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On the origin of the Strait of Gibraltar

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Abstract

Most interpretations of the Early Pliocene opening of the Strait of Gibraltar involve a tectonic process. However, no tectonic structure of this age has been unequivocally documented that could account for such a hypothesis. On the other hand, the sea-level drop of the Mediterranean during the Messinian Salinity Crisis has dramatically enhanced continental erosion and in particular regressive fluvial erosion. We show that such erosional process inevitably developed in the Gibraltar area. We finally propose that regressive fluvial erosion was at the origin of the opening of the Strait of Gibraltar.

Keywords: Strait of Gibraltar; Messinian sea-level drop; Fluvial erosion; Pliocene reflooding

1. Introduction

The Strait of Gibraltar is an E–W narrow neck, 58 km long with a mean depth of about 350 m. Its width ranges from 13 km to the east, to 43 km at the western entrance (Fig. 1). The strait ensures the only water communication between the Atlantic and the Mediterranean. This exchange is crucial for the Mediterranean to compensate the negative hydrological balance with loss through evaporation exceeding the input of water through runoff and precipitation. Nowadays, closing of the Strait of Gibraltar would trigger a complete desiccation of the Mediterranean in about 1000 years (Hsü et al., 1973a).

Before the opening of the Strait of Gibraltar, the Atlantic and Mediterranean waters were connected through the Betic and Rif gateways, which were progressively uplifted and finally closed during the Miocene (e.g. Weijermars, 1988; Benson et al., 1991; Krijgsman et al., 1999b; Martín et al., 2001; Duggen et al., 2003). This triggered the desiccation of the Mediterranean, inducing the so-called Messinian Salinity Crisis (MSC) (Hsü et al., 1973a).

The opening of the Strait of Gibraltar in the Early Pliocene allowed restoring the water exchange between the Atlantic and Mediterranean waters. Surprisingly, the origin of this opening is not so much of a concern to the geological community. Because the Strait of Gibraltar is situated in a long-lived tectonic region, most works have considered that its opening was induced by the collapse of a narrow graben related either to regional extension or strike-slip faulting (pull-apart basin) (e.g. Hsü et al., 1973b; Campillo et al., 1992; Kastens, 1992; Maldonado et al., 1999; Hodell et al., 2001). But, to our knowledge, no major normal faults have been documented on both sides of the Strait of Gibraltar to support these interpretations.

On the other hand, the desiccation of the Mediterranean during the Messinian has induced a dramatic sea-level drop that has been estimated up to 1500 m below the current sea-level (Hsü et al., 1973a; Clauzon et al., 1996). A major consequence of this base-level drop was the strong re-incision of the rivers that were flowing into

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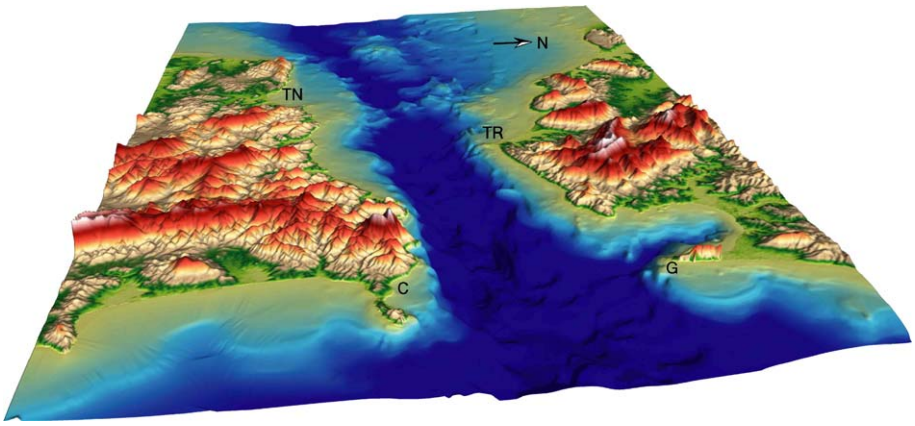

Fig. 1. Digital Elevation Model (view toward the west) of the Gibraltar Strait (land topography: SRTM90 DEM data; Gibraltar Strait bathymetry: isobaths from Giermann, 1961). The strait is 58 km long and narrows to 13 km in width between Point Marroquí, Spain, and Point Cires, Morocco. C: Ceuta; G: Gibraltar; TN: Tanger; TR: Tarifa.

the Mediterranean, resulting in the cutting of deep canyons by regressive erosion all around the Mediterranean region, including the Alboran Sea (e.g. Clauzon et al., 1996). Blanc (2002) proposed, by analysing the morphology of the Strait of Gibraltar, that regressive erosion by an eastwards-flowing stream in the Gibraltar area was the main process by which the Strait of Gibraltar opened.

In the present paper we aim to show that there are no tectonic structures that could account for the opening of the strait by reviewing the previous works that were concerned with tectonics in the Gibraltar area and surrounding regions. Then we discuss the consequences of the sea-level drop on erosion dynamics during the MSC. We present a numerical modelling that shows how fluvial regressive erosion has developed in the Gibraltar area, following the scenario first proposed by Blanc (2002). The erosional parameters used in this modelling have been deduced from a previous study concerning erosion dynamics in the Messinian Rhone valley (Loget et al., 2005) and are succinctly presented here. We finally discuss our results compared to previous interpretations. We conclude that the Strait of Gibraltar most probably originated in a Messinian pirate valley within which a stream flowing eastwards has eventually captured the Atlantic waters, inducing their re-connection with the Mediterranean Sea.

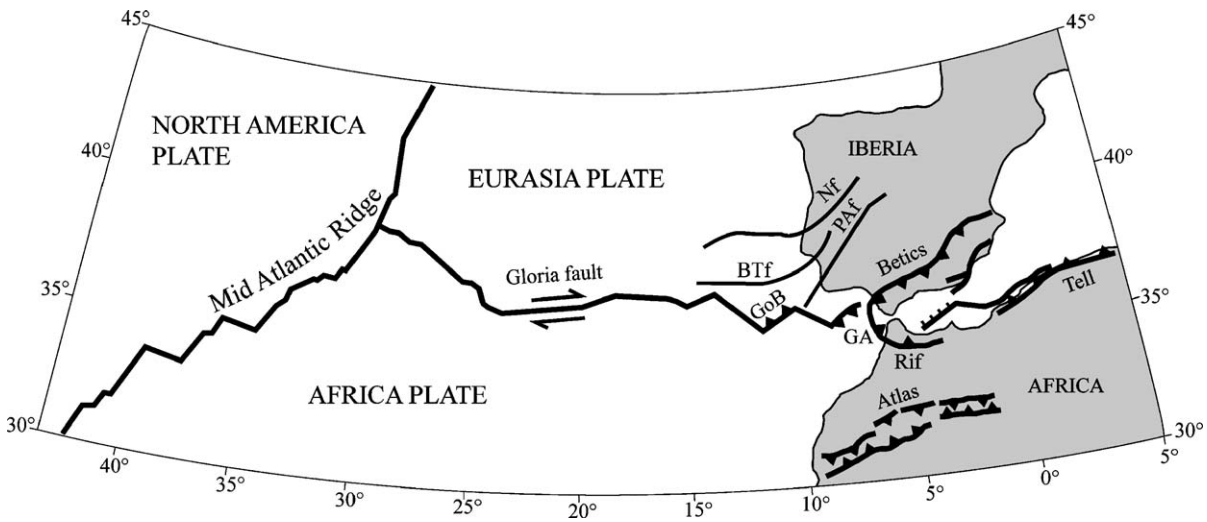

Fig. 2. Plate tectonics framework of the Gibraltar area (modified after Jiménez-Munt and Negredo, 2003). The Gibraltar area is part of the diffuse plate boundary between Africa and Eurasia. Note that no major fault zone follows the Strait of Gibraltar itself. GA: Gibraltar Arc; GoB: Gorringe Bank; BTf: Bato-Tajo fault; Nf: Nazare fault; PAf: Plasencia-Alentejo fault.