Tectonic domains of the Betic Foreland System, SW Iberian Margin: Implications for the Gulf of Cadiz Contourite System

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Introduction

Deep-water sedimentation is influenced by three variables – tectonics, climate and sea-level changes (e.g. Artoni et al., 2005; Leeder, 2011). Together, they control the distribution and architecture of sedimentary successions and, therefore, basin development.

The SW Iberian Margin (SWIM; Fig. 1a,b) occurs in an region of complex interplay between sedimentary, oceanographic and tectonic processes. The seafloor morphology is influenced by regional lithospheric movements, both during the Mesozoic rifting and the following Eurasia-Nubia plate convergence (Figueiredo, 2015; Pereira and Alves, 2013; Terrinha et al., 2009), and by local diapiric processes (e.g. Medialdea et al., 2009; Ramos et al., 2017).

The Gulf of Cadiz Contourite System (GCCS) developed in the SWIM, as consequence of the interaction of the Mediterranean Outflow Water (MOW) with the continental middle slope (Fig.1b). Being developed in a complex tectonic setting, it is a key location for exploring the influence of tectonic activity on deep-water sedimentation.

Fig.1 Geographic location of the SW Iberian Margin: (a) Regional setting, with the main tectonic structures. White rectangle show the study area; (b) Detailed map of the margin showing the main oceanographic and structural features. GB: Guadalquivir Bank, PB: Portimão Bank, AH: Albufeira High. Black circles show earthquake locations. Coordinate system: UTM-29N WGS84. Bathymetric data from the EMODnet Bathymetry Consortium, (2018).
Aims & Methods

This work aims to understand how inherited basin configuration and tectonic activity controlled the evolution of the GCCS. This was achieved based on a tectonostratigraphic analysis of an extensive 2D multibeam seismic dataset complemented by bathymetric and earthquake activity data.

Tectonostratigraphy

*Fig. 3* Chronostratigraphic chart and correlation between the tectonostratigraphic seismic units (SUI, SUII and SUIII) and discontinuities (T1 to T3/Ta to Tf) identified in this work and seismostratigraphic models for the Algarve Basin. The depositional systems are also shown.

Tectonostratigraphy

- The Algarve, Doñana, Sanlucar and Cadiz basins developed in the foreland of the Betic-Rif Orogen.
- Three regional tectonostratigraphic seismic units (SUI to SUIII) were identified across the basins (Fig.3 and 4). They correspond to different phases of the SWIM tectonic evolution.

**Foreland Basin System**

**Wedge-top basins**

**SUIII**
- Miocene-Quaternary Foreland Basin system.
- SUIII sub-units details in Fig.3.

**SUII**
- Accretionary wedge (GCAW) sediments.
- Deformed Triassic, Cretaceous, Palaeogene and Neogene rocks.

**SUI**
- Syn- and post-rift inverted margin.
- Folded Mesozoic and Palaeogene rocks.

*DeCelles and Giles, (1996)*

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Tectonic Structures

Three important tectonic structures were identified (Fig. 5):

- the dextral strike-slip NW-SE Gil Eanes Fault Zone (GEF);
- NE-SW to ENE-WSW Cadiz Fault (CF);
- E-W to ENE-WSW Albufeira-Guadalquivir-Doñana Basement High (AGD).

Based on their location and orientation they were interpreted as being inherited structures from the Mesozoic rift system (e.g. Terrinha et al., 2013).

Fig. 5 Seismic sections and interpretation from lines (a) P74-20 – GEF, (b) IAMGC3 – CF and (c) PD00-824 – AGD. Seismic units (SUI and SUIII), sub-units (SUIIa to SUIIIg) and the identified unconformities (T2 and Ta to Tf) are shown. Vertical exaggeration of 10x. Profiles location is given in Fig. 1c.
The margin’s evolution was strongly influenced by the tectonic structures (GEF, CF and AGD). Together with regional tectonic and paleoceanographic processes, they controlled the growth pattern of the Miocene-Quaternary deposits of the foreland basin system (SUIII).

Based on these observations, the SWIM was divided into four tectonic domains – A, B, C and D – with different structural and seismological characteristics (Fig.6).

**Fig.6 Tectonic Domains of the SWIM.** Back dots: earthquake epicentres. AGD: Albufeira-Guadalquivir-Doñana Structural High, GB: Guadalquivir Bank; AH: Albufeira High, GEF: Gil Eanes Fault, CF: Cadiz Fault, BT: Betic Front Thrust, GDR: Guadalquivir Diapiric Ridge, CDR: Cadiz Diapiric Ridge.
SWIM Tectonic Domains: imprint on Sedimentary Processes

The GCCS depositional and erosional features show different characteristics for each of the tectonic domains previously recognised (Fig.8).

Fig.7 Seismic lines showing the contourite drifts in each of the tectonic domains. Seismostratigraphic interpretation of Hernández-Molina et al., (2016) for the contourite drifts is shown (LQD, MPD, EQD, LPD, IPD, EPD and M; see Fig.3).
**SWIM Tectonic Domains: imprint on Sedimentary Processes**

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<thead>
<tr>
<th>Tectonic Domains</th>
<th>Characteristics</th>
<th>Contourite System</th>
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<tr>
<td><strong>Domain A</strong></td>
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<tr>
<td>- Aseismic zone.</td>
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<td>Abrasive surface.</td>
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<td>- Gentle seafloor, with smooth relief.</td>
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<td>- Sheeted drifts.</td>
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<td>- Diapirs outcrop in the north of the domain.</td>
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<td><strong>Domain B</strong></td>
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<td>- High number of seismic events.</td>
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<td>Sheeted and deformed sheeted drifts.</td>
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<tr>
<td>- Intense diapirism → controlled depocentre evolution.</td>
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<td>- Paleo-mounded drifts against AGD.</td>
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<tr>
<td><strong>Domain C</strong></td>
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<tr>
<td>- <strong>Flexural subsidence</strong>, in response to the tectonic loading caused by the Betics Orogen, led to the increment of accommodation space (Pliocene-Quaternary).</td>
<td></td>
<td>Mounded-sheeted drifts (~50km wide, 75km long and max. thickness of 1.73s TWT).</td>
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<td></td>
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<td>- Main depositional sector of the GCCS.</td>
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<td><strong>Domain D</strong></td>
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<tr>
<td>- <strong>Small accommodation space</strong> or sedimentary input.</td>
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<td>Small sheeted drifts (10-15km wide and ~50km long and max. thickness of 1.45s TWT).</td>
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<td>- Uplifted area, between the Atlantic and Tethys rifting domains (Pereira and Alves, 2013).</td>
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**Structural elements identified as main controls to the evolution of the GCCS**

- **Tectonic subsidence or uplift**
  Flexural subsidence create accommodation space.
  Contrariwise, drifts are not very extensive in uplifted areas, where the accommodation space is limited.

- **Presence of structural obstacles**
  Mounded drifts geometries near important structural obstacles.
  If the seafloor is gentle, sheeted drifts are developed as a consequence of a weak and wide non-focused MOW.

- **Fault-related depressions**
  Contourite channels locally developed along the GEF and F4 faults → influence of fault-generated seafloor morphology (e.g. depressions resulted from the negative flower structures in the GEF southern sector).
Conclusions

- This work demonstrates the **inherited tectonic structures** and the **margin paleo-topography** are the major elements controlling the initiation and the development of the contourite system. The SWIM morphology was shaped by the regional tectonic processes – that conditioned the gateways’ evolution and the diapiric activity – and by the paleoceanography – MOW circulation – throughout the Miocene-Quaternary.

- It was established that **drifts** characteristics (e.g. size and geometry) are **dependent on tectonic-controlled depositional space**, at a basin-wide scale. The presence of **structural obstacles** represents a major controlling factor in drift evolution **imposing the development of mounded geometries** where important structural obstacles conditioned the current circulation.

- Consequently, these results emphasize the **importance of taking tectons into account for contourite systems evolutionary models**. It can be a guide for forthcoming works, where deep-water systems develop in active settings or in areas with important inherited topography (e.g. the Argentinian-Uruguayan margin).

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References

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