Blind Submarine Valleys in the Gulf of Cadiz. Structures of seabed fluid flow.

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Dead end submarine valleys are defined as giant, elongated (3 to 10 km long), collapsed and complex fault-strike features comprising mega-collapses and mega-pockmarks, generated in gas-venting areas and not associated to the collapse of mud-volcano complexes. We detected the dead end valleys above diapiric structures. The collapse processes associated to blind valleys result from fluid escape through migration pathways which, in turn, are created by distension due to diapiric activity or to later tectonic reactivation of these diapirs. The evolution of these blind valleys, and their present-day morphology as furrows, derives from progressive fluid migration as well as from interaction of Mediterranean Outflow Water with the seafloor.

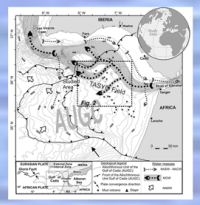

Figure 1.

Geological and oceanographic settings of the Gulf of Cádiz, with geological and tectonic boundaries of AUGC according to Medialdea *et al.* (2004), location of mud volcanoes after Medialdea *et al.* (2009), and oceanographic setting partially modified from Hernandez-Molina *et al.* (2003). Modified from León *et. al.* (2010).

Aquiles DV

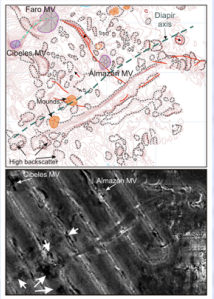

Figure 4.

Backscatter image and geomorphologic mapping of the surrounding area of the Aquiles dead end valley. Note the several mounds and pockmarks with moderate-high backscatter closed to the dead end valley. Modified from León *et. al.* (2010).

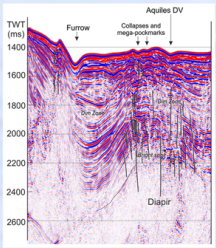

Figure 5.

Multichannel seismic line of Tasyo 8 in the western extreme of Aquiles BV (see figure 2). Show as pockmarks, furrows and dead end valleys are related with diapiric structures. Normal faults above diapirs are related to fluid flow pathways with dim zones and bright spots. Modified from León *et. al.* (2010).

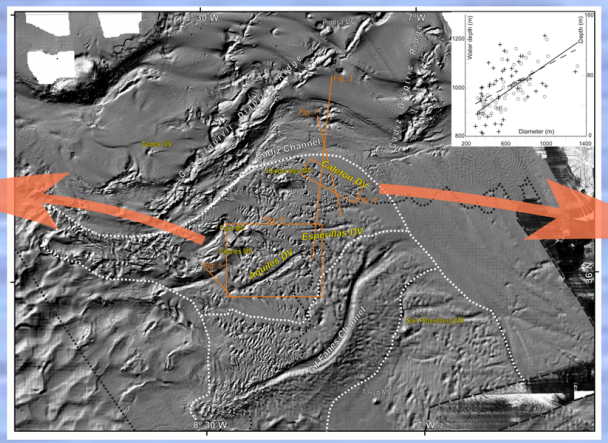

Figure 2.

3D merged multibeam view of TASYO 2000, MVSEIS08, MOUNDFORCE07 cruises and SWIM multibeam compilation (Zitellini *et al.*, 2009). Location of the main fluid escape features of the TASYO field (white dotted line) over a composition of swath bathymetry data and side scan sonar. In this figure, the spatial dimension of the fluid escape features of the subsequent figures of the paper can be compared. The black dotted line shows the limit between TASYO 2000 and SWIM multibeam compilation. Side scan sonar mosaic of NAVOCEANO is shown inside the black dashed line. The locations and directions of the figures and seismic profiles in the text are marked. In the top right image, only pockmarks with subcircular or elliptical shapes have been plotted. Circles: pockmark diameter versus pockmark depth; Crosses: pockmark diameter versus water depth. Modified from León *et. al.* (2010).

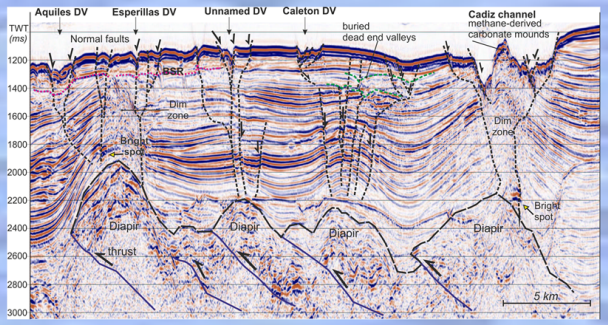

Figure 3.

The multichannel seismic profile belongs to line 1 of MOUNDFORCE07 cruise. This figure crosses the main dead end valleys and pockmarks of the TASYO field. The seafloor comprises an "inverted relief". Note that each depression feature is connected to a diapiric structure. Modified from León *et. al.* (2010).

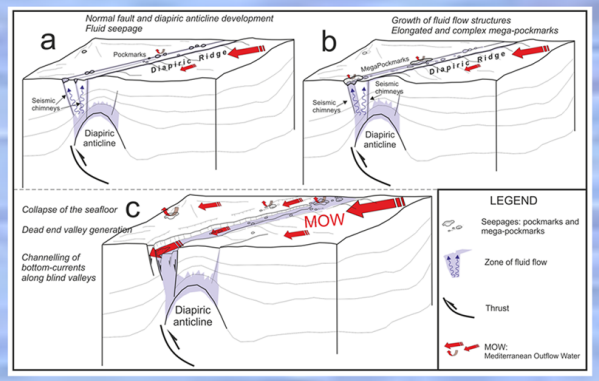

Figure 8.

Model proposed for formation of blind valleys in the Gulf of Cádiz. (a) Onset stage: normal faults development, and generation of isolated pockmarks and strings of fault-strike pockmarks. (b) Growth stage: growth up pockmarks, generating elongated shapes, and generation of isolated collapsed structures by lack of mass due to fluid migration. (c) Mature stage: huge, elongated, collapsed areas, and formation of blind valleys. MOW could run along the dead end valley and remodel into a furrow feature. Modified from León *et. al.* (2010).

The TASYO field is an area of intense seepages featuring several structures related to seabed fluid flow. Some of these, such as collapses and dead end valleys (DVs), are described for the first time in Leon *et al.*, 2010.

DVs are very elongated, complex, collapsed mega-structures of ca.10 km in length. They are characterised by lack of exits, they are limited by collapse structures (i.e. they begin and end in the flank of a collapse), the occurrence of structures related to seabed fluid-flow .

DVs develop above normal faults of diapirs. They represent the final stage in the evolution of a fluid-venting area controlled by linear fluid pathways. These pathways are driven directly by collapse processes caused by fluid escape through migration pathways, which are in turn created by the distension resulting from diapire activity or from late tectonic reactivation of these diapirs.

Dead end valleys are strike-fault features related to diapire normal faults connected to diapire anticlines. Focused seismic chimneys with bright spots and dim zones follow linear pathways along normal faults.

Although the Caleton DV, Esperillas DV and Aquiles DV channel MOW and work as furrows, their origin is linked to gravitational collapse caused by the seabed fluid flow.

Caleton DV

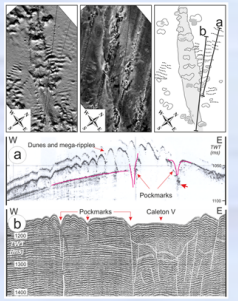

Figure 6.

Morpho-structure of the Caleton dead end valley. Top left, hill-shaded model of the seafloor. Top middle backscatter mosaic. Top right morphological schema; dead end valley (light grey), high backscatter areas (dark grey), sedimentary waves (dotted line), pockmarks (continuous line). Bottom; a) Line 23 (TOPAS) of TASYO 2000 cruise: dunes and mega-ripples nucleated from crater-like depressions of the North Sector. b) Line 25 (sparker) of Anastasya 00/09 cruise. Modified from León *et. al.* (2010).

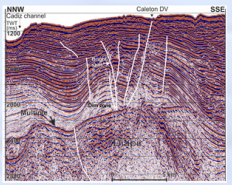

Figure 7.

Multichannel seismic line 10 of TASYO 2000 crossing the Caleton dead end valley (see figure 2). Note that the blind valley is above a diapir structure. Bright spots, collapses and dim zone are related to fluid flow from the diapir to sea floor. Modified from León *et. al.* (2010).

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REFERENCES

Hernández-Molina, F.J., Llave, E., Somoza, L., Fernández-Puga, M.C., Maestro, A., León, R., Medialdea, T., Barnolas, A., García, M., Díaz-del-Río, V., Fernández-Salas, L.M., Vázquez, J.T. Lobo, F.J., Alveirinho-Dias, J.A., Rodero, J., Gardner, J., 2003. Looking for clues to paleoceanographic imprints: A diagnosis of the Gulf of Cadiz contourite depositional systems. Geology, 31 (1), 19-22.

León R, Somoza L, Medialdea T, Hernández-Molina, F.J., Vázquez, J.T., Díaz-del-Río V, González, F.J. (2010) Pockmarks, collapses and blind valleys in the Gulf of Cádiz. Geo-Mar Lett. 30:231-247

Medialdea, T., Vegas, R., Somoza, L., Vázquez, J.T., Maldonado, A., Díaz-del-Río, V., Maestro, A., Córdoba, D., Fernández-Puga, M.C., 2004. Structure and evolution of the "Olistostrome" complex of the Gibraltar Arc in the Gulf of Cadiz (eastern Central Atlantic): evidence from two long seismic cross-sections. Mar. Geol. 209 (1-4), 173-198.
Medialdea, T., Somoza, L., Pinheiro, L.M., Fernández-Puga, M.C., Vázquez, J.T., León, R., Ivanov, M.K., Magalhaes, V., Díaz-del-Río, V., Vegas, R. (2009). Tectonics and mud volcano development in the Gulf of Cádiz. Mar Geol. 261, 48-63.

Zitellini, N. Gràcia, E., Matias, L., Terrinha, P., Abreu, MA., DeAlteris, G., Henriet, JP., Dañobeitia, JJ., Masson, D.G., Mulder, T., Ramella, R., Somoza, L., Diez, S. 2009. The quest for the Africa–Eurasia plate boundary west of the Strait of Gibraltar. Earth Planet. Sci. Lett. 280: 13–50.