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Faulting history at the eastern termination of the High Atlas Fault (Western High Atlas, Morocco)

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Abstract

At its eastern termination, the High Atlas Fault in the Western High Atlas in Morocco, consists of a splay of three faults. In the interjacent fault blocks, Neo- and Paleoproterozoic basement, forming the northernmost extremity of the NW-African Craton, is cropping out. The Precambrian basement witnesses a long history of brittle deformation starting at the end of the Pan-African Orogeny. A subsequent episode of normal faulting can be related to the development of a Hercynian basin along the northern passive margin of the cratonic promontory. With regard to the main tectonic activity in the Western High Atlas, basically two models exist: one emphasising block tectonics reflecting Mesozoic rifting followed by Alpine uplift and inversion, the other emphasising Late Paleozoic dextral wrench tectonics. The analysis of the fault activity along the splay faults reveals a predominantly Alpine history, consisting of the Triassic development of the 'Atlas Rift' along the axial zone of the orogen, followed by uplift and inversion. The Late Jurassic to Cenozoic fault activity took place in a sinistral transpressive regime and was partitioned over the three splay faults. Dextral strike-slip fault activity could not be demonstrated in the fault blocks nor along the splay faults. Therefore the faults were probably not involved in Late Paleozoic dextral wrench tectonics.

Introduction

The Western High Atlas forms the culmination zone of the Atlas mountain chain, a narrow intracratonic orogen which extends from the Atlantic in Morocco to the Mediterranean in Tunisia (Figure 1). A characteristic feature of the Atlas Orogen is the presence of major strike-parallel fault systems. They are considered to have a Paleozoic or even Precambrian origin (Froitzheim et al. 1988). They have known a long history of periodic reactivation due to changing stress fields, caused by the relative movements of the African, American and European plates and some interjacent continental slivers (Dewey et al. 1973). Along the southern limit of the Western High Atlas three such faults can be recognised: the High Atlas Fault, the South Atlas Fault and the Anti-Atlas Fault (Figures 1, 2).

A controversy exists with regard to the tectonic history of this orogen. A review of the ongoing debate is given by Binot et al. (1986). This discussion basically concerns two models. In a first model Meso- and Cenozoic block tectonics is emphasised. The Atlas Orogen is considered as a failed rift arm ('Atlas Rift') of the Atlantic Rift, inverted and uplifted during the Alpine Orogeny (Froitzheim et al. 1988). The other model emphasises Late Paleozoic dextral wrench tectonics. The Atlas Orogen, and more specifically the major strike-parallel fault systems, are considered as the southern limit of a supracontinental Late Hercynian megashear zone (Arthaud & Matte 1977).

Only in the axial zone of the Western High Atlas the Precambrian and Paleozoic basement is cropping out (Figure 2). It is covered to the east and west by Mesozoic strata. Because of the superposition of Precambrian, Paleozoic, Mesozoic and Cenozoic structural

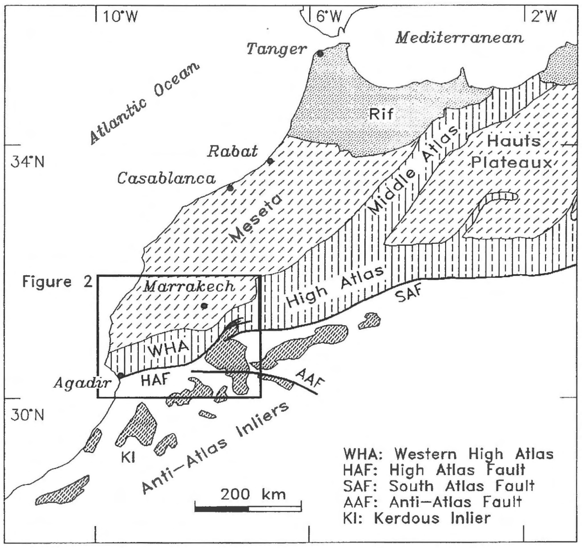

Figure 1. Sketch map of the major tectonic provinces in Morocco: Pan-African province (Anti-Atlas Inliers); Hercynian provinces (Meseta and Hauts Plateaux); Alpine provinces (Middle Atlas, High Atlas and Rif).

features this part of the Atlas Orogen is particularly suitable to study its complex tectonic history.

The most prominent structural feature in the Western High Atlas is the High Atlas Fault (Figure 2). West of the Tichka Plutonic Complex (cf. Gasquet 1992) it forms the southern limit of the orogen. To the east it crosses the axial zone of the orogen, bordering the Ouzellarh Promontory. This Precambrian basement, incorporated in the Atlas Orogen, represents the northernmost part of the NW-African Craton cropping out in the Anti-Atlas Inliers (Figure 1). To the northeast the High Atlas Fault cuts into the basement, forming the Tkent-Tacheddirt Graben (Figure 2; Dresen 1985). Finally, it terminates in a fault splay consisting of three fault zones, the Oukaimeden, Meltsene and Ourika Fault Zones, which can be observed in the upper course of Oued Ourika (Figure 3).

The upper course of Oued Ourika (~ 50 km SE of Marrakech) offers a unique opportunity to study the fault history in this part of the Western High Atlas because it can be related to two unconformities, one of Vendian and one of Triassic age. The former unconformity is observed in the Ourika Inlier, which crops out in the northern fault block between the Oukaimeden and Meltsene Fault Zones (Figures 3, 4). The southern fault block, between the Meltsene and Ourika Fault Zones (Figure 3), consists of the Ourika Gneiss Complex, which shows prominent petrologic and structural similarities with the Paleoproterozoic gneiss complexes in the Anti-Atlas Inliers (Choubert 1963; Proust 1973).

The current work is the result of a detailed study of the fault activity in both fault blocks and along the three splay faults. Based on a geometrical analysis and a quantitative paleostress reconstruction the fault history at the eastern termination of the High Atlas Fault can be constrained. Eventually, new insights into the tectonic history of this part of the Western High Atlas are brought forward.

Methodology

During fieldwork, of which the purpose was to revise the existing geostructural map of the Ourika Inlier (Figure 4; cf. Vogel et al. 1980), a detailed inventory has been drawn up of all brittle features. Their geometry served to determine relative fault movements. Their relationship with the unconformities moreover allowed a relative timing of the fault activity. Besides this rather qualitative approach, fault-activity data from striated fault surfaces, were collected at a number of sites to perform a paleostress analysis. In this way a quantitative reconstruction of the stress field responsible for the fault activity could be achieved. It enabled a correlation with the continental stress regimes for the Atlas region as determined by Mattauer et al. (1977; Figure 7). The paleostress analysis was performed using the software of Delvaux (1993), which is based on the graphical 'right dihedron' method of Angelier & Mechler (1977) and on an analytical rotational optimisation method to obtain the best-fit reduced stress tensor.

Results

Ourika Inlier

The Ourika Inlier crops out in the northern fault block between the Oukaimeden and Meltsene Fault Zones (Figures 3, 4). The entire inlier is covered by subhorizontal Triassic strata (cf. Biron 1982). Our investigations revealed a second angular unconformity within the inlier separating a layered terrigeneous sequence from an underlying volcanic sequence. The former consists primarily of badly sorted conglomerates, and sand- and siltstones with tuffaceous intercalations. The latter is composed of massive series of multicoloured volcanic rocks in which no clear layering could be

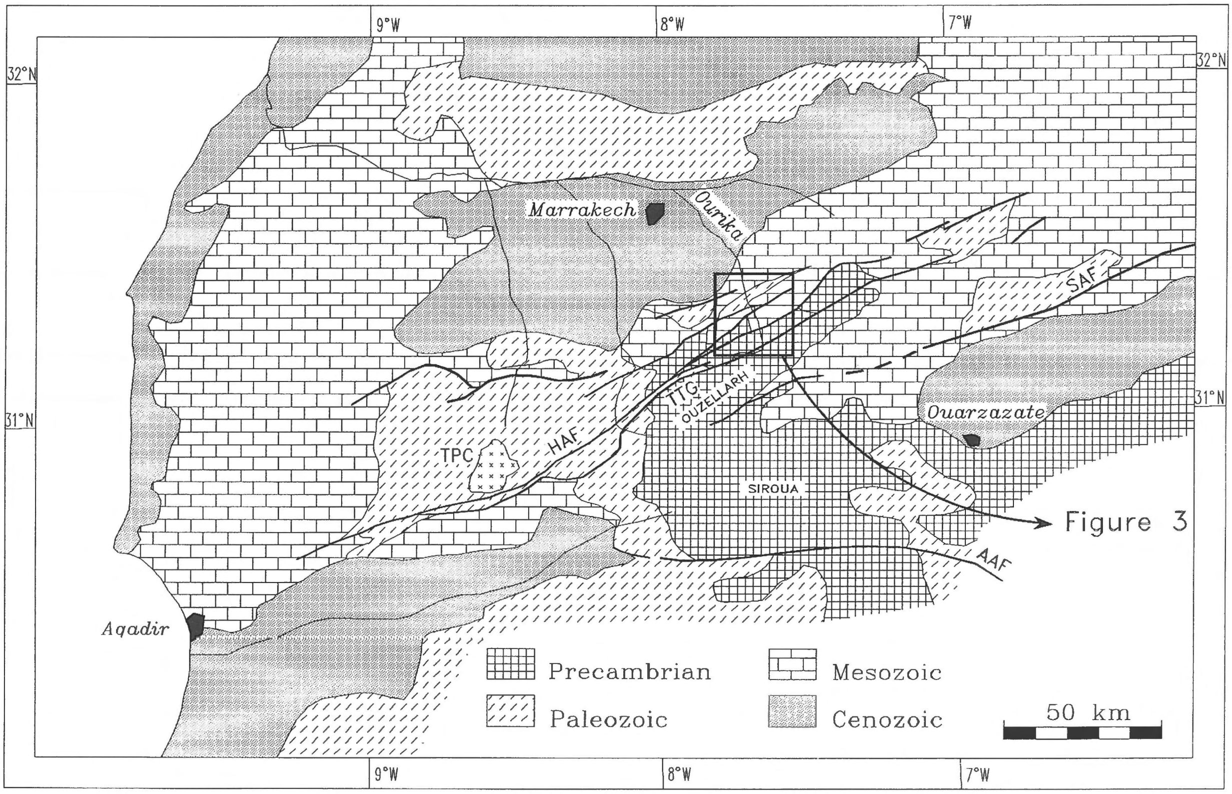

Figure 2. Geological setting of the Western High Atlas (after Froitzheim et al. 1988). TPC = Tichka Plutonic Complex; HAF = High Atlas Fault; TTG = Tkent-Tacheddirt Graben; SAF = South Atlas Fault; AAF = Anti-Atlas Fault.

observed. On the age of both units different opinions exist. Proust (1973) considers the volcanic sequence ('Ouarzazate Series'; Choubert 1963) of Neoproterozoic age. Vogel et al. (1980), on the other hand, did not observe an unconformity and interpreted the volcanic series, together with the overlying conglomerates and tuffs, as part of a concordant Cambrian sequence ('Sidi Chamharouch Series'; Choubert 1963). In our opinion, characteristic carbonate boulders in the conglomerates may be of help in constraining the ages. The origin of these boulders is unknown, and they cannot be dated because of the lack of any fossils (P. Bultynck, pers. comm.). This type of carbonate boulders, however, is typical for the Vendian conglomerates present in the Tkent-Tacheddirt Graben and along the northwestern slopes of the Ouzellarh Promontory (Binot et al. 1986). We therefore assume a Vendian age of the unconformity, in agreement with the Neoproterozoic age of the volcanic sequence as suggested by Proust (1973).

The Precambrian in the inlier and the overlying Triassic formations show no evidence of pervasive ductile deformation. The deformation is of brittle nature and reflects different faulting episodes.

The overall structure of the Ourika Inlier is determined by the Central Anticline, which folds the Vendian unconformity and strata (Figure 4). This open, upright anticline plunges slightly to the northeast. No axial-plane cleavage has been observed. The Central Anticline is cut by a series of faults, themselves fossilised by the Triassic unconformity (Figure 4). However, these faults affect both the Neoproterozoic and Vendian sequences, pointing to a Paleozoic fault activity. The N45°E-striking faults have a concave upwards geometry and dip to the north. The displacement of the unconformity indicates normal fault activity. However, a paleostress analysis on one of these faults (Fault 10) indicates a purely compressive stress field with a N144°E σ_1-direction (Table 1, Figure 5).

An even older, Neoproterozoic, faulting episode has been recognised in the volcanic sequence, in which diffuse brecciated zones are cut off by the Vendian unconformity. In the southern limb of the Central Anti-

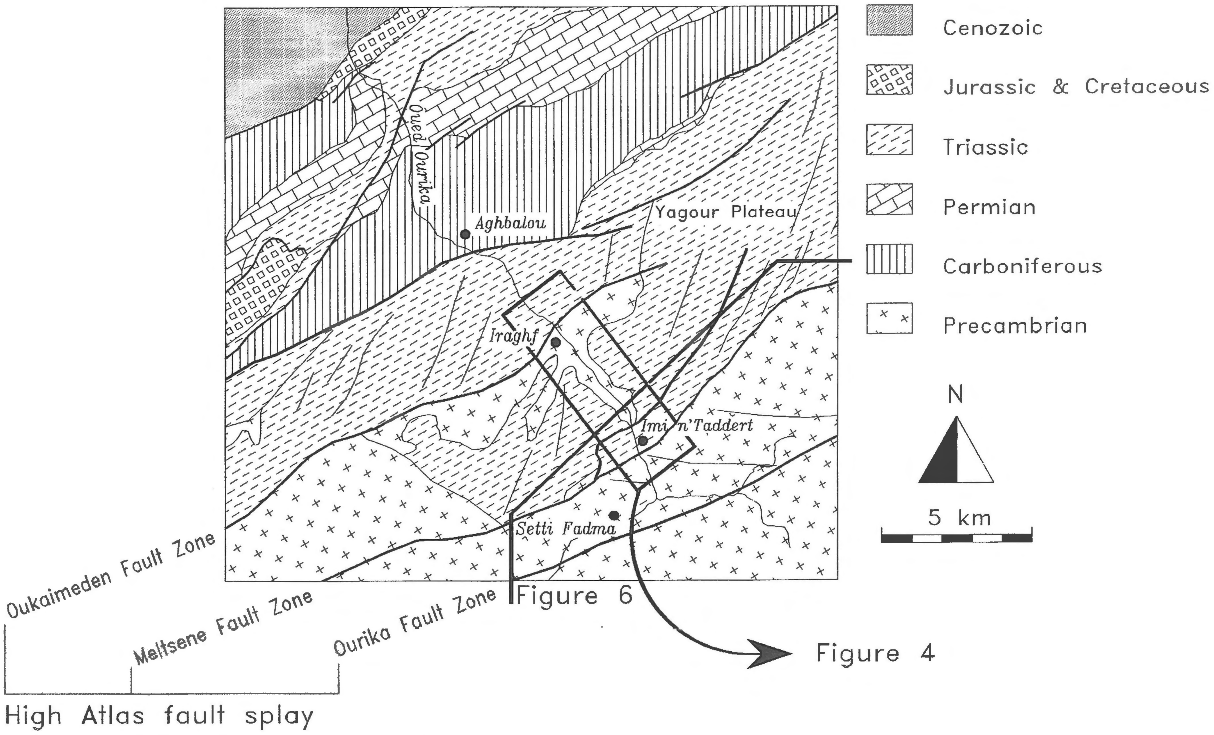

Figure 3. Geological map of the upper course of Oued Ourika (after Vogel et al. (1980) and Biron (1982)).

cline the Paleozoic normal faults follow these brecciated zones.

At the southern extremity of the Ourika Inlier a particular fault-bounded unit is present between Faults 3 and 4 (Figure 4). It primarily consists of granites ('Granite Rose'), unconformably covered by Triassic strata. In the northern part of this fault block the volcanic sequence crops out but the contact between volcanics and granite could not be observed. This alkaline granite is of Neoproterozoic age (580 ± 12 Ma, Juery et al. 1975).

This unit is bounded by two N50°E-striking faults. Both dip steeply southward and clearly show a post-Triassic normal fault activity. The northern fault shows a vertical displacement of the Triassic unconformity of 100 to 120 m. The southern fault contains Upper Triassic arenites of the 'Imi n'Taddert Syncline' (Biron 1982) in its hanging wall, which indicates an even more significant normal fault activity with regard to the basal Triassic strata overlying the Ourika Inlier.

Imi n'Taddert Syncline

The Imi n'Taddert Syncline is situated in the footwall of the Meltsene Fault Zone and separates the Ourika Inlier from the Ourika Gneiss Complex (Figure 4). It is composed of Upper Triassic arenites (Biron 1982). The open, upright syncline has a subhorizontal E-W-trending hinge line.

A paleostress analysis measuring all fault-activity data across the entire syncline shows a strongly compressive strike-slip regime with a N17°E σ_1-direction (Table 1, Figure 5).

Ourika Gneiss Complex

The fault block between the Meltsene and Ourika Fault Zones consists of the Ourika Gneiss Complex (Figure 6). This complex consists of high-grade metamorphic gneisses, amphibolites and migmatites. It is embedded in a granodioritic plutonic complex, which forms the backbone of the Western High Atlas. To the northeast it is also intruded by the 'Granite Rose'. Age constraints are again a matter of debate. By comparison with similar gneiss complexes in the Anti-Atlas

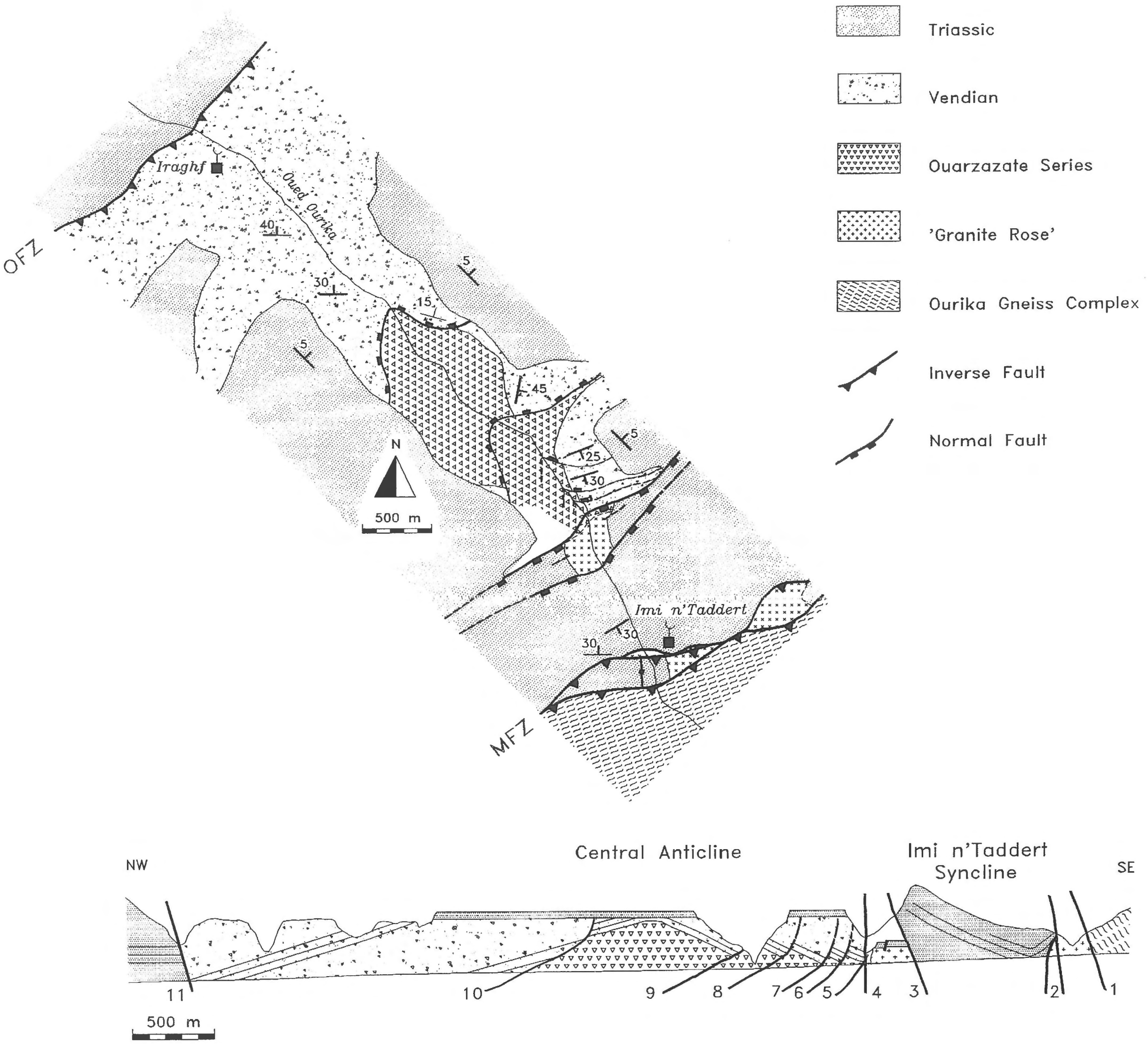

Figure 4. Structural map of the Ourika Inlier. Profile represents structures observed on the northeastern slope of the Ourika valley. Faults 1, 2 = Meltsene Fault Zone (MFZ); Fault 11 = Oukaimeden Fault Zone (OFZ).

Inliers, Choubert (1963) and Proust (1973) consider the Ourika Gneiss Complex of Paleoproterozoic age, reflecting the Eburnian Orogeny. Brabers (1988), on the other hand, considers these high-grade series as Mesoproterozoic shelf sediments gneissified during a Pan-African obduction (724 ± 50 Ma). During the final stages of the Pan-African Orogeny (Brabers 1988) this gneiss complex was intruded by the post-collisional granodiorites (610 ± 15 Ma, Juery et al. 1975) and granites (580 ± 12 Ma, Juery et al. 1975).

The gneisses show a pervasive, multiphase, ductile deformation associated with the development of a gneiss dome. The complex is cross-cut by several N70°W to E-W-trending fault lineaments dividing the complex into fault blocks (Figure 6). Field evidence shows dextral movement along these subvertical faults, implying a counter-clockwise rotation along a vertical axis of these fault blocks.

Oukaimeden Fault Zone

The Oukaimeden Fault Zone is the most northern splay fault of the High Atlas Fault (Figure 3). The fault zone limits the Ourika Inlier to the north (Figure 4). It has

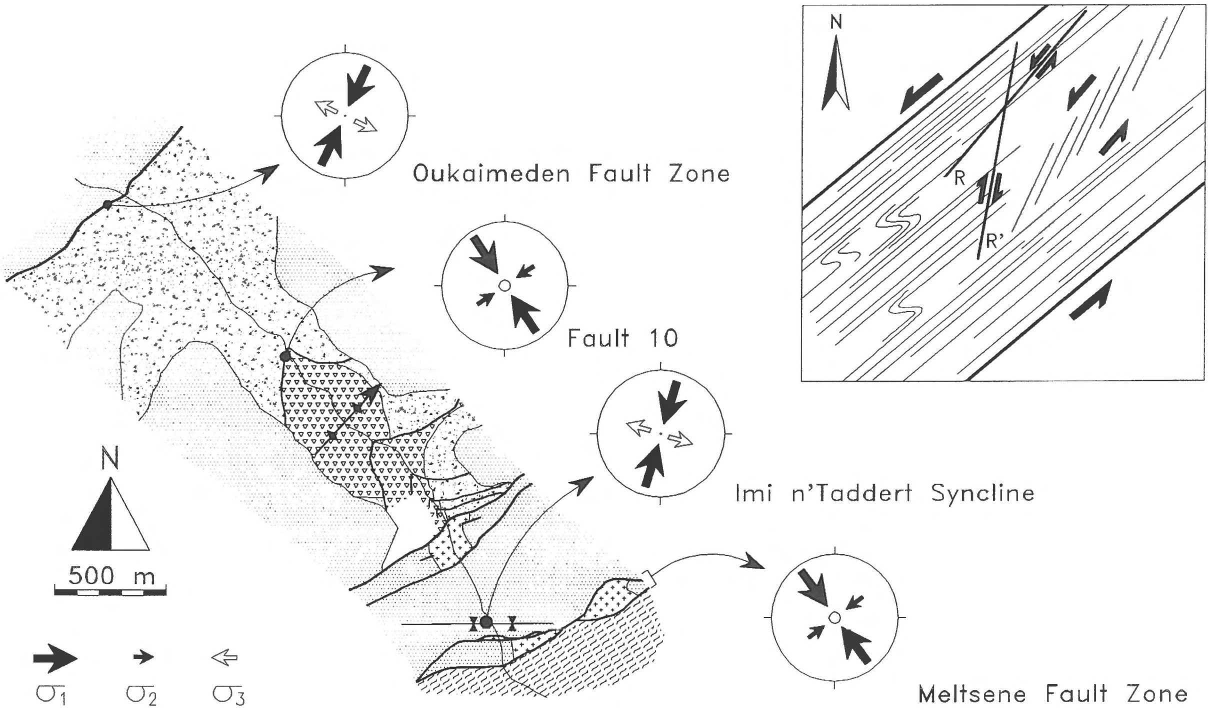

Figure 5. Stress-field reconstruction at four locations in the area shown in Figure 4. Three stress fields (Meltsene Fault Zone, Imi n'Taddert Syncline and Fault 10) are calculated by means of a paleostress analysis (Table 1); the stress field along the Oukaimeden Fault Zone is based on geometrical data. Inset: synthetic sketch (not to scale) of the structural features observed in the Oukaimeden Fault Zone with indication of the subvertical cataclastic foliation, drag folds, Riedel fractures (R = synthetic Riedel shear; R' = antithetic Riedel shear), and en-echelon tension gashes. Legend: see Figure 4.

a N50°E strike and dips steeply to the south (70 to 90°). It varies along-strike from a single fault plane to a narrow (< 50 m) fault zone with a pervasive, subvertical cataclastic foliation.

An inverse fault movement is apparent. Weakly north-dipping Vendian conglomerates in the hanging wall are juxtaposed with subhorizontal Triassic arenites in the footwall (Figure 4). Biron (1982) assumes a vertical displacement of at least 1000 m. In the footwall small-scale drag phenomena are observed.

Indications for sinistral strike-slip faulting are observed in the cataclastic foliation in the fault zone (Figure 5). The foliation shows asymmetric drag folds with subvertical hinges. Moreover, distinct secondary fault sets show a Riedel geometry, indicating sinistral shearing. Sinistral R-planes (synthetic Riedel shear planes) with a N40°E strike and dextral R'-planes (antithetic Riedel shear planes) with a N10°E strike are both recognised. En-echelon extension veins also mark the sinistral R-planes. The individual extension veins strike N25°E. All these subvertical features point to a transtensional stress field with a N25°E σ_1-direction (Figure 5).

Meltsene Fault Zone

The Meltsene Fault Zone separates the Imi n'Taddert Syncline from the Ourika Gneiss Complex (Figure 4). It consists of a series of 100 to 120-m-wide, lens-shaped fault horses, bounded by E-W and NE-SW-striking faults. The overall trend of the steeply south-dipping fault zone is N50°E. The different fault horses consist of Triassic conglomerates overlying strongly fractured and weathered 'Granite Rose'. The unconformity and Triassic strata within the fault horses are subvertical with a N15°E strike. The particular fault block between Faults 1 and 2 at the southern extremity of the Ourika Inlier exhibits a striking similarity with these fault horses and indicates a possible genetic relationship (Figure 4).

The Meltsene Fault Zone brings the Precambrian gneiss complex in its hanging wall in contact with Triassic arenites of the Imi n'Taddert Syncline in its

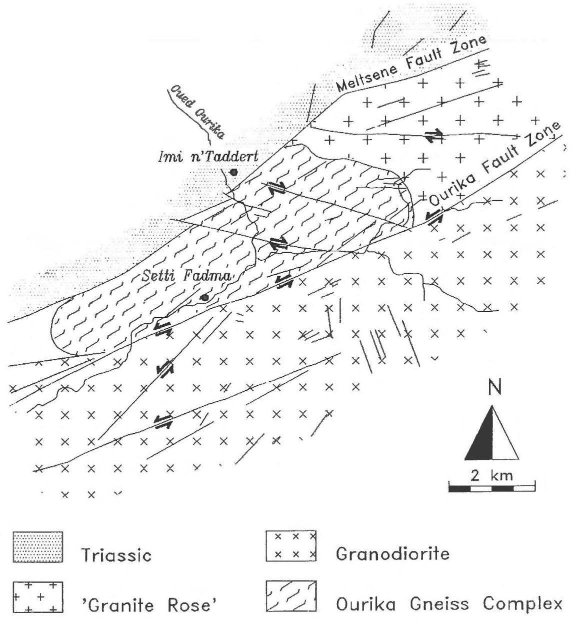

Figure 6. Strike-slip faulting in the Ourika Gneiss Complex (based on aerial photographs and field observations).

footwall. A vertical displacement of over 3000 m is suggested (Proust 1983; Biron 1982). Drag phenomena are observed in its footwall. Triassic pelitic horizons in the direct proximity of the fault even show a cleavage development. A paleostress analysis of the fault-activity data in the Meltsene Fault Zone indicates a strongly compressive stress field with a N146°E σ_1-direction (Table 1, Figure 5).

Sinistral strike-slip fault activity in the Meltsene Fault Zone is expressed by the lens-shaped geometry and the internal tilting in the fault horses. Also the stress field measured in the Imi n'Taddert Syncline as well as the syncline's geometry can be related to this sinistral transpressive fault activity in the fault zone.

Ourika Fault Zone

The southernmost splay fault of the High Atlas Fault is the most prominent feature in this part of the Western High Atlas. It can be traced as a straight lineament with a N60 to N70°E trend over several 100 km on both aerial photographs (Figure 6) and satellite images.

In the upper course of Oued Ourika, this fault zone cuts the Precambrian basement and consists of a 500-m-wide cataclastic zone in which gneisses of the Ourika Gneiss Complex and a whole range of brecciated magmatic rocks are involved. Large lens-shaped bodies of 'Granite Rose' are also incorporated in the fault zone, definitively implying post-Precambrian fault activity.

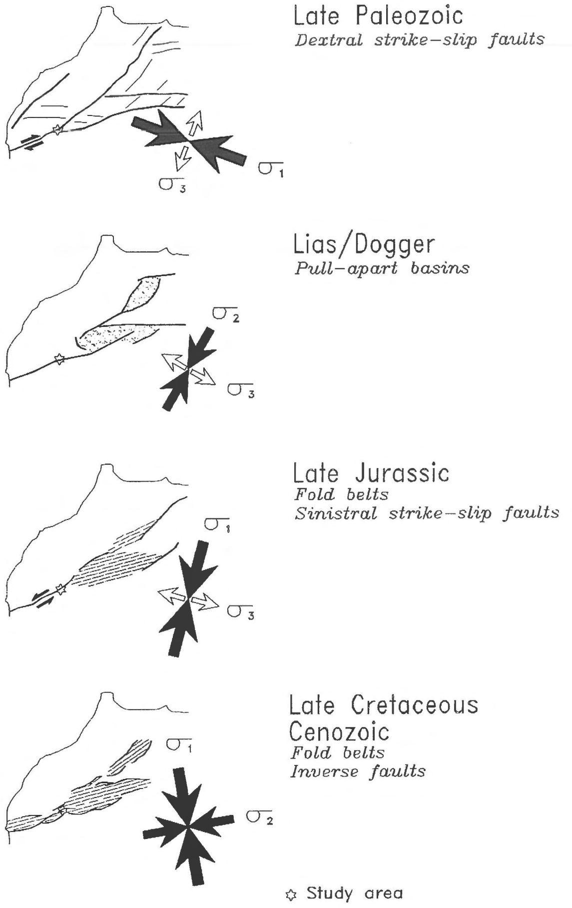

Figure 7. Evolution of the continental stress field in the Atlas region (after Mattauer et al. 1977) with indication of the main tectonic features (strike-slip faults; pull-apart basins (stippled); fold belts (dashed)).

Geomorphologically, a graben-like configuration seems likely. The Ourika Fault Zone can, in our opinion, be considered as the eastern continuation of the Tkent-Tacheddirt Graben (Figure 2).

Internally, the fault zone is dominated by a pervasive cataclasis. However, on all scales secondary faults can be recognised, consistently showing a Riedel geometry indicative for a sinistral strike-slip shear with a NE σ_1-direction. Indications for inverse fault movements are lacking, contrary to Dresen (1985) who described significant inverse fault activity ~ 30 km to the west in the Toubkal region.

Table 1. Results of the paleostress analysis.

Structure	n	σ_1	σ_2	σ_3	R	α	Stress type
Fault 10	28	144/22	246/28	022/54	0.62	10.8	purely compressive
Imi n'Taddert Syncline	41	197/12	360/77	107/04	0.08	20.7	compressive strike-slip
Meltsene Fault Zone	52	326/13	063/29	214/57	0.6	12.5	purely compressive

n: number of fault-plane striation data used; σ_1, σ_2, σ_3: principal stress directions; R: shape ratio of stress ellipsoid (σ_2-σ_3)/(σ_1-σ_3); α: mean deviation angle between observed and calculated slip directions.

Deformation history

Based on the correlations of the fault-activity data with the two unconformities and of the paleostress reconstructions with the continental stress fields for the Atlas region (Figure 7; Mattauer et al. 1977), the brittle deformation history in this part of the Western High Atlas can be constrained.

Only the Ourika Gneiss Complex has witnessed a pervasive ductile deformation under high-grade metamorphic conditions. This deformation occurred prior to the Neoproterozoic magmatism and volcanism. Therefore, a pre-Neoproterozoic discontinuity is inferred. The nature of this discontinuity is a matter of debate. If the Ourika Gneiss Complex is of Paleoproterozoic age, an Eburnian unconformity (± 1800 Ma) can be assumed. If it is of Mesoproterozoic age (Brabers 1988), the development of the gneiss dome and the Neoproterozoic calc-alkaline magmatism and volcanism can all be explained by a post-collisional, Late Pan-African, orogenic collapse. In that case, the pre-Neoproterozoic discontinuity can be interpreted as a basal detachment. Such a monophase Pan-African model complies with recent observations in the Kerdous Inlier in the Anti-Atlas (Figure 1; Nachit et al. 1996).

Brecciated zones in the volcanic sequence in the Ourika Inlier indicate that the brittle deformation history already started during the Neoproterozoic. The subsequent history can be subdivided into two episodes separated by the formation of the Triassic unconformity.

The north-dipping listric normal faults in the Ourika Inlier reflect an extensional episode related to the Hercynian basin development northwest of the Precambrian cratonic promontory, which itself acted as a passive margin (Binot et al. 1986).

During the Triassic a rift basin ('Atlas Rift') developed on the cratonic basement. This rifting was most probably initiated during the Paleozoic, as indicated by the Paleozoic sedimentation in the Tkent-Tacheddirt Graben. The normal faults along the southern extremity of the Ourika Inlier and the Late Triassic age of the arenites of the Imi n'Taddert Syncline clearly indicate that rifting was centred along the axial zone of the Western High Atlas.

The onset of the Alpine collision in the Late Jurassic is characterised in the Atlas region by a N10°E σ_1-direction (Mattauer et al. 1977) causing sinistral strike-slip reactivation of pre-existing fault systems (Figure 7). This sinistral fault activity is apparent along the Oukaimeden Fault Zone as shown by its structural geometry, along the Meltsene Fault Zone as shown by the lens-shaped fault horses and the internal tilting, and along the Ourika Fault Zone as shown by the internal fault geometry. The development of the Imi n'Taddert Syncline is also attributed to this transpressive regime as substantiated by paleostress data (Figure 5). The counter-clockwise block rotations in the Ourika Gneiss Complex (Figure 6) can also be related to this sinistral fault activity. Finally, in the Triassic of the Yagour Plateau, northeast of the Ourika Inlier (Figure 3), Biron (1982) describes N30°E-oriented graben-like structures complying with the general sinistral strike-slip regime. The main episode of the Alpine collision, from the Cretaceous onwards, is characterised by a N170°E σ_1-direction (Figure 7; Mattauer et al. 1977). Both, the Oukaimeden and Meltsene Fault Zones show significant inverse reactivation. Paleostress data in the Meltsene Fault Zone (Figure 5) are consistent with the continental stress field at that time. A similar stress field is observed on one of the normal faults in the pre-Triassic basement (Figure 5), indicating a limited inverse reactivation.

Conclusions

The correlations of the fault-activity data with the Vendian and Triassic unconformities and of the paleostress reconstructions with the continental stress fields for the Atlas region (Mattauer et al. 1977) give new insights into the tectonic history of this northeastern part of the Western High Atlas.

First of all, it has been demonstrated that the northernmost extremity of the NW-African Craton, which is incorporated in the Atlas Orogen, has known a long history of brittle deformation starting at the end of the Pan-African Orogeny.

The prominent structural features in this part of the Western High Atlas reflect on the one hand a Hercynian basin development north of a cratonic promontory and on the other hand a Mesozoic rift development on the Precambrian basement. This rift was inverted and uplifted during Alpine collision.

Moreover, it has been shown that during the Alpine collision the splay faults at the eastern termination of the High Atlas Fault acted differently. The Ourika Fault Zone only bears proof of significant sinistral strike-slip deformation. The Meltsene Fault Zone still shows significant sinistral fault activity besides an even more significant inverse faulting. Finally, the Oukaimeden Fault Zone primarily shows inverse fault movement. This partitioning of fault activity along splay faults fits into the model, suggested for the Western High Atlas by Froitzheim et al. (1986), of a sinistral, transpressive, positive flower structure.

Finally, no indications are found for dextral fault activity which could be correlated with the Late Paleozoic N150°E σ_1-direction (Figure 7; Mattauer et al. 1977). It is therefore fair to assume that the splay faults at the eastern termination of the High Atlas Fault were not involved in Late Paleozoic dextral shearing This shearing, however, is considered as the most prominent episode in the tectonic history of the Western High Atlas by several authors (e.g. Mattauer et al. 1972; Proust et al. 1977; Arthaud & Matte 1977).

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References

Angelier, J. & P. Mechler 1977 Sur une méthode graphique de recherche des contraintes principales également utilisable en tectonique et en seismologie. La méthode des dièdres droits – Bull. Soc. Géol. France (7) 19: 1309–1318

Arthaud, F. & P. Matte 1977 Late Paleozoic strike-slip faulting in southern Europe and northern Africa: Result of a right-lateral shear zone between the Appalachians and the Urals – Geol. Soc. Am. Bull. 88: 1305–1320

Binot, F., G. Dresen, J. Stets & P. Wurster 1986 Die Tizi-n'Test Verwerfungszone im Hohen Atlas (Marokko) – Geol. Rundschau 75: 647–664

Biron, P.E. 1982 Le Permo-Trias de la région de l'Ourika (Haut Atlas de Marrakech, Maroc): Lithostratigraphie, sédimentologie, tectonique et minéralisation. Thèse 3me cycle (unpublished), Université de Grenoble.

Brabers, P.M. 1988 A plate tectonic model for the Pan-African Orogeny in the Anti-Atlas, Morocco. In: Jacobshagen, V.H. (ed) The Atlas System of Morocco – Lecture Notes in Earth Sciences 15, Springer-Verlag, Berlin: 61–80

Choubert, G. 1963 Histoire géologique du Précambrien de l'Anti-Atlas – Notes & Mém. Serv. Géol. Maroc 162: 352 pp

Delvaux, D. 1993 The tensor program for paleostress reconstruction: examples from the East African and the Baikal rift zones – Abstract Supplement 1 to Terra Nova 5: 216

Dewey, J.F., W.C. Pitman, W.B.F. Ryan & J. Bonnin 1973 Plate tectonics and the evolution of the alpine system – Geol. Soc. Am. Bull. 84: 3137–3180

Dresen, G. 1985 Bruchtektonik und Schollenbau im Hohen Atlas südlich von Marrakech (Marokko) – Geol. Rundschau 74: 95–108

Froitzheim, N., J. Stets & P. Wurster 1988 Aspects of Western High Atlas tectonics. In: Jacobshagen, V.H. (ed) The Atlas System of Morocco – Lecture Notes in Earth Sciences 15, Springer-Verlag, Berlin: 219–244

Gasquet, D. 1992 Mise en évidence d'intrusions emboîtées dans le Massif du Tichka (Haut Atlas occidental, Maroc) – C.R. Acad. Sci. Paris 314: 931–936

Juery, A., J.R. Lacelot, J. Hamet, F. Proust & C.J. Allegre 1975 L'age des rhyolites du Précambrien III du Haut Atlas et le problème de la limite Précambrien-Cambrien. 2me Réunion ann. Sci. Terre, Nancy, 230 pp

Mattauer, M., F. Proust & P. Tapponnier 1972 Major Strike-slip Fault of Late Hercynian Age in Morocco – Nature 237: 160–162

Mattauer, M., P. Tapponnier & F. Proust 1977 Sur les mécanismes de formation des chaînes intracontinentales. L'exemple des chaînes atlasiques du Maroc – Bull. Soc. Géol. France (7) 19: 521–526

Nachit, H., P. Barbey, J. Pons & J.-P. Burg 1996 L'Eburnéen existe-t-il dans l'Anti-Atlas occidental marocain ? L'exemple du massif du Kerdous – C.R. Acad. Sci. Paris, série IIa 322: 677–683

Proust, F. 1973 Etude stratigraphique, pétrographique et structurale du Bloc oriental du Massif ancien du Haut Atlas (Maroc) – Notes & Mém. Serv. Géol. Maroc 34: 15–53

Proust, F., J.-P. Petit & P. Tapponnier 1977 L'accident du Tizi n'Test et le rôle des décrochements dans la tectonique du Haut Atlas occidental (Maroc) – Bull. Soc. Géol. France (7) 19: 541–551

Vogel, D.E., R. Misotten & F. Desutter 1980 Carte géologique du Maroc au 1/100 000. Feuille Oukaimeden-Toubkal. Notice explicative. KU Leuven, Belgium, 131 pp