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# THE METAMORPHISM AND AGE OF THE MUŞ-KIZILAĞIÇ METAGRANITE

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ABSTRACT.— The Muş-Kızılağıç leucogranite intruded into the Bitlis metamorphic rocks sometime between Middle Devonian and Late Permian. It was cataclastically metamorphosed by regional metamorphism in Lower Turronian (95 my) following the compression of the continental crust within which it occurs. This medium-pressure and low-temperature metamorphism locally obliterated the primary mineralogy and texture of the granite producing quartz-feldspar-phengite gneisses. The emplacement of an ophiolite nappe over the Bitlis metamorphics in Upper Campanian (75 my) caused reheating of the metagranite through burial.

## INTRODUCTION

Acidintrusive rocks are widely exposed within the Bitlis Metamorphic Belt, especially to the south of Bingöl, southwest of Muş, south of Mutki and around Hizan. The granitic rocks around Muş-Kızılağıç are exposed over an area of approximately 250 km$^2$ and form the largest exposed acid magmatic body in the Bitlis Metamorphics. This body has been termed, mapped and studied as the « Muş-Kızılağıç metagranite» (Fig. 1).

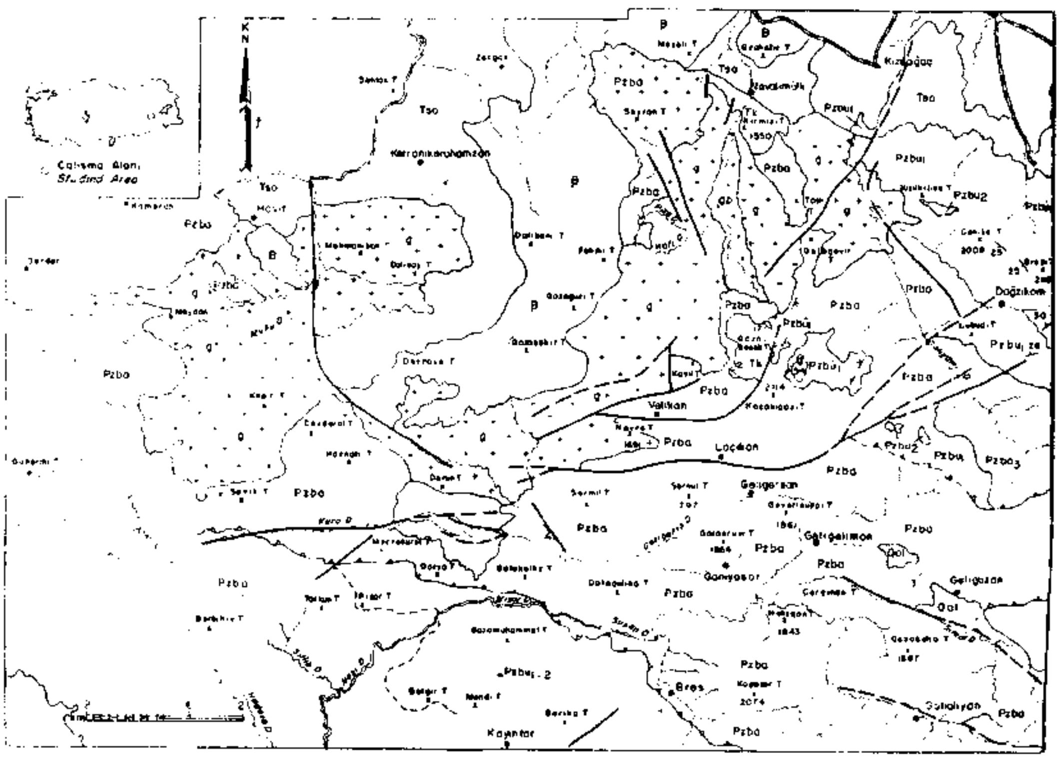


Fig. 1 - Geological map of the Muş-Kızılağıç area. Pzba-Hizan Group; Pzba$_3$-Ohin schists; Pzbü$_1$-Meydan Fm.; Pzbü$_2$-Çırnık Lst.; Tk-Kızılağıç Fm.; Tso-Solhan Fm.; β -Basalt.

The Muş-Kızılağıç metagranite generally lies within the Lower Unit (Göncüoğlu and Turhan, 1983) and is in tectonic contact with the surrounding rocks. At Ko9akigazi Tepe in the study area, the metagranite is observed as intruded into the marble belonging to the lower levels of the Mutki Group. The same relation is also observed elsewhere in the Bitlis Metamorphics e.g. NW of Kesendere, Mutki and SE of Merment. The intruded marbles contain Middle Devonian fossils in the east of Bitlis (Göncüoğlu and Turhan, 1983). Granite pebbles are found at the base of the recrystallised limestone which overlies the lowermost formation ofthe Mutki Group (composed of marble and metasandstone and intruded by the metagranite) in the west of the village of Ka9it located to the southwest of Çatak. Fossils of Lower Permian age are found in the recrystallised limestone at various locations in the Bitlis Metamorphic Belt (Göncüoğlu and Turhan, 1983).

The evidence presented above shows that the metagranite intrusions in the Bitlis Metamorphic Belt took place sometime between Middle Devonian and Lower Permian. On the other hand, Yılmaz (1971) puts forward that the granites around Cacas, located in the southern part of the Bitlis Metamorphic Belt, were emplaced during the Sudetian phase of the Hercynian Orogeny (345 my). This age which was determined on the basis of incomplete evidence but is in agreement with our geological observations is stated as an assumed age in the above author's revision study (Yılmaz et al., 1981) where it is pointed out that the actual age varied from 570 my to 100 my. Helvacı (1983) proposes an age of 347±52 my for the intrusion of the Yayla granite occurring in the eastern part of the Bitlis Metamorphic Belt based on a poorly defined Rb/Sr isochron. It is also put forward that the intrusion age of the Avnik granite lies inbetween 425 my and 250 my. All these ages indicate that the acid intrusive rocks in the Bitlis Belt are most likely related to the same magmatic phase.

The geological evidence related to the age of metamorphism of the Muş-Kızılağıç metagranite suggests a wide range of geological times. The youngest metamorphosed unit in the Bitlis Metamorphic Belt in which the metagranite is located, is the unit formed by the volcanosedimentary rocks of Triassic age (Savcı et al., 1979). On the other hand, the Upper Maestrichtian flysch in the Bitlis Metamorphic Belt (Meriç, 1973) is not metamorphosed. Thus, the metamorphism must have taken place in the period between the Triassic and Upper Maestrichtian.

Samples were collected across a north-south trending traverse along Gelialiyan stream at the southest of Muş-Kızılağıç where freshest exposures in the Bitlis Metamorphic Belt are found. The samples were then studied at Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) in order to check the above mentioned ages determined on the basis of geological observations.

## THE PETROLOGY AND METAMORPHISM OF THE MUŞ-KIZILAĞIÇ METAGRANITE

The Muş-Kızılağıç metagranite macroscopically is medium-grained, light-coloured and with fairly-developed foliation. The size of the pale-pinkish coloured K-feldspar porphyroclasts locally exceeds 1 cm. Microscopically, the rock contains K-feldspar, quartz, plagioclase ($An_{18}$), phengitic muscovite, clinozoisite, biotite, zircon, apatite, rutile, magnetite and pyrite (Table 1). Mylonitic texture and recrystallisation are the conspicuous features in thin sections.

**Table 1 - Modal analyses of the Muş-Kızılağıç metagranite**

| *Mineral* | *BM1a1* | *BM1a2* | *BM1b1* | *BM1b2* |
|---|---|---|---|---|
| Quartz | 37.4 | 38.7 | 38.1 | 39.3 |
| K-feldspar | 48.6 | 49.0 | 50.2 | 48.8 |
| Plagioclase | 8.3 | 6.1 | 5.9 | 6.3 |
| Phengite | 5.4 | 6.1 | 5.7 | 5.4 |
| Clinozoisite | 0.2 | 0.1 | 0.1 | 0.2 |
| Rutile | 0.1 | — | — | — |

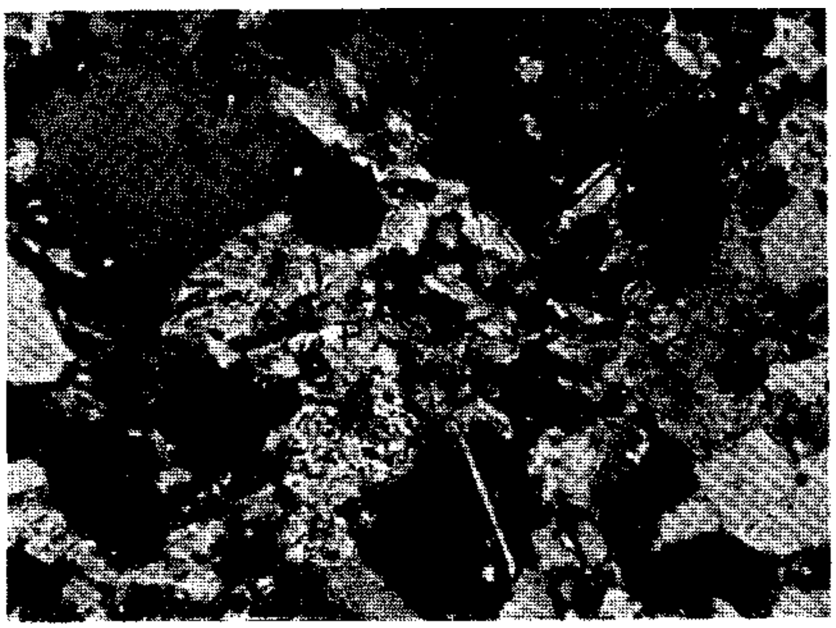

Fig. 2 - Large phengite crystals containing clinozoisite and biotite inclusions; probably altered from biotite.
(P-phengite; Kz-clinozoisite; F-feldspar); X 75, crossed-nicols.

Table 2 - Chemical compositions of the Muş-Kızılağıç metagranite

| | *BM1a1* | *BM1a2* | *BM1b1* | *BM1b2* |
|---|---|---|---|---|
| $SiO_2$ | 77.34 | 76.80 | 76.75 | 77.58 |
| $TiO_2$ | 0.06 | 0.05 | 0.05 | 0.05 |
| $Al_2O_3$ | 12.48 | 12.53 | 12.71 | 12.35 |
| $Fe_2O_3$ | 0.76 | 1.08 | 0.94 | 0.89 |
| MnO | 0.01 | 0.04 | 0.02 | 0.01 |
| MgO | 0.08 | 0.02 | 0.05 | 0.03 |
| CaO | 0.10 | 0.18 | 0.20 | 0.07 |
| $Na_2O$ | 3.96 | 3.96 | 3.88 | 5.00 |
| $K_2O$ | 4.75 | 4.77 | 7.75 | 3.56 |
| $P_2O_5$ | 0.02 | 0.02 | 0.02 | 0.03 |
| $SO_3$ | 0.01 | 0.02 | 0.01 | 0.02 |
| Rb (ppm) | 241 | 237 | 247 | 125 |
| Sr (ppm) | 8 | 6 | 8 | 12 |

## Metamorphism

It is apparent from the petrographic descriptions that the granitic rocks of the studied area have to a large extent lost their primary textures and mineralogical composition as a result of dynamo-metamorphism and transformed into quartz-microcline-albite-phengite schist where the recrystallisation is intense.

The most informative mineral for the conditions of metamorphism under which the new paragenesis developed is phengitic mica. According to Brown (1968), the chemical composition of phengites reflects largely the metamorphic conditions as well as the pre-metamorphism whole-rock composition.

The Muş-Kızılağıç metagranite and the included phengites do not exhibit large compositional variations as seen in Tables 2 and 3. This indicates that the P and T conditions that caused the development of phengites prevailed monotonously in the initial rocks that had similar chemical compositions.

Table 3 - Chemical compositions and RM-2P parameters of the phengites from the Muş-Kızılağıç metagranite (2P:after Graeser and Niggli, 1967; and RM :after Frey et al., 1983).

| | *$Pha_1$* | *$Pha_2$* | *$Phb_1$* | *$Phb_2$* |
|---|---|---|---|---|
| $SiO_2$ | 48.39 | 49.84 | 48.99 | 53.51 |
| $TiO_2$ | 0.25 | 0.23 | 0.34 | 0.19 |
| $Al_2O_3$ | 25.56 | 25.11 | 75.28 | 23.90 |
| $Fe_2O_3$ | 5.99 | 6.64 | 6.41 | 5.52 |
| FeO | 1.31 | 1.58 | 1.37 | 0.89 |
| MnO | 0.07 | 0.08 | 0.08 | 0.02 |
| MgO | 2.11 | 0.97 | 1.63 | 1.56 |
| CaO | 0.22 | 0.22 | 0.31 | 0.08 |
| $Na_2O$ | 0.25 | 0.16 | 0.15 | 0.21 |
| $K_2O$ | 10.51 | 9.87 | 10.13 | 9.26 |
| $P_2O_5$ | 0.02 | 0.02 | 0.03 | 0.02 |
| $SO_3$ | 0.07 | 0.07 | 0.06 | 0.03 |
| LOI | 5.19 | 4.85 | 4.97 | 5.00 |
| Rb (ppm) | 816 | 741 | 761 | 529 |
| Sr (ppm) | 6 | 6 | 8 | 10 |
| 2P | 29.1 | 19.4 | 24.9 | 21.2 |
| RM | 0.15 | 0.16 | 0.16 | 0.14 |

**Table 4 - Structural formula of the phengites from the Muş-Kızılağıç metagranite (on basis of 22 oxygens).**

| | |
|---|---|
| $Pha_1$ —— | $(K_{1.84}Na_{0.07}Ca_{0.03})$ 1.94 |
| | $(Al_{3.75}\overset{+3}{Fe}_{0.62}Ti_{0.03}Mg_{0.43}\overset{+2}{Fe}_{0.15}Mn_{0.01})$ 3.99 |
| | $Al_{1.37}Si_{6.63}O_{20}(OL)_4$ |
| $Pha_2$ —— | $(K_{1.72}Na_{0.04}Ca_{0.03})$ 1.80 |
| | $(Al_{2.82}\overset{+3}{Fe}_{0.68}Ti_{0.03}Mg_{0.20}Fe_{0.18}Mn_{0.01})$ 3.92 |
| | $Al_{1.21}Si_{6.79}O_{20}(OH)_4$ |
| $Phb_1$ —— | $(K_{1.77}Na_{0.04}Ca_{0.05})$ 1.86 |
| | $(Al_{2.76}\overset{+3}{Fe}_{0.66}Ti_{0.04}Mg_{0.33}Fe_{0.16}Mn_{0.01})$ 3.96 |
| | $Al_{1.31}Si_{6.69}IO_{20}(OH)_4$ |
| $Phb_2$ —— | $(K_{1.58}Na_{0.06}Ca_{0.01})$ 1.66 |
| | $(Al_{2.88}\overset{+3}{Fe}_{0.55}Ti_{0.02}Mg_{0.31}\overset{+2}{Fe}_{0.10}Mn_{0.01})$ 3.87 |
| | $Al_{0.88}Si_{7.12}O_{20}(OH)_4$ |

It is thought that the appropriate chemical rock compositions in the studied samples gave rise to the formation of phengite at the expense of muscovite under the P and T conditions discussed below with the reaction (v.d. Plas, 1959);

**Muscovite + Biotite + K-feldspar + Water $\lesseqgtr$ Phengite.**

That such a reaction took place is supported especially by the presence of biotite relics in the large phengite-blasts.

The studies of Lambert (1959) and Ernst (1963) show that with rising temperature the phengite component of white micas and their $SiO_2$ contents decrease paving the way for muscovite to become a stable phase. Beran (1969), using the above anthers' studies takes the phengites in the granitic-gneisses of the Eastern Alps as typomorphic for the «quartz-aroite-muscovite (phengite)-chlorite» sub-facies i.e. the lowermost sub-tacies of the greenschist fades. Ernst (1963) proposes that the P and *T* conditions necessary for the nhengite-muscovite transition correspond to the conditions of the biotite isograd in pelitic-schists. Velde (1965, Figs. *2* and 6) who carried out experimental work related to the formation of phengite states while determining the stability field of the natural phengites that at constant pressure the reaction of v.d. Plas (1959), given above, would be realised by decreasing temperature. Cipriani et al., (1971) point out that the Mg and Na contents of metamorphic white micas would be of great use in determining the metamorphic conditions. The Muş-Kızılağıç samples have been plotted on the Na/Mg diagram developed by the last mentioned authors. Although all the samples except one have the sance ordirate values as those of the medium to high pressure field, they fall outside the defined field (Fig. 3). Therefore the pressure fields defined by Cipriani et al., (1971) are extended towards lower Na values by the samples from Muş-Kızılağıç The low Na content of the phengites provides further evidence that the temperature was not high according to the experimental work of Eugster and Yoder (1955).

It is proposed that the metamorphism of the Muş-Kızılağıç metagranite took place at low temperature ( ~ 400°C) and middle to high pressure (approximately 5 kb), considering together the studies by Velde (1965, Fig.2), Winkler (1976, Fig. 15/2) and Cipriani et al., (1971, Fig.11) and based on the observations in the samples that oligoclase has formed at the expense of albite and clinozoisite is stable together with phengite.

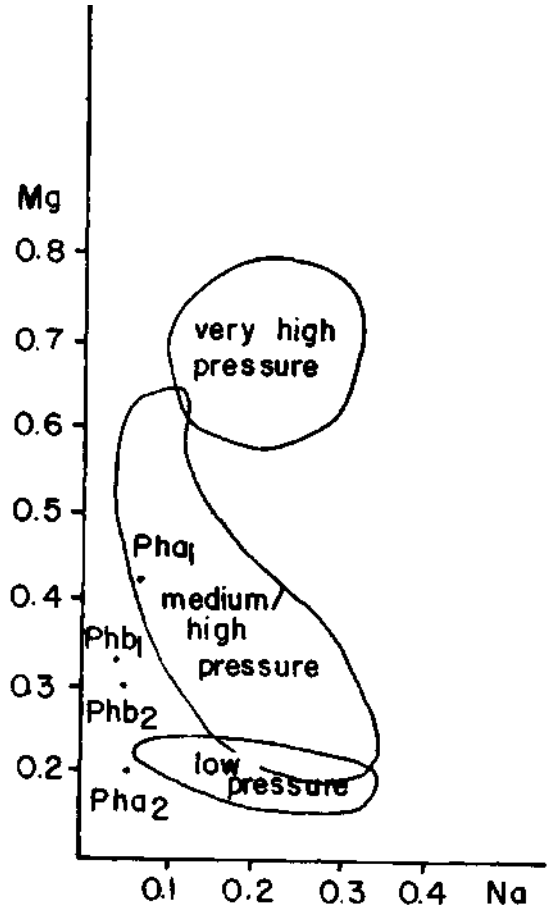


*Fig. 3* - Distribution of white micas from various metamorphic facies according to their Mg/Na values (After Cipriani et al., 1971).

## GEOCHRONOLOGY

Measurements of the whole-rock Rb/Sr ratio, the mineral Rb/Sr ratio and the mineral K/Ar ratio have been carried out together, in order to determine the intrusion and metamorphism ages of the Muş-Kızılağıç metagranite.

### Method

The samples collected for the geochronological study were taken from the freshest parts of the rocks along a 3 km long north-south trending profile and apparently free from joints and cracks. The samples whose weight varied from 7 to 11 kg were first broken in a jaw-crusher to sizes <5 cm and the altered parts were removed. Then they were fragmented down to the sizes <1 cm. The representative samples for the whole-rock Rb/Sr measurement were prepared following the method proposed by Müller (1979). The BGR-Hannover method was applied for the Rb and Sr chemistry. For the analysis of Rb a spike ($Rb^{85}/Rb^{87}$-- 0.007935) which was prepared in the same laboratory and for Sr the spike SRM 988 were used. The Rb isotopes were measured by an «Aldermaston Micromass 30» type mass-spectrometer with double filament and the Sr isotopes by an «Atlas CH4» type mass-spectrometer with a single filament.

The dry Wilfley table has been used to concentrate the phengite grains in addition to the conventional methods.

Phengite grains of 4 different sizes have been concentrated from each sample for the measurements. In this way, the possibility that phengite grains of different chemical compositions and ages could be treated altogether was taken under control.

The method applied for the Rb/Sr whole-rock samples was also used for the Rb/Sr isotope dilutation measurements of the phengites. The K content of the phengites was measured by a double-channel digital pipetted flame photometry of the type EEL-170 which had Li-internal standard. The Ar isotope ratios were measured by the Ar-extraction system developed by H-Kreuzer through increasing the temperature in steps up to 1480°C. Each of the two different sizes of phengite concentrates (99 % pure) from every sample were measured twice for the K/Ar isotopes and the analytical conditions were checked through including the international standard Gl-0 into every series of measurement.

The relative errors in the measurements of $Rb^{87}/Sr^{86}$, $Sr^{87}/Sr^{80}$ and K are 1.5 %, 0.1 % and 0.06 % respectively. The constants for Rb/Sr were taken from Steiger and Jager (1977) and the isochron calculations were carried out by the least squares method of York (1967).

## Rb/Sr whole-rock systematics

The whole-rock Rb/Sr measurement points of the Muş-Kızılağıç metagranite do not form an isochron as seen in Table V. This is a common phenomenon of the metagranites in the Bitlis Metamorphic Belt (Yılmaz, 1981; Helvacı, 1983). The fact that the Rb/Sr method which is generally considered to be the most reliable method for the determination of the intrusion or metamorphism ages, does not yield an isochron in the studied area can be explained in two ways:

**Table 5 - Rb/Sr analytical data of the Muş-Kızılağıç metagranite and phengite**

| *Sample* | *Measured* | *$Rb^{78}$* | *$Sr^{68}$* | *$Rb^{87}/Sr^{86}$* | *$Sr^{87}/Sr^{86}$* | *Age (a) (my)* | *Age (b)(my)* |
|---|---|---|---|---|---|---|---|
| BM1a1 | Whole-rock | 76.55 | 0.8169 | 81.74 | 0.96385 | — | — |
| | Phengite (Pha1) | 305.5 | 0.5768 | 524.5 | 1.4715 | 80.7±1.5 | 102±1.5 |
| BM1a2 | Whole-rock | 66.67 | 0.7416 | 88.87 | 0.94368 | — | — |
| | Phengite (Pha2) | 301.6 | 1.0053 | 296.6 | 1.1644 | 75±1.7 | 108±1.6 |
| BM1b1 | Whole-rock | 68.79 | 0.8314 | 81.79 | 1.01721 | — | — |
| | Phengite (Phb1) | 300.2 | 0.8096 | 366.5 | 1.2646 | 62±1.3 | 107±1.6 |
| BM1b2 | Whole-rock | 34.30 | 1.1530 | 29.41 | 0.89861 | — | — |
| | Phengite (Phb2) | 273.6 | 1.0101 | 232.5 | 1.0378 | 48±1 | 99±1.5 |

**Age (a): the phengite age is calculated with the common Sr($^{87}Sr/^{86}Sr = 0.71014$).**
**Age (b): the phengite age is calculated together with the corresponding whole-rock (whole-rock/mineral isochron).**

a. The size of the collected sample is not suitable for the investigation of the tematics. While the distribution of Rb/Sr in the whole of the metagranite forms a closed-system, the system is open on the collected-sample's scale or the Rb/Sr homogenisation has not been realised at this scale. The first evidence supporting this explanation is the differing deformations and recrystallisations observed at limited areas. The second is the structure of the whole-rock-phengite isograd discussed later.

b. The regional distribution of Rb/Sr in the Muş-Kızılağıç metagranite has not been given adequate consideration. Therefore, the selection of samples with high Rb/Sr ratios as the ideal condition for the Rb/Sr whole-rock systematics has not been realised. The Rb/Sr whole-rock isochron will most probably have formed with larger and greater number of samples.

## Rb/Sr phengite systematics

The age systematics of the Muş-Kızılağıç phengites is given in Table V. An age interval of 99 my to 108 my is produced when the measured phengite isotope ratios are corrected with the common Sr ($^{87}Sr/^{86}Sr$= 0.71014). On the other hand, ages of 81 my and 48 my are indicated when the same phengite isotope ratios are corrected with the Sr isotope ratios of the corresponding rock samples (whole-rock/mineral isochron). This rather wide interval of rock-mineral ages indicates that the equilibrium between the whole-rock Rb/Sr isotope distribution and the mineral Rb/Sr isotope systematics has not materialised. Consequently, this may be taken as evidence of inadequate isotope homogenisation pointed out earlier while discussing the whole-rock systematics. Furthermore, it is determined by microscopic observations that the formation of phengites is a result of the final metamorphism. Therefore, the corrections made with the whole-rock values will not be meaningful.

An interesting scene is produced when the measured values of the Muş-Kızılağıç phengites are plotted in the Nicolaysen diagram (Nicolaysen, 1961); the mineral-mineral isochron used in general for the different minerals of the same rock comes out as aphengite-phengite isochron for the Muş-Kızılağıç sample (Fig.4). The ordering of the four phengite samples in such a way as to form an isochron and the common initial Sr value they share demonstrate that the phengites formed together. These samples produce an age of 95 ± 4 my and a quite high initial Sr value of 0.7657 ± 0.019. It is thought that the high initial Sr value may have been inherited from the biotite with high common Sr values during the biotite-phengite transformation.

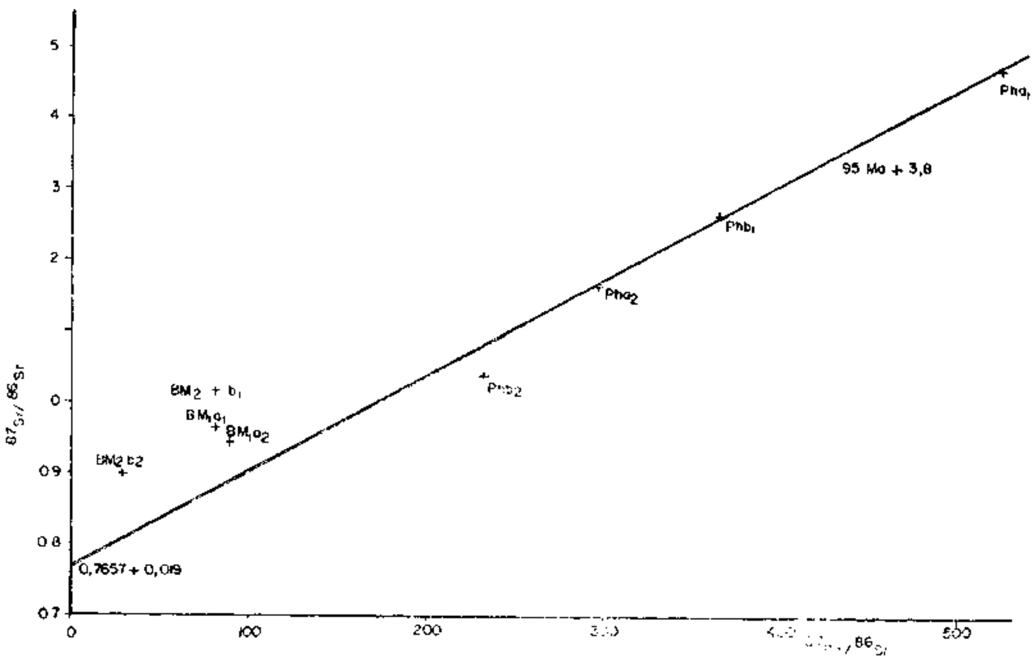


**Fig. 4** - The Nicolaysen diagram of the Muş-Kızılağıç whole-rock and phengite samples. BM-whole-rock; Ph-phengite.

The ages of 99-108 my determined by correcting the isotope ratios measured from the phengites with the common Sr and of 95 ± 4 my determined by the phengite-phengite isochron converge into and support one another within the limits of error.

Jager (1979) states that the blocking temperatures of the phengites for Rb/Sr in the Central Alps are around 500°-550°C. The author points out that the ages determined by the Rb/Sr method in the micas developed during the greenschist metamorphism under such temperatures would directly produce the age of formation of the micas. If it is assumed that the metamorphism of the Muş-Kızılağıç metagranite was realised at temperatures around 400°C as discussed earlier, then it becomes apparent that the determined age of 95 ± 4 my is the age of formation of the phengite, hence the age of metamorphism.

## K/Ar mineral age

The K/Ar modal age of the phengites from the Muş-Kızılağıç metagranite is established to be 75 my within the limits of error (Table 6).

**Table 6 - K/Ar analytical data of the phengites from the Muş-Kızılağıç metagranite**

| *Sample* | *Grain size* | *% K* | *40 Ar rad* | *% rad* | *40K/36Ar 10³* | *40Ar/36Ar* | *Modal age(my.)* |
|---|---|---|---|---|---|---|---|
| $Pha_1g$ | 200-125 | 8.58 | 262.3 | 96.0 | 1619 | 7694 | 77 ±1.2 |
| $Pha_1f$ | 90-63 | 8.82 | 268.7 | 95.3 | 1359 | 6486 | 76.7±1.2 |
| $Pha_2g$ | 200-125 | 8.37 | 248.3 | 93.43 | 974 | 4617 | 74.8±1.2 |
| $Pha_2f$ | 90-63 | 8.67 | 258.2 | 94.07 | 1086 | 5132 | 75 ±1.2 |
| $Phb_1g$ | 200-125 | 8.31 | 250.9 | 94.57 | 1178 | 5613 | 76.1±1.2 |
| $Phb_1f$ | 90-63 | 8.67 | 261.6 | 95.52 | 1454 | 6852 | 76 ±1.2 |
| $Phb_2g$ | 200-125 | 8.56 | 250.2 | 96.97 | 1685 | 7661 | 73.7±1.2 |
| $Phb_2f$ | 90-63 | 8.61 | 250.5 | 94.58 | 1228 | 5635 | 73.3±1.2 |

This age which is rather different from the Rb/Sr ages of the phengites is interpreted in various ways:

a. The phengites inherited the radiogenic $^{40}Ar$ from the rock. The determined age is meaningless.

b. The blocking temperature of the phengites for K/Ar is around 350°C (Purdy and Jager, 1976) and the determined age is the cooling age of the system below 350°C after the formation of the phengite.

c. The determined age indicates loss of argon due to events not reflected into the mineralogical composition of the rocks (tectonics, thermal effects etc).

The first of these possibilities can be put aside. The determined ages are stable within the limits of error and they define a straight line in the $^{40}Ar/^{36}Ar$-$^{40}K/^{36}Ar$ diagram as seen in Fig.5 and Table 6. Therefore, it would be most unlikely that the same proportion of $^{40}Ar$ is inherited by all the samples and grain sizes analysed.

A choice between the other possibilities cannot be made solely on the basis of geochronological data. It becomes necessary to consider the geology of the studied area to interpret the 75 my K/Ar age of the phengites.

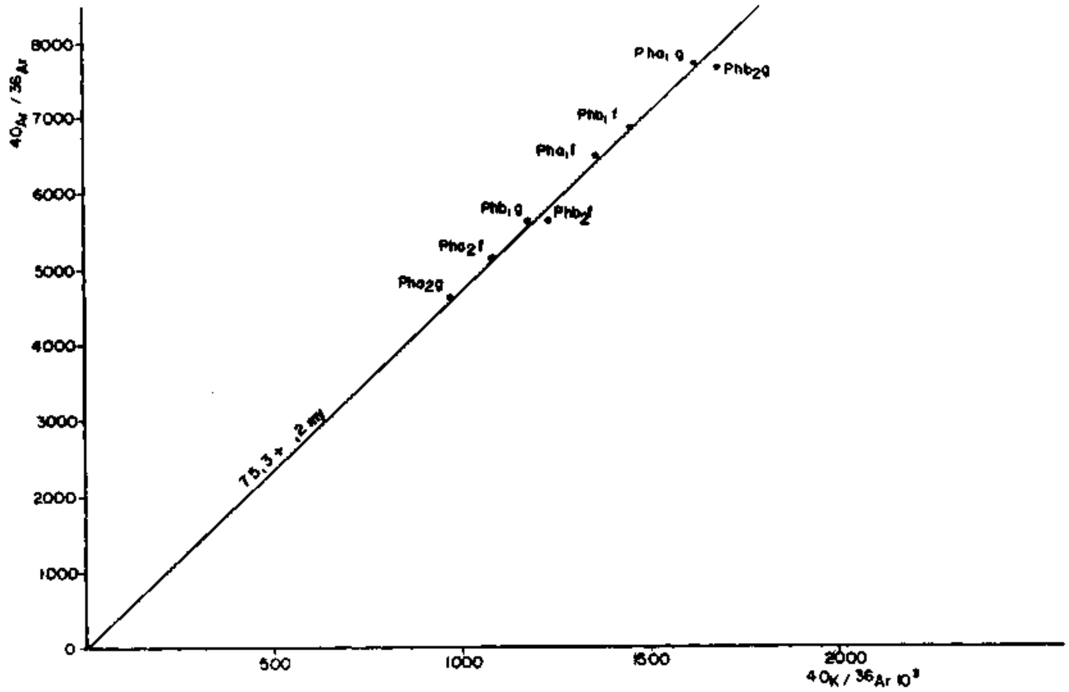


**Fig. 5 - Distribution of the Muş-Kızılağıç phengites in the $^{40}Ar/^{36}Ar - ^{40}K/^{36}Ar$ diagram (compare the measurement points with Table 6).**

It is assumed in the second possibility that the determined age corresponds to the blocking of the phengite for the K/Ar system by the cooling of the metagranite down to temperatures below 350°C. Then the metagranite and the enclosing Bitlis Metamorphics would have to cool at an approximate rate of 5°C/my in the period from 95 my interpreted as the age of formation of the phengite, to 75 my which could correspond to the cooling below 350°C. As far as it is known, this cooling rate is rather a slow rate for the Alpine Belt. On the other hand, geological data show that ophiolitic nappes were emplaced upon the Bitlis Metamorphics during the same time-interval (Göncüoğlu and Turhan, 1983). It is inconceivable that the emplaced ophiolitic nappes caused cooling in the metagranite. Therefore, instead of a cooling in the Bitlis continental crust during the mentioned time interval, reheating must have taken place under the load of the emplaced ophiolitic nappes (Şengör and Yılmaz, 1981) by burial, as assumed by the third possibility.

The fact that the same age is determined from all the analysed samples and grain sizes brings forth the idea of the presence of a thermal event around 75 my which affected the whole unit and caused the opening of the K/Ar system of the phengite. This event was not reflected into the mineralogical composition of the rocks, but responsible for the loss of $^{40}Ar$ from the crystal system of the phengite.

The 75 my age determined by Yılmaz (1971) from chloritised biotites from the Cacas region and the 71 my age determined by Helvacı (1983) in the Avnik region should be the ages related to the reheating.

## CONCLUSIONS

The metagranite in the Muş-Kızılağıç region has been sampled and studied in order to investigate and assign the age of metamorphism and formation of the acid intrusives that are widely exposed in the Bitlis Metamorphic Belt. The geological data show that the intrusion of the metagranite took place sometime between the Middle Devonian and Late Permian.

The Muş-Kızılağıç metagranite which generally exhibits cataclastic deformation and contains phengitic muscovite as a metamorphic mineral has undergone a low-temperature/medium-pressure metamorphism according to the chemical composition of the phengitic muscovite and the metamorphic mineral paragenesis.

The fact that the whole-rock isochron for Rb/Sr in the measured samples is not realised is attributed to the lack of homogenous distribution of Rb/Sr in the rock during the metamorphism.

The phengitic muscovites produced 95 my by the Rb/Sr method and 75 my by the K/Ar method. The former age is interpreted as the age of formation of the phengite, thus the age of metamorphism; and the latter as a secondary effect on the phengite at low temperatures.

It is proposed with the support of the geochronological data that the continental crust material composed of the Bitlis Metamorphics and the acid intrusions intruded during the Palaeozoic was compressed, metamorphosed and started being imbricated during the Lower Turonian; and reheated by burial under the load of the emplaced ophiolitic nappe during the Upper Campanian.

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