# HOW IS ACCOMMODATED THE PARALLEL-TO-THE-TRENCH SLIP COMPONENT IN OBLIQUE CONVERGENT SUBDUCTION: THE ANDEAN CASE

Michel SEBRIER and Olivier BELLIER

URA 1369 CNRS, Géophysique et Géodynamique Interne, bât 509, Université de Paris Sud, F91405 Orsay cedex, France.

Résumé : La composante parallèle à la fosse dans une convergence oblique avec subduction est accommodée par un des déformations décrochantes dans la plaque chevauchante ou par un glissement oblique de la subduction. La comparaison entre les Andes septentrionales et centrales suggère que si la nature de l'avant-arc est océanique, celle-ci favorise une subduction oblique.

Key Words : Sismotectonics, State of Stress, Subduction, Andes, Oblique Convergence.

## INTRODUCTION

Studies of subduction zones in oblique convergent settings argued for a simple strain partioning of the convergence vector between a normal-to-the-trench component, that should be accomodated by thrust mechanisms at the subduction contact, and a parallel-to-the-trench component that should be accommodated by major strike-slip fault(s) (Fitch, 1972; Jarrard, 1986). More recently, a careful re-examination of subduction slip vectors at some oblique convergent margins showed that substantial amount of oblique slip may occur at the subduction contact (McCaffrey, 1992). Consequently, the amount of strike-slip deformation should be significantly lower than previously expected what may explain that the measured transcurrent slip is frequently lower than the one theoretically expected from global models. In order to understand how is accommodated the parallel to the trench component of convergence associated with a subduction zone, we compared two different cases along the same convergent margin: northern and central Andes. In fact, this comparison suggests there is a mechanical effect induced by the oceanic or continental nature of the forearc wedge. Indeed, the orientation of convergence, and its rate remains roughly identical from southern Colombia (3°N) to central Peru (12°S). However, three striking differences are observed: the age of the oceanic lithosphere at the trench is younger in northern Andes than in central Andes, the trench orientation is NW in central Peru while it is NNE in northern Andes, and the forearc wedge is made of oceanic material in northern Andes while it is continental in central Andes. In order to compare northern and central Andes, we calculated in both cases the theoretical component of convergence that is parallel to the trench, then the amount of this component which is accommodated by oblique slip at the subduction contact, and consequently the amount of transcurrent slip that has to be accommodated by deformation of the overriding plate. Then, we compared with the observed deformations. This shows that obliquity is predominantly accommodated by oblique subduction slip in northern Andes while it is essentially accommodated by the deformation of the overriding plate in central Peru.

## METHOD TO CALCULATE THE AMOUNTS OF TRANSCURRENT SLIP

The subduction of the Nazca Plate beneath South America results from a N80°E±5° trending convergence (Fig. 1) with a rate $V_c$=80°±5° (DeMets et al., 1990), Along central Peru, the trench is oriented N150°E, i.e., the trench normal $T_n$ is N60°E while along northern Andes, the trench azimuth is between N20° (Ecuador) and N35° (southern Colombia), i.e., $T_n$ is between N110°E and N125°E. Thus, the obliquity angle, $\alpha$, between the Trench normal and the convergence is 20° in central Peru and -30° to -45° in northern Andes. This allows to calculate the component of convergence, $V_p$, that is parallel to the trench in both central and northern Andes. From the above definitions:

$$V_p = V_c \sin\alpha \quad (1)$$

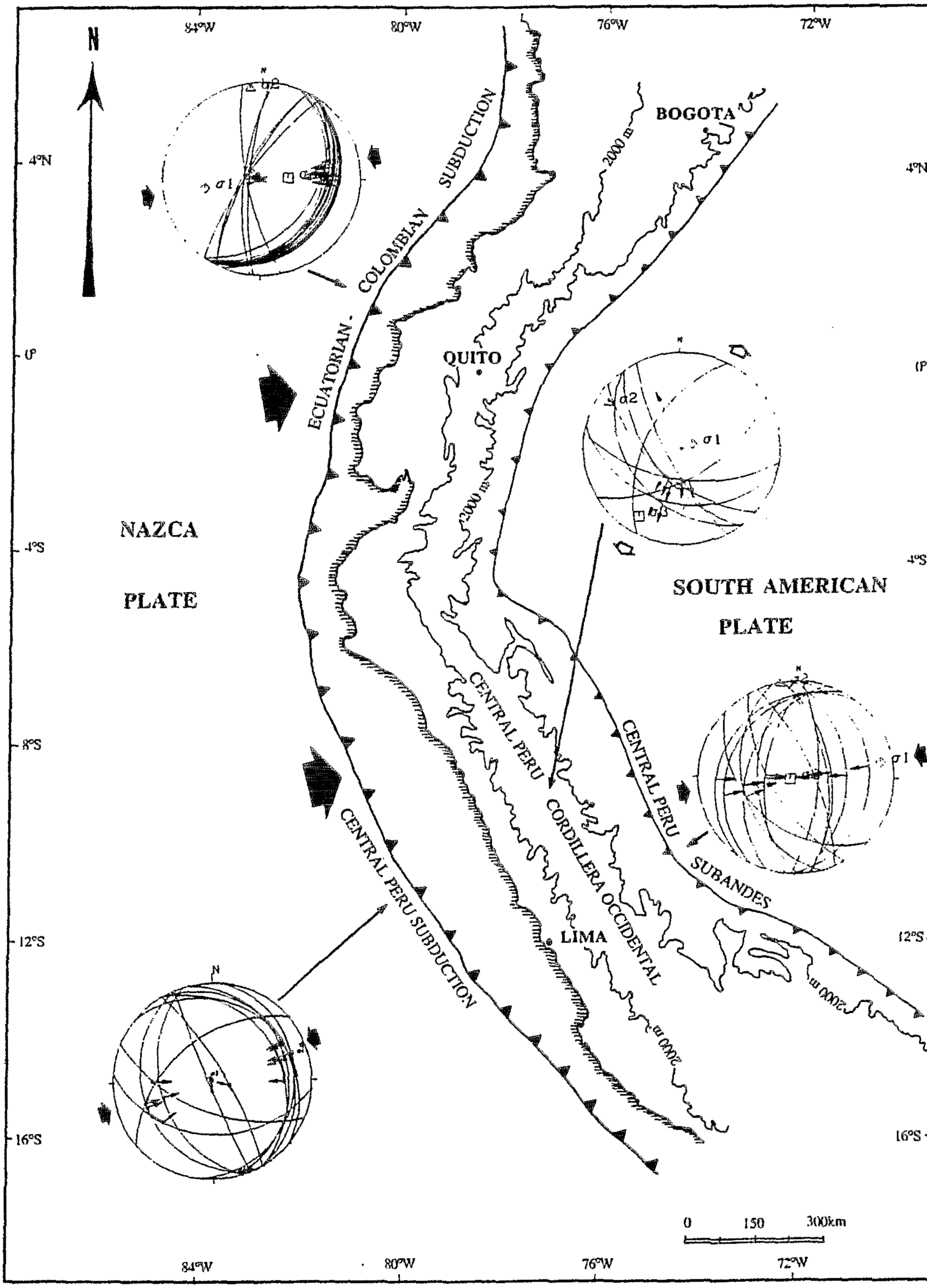


**Figure1**: State of stress along the northern Andes and central Peru subduction zones and in the Subandes, calcutated from available focal solutions. The state of stress in the central Peru Cordillera Occidental has been performed from field data. Small black convergent arrows: σ1; small white divergent arrows: σ3; large black arrows: N80°E trending convergence of Nazca Plate.

Then, taking $V_C$=78 mm/a for northern Andes and $V_C$=80 mm/a for central Peru, we obtain $V_P$=40 to 60 mm/a of theoretical dextral motion in northern Andes and $V_P$=27 mm/a of theoretical left-lateral motion in central Peru. This simple calculation shows that the amount of parallel-to-the-trench component of convergence is higher in northern Andes than in central Peru (Dewey and Lamb, 1992). However, this does not indicate how it is accommodated. In order to address this problem, we used the method proposed by McCaffrey (1992) that calculate the amount of transcurrent slip, $V_S$, that has to be accommodated by the deformation of the overriding plate.

$$V_S=V_C(\sin\alpha-\cos\alpha\tan\beta) \quad (2)$$

with $V_C$ convergence rate, $\alpha$ obliquity angle between the trench normal and the convergence, $\beta$ angle between the trench normal and the slip azimuth of the subduction.

## INVERSION OF SUBDUCTION FOCAL MECHANISMS

In order to determine the mean $\beta$ angle for both northern Andes and central Peru, we used the available shallow thrust focal mechanisms registered by world seismic networks in those subduction zone areas (e.g., Pennington 1981; CMTS by Dziewonski 1981-1992 and USGS catalog 1977-1988). Then, data inversion (same method as Carey-Gailhardis & Mercier, 1987) was performed in the two zones in order to determine the preferred fault plane for each solution (Fig. 1). The most significant result is that the subduction slip vectors are oblique in northern Andes while they are close to the trench normal in central Peru. This calculation allows to estimate $\beta$=8°±7° for central Peru and $\beta$=23°±5° to 38°±5° for northern Andes.

## TRANSCURRENT SLIP RATES IN THE OVERRIDING PLATE

Knowing the $\beta$ angle, the amount of transcurrent slip rate, $V_S$, may be calculated from formula 2 in both northern Andes and central Peru. In northern Andes $V_S$= 7±3 to 10±4 mm/a of dextral slip (see Ego et al., this volume) while in central Peru $V_S$=17±10 mm/a of left-lateral slip. Although $V_S$ value is not precisely constrained in central Peru, it suggests that the overriding plate in central Peru has to accommodate a larger amount of transcurrent slip than the overriding plate in northern Andes. Indeed, in northern Andes only 10-25% of $V_P$ is accommodated by strike-slip deformations in the overriding plate while in central Peru, this appears to be at least 26%. However, major strike-slip fault have been reported in northern Andes, conversely some scarce strike-slip faults are only known in the Cordillera Oriental of central Peru

## DISCUSSION

In northern Andes, $V_P$ is accommodated by major right-lateral strike-slip faults (see Ego et al., this volume). In central Peru, may be accommodated either by the N-S extension that affects the Cordillera Occidental and the Coastal area or by the strike-slip deformations that prevail in the Cordillera Oriental (Sébrier et al., 1988). Indeed, thrust and reverse faults of the Subandes are nearly purely dip slip and consequently cannot account to accommodate strike-slip deformations (Figure 1). N-S trending extension may be interpreted as resulting from normla to the topography gravitational forces and a left lateral component of strike-slip that would accommodate $V_P$. However, the rate of extension that is calculated in the Cordillera Blanca (Sébrier et al., 1988) may explain 1.5 mm/a of left-lateral slip. Thus, the strike-slip deformations of the Cordillera Oriental should at least accommodate of the order of 5 mm/a of left-lateral slip. Finally, the striking difference in the obliquity of subduction slips between northern Andes and central Peru might be explained by the difference of nature of the forearc wedge : oceanic in northern Andes and continental in central Peru. This conclusions appears in good agreement with observations performed by Jarrard (1986) that support the fact that the subduction zone where the overriding plate is oceanic seems to have a more oblique slip than the ones where it is continental. This should indicate that the oceanic or continental nature of the overriding plate induces different mechanical behavior.

## REFERENCES

DE METS C., R.G. GORDON, D.F. ARGUS, & S. STEIN, 1990, Current plate motions, *Geophys. J. Int.*, 101, 425-478.

DEWEY J.F. & S.H. LAMB, 1992, Active tectonics of the Andes. Tectonophysics, 205, 79-95

CAREY-GAILHARDIS E. & MERCIER J.L., 1987. A numerical model for determining the state of stress using focal mechanisms of earthquake population: application to Tibetan teleseims and microseismicity of Southern Perou. *Earth Planet. Sci. Lett.*, 82, 165-177.
DZIEWONSKI A.M. et al, from 1981 to 1992. Determination of CMTS in *Phys. Earth. Planet. Int.*
EGO F., SEBRIER M., LAVENU A., EGUEZ A., and YEPES H., 1993. A new geodynamical model for the Northern Ecuadorian Andes. EUG VII, 4-8 April 1993,Terra abstract 5 (1): 203.
FITCH T.J., 1972, Plate convergence, trancurrent faults, and internal deformation adjacent to Southeast Asia and Western Pacific. *J. Geophy. Res.* , 77, 4432-4460.
JARRARD R.D., 1986, Relation among subduction parameters. *Rev. of Geophysics and Space Physics*, 24, 217-284.
MC CAFFREY R., 1992, Oblique plate convergence, slip vectors, and forearc deformation. *J. Geophy. Res.*, 97, B 6, 8905-8915.
PENNINGTON W.D., 1981. Subduction of the eastern Panama basin and seismotectonics of northwestern south America. *J. Geophy. Res.* , 86, B 11 : 10753-10770.
SÉBRIER M., J.L. MERCIER, J. MACHARÉ, D. BONNOT, J. CABRERA, AND J.L. BLANC, 1988, The state of stress in an overriding plate situated above a flat slab: the Andes of Central Peru, Tectonics, 7, 895-928.
U.S.G.S., N.E.I.C., 1988, World Data Center for seismology. Listing years 1977 to 1988, U.S. Dept. of the Interior.