MIOCENE PLUTONISM IN N. PERU: IMPLICATIONS FOR ALONG-STRIKE VARIATIONS IN ANDEAN MAGMATISM (9-22°S).

N. PETFORD(1), M. P. ATHERTON(1), A. N. HALLIDAY(2)

(1) Department of Earth Sciences, University of Liverpool, Liverpool L69 3BX, UK.
(2) Department of Geological Sciences, University of Michigan, Ann Arbor, USA.

RESUMEN: Combined strontium and neodymium isotope data on the Mio-Pliocene Cordillera Blanca batholith (9-11° S) are compared with acid plutonic and volcanic rocks of similar age and composition from the central Andes (16-20° S). The Cordillera Blanca magmas show no evidence of contamination by, or remobilisation of, mature continental basement, contrasting strongly with central Andean volcanics where elevated $Sr_{(i)}$ and negative εNd reflect significant reworking of old continental crust. These contrasting along strike variations relate to horizontal shortening in the central Andes and magmatic underplating in the north.

KEY WORDS: Peru, Cordillera Blanca batholith, Crustal thickening, magmatic underplating.

INTRODUCTION

Unlike the Himalayas, where crustal thickening is the result of continent-continent collision, the mechanism of crustal thickening beneath the central Andes (up to x2 normal thickness) is still a matter of debate, with current opinion divided between tectonic shortening and magmatic underplating. Significantly, the thickness of the continental crust varies along strike of the chain, and is widely believed to correlate with the observed longitudinal variations in the isotopic compositions of Andean magmas (Harmon & Hoefs, 1984).

The Late Miocene-Pliocene Cordillera Blanca batholith and associated acid volcanics are the youngest magmatic rocks in NW Peru, and represent the final stage in the Andean cycle (200-0 Ma) in this region. The batholith lies directly above the thickened continental root of the Andes which in this sector reaches depths of ~ 60 km (James, 1971; Kono et al., 1988). Thus, the batholith magmas were intruded through crust of similar thickness to the Altiplano (CVZ) region further south, where Miocene basic-intermediate rocks with 'enriched' isotopic compositions are believed to result from large scale crustal contamination of mantle-derived magmas (James, 1982; Hawkesworth et al., 1982; Hildreth and Moorbath, 1988). Given the intrusion into similar thickness of continental crust, the Cordillera Blanca batholith may therefore be expected to show evidence for substantial continental crustal involvement in its petrogenesis.

GEOLOGICAL SETTING

The Cordillera Blanca batholith and associated volcanics are situated in the high western Cordillera of Peru between 9 and 11° S where they form a mountain range with an average elevation of over 4000m. The batholith is a linear body over 120 km in length, lying parallel with the main Andean trend in Peru, and is composed mostly of high silica (70-73 wt%) leucogranodiorite, with a subordinate marginal facies of quartz diorite and tonalite. It intrudes a basinal sequence of Jurassic shales, with both magma ascent and emplacement strongly controlled by periods of extension along the NNW/SSE trending Cordillera Blanca fault system. Radiometric dates from the Batholith range from ca. 13.7 to 2.7 Ma, with combined Pb and Ar-Ar ages from the central region of the intrusion giving an emplacement age here of about 6.0 Ma (see Petford & Atherton, 1992).

ISOTOPIC COMPOSITION OF BATHOLITH ROCKS

Sr and Nd isotopic determinations were carried out on fourteen rocks collected along strike of the intrusion. The isotopic compositions of both Nd and Sr show remarkably little scatter, with average εNd values close to bulk earth (-0.7), while $Sr_{(i)}$ varies between 0.7047 and 0.7057 over a range in SiO_2 of 18 wt % and a distance of ca. 60 km. Given the tectonic position of the batholith above thickened continental crust, the isotopic compositions of these rocks are surprisingly primitive, plotting at or close to bulk earth. Taking the batholith data as a whole, the range in isotopic composition of Nd is just over two epsilon neodymium units. Within the marginal facies, the variation is remarkably small, with εNd varying from +0.16 to a maximum of -0.21 over a silica range of 14 wt%. A basaltic andesite dyke that intrudes the Batholith has an εNd value of +3.5, falling broadly within the compositional range of island arc volcanics.

COMPARISON WITH TERTIARY CENTRAL ANDEAN (16-20°S) MAGMAS.

Isotopically, the batholith rocks contrast strongly with Tertiary-Recent rocks that characterise the Altiplano region of southern Peru and northern Chile (ca. 16-20°S). For example, the high silica ($SiO2 > 70\%$) batholith leucogranodiorites have much lower εNd values - ie. they are much more *primitive* - than the majority of *basic* volcanics from the Altiplano region, where eNd values are generally > -4.0 (Rogers & Hawkesworth, 1989; de Silva , 1991). Similarly, the variation in initial Sr ratios for the batholith rocks from 0.7048 to 0.7054 contrasts with Tertiary volcanic and intrusive rocks from the central Andes, where $Sr_{(i)}$ is generally in excess of 0.706 (eg. Hawkesworth et al., 1982).

Figure 2 shows the range in εNd values for the Cordillera Blanca batholith and associated Upper Miocene acid plutonic stocks of central northern Peru, along with acid volcanics of similar age from the central Andes (16-20° S). The most negative εNd values belong to the volcanics extruded through the very thick crust (70 km) beneath the central Andes. εNd of rocks of the Cordillera Blanca batholith and associated Miocene stocks are much more primitive than those further south, in spite of the crust having a similar thickness. Thus, εNd varies from +4 in the batholith to -12 in the central Andean volcanics although the change in crustal thickness is less than 20% between the two sectors.

Increasing $^{87}Sr/^{86}Sr$ ratios in rocks from the central Andes inboard with time (Rogers and Hawkesworth, 1989), combined with a marked increase in Nd model ages with decreasing emplacement age of granitic intrusions over the past 30 Ma have been interpreted as the result of extensive Tertiary crustal reworking (Miller and Harris, 1988). This reworking coincides with extensive crustal thickening and uplift at 12-10 Ma, with crustal thickening thought to be due to tectonic shortening (Isacks, 1988). Intracrustal melting of this tectonically thickened crust has been proposed to explain the elevated $Sr_{(i)}$ and εNd values seen in central Andean acid volcanics (de Silva, 1991).

TECTONIC IMPLICATIONS

Our favoured explanation for the large variation in isotopic composition of magmas intruded and extruded through crust of abnormal thickness along strike above the thickened keel of the Andes is that different source lithologies were melted. Although Miocene crustal thickening and uplift apparently occurred simultaneously in the northern and central Andes (Kono et al., 1988), Sr, Nd (and Pb) isotopic data from the Miocene stocks and Cordillera Blanca batholith show no evidence for melting of old crustal basement, or significant crustal contamination. Recent work (Atherton & Petford, 1993) has shown the Cordillera Blanca batholith rocks to be similar in composition to Na-rich Precambrian trondhjemite-tonalite-dacite (TTD) suites and that they were produced by partial melting of newly underplated basic crust. Sr and Nd isotopic compositions of the Cordillera Blanca rocks support this model, where rapid recycling of *new*, mantle-derived lower crust results in melt compositions that are virtually indistinguishable isotopically from mantle.

Such magmas contrast markedly with melts produced from melting *old* (Precambrian) basement or tectonically thickened continental crust in the manner proposed for the central Andes at 16-20° S. Clearly, isotopic values in magmatic rocks of the Andes depend on the source which, we maintain, was *new crust* in the north and old continental crust in the south. Over thickened crust does not automatically correlate with contamination of mantle-derived magmas.

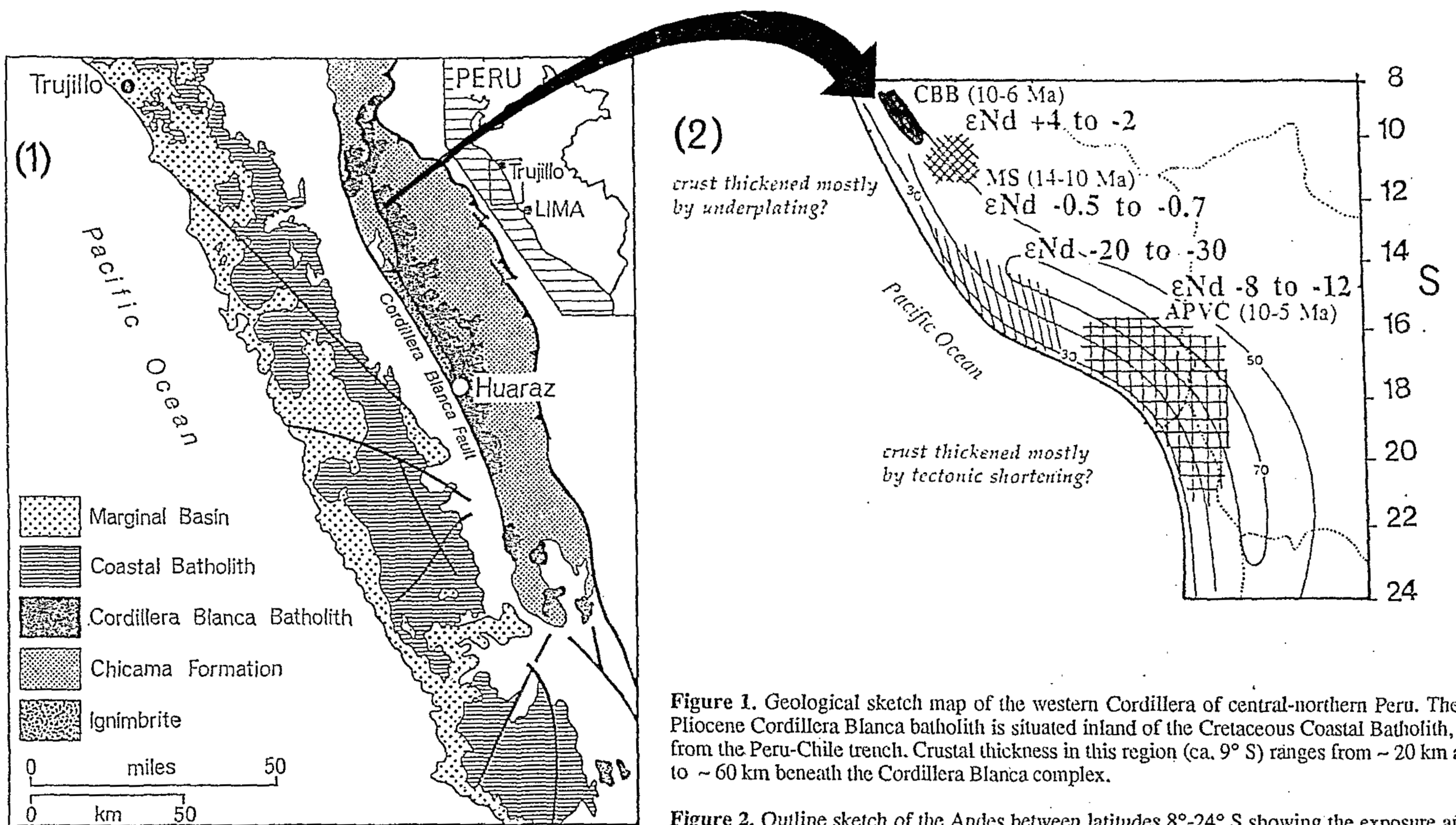

Figure 1. Geological sketch map of the western Cordillera of central-northern Peru. The Miocene-Pliocene Cordillera Blanca batholith is situated inland of the Cretaceous Coastal Batholith, ca 200 km from the Peru-Chile trench. Crustal thickness in this region (ca. 9° S) ranges from ~ 20 km at the coast to ~ 60 km beneath the Cordillera Blanca complex.

Figure 2. Outline sketch of the Andes between latitudes 8°-24° S showing the exposure and range in εNd for selected Upper Miocene plutonic and acid volcanics (ages in brackets). CBB (Cordillera Blanca batholith), MS (Miocene stocks; Soler & Rotach-Toulhoat, 1989), and the Altiplano-Puna volcanic zone (APVC) of the central Andes; de Silva, 1991). The aerial extent of exposed Precambrian basement in southern Peru (hatched) is also shown. Contours show depth to the Moho (James, 1971).

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