Dynamics of double-polarity subduction: application to the Western Mediterranean

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Abstract- *The Western Mediterranean tectonic setting and history is studied by means of three-dimensional numerical models. Goals are to understand its dynamics and to test the feasibility of a double-polarity subduction process that could have a key importance in the complex setup of this area.*

The physical models, the numerical techniques involved, and some results in two and three dimensions are presented in this work.

I. Introduction

Present day tectonic setting of the Western Mediterranean is highly debated. Many researchers have different and conflicting views on the current setup, and, in particular in the geological history of this region. This variety results from the extremely complex data gathered in the region (seismic, petrology, volcanism, topography, gravity and surface structure) that need to be reconciled in a single model.

Recently Vergés and Fernàndez proposed a tectonic history of the region since Cretaceous (last 85 Million years) based on the interaction of two tectonic plates with opposite polarity (opposite direction of subduction, see Figure 2). They explain the formation and evolution of the Betic-Rif orogenic system and the associated Alboran back-arc basin (Fig. 1) by a lateral change in subduction polarity of the Ligurian-Thetys oceanic domain.

Double-polarity subduction and subduction reversal are proposed in many areas, for example [2-4], and studied numerically in 2D for example [5]. Nevertheless, at the moment there is no study to understand its feasibility, dynamics and geological consequences in a realistic three-dimensional study. The third dimension is particularly important in this process, as many subduction zones are oblique and therefore lateral propagation of deformation is expected. Moreover, surface deformation, for example curvature of the trench (the line on the surface of the contact between the plates) may be modified by the interaction between two close by subducting plates.

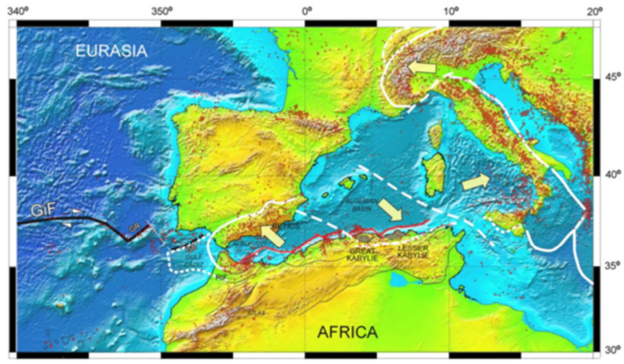

Fig. 1. Vergés and Fernàndez, 2012.

II. Objective

The aim of this study is to analyze the dynamic evolution of a double polarity subduction process and its consequences in order to test the physical feasibility of this interaction and provide geometries and evolutions comparable to the proposed to the Western Mediterranean. While this work is focused on numerical models, analogue modeling will be also carried out within the scope of the Thesis. An interdisciplinary group of researchers at the

Institute of Earth Science Jaume Almera (CSIC) in Barcelona is focused on the study of the Western Mediterranean; this work takes place within that framework, aiming to understand its geological history.

III. Model and Methodology

The dynamic evolution of the Earth at large temporal and spatial scales -for example subduction- is modeled as a multiphase flow problem. Its solution requires advanced numerical techniques usually consuming large amounts of computer resources. The main difficulties involved are: i) the location of the material phases, that bring a double Lagrangian-Eulerian description of the problem, ii) a strong nonlinear character due to the viscous and viscoplastic rheologies involved and iii) the stiffness of the numerical problem produced by large contrast in viscosities that can reach 4 to 6 orders of magnitude and have sharp gradients.

In this study we are using the open source framework *Underworld* developed at Monash University [6]. Underworld solves a non-linear Stokes flow problem using Finite Elements combined with particle-in-cell approach, thus the discretization combines a standard Eulerian Finite Element mesh with Lagrangian particles to track the location of the phases.

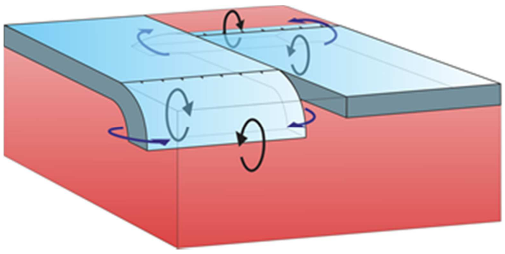

Figure 2. 3D double-polarity subduction model.

The model setup consists of two oceanic plates with viscoplastic rheology subducting into the upper mantle (Figure 2) and the problem is driven by a gravitational Rayleigh-Taylor instability. The main factors to be studied are the interaction between the two plates, the poloidal and toroidal mantle fluxes, the velocity variations of slabs, the stress distribution and the variations in the trench morphology.

With the purpose of being able to study the dynamics of the final model, several preliminary subduction models in 2D and 3D have been developed. The methodology and preliminary results will be presented in this work.

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