U-Pb dating of Siluro-Ordovician volcanism in the Verín Synform (Orense; Schistose Domain, Galicia-Trás-os-Montes Zone)

Datación U-Pb del volcanismo Siluro-Ordovícico del Sinforme de Verín (Orense, Dominio Esquistoso, Zona de Galicia-Trás-os-Montes)

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RESUMEN:

El Grupo Paraño constituye la parte más alta de la estratigrafía del Dominio Esquistoso de Galicia-Trás-os-Montes y está expuesto en el núcleo de la Sinforma de Verín. Como al resto del dominio, a este grupo se le ha atribuido una edad Silúrica. Con el fin de comprobar su edad se ha datado por el método U-Pb en circón una traquita félsica, de afinidades alcalinas, que ha proporcionado una edad Siluro-Ordovícica de 439,6+/-5 Ma. Esta edad demuestra que la estratigrafia del Dominio Esquistoso es más compleja de lo que se suponía, e invalida la correlación entre las rocas volcánicas en Galicia Central y las riolitas alcalinas de la Serie de Queiroga en la zona de Cabo Ortegal, datadas con una edad de 475 Ma por el método U-Pb.

Key words: *Iberian Massif, Schistose Domain, volcanism, U-Pb dating, Siluro-Ordovician*

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Introduction

The rocks of the Schistose Domain of the Galicia-Trás-os-Montes Zone have been traditionally considered Silurian in age. This notion has been challenged by recent palaeontological findings (Pereira et al., 2000; Rodríguez et al., 2004) and U-Pb dating of felsic volcanic rocks near the Cabo Ortegal Complex (Valverde-Vaquero et al., 2005), that show the presence of Ordovician rocks in this domain. In this contribution we present a U-Pb age that demonstrates the Siluro-Ordovician age of the felsic trachytes intercalated in the upper levels of the Paraño Group in the Verín Synform.

Geological Setting

The Schistose Domain of the Galicia-Trás-os-Montes Zone (Farias et al., 1985) is a tectonic unit sandwiched between the Allochthonous Complexes and the underlying Central Iberian Zone, with which it was considered to be in para-autochthonous relationship. Only the Paraño and Nogueira groups, of the original four units, are now considered part of this domain (see Farias and Marcos, 2004). These two units are best exposed in the Verín Synform (Orense), where they form a tectonic slice that cuts folds in the underlying Central Iberian Zone. There, the black and grey carbonaceous shales and siltstones of the Nogueira Group form the base of the domain, and are overlain by a sequence of green to khaki coloured shales/siltstones with interlayered greywacke, quartzite and minor levels of felsic volcanic rocks, the Paraño Group. The Paraño Group used to be correlated with the volcanic rock-bearing parts of the Queiroga and Loiba series of the Schistose Domain under the Ortegal Complex (e.g. Farias and Marcos, 2004).

The volcanic rocks of the Verín Synform crop out in the eastern flank of the structure among with quartzite, greywacke, shale, and minor volcaniclastic rocks from the upper stratigraphic levels of the Paraño Group (Fig.1). The volcanic rocks are restricted to two thin rhyolite levels (5 to 15 meter thick) and felsic trachyte, sandwiched in between, locally 40 meter thick. This trachyte is well exposed near the locality of Navallo, where the sample for U-Pb dating was taken.

%	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	L.O.I	Total
	69.65	15.85	2.82	0.01	0.17	0.07	6.45	4.40	0.41	0.04	0.28	100.14

ppm	V	Cr	Co	Ni	Cu	Zn	Ba	Nb	Rb	Sr	Y	Zr	U	Th	Pb
	0	0	30	4	5	37	38	144	99	26	63	664	1	16	11

ppm	La	Ce	Nd	Sm	Eu	Gd	Er	Dy	Yb	Lu	Y
	116.5	218.2	101.4	18.7	1.4	14.8	6.3	12.7	5.9	0.8	55.2

Major elements done by XRF on fused pellets. Trace elements (V to Th) done by XRF on pressed pellets (Univ. Oviedo). REE done by ICP-OES (UPV, Bilbao). Analytical precision is better than the last reported digit.

Table I.- Mayor and trace element analyses of the Navallo Trachyte (U-Pb sample)

Tabla I.- Análisis de elementos mayores y trazas de la Traquita de Navallo (muestra U-Pb)

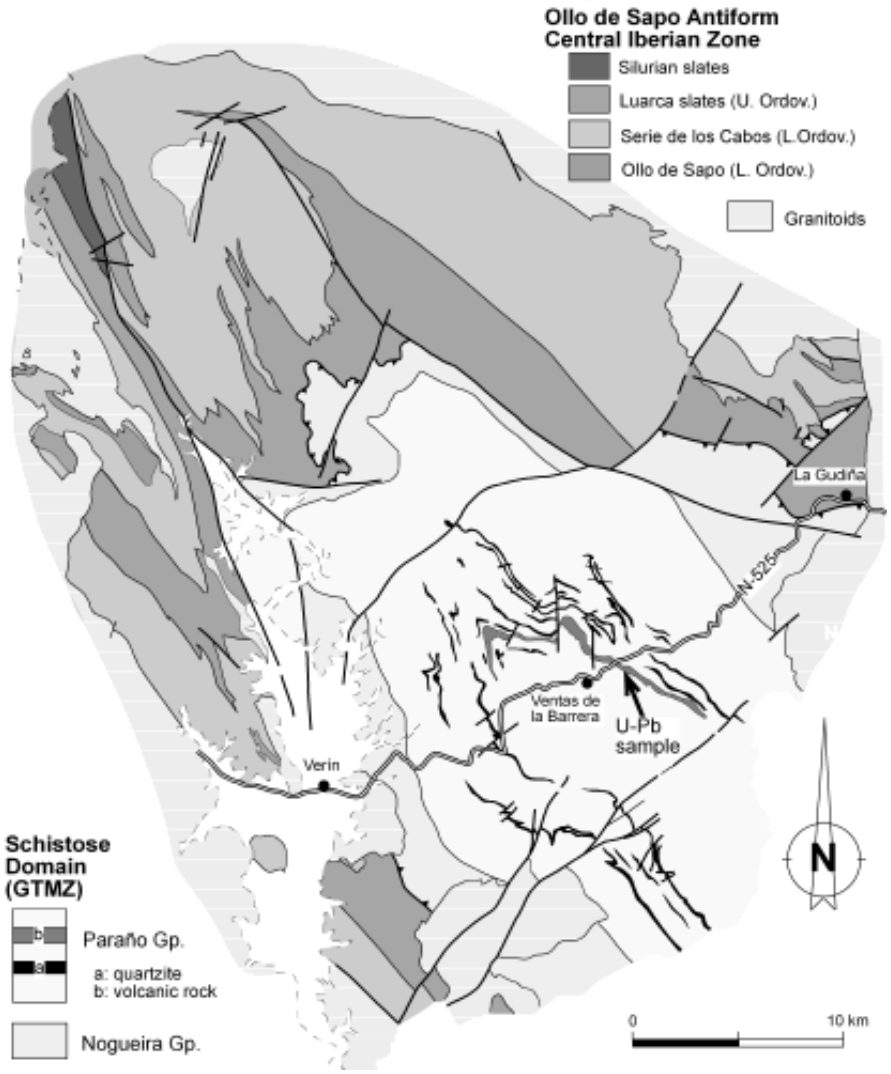

Fig. 1.- Geological map of the northern sector of the Verín Synform (Galicia-Trás-os-Montes Zone, GTMZ) showing sampling locality.

Fig. 1.- Mapa geológico de la parte norte del Sinforme de Verín (Zona de Galicia-Trás-os-Montes, GTMZ) mostrando la localización de la muestra.

Sample petrography and geochemistry

The U-Pb sample is a trachyte with a microporphyritic texture with small microphenocrysts (>1 mm) and glomerophyric accumulations, and a microlithic mesostasis with fluidal textures and devitrified volcanic glass. The main mineralogy is formed by K-feldspar, partially transformed to albite, and plagioclase. The minor and accesory minerals are quartz, opaques, chlorite, muscovite, epidote, carbonate, amphibole and zircon.

The rock presents a high SiO_2 content (69,65%) and high content in alkalis (6,45% Na_2O and 4,40% K_2O; Table I), which is coherent with its classification as a comendite-pantellerite / trachyte following the scheme of Winchester and Floyd (1977). This is consistent with the enrichment in LREE and the Eu negative anomaly observed in the REE multielement pattern (Evensen, 1978) and its within-plate granite (WPG) character in the ORG (Ocean Ridge Granite; Pearce et al., 1984) normalized multielement pattern (Fig.2). This chemistry is typical of alkaline felsic magmas (Whalen et al., 1996), and it is very similar to that of the A-type granites and rhyolites of Whalen et al. (1987).

Analytical method

The rock sample was crushed and the zircons were hand-picked from the concentrated heavy mineral separates after use of a Wifley table, heavy liquids and a Frantz magnetic separator. The zircons are small crystals, ca. 60-80 micron long, with a typical volcanic morphology defined by four-sided prims with broken tips and fluid inclusions. The zircons were dated by isotope dilution and thermal ionization mass spectrometry (ID-TIMS), using a ^{205}Pb-^{235}U spike in the isotopic laboratory of Giessen University (now Frankfurt Geozentrum, Germany). Details of the technique can be found in Valverde-Vaquero et al. (2005). At the time of mass spectrometric analyses, problems were experienced with the gain calibration of the SEM ion counter,

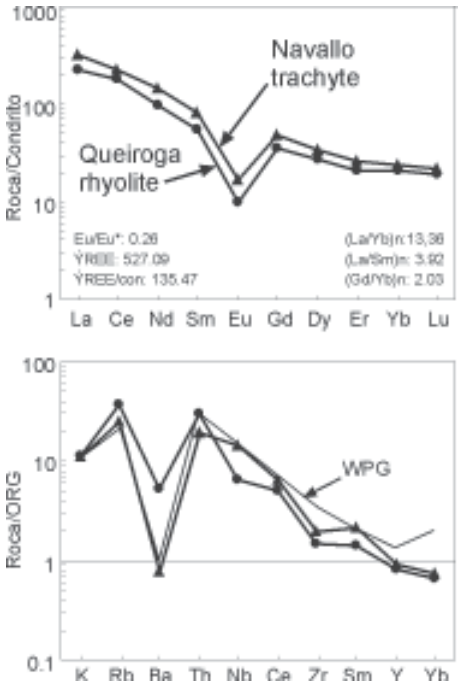

Fig. 2.- Multielement diagrams normalized to chondrite (REE; Evensen et al., 1978) and Ocean Ridge Granite (ORG; Pearce et al., 1984). WPG, Within Plate Granite, Ascension Island.

Fig. 2.- Diagramas multielementales normalizados a condrito (REE; Evensen et al., 1978) y a granito de dorsal oceánica (ORG; Pearce et al., 1984). WPG, granito de intraplaca, Isla Ascensión.

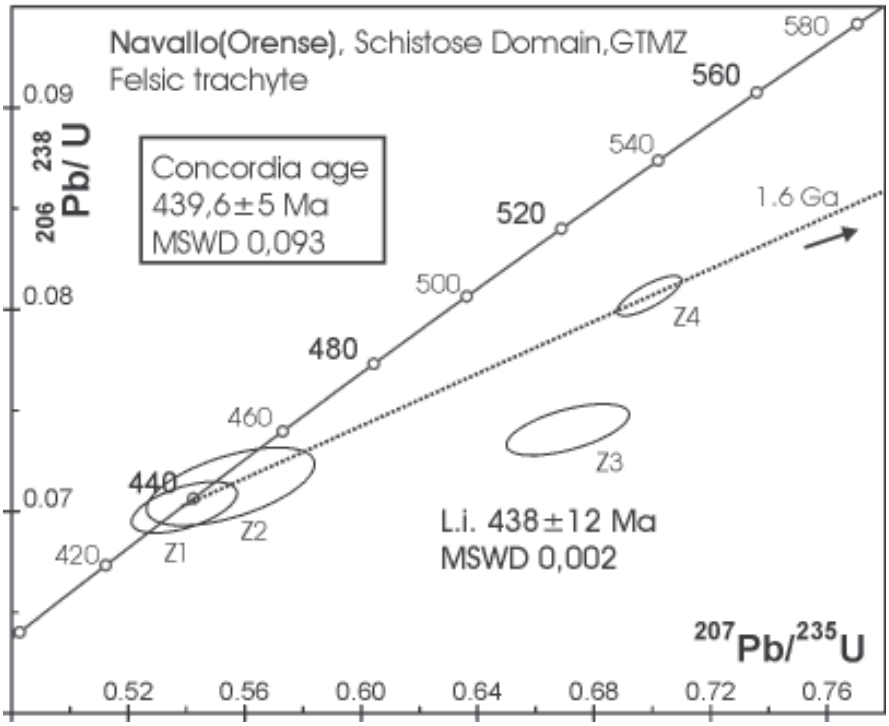

Fig. 3.- U-Pb concordia diagram.

Fig. 3.- Diagrama de concordia U-Pb.

which had to be replaced. This has resulted in analytical uncertainties of each individual measurement that are larger than those typical for TIMS analyses, as it is reflected in the size of the 2 sigma errors (Table II) and uncertainty ellipses (Fig.3).

Results

Four zircon fractions have been analyzed (Fig.3; Table II). Fractions Z1 and Z2 overlap the concordia curve, and fractions Z3 and Z4 are discordant. Fraction Z3 has a high amount of common Pb as indicated by relatively low value of the measured $^{206}Pb/^{204}Pb$ ratio (Table I). The large influence of the common Pb correction in this fraction makes it unreliable and will not be discussed further. The discordancy of fraction Z4 is attributed to the presence of inherited zircon. Fractions Z1, Z2 and Z4 define a mixing line with an upper intercept at 1.6 Ga and lower intercept age of 438±12 Ma. The concordance and equivalence of the analyses of fractions Z1 and Z2 is such that allows definition of a concordia age (*sensu* Ludwig, 1999) of 439,6±5 Ma (MSWD 0,093).

Discussion

The concordia age at 439,6±5 Ma is considered the most accurate age for the extrusion of the felsic trachyte. The relatively large uncertainty of the isotopic measurements prevent a more precise definition of the age, but future analyses by U-Pb ID-TIMS could resolve the Silurian or Upper Ordovician age of this volcanic level. Despite its uncertainty, this age clearly demonstrates the presence of Siluro-Ordovician volcanic rocks in the Verín Synform in Central Galicia. Near Cabo Ortegal, the alkaline rhyolites in the Queiroga Series, with which these rocks were correlated (Fig.4; Farias and Marcos, 2004), have an Early Ordovician age of 475±2 Ma (U-Pb Zrn; Valverde-Vaquero et al., 2005). In the Verín Synform the trachytic volcanic rocks of the Paraño Group correspond to a younger, Siluro-Ordovician magmatic event. This first order conclusion indicates that the stratigraphy of the Schistose Domain (Fig.4) is more complicated than expected, as it shows that the volcanic rocks of the Paraño Group of the Verín Synform are younger than, and cannot be correlated with, the felsic volcanics of the Queiroga series under the Cabo Ortegal Complex.

Sample	Weight	Concentration			Meas.*		Corrected atomic ratios**						Ages (Ma)		
	µg	U ppm	Pb rad ppm	Pb com pgr	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	±2σ	$^{207}Pb/^{235}U$	±2σ	$^{207}Pb/^{206}Pb$	±2σ	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
Felsic trachyte, Navallo (Orense)															
Z1 ,< 60µm prs. AB	22	88	6	15	593.7	0.138	0.0703	±10	0.539	±15	0.0556	±13	438	438	438
Z2 ,< 60µm prs. NA	5	197	15	9	529.7	0.199	0.0713	±16	0.555	±24	0.0564	±19	444	448	469
Z3 ,< 60µm prs. AB	7	210	16	31	238.8	0.171	0.0741	±10	0.671	±17	0.0657	±14	461	521	796
Z4 ,< 60µm prs. AB	5	851	70	24	911.7	0.124	0.08070	±80	0.6994	±90	0.06285	±50	500	538	703

AB, air abrasion; NA, no air abrasion; prs., prisms.
* Measured ratio corrected for blank and fractionation, spike removed.
** Atomic ratios corrected for fractionation, spike, laboratory blanks (2-10 pg Pb and 1 pg U) and initial common Pb (Stacey and Kramers, 1975). Absolute errors reported.

Table II.- U-Pb data. Schistose Domain, Galicia-Trás-os-Montes Zone (Navallo, Orense, NW Iberia).

Tabla II.- Datos U-Pb. Dominio Esquistoso, Zona de Galicia-Trás-os-Montes (Navallo, Orense, noroeste Iberia).

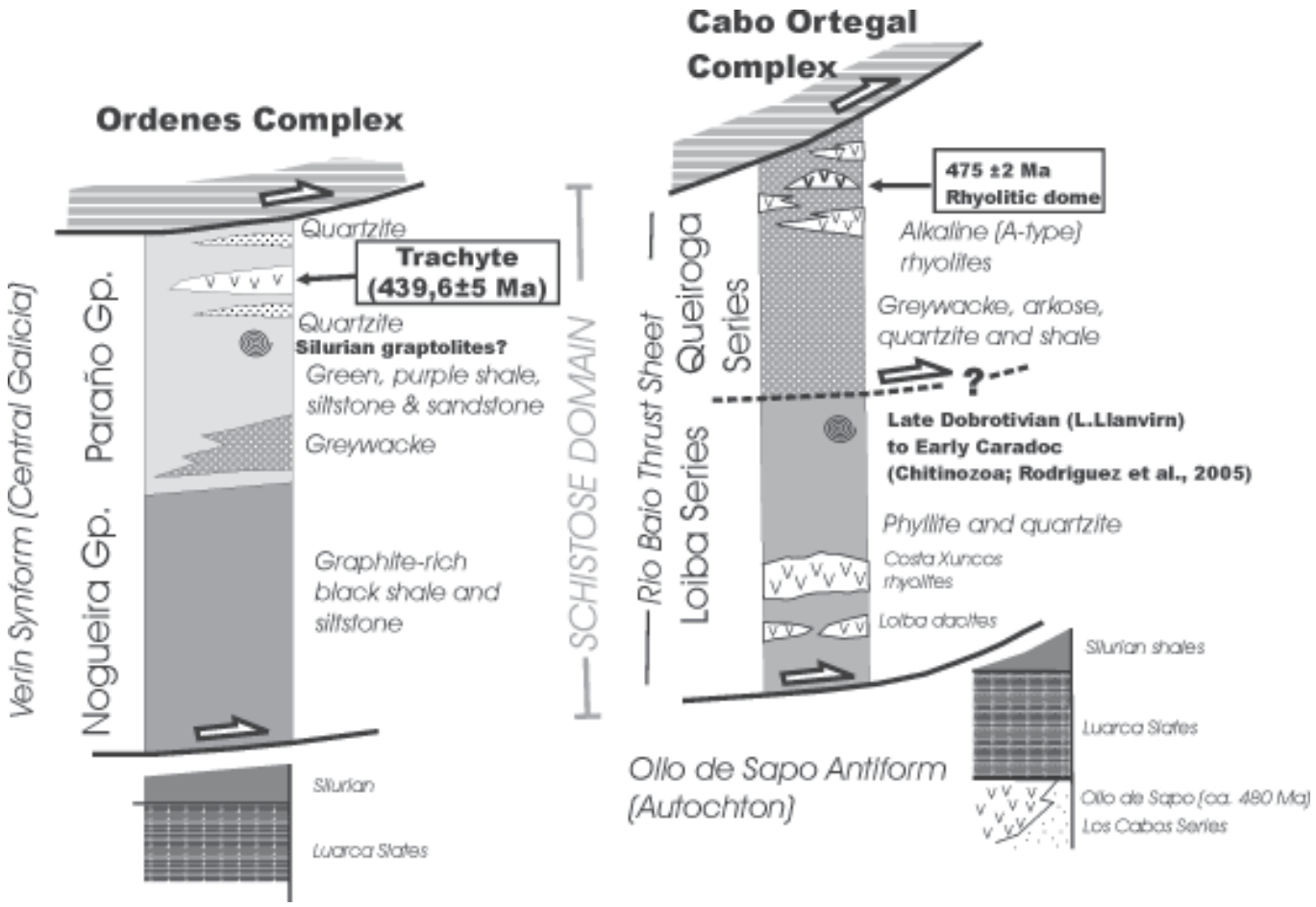

Fig. 4.- Stratigraphic position of the volcanic levels dated by U-Pb (this study; Valverde-Vaquero et al., 2005) in the Schistose Domain of the Galicia-Trás-os-Montes Zone.

Fig. 4.- Posición estratigráfica de los niveles volcánicos datados por U-Pb (este estudio; Valverde-Vaquero et al., 2005) en el Dominio Esquistoso de la Zona de Galicia-Trás-os-Montes.

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