

ORDOVICIAN METAMORPHISM IN THE SIERRAS PAMPEANAS: NEW U-Pb SHRIMP AGES IN CENTRAL-EAST VALLE FÉRTIL AND THE VELASCO BATHOLITH.

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INTRODUCTION

Magmatic activity, during which extensive I- and S-type granitoids were emplaced in the Famatinian belt and synchronous, though sparse, TTG plutons in the Pampean belt, preceded the accretion of the Precordillera terrane (PT) to the proto-Pacific margin of South America (Fig. 1a). These three types of granitoid were mainly emplaced in Early Ordovician times (470–490 Ma, Pankhurst et al., 2001). However, little is known about the timing and characteristics of regional metamorphism during the Famatinian orogeny. A key transect in this study is at 30° 30′–31° 40′S, where Grenvillian basement units of the PT are separated by the Bermejo valley from high-grade rocks of the Sierra de Valle Fértil. Geochronological studies have been carried out in the Sierra de Pie de Palo (PT), on the western side of the transect, by Ramos et al. (1998) and Casquet et al. (2001). We are now able to characterise metamorphism on the eastern side of the transect, i.e. the Gondwana margin. To this end we are presenting new U-Pb SHRIMP geochronological studies of western Sierra de Valle Fértil (Baldo et al., 2001), and central-eastern Sierra de Valle Fértil and Sierra de Velasco (this paper).

The geology of the central and eastern sectors of the Sierra de Valle Fértil is dominated by a metaluminous sequence of hornblende-biotite tonalites/granodiorites, and suites of troctolitic, noritic and hornblende gabbros emplaced in high-grade metapelites, marbles and amphibolites (Fig. 1b). The locations of the three samples selected for the isotopic study are shown in Fig. 1. SVF-3131 is a garnet migmatite composed of Grt + Bt + Pl + Qtz, with Zrn, Mnz, Ap as accessories (mineral symbols after Kretz, 1983). SVF-573 is a cordierite-garnet diatexitic migmatite: Crd (#Mg 77-79) + Grt (Alm 57-69, Py 27-32) + Bt (TiO₂ = 3.2-4.5%) + Sil + Pl (An33-35) + Kfs + Qtz; accessories are Spl (included in Grt, ZnO = 9-11%), Zrn, Mag, Ilm, Mnz. The widespread occurrence of Crd and Spl in the high-grade rocks indicates that anatexis in central-east Valle Fértil took place at considerably lower pressures than in the southwestern side of the Sierra, where Ky is stable and ubiquitous in the high-grade rocks (12 Kbar, Baldo et al., 2001). Finally, VEL-3000 is a cordierite granite from Sierra de Velasco (see chemical analysis in Pankhurst et al., 2001, Table 1): Qtz + Kfs + Bt + Crd + Sill + Pl, with a blastomylonitic fabric.

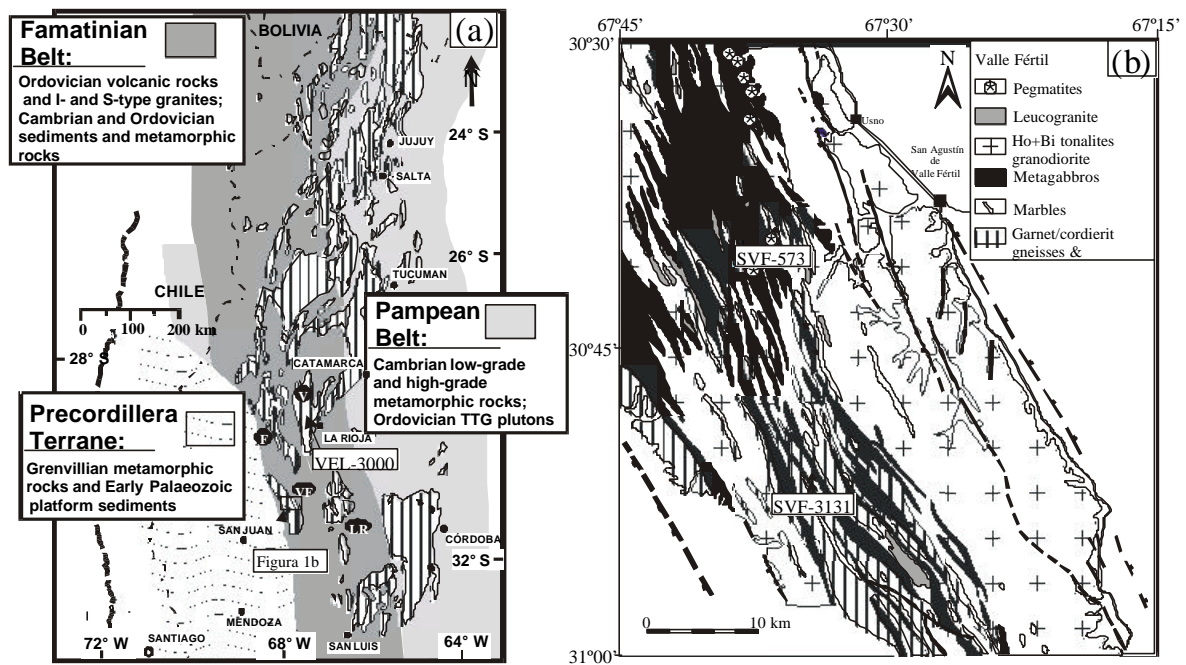


Figure 1. (a) Generalized pre-Devonian geological map of the proto-Andean margin of South America (22-34°S). VF = Sierra de Valle Fértil; V = Sierra de Velasco; F = Sierra de Famatina; LR = southern La Rioja (including Los Llanos, Chepes and Ulapes). (b) Modified geological map of the Sierra de Valle Fértil after Mirrè (1976) showing location of the analysed samples.

RESULTS

U-Pb dating was carried out using a sensitive high-resolution ion microprobe (SHRIMP II) at the Australian National University, Canberra. All data were processed using Isoplot/Ex (Ludwig, 1999). Cathodoluminescence (CL) images of zircons from the three analysed samples show that they consist of cores rimmed by well-developed overgrowths that we interpret as representing new zircon growth during metamorphism (Fig. 2). In all cases the cores show oscillatory zoning characteristic of igneous crystallization. However, the cores in the migmatite

samples are commonly fragments or sub-rounded grains (Fig. 2), indicating a dominantly detrital origin. In SVF-573 and VEL-3000 the overgrowths are homogeneous with low-U high reflectance, while in SVF-3131 they are sector-zoned, typical of those formed at higher temperatures. SHRIMP spot analyses of rims and cores allow independent estimation of the ages of the inherited cores and the metamorphic overgrowths. Results obtained from the migmatites SVF-3131 and SVF-573 are shown in Tera-Wasserburg diagrams (Fig. 3). Fourteen rims from SVF-3131 and six rims from SVF-573 define very similar ages of 465.9 ± 4.4 and 466.5 ± 7.7 Ma,

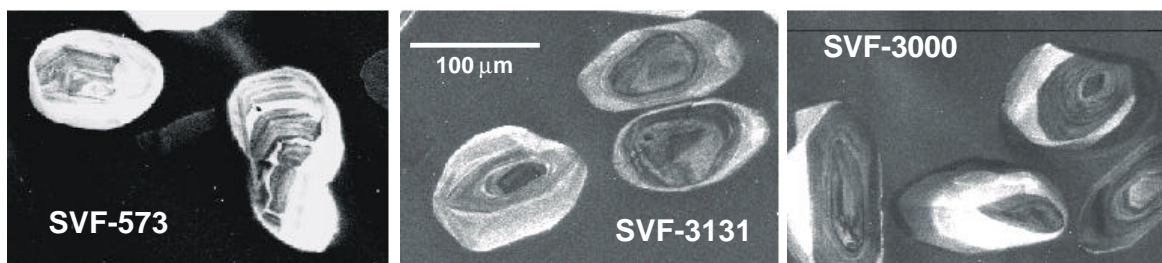


Figure 2. Cathodo-luminescence images of analysed zircons from Valle Fértil migmatites (SVF-3131, SVF-573) and Velasco granite (VEL-3000). All show metamorphic zircon overgrowths on original zoned igneous zircon.

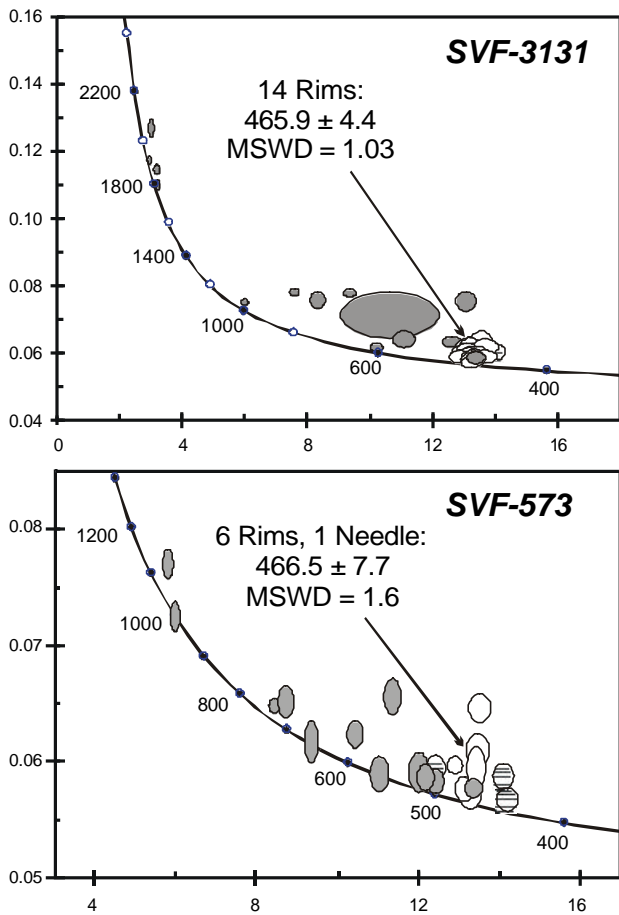


Figure 3. Tera-Wasserburg diagrams for SHRIMP analyses of migmatites from Sierra del Valle Fértil. Error ellipses at 68% confidence level: shaded ones are grain cores, white ones are new zircon overgrowths (cross-hatched ellipses discounted from mean).

respectively (Fig. 3). Inherited ages obtained from the zircon cores of the migmatites range from 500 to 2000 Ma, indicating that the sedimentary parent rocks were derived from Proterozoic to Cambrian sources. Twenty-nine zoned tips and cores from the cordierite granite VEL-3000 in the Sierra de Velasco produced a precise age of 481.4 ± 2.4 Ma, interpreted as the crystallization age of the cordierite granite (Fig. 4). Distinct low-U overgrowths observed in the CL images (Fig. 2) produced an age distribution centred at 469.0 ± 3.9 Ma (Fig. 4).

DISCUSSION

The 460–473 Ma age interval, estimated at the extreme range of the analytical errors for the zircon overgrowths in the analysed samples, corresponds to Upper Arenig–Llandeilo in the time scale of Gradstein

& Ogg (1976). For the migmatites SVF-3131 and SVF-573 from Sierra de Valle Fértil, the new metamorphic zircon was formed during a thermal peak that reached anatectic conditions in both cases. Inherited age patterns in the zircon cores of the migmatites are typical of those found in Cambrian phyllites and S-type granites of the Pampean and Famatinian mobile belts (Pankhurst et al., 2001).

The overgrowths in the granite VEL-3000 from Sierra de Velasco suggest that a 469.0 ± 3.9 Ma (Early Llanvirn) a high-temperature ductile event locally affected the cordierite granite, which crystallized previously at 481.4 ± 2.4 Ma (Early Arenig). This is the first isotopic evidence indicating that a mid-Ordovician metamorphic overprint affected a major unit of the Famatinian granites. This evidence is consistent with recently reported U-Pb SHRIMP ages of I-type leucogranites in the Sierras de La Rioja indicating that previous mid-to-late Ordovician Rb-Sr whole-rock isochrons obtained on these rocks (Pankhurst et al., 1998) are disturbed or reset ages produced by post-emplacement events (Pankhurst et al., 2001). Remarkably, the U-Pb SHRIMP ages

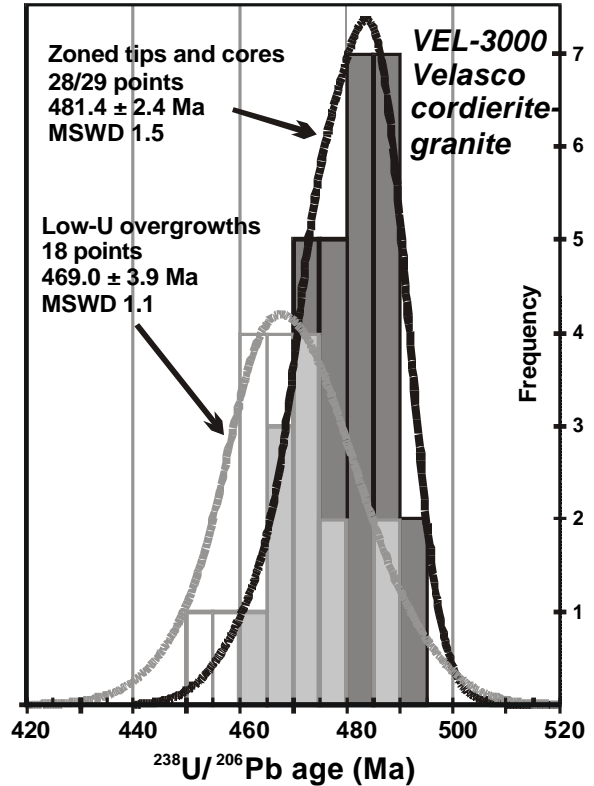


Figure 4. Histograms and relative probability distribution curves for SHRIMP spot ages from zoned zircon and low-U overgrowths from Velasco granite sample VEL-3000.

obtained in metamorphic zircon overgrowths in Grenvillian rocks of the Sierra de Pie de Palo (c. 460 Ma, Casquet et al., 2001) and high-pressure migmatites in south-western Valle Fértil (463.3 ± 3.5 Ma, Baldo et al., 2001) are also in the same age interval. Metamorphic ages appear to decrease to the west, from the Velasco (469 Ma), central-eastern Valle Fértil (466 Ma), southwestern Valle Fértil (463 Ma) and Pie de Palo (460 Ma), but as analytical errors overlap in most cases, further detailed isotopic studies are needed to confirm this observation. This extensive thermal metamorphism took place after the main intrusive period of the Famatinian granites (470-490 Ma, Pankhurst et al., 2001) and closure of the Tremadoc-Arenig Famatina back-arc basin, where an increasingly shallow marine environment culminated later than the middle Arenig (Astini, 1998). Finally, not necessarily all metamorphic ages relate to the same geological process. In the Sierra de Pie de Palo the age of zircon overgrowths has been interpreted as dating ductile thrusting coincident with early uplift Casquet et al. (2001), while in the high to middle pressure migmatites of the Sierra de Valle Fértil they correspond to the metamorphic peak (Baldo et al., 2001; this paper). The estimated metamorphic age range is probably associated with accretion of the PT to Gondwana. This complex amalgamation might have involved, in turn, closure of the Famatina basin on the Gondwana margin, moderate crustal thickening in eastern Valle Fértil, and exhumation of the deep root of the magmatic arc in western Valle Fértil (Baldo et al., 2001) and eastern basement sectors of the exotic PT (Casquet et al., 2001).

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