acta
geologica
polonica

Vol. 30, No. 4 Warszawa 1980

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K-Ar ages of the Owl Mts gneiss raft

ABSTRACT: K—Ar ages have been found for paragneisses, granite gneisses and pegmatites of the Owl Mts raft. The results fall within the 412—489 MA and 643—655 MA intervals. These ages are younger than the primary age of deposition, metamorphism and folding of the Owl Mts raft. Yet similar disagreements are common in the Precambrian massifs of Central Europe. The age of the gabbro massifs surrounding the Owl Mts raft has been indirectly found to fall between Ordovician/Silurian and Upper Devonian.

INTRODUCTION

The Owl Mts raft is commonly regarded as the oldest structural element of the Sudeten Mountains. Its geological position is the subject of long-lasting discussions (*cf.* Grocholski 1967). The common opinion is that the Owl Mts raft is the only element in the Sudeten Mountains correspoding to the Moldanubian structural stage.

At present, the Moldanubian structural stage is exposed only in isolated rafts, the biggest one being the central "Moldanubicum" which includes the western Moravia, southern Bohemia, northern Austria and eastern Bavaria. Also the metamorphozed rafts in the Saxothuringicum area and the Owl Mts are regarded as Moldanubian elements. Most certainly the Moldanubicum is Pre-Palaeozoic. Evidence pointing to its Archean age is non-existant, yet the fact that the Moldanubian series underlie the Middle Bohemian Proterozoic of the Tepla-Barrandien area implies that the oldest metamorphism was terminated prior to the beginning of the young Palaeozoic depositional cycle. The age of the folding of the Moldanubicum is assumed to be Algoman (Kodym 1961) or Karelian (Schmidt 1966). Because of difficulties in applying the general stratigraphic-geochronological schemes, a local scheme is used and the age of the main folding is defined as Moldanubian.

The relationship of the Owl Mts raft to the main Moldanubian area has been the subject of numerous discussions. Kossmat (1925) and Suess (1935) thought that the Owl Mts raft was detached from the Moldanubian massif and shifted to the north during the Variscan orogeny. Conversely, Bederke (1929) assumed its autochtonous position evidenced by the occurrence of gneiss pebbles in the Devonian sediments of the Świebodzice depression. The autochtonous position is also implied by the distribution of structures regarded as Caledonian controlled by the triangular outline of the Owl Mts raft. In relation to these structures the Owl Mts raft acted as a rigid intra-montane mass (Teisseyre, Smulikowski & Oberc 1957; Teisseyre 1958, 1968). According to Oberc (1966, 1971) the Owl Mts raft constituted a rigid block as early as in the Upper Precambrian and was incorporated in the Assyntian structures.

GEOCHRONOLOGY OF THE OWL MOUNTAINS

The geological history of the Owl Mts gneiss raft is very complex. At present, the only indisputable knowledge is that the metamorphic evolution of the Owl Mts gneisses was terminated before the Upper Devonian, as the Upper Devonian sediments occurring in the close neighbourhood of the Owl Mts raft contain gneiss pebbles similar to those occurring in the Owl Mountains. The chronology of other events that led to the formation of the Owl Mts gneisses is based on indirect evidence and, in view of the heterogeneity and incompleteness of data it is largely hypothetical.

Particular difficulties in establishing the geochronology of such a metamorphic complex as the Owl Mountains stem from the fact that a complete reconstruction of its history requires the determination of: 1) the deposition age of the original sedimentary series, 2) the age of the metamorphism (or of the successive metamorphic stages), 3) the age of folding (or the successive folding stages) and 4) the age of uplift. Previous assessments of the age of these phenomena are rather divergent.

The deposition age of the sedimentary series has been defined as Archean (Oberc 1966, 1968; Grocholski 1967) or Lower Proterozoic (Oberc 1971, 1975).

The age of metamorphism poses even more serious difficulties which stem from the complex polymetamorphic processes which produced the present-day rock assemblage. Presumably, in the course of submergence the original sedimentary series was transformed into rocks of the amphibolite facies, partly of granulite or even eclogite facies, and subsequently, due to retrogressive alterations, found itself again under amphibolite facies conditions. The retrogressive alterations were rapid enough to preserve mineral relics distinctive of deeper facies (sphene, rhombic pyroxene, garnet) and probably at the same time anatexis of the rocks set in leading to the formation of migmatites (Smulikowski 1952, Polański 1955). The latest stage of gneiss alteration is thought to have been homogenization and recrystallization which produced homogenous gneisses (Grocholski 1967). Yet evidence is lacking whether recrystallization is related to the Assyntian or to the Caledonian cycle. According to Oberc (1975) it is connected to Young Assyntian movements.

The age of the ultimate uplift of the gneiss raft is defined on the grounds of appearance of gneiss pebbles in the Devonian.

A separate problem, yet related to the evolution of the Owl Mts raft, is the age of the basic massifs (the serpentinites and gabbros of Sobótka, Ząbkowice Śląskie and Nowa Ruda) occurring in close neighbourhood. These massifs are commonly thought to be Old Palaeozoic or Devonian (Teisseyre 1968), but Oberc regards them as Proterozoic and related to the Assyntian orogeny.

CRYSTALLINE ROCKS OF THE OWL MOUNTAINS

The strongly differentiated rock assemblage formed due to polymetamorphic processes is being defined as the oldcrystalline formation of the Owl Mountains. Within this formation two principal rock groups are distinguished by Grocholski (1967): 1) paragneisses and migmatites and 2) microcline granite gneisses. Additionally, within this formation occur subordinate granulites, crystalline limestones, amphibolites as well as pegmatites, granites, quartz and quartz-feldspar veins and hyperites. Among the crystalline rocks accompanying the gneisses the most suitable for radioactive dating are, due to their coarse-crystalline structure, muscovite and biotite pegmatites.

K—Ar DATING

K—Ar dating has been carried out for rocks of the elevated Sudetic part of the Owl Mts raft, while rocks derived from the low Fore-Sudetic part are represented only by three samples of muscovite pegmatites from a quarry near Różana village (Fig. 1).

The rocks examined belong to the three following groups: 1) paragneisses and migmatites, 2) microcline gneisses of the augengneiss series

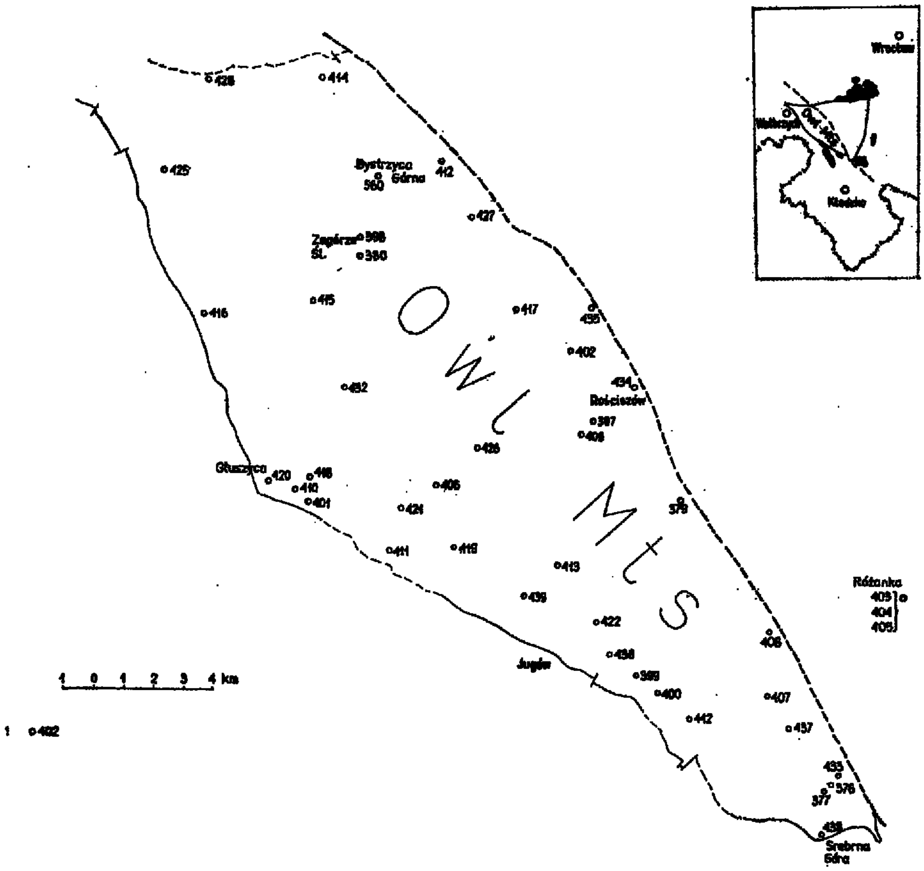

Fig. 1. Situation sketch of the sampling sites
1 — number of samp

and 3) muscovite and biotite pegmatites. The collection has been complemented by a coarse-crystalline amphibolite sample from Bystrzyca Górna supplied by Dr. M. Sachanbiński (University of Wrocław). A total of 44 samples from 42 sites have been examined. The determinations have been completed on the following minerals separated from rocks: muscovite (muscovite pegmatites), biotite (biotite pegmatites, paragneisses and granite gneisses) and hornblende (amphibolite). The argon content has been determined volumetrically and the potassium content by means of flame photometer at the Central Technological and Chemical Laboratory of the Geological Institute. The following constant were used in calculations: $\lambda\beta = 4.72 \cdot 10^{-10}$ year^{-1} and $\lambda_k = 0.854 \cdot 10^{-10}$ year^{-1}. The accuracy of argon and potassium determinations has been calculated with a 95% probability by means of the "t" test on the basis of double determination of sample series (Volk 1965). The results together with the confidence intervals for the individual measurements are listed in Table 1 and illustrated by histograms (Fig. 2).

Table 1

K-Ar ages of the oldcrystalline formation of the Owl Mts

Sample No.	K %	Ar g/g. 10^{-9}	Age MA	Rock	Mineral
379	6.45	229.1	444±26	paragneiss	biotite
380	5.01	179.2*	446±26	,,	,,
412	6.78	225.2	418±26	,,	,,
413	6.64	222.5	421±26	,,	,,
414	6.15	217.7	442±28	,,	,,
415	6.11	234.1	474±31	,,	,,
416	6.50	239.2	458±27	,,	,,
417	6.40	209.1	412±28	,,	,,
425	6.15	208.2	425±27	,,	,,
426	6.17	220.7	446±31	,,	,,
427	5.18	182.7	441±34	,,	,,
428	5.36	183.9	430±34	,,	,,
432	5.98	212.6	444±31	,,	,,
433	5.42	213.3	486±32	,,	,,
434	6.92	250.9	452±26	,,	,,
435	5.82	210.1	450±28	,,	,,
436	5.73	217.8	471±28	,,	,,
437	6.98	234.8	423±26	,,	,,
438	5.51	218.2	489±34	,,	,,
418	7.04	258.8	457±25	granite gneiss	,,
419	6.80	237.8	437±28	,,	,,
420	7.24	243.3	422±25	,,	,,
421	6.97	244.8	439±25	,,	,,
422	6.15	234.8	473±31	,,	,,
439	6.65	226.4	427±28	,,	,,
376	8.03*	279.0	435±22	muscovite	,,
377	8.26*	281.4	427±22	pegmatite	,,
399	8.38	307.3	456±22	muscovite pegmatite	muscovite
400	8.48	309.4	454±22	,,	,,
401	8.42	294.2*	437±16	,,	,,
402	8.40	282.9*	423±15	,,	,,
403	8.22	305.5	462±20	,,	,,
404	8.44	307.8	454±22	,,	,,
405	8.45*	288.7	428±22	,,	,,
407	8.42*	281.8	421±20	,,	,,
410	8.35	311.0	463±23	,,	,,
411	8.71	315.7	452±23	,,	,,
442	6.33	223.5	441±28	,,	,,
397	6.63*	360.8**	643±16	,,	,,
398	5.89	321.2	644±34	,,	,,
406	7.23	263.8*	454±18	,,	,,
408	5.74*	199.3	435±28	,,	,,
409	7.65*	293.6	475±26	,,	,,
560	0.82	45.6*	655±70	amphibolite	hornblende

* — mean of a double determination
** — mean of a triple determination

The results for the individual rock types listed in Table 1 fall within fairly wide intervals: 412—489 MA for paragneisses, 422—473 MA for granite gneisses and 421—463 MA for muscovite pegmatites. Among the biotite pegmatite group three samples show ages between 435 and 475 MA while two are much older (643 and 644 MA) similar to the hornblende from the amphibolite of Bystrzyca Górna which is 655 MA old.

The results compiled in histograms (Fig. 2) indicate, however, that for all the three rock groups the maximum dating frequencies fall within the 420—460 MA interval.

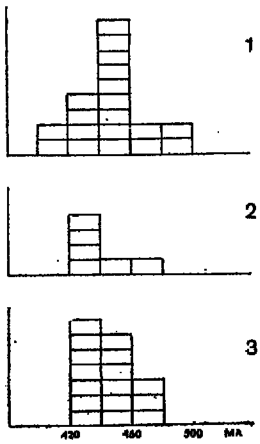

Fig. 2
Histograms of the K—Ar ages
1 — paragneisses, 2 — granite
3 — pegmatites

The scatter of dating results is a resultant value influenced by:

— errors in potassium and argon measurements (expressed by the confidence interval for the individual datings),

— heterogeneity of the rock samples,

— true heterogeneity of the age resulting from the duration of geological processes such as submergence, metamorphism, migmatization, uplift and others,

— processes leading to a partial alteration of the minerals examined (weathering, metasomatism, hydrothermal processes and others) causing a partial removal of potassium while argon is left behind in the crystal lattice.

The wide scatter of datings of biotite from paragneisses and, to a lesser degree, from granite gneisses implies a considerable influence of alteration processes. Considering such a possibility, the relationship has been examined between the age of biotite from these rocks and its potassium content. The graph in Fig. 3 shows a fairly distinct negative correlation between these parameters. Biotite samples older than 460 MA have low potassium contents — less than 6.5%. This dependence indicates that from some biotites potassium was partly removed while argon was retained producing older ages. A smaller scatter of muscovite

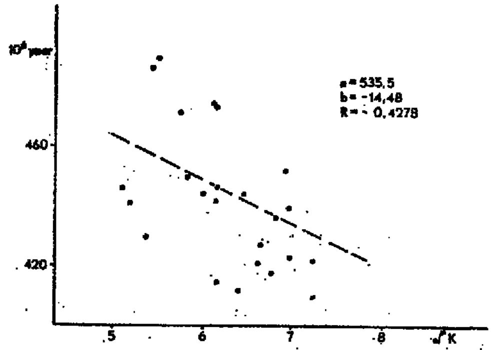

Fig. 3. Dependence between the K—Ar age and the potassium content in biotites from paragneisses and granite gneisses of the Owl Mountains

pegmatite ages (421—463 MA) is probably due to a greater resistivity of muscovite to alteration processes. The above findings inply that the most probable age for biotites and muscovites is between 420 and 460 MA.

In addition to datings presented in this paper, ages of hornblende from amphibolites of Bystrzyca Górna have been reported in literature (Sachanbiński 1973). The K—Ar age determined by Professor Wojtkiewicz is 1340±45 MA (vide Sachanbiński 1973). The age of the same sample (sample No. *560*) determined in our laboratory is 655 MA (the average from two determinations — 648 and 662 MA).

COMPARISON WITH ADJACENT AREAS

All the ages obtained including the youngest falling within the most probable 420—460 MA interval and the older ones (643—655 MA) are considerably younger than could be assumed from the discussed geological evidence concerning the deposition of the original series, the metamorphism and folding.

Up till now a fair number of dating results for Precambrian rocks, and generally speaking, for oldcrystalline massifs of Central Europe have been published. Some examples of the existing disagreements are worth mentioning.

Zoubek (1965) and Smejkal & Melkova (1969) have found that both K—Ar ages and Rb—Sr ages of the Moldanubian rocks representing the oldest structural element of the Bohemian Massif are Variscan, while for the Tepla-Barrandien area representing the upper structural stage Assyntian ages have been obtained. The explanation for this disagreement is the heating of the Moldanubian complex which found itself at a bigger depth during the Variscan orogeny.

According to Lorenz & Burman (1972) the position of the Central European Precambrian rocks in the mobile orogenic zone with an intensive tectonic and igneous activity lasting till the end of the Palaeozoic is unfavourable to radioactive dating. The above authors report that out of 61 datings of assumingly Precambrian rocks occurring north of the Bohemian Massif only three have Assyntian ages within a 735—790 MA interval (amphibolite of Wildenfels near Zwickau, granulite of the Granulite Mountains, keratophyre of the Schwarzburg anticline). All the remaining datings yielded K—Ar ages in the 475—400 and 360—240 MA intervals.

Even older is the age of granulites of the Granulite Mountains reported by Watznauer (1974): the Rb—Sr age is 437 MA, while K—Ar results falling between 350 and 336 MA date, according to the above author, diaphtoritic processes.

Similar Rb—Sr ages have been found for the Moldanubicum in Austria and Bohemia: 469 MA for the massifs of Krems, Melk and Ybbs, 431 MA for the Hochgreding massif, and 430 MA for tre Holubov massif. In Arnold's & Schabert's (1973) opinion these data are indicative of a Palaeozoic age of metamorphism under granulite facies conditions.

For the undoubtedly Precambrian gneisses of the Schwarzwald (Leutwein & Sonet 1974) the Rb—Sr datings yielded 441 MA and for antectites of the same area 430 MA (Watznauer 1974).

Biotite-sillimanite gneisses occurring in the Marianske Lazne area are 426 MA old (Smejkal & Melkova 1969).

Few Assyntian ages have been found in the Bohemian Massif: 500 MA for the Domažlice amphibolite and 525 MA for the Kdyne pegmatite (Smejkal & Melkova 1969). It is striking that the majority of Assyntian ages come from K—Ar datings of granitoids and schists occurring in the basement of the Carpathian Fore-Deep and in the basement of the flysch cover of the Western Carpathians. The above is thus indicative of the Assyntian age of the Moravian block. Hornblende from the biotite-hornblende diorites encountered in the Dražovice borehole yielded 1410 MA, while biotite shows an Assyntian age — 605 MA (Dudek & Melkova 1975).

FINAL REMARKS

Radioactive dating of the crystalline rocks of the Owl Mts formation revealed, that the K—Ar ages for all the rock varieties examined — paragneisses, granite gneisses and pegmatites — fall within the 489—412 MA interval. Considering the previously discussed dependence between the age and the potassium content in the sample, this interval can be limited to 460—420 MA. This age is much younger than the tectonic structures observed within the Owl Mts raft and reflects the last major thermal event which affected the Owl Mts rocks. The term "thermal event" may involve either heating of the rocks to a temperature permitting the release of argon from the crystal lattice or, which is more probable, the uplift of the entire Owl Mts block into a zone of temperatures low enough to retain radiogenic argon in the mineral structure.

The Assyntian age — 643—655 MA — obtained for two samples of pegmatite with coarse-tabular biotite and for amphibole from the coarse-crystalline rock of Bystrzyca Górna is difficult to explain. As much as the age of hornblende from the amphibolite could be regarded as the so called remanent age (analogous to the age of rocks from the Drażovice borehole), it is difficult to imagine that a remanent age could have been preserved in the pegmatitic biotite although the coarse-crystallinity of this mineral considerably favours argon retention. Another justified assumption is the presence of surplus argon in biotite introduced from the surrounding environment.

At present it is not possible to establish precisely the geological meaning of the "thermal event". Perhaps, it marks the time when the deep-seated Owl Mts block returned to shallower zones with temperature lower than 300°C (Jäger 1976).

In view of the possibility of remanent ages, the ages from 420 to 460 MA could hardly mean progressive granulitization, regressive amphibolitization or else migmatization of the Owl Mts raft.

The ages obtained permit to clarify the age problems of gabbro massifs surrounding the Owl Mts gneiss raft. Both the uplift of the raft into shallower parts of the crust and other phenomena that could be responsible for the younger K—Ar ages must be produced intensive dynamic deformations within the raft and its neighbourhood alike. The presence of non-deformed gabbro rocks in the neighbourhood of the massif indicates, that they acquired their present position after the thermal event probably related to the Taconian phase (435 MA according to van Eysling's 1975 geochronological scale). Accordingly, the age of the gabbro rocks may be assumed to fall between Ordovician/Silurian and Upper Devonian (the presence of gabbro pebbles in the basal conglomerates at Dzikowiec). The Assyntian age of the gabbro (Oberc 1971, 1975) is thus hardly acceptable.

The authors are indebted to Professor Dr. J. Znosko and Prof. Dr. J. Burchart for the critical reading of the manuscript.

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WIEK IZOTOPOWY K—Ar KRY GNEJSOWEJ GÓR SOWICH

(Streszczenie)

Uzyskane wyniki badań wieku izotopowego K—Ar skał kry gnejsowej (paragnejsów, granitognejsów, pegmatytów muskowitowych i biotytowych) wykazały, że mieszczą się one w granicach 412—489 MA z tym, że maksimum częstości datowań mieści się w granicach 420—460 MA.

Oprócz tej podstawowej grupy wieków otrzymano wyniki w granicach 643—655 MA dla dwóch próbek pegmatytu z grubotabliczkowym biotytem i jednego amfibolitu. Obydwie te grupy wieków są znacznie młodsze od wieku sedymentacji, metamorfizmu i fałdowania. Niezgodność ta jest zjawiskiem powszechnym na obszarze środkowej Europy, a wieki w granicach 420—460 były stwierdzane wielokrotnie. W tej chwili trudno ocenić, jaki jest sens geologiczny tej daty, możliwe, że jest to wiek, w którym blok gnejsowy uprzednio pogrążony w głębokich partiach skorupy ziemskiej powrócił w partie płytsze o temperaturze poniżej 300°.

Wieki 643—655 MA należy traktować jako wieki reliktowe (bardzo prawdopodobne w przypadku hornblendy z amfibolitu), zachowane w przypadku minerałów o wysokiej retencji argonu lub jako wynik obecności argonu nadwyżkowego (w przypadku biotytu z pegmatytów). Wydaje się, że uzyskane wyniki pozwalają na rozstrzygnięcie wieku masywów gabrowych z otoczenia kry gnejsowej. Zarówno wynoszenie kry w płytsze partie skorupy ziemskiej, jak i inne zjawiska, które mogły wywołać odmłodzenie wieku K—Ar, powodowały z pewnością zarówno w obrębie kry gnejsowej, jak i w jej otoczeniu, intensywne deformacje dynamiczne. Obecność w sąsiedztwie masywu sowiogórskiego niezdeformowanych skał gabrowych, które zajęły miejsce w obecnej strukturze już po tych dynamicznych zjawiskach wyklucza ich assyntyjski wiek. W tej sytuacji należy przyjąć, że formowanie masywów gabrowych nastąpiło między ordowikiem i sylurem a górnym dewonem.