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U-Pb SHRIMP-RG zircon ages and Nd signature of lower Paleozoic rifting-related magmatism in the Variscan basement of the Eastern Pyrenees

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ABSTRACT

The ages of orthogneisses exposed in massifs of the Variscan chain can determine whether they are part of a pre-Neoproterozoic basement, a Neoproterozoic, Panafrican arc, or are, in fact, lower Paleozoic, and their isotopic compositions can be used to probe the nature of their source rocks, adding to the understanding of the types, distribution, and tectonic evolution of peri-Gondwanan crystalline basement. .Using SHRIMP U-Pb zircon geochronology and Nd isotopic analysis, pre-Variscan metaigneous rocks from the Núria massif in the Eastern Pyrenean axial zone and the Guilleries massif, 70 km to the south, have been dated and their Nd signatures characterized.. All dated orthogneisses from the Núria massif have the same age within error, ~457 Ma, including the Ribes granophyre, interpreted as a subvolcanic unit within Caradocian sediments contemporaneous with granitic magmas intruded into Cambro-Ordovician sediments at deeper levels. Orthogneisses in the Guilleries massif record essentially continuous magmatic activity during the Ordovician, beginning at the Cambro-Ordovician boundary (488 ± 3 Ma) and reaching a peak in the volume of magma in the early Late Ordovician (~460 Ma). Metavolcanic rocks in the Guilleries massif were extruded at 452 ± 4 Ma and appear to have their intrusive equivalent in thin, deformed veins of granitic gneiss (451 ± 7 Ma) within metasedimentary rocks. In orthogneisses from both massifs, the cores of some zircons yield Neoproterozoic ages between ~520 and 900 Ma. The age of deposition of a pre-Late Ordovician metapelite in the Guilleries massif is bracketed by the weighted average age of the youngest detrital zircon population, 582 ± 11 Ma, and the age of cross-cutting granitic veins, 451 ± 7 Ma. Older detrital zircons populations in this metapelite include Neoproterozoic (749–610 Ma; $n = 10$), Neo- to Mesoproterozoic (1.04–0.86 Ga; $n = 7$), Paleoproterozoic (2.02–1.59 Ga; $n = 5$), and Neoarchean (2.74–2.58 Ga; $n = 3$). Nd isotopic analyses of the Núria and Guilleries orthogneisses yielded negative ε_{Nd} values ranging between -2.1 and -5.2 at 450 Ma, the same as Ediacaran sediments from northwestern Iberia. We interpret these slightly negative ε_{Nd} values as a signature of Panafrican arc rocks, mixed with an older crustal component as indicated by the inherited and detrital zircon ages we analyzed. The crustal level in which Ordovician melting occurred has not been recognized and the absence of pre-Neoproterozoic basement is a striking feature of the southern part of the Variscan Chain.

1. Introduction

The ages, terrane affinity, and tectonic evolution of orthogneisses in pre-Mesozoic Variscan basement massifs across southern Europe, including the Pyrenean axial zone and the Montagne Noire, have long been the subject of interest and controversy (Guitard et al., 1996; Mattauer, 2004; Zwart, 1979). These orthogneisses play a central role in paleogeographic reconstructions of the Variscan chain (*Variscan* refers to the Late Paleozoic orogenesis of western Europe, ~380–290 Ma) and they record the early stages of the geodynamic evolution of the chain before the assembled crust was thermally weakened by intrusion of voluminous granites beginning in the Early Carboniferous.

The ages of orthogneisses in the massifs bear directly on the debate about the nature of an elusive Gondwanan basement involved in the Variscan of southern Europe. For many years, orthogneisses and other high-grade rocks exposed in the massifs of the Variscan chain have been regarded as either part of a pre-Variscan, Precambrian crystalline basement or as pre-Variscan, lower Paleozoic, rift-related volcanic or intrusive rocks. For example, in the Pyrenees, orthogneisses exposed in the cores of massifs have been considered part of a basement (Guitard,

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1970) topped by Neoproterozoic and Paleozoic (meta-)sedimentary sequences, similar to the relations between Variscan basement and Mesozoic cover in the Alps. Across the Variscan chain in southern Europe, and, in particular, in Iberia (Murphy et al., 2008; Fig. 1A, B), such basement should be peri-Gondwanan and be composed of both pre-Neoproterozoic crystalline rocks and arc-related plutons of Neoproterozoic age. Neoproterozoic arc-related plutons intrude both the older crystalline basement and Ediacaran sediments now exposed in Britanny and across northwestern Iberia (Fernández-Suárez et al., 1998, 2000; Franke et al., 2005; Guerrot and Peucat, 1990; von Raumer et al., 2003). In Iberia, the geochemistry of Late Neoproterozoic sediments (Ugidos et al., 1997, 2010) supports a model in which they are largely derived from the erosion of the arc plutons. Moreover, Pre-Neoproterozoic basement is itself overlain by the Ediacaran sediments (for example, the Brioverian of French Brittany) which are overlain by lower Paleozoic sequences, these latter playing a role equivalent to the Mesozoic cover in the Alps.

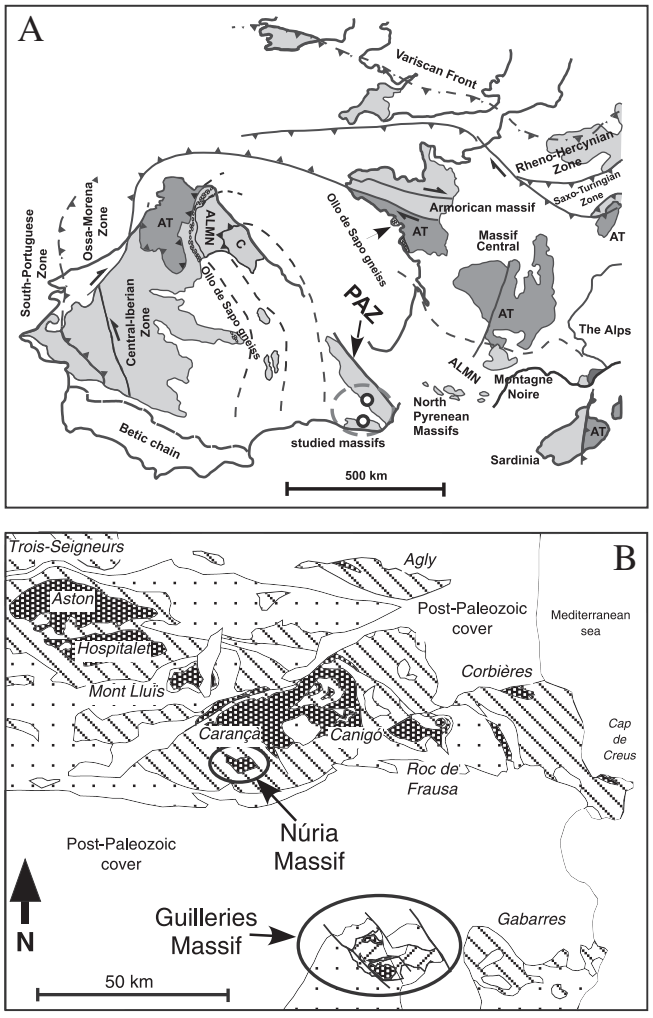

Fig. 1. Maps showing the location of the Núria and Guilleries massifs (A) in the Variscan chain of southern Europe, and (B) in and south of the Eastern Pyrenees, respectively. In (A), major tectono-stratigraphic zones of the Variscan chain are labelled and shaded, and their major bounding faults are shown. The extent of the Ollo de Sapo gneiss, recently used by Bea et al. (2010) and Ballevre et al. (in press) for regional correlations and paleogeographic reconstruction, is also shown. Abbreviations in (A) are: PAZ, Variscan basement of the Pyrenean Axial Zone; AT, Allochthonous Terrains affected by high-pressure Early Variscan metamorphism (shaded dark gray); ALMN, Asturian-Leonese-Montagne Noire zone; C, Cantabrian zone. Simplified geology of the eastern Pyrenees and related rocks in northeasternmost Iberia is shown in (B): map units are pre-Late Ordovician (Caradocian) paragneisses and schists (striped pattern), pre-Variscan orthogneisses (dark pattern), and lower-grade metasediments of the Variscan basement (stippled pattern), all modified from Laumonier et al. (2004).

In the case in which the orthogneisses are lower Paleozoic and rift-related, basement rocks are missing and the penetrative foliation and related metamorphism affecting them and their host metasedimentary rocks are regarded exclusively as of Variscan age (Laumonier et al., 2004; Mattauer, 2004) aside from Ordovician contact metamorphism occurring locally in some massifs (Barbey et al., 2001; Enrique, 2004; Sebastián et al., 1982). Indeed, as more precise ages of orthogneisses have been determined using analysis of single zircons by U-Pb geochronology, interpretation of the orthogneisses a pre-Variscan crystalline basement of Neoproterozoic age or older seemingly could be ruled out because the crystallization ages of dated orthogneiss protoliths from massifs in the Pyrenees and across Iberia are Ordovician (Barbey et al., 2001; Casas et al., 2010; Cocherie et al., 2005; Deloule et al., 2002, Denele et al., 2009; Navidad et al., 2010; Valverde-Vaquero and Dunning, 2000).

Complicating this interpretation are the age data of Castiñeiras et al. (2008) because, although most of the crystallization ages of orthogneiss protoliths they determined are also Ordovician, a few orthogneisses from the Eastern Pyrenees have Ediacaran-lowermost Cambrian ages. Thus, the timespan of pre-Variscan magmatism is enlarged and the extent of metasediments correlative to Brioverian sediments in Brittany (Miller et al., 2001) expanded. In addition, a number of ages from inherited zircon cores show that Archean to Neoproterozoic crustal sources could have been involved in the generation of orthogneiss magmas if the zircon cores are not recycled through sedimentary rocks (Castiñeiras et al., 2008; Cocherie et al., 2005; Montero et al., 2007); similar inherited zircon cores are also found in Variscan granites (Martínez et al., 2008). Determining the ages of other orthogneisses exposed in massifs in the northeastern part of the Iberian Variscan chain can provide critical data needed to determine whether they are part of a pre-Neoproterozoic basement, a Neoproterozoic arc, or are, in fact, lower Paleozoic.

Two massifs are the subjects of this study (Figs. 1B and 2): (1) the Núria massif (Santanach, 1972), and (2) about 70 km to the south, the Guilleries massif (Durán, 1985; Durán et al., 1984). Both massifs are located in the Asturian-Leonese-Montagne Noire zone (ALMN in Fig. 1A) of the Ibero-Armorican arc of the Variscan foldbelt and expose unfossiliferous, probably Ediacaran to Cambro-Ordovician metasedimentary rocks affected by metamorphism and deformation presumably of Variscan age. In the Guilleries massif, Late Carboniferous granites intrude metasedimentary rocks and orthogneisses (Martínez et al., 2008). The Guilleries massif is the largest massif in northeastern Iberia immediately south of the axial zone of the eastern Pyrenees, exposes a wide variety of high-grade gneisses and pelitic rocks, and appears to be at least one source area for pebble conglomerates (synorogenic flysch) of Visean age. The occurrence of Precambrian pebbles would have important implications for the tectonic evolution of the Variscan chain. Before our study, none of the orthogneisses in the Guilleries massif had been dated. Orthogneisses exposed in the Núria massif are very similar to those exposed in the Guilleries massif, and Núria can be considered the southernmost part of the Canigó massif, one of the largest massifs in the Pyrenees.

The goal of our study is to contribute to the debate about the nature of the Variscan basement and its tectonic significance by determining the age(s) of pre-Variscan orthogneisses and analyzing the Sm and Nd isotopic compositions of the rocks we dated in an attempt to identify their source magmas and begin to understand their petrogenesis. We have also determined the ages of detrital zircons from a metasediment intruded by an orthogneiss protolith that also constrain the nature of crust that became involved in the Variscan orogeny. Examining orthogneisses in the Guilleries massif allows use to extend analysis of the Variscan basement eastward to the Mediterranean coast south of the Pyrenees and the similarity of rock types between Guilleries and Núria allows us to link rocks in the Guilleries massif to the Pyrenees.