A revised Ordovician age for the Sisargas orthogneiss, Galicia (Spain). Zircon U-Pb ion-microprobe and LA-ICPMS dating

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ABSTRACT

The Sisargas orthogneiss is located in the Schistose Domain of the Galicia Trás-Os-Montes Zone. It has previously been dated by Allegret and Iglesias (1987) who reported an U-Pb upper intercept at 570 ± 14 Ma, considered to be the crystallization age. For this reason, the Sisargas orthogneiss has traditionally been considered one of the oldest magmatic rocks of the Central Iberian Zone. However, new SIMS and LA-ICPMS data reveal that it crystallized at 479 ± 7 Ma and contains zircons with abundant pre-magmatic cores with ages clustering at 585 ± 15 Ma. This suggests that the Sisargas orthogneiss derives from the melting of a Pan-African protolith.


INTRODUCTION

The Galicia Trás-os-Montes Zone (GTMZ) of the Iberian Massif is located in the northwest of the Iberian Peninsula, thrust over the Central Iberian Zone. It is formed by two superimposed domains: The Schistose Domain and the Allochthonous Complexes Domain (Farias et al., 1987; Arenas et al., 1988) (Fig. 1). The Schistose Domain is situated in the lower part of the GTMZ and is mainly composed of Paleozoic materials and magmatic rocks of essentially felsic composition. The Allochthonous Complexes are situated on top of the Schistose Domain and constitute a superposition of allochthonous units which were displaced long distances and were part of extensive accumulation of nappes (Ries and Shackleton, 1971). These units are composed of ophiolitic materials with arc and oceanic origin and terrains of continental affinity (Arenas et al., 1986; Martínez Catalán et al., 1997, 1999).

The Sisargas orthogneiss is the northernmost part of a north-south band that is generally formed by two-mica augen orthogneisses and crops out in the Schistose Domain and spreads out from San Adrian Cape and the Sisargas Islands, in the north, to Pontevedra in the south (Fig. 1).

The Sisargas orthogneiss has previously been dated by Allegret and Iglesias (1987) using the conventional U-Pb method. The data obtained by these authors were highly
discordant and defined a discordia with an upper intercept at $570 \pm 14$ Ma, which they considered to represent the crystallization age. For this reason, the Sisargas orthogneiss and the Miranda do Douro orthogneiss (crystallization age $618 \pm 9$ Ma, Lancelot et al., 1985) were considered the oldest magmatic rocks of the Central Iberian Zone.

Recently, Bea et al. (2006) revised the age of the Miranda do Douro orthogneiss using cathodoluminescence imaging and single zircon U-Pb microanalysis. The authors obtained a crystallization age of $483 \pm 3$ Ma and concluded that the upper intercept at $618 \pm 9$ Ma (Lancelot et al., 1985) reflected the fact that about 70-80% of zircon grains contained pre-magmatic relictic cores (see also Bea et al., 2007), the age of which clustered around 605 Ma, very close to the 618 Ma age of Lancelot et al. (1985).

For this reason, we decided to investigate the crystallization age of the Sisargas orthogneiss using the same methodology, i.e. cathodoluminiscence imaging and single zircon U-Pb spot analysis.

**SISARGAS ORTHOGNEISS**

The Sisargas orthogneiss is a coarse grained biotite-bearing augen-gneiss, variably deformed and intensively metamorphosed. The augens consist of K-feldspar and synneusis of plagioclase crystals, which are set into a fine-grained groundmass of quartz, plagioclase, K-feldspar and biotite. Muscovite, zircon, apatite, monazite, xenotime and oxides appear as accessory phases. Under the microscope, the gneiss presents an allotriomorphic granular texture, with myrmekitic intergrowths and a foliation marked by micas. Its chemical composition corresponds to a slightly subaluminous granite with $\text{SiO}_2 \approx 72-73\%$, $\text{CaO} \approx 0.8-0.9$, $\text{Na}_2\text{O} \approx 3.2-4.0\%$, $\text{K}_2\text{O} \approx 5.3-5.5\%$ and alumina saturation index (ASI) $\approx 0.95-1.01$.

**METHODS**

One sample of about 10-15 kg was collected for zircon geochronology. Zircons were separated using conventional magnetic and heavy-liquid techniques. Crystals were mounted, polished and studied by cathodoluminiscence imaging under the scanning electron microscope (SEM) at the University of Granada prior to the ion microprobe (SIMS) and laser ablation ICP MS (LA-ICPMS) analysis.

Twelve U-Th-Pb analyses were done on seven grains using a Cameca IMS-1270 ion microprobe at the Nordsim facility in Stockholm (Table 1). Analytical methods broadly follow those described by Whitehouse...
et al. (1999 and references therein). U/Pb ratios were calibrated using the Geostandard 91500 reference zircon (1065 Ma; Wiedenbeck et al., 1995) and include a propagated error component from replicate analyses of 91500 during the analytical session. Errors on 207Pb/206Pb ratios are either the observed analytical uncertainly or the counting statistics error, whichever is highest.

Eight U-Pb analyses were carried out on eight grains using a LA-ICPMS system at the University of Granada (Table 1). The LA-ICPMS system is an Agilent-7500 spectrometer with a 213 nm Nd-Y AG Merchantek laser unit. Ablation was performed in a He atmosphere with a 60 μm diameter laser beam and a repetition rate of 5 Hertz. Spots were pre-ablated during 60 seconds with a laser energy of 50%, ablation was done for 90 s with a laser energy of 75% moving the sample stage upwards 5 μm every 30 seconds. The glass NIST-610 (409 ppm Pb, 460 ppm U) was used as an external standard. The following isotope ratios, determined by TIMS at the University of Granada, were also used: 204Pb/206Pb = 0.06, 207Pb/206Pb = 0.9127, 208Pb/206Pb = 2.1898, 206Pb/238U = 0.2501 and 208Pb/232Th = 0.5402. The coefficient of variation on 12 replicates of NIST-610 measured in the same session was ± 2.4% for 206Pb/238U and ± 0.3% for 207Pb/206Pb. The accuracy was estimated by comparing the results of analyzing the same population of very uniform grains from a diorite with the Nordsim (307 ± 3 Ma) and the LA-ICPMS (309 ± 9 Ma). Common-Pb corrections assumed that most contaminant Pb is present on the surface of the grains or in the resin, and has a composition that can be approximated using the Stacey and Kramers (1975) model for the present day. All ages were calculated using the decay constant recommendations of Steiger and Jäger (1977).

RESULTS AND DISCUSSION

Seventy six zircons were studied by SEM cathodolumiscence imaging. Most of the zircons present typical magmatic oscillatory zoning, in places with a

<table>
<thead>
<tr>
<th>Grain</th>
<th>U (ppm)</th>
<th>Th (ppm)</th>
<th>Pb (ppm)</th>
<th>207Pb/206Pb measure (%)</th>
<th>206Pb/238U measure (%)</th>
<th>206Pb/238U (Ma)</th>
<th>207Pb/235U(Ma)</th>
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<td>102</td>
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<td>257</td>
<td>51</td>
<td>0.0107</td>
<td>1.96</td>
<td>0.0982</td>
<td>3.71</td>
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<td>0.07996</td>
<td>4.01</td>
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<td>1143.7</td>
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<td>0.01748</td>
<td>0.77</td>
<td>0.0760133</td>
<td>1.39</td>
<td>472.3</td>
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</table>

All ages were calculated using the decay constant recommendations of Steiger and Jäger (1977).
convolute zoned inner part. About 35% of the crystals contain discordant restitic cores (Fig. 2, zircons B, D, and F).

The zircons were analysed by the U-Pb method using SIMS and LA-ICPMS. Results are shown in Table 1 and U-Pb data plotted in a Tera-Wasserburg diagram (Fig. 3). These data reveal the presence of two concordant or nearly concordant populations: one around 480 Ma and the other around 580 Ma.

The first population is, by far, the most abundant (Fig. 3) and was obtained from zircons with uniform zoning without inherited cores and from rims of zircons that containing inherited cores. The most concordant data of this population ($1.01 > \frac{^{206}Pb}{^{238}U} \text{age} / \frac{^{207}Pb}{^{235}U} \text{age} > 0.99$) yielded a mean age of 479 ± 7 Ma (95% of confidence interval). The second population appears only in inherited cores of some zircons yielding a mean age of 585 ± 15 Ma (95% of confidence interval).

The age data are interpreted in the following way: The most abundant and concordant population, with an age of 479 ± 7 Ma, is interpreted to represent the crystallization age of the Sisargas orthogneiss. This age is similar to crystallization ages of other Ordovician orthogneisses of the Central Iberian Zone (Valverde-Vaquero et al., 2000; Bea et al., 2006; Montero et al., 2007), but differs from the Ediacaran age proposed by Allegret and Iglesias (1987). We suggest that the less abundant, also concordant, population with an age of 585 ± 15 Ma, represents zircons that were not totally dissolved during the Cambro-Ordovician magmatism. Their presence suggests that the magmatic source of the Sisargas orthogneiss was formed from Pan-African rocks.

Finally, we conclude that the upper intercept of Allegret and Iglesias (1987) at 570 ± 14 Ma does not represent the crystallization age of the Sisargas orthogneiss but instead, indicates the presence of zircons with abundant inherited cores of Ediacaran age.

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