

A review of the Late Cambrian (Furongian) palaeogeography in the western Mediterranean region, NW Gondwana

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Abstract

The Cambrian–Ordovician transition of the western Mediterranean region (NW Gondwana) is characterized by the record of major erosive unconformities with gaps that range from a chronostratigraphic stage to a series. The *hiatus* are diachronous and involved progressively younger strata along the Gondwanan margin, from SW (Morocco) to NE (Montagne Noire). They can be related to development of a multi-stage rifting (further North), currently connected to the opening of the Rheic Ocean, and concomitant erosion on southern rift shoulders. The platforms of this margin of Gondwana occupied temperate-water, mid latitudes and were dominated by siliciclastic sedimentation, while carbonate factories were only episodically active in the Montagne-Noire platform.

The Upper Cambrian is devoid of significant gaps in the southern Montagne Noire and the Iberian Chains. There, the sedimentation took place in a transgressive-dominated depositional system, with common offshore deposits and clayey substrates, and was bracketed by two major regressive trends. The Late Cambrian is also associated with the record of volcanic activity (*e.g.*, in the Cantabrian and Ossa-Morena zones, and the northern Montagne Noire), and widespread development of a tectonic instability that led to the episodic establishment of palaeotopographies and record of slope-related facies associations.

Several immigration events are recognized throughout the latest Middle Cambrian, Late Cambrian and Tremadocian. The trilobites show a stepwise replacement of Acado-Baltic-type families (*e.g.*, the conocoryphid–paradoxidid–solenopleurid assemblage) characterized by: (i) a late Languedocian (latest Middle Cambrian) co-occurrence of Middle Cambrian trilobite families with the first anomocarid, dorypygid and proasaphiscid invaders; (ii) a Late Cambrian immigration replacing previous faunas, composed of trilobites (aphelaspids, catillicephalids, ceratopygids, damesellids, eulomids, idahooids, linchakephalids, lisariids, onchonotinids, and pagodiids), linguliformean brachiopods (acrotretids, obolids, scaphelasmatis, siphonotretids, and zhanatellids), echinoderms (mitrates, glyptocystitid cystoids, and stromatocystoids), and conodonts belonging to the lower *Peltura* Zone; and (iii) the subsequent input of new trilobites (asaphids, calymenids, catillicephalids, nileids and remopleurids), which

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marks the base of the *Proteuloma geinitzi* Zone, associated with pelmatozoan holdfasts (*Oryctoconus*), and a distinct input of late Tremadocian conodonts (*Paltodus deltifer* Zone).

The biogeographic distribution of latest Middle and Late Cambrian trilobites supports brachiopod data indicating strong affinities between the western Mediterranean region, East Gondwana (North China/Korea, South China, Australia, and Antarctica) and Kazakhstan during the late Languedocian, which became significantly stronger during the Late Cambrian. This major shift may suggest modification in oceanic circulation patterns throughout Gondwana across the Middle–Late Cambrian transition.

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1. Introduction

The geological setting of Late Cambrian sedimentary basins bordering NW Gondwana reflects the presence of extensive shallow-water intra- and epicratonic seas. The identification of Late Cambrian fossils and correlation of their respective strata throughout the western Mediterranean region (herewith applied to Morocco, the Iberian Peninsula, France and Sardinia) have been currently constrained by the abundance of stratigraphic gaps, condensed strata and scarcity of shelly fossils, many of which are exclusively endemic and unavailable for intercontinental correlation, as well as by the paucity of calcareous levels suitable for conodont investigation. There, the Late Cambrian represents a transitional time span between: (i) rifting processes recorded across the Neoproterozoic–Cambrian transition in Ossa-Morena (southern Iberian Peninsula; Sánchez-García et al., 2003) and Morocco (Gasquet et al., 2005); and (ii) a succession of magmatic episodes and tectonic perturbations that precluded the opening of the Rheic Ocean. This was the result of the drift of peri-Gondwanan terranes, such as Avalonia and Carolina from West Gondwana (see, e.g., Prigmore et al., 1997; Stampfli et al., 2002; Murphy et al., 2006; but see Landing, 2005, for another point of view). Upper Cambrian strata of the western Gondwanan margin also recorded a major palaeoclimatic influence related to its southward drift that led to a gradual cooling of waters, grading from Early Cambrian subtropical to Late Ordovician subpolar settings (Álvaro et al., 2000, 2003a), and a distinct immigration of East Gondwanan invaders that reached its peak during the late Languedocian (latest Middle Cambrian) and Late Cambrian (Courtessole et al., 1988; Álvaro et al., 1999; Shergold et al., 2000).

The aim of this paper is to document the sedimentary response recorded in NW Gondwana to the opening of the Rheic Ocean and the southward drift into temperate waters during the Late Cambrian. For this, we offer an integrated stratigraphic framework of the Upper Cam-

brian from the western Mediterranean region, based on litho-, bio-, and ecostratigraphic analyses, sequence- and event-stratigraphic approaches, and reconstruction of benthic community replacements. We are confident that this work might be of some help to overcome the difficulties to apply the recently erected Furongian Series in this margin of Gondwana.

2. The Furongian Series

Numerous regional chronostratigraphic subdivisions of the Upper Cambrian have been traditionally used all over the world (e.g., Shergold, 1982; Rushton, 1983; Ludvigsen and Westrop, 1985; Zhang and Jell, 1987; Chang, 1988; Ergaliev, 1990; Palmer, 1998; Geyer and Shergold, 2000; Peng and Robison, 2000; Peng et al., 2001a; Peng and Babcock, 2001; Ahlberg, 2003). Recently, the *International Subcommittee on Cambrian Stratigraphy* selected for the base of a new globally applicable Upper Cambrian Series boundary (named the Furongian Series) the base of the *Glyptagnostus reticulatus* Zone (Shergold and Geyer, 2001).

The agnostoid trilobite *G. reticulatus* has one of the broadest palaeobiogeographic distributions of any Cambrian trilobite. It has been identified in Antarctica, Argentina, Australia, Canada, China, Denmark, Kazakhstan, Norway, Russia, South Korea, Sweden, UK, and USA. *G. reticulatus* is used as a zonal guide fossil in Australia, Kazakhstan, Laurentia, Siberia, and South China (Geyer and Shergold, 2000; Peng and Robison, 2000). Co-occurrences with other agnostoid and polymeroid trilobites allow correlation with Argentina (lower *Aphelaspis* Zone/lower *G. reticulatus* Zone-equivalent; Shergold et al., 1995) and Baltica (*Homagnostus obesus* Zone; Ahlberg, 1998). In addition, the combination of cosmopolitan agnostoids, Gondwanan shelf-dwelling polymeroids, cosmopolitan tropical polymeroids, and other polymeroids from the Jiangnan Slope Belt, where the Furongian was formally defined (Peng et al., 2001b), allows a useful

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