Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 53 (1973)

Heft: 2

Artikel: The barometric significance of the muscovites from the Savoca phyllites (Peloritani, Sicily) : with considerations on the baric conditions during Hercynian metamorphism in Italy

Autor: Atzori, P. / Sassi, F.P.

DOI: https://doi.org/10.5169/seals-41384

The Barometric Significance of the Muscovites from the Savoca Phyllites (Peloritani, Sicily)

With considerations on the baric conditions during Hercynian metamorphism in Italy

By *P. Atzori* (Catania)*) and *F. P. Sassi* (Padova)**)

With 2 figures and 3 tables in the text

Abstract

The b_0 values of the potassic white micas from the Savoca phyllites (74 new measurements) indicate that the metamorphism of these rocks is of low pressure. More precisely, the Savoca phyllites are to be referred to the lowest pressure facies series allowing the appearance of the "chlorite zone".

The available data support the opinion that the metamorphism of the basement of the Mandanici Nappe is entirely Hercynian. A comparison of the b_0 of the potassic white micas from isograde and isochemical Hercynian phyllites from the Peloritani, Calabria (Southern Italy) and the Eastern Alps indicates that the low-grade Hercynian metamorphism in these regions took place under similar baric conditions.

INTRODUCTION

In the Eastern Alps Sassi (1972) has recently recognized systematic differences among the potassic white micas from phyllitic rocks of different age: in fact, the micas formed during the Alpine metamorphism have $b_0 \geqq 9.025$ Å, whereas those attributable to the Hercynian event have $b_0 \leqq 9.005$ Å. Interpreting these results on the basis of previous studies carried out in collaboration with other workers, Sassi explained these differences as linked to the different phengite contents present in the micas as solid solution (Cipriani et al., 1968), and attributed them to the different baric conditions (Cipriani

*) Address: Dott. P. Atzori, Istituto di Mineralogia e Petrografia dell'Università di Catania (Italy).

**) Address: Prof. F. P. Sassi, Istituto di Mineralogia e Petrologia dell'Università, C. Garibaldi 9, 35100 Padova (Italy).

et al., 1971) existing during the two metamorphic events (ZWART, 1969). In fact, since the samples were selected so that their chemical composition and temperature of formation might be taken as substantially constant, the only important variable was the pressure at which they crystallized. On these grounds SASSI (1972) "believes he has found the only method possible today for determining qualitatively whether a low-grade metamorphism is of relatively high or low pressure".

Several geological applications of this method have already been published (GEYSSANT and SASSI, 1972; SASSI and ZANFERRARI, 1972; SCOLARI and ZIRPOLI, 1972; DI PIERRO et al., 1973). However, the principal interest of SASSI's results lies in the fact that they have led the way to systematic analysis of the quantitative relationships existing between pressure of metamorphism and b_0 of the potassic white micas from isochemical and isograde low-temperature rocks of different facies series. Research on this subject has been carried out by SASSI and SCOLARI (1973); their results (to be published soon) clearly show a progressive increase of b_0 with increasing pressure, from the Bosost facies series as far as the glaucophanitic greenschist facies. The present work is intended as a contribution to these investigations as well as to regional petrology. To complete the geo-petrological studies recently carried out by ATZORI and D'AMICO (1972) on the rocks of the Savoca area, it seemed useful to study the potassic white micas of the phyllites with the following aims in mind:

1. To show the baric character of the metamorphism of these rocks, the age of which is believed to be Hercynian.
2. To compare the baric character estimated in this way with that of other Hercynian phyllitic complexes in Italy, with the purpose of obtaining, as far as possible, indications on the general baric conditions of Hercynian metamorphism in this country.

GEOLOGICAL-PETROLOGICAL SETTING

The Savoca phyllites belong to the Mandanici Nappe (OGNIBEN, 1969), made up of low-grade metamorphic rocks covered by unmetamorphosed pelagic limestones of Cretaceous age (Berriasian). The low-grade schists (mostly phyllites, with a few marbles, calc-schists and basic metavolcanics), contain assemblages of the three subfacies of the greenschist facies (GHEZZO, 1967; ATZORI, 1969, 1970), and, in some cases, reach the boundary with the amphibolite facies. According to OGNIBEN's reconstruction (1969), the Mandanici Nappe is interposed between the underlying Galati and Longi Nappes (both made up of an analogous basement of Hercynian "semi-schists" with different post-Hercynian covers), and the overlying gneissic Aspromonte Nappe. As a matter of fact, the Savoca phyllites are tectonically covered by augen gneisses and other less common mesozonal lithotypes, which represent a *Klippe* of the Aspromonte Nappe (Quitzow, 1935; Ogniben, 1960; Atzori and D'Amico, 1972).

As regards the age of the epizonal schists of the Mandanici Nappe, the only certain knowledge we have is that their metamorphism is pre-Alpine: the mesozoic rocks of this nappe show no metamorphic alterations. A more precise chronological attribution is not objectively possible for the moment. However, it can be said that the Hercynian event is documentable at least in some rocks of the Peloritani: in fact, the "semi-schists" of the Longi and Galati Nappes certainly owe their weak recrystallisation to the Hercynian event, as they contain beds with Devonian fossils (Truillet, 1968), while their Mesozoic cover is not metamorphic.

Taking into account the medium- and high-grade rocks, some authors have recently postulated the existence of Caledonian metamorphism of the Barrovian type (intermediate pressure), followed by a Hercynian event of lower temperature and low pressure[1]). In this context, two hypotheses have been put forward: according to Dubois and Truillet (1971), the phyllites of the Mandanici Nappe represent the Hercynian metamorphic products of the paleozoic sediments which were deposited on the gneissic pre-Hercynian basement; on the contrary, according to Ferla (1972), the phyllites too are polymetamorphic like the high-grade rocks, and form an integrant part of the pre-Hercynian basement, whose paleozoic cover with Hercynian metamorphic alteration is represented only by the "semi-schists". These hypotheses implying polymetamorphism are not shared by other workers, at least as regards the Milazzo area (D'Amico et al., 1972).

At the present time, we have no objective data which allow this complex chronological problem to be resolved definitely. However, over and above the big controversial problems regarding substantially the rocks of medium and high temperature, we believe that there is no fact specifically contrary to the attribution of an entirely Hercynian age to the metamorphism of the phyllitic rocks in the Mandanici Nappe. The results of the present work strongly corroborate this affirmation, as do the microstructural data of Atzori and D'Amico (1972).

The event which metamorphosed the Savoca phyllites was polyphase, with a synkinematic ($S_1 \rightarrow S_2$) phase of low temperature, and a post-kinematic phase during which the temperature increased progressively (remaining, however,

[1]) An evolutional model of this type has also been proposed by Dubois (1971) for Calabria (Southern Italy), and by Sassi and Zanferrari (1972) for the Austridic crystalline basement outcropping to the south of the Tauern Window (Eastern Alps).

generally within the greenschist facies, since the occurrence of staurolite is exceptional). For detailed information on the metamorphic evolution of these rocks we refer readers to Atzori and D'Amico (1972): it is, however, to be emphasized here that the microstructural analysis carried out by these authors ascertained that the potassic white micas are always synkinematic, well oriented in the schistosity planes, except for a single case where rare flakes of post-kinematic white mica occur (sample S 33 A).

DESCRIPTION OF THE SAMPLES

For this work 74 samples of phyllites were used, whose approximate location is shown in Fig. 1.

All the samples bear assemblages of the greenschist facies, except for two which, containing chloritoid and staurolite, are to be placed at the boundary with the amphibolite facies. In every case, the potassic white mica is the only white sheet silicate present, as paragonite, pyrophyllite, etc. are absent. On the basis of the mineral assemblages, the samples were classified into four groups, in order of increasing temperature, as follows:

Group 1: chl + mu ± ab + qz (16 samples);
Group 2: bio + chl + mu ± ab + qz (26 samples);
Group 3: alm + bio + chl ± ctd + mu ± ab + qz (30 samples);
Group 4: ctd + staur + alm + bio + chl + mu + ab + qz (2 samples).

As the composition of potassic white mica is thermally controlled – a progressive decrease in the phengite content is to be expected for increasing temperatures (Cipriani et al., 1971), and thus a decrease in the b_0 values – it is obvious that for our purposes the four groups are to be considered separately, and that greater consideration in formulating barometric deductions should be given to the lower-temperature samples.

The influence of the bulk chemical composition of the rocks (or, if preferred, of their mineralogical composition) on the chemical content of the potassic white mica is also considerable. It was for this reason that we selected only carbonate-free samples, the mineralogical composition of which falls into the "*Phyllit*" and "*Quarzphyllit*" fields shown in Figs. 1 and 2 of Fritsch et al. (1967). Moreover, the samples were chosen so that their compositional variability was sufficiently small: the low values of the standard deviations found for the b_0 in each group show that this aim has been reached.

With the purpose of testing the statistical significance of the results, from each selected outcrop two samples were taken, the reciprocal distance of which varied from 15 cm to 2 m. The twin samples each bear the same number,

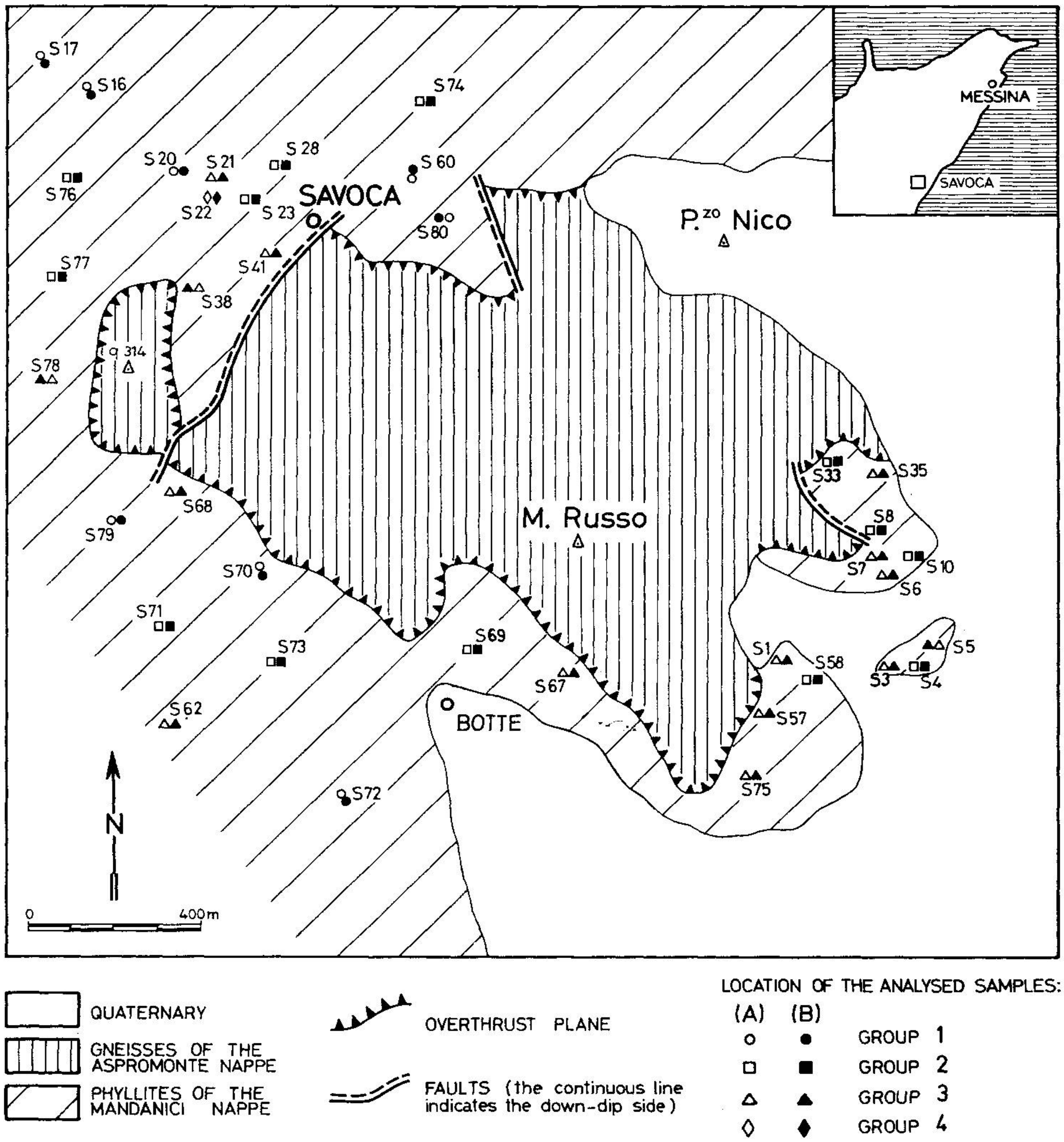

Fig. 1. Approximate location of the samples (geological sketch from ATZORI and D'AMICO, 1972, simplified).

and are distinguished by the letter A or B. Therefore, we have two subpopulations, one A and the other B; each subpopulation contains 37 samples, covers the same area, and is slightly shifted with respect to the other. It is thus possible to test to what extent the conclusions reached separately on each of these two subpopulations differ from each other, and from the conclusions deducible from the total population.

ANALYTICAL RESULTS AND COMMENT

The 74 b_0 values are shown in Table 1, in which the four above-mentioned groups can be seen, together with the subgroups A and B. The arithmetic means and the standard deviations for each group and subgroup are shown in Table 2. The analytical data in these tables, specially those in Table 2, allow the following considerations to be made:

1. Since the values of the standard deviations are sufficiently small and vary only slightly from group to group, comparisons and interpretations can be made taking into consideration exclusively the mean b_0 values.
2. The means and the standard deviations of each group are substantially identical to those obtained for the respective subgroups A and B. This

Table 1. *Analytical data*

Sample	b_0 (Å)	Group
S 16 A	9.001	1
S 17 A	8.998	1
S 20 A	9.002	1
S 60 A	8.990	1
S 70 A	9.000	1
S 72 A	8.988	1
S 79 A	8.998	1
S 80 A	8.993	1
S 16 B	9.001	1
S 17 B	8.996	1
S 20 B	8.994	1
S 60 B	8.993	1
S 70 B	9.001	1
S 72 B	8.991	1
S 79 B	9.000	1
S 80 B	8.998	1
S 4 A	8.990	2
S 8 A	8.998	2
S 10 A	9.003	2
S 23 A	8.999	2
S 28 A	8.987	2
S 33 A	8.996	2
S 58 A	8.990	2
S 69 A	8.999	2
S 71 A	8.995	2
S 73 A	8.999	2
S 74 A	8.986	2
S 76 A	9.004	2
S 77 A	8.995	2
S 4 B	8.991	2
S 8 B	8.999	2
S 10 B	9.001	2
S 23 B	8.990	2
S 28 B	8.998	2
S 33 B	8.996	2
S 58 B	8.988	2
S 69 B	8.999	2
S 71 B	8.995	2
S 73 B	9.001	2
S 74 B	8.990	2
S 76 B	9.003	2
S 77 B	8.996	2
S 1 A	8.990	3
S 3 A	8.986	3
S 5 A	8.983	3
S 6 A	8.987	3
S 7 A	8.998	3
S 21 A	8.999	3
S 35 A	8.993	3
S 38 A	8.996	3
S 41 A	8.995	3
S 57 A	8.984	3
S 62 A	8.992	3
S 67 A	8.992	3
S 68 A	8.993	3
S 75 A	8.998	3
S 78 A	9.004	3
S 1 B	8.994	3
S 3 B	8.991	3
S 5 B	8.986	3
S 6 B	8.987	3
S 7 B	8.983	3
S 21 B	8.986	3
S 35 B	8.996	3
S 38 B	8.991	3
S 41 B	8.982	3
S 57 B	8.989	3
S 62 B	8.986	3
S 67 B	8.991	3
S 68 B	8.992	3
S 75 B	8.999	3
S 78 B	9.003	3
S 22 A	8.984	4
S 22 B	8.986	4

Table 2. *Mean b_0 values ($\bar{x}$) and standard deviations (s) for each group and subgroup of samples from the Savoca phyllites (n = number of samples)*

Group	$\bar{x}_{A+B}$	s	n	$\bar{x}_A$	s	$\bar{x}_B$	s
1	8.997	0.004	16	8.996	0.005	8.997	0.004
2	8.996	0.005	26	8.995	0.005	8.996	0.005
3	8.991	0.006	30	8.993	0.006	8.990	0.006
4	8.985	0.001	2	8.984	—	8.986	—

indicates that the number of samples in each group is more than sufficient for the aims we had in mind, and that the sampling is thus representative from our point of view. Consequently, the high statistical significance of the mean b_0 values is guaranteed.

Taking into consideration points 1. and 2. above, from now on we will only consider the (X_{A+B}) column of Table 2 and disregard the others.

3. Proceeding from Group 1 to Group 4 – that is, in the direction of increasing temperature – a substantial identity of b_0 between Groups 1 and 2 can be noted, and successively a slight decrease in this parameter, first at the appearance of almandine and later at the appearance of staurolite. These variations are linked to the expected decrease in the phengite s.s. content with the increase in temperature (CIPRIANI et al., 1971). Evidently, the thermal rise connected with the appearance of biotite was not sufficient to determine appreciable variations in the b_0, probably because the phengite contents were already low to begin with (i. e., in Group 1). It is just this initial situation that in this case made the "dephengitization" appreciable only at the appearance of staurolite: in fact, in the cases in which decidedly phengitic micas appear in the lowest temperature subfacies, the "dephengitization" is already appreciable at the biotite isograde (SASSI and SCOLARI, 1973).
4. The dependence of b_0 on temperature being ascertained in this case too, for barometric aims we must limit our attention to Groups 1 and 2. The arithmetic mean obtained by these 42 b_0 values turns out to be 8.996 Å (s = 0.005). Considering SASSI's (1972) data, and the much more complete data of SASSI and SCOLARI (1973), this value is very low, and *undoubtedly indicates a low-pressure facies series.*
5. The peaks of the (060) reflections were always very sharp and showed no anomalies. This excludes the presence in these rocks of more than one generation of white mica distinguishable in this way, a conclusion which agrees very well with that reached by ATZORI and D'AMICO (1972) through microstructural analysis: therefore, we have no data supporting the polymetamorphic evolution of these phyllites.

CONCLUSIONS

The results of our work allow the following conclusions to be drawn:

1. We have already shown the high statistical significance of the analytical data, demonstrating that the same results could also be obtained by utilizing only one of the two subpopulations. This shows another positive aspect of the study method proposed by SASSI (1972): *only a few dozen samples from a phyllitic complex are sufficient for an indication of the baric conditions of its metamorphism, provided that the samples are compositionally homogeneous and all of low temperature*, i. e. not thermally "dephengitized".
2. We have thus shown the low-pressure character of these phyllites. In the light of the data presented by SASSI and SCOLARI (1973), and taking into account the undoubted presence of the subfacies qz-ab-mu-chl in the phyllitic complex under consideration, we can add that *we are dealing here with the facies series of the lowest possible pressure allowing the existence of a well-defined "chlorite zone", i. e., a facies series with a slightly higher pressure than that of Ryôke-Abukuma metamorphism.*
3. This conclusion allows us to recognize the "Hercynotype" character of the Savoca metamorphism (ZWART, 1969), a very important result from the chronological point of view too. Since in the regional geology there are no elements for invoking one of the pre-Hercynian events with this baric character, while there is evidence (though in other tectonic units) of the existence of the Hercynian event (Devonian beds in the "semi-schists"), *we believe that the low-pressure character we have revealed is another important element supporting the Hercynian age of the metamorphism of the phyllites belonging to the Mandanici Nappe.*
4. The low-pressure character of the Savoca phyllites has implications also in the chronological problems concerning the other metamorphic rocks of the Peloritani, i. e., the lithotypes in the amphibolite facies making up the basement of the Aspromonte Nappe (as the Hercynian age of the semi-schists forming the basement of the other nappes has already been demonstrated using other methods). In fact, *in future attempts at resolving these problems, our results give valid support for considering the parageneses in the low-pressure amphibolite facies to be contemporary with the metamorphism of these phyllites. On the other hand, caution must be exercised when linking, from the chronological point of view, the low-pressure metamorphism of the Savoca phyllites with the parageneses of the intermediate-pressure amphibolite facies, which should turn out to be widespread on a regional scale.*
5. The considerations made in Point 5 of the preceding section give no support to the hypothesis of poly-metamorphism in the phyllites under study; thus, if it is true that we cannot exclude the possibility that relicts of a pre-

Hercynian metamorphism exist in the rocks of the amphibolite facies, it is also true that the metamorphism of the phyllites is very probably *entirely* Hercynian.

6. Regarding potassic white micas produced by low temperature Hercynian metamorphism, we may add to the data presented in this work, 63 b_0 values from Calabria (S. Italy) (Di Pierro et al., 1973) and 135 from the Eastern Alps (Sassi, 1972; Geyssant and Sassi, 1972). It is therefore possible, and also very interesting, to make a comparison between these data on contemporary micas from quite distant regions. This comparison (Fig. 2 and Table 3) shows a substantial identity of the b_0 values in the three regions, in the sense that the small differences are not significant. *This indicates that Hercynian metamorphism took place under similar baric conditions in the three Italian regions under comparison,* and that it would be improbable to find baric conditions very different from these in the Italian

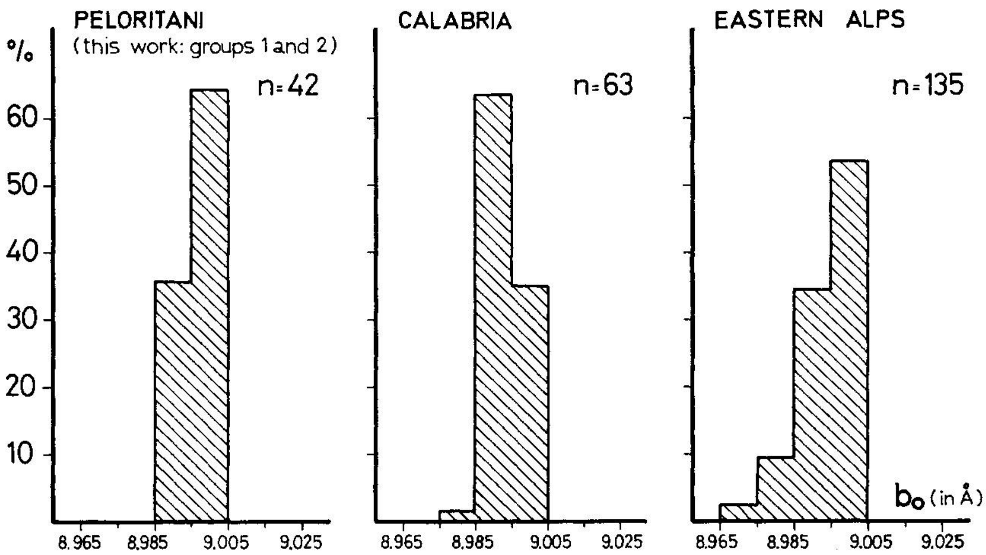

Fig. 2. Comparison of the b_0 of the potassic white micas from isograde and isochemical Hercynian phyllites from the Peloritani (this work), Calabria (Di Pierro et al., 1973) and the Eastern Alps (Geyssant and Sassi, 1972; Sassi, 1972).

Table 3. *Comparison of the b_0 of the potassic white micas from isograde and isochemical Hercynian phyllites from the Peloritani (this work), Calabria (Di Pierro et al., 1973) and the Eastern Alps (Geyssant and Sassi, 1972; Sassi, 1972)*

	$\bar{x}$	s	n
Savoca*) (Peloritani)	8.996	0.005	42
Savoca**) (Peloritani)	8.994	0.006	72
Calabria	8.993	0.005	63
Eastern Alps	8.994	0.008	135

*) Groups 1+2 **) Groups 1+2+3

Hercynian regions which have not yet been studied from this point of view. Present knowledge concerning the certainly Hercynian parageneses in the amphibolite facies occurring in Italy and the general features shown by Hercynian metamorphism in Europe agrees with these conclusions, as do ZWART's ideas (1969) on the peculiarity of the baric characteristics of every metamorphic event, and on their dependence on the type of concomitant orogenic mechanisms.

Acknowledgements

This work was carried out with the financial support of the C.N.R., and is the result of collaboration between the "Centro di Studio per la Geologia e la Petrologia delle Formazioni Cristalline del C.N.R.", Padova, and the "Istituto di Mineralogia e Petrografia" of the University of Catania.

The authors would like to express their gratitude: to Professors L. Ogniben (Catania) and B. Zanettin (Padova) for having made this research possible; to them and to Professors Gb. Dal Piaz (Padova) and C. D'Amico (Messina) for their critical reading of the manuscript; to Professor S. Lorenzoni and his co-workers for having consented to the comparative use of data still in print.

REFERENCES

ATZORI, P. (1969): Studio chimico-petrografico dei calcari cristallini della zona di Alì (Messina) e loro significato geologico. Riv. Mineraria Siciliana 20, 1–19.

— (1970): Contributo alla conoscenza degli scisti epizonali dei Monti Peloritani (Sicilia). Riv. Mineraria Siciliana 21, 1–21.

ATZORI, P., and C. D'AMICO (1972): Rapporti tra gneiss occhiadini e filladi a Savoca (Peloritani-Sicilia). Mineral. Petrogr. Acta 18 (in print).

CIPRIANI, C., F. P. SASSI, and C. VITERBO-BASSANI (1968): La composizione delle miche chiare in rapporto con le costanti reticolari e col grado metamorfico. Rend. Soc. Ital. Mineral. Petrogr. 24, 153–187.

CIPRIANI, C., F. P. SASSI, and A. SCOLARI (1971): Metamorphic white micas: definition of paragenetic fields. Schweiz. Mineral. Petrogr. Mitt. 51, 259–302.

D'AMICO, C., S. GUERRIERI, and E. MACCARRONE (1972): Le metamorfiti di Milazzo (Messina). Per. Mineral. 41, 35–151.

DI PIERRO, M., S. LORENZONI, and E. ZANETTIN-LORENZONI (1973): Phengites and muscovites in alpine and pre-alpine phyllites of Calabria (Southern Italy). N. Jb. Mineral., Abh. (in print).

DUBOIS, R. (1971): Definition d'un socle antéhercynien en Calabre. C.R. Acad. Sci. Paris 272, 2052–2055.

DUBOIS, R., and R. TRUILLET (1971): Le polymétamorphisme et la structure du domain peloritain (Sicile). La notion de socle peloritain antéhercynien. C.R. Acad. Sci. Paris 272, 2134–2136.

FERLA, P. (1972): Serie metamorfiche dei Monti Peloritani occidentali (Messina). Rend. Soc. Ital. Mineral. Petrogr. 28, 125–151.

FRITSCH, W., H. MEIXNER, and H. WIESENEDER (1967): Zur quantitativen Klassifikation der kristallinen Schiefer. 2. Mitteilung. N. Jb. Mineral., Mh., 364–376.

GEYSSANT J., and F. P. SASSI (1972): I lembi di filladi e di quarziti del Padauner Kögel (Brennero) ed il loro significato. Mem. Accad. Patav. SS.LL.AA., cl. Mat. Nat. 84, 5–15.

GHEZZO, C. (1967): Notizie petrografiche e geologiche sui terreni metamorfici rilevati nella tavoletta II SO del foglio Castroreale (Monti Peloritani). Rend. Soc. Mineral. Ital. 23, 47–58.

OGNIBEN, L. (1960): Nota illustrativa dello schema geologico della Sicilia Nord-Orientale. Riv. Mineraria Siciliana 11, 183–212.

— (1969): Schema introduttivo alla geologia del confine Calabro-Lucano. Mem. Soc. Geol. Ital. 8, 453–763.

QUITZOW, H. (1935): Der Deckenbau des Kalabrischen Massivs und seiner Randgebiete. Abh. Ges. Wiss. Göttingen, Mat. Phys. Kl. 13, 63–186.

SASSI, F. P. (1972): The petrological and geological significance of the b_0 values of potassic white micas in low-grade metamorphic rocks. An application to the Eastern Alps. Tschermaks Mineral. Petrogr. Mitt. 18, 105–113.

SASSI, F. P., and A. ZANFERRARI (1972): Il significato geologico del Complesso del Turntaler (Pusteria), con particolare riguardo alla successione di eventi metamorfici prealpini nel basamento austridico delle Alpi Orientali. Boll. Soc. Geol. Ital., 91, 533–557.

SASSI, F. P., and A. SCOLARI (1973): The b_0 value of potassic white micas as barometric indicator in low-grade metamorphism of pelitic rocks (in preparation).

SCOLARI, A., and G. ZIRPOLI (1972): Filoni tardoalpini metamorfici negli scisti austridici e pennidici della Val di Valles (Alto Adige). Mem. Ist. Geol. Miner. Univ. Padova 29, 1–32.

TRUILLET, R. (1968): Etude géologique des Péloritains orientaux (Sicile). Thèse Doct. d'Etat, Paris.

ZWART, H. J. (1969): Metamorphic facies series in the European orogenic belts and their bearing on the causes of orogeny. Geol. Ass. Canada, Spec. Pap. 5, 7–16.

Manuscript received March 1, 1973.