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STUDY OF CHANGES IN CHEMISM OF SOME ROCK-FORMING MINERALS BY AID MICROPROBE ON THE EXAMPLE OF ANDESITE BODY

(Figs. 1–25)

Abstract. The petrological study of a profil of 200 m through a larger andesite body revealed changes in chemical composition of porphyric phenocrysts. These changes caused always changing pressure-temperature conditions of the individual stages of crystallization of the phenocrysts. By the study of chemical composition of porhpyric phenocrysts increased content of aluminium, concentrated into the upper parts of the andesite body, has been found out in magma of intermediate composition. Towards the centre of the body aluminium content gradually decreases and at about 200 m from the marginal zone aluminium content is normal, corresponding to chemical and mineralogical composition of andesite.

Резюме: Петрологическое изучение 200 м профиля по направлению к большому андезитовому телу показало изменения в химическом составе фенокристалов. Эти изменения произошли благодаря меняющимся динамо-температурным условиям единичных этап кристаллизации фенокристалов. Изучение химического состава порфирических фенокристалов показало, что магма интермедиарного состава имела повышенное содержание алюминия, который сконцентрировался в верхней части андезитового теля. Постепенно по направлению к центру тела алюминий уменьшается и приблизительно 200 м от окраинной зоны содержание алюминия нормально, соответствующее химическому и минералогическому составу андезита.

Introduction

In the study of neovolcanic andesites as typical porphyric rocks we meet some problems, conditioned by material composition of crystallizing solution, time of crystallization and the influence of surrounding respectively contaminated rocks. To some questions the studied profile of the andesite body near the community Podzámčok, southerly of Zvolen, gives the answer.

The andesite body (fig. 1) is covered with sediments of the Zvolenská kotlina Basin and therefore also its upper parts have been preserved, which are vesicular, brecciated and jointed with gradual transition into andesite up to massiveone. Changes in material in the time of crystallization process are also indicated in the course of the study of rock-forming minerals, which I studied by means of X-ray microanalyser-microprobe and chemical analyses.

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Petrography of Andesite

The andesite from the borehole HŠ-1 near Podzámčok is light-grey, porous near the upper margin. There it has clastic, brecciated structure, which gradually passes into massive andesite with relatively large femic phenocrysts, whereat the phenocrysts of plagioklases are small, little distinct.

Microscopic observations are in accordance with macroscopic characterization. The highly vesicular structure with hyalopilitic development of groundmass is typical of the most part of the obtained profile. Hyalopilitic groundmass is fluidal, the pores are ordered in direction of fluidality. Porosity gradually decreases as planimetric analyses show:

Depth	55,2 m	132,5 m	177,8 m	211 m
%	10,8	10,8	4,0	0,7

Fluidality is distinct near superficial zones, inside the body it nearly disappears. Porphyric phenocryts are formed by plagioklases, amphiboles and hypersthenes.

Study of Plagioklases

Plagioklase is the essential porphyric phenocryst. It is idiomorphic, very frequently zonal, twinned, with albitic lamellation. Very frequently, mainly in the upper zones, plagioklases contain a great amount of inclusions of mesostasis. The amount of plagioklases is unequable, variable:

Depth	55,2 m	132,5 m	177,8 m	211 m
%	28,4	24,0	25,6	32,6

Basicity of plagioklases measured by the method of symmetric zone displayed gradual decrease of anorthite component with depth of the body. Exact data were delivered by linear scans performed by X-ray analyser. On the basis of these scans I have found out basicity of plagioklases not to be equal even in one thin section. Considerable variation of anorthite component represented by CaO in plagioklase is also to be seen in vertical direction.

I have traced basicity on the basic of Ca-Na scans, to the standard with CaO content 4,05 %. The measurements I have

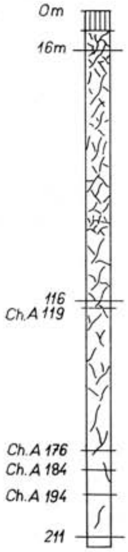


Fig. 1. Profile of Bore-hole HŠ-1 near the Community Podzámčok.

carried out on samples from 16 m, 116 m and 211 m of the borehole profile.

At 16 m plagioklases are of variable composition. The scan with large zonal phenocryst (fig. 2) shows the centre to be more acid than marginal zones. In relation to the standard the centre has about 8,87 % CaO, corresponding to medium basic andesine. The following zones have CaO about 10,12 %, already corresponding to more acid labrador.

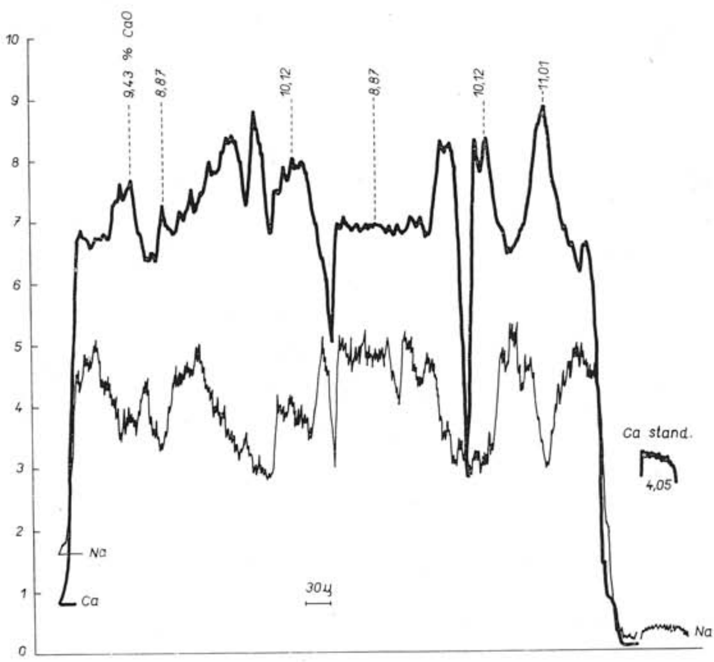


Fig. 2

Proportionately with the increase of CaO the content of Na_2O decreases. The zone on the right grain rim is only slightly developed with andesine value. On the left rim there are still several zones with CaO content varying about 8,87—9,43 % to 8,48 %. Another individual, also zonal, has the centre basic with about 10,12 % CaO. On the left side there is a more basic zone with 10,88 % CaO. These values correspond to labrador (graph 3). Rim zones well developed on the right side show decreasing tendency of CaO 9,49—8,86 % to 8,48 %. The zone about 10 microns thin on the left side terminates crystallization of the individual with about 8,12 % CaO. These rim zones are basic andesines. It is typical that just the rim zones are thinnest ones in zonal crystals.

In graph 4 is Ca-Na scan from smaller porphyric phenocryst. Basicity of this is somewhat lower, CaO value varies in the field for 6—7 % content and one zone touches with its values labrador limits only. The centre of the individual has andesine values with 8,12——8,48—8,86 % of CaO. These values are nearly identical with those of the rim from the centre of zonal plagioklase in graph 2. Similarly as in graph 2 also in this smaller individual the rim zone is more basic (10,12 % CaO) corresponding to labrador. On the basis of these two individuals we may already suppose that plagioklase

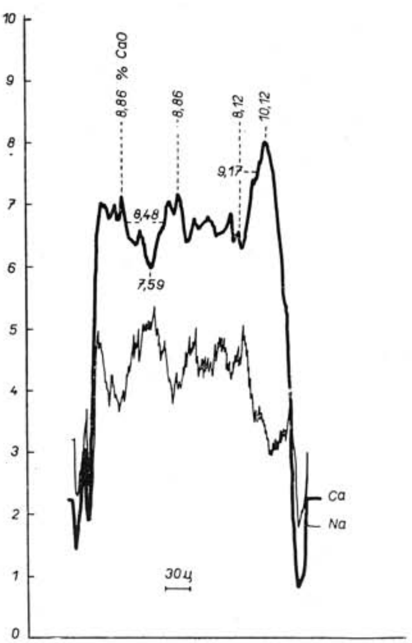


Fig. 3

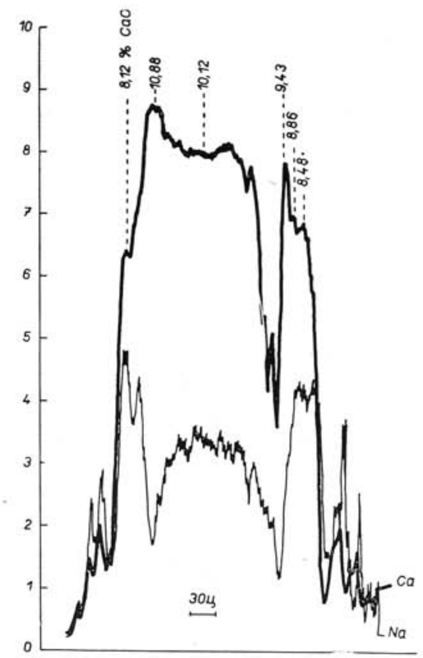


Fig. 4

started to crystallize as andesine but in the course of crystallization enrichment of magma with Ca respectively also Al took place, therefore on more acid core labrador zones deposited. The very rim zones are acid only, corresponding to basic andesines.

Ca-Na scan from a phenocryst about 140 microns in size (graph 5) shows individual simply twinned. In the graph the left half correspond to CaO content in labrador (approximately 10,39 %). The right half indicates content of basic andesine (8,48—9,17 % CaO).

In graph 6 are Ca-Na scans of two microlites. Between them is the scan of standard with 4,05 % CaO. Microlites represent almost the last phase of crystallization of andesite magma. Microlites with dimensions varying from 60 to 120 microns correspond to medium basic andesines (7,59—8,86 to 9,05 %) in CaO content. These contents are lower than in outer zones of large zonal phenocrysts (beside the content of 9,05 %). This means that crystallization of larger porphyric phenocrysts was already terminated in the time of crystallization of microlites of the groundmass.

Also from the middle part of the borehole profile, from the depth of 116 m, I made several Ca-Na scans on plagioklases. In one or another part (under equal conditions as at 16 m) Ca scans vary in the limits 6—7 % respectively 5—6 %, what signifies that basicity of plagioklase phenocrysts in this part of andesite is lower than it was 100 m higher up. In graph 7 the scan is a grain of about 360 microns. The content of CaO varies from 7,56 do 8,60 %. These contents correspond to medium basic andesines according to analyses published by W. A. Deer, R. A. Howie and J. Zussman 1963). The scan from the twinned plagioklase phenocryst had the right half distinctly more acid with higher content of Na_2O. This corresponds to more acid

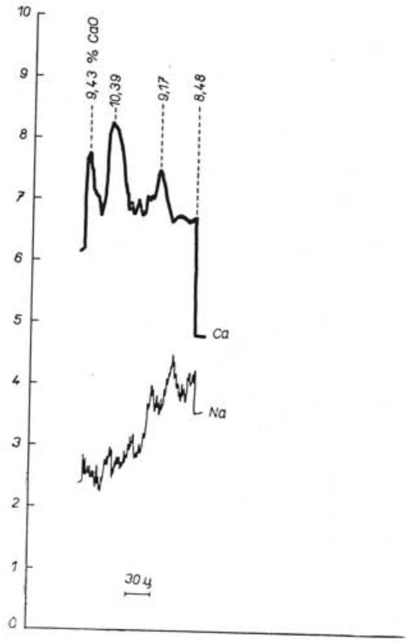


Fig. 5

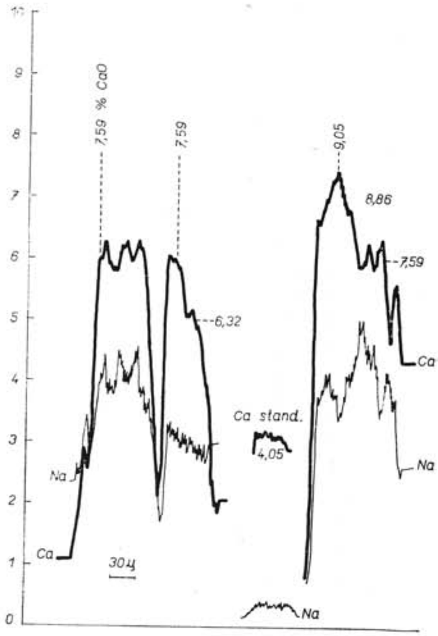


Fig. 6

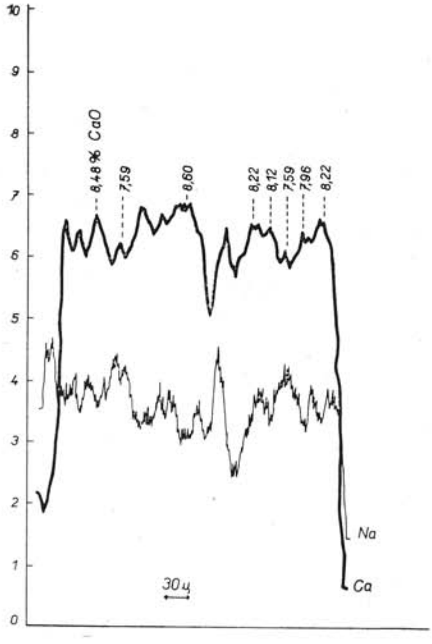


Fig. 7

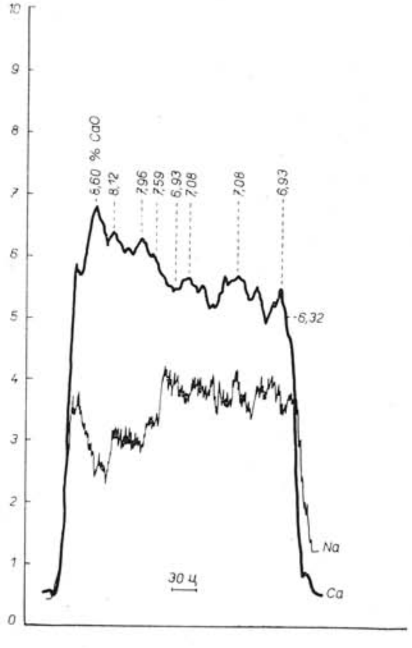
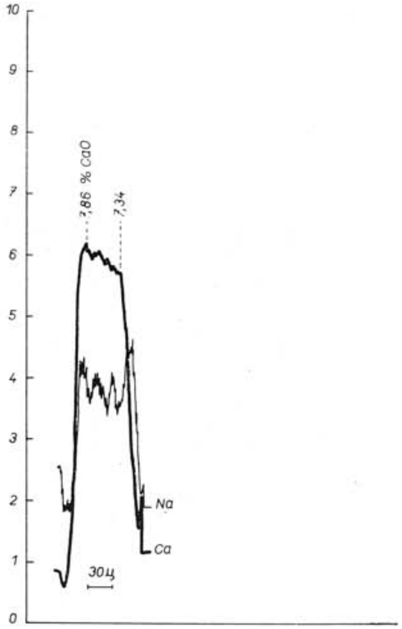


Fig. 8



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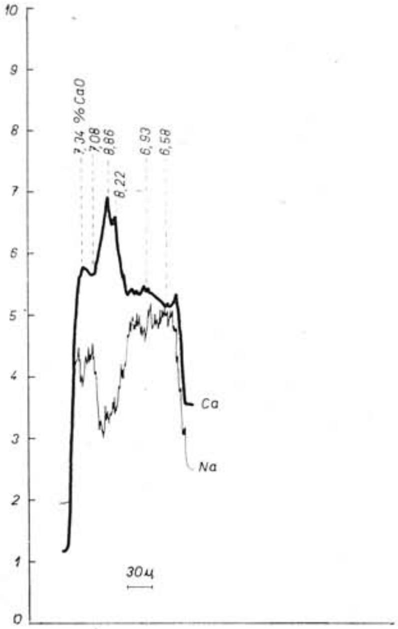

Fig. 10

andesine (CaO from 6,32—7,08 %). The left half of the individual contains 7,59—8,60 % CaO and corresponds to medium basic andesine.

Another smaller grain of plagioklase (graph 9) has similar Ca-Na scans as in graph 8. The right side is again acid andesine (6,58—6,93 %), the centre is basic andesine (8,22—8,86 % CaO) and the left lamella corresponds to medium basic andesine (7,08—7,34 % CaO). According to the scan (graph 10) microlite from this section has small range in Ca content, from 7,34 to 7,86 % CaO only. This content corresponds to medium basic andesines. Comparing the scans on graphs 10, 9, 8 we are finding out plagioklases representend in this section to be only from the andesine group according to CaO contents. Most distinctly are represented medium basic andesines but crystallization continued as far as acid andesines with CaO content 6,32 %.

Distinct decrease in CaO component in plagioklases is shown in scans made from andesite sample, which I took from 211 m deep. From several scans through plagioklases we see not only decrease in CaO but also unstable CaO level in the course of phenocryst crystallization.

In graphs 11 and 12 are scans of Ca of two plagioklases, the centre of which is more acid. In graph 11 there is a plagioklase, which corresponds to basic oligoclase in its values. Equable and concentric to the centre zones with higher (5,85 % CaO) and lower contents of CaO, e. g. 5,32 %, alternate in it. The outermost zone — in the right, has the content corresponding to andesine (6,39 % CaO). In graph 12 Ca scan is more acid oligoclase. The centre with CaO content about 4,05 % is surrounded by zones with higher value of CaO 4,22 to 4,40 % CaO. Then Ca level lowers towards the rim of plagioklase.

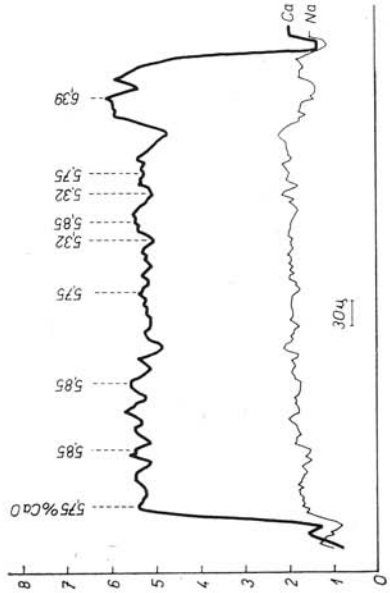

Fig. 11

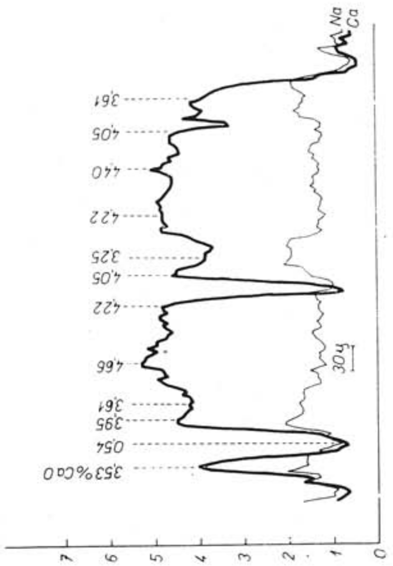

Fig. 12

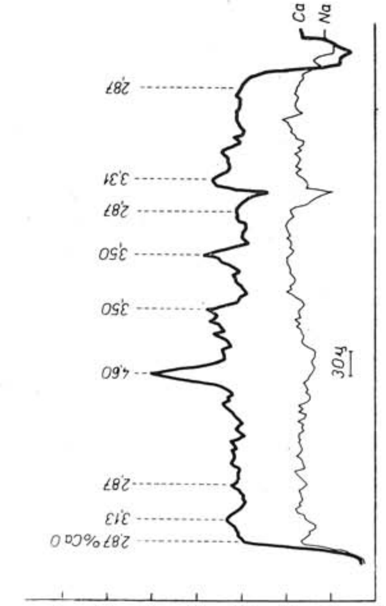

Fig. 13

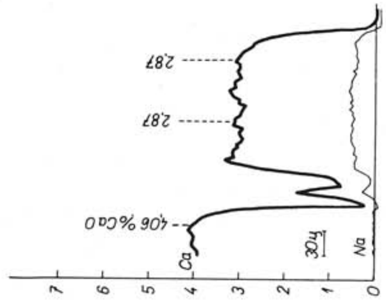

Fig. 14

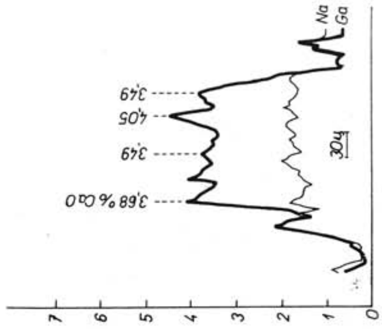

Fig. 15

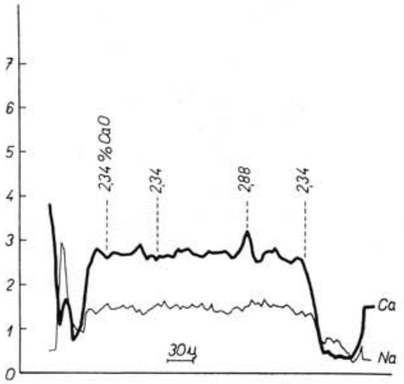

Fig. 16

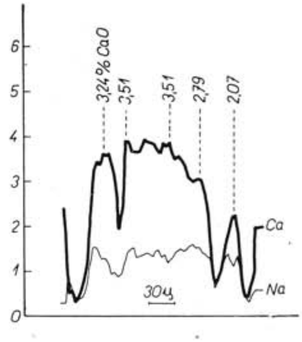

Fig. 17

Another plagioklase in graph has very unbalanced level of CaO content. Lamellas of various basicity alternate but they are within the oligoclase, e. g. 4,6—3,5—2,87 % CaO. Graph 14 represents Ca scan of smaller phenocryst. Its level is generally balanced. It represents an individual, formed after crystallization of oligoclases presented in graphs 11 and 12. Its time of crystallization probably coincides with crystallization of some lamellas in graph 13. Crystallization of oligoclase, Ca scan of which is in graph 15, represents an individual, crystallization of which started with more basic core (4,05 % CaO). After escape of Ca from the magma more acid zones crystallized (3,49 % CaO). On the left side of the individual the more basic rim is with slightly increased content of CaO (3,68 %).

Graphs 16 and 17 represent Ca scans of relatively acid oligoclases, CaO contents of which are so low that in their contents (3,51—2,79—2,34 %) they decrease to the half of more acid oligoclases.

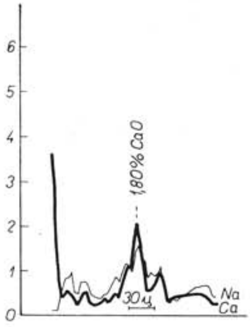

Fig. 18

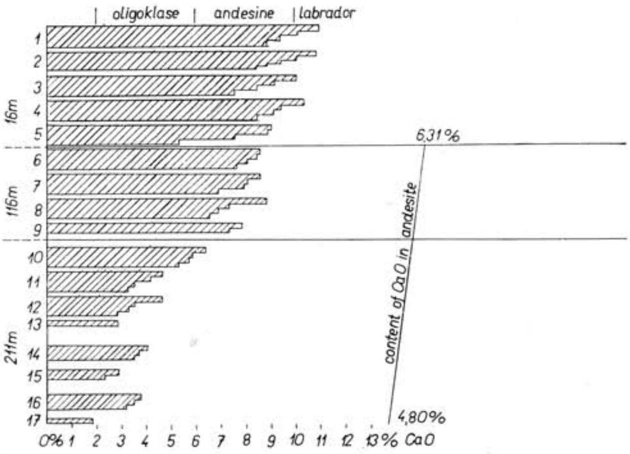

Fig. 19. Content of CaO in Plagioklases

Beside the analysis of phenocrysts of greater dimensions (450—300 μ) I have also scan through some smaller microlites (about 30 μ). On the basis of the analysis of values of these microlites (graph 18) CaO contents of which are 1,8—2,07—3,53 % I conclude that they did not crystallize at once but with various CaO contents in magmatic solution. It may be also supposed that crystallization process of some mocrolites terminated prior to termination of crystallization of rims of some phenocrysts, e. g. in graph 17 and 16.

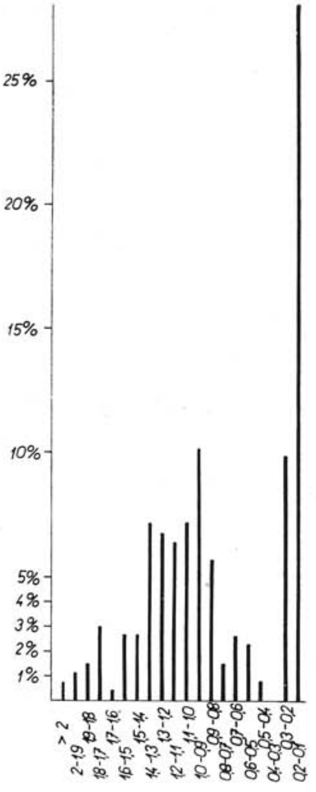

Fig. 20. Frequency Histograms of Plagioklase Phenocryst Dimensions

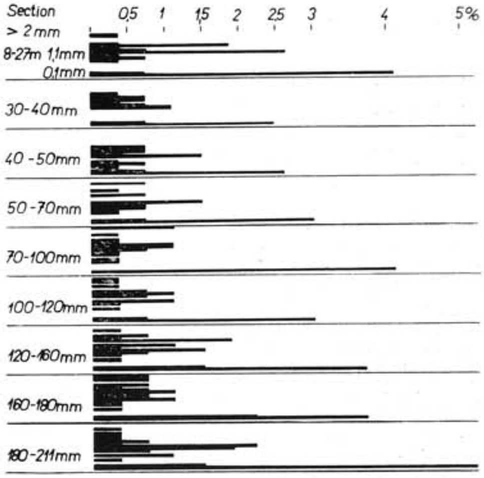

Fig. 21. Frequency Percentage

From these oligoclases I carried also out quantitative analysis by aid of microprobe. The analysis was carried out from several planes of the crystal and this average content of principal oxides was calculated: SiO_2 67,41 %, Al_2O_3 23,20 %, FeO 0,91 %, MgO 0,14 %, CaO 5,94 %, together 97,60 %. Chemical composition is without alkalies, for which I did not have any corresponding standards. These fundamental oxides are sufficient for determination of plagioklase composition. This our one shows higher SiO_2 content, nearly that of albite, the content of Al_2O_3 is for oligoclase, which has CaO about 4—5 % normal. The contents of Mg and Fe oxides are as admixtures. The missing 2,40 % can be calculated for alkalies, however, of which the oligoclase group has more, e. g. only Na_2O varies from 2,18 to 5,81 %.

The mentioned analysis of plagioklase (except alkalies) corresponds to values of oligoclase. The slow scans made through several plagioklases in thin section from the depth of 211 m confirm CaO level about 5 %, also when the scans show lower contents.

From the measured contents of CaO according to analysed lines from the profile I compiled histograms of CaO contents in plagioklases (graph 19). The difference in CaO content at 16 m and 116 m makes about 2 %. This difference gradually increases so that the total difference in CaO content of plagioklases between 16 and 211 m is 5 to 6 %. This decrease in CaO is in direct dependence with decrease in Al_2O_3 and also traceable in chemical analyses of andesite.

119,1 m	6,31 % CaO	18,51 % Al_2O_3
176,0 m	5,61 % CaO	17,89 % Al_2O_3
184,3 m	5,89 % CaO	17,96 % Al_2O_3
194,2 m	4,80 % CaO	16,17 % Al_2O_3

Throughout the whole profile I traced the size of plagioklase phenocrysts. From numerical data I compiled histograms on the basis of frequency of occurences, which I recalculated into per cent. In graph 20 sizes of phenocrysts are to be seen represented. The phenocrysts more than 1,5 mm are represented up to 3 % only. Mostly represented are sizes 0,9—0,8 up to 1,4—1,3 mm, then the number of frequency of smaller phenocrysts decreases much until frequency at dimensions 0,3—0,2 mm up to 10 % respectively at 0,2—0,1 mm up to 28 % increases.

The measured values I further considered according to the sections and compared mutually frequency of individual sizes. In graph 21 are shown 9 sections of the borehole. In each from above downwards per cent histograms of represented sizes are shown, from grain dimensions > 2 mm, the centre of section is 1,1 mm to dimension of 0,1 mm. From comparison it is evident that the section from 30 to 50 m does not contain larger phenocrysts and the most phenocrysts have dimensions from 1,4 to 0,8 mm. According to classification by F. O. Teuscher, modified by P. Niggli (1948) and B. Hejtman (1956) this section of andesite lies at the limit of medium and fine grained rocks.

Further sections are also characteristic by the presence of larger plagioklase individuals, also when the most phenocrysts vary in the limits 1,4—0,8 mm. This does not play an important rôle in general classification of the rock according to grain size, also when in graph 21 a slight shift of frequency to the group with larger phenocrysts is visible as for instance in the section 160—180 m.

From this measuring of plagioklase size also another information is evident, which may be formulated this way: the change of plagioklase basicity from labrador to oligoclase does not result in the change of grain size or granularity of rock is not directly dependent on chemical processes taking place in the course of crystallization. It is probable that granularity development is influenced by Pt conditions of crystallization process only.

Study of Amphiboles

Dark-coloured minerals in andesite are represented by amphiboles and pyroxenes. Amphiboles are andiomorphic, without opacitization. According to extinction they are greenishgrey, α is light-yellow and β dark-greenishbrown. According to optical values amphiboles are not equal. Various variations are to be seen in the group of common hornblende.

It is evident from many measurements of angle 2 V that they belong to hastingsite with commonest angle 2 V from 45° to 61° respectively also 87°. In classification by Berman (1937) the terms pargasite and hastingsite are applied to amphiboles with various Al content. To pargasite amphiboles belong, formula of which is: $NaCa_2Mg_{4,5}$-$Al_{0,5}Al_{1,5}Si_{6,5}O_{22}(OH)_2$ to hastingsite belong amphiboles of the formula: $NaCa_2Mg_4$ $AlAl_2Si_6O_{22}(OH)_2$. Similar terminology is also applied by Foslie (1945). At such a complicateness of the amphibole group optical properties only reflect principal features of chemical composition and with lacking chemical analyses frequently amphiboles are also difficult to identify. Our andesite near Podzámčok includes from 3,7 % to 9,4 % amphibole. They are relatively fresh, therefore we separated them from crushed rock. The chemical analysis was performed by eng. Surová in the laboratories of the Dionýz Štúr Institute of Geology. In the table beside (table 1) complete silicate analysis also values of two amphiboles from the depth of 116 m are presented, obtained by microanalyser.

From some amphiboles of 211 m deep I made linear scans of Si-Al using the standard SiO_4 37,48 % and Al_2O_3 21,44 %. The scans show the level of element content not to be equal. For instance, the scan through the section of the basal plane of small amphibole phenocryst shows variation of Si in the limits of 34,44 % to 37,48 %. The rule is valid that rims of grains show Si increasing towards the groundmass of andesite. The contents of SiO_2 and Al_2O_3 calculated according to this scan correspond to ferrohastingsite (graph fig. 22).

The linear scan through other amphibole is approximately similar, variations in the content of Si are greater, from 35,45 % to 40,51 %. The content of Al_2O_3 keeps approximately the level of 11,42 %. These values correspond to hastingsite. Optical values of 2 V (from 60° to 68°) correspond to Mg-hastingsite. Also pleochroic colours α light-yellowishgreen and β dark-greenishbrown approach Mg-hastingsite.

Table 1

SiO_2	46,65 %	39.01 %	41,25 %
TiO_2	1,90	—	—
Al_2O_3	6,01	12,52	12,87
Fe_2O_3	6,89	—	—
FeO	18,68	15,46	16,16
MnO	0,26	0,44	0,45
MgO	6,24	9,24	10,40
CaO	9,10	9,86	9,56
Na_2O	1,60	—	—
K_2O	0,80	—	—
P_2O^7	0,25	—	—
H_2O^+	1,10	—	—
H_2O^-	0,34		
	99,82		

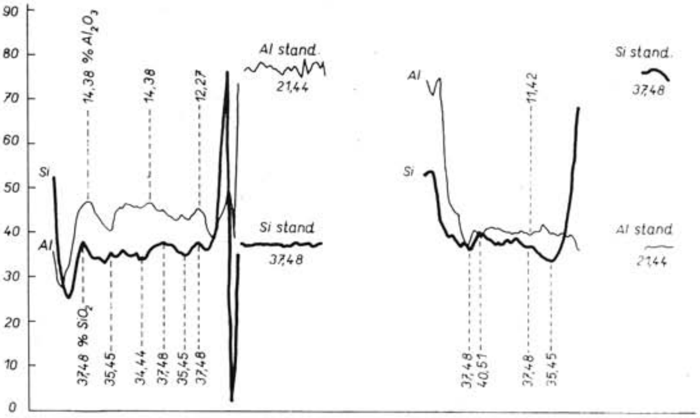

Fig. 22

There are some differences between amphiboles separated by classical analysis and analysis with microanalyser, which could be caused by small inclusions in amphibole phenocrysts.

Study of Hypersthene

Pyroxenes are represented by idiomorphic hypersthene. Along cleavage fissures and near terminal planes it is chloritized. It has typical pleochroic colours, according to α yellowishbrown and according to γ greyishgreen. Hypersthene forms big columnar individuals. Very frequently it has inclusions. The content of pyroxenes in andesite varies from 3 to 7,7 %.

Chemical analysis of separted hypersthenes ranges them to the group with aluminium and high content of iron also included in structure.

Some hypesthenes from the depth of 116 m I analysed by X-ray analyser. The results are given in table 2.

From the mentioned analyses it is evident that a part of Si is substituted by Al^{4+} and therefore these hypersthenes approach so called alumohypersthenes.

In literature similar cases of hypersthenes rich in Al are mentioned. P. Eskola (1952) calls attention to very high Al_2O_3 contents in hypersthenes in garnet granulites. These high contents of Al_2O_3 he puts into connection with the coexistence of hypersthene with amphibole and garnet. D. H. Green (1964) mentions from practice enstatites with high content of aluminium. He comes to the conclusion that substitution Al→Mg Si was taking place in enstatite. H. H. Hess (1952) proves that substitution is a consequence of pressures.

H. H. Hess also remarks that this process can take place in rocks and points to the case of Al→Si substitution in charnockites in granulite facies of hypersthene. T. H. Green (1966, 1968) in his work about experimental study of anorthosites under high pressures also deals with the depth of initial crystallization of andesites. Among other matters he also mentions that 1,70 % Al_2O_3 in hypersthene makes possible to suppose these phenocrysts to have originated not very deep in earth's crust. According to experiments increased content of A_2O_3 can be indicator of higher pressures. He mentions, for instance, the increase in Al_2O_3 from 27 kbar at 1340° to 36 kbar at 1450° from 24,5 % to 27,2 %.

On the basis of these experimental works I come to the conclusion that in mentioned hypersthenes Al points to increased content of aluminium in the magma, which did

Table 2

	Analysis of separated grains	Hyp. 3	Hyp. 4	Hyp. 5	Hyp. 6
SiO_2	41,85	42,66	40,81	44,14	40,57
TiO_2	1,10	—	—	—	—
Al_2O_3	5,96	4,94	5,44	4,21	5,58
Fe_2O_3	11,73	like FeO	like FeO	like FeO	like FeO
FeO	12,86	19,57	25,52	24,87	28,85
MnO	0,68	0,60	0,92	0,92	0,78
MgO	20,14	21,62	23,94	22,01	23,36
CaO	2,44	1,54	1,80	1,87	1,06
Na_2O	0,20	—	—	—	—
K_2O	0,19	—	—	—	—
P_2O_5	0,50	—	—	—	—
H_2O^+	1,57	—	—	—	—
H_2O^-	0,44	—	—	—	—
	99,66	90,83	98,43	98,02	97,20

not form own facies of garnet under insufficient pressures but aluminium passed into hypersthene facies and this way the indenpendent mineral facies of alumohypersthenes has formed. According to A. E. Rinsburg and D. H. Green (p. 93) this could have formed under pressures of 10—15 kbar while independent mineral facies of garnets requires higher pressures of about 20 kbar. According to these considerations alumohypersthene may indicate physical-chemical conditions dominating at the commencement of crystallization of this andesite magma.

From the depth of 211 m I analysed several hypersthenes from andesite particularly aimed to aluminium content. At this level the andesite body does not show excess of aluminium any more (already obvious also from analyses of plagioklases) and therefore a series of normal hypersthenes with rich ferro-silicon component crystallizes (table 3).

From the mentioned analyses of minerals it is evident, that only the upper margin of the andesite body has increased aluminium content, which entered the lattice of minerals of primary crystallization in the time of crystallization process at increased pressures and temperature. In the mentioned eight analyses about 1 % CaO and up to 1,6 % Al_2O_3 appear as standards. Studying pyroxenes in effusive rocks H. Kuno (1954) came to the opinion that most of them contain some Al substituting Mg ions. Similarly it is the case at admixture of Ca entering elementary lattice, causing its slight enlargement, however, which has no marked influence on hypersthene properties. The rôle of some geological thermometer is also supposed because up to the temperature of 1100 °C the highest amount of Ca enters hypersthene lattice. Basing on this supposition we may conclude that hypersthenes in the depth of 116 m crystallized at higher temperatures than hypersthenes from 211 m deep, where Ca content is lower.

Table 3

	Hyp. 1	Hyp. 2	Hyp. 3	Hyp. 4	Hyp. 5	Hyp. 6	Hyp. 7	Hyp. 8
SiO_2	53,37	52,06	52,98	51,84	51,91	51,37	51,19	48,26
Al_2O_3	1,35	1,51	1,54	1,53	1,13	1,60	1,63	1,82
FeO	26,09	26,66	27,17	26,27	25,74	26,53	26,87	25,33
MgO	17,72	17,71	18,17	18,43	18,73	18,88	18,64	17,48
MnO	1,21	1,42	1,37	1,33	1,32	1,37	1,46	1,22
CaO	1,09	1,29	1,02	1,31	1,35	1,14	0,84	1,58
	100,86	100,65	102,25	100,71	100,18	100,89	100,63	95,69

Criteria for Petrographic Sorting of Rocks into Classification Schemes

For correct ranging of rocks petrographic data about the amount of represented minerals as well as about basicity of present plagioklases and degree of crystallization are necessary. Up to present ranging of rocks is made on the basis of present phenocrysts while the groundmass is almost not taken into consideration for its low degree of crystallization. In order to express the ratio groundmass: phenocrysts I applied several planimetric analyses from various parts of the profile. (Table 4.)

In the mentioned analyses are considerable differences in representation of femic minerals. It may be caused by unequal development or accidental plane of thin section. For verification of the right content of femic components I performed analysis of heavy minerals from crushed andesite (176 m deep). From 426 calculated grains I have got the following relations: amphibole 59,2 %, pyroxene 36,8 %, magnetite 3,1 %, apatite and zircon 0,9 %.

Table 4

	55,2 m	132,5 m	177,8 m	211 m
groundmass	52,3 %	50,3 %	56,9 %	55,1 %
plagioklase	28,4	24,0	25,6	32,6
amphiboles	4,8	6,6	9,4	3,7
pyrox̃enes	3,0	7,7	3,5	6,8
magnetite	0,6	0,5	0,5	1,2
apatite	0,1	0,1	0,1	—
pores	10,8	10,8	4,0	0,6

In order to compare these results with planimetric data I recalculated per cent of femic minerals from planimetric analyses recalculated to 100. Comparison is presented in table 5.

Table 5

	55,2 m	132,5 m	177,8 m	211 m	Heavy minerals from 176 m
amphibole	56,5 %	44,0 %	69,6 %	31,6 %	59,2 %
pyroxene	35,4	51,3	25,9	57,9	36,8
magnetite	7,0	4,0	3,7	10,5	3,1
apatite	1,2	0,7	0,8	—	0,9

After verification of the correctness of the content of femic minerals the obtained data may be applied as criterion for terminological ranging of rock.

For ranging of rocks and determining of the right term many systems have been worked out. According to A. Johannsen (1952) the analysed rock belongs into the group 2212 E to andesites described by Ch. L. v Buch. Later classification by F. Ronner is based on basicity of plagioklases and the amount of mafic components. According to basicity of plagioklases he ranges rocks into three groups with content An_{10-45}, An_{45-55} and An_{55-100}. According tho this division andesite in Podzámčok belongs to various fields. The upper part with predominantly represented andesine to acid labrador with content An_{45-55} would belong to the group of leukoandesitebasalt, the middle part with predominating acid andesines would be at the limit andesite-leuko-andesite-basalt with An content up to 45. The lower part, where oligoclases with An_{10-20} are represented, would belong to the group of andesites. Ranging according to mafic components does not show so great differences because according to the content they belong to the group with the content of mafic components 10—50 (graph 23).

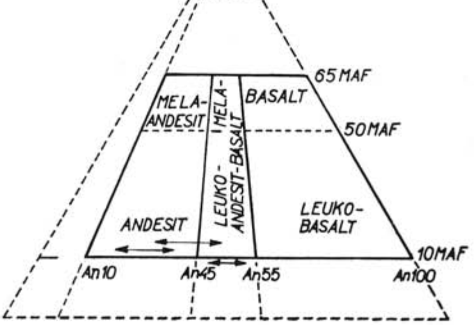

Fig. 23

Chemical Composition

From the studied profile of andesite 4 complete silicate analyses were performed. From the sample 176 m deep also separated out particles of groundmass were analysed. The differences in petrographic composition are also reflected in represented oxides, in the content of which are considerable differences (table 6).

Table 6

	119,1 m*	176,0 m*	184,3 m*	194,2 m*	groundmass** from 176,0 m
SiO_2	58,06 %	56,10 %	55,70 %	54,08 %	60,03 %
TiO_2	0,60	0,62	0,64	0,54	1,10
Al_2O_3	18,51	17,89	17,96	16,17	8,23
Fe_2O_3	1,54	2,42	2,76	3,44	5,33
FeO	4,09	3,09	2,73	2,30	1,28
MnO	0,12	0,09	0,07	0,09	0,10
MgO	2,90	3,42	3,35	4,41	6,71
CaO	6,31	5,61	5,89	4,80	7,25
Na_2O	2,44	2,84	2,34	1,82	2,55
K_2O	2,18	2,22	2,06	2,02	2,90
P_2O_5	0,04	0,06	0,04	0,06	0,80
H_2O^+	1,28	3,77	3,90	6,62	1,92
H_2O^-	2,33	2,42	2,54	3,81	2,08
	100,40	100,55	99,98	100,16	100,28

* Analysed by Jirásková, laboratories of the Dionýz Štúr Institute of Geology.
** Analysed by Surová, laboratories of the Dionýz Štúr Institute of Geology.

The contents of oxides I have plotted in graph 24. The differences are conditioned by mineral composition and differences in chemical composition of minerals, mainly of porphyric phenocrysts. As most acid appears to be the groundmass, relatively poor in Al_2O_3, which is concentrated in plagioklases. CaO, MgO, Fe_2O_3 and FeO are concentrated to mafic microlites and magnetite grains in the groundmass. Most distinct increase shows K_2O, which is bound to glass in the groundmass.

In andesite in direction into the body gradual decrease in aluminium component is to be observed, which is in direct dependence on calcium content. To the deepest parts magnesium, trivalent and bivalent iron are concentrated. With depth sod um markedly decreases. It is the consequence of greater concentration of mafic minerals and predominating development of smaller plagioklase phenocrysts.

In order to complete chemism of andesite in Podzámčok I prepared a series of quantitative spectral analyses on the content of following elements: Pb, Ga, Ni, Cr, Co, V, Zr, Ba, Sr. The contents of individual elements are expressed in g/t. The contents of Pb, Ca, Ni are usually low and seldom reach value more than 10 g/t, their average content is up to 10 g/t. The contents of other elements are plotted in graph 25. From this graph irregular contents are to be seen, which are not following the trend of mineral representation and also not of macroelements distribution.

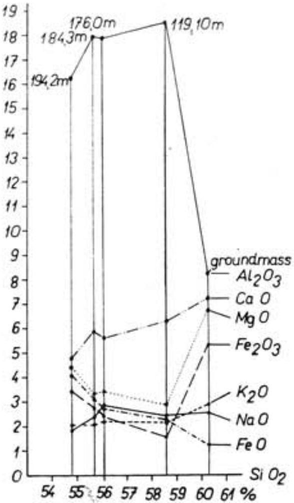

Fig. 24

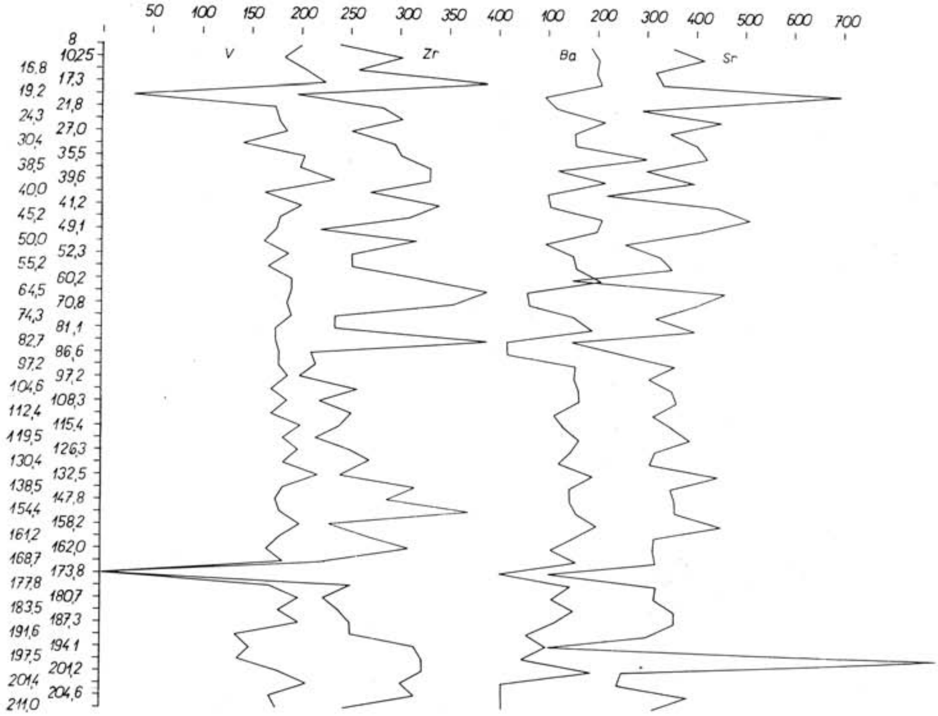

Fig. 25

Conclusion

The mentioned studies and analyses by microanalyser show, as also the 202 m section through the andesite body proved, that the andesite is not equal in petrography as well as in chemism. With increasing depth basicity of plagioklases changes from more basic ones at the periphery of the body to more acid ones towards the centre. Chemical analyses show a decrease in CaO and also Al_2O_3 being in dependence on the change of plagioklase basicity. Mafic minerals in the middle part of the profile show increased content of Al. This higher content of Al is from geochemical side typical of this andesite type and its excess is usually shown by the presence of garnet. In this case, analogously to some experiments, pressures (respectively pt conditions) were not sufficient for formation of garnets and therefore excessive aluminium entered hypersthenes. As these alumohypersthenes represent the first phase of crystallization, we cannot consider them as „determinator" of conditions of crystallization. Experiments (D. H. Green, A. E. Ringwood 1966) proved origin of alumohypersthenes at pressures of 19 kbar and temperatures of 1300 °C or somewhat more than 1300 °C.

Chemical analyses prove the decrease in aluminium towards the centre of the body. Consequently, marginal parts of the andesite body represent the part richer in aluminium.

In the depth of 200 m normal content of aluminium is to be observed only. At this level oligoclase-andesines and normal hypersthenes crystallized, not enriched in Al component.

In classification scheme by F. Ronner this profile of the upper part of the andesite body would be ranged into various categories from leukoandesite-basalt (upper part) to andesite (lower part) on the basis of basicity.

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