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Rb-Sr and U-Pb Age Determinations on the Pegmatite of I Mondei (Penninic Camughera-Moncucco-Complex, Italian Alps) and some Gneisses from the Neighborhood

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With 1 figure and 4 tables in the text

ZUSAMMENFASSUNG

Die in vorliegender Arbeit enthaltenen Resultate absoluter Altersbestimmungen betreffen gesteinsbildende Mineralien aus dem penninischen Camughera-Moncucco-Komplex (Val d'Ossola, Oberitalien). Im Mittelpunkt der Untersuchungen stand der Beryll-Pegmatit von Cava di Mica, I Mondei, NW Villadossola. Der Pegmatit zeigt einerseits mineralogische Ähnlichkeit mit den wohl jungen, tertiären Pegmatiten des Penninikums des Tessins und den zweifellos jungen Pegmatiten des Bergeller Granites, andererseits aber auch eine deutliche Überprägung durch mindestens eine Phase der alpidischen, tertiären Metamorphose, die in diesem Gebiet generell mesozonalen Charakter hatte.

Es liegen Rb-Sr-Altersbestimmungen an vier verschiedenen Glimmerproben des Pegmatites und an Glimmern aus drei benachbarten Gneis-Proben vor (s. Tab. I und II). Die Biotite geben durchwegs junge Alter (19–26 Millionen Jahre), nach Jäger (1962) stellen diese Biotit-Alter Minimalalter der alpidischen Metamorphose dar. Die Muskowit-Alter der Gneise sind etwas höher (rund 33 Millionen Jahre): sie könnten uns die Zeit der alpidischen Metamorphose oder auch nur ein Minimalalter angeben. Die Altersbestimmungen an zwei grobkörnigen Muskowiten aus dem Pegmatit geben ein Alter von rund 200 Millionen Jahren; ein mittelkörniger Muskowit, der mit wohl jungem, feinkörnigem Muskowit verwachsen ist, gibt ebenfalls 200 Millionen Jahre, während für das nicht separierte Gemisch von mittel- und feinkörnigem Muskowit ein Alter von 109 Millionen Jahren (= Mischalter zweier Muskowitgenerationen) bestimmt wurde.

Es zeigte sich wieder einmal, dass grobblättrige Muskowite auch bei starker Metamorphose das radiogene Strontium gut zurückbehalten.

U/Pb-Messungen nach der RaD-Methode und Isotopenmessungen an Blei von drei Uraninitproben geben Alter von 140 bis 170 Millionen Jahren. Wir konnten zeigen, dass solche junge, relativ konkordante Alter auch nur Mischalter sein könnten. Der Uraninit könnte sich vor 200 Millionen Jahren gebildet haben und vor 35 Millionen Jahren einen Teil seines Bleis verloren haben; auch dann ergäben sich Alterswerte von 140 bis 170 Millionen Jahren, wie wir sie finden.

Unsere Altersbestimmungen zeigen, dass der Pegmatit von I Mondei in voralpiner Zeit entstanden ist; die Frage, ob das Intrusionsalter des Pegmatits tatsächlich 200 Millionen Jahre (Trias) ist, oder ob diese Werte nur Mischalter zwischen herzynischer und alpiner Metamorphose darstellen, wagen wir auf Grund unserer Altersbestimmungen noch nicht zu entscheiden. Die Resultate zeigen auf alle Fälle, dass trotz mesozonaler alpidischer Metamorphose im tieferen penninischen Raum noch voralpine mineralogische und strukturelle Relikte nachweisbar sind.

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Pegmatites, rather similar in mineralogical composition, occur in a broad geographic zone in the southern part of the Central Alps[4]). Beryl, garnet, apatite and less frequently uranium minerals occur typically in these pegmatites. The pegmatite dikes are found in different tectonic zones, such as the Penninic nappes, the so called root-zone of the Alps and the crystalline basement of Southern Alps (Insubric zone). The pegmatites in the Penninic zone of the canton Ticino and those in and around the young granite massif of the Bergell have definitely a young, i.e. Tertiary age. From this fact it was concluded (see E. NIGGLI in J. CADISCH, 1953, p. 72–73) that all the other pegmatites in the described region were also of young age, namely the dikes in the Insubric zone and those in the Penninic region in the Val d'Ossola. However the only support for this conclusion was their mineralogical similarity.

The western most pegmatite is the one of the «Cava di Mica» near I Mondei (Municipality of Montescheno, Valle Antrona). The locality lies 3.5 km northwest of Villadossola (Val d'Ossola). The pegmatite of I Mondei contains uraninite, biotite and muscovite. Thus it seemed to us that age determinations on these minerals would be of great interest.

The abandoned quarry lies about 1220 m above sea level. It is in a pegmatite dike which has a breadth of about 10 m and lies completely in an ultrabasic country-rock. According to BEARTH (1956, p. 277), the pegmatite occurs in the crystalline rocks of the Penninic Camughera-Moncucco-complex. The tectonic position of this complex is not yet completely clear; however it is to be distinguished from the Monte-Leone-nappe. BEARTH has pointed out, that the peridotite of I Mondei occurs in big lenticular bodies and that the joints between single bodies are healed by pegmatites. The pegmatite of I Mondei is one of these. According to BEARTH these pegmatites are the western spurs of the pegmatite-dikes of the Centovalli, which are at least partly of Tertiary age. The peridotite itself is considered by BEARTH to belong to the pre-mesozoic Moncucco-series. The grade of the Alpine Tertiary metamorphism in this region is not yet completely clear. At the same time it is highly probable, that the young metamorphism had a meso-zonal character, as shown by the mineral-constituents of the neighboring mesozoic rocks. As already mentioned by BEARTH the pegmatite of the «Cava di Mica» also shows clearly the influence of Alpine metamorphism. The feldspars, especially the sodium rich plagioclase, are granulated. The new crystals have a grain size of about 1 mm; the muscovite crystals, which are up to 20 cm in diameter, are often bent. Both biotite and muscovite are present in fine and coarse grains, which suggests two generations of micas.

Thus the pegmatite is doubtlessly older than the last main phase of Alpine metamorphism, but an early Tertiary age for the intrusion of the pegmatite would still be compatible with this.

A regular increase in the biotite content of the pegmatite is observed as the contact with the peridotite is approached. At the contact itself lenses and bands of practically mono-mineralic biotite-schist can be found.

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[4]) This zone has an extension of about 100 km from the Bergell over the Mera transverse valley, the upper part of the lake of Como, the region of Bellinzona in the canton Ticino, the northern part of Lago Maggiore to the Val d'Ossola.

According to BEARTH (1956) this can be explained by chemical exchanges between the pegmatite and the peridotite, the latter having been changed to a talc-actinolite schist. The pegmatite was described from the mineralogical point of view by E. GRILL et al. (1950, p. 23 and 76). The important minerals are: quartz, K-feldspar, Na-rich plagioclase, muscovite, biotite, beryl (max. length of the crystals is 35 cm), pyrop-rich garnet, tourmaline, zircon, apatite, chrysoberyl, actinolite, uraninite (first found in this pegmatite by A. G. ROGGIANI) and parsonite.

TABLE I. Sample List

Sample	Rock	Locality	Mineral
muscovite 1	biotite-muscovite-gneiss (quartz, olicoclase, muscovite, biotite, zircon, apatite) (Camughera-Moncucco-complex)	400 north of Aulamia west of Cava di Mica	muscovite
biotite 2a	leucocratic feldspar-rich biotite-muscovite-gneiss (with parallel quartz layers and aplitic tourmaline rich layers), similar to the gneisses from Beura, root zone of the Monte Rosa nappe	quarry south of the river Ovesca, 700 m SW of Villadossola	big biotite crystals from the rims of the quartz veins
muscovite 2b			muscovite from the gneiss, separated into two fractions: 50–70 mesh and 70–100 mesh; optical angle: 0 and 37 ± 4°
biotite 3	biotite-muscovite-gneiss with a slight tendency to augengneiss (Camughera-Moncucco-complex)	road cut between Boschetto and Cresti, west of Villadossola	brown biotite
biotite 4a	fine-grained, mono-mineralic biotite-schist from the contact of the pegmatite and the peridotite	Cava di Mica, I Mondei	brown biotite
muscovite 4b	pegmatite	Cava di Mica, I Mondei	big muscovite crystals
muscovite 4d	pegmatite	Cava di Mica, I Mondei	big greenish muscovite crystals
muscovite 4e (tot)	pegmatite	Cava di Mica, I Mondei	medium and fine grained muscovite
muscovite 4e (sep)	pegmatite	Cava di Mica, I Mondei	medium grained muscovite separated from 4e total
uraninite 4f 4g 4h	pegmatite	Cava di Mica, I Mondei	crystals with a diameter of 3–8 mm

We have collected also several samples of gneiss immediately adjacent to and at some distance from the pegmatite dike and we have used micas from these samples for age determinations. Table I and figure 1 contain information about the samples on which measurements have been performed.

The results of the age measurements are listed in Table II, III and IV.

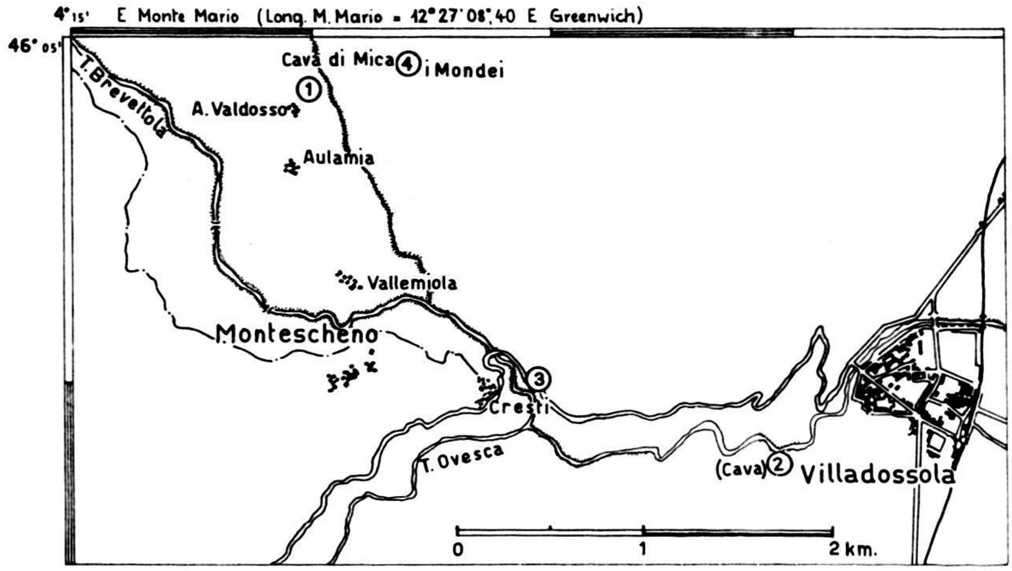

Fig. 1. Location map 1:50000 of the analyzed samples (from sheet Villadossola, Carta d'Italia 1:25000).

TABLE II. Rb-Sr measurements (made at the Pisa Laboratory)

Sample	Rb ppm	common Sr ppm	Sr^{87} rad ppm	Sr^{87} rad / tot Sr^{87}	AGE MY
Muscovite 1	424 424	10.18 ± 0.15 9.70 ± 0.14	0.060 ± 0.012 0.060 ± 0.012	0.078 0.081	33.9 ± 8.2 33.9 ± 8.2
Biotite 2a	1151	4.08 ± 0.06	0.095 ± 0.007	0.25	19.7 ± 1.7
Muscovite 2b 50–70mesh .	791	13.98 ± 0.2	0.113 ± 0.011	0.103	34.3 ± 3.5
Muscovite 2b 70–100 mesh	787	6.45 ± 0.09	0.110 ± 0.010	0.196	33.6 ± 3.3
Biotite 3	564	5.48 ± 0.08	0.046 ± 0.0082	0.106	19.7 ± 3.9
Biotite 4a	869	13.7 ± 0.2	0.094 ± 0.019	0.09	25.9 ± 5.4
Muscovite 4b	504	3.58 ± 0.06	0.430 ± 0.011	0.63	204 ± 6.5
Muscovite 4d	414	7.81 ± 0.12	0.362 ± 0.013	0.40	210 ± 9
Muscovite 4e (tot)	939	15.02 ± 0.2	0.425 ± 0.02	0.29	109 ± 6
Muscovite 4e (sep) . . .	1295	6.65 ± 0.09	1.067 ± 0.03	0.70	198 ± 7
Bern Standard biotite 4B	608	2.95 2.86	0.038 0.045	0.156 0.183	
B. 3203 Standard biotite .	456	11.3	1.80		

TABLE III. Lead Isotopic Composition (measured at the Pisa Laboratory)

Sample	204/206	207/206	208/206	Pb^{206}/Pb^{207} AGE MY	Pb^{206}/U^{238} AGE MY
Uranitite 4f . . .	0.00021 ± 0.00001	0.0827 ± 0.0019	0.0886 ± 0.0015	—	152 ± 8
Uranitite 4g . . .	0.00070 ± 0.00005	0.0597 ± 0.0028	0.025 ± 0.0020	175 ± 100	—
Uraninite 4h . .	0.00057 ± 0.00003	0.0573 ± 0.0005	0.0023 ± 0.0002	150 ± 35	—

Remark: No Pb^{206}/Pb^{207} age is given for sample 4f because of the magnitude of common lead correction.

TABLE IV. RaD measurements (made at the Pisa Laboratory)

Sample	$\frac{Pb^{206}\,\text{rad}}{\text{tot Pb}}$ %	dis/sec/mg tot Pb	dis/sec/mg Pb^{206} rad	AGE MY
Uraninite 4f. . .	81.9	448 ± 18	547 ± 20	167 ± 7
Uraninite 4g . .	90.9	514 ± 21	565 ± 24	162 ± 7
Uraninite 4h . .	91.6	594 ± 24	648 ± 26	142 ± 6

MEASUREMENTS

Rubidium/Strontium

The minerals (muscovite, biotite) used for these measurements have been separated and purified by the procedure described by E. Jäger (1960). Rubidium and strontium contents have been determined by isotopic dilution according to L. T. Aldrich et al. (1956). The «spike» solutions used for these determinations have been prepared at the Pisa Laboratory with enriched Sr^{86} and Rb^{87} from Oak Ridge. The «spike» concentrations have been controlled with shelf solutions prepared with spectrographically pure Sr and Rb salts from Johnson and Matthey. As a further control the Hurley standard biotite B-3203 and the Berne standard biotite have been measured. The mass spectrometric measurements were performed with an Atlas CH_4 mass-spectrometer with electron multiplier detector. The blank determination, using all the chemicals of a normal procedure, are 0.01 μg for Rb and 0.1 μg for common Sr.

Uranium/Lead

The three samples of uraninite have been measured with the RaD-method (Begemann et al. 1953). The Th was separated and a quantitative analysis performed as described by G. Ferrara et al. (1959). The Th content in all the samples was about 1/500 of the uranium quantity. In the sample 4f the uranium and the lead contents have been determined by chemical methods in order to obtain an independent value for the U/Pb ratio. Uranium measurements in this sample have been performed with different methods (thiocyanate colorimetry, polarography) leading to concordant results. Lead traced with Pb^{210} after extraction with dithizone has been determined polarographically.

The isotopic analysis of the lead has been done with the same mass-spectrometer using thermal ionization and a multiplier collector. The sample has been deposited as $PbSO_4$ on a tantalum filament and covered with boric acid (MARSHALL and HESS 1960).

According to the Pb^{204}-content of the samples, a correction for common lead has been made. For the isotopic composition of common lead we have used a mean value of modern European lead corrected for an age of 150 million years.

DISCUSSION OF THE AGE RESULTS

a) *Micas from the gneisses*

Both age values from biotites of gneisses (samples 2a and 3) agree well (19.7 ± 3.9 and 19.7 ± 1,7 MY). They fit well in the general picture of young, Tertiary, biotite ages in the lower Penninic nappes and the root zone, as described by E. JÄGER (1962). The age values indicate the time when the biotites reached a certain temperature during their cooling period after the crystallization resp. recrystallization (Alpine metamorphism). The muscovite ages (sample 1 = 33,9 ± 8,2 and sample 2b = 34.3 ± 3.5 and 33.6 ± 3.3 MY) on both samples agree well also, but they are significantly higher than the biotite ages. The relatively low values of common Sr are remarkable.

There are different possible interpretations. One assumption would be that the muscovite ages indicate the time of the last main Alpine phases. This means that the muscovite started to be a closed system just after the crystallization. The biotite, however, might have lost its radiogenic Sr during the following period of relatively high temperature. Secondly, the age of the muscovite could also be lower than the age of crystallization, because of loss of radiogenic Sr during the cooling period. Finally, it is possible that the muscovite ages are mixed ages. The gneisses could have been already gneisses or granites before the Trias. The Alpine metamorphism may have more or less recrystallized the older muscovites. This might possibly have caused a partial loss of radiogenic strontium. Even a complete recrystallization might give a mixed age; old radiogenic strontium could be inherited by the newly formed muscovite crystal. This could be checked by measuring the common strontium of rubidium poor and strontium rich minerals. The strontium of these minerals should show an enrichment of Sr^{87} too.

b) *Age Results on Minerals from the Pegmatite*

Age values from 26 to 210 million years were found. This wide range is difficult to explain. The highest ages were found on the coarse grained muscovite (samples no. 4b, 4d, 4e sep.). These are concordant, showing ages of about 200 MY, and probably give the age of the intrusion of the pegmatite. However in the Central Alps Triassic pegmatites are unknown. Hence even the concordant muscovite ages may be considered to be mixed ages. The pegmatite could, for instance, have been formed in late Paleozoic time and could have lost part of its radiogenic strontium by the Alpine metamorphism.

The results of the samples 4e (tot) and 4e (sep) are interesting. The sample 4e (tot) is a mixture of medium and fine grained muscovite which occur together intergrown in the same pegmatite. From the petrological point of view we interpret the fine muscovite as a product of secondary Alpine crystallization. The medium grained muscovite could be of primary origin. Indeed the medium grained muscovite gives an age of 198 $\pm$ 7 MY, which is about twice as high as the age of the mixture (109 $\pm$ 6). This shows that at least the age of 109 MY is a mixed age.

The biotite 4a (biotite-schist from the contact of the pegmatite and the peridotite) shows an age of 25.9 $\pm$ 5.4 million years which is, within the limits of error, the same as we found for the biotites from the gneisses. It is possible that the biotite schist was formed with the pegmatite (P. BEARTH 1956). However, it could also be a product of a reaction in Alpine time. The biotite either has lost the old radiogenic strontium or it shows the age of the crystallization in Tertiary time.

These results are consistent with previous dates and show, that the coarse grained muscovites retain their radiogenic strontium much better than the biotite.

Special problems arose in the interpretation of the age results from the uraninite of the pegmatite. As listed in tables III and IV the results obtained by three different methods (Pb^{206}/Pb^{207}, U^{238}/Pb^{206} and RaD) have a small spread, namely 140 to 170 MY. These ages seem to be rather concordant, but it should be mentioned, that the error limits of Pb^{206}/Pb^{207} determinations are very large. All the uraninite ages are lower than the ages of the coarse grained muscovites. For petrological reasons it is highly probable that uraninite and the coarse grained muscovite were formed at the same time during the primary crystallization of the pegmatite. We, therefore, have looked for a model to explain the lowered uraninite ages by lead loss during the Alpine metamorphism.

The following model has been assumed: the uraninite was formed 200 MY ago and lost part of its lead 35 million years ago. With a lead loss of 35% we find the following ages for uraninite 4h:

	calculated age MY	measured age MY
RaD + U^{238}/Pb^{206}	143	142 $\pm$ 6
Pb^{206}/Pb^{207}	187	150 $\pm$ 35[5])
With 23% of lead loss for uraninite 4g:		
RaD + U^{238}/Pb^{206}	162	162 $\pm$ 7
Pb^{206}/Pb^{207}	192	175 $\pm$ 100[5])

The results of our model are not inconsistent with measured ages. This shows once more that concordant lead ages, which are young compared to the half life of U^{235}, may not mean the real age of crystallization.

GEOLOGICAL CONCLUSIONS

The age determinations show, that the beryl pegmatite from I Mondei (Moncucco complex, Penninic region, Val d'Ossola) intruded in pre-Tertiary time. The

[5]) See remark to Table III.

minimum age we find is 200 million years, Triassic. It is certainly older than the Alpine metamorphism. During the Alpine orogeny, the pegmatite was recrystallized but part of the coarse muscovite crystals remained unchanged. This shows that in the southern part of the central Alps the beryl gives no certain indication for the young age of a pegmatite.

Our results show further, that we still find pre-Alpine relicts even in the zone of high grade Alpine metamorphism in the Penninic region. In our case this relict is the pegmatite, which has pre-Alpine features from both the structural and mineralogical points of view.

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