



Late Ordovician (post-Sardic) rifting branches in the North Gondwanan Montagne Noire and Mouthoumet massifs of southern France



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ABSTRACT

Upper Ordovician–Lower Devonian rocks of the Cabrières klippen (southern Montagne Noire) and the Mouthoumet massif in southern France rest paraconformably or with angular discordance on Cambrian–Lower Ordovician strata. Neither Middle-Ordovician volcanism nor associated metamorphism is recorded, and the subsequent Middle-Ordovician stratigraphic gap is related to the Sardic phase. Upper Ordovician sedimentation started in the rifting branches of Cabrières and Mouthoumet with deposition of basaltic lava flows and lahar deposits (Roque de Baudies and Villerouge formations) of continental tholeiite signature (CT), indicative of continental fracturing.

The infill of both rifting branches followed with the onset of (1) Katian (Ka1–Ka2) conglomerates and sandstones (Glauzy and Gascagne formations), which have yielded a new brachiopod assemblage representative of the *Svobodaina havliceki* Community; (2) Katian (Ka2–Ka4) limestones, marlstones, and shales with carbonate nodules, reflecting development of bryozoan–echinoderm meadows with elements of the *Nicolella* Community (Gabian and Montjoi formations); and (3) the Hirnantian Marmairane Formation in the Mouthoumet massif that has yielded a rich and diverse fossil association representative of the pandemic Hirnantia Fauna. The sealing of the subaerial palaeorelief generated during the Sardic phase is related to Silurian and Early Devonian transgressions leading to onlapping patterns and the record of high-angle discordances.

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1. Introduction

The so-called Sardic Phase was originally described in SW Sardinia (Stille, 1939) as an “early Caledonian” structural event characterized by an angular unconformity associated with metallogenic emplacement of ore deposits, E–W-trending faulting, and mild folding. After Mid-Ordovician emergence and erosion, sedimentation was renewed with the record of the alluvial to fluvio-lacustrine Puddinga Beds (Barca et al., 1986; Caron et al., 1997; Martini et al., 1991). In contrast, central–northern Sardinia is characterized by the emplacement of a Middle-Ordovician, sub-alkalic calc-alkalic volcanic suite, constrained between Arenig and Caradoc metasediments and dated at 465.4 ± 1.4 Ma by U–Pb methods (Oggiano et al., 2010). This geodynamic contrast in Sardinia has argued in favor of several interpretations, such as (1) the development of Mid Ordovician intracratonic rifting, controlled by extensional tectonics coeval with compressive tectonics in SW

Sardinia (e.g., Minzoni, 2011), and (2) the emplacement of an Andean-type arc (e.g., Oggiano et al., 2010). In any case, a relative agreement exists on the interpretation of an alkaline volcanic activity encased across the Ordovician–Silurian transition. Volcanic products are associated with Hirnantian glacial diamictites, and interpreted as the onset of rifting pulses (subsequent to the Sardic Phase) responsible for deposition of “puddinga” beds and drastic variations in thickness (Helbing and Tiepolo, 2005; Lehman, 1975; Leone et al., 1991; Ricci and Sabatini, 1978).

Similar discussions about the geodynamic interpretation of laterally equivalent Sardic unconformities (interpreted as both orogenic subduction and transpressive–transtensive modifications of the Rheic Ocean opening patterns) were subsequently reported in eastern Pyrenees (Casas, 2010; Casas and Fernández, 2007; Casas et al., 2010, 2014; Delaperrière and Soliva, 1992; Navidad et al., 2010) and the Alps (Franz and Romer, 2007; Guillot et al., 2002; Handy et al., 1999; Schaltegger et al., 2003; Stampfli et al., 2002; Zurbriggen, 2015; Zurbriggen et al., 1997).

The presence of pseudo-Caledonian deformation pulses, broad Middle Ordovician gaps, and associated volcanics was also reported in the Cabrières klippen of the southern Montagne Noire (Arthaud et al.,

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1976; Boulange and Boyer, 1964; Engel et al., 1980–81; Feist and Etchler, 1994; Gèze, 1949; Gonord et al., 1964) and in the Mouthoumet massif (Berger et al., 1990, 1993, 1997; Bessière and Baudelot, 1988; Bessière and Schulze, 1984; Bessière et al., 1989; Cornet, 1980; Durand-Delga and Gèze, 1956; Gaertner von, 1937; Ovtracht, 1967; Vila, 1965) (Figs. 1 and 2). However, their geodynamic interpretation was dramatically constrained by the lack of a detailed biochronologic control on the stratigraphic framework and geochemical information of their associated Upper Ordovician volcanic complexes. The aims of this paper are (1) to diagnose the time-stratigraphic Mid-Ordovician (Sardic) gap in the Cabrières klippe of the southern Montagne Noire and its neighboring Mouthoumet massif (North Gondwana); (2) to document a reviewed and updated lithostratigraphic framework for the Upper Ordovician (post-Sardic) volcanosedimentary complexes and strata, coupled with a new biostratigraphic sketch controlled by new brachiopod and trilobite assemblages; (3) to characterize the petrography and geochemistry of the associated magmatic activity; and (4) to place this multidisciplinary approach in a North Gondwanan geodynamic context.

2. Geological background

The southern Montagne Noire represents the southernmost part of the French Massif Central. It consists of a framework of nappes and slices, marked in its southeastern edge by the so-called Cabrières klippe (Fig. 3). There, the Upper Ordovician partly infills the Carboniferous–Permian Gabian–Neffiès Basin (*sensu* Gèze, 1949) and forms the summits of the “Grand Glauzy” and “Roque de Bandies” hills, which give names to their homonymous lithostratigraphic units. The Upper Ordovician succession occurs as wild-flysch deposits with exotic blocks of various post-Cambrian ages emplaced by gravity slides

(Engel et al., 1978, 1979; Feist and Etchler, 1994). Exposures of some of these olistolithic blocks allow reconstruction of a nearly complete Lower Ordovician succession including the St Chinian, Maurérie, Cluse de l’Orb, and Landeyran formations (see Álvaro et al., 2014; Vizcaino and Álvaro, 2001, 2003). Unconformably overlying the Lower Ordovician (Bérard, 1986; Gèze, 1949; Thorval, 1935), three lithostratigraphic units are differentiated, from bottom to top (Fig. 4): (1) volcanoclastic deposits associated with interstratified lava flows crosscut by rhyolitic dykes (Gonord et al., 1964), unnamed and with its upper contact broadly dated as Mid-Ordovician by means of acritarchs (F. Martin, *op. cit.* in Nysæther et al., 2002); (2) the Katian (Ka1–Ka2; Caradoc) siliciclastic Glauzy Formation (Colmenar et al., 2013); and (3) the Katian (Ka2–Ka4; Ashgill), mixed (carbonate-siliciclastic) Gabian Formation (Colmenar et al., 2013). The top of the Upper Ordovician is marked by an erosive unconformity that marks the base of Llandovery, graptolite-bearing, black shales, locally known as “tranche noire” (Babin et al., 1988; Centène and Sentou, 1975; Štorch and Feist, 2008).

The Mouthoumet massif lies south of Montagne Noire and north of the North Pyrenean frontal thrust (the latter *sensu* Laumonier, 2015). The massif contains four tectonostratigraphic units, from east (tectonically top) to west (bottom), the Serre de Quintillan, the Félines-Palairac, and the Roc de Nitable thrust slices, and an unnamed parautochthon (Berger et al., 1997; Bessière and Baudelot, 1988; Bessière and Schulze, 1984; Bessière et al., 1989; Cornet, 1980) (Fig. 3). The Ordovician lithostratigraphic subdivision of Mouthoumet has been traditionally reported as informal lithological units compared to neighboring formations from the southern Montagne Noire (Cabrières klippe) and eastern Pyrenees (e.g., Berger et al., 1997; Bessière et al., 1989; Gèze, 1949). As in the case of the Pyrenees and Montagne Noire, the Middle-Ordovician is absent and its gap allows differentiation between a Lower Ordovician sedimentary sequence and an unconformably

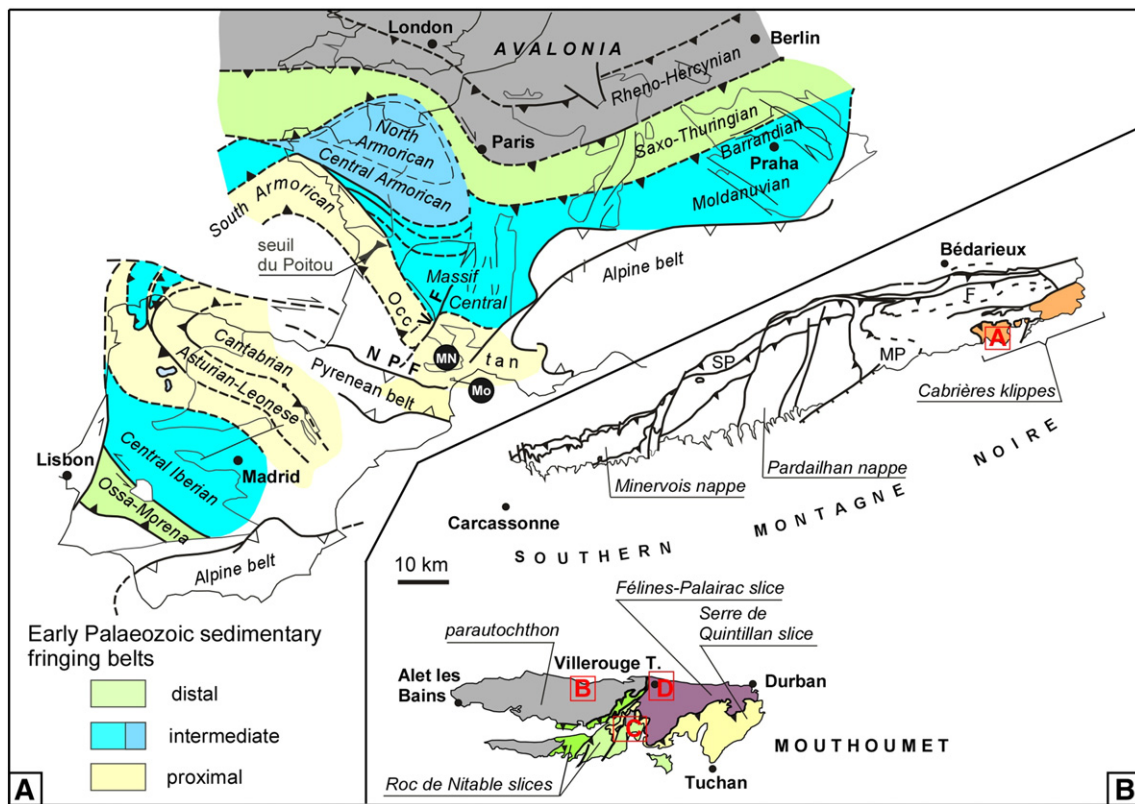


Fig. 1. (A) Major Variscan tectonostratigraphic units of SW Europe with location of the Montagne Noire and Mouthoumet massifs. (B) Variscan nappes and thrust slices of the southern Montagne Noire and Mouthoumet massifs; study areas are colored. Abbreviations: A–D: boxes in Fig. 3; F: Faugères nappe; MN: Montagne Noire; Mo: Mouthoumet massif; MP: Mont Peyroux nappe; NPF: North Pyrenean Fault; SP: St. Pons nappe; VF: Villefrance (or Sillon Houiller) Fault.

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