Stratigraphy of the Late Cretaceous-Paleogene deposits of the Western Cordillera Ecuador: Geodynamic implications.

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STRATIGRAPHY OF THE LATE CRETACEOUS-PALEOGENE DEPOSITS OF THE CORDILLERA OCCIDENTAL OF CENTRAL ECUADOR : GEODYNAMIC IMPLICATIONS

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ABSTRACT

Two accreted oceanic terranes are classically recognized in the Cordillera Occidental of Central Ecuador, the Macuchi island arc to the West, and the Pallatanga oceanic terrane to the East. Detailed stratigraphic studies of the sedimentary cover of the "Pallatanga terrane" show that it actually comprises two terranes. During the late Campanian-early Maastrichtian, the eastern terrane received partially continent-derived turbidites, demonstrating that it was accreted to the Andean margin before mid Campanian times, *i.e.* 85-80 Ma ago. Meanwhile, the western terrane received fine-grained, pelagic siliceous black cherts indicating that it still belonged to the oceanic realm during mid Campanian-Maastrichtian times. Both series are unconformably overlain by a thick, coarsening upward siliciclastic series of Paleocene age, demonstrating that the western terrane accreted to the eastern one during the late Maastrichtian (≈ 69-65 Ma). The thick Paleocene clastic series recorded the uplift of the Eastern Cordillera, which was triggered by the latter accretion, and enhanced by the Late Paleocene accretion (≈ 58 Ma) of the Piñón oceanic terrane of southern coastal Ecuador.

KEY WORDS: Late Cretaceous-Paleogene, Cordillera Occidental of Ecuador, accretion of oceanic terranes, clastic sequences.

INTRODUCTION

The Cordillera Occidental of Central Ecuador is made of accreted oceanic rocks (Fig. 1), associated with a variety of sediments (Faucher and Savoyat 1973; Kehrer and Van der Kaaden, 1979; Feininger and Bristow, 1980; Mamberti, 2001; Kerr et al., 2002). However, the nature, age and accretion date of these oceanic terranes are poorly known and still debated. According to various authors, accretions took place in the Campanian (Lebrat et al., 1987; Aspden et al., 1992; Hughes and Pilatasig, 2002), the Late Paleocene (Daly, 1989; Jaillard et al., 1995; Reynaud et al., 1999), and/or the Eocene (Feininger and Bristow, 1980; Egüez, 1986; Bourgois et al., 1990; Spikings et al., 2001; Kerr et al., 2002).

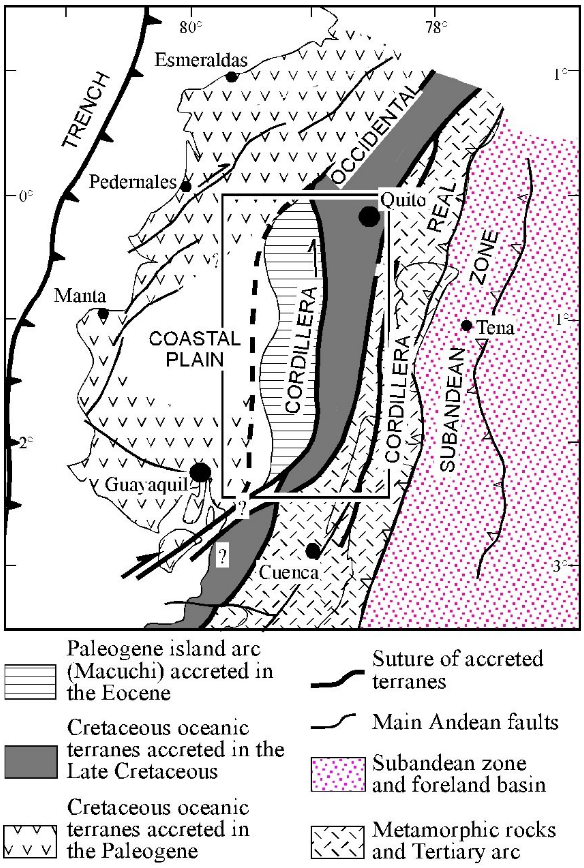

Fig. 1: Structural sketch of Western Ecuador, and location of Fig. 3.

Most authors agree that the Cordillera Occidental of central Ecuador comprises a western island arc terrane (Macuchi terrane, Kehrer and Van der Kaaden, 1979; Baldock, 1982; Egüez, 1986; Hughes and Pilatasig, 2002), and an eastern oceanic terrane of oceanic floor to oceanic plateau nature (Lebrat et al., 1987; Pallatanga terrane of McCourt et al., 1998; Hughes and Pilatasig, 2002; Kerr et al., 2002). Mégard (1989) suggested that the eastern oceanic terrane actually comprises two distinct terranes (Fig. 2). Based on geochemistry studies, Lapierre et al. (2000) and Mamberti (2001) proposed also to subdivide the Pallatanga terrane into an eastern Early Cretaceous terrane (San Juan-Multitud oceanic plateau), and a western Late Cretaceous terrane, which is part of the Caribbean plate.

In this work, we report the results of a lithostratigraphic and biostratigraphic study of the Late Cretaceous-Eocene clastic sediments of the Cordillera Occidental of Ecuador between 0°40'S-2°S, which allow us to better constrain the date of the various accretions and support the existence of two accreted oceanic units within the Pallatanga terrane.

PREVIOUS WORKS

The poorly dated sedimentary rocks of the Cordillera Occidental have long been grouped into the Yunguilla Formation, which has been assigned to the Campanian-Maastrichtian (Thalmann, 1946). The earliest records of pre-Maastrichtian and Tertiary beds were reported by Sigal (1969) and Faucher et al. (1971; Fig. 2). More recently, Eocene limestones (Unacota Limestones) and Middle Eocene turbidites (Apagua Formation) capped by coarse-grained conglomerates (Rumi Cruz Formation) were locally identified (Bristow and Hoffstetter, 1977; Henderson, 1981; Baldock, 1982; Santos and Ramírez, 1986; Egüez and Bourgois, 1986; Bourgois et al., 1990; Fig. 2). During extensive mapping of the Cordillera Occidental of Ecuador, McCourt et al. (1998) dated Paleocene beds ascribed to the Apagua Formation, while Hughes et al. (1999) defined the Early to Middle Paleocene Saquisilí Formation at the eastern edge of the Cordillera Occidental. According to the latter authors, the Paleocene-Eocene interval, represented by the Angamarca Group, comprises the Paleocene-Eocene Apagua Formation, which includes local and/or lens-shaped stratigraphic units, namely the Paleocene-Early Eocene Gallo Rumi Formation, the Early Eocene Pilaló Formation, the Middle Eocene Unacota Formation, and the Late Eocene Rumi Cruz Formation (McCourt et al., 1998; Hughes et al., 1998; Fig. 2).

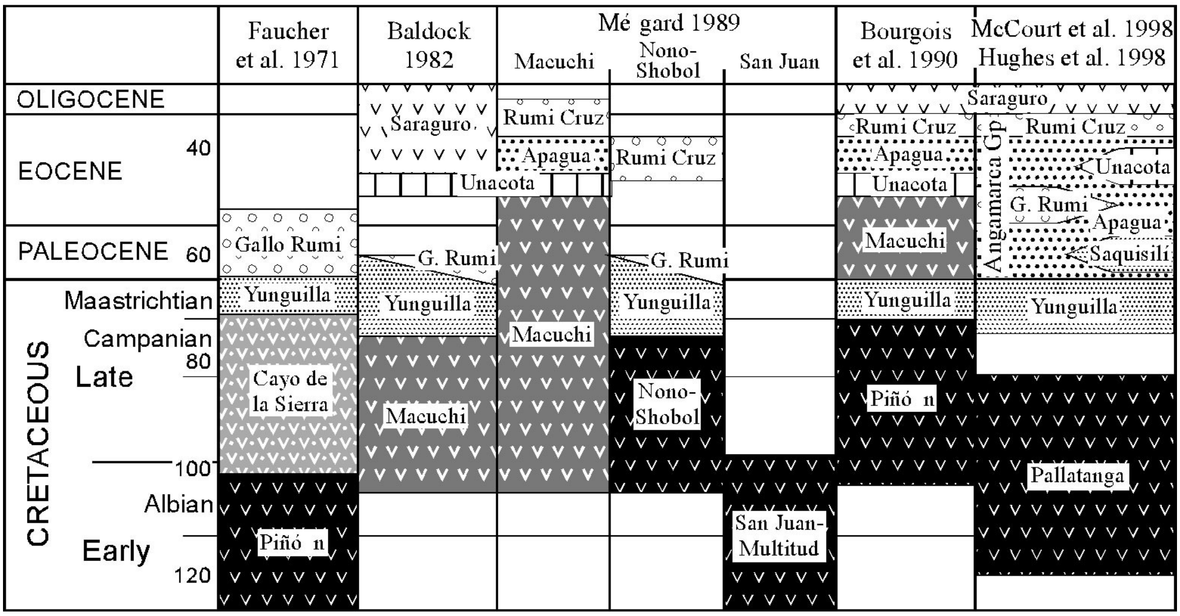

Fig. 2: Previous stratigraphic framework of the magmatic and sedimentary rocks of the Cordillera Occidental of Ecuador (0°-2°30'S). Same caption as Fig. 9.

New detailed mapping of selected areas of the Cordillera Occidental between 0°40'S-2°S (Fig. 3), associated with lithostratigraphic studies and biostratigraphic sampling allowed us to refine the stratigraphic framework of the Late Cretaceous-Eocene deposits of this area.

STRATIGRAPHY OF THE LATE CRETACEOUS-PALEOGENE DEPOSITS OF THE CORDILLERA OCCIDENTAL (0°40'S-2°)

Good outcrops of the Late Cretaceous-Paleogene deposits can be found in two areas of central Ecuador (Fig. 3): West of Latacunga (0°40'S-1°15'S) and West of Riobamba, between the Chimborazo volcano and Pallatanga (1°30'S-2°S).

1. Latacunga traverse (0°40'S-1°15'S, Fig. 3).

The Late Cretaceous-Paleogene outcrops are bounded to the East by a major, North-trending fault system, which contains tectonic slices of sedimentary, metamorphic and basic or acidic intrusive rocks (Pujilí Mélange of Hughes and Pilatasig, 2002), and to the West by a major North-trending fault, which separates the area from the Paleogene Macuchi island arc terrane (McCourt et al., 1998).

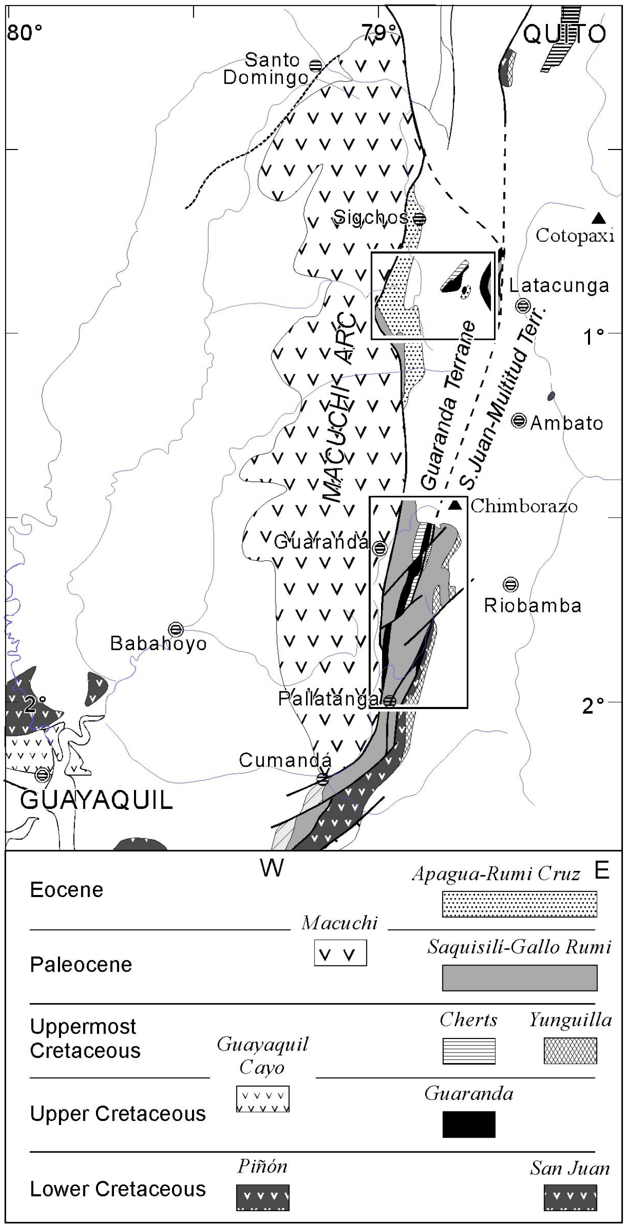

Fig. 3: Structural sketch of the Western Cordillera of Ecuador (0°-2°30'S).

Two areas may be distinguished (Fig. 4).

– East of 78°50'W, the oceanic magmatic basement consists of deformed Mg-rich basalts, which are assumed to be part of the Caribbean Oceanic Plateau (Lapierre et al., 2000; Mamberti, 2001; Kerr et al., 2002; Mamberti et al., 2003), dated radiometrically elsewhere as Turonian-Coniacian (92-85 Ma, Sinton et al., 1998).

The basement is locally overlain stratigraphically by red radiolarites, which can be locally observed in the Pujilí mélange, where they are interbedded with basalts, and on Loma Ashpachaza [74490-990470]. The 100 to 200 m thick interbedded radiolarites and basalts are overlain by pelagic micritic black limestones. Although the contact has not been observed, the radiolarites are thought to be overlain by a deformed series of pelagic, siliceous black cherts, which is clearly exposed north of the Latacunga-Apagua road. These pelagic cherts are lithologically comparable to the cherts of the Guayaquil Formation of the Guayaquil area (Jaillard et al., 1995), although they are probably not exactly coeval. The cherts are frequently deformed by tight to isoclinal folds associated with cleavage, subsequently folded by North trending folds. Their thickness may reach 300 to 500 m.

These fine-grained siliceous deposits (radiolarites, cherts) are devoid of detrital quartz and are interpreted to represent pelagic oozes deposited in an oceanic basin floored by the Turonian-Coniacian oceanic plateau. Although not dated along the Latacunga traverse, we correlate the cherts with those located West of Riobamba, which have been dated as Middle Campanian-Maastrichtian (see below).

Locally (Loma Ashpachaza, Guayrapungu), the black cherts and radiolarites are in fault contact with thin-bedded, fine- to medium-grained lithic sandstones alternating with black slates. North of Guayrapungu [74305-990350], the latter yielded radiolarians of probable Paleocene or Early Eocene age (Egüez, 1986; p. 43). Therefore, we interpret this unit as belonging to the Paleocene Saquisilí Formation.

In the Quebrada Chinchil [74755-990210], both the oceanic basement and the chert succession are unconformably overlain by about 100 m of coarsening-upward sandstones and conglomerates, which rework both metamorphic rocks and the oceanic black cherts (Fig. 4). Although not dated, the Chinchil conglomerates are correlated with the Rumi Cruz Formation, of probable Late Eocene age (see below).

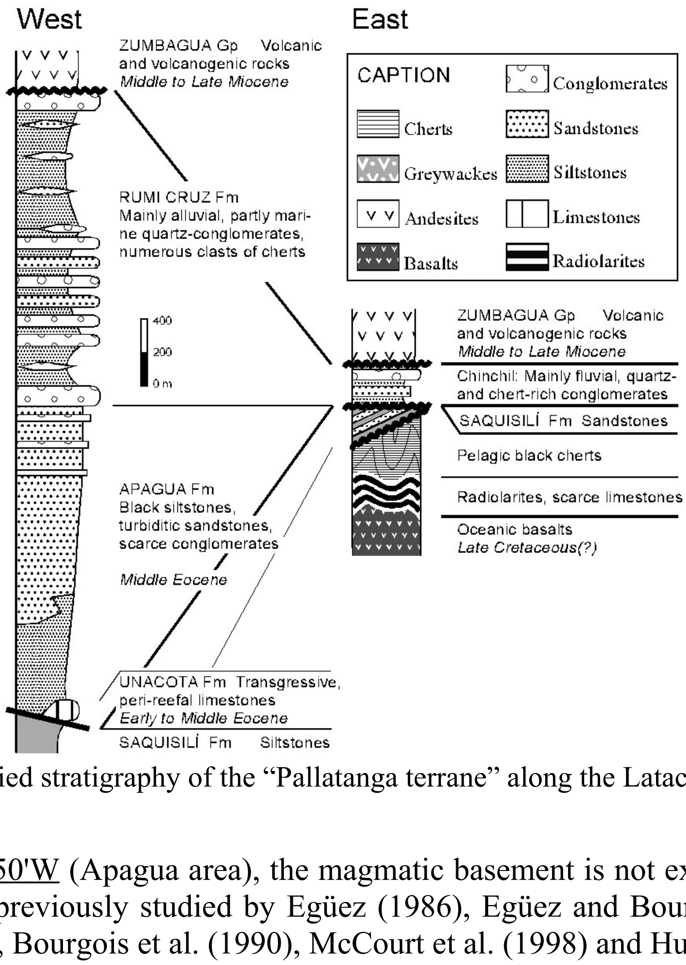

Fig. 4: Simplified stratigraphy of the "Pallatanga terrane" along the Latacunga traverse.

- West of 78°50'W (Apagua area), the magmatic basement is not exposed. The Tertiary sequence has been previously studied by Egüez (1986), Egüez and Bourgois (1986), Santos and Ramírez (1986), Bourgois et al. (1990), McCourt et al. (1998) and Hughes et al. (1999).

Black siltstones and fine-grained sandstones cropping out in the western part of the area [72750-988530] have been dated as Early to Middle Paleocene and ascribed to the Angamarca Group by McCourt et al. (1998). The deposits of this area yielded a palynomorph assemblage (*Echinatisporites* sp., *Foveotriletes* sp., *Polyadosporites* sp., *Polyadosporites mari-*

ae, *Retitricolpites* cf. *antoni*, *Tricolporites* sp.) suggesting a Paleocene-Eocene age. We ascribe this series to the Saquisilí Formation. Due to the complicated structure, its thickness can not be estimated. At least locally, these Paleocene deposits are separated from the Middle Eocene sequence by NW trending faults visible in aerial photographies. One of this faults can be seen along the road Apagua-El Corazón [72840-988570], where it is marked by numerous NW trending dykes, and truncates the southern end of the basal limestones of the Eocene sequence.

The Middle Eocene sequence begins with lens-shaped transgressive limestones of shallow-water, peri-reefal environment (Unacota Formation), dated as Middle Eocene (Bristow and Hoffstetter, 1977; Henderson, 1981; Egüez, 1986; Bourgois et al., 1990). These are overlain by a 1000 m thick, coarsening-upwards succession of siltstones and sandstones organized in turbiditic sequences (Apagua Formation), dated as Middle Eocene (Santos and Ramírez, 1986; Egüez, 1986; Bourgois et al., 1990; Fig. 4). These clastic rocks include sublitharenites, litharenites and subordinate lithic greywackes (Toro and Jaillard, 2002).

The Apagua Formation progressively grades into an approximately 1500 m thick, coarsening-upward series of undated siltstones, sandstones and conglomerates of mainly continental, partially shallow marine environment (Rumi Cruz Formation), which have been assigned to the late Middle Eocene-Late Eocene (Faucher et al., 1971; McCourt et al., 1998). The Chinchil conglomerates probably correlate with the Rumi Cruz Formation (Fig. 4).

As noted by Santos et al. (1986), the Eocene series of the Cordillera Occidental is very similar to the Middle Eocene sequence of the forearc basins of western Ecuador (Faucher and Savoyat, 1973; Evans and Whittaker, 1982; Jaillard et al., 1995) and was deposited in a similar paleogeographic and geodynamic setting.

Throughout the Cordillera Occidental of Central Ecuador, the Late Cretaceous to Eocene sediments are unconformably overlain by Middle to Late Miocene volcanic and volcaniclastic rocks dated as (Zumbagua Group, 17-8 Ma; McCourt et al., 1998; Hughes et al., 1998).

2. Riobamba traverse (1°30'S-2°S, Fig. 3)

Along the Riobamba traverse, two successions (eastern and western) have been recognized, which are separated by a major, N- to NNE-trending fault zone (Fig. 5) characterized by tectonic slices of varied nature (amphibolites, mafic rocks, radiolarites, cherts, volcaniclastic red beds, etc). Therefore, we correlate this fault with the fault system that includes farther north the Pujilí Mélange of Hughes and Pilatasig (2002).

Eastern succession (Fig. 6)

The Yunguilla Formation (≈ 500 m) consists of deformed tuffaceous cherts, fine-grained feldspathic greywackes and lithic arkose turbidites (Toro and Jaillard, 2002). Locally, calciturbidites that carry reworked shallow water, calcareous organisms are present (San Juan Formation of Kehrer and Kehrer, 1969). Along the Pallatanga fault zone, the Yunguilla Formation is associated tectonically with basalts, dolerites and scarce greywackes. Near Hacienda El Rosario, cherts associated with the basalts yielded scarce, non diagnostic palynomorphs (*Polyadospollenites* sp., *Polypodiaceoispollenites* sp.). Although its base has not been observed, the Yunguilla Formation is assumed to rest unconformably on these oceanic volcanic and volcaniclastic rocks (Fig. 6). The Yunguilla Formation is deformed by tight folds showing dispersed, NW- to NE-trending axis directions. This suggests that a first generation of tight folds has been deformed by the susequent regional, N-trending folding phase, which also affected the Tertiary beds.

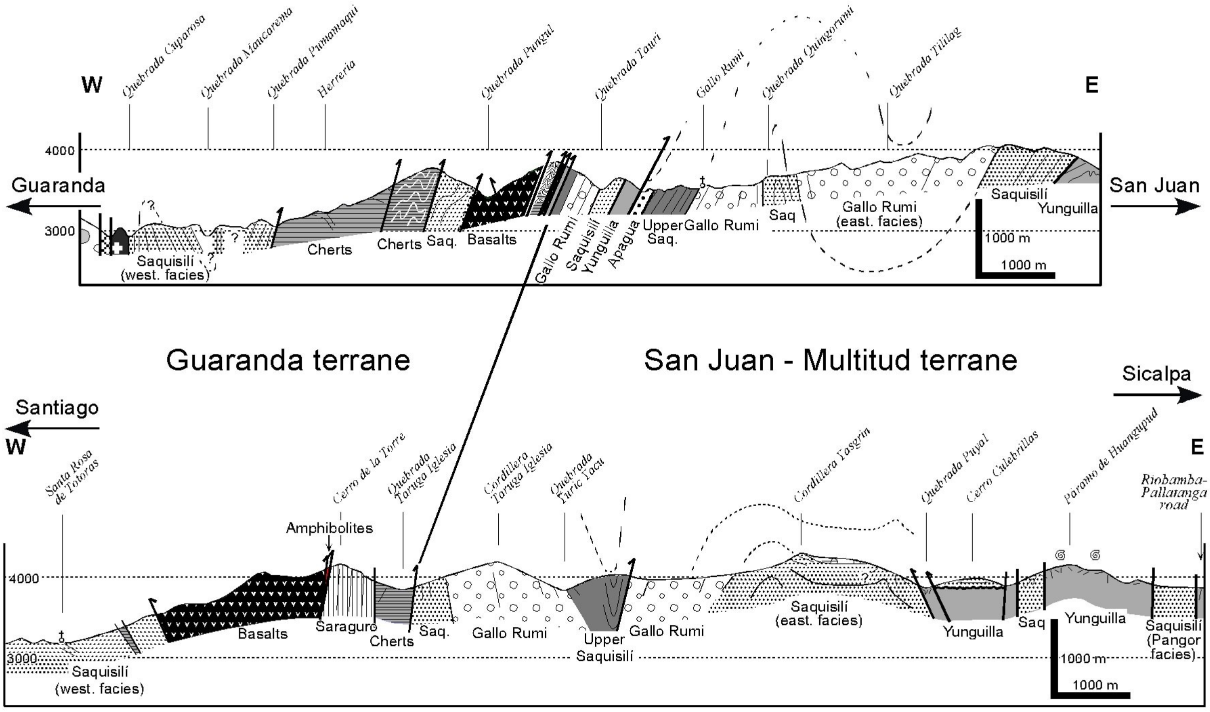

Fig. 5: Geological cross-sections of the Western Cordillera at about 1°30'S. Above : San Juan-Guaranda section; below : Sicalpa-Santiago section.

Near Huangupud [73950-98064] (Fig. 5), the Yunguilla Formation yielded two specimens of *Exiteloceras* sp. of Campanian age (or possibly *Glyptoxoceras* sp. of Santonian-Maastrichtian age) and one *Phylloceras (Neophylloceras)* sp. The latter is comparable to *Phylloceras (Neophylloceras) surya* determined from the Early Maastrichtian Cenizo Formation of northern Peru (Jaillard et al., in press). Together these ammonites indicate a Late Campanian-Early Maastrichtian age (Fig. 7). From the same area, we collected the radiolarian *Amphypindax* cf. *tylotus* of Middle Campanian-Maastrichtian age, associated with benthic foraminiferas (*Haplophragmoides* sp., *Hormosina ovulum*, *Kalamopsis grzybowskii*, *Saccammina* sp., among others). West of San Juan [74200-981980] (Fig. 3), shales interbedded in calciturbidites yielded the planktonic foraminifera *Pseudogümbelina excolata* of Late Campanian-Maastrichtian age, together with less diagnostic benthic foraminiferas and palynomorphs. In this area, the age of the Yunguilla Formation, therefore, is constrained within the Late Campanian-Early Maastrichtian interval (Fig. 7).

The 2000 m to 3000 m thick Saquisilí Formation unconformably overlies the deformed Yunguilla Formation (Fig. 6). The lower part consists of black shales, silts and fine-grained lithic sandstones rich in detrital white micas, interpreted as clastic shelf deposits. It crops out only locally, North of Pallatanga and along the Sicalpa-Santiago road, where it includes olistoliths proceeding from the Yunguilla Formation. The middle part of the formation consists of medium- to thick-bedded, coarse-grained turbidites, which comprise lithic greywackes, sublitharenites and litharenites rich in detrital white mica (Toro and Jaillard, 2002). West of San Juan, this facies directly overlies the Yunguilla Formation (Fig. 5), whereas toward the South and West, it becomes much finer-grained, suggesting that the basin was fed by an alluvial system located in the San Juan area. The upper part of the Saquisilí Formation is composed of coarse-grained sandstones and conglomerates corresponding to the Gallo Rumi Formation of McCourt et al. (1998) (Fig. 2 and 6). Like for the sandstones of the Saquisilí Formation, the Gallo Rumi conglomerates wedge out toward the West and South, supporting the interpretation of a feeding fan located near San Juan. Since the Gallo Rumi conglomerates represent only a local facies, they cannot be considered as a formal formation and will be referred to as the Gallo Rumi Member of the Saquisilí Formation.

The Saquisilí Formation (including the Gallo Rumi Member) yielded numerous benthic foraminiferas. The association of *Bathysiphon* cf. *discretus*, *Bathysiphon* cf. *eocenicus*, *Bathysiphon* aff. *rufescen*s, *Bolivinopsis trinitatensis* and *Haplophragmoides stomatus* indicates a post-Maastrichtian age, whereas the occurrence of *Rzehakina* sp. and *Nodellum* cf. *velascoense* in the upper part of the formation suggests that the Gallo Rumi conglomerates are pre Middle Eocene in age (Fig. 7). Numerous long ranging palynomorphs indicate a Paleogene age. The undifferentiated Saquisilí-Gallo Rumi series is thus ascribed to the Paleocene, with a possible extension into the Early Eocene. Therefore, the lower, finer-grained part of this sequence is correlated with the Saquisilí Formation of Early to Middle Paleocene age defined by Hughes et al. (1998), West of the town of Saquisilí.

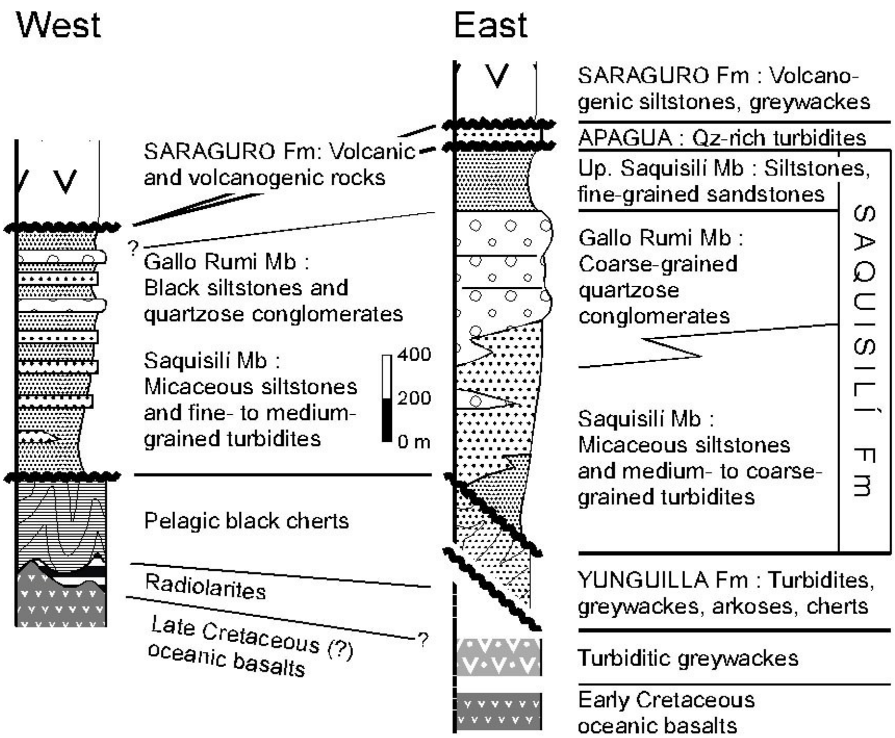

Fig. 6: Simplified stratigraphy of the two units of the "Pallatanga terrane" along the Riobamba traverse. See caption Fig. 4.

The Gallo Rumi conglomerates grade upwards into an approximately 300 m thick series of fine-grained siltstones and sandstones, preliminarily referred to as the Upper Saquisilí Member (Fig. 6). These beds are marked by palynomorphs (*Callimothallus* sp., *Microthallites* sp.) and foraminiferas of Paleogene age. Besides non diagnostic species (*Haplophragmoides* sp., *Trochammina* sp.), the co-occurrence of the benthic foraminiferas *Bolivinopsis spectabilis* (Maastrichtian-Middle Eocene), *Bathysiphon* aff. *eocenicus* and *Bathysiphon* cf. *discretus,* suggests an Early to Middle Eocene age, since *B. eocenicus* characterizes the Middle Eocene deposits of Coastal Ecuador (Ancón Group, Jaillard et al., 1995). Because of its stratigraphic position below the Middle Eocene Apagua Formation (see below), the Upper Saquisilí Member is tentatively ascribed to the Early Eocene (Fig. 7).

The Upper Saquisilí Member is unconformably overlain by feldspathic quartz-sandstones intercalated within black siltstones, dominated by sublitharenites and litharenites (Fig. 6). Along the San Juan-Guaranda road, West of the Gallo Rumi settlement [73635-98220] (Fig. 5), the latter series begins with continental sandstones with ferrugineous paleosoils and root casts, which grade into shallow marine shelf sandstones and then into turbidites, thus indicating a transgression after a period of emergence. These beds yielded a fauna of benthic foraminiferas (*Bathysiphon eocenicus*, *Bolivinopsis spectabilis*, *Haplophragmoides* sp., *Trochammina* sp.) comparable to that of the Upper Saquisilí Member, and suggesting an Eocene age. This, together with the basal unconformity, allows to separate this series from the Saquisilí Formation, and to correlate it with the Apagua Formation, which is dated as Middle Eocene o the West of the town of Latacunga (Egüez and Bourgois, 1986; Santos and Ramírez, 1986; Bourgois et al., 1990; Fig. 4). Additionally, the Apagua sandstones are better sorted, less arkosic, and richer in quartz than the Saquisilí sandstones (Toro and Jaillard, 2002).

The Paleocene-Eocene marine deposits were deformed by mainly N- to NNE-trending, cylindrical folds, and subsequently unconformably overlain by subaerial volcanic and volcaniclastic suites of mainly Oligocene age (Saraguro Group, McCourt et al., 1998).

In the Pallatanga valley, a series of clast-bearing black siltstones, sandstones and conglomerates rich in quartz, metamorphic and volcanic clasts is caught within the Pallatanga fault zone. This series yielded palynomorphs (*Callimothallus* sp., *Fusiformisporites* sp., *Microthallites* sp.) and benthic foraminiferas (*Anomalina* sp., *Bathysiphon gerochi*, *Bulimina* sp., *Cibicides* sp.?, *Clavulinoides* cf. *asper*, *Dorothia* sp., *Haplophragmoides* cf. *eggeri*), among which *Bathysiphon gerochi* indicates a Paleocene age. This series probably represents a lateral facies of the Saquisilí-Gallo Rumi succession, which has been dismembered by the Pallatanga fault zone.

Western succession (Fig. 6)

The basement of the western succession consists of basalts, tuffs, ankaramites and picrites, ascribed to the Caribbean Oceanic Plateau (Mamberti, 2001; Kerr et al., 2002; Mamberti et al., 2003), of Turonian-Coniacian age (Sinton et al., 1998).

This oceanic magmatic basement is stratigraphically overlain by fine-grained siliceous pelagic deposits. Red radiolarites can be seen in Quebrada Trencilla [73475-982360], while in the Quebrada Diablo Sacha [73180-981970], one can observe the stratigraphic contact between the basalts and a series of monotonous well-bedded, pelagic black cherts, similar to those of the Latacunga area (Fig. 6). These cherts are characterized by a rich radiolarian fauna of Campanian-Maastrichtian age (*Gongylothorax* sp., *Rhopalosyringium* sp., *Prunocarpus* sp., *Spongodiscus* sp.?, *Stichocapsa* sp., etc). The presence of *Archeodictyomitra lamellicostata* and *Pseudoaulophacus* cf. *lenticulatus* rather supports a Middle-Late Campanian age (Fig. 7). They are associated with less significant benthic foraminiferas (*Bulimina* sp., *Haplophragmoides* sp., *Hormosina* cf. *gigantea*, *Hormosina ovulum*, *Kalamopsis grzybowskii*, *Saccammina* sp., *Vulvulina* sp.?) and palynomorphs (*Echitricolpites* sp., *Foveodiporites* sp.?, *Microthallites* sp., *Polyadosporites* sp.). Because of their similar lithology and stratigraphic position, these black cherts are correlated and considered coeval, with those of the Latacunga area. The pelagic cherts are intensely deformed and commonly show isoclinal folds, subsequently deformed by N- to NNE-trending folds. The apparent thickness of the chert series may reach several hundred meters.

The Saquisilí Formation unconformably overlies the deformed pelagic black cherts (Fig. 6). It consists of black siltstones and fine- to medium grained lithic sandstones of turbiditic origin. Scarce conglomerate beds are correlatable with the Gallo Rumi conglomerates of the eastern series. As a whole, the Saquisilí Formation of the western succession is thinner (1000 to 1500 m) and finer-grained than that of the eastern succession, indicating that the source areas were located to the East. The Saquisilí Formation yielded mainly benthic foraminiferas (*Bathysiphon* sp., *Bathysiphon* aff. *rufescens*, *Haplophragmoides* sp., *Saccammina* sp.) and few palynomorphs (*Monocolpites* sp., *Monoletes* sp., *Retimonocolpites* cf. *microreticulatus*, *Polyadosporites* sp.). The association of *Bathysiphon* aff. *rufescens* and *Retimonocolpites* cf. *microreticulatus* indicates a Paleogene and more likely a Paleocene age (Fig. 7). This Paleocene series is deformed by NNE-trending folds and faults.

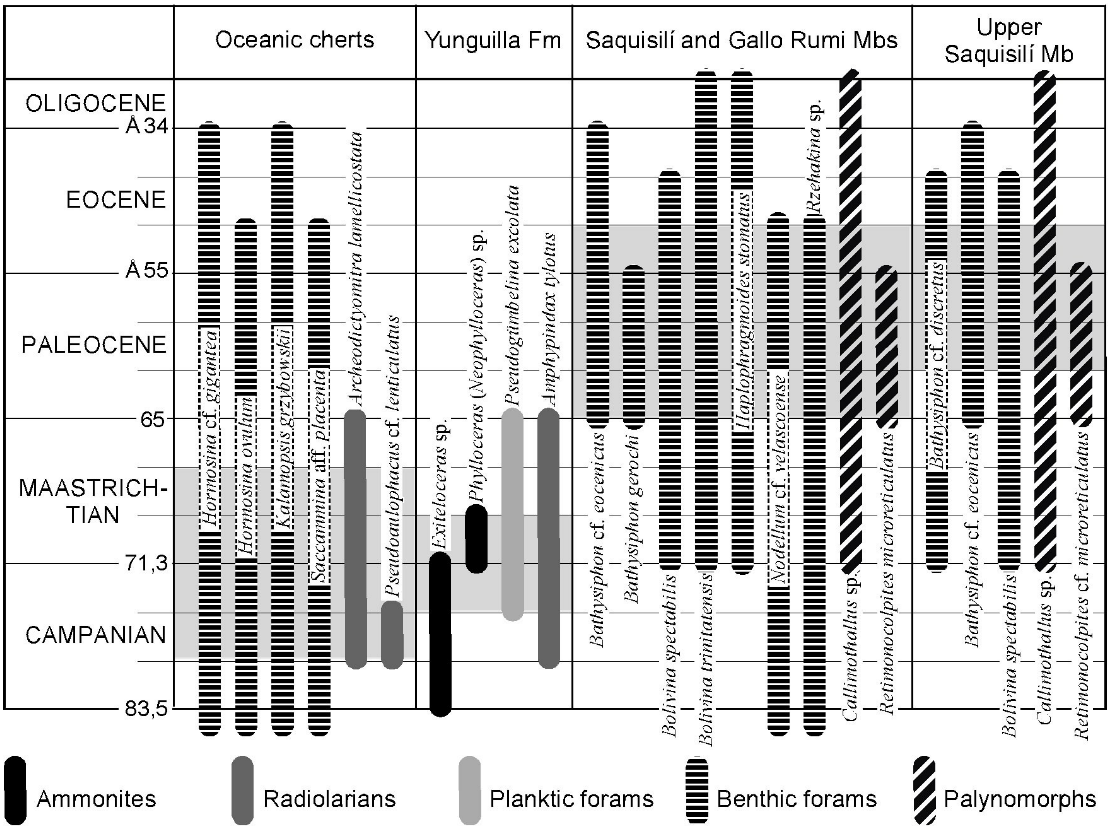

Fig. 7: Diagnostic fossils from Late Cretaceous-Eocene formations of the Riobamba traverse.

The Apagua Formation has not been identified in the western series of the Riobamba traverse. This succession ends up with unconformable subaerial volcaniclastic beds, which are mainly volcanic to the West and Northwest and volcaniclastic to the East and Southeast. These are assigned to the Late Eocene-Oligocene Saraguro Group (38-23 Ma, Dunkley and Gaibor, 1997; McCourt et al., 1998; Fig. 6).

DISCUSSION, GEODYNAMIC IMPLICATIONS

This work leads to revise the present-day stratigraphic nomenclature. Further works should determine wether the radiolarites and pelagic cherts of the Guaranda unit can be considered as formal formations. According to McCourt et al. (1998), the Angamarca Group encompasses all clastic sediments of Paleocene-Eocene age (Fig. 8).

Following our new data, the Angamarca Group includes from base to top: (1) the Saquisilí Formation of Early Paleocene to Early Eocene (?) age, (2) the unconformable late

Early Eocene to Middle Eocene Unacota limestones, (3) the Middle Eocene Apagua Formation, and (4) the Rumi Cruz Formation ascribed to the late Middle Eocene to Late Eocene. The Saquisilí Formation in turn includes from base to top: (a) the lower, fine- to medium-grained Saquisilí Member of Early to Middle Paleocene age, (b) the coarse-grained Gallo Rumi Member ascribed to the Late Paleocene, and (c) the fine-grained Upper Saquisilí Member assigned to the Early Eocene (Fig. 8). Further works may lead to consider the Upper Saquisilí Member as an independent formal formation.

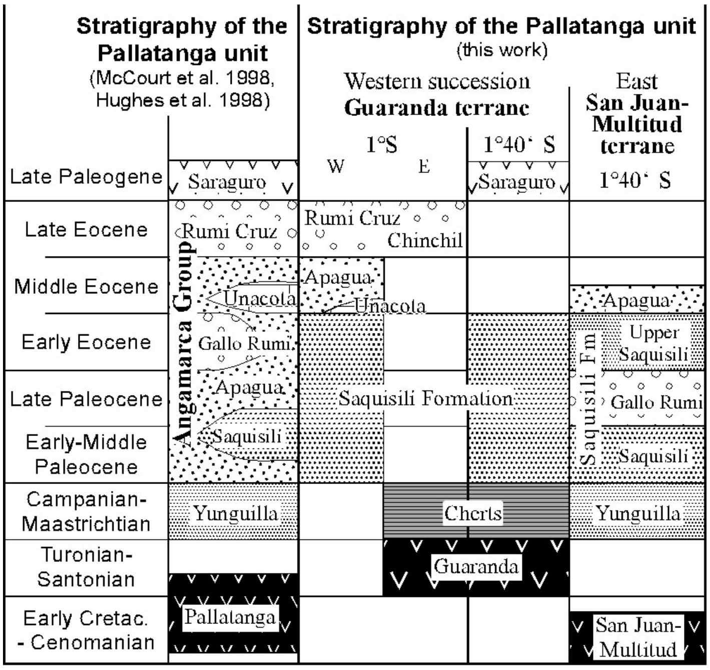

Fig. 8: Synthetic stratigraphic sketch of the Pallatanga unit. Same caption as Fig. 9.

The quartz-bearing turbidites of the Late Campanian-Early Maastrichtian Yunguilla Formation are assumed to rest unconformably on the oceanic magmatic and volcaniclastic rocks, which crop out on the eastern side of the Pallatanga valley, along the Multitud section south of Pallatanga (Lebrat et al., 1985; Mamberti, 2001) and locally south of San Juan (Fig. 3). The arrival of continent-derived detrital quartz upon this oceanic unit demonstrates that it was accreted to the Andean margin before Early Maastrichtian times, and probably before part of the Late Campanian. Since the underlying oceanic rocks are not dated, the age of the accretion can not be specified directly. However, the widespread hiatuses of Late Santonian-Late Campanian deposits in the eastern Andean basins (Mathalone and Montoya, 1995; Jaillard, 1997) suggests that the accretion took place during the Late Santonian - Late Campanian time-span, *i.e.* between 85 and 77 Ma (Lebrat et al., 1987; Aspden et al., 1992; Reynaud et al., 1999; Kerr et al., 2002; Fig. 9).

The Middle Campanian-Maastrichtian pelagic cherts of the Latacunga traverse and of the western series of the Riobamba traverse are at least partly coeval with the Yunguilla Formation (Fig. 9). However, the former unit is a typical oceanic sedimentary deposit, rich in radiolarians and devoid of detrital quartz, whereas the latter is made of quartz-bearing turbidites and locally of calciturbidites reworking shallow-water carbonate shelf deposits. Moreover, while the oceanic cherts are always associated with the radiolarites and basalts of the western unit, the Yunguilla Formation may rest either on the recently accreted terrane (Riobamba traverse), or on the continental margin (Cuenca area, Dunkley and Gaibor, 1998;

Pratt et al., 1998), and hence, represents a "forearc" deposit of the accretionary Andean margin. Finally, it is unlikely that the pelagic cherts series represents a basinal equivalent of the turbidite succession of the Yunguilla Formation, since no transitional facies have been observed. Consequently, we propose that the pelagic cherts and the Yunguilla Formation were deposited in quite distinct, and probably distant areas. Furthermore, the fact that both series are unconformably overlain by similar quartz-rich deposits of Paleocene age implies that the western unit has been accreted to the eastern one after the deposition of both the pelagic cherts and the Yunguilla Formation and before the unconformable Paleocene deposits, *i.e.* during the Middle to Late Maastrichtian (≈ 69-65 Ma; Fig. 9). This conclusion is strongly supported (1) by the high deformation recorded by the pelagic cherts and Yunguilla Formation with respect to the overlying Paleocene-Eocene deposits, (2) by the fact that the Cordillera Real of Ecuador underwent a strong thermal event between 75 and 60 Ma (Aspden et al., 1992; Litherland et al., 1994) and a rapid uplift around 70-65 Ma (Spikings et al., 2001), and (3) by the extensive sedimentary hiatus of Late Maastrichtian age recorded in the margin of northern Peru and Ecuador (Jaillard et al., in press).

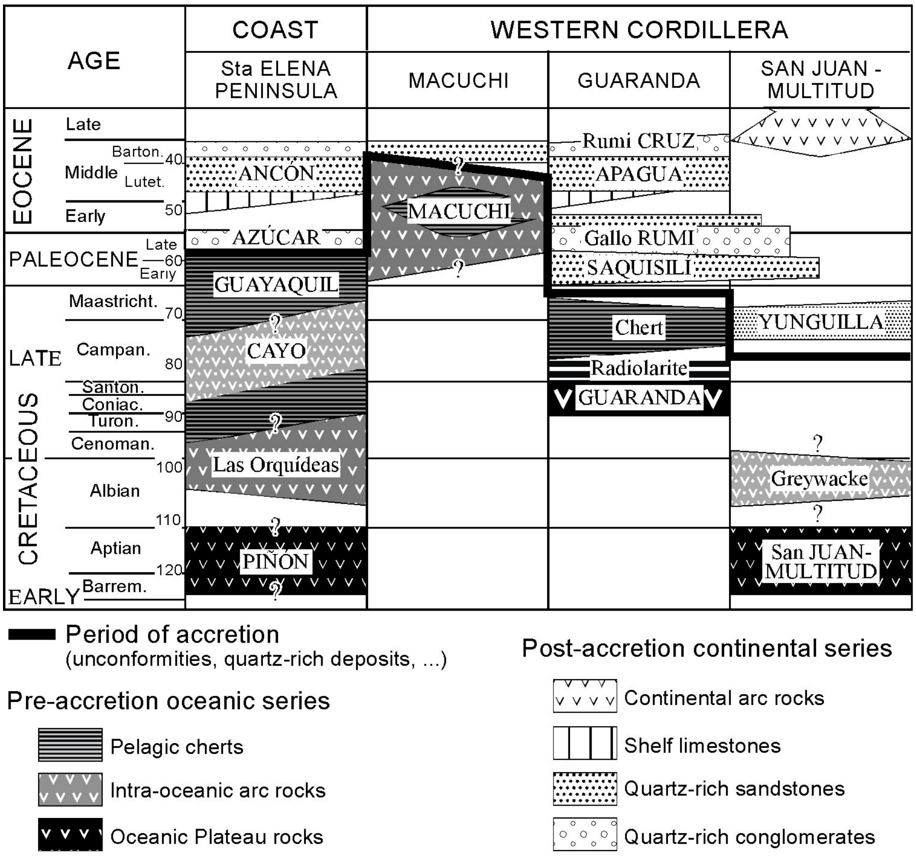

Fig. 9: Chronostratigraphic sketch of the oceanic units of Western Ecuador (0°-2°30'S).

The thick line corresponds to major unconformities and to the appearance of detrital quartz in the oceanic units, and is therefore interpreted as the accretion date of the latter to the Andean margin.

In this interpretation, the Pallatanga unit of McCourt et al. (1998) includes two distinct oceanic terranes. We propose to refer to the eastern Pallatanga unit as the San Juan-Multitud terrane, the basement of which has been dated Southwest of Quito at 123±12 Ma (Lapierre et al., 2000), and to the western Pallatanga unit as the Guaranda terrane, of probable early Late Cretaceous age (Mamberti et al., 2003; Fig. 9).

The Paleocene series of the Cordillera Occidental is a thick, coarsening-upwards clastic sequence, that was derived from an eastern continental source area (Toro and Jaillard, 2002). Therefore, it reflects the continuous and accelerating uplift of the source area, which is corroborated by the widespread uplift of the Cordillera Real identified between 70 and 50 Ma (Spikings et al., 2001; Ruiz et al., 2002). Deposition of the Gallo Rumi conglomerates may be a consequence of the Late Paleocene accretion of the Piñón oceanic terrane of southern coastal Ecuador (Fig. 9), since they roughly correlate with the coarse-grained Late Paleocene Azúcar Group, which seals this accretion event (Jaillard et al., 1995; Fig. 9). Note that farther North, the Paleocene La Cubera unit exhibits a comparable coarsening-upwards trend (Boland et al., 2000), which has been interpreted as the result of the incipient accretion of an oceanic terrane in the Late Paleocene (Kerr et al., 2002).

CONCLUSIONS

The Paleocene-Eocene Angamarca Group can be subdivided into four formal formations, which are from base to top: the Saquisilí Formation (Early Paleocene-Early Eocene), the Unacota and Apagua formations (Middle Eocene), and the Rumi Cruz Formation (late Middle Eocene to Late Eocene). The Saquisilí Formation in turn includes three members, which are from base to top : the Saquisilí, Gallo Rumi, and Upper Saquisilí members.

The Pallatanga oceanic unit of the Cordillera Occidental of Central Ecuador (0°30'S-2°S) includes two distinct stratigraphic successions, which record distinct Late Cretaceous tectonic histories. During the Middle Campanian-Maastrichtian, the western Guaranda terrane received a fine-grained, pelagic siliceous sedimentation devoid of detrital quartz, which overlies radiolarites and basalts and indicates that this terrane still belonged to the oceanic realm. Meanwhile, deposition of quartz-bearing turbidites (Yunguilla Formation) both on the eastern San Juan-Multitud terrane and on the Andean margin (Cuenca) indicates that the latter was already accreted to the continental Andean margin. The quartz-rich Paleocene sedimentation (Saquisilí Formation) is comparable between both units, although the western succession is finer-grained, thus indicating an eastern source area.

These data indicate that the eastern San Juan-Multitud terrane accreted before deposition of the Late Campanian-Early Maastrichtian Yunguilla Formation, whereas the accretion of the western Guaranda terrane occurred after the deposition of both the Yunguilla Formation and the pelagic black cherts and before the deposition of the Early to Middle Paleocene sandstones, *i.e.* during the Late Maastrichtian (≈ 69-65 Ma) (Fig. 9). The fact that the eastern and western units of the Pallatanga terrane experienced distinct tectonic histories during the latest Cretaceous supports the idea that these units belonged to distinct oceanic plateaus, as suggested by their distinct petrographic, geochemical and isotopic signatures (Lapierre et al., 2000; Mamberti, 2001; Mamberti et al., 2003).

The thick Paleocene clastic deposits of the Cordillera Occidental record the exhumation and rock uplift in the Cordillera Real, which may have been driven by the successive accretion of the Guaranda oceanic terrane in the Late Maastrichtian (≈ 68 Ma), and the Piñón terrane of southern coastal Ecuador in the Late Paleocene (≈ 58 Ma) (Fig. 9).

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