CHILEAN SUBDUCTION SYSTEM: STRUCTURE, TECTONICS, AND RELATED SEISMICITY

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RESUMEN: El sistema de subducción de América del Sur entre 15°S y 45°S (la costa de Chile) es analizado utilizando datos sísmicos históricos e instrumentales junto con las últimas estimaciones de edad y velocidad de convergencia de la placa Nazca. Se argumenta que la edad de la placa subducente tiene la principal influencia sobre el régimen de subducción (la configuración de superficie sismofocal y también la fuerza de acoplamiento sísmico) en Chile.

KEY WORDS: Subduction, plate coupling, seismicity, seismic slip, slab detachment

INTRODUCTION

The tectonics, seismic regime and structure of subduction systems prevalently depend on the convergence velocity V and age A of descending lithosphere. The main morphologic features of oceanic plate (ridges and fracture zones) involved in subduction process may modify drasticly the "normal" subduction regime and produce noticeable irregularities. The Chilean subduction system merits a special attention for the big variety of A and a presence of subducting Juan Fernandez ridge and a number of fracture zones. The shape of subducting slab in relation with a distribution of quaternary volcanic activity and an orogenic structure of the South America plate provides an insight on the tectonic history of this zone. An important characteristic of present day seismic regime and plate coupling can be obtained from the distribution of seismic energy release rate and seismic slip along the subduction zone. These estimates are based on the study of catalogs of historical earthquakes and the theoretical models of plate coupling. Subduction zone system of the South America between 15° S and 45° S (the coast of Chile) was studied using historical [CERESIS, 1985] and instrumental (NEIC) seismicity data, the last estimates of age and convergence velocity, morphology of subducting Nasca plate, tectonic structure and volcanic activity of overriding South America plate.

SUBDUCTION TECTONICS AND SEISMICITY

A 3D-image of seismofocal surface of subducting slab was synthesized from filtered NEIC catalog data (Figure 1). Extrapolated strikes of the main fracture zones as well as locations of active volcanoes projected onto that surface revealed a clear segmentation of subducting mode and a linked clustering of active volcanoes confined by the fracture zones.

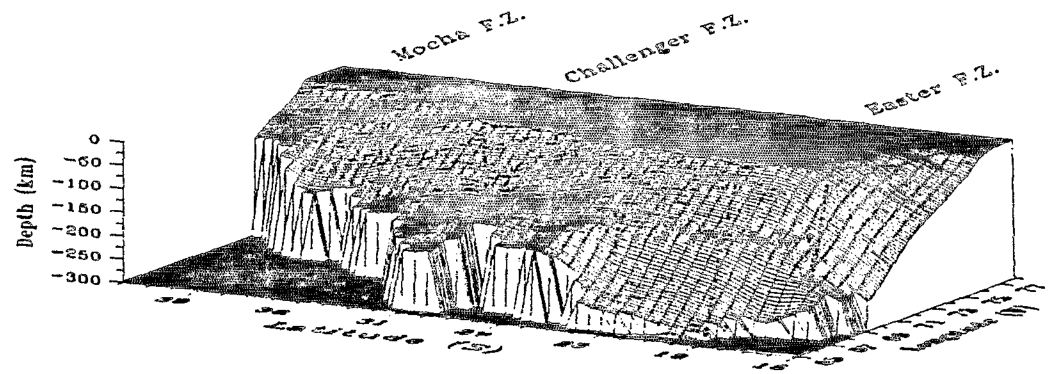

Fig. 1. The shape of Nazca plate subducting under Chile. Dotted lines are the fracture zones and inverted filled triangles are the "roots" of volcanoes (projections of locations of volcanoes onto the surface of the slab).

While the convergence velocity is almost constant (8.1 - 8.4 cm/yr) along the total subduction zone of Chile [DeMets et al., 1990], the age of oceanic lithosphere at the trench varies steadily from 5 m.y. at 45° S to 50 m.y. at 29.9° S, where the Challenger fracture zone intersects the trench (Figure 1,2).

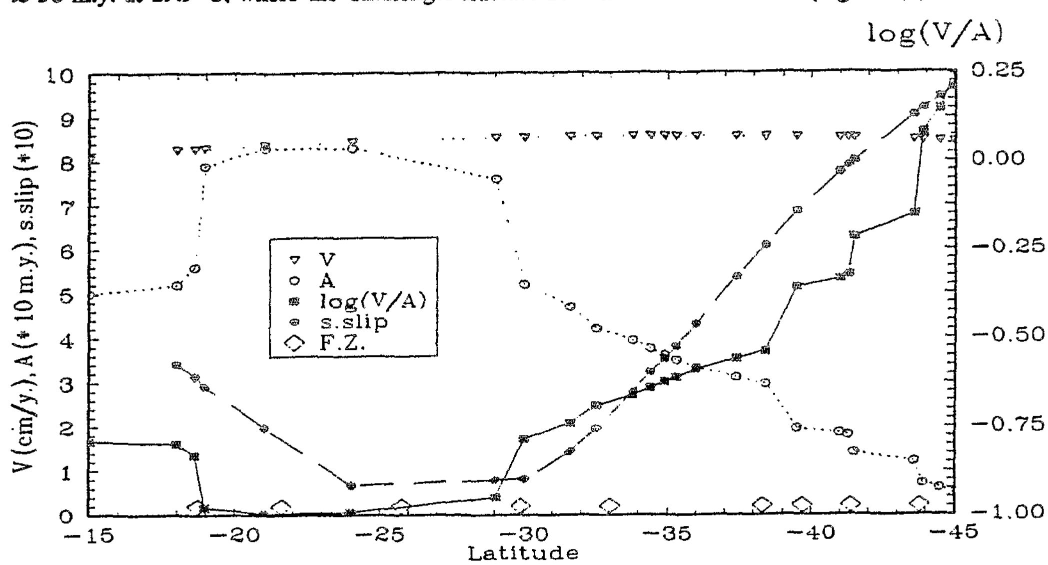

Fig. 2. Variation of age of Nazca plate at the trench, convergence velocity, parameter of coupling (log V/A), and seismic slip along the Chilean trench. Diamonds indicate the intruding points of main fracture zones at the trench.

At this site the age changes drastically up to 75-80 m.y., and drops again to 50 m.y. at the latitude of Easter fracture zone impingement, apr. 19° S [Herron, 1981; Mammerickx et al., 1975; Mayes et al., 1990].
The age of oceanic lithosphere and a state of its buoyancy [Molnar and Atwater, 1978] predominantly control the configuration of subducting slab, the trust and deep seismic regime, the tectonics and volcanism of overriding South-American plate. An important feature of Chilean subduction system is a prominent segment of flattening (apr. 25.5°S-33°S) and ceased volcanic activity (27°S-33°S). Apparently an oblique subduction

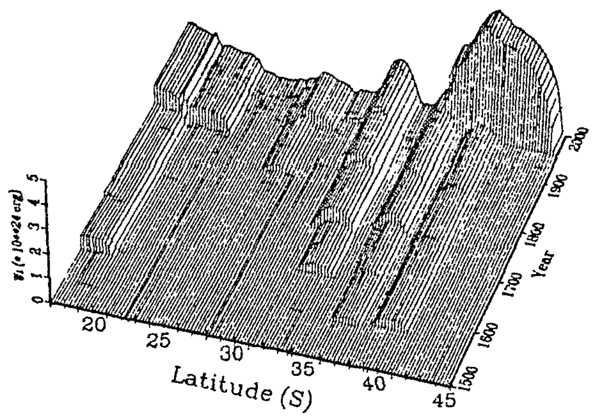

Fig. 3. A three-dimensional Time-Space plot of cumulative seismic energy release along the Chilean subduction zone based on the analysis of catalog of historical events.

of Juan Fernandez ridge [Nur and Ben-Avraham, 1981], and a concept of Gaussian curvature [Cahill and Isacks, 1992] are not convincing as mechanisms of that flattening. An ample distortion of dip and considerable stretching of deep edge of plate is clearly seen between 23°S-26°S, where the buoyancy of plate presumably changes from negative (A > 50 m.y.) to positive. The stretched part of slab conforms adequately to a big gap of deep seismicity (Figure 4).

An analysis of catalog [CERESIS, 1985] of great Chilean thrust earthquakes and the last revisions of a number of historical events [Comte and Pardo, 1991] (Figure 3) enables to estimate a distribution of cumulative seismic energy W , energy release rate W_r , and averaged seismic slip along the Chilean subduction zone (Figure 2). All these properties correlate well with the estimates of coupling between the Nazca and South America plates obtained from the V-model of viscous sedimentary layer interface [Kostoglodov, 1988]. The plate coupling growing up form 29° S to the South agrees with an increase of maximum magnitudes of great historical earthquakes and a rise of W_r . Relatively low values of W_r were obtained for the Northern part of Chile (19°S - 29°S), where the mode of subduction is closer to the "Island arc-type" [Uyeda and Kanamori, 1979]. For the Taltal area (22°S - 25°S) all historical events had magnitudes less than 8.0 (except M_w = 8.0 event, 9 December 1950), nevertheless the seismic coupling here could be of a sufficiently high level to yield earthquakes with a maximum magnitude up to M_w = 8.5.

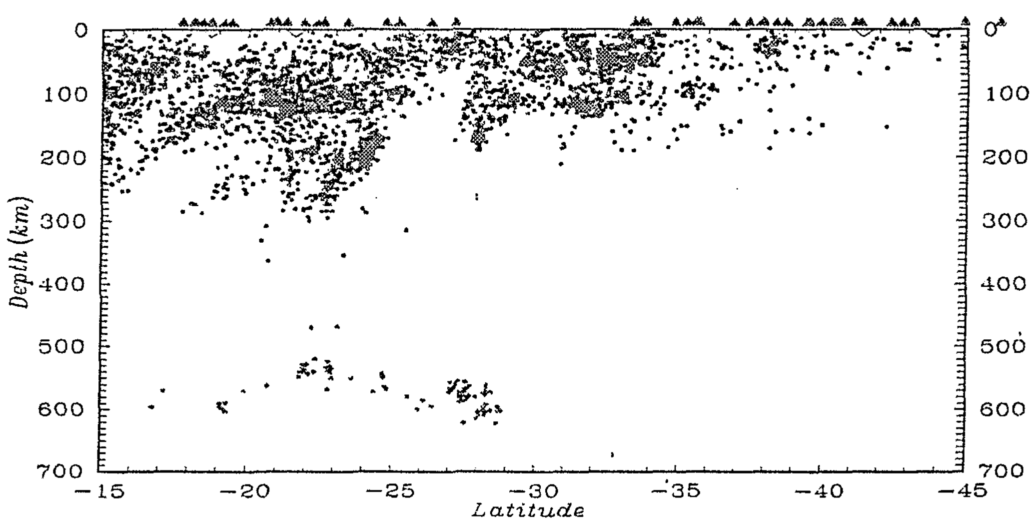

Fig. 4. Vertical projection of seismicity along the Chilean trench. Active volcanoes are shown as filled triangles. The detachment of deeper part of the slab may be to the South of 24°S.

An extended group of deep earthquakes (530-630 km) of Chile matches exactly the higher age zone of Nazca plate (Figure 4). The maximum depths of these events are in agreement with the thermal model of sinking slab with a depressed metastable olivin - shpinel phase transition boundary as a source of deep earthquake faulting [Kostoglodov, 1989]. This denies the hypothesis of Engebretson and Kirby [1992] of probable age discontinuity within the Nazca slab. The deep part of the slab could be fragmentary detached at its southernmost part, where a marked change in dip and depth is observed (the zone of flattened slab).

The Space-Time plot for the historical catalog shows a probable tendency of North-South migration of strong events (M_w >7.0) with a rate of ≈ 7-8 km/y. which is in agreement with an estimate of Barrientos [1991].

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