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# U-Pb geochronolgy of the deformed Juzbado Granite (Salamanca, NW Spain)

*Geocronología U-Pb del granito deformado de Juzbado (Salamanca, NO de España)*

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## ABSTRACT

*This paper reports a study of the crystallization age of the deformed Juzbado Granite through LA-ICP-MS U-Pb geochronology. Seven zircon grains were dated providing ages ranging from 340 to 2500 Ma. The U-Pb age data supply a maximum crystallization age of 340 Ma and insights into the nature of potential source rocks. The ages of the inherited zircon grains or xenocrysts are in agreement with the zircon contents found in the potential source rocks. Given that the intrusion is deformed by the fabric related to the Juzbado-Penalva do Castelo shear zone, its minimum age must be* ca. *308 Ma. Based on the petrological similarities with other granite bodies in the surrounding area (Tormes anatectic dome) its age is likely to be around 320 Ma.*

**Key-words:** *: Juzbado Granite, shear zone, geochronology, Tormes Dome, Variscan.*

## RESUMEN

*Este trabajo se centra en el estudio de la edad de cristalización del granito deformado de Juzbado mediante geocronología U-Pb a través de ablación láser. Se dataron 7 granos de circón, obteniéndose edades comprendidas entre 340 y 2500 Ma. Los datos obtenidos proporcionan una edad máxima de cristalización de 340 Ma y aportan datos sobre la naturaleza de los potenciales materiales fuente. Las edades de circones heredados existentes en el granito son coincidentes con las encontradas en las posibles rocas fuente. Dado que esta intrusión está deformada intensamente por la fábrica relacionada con la Zona de Cizalla de Juzbado-Penalva do Castelo, la edad mínima de este cuerpo es de 308 Ma. La comparación de las características petrológicas de este granito con las de otros en los alrededores (en el Domo del Tormes) permite asignarle una edad en torno a 320 Ma.*

**Palabras clave:** *granito de Juzbado, zona de cizalla, geocronología, Domo del Tormes, Orógeno Varisco.*

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## Introduction

The determination of crystallization ages of granitoid intrusions is paramount in understanding the complex patterns of magmatic evolution of orogenic belts. One of the most complex magmatic areas in the Variscan belt of the Iberian Peninsula is the Tormes anatectic dome (TAD), located in the Central Iberian Zone, where complex intrusive relations have been described and dated (see López-Moro *et al.*, 2018, Pereira *et al.*, 2018). Most crystallization ages obtained for granitoids in this domain are comprised between *ca.* 325 and 318 Ma. These granites are interpreted to have been originated in the course of the orogenic extension that caused extensive decompression and partial melting of the crust.

In this work, we attempted to date one of the granite bodies from the TAD through LA-ICP-MS U-Pb (Laser Ablation–Inductively Coupled Plasma–Mass Spectrometry Uranium-Lead) geochronology using zircon crystals. Given the paucity of zircon grains recovered from the studied sample (7) it was not possible to obtain a reliable crystallization age but only a maximum crystallization age. In addition, the obtained U-Pb zircon ages provide insights on the source rocks of the Juzbado pluton when compared with other intrusive bodies found in the TAD.

## Geological setting

Within the TAD, at its southeastern boundary, there is a distinct granitoid body known as the deformed Juzbado Granite"e (or Traguntia-Juzbado orthogneiss; García de Figuerola and Parga, 1968). This intrusion crops out as an elongated body (*ca.* 18 × 0.5 km) trending N70ºE (Fig. 1), composed of muscovite leucogranite with sparse biotite and occasional tourmaline. The Juzbado Granite shows a ubiquitous macroscopic S-C fabric. At microscopic scale, the main evidence of deformation is widespread quartz recrystallization and the presence of “mica-fish” structures in the C

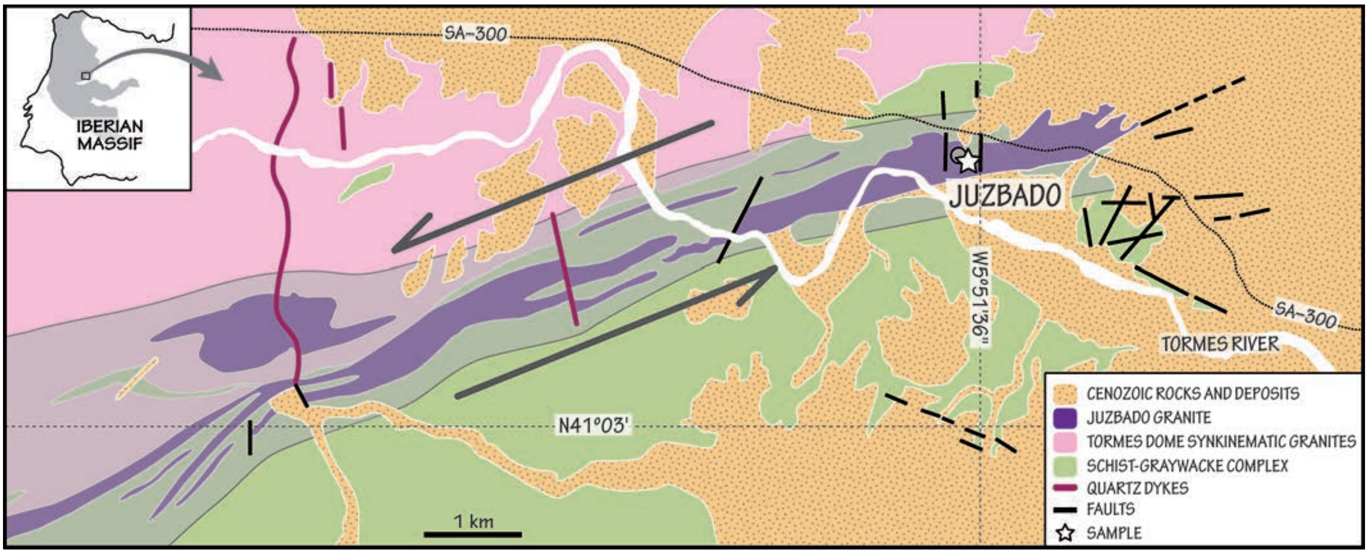


**Fig. 1.- Schematic geological map of the deformed Juzbado Granite and its surrounding area (Villar Alonso *et al.*, GEODE, 2018). Shaded pattern highlights the deformation zone linked to the Juzbado-Penalva do Castelo shear zone. See color figure in the web.**

*Fig. 1.- Mapa geológico esquemático del granito deformado de Juzbado y su entorno (GEODE, Villar Alonso* et al.*, 2018). El área sombreada se corresponde con los lugares en los que se puede observar la deformación relacionada con la zona de cizalla de Juzbado-Penalva do Castelo. Ver figura en color en la web.*

planes (Fig. 2). The Juzbado Granite crops out within the sub vertical, left-lateral Traguntia-Juzbado-Penalva do Castelo Shear Zone (Iglesias and Ribeiro, 1981; Jiménez de Ontiveros and Hernández Enrile, 1983; Fig. 1), which imparts the strong macroscopic fabric. The dated sample was collected in a fresh outcrop within the village of Juzbado (coordinates 41°4'36.63"N - 5°51'39.17"W).

The Juzbado Granite marks the southern boundary of the TAD separating a northern domain characterized by the presence of migmatites, two mica granites, and coarse gneisses from another low grade domain to the south with tourmaline-rich granites (López-Plaza and López-Moro, 2008).

## Geochronology

Zircon grains were separated at the University of Salamanca (Spain). Approximately 10 kg of sample were crushed in a jaw crusher and sieved for the fraction 63-400 μm. Concentrates were obtained using Wilfley table, Frantz isodynamic magnet separator and heavy liquids (diiodomethane). Zircon crystals mounted in resin blocks and polished to approximately half their thickness were analyzed for U and Pb isotopes at the Museum für Mineralogie und Geologie (Senckenberg Naturhistorische Sammlungen, Dresden). Details of the analytical method and protocols can be found in Gutiérrez-Alonso *et al.* (2018).

The studied sample yielded only seven zircon grains and a total of 18 analyses were performed on them. Figure 3 shows the cathodoluminiscence images of the zircon grains and the location of laser spot analyses within each zircon. Table I reports the U-Pb results of the 15 analyses whose discordance is less than 10%.

The following is a description of U-Pb age results keyed to the analyzed crystals shown in figure 3.

Analysis a5 (Fig. 3) and analyses a9 and a10 (zircon image not shown in Fig. 3) are more than 50% discordant and are thus not reported in Table I.

Analyses a6, a7 and a8 (grain 3, from left to right in Fig. 3) yield concordant and overlapping analyses with a concordia age of 340.1 ± 2.6 Ma (Visean) (Fig. 4C). This zircon grain is homogeneous, showing very weak zoning, in contrast to the other crystals with sharper CL domains.

Analyses a4, a11, a12, a13, a14 and a15 were obtained on three different grains (Fig. 3) and they yielded early Cambrian ages. Analysis a4 on grain 2 (Fig. 3) yielded a concordia age of 530 ± 8 Ma. Analyses a11, a12, a13 on grain 4 yielded a pooled concordia age of 539.4 ± 8.2 Ma (MSWD= 0.77). Analyses a14 and a15 (grain 5) yielded a pooled concordia age of 517 ± 5 Ma (MSWD= 0.006).

Analyses a16, a17 and a18 (grain 6) did not yield overlapping analyses but all three are concordant and their $^{206}Pb/^{238}U$ ages are comprised between 950 and 1008 Ma (Stenian-Tonian).

Finally, analyses a1, a2 and a3 (grain 1) yielded concordant to slightly reverse-concordant $^{206}Pb/^{238}U$ ages comprised between 2460 and 2528 Ma (latest Neoarchean-earliest Siderian).

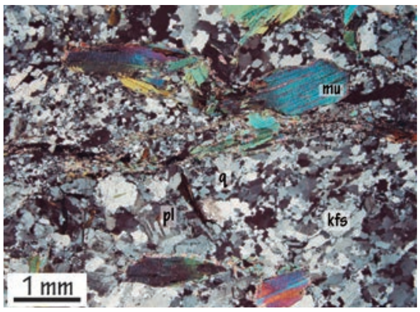


**Fig. 2.- Thin section image (under crossed polarized light) of the studied sample. Note the quartz recrystallization and the presence of highly strained domains corresponding to C planes. mu-muscovite; pl-plagioclase; kfs-potassic feldspar; q-quartz. See color figure in the web.**

*Fig. 2.- Microfotografía de la muestra estudiada (luz polarizada, nícoles cruzados). Obsérvese la presencia de cuarzo recristalizado y de dominios con alta deformación correspondientes a planos de tipo C. mu moscovita; pl-plagioclasa; kfs-feldespato potásico; q-cuarzo. Ver figura en color en la web.*

## Discussion and Conclusions

The above data indicate that the age of the Juzbado granite is not older than Visean (*ca.* 340 Ma). However, given the scarcity of zircon in this sample it cannot be ruled out that the age of the intrusion is younger. López Moro *et al.* (2018) have shown that there are syntectonic granites whose crysta-

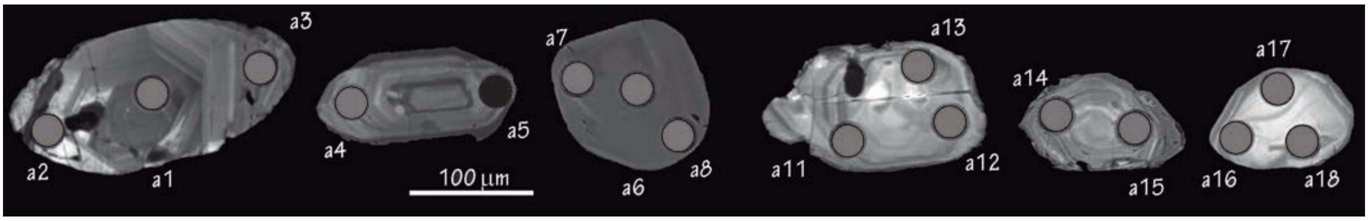


**Fig. 3.- Cathodoluminiscence (CL) images of six of the seven analyzed zircon grains with the position of the ablated spots. Black spot represents a discordant measurement. Ages of the labeled spots are posted in table I**

*Fig. 3.- Imágenes de catodoluminiscencia(CL) de seis de los siete granos de circón analizados indicando la posición de los puntos ablacionados. El punto negro representa un análisis discordante. Las edades de los resultados en cada punto se encuentran en la tabla I.*

llization age is *ca.* 320 Ma and they contain varied amounts of *ca.* 340 Ma inherited zircon crystals as well as other pre-Variscan populations. On the other hand, the deformation that affects this intrusion has been recently dated at *ca.* 308 Ma (Gutiérrez-Alonso *et al.*, 2015; Díez Fernández and Pereira, 2017) and makes it unlikely that this leucogranite belongs to the post-tectonic granitoid suite (*cf.* Gutiérrez-Alonso *et al.*, 2011). Therefore, with the data presented herein, the age of the studied granite is either Visean, as indicated by the youngest analyzed zircon (Fig. 4C), in which case it would belong to the early Carboniferous suite of NW Iberia (Gutiérrez-Alonso *et al.*, 2018) or younger, in which case the granite would most likely belong to the syntectonic leucogranite suite (*e.g.* López Moro *et al.*, 2018).

The older than 340 Ma zircon grains indicate that the source rocks involved in the genesis of the Juzbado granite contained early Cambrian, Stenian-Tonian and latest Neoarchean zircon grains. These inherited zircon grains could in turn derive from primary igneous sources or could have been recycled into pre-Variscan sedimentary rocks or a combination of both.

In conclusion, the deformed Juzbado Granite has a Variscan age that cannot be fully constrained due to the paucity of zircon grains present in it. Its maximum age is 340.1 ± 2.6 Ma as shown by the youngest zircon grain in the sample (Fig. 4C). Its minimum age is constrained by the age of the deformation caused by the Juzbado-Penalva do Castelo Shear Zone. Therefore, without further research it is not possible to assign the Juzbado deformed granite to either the Visean "Early Carboniferous Suite" (ECS, recently proposed by Gutiérrez-Alonso *et al.*, 2018 and roughly coincident with the "Older Granodiorites" Capdevila *et al.*, 1973) or the "Granodioritas Precoces" (De Pablo Maciá, 1981) nor to the ca. 320 Ma syntectonic suite that makes most of the magmatic bodies found in the TAD (López-Moro *et al.*, 2018).

If we take into account the petrological differences between the ECS and the syntectonic suite, our sample is more likely to correspond to the latter, as the ECS bodies are mostly biotite-rich granites and granodiorites. From this point of view, we interpret that the deformed Juzbado Granite is a distinct body within the TAD that shares a common origin with the syntectonic suite.

Regarding the older zircon grains found in the deformed Juzbado Granite, their ages correspond to populations/events found in the Central Iberian Zone: the "Ollo de Sapo" event and the Cadomian, Stenian-Tonian and Neoarchean-Siderian zircon grains found as detrital components in the sedimentary rocks in the region. Small differences of inherited ages with respect to those found in the TAD could be related to the peripheral position of the Juzbado Granite, involving a slight variation in protholiths. In addition, a lower partial melting degree (or a more differentiated granite melt) could account for certain compositional differences of the granite itself, containing abundant muscovite and occasional tourmaline in contrast to tourmaline-lacking two-mica granites from the TAD.


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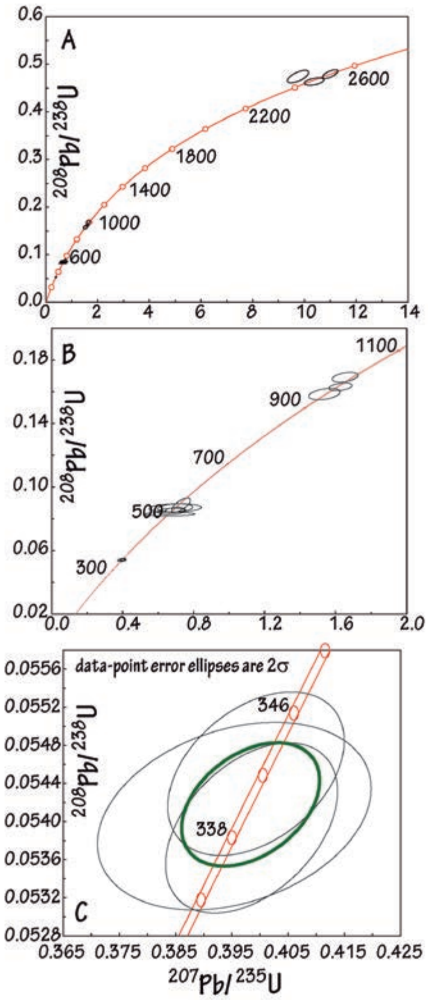


**Fig. 4.- Concordia diagrams with the ages obtained in this study. A) Age of all the concordant analyses shown in Table I. B) Concordant analyses with ages between 300 and 1100 Ma. C) Concordia plot and calculated age of the analyses performed on the youngest zircon grain (Concordia Age: 340.1 ± 2.6 Ma; MSWD of concordance: 0.013; probability of concordance: 0.91). See color figure in the web.**

*Fig. 4.- Diagramas de concordia mostrando las edades obtenidas en este estudio (Tabla I). A) Edades obtenidas en todos los análisis realizados. B) Detalle de las edades concordantes entre 300 y 1100 Ma. C) Diagrama de concordia y edad calculada de los análisis realizados en el circón más joven (Edad: 340.1 ± 2.6 Ma; MSWD de la concordancia: 0.013; probabilidad de concordancia: 0.91). Ver figura en color en la web.*

| Sample Juzbado | Isotopic ratios and 2σ (%) errors | | | | | | Ages and 2σ absolute errors (Ma) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anal. # | $^{206}Pb/^{238}U$a | ±2s | $^{207}Pb/^{235}U$a | ±2s | $^{207}Pb/^{206}Pb$a | ±2s | $^{206}Pb/^{238}U$ | ±2s | $^{207}Pb/^{235}U$ | ±2s | $^{207}Pb/^{206}Pb$ | ±2s | disc% |
| a7 | 0.0541 | 1.49 | 0.3954 | 5.03 | 0.0531 | 4.80 | 339 | 5 | 338 | 15 | 331 | 109 | -2.5 |
| a6 | 0.0539 | 1.35 | 0.3985 | 3.13 | 0.0535 | 2.82 | 338 | 5 | 340 | 9 | 353 | 63 | 4.3 |
| a8 | 0.0545 | 1.29 | 0.3993 | 3.21 | 0.0531 | 2.94 | 342 | 4 | 341 | 9 | 335 | 67 | -2.3 |
| a15 | 0.0830 | 1.14 | 0.6646 | 17.64 | 0.0581 | 17.60 | 514 | 6 | 517 | 74 | 532 | 386 | 3.5 |
| a14 | 0.0848 | 1.91 | 0.6760 | 9.65 | 0.0578 | 9.46 | 525 | 10 | 524 | 40 | 522 | 208 | -0.7 |
| a4 | 0.0857 | 1.54 | 0.6976 | 6.49 | 0.0591 | 6.31 | 530 | 8 | 537 | 27 | 570 | 137 | 7.0 |
| a13 | 0.0870 | 2.48 | 0.6967 | 17.31 | 0.0581 | 17.14 | 538 | 13 | 537 | 75 | 534 | 375 | -0.7 |
| a11 | 0.0870 | 2.39 | 0.6965 | 11.68 | 0.0581 | 11.44 | 538 | 12 | 537 | 50 | 532 | 250 | -1.1 |
| a12 | 0.0887 | 4.13 | 0.7281 | 5.92 | 0.0595 | 4.25 | 548 | 22 | 555 | 26 | 587 | 92 | 6.7 |
| a16 | 0.1587 | 1.83 | 1.5377 | 4.70 | 0.0703 | 4.33 | 950 | 16 | 946 | 29 | 936 | 89 | -1.4 |
| a18 | 0.1633 | 1.22 | 1.6269 | 3.32 | 0.0723 | 3.09 | 975 | 11 | 981 | 21 | 994 | 63 | 1.9 |
| a17 | 0.1694 | 1.45 | 1.6541 | 3.65 | 0.0708 | 3.35 | 1009 | 14 | 991 | 23 | 953 | 69 | -5.9 |
| a2 | 0.4646 | 1.34 | 10.3800 | 2.97 | 0.1620 | 2.65 | 2460 | 28 | 2469 | 28 | 2477 | 45 | 0.7 |
| a3 | 0.4749 | 2.31 | 9.7536 | 3.49 | 0.1489 | 2.62 | 2505 | 48 | 2412 | 33 | 2334 | 45 | -7.3 |
| a1 | 0.4801 | 1.53 | 11.0028 | 2.22 | 0.1662 | 1.61 | 2528 | 32 | 2523 | 21 | 2520 | 27 | -0.3 |

disc%= percent discordance calculated from 207Pb/206Pb and 206Pb/238U ages (negative values: reversely discordant analyses)
a corrected for background, mass bias, laser induced U-Pb fractionation and common Pb using Stacey and Kramers (1975) model Pb composition. 207Pb/235U calculated using 207Pb/206Pb/(238U/206Pb × 1/137,88). Errors are propagated by quadratic addition of within-run errors (2σ) and the reproducibility of GJ-1 (2σ).

**Table. I.- LA-ICP-MS U-Pb results.**

***Tabla. I.- Resultados de los análisis de U-Pb por LA-ICP-MS.***

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