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## Comments on the Cambrian biogeography of Spain

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### ABSTRACT

*The Cambrian faunas recorded in the different areas of the Hesperian Massif do not support evidences of a marked biogeographical differentiation in the Iberian Peninsula throughout this Period. The vertical variations shown by the trilobite and archaeocyathid associations are related to more global factors as are a certain climatic uniformity, the proximity of the Gondwanan continent and the opening of a Mideuropean Ocean.*

### RESUMEN

*Las asociaciones fosilíferas del Cámbrico reconocidas en las distintas áreas del Macizo Hespérico no aportan evidencias positivas que revelen una diferenciación biogeográfica acusada dentro de la Península Ibérica durante este periodo. La variación vertical de las asociaciones de trilobites y arqueociatos está relacionada con factores más generales como una cierta uniformidad climática, la proximidad del continente de Gondwana y la apertura del océano Centro-europeo.*

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**Key words:** Cambrian, paleobiogeography, faunal dynamics, Acado-baltic Province.

### Comments on the Cambrian biogeography of Spain

The Spanish Cambrian materials contain mainly trilobites and archaeocyathids (restricted to the lower part), and to a lesser extent brachiopods, echinoderms, molluscs, hyolithids, colonial scyphopolyps, porifera, algae, stromatolites, Palaeoscolecida, trace fossils and Problematica.

The study of the Spanish Lower Cambrian fossils has allowed to divide the materials of this Epoch into three stages (Ovetian, Marianian and Bilbilian), following mainly the vertical range and biogeographical context of the trilobite associations (17). These latter are represented by 50 species

belonging to 36 genera of Ellipsocephalacea, Redlichiaacea, Olenellacea, Conocoryphacea, Solenopleuracea and Eodiscina (8, 13, 14). A recent work on the coeval archaeocyathid assemblages has allowed to recognize 11 successive biozones (10), detailing even more the tripartite division of the Iberian Lower Cambrian and providing a more accurate correlation with regard to the standardised Siberian Stages and Series. The archaeocyathids are represented in Spain by 114 species belonging to 48 genera.

The Iberian Middle Cambrian fossils, with an abundant trilobite fauna, are well-known. There have been recorded 93 trilobite species, belonging to around 30 genera of Solenopleuracea, Conocoryphacea, Parado-

xidacea, Ellipsocephalacea, Corynoxochacea and Agnostacea (5, 6, 9, 13, 15, 16). The materials of this Epoch have been also divided into three stages in terms of the vertical range of their associations, provisionally designated as *Stage with Aca-doparadoxides*, *Stage with Solenopleuropsidae* and *Stage without Solenopleuropsidae* (13, 16).

After a detailed examination of the biogeographical aspects of the Spanish Lower and Middle Cambrian faunas, the first conclusion is that there are not marked differences between the coeval associations of the currently considered zones within the Hesperian Massif, except for variations due to lithological changes. This is exemplified by the replacement of *Asturiaspis*

by *Acadolenus* in the lower Middle Cambrian, typical trilobite genera of carbonate and shale facies, respectively; and the restriction of some genera to specific lithologies, such as *Badulesia*, characteristic of pelitic facies (15).

The Iberian Lower and Middle Cambrian trilobite associations have been considered by SDZUY (19) as representatives of the mediterranean subprovince of the Acado-baltic faunal province, which comprised during both Epochs at least Europe, the Acadian part of North America, Morocco and Turkey, and whose trilobites are well differentiated from the Laurentian faunas of the «pacific province», providing the existence of the Iapetus at that time. However, the general delination of the faunal provinces is not clear for the Lower Cambrian, since none of them are completely exclusive of the others. In this sense, and according to ROSS (12), «no amount of rearrangement of continental platforms seems to satisfy all the distributional problems encountered for Cambrian fossils». Archaeocyathids, for instance, are well represented in the Lower Cambrian of Spain, Morocco and Sardinia, and although their wide distribution around the world does not clearly suggest faunal provinces, one of a frequent suggestion is that these organisms as reef formers indicate warm-water conditions at a palaeoequatorial position, being possibly equivalent during these times to the late corals. This comes into controversy with the recent and reexamined Cambrian palaeomagnetic data from southern Europe and Gondwanaland (1,11), which indicate that the two plates were juxtaposed at 40 to 67 degrees of southern palaeolatitude. Additionally, of all the archaeocyathid species described in Spain, a 70% consists of endemic plus mediterranean forms (sardic-moroccan), but the remaining 30% is exclusively composed by Siberian species. The same asiatic affinities are also recognized among the coeval Ovetian and Marianian trilobites including well represented genera of the Atdaban and Botoma Stages of the Siberian succession, like *Triangulaspis*, *Pagetillus*, *Judomia*, *Anadoxides*, *Callodiscus schucherti*, *Bonnaspis acinosa* and several Redlichids. These relationships are inconsistent with the up to now palaeogeographical reconstructions,

which do not satisfactory explain the trilobite dispersal of the Gondwanan *Fallotaspis* Zone (Ovetian) to the Cordilleran region of Laurentia. The presence of archaeocyathids in Gondwanan latitudes may be explained by the global existence of a relatively warm climate during the Lower Cambrian, favoured by the effect of an extremely conductive carbon-dioxide rich atmosphere, long time before the first land plants became abundant. In contrast with what it occurs in the Ordovician, the suggested distribution of the trilobite provinces during Cambrian times does not provide evidences of latitudinal variations of water temperatures, and therefore its distributional patterns largely depended on other factors such as lithological control (deep to shallow, and clastic to carbonatic environments), as well as on the presence of physical barriers to migration.

One of these latter is the precaledonian Iapetus which prevented the faunal interchange between the cratonic North American and European faunas throughout the Cambrian and Ordovician Periods, and with remnants in the Silurian, except for specific episodes like the Upper Ordovician «provincial breakdown», related rather to the Caradoc global regressive-transgressive event than to large scale plate movements (4). The opening towards the East of a Mideuropean Ocean during the late Lower Cambrian finished the progression of new Siberian immigrants and promoted the progressive differentiation of the nordic and mediterranean faunas within the Acado-baltic province, whose mixed sequence can be only observed in eastern Newfoundland and in scattered localities of the British Isles (18, 19). At the same time, typical acadobaltic elements, like *Paradoxides*, migrated along the Gondwanaland margins towards the West, reaching South America (Colombia, Bolivia and Venezuela) and towards the East as far as western Mongolia. This oriental pathway was used in an inverse sense by other immigrants, which coming from the middle East reached the Montagne Noire in the latest Middle Cambrian, favouring subsequently the arrival to the center of the mediterranean region of some other «asian invaders» such as trilobites and brachiopods during Upper Cambrian times (2, 3, 20). Neverthe-

less, this incursion is not necessarily related with the «opening» of the Mideuropean Ocean, but with a biogeographic continuity around the epicratonic platforms of Gondwanaland, similar to the migrations of the *Senonopeltis* faunal elements which in an inverse sense used the same pathway during the Middle Ordovician (17). The non-existence of Upper Cambrian trilobites with asiatic affinities in other sites of the Acado-baltic province, specially in its northern region, may be related to the great extension reached by a particular biofacies with Olenid trilobites, indicative of external sites at or near the edges of the oceanic continental shelves. Some of these trilobites were pelagic, reaching a wide interprovincial dispersal, like the genus *Irwingella*, recorded in the Upper Cambrian of Laurentia, the Acado-baltic province and in a great diversity of facies within the oriental provinces, in which had their origins the asiatic elements known in the mediterranean region. That is why Leiostegiacean, Solenopleuracean and Aphelaspidines, with asiatic affinities, represent the shallow water biofacies, equivalent to the Olenid or Olenid-Asaphid biofacies of the external sites, and whose wide peri-Gondwanan distribution shares the same signification with the Lower Cambrian Ellipsocephalacean Protolenidae.

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## Medida de la deformación de pliegues en el extremo oriental del Sistema Central español

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### ABSTRACT

*We propose an areal distribution for the second phase hercynian folds in the easternmost part of the Spanish Central System, based on their morphological characteristics. The analysis of these data allows us to calculate the shortening and the flattening responsible for the Hercynian second phase.*

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**Key words:** Central System, Folds, Shortening, Hercynian.

### Introducción

En el extremo oriental del Sistema Central Español afloran un conjunto de rocas metamórficas y plutónicas de edad paleozóica o pre-paleozóica fuertemente deformadas durante la orogénia hercínica, habiéndose distinguido cuatro fases de deformación sucesivas en la región (Capote 1985, González Casado 1986, González Lodeiro 1981). En esta área se sitúa el límite entre el dominio del «Ollo de Sapo» (grado metamórfico medio-bajo) y la zona axial de la cadena (grado alto-medio), estando separadas estas dos regiones por la zona de cizalla dúctil de Berzosa (Z.C.B.) (González Casado, 1986). En esta región, entre las localidades de Lozoya y Atienza, donde se ha realizado un estudio sobre las distintas características morfológicas de los pliegues desarrollados durante la segunda fase de deformación hercínica, aplicándose las clasificaciones de Ramsay (1967), Hudleston (1973), y William-Chapman (1979).

El objetivo de esta nota es analizar la distribución espacial de los distintos tipos de pliegues F2, su variación

y a partir de su morfología por medio del método propuesto por Bastida (1981), el acortamiento y aplastamiento total sufrido por esta región

### Distribución espacial

Se han diferenciado cinco zonas distintas en las que los pliegues muestran diferentes características morfológicas, los caracteres de cada zona son: **Zona A.** Se extiende por todo el sector comprendido entre la Z.C.B. y el límite occidental del área estudiada (fig. 1). Se caracteriza por la presencia de pliegues cilíndricos, con un ángulo entre flancos menor de 60°, formas «C o D» y amplitudes 3 o 4 (C. Hudleston), pertenecen a la clase 1c o 2 de Ramsay y con valores de  $\sqrt{\lambda_2/\lambda_1}$  entre 0,2 y 0,6.

**Zona B.** Situada en las inmediaciones de la Z.C.B., describiendo una banda continua de marcada orientación N-S. Son pliegues de tipo 2 (C. Ramsay) con valores de  $\sqrt{\lambda_2/\lambda_1}$  próximos a 0,2, siendo el ángulo entre sus flancos siempre menor de 30°. Sus amplitudes

son 3, 4, o 5 y tienen formas B, C, o D (C. Hudleston). Pueden tener uno o los dos flancos laminados, observándose también charnelas aisladas, debido al alto aplastamiento que ha sufrido este área.

**Zona C.** Esta zona se encuentra sólo en la parte central de la Z.C.B., desapareciendo hacia sus extremos. Se caracteriza por la presencia de pliegues con charnela curva, próximos al tipo R (C. William-Chapman), que coexisten con otros pliegues de carácter más cilíndrico.

**Zona D.** Comprende todo la región central entre la zona anterior y el área de Hiendelaencina (fig. 1). En ella se observan pliegues de tipo 1c, con relaciones  $\sqrt{\lambda_2/\lambda_1}$  altas, mayores o próximas a 0,5 (C. Ramsay). El ángulo entre flancos es habitualmente mayor de 90°, y las formas son de tipo D con amplitudes 1 o 2 (C. Hudleston).

**Zona E.** Situada sobre la parte más interna del macizo de Hiendelaencina (fig. 1), se caracteriza por la presencia de pliegues con un bajo ángulo entre flancos, que varía entre 7° y 38°