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Constraining the Permian/Triassic transition in continental environments: Stratigraphic and paleontological record from the Catalan Pyrenees (NE Iberian Peninsula)

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ABSTRACT

The continental Permian–Triassic transition in southern Europe presents little paleontological evidence of the Permian mass extinction and the subsequent faunal recovery during the early stages of the Triassic. New stratigraphic, sedimentological and paleontological analyses from Middle–Upper Permian to Lower–Middle Triassic deposits of the Catalan Pyrenees (NE Iberian Peninsula) allow to better constrain the Permian–Triassic succession in the Western Tethys basins, and provide new (bio-) chronologic data. For the first time, a large vertebra attributed to a caseid synapsid from the ?Middle Permian is reported from the Iberian Peninsula—one of the few reported from western Europe. Osteological and ichnological records from the Triassic Buntsandstein facies reveal a great tetrapod ichnodiversity, dominated by small to medium archosauromorphs and lepidosauromorphs (*Rhynchosauroides* cf. *schochardti*, *R.* isp. 1 and 2, *Prorotodactylus*–*Rotodactylus*), an undetermined Morphotype A and to a lesser degree large archosaurians (chirotheriids), overall suggesting a late Early Triassic–early Middle Triassic age. This is in agreement with recent palynological analyses in the Buntsandstein basal beds that identify different lycopod spores and other bisaccate and taeniate pollen types of late Olenekian age (Early Triassic). The Permian caseid vertebra was found in a playa-lake setting with a low influence of fluvial water channels and related to the distal parts of alluvial fans. In contrast, the Triassic Buntsandstein facies correspond to complex alluvial fan systems, dominated by high-energy channels and crevasse splay deposits, hence a faunal and environmental turnover is observed. The Pyrenean biostratigraphical data show similarities with those of the nearby Western Tethys basins, and can be tentatively correlated with North African and European basins. The Triassic Pyrenean fossil remains might rank among the oldest continental records of the Western Tethys, providing new keys to decipher the Triassic faunal biogeography and recovery.

1. Introduction

The Permian–Triassic mass extinction represents one of the most extensively studied climatic and biological crises in the history of Earth (e.g., Erwin, 1994; Benton and Twitchett, 2003; Sahney and Benton, 2008; Benton and Newell, 2014; Smith and Botha-Brink, 2014). The extinction led to a profound remodeling of the ecosystems and a vertebrate faunal turnover (Benton et al., 2004) that covered a geologically short to extremely short period of time (Bowring et al., 1998; Ward et al., 2005). The Middle–Late Permian continental successions have been accurately constrained by tetrapod remains from Russia (Benton

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et al., 2004, 2012; Surkov et al., 2007), Morocco (Voigt et al., 2010), France (Gand et al., 2000; Reisz et al., 2011), Italy (Valentini et al., 2007, 2009; Avanzini et al., 2011; Bernardi et al., 2015), Brazil (e.g., Cisneros et al., 2012, 2015; Costa da Silva et al., 2012), China (e.g., Xu et al., 2015) and South Africa (e.g., Smith and Botha-Brink, 2014), whereas the earliest part of the Triassic provides a much more scarce paleontological record. In fact, most of the Early Triassic continental record is late Olenekian in age, with the exception of a few areas and basins with Induan sediments and vertebrate fossils (e.g., the South African Karoo Basin, Smith and Botha-Brink, 2014, or the Russian East European Platform, Benton et al., 2004).

Accordingly, the basal Triassic record of the Iberian Peninsula and Balearic Islands has not yet been documented, as the older Triassic successions have been attributed to a late Early Triassic (Olenekian) age (Dinarès-Turell et al., 2005; Linol et al., 2009; Bourquin et al., 2011; López-Gómez et al., 2012; Galán-Abellán et al., 2013; Borruel-Abadía et al., 2015). Until now, vertebrate fossils have been characterized only from the Middle and Late Triassic of both fluvial and coastal–alluvial facies (e.g., Calzada, 1987; Demathieu and Saiz de Omeñaca, 1990; Pérez-López, 1993; Gand et al., 2010; Fortuny et al., 2011a,b; Díaz-Martínez and Pérez-García, 2012; Mateus et al., 2014; Brusatte et al., 2015; Díaz-Martínez et al., 2015; Mujal et al., 2015 and references therein).

In the Catalan Pyrenean Basin (NE Iberian Peninsula), Robles and Llompart (1987) reported tetrapod footprints that correlated the equivalent fossil-bearing red sediments to the Late Permian. Moreover, in the nearby Palanca de Noves tracksite (Ribera d'Urgellet, Catalonia), Fortuny et al. (2010) preliminarily identified four morphotypes of tetrapod footprints, here re-described and analyzed in detail. However, the age of this unit, together with the geology of this area, is still a subject of uncertainties. Here we present new geological, paleontological (i.e., vertebrate assemblages), and palynological data from the Permian and Triassic sequences of selected areas of the Catalan Pyrenees. Our data, framed in an interregional stratigraphic picture (i.e., Spanish Cantabrian Mountains, northern Italy, northern Morocco and southern France), precise with more confidence the transition from the Permian to the Triassic periods, and sheds light on the first onset of recovery after the end-Permian mass extinction of the Western Tethys.

2. Geological setting

All the studied tetrapod remains come from the continental succession that includes the Upper Carboniferous (?)–Lower Triassic of the Gramós Basin in the SE Catalan Pyrenees (Fig. 1). Since the last century this stratigraphic succession has been described from a sedimentological, petrological, structural and stratigraphical point of view (e.g., Viennot, 1929; Dalloni, 1930; Schmidt, 1931; Ashauer, 1934; Mey et al., 1968; Nagtegaal, 1969; Hartevelt, 1970; Gisbert, 1981; Martí, 1983; Speksnijder, 1985; Saura, 2004; Saura and Teixell, 2006; Pereira et al., 2014; Gretter et al., 2015). In this work we have adopted the most recent unit subdivision (Gisbert, 1981), comparing it with others (e.g., Mey et al., 1968; Nagtegaal, 1969). The Stephanian–

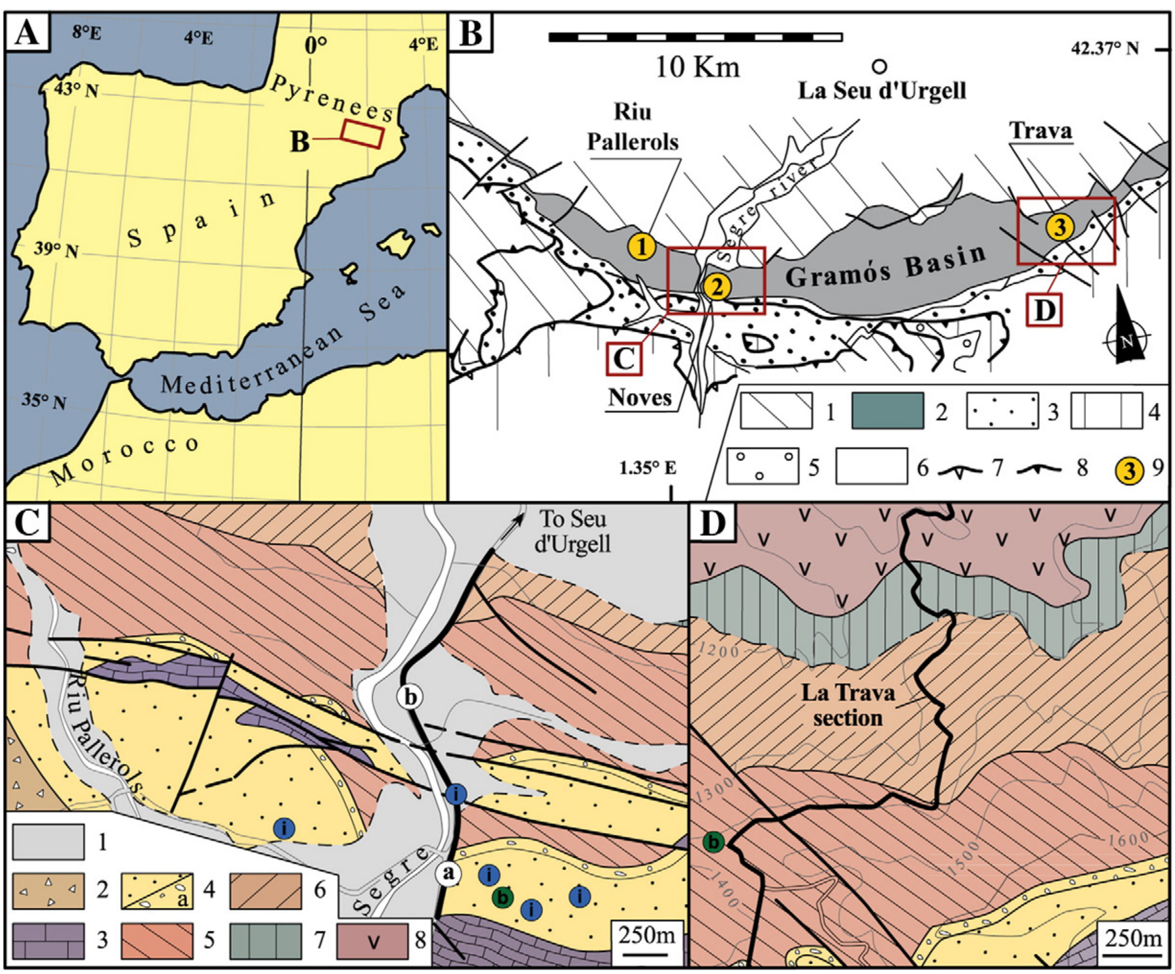

Fig. 1. A–B) Geographic location and simplified geological map of studied areas (modified from Hartevelt 1970; Saura and Teixell 2006). (1) Variscan Basement (2) Stephano-Permian deposits (3) Triassic (4) Jurassic–Cretaceous (5) Cenozoic cover (6) Quaternary (7) Alpine backthrusts (8) South-directed thrusts (9) Location of sampling sites and of measured sections. **C–D**) Geological sketch map of the Segre Valley and La Trava area: (1) Alluvial deposits, (2) Middle and Upper Triassic deposits, (3) Muschelkalk, (4) Buntsandstein, (5) Upper Red Unit, (6) Lower Red Unit, (7) Transition Unit, 8) Grey Unit (volcanic rocks).