Pan-African displaced terranes in the Tuareg shield (central Sahara)

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ABSTRACT

Concepts developed in the recently published model of the Aïr region (eastern Tuareg shield; Niger, Africa) as a college of three displaced terranes integrated in a single geodynamic model lead us to propose a terrane map of the Tuareg shield (500 000 km^2). The 23 terranes recognized have their own lithological, metamorphic, magmatic, and tectonic characteristics and are separated by subvertical strike-slip megashear zones that can be traced for hundreds of kilometres, or by major thrust fronts. Some of these boundaries have ophiolitic assemblages or molassic deposits. The Tuareg shield was shaped and partly accreted during the Pan-African orogeny (750–550 Ma), but not as a homogeneous body.

INTRODUCTION

The Tuareg shield, in the Trans-Saharan belt of Northern Africa (Fig. 1), formed during the Pan-African orogeny (750–550 Ma) and is characterized by major north-south–oriented shear zones delimiting crustal blocks with different geology. Correlations between the blocks are difficult (in places impossible), except through geochronologically based links. These geochronological correlations have led to the hypothesis of large horizontal movements along the shear zones (Caby, 1968) and to the concept of amalgamation of microcontinents (Black, 1978). A recent study of the Aïr mountains (Niger; Fig. 1) has demonstrated the existence there of three terranes for which interrelations during the Pan-African orogeny have been partly deciphered (Fig. 2; Liégeois et al., 1994). Using these results, published work on the Tuareg shield (Caby, 1987; Boullier, 1991, and references therein) and the historical field reports, we propose that the structure of the entire Tuareg shield is similar to that of the Aïr. Here we present a terrane map of the Tuareg shield (Fig. 3) and suggest guidelines for its interpretation.

THE KEY: STRUCTURE OF THE AÏR REGION

As a result of comprehensive field study of the Aïr region (Black et al., 1967) and recent expeditions, three distinct terranes (from east to west: Aouzegueur, Barghot, and Assodé; Fig. 3) have been defined and integrated in a geodynamic model characterized by a two-stage Pan-African orogeny (Liégeois et al., 1994). The early Pan-African orogeny (750–660 Ma) was a strong collisional event following west-dipping subduction east of the Aïr region (Fig. 2). This collision generated high-pressure metamorphism, lower crustal anatexis, regional thrusting, and medium- to high-K calc-alkalic plutonism. The late Pan-African orogeny (650–580 Ma) produced large horizontal displacements along north-south megashear zones and high-K calc-alkalic batholiths related to an east-dipping subduction zone west of the Aïr region (Fig. 2). Except on their western edges, the Aouzegueur and Barghot terranes were little affected by the late Pan-African phase, whereas the Assodé terrane recorded both phases.

The Aouzegueur terrane comprises an ophiolitic assemblage and shelf sedimentary rocks affected by greenschist facies metamorphism and intruded at ca. 730 Ma (determined by U-Pb zircon analysis; Caby and Andreopoulos-Renaud, 1987) by a late kinematic medium-K calc-alkalic tonalite-trondhjemite-granodiorite suite containing pendants of ultramafic-mafic amphibolites.

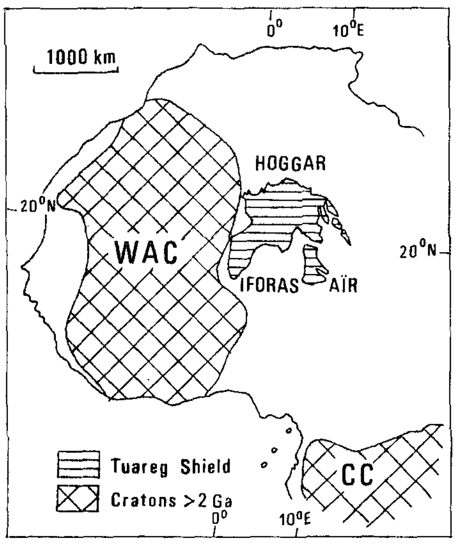

Figure 1. Schematic map of western Africa showing location of Tuareg shield. WAC is West African craton; CC is Congo craton.

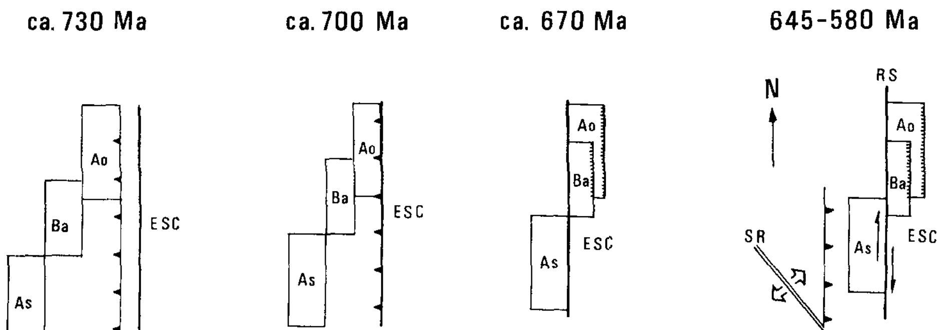

Figure 2. Plan views of relative movements of terranes of Aïr region during Pan-African orogeny. Lines with arrowheads indicate subduction trenches; ESC is East Saharan craton; Ao is Aouzegueur; Ba is Barghot; As is Assodé-Issalane; RS is Raghane shear zone; SR is spreading ridge. For dimension of terranes, see Figure 3. At ca. 670 Ma, thrusting of Aouzegueur and Barghot onto East Saharan craton ended while Assodé collided with craton; lithospheric thickening was followed by continental lithospheric mantle delamination. Between 645 and 580 Ma, Assodé moved north ~1000 km along Raghane shear zone, and there was abundant calc-alkaline magmatism in Assodé. For more details, see Liégeois et al. (1994).

The Barghot terrane is composed of a reworked migmatitic basement and monocyclic (shelf sedimentary rocks) gneissic series affected by upper amphibolite facies metamorphism and cut by high-K late- to postkinematic calc-alkalic batholiths and plutons emplaced between 715 and 665 Ma (U-Pb zircon analysis; Liégeois et al., 1994).

These two terranes are associated in a thrust belt formed by several sheets displaying west to west-southwest dips of 20° to 40° with a stretching lineation that changes from N20°E to N90°E as one goes up the nappe structure (Boullier et al., 1991). This thrusting event ended ca. 680–670 Ma. The thrust belt is cut by a postkinematic pluton (U-Pb zircon analysis of ca. 664 Ma; Liégeois et al., 1994) and covered by a widespread, thick molasse deposit (Proche-Ténéré Group). After 660 Ma, the Aouzegueur and Barghot terranes constituted a nearly stable area little affected by late Pan-African events. For this reason, we suggest that these two terranes were thrust upon a rigid cratonic block (Fig. 2, East Saharan craton; Black and Liégeois, 1993).

The Assodé terrane is composed of a migmatitic basement and several supracrustal sequences metamorphosed in the amphibolite facies. During the early Pan-African orogeny, this terrane was not thrust upon the East Saharan craton, but strong collision led to Tibetan-type crustal thickening (Fig. 2). This behavior may be due to the greater distance of the Assodé terrane from the Aouzegueur trench, as suggested by the absence of subduction-related rock types. Resulting metamorphism (6 kbar, 700 °C) led to partial melting of the lower crust and production of a large volume of potassic anatectic granite (ca. 666 Ma; Rb-Sr analysis) in response to delamination of the continental lithospheric mantle of this terrane (Fig. 2; Black and Liégeois, 1993; Liégeois et al., 1994).

During the late Pan-African orogeny the delaminated Assodé terrane—unprotected and not attached to the East Saharan craton, and driven by an oblique spreading ridge—moved north ~1000 km along the Raghane dextral shear zone, which marks the western limit of the rigid craton (Figs. 2 and 3). This movement affected the Proche-Ténéré molasse and generated the Tiririne intraconti-

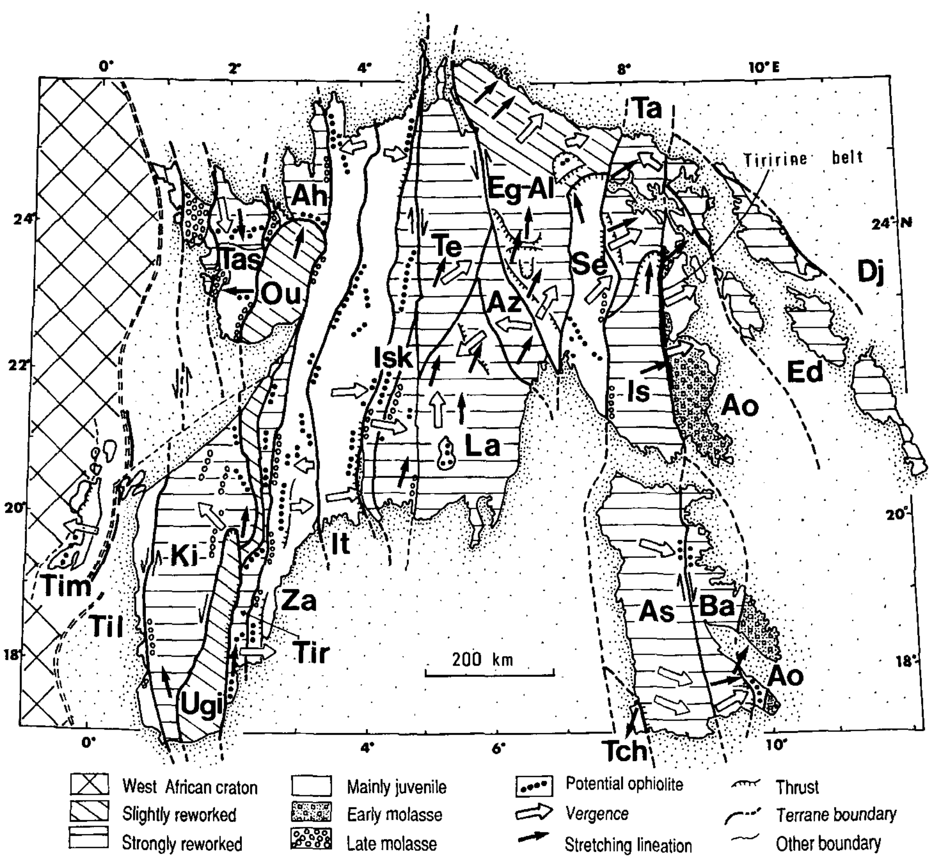

Figure 3. Terrane map of Tuareg shield. Each solid arrow corresponds to movement direction determined from field and laboratory work (Boullier and Bertrand, 1987). Double dashed line is eastern boundary of West African craton as marked by gravity anomalies. From east to west, 23 terranes are as follows: Djanet (Dj)—low greenschist facies volcaniclastic sedimentary rock; Edembo (Ed)—greenschist facies sedimentary rock and rhyolite; amphibolite facies granite-gneiss of unknown age; Aouzegueur (Ao)—greenschist facies shelf sedimentary rock, ophiolite, amphibolite, tonalite-trondhjemite-granodiorite (730 Ma); Barghot (Ba)—upper amphibolite facies gneiss including old basement and shelf metasedimentary rock, high-K calc-alkalic granitoids (715–665 Ma); Assodé-Issalane (As-Is)—widespread anatexis and upper amphibolite facies gneiss, including old basement, several supracrustal sequences, alkalic gneiss, anatectic potassic granite (670 Ma), and high-K calc-alkalic granitoids (645–580 Ma); Tchilit (Tch)—greenschist facies metaignimbrite, metabasalt, quartzite, conglomerate, and phyllite intruded by high-level granite sills; Tazat (Ta)—undifferentiated basement, alkalic gneiss, moderately deformed fluviatile-deltaic quartzite, and calcareous sedimentary rock; Sérouénout (Se)—diversely retrograde metamorphosed upper amphibolite facies gneiss, graphitic aluminous mica schist, foliated granodiorite, and high-K calc-alkalic granitoids (to 580 Ma); Egéré-Aleksod (Eg-Al)—Archean and Eburnian (2.1 Ga) granulitic gneiss, supracrustal banded ironstone, quartzite, and marble, Pan-African high-*P* amphibolite facies gneiss with eclogite, foliated granodiorite, absence of huge granitoid batholiths; Azrou-n-Fad (Az)—similar to Egéré area of Eg-Al terrane; Tefedest (Te)—amphibolite facies basement gneiss and several supracrustal sequences including marble, calc-alkalic granitoids; Laouni (La)—amphibolite facies gneiss including old basement and several supracrustal sequences, greenschist facies shelf sedimentary rock, anatectic potassic granite, and Sn-W–bearing granite (540–520 Ma); Iskel (Isk)—greenschist facies platform sedimentary rocks with stromatolite-bearing marble, mafic-ultramafic sills, calc-alkalic granitoids (870 Ma), postkinematic K-rich granite and syenite (840 Ma), and volcaniclastic sequences; In Teidini (It)—greenschist facies graywacke, volcanic and clastic rocks, and calc-alkalic granitoids (650–550 Ma); Tin Zaouatene (Za)—high-*T*–low-*P* amphibolite facies gneiss, graphitic mica schist, migmatite and anatectic granite, high-K calc-alkalic granitoids, and greenschist facies molasse; Tirek (Tir)—basement gneiss, supracrustal sequences with quartzite and marble, intruded by various Pan-African granitoids; Ahnet (Ah)—greenschist facies post-Eburnian deltaic quartzite and 1.8 Ga rhyolite, covered by shelf sedimentary rock and stromatolite-bearing marble overlain by basalt and rhyolite; In Ouzzal (Ou)—Archean protoliths with 2.1 Ga granulite facies metamorphism, late Pan-African calc-alkalic granite, and ca. 520 Ma alkalic complexes; Iforas granulitic unit (Ugi)—diversely retrograde metamorphosed 2.1 Ga granulites with remnants of greenschist facies Neoproterozoic quartzitic cover, cut by numerous Pan-African mafic and granitic plutons; Tassendjanet (Tas)—Eburnian gneiss covered by shelf sedimentary rock with stromatolite-bearing marble, voluminous mafic-ultramafic rock ca. 800 m.y. old, overlain by greenschist facies Neoproterozoic andesite and related trough graywacke; Kidal (Ki)—basement gneiss late Paleoproterozoic and Neoproterozoic supracrustal platform sequences intruded by deformed granodiorite and tonalite (695 Ma) unconformably overlain by graywacke and tillite with andesitic volcanic rock cut by composite high-K calc-alkalic batholith (630 to 570 Ma), alkalic ring complexes, and volcanic rocks (560–540 Ma); Tilemsi (Til)—greenschist to amphibolite facies oceanic island-arc volcanic rocks and graywacke cut by laccoliths of gabbronorite (730–710 Ma); Timétrine (Tim)—low-*T*–high-*P* ophiolitic sequence and shelf metasedimentary rock.

nental linear fold belt in Algeria (Fig. 3; 200 by 15 km, 8000 m thick; Bertrand et al., 1978). The thrusting at the northern rounded tip of the Assodé-Issalane terrane also probably resulted from that movement (Fig. 3). Mylonites of the shear zone (5 to 10 km wide) show an amphibolite facies mineral assemblage. During the same time interval (645–580 Ma), large north-south–elongated, high-K calc-alkalic batholiths were emplaced, the older plutons (ca. 645 Ma, U-Pb zircon) of which are younger than the latest high-level pluton (ca. 664 Ma, U-Pb zircon) in the adjacent Barghot terrane.

The main Phanerozoic events were important northwest-southeast sinistral wrench faults well marked by quartz veins (ca. 525 Ma), the intrusion at ca. 410 Ma of anorthosite-bearing alkaline ring-complexes along the Raghane shear zone (Moreau et al., 1994), and the emission of alkaline lava flows related to Cenozoic doming of the shield.

ASSEMBLY OF DISPLACED TERRANES IN THE TUAREG SHIELD

The concepts described above allowed recognition of the northern prolongation of the Aïr terranes in the Algerian Hoggar (Fig. 1) and the identification of terrane boundaries in the entire Tuareg shield. Working criteria for distinguishing these terranes are mainly the following. (1) Boundaries between terranes may be thrust fronts, some having ophiolitic remnants, or steep ductile megashear zones that acted as strike-slip faults under greenschist facies conditions during the late stage of the collision. (2) On either side of these boundaries, some features are incompatible if no large relative movements are envisioned—i.e., contrasting metamorphic regimes, lithological sequences, geochronological data, vergences, and major geologic events (e.g., anatexis). (3) Spoon-shaped thrusts at the tip of terranes, triple points indicating truncation of welded terranes by later displacement of another terrane, and molasse facies along terrane boundaries are other discriminators.

With these criteria, we have reviewed published studies (see references in Boullier, 1991; Bertrand and Caby, 1977), 1955–1962 reports of the Bureau de Recherches Minières de l'Algérie, which are for many areas the unique available source of precise field observations, and some more recent reports of the Société Nationale de Recherche et Exploitation Minière (Algiers). Our aim was to track down the terranes that make up the Tuareg shield, the ultimate goal being to try to determine the original position of these terranes.

Much of our knowledge of the 23 displaced terranes is limited (Fig. 3). Caby and Andreopopoulos-Renaud (1987) described briefly three contrasting metamorphic terranes to the east—the Djanet, Edembo, and Aouzegueur terranes—and outlined their northern limits. As described above, Liégeois et al. (1994) have defined Aouzegueur, Barghot, and Assodé-Issalane and have proposed a model for their Pan-African evolution. The central Hoggar has been considered to represent a pile of crystalline nappes with several occurrences of eclogite (Sautter, 1985; Bertrand et al., 1986). Cottin et al. (1990) reported high-temperature (T), low-pressure (P) metamorphism and anatectic potassic granite farther south in the Laouni terrane, similar to those of the Assodé terrane. Egéré-Aleksod, where old rock units (Archean and 2.1 Ga; Latouche and Vidal, 1974) are known, is almost devoid of granite batholiths (Fig. 4), but displays Pan-African

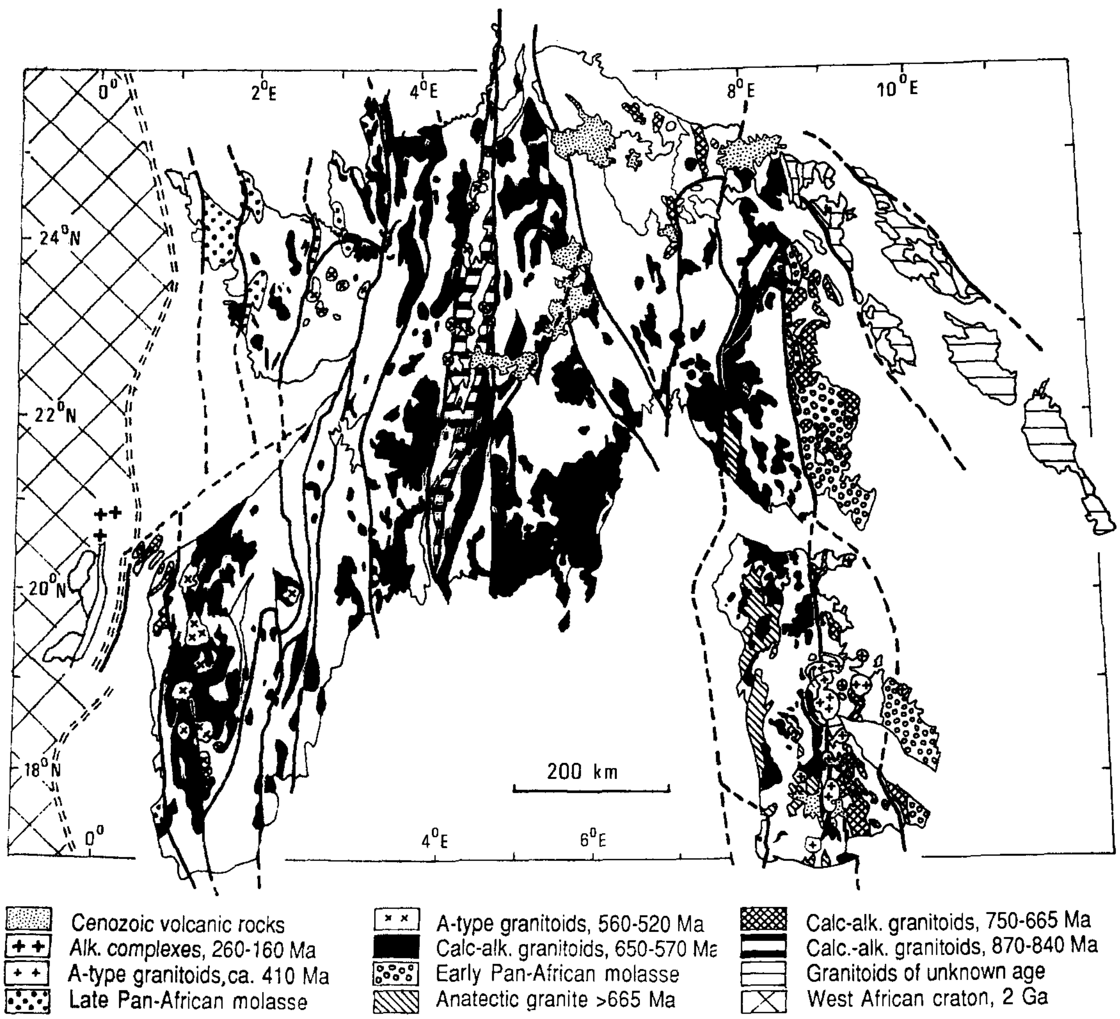

Figure 4. Different types of Pan-African granitoids and Phanerozoic alkalic magmatic rocks in terranes of Tuareg shield. Double dashed line is eastern boundary of West African craton as marked by gravity anomalies.

high-T, high-P metamorphism. In western Hoggar, the only terrane to have ages in the range 870–840 Ma for synkinematic to late-kinematic granitoids (Pharusian I; Caby et al., 1982) is the Iskel, overlain by late Neoproterozoic age volcaniclastic assemblages. In Ouzzal, 2.1 Ga granulites differ from the Iforas granulitic unit, which was much more affected by Pan-African retrograde metamorphism. Both the east and west shear zones represent cryptic sutures, as evidenced by the presence of eclogites in the west and granulitic metagabbro with relict glaucophane southeast of Ahnet. The Kidal terrane comprises an old basement with a metasedimentary arenaceous cover and remnants of supracrustal rocks correlatable with the well-characterized early Neoproterozoic platform stromatolite series in the Tassendjanet terrane. The Kidal terrane also comprises Neoproterozoic volcanic-sedimentary sequences, tonalitic plutons, a huge late-kinematic high-K calc-alkalic composite batholith, and alkalic-peralkalic plateau lavas, dike swarms, and ring complexes (640–540 Ma; Liégeois et al., 1987). The Tilemsi juvenile terrane within the suture zone is similar to modern intraoceanic arcs and formed in the 730–700 Ma interval (Caby et al., 1989). The Timetrine terrane comprises a dismembered ophiolitic sequence as well as passive margin sediments thrust upon the 2 Ga West African craton (Caby, 1987). The Pan-African evolution of the Adrar des Iforas (southwestern Tuareg shield; Fig. 1) has been interpreted in terms of a complete Wilson cycle (Black et al., 1979; Caby et al., 1981). Assembly of the Tilemsi and Timetrine terranes along the Kidal terrane resulted from late strike-slip movements.

SUMMARY AND CONCLUSIONS

We interpret the Tuareg shield as an amalgamation of displaced and differing terranes during a two-phase Pan-African orogeny (750–660 Ma and 650–550 Ma). Moreover, our recent reappraisal of the Aïr region (Niger) has shown that at least some of the terranes formed in a common paleogeodynamic environment.

The collision with the East Saharan craton was early (ca. 700 Ma) and at the start of intense regional metamorphism and probably continental lithospheric mantle delamination (Liégeois et al., 1994), whereas that with the West African craton was late (ca. 600 Ma) and mainly related to major movements along north-south megashear zones.

The distribution of the abundant Pan-African granitoids resulted directly from relative movements of the terranes and becomes clear when considered in this proposed framework (Fig. 4). Continuous Saharan outcrops highlight the major importance of the megashear zones in the architecture of the Tuareg shield. This structure is probably a common feature of granitic-gneissic basements affected by the Pan-African orogeny.

ACKNOWLEDGMENTS

We thank A. Kröner and J. J. W. Rogers for constructive reviews. This is a contribution to International Geological Correlation Program project 288.

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Manuscript received January 3, 1994
Revised manuscript received April 4, 1994
Manuscript accepted April 8, 1994

Printed in U.S.A.