# THE PALEOZOIC BASEMENT OF THE CENTRAL ANDES (18°-26°S) A METAMORPHIC VIEW.

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## INTRODUCTION

Scarce outcrops of metamorphic rocks in the Central Andes (18°-26°S) occur in all mountain chains from the Coastal Cordillera in Chile to the Cordillera Oriental in Argentina (Fig.1). However, the present state of knowledge on the metamorphic conditions and on age relations of metamorphism and cooling did not allow a correlation of the scattered outcrops (summarized in Damm et al., 1990; Miller et al., 1994). Nevertheless, the occurrence of Pre-Mesozoic metamorphic rocks is very important for the different geotectonic interpretations of the Paleozoic Andean history that are mainly based on the sedimentary-faunistic record and the tectonic-magmatic evolution of the basins. The major lines of discussion are:

(1) The allochthonous terrane development of the Pacific Margin (23°-25°S; e.g. Ramos, 1988) started with the collision of the Arequipa-Antofalla craton in the Late Proterozoic (700-600 Ma, final collision at 570 Ma) and continued with a rifting-collision history of the Cambrian-Ordovician basins (540- 470 Ma) with a para-authochtonous Arequipa Massif (ensialic development, Damm et al., 1990). The last major event was the advent of the Chilenia terrane (440-360 Ma). A similar history for a section at ca 30°S was recently discussed by Astini et al. (1995).

(2) The ± continous subduction history of the Pacific margin started from a passive margin setting during the Mid-Ordovician. Since that time, subduction triggered the processes of magmatism, basin formation and tectonics (Coira et al., 1982). The collision of the Arequipa microplate was in the Late Ordovician.

(3) The Paleozoic Andes formed together with the North American Appalachians in a single orogeny during the collision of the Laurentia and Gondwana continents in the Ordovician (Dalziel et al., 1994).

(4) An intracratonic evolution of a Pre-Cambrian crystalline area that stabilized in Late Proterozoic-Early Cambrian was suggested for the Paleozoic by Hongn (1992) and Mon & Hongn (1991).

The collision of allochthonous terranes or the rifting and collision of para-allochthonous terranes should have a major impact on the crustal thickness and on the thermal regime in the crust, therefore on the physical conditions of metamorphism in the crust. The repeated process should lead to poly-deformation and poly-metamorphism or to belts of metamorphic rocks with different isotopic ages.

We present new data on the metamorphic conditions from all outcrops of high grade metamorphic rocks in N-Chile and from a selected area in NW-Argentina. Field relations (Fig. 1) in N-Chile (Lucassen et al., 1994) and in parts of the Hombre Muerto-Sierra de Quilmes in NW- Argentina (Becchio, Viramonte) were studied during several field trips. Based on the mineral chemistry we calculated P and T by various

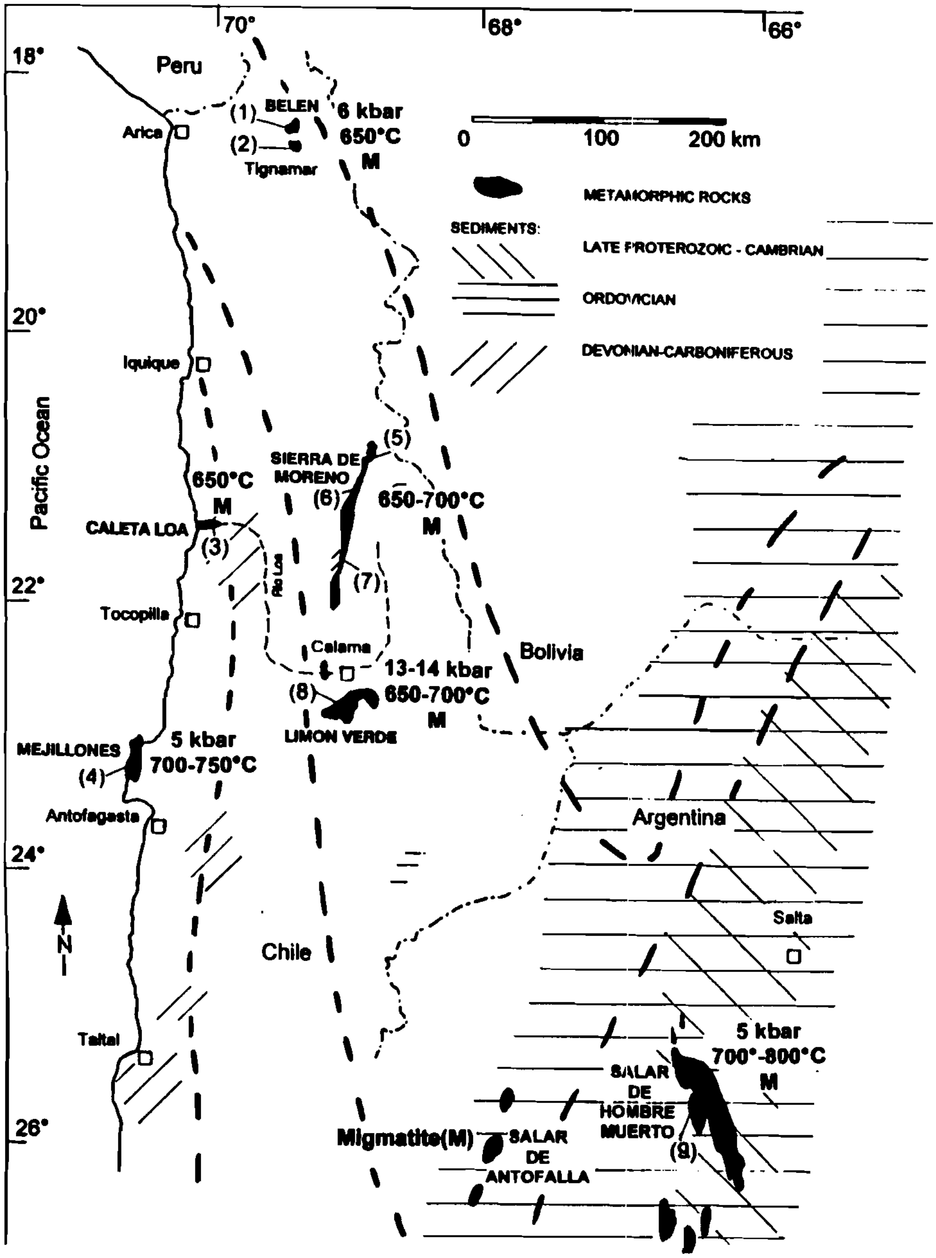


**Figure 1** Distribution of Paleozoic metamorphic basement and sediments (Bahlburg & Breitkreuz, 1991) in N-Chile and NW-Argentina. Peak-metamorphic conditions are shown for the different locations. Numbers in parentheses indicate the sample locations for age determinations (see text). Possible terranes (heavy dashed lines; Ramos, 1988) are from the Coast to the east at the latitude of Antofagasta: Mejillonia Displaced Terrane- Chilenia Terrane- Arequipa-Antofalla Craton-Pampean Terrane.

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thermobarometers and multi-equilibria calculations (Berman, 1991). Along a W - E section, we determined ages on minerals in the Sm-Nd system and in the K-Ar system. Sm-Nd ages were determined at the isotope laboratory at the RHBNC, K-Ar ages at the laboratory at the Universität Göttingen and by Krueger Enterprise Inc., M.A., USA.

## METAMORPHIC CONDITIONS AND ISOTOPIC AGES

Ductile deformation causes one major foliation ($S_1$) N-S trend in all outcrops. $S_1$ is marked by the alignement of the peak-metamorphic mineral assemblages. A wider spaced foliation ($S_2$) is rare and was also formed close to peak-metamorphic conditions. Granoblastic fabrics are common in migmatite and in rocks transitional to granulite. $S_1$ in these rocks is frequently marked by compositional layering. We found no relics of the prograde development in metasedimentary rocks. Primary magmatic fabrics of the protolith are preserved in deformation-protected areas of some orthogneisses. Neither mineral relics nor fabric relics of older metamorphic and deformational events were found. Reaction textures between minerals are absent except retrograde reactions (sericitisation, chloritisation). The only prograde reaction texture found is the breakdown of muscovite into fibrous sillimanite (Hombre Muerto). Chemical zoning of minerals is absent or weak in most samples and restricted to small retrograde rims. A late brittle deformation is obvious in the kinking or disruption of grains and the formation of small quartz or calcite veins.

*Belen-Tignamar.* Temperature in the Belen paragneiss [biotite (bt)-garnet (grt)-kyanite (ky)-muscovite (ms)-plagioclase (pl)-quartz (qtz)] which occurs together with bt-hornblende (hbl) orthogneiss was 650°C at 6 kbar. The T at the given P agrees with the local occurrence of migmatite. Temperature of the Tignamar metapelite (bt-grt-ms-potassic feldspar (kfs)-staurolite (st)-pl) ca 15 km south of Belen was ~ 550°C at 5 kbar (PT from multi-equilibria, GASP barometry, gt-bt thermometry). Migmatites were not found in this area. Metabasites, which are garnet-free, are rare in both areas.

*Sierra de Moreno.* Gneiss or migmatite (bt-pl-qtz) are the most common rock types. Metabasite is rare and does generally not contain grt. Locally calcsilcate occurs. Mineral assemblages are not suitable for barometry. Calculated temperatures are 550°-650°C (grt-bt) and ~ 700°C (hbl-pl thermometry). This agrees with the occurrence of abundant migmatite.

*Caleta Loa.* Migmatite (bt-pl-qtz) is the dominant rock type. Grt-bt pairs yield temperatures between 600-750°C.

*Mejillones.* Gneiss (bt-pl-qtz±grt) with subordinate amphibolite (hbl-grt-pl±qtz) comprise the high grade rocks. Temperatures were around 700°C-750°C at ~ 5 kbar (PT from hbl-pl-grt thermobarometry, hbl-pl thermometry). Hbl-cpx equilibra were found in few samples, confirming the high T conditions.

*Limon Verde.* The metamorphic succession comprises mainly gneisses (bt-qtz-grt±pl) with small intercalations of amphibolite (hbl-grt-orthozoisite (zoi)±pl±qtz). Pressures are 13-14 kbar at 650-700°C. (PT from hbl-pl-grt thermobarometry; hbl-pl thermometry).

*Hombre Muerto - Sierra de Quilmes.* Main rock types are migmatic gneisses (bt-pl-kfs-qtz-ms±grt), cordierite (cd)-bearing in more aluminous whole rock compositions. Subordinate metabasites (hbl-cpx-pl± scapolite) and calcsilcate (calcite-cpx-grt-zoi-titanite (tit)-qtz) were found. Two samples (bt-grt-ms-pl-cd-qtz) from the Sierra de Quilmes yield T of ~ 700-800°C at 5 kbar for core compositions of the minerals with biotite I and ~ 470°C at 3 kbar for rim compositions with a secondarily formed biotite II that only occurs in contact with garnet (PT from multi-equilibria). The breakdown of muscovite is indicated by fibrous sillimanite in muscovite grains.

Locations of samples used for isotopic age determinations are labelled with numbers (Fig. 1). Sm- Nd mineral isochrons were determined at *Mejillones* (4): Amphibolite (hbl-pl-grt) 524±12 Ma, $Nd_i$=0.512332 ±13; *Sierra de Moreno (Qda. Choja)* (5): Calc-silicate (grt-zoi-cpx-tit) 512±18 Ma, $Nd_i$=0.511813±29; *Hombre Muerto (Argentina)* (9): Calc-silicate (grt-zoi-cpx-tit-wr) 508±3Ma, Ndi=0.511649±4; *Limon Verde* (8): amphibolite (hbl-zoi-grt-wr) 308±146, $Nd_i$=0.512349±179. The poorly defined Limon Verde age will be redone.

K-Ar ages on mineral separates were determined for the same locations and for additional samples from Belen-Tignamar, Caleta Loa and Sierra de Moreno. K-Ar ages on intrusions were made to evaluate the influence of Carboniferous to Permian intrusions on the isotope system of the metamorphic rocks. *Belen* (1) orthogneiss (hbl) 358±10Ma; *Tignamar* (2) orthogneiss (hbl) 389±11Ma; *Caleta Loa* (3) orthogneiss (bt) 170±3; *Mejillones* (4) amphibolite (hbl) 152±5Ma, gneiss (bt) 151±3Ma; *Sierra de Moreno* (5) amphibolite (hbl) 406±6Ma, migmatite (bt) 296±6Ma; (6) migmatite (hbl) 422±12Ma; (7) a sucession of samples from the contact with granite (bt) 300±8Ma, micaschist (bt) 284±6Ma, amphibolite (hbl) 327±9) Ma, amphibolite (hbl) 382±11Ma; *Limon Verde* (8) amphibolite (hbl) 235±6Ma; gneiss (bt) 234±5Ma; *Hombre Muerto* (9) migmatic gneiss (bt) 392±8Ma.