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Review article

A Pliocene mixed contourite–turbidite system offshore the Algarve Margin, Gulf of Cadiz: Seismic response, margin evolution and reservoir implications

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ABSTRACT

A buried mixed contourite–turbidite system has been identified in the Pliocene succession of the Algarve basin in the northern Gulf of Cadiz. This margin is currently dominated by the Mediterranean Outflow Water and associated contourite deposition. Analysis of seismic data along with careful geographical and oceanographic reconstructions of the margin show the gradual move from a turbidite-dominated towards a contourite-dominated margin, and the subsequent 'birth' of an impressive elongate mounded contourite drift system- the Faro-Albufeira drifts. The contourite drift can be distinguished from downslope (turbiditic and mass transport deposits) based on the acoustic character, distribution analysis and through careful margin reconstruction. In the earliest Pliocene, Seismic Unit P1 has been interpreted as a dominant down-slope (most likely turbidite) system sourced mainly from the northeast. There is clear evidence of contourite reworking at Seismic Unit P2, where upslope progradation and a sheeted morphology are observed. High amplitude reflections are thought to be a result of more vigorous bottom currents in the early Upper Pliocene that were capable to redistributing coarser sediments. However, in the northeast of the study area a thick sequence of chaotic seismic facies has been interpreted as mass transport deposits sourced from the north indicate that the bottom currents were unable to dominate over the entire margin due to high down-slope clastic influx. Semi-transparent Seismic Unit P3 indicates that the Upper Pliocene initially experienced a reduction in bottom current intensity; however upslope progradation shows that a mixed system was maintained. Above the Base Quaternary Discontinuity (*ca.* 2.6 Ma), highly erosive discontinuities and high amplitude seismic reflections are evidence of pronounced intensification of the Mediterranean Outflow Water and a move to a fully contourite-dominated slope. Mixed turbidite–contourite systems such as the one identified in the Algarve Basin could provide impressive petroleum potential where downslope clastics are winnowed and reworked by bottom water currents to leave good reservoir properties. Here, we present a conceptual model for sheeted drifts as hydrocarbon reservoirs in the subsurface.

1. Introduction

The term 'contourite' is accepted for those sediments deposited or substantially reworked by bottom currents (Heezen et al., 1966; Rebesco and Camerlenghi, 2008). Major accumulations of contourite deposits are referred to as "drifts". Where currents are strong enough, a variety of erosional and depositional features are developed (Evans et al., 1998; García et al., 2009; Hernández-Molina et al., 2008; Masson, 2001; Nelson et al., 1993; Preu et al., 2013; Stow et al., 2009; Stow and Mayall, 2000). An association of various drifts and related erosional features is commonly termed a contourite depositional system (CDS) (Hernández-Molina et al., 2003, 2008). Mixed contourite–turbidite systems are developed where bottom currents have interacted with downslope processes (Faugères et al., 1999; Rebesco and Camerlenghi, 2008).

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The use of seismic data is vital to contourite drift identification and interpretation. Drifts are primarily identified by external geometry and internal architecture. This is useful for drifts of mounded morphology, but much more challenging with aggradational sheeted drifts. For these, the seismic facies could be an additional important diagnostic tool. It is, therefore, of great importance to fully understand the acoustic response of sedimentary drifts. Work by Faugères et al. (1999), Howe (2008), Nielsen et al. (2008) and Shanmugam (2006) have provided an initial overview to the seismic response of contourites and outline the processes by which to analyse and describe drifts using geophysical data. There are several types of contourite drifts, defined mainly on their morphological, sedimentological and seismic characteristics (Faugères and Mulder, 2011; Faugères et al., 1999; McCave and Tucholke, 1986; Rebesco, 2005; Rebesco and Camerlenghi, 2008; Rebesco and Stow, 2001; Stow et al., 2002b). The generation of each drift type is controlled by a complex set of factors, most importantly the local morphology of the seabed, the bottom water current conditions and the sediment supply (Faugères and Stow, 1993; Faugères et al., 1999; Shannon et al., 2005; Viana et al., 1998). Often, a complex CDS is formed, consisting of many different drift types and erosional elements. A given contourite accumulation may also evolve over time between drift types. Since the primary identification of contourites is usually by overall drift geometry (Nielsen et al., 2008), many known drifts are those with some topographic relief from the seabed, i.e. those of mounded external morphology. Much less is known about the identification of sheeted drifts both on the seabed and in the subsurface. In recent years, the hydrocarbon potential of contourite deposits has been explored (Viana et al., 2007), and it is seen that clastic reservoir (sand-rich) facies are most commonly found as sheeted drifts, or as localized channel accumulations. It is therefore of great importance that these drifts are characterized and made identifiable in the subsurface and distinguishable from down-slope deposits.

This work examines a buried contourite sheeted drift within a mixed system in the Gulf of Cadiz using seismic data. The key aims are therefore; 1) Characterize the along- and down-slope components of the system on all scales (drift-, depositional unit- and seismofacies-scale); 2) Assess the interaction between along- and down-slope processes; 3) Propose a depositional model for the Algarve Margin Pliocene section; 4) Identify any key criteria to aid the identification of sheeted contourite drift systems elsewhere; and 5) Use the above information to make conclusions on the identification of contourites in the subsurface for hydrocarbon exploration.

2. Geological and oceanographic setting

2.1. Geological setting and margin evolution

The study area is located along the Algarve Margin in the western Gulf of Cadiz (Fig. 1A). This region has had a complex geodynamic

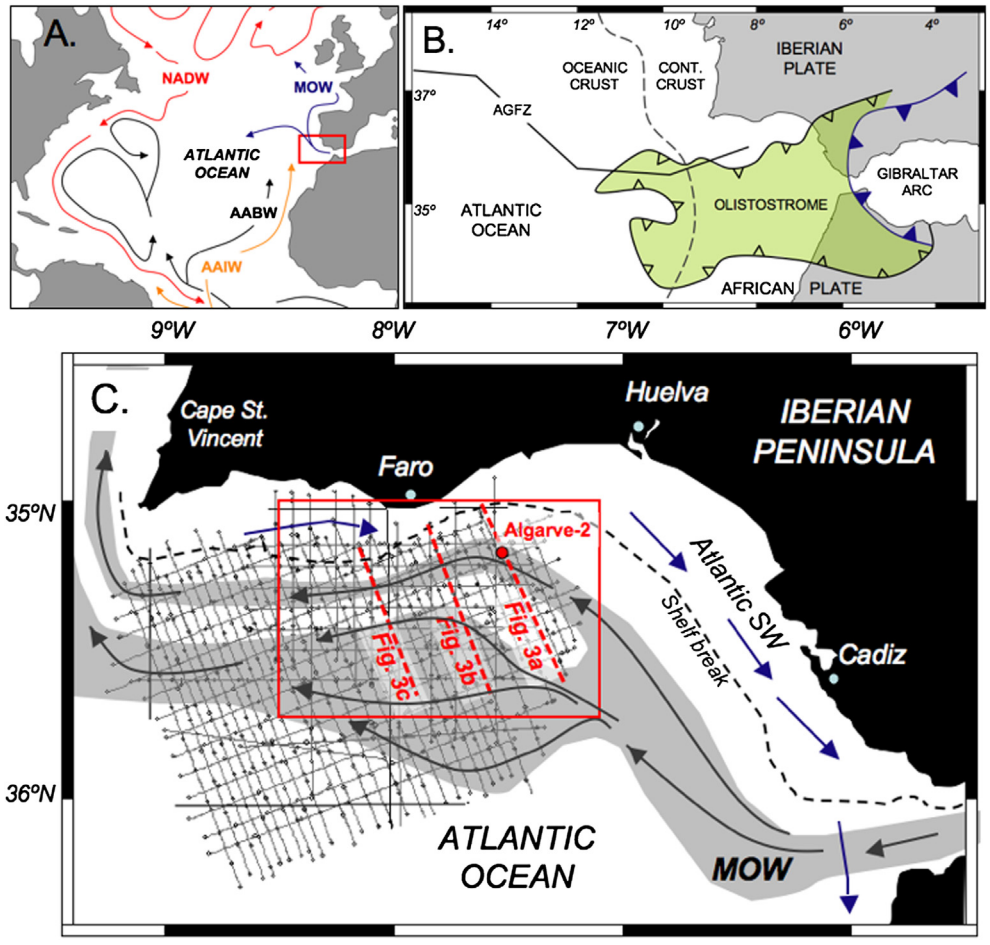

Figure 1. A) Location map for the study area (boxed). AABW = Atlantic Bottom Water; AALW = Atlantic Intermediate Water; MOW = Mediterranean Outflow Water; NADW = North Atlantic deep Water. B) Tectonic and Location Map for the study Area. Modified from Maldonado and Nelson (1999). C) The study area is located along the northern margin of the Gulf of Cadiz and is influenced by the Mediterranean Outflow Water. The seismic surveys used for this study are indicated. Study area highlighted in box. Red dashed line indicated position of the seismic lines on Fig. 3. MOW = Mediterranean Outflow Water. Atlantic SW = Atlantic Surface Water.