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Research paper

Diversion and morphology of submarine channels in response to regional slopes and localized salt tectonics, Levant Basin

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A B S T R A C T

In the Levant Basin, submarine channels are abundant around the Nile deep-sea fan (NDSF), an area which is also affected by salt tectonics related to the Messinian salt giant. Here we focus on the relationship between submarine channels and obstacles formed by salt tectonics. Initially, we use methods developed for terrestrial morphological analysis and quantify channel sinuosity, width and slope in search for consistent relationships between morphometric parameters and channel response to obstacles. However, this traditional analysis did not yield robust conclusions. Then, we apply two new morphometric parameters suggested here to express the distortion of channels by obstacles: diversion angle (Ω), defined as the acute angle between the regionally influenced channel direction and the strike of the tectonic obstacle and incident angle (α), defined as the angle between the direction of the regional bathymetric slope and the average direction of the channel. These parameters illustrate the influence of the regional-scale basin geometry and the superimposed tectonic-influenced seabed patterns, on channel development. We found hyperbolic relationships between incident angle (α) and diversion angle (Ω) in which channels flowing approximately parallel ($\alpha \sim 0°$) to tectonic folds are (obviously) not diverted; channels nearly orthogonal ($\alpha \sim 90°$) to obstacles, crosscut them right through and, again, not diverted much. In contrast, channels with a general direction diagonal to the obstacles ($\alpha \sim 40°$), are diverted by ten degrees ($\Omega \sim 10°$). This diversion accumulates along large distances and significantly influences the regional development of channels around the NDSF. Noteworthy, this phenomenon of channel diversion, indirectly deteriorate normal slope-sinuosity relationships known from terrestrial studies. In light of these findings, we suggest that these new parameters can be applied to other basins, where submarine channels interact with seabed obstacles.

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1. Introduction

While submarine channels are quite abundant along the present-day seafloor, these deposits are rarely exposed on land, and hence, not sufficiently understood (Peakall et al., 2000; Weimer et al., 2006). In recent years, the need to study submarine channel systems has increased for basic understanding of their evolution but also for practical reasons: (1) assessing the geo-hazard risks associated with industrial infrastructure laid on the sea floors (pipelines, cables, facilities); and (2) for tracking and characterizing ancient and buried turbidite units that may contain hydrocarbons. Therefore, it is important to study modern submarine channel systems, assess how active they are, and use them to better understand ancient, buried systems that are not imaged at similar details. This study focuses on the Levant Basin, where recent prolific gas discoveries have enhanced the need for a deeper understanding of the submarine system of the Eastern Mediterranean Sea and its relations to the adjacent Nile deep sea fan (NDSF).

Submarine channels as a part of Turbidite Systems around the western and northern slopes of NDSF (Fig. 1a) were documented in a series of studies (Gaullier et al., 2000; Loncke et al., 2002, 2006, 2009; Ducassou et al., 2008, 2009). The western province of the NDSF is probably the best-documented and the most active part of the Nile fan in terms of turbidite deposition, at least over the past 130,000 years (Maldonado and Stanley, 1979; Bellaiche et al., 2001; Loncke et al., 2002; Ducassou et al., 2007). In that area, where the

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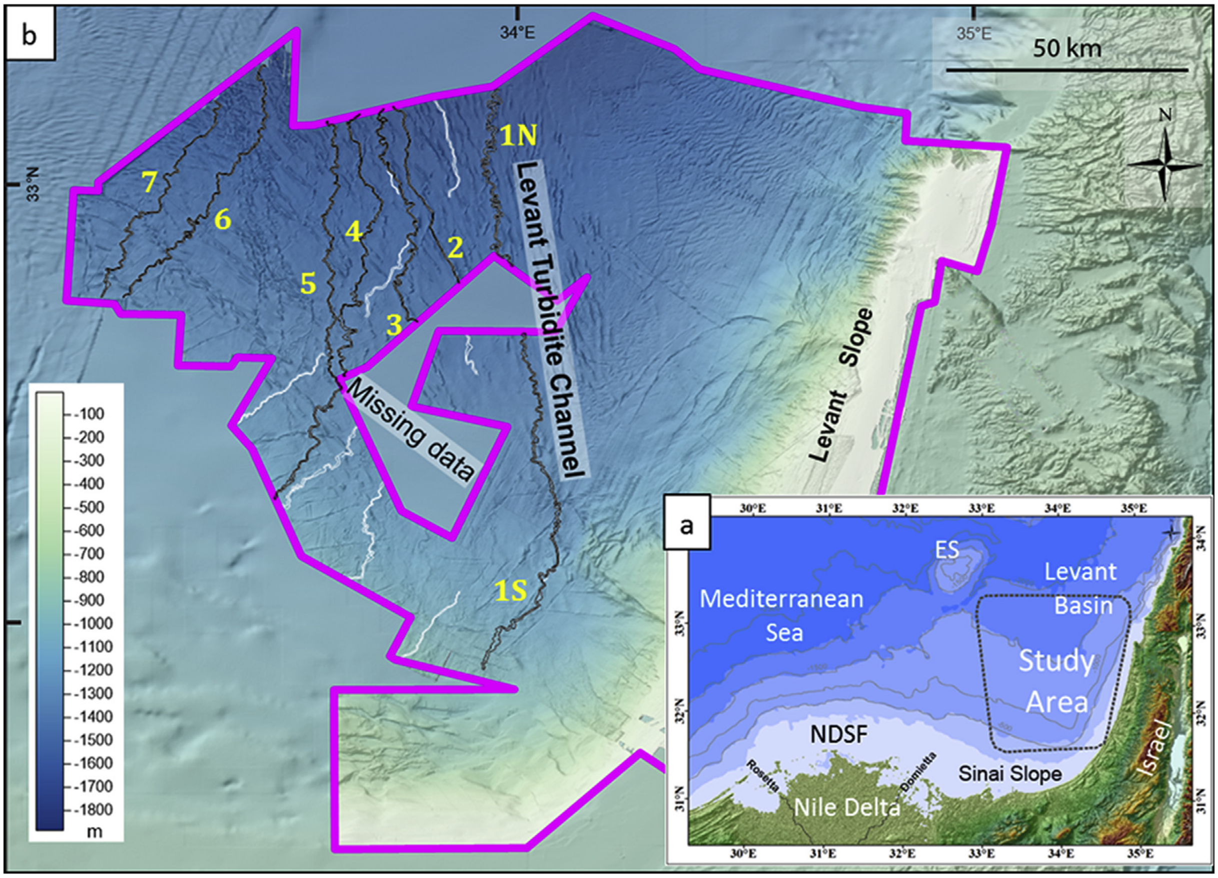

Fig. 1. a) Location map and bathymetry of the southeastern Mediterranean with contour intervals = 500 m. ES = Eratosthenes Seamount. NDSF = Nile deep-sea fan. b) The study area in the southern Levant Basin. Submarine channels 1–7 analyzed in this study. Map prepared based on data from Gvirtzman et al., 2015.

Rosetta canyon is directly connected to the deep sea fan, a series of active well-ramified channel–levee systems have been identified. Turbidite sediments are currently transported through this system ~300 km from the shelf edge (Huguen, 2001; Loncke et al., 2002; Ducassou et al., 2013) confirming earlier suggestions (e.g., Normark et al., 1993) stating that gravity flows are remarkably mobile and can travel long distances via submarine channels until settling at distal submarine fans. In the eastern province of the NDSF (Levant Basin), where evidence for turbidite flow have yet to have been documented, we use the term ‘submarine channel’ to describe incised conduits for downslope sediment transport, without any implication for process or flow type.

The southern part of the Levant Basin was recently described by Gvirtzman et al. (2015), who showed that the off-Sinai slope contains a net of submarine channels similar to those described north and west of the NDSF unlike the nearby Levant slope, which does not present any channels (Fig. 1b). The width of the off Sinai channels (labelled 2–7) range between 200 and 700 m and their depth relative to respective shoulders is 10–40 m. Wider and more sinusoidal (Fig. 1b) than these channels is the 270–km-long Levant turbidite channel (Gvirtzman et al., 2015), which runs along the lowest points in the valley formed between the Sinai and Levant slopes.

Salt tectonics significantly deforms the Levant Basin shaping the seafloor morphology (e.g. Garfunkel, 1984; Garfunkel and Almagor, 1984, 1987; Gradmann et al., 2005; Netzeband et al., 2006; Bertoni and Cartwright, 2006, 2007; Cartwright and Jackson, 2008; Gvirtzman et al., 2015). This study focuses on the relationships between submarine channels and lineaments produced by salt tectonics. Interestingly, a few of the channels in the Levant Basin do not always take the steepest downslope path (i.e. do not follow the maximum slope). Rather, at certain segments they are deflected towards the northwest by elongated tectonic ridges forming a zig-zag channel pattern (Gvirtzman et al., 2015). Therefore, our goal is also to understand how seabed obstacles that originate in salt tectonics influence submarine turbidite channels in the Levant Basin and in general.

To achieve this goal we begin with a classic morphometric analysis measuring channel sinuosity, width, and slope, looking for consistent relationships between these parameters and the channel response to tectonic related obstacles. Then, we introduce a morphometric parameter that expresses the distortion of channels by obstacles. This parameter quantifies and assists in explaining the influence of the regional basin geometry and the superimposed tectonic influenced seabed pattern on channel development.

We conclude this study with insight and implications derived from our research; comparing channel flow direction to the regional basin architecture allows for the immediate identification of regions in which channel morphology is affected by tectonics. This is done by demonstrating the potential applicability of our new analysis method in our neighboring region; The analysis presented here demonstrates how channel morphology can be used to trace areas with very gentle tectonic elements that cannot be traced without high resolution bathymetry data by emphasizing the differences between the western province off the NDSF and the Levant basin in the east. To give this new method an even broader applicability, we present several examples from different basins around the world and discuss how tectonic obstacles may affect channels

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