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Perspective

The Pyrenean ‘Danian revolution’

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Recent work on Cretaceous to Palaeocene geology of the Pyrenees has revealed the need for a better support, or total rethink, of certain concepts that were until now considered as established facts. The palaeogeography at this time, controlled during the Cretaceous by transform faulting between the European and Iberian plate margins, played a vital role in the geodynamic evolution of the mountain belt.

In the western Pyrenees, the breccia overlying the Jurassic–Cretaceous cover rocks was until now interpreted as ‘collapse’ breccia [4], formed during the Early Cretaceous above dissolved Triassic salt diapirs. However, the discovery of Palaeocene planktonic Foraminifera in this breccia [9] strongly supports the presence during the Danian of a submarine trough superposed on the internal axial part of the belt, and which has already been identified from Roussillon [8] to the Bigorre. The breccia overlies, with a marked angular unconformity, a succession affected by Middle Cretaceous structures and thermal metamorphism as well as synschist folds attributed to the end-Cretaceous tectogenesis. The position of this trough stands out by the fact that it is oblique to the Cretaceous marine palaeorift: to the east of Lourdes it lies on the European palaeomargin, whereas in the west it follows the Béarn foothills believed to belong to the North Iberian margin.

Certain outcrops in this same area, until now assigned to the Carboniferous and Triassic [1], have recently been interpreted as Late Cretaceous turbidites [3] on a micropalaeontological basis. These turbidites would have been deposited in an extensional/transtensional context in a basin undergoing subsidence from the Turonian to end-Maastrichtian. Furthermore, the same authors relate the weak metamorphism of these formations to the thermal influence of ophites, the age of which is consequently also brought into question. An emplacement age of post Late Cretaceous, i.e., Danian (58–69 Ma) is proposed [3] on the basis of $^{40}Ar/^{39}Ar$ geochronological data.

These ophites, which were identified before 1781 [7], have been the subject of long-standing discussion, particularly concerning their age and that of the commonly associated variegated clays, limestone and gypsum. Nevertheless, a Triassic age was generally accepted for this tholeiitic basic magmatism, both for the Pyrenees and the Alps of the western Mediterranean. This age was considered as an established fact, supported by both geological observations that indicated an association with ‘Keuper’ formations, and geochronological data [5].

The geodynamic context of the Danian thus needs to be reconsidered in view of these new constraints. We know that during the Cretaceous, the ‘North Pyrenean’ alkaline magmatism was directly related to an extensional regime associated with the opening of the Bay of Biscay and, in its continuation of the ‘North Pyrenean’ marine basin, to the transform fault zone separating the Iberian and European plates. With a dominant Albian–Cenomanian age of 108 to 91 Ma, and a minor episode between 88 and 86 Ma, this volcanic activity coincides with [6] the Barremian-Albian extensional period (127–99 Ma), followed by sinistral strike-slip faulting between the Albian and Early Senonian. Polyphase compression then took over between the end-Cretaceous and Early Miocene (90–20 Ma), bringing the European and Iberian plates closer together [2]. The expression of Pyrenean compression, which affected all formations from the Palaeozoic (previously deformed during the Hercynian) to the Maastrichtian flysch, is characterised by fold and fault structures [1]. After karstification and erosion, these structures were covered by Danian–Selandian (Early Thanetian) breccia [9] in a submarine ‘trough’ between the Iberian and European plates.

The genesis and emplacement of tholeiitic ophite magma requires that the mantle lithosphere, directly beneath the zone of ophite generation, has a composition of lherzolite without garnet (i.e., less than 60 km depth). This indicates that at about 60 Ma,

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this zone was still undergoing major crustal thinning beneath a rift-type structure, causing the development of magmatic chambers and fractional crystallisation. The presence in Béarn (Aspe Valley) of both alkaline rocks of Cretaceous age and tholeiitic ophites cannot be explained by a simple rift setting, where we would expect an evolution with time from alkaline to tholeiitic magmatism, corresponding to an increase in the rate of partial melting. After the major compressional phase at the end of the Cretaceous, the genesis of Eocene ophites should thus be linked to a new extensional episode related to a marked asthenospheric rise during the Danian, and for which evidence is currently lacking.

This putative 'Danian revolution' consequently opens up new scope for research into the sedimentology and location of Late Cretaceous formations, as well as the detailed geochronology of the tholeiitic magmatism. New U–Pb zircon data are needed to help resolve discussions concerning possible reopenings of the K–Ar system in the ophites.

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