Allochthonous terranes involved in the Variscan suture from NW Iberia: A review of their origin and tectonothermal evolution

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NW Iberia includes a rather complete section of the Variscan suture, where different terranes with continental or oceanic affinities appear with clear structural relationships. Three groups of terranes, namely upper, ophiolitic and basal units and a frontal tectonic mélange appear in Galicia, in Cabo Ortegal, Órdenes and Malpica-Tui complexes. They constitute a huge allochthonous pile thrust over the Iberian parautochthonous and autochthonous domains, which represent the section of the Gondwanan margin that escaped continental subduction during the Variscan cycle (Schistose Domain of Galicia-Trás-os-Montes and Central Iberian Zone).

In the upper units, ca. 10000 m of terrigenous sediments (Órdenes Series) intruded by large massifs of Cambrian (ca. 500 Ma) I-type calc-alkaline granitoids (Corredoiras orthogneisses) and tholeiitic gabbros (Monte Castelo gabbro), are considered to represent a section of a magmatic arc built up in the periphery of Gondwana during Neoproterozoic-Cambrian times. Nd model ages from the Cambrian topmost turbiditic series (Ares-Sada greywackes) are relatively young (720-1215 Ma) and suggest relative proximity to some Avalonian terranes. The uppermost part of this terrane was affected by metamorphism ranging between the greenschist facies and the intermediate pressure granulite facies conditions (IP upper units), dated at 496-484 Ma. The IP upper units can be considered a relic section preserving the Cambrian tectonothermal activity that took place in the peri-Gondwanan arc almost intact. That activity was caused by magmatic underplating followed by accretion of arc slices, which developed counter-clockwise P-T paths evolution. However, the lower part of this terrane shows a completely different tectonothermal activity, because it was affected by a generalized high-P and high-T metamorphic event (HP-HT upper units; Cedeira and Capelada units in the Cabo Ortegal Complex, Sobrado Unit in the Órdenes Complex). This event developed extensive recrystallization under eclogite and granulite facies conditions, the peak pressures being in the range of ultra-high-P metamorphism (proved minimum pressure at 22 Kb, with some indications of higher values). The high/ultra-high-P metamorphism (ca. 400 Ma) was followed by drastic and fast exhumation coeval with partial melting (ca. 390 Ma). The development of extensional detachments (ca. 375 Ma), recumbent folds and thrusts drove the exhumation of this high-P complex later on.

True MORB ophiolites derived from typical oceanic lithosphere are unknown in the Variscan suture of Galicia. On the contrary, the mafic-ultramafic sequences preserved in NW Iberia were generated in supra-subduction settings, their mafic rocks showing island-arc tholeiitic composition. There exist two critical oceanic to transitional crust-forming events: a Middle-Late Cambrian phase (ca. 500 Ma, lower ophiolitic units, Vila de Cruces Unit), and a Middle Devonian phase (ca. 395 Ma, upper ophiolites, Careón and Purrido units). Both types of mafic units were accreted beneath the upper units during Variscan convergence, the upper ophiolites first (ca. 391-377 Ma), and then the lower ophiolites (ca. 367 Ma). Due to their buoyant nature, many Devonian ophiolites escaped from early-Variscan subduction, so they are the most common ophiolites preserved in the Variscan suture across Europe. The mafic-ultramafic sequence of the Bazar Unit has been interpreted as peri-Gondwanan oceanic lithosphere accreted beneath the magmatic arc system at 480 Ma. This unit is the only one in NW Iberia showing low-P granulite facies conditions, which has been linked to mid-ocean ridge subduction under Gondwana and the opening of an asthenospheric window.

The basal units consist of a thick sequence of Ediacaran-Early Ordovician terrigenous metasedimentary rocks intruded by Cambrian to Ordovician granitoids (calc-alkaline to peralkaline) and minor mafic igneous rocks. These

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units are considered to outline the most external part of the Gondwanan paleomargin. However, detrital zircon age populations along with (very old) Nd model ages obtained from well-preserved turbiditic series (ranging between 1782 and 2223 Ma) indicate a paleoposition further to the East than the arc-related section preserved in the upper units. The basal units also represent a continental paleosubduction zone affecting a wide and continuous section of the margin at the onset of the Variscan collision (ca. 370-360 Ma). Subduction polarity was to the W (present-day coordinates) and included right-lateral components. Continental layers were imbricated below previously accreted ophiolites, while a variety of C-type eclogites, blueschists and lawsonite bearing metabasites developed. The basal units can be subdivided in two main groups according to their tectonothermal evolution: an upper group with high-P and medium-high-T metamorphism (Agualada and Espasante units); and a lower group with high-P and low-medium-T metamorphism (Ceán, Malpica-Tui, Lamas de Abad, Santiago, Cercio, Lalín and Forcarei units). The upper group is considered the closest section to the overlying mantle wedge during Variscan subduction, whereas the lower group accounts for the cooler sections of the subduction wedge. The arrival of thicker, more buoyant continental crust blocked the subduction, leading to several thrusting events that transported the subduction complex onto the adjacent, inner sections of the margin, represented by the parautochthonous sequences of the Schistose Domain.

The Somozas mélange is a piece of the Variscan continental subduction channel developed between the section of the Gondwanan margin represented by the basal units and their respective overlying mantle wedge. The subducted continental margin was exhumed later on and emplaced over the mélange zone. The mélange appears as a unique element at the easternmost contact between the allochthonous terranes and their relative autochthon. The mélange unit consists of ca. 500 m of serpentinite showing block-in-matrix texture. The blocks are variable in size and include metasedimentary rocks, volcanics, gabbros, granitoids and high-P rocks. As a major plate boundary, and given the nature and sensitive structural position of this unit, multiple tectonic events have left strong imprint on it.

Continental convergence did not decline after Variscan subduction and early Variscan nappe tectonics. The allochthonous pile and the suture zone were transferred onto the Gondwana mainland, thus triggering the thermal and gravitational collapse of the collisional wedge. The convergence continued during the Pennsylvanian, when the entire allochthonous pile was subjected to heterogeneous reworking in strike-slip systems.

Considering the allochthonous character of the nappe pile and the strong deformation associated to the Variscan collision, there are problems to identify the original tectonic setting of some terranes and thence, it is almost impossible to reconstruct the paleogeographic setting during the Variscan and pre-Variscan times in detail. Key features to perform any evolving model for the Variscan convergence should consider the existence of two different high-P metamorphic events, both of them affecting continental or transitional crustal sections that belonged to the margin of Gondwana. On the other hand, the ophiolitic units provide evidence for two stages of generation of oceanic or transitional crust precisely within the paleogeographic domain that separated the two sections recording the high-P events. Previous models developed in NW Iberia suggested that the upper units represent a peri-Gondwanan terrane drifted away from the main continent during the opening of the Rheic Ocean. The lower and upper ophiolitic units would be generated respectively during the opening (rifting) and the beginning of the closure (by intraoceanic subduction) of this Paleozoic ocean. In those models, the two high-P metamorphic events would be related first to the accretion of the drifted terrane to the southern margin of Laurussia (upper units), and then to the subduction of the thinned Gondwanan margin after complete closure of the Rheic Ocean (basal units).

The previous models have important problems to explain the high/ultra-high-P metamorphic event and the exhumation of deeply subducted transitional-type sections. On the other hand, the recently discovered participation of an older continental crust in the generation of some protoliths belonging to both types of ophiolitic units (Purrido and Vila de Cruces units), along with their highly depleted Sm-Nd isotopic signature, make difficult their relationship to open wide oceanic domains. A two-stages collisional model affecting a wide Gondwanan platform may explain most of the evidences in NW Iberia. This platform would contain Cambrian back-arc sections with transitional crust (ca. 500 Ma) filled by siliciclastic material, and also the remnants of a previous Ediacaran-Cambrian magmatic arc. Collision of this platform with the southern margin of Laurussia, in a dextral convergence setting, would have caused imbrication and subduction of transitional crustal sections to high/ultra-high-P depths (ca. 400 Ma), followed by exhumation and subsequent generation of ephemeral supra-subduction or pull-apart oceanic basins (ca. 395 Ma), finally closed during the second event of collision and restarted subduction of the Gondwana margin to the North (ca. 370 Ma). According to this model the upper units of NW Iberia would represent the lower plate to the Rheic Ocean suture.

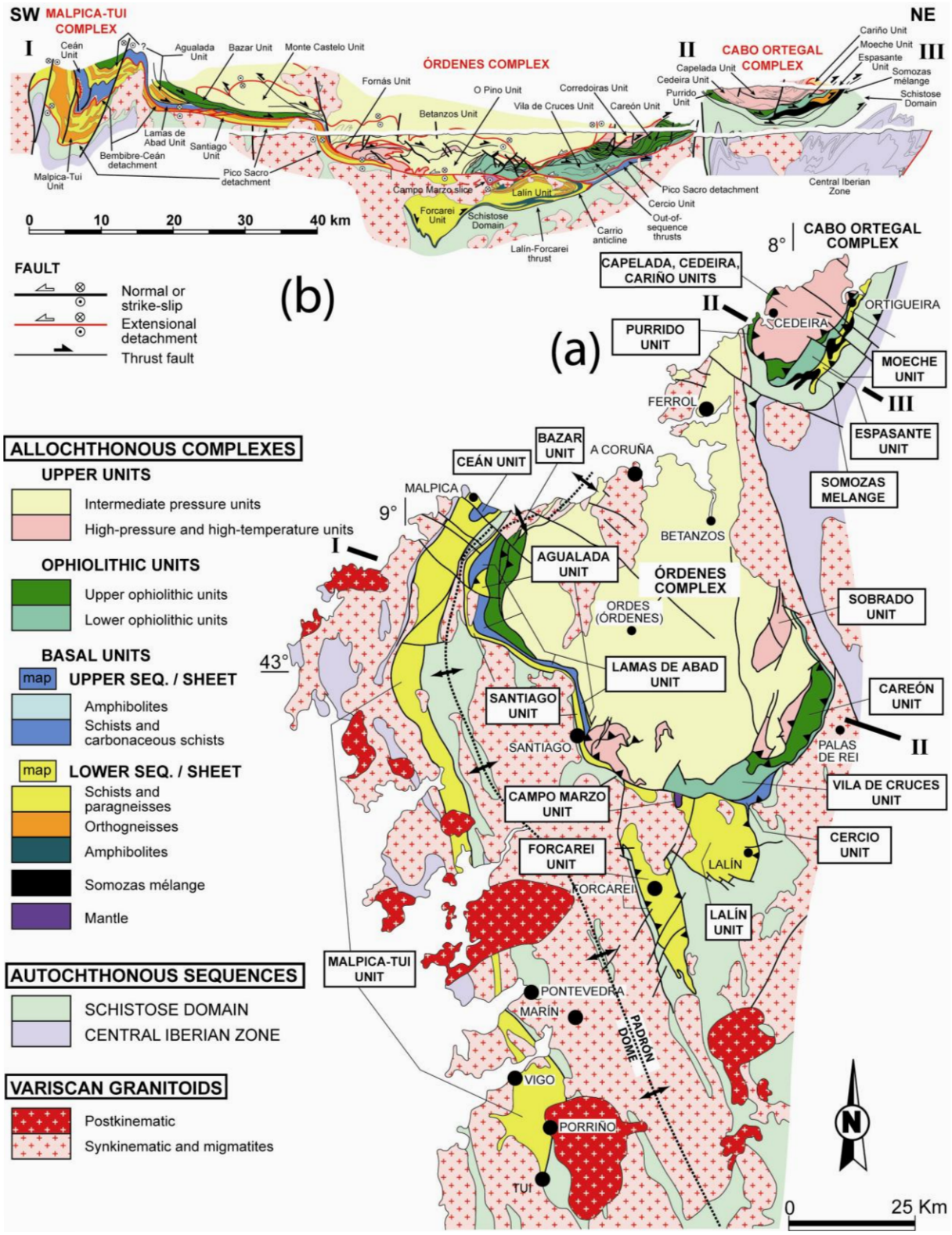

Fig. 1.- (a) Map showing the allochthonous complexes of Órdenes, Cabo Ortegal and Malpica-Tui in NW Spain. (b) Composite cross section showing the general structure of the allochthonous complexes. For the basal units, the section includes further details than the map (see legend).