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The evolution of a mid-crustal thermal aureole at Cerro Toro, Sierra de Famatina, NW Argentina

P.H. Alasino [a,b,*], C. Casquet [c], M.A. Larrovere [a,b], R.J. Pankhurst [d], C. Galindo [c], J.A. Dahlquist [e], E.G. Baldo [e], C.W. Rapela [f]

[a] Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja (CRILAR-CONICET), Entre Ríos y Mendoza s/n, Anillaco 5301, La Rioja, Argentina
[b] INGeReN-CENIIT-UNLaR, Av. Gob. Vernet y Apostol Felipe, 5300 La Rioja, Argentina
[c] Dpto. de Petrología y Geoquímica - IGEO (Universidad Complutense, CSIC), 28040 Madrid, Spain
[d] British Geological Survey, Keyworth, Nottingham NG12 5GG, United Kingdom
[e] CICTERRA-CONICET-UNC, Av. Vélez Sarsfield 1611, Pab. Geol., X5016CGA Córdoba, Argentina
[f] CIG-CONICET-UNLP, Calle 1 No. 644, 1900 La Plata, Argentina

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ABSTRACT

A more than 12 km wide sheeted tonalite complex in western Sierra de Famatina, NW Argentina, was emplaced at middle crust levels (ca. 5 kbar), coeval with regional metamorphism during an early phase of the Ordovician Famatinian orogeny (ca. 480 Ma). Advective heat from the tonalite complex caused a rise in the host regional temperatures (≤700 °C) by a maximum of ca. 100 °C, developing an aureole (~3 km wide) parallel to the igneous contact. This was accompanied by significant melting (ca. 40%) of the host rocks that hybridized to a variable extent with the tonalitic magmas. Three metamorphic zones were distinguished in a cross-section through the aureole: (1) an external zone consisting of metatexitic gneisses, amphibolites and minor tonalites, (2) an intermediate zone formed by screens of highly melted gneisses, amphibolites and metagabbros lying between tonalite and newly formed leucogranitoid and hybrid rock sheets, and (3) an internal zone formed almost exclusively of massive tonalite and minor hybrid rocks. Incongruent melting of biotite in gneisses of the intermediate zone produced peritectic cordierite and garnet. Hybrids resulting from variable mixing of anatectic granitoids and tonalite magma developed in the innermost part of the aureole at 750–800 °C. Increased water activity within this zone eventually promoted increased melting of plagioclase + quartz in the gneisses. Leucogranitoid magmas formed in part by extraction from the hybrid magmas led to heterogeneity of the Sr-isotope composition. The Cerro Toro contact aureole shows that assimilation of metasedimentary rocks through partial melting can play an important role during emplacement of tonalitic magmas at mid-crustal levels.

1. Introduction

Thermal aureoles induced by advection of magmas are an excellent natural laboratory for the study of the wall-rock magma interaction processes (e.g., Paterson and Farris, 2008; Paterson et al., 1991 and references therein). Classical examples of thermal aureoles occur when hot magmas intrude upper crustal levels, causing contact metamorphism due to the high thermal contrast between magma and wall-rock. These effects are rather well understood today after long research following the first recognition of contact metamorphism in the late 18th century by James Hutton (e.g., Kerrick, 1970; Pattison and Harte, 1985; Rastall, 1910, among many others). However, mid-crustal thermal aureoles show greater complexity, due to reduced thermal contrast between magma and the host rocks (which are often affected by pre- or syn-regional metamorphism). In contrast with epizonal contact metamorphism, slow cooling (e.g., Nabelek et al., 2012) permits processes such as assimilation, mingling, mixing and partial melting of the country rocks (e.g., Barnes et al., 2002; Finger and Clemens, 1995; Greenfield et al., 1996; Harris et al., 2003; Jung et al., 1999; Saito et al., 2007; Ugidos and Recio, 1993; Yardley and Barber, 1991). When assimilation occurs its chemical effects are often recognizable, but the physical processes that caused them are less obvious (e.g., Clarke, 2007; Erdmann et al., 2009).

A new example of a contact thermal aureole at mid-crustal level is described from Cerro Toro, in the western Sierra de Famatina (Sierras Pampeanas, NW Argentina, see Fig. 1a). Here, at paleodepths of ca. 17 km, voluminous metaluminous magmas formed a huge sheeted complex (ca. 12 km wide) in predominantly metasedimentary country rocks. A 3-km wide hybridization zone is well displayed along the contact, containing many screens and stoped blocks of host rocks. Although conceptual models of hybridization have recently been well established (e.g., Beard, 2008; Beard et al., 2005), many questions still remain open

* Corresponding author at: Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja (CRILAR-CONICET), Entre Ríos y Mendoza s/n, Anillaco 5301, La Rioja, Argentina.
E-mail address: palasino@crilar-conicet.gob.ar (P.H. Alasino).

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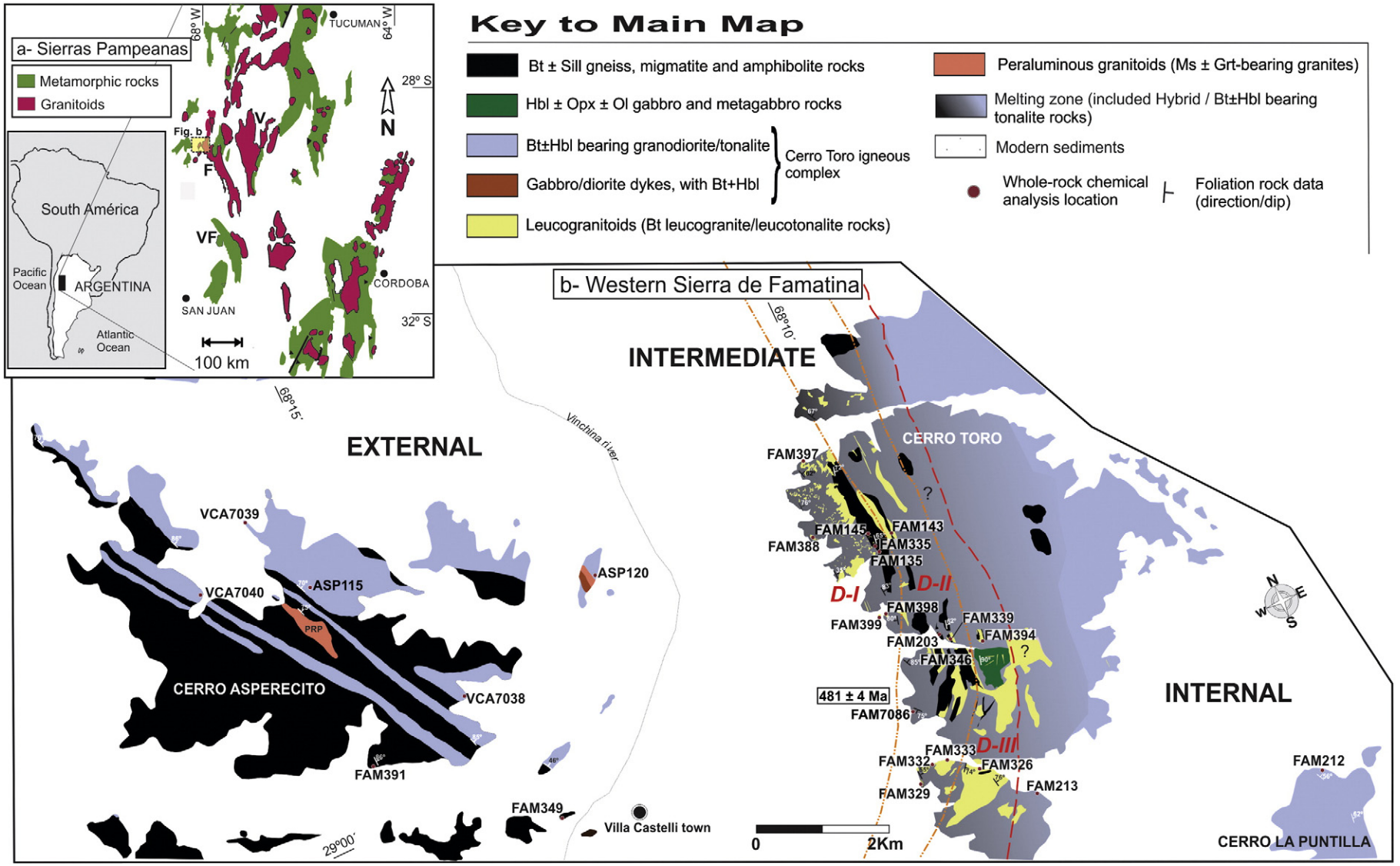

Fig. 1. Simplified geological maps of NW Argentina: (a) Sierras Pampeanas and (b) western Sierra de Famatina. Key for (a): F, Sierra de Famatina; V, Sierra de Velasco; SF, Sierra de Valle Fértil. In (b) from W to E the external, intermediate and internal zones. Limit between external and intermediate zones is not visible, as a reference to this take the Vinchina river. The intermediate and internal zones are limited by a red dashed line, this corresponds to main intrusive contact. In the intermediate zone, the domains I (D-I), II (D-II) and III (D-III) are based on the predominance of specific rock-types: D-I, Bt–Sill ± Crd migmatite blocks; D-II, Bt–Sill ± Grt ± Crd migmatite blocks; and D-III, Bt ± Amp ± Cpx ± Kfs hybrid rocks. PRP Peñón Rosado pluton. Sample FAM175 is outside the mapped area (see Supplementary data).