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Geodynamics

Tectonics of the North African Variscides (Morocco, western Algeria): an outline

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Abstract

The Palaeozoic terranes that crop out north of the South Atlasic Line constitute the Variscan Belt of North Africa. Subdivision of the belt into five structural zones separated by major shear zones results from a polyphase evolution including very localised Prevariscan events (450–430 Ma), which correspond to the Caledonian cycle, and Variscan events involving three main stages: Eovariscan (370–360 Ma), Mesovariscan (330–320 Ma), and Neovariscan (300–290 Ma), followed by Tardi-Variscan events during Early Permian–Triassic times. During the Variscan evolution, the geodynamic context is transtensive–transpressive, and controls the opening and closure of Devono-Carboniferous basins. The Variscan deformations are accommodated by folding and combination of thrusting and strike-slip faulting associated with a low-grade to medium-grade metamorphic evolution, characteristic of the external zones of the orogens. The lack of oceanic crust, and thus of suture zone in the Palaeozoic series suggests that the North African Variscan Belt is an intracontinental part of the Variscan orogen, which evolved near the margin of the West African Craton. The links with the other Periatlantic Palaeozoic segments still remain a subject of discussion. ***To cite this article: C. Hoepffner et al., C. R. Geoscience 338 (2006).***

Résumé

Structure de la chaîne varisque d'Afrique du Nord (Maroc, Algérie occidentale) : un aperçu. Les terrains paléozoïques qui affleurent au nord de la ligne Sud-Atlasique constituent la chaîne varisque d'Afrique du Nord. Le découpage en cinq zones structurales, séparées par des zones de cisaillement, résulte d'une évolution polyphasée comprenant des événements prévarisques (450–430 Ma), très localisés, qui se rattachent au cycle calédonien, et des événements varisques où trois grandes étapes peuvent être distinguées : Éovarisque (370–360 Ma), Mésovarisque (330–320 Ma) et Néovarisque (300–290 Ma), suivies par les événements tardi-Varisques (Permien inférieur–Trias). L'évolution varisque se déroule dans un contexte géodynamique de type transtension–transpression, contrôlant l'ouverture, puis la fermeture des bassins dévono-carbonifères. Le raccourcissement est accommodé par des plis syn-schisteux et des décro-chevauchements associés à un métamorphisme de faible à moyen degré, caractéristiques des zones externes des orogènes. L'absence de croûte océanique dans les séries paléozoïques, et donc de zone de suture, suggère que l'Afrique du Nord est une partie intracontinentale de l'orogène varisque, qui a évolué près de la bordure du craton Ouest-Africain. Les raccords avec les autres segments paléozoïques péri-atlantiques demeurent encore un sujet de discussion. ***Pour citer cet article : C. Hoepffner et al., C. R. Geoscience 338 (2006).***

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1. Introduction

The Palaeozoic of North Africa is part of the peri-Atlantic Palaeozoic chains, and more particularly of the Variscan belt, built up during the Late Palaeozoic by collision between Gondwana and Laurussia [77].

Outside of the Rifian–Kabylian Alpine allochthons (not considered in this paper), the Variscan terranes of North Africa crop out widely in Morocco and much lesser in westernmost Algeria; they form the Palaeozoic inliers and massifs of the Moroccan and West Algerian Mesetas, and of the Atlas chain (Fig. 1). These elements constitute the Variscan orogenic domain or 'Mesetan' domain, which is opposed to the weakly deformed Saharan domain (Anti-Atlas, Ougarta). The relationships between these two fields are not perfectly clear. Their respective positions during most of the Palaeozoic are in debate, except at the end of Carboniferous, where the Anti-Atlas area can be delineated as the southern foreland of the chain.

The Moroccan Variscan orogen was the object of several synthesis and attempts of interpretation [39,60, 81,83,93,94,96]. According to these authors, during the Palaeozoic, North Africa was located at the margin of Gondwana, and went through an intracontinental evolution. There is no geological argument indicating the existence of an oceanic lithosphere during the Palaeozoic. The crustal thinning events recorded during various periods, from Cambrian to Carboniferous, did not result in the formation of any documented oceanic crust in the area. Some geodynamical models, mainly based on the study of the Carboniferous magmatism, postulate, however, the existence of an oceanic crust [20,72, 101]. A more or less broad oceanic domain would have separated the Meseta domain and the Saharan platform during the Early Palaeozoic [52] or the Devonian [106]. However, the palaeomagnetic data in support of these models are controversial [73]. In the present paper, we show that the hypothesis of exotic Mesetan terranes before the Eovariscan events is not supported by undeniable field data.

This note focuses on the tectonics of the Moroccan Meseta Domain during the Palaeozoic, and more particularly during the Variscan orogeny from Late Devonian to Late Permian. Based on stratigraphic, structural and radiometric arguments, it is possible to distinguish several events or phases of deformation: (*i*) Eovariscan events (370–360 Ma), (*ii*) Mesovariscan or Intravisean events (330–320 Myr), (*iii*) Neovariscan events developed at 300–290 Ma (main Variscan phase), (*iv*) Tardi-Variscan events between Early Permian and Late Triassic.

2. Structural framework

According to the different synthesis quoted above, it is possible to subdivide the Variscan belt of North Africa into five structural zones (Fig. 2).

(1) The *Sehoul Zone* or 'Caledonian' zone is located at the northwestern corner of western Meseta, and extends under the foredeep basin of the Rif belt, and offshore in the Atlantic margin. Cambrian deposits were folded, metamorphosed and granitized between 450–430 Ma. This terrane was attached to the main Meseta terranes between Upper Silurian and Upper Devonian along the Rabat–Tiflet Fault Zone (RTFZ).

(2) The *Coastal Block*, which corresponds to the Atlantic lowlands consists of Lower to Middle Palaeozoic deposits. The Variscan deformation is generally weak, but its intensity increases towards the Eastern limit of the Coastal Block, i.e. the Western Meseta Shear Zone (WMSZ).

(3) The *Central Zone* includes the larger massifs of western Moroccan Meseta. All the Palaeozoic systems are represented from Cambrian to Permian. An Early–Middle Palaeozoic, more or less subsident, marine platform is replaced during the Late Devonian–Carboniferous by syn-orogenic basins with basic magmatism in a context of crustal thinning. Variscan deformation is strong and polyphased (between 330 and 300 Ma), with Barrovian-type metamorphism along the WMSZ, and scattered syn- or late-orogenic granitoid bodies. This zone is crosscut by an important thrust zone, i.e. the Smaala–Oulmès Fault zone (SOFZ) and limited towards the East by the Tazekka–Bsabis–Bekrit Fault Zone (TBBFZ).

(4) The *Eastern Zone* includes the small inliers of the Moroccan Eastern Meseta and Algeria (Midelt, Debdou, Mekkam, Beni Snassen, Traras, North of Tamlelt). The Palaeozoic series (Ordovician to Westphalian) are characterized during Lower and Middle Devonian by turbiditic deposits, and during Lower Carboniferous by volcanoclastic rocks with calc-alkaline magmatism. Deformation is polyphased with two main events at 370

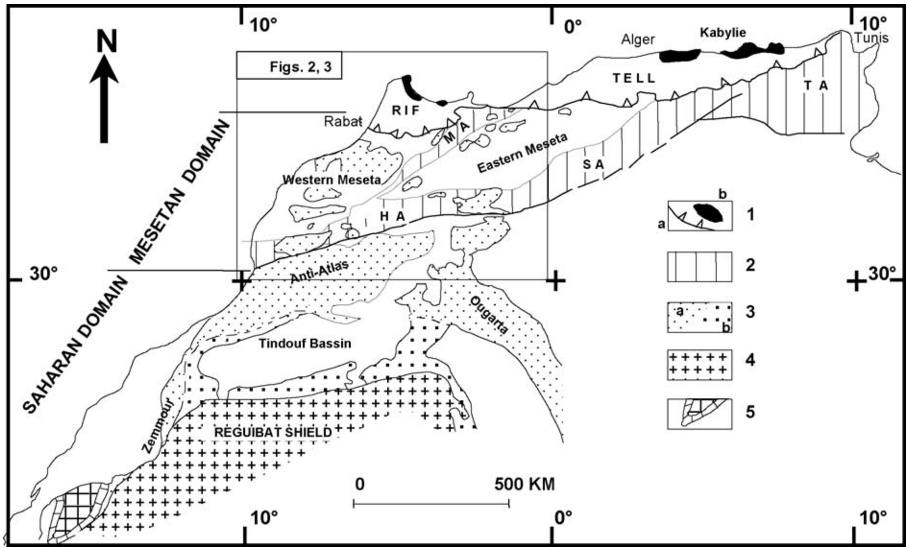

Fig. 1. Structural domains of North Africa and location of the Palaeozoic terranes (after [60]). **1**: Rif–Tell = Maghrebide belt, **a**: southern front of the belt; **b**: Palaeozoic allochthonous terranes of the Maghrebide internal zones. **2**: Atlasic belt (**HA**: High Atlas, **MA**: Middle Atlas, **SA**: Saharan Atlas, **TA**: Tunisian Atlas). **3**: Palaeozoic terranes, **a**: deformed by the Variscan orogeny, **b**: undeformed. **4**: West-African craton (Archean and Eburnian). **5**: Mauritanides allochthons.

Fig. 1. Domaines structuraux de l'Afrique du Nord et localisation des terrains paléozoïques (d'après [60]). **1** : Chaîne Rifo-Tellienne = Maghrébides, **a** : front sud de la chaîne, **b** : terrains paléozoïques allochtones des Maghrébides internes. **2** : chaîne atlasique (**HA** : Haut Atlas, **MA** : Moyen Atlas, **SA** : Atlas saharien, **TA** : Atlas tunisien). **3** : Terrains paléozoïques, **a** : déformés par l'orogenèse varisque, **b** : non déformés. **4** : Craton Ouest-Africain (Archéen et Éburnéen). **5** : Unités allochtones des Mauritanides.

and 300 Myr followed by emplacement of late orogenic granitic plutons.

(5) The *Southern Zone* marks the limit between the Mesetan and Saharan domains; it is located south of the Atlas Palaeozoic Transform Zone (APTZ). The Palaeozoic series are similar to that of the Anti-Atlas from Cambrian to Devonian, whereas the Carboniferous is characterized by subsident detrital basins. Variscan deformation is somewhat stronger than in the Anti-Atlas, but metamorphism is virtually lacking (very low-grade greenschist facies in the main shear zones) and magmatism is not recorded. This zone is limited to the south by the folds and overthrusts of Tamlelt and Tineghir which correspond to a South Morocco Variscan Front (SMVF), which connects towards the west with the Tizi n'Test Fault Zone (TTFZ).

3. Prevariscan events

3.1. Sehoul Zone

The stratigraphic sequence of this zone consists of Cambrian pelites and greywackes, the primary sedimentary structures of which are indicative of a deltaic environment [37]. A tectono-metamorphic episode, with southward increasing intensity, corresponds to east–west-trending, south-verging overturned folds with spaced to slaty cleavage generated in a very low- to low-grade regional metamorphism. The Cambrian metasediments are intruded by granitic bodies. The metamorphism is dated at 453 ± 8 Ma (K/Ar method on micas, [38]) and the granites at 430 ± 3 Ma (Rb/Sr, [25], recomputed). According to the radiometric data, these events correspond to the Caledonian orogeny [79]. Likewise, in the Atlantic offshore of El Jadida, Lower Cambrian granodiorite has been mylonitized at 455 Ma [102]. Therefore, it is likely that a 'Caledonian' belt wraps around the northwestern Meseta [13,34] (Fig. 2); the convergence between these two domains was probably realized by ductile wrenching and/or thrusting of the Sehoul Zone upon the main Meseta domain prior to the Late Silurian as within the RTFZ, Silurian deposits unconformably overlay a Caledonian mylonitized granite tectonically inserted into unmetamorphosed Lower Ordovician shales [37].

3.2. Main Mesetan domain

From Neoproterozoic until Middle Devonian, the sedimentation is organized in a positive megasequence [93]: Cambrian and Ordovician silicoclastics, Silurian black shales, Lower and Middle Devonian limestones.

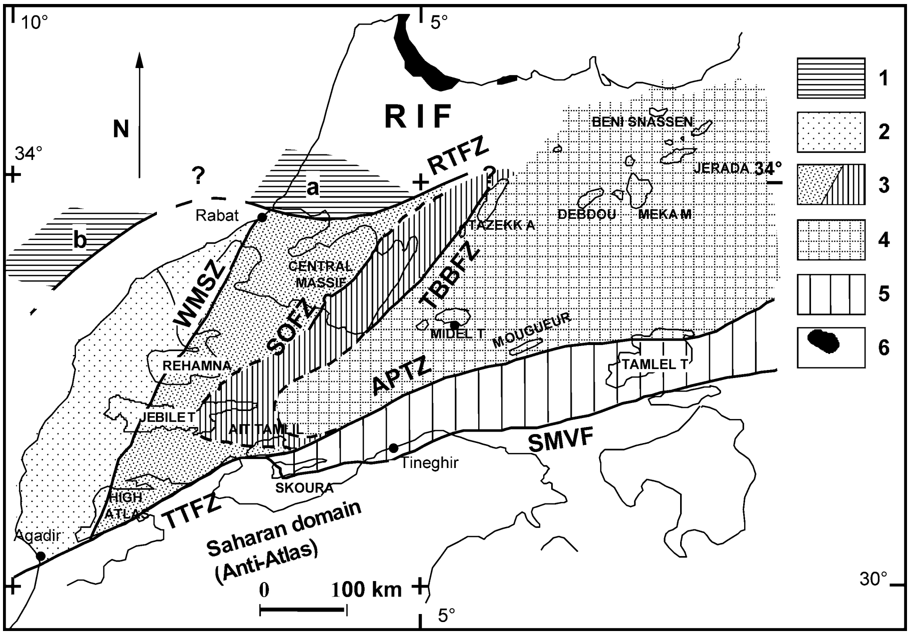

Fig. 2. Structural zones of the Variscan domain of Morocco and Western Algeria (Mesetan domain) with the main Palaeozoic massifs delineated (after [60]). **1**: Sehoul Zone (**a**) and its likely prolongation to the west (**b**). **2**: Coastal Block. **3**: Central Zone, subdivided into Western Subzone (**a**) and Eastern Subzone (**b**). **4**: Eastern Zone. **5**:. Southern Zone. **6**: Internal Zones of the Rif belt. Main structural limits: **RTFZ**: Rabat–Tiflet Fault Zone; **WMSZ**: Western Meseta Shear Zone; **SOFZ**: Smaala–Oulmès Fault Zone; **TBBFZ**: Tazekka–Bsabis–Bekrit Fault Zone; **APTZ**: Atlas Palaeozoic Transform Zone; **SMVF**: South Moroccan Variscan Front; **TTFZ**: Tizi n'Test Fault Zone.

Fig. 2. Les zones structurales du domaine varisque au Maroc et en Algérie occidentale (domaine mésétien) et principaux massifs paléozoïques (d'après [60]). **1** : Zone des Sehoul (**a**) et son prolongement probable vers l'ouest (**b**). **2** : Bloc côtier. **3** : Zone centrale divisée en sous-zone occidentale (**a**) et sous-zone orientale (**b**). **4** : Zone orientale. **5** : Zone sud. **6** : Zones internes du Rif. Principales limites structurales : **RTFZ** : zone de failles de Rabat–Tiflet ; **WMSZ** : zone de cisaillement de la Meseta occidentale ; **SOFZ** : zone de failles Smaala–Oulmès ; **TBBFZ** : zone de failles Tazekka–Bsabis–Bekrit ; **APTZ** : Zone transformante paléozoïque de l'Atlas ; **SMVF** : front varisque sud-marocain ; **TTFZ** : zone de failles du Tizi n'Test.

An extensional tectonic context is well documented during the Cambrian with the Middle Cambrian rift trending NNE–SSW in the Coastal Block [15]. Basic magmatic rocks of alkaline affinity accompany this intraplate extension, essentially during Middle Cambrian and Silurian [34,41,87–89]. Tilted blocks are described in the Devonian [40]. A turbiditic basin opened during Devonian in eastern Morocco and Algeria; the clastic and deep water characters of the sedimentation distinguishes this zone from the western Meseta carbonate shelf.

The tectono-metamorphic and magmatic Caledonian events documented in the Sehoul Zone are not observed in the main Meseta domain. However, contemporaneous 'epirogenic' movements are described in the Coastal Block and in the RTFZ, where the detrital, continental deposits ('Old Red Sandstones' type) of Upper Silurian and Lower Devonian overlay directly (locally with angular unconformity) the Cambrian and Lower Ordovician strata [16,37,81,92].

4. Eovariscan and Mesovariscan (Intra-Visean) events

4.1. Eastern Zone

4.1.1. Eovariscan phase (370–360 Ma)

In the Meseta Eastern Zone (Figs. 2 and 3), the earliest deformations of the Lower Palaeozoic and Devonian deposits are attributed to the Eovariscan phase, based on isotopic datings of the metamorphic rocks. Metamorphism is important at Midelt and North Tamlelt (greenschist to amphibolite facies with biotite and garnet), whereas it is weak elsewhere (very low- or low-grade greenschist facies). This tectono-metamorphic event has been dated at 366 Ma at Midelt (Rb/Sr method, [26]), and 370 Ma at Debdou-Mekkam (K/Ar on white micas, [63]).

Two stages of deformation (D1 and D2) are distinguished; they correspond to a progressive deformation during the Eovariscan phase [57,109]. The D1 and D2 structures are well exposed in Midelt and North Tamlelt,

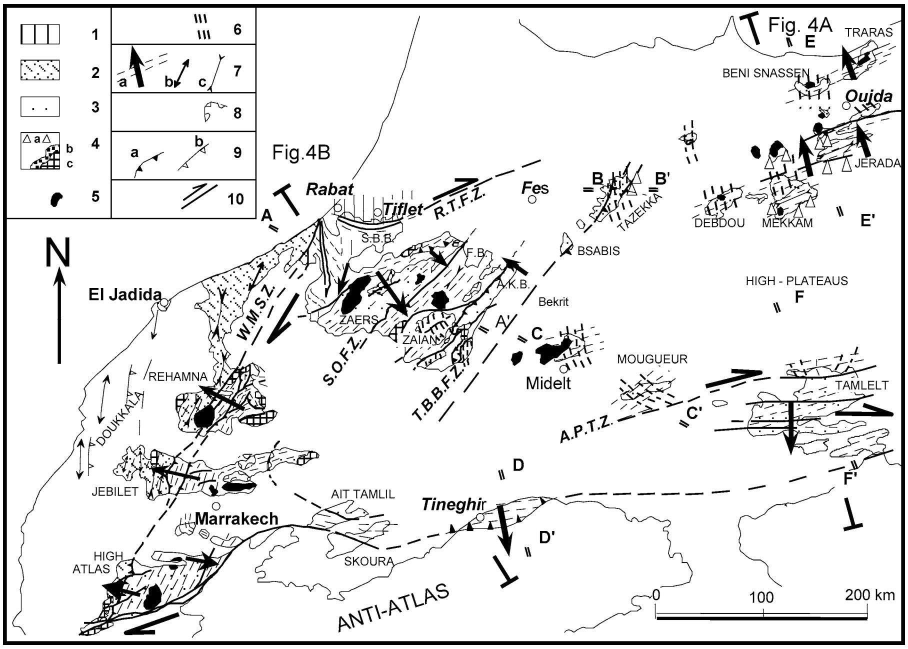

Fig. 3. Structural map of the Mesetan Domain. **1**: Sehoul Zone; **2**: Coastal Block (Lower to Middle Palaeozoic); **3**: Lower to Middle Palaeozoic of Western Meseta and Eastern and Southern Zones; **4**: Carboniferous; **a** (triangles): volcanoclastic series of the Eastern Zone, **b**: Upper Westphalian redbeds, **c**: Late Stephanian–Lower Permian redbeds; **5**: Variscan granitoids; **6**: Eovariscan structures (cleavage, fold axis); **7**: Variscan structures, **a**: cleavage trajectories and main vergence, **b**: anticlines, **c**: synclines; **8**: gravity nappes; **9**: main Variscan thrusts (**b**: subsurface data); **10**: strike-slip faults. **RTFZ**, **WMSZ**, **SOFZ**, **TBBFZ**, **APTZ** (see Fig. 2). **SBB**: Sidi Bettache Basin; **AKB**: Azrou-Khénifra Basin; **FB**: Fourhal Basin.

Fig. 3. Carte structurale du domaine mésétien. **1** : Zone des Sehoul ; **2** : bloc côtier (Paléozoïque inférieur et moyen) ; **3** : Paléozoïque inférieur et moyen de Meseta occidentale et des Zones orientale et méridionale ; **4** : Carbonifère ; **a** (triangles) : séries volcanoclastiques de la Zone orientale, **b** : couches rouges du Westphalien supérieur, **c** : couches rouges du Stéphanien terminal–Permien inférieur ; **5** : granitoïdes varisques ; **6** : structures éovarisques (schistosités, axes de plis) ; **7** : structures varisques, **a** : trajectoires de schistosité et vergence dominante ; **b** : anticlinaux ; **c** : synclinaux ; **8** : nappes gravitaires ; **9** : principaux chevauchements varisques (**b** : d'après les données de subsurface) ; **10** : décrochements. **RTFZ**, **WMSZ**, **SOFZ**, **TBBFZ**, **APTZ** (voir Fig. 2). **SBB** : Bassin de Sidi Bettache ; **AKB** : bassin d'Azrou–Khénifra ; **FB** : bassin de Fourhal.

where the Lower Palaeozoic metamorphic series crop out. Elsewhere, it is difficult to separate D1 and D2. The earliest recognizable structures (D1) consist of a gently dipping, bedding-parallel foliation or slaty cleavage associated with isoclinal, recumbent folds trending east–west or NW–SE at Midelt and NW–SE to NNE–SSW in North Tamlelt. The foliation is generally refolded during the D2 stage by NW–SE to east–west trending, overturned folds with crenulation cleavage or differentiated layering. Fold vergence is toward the west or the southwest, rarely toward the east. It seems that D2 is associated with horizontal shearing (S/C structures, sheath folds, dispersion of the folds axis) probably related to top-to-the-west or south-west thrusts. A stretching and/or mineral lineation is locally well developed (Midelt, Tamlelt), generally gently dipping and parallel to the fold hinges. Locally, finite strain ellipsoid measurements indicate flattening or plane strain. A recent work [53] proposed that in the Midelt area, all the structures (D1 and D2) and metamorphism would be Intravisean events related to the ascent of the granitoids between 330 and 320 Ma. However, this hypothesis does not explain the structures observed elsewhere in weakly metamorphic or unmetamorphosed rocks, nor fits the reported isotopic datings of the metamorphic rocks at 366–370 Ma.

4.1.2. *Intravisean phase (330–320 Ma)*

This period corresponds in the Eastern Zone to the opening of volcano-clastic basins (Debdou-Mekkam, Jerada, Traras). The Lower Carboniferous deposits (conglomerates, limestones) dated from the Late Visean and Early Namurian [14,67,80] unconformably overlain the older rocks, weakly deformed by the Famenno-Tournaisian episode. These sediments are associated with pyroclastites and calc-alkaline lavas, e.g., andesites, dacites, rhyolites and ignimbrites [14,24,71]. South of Oujda, volcanism is coupled with chaotic facies sedimentation localised along ENE–WSW faults. This indicates that the volcanism is contemporaneous with extensional or transtensive tectonics [35,65,108]. Simultaneously, the oldest granitoids emplaced in the

Midelt metamorphic rocks (333–319 Myr; U–Pb on zircons [91]), and in more superficial levels southwest of Oujda (328–321 Myr, Rb–Sr [85]). Petro-structural studies carried out in the Midelt granitoids have led to ambiguous conclusions, suggesting that the plutons emplaced in their country rocks either in a low-angle crustal shear-zone [30] or along normal NE–SW faults [42], or else in the form of diapirs [53]. As well as the opening of the volcano-clastic basins, the emplacement of the granitoids can be integrated in an extensional or more probably transtensive context.

4.2. *Tazekka–Bsabis–Bekrit Fault Zone (TBBFZ)*

The TBBFZ encompasses the whole Tazekka massif and corresponds to the kilometre-wide contact zone between the Eastern Zone and Central Meseta [18,57,84] (Figs. 2 and 3). The Ordovician, Silurian and Devonian rocks are involved in west-vergent thrust sheets, either metamorphic or displaying pervasive slaty cleavage or else unmetamorphosed. Stacking of tectonic slivers resulted from folding and westward thrusting in a compressive context. The very low- or low-grade metamorphism has been dated at 320 Myr (K–Ar on white micas, [63]). Just after the Intravisean episode, a small granite stock emplaced in the Ordovician slates of the Tazekka massif [66]. On the eastern side of the massif, the Ordovician basement is unconformably covered by a volcano-clastic complex of Late Visean–Early Namurian age [24,57]. This complex is contemporaneous with the volcano-clastic basins of the Eastern Zone, which display volcanic rocks of similar calc-alkaline affinity [71]. The opening model of the Tazekka basin is controversial: (*i*) extension or transtension relaying the former Intravisean compression [24,51] or (*ii*) persistence of compression [11].

To conclude, the Variscan evolution of the TBBFZ in the Tazekka massif seems very similar to that of the Eastern Zone, but the isotopic ages suggest that compression is more recent here, 320 Ma instead of 370 Ma. This could indicate a westward ‘migration’ of the regional shortening between Late Devonian and Late Visean [93,96], or else that the Eastern Zone collided with the Tazekka and neighbouring western Meseta during the Visean.

4.3. *Central Zone*

4.3.1. *East Central Subzone (Azrou–Khénifra–Zaian, eastern Jebilet, Ait Tamelil)*

The development of the Variscan orogeny in this subzone is characterized by the synchronism of deformations with Lower Carboniferous sedimentation. This is recorded at map scale by olistostromes and gravity-driven nappes [4,18,64] sliding in a wide, syn-orogenic basin formed after the Late Visean transgression.

Two types of markers characterize the Early Variscan evolution in this area: (*i*) sedimentary markers, related to the filling up of a foreland basin (turbiditic deposits, gravitational slides, chaotic deposits near active faults), (*ii*) tectonic markers, related to the shortening of the basement and westward thrusting of the internal zones of the basin (folds with axial plane cleavage, and thrust with stacking of tectonic slivers). The distribution of these markers is, on the one hand, chronological, related to the successive tectonic events, and, on the other hand, spatial, related to the structural sub-zones or structural levels as follows.

4.3.1.1. Eovariscan (Famennian–Tournaisian) phase. This phase has been recognized in the northeast part of Central Meseta (Azrou and Mrirt areas), where Devonian rocks, at the bottom of the basin, registered an extensional deformation before and during the Tournaisian. Tilted blocks and decametric slumps are described in the Devonian layers [19]. The facies and thickness of the Upper Tournaisian series reveal the occurrence of a half-graben system during this period, and the tilted block structures indicate a SW–NE direction of extension.

4.3.1.2. Intravisean phase (330–320 Ma). The age of folding is determined by isotopic dating at 330–320 Ma (K–Ar on white micas, [63]) obtained from the Cambrian and Ordovician rocks forming the bottom of the basin, from the Ordovician allochthonous units and from the Carboniferous autochthonous deposits. This Intravisean (Meso-Variscan) phase is marked by a heterogeneous deformation. At the eastern margin of the basin, the allochthonous terranes display northwest to NNE trending isoclinal folds with spaced or slaty cleavage and very low- to low-grade metamorphism. Folding is followed by gently dipping thrusts with top-to-the-west motion. In the pre-Visean autochthonous rocks of the ‘Zaian Block’, the Intravisean structures consist of a subhorizontal mylonitic fabric in the Neoproterozoic rhyodacites, and a slaty or spaced cleavage in the overlying Cambro-Ordovician series, with a well-developed east–west to NW–SE-trending stretching lineation [4,18,23]. The associated submeridian folds are recumbent or overturned toward the west. Upper Visean sequences unconformably cover these pre-Visean deformed rocks. In the Visean autochthonous deposits, the Intravisean deformation is marked by map-scale NE–SW-trending folds overturned to the northwest. The pelitic rocks display spaced cleavage associated with very low-grade metamorphism, and superimposed by shear surfaces subparallel to the fold axial planes.

The Intravisean phase is accompanied by the emplacement of allochthonous units or nappes of the Azrou–Khénifra [4,18], eastern Jebilet [5,64] and Ait Tamelil areas [69,70]. Two types of nappes are distinguished: (*i*) large allochthonous units including Ordovician, Silurian, Devonian and Visean rocks, moderately deformed before their emplacement by gravity sliding and, locally, back compression mechanisms. They originate from the eastern uplifted margins of the basin (TBBFZ and Eastern Zone), (*ii*) weakly metamorphic units involved in westward thrusts that overlay the autochthonous Carboniferous rocks and previous gravity nappes. This overthrusting tectonics represents the latest stage of the Intravisean deformation in the East Central subzone.

These data can be integrated into a model of evolution of the Carboniferous Basin from the Azrou–Khénifra to eastern Jebilet and Ait Tamelil areas. The basin opening begins during the Tournaisian and Early Visean in a transtensive context controlled, in the Azrou–Khenifra basin, by NE–SW dextral transcurrent faults (TBBFZ and SOFZ, Fig. 5B). Blocking of this transcurrent movement during the Late Visean changes the TBBFZ into a zone of reverse faults with westward and southwestward thrusting. The eastern margins are folded and uplifted while gravity nappes are detached from the substratum and slide into the basin. Finally, the eastern part is sheared and tectonic slices are thrust onto the central part of the basin. In other words, from sedimentation to deformation, the Azrou–Khénifra basin evolves from a transtensive to a transpressive foreland-type basin [19]. Some pillow lavas and doleritic sills and dykes are described in the Upper Visean and Namurian sequences of the western part of the basin (Fourhal Basin); the magma shows a transitional to tholeiitic affinity [71,99], but locally, a calc-alkaline trend is evidenced [101].

From the Late Visean to the Early Westphalian, the whole East Central subzone belonged to a compressional foreland basin system. Similar models were recently proposed [9,10,19], where the Azrou–Khénifra and Fourhal basins are the depocentres resulting from the northwestward propagation of synsedimentary thrust and fold system. Shortening and sedimentation migrated progressively toward the west from Late Visean to Early Westphalian. From the point of view of their evolution and age, these basins are similar to the Carboniferous foreland basins of the south European Variscan belt [28,44,54,68].

4.3.2. West Central subzone (Central Morocco, Rehamna, Central Jebilet, Marrakech High Atlas)

In the West Central Sub-Zone of the Moroccan Meseta, the Eovariscan phase corresponds to the opening of a Late Devonian–Carboniferous basin, i.e. the Sidi Bettache Basin (SBB) and its prolongations in the Rehamna, Jebilet and Haouz massifs. The SBB is interpreted as a transtensive basin [92], controlled by dextral motion along NNE–SSW fault zones, mainly the WMSZ and the SOFZ. Near the margins, some isotopic datings at 320 Ma (K–Ar on micas [38,63]) indicate a very low-grade metamorphic event associated with Intravisean deformation contemporary with the opening of the basin. The palaeogeographical pattern would involve emerged ridges or uplifted blocks (Zaers–Oulmès, Coastal Block and Sehoul Zone) and subsident depocentres that would coincide with the regional anticline and syncline structures resulting from the final Variscan shortening, respectively [92]. According to this model, the geological units are essentially autochthonous. The same transtensive context was recently used to explain the opening of the Carboniferous basin of the Rehamna [40] and Central Jebilet [47]. This model has been discussed, because the synsedimentary kinematics along the fault zones is not well documented and the Intravisean emersion of the Zaers–Oulmès ridge is controversial [98], but it remains the more likely explanation for the sedimentary facies distribution during Devono-Carboniferous times.

The basin development is accompanied by a moderate mafic magmatism with lava flows interbedded in the Carboniferous sedimentary rocks, and intrusive bodies like sills and dykes. The geochemical affinity is alkaline to transitional-tholeiitic [1,49,71,100], consistent with an extensive pre-orogenic context. In this context, a model of tilted blocks is often evoked to explain the rising of the ridges [107,111]. Thus, during the Devono-Carboniferous period, the West Central Sub-Zone could be regarded as an area evolving in an extensional or transtensional context, whereas the East Central Sub-Zone recorded compressional events. However, there are also compressive deformations which could be related to the basin formation in the western sub-zone. In the pre-Carboniferous rocks of the Zaers–Oulmès ridge, folds with spaced cleavage [107] and imbricate thrusts [21] have been described, and thus, the ridges could be interpreted as antiformal stacking of tectonic slivers associated with westward-verging thrusts and folds [9], or with positive flower structures in a transpressive context

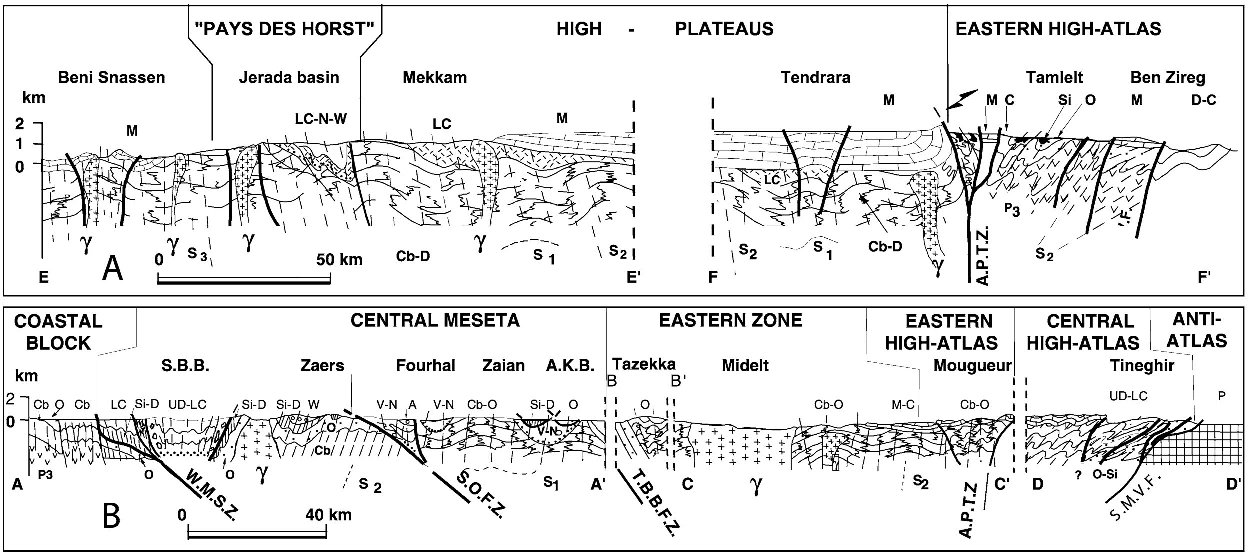

Fig. 4. Simplified geological sections across the eastern (4A) and western parts (4B, after [60], modified) of the Mesetan Domain (see location in Fig. 3). **P3**: Neoproterozoic; **Cb**: Cambrian; **O**: Ordovician; **Si–D**: Silurian to Middle Devonian; **UD–LC**: Upper Devonian, Lower Carboniferous; **C**: Carboniferous; **V–N**: Visean–Namurian; **W**: Upper Westphalian; **A**: Autunian; γ : granitoids. **S1**: composite cleavage (Eovariscan and Intravisean phases), **S2**: Late Variscan cleavage. **SBB**: Sidi Bettache Basin, **AKB**: Azrou–Khénifra Basin, **M**: Mesozoic cover (High Atlas). **RTFZ**, **WMSZ**, **SOFZ**, **TBBFZ**, **APTZ** (see Fig. 2).

Fig. 4. Coupes géologiques simplifiées dans les parties orientale (4A) et occidentale (4B, d'après [60], modifié) du domaine mésétien (localisation : Fig. 3). **P3** : Néoprotérozoïque ; **Cb** : Cambrien ; **O** : Ordovicien ; **Si–D** : Silurien–Dévonien moyen ; **UD–LC** : Dévonien supérieur–Carbonifère inférieur ; **C** : Carbonifère ; **V–N** : Viséen–Namurien ; **W** : Westphalien supérieur ; **A** : Autunien ; γ : granitoïdes. **S1** : schistosité (phases éovarisque et intraviséenne) ; **S2** : schistosité (phase varisque). **SBB** : Bassin de Sidi Bettache ; **AKB** : bassin d'Azrou–Khénifra ; **M** : couverture mésozoïque (Haut Atlas). **RTFZ**, **WMSZ**, **SOFZ**, **TBBFZ**, **APTZ** (voir Fig. 2).

[60]. In the Carboniferous rocks of the Central Jebilet, structural studies [47–49] show the broadly syntectonic character of the bimodal magmatism. The latter is dated at 330 Myr (U/Pb on zircons, [50]), i.e. Late Visean, which shows that the Devono-Carboniferous basins of West Central Sub-Zone recorded Intravisean events and also evolved in a broadly compressive context.

4.4. *Coastal Block*

During the Late Devonian, the central part of the Coastal Block rose up and constituted a NNE-trending ridge. On the western side of this ridge, under the recent coastal basins (Doukkala, Chaouia), an Upper Devonian–Lower Carboniferous basin is known from subsurface data [6,32]. The eastern side of the uplifted Coastal Block is interpreted as the western limit of the Carboniferous basins (Sidi-Bettache, central Jebilet) [17,78,96]. As in the West Central Sub-Zone, these Eovariscan events can be integrated in a transtensive or extensive context. However, the recent reinterpretation of seismic data in the Doukkala basin [32] shows that NNE-trending folds and west-verging thrusts are unconformably covered by weakly deformed Upper Devonian and Carboniferous rocks. This interpretation would indicate that at least part of the structures of the Coastal Block have developed during the Eovariscan compressive episode.

5. Neo- and Tardi-Variscan events

Late Carboniferous deformations affected the whole Mesetan Domain. This classical Hercynian phase also labelled the 'main' phase [81] or Westphalian phase [96] began during the Westphalian, and the resulting structures are sealed by unconformable Upper Stephanian or Lower Permian continental redbeds. Moreover, the micas neoformed during the deformation yield K/Ar ages between 300–290 Ma [63], i.e. close to the Westphalian–Stephanian limit. The structures resulting from the Neovariscan events superimposed to the previous events are described hereafter along two complementary transects (Fig. 4).

5.1. *Neovariscan events in the eastern transect*

This transect (Fig. 4A) crosscuts the Eastern and Southern Zones which are separated one from each other by the Atlas Palaeozoic Transform Zone (APTZ), widely exposed in the northern part of the Tamlelt inlier. In the Eastern Zone, the Lower Palaeozoic rocks, previously deformed during the Eovariscan events, constitute a basement covered by Carboniferous deposits. This generates a marked contrast between the Variscan deformation in the basement and cover, respectively. The Eovariscan basement is moderately deformed during the Neovariscan stage. East- to ENE-trending folds (often kink-bands) with generally steeply dipping axial planes are overprinted by brittle dextral shear zones parallel to the fold axial planes. The Carboniferous cover displays east- to ENE-trending overturned folds. Their most usual vergence is to the north, as exemplified by the Ez–Ziroug syncline in the Mekkam inlier [57] and the Jerada syncline [45]. Folding is followed by northward thrusting. Some localized décollements are observed near the basement-cover contact. Spaced or crenulation cleavages are associated with a very low-grade metamorphic evolution. Small granitic bodies emplaced after these deformations at about 286 and 247 Ma [85]. Their petrological and geochemical characteristics indicate a post-collisional emplacement [36,56].

In the Southern Zone, which is represented along this transect by the Tamlelt inlier, the Variscan deformation results in a combination of southward thrusting and dextral strike-slip faulting. ENE-trending, upright or overturned folds are associated with east–west dextral, ductile shear zones [61]. Spaced or continuous axial plane cleavage is well developed, coeval with a low-grade metamorphic evolution. S/C structures and subhorizontal stretching lineations parallel to the fold axes characterise a wrench dominated, transpressive fabric. Thus, during the main Variscan stage, the Southern Zone evolved in a transpressive context corresponding to the eastward motion of the Eastern Zone along the APTZ, and more generally to the ongoing eastward translation of the Meseta domain along the African margin [62]. All the Variscan structures observed along this transect indicate a NW–SE to north–south shortening in a transpressive context, controlled by dextral translation along ENE–WSW and east–west fault zones, especially the APTZ. In comparison with the western Meseta (see below), ductile shortening seems relatively weak. This difference is probably due to the presence of the more or less rigid basement, previously deformed during the Eovariscan stage.

5.2. *Neovariscan events in the western transect*

This composite transect (Fig. 4B) crosscuts the Coastal Block, the Central Zone (Moroccan Central Massif), the Eastern Zone (Midelt), and the Southern Zone (Tineghir). In the Coastal Block, the Variscan deformation is weak. The kilometric-scale, NNE-trending folds are either upright or overturned toward the west, especially in the western Rehamna and Jebilet where folding is followed by westward thrusting. The intensity of deformation and the associated metamorphism increase from west (spaced cleavage) to east (slaty cleavage and schistosity) [95]. The eastern limit of the Coastal Block corresponds to the Western Meseta Shear Zone (WMSZ) [97], with complex movements combining west-verging folds and thrusts and dextral wrench-faults.

The transect crosses the northern part of the Meseta Central Zone (Moroccan Central Massif), where the Variscan deformation is complex and polyphased. The main structures are NNE- to northeast-trending folds. The regional antiformal and synformal structures could correspond respectively to the ridges and depocentres formed during the Eovariscan episodes [92], but this interpretation is controversial [98]. The orientation of the former structures and the displacement along their limits could explain the local disturbances of the Variscan structures (cleavage, fold axis), especially in the Sidi Bettache Basin (SBB), where the Devono-Carboniferous series display north–south to N140-trending folds related to dextral shearing of the WMSZ, and N70 and N110 folds related to the dextral motion of the Sehoul Block along the RTFZ (Fig. 3). Elsewhere in central Morocco, the folds associated to brittle–ductile thrusts (locally nappes) are generally overturned to the southeast, rarely towards the northwest [22]. These opposite verging directions can be interpreted either as the result of polyphased tectonics, with the southeast-facing structures being more recent as they affect Upper Westphalian deposits discordant upon northwest-vergent folds [59,98], or else as forming a system of coeval, antithetic folds and thrusts in a globally northwest-facing regional structure [9,10,12,76]. The deformation intensity is highly variable, very weak in the Carboniferous synclines where cleavage is not observed and metamorphism absent or very low grade, and much more intense elsewhere, with a conspicuous slaty cleavage coeval with low-grade greenschist-facies metamorphism.

In the southern part of the Central Zone (Rehamna, Jebilet, Marrakech High Atlas), the Variscan deformation results in NNE-trending, WNW-facing folds associated with ductile westward thrusting and dextral wrenching, well marked along the WMSZ. A subhorizontal stretching lineation parallel to the fold axes is well developed. Southeast-facing folds associated with ductile dextral shear zones are observed near the eastern limit of the Palaeozoic massif of the Atlas of Marrakech [33]. As in the Moroccan central massif, the cleavage trajectories and fold axis trends display some variations, especially in the Carboniferous series: N70 in Eastern Jebilet, N110–N140 in the Haouz and Ait Tamelil inliers [55,70] (Fig. 3). The most complex, polyphased Variscan deformations are found in the southern–central Rehamna, where they are associated to prograde Barrovian metamorphism ranking from low grade to medium grade (staurolite–kyanite–garnet sub-facies). The culmination of metamorphism and deformation has been ascribed to a high thermal gradient during the Variscan shortening with combined ductile thrusting and wrench faulting [58,75,96]. However, stacking of synmetamorphic nappes or slices has been also evoked to explain the burial of the metamorphic rocks [27,29] before their subsequent exhumation in an extensional context likely resulting in the negative inversion of the ductile thrusts [2,8].

The transect (Fig. 4B) then crosses the Meseta Eastern Zone through the TBBFZ (projected from the Tazekka massif), and the Midelt and Mougueur inliers (Figs. 3 and 4B). There, the Variscan deformation displays the same characteristics as in the north–south transect (Fig. 4A). Finally, the Southern Zone is represented by the Tineghir area, where Carboniferous detrital deposits fill up a subsident basin on the northern margin of the Saharan platform. The Variscan structures are represented by east-trending, south-facing fold-and-thrust systems associated with east-trending dextral strike-slip faults. This structure is typical of a foreland zone of deformation associated with an orogen [82,105]. So, from Tineghir to Tamlelt, the Southern Zone is deformed in a transpressive context that can be related to the eastward motion of the Mesetan domain along the APTZ. Towards the west, the Southern Zone would connect with the ENE-trending Tizi–n'Test Fault Zone (TTFZ) through the N120 Skoura Fault [90]. The TTFZ–APTZ system makes up the limit between the orogenic domain (Meseta) and the pericratonic domain (Anti-Atlas).

Scattered, syn- to post-tectonic granitoids emplaced in the Central Zone during and after the Late Carboniferous tectonic events. Kinematic studies of some of these massifs evidence a ductile–brittle deformation resulting from the interference between emplacement and regional deformation, the granitic magma being transferred through the crust via the NNE–SSW and ENE–WSW shear zones, and emplaced in extensional zones up to shallow crustal levels [29,48–50,74]. The transpressive–transtensive context corresponds to the late compressional events and perhaps to the beginning of a post-thickening extension. Most of these granitoids emplaced between 305 and 270 Ma [8,56,85], thus they are contemporaneous with the Stephanian and Lower Permian redbeds that unconformably overlay the Variscan structures without reworking granitic or metamorphic pebbles. These continental deposits and the associated calc-alkaline volcanism fill up small pull-apart basins that can be considered as the surface expression of the tectonic processes which controlled the granitoids emplacement at depth [8,31,43,110].

5.3. Tardi-Variscan events

The latest compressive deformations affect the Upper Stephanian and Lower Permian (Autunian) molasses of the Variscan belt. The continental redbeds are by place moderately folded, but deformation is principally accommodated by brittle, reverse and strike-slip faults. The direction of compression is initially oriented east–west, then NW–SE to north–south [3,46,86].

6. Discussion and conclusion

6.1. New insights on the Eovariscan events

In the previous models of the Moroccan Variscan belt, the Eovariscan and Intravisean compressive events were supposed to be virtually limited to the Eastern Zone and East-Central Sub-Zone, whereas the western zones (West-Central Sub-Zone, Coastal Block) had evolved supposedly in an extensive or transtensive context [93,96]. However, Eovariscan compressive structures were described in the western Meseta and even in the Coastal Block, being probably responsible for the initial structuration of the basins and the development of uplifted ridges and depocentres [60]. Accordingly, a model of generalized and continuous shortening from Late Devonian until Namurian has been proposed [10,101]. The mafic magmatism within the Devono-Carboniferous basins of West-Central Sub-Zone is alkaline to transitional-tholeiitic, but its geochemical signature remains ambiguous, anorogenic or orogenic, corresponding either to intracontinental extension or back-arc basin formation [47,71]. To conclude, the geodynamic context of the chain during the Eovariscan period is characterized by compressive and extensive tectonic events that can be contemporaneous or more or less separated in time, but most likely controlled by, or at least involving dextral movements along NNE-trending fault zones in a transtensive–transpressive context. Such a tectonic regime fits a general model of oblique convergence between Gondwana and Laurussia [103].

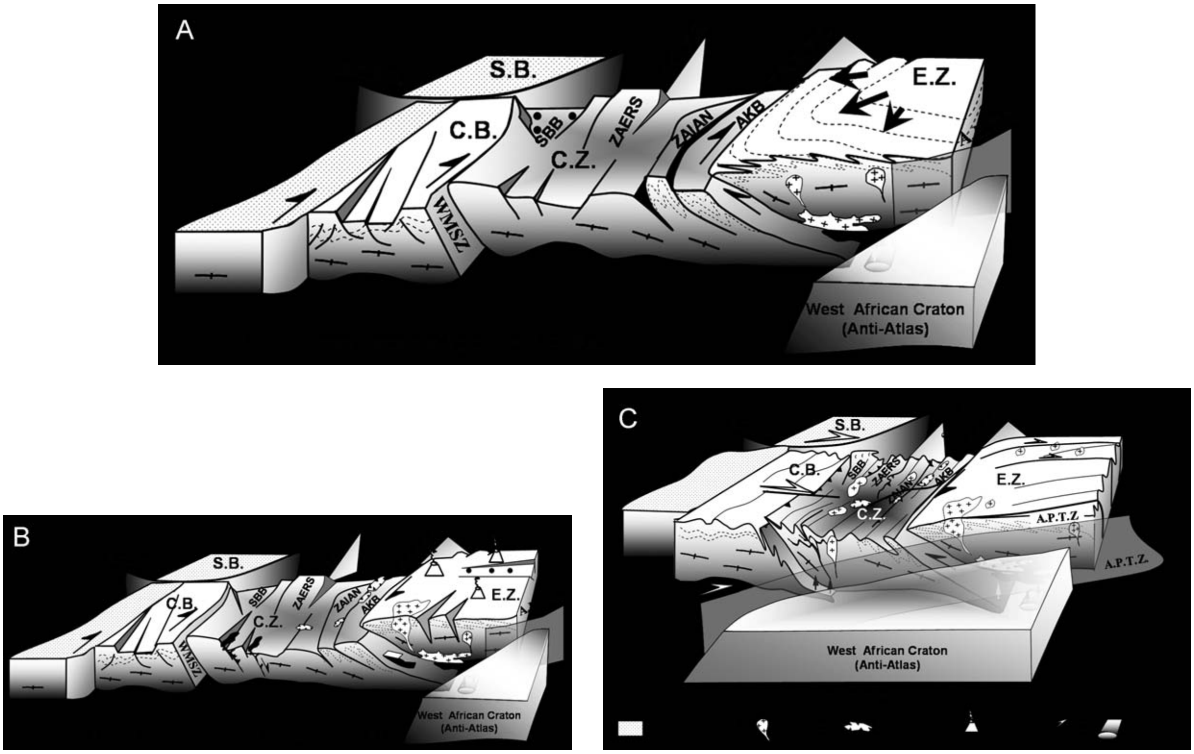

Fig. 5. Geodynamical model for the Mesetan orogen. **1**: Caledonian block; **2**: Eovariscan structures; **3**: Magmatic melting; **4**: Granitic bodies; **5**: Chaotic deposits; **6**: Gravity nappes; **7**: Carboniferous alkaline and tholeiitic volcanism (lava flows, dykes and sills); **8**: Carboniferous calc-alkaline volcanic flows; **9**: Eovariscan and Variscan NE–SW dextral strike-slip; **10**: Late Variscan east–west dextral strike-slip; **11**: Hypothetical remnants of oceanic crust.

Fig. 5. Modèle géodynamique de l'orogène mésétien. **1** : Bloc calédonien ; **2** : structures éovarisques ; **3** : fusion partielle ; **4** : granites ; **5** : dépôts chaotiques ; **6** : nappes gravitaires ; **7** : volcanisme alcalin et tholéiitique carbonifère (coulées, dykes et sills) ; **8** : volcanisme calco-alcalin carbonifère ; **9** : décrochements dextres NE–SW ; **10** : décrochements dextres est–ouest tardi-varisques ; **11** : reliques de croûte océanique (hypothétique).

6.2. A revised tectonic model

In the tectonic interpretation proposed here (Fig. 5), we assume that most of the Meseta was located at the margin of Gondwana during Cambrian–Ordovician times. At the end of Silurian, an allochthonous terrane deformed during tectono-metamorphic events spanning Ordovician to Early Silurian (450–430 Ma) collides with the still undeformed Meseta. This terrane would form a part of a 'Caledonian belt', perhaps discontinuous, belonging to North Africa. The Late Devonian–Tournaisian period (Fig. 5A) corresponds to the Eovariscan phase of the Variscan orogeny. Tectono-metamorphic events dated at 370–360 Ma are well recorded in the Eastern Zone. Shortening would extend towards the west up to the Coastal Block, although with a decreasing intensity. The resulting deformations are contemporaneous with the opening of the Devono-Carboniferous basins. The geodynamic context is transtensive–transpressive, controlled by dextral motions along NNE-trending crustal faults. Localized compressive deformations were probably responsible for uprising of the ridges. During the Early Carboniferous (Fig. 5B), the Intravisean or Mesovariscan phase corresponds to the opening and filling up of detrital and volcanic-detrital basins. Crustal thinning was more important in the Central Zone (transitional-tholeiitic magmatism) than in the Eastern Zone ('orogenic' calc-alkaline magmatism), which was in situation of post-thickening extension. The geodynamical context is still transtensive–transpressive. A metamorphic event dated at 330–320 Ma is associated with compressive deformations like folding and uprising of the TBBFZ and eastern margin of the East Central Sub-Zone from where gravity nappes originated and slid towards the basins (Azrou, Jebilet, Ait Tamelil). The major, Neovariscan phase (Fig. 5C) spans from Late Westphalian to Early Permian (300–290 Myr). The whole Mesetan Domain, which is now entirely emerged, suffered a generalized compression. The shortening is important in the Central Zone with polyphased tectonic–metamorphic events,

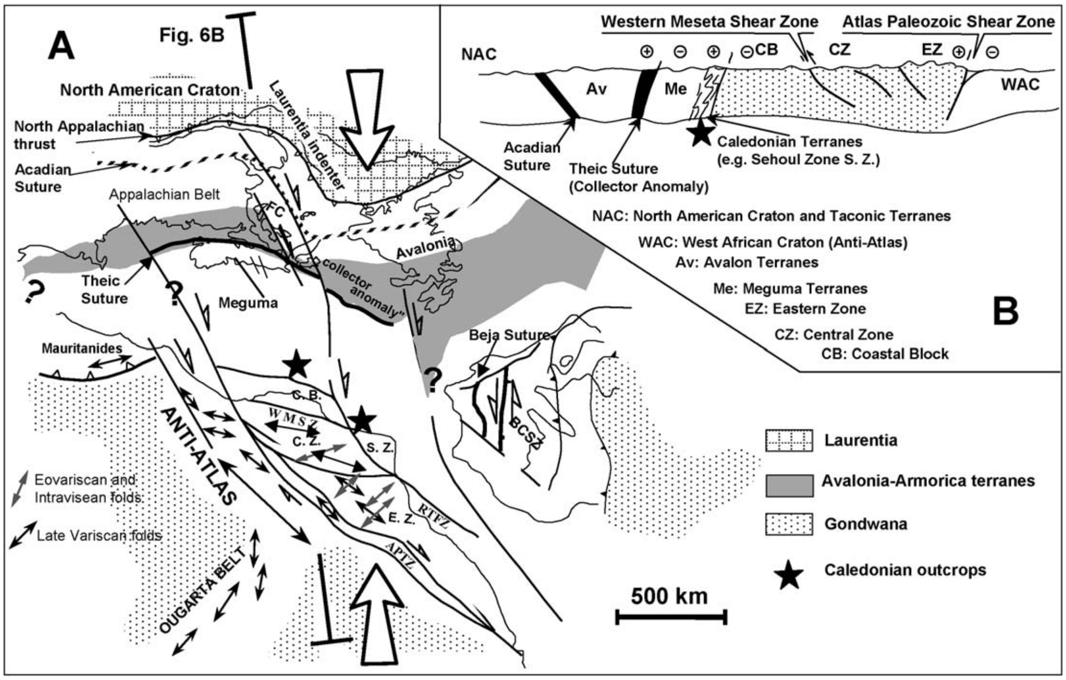

Fig. 6. The North African Variscides in the frame of the Periatlantic Palaeozoic belts at the end of Permian. **A**: Restored map, after [62,77]; **B**: schematic cross-section showing the possible situation of the Mesetan Domain between the North American and West African cratons.

Fig. 6. La chaîne varisque d'Afrique du Nord dans le cadre des chaînes paléozoïques péri-atlantiques, à la fin du Permien. **A** : Carte d'après [62,77] ; **B** : coupe schématique montrant une situation possible du domaine mésétien entre les deux cratons, nord américain et ouest africain.

the intensity of which reaches the medium grade (amphibolite facies). The progressive and complex deformations are controlled by northeast- to NNE-trending ductile shear zones combining westward thrusting and dextral wrenching, and by dextral motion along ENE-trending strike-slip faults like the RTFZ and APTZ. This Variscan phase results in the final suturing of the Meseta Domain and West African Craton through dextral transpression and southward thrusting, with the Anti-Atlas acting as the southern Variscan foreland (see Burkhard et al., this issue).

6.3. Drifted versus para-autochthonous Meseta?

In our model, the North-African Variscan Belt corresponds to a tectonic prism involving a continental crust moderately thinned during Early Palaeozoic extensional events, then shortened during the Laurentia–Gondwana collision (Fig. 6). Thus, the North-African Variscides clearly belong to the Periatlantic Palaeozoic chains, and more particularly to the southern branch of the Variscan Belt [7,77,93,104]. The similarity between western Morocco and the South Portuguese Zone has been noted, especially with respect to the development of Devono-Carboniferous basins with bimodal magmatism [96]. However, given the lack of suture zone in Morocco, it seems that the Variscan Belt of North Africa would be rather prolonged in the Central Iberian Zone [104]. The limit with Laurentia is not clear because the contact between the Moroccan Meseta and the Gondwanan terranes (Avalon, Meguma) has been obscured by the opening of the Atlantic Ocean. This limit is probably underlined by Caledonian terranes like the Sehoul Zone (6.3B). By contrast, the limit with the West African Craton crops out in Morocco and corresponds, at least during the Neovariscan phase to a major, transcurrent dextral shear zone (APTZ–TTFZ). According to most previous studies, it seems that the Mesetan Domain evolved at the margin of the West African Craton, and that the various extensional events recorded in the Palaeozoic formations never reached the stage of oceanization [39,93]. In the lack of ophiolites and of high-pressure, low-temperature metamorphism in the North African Variscides, it is difficult to argue for a model of mountain building by a classical subduction–collision process [20,101]. The shortening of the Palaeozoic cover and Late Proterozoic basement likely was mainly controlled by crustal-scale ductile shear zones like the WMSZ and APTZ, combining dextral motion and overthrusts, compatible with an oblique convergence between Laurentia and Gondwana.

References

[1] M. Aarab, Genèse et différenciation d'un magma tholéiitique en domaine extensif intracontinental: exemple du magmatisme pré-orogénique des Jebilet (Maroc hercynien), thèse, Marrakech, Maroc, 1995, 253 p.

[2] A.M. Aghzer, R. Arenas, Détachement et tectonique extensive dans le massif hercynien des Rehamna (Maroc), J. Afr. Earth Sci. 21 (3) (1995) 383–393.

[3] L. Ait Brahim, A. Tahiri, Rotation horaire des contraintes et mécanismes d'ouverture et de fermeture des bassins permiens du Maroc central, in : F. Medina (Ed.), Le Permien et le Trias du Maroc, état des connaissances, PUMAG, Marrakech, Maroc, 1996, pp. 87–98.

[4] A. Allary, A. Lavenu, M. Ribeyrolles, Étude tectonique et microtectonique d'un segment de chaîne hercynienne dans la partie sud-orientale du Maroc central, Notes Mém. Serv. Géol. Maroc, vol. 261, 1976, 169 p.

[5] H. Bamoumen, Géométrie et cinématique de la déformation dans les nappes hercyniennes des Jebilet centre-orientales (Maroc), thèse, Marrakech, Maroc, 1988, 189 p.

[6] A. Barbu, Le concept de zone pétrolière potentielle dans l'exploitation du bassin de Doukkala (Maroc occidental), Mines Géol. Rabat 42 (1977) 49–57.

[7] J.-P. Bard, Démembrement anté-mésozoique de la chaîne varisque d'Europe occidentale et d'Afrique du Nord : rôle essentiel des grands décrochements transpressifs dextres accompagnant la rotation horaire de l'Afrique durant le Stéphanien, C. R. Acad. Sci. Paris, Ser. IIa 324 (1997) 693–704.

[8] T. Baudin, P. Chévremont, P. Razin, N. Youbi, D. Andries, C. Hoepffner, D. Thiéblemont, E. Chihani, M. Tegyey, Carte géologique du Maroc au 1/50 000, feuille de Skhour des Rehamna, Mémoire explicatif, Notes Mém. Serv. Géol. Maroc, vol. 435, 2003, 114 p.

[9] M. Benabbou, Dynamique des bassins d'avant-pays carbonifères : signatures tectoniques, sédimentaires et magmatiques de l'évolution de la chaîne hercynienne du Maroc central septentrional, thèse, Marrakech, 2001, 312 p.

[10] M. Benabbou, J.-C. Soula, S. Brusset, M. Roddaz, A. Ntarmouchant, Y. Driouch, F. Christophoul, M. Bouabdelli, C. Majesté-Menjoula, D. Béziat, P. Debat, J. Déramond, Contrôle tectonique de la sédimentation dans le système de bassins d'avant-pays de la Meseta marocaine, C. R. Acad. Sci. Paris, Ser. IIa 332 (2001) 703–709.

[11] A. Bennouna, M. Ben Abbou, C. Hoepffner, F. Kharbouch, N. Youbi, The Carboniferous volcano-sedimentary depocentre of Tazekka Massif (Middle Atlas, Morocco): New observations and geodynamic implications, J. Afr. Earth Sci. 39 (3–5) (2004) 369–374.

[12] A. Bensahal, Structure hercynienne de l'anticlinorium de Khouribga-Oulmès entre Ezzhiliga et Tiddas (Maroc central hercynien). Structure du socle ordovicien–dévonien ; formation et déformation de sa couverture carbonifère : le bassin westphalien de Sidi Kassem, thèse, Rabat, 2001, 248 p.

[13] A. Bensalmia, Étude géophysique du socle de la Meseta marocaine et des provinces maritimes canadiennes. Essai de reconstitution de la marge nord-occidentale du Gondwana, thèse, université de Rennes-1, 2001.

[14] M. Berkhli, D. Vachard, J.-C. Paichler, A. Tahiri, Séries volcano-sédimentaires du Carbonifère inférieur du Maroc oriental : datation, composition et implication structurale, C. R. Acad. Sci. Paris, Ser. IIa 329 (1999) 89–94.

[15] C. Bernardin, J.-J. Cornée, M. Corsini, S. Mayol, J. Muller, M. Tayebi, Les variations d'épaisseur du Cambrien moyen en Meseta marocaine occidentale. Données de surface et de subsurface. Signification géodynamique, Can. J. Earth Sci. 25 (1988) 2104–2117.

[16] N. Beun, D. Boulanger, P. Huvelin, K. Tajeddine, Le Paléozoique de Khémis N'Ga : un paléorelief sous la série gypseuse jurassico-crétacée des Mouissat (région de Safi, Maroc), C. R. Acad. Sci. Paris, Ser. II 320 (1986) 39–42.

[17] M. Bordonaro, J.-L. Gaillet, A. Michard, Le géosynclinal carbonifère sud-mésétien dans les Jebilet (Maroc). Une corrélation avec la province sud-pyriteuse dans le Sud de l'Espagne, C. R. Acad. Sci. Paris 233 (1979) 707–710.

[18] M. Bouabdelli, Tectonique et sédimentation dans un bassin orogénique : le sillon viséen d'Azrou–Khénifra (Est du massif hercynien central du Maroc), thèse, Strasbourg, 1989, 262 p.

[19] M. Bouabdelli, A. Piqué, Du bassin sur décrochement au bassin d'avant-pays : dynamique du bassin d'Azrou–Khénifra (Maroc hercynien central), J. Afr. Earth Sci. 22 (2) (1996) 213–224.

[20] J. Boulin, M. Bouabdelli, M. El Houicha, Évolution paléogéographique et géodynamique de la chaîne paléozoique du moyen Maroc : un essai de modélisation, C. R. Acad. Sci. Paris, Ser. II 306 (1988) 1501–1506.

[21] Y. Cailleux, Les écailles anté-viséennes d'Ezzheliga. Leur importance dans l'interprétation structurale du Maroc central, C. R. Acad. Sci. Paris, Ser. II 301 (1985) 497–502.

[22] Y. Cailleux, A propos de la vergence de la phase asturienne dans le Maroc central, in : 112e Congr. Soc. Sav., colloque Géologie africaine, Lyon, 1987, pp. 63–76.

[23] Y. Cailleux, Le Cambrien et l'Ordovicien du Maroc central septentrional, in : Géologie du Paléozoique du Maroc central et de la Meseta orientale, Bull. Inst. Sci. Rabat 18 (1994) 10–31.

[24] F. Chalot-Prat, Pétrogénèse d'un volcanisme intracontinental tardi-orogénique hercynien. Etude du complexe volcanique du Tazekka et de zones volcaniques comparables dans le Mekkam et la région de Jerada (Maroc oriental), thèse, université Paris-6, 1990, 217 p.

[25] R. Charlot, M. Rhalib, D. Tisserant, Étude géologique préliminaire des granites de la région de Rabat–Tiflet, in: Notes Serv. Géol. Maroc, vol. 33 (249), 1973, pp. 55–58.

[26] N. Clauer, D. Jeannette, D. Tisserant, Datations isotopiques des cristallisations successives d'un socle hercynien et cristallophyllien (Haute Moulouya, moyen Maroc), Geol. Rundsch. 69 (1980) 63–83.

[27] M. Corsini, J.-J. Cornée, J. Muller, A. Vauchez, Cisaillement ductile synmétamorphe et déplacement tangentiel vers le sud-ouest dans les Rehamna (Maroc hercynien), C. R. Acad. Sci. Paris, Ser. II 306 (1988) 1389–1394.

[28] J.J. Delvolvé, D. Vachard, P. Souquet, Stratigraphic record of thrust propagation, Carboniferous foreland basin, Pyrenees, with emphasis on Pays de Sault (France/Spain), Geol. Rundsch. 87 (1998) 363–372.

[29] H. Diot, Mise en place des granitoïdes hercyniens de la Meseta marocaine, thèse, université de Toulouse, 1989, 182 p.

[30] H. Diot, J.-L. Bouchez, Les granitoïdes hercyniens de la Haute Moulouya (Maroc) : leur structure primaire déduite de l'ASM. Indication sur leur mise en place, Bull. Soc. géol. France 4 (1989) 705–716.

[31] M. Doblas, R. Oyarzun, J. Lopez-Ruiz, J.M. Cebria, N. Youbi, V. Mahecha, M. Lago, A. Pocovi, B. Cabanis, Permo-Carboniferous volcanism in Europe and northwest Africa: a superplume exhaust valve in the centre of Pangaea?, J. Afr. Earth Sci. 26 (1) (1998) 89–99.

[32] H. Echarfaoui, M. Hafid, A. Ait-Salem, Structure sismique du socle paléozoïque du bassin des Doukkala, Maroc occidental. Indication en faveur de l'existence d'une phase éovarisque, C. R. Geoscience 334 (2002) 13–20.

[33] A. Eddif, D. Gasquet, C. Hoepffner, N. Ait Ayad, Les intrusions de Wirgane (Haut Atlas occidental) : témoins d'un magmatisme syn à tardi-cinématique hercynien ?, J. Afr. Earth Sci. 31 (3–4) (2000) 483–498.

[34] A. El Attari, Étude lithostratigraphique et tectonique des terrains cambro-ordoviciens du Môle côtier (Meseta occidentale, Maroc), thèse, université Mohammed-V, Rabat, 2001, 389 p.

[35] O. El Ghazi, P. Huvelin, Présence d'un olistostrome dans le Viséen supérieur volcano-sédimentaire de Tannecherfi (Maroc oriental). Simultanéité de la resédimentation et de l'activité volcanique, C. R. Acad. Sci. Paris, Ser. II 292 (1981) 91–96.

[36] H. El Hadi, A. Tahiri, A. Reddad, Les granitoïdes hercyniens post-collisionnels du Maroc oriental : une province magmatique calco-alcaline à shoshonitique, C. R. Geoscience 335 (2003) 959–967.

[37] A. El Hassani, La bordure nord de la chaîne hercynienne du Maroc : chaîne « calédonienne » des Sehoul et plate-forme nord-mésétienne, thèse, université de Strasbourg, 1990, 207 p.

[38] A. El Hassani, S. Huon, C. Hoepffner, H. Whitechurch, A. Piqué, Une déformation d'âge Ordovicien moyen dans la zone des Sehoul (Meseta marocaine septentrionale). Regard sur les segments « calédoniens » au NW de l'Afrique, C. R. Acad. Sci. Paris, Ser. II 321 (1991) 1027–1032.

[39] A. El Hassani, A. Tahiri, O. Walliser, The Variscan Crust between Gondwana and Baltica, Cour. Forsch.-Inst. Senkenb. 242 (2003) 81–87.

[40] F. El Kamel, Etudes géologiques du Paléozoique de Mechra Ben Abbou et d'Oulad Abbou, Meseta occidentale, Maroc, Notes Mém. Serv. Géol. Maroc, vol. 462, 2004, 187 p.

[41] F. El Kamel, T. Remmal, A. Mohsine, Mise en évidence d'un magmatisme alcalin d'intraplaque post-calédonien dans le bassin silurien des Ouled Abbou (Meseta côtière, Maroc), C. R. Acad. Sci. Paris, Ser. IIa 327 (1998) 309–314.

[42] A. El Mouraouah, H. Diot, A. El Amrani, Les massifs granitiques de la haute Moulouya : laccolites granitiques en Meseta marocaine orientale, C. R. Acad. Sci. Paris, Ser. II 296 (1993) 1469–1476.

[43] M. El Wartiti, J. Broutin, P. Freytet, M. Larhrib, N. Toutin-Morin, Continental deposits in Permian basins of the Mesetian Morocco, Geodynamic history, J. Afr. Earth Sci. 10 (1/2) (1990) 361–368.

[44] W. Engel, R. Feist, W. Franke, Synorogenic gravitational transport in the carboniferous of the Montagne Noire (S. France), Z. Dtsch. Geol. Ges. 129 (1978) 461–472.

[45] A. Erraji, Analyse des terrains carbonifères de la région de Jerada (Maroc oriental) à partir des données de terrain, de forage et de sismique réflexion, thèse, université Mohammed-V, Rabat, 1997, 236 p.

[46] A. Errami, Évolution tardi-hercynienne et alpine des bassins du Paléozoïque supérieur de la bordure sud-occidentale du massif ancien du Haut Atlas : rôle des inversions tectoniques, thèse, université Mohammed-V, Rabat, 2001, 193 p.

[47] A. Essaifi, Relations entre magmatisme–déformation et altérations hydrothermales : l'exemple des Jebilet centrales (Hercynien, Maroc), Mém. Géosci. Rennes, vol. 56, 1995, 340 p.

[48] A. Essaifi, J.-L. Lagarde, Reconnaissance de corps granitiques syntectoniques dans les séries magmatiques « préorogéniques » des Jebilet centrales (Hercynien, Maroc), Implications géodynamiques, C. R. Acad. Sci. Paris, Ser. II 310 (1990) 67–73.

[49] A. Essaifi, J.-L. Lagarde, R. Capdevila, Deformation and displacement from shear zone patterns in the Variscan upper crust, Jebilet, Morocco, J. Afr. Earth Sci. 32 (3) (2001) 335–350.

[50] A. Essaifi, A. Potrel, R. Capdevila, J.-L. Lagarde, Datation U–Pb : âge de mise en place du magmatisme bimodal des Jebilet centrales (chaîne varisque, Maroc). Implications géodynamiques, C. R. Geoscience 335 (2003) 193–203.

[51] M. Essamawal, Analyse tectonique et microtectonique du complexe volcano-sédimentaire carbonifère dans le massif hercynien du Tazekka (Moyen Atlas, Maroc) Conséquence sur le contrôle structural de la minéralisation en antimoine de Boujaada, thèse, université Mohammed-V, Rabat, 1999, 184 p.

[52] H. Feinberg, T. Aifa, J.-P. Pozzi, D. Khattach, J. Boulin, Courbes de dérive apparente des pôles magnétiques de l'Afrique et de la Meseta marocaine pendant le Paléozoique, C. R. Acad. Sci. Paris, Ser. II 310 (1990) 913–918.

[53] F. Filali, M. Guiraud, J.-P. Burg, Nouvelles données pétro structurales sur la boutonnière d'Aouli-Mibladen (haute Moulouya) : leurs conséquences sur la géodynamique hercynienne au Maroc, Bull. Soc. géol. France 4 (1999) 435–450.

[54] W. Franke, W. Engel, Synorogenic sedimentation in the Variscan belt of Europe, Bull. Soc. géol. France 8 (1986) 25–33.

[55] J.L. Gaillet, La tectonique du Dévono-Dinantien du Haouz occidental et l'hypothèse d'une transformante varisque au Sud de la Meseta marocaine, Sci. Géol. Bull., Strasbourg 39 (4) (1986) 361–370.

[56] D. Gasquet, J.-M. Stussi, H. Nachit, Les granitoïdes hercyniens du Maroc dans le cadre de l'évolution géodynamique régionale, Bull. Soc. géol. France 4 (1996) 517–528.

[57] C. Hoepffner, La tectonique hercynienne dans l'Est du Maroc, thèse, université Louis-Pasteur, Strasbourg, 1987, 280 p.

[58] C. Hoepffner, P. Jenny, A. Piqué, A. Michard, Le métamorphisme hercynien dans le massif des Rehamna, in: Notes Mém. Serv. Géol. Maroc, vol. 303, 1982, pp. 130–149.

[59] C. Hoepffner, M. El Wartiti, A. Bensahal, K. Ghazali, The Westphalian basin of Sidi Kassem (Central Massif, Morocco). Continental sedimentation and Late Variscan deformations, in: S. Crasquin-Soleau, E. Barrier (Eds.), Peri-Thetys Memoir 5, in: Mém. Mus. Natl Hist. Nat., vol. 182, 2000, pp. 11–22.

[60] C. Hoepffner, A. Soulaimani, A. Piqué, The Moroccan Hercynides, in: O. Catuneanu, R. Guiraud (Eds.), Phanerozoic evolution of Africa (special issue), J. Afr. Earth Sci. 43 (2005) 144–165.

[61] M.R. Houari, C. Hoepffner, Structure des terrains paléozoïques à la limite sud de la chaîne hercynienne du Maroc (Haut atlas oriental), Afr. Geosci. Rev. 7 (1) (2000) 39–53.

[62] M.R. Houari, C. Hoepffner, Late Carboniferous dextral wrench-dominated transpression along the North African craton margin (Eastern High-Atlas, Morocco), J. Afr. Earth Sci. 37 (2003) 11–24.

[63] S. Huon, A. Piqué, N. Clauer, Etude de l'orogenèse hercynienne au Maroc par la datation K/Ar de l'évolution métamorphique de schistes ardoisiers, Sci. Géol. Bull. Strasbourg 40 (1987) 273–284.

[64] P. Huvelin, Étude géologique et gîtologique du massif hercynien des Jebilet (Maroc occidental), Notes Mém. Serv. Géol. Maroc, vol. 232, 1977, 308 p.

[65] P. Huvelin, Le Carbonifère du massif du Tazekka (Maroc) : volcanisme et phénomènes de resédimentation, C. R. Acad. Sci. Paris, Ser. II 303 (1986) 1483–1488.

[66] P. Huvelin, Le Carbonifère du Tazekka (Maroc) : volcanisme, mise en place des granites et des minéralisations en antimoine, Ann. Soc. géol. Nord, Lille 1 (1992) 129–133.

[67] P. Huvelin, B. Mamet, Essai de datation des transgressions et des phénomènes de resédimentation dans le Viséen supérieur–Namurien du Maroc oriental, Ann. Soc. géol. Nord, Lille CVIII (1989) 59–67.

[68] A. Izart, Les bassins carbonifères de la Meseta marocaine, étude sédimentologique et approche du contexte structural. Part de la tectonique et de l'eustatisme, Géol. Méditerr. XVIII (1–2) (1991) 61–72.

[69] J. Jenny, A. Le Marrec, Mise en évidence d'une nappe à la limite méridionale du domaine hercynien dans la boutonnière d'Ait Tamelil (Haut Atlas central, Maroc), Eclog. geol. Helv. 73 (3) (1980) 681–696.

[70] J. Jenny, A. Izart, J.-L. Lesage, La boutonnière d'Ait Tamelil, évolution tectono-sédimentaire durant le Viséen et structuration du segment hercynien du Haut Atlas central (Maroc), in : Notes Mém. Serv. Géol. Maroc, vol. 335, 1989, pp. 239–250.

[71] F. Kharbouch, Les laves dévono-dinantiennes de la Meseta marocaine : étude pétrochimique et implications géodynamiques, thèse, université de Brest, 1994, 351 p.

[72] F. Kharbouch, T. Juteau, M. Treuil, J.-L. Joron, A. Piqué, C. Hoepffner, Le volcanisme dinantien de la Meseta marocaine nord-occidentale et orientale. Caractères pétrographiques et géochimiques et implications géodynamiques, Sci. Géol. Bull., Strasbourg 38 (1985) 155–163.

[73] D. Khattach, M. Robardet, H. Perroud, A Cambrian pole for the Moroccan Coastal Meseta, Geophys. J. Int. 120 (1995) 132–144.

[74] J.L. Lagarde, Granites tardi-carbonifères et déformation crustale. L'exemple de la Meseta marocaine, Mém. Doc. CAES, Rennes, vol. 26, 1989, 342 p.

[75] J.L. Lagarde, A. Michard, Stretching normal to the regional thrust displacement in a thrust-wrench shear zone, Rehamna Massif, Morocco, J. Struct. Geol. 8 (1986) 483–492.

[76] A. Lakhloufi, N. Hamoumi, A. Saquaque, Vergence des structures varisques et modalités de la structuration du bassin de Sidi Bettache (Maroc hercynien nord-occidental) : implications géodynamiques, Bol. Real Soc. Esp. Hist. Nat. 96 (3–4) (2001) 17–28.

[77] P. Matte, The Variscan collage and orogeny (480–290 Ma) and the tectonic definition of the Armorica microplate: a review, Terra Nova 13 (2) (2001) 122–128.

[78] S. Mayol, J. Muller, Mise en évidence d'une unité allochtone hercynienne précoce (antéschisteuse) dans les Jebilet occidentales (Maroc). Étude de la structuration de la zone de contact, C. R. Acad. Sci. Paris, Ser. II 300 (1985) 369–372.

[79] W.S. McKerrow, C. Mac Niocaill, J.F. Dewey, The Caledonian orogeny redefined, J. Geol. Soc. Lond. 157 (2000) 1149–1154.

[80] R. Médioni, Mise au point stratigraphique sur les terrains carbonifères de la bordure septentrionale des Hauts Plateaux marocains, in: Notes Serv. Géol. Maroc, vol. 41 (285), 1980, pp. 25–37.

[81] A. Michard, Éléments de géologie marocaine, Notes Mém. Serv. Géol. Maroc, vol. 252, 1976, 408 p.

[82] A. Michard, A. Yazidi, F. Benziane, H. Hollard, S. Willefert, Foreland thrusts and olistostromes on the pre-Saharan margin of the Variscan orogen, Morocco, Geology 10 (1982) 253–256.

[83] A. Michard, Y. Cailleux, C. Hoepffner, L'orogène mésétien du Maroc : structure, déformation hercynienne et déplacements, in : Notes Mém. Serv. Géol. Maroc, vol. 335, 1989, pp. 313–327.

[84] P. Morin, L'accident de Bsabis Tazekka, un linéament majeur de la tectonique hercynienne au Maroc (Ouest de Taza), C. R. somm. Soc. géol. France (1973) 64.

[85] Z. Mrini, A. Rafi, J.L. Duthou, P. Vidal, Chronologie Rb/Sr des granitoïdes hercyniens du Maroc, conséquences, Bull. Soc. géol. France (1992) 281–291.

[86] J. Muller, J.-J. Cornée, F. El Kamel, Évolution tectono-sédimentaire d'un bassin molassique post-orogénique : l'exemple des séries conglomératiques stéphano-triasiques de Mechra-Ben-Abbou, Rehamna, Maroc, Géol. Méditerr. 1–2 (1991) 109–120.

[87] H. Ouali, B. Briand, J.-L. Bouchardon, P. Capiez, Le volcanisme cambrien du Maroc Central : implications géodynamiques, C. R. Geoscience 335 (2003) 425–433.

[88] H. Ouali, B. Briand, J.-L. Bouchardon, M. El Maataoui, Mise en évidence d'un volcanisme alcalin intraplaque d'âge Acadien dans la Meseta nord-occidentale (Maroc), C. R. Acad. Sci. Paris 330 (2000) 611–616.

[89] H. Ouali, B. Briand, M. El Maataoui, J.-L. Bouchardon, Les amphibolites de la boutonnière de Midelt (haute Moulouya, Maroc) : témoins d'une extension intraplaque au Cambro-Ordovicien, in : Notes et Mém. Serv. Géol. Maroc, vol. 408, 2001, pp. 177–182.

[90] H. Ouanaimi, J.-P. Petit, La limite sud de la chaîne hercynienne dans le Haut Atlas marocain: reconstitution d'un saillant non déformé, Bull. Soc. géol. France 163 (1992) 63–72.

[91] D. Oukemeni, J. Bourne, T.E. Krogh, Géochronologie U–Pb sur zircon du pluton d'Aouli (Haute Moulouya, Maroc), Bull. Soc. géol. France 166 (1995) 15–22.

[92] A. Piqué, Evolution structurale d'un segment de la chaîne hercynienne : la Meseta nord-occidentale, Sci. Géol. Mém., Strasbourg 56 (1979), 243 p.

[93] A. Piqué, Geology of Northwest Africa, Borntraeger, Berlin, Stuttgart, 2001, 310 p.

[94] A. Piqué, A. Michard, Les zones structurales du Maroc hercynien, Sci. Géol. Bull., Strasbourg 34 (2) (1981) 135–146.

[95] A. Piqué, E. Wybrecht, Origine des chlorites de l'épizone. Héritage et cristallisations synschisteuses. Exemple des grauwackes cambriennes du Maroc occidental, Bull. Miner. 110 (1987) 665–682.

[96] A. Piqué, A. Michard, Moroccan Hercynides: a synopsis. The Paleozoic sedimentary and tectonic evolution at the northern margin of West Africa, Am. J. Sci. 289 (1989) 286–330.

[97] A. Piqué, D. Jeannette, A. Michard, The Western Meseta Shear Zone, a major and permanent feature of the Hercynian belt of Morocco, J. Struct. Geol. 2 (1980) 55–61.

[98] P. Razin, D. Janjou, T. Baudin, A. Bensahal, C. Hoepffner, D. Thiéblemont, P. Chèvremont, R. Benhaourch, Carte géologique du Maroc au 1:50 000, feuille de Sidi Matla Ech Chems, Mémoire explicatif, Notes Mém. Serv. Géol. Maroc, vol. 412, 2001, 70 p.

[99] T. Remmal, L'évolution tectono-magmatique intracontinentale du cycle hercynien. Étude du complexe magmatique du district d'El Hammam et de zones comparables pour le mag-

matisme pré-orogénique dans le Massif central et les Rehamna (Meseta occidentale marocaine), thèse, université de Casablanca, Maroc, 2000, 267 p.
[100] T. Remmal, F. El Kamel, A. Mohsine, Le bassin viséen de Mechraâ Ben Abbou (Meseta occidentale, Maroc) : une structure sur décrochement N80 associée à un magmatisme tholéiitique d'intraplaque, Géol. Méditerr. XXIV (3–4) (1997) 225–239.
[101] M. Roddaz, S. Brusset, J.C. Soula, D. Bézat, M. Benabbou, P. Debat, Y. Driouch, F. Christophoul, A. Ntarmouchant, J. Déramond, Foreland basin magmatism in the western Moroccan Meseta and geodynamic inferences, Tectonics 21 (5) (2002) 1043.
[102] E. Ruellan, Géologie des marges continentales passives : évolution de la marge atlantique du Maroc (Mazagan) ; étude par submersible, *seabeam* et sismique réflexion. Comparaison avec la marge NW-africaine et la marge homologue est-américaine, thèse, université de Brest, France, 1985, 297 p.
[103] D. Shelley, G. Bossière, A new model for the Hercynian orogen of Gondwanan France and Iberia, J. Struct. Geol. 22 (2000) 757–776.
[104] J.F. Simancas, A. Tahiri, A. Azor, F.G. Lodeiro, D.J. Martinez Poyatos, H. El Hadi, The tectonic frame of the Variscan-Alleghanian orogen in southern Europe and northern Africa, Tectonophysics 398 (2005) 181–198.
[105] S. Soualhine, J. Tejera de León, C. Hoepffner, Les faciès sédimentaires carbonifères de Tisdafine (Anti-Atlas oriental) : remplissage deltaïque d'un bassin en *pull-apart* sur la bordure méridionale de l'Accident sud-atlasique, Bull. Inst. Sci. Rabat 25 (2003) 31–41.
[106] G.M. Stampfli, G.D. Borel, A plate tectonic model for the Paleozoic and Mesozoic constrained by dynamic plate boundaries and restored synthetic oceanic isochrons, Earth Planet. Sci. Lett. 196 (2002) 17–33.
[107] A. Tahiri, Le Maroc central septentrional : stratigraphie, sédimentologie et tectonique du Paléozoique; un exemple du passage des zones internes aux zones externes de la chaîne hercynienne du Maroc, thèse, université de Brest, 1991, 311 p.
[108] A. Torbi, Stratigraphie et évolution structurale paléozoïque d'un segment de la Meseta orientale marocaine (les monts du SE d'Oujda) : rôle des décrochements dans la formation de l'olistostrome intraviséen et le plutonisme tardi-hercynien, J. Afr. Earth Sci. 22 (4) (1996) 549–563.
[109] A. Vauchez, Les déformations anté triasiques dans la boutonnière d'Aouli-Mibladen, C. R. Acad. Sci. Paris, Ser. D 282 (1976) 425–428.
[110] N. Youbi, B. Cabanis, F. Chalot-Prat, Y. Cailleux, Histoire volcano-tectonique du massif permien de Khénifra (Sud-Est du Maroc central), Geodin. Acta 8 (1995) 158–172.
[111] M. Zahraoui, La plate-forme carbonatée dévonienne du Maroc occidental et sa dislocation hercynienne, thèse, université de Brest, 1991, 261 p.