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Erosional versus aggradational canyons along a tectonically-active margin: The northeastern Ligurian margin (western Mediterranean Sea)

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ABSTRACT

Submarine canyons are usually described as erosive conduits incising the continental slope through retrogressive sediment failures and active erosion by gravity flows. Only a few studies have revealed that canyon deepening is possible under conditions of net sediment deposition.

In the present study, we used bathymetry/backscatter data, chirp and seismic-reflection profiles collected within the framework of the MALISAR project to investigate nine active canyons belonging to one canyon system built in the eastern part of the Ligurian margin (western Mediterranean) since the Messinian Salinity Crisis. By comparing their planform pattern and architecture, we identified two sets of canyons located along the western and eastern segments of the margin. Sub-surface data showed that despite their contrasting sizes, both western and eastern canyons exhibit V-shaped cross sections, concave-up longitudinal bathymetric profiles and their thalwegs are marked by erosive structures or coarse-grained deposits. Their present-day activity could thus be controlled by similar sedimentary processes dominated by erosive sandy turbidity currents originating from canyon breaches or other mass-wasting processes. However, according to the seismic profiles, the Plio-Quaternary evolution of the two sets of canyons differed dramatically. The western canyons are mainly aggradational systems, with the progressive building of thick levees composed of sigmoidal shaly lateral accretion packages and the amalgamation of paleo-thalwegs infilled with coarse-grained deposits. In contrast, eastern canyons developed as by-passing conduits during the Plio-Quaternary. It is important note that the present-day morphology of the eastern canyons was not caused by erosion of previous deposits, as described for other large canyons, but by the gradual building of 700-m-thick adjacent levee-like accumulations.

Here, both the spatial and temporal distribution of the tectonic activity is thought to have strongly constrained the building style of the canyons. More particularly, aggradational canyons have thick infillings consisting of several amalgamated units separated by erosive surfaces. This contribution could thus be of interest for both academia and industry as it helps understand the processes and factors controlling the formation of canyons and represents an unusual analogue model for potential reservoirs derived from continental slope processes.

1. Introduction

Submarine canyons are the most common conduits for erosion-derived particles, organic matter and nutrients transported from land to the base of continental margins (Normark and Carlson, 2003; Shepard, 1981; Twichell and Roberts, 1982). Submarine erosion is thought to be the main process involved in canyon development (Baztan et al., 2005; Popescu et al., 2004; Twichell and Roberts, 1982) through (1) repeated and continuous action of gravity flows including debris flows, turbidity currents linked to breaching of canyon heads or walls (Pratson and Coakley, 1996; Sultan et al., 2007) or flood events (hyperpycnal flows), (2) retrogressive erosion within the canyon heads related to the triggering of submarine landslides, and (3) up-and-down currents related to tides or internal waves, and cascading currents which are also now recognised to play a key role in local seafloor erosion, in depositing substantial volumes of sandy particles and in maintaining thalweg morphology (Gaudin et al., 2006; Mulder et al., 2012; Trincardi et al., 2007).

Many authors have distinguished between submarine canyons based on their morphological/architectural characteristics, and submarine canyons are often divided into two groups, erosional and depositional canyons (Goff, 2001; Jobe et al., 2011). Erosional canyons

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deeply incise the continental shelf and are characterised by terraces and numerous failure scars, and are often associated with sand-prone continental slopes (Adams and Schlager, 2000). The main mechanisms involved in their development are thought to be erosive turbidity currents (linked to coarse-grained gravity flows) and mass-transport processes (Paull et al., 2013; Shepard, 1981). They are often associated with coastal mountain belts (Covault et al., 2011; Gervais et al., 2006) or large fluvial systems (Babonneau et al., 2002; Green and Uken, 2008; Shepard, 1981). Depositional canyons do not reach the shelf edge; they are more aggradational, often have a U-shaped cross section, smooth inner walls lacking terraces or slumps (Jobe et al., 2011). They are associated with mud-rich infilling originating from hemipelagic deposition, dilute turbidity currents and bottom currents. So, canyons classically interpreted as net-erosional environments may in fact develop under net depositional conditions (Straub and Mohrig, 2009; Zhu et al., 2010). Both erosive and aggradational canyons can be found in both passive and active margins and the factors which control their behaviour are still the subject of debate.

In the present study, based on bathymetry/backscatter data, chirp and seismic-reflection profiles collected within the framework of the MALISAR project, we investigated nine erosive and aggradational canyons built since the Messinian Salinity Crisis in the eastern part of the Ligurian margin (western Mediterranean). Here, the spatial and temporal distribution of the tectonics activity is thought to strongly constrain the building style of the canyons. More particularly, aggradational canyons have thick infillings consisting of several amalgamated units separated by erosive surfaces. This paper could thus interest both academia and industry, as it helps understand the processes and factors controlling the formation of canyons and provides an unusual analogue model for potential reservoirs derived from continental-slope processes.

2. Geological setting

The Gulf of Genova (GOG) is located in the northernmost part of the Ligurian Sea (north-western Mediterranean), and extends between the cities of Imperia to the west and La Spezia to the east (Fig. 1). In its western part, it is bordered by the E-W trending Ligurian Alps, which in turn, are connected to the NW-SE Apennine chain by the Voltri Massif (Fig. 1).

2.1. Morphology of the margin

The western part of the Ligurian margin has been widely studied in the last three decades mostly because of the presence of the large Var Turbidite System (Migeon et al., 2006; Piper and Savoye, 1993; Savoye et al., 1993), the triggering of the so-called 1979 submarine landslide offshore Nice city airport (Dan et al., 2007; Gennesseaux et al., 1980; Mulder et al., 1997), and the current activity of hyperpycnal flows (Mulder et al., 2001). The margin is characterised by a narrow continental shelf (2–3 km) and a steep continental slope (6–11°; Migeon et al., 2011). The latter is moulded by submarine canyons heading on the continental shelf at the mouth of mountain-supplied rivers and by numerous submarine scars (Migeon et al., 2011).

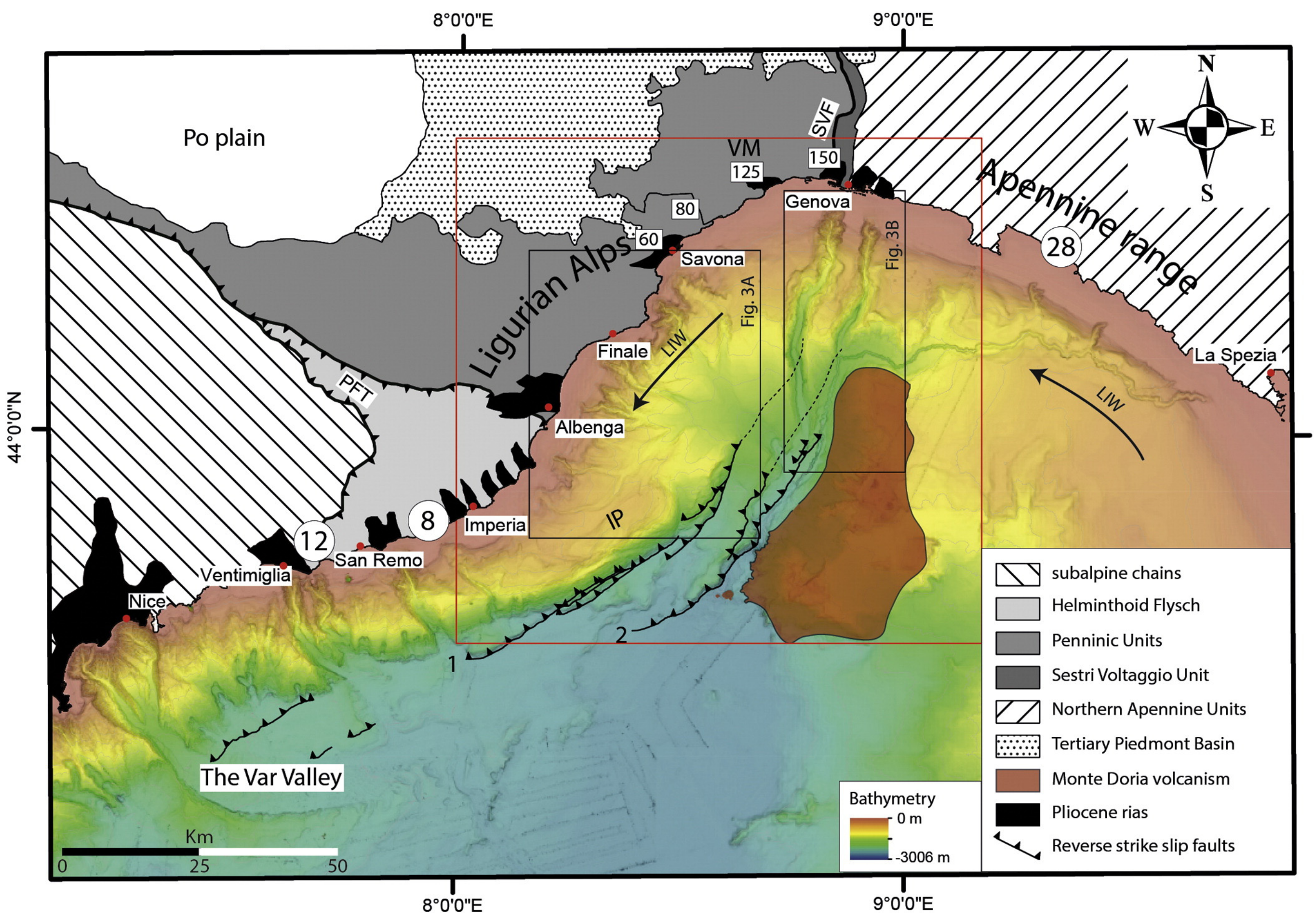

Fig. 1. Simplified tectonics map and shaded bathymetric map of the Ligurian margin collected during the MALISAR project. The red square shows the extent of the studied zone. Numbers in circles indicate terraces elevations formed 125 ky ago (Federici and Pappalardo, 2006). Numbers in squares indicate correlated terraces (probably Quaternary in age) elevation (Carobene and Firpo, 2002). VM: Voltri Massif; SVF: Sestri Voltagio Fault; PFT: Penninic front thrust; IP: Imperia Promontory. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)