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The Pan-African Trans-Saharan Belt in the Hoggar Shield (Algeria, Mali, Niger): A Review

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1 Introduction

The Pan-African belt of central northwest Africa is part of the Transaharan belt (Cahen et al. 1984) and has been interpreted by Black et al. (1979) and Caby et al. (1981) as a collision belt formed during a Wilson cycle. The Tilemsi suture zone separates the stable West African Craton (passive margin) from the mobile belt (active margin). Pan-African deformation and metamorphism affected the whole Hoggar shield from the Tilemsi region at least to the 8°30′E lineament and is recognized on a 1000-km-wide area (Fig. 1). Actually, the Transaharan belt appears as a complex assemblage of NS trending geological domains which have undergone different evolutions. Large areas are still poorly known and several interpretations have been proposed for some others. In this review paper, I will present the geological evolution of each domain and discuss these different interpretations. Correlations of these domains with the Togo-Benin belt and with the Nigerian shield have been proposed by several authors (Bessoles and Trompette 1980; Caby et al. 1981; Ajibade et al. 1987; Caby, in press).

Bertrand and Caby (1978) subdivided the Hoggar shield into three main structural domains, respectively from east to west: the eastern Hoggar, the central polycyclic Hoggar and the Pharusian belt. I will keep the main first-order domains but will disthinguish some additional subdivisions in the Pharusian belt in the light of the recent studies in the Adrar des Iforas: the eastern Pharusian belt, the western Pharusian belt, the central Iforas batholith, the Tilemsi island-arc domain and the Gourma-Timetrine foreland nappes.

For each domain I will present the lithology, the tectono-metamorphic evolution and the Pan-African magmatism.

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2 The Eastern Hoggar: The Tiririne-Aouzeguer Belt

2.1 *In Algeria*

2.1.1 The Djanet-Tafassasset Domain

The Tiririne Pan-African belt (Bertrand et al. 1978) is parallel to the 8°30′ meridian and separates the polycyclic Central Hoggar to the west from the Djanet-Tafassasset domain to the east. The latter is a segment of a pre-Pan-African fold belt trending NW-SE which was subdivided into three domains separated by vertical shear zones (Caby and Andreopoulos-Renaud 1987). The stratigraphic relationships between these three domains are unknown. The Tiririne Formation lies unconformably on the basement of the western domain which is composed mainly of granitoids, remnants of a shelf-type carbonate sequence, felsic lavas and related intrusives, and terrigeneous and volcanic-derived flysh-type deposits; ultramafic and mafic rocks have also been observed by the same authors. A syn- to late-tectonic batholith crosscutting the ultramafics has been dated at 729 ± 8 Ma by U/Pb on zircons (Caby and Andreopoulos-Renaud 1987).

2.1.2 The Tiririne Formation

The Tiririne Formation is exposed in variably complex synclines in which it reaches a thickness of up to 8000 m (Fig. 2; Blaise 1957, 1961; Bertrand et al. 1978). The base (Unit I) is characterized by clays and limestones. The overlying Unit II is almost entirely clastic with sequences of polymictic conglomerates (of possible glaciogenic origin), arkoses, greywackes and silts; some limestones occur towards the south. The detrital source seems to be exclusively located to the east. Unit III has a more regular lateral development of clastic sediments with more mature rock types including red beds on top.

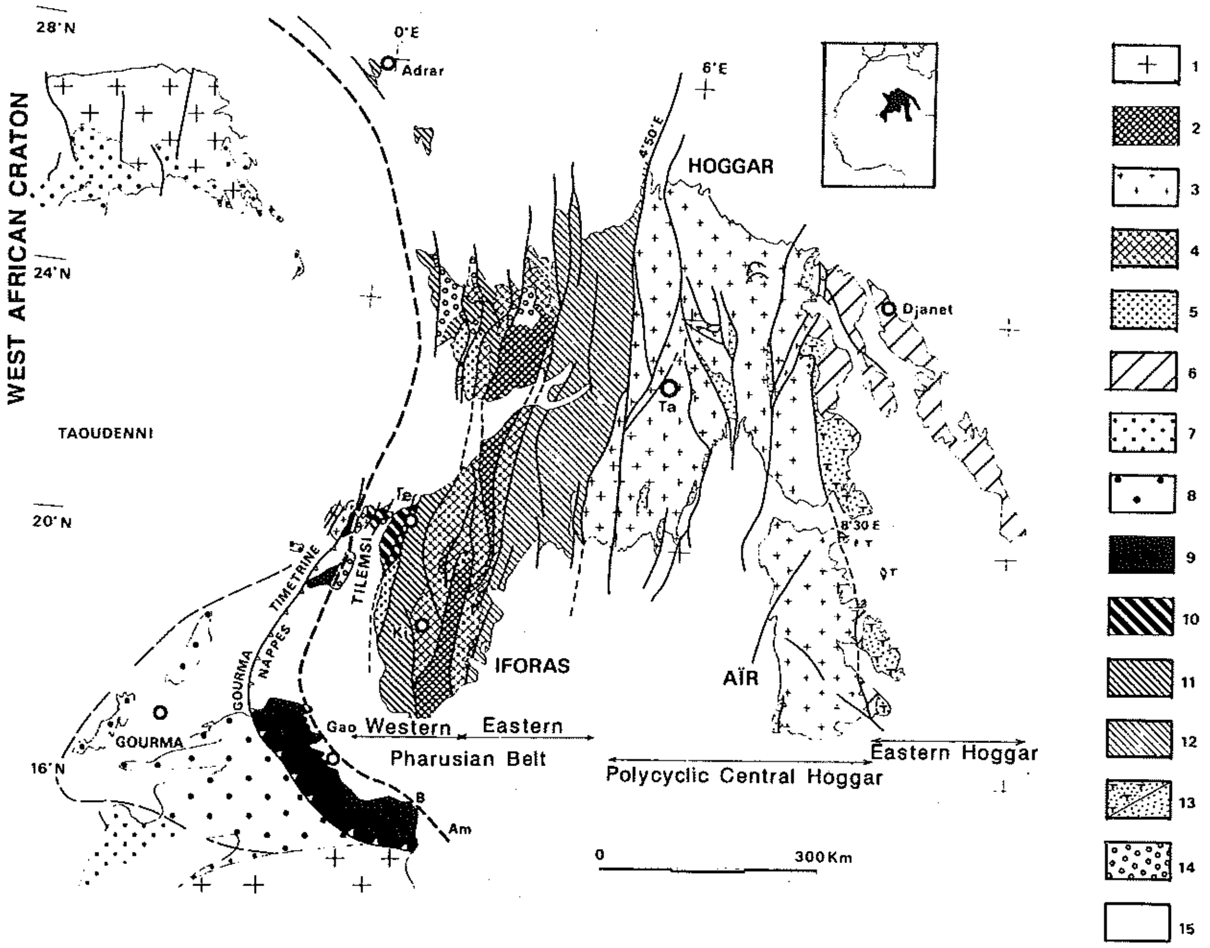

Fig. 1. Simplified geological map of the Touareg shield and adjacent areas (modified from Caby et al. 1981). *1* Reguibat and Leo shields; *2* slightly reactivated Eburnean granulites within the Pharusian belt; *3* reactivated pre-Pan-African gneisses; *4* undifferentiated gneisses highly reactivated during the Pan-African; *5* gneisses affected by late high-temperature - low-pressure metamorphism; *6* undifferentiated rocks of the eastern Hoggar (metamorphism at ca. 730 Ma); *7* Upper Proterozoic shelf sediments; *8* slope-basin sediments of the Gourma aulacogen; *9* Gourma and Timetrine nappes; *10-12* Late Upper Proterozoic greywackes and magmatic rocks of the Tilemsi island arc *(10)*, of the western Pharusian belt *(11)*, of the eastern Pharusian belt *(12)*; *13* Late Upper Proterozoic volcanodetritic schist belts in the central and eastern Hoggar with *T* Tiririne and *Proche Ténéré* Groups; *14* molassic *Série Pourprée* or Nigritian; *15* Palaeozoic and Mesozoic cover. *Ta* Tamanrasset, *Ki* Kidal, *Te* Tessalit

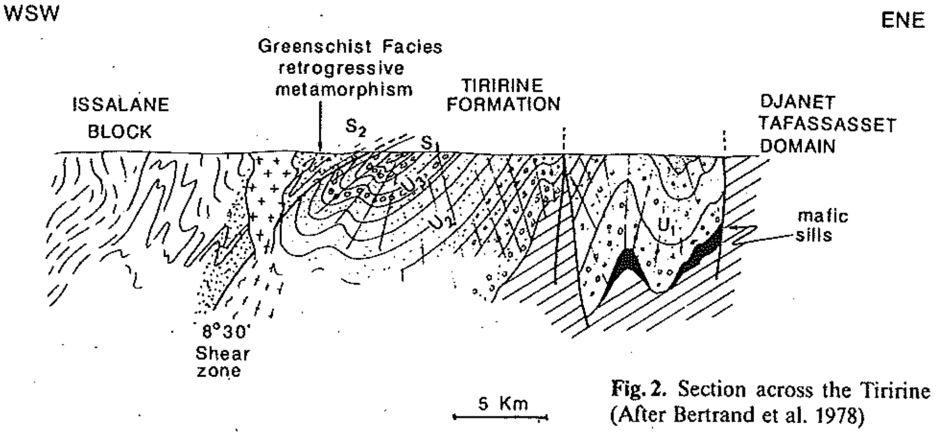

Fig. 2. Section across the Tiririne linear fold belt in Algeria (After Bertrand et al. 1978)

Some pretectonic igneous rocks have intruded the Tiririne Formation: olivine gabbros, layered sills of mafic biotite diorites, dykes of diabase and by dykes and sills of rhyolites to rhyodacites and of granodiorites which have been dated at 660±5 Ma by U/Pb on zircon (Bertrand et al. 1978).

2.1.3 The Tectono-Metamorphic Evolution of the Tiririne Belt

The structure of this linear fold belt is controlled by the 8°30′E dextral shear zone which grades progressively to the north into a thrust (Bertrand et al. 1978). Mylonites and ultramylonites outline the shear zone and exhibit a horizontal NS-trending stretching lineation. A metamorphic and strain gradient is described by the authors from south to north along the belt and from east to west in the Tiririne Formation across the belt:

Zone A: very low grade to lower greenschist facies with incipient E-W shortening to the south of 22°30′N.

Zone B: intense deformation under greenschist-facies conditions to the north of 22°30′N. In the western Issalane block, tight folds with westward dipping N-S striking axial planes deform an earlier pre-Pan-African foliation. In the Tiririne Formation along the shear zone, folds are tight to isoclinal with steep fold axes and vertical axial-plane cleavage. Strain decreases eastward.

Zone C: very high strain under middle to upper amphibolite-facies conditions reaching migmatization. In this zone a thrusting component of the Issalane block onto the highly deformed Tiririne Formation has been recognized. A synkinematic adamellite has been dated at 604±13 Ma and a late kinematic granitic pluton yielded 585±14 Ma by U/Pb on zircon (Bertrand et al. 1978).

2.2 In Niger (Aïr)

2.2.1 The Eastern Domain

In the Aouzeguer region (SE Aïr, Fig. 3), an eastern basement (Eberjeghi gneisses and granodiorite) is overlain by the molassic Proche Ténéré Formation which has been described by Raulais (1959), Black at al. (1967), Kehrer et al. (1975) and Cosson et al.

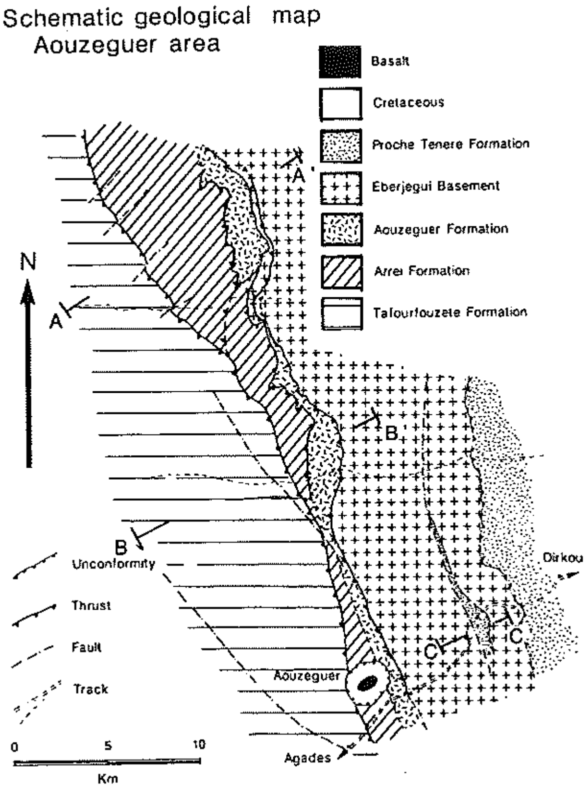

Fig. 3. Geological map of the Aouzeguer area modified after Kehrer et al. (1975). Cross-sections of Fig. 4 are located

(1987). This formation has been correlated with the Tiririne Formation with which it is in continuity across the border and similar in lithology: siltstones, sandstones, arkoses with conglomeratic intercalations, fan-conglomerates, breccias and calcitic greywackes with some siliceous tuffs.

2.2.2 The Western Domain

The western basement is composed of three main lithological and structural units which are separated by westward dipping thrusts (Cosson et al. 1987). These units are, from west to east and from top to bottom (Fig. 4):

1. The Tafourfouzète Unit, mainly composed of granitic gneisses with amphibolitic layers and of a platform sedimentary sequence (quartzites, aluminous schists and marbles). No basement-cover relationship has been observed between the sediments and the gneisses.
2. The Arrei Unit, made up of quartzofeldspathic, arenitic and volcanoclastic sediments with tholei-

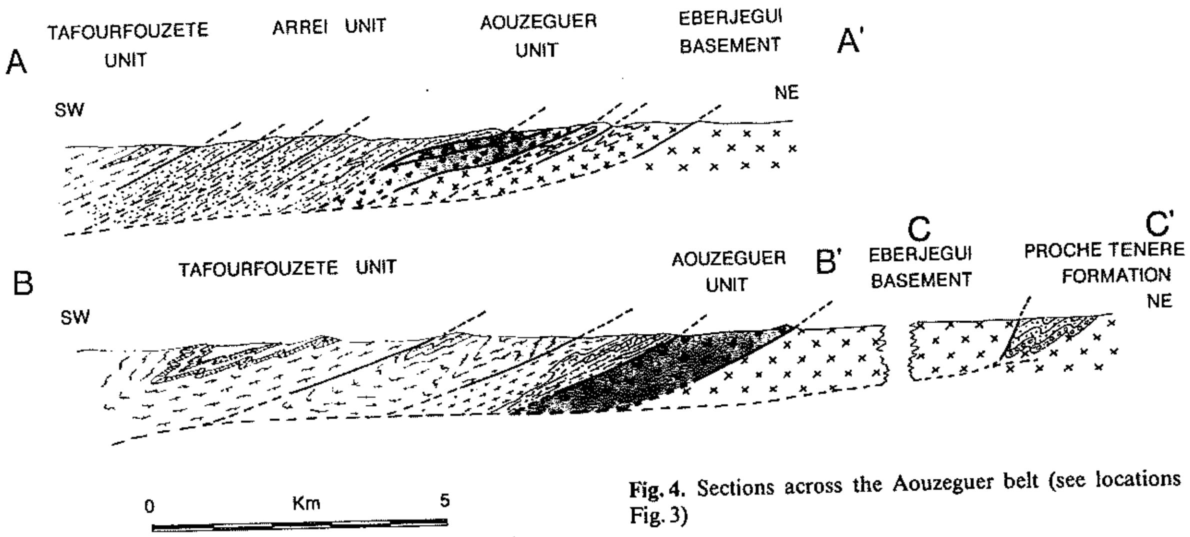

Fig. 4. Sections across the Aouzeguer belt (see locations in Fig. 3)

itic basaltic sills. Granitic bodies were emplaced into the sediments before the deformation.

3. The Aouzeguer Unit, composed of serpentinized ultramafics and gabbroic cumulates, diorites and granophyres. Some rodingites have been observed and suggest an oceanic metamorphism.

2.2.3 Tectono-Metamorphic Evolution

The three western units were thrust onto the Eberjeghi basement and the Proche Ténéré Formation is involved in this deformation. The metamorphic grade decreases across the tectonic pile from top (amphibolite facies) to bottom (greenschist facies) with breaks along the thrust planes. All the structural units show a westward-dipping foliation or schistosity with a well-expressed stretching lineation: elongated pebbles, fibres in extension veins, quartz and feldspar ribbons. This stretching lineation trends N100° to N80° in the uppermost Tafourfouzète Unit, N60° to N40° in the intermediate Arrei Unit and N40° to N20° in the lowermost Aouzeguer mafic and ultramafic schists Unit, and in the foliated Proche Ténéré molasse and Eberjeghi basement (Cosson et al. 1987).

This change in the stretching lineation direction could be interpreted either as a rotation in time or as due to contemporaneous combined wrenching and thrusting during shortening (Burg et al. 1987). In the latter case, the wrenching component would be compatible with the dextral sense of shear along the Tiririne belt (Bertrand et al. 1978).

2.3 Comparison and Discussion

Does the Aouzeguer-Tiririne belt correspond to a Pan-African suture zone? To the north, Bertrand et al. (1978) have shown that the Tiririne belt separates two different continental basements: the eastern Djanet-Tafassasset basement and the western Issalane basement, the latter being compared to the Central Hoggar. However, the Aouzeguer mountains are the only known occurrence of ultramafics along the belt. Pre-730 Ma ultramafic bodies have been described by Caby and Andreopoulos-Renaud (1987) in the Tiririne basement. Moreover, Kehrer et al. (1975) describe pebbles of ultramafic schists in the Proche Ténéré conglomerates. Consequently, the Aouzeguer Formation could represent earlier oceanic rocks that may represent a pre-730 Ma suture subsequently reworked during a Pan-African (s. s.) shortening event involving the Tiririne and Proche Ténéré, Upper Proterozoic, molassic Formations.

3 The Polycyclic Central Hoggar

3.1 The Main Lithological Associations

Independent of any stratigraphic interpretation, three main lithological associations may be defined in Central Hoggar (Fig. 5): (1) quartzo-feldspathic gneisses and granites, (2) banded high-grade metasediments including quartzites, marbles and metapelites, and (3) low-grade metavolcanics and greywackes.

The two former associations represent the Suggarian and the latter the Pharusian, as defined by Kilian (1932) and Lelubre (1952). Among the high-grade metasediments two groups were formerly distinguished: (1) those intimately associated with quartzo-feldspathic gneisses, the Arechchoum Series and (2) the Aleksod Series which lies in structural unconformity upon group 1. The two groups are very similar in lithology but a set of mafic dykes was emplaced in the older group prior to the main deformation (Bertrand 1974). In places, statigraphic unconformities are preserved, for example in the Gour Oumelalen area (Latouche 1978) and in the Tazat area (Blaise 1967; Bertrand et al. 1968), but tectonic contacts are more usual. From the distinction of these two groups of metasediments, together with a non-critical acceptance of a classical Pharusian unconformity below the low-grade schists (which was considered as giving a lower limit for the Upper Proterozoic), the existence of a Kibaran event at about 1000 Ma was previously proposed in Central Hoggar (Bertrand 1974). Some geochronological data seemed at that time to support this assumption (Bertrand and Lasserre 1976). In fact, recent structural and geochronological investigations do not confirm the existence of a Kibaran event in Central Hoggar (Bertrand et al. 1986a; Barbey et al. 1989).

On the basis of geochronological data (Picciotto et al. 1965; Latouche and Vidal 1974; Bertrand and Lasserre 1976; Bertrand et al. 1978, 1984b, 1986a; Vialette and Vitel 1981), the Eburnean event dated at about 2000 Ma is seen in quartzo-feldspathic gneisses including orthogneisses and charnockites and from the older metasediments, whereas the Pan-African event corresponds to nappe tectonics and granitoid emplacement ca. 600 Ma ago. No age older than Eburnean is well constrained in Central Hoggar but Rb/Sr whole-rock results (Bertrand and Lasserre 1976) and a Pb/Pb whole-rock isochron (3480±90 Ma) quoted by Latouche (1978) suggest that Archean crust is involved.

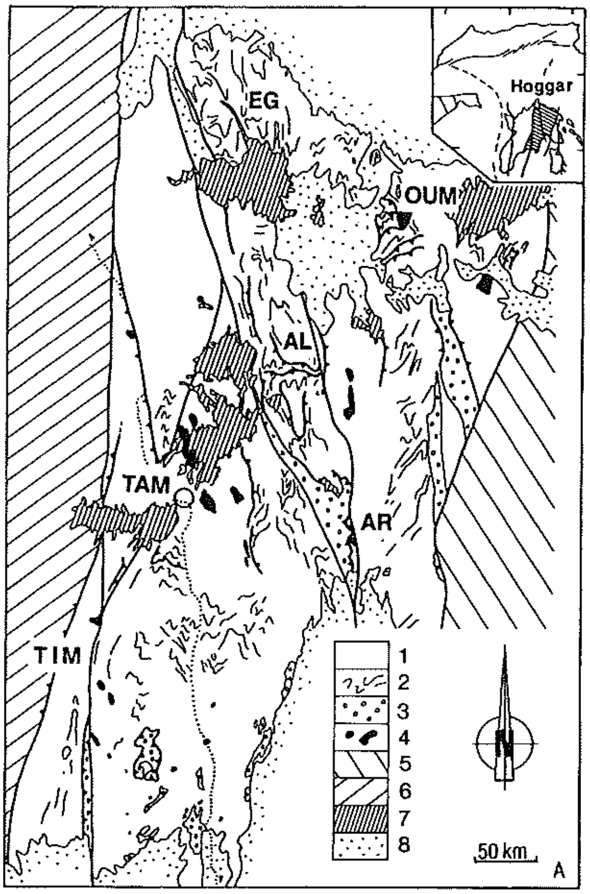

Fig. 5. Polycyclic Central Hoggar (modified after Bertrand et al. 1986a). *1* Granites and quartzofeldspathic gneisses; *2* high-grade metasedimentary rocks (*1* + *2* Suggarian); *3* low-grade schists (Pharusian); *4* Taourirt granites; *5* Issalane domain; *6* eastern Pharusian belt; *7* and *8* Phanerozoic lavas and sediments. Localities on map are Aleksod *(AL)*, Arefsa *(AR)*, Egere *(EG)*, Oumelalen *(OUM)*, Tamanrasset *(TAM)* and Timgaouine *(TIM)*

3.2 *The Main Pan-African Tectono-Metamorphic Evolution*

The metamorphic evolution of Central Hoggar reflects the dual influences of the Eburnean basement and of the Pan-African imprint (Latouche 1978; Vitel 1979; Ouzegane 1981). Detailed structural, metamorphic and geochronological work of a case study area situated to the SW of Tamanrasset (Boullier et Bertrand 1981; Ouzegane 1981; Bertrand et al. 1986a) has shown that the tectono-thermal history of the Central Hoggar may be interpreted as resulting from Pan-African thrust tectonics and crustal thickening. This area is characterized by a strong contrast between two completely different tectonic units separated by a mylonite belt gently dipping toward the NE (Fig. 6). The tectonic units are as follows:

Lower Tectonic Unit: the Iherane Gneisses and Migmatites. This comprises granulite-facies metasediments which are invaded by migmatites and nebulitic granites. Two successive metamorphic assemblages were defined by Ouzegane (1981) and correspond respectively to more than 8 kbar and 800 °C

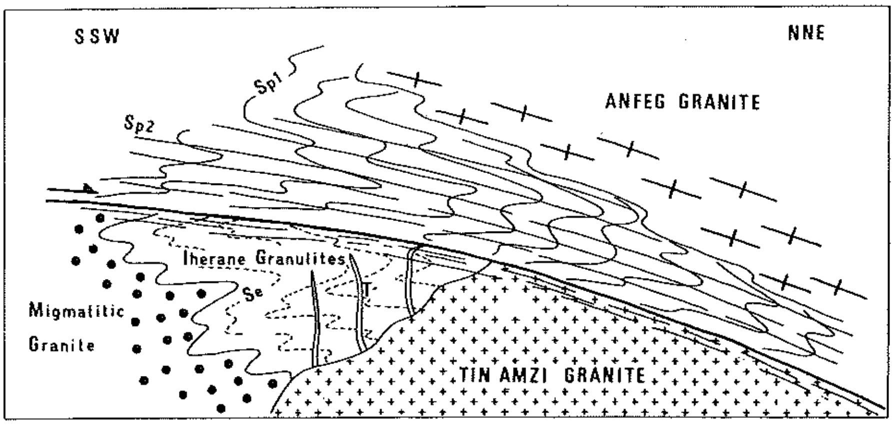

Fig. 6. Tectonic evolution in the Tin Amzi area (after Bertrand et al. 1986a). *Se* is the Eburnean foliation in the granulites; *Sp1* is the main Pan-African refoliation in the gneisses; and *Sp2* is the superimposed lower-grade foliation.

(M1) and to 5 ± 1.5 kbar and 600 ± 50 °C (M2). M2 associated migmatitic granites are related to or slightly postdate large-scale EW recumbent isoclinal folds. These folds are in turn refolded by NE-trending open folds. A third retrogressive assemblage is observed within the mylonite belt. The Iherane gneisses and migmatites are crosscut by the Tin Amzi high-level plutonic complex (granitic to granodioritic) which is itself deformed under relatively low-temperature conditions in the mylonite belt.

The Upper Tectonic Unit. In this unit, gneisses have a gently northeastward dipping foliation Sp1 and show a conspicuous NE stretching lineation. This foliation corresponds to upper amphibolite-facies conditions and to a complete tectonic and metamorphic reworking of ancient gneisses similar to the Iherane granulitic gneisses (lower unit). This Sp1 foliation is deformed by tight overturned folds with NW-trending axes, developing locally a new axial planar cleavage Sp2 at low angle to the first foliation (less than 30° toward the northeast). The Anfeg and Amsel plutons crosscut Sp1, but Sp2 affects their outer zone. They are considered as broadly syntectonic and emplaced under amphibolite-facies conditions.

The Mylonitic Belt. This separates the two tectonic units described above and is 50 to 100 m thick. The mylonitic surface is parallel to Sp2 and reflects epidote-amphibolite facies conditions, it bears a N30° stretching lineation and shows shear sense criteria which indicate a NNE sense of movement for the upper unit. The overall parallelism between Sp1, Sp2 and the mylonitic foliation suggests a continuum between these deformation phases: they are interpreted as the result of progressive tangential deformation occurring while metamorphic conditions were waning (Bertrand et al. 1986a).

U/Pb studies on zircon on both lower and upper unit rocks (Bertrand et al. 1986a) have shown that: (1) the granulitic M2 metamorphism and the associated migmatites are 2075 ± 30 Ma old; (2) the emplacement age of the Tin Amzi plutonic complex in the lower unit is not known precisely ($612 + 50/-20$ Ma), but sphenes indicate cooling ages of 578 ± 6 Ma, and (3) the emplacement of the Anfeg pluton in the upper unit took place at 615 ± 5 Ma.

These results confirm the existence of important Pan-African thrust tectonics in Central Hoggar (Boullier and Bertrand 1981; Bertrand et al. 1986a) which partly reworked the continental Eburnean crust 615 Ma ago. Similar thrust tectonics have also been described in other places in Central Hoggar (see Bertrand et al. 1986a for a review) and in the Timgaouine area (Lapique et al. 1986), where horizontal foliation and associated stretching lineation are well expressed in the Aouilene orthogneisses (Fig. 7) and dated between 629 Ma (zircons) and 614 Ma (sphenes; Bertrand et al. 1986b). Farther west, thrusting grades to wrenching along the Tin Di-Tin Eifei lineament, which may be considered as a major decoupling zone outlining the true limit of the so-called Central Polycyclic Hoggar (Lapique et al. 1986).

In Aleksod, occurrence of eclogites in one of the major mylonitic zones stresses the importance of these thrusts. Sautter (1985), from a petrological study, indicated that the eclogites suffered high-pressure hydrous eclogite-facies conditions at 750 °C and more than 15 kbar, and subsequently

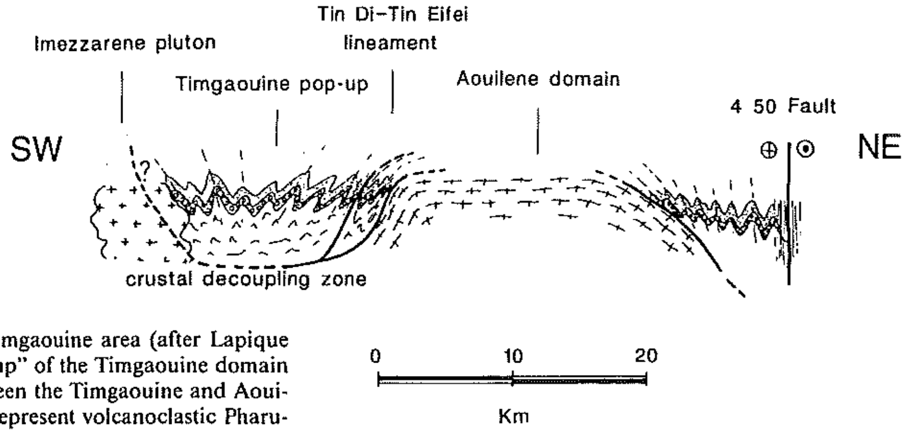

Fig. 7. Interpretation of the Timgaouine area (after Lapique et al. 1986) showing the "pop-up" of the Timgaouine domain and the decoupling zone between the Timgaouine and Aouilène domains. The sediments represent volcanoclastic Pharusian II Group

have been retrogressed with the host rocks (metasediments, orthogneisses) under upper amphibolite-facies conditions.

As can be seen in the Timgaouine area and in the Arefsa, the Pan-African thrust tectonics involved not only the Eburnean basement and high grade metasediments, but also the so-called Pharusian sediments of Upper Proterozoic age (Pharusian II in Timgaouine, Lapique et al. 1986; volcanoclastics of the Arefsa in the classical definition area of Pharusian, unpublished observations by Briedj and Bertrand).

3.3 *Late Pan-African Tectonic Evolution*

After the tangential tectonics, shield-scale strike-slip ductile shear zones and brittle faults were pruduced, which were long considered the main tectonic manifestation of the Pan-African event in Central Hoggar (Bertrand and Caby 1978; Vitel 1975). These vertical shear zones did not operate at the same time; some of them were related to the thrust tectonics, such as the Tin Di-Tin Eifei lineament (Lapique et al. 1986), while others clearly postdate this event, such as the 4° 50′ dextral fault. The Taourirt granites (Boissonnas 1973), which are post-tectonic relative to the thrusting event, crosscut some of these shear zones (In Amguel) but are also deformed by some others (4° 50′). There seems to be an overall control of the Taourirt granites by the latest wrench faults.

3.4 *Pan-African Magmatism*

The Pan-African granitic plutonism of Central Hoggar has been studied recently (Bouabsa 1987; Moulahoum 1988; Bertrand et al. 1987). Syntectonic plutons (Anfeg, Tefferkit) show subalkaline (or monzonitic calc-alkaline) affinities with variable mantle contamination (Anfeg: 615 Ma, Sri = 0.705). The post tectonic "Taourirt" granites are high-level intrusive plutons with subvolcanic apical differentiations; they are peraluminous in character suggesting a crustal origin (In Tounine granite: 521 Ma, Sri = 0.723, Moulahoum 1988). The Sn-W mineralizations are related to a younger magmatic group of unknown age: the albite-topaz-bearing fine-grained granites and porphyry dykes which crosscut the Taourirt granites. Earliest magmas have been interpreted as formed at the crust-mantle interface during the thrusting event. The peraluminous "Taourirt" magmatism is controlled by local extensional structures induced by the wrench fault network.

4 The Eastern Pharusian Belt

In the eastern branch of the Pharusian belt, large areas remain unknown, especially in the N, NE and SW, on both sides of the traverse mapped by Gravelle (1969) between 22° N and 23° N.

In the Silet area (Fig. 8) studied by Gravelle (1969), two distinct tectono-metamorphic cycles were defined, Pharusian I and Pharusian II, separated by a major unconformity (Bertrand et al. 1966).

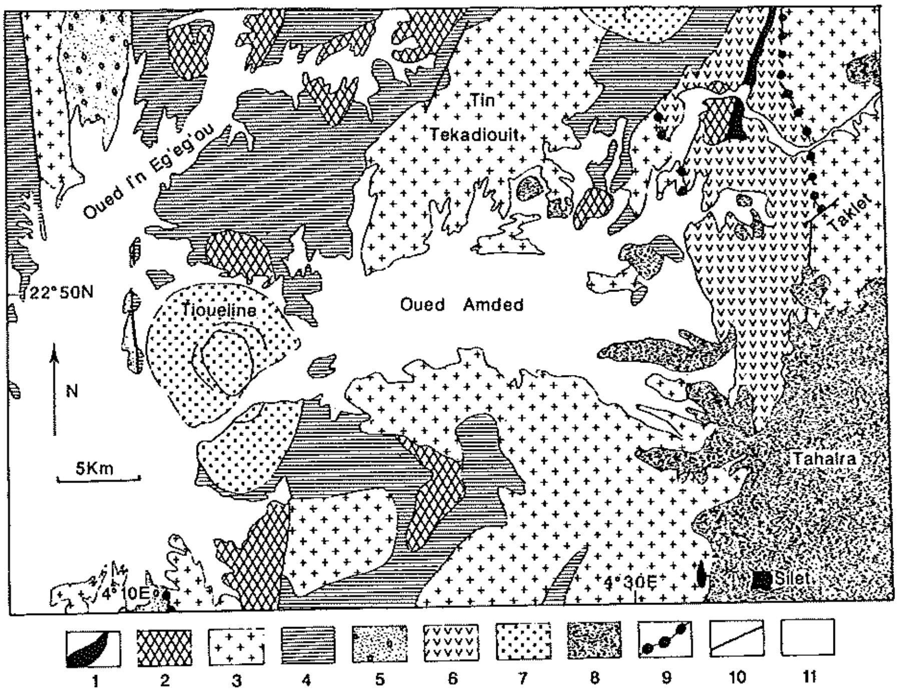

Fig. 8. The Silet area (after Gravelle 1969). *1* Serpentinized ultramafics; *2* metamorphic gabbros and diorites; *3* calc-alkaline Pharusian I granitoids; *4* volcanic and volcanoclastic Pharusian I Group; *5* gresopelitic Pharusian II Group; *6* Irrelouchem Pharusian II volcanics; *7* post-tectonic Taourirt granites; *8* Phanerozoic basalts; *9* unconformity; *10* fault; *11* alluvial sands

4.1 Pharusian I

The oldest cycle began with the deposition of a carbonate platform formation (Timesselarsine Series) on a presumed Eburnean basement: the unconformity occurs near Timgaouine where Conophyton stromatolites are well preserved (Gravelle and Lelubre 1957). Some pillow or massive basalts with transitional to weakly alkaline affinities indicate a continental-rift environment (Dupont et al. 1987; Dupont 1987).

Lenses of ultramafic to mafic material are also present in the Timesselarsine Séries (Gravelle 1969). A preliminary geochemical and petrographical study precludes an oceanic tholeiitic affinity as proposed by Abed (1983), but suggests an island-arc or marginal-basin environment (Dupont 1987).

The major magmatic event occurring during the Pharusian I cycle is represented by early calc-alkaline quartz diorites and tonalites and by the post-tectonic emplacement of the Taklet batholith: granodiorites, diorites, calc-alkaline granites described by Gravelle (1969), Fabriès and Gravelle (1977), Dupont (1987) and Dupont et al. (1987). Caby et al. (1982) have obtained ages of $868 \pm 8 - 5$ Ma for the older group and 839 ± 4 Ma for the Taklet batholith (U/Pb on zircons). The Timesselarsine Series was deformed by isoclinal recumbent folds under greenschist to amphibolite-facies metamorphic conditions (Lapique et al. 1986; Boullier 1982) prior to the emplacement of the older calc-alkaline magmatism ($868 + 8 - 5$ Ma). Thus the Pharusian I cycle has been interpreted by Dupont (1987) as a rifting event followed by a subduction.

4.2. Pharusian II

The Pharusian II cycle began with the deposition of the Amded Series which contains detrital elements from the Pharusian I Formation described above. The upper part of the Amded Series is intruded by dolerites, basalt and rare tholeiitic andesites in an island-arc site (Dupont et al. 1987; Dupont 1987; Lapierre et al. 1987). The calc-alkaline Irrelouchem Volcanic Series overlies the Amded Series and has been dated at 680 ± 36 Ma (Liégeois, in Dupont 1987) by Rb/Sr isochron (Sri = 0.7031).

Finally, granodiorites and rare granites were emplaced which display calc-alkaline geochemical characteristics similar to those of the Irrelouchem Series, suggesting an active margin site.

All the Pharusian II magmatic episodes have island-arc (Dupont 1987) or active continental margin (Chikhaoui 1981) characteristics. They predate the D2 Pan-African (s. s.) event which is expressed by vertical schistosity, open folds and, in the Timgaouine area, by wrenching grading to thrusting (Fig. 7, Lapique et al. 1986) which occurred between 629 and 614 Ma (Bertrand et al. 1986b), (Sect. 4.3 and Fig. 7 in this volume).

The Immezarene pluton is late tectonic relative to D2; it is a porphyritic granite which has been dated at 583 ± 7 Ma (Bertrand et al. 1986b).

5 The Western Pharusian Belt

The two branches of the Pharusian belt are very different in lithology and are separated by the Adrar Fault. If the eastern branch is not well known near the Adrar Fault, more data are available on the western branch, especially in its southern part (Central Iforas), where extensive work has been done since 1976.

5.1 *The 3.5–2 Ga Old Basements*

5.1.1 The Granulitic Units

Two major granulitic units (In Ouzzal and Iforas granulitic units) and two smaller units (Adrar Bezzeg and Tin Essako, in Mali, Fig. 9) are involved in the Pharusian belt. Another may exist north of Adrar Bezzeg in Algeria (Kiniakine, pers. commun.). They form narrow, several hundred km-long NS-trending domains with mylonitic margins. Although the two units show some slight differences in the rock-type ratio, metamorphic grade and intensity of Pan-African reworking, they present similar Archaean and Eburnean evolutions.

Both units comprise granitic gneisses, charnockitic intrusives, ultramafics and mafics and metasediments (aluminous, Al-Mg, quartzofeldspathic gneisses, magnetite bearing quartzites and marbles). Norites are often intrusive into the metasediments. Granitic gneisses and charnockitic intrusives often have subalkaline (or monzonitic calc-alkaline) affinities. The Archaean age of the material is indicated by Rb/Sr data (Ferrara and Gravelle 1966) and by U/Pb data on zircon (upper intercepts, Lancelot et al. 1976). However, the lower U/Pb intercept (zircon data, same authors) shows that the age of the granulitic metamorphism is Eburnean (~2.1 Ga).

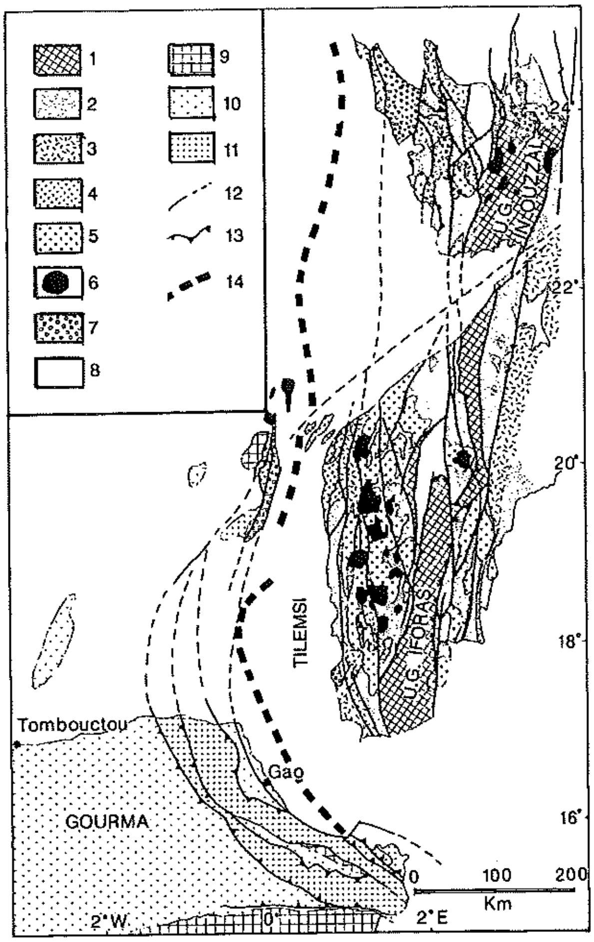

Fig. 9. Simplified geological map of the western Pharusian belt, the central Iforas batholith, the Tilemsi magmatic island arc and the foreland nappes (after Boullier 1982, and Fabre et al. 1982). *1* 2 Ga granulitic units (*U. G. Iforas* and *U. G. In Ouzzal); 2* 2 Ga basement and Middle to Upper Proterozoic sediments reworked during Pan-African tectonics; *3* volcanoclastic Late Upper Proterozoic sediments; *4* Tilemsi Island-Arc Group; *5* Pan African granitoids (mainly in the central Iforas batholith); *6* post-tectonic alkaline granitoids and rhyolites (east of the suture zone); undersaturated Permian alkaline ring-complexes (west of the suture zone); *7 Série Pourprée* and Nigritian molasses; *8* Phanerozoic cover; *9* 2 Ga basement of the West African craton; *10* passive margin sediments; *11 (10)* involved in Gourma and Timetrine nappes; *12* fault; *13* thrust; *14* suture zone as defined by gravity anomalies (Bayer and Lesquer 1978)

Just after the granulitic metamorphic event, several episodes of Eburnean magmatic activity can be distinguished: (1) intrusion of syenites, (2) intrusion of an early generation of carbonatites and (3) intrusion of late carbonatites. These late carbonatites show uncommon mineralogy and high REE concentrations (Ouzegane et al. 1988). The carbonatitic events have been dated at

1994+22/−17 Ma by U/Pb on zircon (Bernard-Griffiths et al. 1988).

The granulitic metamorphism of the In Ouzzal Unit has been described by Ouzegane (1987) and Kienast and Ouzegane (1987), especially on the basis of the mineralogy of Al-Mg sapphirine-bearing granulites. They defined two stages of granulitic metamorphism: an early high-pressure granulitic metamorphism (10 ± 1.5 kb, 800-900 °C) which they supposed to be Archaean in age, and a later low-pressure stage attributed to the Eburnean (5 ± 1.5 kb, 700-800 °C).

In the Iforas Unit, from structural and petrographical evidence, Boullier (1982) and Boullier and Barbey (1988) assumed that both stages of granulite metamorphism are Eburnean in age and reflect a classical (P, T, t) history related to thickening and subsequent uplift of the crust during the Eburnean event. Such an uplift is supported by the existence of unconformable Proterozoic sediments lying on both the In Ouzzal and Iforas granulitic units.

5.1.2 The Non-Granulitic Basements

In NW Hoggar the Tassendjanet basement is composed of 2090 Ma granites crosscutting a metasedimentary formation (quartzites and marbles) of probable Early Proterozoic age (Caby 1970; Allegre and Caby 1972). Another basement inlier is exposed at the border between Algeria and Mali (Tisangenine inlier, Caby 1973) and presents many similarities to the Tassendjanet basement.

5.2 The Middle to Upper Proterozoic Formations

Post-Eburnean sedimentary of volcanoclastic formations are known in the NW Hoggar and Iforas regions.

5.2.1 Middle Proterozoic Quartzites

In NW Hoggar where these formations were deformed and metamorphosed during Pan-African events, their age has been determined by dating intrusive rhyolitic sills at 1755 ± 10 Ma (Caby and Andreopoulos-Renaud 1983). An unmetamorphosed and well-preserved equivalent is known in the Ahnet mountains north of the In Ouzzal Granulitic Unit (Moussine-Pouchkine et al. 1988).

In the Iforas region, Middle Proterozoic quartzitic formations are abundant in the Tin Essako area, where many alkaline rhyolitic sills or lavas occur as in NW Hoggar. Their basement is not known but is suspected to be similar to the Eburnean granulitic units (Davison 1980; Boullier 1982).

5.2.2 Upper Proterozoic Platform Sequence

In the Tassendjanet area, the non-granulitic basement is unconformably overlain by a platform sequence, the so-called Stromatolite Series (Caby 1970; Moussine-Pouchkine et al. 1988). It is composed of quartzites with a basal microconglomerate, black and purple pelites, marbles and dolomites with Conophyton. The same formation overlies the Adrar Bezzeg granulitic unit in the Ourdjan hills in the Iforas region (Fabre et al. 1982). This formation has been correlated with the platform cover of the West African Craton in the Taoudeni Basin (Atar Group, Bertrand-Sarfati 1972). In the Tassendjanet area, pretectonic mafic sills emplaced in the Stromatolites Series have been dated at 793 ± 32 Ma (Clauer 1976).

5.2.3 Upper Proterozoic Volcanoclastic Formations

Volcanoclastic formations are well known in NW Hoggar where they are called *Série Verte* (Green Series) by Caby (1970). An undeformed and unmetamorphosed equivalent of the *Série Verte* outcrops in the northern part of the In Ouzzal unit but the unconformity has never been observed. It is mainly composed of unmetamorphosed andesitic lava flows (Chikhaoui et al. 1978; Chikhaoui 1981). Porphyritic andesitic dykes which crosscut the granulites may be related to this volcanic episode. The Stromatolite Series and the *Série Verte* are generally separated by tectonic contacts.

The volcanoclastic formations are rarely well dated except for the Tafeliant Group in the Iforas region: it unconformably overlies a 696-Ma quartz diorite (Caby and Andreopoulos-Renaud 1985) and is intruded by 634-Ma rhyolitic dykes (Liégeois 1987). In the northern Iforas region, the Oumassene volcanoclastics are also of assumed Upper Proterozoic age and are composed of andesitic lavas, breccias and rare sediments (tuffs, conglomerates and arkoses, Chikhaoui 1981). Many other volcanoclastic formations of the Iforas region also show similarities to the Tafeliant Group or the Oumassene formation (see for example the Ibedouyen volcaniclastics, Boullier 1982). Correlations with the Pharusian I and Pharusian II groups in the eastern Pharusian belt are impossible, because of the difficulty of comparing terranes on both sides of the Adrar Fault and the lack of geochronological data.

5.3 The Kidal Gneissic Assemblage

The Pan-African evolution of the Iforas granulitic unit and of the whole central Iforas in the western Pharusian belt cannot be dissociated from the evolution of the Kidal Assemblage, which has been defined by Boullier et al. (1978) as "resulting from the common high-grade tectono-metamorphic evolution during the major deformation phase of a granulitic basement, metasediments and pre- to syn-tectonic intrusives".

The basement is probably made of Eburnean granulites identical to the main In Ouzzal and Iforas granulitic units and to the smaller Adrar Bezzeg granulitic unit (see Fig. 11 for location), as the same rock types have been observed (spinel clinopyroxenites, norites, magnetite-bearing quartzites, etc.; Boullier 1982).

North and east of the Iforas Granulitic Unit, part of the metasediments is attributed to the Middle Proterozoic; thick aluminous quartzites are associated with alkaline metavolcanic or meta-igneous gneisses dated at 1837 ± 179 Ma (Caby and Andreopoulos-Renaud 1983).

West of the Iforas Unit, platform-type metasediments from the Kidal Assemblage (quartzites, schists and marbles) are overlain by basaltic flows with tholeiitic affinities (Leterrier and Bertrand 1986). Such metasediments are assumed to represent a Upper Proterozoic shelf-type formation similar to the Stromatolite Series.

Pretectonic intrusives range from ultrabasites to gabbros and anorthosites. They show the same chemical affinity as the basaltic flows cited above and have been attributed to a back-arc spreading center (Leterrier and Bertrand 1986). The large (60% of the volume of the Kidal Assemblage) pretectonic metadiorite-metatonalite plutons suggest a significant change in the geotectonic environment; a continental setting related to a subsidiary back-arc spreading developed during a subduction stage is the most likely interpretation (Leterrier and Bertrand 1986).

5.4 The Pan-African Tectono-Metamorphic Evolution

In Central Iforas, three successive ductile deformation phases (D1, D2, D3) have been defined by Boullier (1979, 1982) and a fourth brittle phase (D4) has been described by Ball (1980). Correlations between the D2, D3 and D4 phases and the main magmatic episodes of the Iforas Batholith have been discussed by Boullier et al. (1986) and Liégeois et al. (1987) (see Sect. 6.3 in this volume).

Figure 10 gives a schematic interpretation of the central Adrar des Iforas and its tectonic pile comprising three main structural units: from bottom to top, the Kidal gneissic assemblage, the Iforas granulitic Unit and the allochthonous metasediments.

The main deformation phase in Central Iforas is D1, which can be subdivided into two subsidiary phases interpreted as a continuum (Boullier 1982; Champenois et al. 1987). D1 corresponds also to a continuous metamorphic evolution (10 ± 1 kbar and 700 °C ± 50 °C, to 7–8 kbar and 650–750 °C); migmatization took place in the latest stage. The S1 foliation, where not affected by the later deformation events, is flat-lying and bears a roughly N-S trending stretching lineation. The S1 foliation in the Kidal Assemblage and the mylonitic foliation of the northern and eastern borders of the Iforas granulitic Unit and of the southern tail of the In Ouzzal Unit, are parallel. The Kidal Assemblage lies structurally below the Eburnean granulites (Fig. 10). Assumed Upper Proterozoic platform sediments (equivalent to the Stromatolites Series) have also been involved in the D1 thrust tectonics and form an uppermost nappe above the Iforas granulites (Ibedouyen, Boullier et al. 1978; Boullier 1982). This D1 event has been interpreted as resulting from the thrusting of the granulites onto the Kidal Assemblage in a roughly northward direction (Boullier et al. 1978; Wright 1979; Davison 1980; Boullier 1982; Champenois et al. 1987). Caby (1987a) favoured an alternative interpretation, contending that the Eburnean granulites are rooted in and outlined by vertical strike-slip lithospheric shear-zones. Two ages have also been suggested for the D1 tectonics considering the relationship between the D1 and D2 structures relative to a 696 Ma old intrusive in the southermost part of the central Iforas; D1 is considered to be younger than 696 Ma by Ball and Caby (1984) and Caby and Andreopoulos-Renaud (1985) and older than 696 Ma by Boullier et al. (1978).

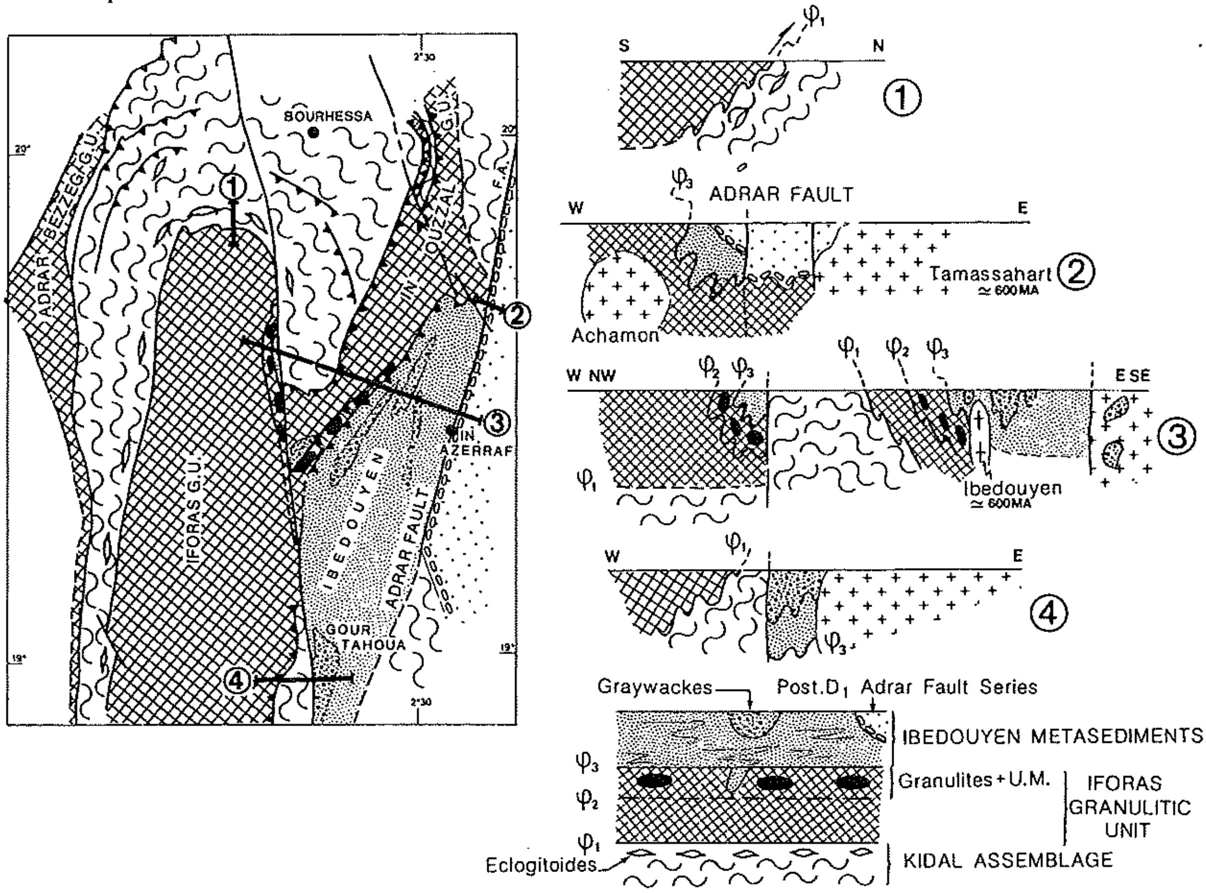

Fig. 10. Interpretation of the Central Iforas domain. The superposition of the different structural units is schematized in the lower right section

The D2 phase refolds the S1 foliation and thrust planes and corresponds to a NS-SE to E-W shortening, which is expressed by upright to overturned folds and by some sinistral NS to NNE-SSW wrenching movements (Boullier 1982). In the Ibedouyen hills (Fig. 10), a volcanoclastic formation is also involved in the D2 deformation and may be correlated to the Tafeliant Group described by Ball and Caby (1984). The age of the D2 phase is constrained between 620 Ma and 590 Ma (Ball and Caby 1984; Bertrand et al. 1984a; Liégeois and Black 1984; Liégeois et al. 1987; Caby et al. 1985; Caby and Andreopoulos-Renaud 1989). Metamorphic conditions were lower in the Kidal assemblage during D2 but still in amphibolite facies.

The D3 phase is characterized by NS to N 20° dextral shear zones, one of which bounds the Iforas granulitic Unit on the west (Abeibara-Rahrous shear zone) and was active between 566 and 535 Ma (Lancelot et al. 1983). A 7 km offset of the Abeibara-Rahrous shear zone has been estimated by Boullier (1986). The D3 phase corresponds to NE-SW compression.

The Iforas granulitic Unit has recorded the whole Pan-African evolution: deformation, metamorphism and magmatism (Boullier 1979, 1982; Bertrand et al. 1984a; Boullier and Barbey 1988). The deformation is expressed within the Iforas Granulitic Unit by curved shear zones, mainly attributed to D2, which controlled gabbroic to granitic intrusives. Prograde metamorphism superimposed on Eburnean resorption coronitic reactions indicates that the granulites suffered P, T conditions as high as 620±50 °C and 5±1 kbar; Boullier and Barbey (1988) integrated this metamorphic evolution in the Pan-African structural thrusting scheme proposed by previous authors (Boullier et al. 1978; Wright 1979; Davison 1980; Boullier 1982; Champenois et al. 1987).

5.5 *The Molassic Formations*

Molassic sediments were named Nigritian by Karpoff (1960) in the Adrar des Iforas region and are equivalent to the *Série Pourprée* (Purple Series) of NW Hoggar (Caby and Moussu 1967). In the Adrar des Iforas, the molasse series begins with ignimbrites, felsic lavas, breccias and rhyolites which are intruded by the latest alkaline ring-complexes and which could have been fed by the NS dykes dated at 543 ± 9 Ma (Liégeois and Black 1984). The molassic sediments show important sedimentological variations across the Touareg shield (they are, for example, much more developed in the Pharusian belt than in the polycyclic central Hoggar) and in the western pharusian itself, where they were deposited in isolated basins (Fabre et al. 1988). They probably suffered the D3 tectonic event (NS dextral shear zones).

Along the Adrar Fault, a clastic sedimentary series lying unconformably on the deformed and metamorphosed Upper Proterozoic marbles has been attributed by Caby et al. (1985) to the *Série Pourprée* molasse. It is intruded by granites at $581 + 7/-6$ Ma, very similar to the Immezzarene pluton in the eastern Pharusian belt (583 ± 7 Ma, Bertrand et al. 1986b). These granites are considered as pre-D3 by Caby et al. (1985) but as syn- to late-tectonic relative to a Pan-African thrusting event by Boullier et al. (1978) and Lapique et al. (1986). These conflicting interpretations of the structural evolution of the sediments along the Adrar Fault raise one of the most important remaining questions about the structural and geodynamic evolution of the whole Hoggar Shield. No modern structural data and no detailed maps are available in the 100 km-wide area between the Adrar fault and the Timgaouine region. This area is crucial to our understanding of the relationship between the 2-Ga-old reworked basement of both the western Pharusian belt and the Polycyclic Central Hoggar, the 850-Ma-old Pharusian I terrane lying in between. Is there another suture here?

6 The Central Iforas Batholith

A large (250×100 km^2) composite calc-alkaline batholith occurs close to the Pan-African suture (Fig. 9) between the Tilemsi island-arc terrane and the reworked basement of the western Pharusian belt (Kidal Assemblage), affected by the D1 nappe tectonics. Three main magmatic stages have been distinguished (Liégeois et al. 1987).

6.1 *The Cordilleran Stage*

The cordillera (by anology with the Andes) is older than 620 Ma and is essentially composed of volcanosedimentary sequences (Chikhaoui 1981) representing marine, aerial or subaerial environments (Fabre 1982). Some pretectonic plutons are also observed (Ball and Caby 1984). In the Adrar des Iforas region, the Tafeliant Series lies unconformably on platform sediments and on a $696 + 8 - 3$ Ma old granodiorite (U/Pb on zircon, Caby and Andreopoulos-Renaud 1985) and contains glaciogenic conglomerates (Caby and Fabre 1981) and rhyolitic sills which have been dated at 634 Ma (Rb/Sr whole rock isochron, Liégeois 1987). This series is considered to be older than the D1 event by Ball and Caby (1984) and Caby and Andreopoulos-Renaud (1985), whereas it is considered by Boullier (1982) and Liégeois et al. (1987) to lie on folded platform sediments and thus to post-date this D1 tectonic event. Large cordilleran-related plutons are rare. To the north, the Oumassene formation is probably a time-equivalent of the Tafeliant formation, but it comprises a large volume of andesite flows and tuffs in addition to restricted basal clastics and agglomerates (Chikhaoui 1981). Similar, more felsitic formations crop out along the eastern edge of the central Iforas Batholith; they rest unconformably upon deformed (D1) assumed Upper Proterozoic quartzites and marbles (Ourdjan area, J. M. Bertrand, pers. commun., 1990).

6.2 *The Collision Stage*

The Iforas batholith is essentially late- to post-tectonic. Its emplacement occurred after the closure of the western ocean and during the collision of the western Pharusian belt with the West African Craton (620-580 Ma; Bertrand and Davison 1981; Liégeois and Black 1984, 1987; Liégeois et al. 1987; Caby and Andreopoulos-Renaud 1989). Although diachronism possibly exists between different parts of the batholith, the same evolution of intrusive phases has been observed from mafic to more felsic compositions: quartz monzodiorites, granodiorites, porphyritic or fine-grained granites. All the late-tectonic plutons display a well-defined high-K calc-alkaline trend (Liégeois et al. 1987) and similar ages (Rb/Sr isochrons 595 ± 25 to 581 ± 15 Ma) with similar Sri ratios (0.7033 to 0.7053).

6.3 Post-Collision Magmatism

6.3.1 The Calc-alkaline to Alkaline Transition

This transition occurred in post-tectonic conditions relative to D2 and after considerable uplift of the belt. The relationships with D3 (NS to N20° dextral strike-slip shear zones or faults) and D4 tectonics (brittle sinistral NNW-SSE and dextral ENE-WSW conjugate faults, Ball 1980) have been discussed in detail by Boullier et al. (1986), while the petrographic, petrogenetic and geochronological point of view has been given in Liégeois and Black (1984, 1987).

The latest calc-alkaline magmatic stage is expressed by spectacular E-W acid dyke swarms (Fig. 11) which are clearly younger than D3. They have yielded Rb/Sr isochrons in the range 565 ± 14 Ma and 544 ± 12 Ma (Liégeois and Black 1984). Unroofing began during or just after the emplacement of the E-W dykes, leading to cooling of the crust.

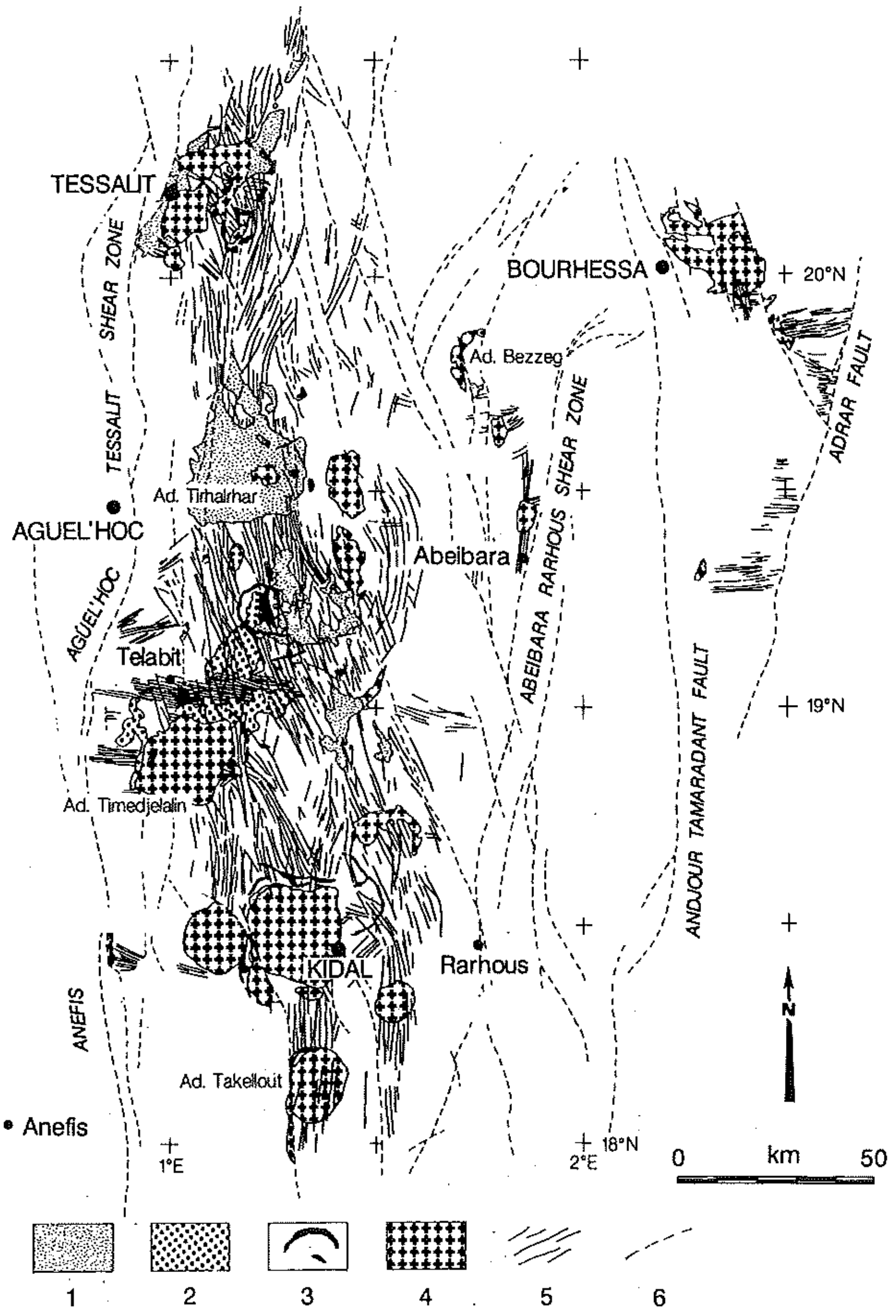

Fig. 11. Geological map of the alkaline province of the Adrar des Iforas after Fabre et al. (1982) and Boullier et al. (1986). *1* rhyolites; *2* alkaline granite of Tarhmert; *3* ring dykes; *4* alkaline ring complexes; *5* dykes; *6* faults

6.3.2 The Alkaline Stage

Subsequently, NS felsic alkaline dyke swarms (Fig. 11) were intruded (543 ± 9 Ma, Rb/Sr isochron, Liégeois and Black 1984) along the entire length of the batholith; they predated and were partly contemporaneous with the emplacement of the alkaline ring-complexes which are typical A-type granitoids (Ba et al. 1985). The slightly arcuate shape of the NS dykes swarms also seems to outline the large positive gravity anomalies described by Ly et al. (1984). These anomalies have been interpreted as resulting from the presence, at depth (12 km), of dense intrusive mafic bodies related to the alkaline magmatism. Two ring-complexes have been dated by Liégeois and Black (1984) by Rb/Sr isochrons: Kidal at 561 ± 7 Ma and Timedjelalen at 549 ± 6 Ma. In the Iforas batholith, the transition from subduction-related calc-alkaline magmatism to within-plate alkaline magmatism in a very short time-span (560–540 Ma) corresponds also to a reversal of the regional stress field during and after collision ($\sigma 1$: N 135–110°(D2); N 50–60°(D3); N 105°(D4); Boullier et al. 1986). Liégeois and Black (1987) suggested that the first reversal (D2–D3) is responsible for the slicing of the eastward-dipping subducted plate (lithosphere beneath the West African Craton), thereby allowing the rise of asthenospheric mantle believed to be the source of the alkaline magmatism. The tapping of this new source occurred between D3 and D4 events.

7 The Tilemsi Island-Arc

7.1 Lithology

The 100 km-wide Tilemsi magmatic arc preserved along the suture zone (Figs. 9, 12) has been studied by Caby et al. 1989).

Bimodal volcanics overlying a marble-dolomite sequence represent the oldest unit of the Tilemsi Group. Pillowed metabasalts interfingered with dacitic breccias represent arc tholeiites. They are overlain by a 3-km-thick unit of volcanic greywackes and conglomerates showing turbiditic sedimentary features and cut by various dyke swarms.

Near Tessalit, these formations are overlain by a metapelitic unit which was interpreted as a glacio-marine deposit and correlated with the Tafeliant formation (cordilleran stage, Sect. 6.1).

7.2 Magmatism

Several generations of plutons and associated dykes were emplaced in the Tilemsi group (Caby et al. 1989):

1. laccoliths of layered gabbro intruded the oldest carbonate formation. Geochemical data suggest a tholeiitic character and a MORB affinity (Liégeois 1987; Caby et al. 1986);
2. gabbro-norite lopoliths induced an early high-temperature metamorphism in the greywackes which were transformed in grey gneisses displaying granulite-facies assemblages. A mobilisate has yielded a 710 + 6 − 3 Ma age (U/Pb on zircon) for the metamorphism of the grey gneisses;
3. metaquartz-dioritic sheets intruded the grey gneisses and the high-grade metagreywackes at 726 + 7 − 3 Ma;
4. granodiorites with a calc-alkaline affinity were emplaced within the volcano-sedimentary formations at 635 ± 5 Ma to the east of the arc.

7.3 Deformation

Pan-African deformation and metamorphism affected the whole Tilemsi arc (Caby et al. 1989). In the north, upright folds are associated with steep, axial-plane, slaty cleavage generated in a flattening regime. Strain progressively increases toward steep, N-trending sinuous shear zones developed in greenschist-facies conditions.

Towards Aguel'hoc to the south, low-dipping and recumbent folds are associated with amphibolite-facies metamorphism. The metamorphic grade increases toward the Aguel'hoc gneisses, dominantly metasedimentary in origin (cordierite-bearing gneisses, marbles, quartzites) but including also the same meta-igneous suite as in the Tilemsi arc. The Aguel'hoc gneisses are characterized by upper amphibolite to granulite-facies assemblages and interlayered with synmetamorph trondjhemite, norite and troctolite bodies. A model Rb-Sr age on biotite at 575 ± 10 Ma indicates the age of cooling under the retention temperature for biotite in this province (Bertrand and Davison 1981).

7.4 Interpretation

The Tilemsi arc is characterized by an abundance of pre-, syn- und post-tectonic mafic to intermediate plutons and by the lack of granites.

Sr, Nd and Pb isotope studies on metaquartz-diorites and on metagreywackes are in agreement with a depleted mantle source, excluding any significant derivation from an older sialic source and supporting an ensimatic origin for the magmatic arc (Liégeois 1987; Caby et al. 1989). On the other hand, the Sr and Nd isotopic compositions of a pretectonic granodiorite suggests the presence of a crustal reservoir. This change in magmatic source is interpreted by Caby et al. (1989) as the result of accretion of the ensimatic arc to the western Pharusian belt, before the continent-continent collision. From the similarity of the Pb and Nd isotopic characteristics of the magmatic rocks of the island-arc and of the batholith, Liégeois (1987) suggested that the same mantle source was available during the subduction stage and the collision stage, but with greater crustal contamination during the latest stage.

8 The Gourma-Timetrine Foreland Nappes

These nappes were thrust onto the West African craton (Timetrine) or onto its passive margin (Gourma). They are exposed west of the gravity high (Bayer and Lesquer 1978; Ly 1979) and interpreted as outlining the suture.

8.1 Timetrine

Several nappes are exposed in the Timetrine area and were extensively described by Caby et al. (1981) and Caby (1987a). The highest nappe is made of oceanic material represented by serpentinites, metagabbros and diabases (Karpoff 1960; Leblanc 1976; Caby et al. 1981). The lowest unit is composed of sericite quartzites, chlorite-albite schists and pillowed basalts, which probably represent the sediments and lavas deposited on the passive margin (Caby et al. 1981).

8.2 Gourma

This area was studied by Reichelt (1972), Caby (1979), Moussine-Pouchkine and Bertrand-Sarfati (1978), Lesquer and Moussine-Pouchkine (1980) and Davison (1980). The Gourma basin s. s. represents a passive margin basin with flysh-type terrigeneous sediments which are affected by upright folds with a steep axial-planar slaty cleavage parallel to the Gourma arc. The Gourma basin has been interpreted as an aulacogen (Moussine-Pouchkine and Bertrand-Sarfati 1978; Lesquer and Moussine-Pouchkine 1980).

The foreland nappes (Fig. 12) consist mostly of sericite-chlorite phyllites and of a series with quartzites, marbles and siliceous dolomites. A nappe of rooted turbiditic terrigeneous sediments was also emplaced as one of the highest nappes close to the Bourré window which is part of the Eburnean basement (de la Boisse and Lancelot 1977).

The internal nappes (Fig. 12) consist of aluminous quartzites and schists which have undergone high-pressure metamorphism with P, T conditions estimated at 15 kb and 550 °C (de la Boisse 1981). These nappes are rooted beneath the Amalaoulaou granulitic mafic body which was dated ca. 800 Ma by U/Pb on zircon (de la Boisse 1979) and was partially overprinted by eclogitic metamorphism. These mafic rocks are located on the site of the gravity high (Bayer and Lesquer 1978).

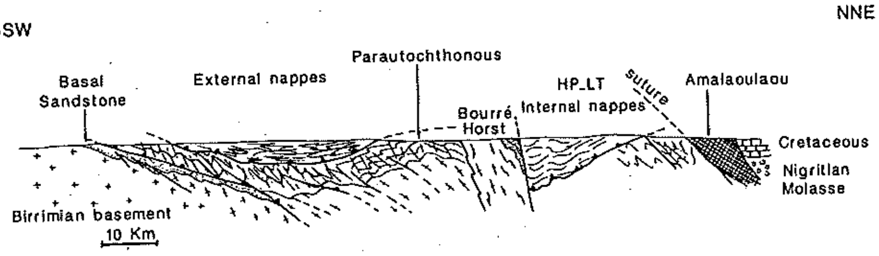

Fig. 12. Section across the Gourma nappes between the suture zone and the Eburnean basement (after Caby 1979). The external nappes are thrust onto the ca. 2 Ga-old Birimian basement and its autochthonous sedimentary cover. The Bourré Horst represents a slice of the same basement and cover. The mafic Amalaoulaou complex is exposed in an internal position relative to the HP-LT nappes and is a lateral equivalent to the Tilemsi magmatic island arc

9 Conclusion

The Hoggar shield is a complex assemblage of NS trending domains whose stratigraphic and tectono-metamorphic evolution is not always easy to correlate. To summarize, several domains may be distinguished from E to W:

1. The Djanet-Tafassasset domain in eastern Hoggar and its Nigeran equivalent, the Eberjegui domain, was involved in a magmatic event at ca. 730 Ma (Caby and Andreopoulos-Renaud 1987). This domain is probably not very wide as Pan-African (s. s.) granites have been recognized in the Tibesti Massif by Pegram et al. (1976);
2. The polycyclic central Hoggar, where two main tectonic, metamorphic and magmatic events at 2 Ga and 600 Ma have been recognized;
3. The Pharusian I domain, which is only known in a narrow NS-trending belt west of the Tin Di-Tin Effei lineament and of the 4°50′E fault, and which was involved in two main orogenic events at around 850 Ma and 600 Ma;
4. The western Pharusian belt of the Iforas and of NW Hoggar, in which an Eburnean basement and its Middle to Upper Proterozoic assumed sedimentary cover was involved in an early Pan-African event (pre-696 Ma) and in the Pan-African (s. s., ca. 600 Ma) event (Boullier et al. 1978), or only in the Pan-African (s. s.) event (Ball and Caby 1984). Volcanoclastic sediments of a cordillera were deformed before and during the emplacement of the Pan-African (s. s.) Central Iforas Batholith;
5. The Tilemsi island-arc domain;
6. The Timetrine and Gourma foreland nappes.

Except for the two westernmost domains, the whole shield presents as a common feature the various sedimentary formations, often volcanoclastic and glaciogenic, deposited between 730 and 600 Ma: the Tiririne and *Proche Ténéré* Formations, the low-grade Pharusian sediments in central Hoggar, the Pharusian II Formation, the *Série Verte* in NW Hoggar, the Tafeliant Group and the Ibedouyen greywackes in the Adrar des Iforas. All these sedimentary formations have suffered Pan-African deformation and metamorphism at ca. 600 Ma; consequently, even if these Upper Proterozoic sedimentary formations (and particularly the associated volcanics) show different depositional environments and tectonic evolution from one domain to another, it can be assumed that the Hoggar shield was an entity just before the deposition of these series and that the major accretion event took place before that time (Caby 1987b).

What are the traces of this accretion event? They could be seen in the basement of the Late Proterozoic series, as in the Eberjegui or Djanet-Tafassasset domains, or in the Pharusian I domain where pre-730 Ma or pre-850 Ma respectively, and post-2 Ga deformation is clearly expressed. In contrast, no deformation has been observed in Polycyclic Central Hoggar between 2 Ga and 615 Ma. In the western Pharusian belt, two interpretations have been proposed and supplementary geochronological data are necessary to solve the uncertainty. Boullier et al. (1978) and Boullier (1982) suggested that the thrust tectonics involving the 2 Ga granulites represent an early Pan-African event, which could be related to the main accretion event. Ball and Caby (1984) interpreted the thrust tectonics as strictly equivalent to the shortening deformation of the Late Proterozoic Tafeliant Group; in the latter case the central Iforas behaved passively during the accretion stage as did the Polycyclic Central Hoggar. However, it should be stressed that the continental blocks represented are very different: in Central Polycyclic Hoggar, Archaean rocks are rare, Lower Proterozoic sediments are abundant and Pharusian sediments and volcanics correspond probably to uppermost Proterozoic, while in the western Pharusian belt, Archaean material is dominant, the Middle Proterozoic is represented by thick fluviatile quartzites and the Upper Proterozoic by a carbonate platform.

The Upper Proterozoic volcanic and volcanoclastics sediments emplaced or deposited later than ca. 800 or 700 Ma, have different chemical characteristics throughout the Hoggar shield. Tholeiitic basalts were observed in the Arrei unit (Aouzeguer belt, Cosson et al. 1987) and calc-alkaline andesitic basalts in Arefsa (Central Hoggar, Leterrier and Briedj, pers. commun.); calc-alkaline series have been described in Pharusian II (Dupont 1987) and in the Adrar des Iforas region (Chikhaoui 1981). This suggests that one or several subduction zones operated during the Upper Proterozoic and were accompanied by some local extensional tectonics.

During the Pan-African deformation (s. s.) the accretion scars were reworked, mostly inducing strike-slip movement during the continent-continent collision along the Tilemsi suture on the west: Tiririne-Aouzeguer belt, Tin Di-Tin Effei lineament, Adrar Fault (?). These strike-slip movements could well be explained as the result of an oblique collision with the West African Craton margin.

Many questions remain to be answered before an understanding of the global evolution of the Hoggar shield is possible: what is the exact age of D1 in the Adrar des Iforas? Why were some large sialic domains deformed by thrusting during the collision and others by wrenching? What were the relative importance, the kinematics and the succession in time of the Pan-African strike-slip shear-zones? Is there any space and time migration of the deformation? The Pan-African Trans-Saharan belt of West Africa has been interpreted as the result of a Wilson Cycle ending around 600 Ma with collision and suturing between the West African Craton and the Pan-African mobile belt by Black et al. (1979) and Caby et al. (1981). If the latest stages of the Pan-African history of the belt are now well known, the first stages and especially the accretion stage of this history need to be better understood.

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