THE EASTERN CORDILLERA OF SOUTHERN BOLIVIA: A KEY REGION TO THE ANDEAN BACKARC UPLIFT AND DEFORMATION HISTORY

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INTRODUCTION

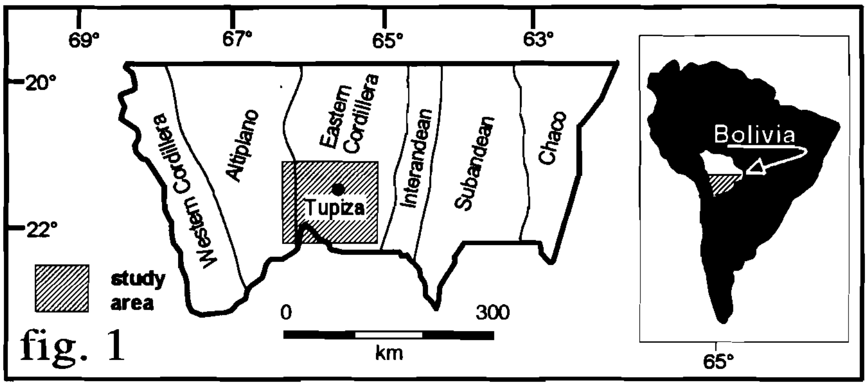
The back-arc region of Southern Bolivia comprises three major units (fig. 1): The Altiplano, forming a high plateau at about 4000m, is an intramontaneous basin with Cenozoic infill. The Eastern Cordillera (EC), reaching more than 5000m altitude, is built up mainly of a very thick pile of Ordovician anchimetamorphic sediments. In places, it is covered by Cretaceous and Paleogene or Neogene sediments, respectively, among which continental ones prevail. To the W the EC is overthrust upon the Altiplano. The Subandean ranges with Late Paleozoic to Neogene rocks, form part of an E-verging fold-and-thrust belt, together with the eastern part of the EC (Interandean). As the Altiplano and the Subandean units have been subject of oil prospection, geological exploration was much more intensive, there, than in the EC. Looking, however, for a geodynamic model of the back-arc evolution in Meso- and Cenozoic times, the EC plays a key role. In this view we present new results from extensive field work in the western part of the southern EC (Tupiza Region) combined with K/Ar and apatite fission track dating. The onset of major deformation phases, deformation style and progress can be well outlined herein through Cenozoic times.

GEOLOGICAL FRAMEWORK

The EC is bound to the adjacent physiographic provinces by a pair of divergent thrust systems. To the west the Paleogene-Neogene sediment infill of the Altiplano basin is overthrust at the San Vicente thrust system by turbiditic rocks of Llanvirn-Caradoc age (Erdtmann et al., 1995) whereas at the eastern border of the EC, accomodated thin-skinned folding and thrusting in Cambrian to Triassic strata of the Interandean zone refer to a basement involved thrust (Kley, in press).

The oldest Mesozoic rocks of the Southern EC are swarms of mafic dikes and sills intruding Ordovician strata. These rocks are exposed in the area of Cornaca, 50 km N of Tupiza. A sample of a dike N of Cornaca yielded an Early Jurassic age of 184.0$\pm$4.9 Ma (K/Ar, whole rock). The emplacement of these magmatic rocks is due to extensional processes that culminated east of South America in the opening of the South Atlantic.

Predominantly continental Cretaceous sediments of the Puca Group are completely recorded for the timespan ?Kimmeridgian to Paleocene in a back-arc rift setting. In the southern part of the high fragmentated Potosi basin discontinuous Cretaceous successions from the N-trending synclines of Tupiza and Camargo reflect active rifting processes accompanied by normal faults and alkaline basaltic volcanism. In the syncline of Tupiza Coniacian basanitic lava-flows of the Aroifilla Fm. (Sempere, 1994) are the youngest Cretaceous strata. However, Tertiary conglomeratic rocks of the Tupiza region include Pucalithus limestone fragments of the El Molino Fm. (Maestrichtian) which does not crop out in the area, at present.



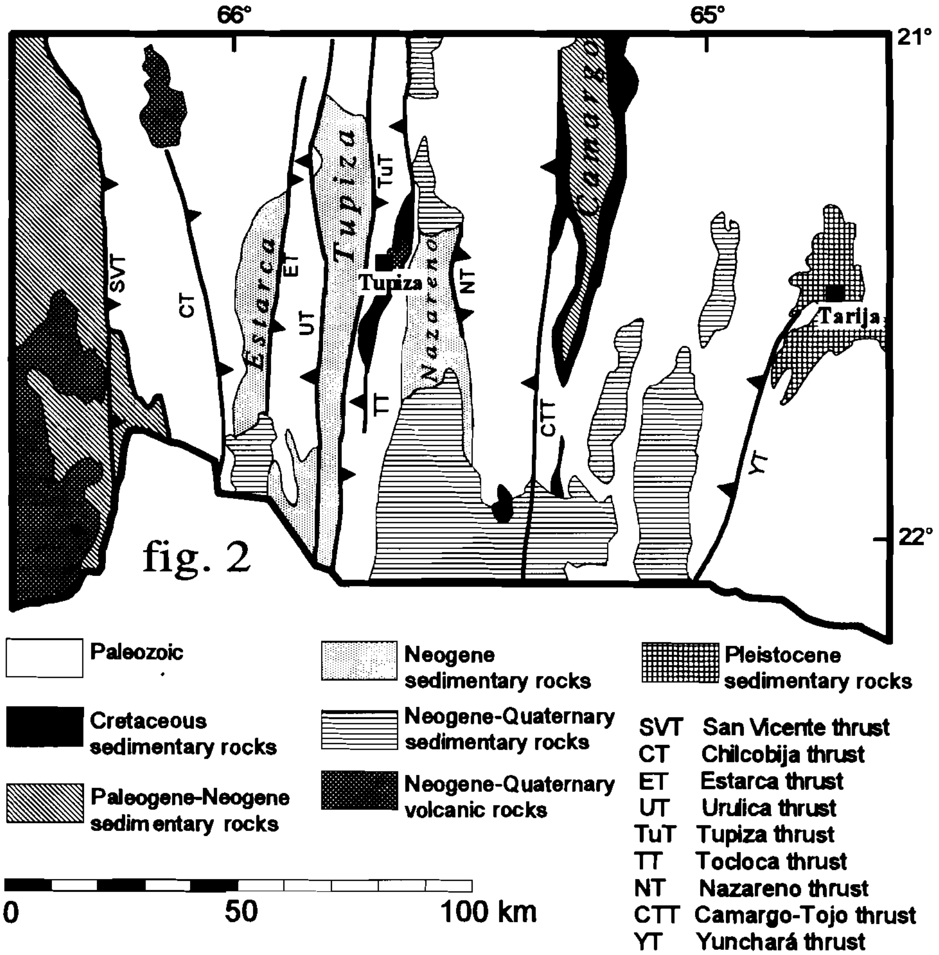


Fig. 1: Major physiographic and structural provinces of the Southern Bolivian Andes.
Fig. 2: Generalized geological map of the Tupiza-Tarija region, Southern Bolivia.

Tertiary continental strata occuring in the EC are conserved in a twofold record. In the Camargo syncline Paleogene to probably Oligocene deposits represent a paleo-foreland basin, whereas fault-related Late Oligocene to Middle Miocene deposits in the area of Tupiza have been developed within intramontaneous basins (fig. 2). Here the sedimentary infill is mainly conglomeratic and composed of fragments of the underlying Ordovician and Cretaceous rocks and trachyandesitic volcanics, which intruded into Cretaceous and lowermost Tertiary strata.
Deformation in the backarc has migrated eastward since late Oligocene times and is essentially chracterized by a major eastward shift from the Altiplano and the EC to the Subandean Ranges at about 10 Ma (Kley et al., in press).

CENOZOIC BASINS OF TUPIZA

The Tertiary redbeds of the Tupiza area are preserved in three distinct N-trending depressions called the Tupiza, Estarca and Nazareno basin.
<u>The Tupiza basin</u> is a complex of four partly overlapping Tertiary basins being affected by syn- and postsedimentary thrusting. Here the oldest Cenozoic sediments belong to the tightly folded Catati Fm. and the transitionally overlapping first "member" of the Tupiza Fm. (m1). Both successions are bounded to the east by the W-vergent Tupiza thrust . The base of the Catati Fm. is marked by a sharp angular unconformity to the Ordovician basement.
Since no datable materials and no upper contact to the following members exist, the age of these deposits can only be predated by the rhyodacitic intrusion of Kharachi Orkho, which breaks through these strata. A whole-rock sample from this locality yielded a K/Ar age of 21.4$\pm$0.5 Ma. The lowermost stratigraphic limit can be considered as post-Cretaceous because of the numerous limestone pebbles included in the Tupiza Fm. m1.
In the syncline of Cerro Bolivar (S of Tupiza) the Tupiza m2 can be subdivided into two parts. The lower conglomeratic part contains only pebbles of the underlying Ordovician rocks. Eastward directed paleocurrents indicate that these conglomerates were deposited in a basin separate from that of Tupiza m1. The upper part consists of 250 m thick trachyandesitic lava-flows. A basal sample from the western hinge of the syncline obtained a biotite K/Ar age of 21.7$\pm$0.4 Ma. N of Tupiza identic lava-flows overlie the Ordovician, forming a wide anticline. Previous assumptions that these lavas are much younger than those of Cerro Bolivar can definitely be denied, as a sample collected at the eastern hinge of the anticline (E of Estancia Tolonias) yielded a biotite K/Ar age of 21.6$\pm$0.4 Ma. The source of these lava-flows is assumed to be the subvolcano of Mojon Pampa (E of Tupiza), because of its central position and the geochemical composition of its rocks.
The overlying Tupiza m3 consists of polymictic conglomerates containing clasts of trachyandesites from its base. The outcrops are restricted to the east of Rio Tupiza and demonstrate a separate basin configuration with a southward dipping basin axis. Biotites from a dacitic pyroclastic tuff from the lower parts close to Tupiza yielded a K/Ar age of 17.6$\pm$0.5 Ma.
The westernmost part of the Tupiza basin is covered by conglomerates of the Oploca Fm.. Coglomerates similar to the Tupiza Fm. m3 are locally preserved beneath the Oploca Fm.. This basin-infill is embraced to the east by the W-vergent Oploca thrust located W of the Tupiza thrust and to the west by the E-vergent Urulica thrust. Both thrusts have caused gentle folding at the basin margins where lower strata come to light. Biotites from thick pyroclastic intercalations from the western margin (S of Chifloca) gave a K/Ar age of 17.0$\pm$0.4 Ma. In a small area (N of Palquisa) at the eastern margin the Oploca Fm. unconformably overlies a folded gipsyferous silty to sandy succession with tuffaceous layers in its lower parts. Biotites from these tuffs have been dated with a K/Ar age of 24.3$\pm$0.6 Ma.
<u>The Estarca basin</u> contains essentially Ordovician clast bearing fanglomerates of the similar named formation bound to the east by the W-vergent Estarca thrust. The lack of volcanogenic material suggests that the Estarca Fm. is coeval with the upper parts of the Oploca Fm.. This assumption can be supported by the simultaneous development of the Urulica thrust as the backthrust of the Estarca thrust later than about 17 Ma.
Conglomerates of the Nazareno Fm. are located east of the Cretaceous syncline of Tupiza in the <u>Nazareno basin</u>. Undeformed tuffaceous layers from the fine grained upper parts were dated at

12.79±0.12 Ma (Ar/Ar) by Gubbels et al. (1993). This upper section consists of fluvial and pediment deposits which are connected with the origin of the San Juan del Oro peneplain. The southern prolongation of this surface at the Argentinian boarder covers also the Tupiza and the Estarca basins. Lava-flows from the Tupiza Fm. m2 locally enter the basin at its western edge (Rancho Chuchuli) in a basal position. Biotites from a trachyandesitic sample from this locality yielded a biotite K/Ar age of 21.3±0.4 Ma. Here ongoing conglomeratic sedimentation is recorded by progressive angular unconformities which demonstrate synsedimentary folding. The eastern limit of the basin is marked by the westvergent Nazareno thrust.

APATITE FISSION TRACK DATA

Two Oligocene ages have been obtained from apatites of magmatic rock samples of pre-Cenozoic origin. Coniacian basanitic lava-flows from the top of the Aroifilla Fm. exposed near Tupiza yielded an age of 32.1±4.9 Ma. Apatites from an Early Jurassic dike intruded into the Ordovician rocks in the area of Cornaca have been dated with 29.7±2.7 Ma. These data testifie to an early Tertiary uplift of the EC.

CONCLUSIONS

The fission track data point to an Early Oligocene uplift of the EC, which may have caused erosion of the Cretaceous-Paleocene cover. This event was followed by the deposition of the probably Late Oligocene Catati and Tupiza m1 Fms..

Neogene basin development started with a major tectonic pulse at 24-22 Ma which effected an angular unconformity at their bottom. The basins are mainly controled by W-verging overthrusts, which probably pass into a deep-seated detachment plane near the brittle/ductile transition zone. Within the single basins compressive deformation is heterogenous. In the Nazareno basin, continuous deformation is recorded from 22 to 12 Ma, whereas in the Tupiza and Estarca basins thrust activity happened later than 17 Ma.

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