DEFORMATION AND AND GRANITOID EMPLACEMENT ALONG A MAJOR CRUSTAL LINEAMENT: THE CORDILLERA BLANCA, PERU.

MICHAEL. P. ATHERTON AND NICK PETFORD

Department of Earth Sciences, Universtiy of Liverpool, PO. Box 147, Liverpool, U.K.

Resumen

El Batolito de la Cordillera Blanca representa el ultimo evento plutonico en el ciclo Andino. Este pluton fue emplazado a lo largo de un mega-lineamiento durante un periodo de extension, ocurrido hace 5.2 Ma.

El margen occidental ha sido deformado por transpression durante el event tectonico regionale Quechua 3, probablemente relacionado con un alto grado de convergencia de la Placa de Nazca.

Introduction

The Cordillera Blanca Batholith of NW Peru (Fig. 1) together with contemporaneous ignimbrites of the Yungay formation are the youngest magmatic events of the Andean cycle in Peru. They overly the thick crustal keel of the Andes. The Batholith strikes NNW-SSE, and is 200 Km long, reaching nearly 7000 m in height near Yungay. The western margin abuts against a major fault system which extends southwards for a distance of nearly 400 km (Fig. 2.). To the west of this fault the contemporaneous ignimbrites lie within the 15 km wide Callejon de Huaylas intercordilleran basin, a subsiding graben of at least Pliocene age. K/Ar dates of 7.6 - 6.2 Ma indicate the graben was already in existence by that time.

K/Ar ages of the Batholith vary from 13.5 to 2.7 Ma indicating magmatism has occurred along this lineament over a long period of time. The Batholith and ignimbrites are clearly related to this major crustal fault system, which is still active, and now shows a normal movement sense, which towards the south has an en-echelon (N 140 E) left hand pattern (Sebrier *et.al*, 1988). However, slip vectors indicate a sinistral strike slip component, producing not orthogonal extension but nearly N-S extension as shown by the recent kinematics of the fault zone. This extension postdates the Pliocene compressional period.The Cordillera Blanca and its southerly extension (Fig. 2.) lie above a high conductivity zone (0.1 SM^{-1}) which parallels the general Andean trend and lies 50 km or less from the surface (Wilson, 1985) . It is best explained by the presence of a small melt fraction (0.05) in highly conducting rock. This may correlate with two low velocity zones found by Ocola & Meyer, (1972) at 10 and 35 Km, also explained in the same manner. Geothermal springs along the line of the fault and a measuredhigh geothermal gradient of 40-60 ^{o}C /km (Uyeda & Watanabe, 1970) confirm high heat flow along this megastructure, and therefore hot material at a high level in the crust

^{40}Ar-^{39}Ar Step heating ages

A detailed ^{40}Ar-^{39}Ar study confirm a late Miocene (5.20 Ma) age for the central region of the Batholith, and shows that the Batholith youngs in a westerly direction away from the undeformed core towards the intensely deformed western margin. This 'younging', as revealed by K/Ar dating may be explained in terms of argon loss due to deformation and recrystallisation as deformation increases towards the fault. The timing of deformation is consistent with Quechua 3, the last major compressional event in northern Peru.

Intrusion style, deformation and tectonoic environment.

The late assymmetrical deformation (Fig. 3.) seen within the Batholith is very different to that seen in ballooning diapirs with symmetrical shear strains, and indicates the strong fault control on emplacement. Kinematic indicators imply the Cordillera Blanca fault system has suffered sinistral strike slip motion during the upper Tertiary. The structural data summarised in Fig. 3. emphasise the deformation occurred after the emplacement. The ductile/plastic to brittle deformation style seen in the batholith is consistent with rapid hanging wall uplift of 1.4 mm/yr.

Emplacement of the Batholith

It is considered that the source region was tapped at depth by the deeply penetrating crustal lineament whose surface expression is the Cordillera Blanca fault system. Melting was induced by decompression followed by fracture controlled ascent of the liquid to high structural levels, then emplacement within the Jurassic (Chicama) basinal rocks. Post emplacement fault movements, superimposed upon earlier magmatic fabrics deformed the wastern margin and are essentially compressional in form. Quaternary and recent faulting at the western margin of the Batholith near the graben structure indicates a N-S stretching reaching 8% (Bonnot, 1984)

Extension and compression in the high Andes of Northern Peru

Analysis of the sedimentary, volcanic and structural data indicate there were 6 discrete compressional periods from the upper Eocene to the present, of which Quechua 1 (20 - 12.5 Ma), Quechua 2 (9.5 - 8.5), Quechua 3 (6 Ma) and a Quaternary phase at ca 2.0 Ma are relevant (Megard, 1984). They have been related to periods of high convergence rate. Basins forming between these periods were extensional. Magmatism can be both extensional and compressional, although we think the compressional periods were late in the intrusion sequences, as noted above for the Cordillera Blanca Batholith. The presence of undeformed granite to the east of the fault with an increasing apparent age as shown by the K/Ar data, together with the Tertiary and neotectonic and argon data, suggests sequential intrusion in a strike-slip environment. This was probably transtensional, with later intrusion occurring towards the fault zone as the movements became transpressional. This may suggest a half-flower type structure for the Batholith, with successive intrusion during the transtensional periods.

Conclusions

In general, the prevailing regime during the Miocene, Pliocene and Pliestocene appears to have been extensional with short lived compressional events perhaps induced by convergence. The Batholith was intruded during extensional periods. Strike-slip movements during the intrusion interval of the Batholith (13 - 3 Ma) correlates with the predicted strike-slip movements from Nazca plate reconstructions indicated for the Andean margin by Snyder (1987).

References

BONNOT, D. (1984). Neotectonique et tectonique active de la Cordillera Blanca et du Callejon de Huaylas (Andes nord-peruviennes), thesis , University Paris-Sud, Orsay, 115p.

MEGARD, F. (1984). The Andean orogenic period and its major structures in central and northern Peru. *J. Geol. Soc. London.* **141,** 893-900.

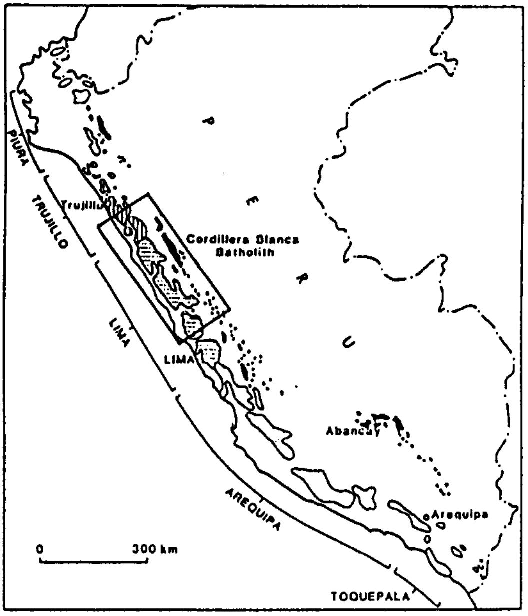
OCOLA , L.C. & MEYER, R.P. (1972) . Crustal low velocity zones under the Peru Bolivia altiplano. *Geophys. J. Astron. Soc.* **30,** 199-209.

SEBRIER, M., MERCIER, J.L., MACHARE, J., BONN0T, D., CABAREZ,J. & BLANC, J.L.. (1988). The state of stress in an overriding plate situated above a fault slab: the Andes of central Peru. *Tectonics.* **7,** 895-928.

SNYDER, D. (1987). New Nazca plate reconstructions and implications for intermontaine basin evolution in the Andes. In: Pacific Rim Congress 87. *Aust. Inst. Mining. Metal.* 923-926.

UYEDA, S & WATANABE, T. (1970) Preliminary report of terrestrial heat flow study in the South American Continent; distribution og geothermal gradients. *Tectonophysics.* **10,** 235-242.

WILSON, C.D.V. (1985). The deeper structure of the Central Andes and some geophysical constraints. In Magmatism at a Plate Edge. (eds) Pitcher, W.S., Atherton, M.P., Cobbing, E.J. & Beckensale, R.D. Blackie Halstead Press, 13-18.



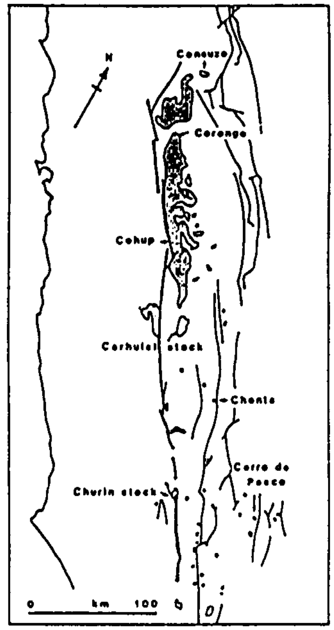


Fig. 1. Geological sketch map of the Andean Batholiths of Peru.

Fig. 2. Enlargement of boxed area in Fig. 1. showing the relationship between the Cordillera Blanca fault system, Batholith and associated stocks.

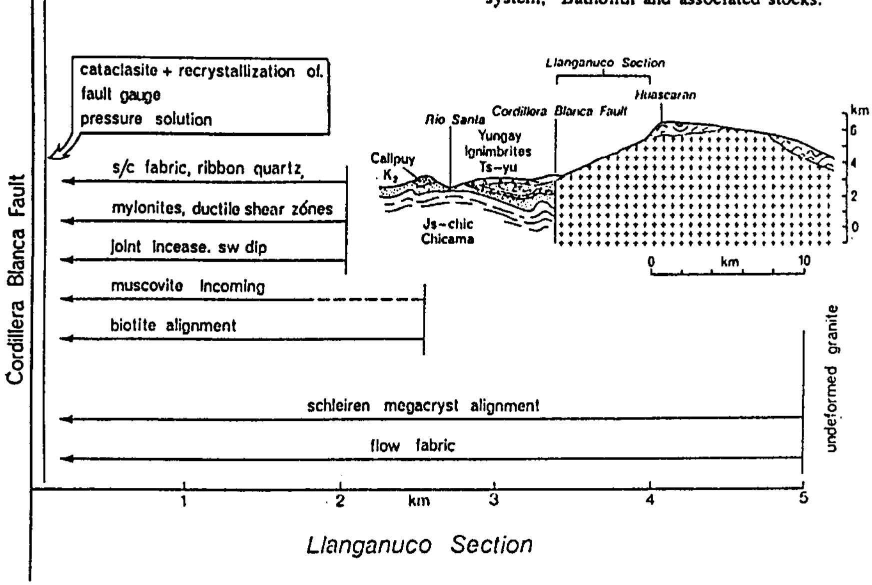


Fig. 3. Synoptic diagram showing the variation in deformation style in the granite towards the fault system.