# THE MESOZOIC-CENOZOIC EVOLUTION OF THE ECUADORIAN ANDES

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**RESUMEN:** Los principales eventos en la evolución geodinámica del Ecuador han sido registrados en el Triásico, Jurásico, Cretácico inferior, Campaniano y Eoceno superior-Oligoceno. Estos eventos se han determinado a partir de levantamientos geológicos regionales y la determinación radiométrica de aproximadamente 350 muestras.

**KEY WORDS:** Ecuador, Andes, Autochthonous/Allochthonous, accretionary prism, geochronological, Mesozoic-Tertiary evolution.

## MESOZOIC-CENOZOIC EVOLUTION

Recent studies by various groups, including the publication of ca. 350 radiometric ages, allow a more precise interpretation of the geological evolution of the Ecuadorian Andes.

In the Cordillera Real (Eastern), during the Late Triassic, the semi-pelitic, Loja division sediments were metamorphosed. This event was accompanied by regional, dextral (transpressional) shearing, the emplacement of syn- to late- tectonic, granitoid batholiths (of S- and I-type character) and mafic amphibolite bodies, migmatite formation and, possibly, minor volcanism in the east. Zircon and monazite, U/Pb dates indicate plutonic ages of 228 ± 1 Ma and 227.6 ± 3.2 Ma.

In the Middle-Late Jurassic (ca. 190-140 Ma), major, volcano-plutonic activity occurred throughout the sub-Andean zone and in the eastern part of the Cordillera Real, to the north of 2°S. During this period the Zamora, Abitagua, Azafran, Chingual and Rosa Florida batholiths were emplaced and the (?)contemporaneous, volcanic Misahuallí and the volcano- sedimentary Upano sub-divisions were formed.

Following the cessation of this activity, in the Late Jurassic-Early Cretaceous (ca. 140-120 Ma), the Cordillera Real and sub-Andean zone were deformed, uplifted and eroded. Young, K/Ar mineral ages (ca. 135-120 Ma) and a reset, Rb/Sr whole-rock isochron (120 ± 5 Ma) obtained from the Jurassic batholiths are interpreted to relate to this event which, within the Cordillera, included an important component of (?)dextral shearing along steep-to-vertical, NNE/SSW-trending zones.

The western structural (?autochthonous) limit of the Cordillera Real is defined by the Baños-Las Aradas fault zone which represents the southern extension of the Romeral fault in Colombia. Westward of this structure, and possibly mainly during Late Jurassic-Cretaceous time, the principle elements of an accretionaly prism complex were assembled. Much of this complex is now buried by Tertiary and Quaternary volcanic deposits but it includes: the east-west trending, metamorphic rocks of El Oro province in the southwest, the Late Jurassic volcanic, oceanic arc sequence of the Alao division and the quartzose/pelitic metasediments of the (?)Lower Jurassic Guamote division in Central Ecuador, and various "basement/metamorphic" windows reported from the Chota valley, in the north, and the Chaucha/Manu areas, in the south.

Detailed mapping in the El Oro Province has established that the accretionary complex contains inclusions of both 'continental' and 'oceanic' affinities. The former include a variably metamorphosed (HT/LP), semi-pelitic sequence, syn-to late-tectonic, S- and I-type character granitoids, migmatites and amphibolites, all of which can be correlated with rocks occurring in the Loja division of the Cordillera Real to the east. It is suggested that the El Oro rocks were tectonically scavenged from the western margin of this Cordillera (or possibly its southern extension into northern Peru-the Olmos Arch) and incorporated into the accretionary prism from ca. 140 Ma onwards, most probably as a result of dextral shearing. High-pressure inclusions (blueschists and eclogites) of oceanic origin were also tectonically emplaced into the accretionary complex. A single K/Ar (phengite) determination for the El Oro Province gave an (?cooling/ emplacement) age of 132 $\pm$ 5 Ma and similar dates, obtained from Colombian blueschists, that are interpreted to represent the northward continuation of the accretionary complex, range from 125 $\pm$ 15 to 120 $\pm$ 5 Ma.

In the Early-Late Cretaceous (ca. 120-85 Ma), in the sub- Andean zone, and probably extending westwards over the Cordillera Real, the epicontinental sandstones, shales and limestones of the Hollin and Napo formations were deposited, with marked unconformity, over eroded, deformed, pre-Cretaceous lithologies. The depositional environments recorded by these sediments and the general absence of plutonism, indicate a period of relative tectonic quiesence. However, volcanic debris was shed into the extensional (?transtensional) Alamor/Lancones basin which was forming above the accretionary complex in southwest Ecuador and northwest Peru. Paleomagnetic data from the Lancones basinal sediments suggest progressive, clockwise (up to 90°) rotation took place during Early-Late Cretaceous time, implying a dextral shear regime, possibly with a limited subduction component. This rotation would also account for the marked east-west structural trend of the accretionary complex in the El Oro Province.

Following the deposition of the Upper Napo formation in the east, a major period of Upper Cretaceous (Campanian, ca. 83-73 Ma) uplift and erosion affected the Cordillera Real and sub-Andean zone. This event coincides with a regional, thermal disturbance (resetting) of the K/Ar mineral ages and the emergence of the Cordillera as a positive topographic feature. During this period plutonic activity was restricted.

In the uppermost Cretaceous-Paleocene (ca. 73-60 Ma) the continental Tena formation was deposited along the eastern margin of the Cordillera Real and the marine Yunguilla formation was laid down in the west, in (?)tensional basins developed on top of the Late Jurassic-Cretaceous accretionary complex. During Early Tertiary time (60-38 Ma) the calc-alkaline, oceanic Macuchi-Sacapalca arc and associated marine sediments developed on top of the oceanic, Early Cretaceous Piñon terrane which was probably located somewhere to the west. To the east in the sub- Andean zone and Oriente, the widely distributed, continental Tiyuyacu formation was deposited. In the Cordillera Real a number of generally small (undeformed) stocks and plutons were emplaced.

Near to the Oligocene-Eocene boundary (ca. 38-35 Ma) an important change resulted in regional uplift and erosion and probably, the widespread reactivation of older structures. It was possibly at this time that the Early Cretaceous, oceanic Piñón terrane, together with its Upper Cretaceous-Lower Tertiary (pre-Oligocene), marine cover sequence, and the Macuchi-Sacapalca arc were accreted. The Piñón terrane now forms the basement of the Cordillera Occidental (Western) and Coastal Plain and the tectonic contact between this terrane and the western limit of the Late Jurassic-Cretaceous accretionary complex is marked by the Calacali-Pallatanga fault in Ecuador and by the Cauca-Patía fault in Colombia. During the accretion the Cordillera Occidental was deformed and sliced-up by a series of dextral, NNE-SSW trending, horse tail faults that terminated in the Calacali-Pallatanga fault. In the Oligocene (ca. 35-27 Ma) the continental, calc-alkaline Saraguro volcanic arc developed over the Ecuadorian Andes. Dextral, transtensional, intermontane basins were opened between the Cordillera Real and Cordillera Occidental. In the coastal (forearc) region sedimentation changed from marine to continental and in the Oriente (back-arc), the continental Orteguaza formation was deposited.

At ca. 26 Ma there was a major reorientation in the relaitve motions of the oceanic and South American plates. Events relating to this change are not well-documented but in the Cordillera Occidental, Miocene (ca. 20-9 Ma) granitoid batholiths were emplaced and Miocene-Pliocene (ca 20-4 Ma) acid-intermediate, volcanic activity (Pisayambo Group) was widespread.

At ca. 2 Ma the Carnegie ridge came into contact with the active subduction zone. This collision brought about the cessation of volcanic activity to the south of ca. 2'30'S, whereas to the north, large, andesitic, stratiform volcanoes were formed, especially along reactivated, regional structures such as the Baños-Las Aradas and the Calacali-Pallatanga faults. The oblique, NE-SW trending, regional faults, especially in the Cordillera Occidental were also reactivated, movements along which continue until the present-day.