Seafloor geomorphology of the Passage of Lanzarote (West Africa Margin): Influences of the oceanographic processes

Juan-Tomás Vázquez[1], Desirée Palomino[1], MªCarmen Fernández-Puga[2], Luis-Miguel Fernández-Salas[3], Eugenio Fraile-Nuez[4], Teresa Medialdea[5], Olga Sánchez-Guillamón[1], Luis Somoza[5] and SUBVENT team

1 Instituto Español de Oceanografía, C.O. de Málaga, Puerto Pesquero s/n, 29649, Fuengirola, Spain. juantomas.vazquez@ma.ieo.es, desiree.palomino@ma.ieo.es, olga.sanchez@ma.ieo.es
2 Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz. 11510 Puerto Real, Spain. mcarmen.fernandez@uca.es
3 Instituto Español de Oceanografía, C.O. de Cádiz, Muelle de Levante, Puerto Pesquero s/n, Cádiz. luismi.fernandez@cd.ieo.es
4 Instituto Español de Oceanografía, C.O. de Canarias, Santa Cruz de Tenerife, Spain. eugenio.fraile@ca.ieo.es
5 Instituto Geológico Minero de España, c/ Río Rosas 23, 28003 Madrid. España. t.medialdea@igme.es, l.somoza@igme.es

Abstract: *The seafloor morphology of the Passage of Lanzarote has been analysed with the aim to know the active processes on the bottom surface related to the oceanographic context. Multibeam bathymetric data and high and very high resolution seismic profiles obtained in the SUBVENT2 cruise have been used. Five main morphological groups have been analysed: (a) Volcanic or diapiric submarine hills; (b) Tectonic features on the continental slope (linear scarps and a rhombohedral depression) related to normal faults; (c) Submarine venting at top of diapirs initially triggered circular depressions; (d) Sedimentary instabilities (gullies, canyons, mass transport deposits) are present specially on the Fuerteventura-Lanzarote ridge; and (e) Contouritic bottom features both erosive (central valley, marginal valleys) and depositional (plastered drifts) are on the central part of the passage, and are generated by the interaction of MW and the interface MW-AAIW with seafloor.*

Key words: *Seafloor morphology, bottom-current interaction, West Africa Margin, Canary Islands.*

INTRODUCTION

Islands and seamounts constitute barriers to water mass flows and control deep-sea sedimentation systems. One example is the Passage of Lanzarote (PoL) which corresponds to the Atlantic Ocean region extended between the West Africa continental margin and the NE-SW volcanic ridge of Fuerteventura-Lanzarote (FLR) (Fig. 1). On the sea-surface the PoL has 100km width to the south, but increases northwards up to 250km. The PoL results from the elevation of the volcanic FLR culminated with the formation of Lanzarote and Fuerteventura volcanic islands, dated at 15.5 and 20.6My respectively. The FLR constitutes a wall of 350km length, 8-20km width, 1200m height respect to the PoL seafloor and 8º of average gradient (up to 40º). The continental margin has arc geometry, from S to N, its orientation changes from NE-SW to ENE-WSW, simultaneously increasing their width (from 45 to 170km) and reducing their gradients (from 7º to 1-2º). The margin corresponds to the Tarfaya basin offshore, that is characterized by salt mobility (Tari et al., 2012). The central seafloor surface of the PoL extends between 1240 and 1460m water depth, its width varies between 20 and 50km, and it shows a smooth longitudinal profile (0.2-0.5°) although locally the gradients increase until 15º in relation to local reliefs.

There are three water masses through the PoL: The upper thermocline North Atlantic Central Water (NACW), which spans from the surface to the approximate neutral density ($\square_n$) value of 27.3kg.m^{-3} (roughly 600m depth). NACW shows a mean southward transport of -0.81Sv, except in autumn that flows northwards. At intermediate levels, two water masses interleave in the PoL: Antarctic Intermediate Water (AAIW) and Mediterranean Water (MW). AAIW is found below the NACW, mainly between the layers 27.3 and 27.7kg.m^{-3} (roughly 600–1100m depth) with its core centred at 27.6 kg.m^{-3} (roughly 900m depth). AAIW flows basically northwards with a mean mass transport of +0.09Sv. The MW reaches deeper than AAIW, roughly from 900m to the bottom of the PoL ($\square_n$ > 27.45kg.m^{-3}) with a mean southward transport of -0.05Sv and a similar seasonal pattern of the NACW (Fraile-Nuez et al., 2010).

The main aim of this work is to define the PoL seabed morphology in relation to oceanographic and geologic processes. A data set has been obtained in the SUBVENT2 expedition aboard the R/V Sarmiento de Gamboa (March-April, 2014): multibeam bathymetry (ATLAS Hydroacustic-DS), very high (parametric ATLAS Parasound) and high (airguns) resolution seismic profiles. A previous multibeam bathymetric grid (90x90m) from the Instituto Hidrográfico de la Marina (MDEF, Spain) has been also used.

MORPHOLOGY

It has been identified 10 morphological types on the seafloor: *i)* 15 *submarine hills* that show cylindrical or subrounded shapes (2-10.5km diameter) and elongated and flat at top (1.2-8.5km length). Their bases range between 1225 and 1530m and their tops between 828 and 1336m water depth. At the top, they show cones, ridges, slides, and terrace levels around 915-930m and 1130-1150m water depth. Some minor individual cones or ridges have also been observed in the area. *ii) Gullies* are located in the eastern flank of FLR. They show E-W to NE-SW trends and 1-5km length. *iii)* Two *canyons* have been located, one to the northeast of the FLR with an E-W to NE-SW trace, 33km length, width between 37km in the headwall and 2.5km in the slope, and 50m of incision. The second is located on the continental margin, with a NW-SE direction, 13km length, 2km width and 180m of incision. *iv) Mass transport deposits* are present along the FLR lower slope as foot of slope fans. *v) Linear normal fault scarps* with 10km length and up to 20m deep have been located on the continental slope. *vi)* A *rhombohedral depression* present at 960m depth on the continental slope, with 5km length and 0.8km width, related to normal faults. *vii) Circular depressions,* with a diameter of 2.5km and 90-130m deep, are located on the continental slope at water depths of 1170-1210m. They have asymmetrical profiles and present erosive features (truncated reflectors) on seismic profiles. *viii)* The *central valley* of the PoL has 100km length in a NE-SW direction, and is located at the foot of the slope. From 1290m water depth, the valley deepens toward the NE down to 1460m and toward the SW down to 1320m water depth. It shows erosive features on seismic profiles. *ix) Elongated depressions* are located around the submarine hills and could be classified as contouritic marginal valleys. They have so different lengths (1-17km) and widths (0.5-2km), the larger ones correspond to the coalescence of smaller. They are best developed to the east and south of the submarine hills, but their bases (1270-1530m water depth) are shallower than the central valley westwards. They show 180m of incision distributed in successive levels and clear erosive features on seismic profiles. In some cases a terrace level has been located at a depth (~1150m) similar to described on submarine hills. *x)* Some minor contouritic deposits (thickness around 50ms) are distributed along the area, they are *plastered* drifts NE-SW oriented, located between the submarine hills (6-10km of length) and related to the central valley, the three most important are situated around 1360-1385m, 1345-1355m and 1325-1315m water depth. The former have associated a contouritic channel with 10m deep.

DISCUSSION

The mapped features can be grouped into five main groups based on their distinct origin: (a) Submarine hills that have volcanic or diapiric origin, which are the most significant features of the central part of the PoL together with marginal valleys. (b) Tectonic features, such as the linear scarps and a rhombohedral depression which are related to normal faults at top of diapirs on the continental slope. (c) Circular depressions on the continental slope must be initially related to venting from diapirs, however must be reworked by bottom current dynamics. (d) Features related to sedimentary instabilities as canyons, gullies and mass-transport deposits at the FLR. (e) Bottom features related to contourite processes have been differentiated mainly produced by erosion processes such as the central valley and the marginal valleys around submarine hills, but also minor scale plastered drift deposits are present.

The shallower depth of seafloor in the PoL respect to the northern and southern adjacent regions favours the interaction of MW and the AAIW-MW interface with seabed. The central valley works a contouritic channel with structural control that favours the funnelling and acceleration of the MW eroding the seafloor. This process is focused in the base of the slope. Similarly, the marginal valleys must be related to the intensification of MW but also of the AAIW-MW interface with seafloor (down 900-1100m water depth) and their interaction surrounding the submarine hills that produce successive incisions with some characteristic terrace level. Locally this interface and the core of AAIW eroded the top of the hills around 900m water depth.

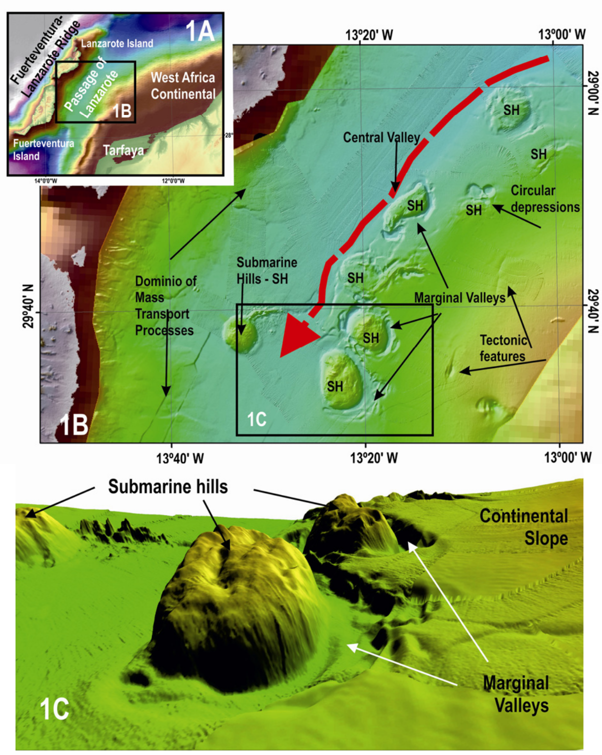

FIGURE 1. A) Situation Map; B) Compilation bathymetric map of the Lanzarote Passage; C) 3D scheme of a submarine hill and the associated marginal valley, view from SSE.

ACKNOWLEDGEMENTS

This research is supported by the SUBVENT (CGL2012-39524-C02) and MONTERA (CTM2009-14157-C02) projects, Spanish MINECO.

REFERENCES

Fraile-Nuez, E., Machín, F., Vélez-Belchí, P., López-Laatzen, F., Borges, R., Benítez-Barrios, V., Hernández-Guerra, A. 2010. Nine years of mass transport data in the eastern boundary of the North Atlantic Subtropical Gyre. Journal of Geophysical Research C: Oceans, 115 (9), art. no. C09009.

Tari, G., Brown, D., Jabour, H., Hafid, M., Louden, K., Zizi, M. 2012. The conjugate margins of Morocco and Nova Scotia. Regional Geology and Tectonics, pp. 284-323.