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Ordovician ferrosilicic magmas: Experimental evidence for ultrahigh temperatures affecting a metagreywacke source

A. Castro [a,*], A. García-Casco [b], C. Fernández [c], L.G. Corretgé [d], I. Moreno-Ventas [a], T. Gerya [e], I. Löw [e]

[a] Departamento de Geología, Universidad de Huelva, Campus del Carmen, 21071 Huelva, Spain
[b] Departamento de Mineralogía y Petrología, Instituto Andaluz de Ciencias de la Tierra, Universidad de Granada-CSIC, Avenida Fuentenueva sn, 18002 Granada, Spain
[c] Departamento de Geodinámica y Paleontología, Universidad de Huelva, Campus del Carmen, 21071 Huelva, Spain
[d] Departamento de Geología, Universidad de Oviedo, Arias de Velasco, s/n, Oviedo Spain
[e] Department of Earth Sciences, ETH Zurich, Clausiusstrasse 25, CH-8092, Zurich, Switzerland

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ABSTRACT

Peculiar magmatic rocks were erupted and emplaced at depth at the margin of the Gondwana supercontinent during the Cambro-Ordovician transition. These rocks are characterized by high contents in silica and iron but they do not have equivalents in the high-silica members of the calc-alkaline series. They have particular geochemical signatures, with Al saturation index, ASI >1, FeO>2.5 wt.%, MgO>0.8 wt.% for very low contents in calcium (CaO<2.0 wt.%), supporting a derivation from near-total melting (>80 vol.% melt) of metagreywackes. The results from inverse experiments indicate that the most plausible conditions are within the range 1000 °C (excess water) and 1100–1200 °C (subsaturated and dry) at pressures of 1.5 to 2.0 GPa. A tectonic scenario implying melting of subducted sediments within an ascending mantle-wedge plume is suggested for the generation of primary ferrosilicic melts at the Gondwana continental margin during Upper Cambrian to Lower Ordovician times.

1. Introduction

The generation of silicic (SiO_2>63 wt.%) magmatic rocks of dacite to rhyolite compositions (and their plutonic equivalents) is directly related to the differentiation and evolution of the continental crust (Taylor and McLennan, 1985; Condie, 1997). Recycling of older crustal materials, either sedimentary or igneous, into silicic magmatism is widely supported by isotope geochemistry (McCulloch and Wasserburg, 1978; Allègre and Ben Othman, 1980) and laboratory experiments (Thompson, 1982; Vielzeuf and Holloway, 1988; Patiño Douce, 1999). However, only a little part of the silicic magmas may be produced at conditions predicted by currently accepted thermal models for the continental crust. With the exception of anatectic leucogranites, which may be produced from metasedimentary sources at temperatures of the order of 650 to 800 °C and middle crustal pressures (0.5 to 1.0 GPa), most of the silicic magmas need higher temperatures out of the range predicted by crustal thermal models.

Here we report a particular case of ferrosilicic magmatic rocks developed at the Gondwana margin at conditions exceeding any thermal model prediction for the continental crust. The peculiar geochemical features of these magmatic rocks, together with melting experiments supporting a derivation form metagreywackes, were reported in a previous paper (Fernández et al., 2008). In this study we show a complementary experimental proof derived from the application of inverse techniques to a model magma composition representing averaged Ordovician ferrosilicic magmas form Iberia. The aim of this study is to explore experimentally the near-liquidus phase relations for this particular system in order to produce an estimate of the required pressure and temperature conditions at which these particular liquids are segregated. This estimation will be independent of the source composition and it will be used to test the previous results from partial melting experiments (Fernández et al., 2008).

The application of alternative thermal models is also explored here in order to find a plausible scenario for magma generation at ultrahigh temperature in an active continental margin. Currently accepted models that have been proposed to account for thermal anomalies in the continental crust, including those of lithosphere delamination (Platt and England, 1993; Willner et al., 2002) and basaltic underplating (Petford and Atherton, 1996; Annen and Sparks, 2002) are not enough to account for the mantle-like thermal conditions required according to the experimental study. The solution to this paradox, recycling of continental rocks (metagreywackes) but not within the continental crust, requires the introduction and heating of sedimentary reservoirs into the hot mantle at temperatures higher than those predicted by thermal models in the continental crust. Near-total melting (>80 vol.% melt) also requires that progressive melt extraction from the source does not take place during melting, as it typically happens in the continental crust, where melting is commonly

* Corresponding author.
E-mail address: dorado@uhu.es (A. Castro).

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accompanied by tectonic deformation (e.g., Brown, 1994). A plausible model accounting for recycling of crustal materials at ultra-high temperature (>1000 °C) within a closed system is offered by silicic cold plumes ascending through the mantle wedge (Gerya and Yuen, 2003; Gerya and Stoeckhert, 2005). These may transport fertile materials, dragged by subduction erosion (von Huene and Schöll, 1991) at the continental margin, to hot areas of the mantle wedge. The application of these models to the generation of ferrosilicic magmas is followed in this paper.

2. Geological setting and features of ferrosilicic magmatic rocks (FMR)

The rocks studied are characterized by high Fe and Mg contents (FeO>2.5 wt.%, MgO>0.8 wt.%), high silica values ranging from 65 to 70 wt.% SiO_2, and very low CaO (<2.0 wt.% CaO). Therefore, the term *ferrosilicic* is used in this paper to refer to these rocks, which are poorer in Ca than normal dacites and richer in Fe than normal rhyolites. The identification of these ferrosilicic rocks as derived from crystallisation

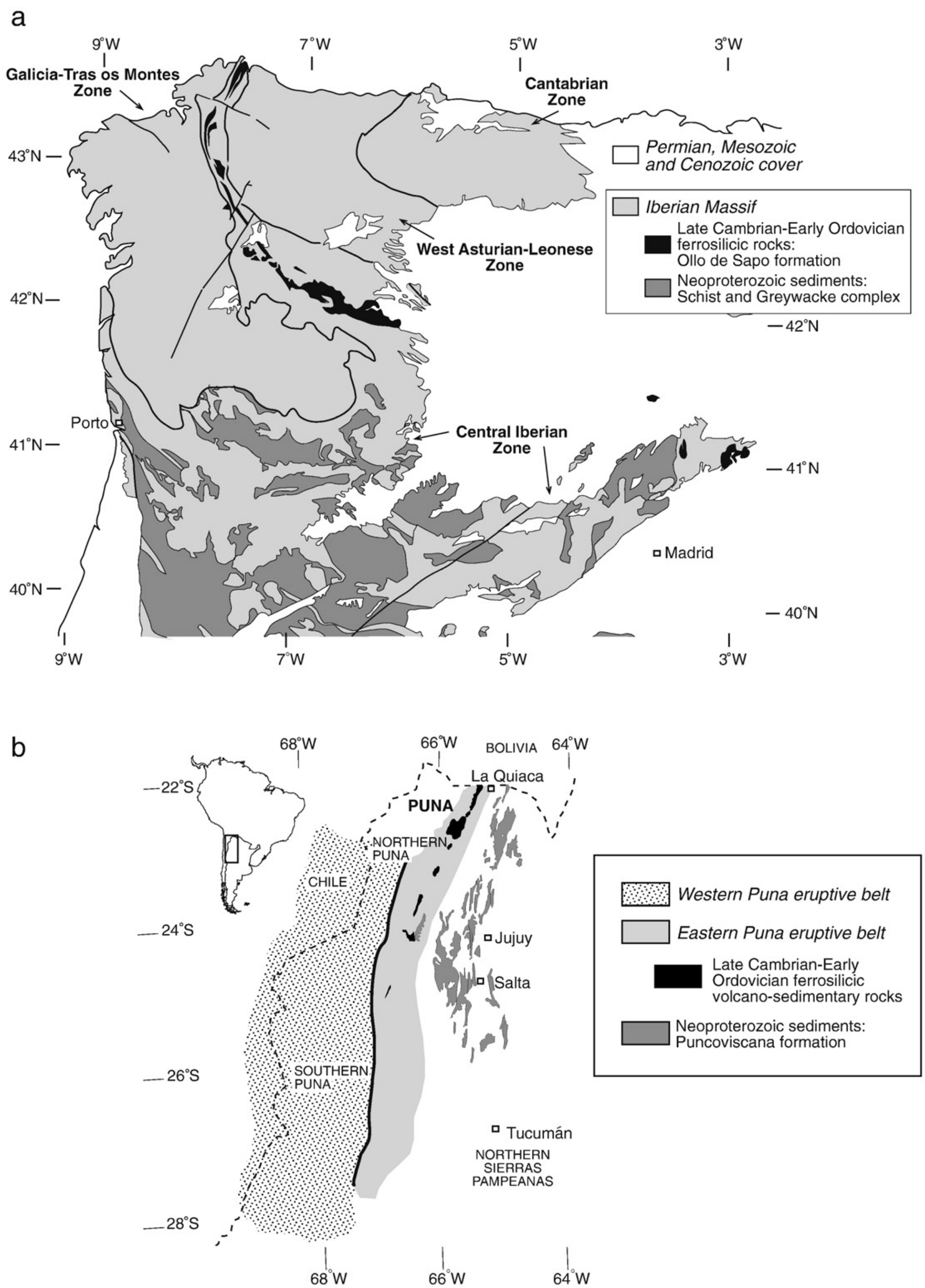

Fig. 1. Geological sketch map of (a) northwest Iberia and (b) northwestern Argentina.