HOLOCENE SEISMICITY AND TECTONIC ACTIVITY OF THE QUITO FAULT (ECUADOR): A PALEOSEISMIC HISTORY RECORDED IN LACUSTRINE SEDIMENTS

Christian HIBSCH(1), Alexandra ALVARADO(2), Hugo YEPES(2), Michel SÉBRIER(3)
Victor Hugo PÉREZ✝(2)

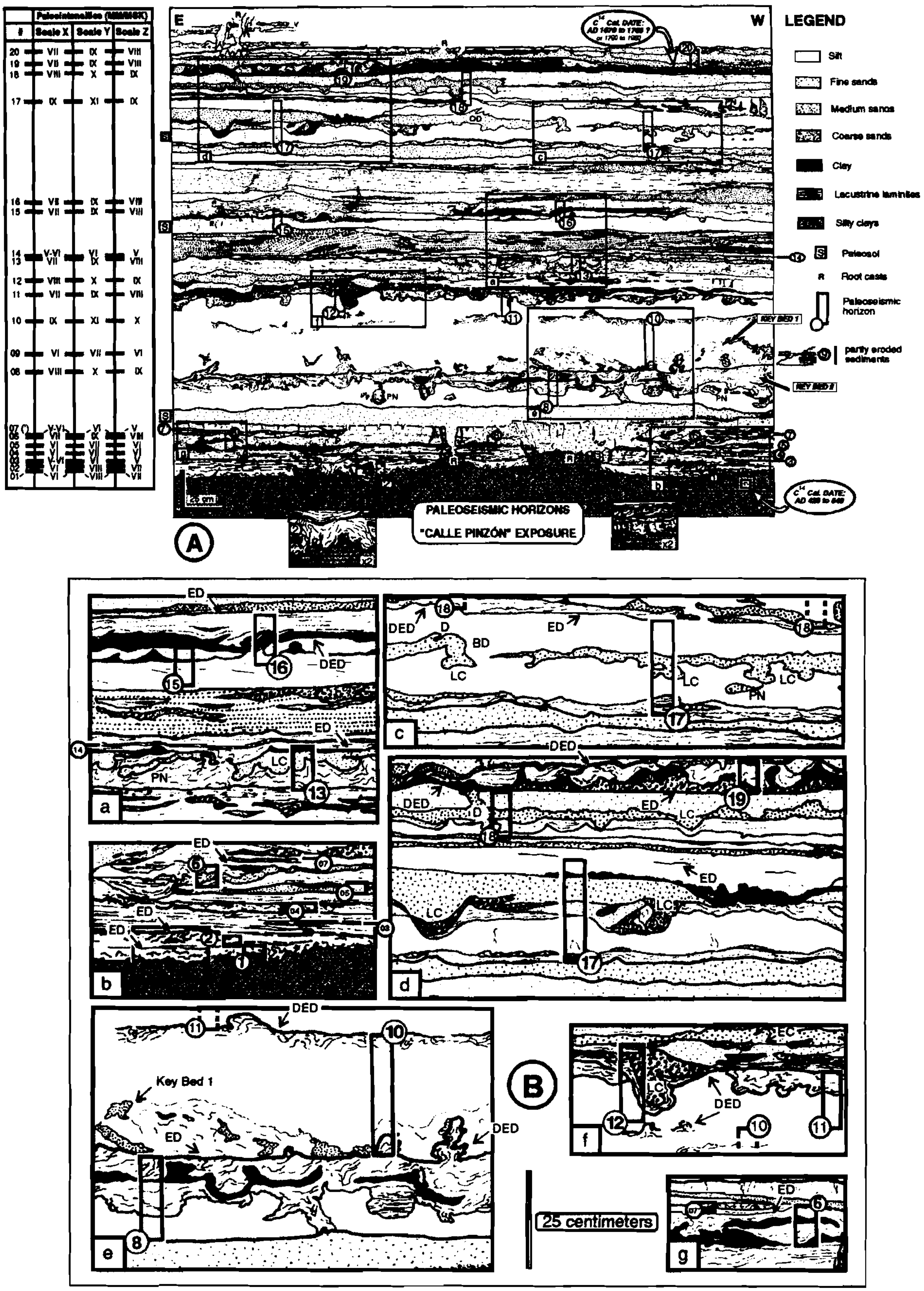
(1) Institut Français d'Etudes Andines, Ecuador, (*write to:* 45 Av. de Nonneville, 93600 Aulnay-sous-bois, France. Fax: (33-1) 48.66.25.46; E-mail: hibsch@world-net.sct.fr)
(2) Instituto Geofisico, Escuela Politécnica Nacional, Quito, Ecuador. Fax: 593-2 567-847, E-mail: hyepes@instgeof.ecx.ec
(3) URA-CNRS (1369) Géophysique et Géodynamique interne, Bât 509, Université de Paris-Sud, F-91 405 Orsay, France. Fax: 33-1 60-19-14-46, E-mail: sebrier@geol.u-psud.fr

KEY WORDS: paleoseismicity, neotectonics, paleoliquefaction, Holocene, Ecuador

INTRODUCTION

Over the 460 years of Ecuadorian written history, several seismic events were registered, some of them reaching intensity IX (MSK) in Quito (CERESIS, 1985; Del Pino and Yepes, 1990). From the various seismogenic sources able to produce damage in the city, the Quito Fault is thought to be able to produce higher intensities in case of a rupture of the fault along its entire length (45 Km), making this structure the potentially more dangerous seismogenic source for the city. In the historical record, such activity of this fault was only registered once in 1755, were part of this fault could have ruptured producing an intensity VIII-IX (MSK) in Quito (Del Pino and Yepes, 1990). In order to assess the recurrence of major events, clearly overpassing the historical time span, it has been necessary to study the geological record. The paleoseismicity was evidenced by mean of the analysis of earthquake-induced paleoliquefaction horizons produced in a lacustrine environment. Evidences of the regional and local seismic activity were observed during the analysis of the Holocene sediments of Quito, as well as evidences of the Quito fault activity such as synsedimentary faults and seismotectonic deformation.

The Quito reverse fault system is active at least since the Late Pleistocene. The fault dip to the west below the city. Its Quaternary activity has created a series of tectonic ridges bordered to the east by a scarp of about 500m high due to compressive folding at the upper termination of the fault (Winter, 1990; Soulas *et al.*, 1991; Ego, 1995). Normal faulting occurred at the back of the overriding block and created a kind of piggy back basin filled by fluvial-lacustrine deposits until the 17th century. The sedimentological analysis of these deposits allowed us to precise the paleoseismic history of Quito for the rest of AD. times (pre-Hispanic history). A relatively complete paleoseismic record was observed in the northern basin, where a particular exposure in the "Calle Pinzón" shows the succession of at least 20 earthquake-induced contorted bedding horizons (Fig. 1). These paleoseismic features occurred at the bottom of lakes, at the water - sediments interface, as shown by erosional disconformities (Fig. 1). From the comparizon between published examples (Sims, 1975), relation between horizontal ground acceleration and intensity such as log


E
W
LEGEND
Silt
Fine sands
Medium sands
Coarse sands
Clay
Lacustrine laminites
Silty clays
Paleosol
Root casts
Paleoseismic horizon
partly eroded sediments
KEY BED 1
KEY BED 2
25 cm
PALEOSEISMIC HORIZONS
"CALLE PINZÓN" EXPOSURE
A
B
Key Bed 1
ED
DED
LC
PN
BD
EC
25 centimeters

$a_H = 0.014 + 0.30 \ln_{MM}$ (Trifunac and Brady, 1975) and intensity distribution inferred from the historical seismicity (Del Pino and Yepes, 1991), we propose to define a scale of seismic paleointensity according to the thickness of earthquake-induced contorted bedding horizons :

In <=> $x^{(n-n_0)} \cdot h_0$ [± 1/3 In] (cm.), where n => intensity value (MM or MSK; n is an integer value), n_0 => intensity threshold able to produce contorted bedding, h_0 => thickness of the contorted bedding horizon produced by an intensity n_0 and x => multiplier factor obtained with the relation between acceleration and intensity $a_{Hn+1} = x \cdot a_{Hn}$ thus giving x=1.995 (Trifunac and Brady, 1975); n_0 and h_0 should vary according to the sediment type. In Quito lacustrine sediments, beeing clay, silts and silty sands alternations, we chose n_0 = V and h_0 = 1.25 cm. The obtained intensity distribution for intensities I≥VII (MM/MSK) shows a good coherence with the intensity distribution inferred from the historical seismicity (Fig. 2). The geological record covers an average 1500 years period which complete the Hispanic historical record.

CONCLUSIONS

Both the historical seismicity and geological paleoseismicity indicate an average recurrence of 115 yr. for major events with intensities I≥VIII. We must notice that the last seismic event corresponding to this intensity range occurred in 1868, more than 125 years ago, but also that, within the 460 years of historical seismicity, this recurrence varied from 168 to just 9 years (Del Pino and Yepes, 1990). The use of the above mentioned scale also permit to evidence the probable occurrence of a major event of intensity IX-X (MM/MSK) between the 10th and the 16th century. Several paleoseismic horizons were successfully correlated with this event thanks to the presence of a volcanic key bed deformed by this paleoseismic shaking. These horizons were also correlated with seismotectonic deformation in the basin, making the Quito fault the most probable seismic source able to explain this major intensity overpassing the historical maximum intensity by almost one degree.

REFERENCES

CERESIS, 1985. - *Catálogo de terremotos para América del Sur. Vol. 5-6, Ecuador, Lima.*

DEL PINO, I. & YEPES, H., 1990. - Apuntes para una historia sísmica de Quito. *in: Centro Histórico de Quito. Problematica y perspectivas. Dirección de Planificación. I. Municipio de Quito, Ecuador.*

EGO, F. (1995).- Accomodation de la convergence oblique dans une chaîne de type cordilléraine: les Andes d'Equateur. *Thèse Univ. Paris XI, 256 p.*

SIMS, J. D., 1975. - Determining earthquake recurrence intervals from deformational structures in young lacustrine sediments. *Tectonophysics, 29: 141-152.*

SOULAS, J.P., EGÜEZ, A., YEPES, H. & PÉREZ, V.H., 1991. - Tectónica activa y riesgo sísmico en los Andes Ecuatorianos y el extremo Sur de Colombia. *Boletín Geológico Ecuatoriano, 2, N° 1: 3-11.*

TRIFUNAC, M.D., & BRADY, A.G., 1975. - On the correlation of seismic intensity scales with the peaks of recorded strong ground motion. *Bulletin Seismological Society of America, 65, N° 1: 139-162.*

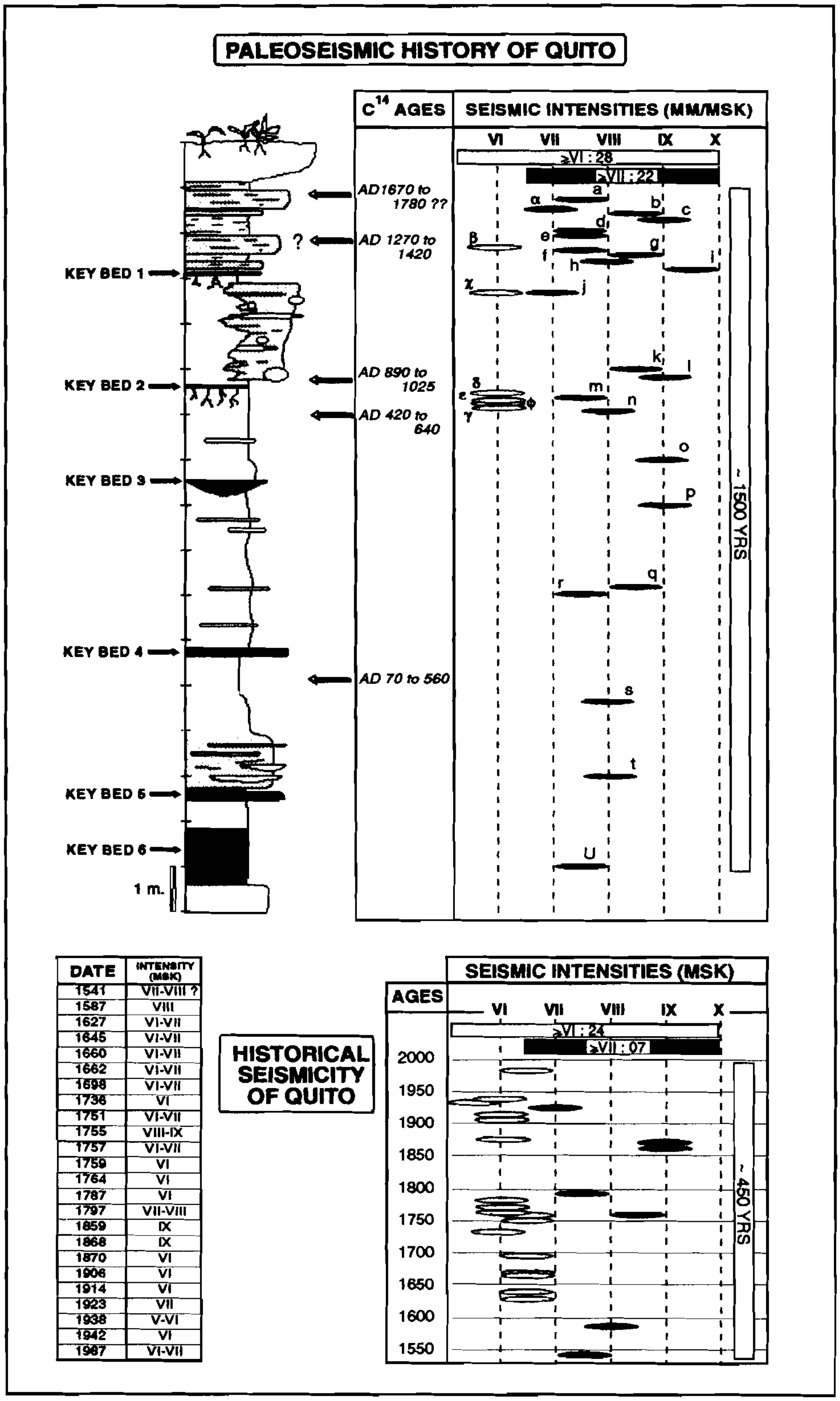
WINTER, T., 1990. - Mécanismes des déformations récentes dans les Andes équatoriennes. *Thèse Univ. Paris-Sud, Orsay, 205p.*

Figure 1: Drawing of the paleoseismic horizons from the "Calle Pinzón" exposure (#C2).

A: General view; position of dated samples; Zooms a & b are showing different soil response to the same paleo-earthquake due to the presence of a thick underlying silty argillaceous deposits; a to f refer to zooming in B; the intensities attributed to the paleoseismic horizons refer to different paleoseismic scales X, Y and Z (scale Z for Figure 2); PN: Pseudo-Nodules, OD: Oriented Dikes.

B: Detail view of a to f areas from A; LC: Load Casts, PN: Pseudo-Nodules, D: Dikes, BD: Bed Disruptions, ED: Erosional Disconformity, DED: Deformed Erosional Disconformity (due to the effect of the following paleoseismic event).

——>



DATE	INTENSITY (MSK)
1541	VII-VIII ?
1587	VIII
1627	VI-VII
1645	VI-VII
1660	VI-VII
1662	VI-VII
1698	VI-VII
1736	VI
1751	VI-VII
1755	VIII-IX
1757	VI-VII
1759	VI
1764	VI
1787	VI
1797	VII-VIII
1859	IX
1868	IX
1870	VI
1906	VI
1914	VI
1923	VII
1938	V-VI
1942	VI
1987	VI-VII

Figure 2: Historical seismicity of Quito and complementary paleoseismic history obtained with geological analysis. To notice the few amount of low intensity events detected by the method of paleoliquefaction analysis, the relatively good coherence between historical intensity distribution and paleoseismic intensity distribution for the number of events with I > VII (considering about three times the duration of the geological record with respect to the historical record), and the show off of a possible paleo-earthquake of intensity IX-X between the 10th. and the 16th. century.