THE VARISCAN BELT OF MOROCCO

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Se presentan y discuten varias zonas estructurales. Durante el Paleozoico Inferior la evolución sedimentológica fue idéntica en la mayor parte de Marruecos, desde la zona norte hasta el cratón Africano. La distensión y las deformaciones del Paleozoico Superior individualizaron distintas zonas estructurales. Las zonas de Sehoul (Rabat-Tiflet) y del Rif Interno son terrenos exóticos que se unieron al resto de Marruecos durante el Paleozoico Medio y el Terciario respectivamente.

Palabras clave: Zonas estructurales, Marruecos, Cadena Hercínica.

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Several structural zones are presented and discussed. The sedimentological evolution was roughly similar in most parts of Morocco, from the African shield to Northern Morocco, during the Lower Palaeozoic. Upper Palaeozoic distension and folding episodes individualized distinct structural zones. The Sehoul (Rabat-Tiflet) and Palaeozoic Internal Rif zones are exotic terranes accreted to the rest of Morocco respectively during the Middle Palaeozoic and Tertiary.

Key words: Structural zones, Morocco, Variscan belt.

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Morocco is divided into three geographic domains:

– i.—Southern Morocco (Sahara and Saharan margin (Fig. 1.2)). Precambrian basement outcrops in the Dorsale reguibate and in several inliers of the Anti-Atlas. It is covered by Palaeozoic and Mesozoic sedimentary sequences (Tindouf basin, Anti-Atlas, El Aïoun basin).

– ii.—Central Morocco. Palaeozoic rocks constitute several massifs (Central massif, Rehamna, etc...) which are cartographically separated by a meso- and cenozoic cover. This cover is thin and it remained unfolded in the stable Meseta domain. It is thicker and it has been deformed by meso- and cenozoic orogenic episodes in the Atlas domain.

– iii.—Northern Morocco. This is the Rif domain, a segment of the Alpine belt of Western Mediterranean. It comprises Palaeozoic and Meso-Cenozoic rocks, thrust southward upon central Morocco.

Since the beginning of the century, Morocco has been subjected to the geological exploration. The existence of a Variscan (= Hercynian) belt has been recognized very soon (Gentil, 1918) and compared to the Iberian Meseta (Lecointre, 1926). Later, the development of regional studies (see Michard, 1976) allowed to individualize several structural zones within Variscan Morocco. These zones will be enumerated below and their stratigraphic and structural evolution will be resumed. The present paper tries to emphasize those characters which are relevant for establishing correlations with other parts of the Variscan orogen.

SAHARA

This domain (Fig. 2) is constituted by the west African shield, which outcrops in the Dorsale reguibate and by its sedimentary cover, represented in the Tindouf basin. The shield has been strongly deformed during the Eburnean orogeny and it is stable since 1,800 Ma. Its Upper Proterozoic and Palaeozoic cover is relatively thin (~3,500 m). The sedi-

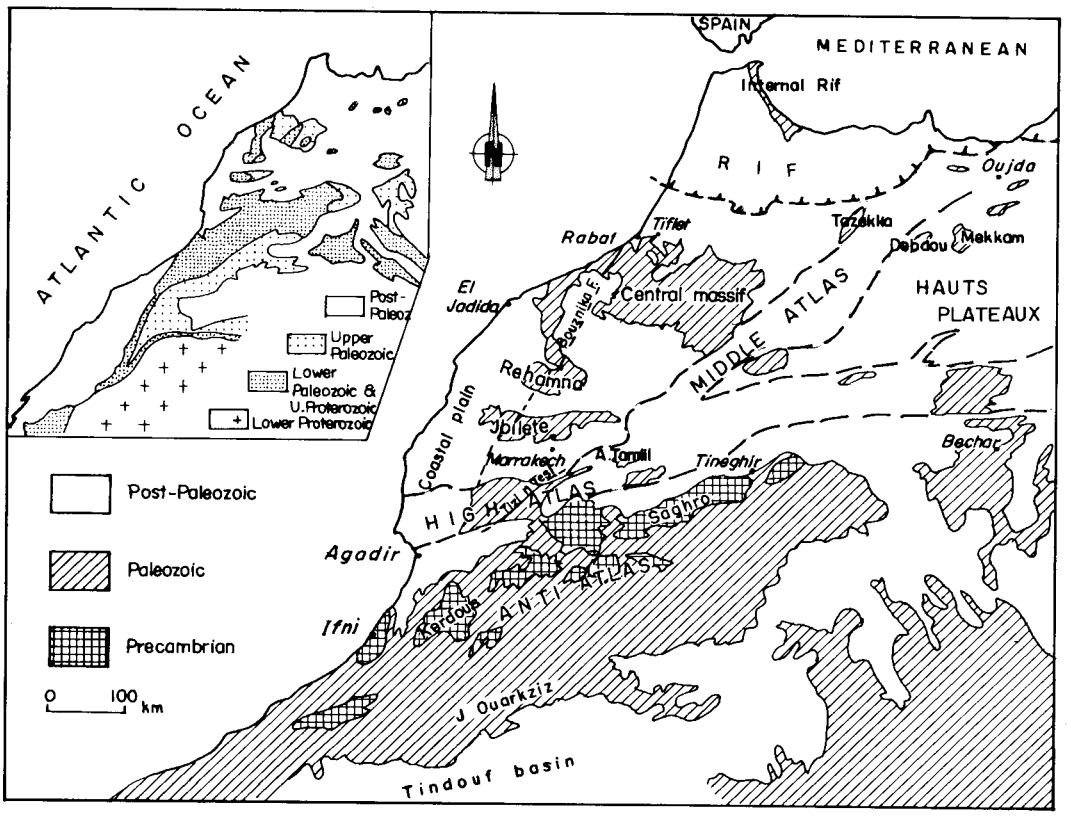

Fig. 1.–Simplified geological map of northern Morocco.

mentary facies are mostly sandstones and argillites (Conrad, 1972; Deynoux *et al.*, 1985). These Tindouf series are undeformed and consequently this zone remained outside of the Variscan realm. In southwesternmost Morocco, the Ouled Dlim region belongs to the Mauritanides belt (Sougy, 1962; Lecorché, 1983).

SAHARAN MARGIN

The Saharan margin distinguishes itself from the Saharian domain by the presence of two episods of deformation:

– i.–The old Eburnean basement has been affected by the Panafrican orogeny between 680 and 570 Ma (Leblanc and Lancelot, 1980). The polydeformed Precambrian series outcrop in the so-called «Boutonnières de l'Anti-Atlas».

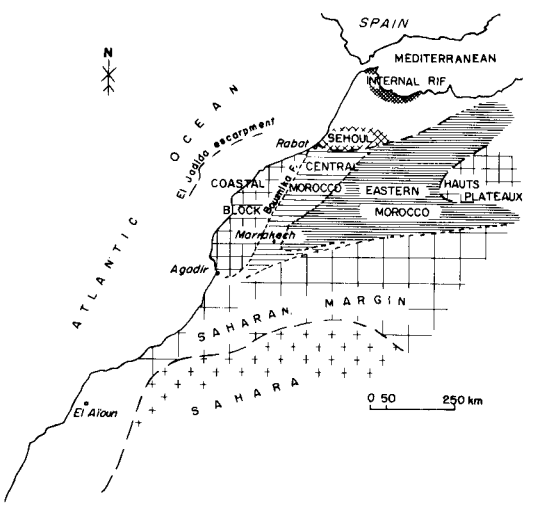

Fig. 2.–Structural domains of the Variscan belt of Morocco. Schematic map.

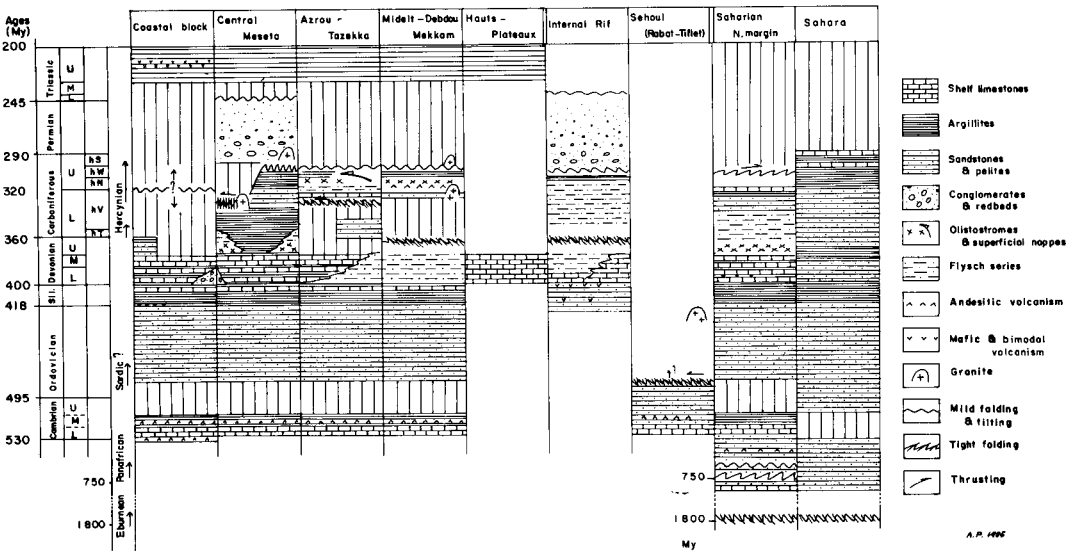

Fig. 3.–Structural domains of the Variscan belt of Morocco. Synthetic stratigraphic columns.

– ii.–The Upper Proterozoic and Palaeozoic series have suffered a mild Variscan deformation marked by kilometric-scale structures. Neither penetrative structures (for instance a generalized cleavage) nor a metamorphic evolution accompanied this deformation.

Structurally, the Saharan margin domain is constituted by the Anti-Atlas anticlinorium, bordered on its two flanks by Carboniferous series. The Anti-Atlas anticlinorium displays, around the Precambrian inliers («Boutonnières») which are aligned in an WSW-ESE direction, Lower Palaeozoic marine series. Their lithological facies and the associated faunas indicate a shallow water environment. Their Variscan deformation, largely controlled by old (Panafrican ?) deep structures (Jeannette & Piqué, 1981) is not accurately dated. It is thought to have occurred during Carboniferous, probably during the «Sudetic» (Upper Visean) Phase. The southern flank of the Anti-Atlas anticlinorium is the northern part of the Tindouf basin and it belongs to the Saharan domain (see above). There, the Upper Visean Jbel Ouarkziz series is a paralic sequence. Southward, it grades upwards to the Betana series of Namurian age where terrestrial facies predominate. Both Ouarkziz and Betana series are undeformed. The northern flank of the Anti-Atlas is represented by Upper Devonian and Carboniferous series which outcrop at Tineghir (Michard *et al.*, 1982) and, farther to the east, in the Algerian zones of Bechar and Ben-Zireg (Pareyn, 1961). There, the Lower Carboniferous sediments deposited in a narrow and subsident trough (Fig. 3). They were fault-induced olistostromes, wildflysch and turbidites. In the Bechar basin, the series remained marine up to Lower Westphalian which is represented by paralic coal bearing sequences. The deformation was «asturian» (Upper Westphalian), characterized by a southern tectonic vergence.

COASTAL BLOCK

This domain is constituted by the Coastal Plain and the western part of Rehamna and Jbilete massifs. Westward, it prolongates offshore (Ruellan, 1985). Eastward, it is limited from Central Morocco by the Bouznika faulted zone.

Its synthetic stratigraphical column comprises:

– Precambrian strata: felsic volcanic rocks which outcrop (by low tide only!) at El Jadida. They are overlain by Cambrian deposits.

– Lower Palaeozoic (Cambrian to Silurian): Lower Cambrian limestone («calcaire à *Archeocyathus*»); Middle Cambrian siltstones

and greywackes («schistes à *Paradoxides*») with contemporary basaltic and trachytic and breccias; Ordovician sandstones and argillites (the Ashgillian «argiles micro-conglomératiques» are interpreted as tilloids contemporaneous with the Late Ordovician glaciation); Silurian dark shales («argiles à Graptolites») with thin mafic flows. These Lower Palaeozoic facies and faunas are similar to those of the Anti-Atlas (Destombes *et al.*, 1985). Obviously, the Coastal Block and the Anti-Atlas were then parts of the same epicontinental platform.

– Devonian: reefal buildings developed during Lower and Middle Devonian along NNE-SSW ridges separated by small basins filled with marls and pelites. A general emersion occurred by the end of Frasnian. Famennian is represented only in the core of synclinoria by black shales and, in Safi drill, by quartz arenites. No Carboniferous deposits are known. Some observations suggest that the Coastal Block was an uplifting landmass since Upper Devonian through Carboniferous, acting as a source land for adjacent countries.

Deformation affected Upper Devonian strata and it predated Triassic. It is not otherwise dated. It indicates a weak regional shortening which produced NNE-SSW kilometric gentle folds. The series do not show any metamorphic evolution (Wybrecht *et al.*, 1985). However, toward the eastern limit of the Coastal Block, deformation became stronger: folds are tighter and their axial plane is outlined by a regional cleavage, itself contemporaneous with a low-grade metamorphism. This eastern boundary of the Coastal block, where rocks are cleaved and metamorphic, corresponds to the Bouznika faulted zone. This zone is interpreted antagonistically as a major shear zone (Piqué, 1979; Piqué *et al.*, 1980), located on ancient synsedimentary normal faults (Cornée *et al.*, 1985) or as a post-metamorphic thrust, subsequently refolded (Sougy, 1978).

Correlations are easy with the Anti-Atlas which yields the same sedimentological and broadly the same structural evolution. On the other side of the present Atlantic ocean, obvious similarities have been emphasized, at least concerning Lower Palaeozoic stratigraphy, with the easternmost Appalachians (Piqué, 1981a) and, more largely, the Avalonian plate (Rast and Skehan, 1983). However, recent oceanological studies (Ruellan, 1985) suggest that the El Jadida (Mazagan) escarpment represents the western limit of the Coastal Block: several samples, dragged and drilled on the continental rise, NW of the escarpment by the D.S.D.P. oceanological team (Kreuzer *et al.*, 1984) are granodioritic gneisses. Radiometric studies showed a polyphased history quite different from the Coastal block history, which could rather be compared with the Rabat-Tiflet zone (see below).

CENTRAL MOROCCO

This domain is separated from the Coastal Block by the above described Bouznika faulted zone. To the South, its contact with the Saharan margin is largely obscured by the Atlasic deformation. This limit corresponds in part to the Tizi n'Test fault (Petit, 1976). Toward north and east, its limits with other structural domains are also tectonic elements which will be presented below.

Its stratigraphic column can be divided into two periods:

– Lower Palaeozoic deposits indicate a stratigraphic history broadly similar to the contemporary evolution of Coastal block and Anti-Atlas, marked by a decrease of the detrital supplies issued from the Saharan domain. During Lower and Middle Devonian, Central Morocco was a carbonate shelf with reef barriers. The sedimentation was exclusively biochemical and no detrital sediments were coming from the south.

– Upper Devonian and Lower Carboniferous deposits contrast strongly with underlying strata, although they are conformable upon them. They are greywackes and breccias, coming from surelevated zones: Coastal block, Sehoul block (see below) and internal ridges. These detrital and sometimes chaotic materials alternated with an alkaline to tholeiitic magmatism, mostly effusive (Piqué and Kharbouch, 1983). Regional distribution of these facies suggest they deposited in a subsident pull-apart rift-type basin: the Sidi-Bettache basin, which remained marine and subsident as long as Namurian and, locally, Lower Westphalian (Piqué, 1984). In the Jbilete massif, in southern central Morocco, the

Sarhlef series (Huvelin, 1977) represents the Upper Visean and perhaps also older stages. It was deposited in a shallow but subsident basin which prolongates southward the Sidi-Bettache basin. Westward, the Sarhlef series passes laterally to the Skhirat Formation, which has been described either as a mylonitic breccia (Sougy, 1978) or an olistostrome, at the western limit of the basin (Bordonaro *et al.*, 1979; Mayol and Muller, 1985). Eastward, the Kharrouba sequences (see below) are, at least in part, a coeval series. The Sarhlef series is characterized by an important magmatic activity during which gabbros and bimodal volcanic series emplaced. They correspond, by their chemistry, to the flows of the Sidi-Bettache basin. This volcanism was accompanied by the deposition of pyritic-rich beds.

In the northwestern part of this domain, preliminary results (Huon, 1985) based upon K-Ar dating of the low-grade metamorphism suggest that the symmetamorphic deformation ocurred at different times: during Upper Visean («Sudetic» Phase) at the margin of the former Sidi-Bettache basin and during Stephanian in the center of the basin. The amount of the deformation, as well as metamorphism intensity were maximum at the margins of the basin. Except in the most metamorphic zones, fold axial planes are steeply dipping and their axes show important virgations due to the adaptation of the deformation to the ancient limits of the basin.

Similarities, especially for Upper Devonian-Lower Carboniferous sedimentological and magmatic history, appear with the South-Iberian basin: Pyritic belt (Oliveira, 1982) and farther, with the armorican Bassin de Châteaulin (Rolet, 1984) and other north european zones. In America, the Fundy basin yields a comparable evolution.

EASTERN MOROCCO

This domain comprises the eastern part of Massif central and Jbilete and several inliers in the Atlasic domain and east of the Middle Atlas. Its western limit with Central Morocco is a thrust, conspicuous in the Massif central (Cailleux, 1978) and in the Jbilete (Huvelin, 1977). Its southern and eastern boundaries are hidden beneath Meso- and Cenozoic deposits and their location is therefore rather speculative. All these limits are represented, of course, in their present position.

During Lower Palaeozoic, the stratigraphic evolution was roughly parallel to this of the rest of Morocco, indicative of stable epicratonic basin conditions. However, sedimentological studies (Hamoumi, in prep.) suggest that eastern Morocco was occupied by a turbiditic basin since Ashgillian. This basin contrasted strongly with the coeval platform in Central Morocco. This relatively deeper basin persisted, from Marrakech to Oujda as long as Lower and Middle Devonian. Locally, structural studies allow to reconstruct the initial disposition of different Devonian series in this Marrakech-Oujda trough. They show a W-E succession of pelagic facies in the Azrou-Tazekka region (chert limestones, nodular limestones: «calcaires griottes») and proximal turbidites in Midelt-Debdou-Mekkam. More easterly, reef limestones similar to the facies of Coastal Block and Central Morocco suggest the presence, eastward, of a shallow carbonate shelf (see below).

By the end of Devonian, most part of eastern Morocco: Midelt-Debdou-Mekkam area (Fig. 3) was folded during the «bretonnic» orogenic event. This deformation, dated at 360 Ma, is the main orogenic episode. Folds are recumbent and metamorphism generally reaches the low-grade. Their tectonic vergence is almost everywhere toward West. The westernmost parts of eastern Morocco (Azrou-Tazekka: Fig. 3) which were not affected by this first phase were deformed by «sudetic» folds dated by a contemporary metamorphism at 330 Ma. Their style is similar to the «bretonnic folds». These paroxysmal events were followed by an isostatic uplift, a rapid erosion and a marine transgression. The first deposits, lying unconformably upon slates, represent Middle to Upper Visean. They are Culm (= flysch) series. Upon these series, superficial gravitary nappes emplaced, in northeastern Morocco. Uppermost Visean olistostromes deposited, accompanied by a calc-alkaline volcanism and, finally, by paralic Namurian and Lower Westphalian series. A Late Carboniferous «asturian» Phase gently folded these series. This Palaeozoic evolution, marked successively by the Devonian pelagic and turbiditic sequences, by the «bretonnic» orogeny, by Lower Carboniferous Culm series and fi-

nally by an asturian deformation, is very similar to the evolution of some parts of southern Europe, especially French Montagne Noire and Corsica (Bourrouilh *et al.*, 1980; Piqué, 1981b).

Southeast of eastern Morocco, in the Hauts-Plateaux area, Palaeozoic rocks are hidden beneath Mesozoic and Cenozoic deposits. Therefore, they are not directly accessible. However, some rocks issued from this area are known in the allochthonous Upper Visean series of Eastern Morocco (see above). Locally this allochthon contains olistoliths of Lower-Middle Devonian reefal limestone. It is thought to have originated southeastward, in the Hauts-Plateaux zone. So, the Hauts-Plateaux area was therefore, at least locally, a carbonate shelf during Lower-Middle Devonian, contrasting with the flysh basin which extended by this period through Eastern Morocco. No other indication about Palaeozoic series of this zone can be given presently as long as the study of oil boreholes is not allowed.

SEHOUL (RABAT-TIFLET)

The Sehoul zone outcrops only over several square kilometers at the northern end of western Morocco, from which it is separated by a tectonic contact. Westward, in the Rabat area, this contact is a reverse fault, with a southern vergence. Eastward, it is a subvertical fault. It probably prolongates under Tertiary and Recent deposits.

The stratigraphic column is a thick pile whose total thickness (one or several thousand meters ?) is unknown. At the visible base, it is constituted by greywackes with ovoid concretions of metric scale and carbonated beds. Upward, the greywackes grade to arenites. They contain micropebbles of trachytic rocks and conglomeratic beds. The stratigraphic datation of this series results from:

– i.–the nature of the greywackes-carbonates alternances. After deformation, this lithology presents exactly the same facies as the «Schistes à trous» which are known to represent the transition between the Lower Cambrian carbonates and the Middle Cambrian greywackes.

– ii.–The recent discovery of a graptolite which indicates a Tremadocian age (Lopez, oral commun.).

The deformation of this Cambro-Ordovician series is polyphased.

– E-W trending F1 folds, contemporaneous with a low-grade metamorphism, are recumbent with a southern vergence. During the course of deformation, the folding evolved to thrusting and the folded series were cut into several tectonic units imbricated to the south. This composite orogenic event predated the emplacement of the Rabat granite. This granite, presently cleaved and mylonitized, has been dated together with the Tiflet granite, at 430 ± 2 Ma ($\lambda = 1.42\text{-}10^{-11}$ $year^{-1}$) by Charlot *et al.* (1973). Consequently, this event, which affected Cambrian and Lower Ordovician strata and predated Lowermost Silurian, was a pre-Variscan deformation.

– E-W trending F2 folding was responsible for a crenulation cleavage and an associated very low-grade metamorphism. These D2 structures are restricted to the southern part of the Sehoul domain, where it was thrusted upon the Lower and Middle Palaeozoic series of the Rabat anticline. Clearly, this event, during which Rabat and Tiflet granite were sheared, represents the Variscan deformation.

By a stratigraphic column where Tremadocian is represented and overall by its pre-Variscan, Lower Palaeozoic deformation, this zone distinguishes from western Morocco. More generally, it is exotic with regard to other domains of Variscan Morocco. This is a large agreement to consider that it has been accreted to the rest of Morocco (by large scale thrusting or wrench faulting) after the end of Ordovician and before, at the most, Upper Devonian, when pebbles of phyllites and undeformed Rabat granite are found in the Sidi-Bettache basin. Two origins have been proposed for this exotic domain:

– an «eastern» origin: similarities with the lithostratigraphic column of Kabylia and the existence of the pre-Variscan orogeny (which is Cambrian in age in Kabylia) could suggest that the Sehoul domain belonged to the Kabylia-Betic-Rif-Menorca zones from which it separated during Lower Palaeozoic (Piqué, 1982)

– a «western» origin: it could represent a part of the Meguma zone (Schenk, 1980), as

suggested by its lithology and by the «taconic» age of Rabat and Tiflet granites.

INTERNAL RIF

This massif is clearly allochthonous: it constitutes a part of Tertiary nappes of the alpine Rif system. The existence of a Variscan deformation is now well established (Michard and Chalouan, 1978; Chalouan, 1986), at least in the upper nappes: the Ghomarides complex.

The stratigraphic column, following Chalouan (1986), comprises:

– Upper Ordovician and Lower Silurian thin clastic sediments: silts and pelites with restricted conglomeratic episodes and volcanic flows

– Upper Silurian and Devonian: calcareous deposits, from intertidal to shelf environment (Talembote and Beni Hozmar units) and flysch series with spilitic flows (Akaïli and Koudiat Tizian units)

– Lower Carboniferous: unconformable flysch series, proximal in Talembote and Beni Hozmar units, distal in Koudiat Tizian and Akaïli units.

The variscan deformation was polyphased and represented successively by:

– Post-Devonian, pre-Visean («bretonnic» ?) F1 folds, deversed to recumbent. They trend NNE-SSW. They were accompanied by a low-grade metamorphism

– Post-Visean, pre-Permian («asturian» ?) F2 gentle folds contemporaneous with a very low-grade metamorphism.

In the lower nappes of the internal Rif (Sebtides), post-Permian alpine metamorphism and deformation overprint questionable Variscan or even older structures.

On the basis of stratigraphic and sedimentological arguments (Bourrouilh *et al.*, 1980), the Ghomarides zone has been correlated with Kabylia, Betic and Menorca. All together, these zones constituted during Palaeozoic a wide domain, at the northern margin of the African continent, from which they have been separated during the Tertiary orogeny. More recently, the internal Rif has been correlated with eastern Morocco (Hoepffner, 1987).

CONCLUDING REMARKS

Considering the above described domains, it is obvious that most of them, except Sehoul and Internal Rif, shared a common evolution during Lower Palaeozoic: they were parts of the same epicratonic platform, north of the West African shield. Since Devonian, successive crustal distention and deformation phases occurred, strongly controlled by basement fractures. These events created distinct domains in the initially continuous platform: Saharan margin, Coastal block, etc... Each of these zones is separated from the others by a tectonic contact, e.g. the Bouznika faulted zone. However, these structural domains are not distinct terranes:

– i.–During Lower Palaeozoic, they belonged to the same epicontinental shelf, itself related to the west African craton. From Ordovician to Devonian times, this shelf registered a continuous decrease of the supplies issued from the Sahara domain. Dislocation of the shelf began during Lower to Middle Devonian in eastern Morocco, when the Marrakech-Oujda turbiditic trough established. It continued at the end of Devonian when the Sidi-Bettache basin initiated in Central Morocco. During Dinantian times and more especially during Upper Visean, a regional pattern of uprising areas and subsiding basins characterized Morocco. Coastal Block, Sehoul zone, western and central Anti-Atlas surelevated and acted as source land for the sedimentary basins of central and eastern Morocco. However, these various domains re main close to each other and the different sedimentological facies from one domain to the other are explained by lateral facies changes.

– ii.–The Variscan deformation concentrated often along the limits between the above described domains. This is particularly true for the western Meseta Shear Zone, between Coastal Block and Central Morocco. However, there is no evidence for large scale displacements, neither by transcurrent faults nor by major thrusts, along these limits.

On the other hand, the Sehoul and Internal Rif domains are clearly distinct terranes. The Lower Palaeozoic evolution of the Sehoul domain, particularly with its pre-Variscan deformation, distinguishes from the rest of Varis-

can Morocco and the limit between these two domains is a tectonic contact. The Sehoul terrane was accreted to Morocco before Devonian. Its origin is still under debate: this suspect terrane is either african or american, depending on its location during its pre-Variscan deformation.

The Internal Rif is, of course, an alpine terrane, thrusted southwestwards during the Tertiary orogeny. Nevertheless, many arguments are consistent for an african origin, together with Kabylia and Betic, at the northern part of the African continent.

During Palaeozoic times, Variscan Morocco presents similarities with other regions:

– i.–Through its weakly deformed margin (Anti-Atlas) it is related to the undeformed Saharan domain which represents here the southern continent involved in the Variscan orogeny.

– ii.–Coastal block and Central Morocco belong to the Avalonian plate. They are thus related to eastern Appalachians on one hand and southwest Iberia and northern Europe on the other hand.

– iii.–Eastern Morocco, with the Internal Rif, can prolongate into southern Europe.

Finally, even if many uncertainties subsist for the Palaeozoic time span concerning the relations between Africa, Europe and eastern America, due essentially to the lack of reliable paleomagnetic data, the study of Variscan Morocco can afford valuable arguments for the reconstitution of the Variscan puzzle.

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