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Geomorphology of the Avilés Canyon System, Cantabrian Sea (Bay of Biscay)

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ABSTRACT

The Avilés Canyon System (ACS) is a complex, structurally-controlled canyon and valley system constituted by three main canyons of different morphostructural character. They are, from east to west: La Gaviera Canyon, El Corbiro Canyon and Avilés Canyon. In addition to this ACS, a new canyon has been surveyed: Navia Canyon.

We present for the first time a high resolution multibeam map showing with great detail the morphological and structural complexity of this segment of the Cantabrian margin.

ACS presents a tectonic imprint marked by NW–SE, NNE–SSW and E–W structures. The morphology of their reaches as well as their single mouth, in addition to some rock dredges in their major valleys, demonstrates active down-slope flushing.

The continental shelf shows a flat, uniform slope with local and well defined rock outcrops south of Aviles Canyon head. Sedimentary zones are limited, showing thin unconsolidated sedimentary cover.

Strong continental margin water dynamics avoid thicker sediment deposition, being littoral sedimentary dynamics responsible for transport to the canyons heads and conduit to the Biscay Abyssal plain.

Biscay Abyssal Plain shows evidence of a strong westward current affecting the surveyed strip of this more than 10 km wide plain. Presence of two parallel deep sea channels, erosive scarps, and erosion of gully divides on the lower slope, may indicate that this is part of the distal fan at the termination of the large turbiditic system fed by Cap Ferret, Capbreton and other large canyons (Santander, Torrelavega, Lastres and Llanes) to the west of ACS.

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1. Introduction

Within the framework of the EU-funded INDEMARES (LIFE+) project "Inventory and designation of marine Natura 2000 areas in Spanish sea", the R/V Vizconde de Eza, of the Spanish Secretariat General of Fisheries (SGP), carried out two cruises in 2010 and 2011 in the Avilés Canyon area, in the central Cantabrian Sea (North Iberian continental margin). During these cruises, R/V Vizconde de Eza mapped 6282 km^2 of the seafloor of the margin, from 43° 37.60′N to 44° 18.37′N and from 006° 46.75′W to 005° 18.70′W, including continental shelf, continental slope and a narrow band of abyssal plain attached to the base of the continental slope (Figs. 1 and 2).

The main objective of the investigation was to locate and map possible Vulnerable Marine Ecosystems (VME) and, as the project specifies, "*…to increase knowledge on marine species and habitats, their conservation status and threats, and this will make possible the selection and proposal of sites to be included in the existing Natura 2000 network*".

Following the ecosystemic approach, the investigation was multidisciplinary, involving geology–geophysics, biology (benthic and pelagic), ecology and physical oceanography. This paper deals with the geomorphology and shallow structure of the area. Others will publish elsewhere on the results of the sedimentation, biological, oceanographic and ecologic investigations.

The results of this study, in turn, will provide an essential base for the other investigators. For example, knowledge on the configuration

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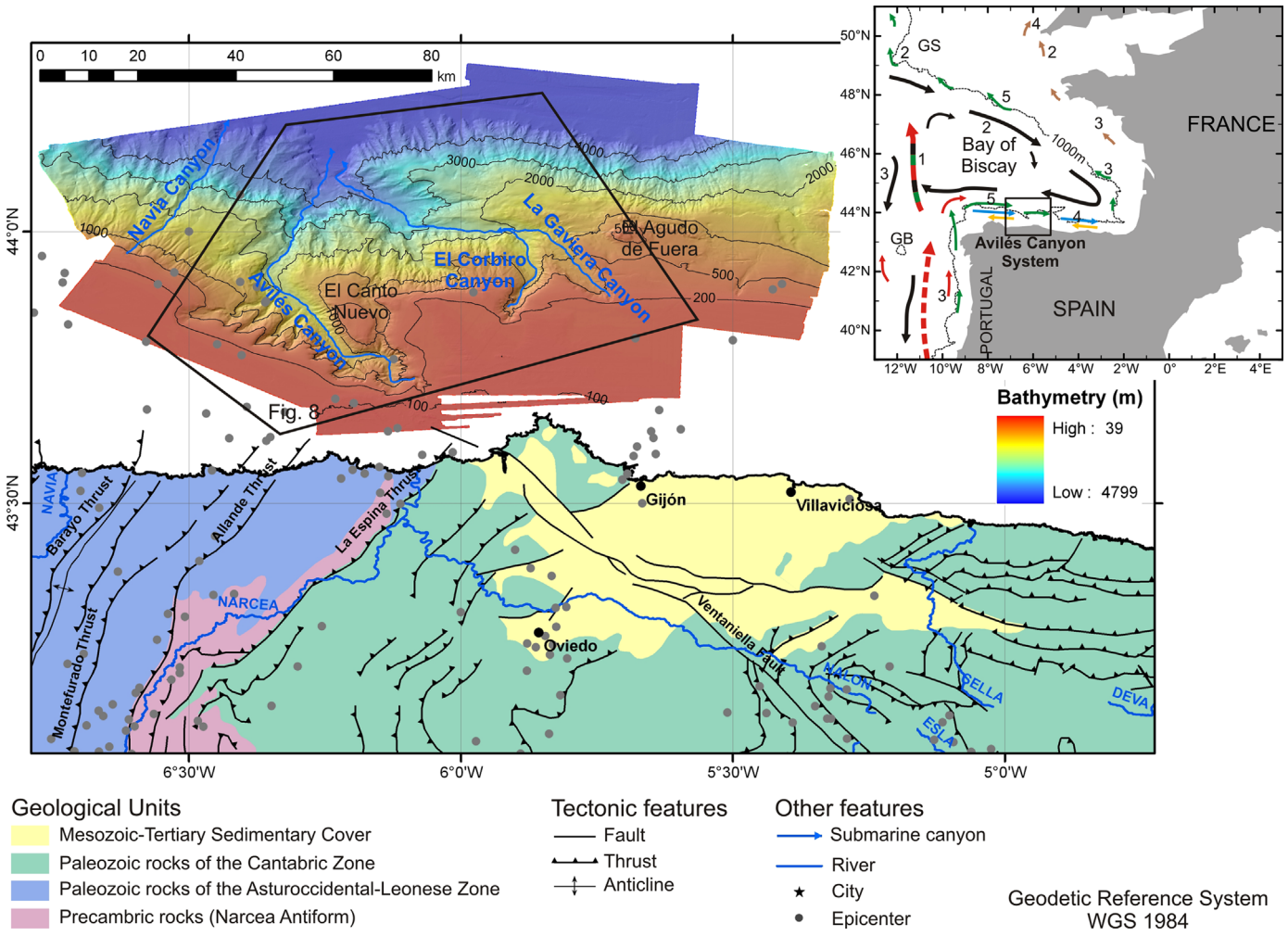

Fig. 1. Multibeam bathymetry of studied area. Onshore Geology from Julivert (1971) and Pérez-Estaún et al. (1988). Epicenters from Spanish National Geographic Institute (IGN) database. Black box indicates location of Fig. 8. Inset: main hydrographic circulation patterns and mean flow values (numerals in cm s^{-1}) largely from Pingree (1993) and González-Pola et al. (2012). Red arrows=Mediterranean Water; black arrows=North Atlantic Current; orange and blue arrows=continental spring–summer/autumn–winter wind driven shelf currents; green arrows=European slope current (Pingree et al., 1999); brown arrows=Armorican/Western English Channel shelf currents; GS=Goban Spur; GB=Galicia Bank. 1000 m isobath is shown (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

of the seafloor is essential in understanding the distribution of benthic communities and bottom circulation patterns. In addition, the shallow structure could provide data regarding changes that have taken place in time on circulation patterns and the distribution of sessile communities.

1.1. Geologic and oceanographic setting

Since Francis P. Shepard published the early works on the origin of submarine canyons (Shepard, 1936, 1963, 1981; Shepard and Dill, 1966), the importance of submarine canyons as the main conduits for matter and energy transfer from the continental shelf to the deep seabed has been studied by many authors in different latitude locations and geomorphologic and tectonic settings (Laberg et al., 2007; Taylor et al., 2000; Lastras et al., 2011a, 2011b; Antobreh and Krastel, 2006; Canals et al., 2006; Arzola et al., 2008; Vachtman et al., 2013). The advent of the modern swath bathymetry systems permits an unprecedented high resolution seascape vision of the canyon systems, which in some cases and using advanced visualization tools permits a very accurate 3D representation of the canyon realms (see 3D views in additional material on the web version) and very realistic "flight-through" video (see *"Avilés_Flythrough.wmv"* in web version).

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.dsr2.2013.09.031.

The interplay between canyon morphology, hydrography and biodiversity has been demonstrated in recent years (De Leo et al., 2010; Cunha et al., 2011). Canyons also have been cited as preferential areas to growing cold-water corals in the Bay of Biscay (De Mol et al., 2011). Nevertheless, studies of the morphology and structure of the canyons in the Cantabrian Margin are scarce, being the Cantabrian margin possibly the less studied area of the Spanish margins (Ercilla et al., 2008; Cirac et al., 2001; Mulder et al., 2012).

The area of influence of the Avilés Canyon System, objective of this work, is located approximately between latitude 43° 37.60′N and 44° 18.37′N and from 006° 46.75′W to 005° 18.70′W longitude (Figs. 1 and 2). This region is part of the compressive continental margin north of the Iberian Peninsula.

The complex tectonic history of this margin started with the rifting of the Bay of Biscay (from Triassic to Lower Cretaceous) and the development of a passive margin (Upper Cretaceous), finishing with a compressive Cenozoic phase that leads to a partial closure of the Bay of Biscay (Boillot et al., 1979; Thinon et al., 2001; Gallastegui et al., 2002). This last phase developed a narrow convergent margin to the south (the actual North Iberia margin) and the uplift and deformation of the Cantabrian Mountains (Pérez-Estaún et al., 1995;

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