriatic Sea to the south of the Po River delta (Buttinelli et al., 2011; Donda et al., 2011), whereas no major evaluations have been performed in the northernmost sector of the Adriatic Sea due to the scarcity of available data.

In 2009, OGS has performed a geophysical survey in the study area, where about 820 km of 2D multichannel seismic and Chirp profiles, together with multibeam data along the ship tracks, have been acquired (Fig. 1). The target of the survey was addressed to the characterization of the Plio-Quaternary geological and structural setting of the study area. In fact, whereas the onshore geological setting of the Northern Adriatic Sea region is well known by now, the available information on the structural and stratigraphical

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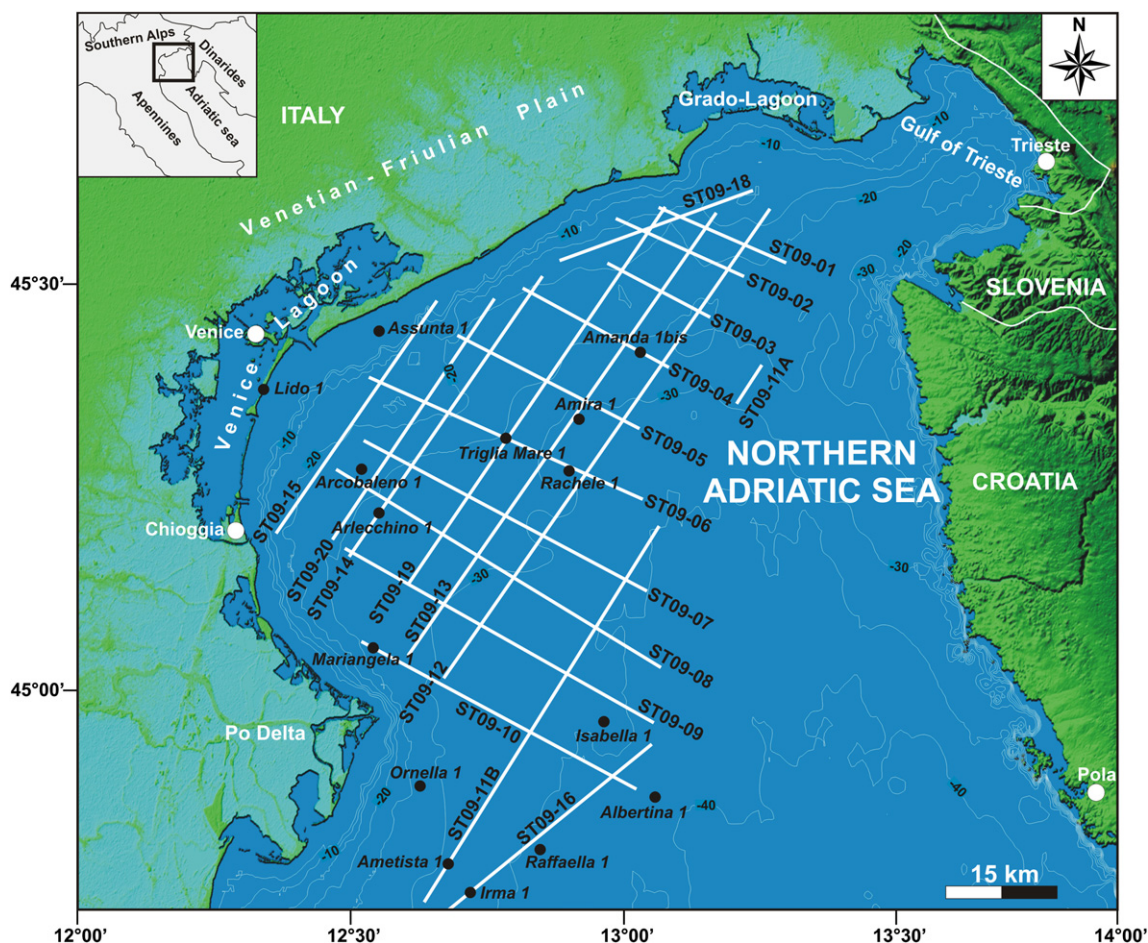


Figure 1. Location map of the multichannel seismic profiles and Chirp data collected in the framework of the OGS/STENAP geophysical survey. The position of the boreholes, which information have been made available through the ViDEPI project and analyzed for this study, is also indicated.

setting of the offshore area are represented by tectonic, stratigraphic and sedimentary reconstructions at a broad regional scale (Fantoni and Franciosi, 2010; Ghielmi et al., 2010), except for the Gulf of Trieste, where a detailed tectonic reconstruction has been provided by Busetti et al. (2008, 2010) and Carulli (2011). The Neogene and Quaternary succession of the Northern Adriatic Sea was deeply investigated through multidisciplinary studies performed by Eni in the framework of the hydrocarbon exploration, but most of the results of such studies are not publicly available. Geological studies have been also performed in the Northern Adriatic Sea by several research Institutions, but they were mainly addressed at the reconstruction of its Quaternary stratigraphic evolution (Storms et al., 2008; Foglini et al., 2012).

The seismostratigraphic and structural interpretation performed on the new OGS seismic dataset led to identify peculiar seismic facies, interpreted as due to fluid leakages. Offshore the Grado Lagoon, they are mainly represented by CH₄-rich gas (Conti et al., 2002; Gordini et al., 2012) and are locally associated to submarine rock exposures, whose origin is still debated. These rock formations have been initially interpreted as beachrocks (Stefanon, 1970; Newton and Stefanon, 1975), while the most recent hypothesis suggests they are most likely related to seeping methane and cementation processes, and have been then classified as methane-derived carbonates (Conti et al., 2002; Gordini et al., 2012). In the Black Sea, where similar deposits have been studied, Peckmann et al. (2001) suggested that gas leading to carbonate deposition and the cements have the same age; for the Northern Adriatic Sea outcrops

this hypothesis cannot be confirmed nor rejected due to the lack of chemical analyses on gas samples.

In this study, we discuss the possible relationship between gas seepages and the regional tectonic setting of the study area, addressed to the definition of its suitability for CO₂ geological storage.

2. Geological setting

2.1. Structural setting

The study area lies at the northern boundary of the Adria microplate which represents the foreland of the Southalpine, Dinaric and Apennine chains (Fig. 2). The Cenozoic architecture of the Adria plate was conditioned by the extensional features developed during the Mesozoic rift (Fantoni and Franciosi, 2010). The extension reached its climax phase between the mid-late Jurassic and Early Cretaceous, when carbonate platforms and basins formed (Massari et al., 1986; Fantoni et al., 2002; Fantoni and Franciosi, 2010).

The Cenozoic deformational phase took place at different times and with variable directions of tectonic shortening, leading to a very fragmented evolution of the whole area (Fantoni and Franciosi, 2010; Ghielmi et al., 2010): 1) the Dinaric chain has been deformed from Late Cretaceous to Pleistocene, in a dominant E–W direction; 2) the Southalpine chain formed mainly from Middle Miocene to Pleistocene, under a predominant N–S compression; 3) in the Apennine chain, where the deformation

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