LATE PERMIAN-EARLY MESOZOIC RIFTS IN PERU AND BOLIVIA, AND THEIR BEARING ON ANDEAN-AGE TECTONICS

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Rifting in Peru and Bolivia

Late Permian-Triassic rifting (Fig. 1) is recognized in the Eastern Cordillera of Peru (Laubacher, 1978; Noble et al., 1978; Mégard, 1978; Dalmayrac et al., 1980; Rosas and Fontboté, 1995; Rosas et al., 1997; Jacay et al., 1999) and proved to have extended into Bolivia in the Jurassic (Sempere et al., 1998). The rifting zone appears to coincide with the axis of the Eastern Cordillera in both countries. Rifting produced subsident grabens in which the Mitu Group red alluvial deposits and volcanics accumulated over preserved Late Paleozoic strata, and generated a thermal sag that progressively expanded the basin. Predominantly alkaline volcanic rocks were erupted, in relation with pluton emplacement at depth. Plutons from the Eastern Cordillera of southern Peru have a signature similar to those in the Oslo graben, an aborted rift system in Norway (Kontak et al., 1985). Most plutons are cut by younger basic dykes. South of 17°S, the rifting zone is characterized by elongated swarms of basic dykes and sills that intrude mainly Paleozoic rocks. When Mesozoic strata occur in such areas, basaltic flows, sills and/or dykes are generally also observed in the Mesozoic. In Bolivia, a basanite dyke intruding Ordovician rocks (Tawackoli, 1997) and a tholeiitic sill of large areal extension intruding Mesozoic strata (Sempere et al., 1998) were respectively dated 184 ± 4.9 Ma and 171.4 ± 4.2 Ma.

Mitu paleoenvironments include alluvial fans, rivers and (playa-)lakes. In southern areas, red continental strata overlie volcanic flows that in turn overlie the Late Permian-Triassic Ene (=Vitiacua, =Chutani) Fm. In Bolivia, infills of coeval grabens characteristically include a basal unit, generally no more than several tens of m thick, consisting of alluvial pale sandstones and/or reddish conglomerates, which is transitionally overlain by a thick red mudstone unit of alluvial to lacustrine origin. This succession is postdated by the fluvio-eolian Ravelo Fm. Eolian sandstones, locally associated with basalts, are also found in the Lower Huancané Fm northwest of Lake Titicaca (Newell, 1949) and in the Caycay Fm of the Cusco area (Carlotto, 1998). In the Peruvian Oriente, red alluvial and eolian strata (Sarayaquillo Fm) grade westwards into the Pucará Group carbonates, which reflect a transgression that initiated in the Norian and progressed from north to south following the Mitu rift axis (Mégard, 1978; Rosas et al., 1997; Sempere et al., 1998). Basalts with within-plate signature commonly occur in the Pucará Group (Rosas et al., 1997).

In southern Peru, the Yura basin apparently originated by rifting in the Liassic (Marocco and Delfaud, 1986). The succession in the Arequipa area begins with thick lavas and subordinate continental deposits (Chocolate Fm) that resemble those of the Mitu Group, suggesting development of similar processes. Transgressive shallow-marine limestones of Toarcian-Bajocian age (Socosani Fm) overlie the Chocolate Fm (Vicente et al., 1982), just as the Norian-Liassic Pucará Group overlies the Mitu Group in the Eastern Cordillera of central Peru. These relationships and the occurrence of Sinemurian marine intercalations in the upper Chocolate Fm suggest that rifting developed in this area later than in the East--ern Cordillera. Rifting culminated in the late Bajocian-Bathonian with considerable downwarp of the Arequipa region (Vicente et al., 1982).

Deposits typical of the Yura basin are known in the Lagunillas area (15°50'S, 70°30'W), i.e. at the Western Cordillera-Altiplano transition. To the NE, outcrops at Las Huertas and Cerro Sipín (Newell, 1949), and at Yanaoco on the NW corner of Lake Titicaca (Sempere and Carlotto, unpublished), form a series of localities where a limestone-bearing unit overlies the Paleozoic basement, documenting a transgression that developed in a NE shallow-marine extension of the Yura basin.

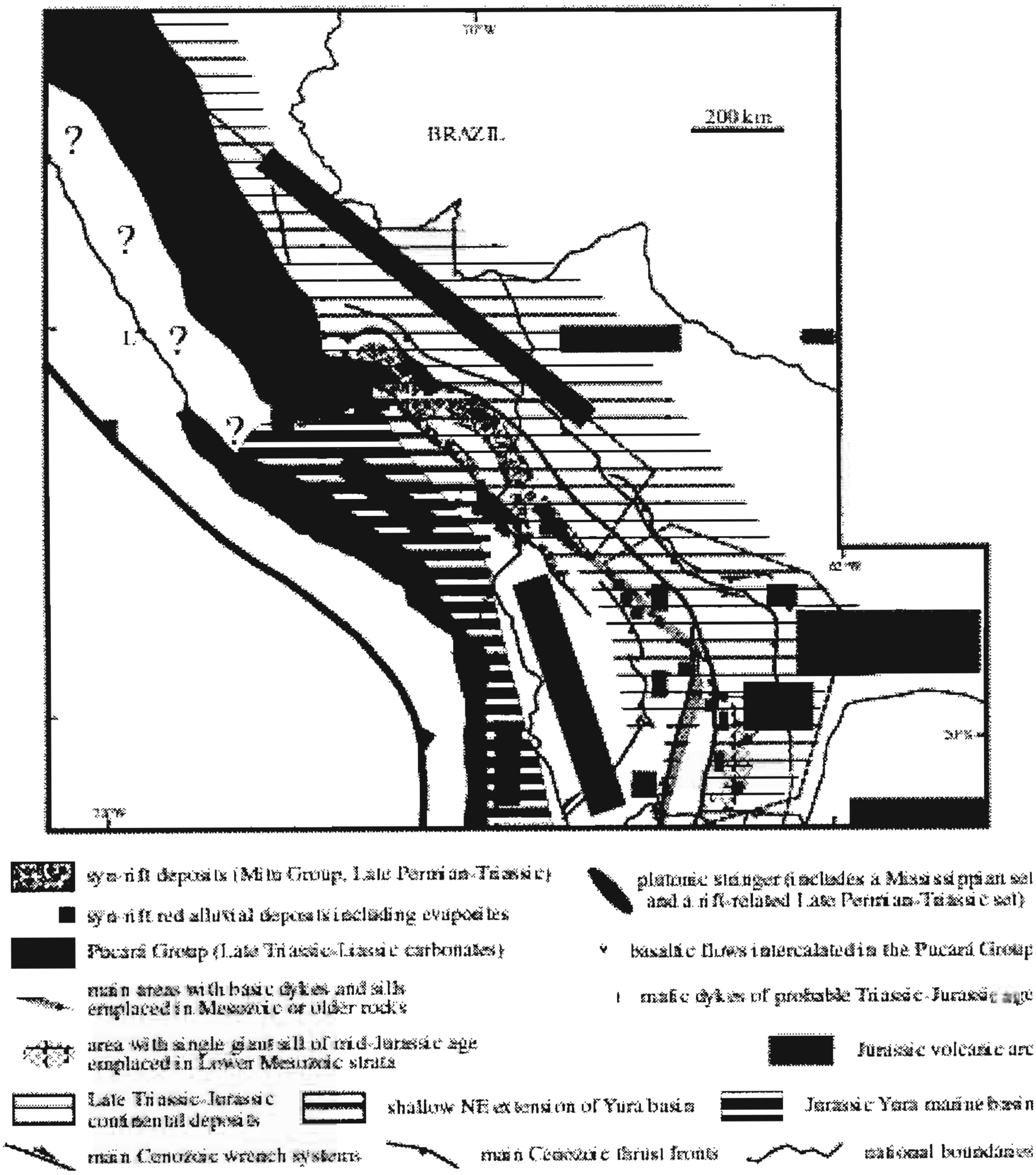

Figure 1: Principal Early Mesozoic geologic elements of central Peru and Bolivia. The axis of the eastern, Late Permian-Middle Jurassic, rift system is defined by the Mitu group, coeval granitoids, and basic dyke swarms, and approximately coincides with the axis of the Eastern Cordillera of Peru and Bolivia. Cities: C: Cochabamba, Cu: Cusco, L: Lima, P: Potosí, SC: Santa Cruz, Tu: Tupiza.

Latest Jurassic - earliest Cretaceous tectonics

The Eastern Cordillera of central Peru is traditionally believed to have behaved as a structural high since the Late Triassic (Mégard, 1978, 1987; Dalmayrac et al., 1980; Jaillard, 1994), in part because in this area the onlapping Cretaceous deposits are much thinner than to the west. The reconstruction of a Late Permian - Middle Jurassic rift system along the same area implies instead that absence of Late Triassic - Jurassic deposits reflects uplift and erosion during the latest Jurassic-earliest Cretaceous. In central Peru, this uplift is documented by the Copuma (Jacay, unpublished) and Upper Sarayaquillo conglomerates that overlie Lower to Middle Jurassic strata respectively west and east of the "Marañón geanticline"; the former unit underlies the Lower Cretaceous Goyllarisquizga Fm with an angular unconformity. Uplift of this previously rifted area points to coeval incipient rift inversion.

At the Altiplano-Western Cordillera transition (15°47'S, 70°36'W), a locally angular unconformity separates the Saracocha conglomerates and overlying transgressive Cretaceous strata from underlying marine strata of Jurassic age (Newell, 1949; Carlotto and Sempere, unpublished). A post-Dogger, pre-Tithonian, unconformity was also identified in coastal southern Peru (Rüegg, 1961). Reliable data document that the Tithonian-Berriasian interval was a period of marked tectonic instability (Mégard, 1978; Laurent, 1985; Jaillard, 1994) that was postdated by northeasterly onlap of late Early Cretaceous strata.

In Bolivia, a tectonic event was assigned to the Kimmeridgian on the basis of tentative correlation with the Kimmeridgian-age Araucan event known in the greater Neuquén basin of Argentina and Chile (Sempere, 1994). However, current research definitely shows that Mesozoic Bolivia was connected to eastern Peru, and not to southern basins. The late Early Cretaceous onlap developed on the erosional surface that separates the Serere Group from the overlying Puca Group. Evident correlation with Peru shows that this unconformity must be of latest Jurassic-earliest Cretaceous age.

Influence on Andean tectonics

Reconstruction of rifted areas in the Andes of Peru and Bolivia sheds some light on the structure and building history of the Andes at these latitudes. In the Yura basin, Late Cretaceous-Early Paleogene compressional tectonics (Vicente, 1989) probably resulted from inversion of the southwestern Jurassic rift. The Eastern Cordillera of Peru and Bolivia appears to result from inversion of the eastern rift. Compressional failure of this rift system in the late Oligocene explains the apparent jump in shortening location observed by Sempere et al. (1990). The Altiplano, which underwent little Cenozoic surface shortening, appears as a paleogeographic block that was limited by 2 rift systems during most of the Mesozoic (Fig. 1). In the central and northern Oriente region of Peru, Cenozoic structures proceed from reactivation of preexistent faults (Laurent, 1985). In the Eastern Cordillera of central Peru, ultramafic rocks, including peridotites, occur mainly within locally high-grade Precambrian metamorphics but are possibly of Early Mesozoic age (Sempere et al., 1998; Jacay et al., 1999); in any case, these occurrences suggest that rift inversion uplifted relatively deep levels of the lithosphere in this area.

Because rift inversions can affect different structural depths, the amount of inversion-derived uplift can also be perceived from the distribution of Late Paleozoic-Triassic granitoids. Exposed granitoids nearly disappear north of 6°S, although the rift system continues into the Ecuadorian foreland basin (P. Baby, pers. com.), suggesting that shortening in the Eastern Cordillera considerably decreases north of this latitude. Shortening and/or depth of rift inversion in the Eastern Cordillera apparently also decrease southeast of 17-18°S, where exposed granitoids disappear and only basic dyke swarms crop out, because this segment of the Eastern Cordillera, although of tectonic origin, is geomorphically not a true, high and narrow, cordillera but a broad highland region affected by large-scale erosional surfaces.

Many thrusts in the Eastern Cordillera probably originated by compressional reactivation of earlier normal faults. The geometry of the Late Permian-Jurassic rift faults presumably determined the vergence of many Andean-age thrusts, as SW(resp. NE)-vergent thrusts are predominant southwest (resp. northeast) of the rift axis. In the N-trending segment of the Eastern Cordillera, south of 19°S, tectonic displacements were possibly more transpressional, reactivating ancient wrench faults.

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