Tectonophysics 695 (2017) 27–52

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

A review of the geodynamic evolution of flat slab subduction in Mexico, Peru, and Chile

V.C. Manea [a,b,*], M. Manea [a,b], L. Ferrari [b], T. Orozco-Esquivel [b], R.W. Valenzuela [c], A. Husker [c], V. Kostoglodov [c]

[a] National Institute for Earth Physics, Măgurele, 12 Călugăreni str., 077125, Ilfov, Romania
[b] Computational Geodynamics Laboratory, Centro de Geociencias, Universidad Nacional Autónoma de México, Campus Juriquilla, Querétaro, Qro. 76230, Mexico
[c] Departamento de Sismología, Instituto de Geofísica, Universidad Nacional Autónoma de México, 04510, Mexico City, D. F., Mexico

ARTICLE INFO

Article history:
Received 7 January 2016
Received in revised form 21 November 2016
Accepted 29 November 2016
Available online 6 December 2016

Keywords:
Subducting slabs geometry
Flat-slab subduction
Oceanic plate and overriding plate structure
Numeric modeling of slab flattening

ABSTRACT

Subducting plates around the globe display a large variability in terms of slab geometry, including regions where smooth and little variation in subduction parameters is observed. While the vast majority of subduction slabs plunge into the mantle at different, but positive dip angles, the end-member case of flat-slab subduction seems to strongly defy this rule and move horizontally several hundreds of kilometers before diving into the surrounding hotter mantle. By employing a comparative assessment for the Mexican, Peruvian and Chilean flat-slab subduction zones we find a series of parameters that apparently facilitate slab flattening. Among them, trench roll-back, as well as strong variations and discontinuities in the structure of oceanic and overriding plates seem to be the most important. However, we were not able to find the necessary and sufficient conditions that provide an explanation for the formation of flat slabs in all three subduction zones. In order to unravel the origin of flat-slab subduction, it is probably necessary a numerical approach that considers also the influence of surrounding plates, and their corresponding geometries, on 3D subduction dynamics.

Contents

* Corresponding author at: National Institute for Earth Physics, Măgurele, 12 Călugăreni str., 077125, Ilfov, Romania.

http://dx.doi.org/10.1016/j.tecto.2016.11.037
0040-1951/

1. Introduction

In the framework of plate tectonics, subduction zones are among the major tectonic features where Earth's lithospheric plates return to the mantle. One tectonic consequence of the subduction process is the occurrence of inter-plate and intra-plate earthquakes which define Wadati-Benioff zones, in other words, the present-day shape of sinking slabs. This valuable information combined with tomographic anomalies provide a powerful tool used to provide a short-term snapshot of the subduction process where the cold oceanic lithosphere sinks into the fluid-like mantle with a variety of dips and shapes. Traditionally, subduction zones were classified in two main categories: the Marianas type and the Peru-Chile type (Uyeda and Kanamori, 1979). Whereas the Marianas subduction zone is characterized by an old oceanic plate that is subducting at an almost vertical angle, the Peru-Chile type is known for its relatively fast and young oceanic plate that subducts beneath the South American plate less steeply, including horizontal slab segments (e.g., Barazangi and Isacks, 1976; Cahill and Isacks, 1992; Ramos and Folguera, 2009). This particular phenomenon of flat subduction in known to occur only in three places worldwide: Central Mexico, Peru and Central Chile (Fig. 1). In other locations where it was previously suggested the slab dip angle is shallow rather than horizontal (e.g., Cascades, McCrory et al., 2012; Nankai Trough, Matsubara et al., 2008; Ecuador, Yepes et al., 2016) or with a complex geometry because of the proximity to a triple point (eastern part of the Alaska subduction zone, Ratchkovski and Hansen, 2002, Jadamec and Billen, 2012). On the basis of their particular, but rather similar slab geometries and subduction settings, in this review we discuss only the Mexican, Peruvian and Pampean (Chilean) flat-slab subduction zones.

In this paper we review the recent progress in understanding how flat-slabs form, evolve and interact with the surrounding mantle over geological time scales. Although clues to the dynamics of the flat-slab subduction processes can be found in several measurable parameters, as convergence rates or incoming plate ages, their long-term dynamic evolution is still uncertain due to its transient character. Lifetime of the South America and Mexico flat-slab segments is <20 Myr (Ramos and Folguera, 2009; Ferrari et al., 2012), and present-day observations are insufficient to understand subduction dynamics without additional insights provided by complementary observations and techniques, as geochemistry, tectonic records, geochronology and numerical modeling. However, in the last decade, knowledge of the flat-slab subduction dynamics has considerably increased (e.g. Espurt et al., 2008; Pérez-Campos et al., 2008; Gerya et al., 2009; Manea et al., 2012; Skinner and Clayton, 2013; Kusky et al., 2014; Eakin et al., 2015; Gérault et al., 2015; Hu et al., 2016). While the vast majority of subducted slabs plunge into the mantle at different, but positive dip angles, the end-member case of flat-slab subduction seems to strongly defy this rule as the slab moves horizontally several hundreds of kilometers before diving into the surrounding hotter mantle. Recent improvement in geological, petrological, and geochemical records, coupled with computational algorithms and fast growing computing resources, has contributed to first-order understanding of the evolution of subduction zones in general, and flat-slab subduction systems in particular. Although several alternative mechanisms have been proposed to explain this particular type of subduction (e.g. Cross and Pilger, 1982; van Hunen et al., 2002; Manea and Gurnis, 2007; Manea et al., 2012), the analysis of real cases of flat-slab subduction has been somewhat limited.

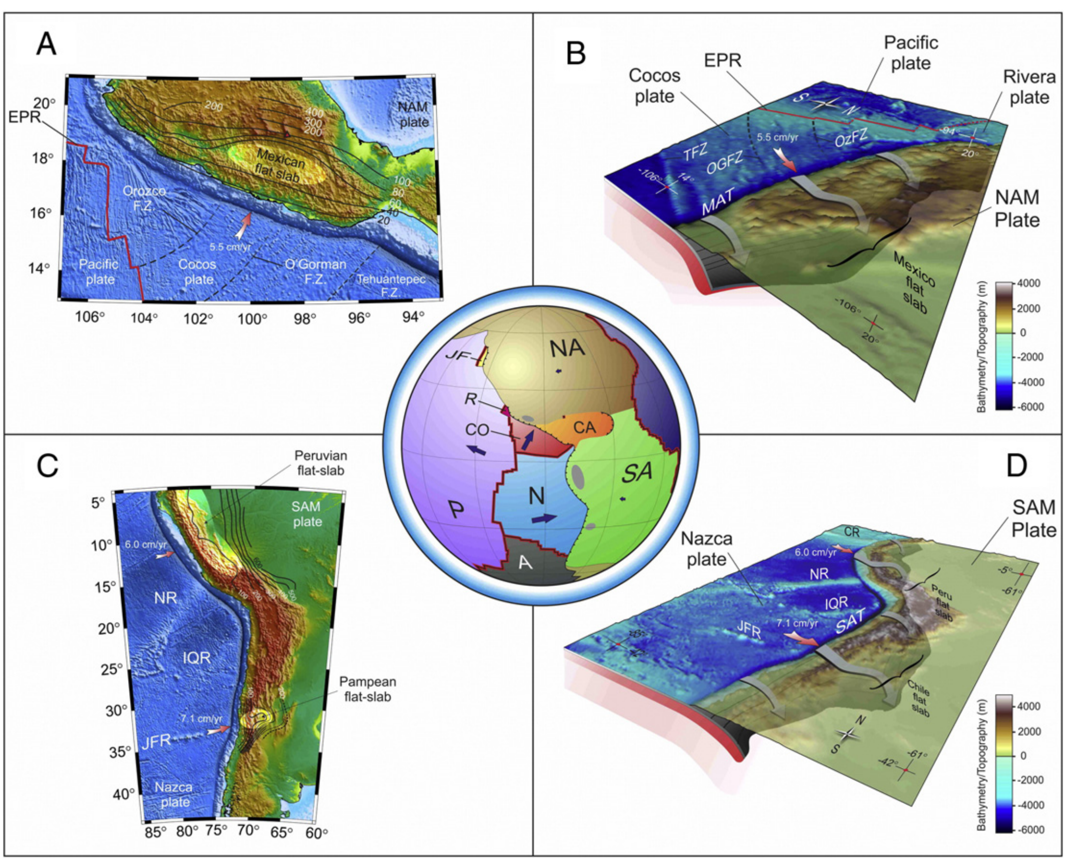

Fig. 1. The Mexican, Peruvian and Chilean flat-slab bathymetric and topographic maps (A, C). Three-dimensional visualization of the Mexican and Andean subduction zones (B, D). Large curved gray arrows are used to facilitate viewing of subducting slabs geometry beneath Mexico and South America. Surface relief is shown as a semi-transparent layer. Labeled black contours indicate depths to the slab surface from the Earth's surface. Red arrows show the direction of the Cocos and Nazca plates movement relative to North (NAM) and South America (SAM) plates. EPR – East Pacific Rise, MAT – Middle America Trench, SAT – South America Trench, NR – Nazca Ridge, IQR – Iquique Ridge, JFR – Juan Fernandez Ridge. Central inset – global view of present day tectonic plates: JF – Juan de Fuca, Co – Cocos, R – Rivera, NA – North America, P – Pacific, SA – South America, CA – Caribbean, N – Nazca.