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Correlation of Late Neoproterozoic sequences of the Eastern Pyrenees based on U-Pb (SHRIMP) zircon data

Correlación de las series neoproterozoicas del Pirineo oriental a partir de datos U-Pb (SHRIMP) en zircones

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Abstract: New geochronological data from pre-Variscan igneous rocks of the Eastern Pyrenees (Canigó, Roc de Frausa and Cap de Creus massifs) confirm the presence of Neoproterozoic series in the Pyrenees, as the Balaig micaschists in the Canigó massif and the Lower Series in the Roc de Frausa and Cap de Creus massifs. That is, most of the pre-Upper Ordovician sequence in these massifs has to be Late Neoproterozoic in age. These geochronological data allow the correlation of the series along the Eastern Pyrenean massifs. The data also show two different ages (Late Neoproterozoic and Early Ordovician) and significance for the large bodies of granitic orthogneisses intruded at different levels in the series.

Key words: Late Neoproterozoic, Pyrenees, U-Pb SHRIMP.

Resumen: Se han obtenido nuevos datos geocronológicos en rocas ígneas pre-variscas del Pirineo oriental (macizos del Canigó, Roc de Frausa y Cap de Creus). Se han datado metavulcanitas ácidas interestratificadas en la serie y gneises que derivan de granitos prevariscos. Las rocas metavolcánicas confirman la edad neoproterozoica de los esquistos de Balaig en el macizo del Canigó y de las series inferiores de los macizos del Roc de Frausa y del Cap de Creus. Estos datos implican que la mayor parte de la serie pre-ordoviciana superior tiene edad neoproterozoica y permiten correlacionar las series de los tres macizos. Las dataciones en los gneises evidencian dos edades distintas (neoproterozoica y ordoviciana inferior) para los protolitos intruidos en niveles distintos de la serie.

Palabras clave: Neoproterozoico, Pirineo, U-Pb SHRIMP.

INTRODUCTION

In the Pyrenees, Alpine tectonics has exposed an extensive E-W trending area where a thick pre-Variscan succession crops out (Fig. 1). The lower part of this succession is a thick azoic metasedimentary sequence, pre-Upper Ordovician in age, locally cut by orthogneiss sheets near the base of the sequence (Cavet, 1957; Guitard, 1970) (Fig. 2). The age of this pre-Upper Ordovician series is an unsolved question due to its azoic character. According to its stratigraphical position, this series has been attributed to the Cambro-Ordovician (pre-Caradocian) (Cavet 1957) and correlated with the Cambrian and Ordovician successions of the southern slopes of the Montagne Noire. A Middle/Late Cambrian age (Abad, 1987; Laumonier 1988) or Late Cambrian/Early Ordovician has been proposed for its upper part. *Archaeocyata* of Lower Cambrian age have been found in an isolated outcrop of the Eastern Pyrenees bounded by Alpine faults (Abad, 1987). However, the lack of continuity of this outcrop with the neighboring massifs does not allow any correlation with the pre-Upper Ordovician successions of the Pyrenees.

geochemistry and the improvement in the geochronological methods have allowed an important advance in the reconstruction of the pre-Variscan evolution and the beginning of the Variscan cycle in the European realm. In this sense, recent radiometric dating of interlayered volcanic rocks has given a Neoproterozoic age for the lower part of the succession (581±10Ma, Cocherie et al., 2005). This age arises other questions such as the correlation of this succession with comparable series of the Pyrenean massifs, the position of the Neoproterozoic-Cambrian boundary, the age of the upper part of the succession and the extent and significance of the Upper Ordovician unconformity. We are gaining insight into these problems, through dating and correlating the oldest stratigraphic series present in the Eastern Pyrenees. New geochronological data comes from the low- to- medium-grade Variscan metamorphic areas of the Cap de Creus, Roc de Frausa and Canigó massifs (Castiñeiras et al. submitted). This will allow discussing on the correlation with the late Precambrian to Ordovician series present in the Pyrenees and on the existence of the Cadomian basement.

THE LOWER SERIES OF THE EASTERN PYRENEES

The lower part of the Pre-Upper Ordovician series consists of a thick sequence (up to 3000m) of metapelites and metagreywackes, locally cut by orthogneiss sheets near the base of the sequence. Cavet (1957), in the Canigó massif, divided this succession in two parts, the Canavelles series, forming a lithologically varied lower part and the Jujols series, comprising a more monotonous upper part. A well dated Upper Ordovician series, generally beginning with Caradocian conglomerates (Hartvelt, 1970), lies unconformably over the former metasediments (Casas and Fernández, 2007). The absence of a biostratigraphic control on the pre-Upper Ordovician sequence makes it difficult to evaluate the magnitude of this unconformity. Nevertheless, it is suggested that at least the Lower and

Middle Ordovician sediments might have been removed before the deposition of the Upper Ordovician rocks. The lithologically varied lower series contains abundant centimetric to decametric thick layers of metabasites, rhyodacitic metatuffs, marbles, quartzites and calc-silicates. The orthogneisses may constitute thick units, as in the Canigó massif (about 2km) or thinner (100m) as in the Cap de Creus massif. These common lithological features among the three studied massifs allow us to compare the series, although the three massifs display different characteristics and thicknesses of the series. The Canavelles series of the Canigó massif is similar to the intermediate and upper series of the Roc de Frausa massif. In turn, the Cap de Creus series is characterized by thin interbedded discontinuous layers of plagioclase-amphibole rocks several centimeters thick.

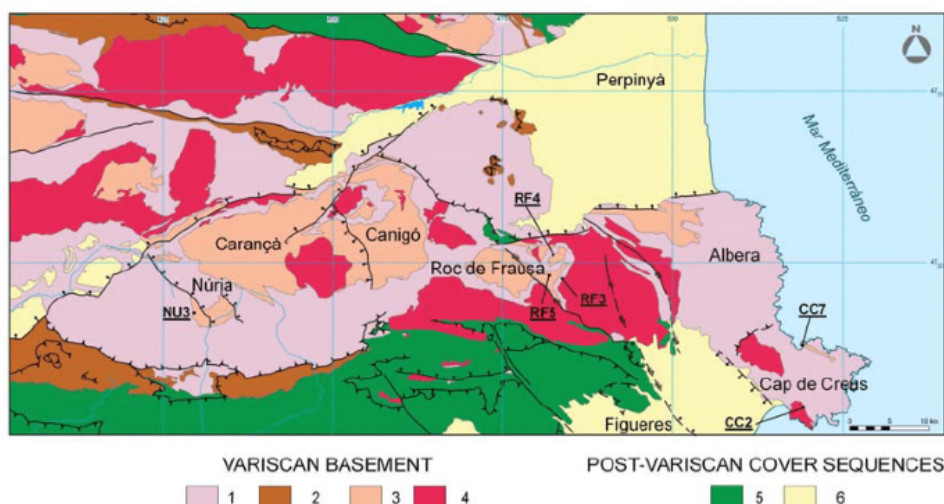


FIGURE 1. Geological sketch of the Variscan basement of the Eastern Pyrenees and cover sequences with location of the stratigraphic columns and the studied samples 1: Pre-Upper Ordovician metasedimentary sequence; 2. Pre-Variscan Paleozoic: Upper-Ordovician-Carboniferous; 3. Orthogneisses; 4. Variscan granitoids; 5. Mesozoic and Paleogene cover sequences; 6. Neogene cover sequences.

THE PRE-VARISCAN IGNEOUS ROCKS

Pre-Variscan volcanic rocks are represented by basaltic andesites transformed to metabasites and by rhyolitic and rhyodacitic tuffs transformed into metatuffs, known as *gneiss granulé* by French geologists (Guitard, 1970). Metatuffs have calc-alkaline affinity and are related to an explosive volcanism. They are especially well developed in the southern slope of the massif, where they form a thick level up to 200 m in the uppermost part of the Canavelles Series, giving rise laterally to conglomerates, black shales, limestones and feldspathic sandstones (Fig. 2). The metatuffs are spatially associated with metabasites, former basalts or basaltic andesites. Protoliths of both lithologies are massive layers of lavas, discontinuous lense shaped subvolcanic gabbroic bodies or volcanoclastic tuffs.

The orthogneisses represent thick laminar intrusions of subaluminous composition. In the Pyrenees, orthogneissic bodies outcrop at different structural positions in the same massif (Fig. 2).

GEOCHRONOLOGICAL DATA

The new geochronological data provide Late Neoproterozoic-Early Cambrian ages (560-540 Ma) for the rhyodacitic metatuffs interbedded in the Pre-Upper Ordovician successions of the three massifs: (560,1±11Ma) for the Cap de Creus tuffs, (548±8Ma) for the Roc de Frausa tuffs and about (540Ma) for the Canigó tuffs. Zircons analyzed in the orthogneisses reveal Ordovician ages (476±7Ma) for the upper gneiss layer of the Roc de Frausa massif and Late Neoproterozoic-Early Cambrian ages for the lower gneiss layer of this massif (Mas Blanc gneisses, 560±7Ma) and for the Port gneisses (553±4Ma) in the Cap de Creus massif. Mas Blanc and Port gneisses can

be interpreted as the plutonic equivalents of the Late Neoproterozoic-Early Cambrian volcanics and their age represents their emplacement age.

DISCUSSION

Geochronological data allows to propose the acid metatuffs as a key level to correlate between study massifs. Comparable Late Neoproterozoic-Early

Cambrian age for acid metavolcanics furnishes a reference data between the three different areas.

The upper and intermediate units of the Roc de Frausa are similar to the lower sequences of the Canigó Massif. Metavulcanites dated by us and by other authors (Cocherie *et al.*, 2005) give comparable radiometric ages (~550Ma), so correlation of the series is straightforward. The metavolcanic layers of the Cap de

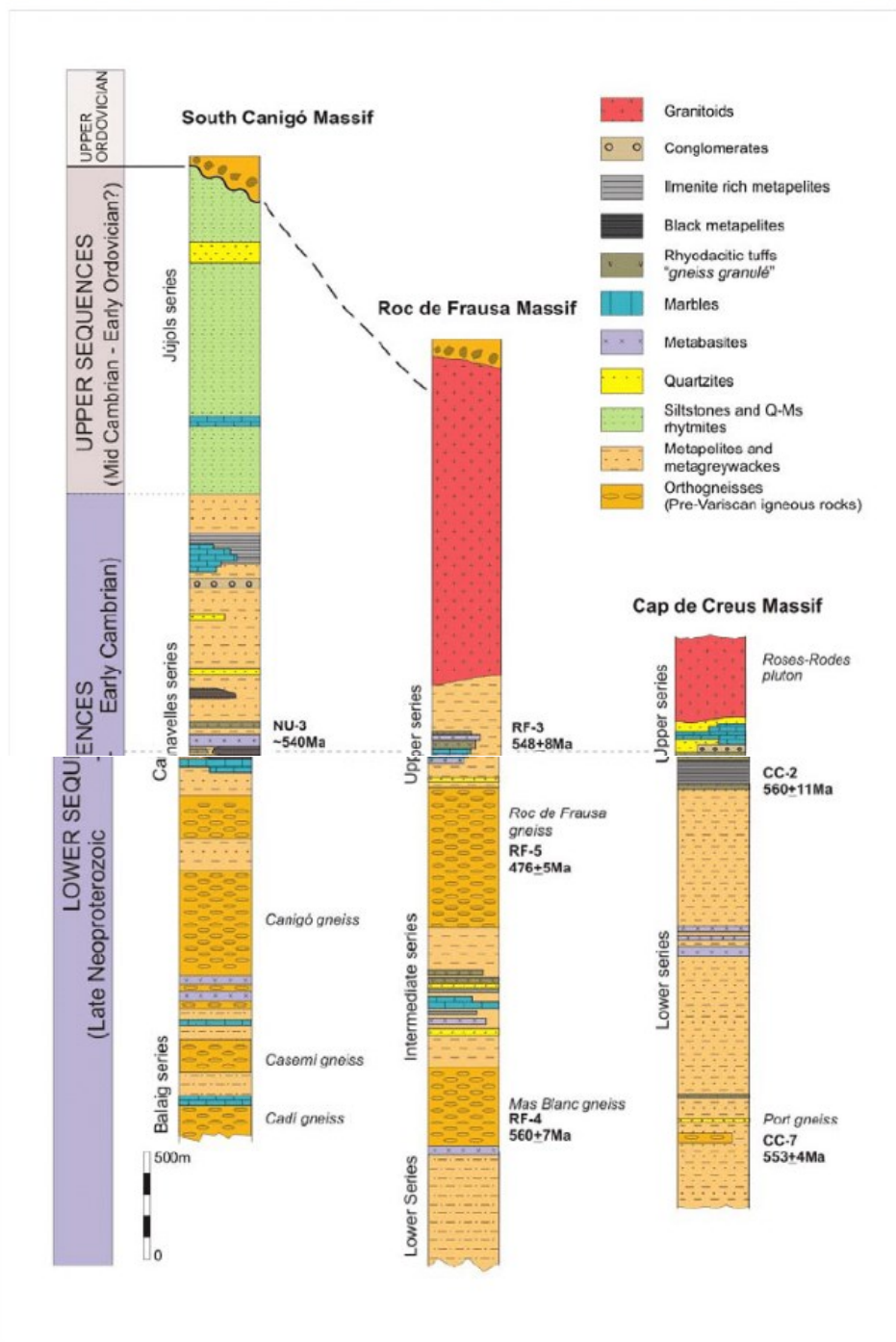


FIGURE 2. Synthetic stratigraphic columns of the pre-Upper Ordovician rocks of the Canigó, Roc de Frausa and Cap de Creus massifs with the location of the studied samples.

Creus (560 ± 11 Ma) allow correlation with the Roc de Frausa and Canigó metavulcanites, although lithological characteristics of the Cap de Creus sequence are different to the sequences of the other two massifs.

The Upper sequence of the Canigó Massif is lacking in the Roc de Frausa and Cap de Creus massifs. In this massifs, Variscan granitic stratoid intrusion (La Jonquera and Roses-Rodes granites) are emplaced in between the upper unit and the Upper Ordovician metasediments. We propose that the Neoproterozoic-Cambrian boundary can be located in the lithological varied group located on top of the Lower Sequences in the Canigó massif (Fig. 2). In the Roc de Frausa and the Cap de Creus this boundary is not visible as the Variscan granitoids truncates the sequences. The age of the lowermost series in the three massifs, Balaig series in the Canigó massif, and Lower series in Roc de Frausa and Cap de Creus massifs, remains unsolved, although a Neoproterozoic age (more than 600 Ma?) can be proposed.

The Roc de Frausa orthogneisses (476.2 ± 7.3 Ma) are comparable in age to the Canigó gneisses (471 ± 8 Ma, Cocherie et al., 2005) and they represent the eastern termination of the Canigó laccolith. These orthogneisses are the result of a widespread Early Ordovician magmatic event in the Pyrenees and in the rest of the European Variscides (Delaperrière and Lancelot, 1989; Roger et al., 2004). The Mas Blanc gneisses are similar in age (560.1 ± 7.3 Ma) to the Port gneiss (576.4 ± 8.1 Ma). This older magmatism could be related to the final stages of the Cadomian orogeny.

These data provide a better fit of the pre-Variscan rocks of the Pyrenees with the rest of the Iberian Massif, characterized by the large development of Precambrian series and the presence of volcanic and plutonic bodies ranging from Late Neoproterozoic to Ordovician in age. Moreover, new data confirm the absence of a Cadomian basement in the Pyrenees. The presence of such a Cadomian basement constructed as a result of Late Cadomian-Cambrian deformation and metamorphism has been object of controversy in other areas of the Iberian massif.

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