LATE CRETACEOUS TO TERTIARY EVENTS IN THE WESTERN CORDILLERA OF ECUADOR

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INTRODUCTION

Between 1995-2000 the British Geological Survey (BGS) in partnership with the Dirección Nacional de Geología (DINAGE, ex-CODIGEM) carried out systematic geological mapping and geochemical surveys of the Cordillera Occidental between 1^0 N - 4^0 S, some 36,000 km^2. As a result of the survey it is possible to recognise a series of regional events that provide a temporal and spatial geotectonic framework for the Late Cretaceous-Miocene evolution of this part of the Northern Andean margin.

CONCLUSIONS

Three separate oceanic terranes were identified during the 5 year mapping programme, from oldest to youngest they are the Pallantaga, Naranjal and Macuchi Terranes. Regional stratigraphic combined with detailed geochemical evidence suggests they are distinct both from each other and the coastal Piñon Terrane (cf. Kerr et al. 2002). The construction of the modern Cordillera Occidental began in the Late Cretaceous (c.65-85Ma) following the incorporation of the oceanic Pallatanga Terrane (**PT**) on to the Andean margin. **PT** comprises the Pallatanga Unit (McCourt et al. 1997) which is dominated by oceanic plateau basalts, together with its associated sedimentary cover sequences (Boland et al., 2000; Dunkley and Gaibor, 1997; Hughes and Bermudez 1997; McCourt et al., 1997;). The eastern limit of the **PT** is defined by the Calacali-Pallatanga Fault Zone (**CPFZ**) (Aspden et al., 1987) and its, poorly exposed, western margin is defined by the Toachi Fault, locally corresponding to the Mulaute Shear Zone (**MSZ**) of Hughes and Bermudez, (1997), which continues south as the buried Chimbo Lineament. The age of the Pallatanga Unit is not well established, although Reynaud et al. (1999) quote an Sm/Nd isochron age of 123 ±13 Ma from the west of Quito. The precise timing of the **PT** accretion is unknown but various observations (Aspden et al., 1992; Noble et al., 1997; Jaillard et al. 1999) suggest that it approached obliquely from the south/south west and first came into contact with the then continental edge prior to the Late Campanian. Subsequent marginal parallel transport of the **PT** probably continued throughout much of the Paleocene.

In the 0^o-1^0N sector of the cordillera immediately to the west of the Toachi Fault (**MSZ**) is the Naranjal Terrane (**NT**) comprising lavas of the Naranjal Unit together with its associated volcanosedimentary sequences.

Radiolarian remains indicate consistent Campanian-Maastrichtian ages. The Naranjal Unit consists mainly of volcanic arc andesites and basalts but some analyses have geochemical signatures more compatible with an oceanic plateau setting (Kerr et al., 2002; Boland et al., 2000). Based on sedimentary and geochronological evidence the timing of the **NT** accretion is well constrained as Early Eocene.

Following the **NT** accretion, there was a widespread marine transgression which led to the deposition of the Middle to Late Eocene Zapallo and Tortugo units in the 0-1° N sector. Further east, the Silante Unit was also deposited and although previously poorly dated the discovery of foraminiferal remains of probable Middle- Late Eocene-Early Oligocene age (Boland et al., 2000) confirms its age. Although the exact nature and timing of the **NT** accretion most likely varied from place to place, nevertheless from about the Middle Eocene significant changes in the sedimentological record are apparent over large areas of the Northern Andes. For example, in the coastal regions of western Ecuador (with the exception of the Progresso Basin) Paleocene and Cretaceous sequences are unconformably overlain by late Early Eocene to Late Eocene shallowing upwards successions (Benitez, 1995; Jalliard et al., 1995; Reynaud et al., 1999). Similarly in southern Colombia, Middle Eocene-Oligocene marine sediments of the Calcareous Detrital Formation occur along the cordilleran foothills and Pacific Coastal Plain overlying Cretaceous-Tertiary basement sequences (McCourt et al., 1991).

Southwards of the Naranjal outcrop is the Macuchi Terrane (**MT**) which is dominated by the Macuchi Unit a volcanic-rich clastic sequence which also includes pillow lavas/breccias, minor limestones and diabase bodies. Geochemical evidence indicates that the unit varies in composition from basaltic to andesitic and represents the remnants of an oceanic island arc (Hughes and Pilatasig, 2002). Kerr et al. (2002) while noting the geochemical similarities between these rocks and those of the Naranjal Unit also suggested that some of the more 'primitive' (MgO rich) lavas of the Macuchi Unit may have formed in a back-arc basin. Poorly constrained palaeontological and radiometric evidence (Eguez, 1986) suggests that part of the Macuchi is of Early Eocene age. Although the along strike physical continuity between the **NT** and **MT** is interrupted by extensive alluvial fan deposits, both occupy analogous structural positions within the cordillera juxtaposed against the western margin of the **PT** along the line of the Toachi Fault-**MSZ**-Chimbo Lineament. Detailed structural analysis of the **MSZ** is still required but the presence of gently dipping to subhorizontal stretching lineations and dextral kinematic indicators within the zone and its southern continuation are consistent with a model of oblique emplacement from the southwest (Boland et al., 2000). It is tempting to suggest a similar (Early Eocene) accretionary age for both terranes. Evidence from the southern part of the cordillera, however, suggests that the final accretion of the Macuchi Terrane possibly did not occur until the latest Eocene-earliest Oligocene (Dunkley and Gaibor, 1997).

To the south of the Equator the Angamarca Group, which is everywhere separated from the Macuchi Unit to the west by the Chimbo Lineament, was deposited. It comprises a turbiditic, quartzo-feldspathic, often sericitic, sandstone/siltstone/mudstone sequence that includes conglomerate and breccia horizons and minor limestone. Abundant palaeontological evidence (Santos and Ramirez, 1986; Eguez, 1986) indicates Middle to Late Eocene ages for parts of the group but it is possible that sedimentation continued into the Oligocene since the upper, eastern, portion of the section has not been dated. Samples from the western Angamarca outcrop, towards its contact with the Macuchi Unit, yielded sparse but diagnostic planktonic foraminifera of Early to Middle Paleocene age and McCourt et al. (1997) proposed that the Angamarca Group ranges from Paleocene to Eocene in age. In view of the regional evidence mentioned above, however, this interpretation seems open to question and our preferred working hypothesis would be to suggest that, in common with other areas in the Northern Andes, sedimentation in the Angamarca basin probably commenced in the Middle Eocene.

In addition to the changes in sedimentation, changes in subduction zone dynamics during the Eocene lead to the development of widespread volcano-plutonic arc activity along the continental margin. In the north west of the cordillera the 44-35Ma Santiago plutons represent the intrusive base of this arc which helped source the post-accretion, andesitic, sedimentary units such as the Silante. Further north intrusive ages of 44-39Ma recorded from dioritic plutons which intrude the Timbuqui volcanic arc (McCourt et al., 1991) suggest that correlatives of both the Naranjal Unit and the Santiago plutons are present in Colombia. Elsewhere in Ecuador, however, the peak of batholithic emplacement seems to be much later with ages of 26-15Ma.

Between 2^0S-4^0 S extensive continental margin volcanic activity gave rise to the Saraguro Group a calc-alkaline sequence of intermediate to acidic composition consisting mainly of lavas, welded ash-flow tuffs and reworked volcaniclastic rocks (Dunkley and Gaibor, 1997). Based on radiometric evidence the group ranges from Middle Eocene to Early Miocene in age c.40-20Ma (Dunkley and Gaibor,1997; Pratt et al., 1997; Steinmann, 1997; Hungerbuhler, 1997). In the southern/central portion of the cordillera the deformation and erosion of older dacitic-rhyolitic volcanic units and the change to less evolved, andesitic material within the Saraguro Group led Dunkley and Gaibor (1997) to propose an ‘end Eocene-basal Oligocene’ age for the **MT** accretion. Although the regional significance of the ‘intra-Saraguro deformation’ remains to be established, the radiometric age data clearly indicates that ‘Saraguro Arc’ activity continued until the Early Miocene.

From about Middle Miocene time, possibly influenced by the arrival of the aseismic Carnegie Ridge at the Ecuador Trench, there was a change in Andean geodynamics which saw the development of a series of extensional basins (Steimann, 1997; Hungerbuhler, 1997; Spikings et al., 2001). In the cordillera a period of erosion and regional deformation preceded the deposition of a series of post-Early Miocene volcanic and volcanoclastic dominated units and the development of a new magmatic arc which continues until the present-day. These include the Tarqui, Quimsacocha, Turupamba, Turi, Uchucay, Santa Isabel Fms/Units and the Ayancay Group (Pratt et al., 1997) ranging in age from c. 20-8Ma. At this time the Chaucha Batholith (12-8Ma) was also emplaced. Further north is the Cisaran Formation (16.8-8.0Ma) which in part rests unconformably on folded Saraguro Group strata (Dunkley and Gaibor, 1997) and the Zumbagua Group (12.5-6.0Ma) which also has discordant contact with the underlying Angamarca Group sediments (Hughes and Bermudez, 1997).

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