Journal of Structural Geology, Vol. 2, No. 1/2, pp. 55 to 61.
Pergamon Press Ltd. 1980. Printed in Great Britain.

0191-8141/80/0601-0055 $02.00/0

The Western Meseta Shear Zone, a major and permanent feature of the Hercynian belt in Morocco

A. PIQUÉ, D. JEANNETTE and A. MICHARD
Institut de Géologie, Université Louis Pasteur, 1 Rue Blessig, 67084 Strasbourg-Cedex, France

(*Received* 17 *June* 1979; *accepted* 20 *November* 1979)

Abstract—We describe the permanence of dextral shearing along the WMSZ through Middle to Late Palaeozoic time. It determined the development of the sedimentary basins and then controlled Hercynian folding and metamorphism.

INTRODUCTION AND GEOLOGIC SETTING

THE MOROCCAN Meseta is a fragment of the Variscan (Hercynian) chain formed during the Late Palaeozoic at the northern edge of the Saharan shield. This ensialic belt appears to be divided into several domains whose paleogeographic and tectonic evolutions are somewhat different. One of them, the Western Meseta Shear Zone (WMSZ), is constituted by the western boundaries of basins of Lower Carboniferous age and roughly quadrangular shape. This succession of sedimentary troughs can be followed, in a NNE–SSW direction for over 300 km, from the Sidi-Bettache area (North Western Meseta) to the Rehamna and (probably) the Jbilet massifs (Fig. 1). Regionally, this zone separates the Coastal Block, a slightly deformed domain in the westernmost Meseta, from the central and eastern parts of the Meseta, which are intensively affected by pre- and post-Visean events.

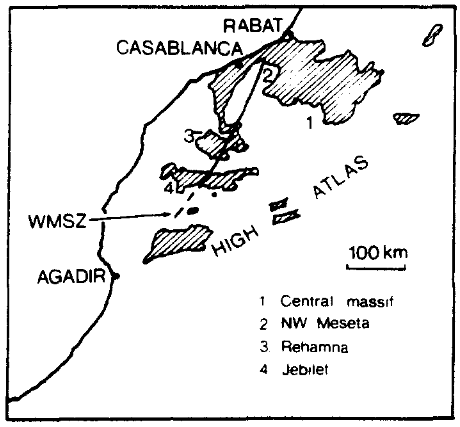


Fig. 1. Situation of the Western Meseta Shear Zone (WMSZ) in the Hercynian massifs of Morocco (hatched).

Broadly speaking, the WMSZ is characterized throughout the Middle and Upper Palaeozoic by a thin sedimentary cover on the platform (Coastal Block), contrasting with the thickness of the pile inside the trough, and by a relatively strong, syn-metamorphic deformation in which shearing processes are dominant.

The aim of this paper is to summarize the paleogeographic and tectonic evolution of this major and permanent structure, using various detailed publications (Piqué 1979, Hoepffner *et al.* 1975, Michard *et al.* 1978), and to show its general characteristics as a shear zone. Moreover, we think that this structural regime is widely (but not exclusively) representative of the Hercynian evolution of the northern margin of Africa.

PALEOGEOGRAPHIC EVOLUTION

The Lower and Middle Palaeozoic succession is characterized by shales, quartzites and limestones deposited uniformly over the whole region, except in the southern part of the Coastal Block where the Silurian and Lower Devonian are regressive. At the end of the Devonian, the region underwent a sudden differentiation. From Rabat to the Rehamna, and probably further south, a narrow 15 km wide zone—the future shear zone—received chaotic deposits and proximal turbidites and is characterized by volcanic flows (andesitic or bimodal). West of this line, a raised block acted as a source for the sediments. Easterly, on the contrary, a subsiding trough, the Sidi-Bettache basin, initiated. This pattern suggests that at the end of the Devonian the crust had been deformed by a system of faults due to a regional arching. Some volcanic materials ascended along these faults and then became interbedded with the chaotic sediments deposited on the scarp. The regional extension of this faulted zone, its linear trend and the occurrence of volcanic flows indicate that it is located upon an important fracture zone in the basement, reactivated at the end of the Upper Devonian. Moreover, the outline and the alignment of the sedimentary basins suggest that they are the result of the same regional mechanism. They may represent pull-apart basins, initiated by transcurrent movement along dextral faults showing curvatures or changes of trend (cf. Crowell 1974) (Fig. 2).

TECTONIC EVOLUTION

The evolution of the western margin of these basins during the Hercynian paroxysmal folding events will be

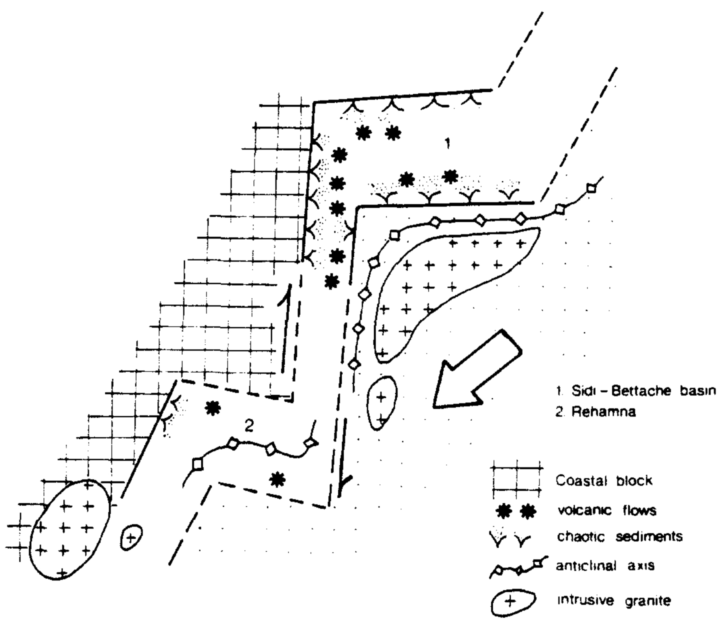


Fig. 2. Diagrammatic representation of the WMSZ during earlier synsedimentary stages.

followed in two main regions, each of them corresponding to a different structural and metamorphic level: the Northwestern Meseta, with anchi- to epimetamorphism; and the Rehamna Massif, with epi- to mesometamorphism.

The northern part of the WMSZ

Regionally this zone (Fig. 3) separates the Coastal Block to the west from the Sidi-Bettache basin (Korifla river region) to the east. We divide it into four subzones.

Structural trends. The Ben-Slimane subzone is characterized by upright NW–SE F_1 folds, whose axes are horizontal or slightly plunging. Parallel to their axial planes a coarse cleavage often develops. In the Cherrat river subzone, the fundamental F_1 folds, here upright and open, show dispersed axes within N–S axial planes (Fig. 3). This dispersion is permitted by the tendency of the hinges to separate by shearing of the limbs. Considering that this shearing is never accompanied by refolding of the axial plane cleavage, one may assume that the shearing motion took place in the same stress field as that of the folding itself, and therefore that it represents a late stage of the same folding episode in the corresponding subzone. During a first stage, buckling appears, then, during a stage of flattening, cleavage appears and provides a new anisotropy which permits the shearing displacement of the slices.

This kind of deformation appears locally in the Ben-

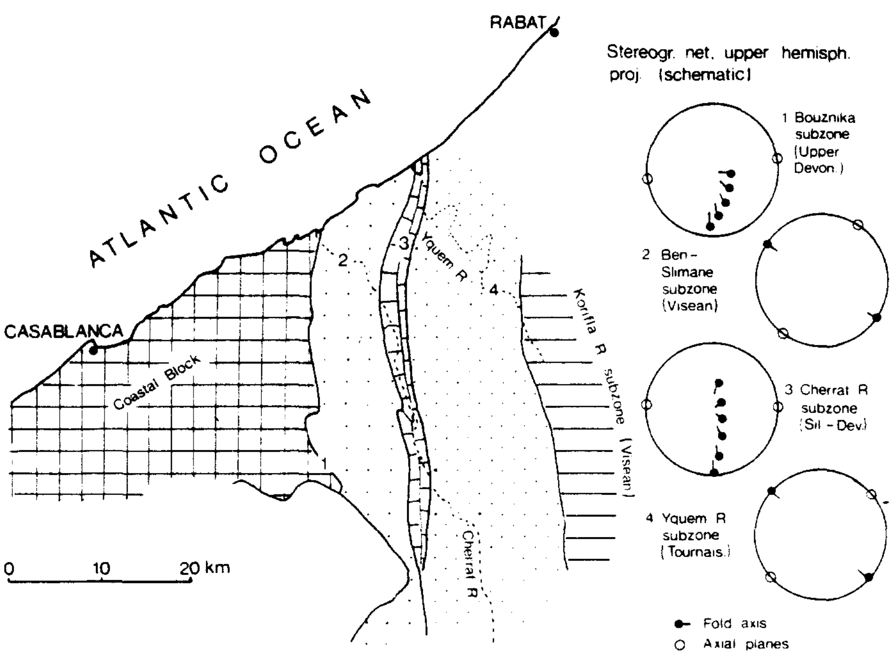


Fig. 3. The northern part of the WMSZ; structural trends and folding.

Slimane subzone: wide strips (ribbons), with horizontal NW–SE axes, separated by narrow strips with axes dispersed in N–S axial planes. This deformation is similar on a metric scale to that of the Cherrat river subzone. Once again, as in the Cherrat subzone, there seems to be no time-relation from one system to another, and therefore it seems likely that the NW–SE and N–S folds are, if not strictly contemporaneous, at least developed during the same episode of deformation.

More generally the western limit of the Sidi-Bettache basin shows two megaribbons: the Ben-Slimane and the Yquem river subzones, where folds are predominantly NW–SE. Three narrower strips which form the borders of the megaribbons, are characterized by important shearing in N–S axial planes. They are the Bouzniqa faulted subzone, the Cherrat river subzone and a third strip, less developed, at the eastern limit of the Yquem river zone.

A simple model gives an explanation for this complex arrangement. The NW–SE folds are en échelon folds; they were initiated in ribbons, each situated between two potential dextral strike-slip faults. During the deformation the shearing progressively concentrated in narrow N–S strips of various widths, especially in the Bouzniqa and Cherrat river subzones. At the same time, the strike-slip motion increased and the folds were bent at the limits of the ribbons, where axial planes became N–S. After the fundamental and complex F_1 episode, but in continuity with it, the strike-slip motion acted in a discontinuous way along strike-slip faults.

Metamorphism and deformation. The very low degree of the metamorphism has been calibrated by the determination of the phyllosilicate assemblages, including mixed-layer minerals, and illite crystallinity. On this basis, no metamorphic or even diagenetic evolution can be determined in the centre of the Coastal Block and the Korifla river region, whereas a diagenetic, then anchimetamorphic and, finally, metamorphic evolution is obvious from these regions towards the Bouzniqa and Yquem river subzones (Fig. 4). Regionally, the western margin of the Sidi-Bettache basin, that is the Western Meseta Shear Zone, appears to have suffered a metamorphism which is more accentuated than in the adjacent parts of the Meseta. More detailed study shows that metamorphism is more important in the Bouzniqa and Yquem river subzones where it reaches the epizone, and is less developed in the Cherrat river subzone which is characterized only by a diagenetic evolution. The intensity of the metamorphism is not related to the stratigraphic level. It is therefore clear that the distribution of the metamorphism in the Western Meseta is due to syntectonic heat flow, which was more important along the shear zone.

Mapping of the structural levels (according to cleavage type and fold wavelengths and profiles) shows that the deformation is not evenly distributed throughout the Meseta. Its distribution is roughly parallel with the intensity of metamorphism. The rocks are strongly deformed in the WMSZ, especially in the Bouzniqa faulted subzone and in the Yquem river subzone.

The Southern part of the WMSZ in the Rehamna Massif

The Rehamna Massif includes a northern part with very low to low metamorphism, whose stratigraphic and tectonic setting allows a good correlation with the

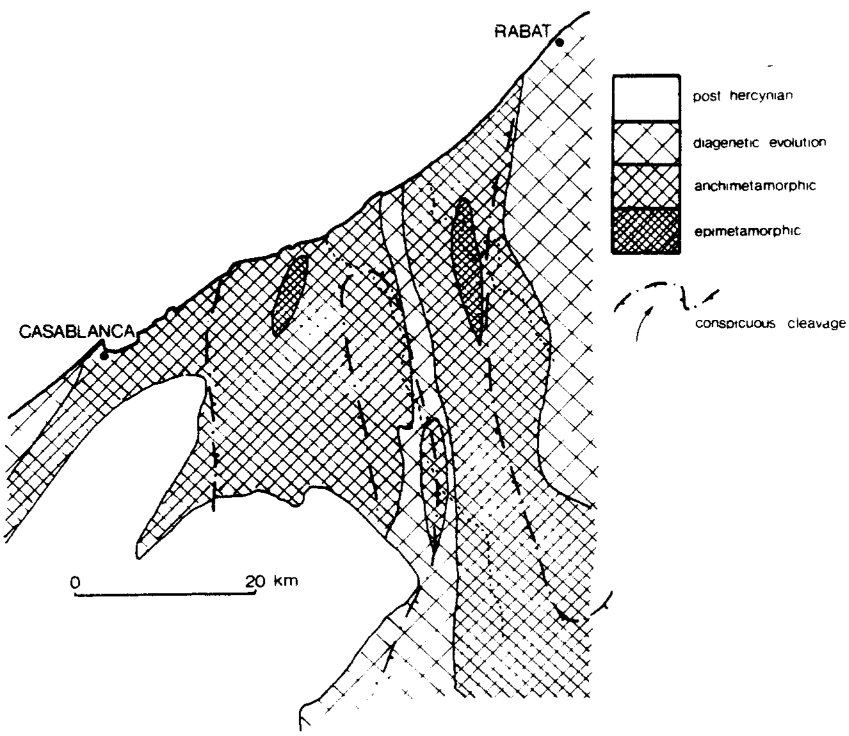


Fig. 4. The northern part of the WMSZ; metamorphism and cleavage repartition.

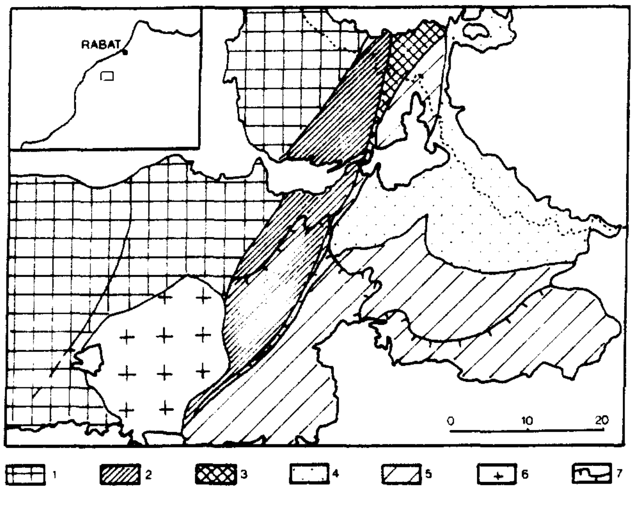


Fig. 5. The southern part of the WMSZ in the Rehamna massif: general setting of the structural subzones and of the thermal structure. 1: Coastal block (Cambro-Ordovician). 2: Skhour subzone (mainly Cambro-Ordovician). 3: Devonian of Northern Rehamna and east margin of (2). 4: Cambro-Ordovician of Eastern Rehamna and of the east margin of (2). 5: Devonian and Lower Carboniferous of Eastern Rehamna. 6: Intrusive granite. 7: Biotite-garnet northern limit.

northern part of the WMSZ. We shall consider here the principal part of the massif (central and southern parts), affected by a high thermal syntectonic heat flow. It is divided in three subzones; from west to east, the Coastal Block, the Central Rehamna (Skhour subzone) and the Eastern Rehamna (Fig. 5).

The Eastern Rehamna. In this subzone two synmetamorphic episodes of folding are known. F_2 folds are superimposed on F_1 folds and they deform the S_{0-1} foliation. The F_2 folds have N–S steeply dipping axial planes marked by a metamorphic F_2 foliation. The F_2 folds' asymmetry indicates tectonic transport to the West, and their oblique orientation relative to the major reverse fault of the massif (Fig. 5) is in accord with a dextral slip along faults. The F_2 axes are commonly dispersed in the axial plane and sometimes present a marked curvature. In every case, the succession of folds is interrupted by shear planes parallel to the F_2 axial planes, and commonly localized in their shorter and western limbs. At the outcrop scale, the pattern often realized is constituted by strips of various widths in which F_2 hinges are preserved, and by narrower zones, in which F_2 folds are no longer recognizable (S_{0-1} foliation transposed into S_2). Thus folded strips are separated by narrow zones characterized by planar structures (Fig. 6a). A similar pattern also characterizes the microscopic scale: in the folded domains, for instance at the hinge of a metric-scale fold, the S_2 planes isolate microlithons. The bending of the S_{0-1} foliation inside the microlithons indicates moderate movements along S_2 planes. Newly crystalized muscovite and biotite grew around F_2 hinges in polygonal arcs. In the planar domains, where S_2 foliation is generalized, the microlithons disappear, the S_{0-1} foliation is reoriented into S_2, and the new phyllosilicates develop parallel to S_2. Garnet, chloritoid and staurolite crystals indicate, by the disposition of their inclusions, that they grew during and after shearing along S_2 planes (Fig. 6b).

Regionally, inside the Eastern Rehamna, the folded domains become proportionally less important towards the west. When passing through the Skhour subzone limit, marked by steeply dipping thrust faults, the planar structure is the dominant feature.

The Central Rehamna. The Skhour subzone is characterized by a planar to linear structure, where folds are rarely preserved. Generally the most salient feature is a steeply east dipping foliation (S-tectonites). The phyllosilicates lie parallel to this F_{1-2} foliation; the garnet crystals are rotational, and the chloritoid and/or staurolite crystals are syn- to post-kinematic. Outcrops show few F_1 folds, they are mostly so flattened and stretched that they have been destroyed. Their hinges form rods and their limbs are disrupted by an intense boundinage.

In the core of the subzone, the dip of the foliation decreases whilst the horizontal L_2 lineation develops ($L + S$ tectonites). Kyanite appears, late to post-kinematically crystallized. In a Devonian conglomeratic layer, the deformation of the pebbles is essentially extensional, reaching axial ratios of $X/Y = 20$. These prolate pebbles indicate a main flow, nearly horizontal in the NNE–SSW direction. At the western margin of this central subzone, the structure progressively passes to the simple folding of the Coastal Block as the metamorphism decreases.

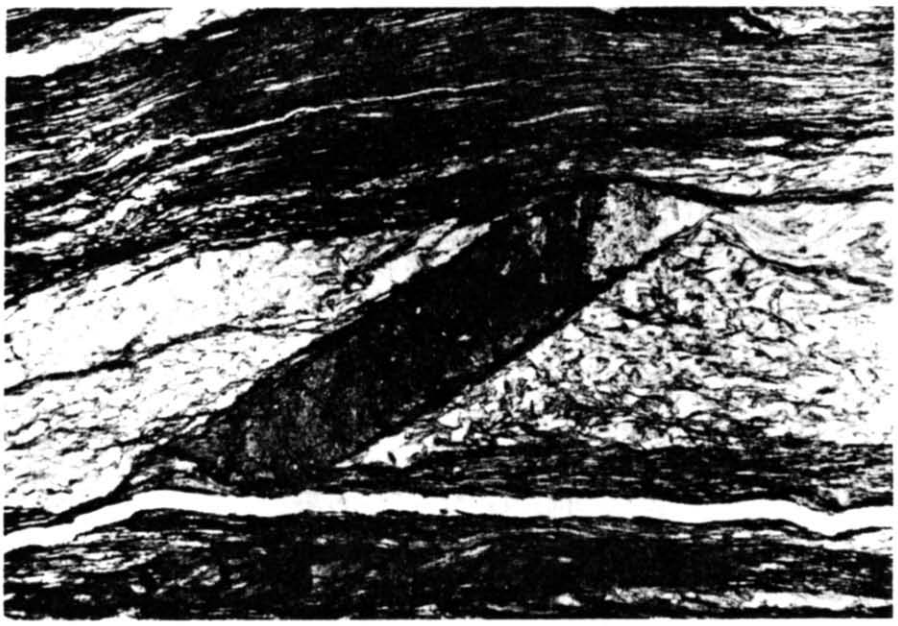
DISCUSSION

Both regions considered here are parts of the same major structure — a long narrow zone between the continuous Coastal Block and the more complicated Central Meseta domain — and consequently must be explained by the same major mechanism. The structural pattern of the whole region was initiated early during the sedimentary period. The general shape and the related facies of the Sidi-Bettache basin suggest dextral slip faults (Fig. 2). The same faulted zone acted again during the syn metamorphic tectonic period — early Late Carboniferous — with a syn metamorphic dextral slip. The en échelon disposition of the folds in the northern part, their asymmetry and their orientation in the southern one, also suggest such dextral displacements. The displacements continued and accentuated the synsedimentary movements. They correspond to the northward slip of the rigid Coastal Block relative to the Central Meseta region.

In the northern part, the shear zone is constituted by an alternation of 'ribbons', showing en échelon major folds, and narrower strips characterized by planar structures. The strips are the result of the progressive concentration of the shearing motion. In a later stage of the tectonic evolution, strike–slip faults, still generally dextral, appeared in the same strips.

In the southern part (Rehamna), the shear deforma-

(a)



(b)

Fig. 6. (a) Eastern Rehamna. The So_{-1} foliation is refolded by F_2 folds. The development of shear planes, parallel to the F_2 folds axial planes leads to a planar structure which is mostly localized on the shorter limb of these folds. (vertical view, length of the rule is 15 cm) (b) A chloritoid crystal is situated in a microlithon which shows folded S_1 between two planar domains in which S_1 is parallel to S_2. The sigmoid S_1, inside the chloritoid prism, shows that this crystal grew during shearing. The development of the S_2 foliation (parallel to the length of the picture) is synmetamorphic. (Crossed nicols, the length of the photomicrograph represents about 5 mm.)

tion is typical of a deeper structural level than that which operated in the northern region. This is related to a higher syntectonic thermal flow. A zone of relatively high thermal flow probably extended from the Rehamna up to the Central Meseta. The Rehamna area corresponds to the intersection of this NE–SW trend with the WMSZ. There, a transverse tectonic gradient existed as in the northern part of the WMSZ. In the eastern Rehamna subzone, folded domains pass progressively to planar domains (*S*-anisotropy), where the reverse limbs of the folds are disrupted. In the core of the central subzone, west of a major reverse dextral fault, this planar anisotropy evolved towards a linear *L*-anisotropy where the mineral and stretching lineations are horizontal parallel to the strike–slip faults. This tectonic pattern is parallel to the variations in the metamorphic grade, which reach a maximum intensity (staurolite and kyanite) in the zone of *L*-tectonites.

The amount of dextral slip of the Coastal Block is unknown. The displacements along the shear zone perhaps decrease to the south where they might be partly transformed in the transverse (E–W) folding of the cover, and in the vertical uplifting of basement blocks. This uplifting might have produced some décollements of the cover and its deformation by low-angle thrusts.

REFERENCES

Crowell, J. C. 1974. Origin of late Cenozoic basins in southern California. *Spec. Publs. Soc. econ. Palaeont. Miner., Tulsa.* **22**, 190–204.

Hoepffner, Ch., Jeannette, D., Jenny, P., Michard, A. & Piqué, A. 1975. Relations entre une tectonique de décrochement et un métamorphisme à disthène dans le massif hercynien des Rehamna (Maroc). *Bull. Soc. géol. Fr.* **17**, 421–429.

Piqué, A. 1979. Evolution structurale d'un segment de la chaîne hercynienne: la Meseta marocaine nord-occidentale. Thèse, Université Louis Pasteur, Strasbourg.

Michard, A., Hoepffner, Ch. & Jenny, P. 1978. Le couloir de cisaillement calèdono-hercynien de Meseta occidentale sur la transversale de Mechra-ben-Abbou (Rehamna, Maroc). *Bull. Soc. géol. Fr.* **20**, 889–894.