A WEDGE MODEL FOR THE QUATERNARY TECTONICS OF THE ANDES OF ECUADOR

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Résumé

Jusqu' au Pléistocène inférieur la Cordillére Reale et la Zone Subandine ont étées interessées par des failles obliques dextres et des décrochements dextres avec direction NNE-SSW. Dans le même temps la Vallée Interandine a étée une zone de décrochement senestre. Içi on va proposer un modèle cinématique des mouvements du blocus croutal de la Cordillere Reale que a ete eleve et poussé vers Nord relativement à l'avant-pays Amazonique et à la Cordillére Occidentale.

Key Words: Ecuador, Andes, Tectonics, Quaternary

Introduction

The NNE-SSW Andean Chain in Ecuador is characterized by the presence of the parallel ranges of the Cordillera Occidental (CO) and the Cordillera Real (CR) divided by the narrow depression of the Interandean Valley (IV) and connected to the Amazonian Platform by the Subandean Zone foothills. The deformations occurred in this region since Miocene, are the result of a complex interaction among Nazca, South American and Caribbean plates. The diffuse and high seismicity of the Ecuadorian Andes (with events ranging up to Ms = 7) suggests that this region is still subjected to strong tectonic activity. In this area some works infer a western dextral transcurrent boundary of northern South America which passes trough Ecuador in an area comprised between the Cordillera Occidental and the Amazonian Platform (Pennington, 1981; Feininger and Seguin, 1983). Recent structural field works (Ferrari and Tibaldi, 1989 and in press; Tibaldi and Coltelli, 1989; Pasquarè et al., in press; Tibaldi and Ferrari, in press) provided a more precise picture of the tectonic evolution of the Ecuadorian Andes. The integration of the structural data collected in the field and their comparison with other geological and geophisical informations prompt us to attempt the synthesis on the regional tectonics of Ecuador which is exposed in this work.

Evolution of the Quaternary deformations

The main structures of the chain were built during a major phase of deformation (Pasquarè et al., in press) which occurred before Pleistocene and produced mainly pure thrusts. A change in the deformative mechanisms can be envisaged between the end of Pliocene and Early Pleistocene. Indeed deformation occurred during the Quaternary both in the CR and in the IV. In many cases this new tectonic situation led to the reactivation of the pre- existing structures with an along-strike component of motion. Microtectonic results allow to divide the quaternary deformative history in two tectonic phases occurred during Early-Middle Pleistocene and Late Pleistocene-Holocene. In the northern CR most of the thrust planes and reverse faults developed during the previous phase show the superimposition of an oblique-slip striation. Reduced stress tensor solutions for these fault populations indicate that these structures were reactivated by a stress field with a mean E-W direction of the greatest principal stress (sigma 1) (Ferrari and Tibaldi, 1989 and in press). The numerous NNE trending right-lateral strike-slip faults which cut all the previous structures, represent the evidence of a second phase of deformation characterized by a mean WSW-ENE direction of the sigma 1. The development of these structures can be dated at the Late Pleistocene because they cut the oldest rocks of Reventador Volcano which yielded a radiometric age of about 0.35 M.a. (INECEL, 1988). Lacustrine and pyroclastic deposits which fill the IV display the superimposition of a tensional phase on a older compressive one. Late Pliocene to Early Pleistocene sediments and lava flows are affected by folds with a mean E-W axis and reverse and strike-slip faults which are consistent with a N170°-180° sigma 1. Volcanic and fluvial deposits dating from 100.000 y. B.P. to Holocene show no evidence of compressive deformation but are affected by NNE to N-S trending left-lateral normal and pure normal faults supporting an average N 80° direction of the least principal stress (sigma 3). The general architecture of the IV, which resambles a semi-graben, and the overall predominance of left-lateral component of movements in the faults of both the phases suggest that the area has been dominated by a tectonic regime which changed from transpressive to transtensive (Tibaldi and Coltelli, 1989; Tibaldi and Ferrari, in press).

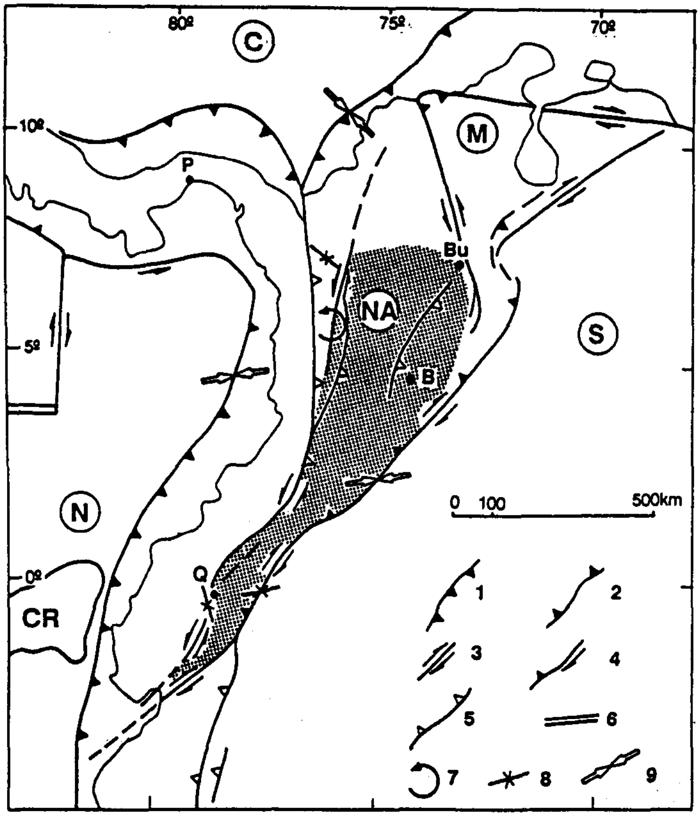

Fig. 1. Main Quaternary tectonic structures of northwestern South America. Dotted area: extruded crustal wedge according to the model presented in this work; 1. trench, 2. thrust, 3. strike-slip fault, 4. right- lateral strike-slip fault with a reverse component, 5. inactive thrust, 6. oceanic ridge, 7. block rotation inferred from paleomagnetic data (after McDonald, 1980), 8. orientation of sigma 1 deduced from microtectonics (in Colombia after Taboada and Philip, 1989), 9. relative block motion (after Kellog and Bonini, 1985), C. Caribbean Plate, SA. South America Plate, M. Maracaibo Block, N. Nazca Plate, NA. North Andean Block, CR. Carnegie Ridge, P. Panama City, Bu. Bucaramanga, B. Bogota', Q. Quito.

Discussion and conclusions

In our interpretation the CR represents a wedge-shaped crustal block which is being uplifted and extruded toward the North as a consequence of the nearly E-W convergence of the Nazca and South American plates (Fig. 1). The relative motion of this block with respect to the adjacent sectors can explain the right-lateral and left- lateral shear component respectively observed in the eastern CR and in the IV since Early Pleistocene. The eastern limit of the CR block is represented by the East Andean thrust system. The western limit is expressed by the Tertiary suture zone between oceanic and continental crust which underlies the IV (Feininger and Seguin, 1983). Both are inherited structural features reactivated in Quaternary times with a strike- slip component of motion. From the Gulf of Guayaquil to the NNE two fault systems split apart: the eastern one, with a right-lateral component of motion, limits to the South the IV (Puna-Pallatanga and Jambeli-Naranjal fault system of the Geological Map of Ecuador), crosses the CR and then reaches the East Andean thrust system; the western one, with a left-lateral component of displacement, goes through the CO (Milagro-Guaranda fault system of the Geological Map of Ecuador) and reaches the IV North of Riobamba where it connects to the suture zone. According to recent neotectonic surveys however (Soulas, 1989), the rates of displacement would be greater in the eastern system along which would be concentrated from 60% up to the 90% of the total motion.

The seismicity of the region appears to be consistent with the proposed model. Shallow events collected integrating the NOAA, CERESIS and Observatorio Astronomico de Quito (1981) catalogues for the years 1905-1985 A.D. shows that seismicity is concentrated along two broad belts with a N-S to NNE-SSW orientation. Apart from the obvious seismicity related to the trench zone, the second seismic zone is centered on the IV and CR up to the Guayaquil Gulf where the two belts merges. No great earthquakes are reported along the CR South of Latitude 2° S, which represents the southern limit where the East Andean Thrust system is reactivated with a right-lateral component of motion.

The previously exposed tectonic model can be conveniently extended to the whole tectonics of Northern Andes (Fig. 1) The right-lateral strike-slip fault system of eastern CR continues in the colombian territory where seismological studies

(Pennington, 1981) suggest a right-lateral displacement along the East Andean Thrust system. The left-lateral shear zone of Interandean valley could be inferred northward along the fault zone of the Cauca Valley where anticlockwise rotation of Late Miocene rocks have been proved by paleomagnetic studies (MacDonald, 1980). In this frame the CR crustal block of Ecuador could represent the southern termination of the North Andean Block of Kellogg and Bonini (1982), a broad zone of uplifting and compression which results from the oblique convergence between Nazca and South American plates with the influence of the Caribbean one in its northern part. The concept of rigid block however has to be carefully considered in the light of recent gravity and geodetic measurements which showed different rates of uplifting within the block itself (Lüschen, 1986).

Acknowledgments

This work was supported by a contract between University of Milan and ELC-Electroconsult, Milan. A. T. benefied of a Ph. D. grant from Ministero Italiano della Pubblica Istruzione.

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