

Permian alkaline undersaturated and carbonatite province, and rifting along the West African craton

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Recent work^{1,2} carried out in north-east Mali, which showed the Pan-African orogeny (600 Myr) to be the result of a collision between the passive margin of the West African craton and the active margin of a continental mass situated to the east, has also outlined an entire province of alkaline undersaturated ring complexes and carbonatites, the first to be discovered in West Africa excluding Morocco^{3,4} (Fig. 1). This province is quite distinct petrologically and structurally from the Iforas alkaline younger granite province situated in the Pan-African domain east of the suture which has yielded Rb/Sr whole-rock ages of between 560 and 520 Myr (ref. 5). The undersaturated province is located along a well-defined rift on the edge of the West African craton which is totally devoid of Pan-African magmatism. We report here that the Permian radiometric age obtained for one of these intrusions shows the existence of a hitherto unsuspected important tectono-magmatic event in this part of Africa, which may have far-reaching structural implications as well as economic interest.

The alkaline undersaturated province largely masked by Cretaceous-Tertiary sediments comprises: a few typical ring-complexes including the Tadhak with diameter of 12 km (long. 0°, lat. 20° 30' N), Tikarkas 4 km in diameter (long. 0° 06' E, lat. 20° 44' E) and other occurrences about 50 km to the north-east which have not yet been studied⁶, several carbonatite plugs (long. 0° 06' E, lat. 20° 09' N, long. 0° 03' E, lat. 20° 04' N) which at present are being investigated by the United Nations Revolving Fund, and NNE to NE trending dyke swarms displaying a wide variety of undersaturated rocks including microsyenites, phonolites and banded carbonatites. The Tadhak complex which has been dated is composed of four main units which are concentrically disposed: (1) an outer fine-grained nepheline syenite displaying pronounced flow structure; (2) a leucocratic nepheline syenite; (3) a lenticular unit of nepheline melteigte grading to a nepheline jolite, containing enclaves of pyroxenite displaying cumulate textures; (4) an inner foyaïtic nepheline syenite. These phases are cut by numerous foyaïte and tinguaité dykes and a small carbonatite plug occurs in the eastern part of the complex⁴.

Thirteen Rb/Sr analyses of the Tadhak complex taken from the different parts of this composite intrusion (Fig. 2, Table 1) give a lower Permian age of 262 ± 7 Myr (MSWD = 2.7) with an $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio of 0.70457 ± 0.00004 (with the omission of sample T16: 12WR, 269 ± 9 , 0.70455 ± 0.00004 , MSWD = 2.2). The age and margin of error at 2σ level were calculated by the Williamson method⁷. In view of the absence of later deformation, this age is interpreted as dating the intrusion and the low initial ratio suggests a mainly mantle source.

The Tadhak and related alkaline plutons outcrop at the northern end of the Tilemsi trough which approximately coincides with the Pan-African suture. The suture is characterized by the presence of important positive gravity anomalies shown to be produced by unrooted metabasic and ultrabasic bodies⁸ thought to represent the relics of deep seated portions of island arcs⁹. Geological³ and geophysical¹⁰ data show that

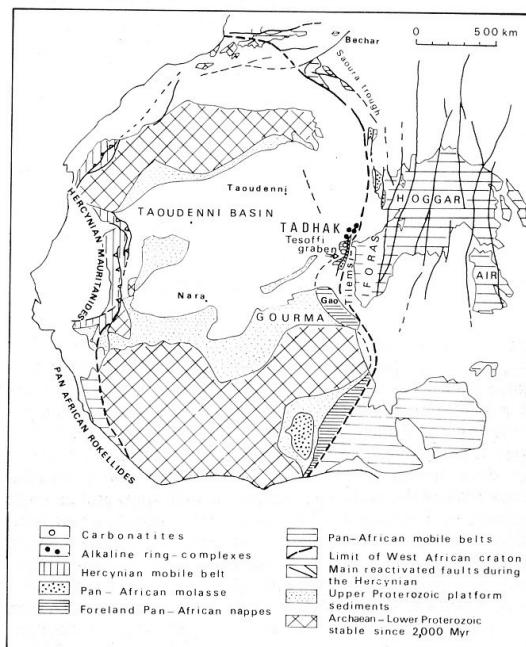


Fig. 1 North-east Mali showing the limit of the West African craton.

the Tilemsi trough, filled with Cretaceous to Eocene sediments (800 m), is partly superimposed on an earlier graben (Tessoffi graben, Fig. 1) filled with red molasse sediments which outcrops in a 10 km wide north-northeasterly trending strip 150 km long. The older graben contains over 2,000 m of purple arkosic sandstones and conglomerates and by analogy with the Serie Pourprée of northwestern Hoggar it was mapped as a Pan-African molasse. In the absence of palaeontological data, however, doubt may be cast on this attribution as the source of the sediments is from the west. This is indicated by the widespread occurrence of abundant pebbles of undeformed limestone and dolomite typical of the Upper Proterozoic of the Taoudenni Basin and of some locally derived metaquartzite pebbles (Timetrine). The absence of material from the east

Table 1 Rb/Sr analyses of samples from Tadhak

Samples	Rb (p.p.m.)	Sr (p.p.m.)	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Rb}/^{86}\text{Sr}$
T10	139	514	0.70739 ± 4	0.7825
T16	154	91.4	0.72191 ± 5	4.882
T25	140	2140	0.70525 ± 5	0.1893
T29	98	4136	0.70474 ± 4	0.0688
T35	0.8*	1415	0.70463 ± 5	0.00164
T42	40.5	1398	0.70483 ± 3	0.0838
T59	221	1315	0.70647 ± 5	0.4862
T66	156	1039	0.70629 ± 4	0.4344
T76	546	5324	0.70566 ± 4	0.2967
T84	274	1368	0.70677 ± 4	0.3795
T102	160	1454	0.70591 ± 5	0.3184
T108	129	2345	0.70517 ± 6	0.1591
T149	179	683	0.70741 ± 4	0.7583

The isotopic composition and the concentration analyses were carried out at the Belgian Centre for Geochronology (MRAC-ULB). Rb and Sr concentration was measured by X-ray fluorescence (except* which was done by isotope dilution). Errors on Rb/Sr and $^{87}\text{Rb}/^{86}\text{Sr}$ ratios are 2%. Errors on $^{87}\text{Sr}/^{86}\text{Sr}$ are given at the 2σ level in 10^{-5} . 20 measurements on standard NBS987 give: 0.710218 ± 0.000035 . Normalization for $^{86}\text{Sr}/^{88}\text{Sr} = 0.1194$. $\lambda \text{Rb} = 1.42 \cdot 10^{-11} \text{yr}^{-1}$.

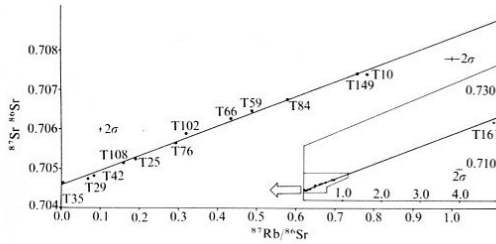


Fig. 2 Rb/Sr analyses of the Tadhak complex (see Table 1).

(central Iforas) suggests that these sediments were deposited after erosion of the Pan-African mountain belt and peneplanation, a $^{39}\text{Ar}/^{40}\text{Ar}$ cooling age of 520 Myr having been obtained on a blue amphibole from the Pan-African foreland nappes bordering the graben to the west (H. Maluski, unpublished data). It seems reasonable, therefore, when taking into account the close spatial relationships between the dated alkaline intrusions and the graben, to ascribe the pull-apart graben horst tectonics to the Permian. This time relationship has now been partly confirmed by the discovery of fenitized alkaline rocks in the Tesoffi conglomerates (J. F. Sauvage, personal communication). The persistent mobility along the suture zone has been noted 1,000 km further north with the Saoura trough filled with over 6 km of Palaeozoic sediments located close to the Pan-

African suture and affected by open folds of Upper Permian age¹¹. More recent mobility of the suture zone is shown by the presence of over 1,500 m of Cretaceous sediments in the region of Gao.

We conclude that there is a reasonable probability that a Lower Permian age can be assigned to the undersaturated complexes (including carbonatites) of the Tadhak province. This may relate to a widescale episode of rifting in Pangaea whose manifestations elsewhere include alkali magmatism in, for example, Corsica¹², the North Sea and southern Norway. The location of the province along the edge of the West African craton in relation to a pre-Cretaceous graben indicates the presence of hidden Upper Palaeozoic rifts beneath the extensive Mesozoic cover and may explain certain features of the subsurface geology of the Taoudenni basin.

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