NEOGENE FISSION-TRACK STRATIGRAPHY OF SOUTHERN ECUADORIAN BASINS: IMPLICATIONS FOR REGIONAL TECTONIC HISTORY

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INTRODUCTION

Uplift and deformation of the Andes are related to the subduction of the Nazca plate underneath the South American continent. The Ecuadorian Andes consist of two parallel N–S striking mountain chains separated by the Interandean valley. The Cordillera Real in the east consists of Paleozoic and Mesozoic metamorphic rocks and the Cordillera Occidental in the west of Cretaceous to Neogene volcanics. In the Interandean zone several sedimentary basins developed during the Neogene. Uplift and deformation events are recorded in the mostly continental basin fill series, revealing a detailed Neogene history of the Ecuadorian Andes.

The project consists of a detailed analysis of stratigraphy, sedimentology and deformation of several basins in southern Ecuador (Fig. 1, Cuenca, Nabón, Girón, Santa Isabel, Loja, Malacatos-Vilcabamba, Catamayo-Gonzanamá, Playas and Zumba). The stratigraphic framework and the timing of basin fill deformation is established by fission-track age determinations in intercalated pyroclastics. A study of microfossil and facies patterns allows the reconstruction of depositional environments.

BASIN STRATIGRAPHY

The geological frame of the sedimentary basins is hardly known, except for that of Nabón (Hungerbühler et al., 1995). Earlier studies focused on the Cuenca basin, resulted in a geological map and established the stratigraphy. Timing of the basin fill was based on two K-Ar analysis of intercalated pyroclastics (Lavenu et al., 1992). Correlation from other basins to the Cuenca basin was based purely on lithological similarities (Putzer, 1968). However, our fission-track ages as well as fossil mammal data (Madden et al., 1994) show considerable variability in timing of sedimentation from basin to basin.

In the Nabón basin (Winkler et al., 1993; Hungerbühler et al., 1995) the continental fill (about 600 m) consists of primary and reworked volcaniclastic sediments. A detailed stratigraphic analysis with 12 fission-track ages and paleomagnetic stratigraphy showed that the sedimentation took place during a very short period of time (8.5 – 7.9 Ma). High sedimentation rates of dominantly volcaniclastic material in the Nabón basin relates to the acidic volcanic activity at the time. Synsedimentary compressional deformation features (growths folds and sedimentary wedges) in the scale of several 100 m indicate a WNW-ESE shortening, perpendicular to the basin axes.

In the other basins the fill series consist of alluvial and lacustrine sediments derived mainly from the Cordillera Real and coeval volcanics. The sediments rest unconformably on a volcanic unit (Late Oligocene – Early Miocene) and turbidite series (Late Cretaceous) in the northern region and on metamorphic units (Devonian) and volcanic series (Paleogene) in the south. Most of the basins were developed in a half graben setting during extension. There is evidence for a marine or brackish environment (ostracods, shrimps) at the base of the series of Cuenca and Malacatos-Vilcabamba. Deposition took place during relatively short time ranges in the Middle and Late Miocene and sediment

accumulation was rapid: Malacatos-Vilcabamba (1500 m) 4 Ma, Loja (1000 m) 3 Ma and Cuenca (2700 m) 7 Ma. Facies distribution, transport directions and metamorphic pepple components in the sediments indicate an eastern source area for all the basins. There is almost no input derived from the West. Therefore, there is no evidence for a pronounced positive relief of a western mountain chain (Cordillera Occidental) during the time of sedimentation.

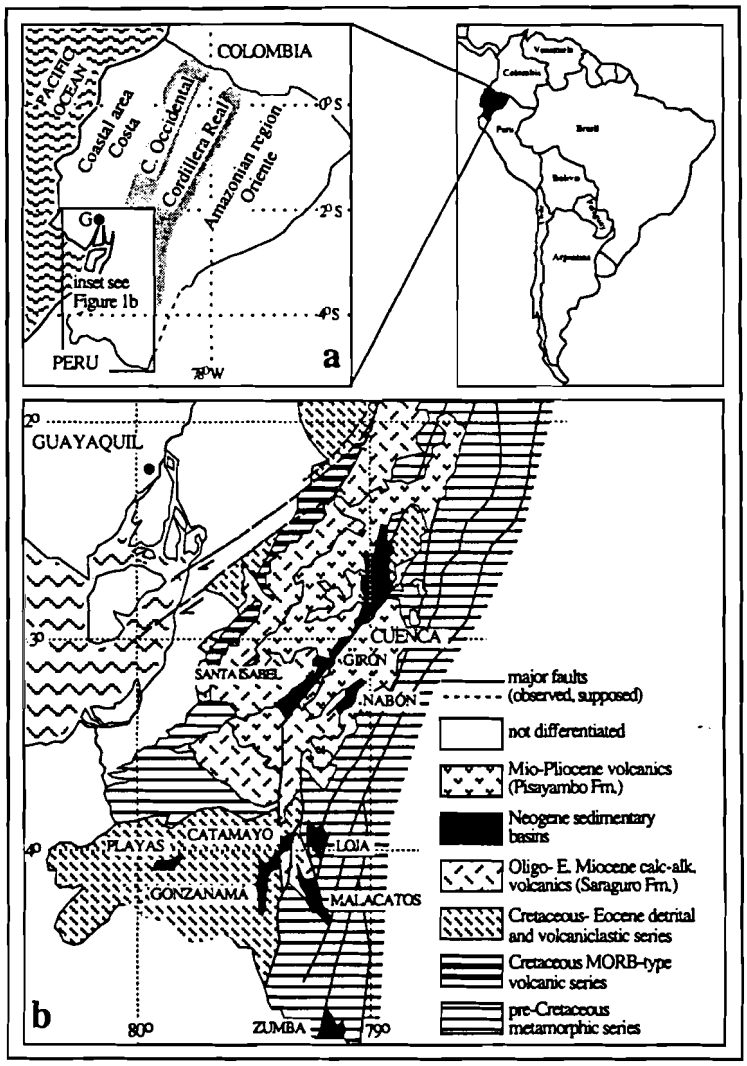

Fig. 1. Simplified maps of Ecuador, a) Morphotectonic areas of Ecuador, b) Geological map of southern Ecuador with position of the main Neogene sedimentary basins (after Litherland et al., 1993).

Zircon fission-track ages of volcanic horizons are the first age determinations of Neogene sediments in southern Ecuador on a regional scale. They indicate much younger and shorter periods of sedimentation in the basins than previously assumed. The obtained chronostratigraphy is summarised in Fig. 2, which is based on about 80 fission-track age determinations. The data show synchronous sedimentation of basin fill in Cuenca, Malacatos-Vilcabamba, Santa Isabel and Loja, the oldest preserved sediment being 15-14 Ma. Basal sediments in Girón are clearly older than in the other basins. Sedimentation was continuous within individual basins but was variable in time between them. Airfall deposits from the top of the Loja and Malacatos-Vilcabamba basin series give an age of about 11 Ma, assuming a shorter sedimentation period than in the Cuenca basin (top at 8 Ma). The basin fill of Nabón is clearly younger than in all other basins. The basin series are often sealed by young pyroclastics of an age between 6 and 2 Ma, indicating regional volcanic events in southern Ecuador. Where these young pyroclastics are missing it is difficult to estimate how much sediment has been removed by denudation.

Together with the zircons, coeval apatites have been dated. Since apatite has a blocking temperature of 100±5°C (Harrison, 1985) some estimation of burial depth can be obtained by measuring the amount of annealing, both through the age determination as well as track length measurements.

There are major unconformities in the sequences with good correlation from basin to basin, implying regional activity rather than local events. The basal unconformity between the volcanic basement and the basin fill series represents a long time gap (4 to 15 Ma). In addition several minor discordances are present in all fill series. The angular unconformity at around 8 Ma marks a younger regional tectonic event which can be observed in the northern part of the studied area.

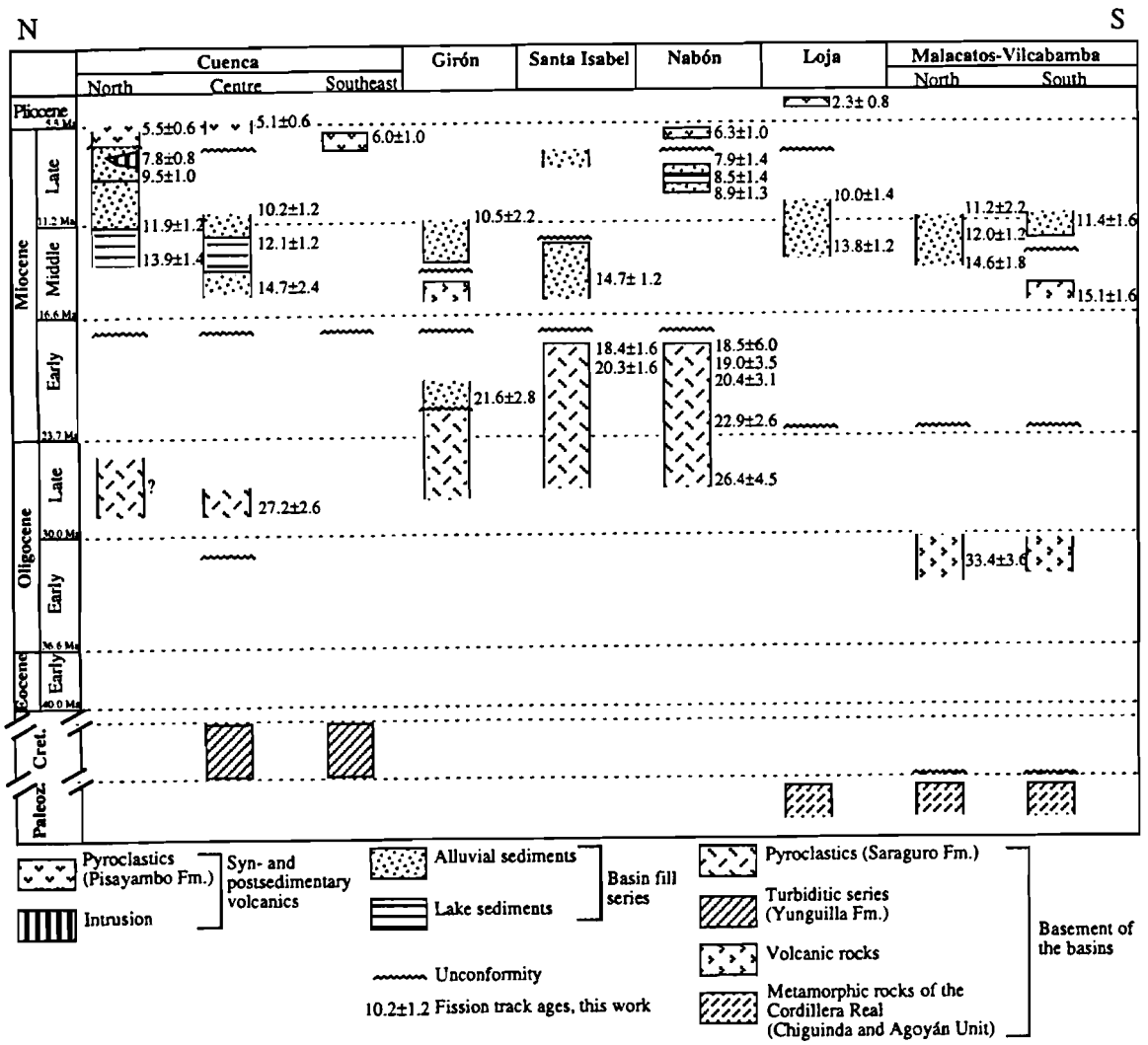

Fig. 2. Chronostratigraphic correlation chart of basement and fill of the Miocene basins in southern Ecuador, based on about 80 zircon fission-track age determinations. These ages were determined using the external detector method. The zircons were extracted using standard separation techniques and were mounted in teflon and polished. Etching was carried out at 210°C in a eutectic melt of KOH and NaOH for 36 - 100 h. Samples were irradiated together with Fish Canyon Tuff age standard and glass dosimeter (CN1 and NBS SRM 612). All ages were determined using the zeta approach. Errors are expressed as 2 σ.

DEFORMATION OF THE BASIN FILL SERIES

Most of the basin series suffered dominant, postsedimentary deformation in an E–W compressional regime which is related to the convergence of the Nazca plate. This deformation is characterised by large

scale thurst faulting, inverse faults and folding. The timing of the postsedimentary deformation is provided by fission-track ages of undeformed sediments which unconformably overlie the basin series. A Latest Miocene age is indicated.

In particular the strong postsedimentary E-W shortening in the Cuenca basin caused west and east vergent thrust faulting. The faults can be traced in N-S strike direction over more than 80 km. The timing of the deformation can be clearly determined. It postdates the depositon of the Mangán Formation (uppermost basin fill, 9.5 Ma) and was completed before the intrusion of the Cojitambo dacite (7.8 Ma), which cuts the deformed sediments discordantly. Coeval compressional synsedimentary deformation is restricted to the basins of Nabón and to the top of Malacatos-Vilcabamba series. A major pulse of uplift during this deformation event can be assumed.

CONCLUSIONS

Sedimentation in the individual basins took place during relatively short periods in the Middle and Late Miocene. Two major unconformities indicate periods of higher tectonic activity between 18 - 15 Ma and around 8 Ma.

Sedimentological features such as evidence for flow direction from the basins, fragmentary facies relations and discordant basin sediments outside of the main basin domains suggest that the preserved sedimentary series represent only relicts of larger basinal areas.

Observed half graben configurations confirm early extensional settings during basin development. There is no evidence for synsedimentary transpressional tectonics as assumed, except in the young Nabón basin.

Most of the basin series suffered a dominant, postsedimentary deformation around 8 Ma, in an E-W compressional regime, which correlates to the synsedimentary deformation in the Nabón basin.

The marine or brackish facies at the base of some basin fills and the strong volcanic input suggest perhaps that the older basins were formed in a volcanic arc environment at or below sealevel. Only the young Nabón basin shows clear evidence for a truly intermontane setting.

A dominant eastern source area and marine or brackish ingressions from the West indicate a younger age for the uplift of the Cordillera Occidental (Steinmann et al., 1996) than generally assumed.

REFERENCES

Harrison T.M., 1985. A reassessment of fission-track annealing behaviour in apatite. Nuclear Tracks, 10, 329-332.

Hungerbühler D., Steinmann M., Winkler W., Seward D., Egüez A. and Heller F. 1995. An integrated study of fill and deformation in the Andean intermontane basin of Nabón (Late Miocene, southern Ecuador). *Journal of Sedimentary Geology*, 96, 257-279.

Lavenu A., Noblet C., Bonhomme G., Egüez A., Dugas F. and Vivier G. 1992. New K-Ar age dates of Neogene to Quaternary volcanic rocks from the Ecuadorian Andes: Implications for the relationship between sedimentation, volcanism and tectonics. *Journal of South American Earth Sciences*, 5 (3-4), 309-320.

Litherland M., Egüez A. and Zamora A. 1993. Mapa geológico del Ecuador, escala 1:1'000'000. Quito: CODIGEM, BGS.

Madden R.H., Burnham R., Swisher C.C.III., Carlini A.A. and Walton A.H. 1994. Mammalian paleontology, paleobotany and geochronology of the Miocene intermontain basins of Southern Ecuador. *Journal of Vertebrate Paleontology*, in press.

Putzer H. 1968. Tertiäre Lignite im interandinen Graben von Ecuador als Beispiel für synorogene Kohlenbildung in intermontanen Becken. *Geologisches Jahrbuch, Hannover*, 85, 461-488.

Steinmann M., Seward D. and Hungerbühler D. 1996. Thermotectonic history of the Andes, south Ecuador: Evidence from fission-track dating. *Third International Symposium on Andean Geodynamics*, Saint-Malo, 17-19 September 1996, this volume.

Winkler W., Egüez A., Seward D., Ford M., Heller F., Hungerbühler D. and Steinmann M. 1993. A short-lived compression related sediment fill in the intermountain basin of Nabón (Late Miocene, southern Ecuador). *Symposium International "Geodynamique Andine"*, Oxford, 21-23 September 1993, edited by ORSTOM, 321-324.