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K/Ar AGES OF THE MUSCOVITES OF THE URGUNT VALLEY GRANITE, WAKHAN (HINDU KUSH, NE AFGHANISTAN)

RIASSUNTO. — Muscoviti di una massa leucogranitica intrusa diapiricamente in una potente formazione argilloscistosa del tardo Paleozoico o del Triassico nel distretto del Wakhan (NE Afghanistan) danno età K-Ar di 62-64 m.a. Le relazioni di campagna e la composizione della massa magmatica corrispondono a quelle dei graniti orogenici post-tettonici. Non c'è indizio di successive deformazioni e/o ricristallizzazioni, e le età misurate possono essere accettate come età primarie di raffreddamento.

La massa granitica appartiene ad una zona tettonica caratterizzata da deformazioni Alpine precoci (fase Cimmerica), senza successive importanti deformazioni; l'età 62-64 m.a. indica che l'attività magmatica perdurò a lungo dopo la principale fase di piegamento.

ABSTRACT. — Muscovites from a leucogranitic body diapirically intruded into a thick, upper-Paleozoic or Triassic slate formation in the Wakhan district (NE Afghanistan) give K-Ar ages of 62-64 m.y. Field relationships and composition of the magmatic mass are typical of orogenic, post-tectonic granites. There is no evidence of later deformation and/or recrystallization, and the measured ages can be assumed to be primary cooling ages.

The granite belongs to a tectonic zone of early Alpine, Cimmerian folding with no subsequent, Alpine significant movements, and the 62-64 m.y. age suggests that magmatic activity long outlasted the main folding stage.

Introduction

Urgunt valley is part of the Wakhan district, which is a narrow corridor extending eastwards from north-eastern Afghanistan into Central Asia, and borders with the U.S.S.R. in the north, China in the east, and Pakistan in the south. The whole district is located in the Eastern Hindu Kush region south of the Pamir mountain range, and is part of a tectonic zone in which orogenic movements of predominantly Cimmerian age took place (DESIO, 1976; 1977). KAFARSKIY & ABDULLAH (1976) pointed out that such a zone extends in a NE direction as a relatively narrow strip between two « median (stable) masses », the Badakshan-South Pamir mass in

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the NW, and the Khazarian mass in the SE: according to them, Paleozoic to Mesozoic troughs filled by clastic sediments and superimposed on a Baikalian basement were negligibly affected by late Alpine movements. The latter concept was already discussed by DESIO (1965). Granitic, granodioritic to quartz-dioritic intrusive bodies of batholithic to stock-like sizes are a major feature of this tectonic zone as well as of the adjacent tectonic zones, but in most cases their time relationships are not very well known, and radiometric data are very limited.

In this report geological data and K/Ar ages of micas of a minor granitic mass intrusive into a clastic metasedimentary sequence in the Eastern Hindu Kush are given. Although the granitic body itself is not very large and its connection with nearby plutonic masses is concealed, its level of intrusion, composition and tectonic position within the regional structural framework make it interesting. Knowledge of the main structural and age relationships of the formations in the Urgunt valley may also serve to verify current ideas on the structure of the Eastern Hindu Kush mountain chain, as well as on its geological evolution.

Geological setting

Urgunt valley is a 22 km long, deeply excavated glacial valley originating in the 6,000 m — to more than 7,000 m — high crest of the main Eastern Hindu Kush range along the Pakistan-Afghanistan border (fig. 1). The valley runs in a SSE-NNW direction, until it reaches the Main Amu Darya valley (ancient Oxus, locally called Ab-i-Panja) in the NW, at an altitude of about 2,400 m: being roughly normal to the main structural trends of the region and vertically cutting across the formations for more than 4,000 m it clearly exposes a wide range of structures, thus affording a good insight into a region with difficult access.

Little is known of this far-away area. Information so far published includes only the papers of BLANFORD (1878), HAYDEN (1916), BRUEKL (1935) and DESIO et al., (1968). In the latter paper 4 main formations are recorded in Wakhan:

1) quartz-dioritic rocks (« Qala Panja quartz-diorite ») exposed in eastern Wakhan and near Qazi Deh in western Wakhan, of undetermined age and stratigraphically underlying the two following formations;
2) pelitic to siltitic pre-Cretaceous metasediments (« Khandut Slates ») widely outcropping in the middle and upper slopes of southern Wakhan;
3) a granodioritic lower Cretaceous batholith exposed in the axial part of the Hindu Kush mountain chain (« Babatangi-Lunkho granodiorite »);
4) a complex of middle- to upper-grade gneissic rocks, encompassing various lithologies (« Qala Wust gneiss »), said to envelope the Qala Panja quartz-diorite and also to outcrop as a discontinuous strip in the lower slopes of the Amu Daria valley.

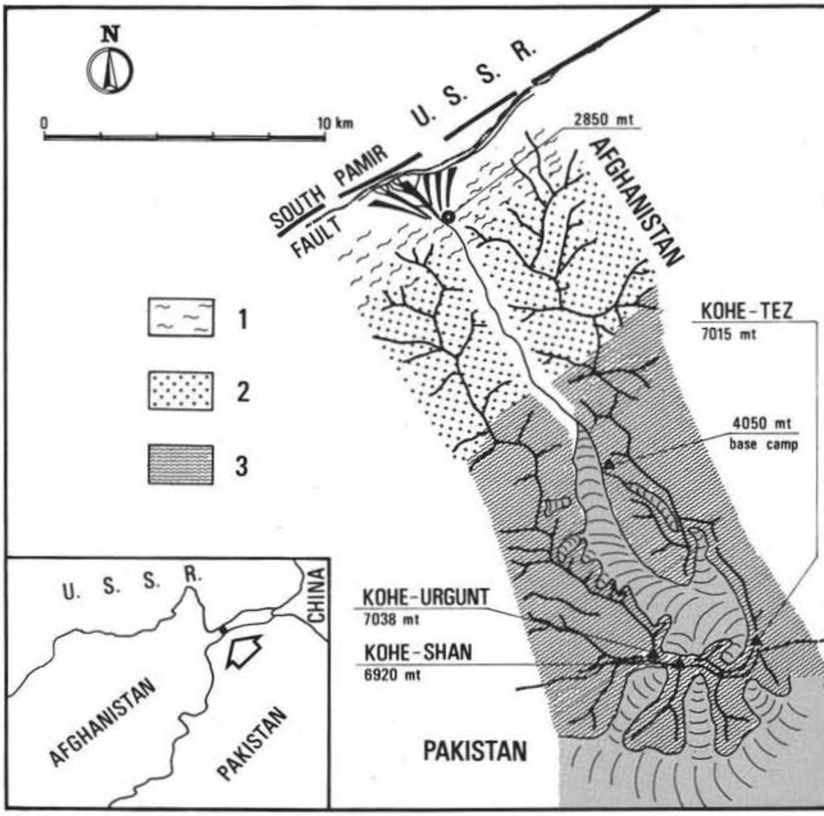

Fig. 1. — Geological sketch-map of the Urgunt valley.
1: gneiss and migmatites; 2: Urgunt granite; 3: Slate Formation.

The same authors underline the importance of a great fault, thought to represent an ancient scar in the earth's crust, which runs along the Amu Darya valley. It is called « peripheric southern fault of the Pamir » by the Russian geologists, and its south-western extension (the Zebak-Munjan fault) separates the two main structural units of the whole region:

a) the cratonized block (or median stable mass) of the south-west Pamir lying in the north and north-west, and

b) the previously mentioned, and little known, geosynclinal belt of the eastern Hindu Kush, folded in an early Alpine stage (Cimmerian deformation) and partially reworked in a later, main Alpine stage (middle to late Tertiary).

In central Wakhan, where Urgunt valley is located, the fault zone is to be identified with the Amu Darya valley bottom and is largely covered by alluvial sediments.

Outline of geology of the Urgunt valley

Apart from extensive glaciers and Quaternary deposits, two main formations occur in the Urgunt valley:

a) a Slate Formation in the upper part, including the highest peaks along the Afghanistan-Pakistan border, and

b) a leucogranitic body in the lower part.

The granite is intrusive into the Slate Formation, and the contact is generally very sharp, being characterized by a small contact aureole. A relatively narrow band of migmatitic gneiss is well exposed at the very end of the Urgunt valley, where it passes into the Amu Darya valley. The geological sketch-map of fig. 1 shows these main features. Thick talus deposits, which have developed to an unusual extent and thickness, testify the rapid uplift of the whole region (see for instance HAMRABAEV et al., 1976).

The Slate Formation

The Slate Formation is a complex built by a thick sequence of various lithologic types, by far the most common being black (graphitic), strongly laminated, mm- to cm-thick slates. Other rock types include graphitic siltites rarely grading into sandstones (mainly orthoquartzites and arkoses), and subordinately into marls. Impure, non-fossiliferous limestones are also present. Field and petrographic observations suggest that the depositional environment has been from littoral to infraneritic, and that the formation cannot be regarded as a typical turbiditic complex.

The thickness of the whole formation is estimated to be no less than 2,000 m, and is most probably well over this figure. Gravity translation structures are a most important feature: slump bedding, piled folds, contorted stratification, intraformational thrust structures, slump overfolds or recumbent slump folds and in some cases also overturned slump folds are common. The amplitude of the folds ranges from a few meters to about one km. Décollement structures can be observed, and in some cases also « pelitic injections » typical of siltitic marls. Elsewhere the Slate Formation is characterized by chaotic deposits most probably representing submarine sliding.

By generally showing a dimensional preferred orientation of quartz grains and/or sutured quartz boundaries, quartzites and arkoses give evidence of either light dynamic deformation or of weak, mainly static recrystallization. Several types of static growth, as for instance comb structures in orthoquartzites and « cross micas » (muscovite, chlorite and subordinate biotite) in minute, isolated flakes transversal to the bedding or to the main foliation in pelitic and semi-pelitic rocks, are also common. The generally faint metamorphic imprint has often brought about a mere induration of the slates, and has seldom erased the primary sedimentogenic character.

The Urgunt granite

The Urgunt granite is a composite mass stretching, as far as could be ascertained from reconnaissance field work, for at least 20 km in a ENE-WSW direction roughly parallel to the Amu Darya valley, on its left (orographic) side. In the proximity of Urgunt valley but also elsewhere along the main valley the outcrops consist of a more or less migmatitic gneiss, which is from some hundreds of meters to more than 1 km wide, and gradually gives way to the granitic rocks. In the Urgunt valley the granitic body is about 8 km wide.

The plutonic mass consists of fine- to medium-grained, two-mica leucogranitic rocks. Various facies occur. Close to the contact with the Slate Formation the granite

TABLE 1

Mineralogical and chemical composition (average, $n = 6$; standard deviation in parentheses) of the main facies of the Urgunt granite

Quartz	32.3	SiO_2	73.42	(± .56)
K-feldspar	26.4	TiO_2	.18	(± .03)
Plagioclase (An 10 to 15)	26.6	Al_2O_3	15.29	(± .26)
Muscovite	10.7	Fe_2O_3	1.44	(± .22)
Biotite	3.5	MnO	.02	(± .01)
Accessories (mainly apatite)	0.5	MgO	.28	(± .05)
	100.0	CaO	.81	(± .08)
		Na_2O	2.31	(± .06)
		K_2O	5.10	(± .17)
		P_2O_5	.35	(± .09)
		H_2O	.80	

is quartz-rich, fine-grained and carries no biotite. In the central part of the pluton the texture is distinctly even-grained and isotropic; biotite is present, but is very subordinate to white mica. The latter mineral is mostly interstitial, and often occurs as large plates intergrown with minor biotite. The textural relations suggest that such mode of occurrence is not due to biotite overgrowth on muscovite, but rather to an equilibrium intergrowth. The rocks are remarkably fresh. The mineralogical composition and the chemical composition (average of 6 chemical analyses, with standard deviation) is shown in table 1. The data closely conform to the averages of leucogranites recorded by DIDIER & LAMEYRE (1969).

A porphyritic facies, with well-developed K-feldspar megacrysts up to 4 cm long, is exposed close to the main valley and takes on more or less foliated textures until, when approaching the Amu Darya valley, a gneissose-loocking two-mica granitic rock prevails. Black tourmaline crystals can be found in all facies of the granite, but are especially abundant close to the Slate Formation. Xenoliths of various sizes, up to more than hundred meters across, are common in the pluton. At least some of them, which show a rather flat, subhorizontal contact and occur in the uppermost reaches of the mountains delimiting the lower part of the valley, are most probably remnants of the metamorphic cover.

The gneiss complex

Layered, augen, flaser and cataclastic textures can be observed in the gneissic rocks. White mica is again more abundant than biotite. However, while deformation textures as a rule are prevalent close to the great fault in the Amu Darya valley and tend to conform to the regional ENE-WSW trend with a 40-45° dip to the south, there is also evidence of a late mainly thermal event which caused widespread recrystallization of quartz and feldspar, and probably originated large, non-deformed K-feldspar porphyroblasts. The earlier, foliated textures are thereby frequently obliterated, and in several localities migmatitic rocks have been formed. Nebulitic inclusions and structures in a strongly heterogranular, leucocratic (granitoid) and more or less isotropic matrix are common; pegmatoid patches, pods and veins, the latter most often of aplitic composition, are also widespread. Such mesoscopic structures can, however, very seldom be traced for more than some tens of meters.

Structure

The general structural pattern displayed by the Slate Formation as a whole is simple. It consists of a large asymmetric syncline with an apparently subhorizontal axis trending roughly N 55-60° E across the central part of the valley. The syncline has steep limbs: the northern one is steeper and irregularly truncated by the granitic body, while the southern one shows major ondulations and rises towards the crest of the Hindu Kush range. Pegmatitic to aplitic, quartz-rich dikes and veins of any size, obviously connected to the granite intrusion, in some places cut the traslation structures of the Slate Formation and in others are truncated by them. Elsewhere, and especially at a great distance from the contact, they underwent the same type of deformation affecting the Slate Formation. It is therefore inferred that both the large-scale and small scale displacement of the formation can be attributed to the granite emplacement.

This idea is also supported by the parallelism of the structural trend of the Slate Formation and of the axis of the (elongated) granitic body. By variously displacing and injecting the Slate Formation the granite intrusion heated up the earlier rocks, but the overall effect although widespread is rather small owing to the high level of intrusion. The conspicuous cross-cutting relationships point to a diapir-like intrusion; both the lack of fluxion structures typical of synkinematic granites and the mineralogical composition similar to that generally held to be representative of postkinematic granites support this conclusion.

K/Ar ages

Muscovite of the main, non-porphyritic granitic facies has been considered apt for age determination. Accordingly, muscovites from two samples (HK 1 and HK 32), collected about 1 km from each other, have been concentrated using the standard enrichment methods, and carefully checked in order to avoid admixtures of the biotite-muscovite intergrowths. The choice of muscovites for the radiometric measurements has been dictated by its noteworthy abundance in the rocks (7.2 to 11 in volume per cent) and consequent ease of separation, and by the well-known standardization and simplicity of experimental procedures, which allow a remarkable

TABLE 2

K/Ar age determinations of muscovites of the Urgunt valley

sample	^{40}Ar rad. CCSTP / g	^{40}Ar rad. %	% K	t ± ε (m.y.*)
HK 1	2.2734 10^{-5}	91.57	9.02	62.1 ± 1.2
HK32	2.3752 10^{-5}	85.82	9.05	64.6 ± 1.4
HK36	2.7850 10^{-5}	83.01	9.09	75.2 ± 1.5
HK37	2.9187 10^{-5}	91.38	7.80	91.5 ± 1.8

* m.y. = million years

accuracy. But most important is the fact that the textural features of the rocks as well as the field relationships of the plutonic body and of the intruded Slate Formation show no evidence of subsequent deformation, metamorphism, and/or magmatic activity. These conditions would conform to the requirements of an « ideal » clock (DAMON, 1970). It can be assumed, therefore, that the cooling ages represent formation time, or in other words, that the K/Ar blocking temperature — which for muscovite and phengite is known to be around 350° — satisfactorily documents the cooling of the granite intrusion.

The radiometric K/Ar age of muscovites of two samples (HK 36 and HK 37) from the gneissose facies at the outlet of the Urgunt valley into the major Amu Darya valley, collected close to each other, has also been determined. The aim was to gain an insight into the age relations of the marginal gneiss and migmatite complex, which in the field does not suggest an obvious relationship to the granite.

The argon determination has been made by isotopic dilution using the mass spectrometer MS 10 of the A.E.I.; for extraction the technique perfected by NICOLETTI & PETRUCCIANI (1977) has been employed. The determination of potassium has been carried out using the spectrophotometer 243 of the E.I. with Li as internal standard. Age determinations carried out on laboratory and international standards gave the following results (standard in parentheses): muscovite P 207 80.2 ± 1 (81 ± 1); muscovite Bern 4 M 18.1 ± 0.8 (18.7 ± 0.5); biotite Elba 73 ± 0.4 (7.1 ± 0.3); biotite LP 6 123 ± 3 (125 ± 2); phonolite M 2 7.5 ± 0.3 (7.4 ± 0.2); obsidian M.te Arci 2.95 ± 0.2 (3 ± 0.2).

The results are shown in table 2.

Discussion

A difficult problem arises from the 75 (± 1.5) and 91 (± 1.8) m.y. age determinations of muscovites from the Urgunt gneiss, which can be identified with the Qala Wust gneiss of Desio et al. (1968). Since there is every reason to assume that these muscovites are coeval, it is apparent that the above ages are due to argon loss or respectively gain in a system subjected either to a complex thermal history, or to a strong tectonic activity and/or metasomatism. It will be recalled that the Baikalian basement is extensively exposed, mostly as high-grade gneisses and related rocks, in the Nuristan-Eastern Hindu Kush tectonic zone (in central and south Badakhshan, SW of Wakhan: see for instance Desio et al., 1964), and that slices or tectonic wedges consisting of it are known to occur along the Zebak-Munjan-South Pamir fault (Belyaevsky, 1976; Kafarskiy & Abdullah, 1976). It can then be speculated that the ascent and intrusion of the Urgunt magma, possibly aided by reactivation of the South Pamir fault, brought about extensive reheating and recrystallization in a slice of basement close to the Urgunt valley, and locally favoured partial melting and migmatite development as well. In such circumstances argon loss from muscovites must be expected and the resulting ages may not be geologically significant (e.g., Shafiqullah & Damon, 1974).

As for the Slate Formation of the Urgunt valley, which can be identified with the Khandut Slates of Desio et al. (1968), there is little doubt that it must be attributed to the late Paleozoic or Triassic in accordance with the age generally given to black slates elsewhere in Wakhan (Kafarsky & Abdullah, 1976; Norin, 1976).

While turning to the age of the Urgunt granite, it must be kept in mind that any extension of the muscovite radiometric ages to the granitic body is subject to an unknown degree of approximation. Besides the well-known limitations of the single sample conventional K-Ar determination (see for instance Harper, 1970; Shafiqullah & Damon, 1974), the possibility of excess Ar^{40} incorporation into the granitic melt (Fyfe et al., 1969) should also be taken into account. However, leaving aside the possible source of error caused by the latter, the mineralogical and textural relations of the Urgunt granite warrant with reasonable confidence, as has been previously observed, the extension of the muscovite ages to the granite intrusion.

According to the time scale in Van Eysinga (1975) the radiometric clock indicating the cooling ages of muscovites from the Urgunt granite has been set in the early Paleocene. Assuming that the 62-64 m.y. radiometric ages of the Urgunt muscovites also adequately represent the age of the same composite body of granite well beyond the limits of the Urgunt valley, and that two-mica granites are typical representatives of orogenic, post-tectonic magmatic activity, the placing of this area in a structural zone of early Alpine deformation with no subsequent major movements appears to be substantially correct. In the Nuristan-Eastern Hindu Kush tectonic zone middle- to upper-Cretaceous ages (86-93 m.y.: DESIO et al., 1964) have been obtained, admittedly with some uncertainty, from a small granodioritic body near Zebak not far away from Wakhan, while for the Tirich Miri granite, which belongs to the axial batholith of the Eastern Hindu Kush range, a lower Cretaceous radiometric age (115 ± 4 m.y.) is recorded (e.g., DESIO, 1977). The latter ages are, however, still dubious and in some papers (e.g., GAMERITH, 1973) a Tertiary magmatic activity is assumed. Since the early Paleocene age of the leucogranitic, diapiric Urgunt intrusive mass seems to be quite reliable, acceptance of the classical division of orogenic granites into syntectonic and post-tectonic types adds weight to the likeliness of a substantially earlier, i.e. Cretaceous age for the igneous activity related to the axial Eastern Hindu Kush batholith (Babatangi-Lunkho granodiorite).

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