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CARBONIFEROUS SUBDUCTION COMPLEX IN THE SOUTH PORTUGUESE ZONE COEVAL WITH BASEMENT REACTIVATION AND UPLIFT IN THE IBERIAN MASSIF

BY

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ABSTRACT

The formation of thick piles of flysch-like sediments needs the existence of narrowed seas, active denouement of neighbouring continents, and generalized marginal subsidence. These conditions are present during the initial and final stages of Wilson's perceptive cycle. In this context, the Late Precambrian flysch of the Iberian Massif must be related to the initial rifting, whilst the Culm of southwestern Iberia was accumulated during an episode of Upper Palaeozoic subduction that remained active after the impingement of Iberia against North America. Culm sediments shed from the uplifted collision zone and fed into a remnant ocean that remained at the nonsutured southern border of Iberia. This model of synorogenic flysch formation has been described elsewhere for similar plate arrangements.

On other grounds this model provides a framework that explains the different structural and magmatic trends of the Ossa-Morena Zone (near the active margin) in the context of the rest of the Massif (basement reactivation). In addition to this, it seems to support a partly primary origin for the Iberian arc versus a secondary origin.

RESUMEN

Para la formación de potentes series de tipo flysch es necesaria la existencia de areas marinas estrechas, la denudación activa de los continentes que las rodean y subsidencia generalizada en las margenes. Estas condiciones se cumplen en las fases iniciales y finales del ciclo de Wilson. En este sentido, el flysch precámbrico superior del Macizo Iberico corresponde a la fase inicial de apertura, mientras el Culm de la zona Surportuguesa esta relacionado con un proceso de subducción que permaneció activo después de la colisión de las placas ibérica y norteamericana. La zona de colisión corresponde al area madre de los depositos del Culm, los cuales se acumularon en un area oceánica residual situada en el borde no suturado de la placa ibérica. Este modelo de formación de flysch sinorogénico ha sido utilizado anteriormente para otras areas con similar disposición de placas.

Por otra parte, este modelo permite explicar la diferencia de las estructuras y el magmatismo de la zona Ossa-Morena (situada junto a una margen activa) frente a las estructuras y el magmatismo del resto del Macizo (zona de reactivación cortical). Además este modelo parece favorecer la hipótesis de un origen primario para el Arco Ibero-Armoricano.

INTRODUCTION

One of the most interesting features of the Iberian Massif is the substantial difference between its northern and southern halves. This difference is most marked when one considers the occurrence at the southern border of a voluminous Carboniferous flysch (the Culm of the Iberian Pyrite Belt) that does not have its counterpart in the northern border. In current geotectonic models for the Iberian Massif these differences have not been emphasized and have even been underestimated, describing the Iberian Hercynian Belt as a double-vergence chain, in Auboin's terms.

This paper deals with the possible geotectonic connection of this Carboniferous flysch with respect to the rest of the Massif. In this context, a model is proposed here in order to conciliate the structural and magmatic patterns of the Galicia-Castile central zone with those of the more 'external' zones. Constraints due to the general arrangement of the Hercynian Belt and its transatlantic extensions, have been taken into account in order to define the possible plate arrangement for the Iberian Massif.

It has been stressed elsewhere (Vegas, 1978) that the Iberian Massif – that is, the Hercynian Belt of Iberia – formed part of a long-lived Atlantic-type continental margin whose evolution ended with a compressive, deformational period. During this evolution two main periods of flysch deposition can be distinguished in contradiction with the classic bearing of flysch as orogenic sediments. The older flysch-like sediments of the Iberian Massif correspond to the early stages of the above-mentioned margin, whilst the younger ones can be attributed to an ocean vanishing stage that ended the Variscan orogenic cycle.

For the purpose of this paper, a concise history of the sedimentary-tectonic evolution has been reviewed in order to settle the final, coeval processes as huge turbidite deposition and the formation of high-strain zones and massive granite intrusions.

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SEDIMENTARY EVOLUTION OF THE IBERIAN MASSIF PRIOR TO THE MAIN HERCYNIAN DEFORMATION

Briefly, this evolution may be related to that of a long-lived passive margin that started with the drifting apart of North America and Eurasia at some 850 M.y. B.P., this age being fixed after the commencement of the miogeocline deposits of the eastern coast of the United States (Stewart, 1976).

In this sense, Late Precambrian sediments of the 'European' margin must also record the early stages of the new distensive (sedimentary) zone created after the Grenville event.

An outline evolution of this margin, on the basis of Iberian data, can be expressed in the following successive stages:

1) Formation of flysch-like sediments (Narcea, Serie Negra, part of the Xisto-Grauvaquico complex etc. during the juvenile stage of the margin in Late Precambrian times; 2) Platform sedimentation due to the formation of a vast shelf-rise couple on which shallow-water facies were laid down during Cambrian and Ordovician times; 3) Broadening of the oceanic area with a considerable amount of deeper facies deposited on the stretched rise during Silurian times.

All these three chapters of the pre-orogenic history of the Iberian Massif can be easily related to an inactive margin evolution, including intermediate disturbances.

Stage 1 represents the sedimentation in a zone of strong subsidence bounded by extensive continental areas of low relief where denouement was nevertheless active. This environment concurs with those described by Bott (1976) for the juvenile phase of a continental margin. During this initial stage a narrow trough, created by rifting, collected debris from the neighbouring mainlands, the huge volume of sediments being caused by active and continuous subsidence by brittle fracture in the upper part of the crust and possible mass transfer in the lower part, and this initial, strong subsidence may continue unless a change in the plate arrangement does occur (Bott, 1976). This change in subsidence is reflected in the mixtite- or dyamictite-like sediments situated at the top of the Late Precambrian series of central Spain. These sediments point to strong block-faulting at the end of Late Precambrian times, coinciding with worldwide Pan-African disturbances (major changes in world plate arrangement). These Pan-African disturbances are reflected in Iberia by epeirogenic movements that cause local fault scarps and troughs on which mixtites were laid down. The sedimentary features of these chaotic deposits lead them to compare to the A_1 turbidite facies of Mutti and Ricci-Lucchi's (1975) model and hence to suppose a depositional mechanism by debris flow, mudflow and tectonic control. At this point, the author would emphasize that Stille's diastrophic phases must be taken with caution since they can mean merely vertical or epeirogenic movements inside the plates, where no true molasse deposits or pervasive deformation structures are to be found.

Stage 2, as mentioned above, corresponds to a new picture of this margin, that comprises the Cambrian up to the latest-Ordovician time interval, during which a broad shelf was growing up. This shelf is typified by uniform facies that covered all the margin (Armorican Quartzite, *Calymene* shales and so on) and by the development of a Bahamian-type carbonate bank in Lower Cambrian times. Perhaps as an inherited Late Precambrian feature, the margin was divided into two basins or syneclises by an intermediate threshold or anteclise that coincides with the so-called 'Ollo-de-Sapo' Anticline. This central anteclise (Vegas, 1978) played an important role in the Lower Palaeozoic sedimentation (differences between the carbonate bank in both syneclises) and during Sardic disturbances that acted again as epeirogenic movements inside the Iberian margin. These disturbances are marked by an unconformity that separates Middle–Upper Tremadocian clastics from the Lower Cambrian or Late Precambrian in the oceanwards syneclise. This unconformity overstepped the central Ollo-de-Sapo swell and was diluted within the monotonous Middle Cambrian to Arenigian clastic series laid down on the Asturian-Leonese (landwards) basin.

The end of these Sardic movements is reflected by the widespread formation of the Armorican Quartzite that covered all the margin except the outer border, the Ossa-Morena Zone, where instead of shallow-water sediments, deeper facies were laid down, pointing to the further plate margin established at the end of the Silurian times (Vegas & Muñoz, 1976). Another special realm during the Ordovician sedimentation was situated within the Astur-Leonese basin, where a deep trough collected turbidites of Middle–Upper Ordovician age (Marcos, 1973). This late realm ought te be matched to intraplate instability in the context of Caledonian crustal activity.

Stage 3 of the evolution above outlined, corresponds to the uniform Silurian sedimentation alongside the margin. This uniform rate of subsidence and sedimentation can be fairly related to crustal downwarping in a mature Atlantic-type margin. The Silurian strata of the Iberian margin rest by means of a slight unconformity on the upper beds of the Ashgill that show in several sites tilloid-like features as in the northern part of the Armorican Massif (Robardet & Vegas, in prep.). This unconformity appears to be more relevant towards the continental border of the margin (i.e. the Cantabrian Zone) where Silurian strata lie on the lowest Ordovician beds, the Armorican Quartzite (Julivert et al., 1972). Bearing in mind these Silurian sedimentary conditions, it is possible to envisage a broad, stable margin displaying a flat topography though some slight irregularities in the Central Galicia–Northern Portugal area announced the uplift and erosion that occurred during Devonian times, and the start of the plate uncoupling at the margin boundary.

SEDIMENTATION AND TECTONISM DURING THE OROGENIC STAGE OF THE IBERIAN MARGIN

After a dilated time interval during which the Iberian miogeoclinal pile was built up, the margin was converted into an active or Pacific-type margin and hence became a consuming plate boundary. This changeover must have occurred at the end of Silurian times, and subsequently the margin underwent a compressive regime that caused the progressive obliteration of the Palaeozoic ocean between America and Europe after the Caledonian suture. The problem is how the ultimate stage of this obliteration can be envisaged, i.e. the continent–continent collision that originated the most part of the Iberian Hercynian orogenic belt.

The Hercynian belt of Europe has been explained in terms of continental collision, basement reactivation, and subsequent vanishing of the so-called 'Rheic' ocean, by Dewey & Kidd (1974), Dewey & Burke (1973), and Burke et al. (1977). Several new aspects can be added to this collision outline if the Late Precambrian and Palaeozoic geology of Iberia is taken into account at a more detailed level. In the author's point of view, the main fact to be included into the Iberian collisional model, is the coexistence of a broad zone of basement reactivation, including the most part of the Iberian Massif, and a relatively narrow zone that can be related to subduction processes. Both zones can be used to delimit the orogenic activity of Iberia during Carboniferous times. To arrive at this Carboniferous picture, it is possible to envisage a complex plate-margin evolution that started in Early Devonian with

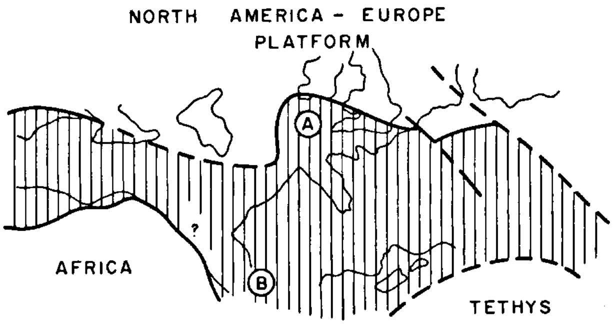

Fig. 1. The Late Palaeozoic fold belt between Europe, North America and Africa in a pre-Triassic reconstruction. A: Ibero-Armorican promontory, B: Southern Iberian embayment.

the conversion into an active margin. The geometry of a convergent plate boundary may lead to the coexistence of different geotectonic processes at the same plate margin (Dewey, 1976, fig. 1). Thus an arch-shaped margin like the Iberian one, may provide an 'early' impact at the salient (the Ibero-Armorican promontory) whilst subduction and its effects may continue at the entrant (the southern Iberian embayment) (Fig. 1).

With regard to this plate-margin evolution, some aspects related to the Devonian sedimentation can be explained. Outcrops of Devonian strata are scarce inside the central part of the Massif whilst Devonian sediments were fed into a basin developed towards the Cantabrian Zone. Disturbances in the Devonian sedimentation as non deposition or substantial erosion can be interpreted as premonitory uplifts within the active margin, whereas the absence of Devonian sediments that starved the trench-arc area, is due to the processes of self-destruction of convergent margins involved in a collision event. Notwithstanding, the Devonian accretionary prism was conserved at the non-sutured part of the margin in southern Iberia. Other areas of Devonian (and Carboniferous) sedimentation were provided at the rear of the preserved active margin (Terena and Pedroches Synclines, the latter being fitted to a distensive area).

By introducing this plate arrangement, it is also possible to explain other features like magmatism and deformation in order to justify the model of collision and simultaneous subduction proposed here.

On large scale maps of the Iberian Peninsula the Hercynian granites appear to be grouped in two main zones. The northern one embraces extensive areas of coalescent bodies from Galicia to the Gredos and Guadarrama ranges. On the other hand the southern zone comprises elongated granitic plutons that draw out preferred lines or belts, like the Pedroches batholith, the Burguillos axis and so on. This merely geometric division has a genetic origin. So the Galicia-Castile granites have been interpreted as 'Himalayan' ones, whilst the southern ones correspond to 'Andean' granites (Capdevila et al., 1973). The latter were also included in a subduction scheme for the Iberian Massif by Vegas & Muñoz (1976) with respect to volcanicity and metamorphism in the Ossa-Morena and South Portuguese Zones. In this context, the granites of northwestern and central Spain can be attributed to a collision event that provided an abnormal thickening of the crust enough to cause partial melting of the lower levels as the origin of the Late Hercynian granites, whose shallow emplacement masks early structures and makes the most impressive feature bearing in mind its widespread extension.

Figure 2, taken from Capote & Vegas (1977), schematically depicts the relationship among the granites related to the subduction realm and those related to the collision one. The abnormal thickening of the crust may be explained as a result of a system of crustal thrusts, one of them being the major Berzosa Fault that shows a clear relationship with the occurrence of kyanite-bearing rocks along it (Capote et al., 1977). The values of K_2O ratio and radiometric ages of granites in southern Iberia (Fig. 3) point to a certain polarity that supports the model here presented (Capote & Vegas,

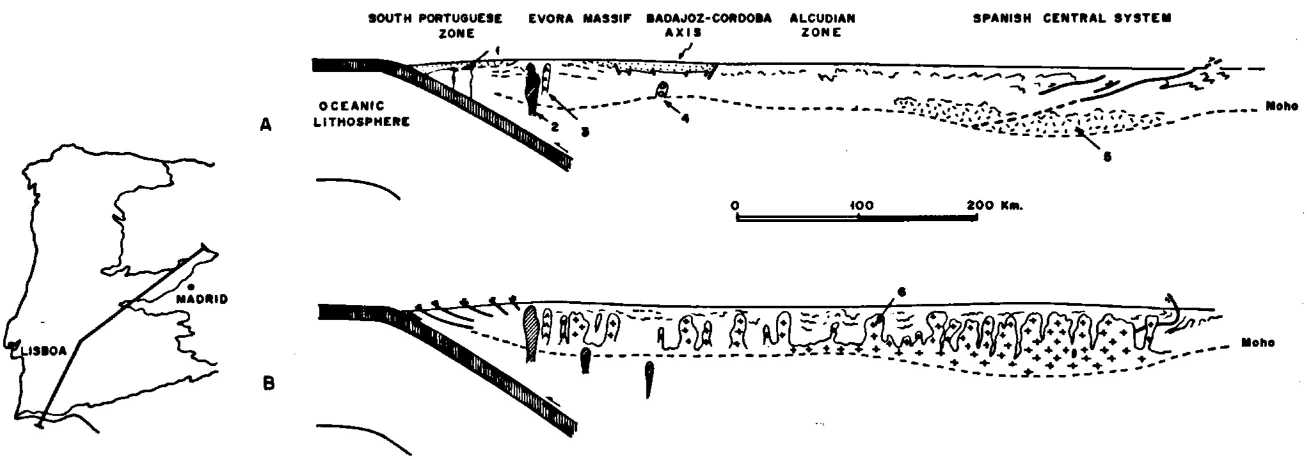

Fig. 2. Schematic cross-section of southwestern Iberia showing the relationship among subduction, granites and abnormal thickening of the crust. A: Before the third (ultimate) Hercynian fold event; B: After the third Hercynian fold event. Ornamentation: 1, volcanics of the Pyrite Belt; 2, mafics; 3, porphyries; 4, granite-gneiss (Ordovician?) of the Badajoz-Cordoba axis; 5, lower crust zone with partial melting processes; 6, post-tectonic granite bodies. After Capote & Vegas (1977).

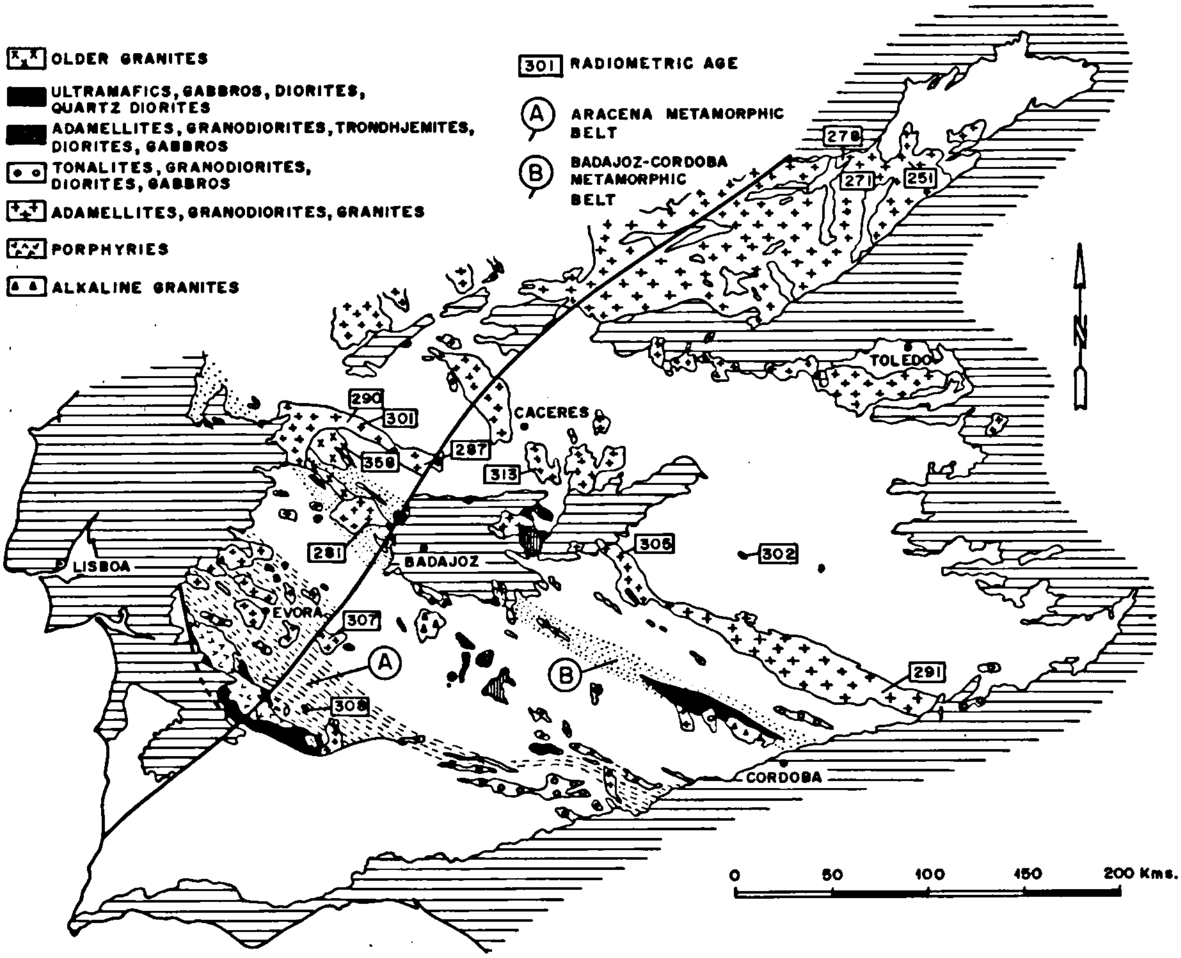

Fig. 3. Granitic and metamorphic alignments of the southern part of the Iberian Massif. After Capote & Vegas (1977), based on Aparicio et al. (1977), Bard & Fabriés (1970), Carvalho (1971), Mendes et al. (1972), Penha & Arribas (1974).

1977). In the same way the NW–SE trending parallel metamorphic belts of the Ossa-Morena Zone (p.e. Vegas & Muñoz, 1976) can be interpreted, whilst the regional metamorphism of the more central areas must be caused by the thermal event that gave rise to the huge magma intrusions and hence must be assigned to the collision above outlined. Notwithstanding, it must be pointed out that early magmatic and metamorphic events were destroyed in the collision realm.

With regard to deformational processes, several aspects appear to be relevant in the duality of subduction and collision. The southernmost part of the Massif has been described as an active margin that caused the structures of the entire Massif (Bard et al., 1973). Although the southern border can be related to a frontal subduction during Late Palaeozoic times, the majority of the Massif does not represent in any way the result of an Andean-type orogen. On the contrary, the Galicia-Castile high-strain zone must be attributed to collisional events that caused tectonic transport towards an 'exogeosyncline' located in the present-day Asturian region. This transport originated the decollement tectonics and nappe emplacement of the Cantabrian Zone described by Julivert (1971). The progression of the convergence after the frontal collision produced major crustal shortening and subsequent basement reactivation. Meanwhile subduction persisted at the southern border, and the sedimentary prism was accreted at this plate margin that formed a synthetic belt.

Occupying an intermediate position, a low-strain area can be distinguished in the eastern part of the East Lusitanian-Alcudian Zone. This moderately deformed zone underwent in a much weaker way the influences of both collision and subduction processes because of its distance from the collisional front and the subduction zone.

The relationships among these zones are depicted in Figure 4, that shows also the different cross-sections that characterize them.

The timing of these orogenic events can be established only by means of indirect data. The start of the subduction or uncoupling can be fixed as Early Devonian all along the margin, including the zone destroyed during terminal collision. This date may be inferred from the discontinuity or absence of Devonian strata in the Galician area and the development of an exogeosyncline towards the Cantabrian Zone. These may attest to an uplift that announces the former

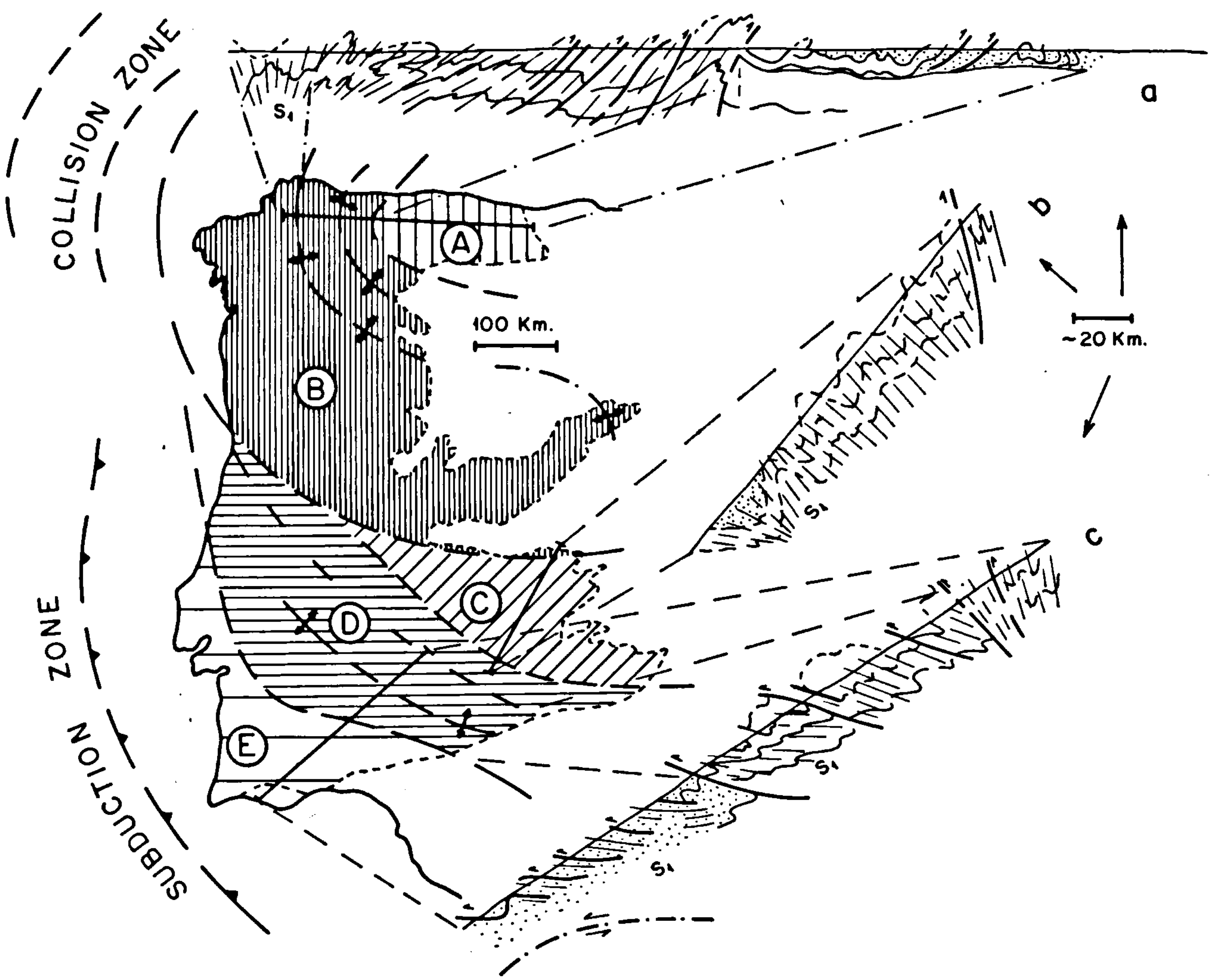

Fig. 4. Geotectonic divisions of the Iberian Massif related to a subduction-collision model. A: 'Internal' zone of detached nappes (Cantabrian Zone), B: High-strain zone related to collision (West Astur-Leonese plus Galicia-Castile Zone), C: Intermediate low-strain zone (Easternmost part of the East Lusitanian-Alcudian Zone), D: High-strain zone related chiefly to subduction (Ossa-Morena plus western part of the E. Lusit.-Alcudian Zone), E: External zone above subduction (South Portuguese Zone).
Profile a) after Martinez Catalán et al. (1977), Marcos (1973) and Julivert (1971); c) after Vegas & Muñoz (1976).

elevated area which became a source-area during Carboniferous times.

In a similar way the commencement of the collision may be related to the early stages of nappe formation in Cantabria. The movement of the nappes has been estimated by Julivert (1971) as Intra Westphalian and this movement may ensue the crustal shortening by collision. On the basis of this nappe emplacement, collision may have occurred at least in Late Devonian, as collisional effects migrated towards the interior of the Iberian plate. The age of the first main phase of deformation, responsible for recumbent folds and flat cleavage, may correspond also to these Middle to Early Devonian times.

With regard to the South Portuguese Zone, the deformation started in Middle Westphalian and Early Hercynian phases corresponding to continuous sedimentation.

As for deformational processes, the intrusion of Hercynian granites may be matched to the above-mentioned scheme. So the 'gneissic granites' of northwestern Iberia have been dated as 340 ± 10 m.y. B.P.; the 'older granites' (non deformed) yield an age of 298 ± 10 m.y. and the 'younger granites' have been dated as 280 ± 10 m.y. (Priem et al., 1970). The gneissic granites must record the early stages of collision as remnants of the destroyed active margin segment, and the 'older' and 'younger' postdate the late deformation phases, pointing to two main periods of intrusion that culminated in the uplift and reactivation of the basement at the end of Carboniferous times.

In the non-collisional segment the age of the granites suggests the activity of the subduction zone. The ages of different granite bodies have been plotted in Fig. 3. Despite the few data available, a certain polarity can be envisaged, and the difference between the 'basement reactivation' granites and the 'subduction' granites is also outlined.

The end of the Hercynian compressive events may be fixed as the start of the molasse stage of the chain. This molasse stage corresponds to Stephanian and Permian sediments that starved fault-bounded basins that became clearly continental grabens or semi-grabens in Autunian times.

GEOTECTONIC SETTING OF THE CARBONIFEROUS SEDIMENTATION IN THE IBERIAN MASSIF

The above-mentioned plate arrangement leads to a speculative picture in which continuous flysch sedimentation on the South Iberian embayment is coeval with uplift and erosion in the Ibero-Armorican arch-shaped promontory. This picture is completed by the development of an exogeosyncline towards the stable foreland and by the ill-defined but possible conservative plate margin that can solve the southeastern border of the chain (Fig. 5).

This reconstruction, in the outhor's opinion, may be useful in the explanation of the different Upper Carboniferous sedimentation zones. In this context, the Carboniferous sediments can be grouped in four realms. Among these the zone that collected the major amount of sediments was the southern active segment on which a voluminous subduction complex was laid down. There the sediments are made up of Culm facies that can be subdivided in the following lithofacies: a) Greywackes and quartzites, with volcanic and igneous clast debris, b) dark shales, c) coarse-grained greywackes, with clasts of granite and still metamorphosed shales, d) conglomerates containing crystaline boulders. Lecolle (1977) has described a shallow-marine environment for these deposits on the basis of the intensity of marine currents, ripple-marks, load-casts etc. Some fluviatile influences have been also described as well as preferred 'oceanwards' subsidence or sagging. These sedimentary features plus the subduction arrays lead the present author to place the Iberian Culm above a subduction zone whose arc-trench gap reached a considerable magnitude. This plate arrangement provides a framework that explains the huge accumulation of sediments on the shallow-water environment situated between the trench and the emerged border of the chain. It has been established that the formation of thick piles of flysch-type sediments needs the existence of narrow, marine, subsiding troughs bordered by uplifted continental areas providing continuous flow debris. These conditions are the most favorable when considering the model above outlined (Fig. 5). In this sense the wedge-shaped oceanic area collected the debris shed from the collisional, uplifted area that underwent continuous and active denouement. The flysch-like sediments starved the area comprised between the trench and the arc-collision boundary. The composition of the debris indicates an autochthonous origin as erosion of the arc volcanics and an allochthonous origin as erosion of the reactivated basement (granitic and metamorphic debris).

This model shows many similarities with those described by Graham et al. (1975) for other Palaeozoic flysch dispersal areas and based on the present-day plate arrangement of the Himalayan-Bengal area. Nevertheless the Iberian Culm can also be compared to the accretionary prism of the Aleutian

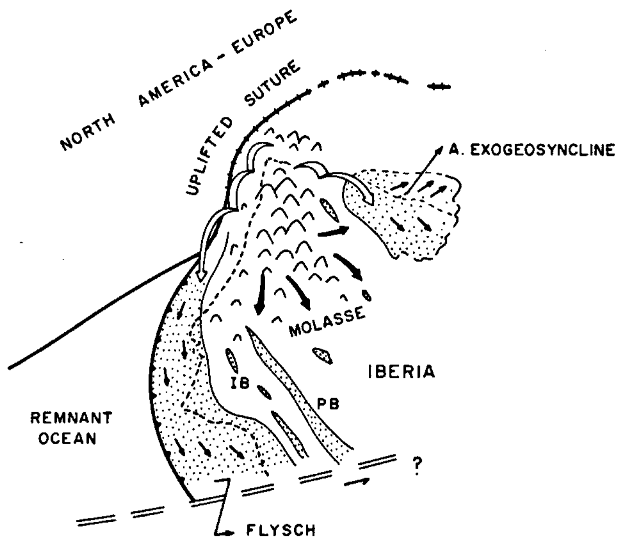

Fig. 5. Conceptual model for flysch and molasse sedimentation in the Iberian plate during Carboniferous times. PB: Pedroches basin, IB: Intermontane basins. Based on a model of flysch dispersal by Graham et al. (1975).

Arc with regard to the shallow formation and the continental influence. This later feature can suggest the existence of major streams descending from the uplands and providing fluviatile characteristics to the coarse-grained sediments. In this sense the convergence patterns with the Aleutian sedimentation must be due to the neighbouring continental landmass and the rate of basinal subsidence.

The other area that collected a great amount of Upper Carboniferous sediments lies far across the uplifted area (Fig. 5) and constitutes an exogeosyncline that evolved to a Stephanian molasse basin. There more than 6000 m of sediments were laid down. The final stage of this basin constitutes the Central Asturian coal basin. The source area of the sediment was undoubtedly the reactivated terrains of the Galicia-Castile Zone.

Other zones of Carboniferous sedimentation can be found within the reactivated basement. The most important of them is the Pedroches realm (Fig. 5) that runs parallel to the Hercynian trends between the Guadalquivir Lineament and the Portuguese boundary, where it decreases in length and disappears. This zone may be related to a back-arc distensive zone that collected Culm-type sediments. Several small intermontane basins were also the site of Carboniferous paralic and limnic sedimentation; some of them contain moderately deformed Westphalian strata resting unconformably over Late Precambrian and Early Palaeozoic rocks in the Ossa-Morena Zone; the rest are grabens infilled by coal-bearing clastic series. All these intermontane basins point to the ultimate stages of the Hercynian cycle.

PLATE IMPLICATIONS OF THE IBERIAN CARBONIFEROUS SEDIMENTATION MODEL

The model presented here has the advantage of conciliating the 'collision-subduction' main features and providing a rational plate frame for the four Carboniferous realms that can be distinguished in the Iberian Massif.

Other features can be indirectly related to this model, although some imprecisions, based on ill-defined data, can be argued.

The main fact stressed here is that the Hercynian history of western Iberia may be expressed in terms of the evolution of a continental margin in a complete Wilson's cycle of opening and vanishing ocean. The complexities of the final stages of the margin are similar to those enhanced by Dewey (1976) to explain the evolution of ancient margins.

Various alternative hypotheses can be proposed for other connected features of the Hercynian chain, among them:

The South Portuguese zone may lie near a not fully sutured zone after cessation of plate convergence. This can explain the 'oceanic gap' in the recent reconstruction of the Atlantic fit by Le Pichon et al. (1977).

Another point of interest is what, if any, features of the suture zone may now lie across the Atlantic. These features could be arc-shaped magnetic anomalies described by Lefort & Hawort (1977) in the continental plateau of Newfoundland. These anomalies are clearly parallel to the Iberian Arc and may be remnants of basic rocks squeezed inside the suture zone. The connection of these features may complete the Hercynian loop between Europe and North America.

Another tentative hypothesis could be to relate the rounded ultramafic outcrops of Galicia and northern Portugal with the suture zone lying westwards.

With respect to the shape of the Iberian plate prior to the main orogenic events, this model seems to support the primary origin of the Iberian promontory (as guessed by Matte & Ribeiro, 1975) rather than a secondary origin (as supposed by Ries & Shackleton, 1976).

And finally a further point of interest is to try to solve the problem of the eastwards continuation of the Iberian Hercynian belt. In the plate model presented here this boundary can be explained as a conservative plate boundary connecting the Iberian subduction zone with a probable subduction zone in the Tethys-Southern Europe orogenic zone.

REFERENCES

Aparicio, A., Barrera, J. L., Casquet, C., Peinado, M. & Tinao, J. M., 1977. Caracterización geodinámica del plutonismo postmetamorfico del SO del Macizo Hespérico. Studia Geologica, Salamanca, 12, pp. 3-39.

Bard, J. P., Capdevila, R., Matte, P. & Ribeiro, A., 1973. Geotectonic model for the Iberian Variscan orogen. Nature Phys. Sc., 241, pp. 50-52.

- & Fabriés, J., 1970. Aperçu pétrographique et structural sur les granitoïdes de la Sierra Morena occidentale (Espagne). Bol. Inst. Geol. Min. España, 81, pp. 112-127.

Bott, M. H. P., 1976. Formation of sedimentary basins of graben type by extension of the continental crust. In: M. H. P. Bott, ed., Sedimentary basins of continental margins and cratons. Tectonophysics, 36, pp. 77-86.

Burke, K., Dewey, J. F. & Kidd, W. S. F., 1977. World distribution of sutures - The sites of former oceans. In: M. W. McElhinny, ed., The past distribution of continents. Tectonophysics, 40, pp. 69-99.

Capote, R. & Vegas, R., 1977. La unidad hercínica Centro-Sur. I Col. sobre Tectonica de Placas, Fund. Gomez Pardo, Madrid (to be published).

-, Fernandez Casals, M. J., Gonzalez Lodeiro, F. & Iglesias Ponce de León, M., 1977. El límite entre las zonas Astur Occidental-Leonesa y Galaico-Castellana en el Sistema Central. Bol. Geol. Min., 88, pp. 517-520.

Capdevila, R., Corretgé, L. G. & Floor, P., 1973. Les granitoïdes varisques de la Meseta Ibérique. Bull. Soc. géol. France, 15, pp. 209-228.

Carvalho, D., 1972. The metallogenetic consequences of plate tectonics and the Upper Paleozoic evolution of southern Portugal. Est. Not. Trab. Serv. Foment. Min., 20, pp. 297-320.

Dewey, J. F., 1976. Ancient plate margins: Some observations. In: J. C. Briden, ed., Ancient plate margins. Tectonophysics, 33, pp. 379-385.

- & Burke, K. C. A., 1973. Tibetan, Variscan, and Precambrian basement reactivation: Products of continental collision. Jour. Geol., 81, pp. 683-692.

- & Kidd, W. S. F., 1974. Continental collisions in the Appalachian - Caledonian orogenic belt; variations in style related to complete and incomplete suturing. Geology, 2, pp. 543-546.

Graham, S. A., Dickinson, W. R. & Ingersoll, R. V., 1975. Himalayan-Bengal model for flysch dispersal in the Appalachian-Ouachita system. Geol. Soc. America Bull., 86, pp. 273-286.

Julivert, M., 1971. Décollement tectonics in the Hercynian Cordillera of Northwest Spain. American Jour. Sci., 270, pp. 1-29.

-, Marcos, A. & Truyols, J., 1972. L'évolution du Nord-Ouest de l'Espagne pendant l'Ordovicien-Silurien. Bull. Soc. géol. minéral. Bretagne, (C) 4, pp. 1-7.

Lecolle, M., 1977. La ceinture sud-ibérique: Un exemple de province á amas sulfurés volcano-sédimentaires. Thèse Doct. d'Etat, Univ. Paris VI.

Lefort, J. P. & Haworth, R. T., 1977. L'arc Ibero-Armoricain: Une structure précambrienne de la Plateforme Avalonienne. V Réunion annuelle de Sciences de la Terre, Rennes, p. 311.

Le Pichon, X., Sibuet, J. C. & Francheteau, S., 1977. The fit of the continents around the N. Atlantic. Tectonophysics, 38, pp. 169-209.

Marcos, A., 1973. Las series del Paleozoico Inferior y la estructura herciniana del occidente de Asturias (NW de España). Trab. Geol. Oviedo, 6, pp. 1-113.

Martinez Catalán, J. R. & Gonzalez Lodeiro, F., Iglesias Ponce de León, M. & Diaz Balda, M. A., 1977. La estructura del Domo de Lugo y del Anticlinorio del 'Ollo de Sapo'. Studia Geologica, 12, pp. 109-122.

Matte, P. & Ribeiro, A., 1975. Forme et orientation de l'ellipsoïde de déformation dans la virgation hercynienne de Galice. Relations avec le plissement et hypothèses sur la genèse de l'arc ibero-armoricain. C. R. Acad. Sci. Paris, 280, pp. 2825-2828.

Mendes, F., Fuster, J. M., Ibarrola, E. & Fernandez Santín, S., 1972. L'âge de quelques granites de la Sierra de Guadarrama (Système Central Espagnol). Rev. Fac. Ciên. Lisboa, 2ª ser., 17, pp. 345-365.

Mutti, E. & Ricci Lucchi, F., 1975. Turbidite facies and facies associations. In: Examples of turbidite facies associations from selected formations of the Northern Apennines, pp. 21-36.

Penha, M. H. & Arribas, A., 1974. Datación geocronológica de algunos granitos uraniferos españoles. Bol. Geol. Min., 85, pp. 271-273.

Priem, H. N. A., Boelrijk, N. A. I. M., Verschure, R. H., Hebeda, E. H. & Verdurmen, E. A. T., 1970. Dating events of acid plutonism through the Paleozoic of the Western Iberian Peninsula. Eclogae Geol. Helvetiae, 63, pp. 255-274.

Ries, A. C. & Shackleton, R. M., 1976. Patterns of strain variation in arcuate fold belts. Phil. Trans. R. Soc. London, (A) 283, pp. 281–288.

Stewart, J. H., 1976. Late Precambrian evolution of North America: Plate tectonics implication. Geology, 4, pp. 11–15.

Vegas, R., 1978. Sedimentation and tectonism in the Iberian Massif prior to the Hercynian deformation (Late Precambrian to Silurian times). Cuad. Semin. Estud. Ceram. Sargadelos, 27: Geologia de la parte Norte del Macizo Iberico, pp. 271–286.

– & Muñoz, M., 1976. El contacto entre las zonas Surportuguesa y Ossa-Morena en el SW de España. Una nueva interpretación. Com. Serv. Geol. Portugal, 60, pp. 31–51.