PROVENANCE OF THE UPPER CRETACEOUS TO MIDDLE EOCENE CLASTIC SEDIMENTS OF THE WESTERN CORDILLERA OF ECUADOR

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INTRODUCTION

The petrographic study of the upper Cretaceous to middle Eocene clastic sediments of the Western Cordillera of Ecuador (WCE), aims to determine their sources and their relationship with the tectonic evolution of the Andes. Sandstone petrography reflects both the source areas and the tectonic setting of the depositional areas. Quantitative sandstone detrital modes, determined by point counting on thin sections, can be used to index provenance studies (Schwab 1986). Sandstone framework mineralogy modes are expressed by Q-F-L, Qm-P-K, and Qp-Lv-Ls diagrams. In these diagrams and in the classical classification diagrams of sandstones, Q = Qt = total quartz grains (monocrystalline Qm, and policrystalline Qp); F = total feldspar grains, K = K feldspar, P = plagioclase; and Lt = total lithic fragments (stable, and total unstable lithic fragments L), Lv = volcanic rock fragments, and Ls = sedimentary rock fragments (Tucker 1991). In addition, we used the FLvLs and QMxOM diagrams, where: Mx = total matrix content, and OM = estimated organic matter content in thin section.

GEOLOGICAL SETTING

The basement of the WCE (Fig. 1) is made of several oceanic terranes accreted successively to the Andean margin between the Late Cretaceous (~80-85 Ma) and the Eocene (~40 Ma, Feininger & Bristow 1980, Hughes et al. 1999, Reynaud et al. 1999). In the study areas (Fig. 1), the Late Cretaceous - Palaeogene, mainly turbiditic deposits comprise (Fig. 2): the black cherts, greywackes and limestones of the upper Campanian - Maastrichtian Yunguilla Fm. These are unconformably overlain by the Saquisilí Fm (1000 m) of lower to middle Palaeocene age (Hughes et al. 1999), composed of siltstones and fine- to medium-grained quartz-sandstones, rich in muscovite and heavy minerals. Although dominated by conglomerates, the overlying Gallo Rumi Fm (1000 m) exhibits the same composition as the Saquisilí Fm. It is ascribed to the upper Palaeocene, and grades upwards into siltstones and very fine-grained sandstones. An angular unconformity separates the Gallo Rumi Fm from the middle Eocene Apagua Fm (2000 m). The latter comprises mainly medium-grained quartz-sandstones. The Apagua Fm is overlain by the continental Rumi Cruz Fm (1500 m) assigned to the upper Eocene (Hughes et al. 1999). The Rumi Cruz conglomerates are rich in clasts of black cherts and quartz.

RESULTS

Standard diagrams for arenites and greywackes classification (Dott 1964, Folk et al. 1970, Pettijohn et al. 1987), evidence that (1) the Yunguilla Fm sediments are mainly fine-grained feldspathic greywackes; (2) the Saquisilí Fm sediments are mainly lithic greywackes, litharenites and sublitharenites; and (3) the turbidites of the Apagua Fm are mainly sublitharenites, litharenites, and lithic greywackes.

According to the Q-F-L diagram (Dickinson 1985, Fig. 3), the Yunguilla Fm derived mainly from the erosion of a transitional magmatic arc terrane, and in a minor part from the erosion of basement rocks. Between the Maastrichtian and the Palaeocene, the source area changed dramatically. The Palaeocene Saquisilí Fm recycled an orogen rich in both quartz grains and lithic fragments. Finally, the petrography of the middle Eocene Apagua Fm suggests that it recycled an uplifted orogen marked by abundant metamorphic clasts. This evolution of the source areas correlates with variations of the grain size (Fig. 9), and of the matrix and organic matter contents (Fig. 4). Both the average grain size and median of the maximum grain size increase from the Yunguilla Fm (183.8 μ and 683.8 μ, respectively) to the Apagua Fm (374.4 μ and 1514.2 μ, respectively) (412.4 μ and 1788.8 μ, respectively in the Saquisilí Fm). The Q-Mx-OM diagram shows a clear trend from matrix and OM rich samples in the Yunguilla Fm, to medium to poor contents in matrix and OM in the Saquisilí and Apagua Fms.

According to the Qm-P-K diagram (Dickinson & Suczek 1979), which characterizes the tectonic setting of the source areas, the latest Cretaceous Yunguilla Fm is dominated by volcanic grains and clasts, indicating a magmatic arc source (Fig. 5). The Paleocene Saquisilí Fm shows a clear increase of the plutonic/volcanic ratio, evolving from a magmatic arc source to a circumpacific VP suite of modes. Finally, the composition of the Apagua Fm and the increasing maturity and stability of its clastic components indicates an evolution to continental block, dominantly crystalline source areas. The Qp-Lv-Ls diagram (Dickinson & Suczek 1979) suggests a complex evolution of source areas (Fig. 6). The Yunguilla Fm is marked by fine clastic sediments of basin to shelf environment, rich in volcanic lithics and in fine-grained siliceous sediments, some of diagenetic origin. In the overlying Saquisili Fm, the sandstones rich in cherts of chemical to biochemical origin indicate the influence of collisional orogenic setting. The sandstones of the Apagua Fm are rich in cherts, Lv and Ls, suggesting a composite tectonic setting, dominated by both collisional orogenic and subduction complex sources.

The F-Lv-Ls diagram (Fig. 7) shows another well defined trend. The fine-grained sediments of the Yunguilla Fm are very rich in feldspars, whereas the sandstones of the Saquisilí Fm are rich in feldespars and in volcanic rock fragments. The Apagua Fm is characterized by roughly equal proportions of the three modal components: F, Lv and Ls. Therefore, from the Palaeocene to the Eocene, the source areas changed from a transitional plutonic arc terrane to an arc orogen. We interpret this trend as the result of the progressive uplift of the source areas.

CONCLUSIONS

The upper Campanian-lower Maastrichtian Yunguilla Fm is made of fine-grained feldspathic greywackes, deriving from a transitional magmatic/volcanic arc terrane, and possibly deposited in a marine forearc basin.

The lower to middle Palaeocene Saquisilí Fm is made of sandstones, classified as lithic greywackes, litharenites, sublitharenites, rich in feldspars and in volcanic rock fragments. It was deposited in a collisional setting, and recycled probably a metamorphic and partly plutonic uplifted basement.

The middle Eocene sandstones of the Apagua Fm are sublitharenites, litharenites and lithic greywackes, marked by a high maturity and stability of the clastic components. It may have deposited in a composite tectonic environment, recycling uplifted plutonic and metamorphic areas (continental block sources/crystalline source).

The increasing occurrence of plutonic or metamorphic fragments in the Saquisilí and Apagua Fms indicates that the crystalline basement was uplifted and increasingly eroded during the lower Paleocene-middle Eocene interval. The trend from volcanic (Yunguilla Fm) to plutonic/metamorphic (Saquisilí and Apagua Fms) source areas correlates with a coarsening upwards trend, and with a decrease of the matrix and organic matter contents.

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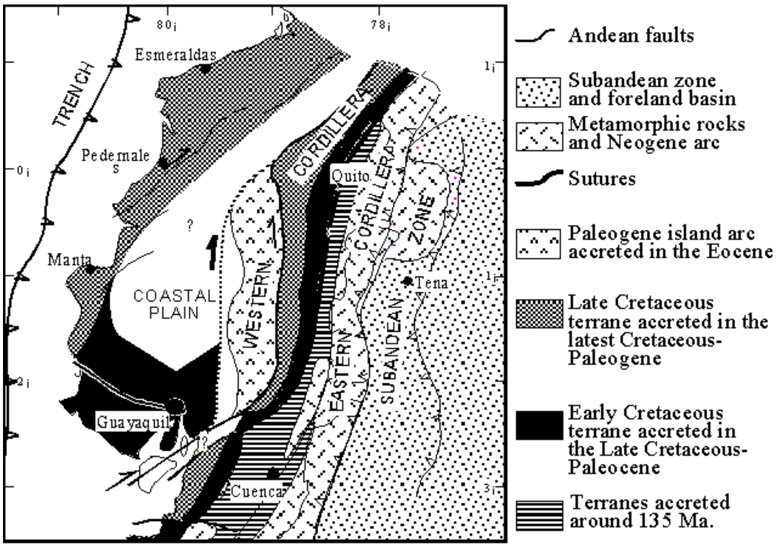

Fig. 1 : Oceanic terranes accreted in Ecuador

Unit	Age
Saraguro	Oligo-Miocene
Rumi Cruz	Upper Eocene
Apagua	Middle Eocene
Gallo Rumi	Upper Paleocene ?
Saquisilí	Low.-Mid. Paleocene
Yunguilla	Up. Camp.-Low. Maastr.

Fig. 2 : Stratigraphic succession of the study area

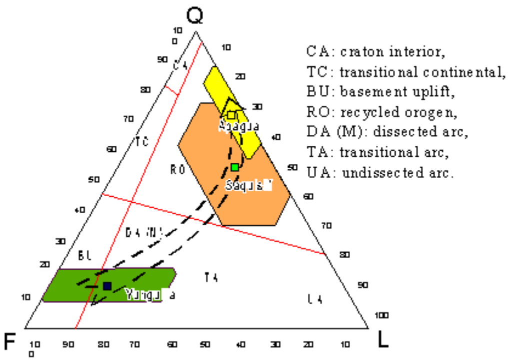

Fig. 3. Q-F-L diagram (discrimination of source areas)

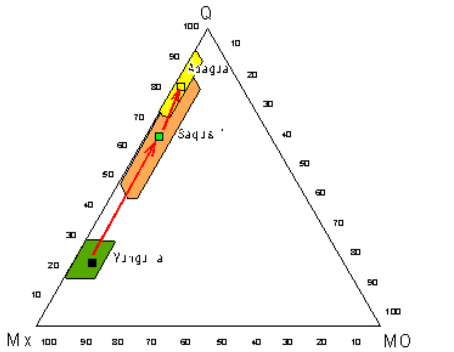

Fig. 4. Matrix (Mx) and organic (MO) contents.

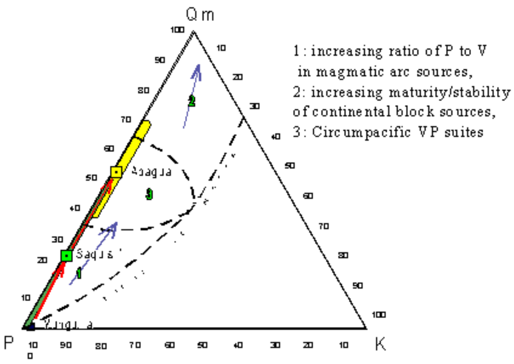

Fig. 5. Q-P-K diagram.

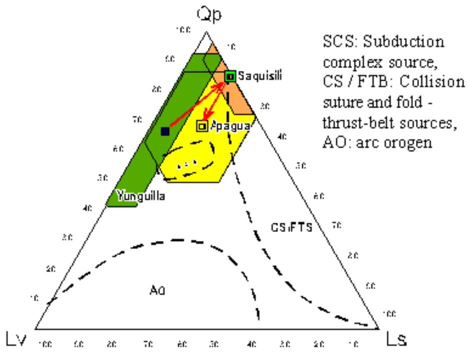

Fig. 6. Qp-Lv-Ls diagram.

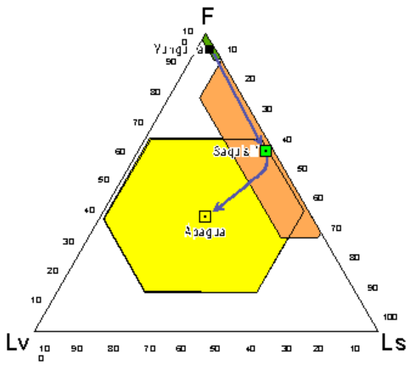

Fig. 7. F-Lv-Ls diagram.

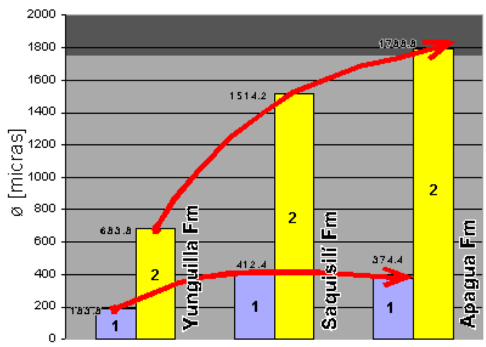

Fig. 8. Grain size variation (1: phi moyen, 2: phi max)