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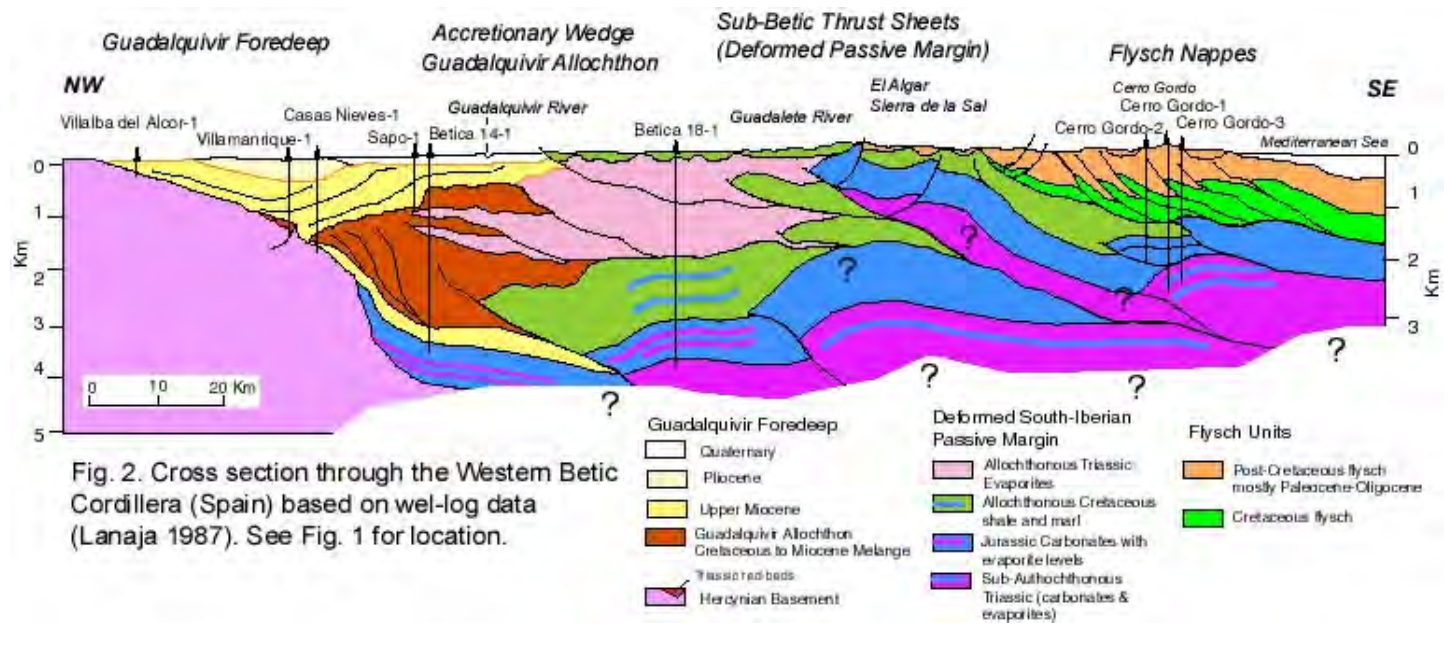
## A Cretaceous Allochthonous Evaporitic Province within the Betic-Maghrebian Domain. Comparison with the present-day Gulf of Mexico

### Abstract

Field, seismic and well-log data suggest that most of the Triassic of the external domain of the Betic-Maghrebian domain of the Western Mediterranean is allochthonous. Allochthonous Triassic is much more abundant in the Guadalquivir Allochthon (i. e. Westernmost Sub-Betic realm) of the Betic Cordillera than in the Rif. Triassic evaporites are directly in contact or inbedded within Upper Cretaceous-Paleogene deep-water sediments and the Jurassic is absent. In the Rif Cordillera the so-called " marnes a gypse " suggest evaporitic re-sedimentation within the actual Prerifaine Nappe. Along the Central Rif, exploration well BB-1 encountered several meters thick Triassic breccia that constitute the basal detachment of the area. Further east in Algeria and Tunisia several Triassic " salt glaciers " emplaced during Albian to Turonian time have been described along the Tell Cordillera. Restoring the lateral displacement of Africa and Iberia the Betic and Maghrebian (i. e. Rif and Tell Cordilleras) passive margins were facing each other during Triassic and Jurassic times. During Neogene time after the emplacement and collision of the Alboran Block the allochthonous evaporitic province was dismembered and thrust onto the passive margins of Iberia and North Africa. The Gulf of Cadiz and the Prebetic Zone represents the only preserved segments of the south Iberian Mesozoic passive margin. All these observations suggest that during Cretaceous time the South Iberian and



Fig. 1. Landsat image of the Betic-Maghrebian Domain. The location of cross-section of figure 2 and the field examples of figure 3 are indicated.



North African margins resembled the present day Gulf of Mexico. Therefore the Betic, Rif and Tell Cordilleras could provide field analogs of exploration allochthonous salt provinces.

## Introduction

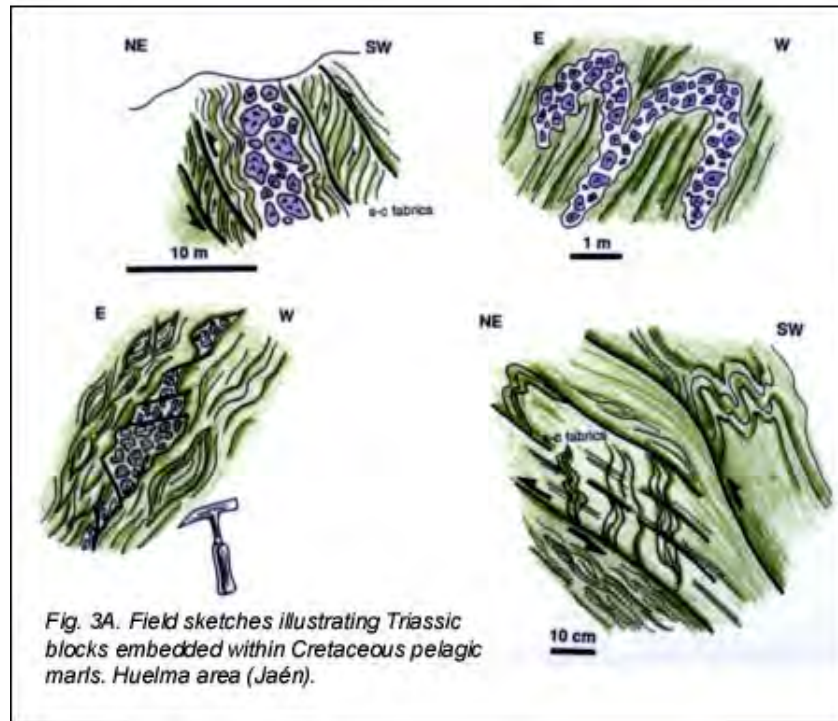
Field, seismic and well-log data suggest that most of the Triassic of the external domain of the Betic-Maghrebian domain of the Western Mediterranean is allochthonous. Allochthonous Triassic is much more abundant in the Guadalquivir Allochthon of the Betic Cordillera than in the Prerifaine Nappe of Morocco. Triassic evaporites are directly in contact or intermixed with Upper Cretaceous-Paleogene deep-water sediments and the Jurassic is absent. The structure of the External domain of the Betic, Rif and Tell Cordilleras is the result of piggy-back sequence of emplacement, that is, the upper units were emplaced first, and the later emplacement of the lower units deformed the uppermost ones by underneath. The first unit to be emplaced was the accretionary wedge (i. e. Guadalquivir and Prerifaine Nappe) and the passive margin units were emplaced afterwards. This evolution result in the presence of numerous tectonic windows of passive margin units (i. e. Jurassic and Lower Cretaceous) surrounded of intermixed Triassic and pelagic Upper Cretaceous and younger sediments.

## Allochthonous Triassic vaporites

### Western Betic Cordillera

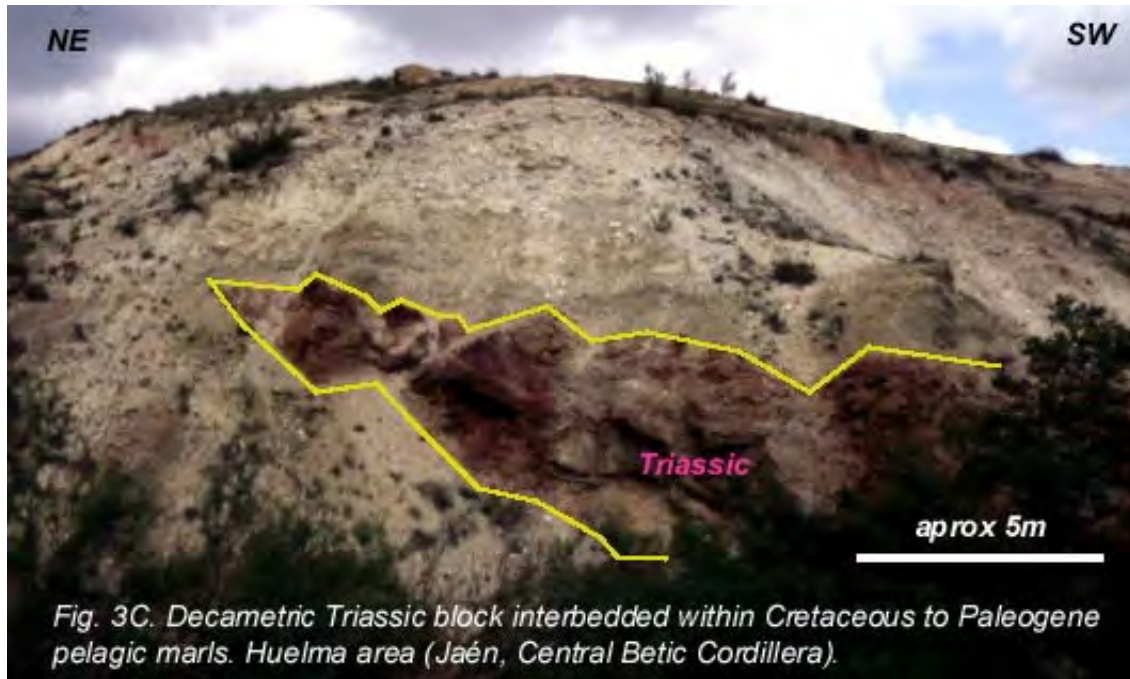
The thickest allochthonous Triassic evaporitic section was encountered by well Bornos-1, which drilled 2500 meters of Triassic salt. Further west, Jerez de la Frontera region, the well Betica 18-1 also encountered 1500 m of allochthonous Triassic salt within the Guadalquivir Allochthon detached from Sub-Betic Maastrichtian shale (Fig. 2, see Fig. 1 for location). This well also encountered sub-autochthonous Triassic salt, dolomite and anhydrite. Further north well Betica 14-1 located along the Guadalquivir valley drilled several hundred meters thick Triassic salt interbedded within Miocene marls of the Guadalquivir Allochthon (Fig. 2).

The Guadalquivir Allochthon involves Upper Cretaceous deep-water pelagic facies "Capas Rojas" and deep-water pelagic marls with radiolarian. Pelagic deposits are mixed with Triassic evaporites, mainly gypsum and salt, shales, siltstones and occasional sandstones. Upper Cretaceous deep-water sediments above a low angle detachment systematically overlie Triassic evaporites and shales.



### Central Betic Cordillera

The Guadalquivir Allochthon thins out towards the Central Betic Cordillera mainly occupied by the Sub-Betic thrust sheets characterized by a thick Jurassic section encountered by the Nueva Carteya-1 and Fuensanta de Martos-1 wells (Lanaja 1997). Triassic sediments constitute kilometric scale thrust sheets to centimetric or decametric blocks inter-bedded within Cretaceous-Paleogene marls (Fig. 3). At a mesoscopic scale the structure of the Triassic is



characterized by multiple decollement tectonics, disharmonic folding, s-c type shear fabrics and gypsum cracks. Re-sedimentation processes and slumps are common within the section, very well exposed near Jodar (Jaen) and Huelma (Granada) (Fig. 3). These observations suggest that Triassic evaporites were emplaced during Upper Cretaceous time in deep-water setting.

### *Prerifaine Nappe Rif Cordillera (Morocco).*

The Prerifaine Nappe of the Rif is the equivalent of the Guadalquivir Allochthon and represents an Accretionary Wedge (Flinch 1993). Often Triassic shales and evaporites (mainly gypsum) are intermixed with deep-water Upper Cretaceous marls; these deposits are referred to locally as "marnes à gypse". Locally these sediments have a breccia character including blocks of metamorphic and igneous rocks and are referred to as "brèche polygénique à matrice gypseuse". These deposits are well exposed in the Ouerha valley of the Central Rif (Asebriy et al. 1987). Lower Eocene sediments unconformably overlie Triassic evaporites, suggesting that the emplacement was already completed at that time. In the south-central Rif, Had-Kourt-Teroual area, well BB-1 encountered two Triassic breccia levels 20 and 67 meters thick, which represent the basal detachment of the Prerifaine Nappe detached from the Jurassic Imbricates (Service Géologique du Maroc 1984 and 1990). Along the Rharb Basin, Triassic shales and evaporites are inter-bedded with Cretaceous marls of the Prerifaine Nappe. The exposed Triassic Ridge of Souk el Arba and the Triassic-Cretaceous imbricates of El Fokra-1 well are examples of this type of "mélange".

### *"Zone des Dômes" Tell Cordillera (Algeria and Tunisia)*

Mostly field studies in Algeria and Tunisia (Vila 1995) suggest that Triassic "salt glaciers" were emplaced during Turonian and Albian time, slightly earlier than in the Betic Cordillera. Even though the allochthony of the Triassic salt glaciers of the "Zones des Dômes" Algeria and NW Tunisia is still subject of debate published data indicates that the Triassic reached an early or advanced tongue stage (in the sense of Wu et al. 1990) and perhaps only exceptionally reached the allochthonous sheet stage like in the Betic Cordillera. Further east in Tunisia the front of the Téboursoûk unit separates these tongues from the more proximal diapirs (Vila et al. 1999).

### **Comparison with the Gulf of Mexico**

The Triassic evaporites of the Betic, Rif and Tell Cordillera are interpreted as passive margin type allochthonous evaporites emplaced during passive margin stage (before Neogene compression) in a similar way that the allochthonous salt of the Gulf of Mexico. Reworked Triassic salt and gypsum (i. e. blocks and slumps) within the pelagic Mesozoic section support this hypothesis. This hypothesis would help to explain the presence of large volumes of Triassic sediments within the Guadalquivir Allochthon as well as the absence of Jurassic strata. In the offshore Louisiana area though, the *Sigsbee salt nappe* can reach a thickness of around 7 Km and a length of about 200 Km (Worall and Snelson 1989) that contrasts with the dimensions of the evaporitic sheets of the Guadalquivir Allochthon that reach at least 2.5 kilometers of thickness in the Western Betic Cordillera but difficult to evaluate because of erosion. The allochthonous Triassic occupies the external zones of the Western and Central Betic Cordillera, extending along more than 200 kilometers. While the allochthonous evaporites of the Gulf of Mexico consist mostly of salt and are Jurassic in age the ones of the Betic Cordillera are Triassic and apart from salt include also gypsum, anhydrite and shale.

Omissional contacts between Triassic and Cretaceous or Paleogene pelagic sediments with locally preserved roll-over structures, are the most widespread evidences of extensional mini-basins overlying the allochthonous Triassic of the Betic Cordillera. While in the Gulf of Mexico supra allochthonous salt withdrawal basins (i. e. mini-basins) and related extensional systems are always preserved in the Betic Cordillera are inverted, carried piggy-back on the Guadalquivir Allochthon and strongly deformed due to Neogene compression.

### **Palaeogeographic Implications.**

Triassic half-grabens superimposed on the Hercynian basement of the Iberian Meseta represent the initial rifting of the margin. Moguer-1, Villamanrique-1 and Casas Nieves-1 wells in the Guadalquivir Basin and well KC-1 underneath the Rharb Basin encountered Triassic red-beds filling half-graben structures overlying the Hercynian Basement, discordantly covered by evaporitic deposits that thickened towards the Tethys (SSE). A widespread Lower Jurassic carbonate platform occupied the south Iberian margin. The carbonate platform was broken up during Middle Jurassic time and the region became an Atlantic-type passive margin. Allochthonous salt deposits may occupy distal positions of passive margins. A tentative hypothetical reconstruction of the External zones of the Central Betic Cordillera suggests northward displacement of the Guadalquivir Allochthon in the order of 200-Km (Flinch et al. 1996).

Conventional Cretaceous palaeogeographic reconstructions of North Africa and South Iberia do not consider the allochthonous Triassic evaporitic province that probably occupied the Western Tethys. Reconstructing the location of the Iberian plate, Algeria and Tunisia are facing the Sub-Betic area, before the lateral westward displacement of Iberia. The proximal part of the South Iberian margin, relatively undeformed can be studied in the Eastern Pre-Betic Cordillera, Alicante region, and the northwestern Gulf of Cadiz where the most incipient and proximal Triassic diapiric stage associated to listric normal faulting can be still seen. In a similar palaeogeographic position in the north African side of the margin are located the Rides Prerifaines and the Guercif Basin of Morocco. The "Zones des Domes" of Algeria and NW Tunisia represent a more distal stage of Early and Advance Tongue stages (Wu et al. 1990) but do not reach the Allochthonous sheet stage with overlying withdrawal basins that existed and were incorporated later on to the Guadalquivir Allochthon.

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