U-Pb DATING WITH SUB-MILLION YEAR PRECISION OF EARLY ANDEAN PLUTONIC ROCKS IN THE COASTAL CORDILLERA OF CHAÑARAL, NORTHERN CHILE

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INTRODUCTION

The central Andes represents a continental boundary complex characterised by subduction of oceanic crust beneath the western margin of the South American continent. Subduction has been active and continuous since the Jurassic, i.e. since the Pangea-Godwana breakup (Mpodozis and Ramos, 1990). The associated deformation, magmatism and metamorphism define what is called the Andean orogeny (Mpodozis and Ramos, 1990) or Andean Cycle (Coira et al., 1982). The tectonic conditions along the margin during the Jurassic and early Cretaceous (early stages of the Andean Cycle) were characterised by an extensional regime with the consequent development of an arc–back arc pair (Mpodozis and Ramos, 1990). The Jurassic-Cretaceous magmatic complexes in northern Chile developed above a basement that consists of a penetratively deformed, Palaeozoic, low-grade metasedimentary sequence associated with a fore arc basin and plutonic (S and I type) and volcanic units of Permo-Triassic age (Berg and Baumann, 1985; Dallmeyer et al., 1996). The Jurassic-Cretaceous plutonic complexes range from calc-alkaline hornblende-biotite gabbros, through diorites, tonalites and granodiorites with subsidiary granites that were emplaced in the upper crust (Dallmeyer et al., 1996).

The present research presents preliminary results of U-Pb zircon geochronology on nine Jurassic and Cretaceous plutonic rocks in the Coastal Range of

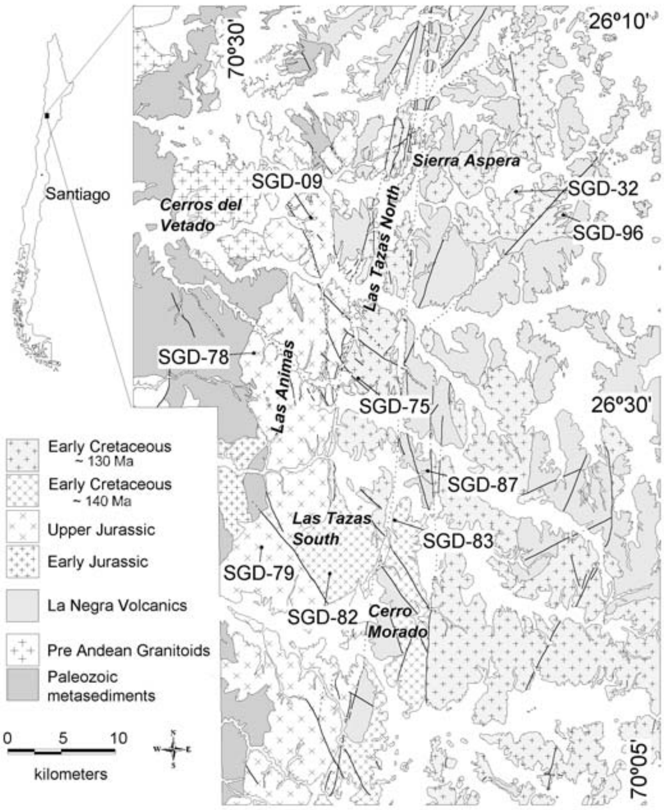

Fig.1 Geological Map of the Coastal Cordillera in the Chañaral area; based on Godoy and Lara (1998) and Lara and Godoy(1998). The main plutons and U-Pb sample locations are shown.

Chañaral (Fig. 1). The new data are compared with published data allowing a discussion of magmatic evolution in the early Andean stages.

GEOLOGICAL CONTEXT

Detailed regional geological maps (scale 1:100.000) have recently been published by the Geological Survey of Chile covering the area of interest (Godoy and Lara, 1998; Lara and Godoy, 1998). The geology of the area has also been examined by Berg and Baumann (1985); Brown et al (1993) and Dallmeyer et al., (1996). The oldest rocks are grouped into the Paleozoic Chañaral metamorphic complex and consist of marine sequences with turbiditic facies of quartzites and slates. The metamorphosed sequences are intruded by S-type Permo-Triassic plutons (e.g Cerros del Vetado pluton).

The first record of "Andean" magmatic activity in the area is represented by the basal levels of the La Negra volcanic formation, which is composed of andesites and basaltic andesites with a few intercalations of conglomerate and calcareous sandstone (Godoy and Lara, 1998). In the Antofagsta region andesitic lavas have given a Rb-Sr age of 186 ± 14 Ma (Rogers and Hawkesworth, 1989), which we interpret as a minimum age.

Plutons or plutonic complexes in the area usually present elongate shapes, sometimes bordered by mylonite zones such as the trench parallel Atacama Fault system (Brown et al., 1993). Previous geochronologic data show that plutonic activity has four main peaks in the study area (Early Jurassic, ~190-180 Ma; Late Jurassic ~160 Ma; ~140 Ma and ~130 Ma). Each distinct episode of magmatism was located successively eastward, inboard from the subduction zone.

METHODS

U-Pb analyses were carried out at the Royal Ontario Museum using methods described in Krogh (1973, 1982) except that dissolution capsules and columns were scaled down to reduce blank. All errors are given at 2 sigma levels. Current Pb blank levels of less than 1 picogram permit precise analyses of fractions consisting of one or several grains. Only grains that showed no evidence of cores, cracks or alteration were selected for laboratory abrasion and analysis. Precise ages on Mesozoic zircon must rely on the $^{206}Pb/^{238}U$ decay system. Corrections for ^{230}Th disequilibrium are no more than 0.1 Ma but these ages can be biased by secondary Pb loss as well as inheritance from Phanerozoic sources while still preserving concordancy. Reproducibility of concordant data is the best argument that sources of bias have been avoided.

RESULTS AND DISCUSSION

Most of the data are concordant and $^{206}Pb/^{238}U$ ages from individual samples agree within analytical error for six of the nine samples (Fig 2). Only one sample, SGD-83, contained evidence for much older inheritance in the form of an imprecise discordant datum (off scale on Fig 2), which gives an upper concordia intercept of about 1100 Ma when regressed with the concordant data.

Zircons from disturbed samples show a large range in U concentrations, which seem to be correlated with age. The youngest datum from SGD-09 (155.2 ± 0.6 Ma) shows a U concentration of 200 ppm versus 20-40 ppm for the two older data, which agree in age at 156.4 ± 0.3 Ma. Th/U ratios are uniform and unusually high for

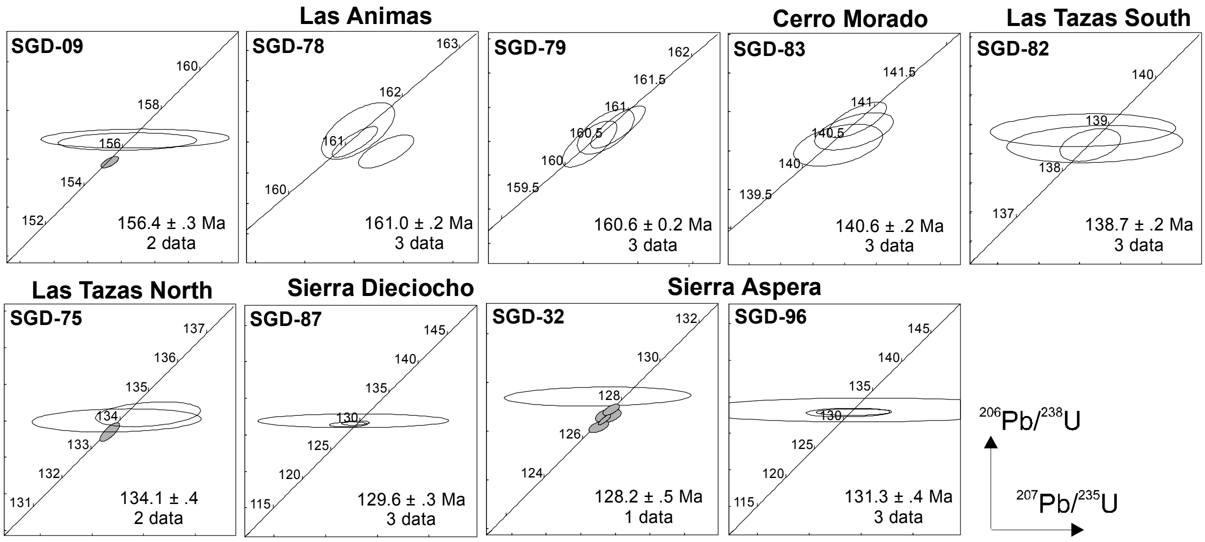

Fig. 2 Concordia diagrams for the 9 new U-Pb zircon dates; samples locations given in Fig. 1. Ages are calculated using $^{206}Pb/^{238}U$ on the unfilled error ellipses (see text for discussion).

zircon, which suggests that none the grains are inherited. The fact that the higher uranium fraction shows a younger age suggests that it may have suffered minor secondary Pb loss (<1%) and that the age of the two low U fractions is closer to the time of crystallization. Similarly with SGD-32, an exceptionally low U fraction (14 ppm vs 100-300 ppm) gives the oldest $^{206}Pb/^{238}U$ age of 128.2 ± 0.5 Ma, which is most likely to represent primary crystallization. Data from the other fractions range in age down to 126.6 ± 0.3 Ma. The two oldest data from SGD-75, which agree at 134.1± 0.3 Ma, are more likely to give the primary age than a slightly younger, higher U datum (16 ppm versus 140 ppm). Further work will be required to confirm the accuracy of these ages.

The new ages can be assigned to three of the main plutonic peaks: Upper Jurassic, Jurassic-Cretaceous and Early Cretaceous. Late Jurassic samples are from the Las Animas complex, quartz diorites to granodiorites that intrude Palaeozoic metamorphic rocks and the lavas of the La Negra formation. Its eastern border is sharp and defines one of the main lineaments of the Atacama Fault Zone. Three ages range from 156.4 ± 0.3 to 161.0 ± 0.2 (SGD-09, SGD-78 and SGD-79; Figs. 1 and 2) with the youngest pluton appearing in the north.

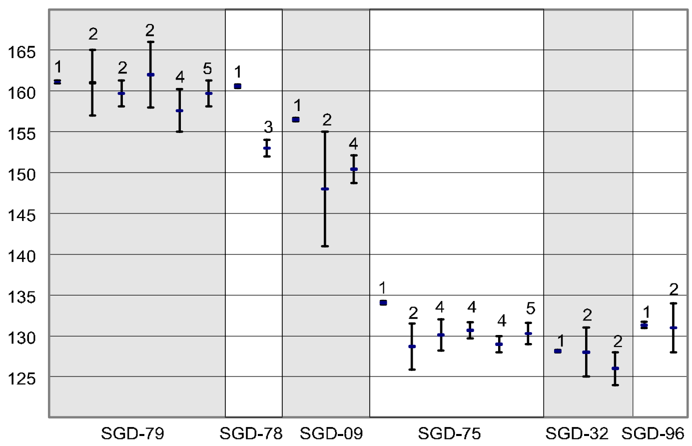

Fig. 3 Comparison of new U-Pb zircon ages with pre-existing geochronology, including errors. Numbers identify radiometric methods; 1: U-Pb zircon age, this work; 2: K-Ar; 3: Ar-Ar; 4: Rb-Sr; 5: previous U-Pb. References in Godoy and Lara (1998) and Lara and Godoy (1998).

A monzodiorite from the Cerro Morado pluton (SGD-83) has been dated at 140.6 ± 0.2, indicating a slightly older age for the pluton than the one suggest by Lara and Godoy (1998). A granodiorite (SGD-82) from the southern pluton of the Las Tazas complex is 138.7 ± 0.2 Ma old.

The Early Cretaceous northern Las Tazas complex appears to be distinctly younger than the southern segment, according to the 134.1 ± 0.3 Ma age obtained from a quartz diorite (SGD-75). A quartz monzodiorite of the Sierra Dieciocho pluton, partially mineralised with iron oxide stockwork in the area of the Manto Verde iron mine, gives an age of 129.6 ± 0.3 (SGD-87). A preliminary age of 128.2 ± 0.5 Ma was obtained from the interior of the Sierra Aspera pluton (SGD-32) while a sample from the pluton margin (SGD-96) proved to be 3 m.y. older (131.3 ± 0.4 Ma). Both results are comparable to previous less precise ages (Fig. 3) but are clearly resolved, indicating that the compositional zonation in Sierra Aspera (interior granodiorite grading to exterior quartz diorite) was established over at least several million years and is unlikely to have resulted from crystallization of a single magma.

Geobarometry studies in some of the plutons indicate an epizonal emplacement (Dallmeyer et al., 1996) suggestive of later rapid cooling processes. This is corroborated in some areas by the similarity in ages obtained using isotopic systems and minerals with different closure temperatures (Fig. 3; SGD-79, SGD-32 and SGD-96). Despite this general agreement differences are evident when comparing some previous ages with the new U-Pb data for closely located samples of the same plutonic units (Fig. 3; SGD-78, SGD-09 and SGD-75). Berg and Baumann (1985) noted such discrepancies and inferred that major thermal events perturbed the Rb-Sr system. In these cases, less robust systems in terms of closure temperature have probably suffered some degree of resetting due to post-crystallization thermal effects related to emplacement of adjacent plutons, shearing and /or widespread dyke intrusions.

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