Multi-parametric analysis of submarine slides on the Algerian continental slope (Western Mediterranean)

A. Cattaneo[1], N. Sultan[1], R. Silva Jacinto[1], B. Savoye[1], G. Dan[2], A. Nouguès[2], K. Yelles[3], N. Babonneau[4], P. Strzerzynski[4] and J. Déverchère[4]

[1] Département Géosciences Marines, Ifremer, Plouzané, France
[2] FUGRO, France
[3] CRAAG, Alger, Algeria
[4] Domaines Océaniques, UEM-UBO, Plouzané, France

INTRODUCTION

The Algerian margin is a Cenozoic passive margin along the plate boundary between Eurasia and Africa, presently reactivated in compression. The deformation is expressed by ESE-WNW-aligned seafloor escarpements that represent the seafloor expression of thrust-folds. These structure are associated with a crustal shortening (GPS data, Calais *et al*., 2003) and moderate to large earthquakes (Déverchères *et al*., 2005; Domzig *et al*., 2006).

The Algerian continental margin is one of the most seismically active area in the Western Mediterranean, having experienced several moderate to strong earthquakes during the last century in the coastal zone. The most violent instrumentally recorded earthquake occurred on October 10, 1980 in El Asnam (Chlef currently), and reached a magnitude of 7.3 (Ms). More recently, on May 21, 2003 an earthquake with a magnitude of 6.9 struck the city of Boumerdès, on the coast near Algiers, and generated significant gravity flows recognized by numerous submarine cable breaks offshore.

The morphology of the continental slope offshore central Algeria presents abrupt escarpments (e.g., S1 and S2 on Fig. 1) that are probably the surface expression of active tectonic structures (Déverchère *et al*., 2005; Domzig *et al*., 2006; Kherroubi *et al*., 2008). Numerous submarine landslides are present along these structures, possibly indicating a link between seismicity and seafloor instability. The aim of this paper is to characterize the controlling factors of some of these submarine slides by integrating an exhaustive set of observations (morpho-sedimentary analysis, sediment sampling for geotechnical tests, and in situ measures) with numerical modeling, in order to test the impact of earthquakes as a triggering mechanisms for submarine slides.

DATA AND METHODS

The present study summarizes data from four campaigns led from 2003 to 2007 in the Algerian offshore area. The dataset includes multibeam bathymetry, high resolution reflection seismic, seafloor imagery, seafloor samples and in situ tests. The study focuses on a set of slides that are particularly evident from side scan sonar (SAR) images and CHIRP profiles. These geophysical data are complemented by sediment sampling and in-situ measurement (CPTU and piezometer). Laboratory tests (triaxial and oedometric) on undisturbed samples from piston cores allow to constrain the mechanical properties of the sediment and to provide the basis for the application of numerical model to assess slope stability.

RESULTS

Along the S1 escarpment (Fig. 1), the seafloor morphology reveals the presence of numerous destabilized areas. The destabilized areas are created by several cohesive slides, characterized by a mean surface of 0.4 km2 (Dan *et al*., a, in press). Geotechnical measurements on a slide on the S1 escarpment (black arrow, Fig. 1) reveal the underconsolidated nature of the sediment from this area at different depths. This underconsolidated state of the sediment is compatible with the liquefaction of sand beds within an overall muddy succession, due to an earthquake load. From the OCR profile, we believe that the deformation features identified in this slide (liquefaction, collapse and slope failure) are not very recent and they are not related to the Boumerdès earthquake of 2003, even if this earthquake affected the study area (Dan *et al*., b, in press).

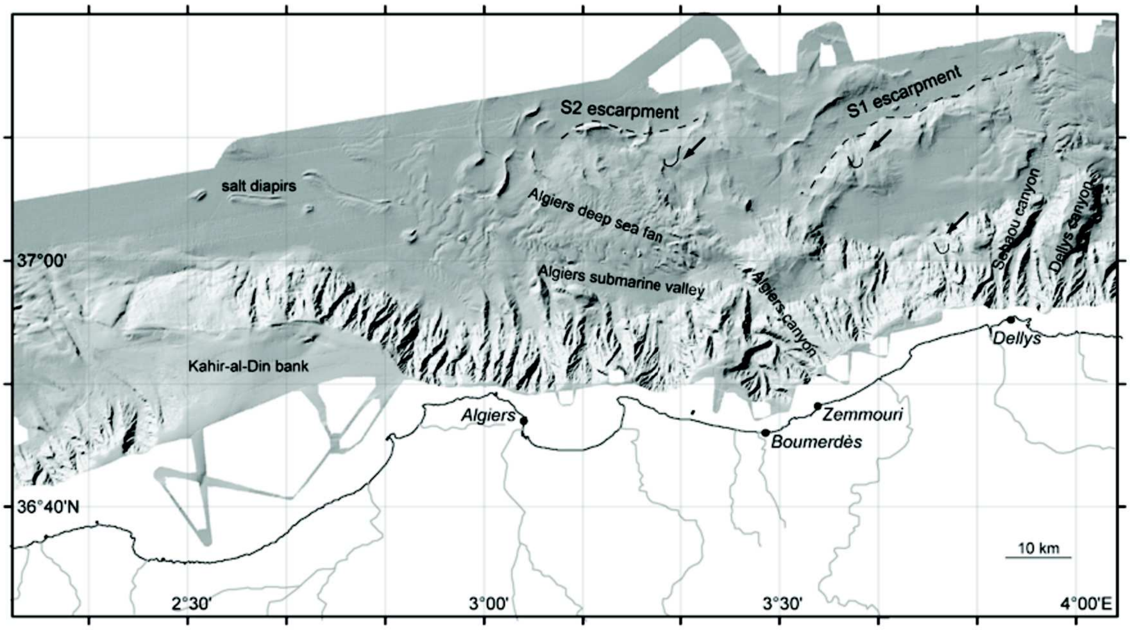

Fig. 1. Bathymetry of the area offshore Algiers showing the main morphologic features. Black arrows show the location of studied submarine slides.

Coupled CHIRP and side scan sonar profiles reveal the presence of a well-defined slide scar with associated deposits showing transparent echo-facies in about 2700 m water depth, along the S2 escarpment (Figs. 1, 2). An assessment of the slope stability was developed using numerical modeling software FEMUSLOPE (Sultan *et al.*, 2001) in static conditions, and SAMU 3D (Sultan *et al.*, 2007) in pseudo-static conditions. The modeling results show that the only condition to attain rupture is when a seismic acceleration of 0.3 g is applied.

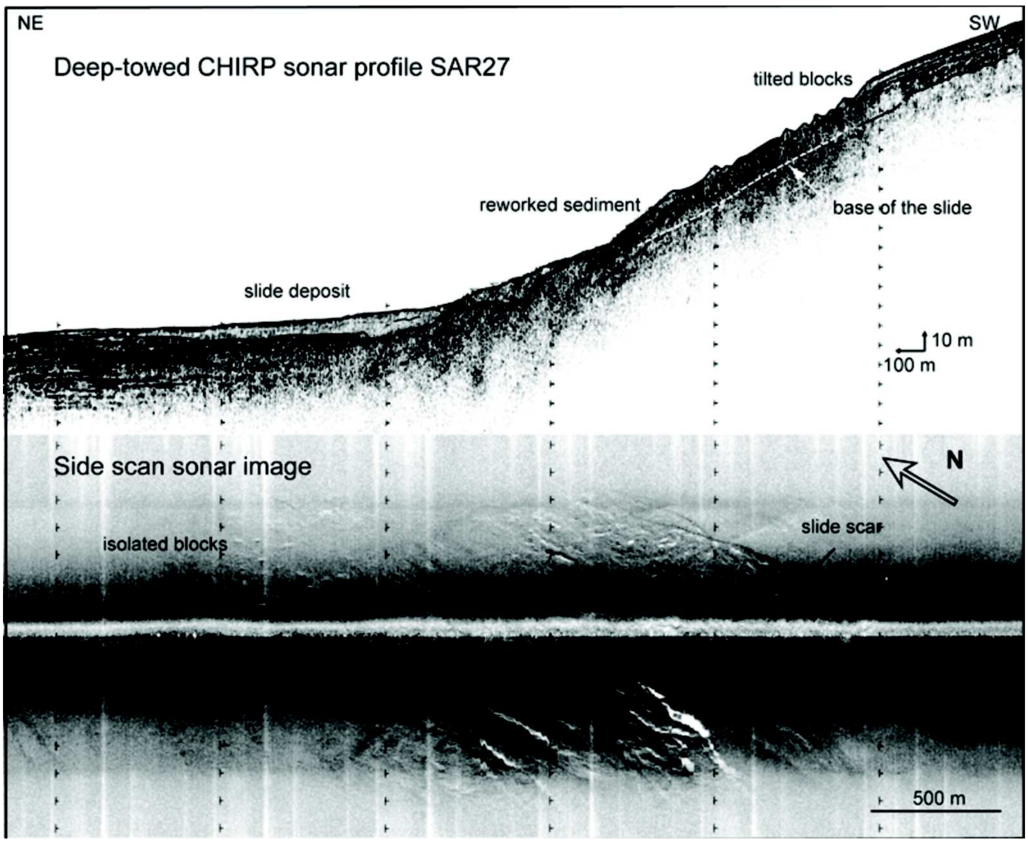

Fig. 2. Chirp-sonar profile (above) and side scan image (below) of a submarine slide in 2700 m of water depth in the area of the S2 escarpment (see arrow on Fig. 1).

CONCLUSIONS AND PERSPECTIVES

On the continental slope offshore Algeria, there are numerous relatively small-size submarine landslides mainly located on canyon flanks and at the foot of continental slope escarpments of tectonic origin. We present here a study on slides located along the escarpments through an integrated approach including geophysical, sedimentological and geotechnical observations to be used for numerical modeling of slope stability. Based on slope stability models, there is need of an external load, such the acceleration of an earthquake, to trigger a slide in the study area. Being an earthquake the likely triggering mechanism for the observed slides, the associated rupture mechanism could be the liquefaction of thin silty and sandy layers present in the continental slope sedimentary units. The link between a specific sliding event and a known earthquake, however, still needs to be proved. Future work will focus on the refinement of the stratigraphy and chronology of the slides by 14C datations and micropaleontological ecozones.

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