A cryptic Early Palaeozoic event in the Narcea Antiform? $^{40}Ar/^{39}Ar$ amphibole data in the Puente de Selce granitoid

¿Un evento críptico durante el Paleozoico inferior en el Antiforme del Narcea? Edades $^{40}Ar/^{39}Ar$ de anfíbol en el granitoide de Puente de Selce

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RESUMEN

Las edades $^{40}Ar/^{39}Ar$ obtenidas a partir de anfíboles del granitoide Neoproterozoico de Puente de Selce, localizado en el Antiforme del Narcea junto con la existencia de fábricas de deformación relictas generadas en condiciones de media-alta temperatura en las mismas rocas puede ser interpretada como debida a un evento críptico de edad Paleozoico Inferior fuertemente retrabajado durante la deformación varisca. La naturaleza y la cinemática de este posible evento no pueden precisarse pero si se puede intentar correlacionar con otros eventos tectonometamórficos de edad Paleozoico inferior presentes en el NW de la península ibérica.

Key words: *Narcea Antiform, Lower Palaeozoic, $^{40}Ar/^{39}Ar$ geochronology, amphibole.*

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Introduction

The tectonic evolution of NW Iberia during the Early Paleozoic is obscured by the ubiquitous Variscan deformation developed in Devonian and Carboniferous times. This Variscan deformation is recorded in the sedimentary rocks of the Cambrian to Carboniferous passive margin sequence bordering the northern margin of the Gondwana continent and deposited on a basement of Neoproterozoic-age rocks composed of clastic sedimentary rocks, volcanics and granitoids. The processes involved in the development of the long-lived passive margin are not fully understood. The purpose of this paper is to discuss the possibility of a thermal event of Early Paleozoic age related to the development of the aforementioned margin that may be linked to widespread coeval magmatism (Valverde-Vaquero and Dunning, 2000) and deformation, (Díaz García, 2002).

The intensity of Late Paleozoic tectonothermal activity is such that evidence of earlier Paleozoic events may be largely obliterated and only subtle evidence might be preserved. Evidence of Early Paleozoic tectonism is important because it helps document the rift and drift of peri-Gondwanan terranes. In order to test the hypothesis of a thermal event in Early Paleozoic times, as suggested by illite crystallinity data from the Cantabrian Zone (Keller and Krumm, 1992, 1993), we analyzed amphiboles of the Ediacaran Puente de Selce granitoid (ca. 600 Ma., Fernández-Suárez *et al.*, 1998) by the $^{40}Ar/^{39}Ar$ method. This granitoid is located in the basement to the Paleozoic sequence and intrudes the Ediacaran sediments and volcanics of the Narcea Antiform at the boundary between the Cantabrian and the West Asturian Leonese Zones (Gutiérrez-Alonso, 1992, 1996; Gutiérrez-Alonso and Fernández-Suárez, 1996; Fernández-Suárez *et al.*, 1998), (Fig. 1A). The Narcea Antiform, is a broad antiformal stack culmination at the foreland-hinterland

Power	36Ar/40Ar	39Ar/40Ar	r	Ca/K	%40Atm	%39Ar	40Ar*/39K	Age
2.00	0.000540±0.000029	0.020328±0.000305	0.092	0.968	15.94	12.56	41.345±0.784	472.06±7.87
3.00	0.000125±0.000032	0.035825±0.000504	0.017	0.669	3.69	10.27	26.884±0.465	320.60±5.08
4.00	0.000109±0.000027	0.030726±0.000345	0.024	4.669	3.20	10.68	31.504±0.437	370.39±4.65
5.00>	0.000087±0.000020	0.023283±0.000206	0.157	10.773	2.56	20.14	41.849±0.400	477.12±4.01
5.50>	0.000038±0.000057	0.027066±0.000385	0.023	8.366	1.09	7.87	36.542±0.796	423.16±8.22
6.00>	0.000018±0.000036	0.028078±0.000301	0.029	6.939	0.53	7.95	35.426±0.525	411.60±5.45
7.00>	0.000070±0.000023	0.027329±0.000256	0.060	7.401	2.04	9.62	35.842±0.402	415.92±4.16
<7.50>	0.000057±0.000022	0.022653±0.000193	0.220	13.796	1.68	20.91	43.403±0.390	492.63±3.87

Table I.- Analytical results

Tabla I.- Resultados analíticos

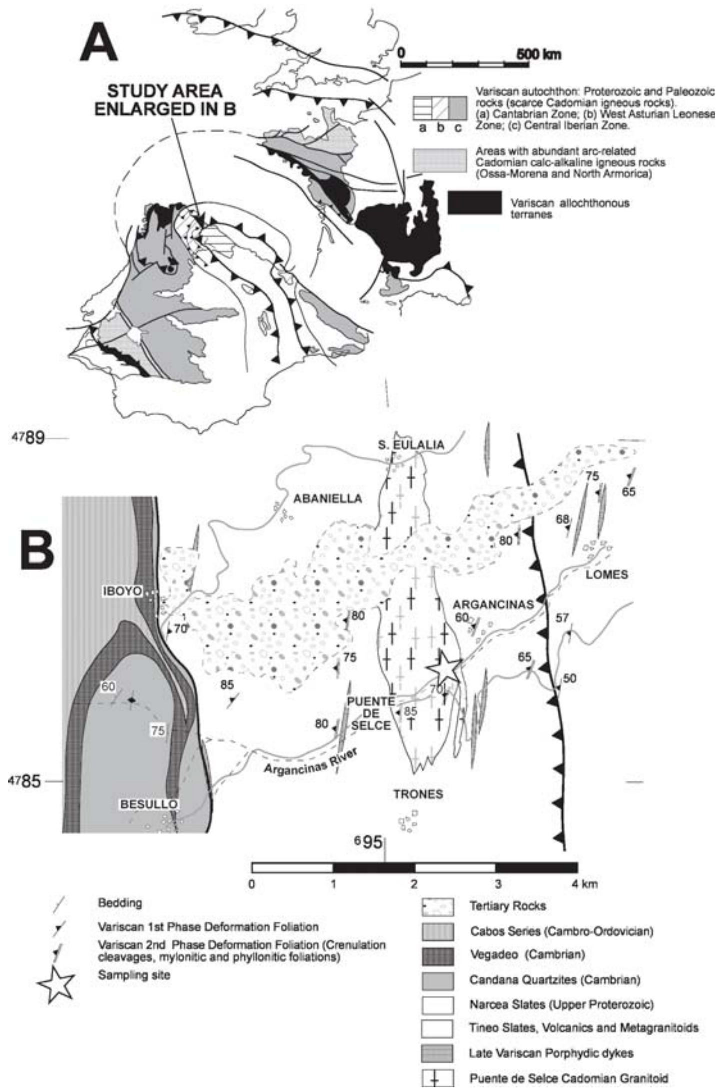

Fig. 1.- A: Geological sketch of Western European Variscan Belt with location of the study area. B: Geological map of the Narcea Antiform where the Puente de Selce granitoid is emplaced and location of the studied sample.

Fig. 1.- A: Esquema geológico del Cinturón Varisco de Europa Occidental donde se indica la situación del área de estudio. B: Mapa geológico del sector del Antiforme del Narcea en el que se localiza el granitoide de Puente de Selce y situación de la muestra estudiada.

transition in the Variscan orogen of northwestern Iberia. The main structural and metamorphic features of this area have been described in detail elsewhere (Gutiérrez-Alonso, 1996; Gutiérrez-Alonso and Nieto, 1996).

The Ediacaran granitoid intrusion (Fig. 1B) was polydeformed by Variscan events, of which, the regional phase 2 is the most prominent (D2, dated at ca. 320 Ma, Dallmeyer *et al.*, 1997, whole rock $^{40}Ar/^{39}Ar$ on phyllonites). In the granitoids, D2 deformation is recorded as mylonitic and phyllonitic metre-scale bands and phacoid shaped bodies of slightly deformed granitoids inside the shear bands. At the outcrop scale, the granitoids show intrusive relationships with the host Ediacaran metasediments.

The ages of the granitoid emplacement and of the main D2 variscan shear zone set the maximum and minimum time constraints on the possible ages of the amphiboles in the granitoid. On the other hand, as the deformation and illite crystallinity data from the country rocks (Gutiérrez-Alonso and Nieto, 1996) indicate low temperature (<300ºC) deformation, quartz CPO (Crystallographic Preferred Orientation) studies (Fig. 2) indicate that in addition to the low temperature shear zone development (revealed by the girdle patterns in the CPO stereographic plots) there is an inherited component that has been deformed at higher temperature conditions as can be seen in the maxima centered in the Y axis (the centre of the stereonet). It is noteworthy that these maxima do not appear in the CPOs developed in the surrounding lithologies indicating that they might not have recorded such event or that this event has been obliterated during later Variscan deformation events. From this point of view, the $^{40}Ar/^{39}Ar$ dating of amphiboles which have a closing temperature of 525 ± 25 ºC (Harrison, 1981) can shed light on the possible existence of a thermal event between the intrusion and the deformation of the Puente de Selce Granitoids.

The Puente de Selce Granitoid

The Puente de Selce intrusion is composed of coarse- to medium-grained hypidiomorphic to slightly porphyritic dark coloured granodiorites and tonalites (Corretgé, 1969; Gutiérrez Alonso and Fernández-Suárez, 1996). Rare centimetre-size microgranular mafic igneous enclaves are present These granodiorites and tonalites are composed of plagioclase, amphibole, biotite,

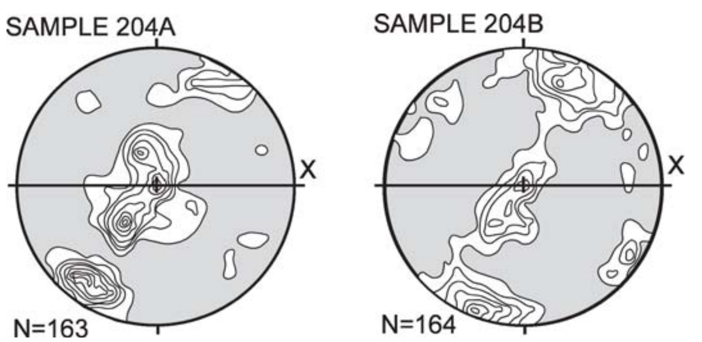

Fig. 2.- Lower hemisphere, Wulff projections of the orientation of quartz <c> axis in the more deformed bands of the Puente de Selce granitoid. Density intervals are 1%. Data from Gutiérrez Alonso (1992). See explanation in the text.

Fig. 2.- Proyección estereográfica (Falsilla de Wulff, hemisferio inferior) de las orientaciones de ejes <c> de cuarzo en bandas deformadas del granitoide de Puente de Selce. Intervalos de densidad del 1% Datos según Gutiérrez Alonso (1992).

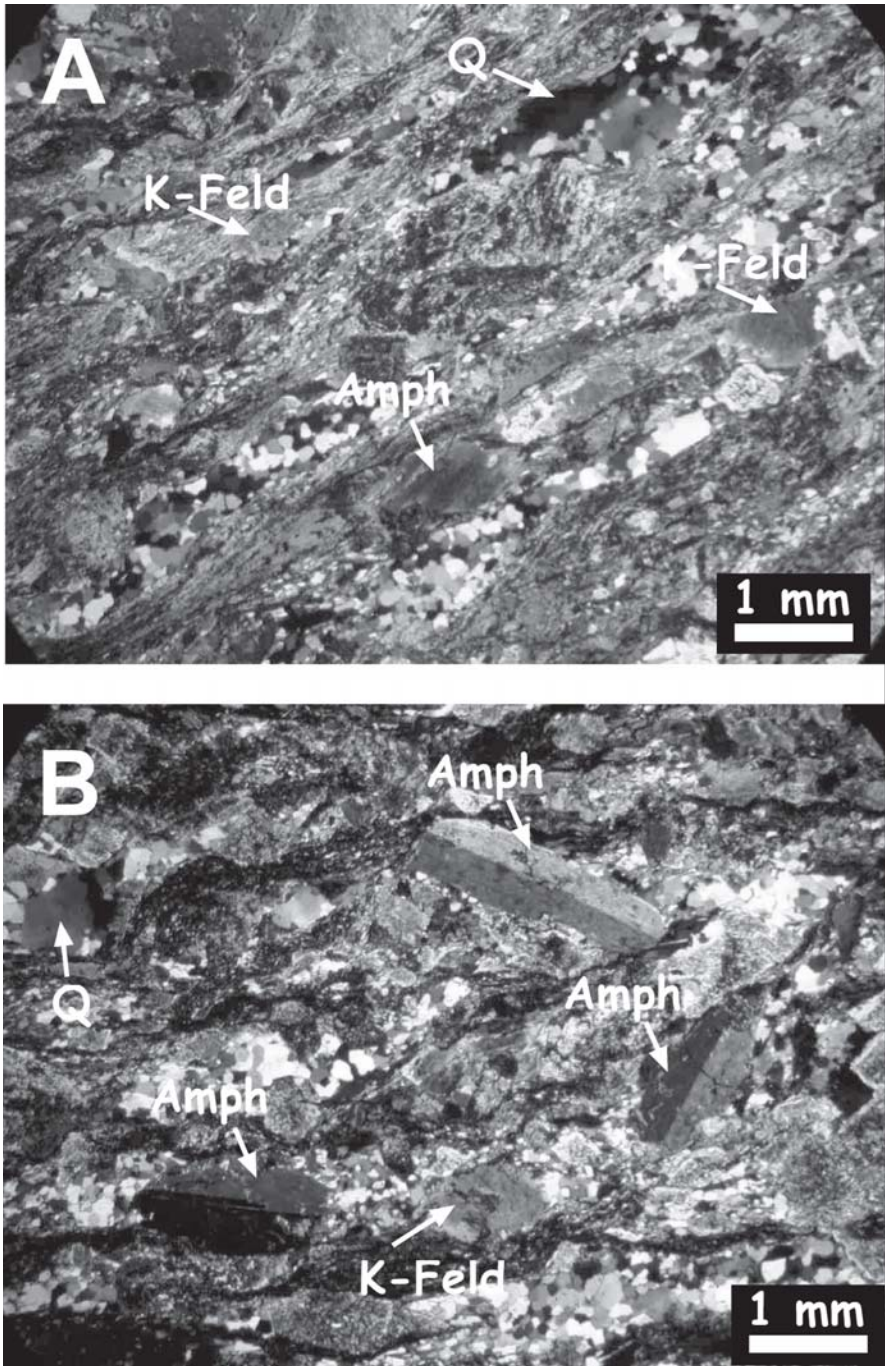

Fig. 3.- A: Microphotograph of the more deformed bands of the Puente de Selce granitoid where dynamic recristallyzation of quartz can be appreciated and the CPO study was performed. Amphibole crystals acted as porphyroclasts. B: Less deformed facies of the Puente de Selce granitoid where undeformed twinned prismatic crystals of amphibole can be appreciated. This microphotograph corresponds with the studied sample.

Fig. 3.- A: Microfotografía de las zonas más deformadas del granitoide de Puente de Selce en las que se aprecia la recristalización dinámica del cuarzo y donde los estudios de orientación preferente de ejes <c> fueron realizados. Se observa como los cristales de anfíbol actuaron como porfiroclastos. B: Facies menos deformada del granitoide de Puente de Selce donde se observan prismas maclados de anfíbol sin deformación apreciable. Corresponde a la muestra analizada.

pyroxene, quartz and scarce K-feldspar as essential minerals, and apatite, zircon, allanite and rare epidote as main accessory minerals.

Geochemically, the Puente de Selce granitoid is formed by I-type high-K calc-alkaline tonalites and granodiorites which have evolved by fractionation of plagioclase, biotite, amphibole and apatite (Gutiérrez-Alonso and Fernández-Suárez, 1996). Major and trace element contents and variation trends are characteristic of granitoids generated in an Andean-type continental arc setting. Melting of amphibolitic rocks of andesitic composition in the lower crust at T>850°C is the most likely mechanism for the generation of these rocks (Gutiérrez-Alonso and Fernández-Suárez, 1996).

The Puente de Selce granitoid contains abundant hornblende (Fig. 3 A and B) with prismatic habit when the granitoid is not very deformed. When deformed, they have overgrowths of brown amphibole and occasionally show altered cores of-possible pyroxene relics.

^{40}Ar/^{39}Ar geochronology

Amphibole concentrates were obtained from the studied sample (SELCE) collected in the road between Puente de Selce and Argancinas (Fig. 1B). The minerals were separated and concentrated by standard techniques at the Universidad Complutense, Madrid; and later selected by handpicking under a binocular microscope from fractions that ranged in size from 40 to 60 mesh. Amphibole separates were loaded into Al-foil packets and irradiated together with Hb3gr (1072 Ma) as a neutron-fluence monitor at the McMaster Nuclear Reactor (Hamilton, Ontario). ^{40}Ar/^{39}Ar analyses were performed by standard laser step-heating techniques described in detail by Clark *et al*. (1998) at the Geochronology Research Laboratory of Queen's University, Kingston, Ontario, Canada. The data are given in Table I and plotted in figure 4. All data have been corrected for blanks, mass discrimination, and neutron-induced interferences.

For the purposes of this paper, a plateau age is defined when the apparent ages of at least two consecutive steps, comprising a minimum of 55% of the $^{39}Ar_k$ released, agree within 2s error with the integrated age of the plateau segment. We further define a so-called «pseudoplateau», which follows the requirement of a plateau age, but has a $^{39}Ar_k$ percentage that can be lower than 55%. Errors shown in Table I and on the age spectrum and isotope-correlation diagrams represent the analytical precision at ±2s.

Results and discussion

If the tectonothermal history of the Narcea region consisted of just Cadomian and Variscan events, then one would expect ^{40}Ar/^{39}Ar amphibole spectra to represent Cadomian cooling ages with variable resetting to Variscan-aged

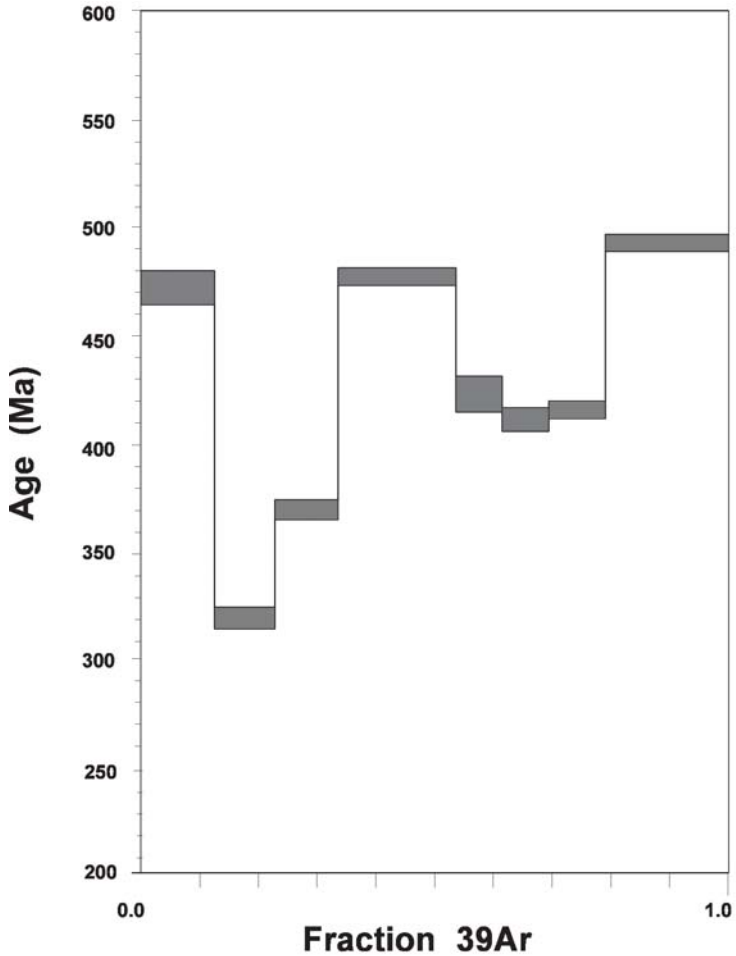

Fig. 4.- Results of the $^{40}Ar/^{39}Ar$ experiment in the amphibole concentrate. See explanation in the text.

Fig. 4.-Resultados del experimento $^{40}Ar/^{39}Ar$ en el concentrado de anfíboles. Explicación en el texto.

events. However, as can be seen in figure 4, despite the fact that this intrusive body is unequivocally Cadomian in age, the $^{40}Ar/^{39}Ar$ amphibole analyses record a disturbed age spectrum in which evidence for the initial cooling of the hornblende is not preserved. The highest temperature step yields a pseudoplateau «age» of 498 ± 3.92 Ma corresponding to 21% of ^{39}Ar (Fig. 4, Table I). Another pseudoplateau «age» of 418 ± 3.92 Ma from three temperature steps (= 25.4% of ^{39}Ar) can also be determined while the integrated age for the whole experiment is 439 ± 2 Ma.

The ~498 Ma amphibole age (or the integrated ~439 Ma age) could be regarded as a minimum age for the cooling of the Puente de Selce granitoid, but since its intrusion age is established at 600 Ma, it can also be interpreted as the age of re-heating or deformation under amphibolite conditions. Although the exact significance of the data is unclear, they do suggest a more complicated history than previously considered, involving post-Cadomian and pre-Variscan tectonothermal activity. These age spectra may reflect the existence of a medium-high temperature event that could be related with the Early Paleozoic extension and possibly with the drift of Avalonian terranes and the opening of the Rheic ocean (Fernández-Suárez *et al.*, 1998), future testing of such model requires further investigation using more detailed geochronology.

Conclusions

The amphibole $^{40}Ar/^{39}Ar$ ages of the Puente the Selce Ediacaran granitoid, together with structural evidence derived from the quartz CPO's analysis suggest a tectonothermal event in Early Paleozoic times which is in accordance with coeval events recorded elsewhere in NW Iberia that might be related to the rift-drift transition during the Rheic ocean opening and undocking of Avalonian terranes. Because of the intense Variscan overprint the nature and kinematics of this event remain enigmatic.

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