THE SAN LORENZO FAULT, A NEW ACTIVE FAULT IN RELATION TO THE ESMARALDAS-TUMACO SEISMIC ZONE

Essy SANTANA (1) and Jean François DUMONT (2)

(1) INOCAR, Laboratorio de Geologia Marina, Base Naval Sur, Guayaquil, Ecuador (geologia@inocar.mil.ec)
(2) IRD, A.P. 09 03 30096 Guayaquil, Ecuador (dumontjf@ecnet.ec)

KEY WORDS: South America, earthquakes, neotectonics, subduction, faults

INTRODUCTION

The coast of northwest Ecuador and southwest Colombia has registered some of the most important earthquake of South America (Herd et al., 1981)(1906, Ms 8.7; 1942, Ms 7.9; 1958, Ms 7.8; 1979, Ms 7.9) (Fig. 1). Most of these earthquakes (1906, 1958 and 1979) have been accompanied by tsunamis (Espinoza, 1992). From Rio Verde (Ecuador) to Buenaventura (Colombia) the coast is low, and consists in a wide margin of beach ridges, tidal channels and mangroves. Wet tropical climate as well as the proximity of the Western Cordillera about 50 km away to the southeast provides precipitation through a dense network of rivers. Such conditions, low topography, dense river network and active deformations are basically favorable to observe river patterns anomalies related to active deformation (Schumm et al., 2000).

GEOLOGIC AND GEODYNAMIC BACKGROUND

Northeast of Esmeraldas the morphology of the coast changes drastically (Fig. 1). The coastal cordillera of Manabi sinks in the Pacific Ocean near Esmeraldas, leaving place to a low coast, and finally the tidal channels, swamps and mangroves of the Bay of Ancon de Sardinas. The city of San Lorenzo is located at the border between wetland and terra firme (Fig. 2). The San Lorenzo area is part of the Borbon Basin, a NE-SW trending fore arc basin (Deniaud, 2000). The Borbon basin comprises up to 5000 m of tertiary mudstone resting on a basement of Cretaceous basalts. The Pliocene is represented by deep-water mudstone. The area was folded into NE-SW structures and subsequently emerged during the late Pliocene (Evans and Whittaker, 1982). During the late Pliocene the sedimentation continued in the northern Borbon Basin, is the area of the Gulf of Ancon de Sardinas. The structure of this basin trends E-W to WNW-ESE, nearly orthogonal to the structure of the previous Mio-Pliocene basin (Deniaud, 2000). To the south it is bordered by NW-SE trending faults showing a left hand offset of the NE-SW tertiary structures (CODIGEM and BGS, 1993). The northern limit of the basin follows the Mataje River, which is also the northern limit of the Bay of Ancon de Sardinas.

Along the North Andean margin the Nazca plate is subducting eastwards beneath South America at a rate of about 5-7 cm/a (see a synthesis in (Gutscher et al., 1999), and a nearly W-E trend. The convergence obliquity that increases northward from the Gulf of Guayaquil to south Colombia (Fig. 1) controls the slip rate in the upper plate along the Pallatanga-Bocono wrench fault zone (Ego et al., 1996). The recent deformation in the coastal areas of Ecuador is represented by near N-S extension (Dumont et al., 1997). The Nazca plate, which is subducted in the Ecuadorian-south Colombian trench, has been formed since the break out of the Farallon plate about 25 Ma (Hey, 1977). The structure is rather complex, including the Carnegie ridge in front of the Manabi region of Ecuador, and the Malpelo Rift in front of north Ecuador-south Colombia. The E-W trending Malpelo Rift is interpreted as a former part of the Galapagos rift, (Gutscher et al., 1999; Lonsdale and Klitgord, 1978) active from ca. 17 to 8 Ma. The Yakina Graben a N-S transform structure of the Malpelo rift fronts obliquely the subduction zone, closer to the south than to the north.

THE SAN LORENZO SCARP LINE AND FAULT

The new fault has been first observed on aerial photos. The morphological evidence is a linear line of bluff observed along about 25 km, from the south of San Lorenzo to the Colombian border, and extending to Colombia according preliminary observations. Southward the line of bluff joins the border of the Rio Los Atajos, but another bluff line appears westward towards Valdez (Fig. 2). The interpretation of the lineament as a fault is supported by the continuous linear trend, and different drainage pattern on each side of the line (Fig. 2).

South of San Lorenzo the main scarp line limits mangrove and tidal channels to the west from 10 to 20 m elevation upland to the east. Near San Lorenzo the fault divides in two segments, the main scarp following the eastern segment. However this segment suddenly stops 10 km the north, and the scarp line shift west to the main fault line (Fig. 2). The wetlands located west of the scarp include drowned beach ridges. Along the Rio Los Atajos these beach ridges were C14 dated of 5000 BP (Tihay, 1989).

Near Tambillo (Fig.2) a very chaotic accumulation of pebbles and trees trunks in a limy matrix crops out at the foot of the scarp below 1 m of recent sediments. The chaotic aspect leaves no doubt to the fact that the material has been takes off down the scarp, because there is no river able to transport the material. The C14 dating of a tree trunk gave 111 year BP. This catastrophic deposition is hypothetically correlated with the 1906 earthquake. This earthquake occurred the 31 of January, that is during the rainy season on the coast. Therefore weather conditions may have favored up root trees on the slope of the scarp. A tsunami with a 5m runup is associated with this earthquake (NOAA-NESDIS wesbsite). However, the possibility to the wave to reach the scarp with a high energy is relatively low, because it is distant of 15 km from the open sea through an area of mangroves, and in indirect line with respect to the main tidal channels.

FAULT DATA

The tectonic observations have been made on the NE trending secondary fault scarp south of San Lorenzo (Fig. 2). The fault cuts weathered material from the paleo San Lorenzo alluvial cone, probably of late Pliocene early quaternary age (Winckell and Zebrowski, 1997).The San Lorenzo river cuts the escarpment, describing a local swing against the scarp line. Observed along 20 m, the fault plane trends to the NE, with W-E trending deviations. The observations were made at the lower part of the morphologic scarp, in an area not related to landslide. The fault planes have a high dip to the northwest except one plane dipping to the south-southeast (fig.

2). The slickensides (see stereogram Fig. 2) show a relative dispersion due to the high dip of the fault planes. High dip fault planes are frequently observed where a normal fault plane reaches the topographic surface. The calculation of the main axis with the Carey method (Carey et al., 1987) gives a NNW extension with a maximum stress vector near vertical.

CONCLUSION

Morphologic and tectonic data are coherent to identify the scarp between wetland and terra firme as a fault, formed after the upper Pleistocene, and existing since 5000 y/BP(Tihay, 1989). This scarp has been reactivated during the 1906 earthquake, or affected by the corresponding tsunamis. The tectonic elements suggest a N-S extension, with a trantensive movement of the faults. This geometry of the deformation seems to favor a tectonic origin of the movement instead of a simple gravitational effect. On a regional scale these NNE trending right hand transtension faults are geometrically coherent with the NW trending left hand faults bordering the late Pliocene to Quaternary Borbon Basin (CODIGEM and BGS, 1993). The lineament line along the Rio Mataje may be part of this system. This main structural pattern may result in a division of the area in coastal blocks bordered by trantension faults, prone to favor gravitational sliding in the slope of the margin. The relatively important effect of the N-S extension accompanied here by a notable subsidence may be related either to the increasing of the obliquity in this area, or to elements related to the structure of the subducting plate, such as the presence of deep fracture like the Malpelo Ridge or the Yaquina Graben.

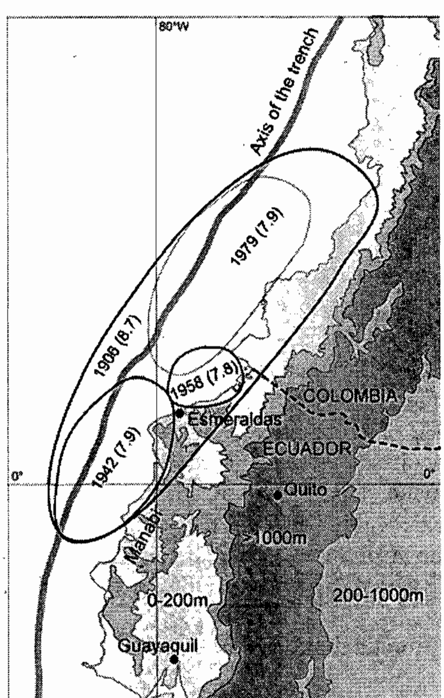

Fig. 1. Position of earthquakes in the Esmeraldas-Tumaco area, from Herd et al. (1981)

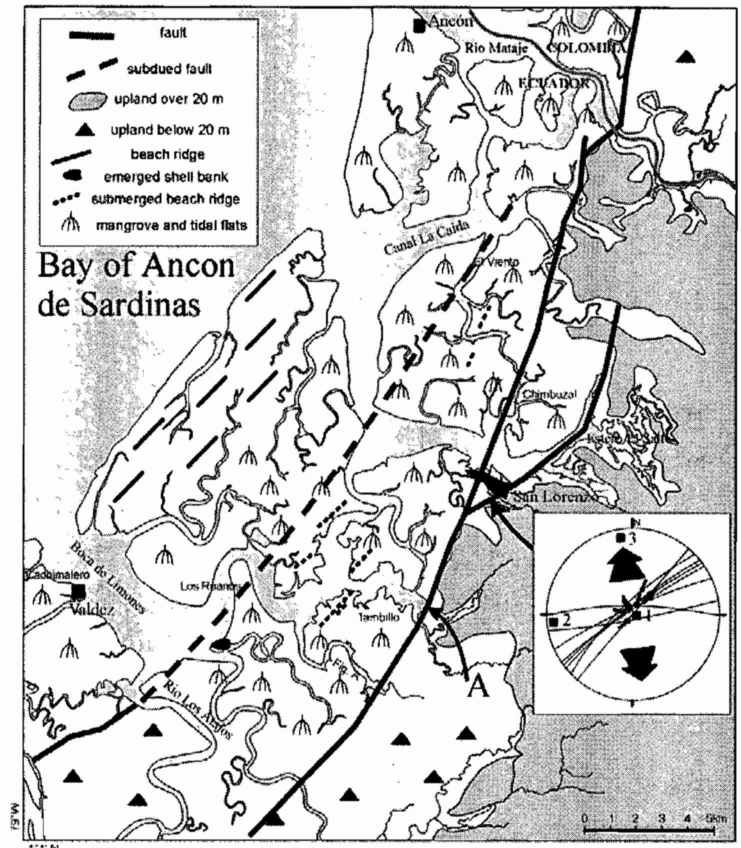

Fig 2: synthetic map of the San Lorenzo area. Point A is the location of the C14 sample of 111 year BP.

References

Carey, E., Gailhardis and 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. Len., 82: 165-177.

CODIGEM and BGS, 1993. Mapa geologico de la Republica del Ecuador. British Geological Survey.

Deniaud, Y., 2000. Enregistrements sédimentaire et structural de l'évolution géodynamique des Andes Equatoriennes au cours du Néogène: Etude des bassins d'avant arc et bilan de masse. Doctor Thesis, Joseph Fourrier, Grenoble, 243 pp.

Dumont, J.F. et al., 1997. Extensional tectonics in the coastab block of Ecuador: preliminary resulta and implications., Workshop on Late Quaternary Coastal Tectonics, London.

Ego, F., Sebrier, M., Lavenu, A., Yepes, H. and Egues, A., 1996. Quaternary state of stress in the Northern Andes and the restraining bend model for the Ecuadorian Andes. Tectonophysics, 259: 101-116.

Espinoza, J., 1992. Terremotos Tsunamigénicos en el Ecuador. Acta Oceanográfica del Pacífico, 7(1): 21-28.

Evans, C.D.R. and Whittaker, J.E., 1982. The geology of the western part of the Borbón Basin, North west Ecuador: Trench forearc Geology. Geol. Soc. London, 10: 191-200.

Gutscher, M.A., Malavielle, J., Lallemand, S. and Collot, J.Y., 1999. Tectonic segmentation of the North Andean margin: impact of the Carnegie Ridge collision. Earth and Planetary Sciences Letters, 168: 255-270.

Herd, D.G. et al., 1981. The Great Tumaco Colombia earthquake of 12 december 1979. Science, 211: 441-445.

Hey, R., 1977. Tectonic evolution of the Cocos-Nazca speading center. Geological Society of America Bulletin, 88: 1404-1420.

Lonsdale, P. and Klitgord, K.D., 1978. Structure and tectonic history of the eastern Panama basin. Geol. Soc. of Am. Bull., 89: 1-9.

Schumm, S.A., Dumont, J.F. and Holbrook, J.M., 2000. Active Tectonics and Alluvial Rivers. Cambridge University Press, 276 pp.

Tihay, J.P., 1989. Aspects geomorphologiques de l'environnement du site archéologique de la Tolita (Equateur), Universite de Pau et des Pays de l'Adour, Pau.

Winckell, A. and Zebrowski, C., 1997. Los paisajes costeros. Los paisajes naturales del Ecuador, Geografía física del Ecuador. CEDIG, pp. 208-319.

IRD
Institut de recherche pour le développement

UNIVERSITE PAUL SABATIER TOULOUSE III

Géodynamique andine
Andean Geodynamics
Geodinámica Andina

Résumés étendus
Extended abstracts
Resúmenes expandidos

Organisateurs **Organizers** **Organizadores**

Institut de recherche pour le développement
Paris

Université Paul Sabatier
Toulouse
France

2002

ISAG

IRD
Institut de recherche pour le développement

UNIVERSITE PAUL SABATIER
TOULOUSE III

GÉODYNAMIQUE ANDINE
ANDEAN GEODYNAMICS
GEODINAMICA ANDINA

5th International Symposium on Andean Geodynamics

Université Paul Sabatier, Toulouse, France,
16-18 Septembre 2002

Résumés étendus
Extended abstracts
Resúmenes ampliados

Organisateurs / Organizers / Organizadores
Institut de recherche pour le développement
Université Paul Sabatier

IRD
INSTITUT DE RECHERCHE POUR LE DÉVELOPPEMENT
Paris, 2002

COMITÉ D'ORGANISATION
COMITE ORGANIZADOR
ORGANIZING COMITTEE

P. Baby (IRD-Toulouse), J. Darrozes (Univ. Paul Sabatier-Toulouse), J. Deramond (Univ. Paul Sabatier-Toulouse), B. Dupré (CNRS-Toulouse), J.-L. Guyot (IRD-Toulouse), G. Hérail (IRD-Toulouse), E. Jaillard (IRD-Quito), A. Lavenu (IRD-Toulouse), H. Miller (Univ. München), T. Monfret (IRD-Géoscience Azur), G. Wörner (Univ. Göttingen)

Comité scientifique et représentants nationaux
Comité Científico y Representantes Nacionales
Scientific Advisory Board and National Representatives

R. Armijo (IPG, Paris), J.-P. Avouac (CEA, Paris), R. Charrier (Univ. Chile, Santiago), J.-Y. Collot (IRD, Géoscience Azur), L. Dorbath (IRD, Strasbourg), S. Flint (Univ. Liverpool), B. France-Lanord (CNRS, Nancy), L. Fontboté (Univ. Genève), Y. Gaudemer (Univ. Paris VII), R. Gaupp (Univ. Jena), F. Hervé (Univ. Chile, Santiago), T.E. Jordan (INSTOC, Cornell), J. Mojica (Univ. Bogotá), O. Oncken (Univ. Potsdam), L. Ortlieb (IRD, Bondy), R.J. Pankhurst (Brit. Antartic Surv.), V. Ramos (Univ. Buenos Aires), P. Ribstein (IRD, Paris), C. Robin (Univ. Clermont-Ferrand), S. Rosas (Univ. Lima), F. Sàbat (Univ. Barcelona), M. Schmitz (FUNVISIS, Caracas), R. Suárez Soruco (YPBF, La Paz), M. Rivadeneira (Petroproducción), W. Winkler (ETH, Zürich).

APPUIS FINANCIERS
FUNDINGS
APPOYO FINANCIERO

L'organisation de l'ISAG 2002 et les bourses accordées à un certain nombre de collègues latino-américains ont été possibles grâce au soutien financier de l'IRD (notamment de la Délégation à l'Information et à la Communication), de la région Midi-Pyrénées, de l'Université Paul Sabatier et de l'Andean Comittee de l'ILP.