*Acta Mineralogica-Petrographica, Szeged, XXII/1, 97—112, 1975*

# A COMPARATIVE PETROLOGIC STUDY OF SARMATIAN PYROXENE-ANDESITES NEAR TELKIBÁNYA—PÁNYOK (TOKAJ-MTS, NE-HUNGARY)

M. NÉMETH

## ABSTRACT

As a result of the author's investigations, it has been stated, that the acidic pyroxene-andesite of the belt between Szurokhegy in Kéked and Magostér in Telkibánya (both in NE-Hungary) belongs to the leucogabbroidic type of igneous rocks defined by NIGGLI. (The foliated rocks of the Hosszúkő in Telkibánya characterized by parallel lamellae belong to this group, too.) This fact refers to the basic character of the original magma corroborated also by the presence of hypersthene and bronzite as well as that of diopside and endiopside from among the monoclinic pyroxenes. The latter minerals are missing in the foliated andesite of Hosszúkő. This can be explained by a relatively rapid ascendence of the rock as compared to that of the acidic pyroxene-andesite. In this case there was not time for a fractional crystallization.

The path of the acidic pyroxene-andesite interrupted by "stopovers" (i.e. by magma-chambers) could be traced easily by minerals which crystallized from it. From the clinopyroxene lamellae of the hypersthene appearing first and containing 51—52 mol% of $MgSiO_3$, $Ca^{2+}$ and $Fe^{2+}$ ions have been removed in a temperature range of 800—1000 °C. This phenomenon — together with an intake of $OH^-$ ions — have resulted in uralitization consisting of structural realignment and starting along transversal clefts. (The clinohypersthene lamellae are lamellae parallel to the (100) plane of the orthopyroxene with higher $Ca^{2+}$ and $Fe^{2+}$ content as compared to their environment.) Assuming that more significant Si addition from the surroundings necessary for pyroxene → amphibole transformation is impossible, $Mg^{2+}$ and $Fe^{2+}$ are released by this transformation process. The release of $Mg^{2+}$ has lead to formation of $MgSiO_3$-rich orthopyroxene types (i.e. bronzite), while the released $Fe^{2+}$ content which attained a higher oxydation-reduction potential in an $OH^-$-rich environment, could not be fixed in the orthopyroxene, but have been separated as hematite. Thus the bronzite-formation is promoted by the amphibolization in a double way.

In this environment characterized by relative low $Fe^{2+}$ content, diopside and endiopside are formed instead of augite. Lacking this quiet, fractional crystallization clinohypersthene and augite have formed in the foliated andesite.

Under thicker cover and in presence of higher volatile concentration even the chloritization of the uralite has started (Hasdát-völgy), and the released Ca content has been fixed in apatite crystals. This phenomenon is the sign of a commencing propylitization, though in that case higher temperature (epidote) and $H_2S$ addition (pyrite) should also be reckoned with.

## INTRODUCTION

This study deals with the ortho-rocks of the so called "acidic pyroxene-andesite" and "foliated pyroxene-andesite" sequence of Sarmatian age in the area between Telkibánya—Pányok *(Fig. 1)*. The ortho-andesite is represented by samples of acidic pyroxene-andesite from the Nagy-hegy near Pányok, from the quarry of Pányok, from a pasturage in tront of the inlet of the Hasdát-völgy, as well as from the Baglyas-völgy in Telkibánya. These are compared according to the mineralogical and petrological composition to the foliated orthoandesite from Hosszúkő in Telkibánya representing a younger magmatic phase.

The author's aim was a more detailed mineralogical investigation of the pyroxenes in the acidic- and foliated pyroxene-andesites; the determination of the crystal-

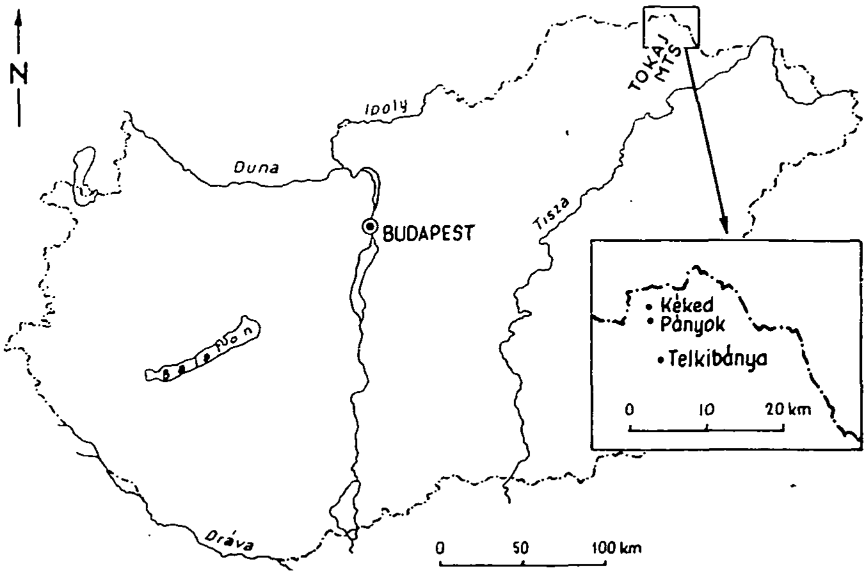



*Fig. 1.* Location of the investigated area.

lization sequence of the pyroxenes as well as observations concerning the alterations of pyroxenes.

In the course of microscopic investigations the composition of the orthorhombic and monoclinic pyroxenes in mol% has been determined by universal stage method. In the case of orthorhombic and non-twinned monoclinic pyroxenes only the 2V has been measured, while for monoclinic crystals twinned by (100) plane values of 2V, $\gamma/c$, A/c have been estimated. Substituting the data collected this way into the so-called Hess-diagram the composition of pyroxenes in mol% can be stated [KUBOVICS, 1968; SZTRÓKAY, K. *et al.* 1970].

The mineralogical composition in volume percents and grain-size distribution have been measured along straight lines (8 lines for each thin section).

## COMPARATIVE STUDY OF THE PYROXENE-ANDESITES

### *Petrologic description*

*1.* According to the microscopic observations the *acidic pyroxene-andesite* is composed not only of orthominerals. Uralitized-chloritized pyroxenes and opacitic amphiboles also can be found always. The quantity of these, however, is under 5%, thus the rock involved is allowed to be defined as ortho-andesite.

As for the phenocrysts of the ortho-andesite, the *plagioclase* crystals are platy and twinned, mostly by Carlsbad-law. In general, three generations could be separated:

*1)* Plagioclases with a length of 3000—500 μ.
*2)* Plagioclases with a length of 500—180 μ.
*3)* Plagioclase lathes of the groundmass.

The plagioclase generations listed above differ from each other mostly in their inclusion content. The plagioclase crystals of the first generation have groundmass-inclusions either forming zones or spacing parallel to the longitudinal axis of the crystals. In the sample taken from the entrance of the Hasdát-völgy, sporadically first generation plagioclase crystals with clinopyroxene inclusions can be found (Plate II. *Fig. 1*).

So-called "plagioclase-knots" occur also frequently. These are composed of well rounded (i.e. resorbed), sometimes sericitic first-generation plagioclase grains and hypersthene crystals with a number of longitudinal clefts and altered along transversal cleavages (Plate I, *Figs. 1—2*). Every now and then one or wto clino-pyroxene grains could also belong to such an holocrystalline nodule. The plagioclase crystals of the second generation are inclusion-free, unaltered and angular. Their composition is of labradorite-andesine character with an 50% of anorthite content in general.

Mafic components of the rock are mostly orthorhombic pyroxenes, clinopyroxenes as well as amphiboles. Their sizes remain under those of the plagioclase crystals. The *orthopyroxenes* are the most abundant mafic components having two generations of different composition. The first one is characterized by larger, elongated crystals (1000—500 μ in length) of fairly platy appearence. The average of the 2V values is −55,2° varying between −51 to −57,5° (Table 1). This average value means an orthorhombic pyroxene with an $MgSiO_3$ content of 51—52%, which corresponds to the composition of the *hypersthene*. These pyroxene crystals are characterized by the dominance of the longitudinal cleavages as well as by frequent occurrence of magnetite inclusions with a diameter of 30—100 μ (Plate I, *Figs. 3—4*).

TABLE 1

*2V values of orthopyroxene crystals from the Nagy-hegy in Pányok*

| First generation without pigeonite-rim | Second generation with pigeonite-rim | |
|---|---|---|
| | Central part | Marginal part |
| −51° | −61° | −76° |
| * −52° | −61,5° | −77° |
| −55° | −62° | −82° |
| −56,5° | −67° | −83° |
| −56,5° | −68° | −83° |
| −56,5° | −69° | |
| −57° | | |
| −57,5° | | |
| Average −55,2° | −64,7° | −80,2° |

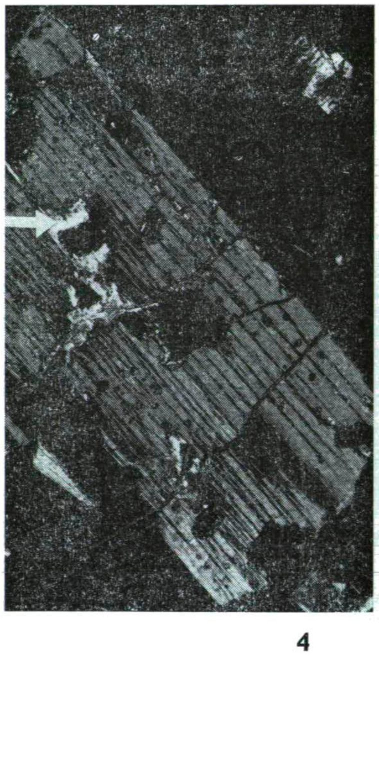
* Orthorhombic pyroxene belonging to a plagioclase-knot.

The second generation are of shorter and less wide pyroxene crystals showing definitely lathy forms sometimes, and characterized by transversal clefts (Plate II, *Figs. 2—3*). The magnetite inclusions are much less frequent as compared those in the first generation. The average 2V value of the second-generation orthopyroxenes is −64,7° varying from −61° to −69°. As for their chemical composition, their $MgSiO_3$ content amounting to 70 mol% marks the *bronzitehypersthene* border. An emphasized increase of the 2V values could be stated in these orthopyroxene

1

2

3



4

varieties moving towards the rims, as a result of which the average value of 2V might be as high as $-80,2°$ (Table 1). This value corresponds to an $FeSiO_3$ content of 16—17% only, on the basis of which the minerals involved could be defined as *bronzite*. Second-generation orthorhombic pyroxenes could be repeatedly observed to have monoclinal pyroxene rims (Plate II, *Fig. 4*).

Consequently, the optically oriented coalesce of monoclinic pyroxene and hypersthene mentioned several times by earlier papers too [LIFFA, A. 1953; HERRMANN, M. 1952; SZÉKY-FUX, V. 1970 is only for the bronzitic hypersthenes of the second generation in the area involved.

The alteration processes of all orthopyroxene varieties start along transversal cleavages and advancing step by step, extend to the longitudinal cleavages too. The alteration product is a fibrous, slightly pleochroic *uralite* with length-fast elongation and showing polarization colour of first-order orange to second-order blue (Plate I, *Figs. 3—4*). The fibres are spaced parallel to the "c" axis of the orthopyroxene. The alteration process is more advanced in the case of hypersthenes of the first generation. In the andesite at the inlet of the Hasdát-völgy the weathering of the hypersthene is even more advanced. Pale green, slightly pleochroic *chlorite* and *uralite* — both after hypersthene — are frequent. In these pseudomorphoses unaltered orthopyroxene fragments are "floating" (Plate III, *Fig. 1*). Sometimes *apatite* lathes are found in the chlorite-knots. A type of chlorites with a polarization colour of first-order gray as well as lower in refractivity and less in size than the uralite fibres could be found in the uralite pseudomorphoses and along the late transversal clefts of the hypersthene; i.e. at the starting points of the alteration processes. The hypersthene crystals from the Baglyas-völgy have suffered a nontronitic alteration.

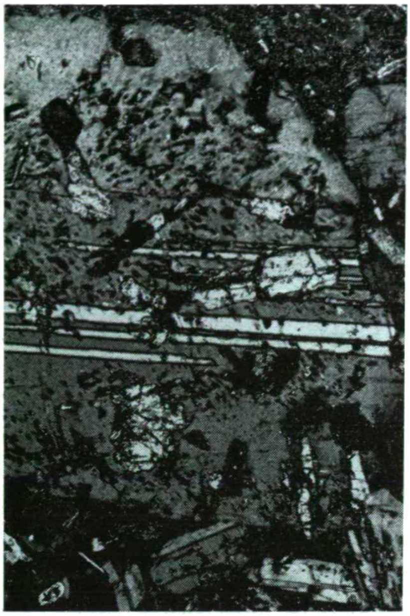
The *monoclinic pyroxenes* less in size and quantity then the orthorhombic ones, have two modifications. One of them appears to be a rim of the second generation of the orthopyroxenes mentioned above (Plate II, *Fig. 4*). These are elongated *pigeonite* crystals with 2V values of 5—8°. The other modification is made up from independent isometric crystals having octogonal sections parallel to the (001) plane. Sometimes twinning by the (100) plane can be observed (Plate III, *Fig. 2)*. On the basis of their 2 V, $\gamma/c$ and A/c values, these independent monoclinic pyroxenes are *diopsidic* or *endiopsidic* composition or mark the diopside→endiopside transition *(Fig. 2)*. According to DEER, W. A.—HOWIE, R. A.—ZUSSMANN, J. [1963] such joint occurrence of Ca-rich and Ca-poor phases refers to an period of quiescence, and — according to PANTÓ, G. [1964] — shows a magma chamber below a depth of 10 km [in PANTÓ, GY. 1970. p. 200]. Moreover, DEER, W. A. *et al.* [1963] stated also, that could be found mostly in well differentiated rocks jammed under the surface.

Besides the feldspar-knots already mentioned in discussing the other autigenic inclusion-type of the rocks, the monoclinic pyroxenes are dominating together with plagioclase and more rarely also with uralitized hypersthene and magnetite. The distribution of the minerals in the authigenic inclusion of the andesite of the quarry in Pányok in vol% is as follows: plagioclase 31%, monoclinic pyroxene 55%; ortho-

---

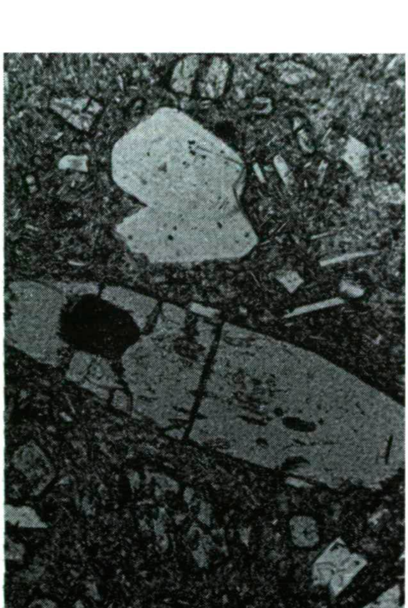
PLATE I

1. A plagioclase-knot with altered pyroxenes. — Acidic pyroxene-andesite, Pányok, Nagy-hegy— 1 N, 30x.
2. The same. — 2 N, 30x.
3. An uralitized (arrow) orthopyroxene (hypersthene) of first generation with magnetite inclusion. — Acidic pyroxene-andesite, Pányok, Nagy-hegy — 1 N, 72x.
4. The same. — 2 N, 72x.



1

2



3

4

pyroxene 11%, opague minerals 3%. These "mineral nodules" are of holocrystalline character. Their grain-size cumulative curve is shown in the *Fig. 3*. In and around the holocrystalline nodules of the sample from Hasdát-völgy, chloritized biotites, strongly pleochroic in their unaltered parts, have an widespread occurrence (Plate III, *Fig. 3*).

The *amphiboles* are of 2000—600 μ in length, and are coated by thicker-thinner opacitic rim, while their central part is composed of clay minerals. Small plagioclase inclusions up to 50×40 μ, and — rarely — hypersthene could be found in it. Moreover in the amphibole from the Hasdát-völgy, biotite inclusions also could be observed. There are more amphiboles than pyroxenes in the sample from Baglyas-völgy, but it may be the result of hypomagmatic effects.

The *groundmass* of the rock is composed of microlits of acidic plagioclase and clinopyroxenes as well as magnetite grains. Its texture is microholocrystalline porphyritic. The grain-size cumulative curve of the samples from Nagy-hegy in Pányok has not any distinct maximum and shows an even running. The other samples, however, are characterized by steep curves showing only one maximum *(Fig. 4)*. The latter type of curves refers definitely to a subvolcanic solidification as opposed to the textural character of the Nagy-hegy in Pányok forming a transition between the subvolcanic and surficial solidification.

The microlits of the groundmass of the andesite from the quarry in Pányok are of 5 μ in size, while their lower limit is 10 μ in the samples taken from the Hasdát-völgy. The accessorial components of the rock are: *magnetite, limonite, hematite* and — in the sample from the Hasdát-völgy only — even corroded *quartz* grains can be seen. The quantitative composition of the acidic pyroxene-andesite is given in vol. percents in the Table 2.

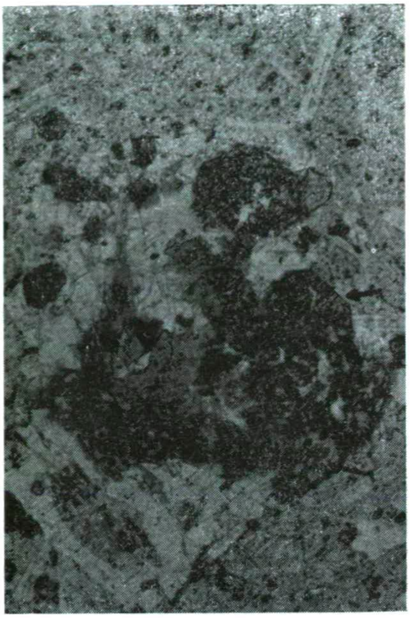
TABLE 2

*The mineralogical composition of the acidic pyroxene — andesites in vol. percents*

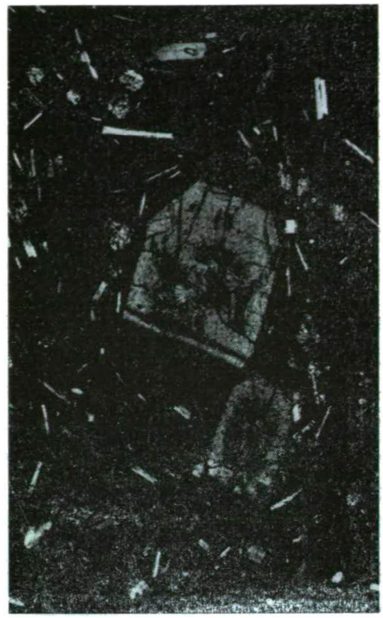
| | Acidic pyroxene— andesite of Pányok | | | Foliated pyroxene-andesite of Telki-bánya |
|---|---|---|---|---|
| | Nagy-hegy | Quarry | Hasdát-völgy | Hosszúkő |
| Groundmass | 25 | 13 | 25 | 56 |
| Plagioclase | 57 | 70 | 63 | 32 |
| Orthopyroxene | 11 | 11 | 6 | 7 |
| Clinopyroxene | 3 | 4 | 4 | 4 |
| Opacitic amphibole | 2 | 1 | 1 | — |
| Opaque | 1 | 0,5 | 0,5 | 1 |
| Other minerals | 1 | 0,5 | 0,5 | — |
| Total | 100 | 100 | 100 | 100 |

PLATE II

1. A plagioclase with pyroxene inclusion. — Acidic pyroxene-andesite, Pányok, Hasdát-völgy. — 2 N, 72x.
2. An orthopyroxene of second generation formed shape of a lath. — Acidic pyroxene-andesite, Pányok, quarry. — 2 N, 53x.
3. An orthopyroxene of second generation. — Acidic pyroxene-andesite, Pányok, Nagy-hegy. — 1 N, 72x.
4. An orthopyroxene of second generation with pigeonite-rim (arrows). — Acidic pyroxene-andesite, Pányok, Nagy-hegy. — 2 N, 120x.



1



2

3

4

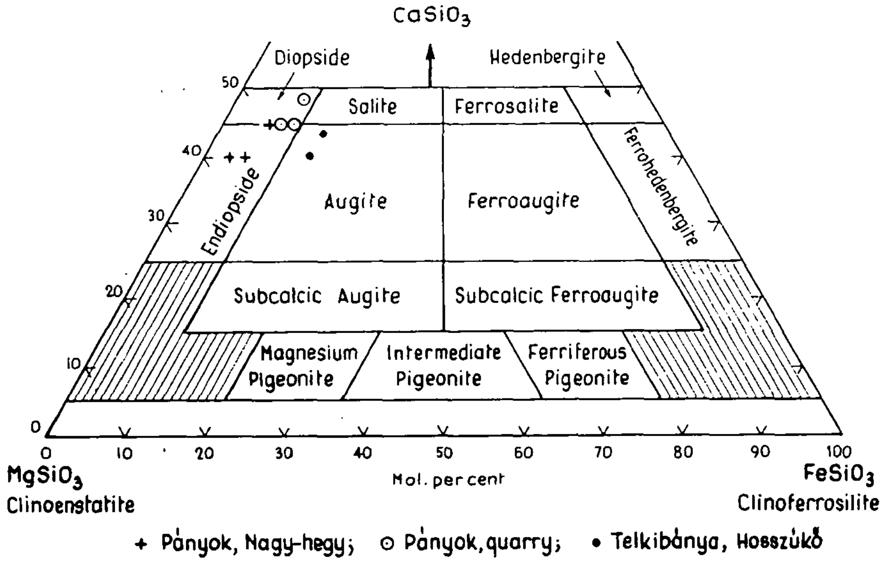



*Fig. 2.* The investigated clinopyroxenes in the system by POLDERVART—HESS [1951].

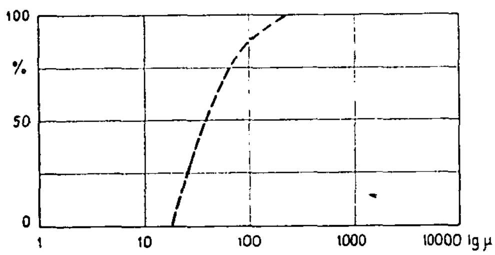



*Fig. 3.* Grain-size cumulative curve of pyroxene-knot occurred in acidic pyroxene-andesite. — Pányok, Nagy-hegy.

*2.* The chemical composition of the *foliated pyroxene-andesite* of Hosszúkő in Telkibánya is similar to that of the acidic pyroxene-andesite excepting the quantity of the alkalies in which slight differences can be stated. Accordıng to the geologists having mapped this area, the formation of these foliated rocks has taken place at the end of the Sarmatian [M-34 XXXIV Sátoraljaújhely, 1966]. Along the lamellae of this rock mineral assemblages of low-temperature hydrothermal origin have been

---

PLATE III

1. Pseudomorphous uralite, chlorite after hypersthene in a plagioclase-knot with unaltered pyroxene-particles (arrows). — Acidic pyroxene-andesite, Pányok, Hasdát-völgy. — 1 N, 53x.
2. Twins of clinopyroxenes. — Acidic pyroxene-andesite, Pányok, quarry. — 2 N, 72x.
3. A holocrystalline nodule of plagioclase, chloritized hypersthene, biotite, chlorite. — Acidic pyroxene-andesie, Pányok, Hasdát-völgy — 1 N, 72x.
4. An inclusion derived from basement rocks. — Acidic pyroxene-andesite, Pányok, quarry. — 2 N, 30x.

found. These assemblages consisting of small prisms of *barite* with a lot of *calcite* needles and *strontianites* on it have not been known until now. The strontianite gives a whitish transparent and fibrous mineral aggregate upon the surface of the minerals formed earlier.

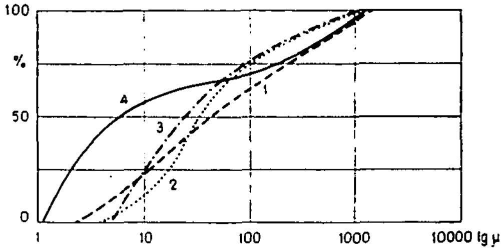



*Fig. 4.* Grain-size cumulative curves of acidic pyroxene-andesite (1—3) and that of foliated pyroxene-andesite (4).

The *plagioclase* crystals of the rock are not zoned, are not altered and do not contain any glass or opaque inclusions. There are two plagioclase generations:

*1)* a generation consisting of elongated crystals of 1200—100 μ;
*2)* the plagioclase lathes of the groundmass.

The mafic components are: hypersthene and monoclinic pyroxenes. The amphiboles are lacking. The *hypersthene* is of elongated, lathy appearance showing slight pleochroism (yellowish and greenish) and an oblique extinction of 5—10° as compared to the direction of the elongation. The average of the 2V values is −60° (with −57° and −65° as extreme values); i.e. the hypersthene crystals contain 64 mol% of $MgSiO_3$. The monoclinic pyroxenes are of augitic composition showing twins by (100) frequently *(Fig. 2)*.

The authigenic inclusions made up from pyroxene and plagioclase can be found in this rock too. The other type of the monoclinal pyroxenes, the *pigeonite,* however, occurs in this rock only as rim of some hypersthene crystals. All the pyroxene grains are absolutely unaltered. There are shapeless and resorbed feldspar and pyroxene debris of size comparable to that of the phenocrysts scattered all over the rock.

The characterictic accessorial component of the rock is the *magnetite.*

The fissures of the sample is filled by fibrous, radial, slightly pleochroic *barite*, being length-fast in the direction of the elongation, showing a polarization colour of first-order yellowish gray, and characterized by straight extinction. The lower limit of the sizes of the microlites in the *groundmass* is around 1 μ. The texture of the rock is microholocrystalline-porphyritic. Its grain-size cumulative curve shows two maxima *(Fig. 4)*. Grains of the 100—10 μ are almost totally missing, and the curve refers to a solidification of the surface. The redissolved mineral debris might point to a "stopover" of the ascending magma. After this interruption the eruption has taken place within a relatively short period. Supposedly there may have been an other but less significant disturbing factor on the way of the ascending magma as it is testified by the presence of the pigeonite in the authigenic pyroxene inclusions. Consequently the eruption of the foliated pyroxene-andesite at the end of the Sarmatian has taken place more smoothly than that of the acidic pyroxene-andesite. As a result of this relative smooth eruption, preconditions necessary for forming uralite have not existed, and the orthopyroxenes which have crystallized belong to the hypersthene-group.

In connection with the ortho-pyroxene-andesites, the *basement rock inclusion* found in the rock of the quarry of Pányok is also to be mentioned. (Plate III, *Fig. 4.*). Its size is 6×2,5 mm, and its components are: quartz (30—120 μ), magnetite (30—250 μ), biotite (200—370 μ). The biotite plays a more significant role in the central part of the inclusion. The distribution of the hematite shows a pattern parallel to the longitudinal axis of the inclusion.This phenomenon undoubtedly refers to the partial melting and redistribution of the material of the inclusion. A contact zone consisting of epidote crystals can be observed in the andesite aruond the inclusion. The andesite is holocrystalline in a 180—560 μ wide zone around the inclusion. Over this zone the feldspar lathes of the groundmass are more and less parallel to the outlines of the inclusion. Similar basement inclusions are described by SZABÓ, J. [1867] from Szokolya in Erdőbénye, and from Párkány in Tállya; and by SZÁDECZKY GY. [1897] from Rudabányácska and Kovácsvágás, as well as by HERRMANN, M. [1952] in the andesite from Borinzás.

On the basis of the petrologic characteristics listed above, the ortho-andesites described here could be qualified as monoclinic pyroxene bearing hypersthene-andesite. The only exception is the sample from Baglyas-völgy, which — in turn — could be pigeon-holed to the group of the amphibole bearing hypersthene-andesites.

The term "monoclinic pyroxene bearing" is considered more appropriate as opposed to the term "augitic" used so far, as the monoclinic pyroxenes in the acidic pyroxene-andesite of the area have been determined as diopside and endiopside. The attention had already been directed by HERRMANN, M. [1952] and by LIFFA, A. [1953] to the diopsidic character. The author's investigations, carried out by universal stage method, have confirmed this fact allowing the exact determination of the composition of the minerals.

## CHEMICAL CHARACTERISTICS

According to VINOGRADOV [1955] the average $SiO_2$-content of the andesite is 57,00%. The acidic pyroxene-andesites in the Tokaj Mts., however, have an $SiO_2$ content as high as 60,01 % in average [M-34 XXXIV. Sátoraljaújhely, 1966] (Table 3).

The question arose, whether the term "andesite" is correct, in our case? Whereas the classical term "andesite" has been defined by our predecessors taking into consideration the phenocrysts of the rock only (i.e. neglecting the chemical and mineralogical composition of the groundmass), the acidic pyroxene-andesite can be rightly considered as andesite in this respect. SZÁDECZKY—KARDOSS, E. remarked [1968, p. 149], that the classification based on mineral components estimated from the chemical composition of the rock by a theoretical way, came to a deadlock, if this important character of the ancient nomenclature had not been taken into consideration, because the majority of the andesites got to the rhyodacite-field of the RITTMANN-diagram on the basis of their estimated minerals [GYARMATI, P. 1961]. This is the case, because in the course of a total crystallization an other mineralogical composition is formed, as, though with progressing of the crystallization more and more acid minerals, even quartz ,originated from the more and more acidic melt, the fields of the diagram have been determined on the basis of the classical definition. The difficulty of the andesite problem is underlined by the fact that famous foreign petrologists [e.g. AHRENS, L. H., 1964], studying the chemical composition of the igneous rocks by statistical methods, have neglected the andesite and diorite, stating that the $SiO_2$ distribution of these two rock-types is rather complicated without reason, and admittig that these names mark a rather large group of rocks instead of well defined rocks with fairly constant composition.

TABLE 3

*Chemical composition of the Sarmatian pyroxene-andesites compared with international average of andesites by* VINOGRADOV *[1955]*

| | International average | Acidic pyroxene-andesite | | | | | Foliated pyroxene-andesite |
|---|---|---|---|---|---|---|---|
| | | Average for the whole Tokaj Mts* | Kéked, Szurokhegy | Pányok, quarry | Telkibánya, Magostér | Pányok, Nagyhegy | Telkibánya, Hosszúkő |
| Analyst: | — | — | Emszt, K. | Ikrényi, K | Emszt, K. | Ikrényi, K | Ikrényi, K. |
| | % | % | % | % | % | % | % |
| $SiO_2$ | 57,00 | 60,01 | 57,38 | 60,00 | 60,03 | 62,40 | 61,30 |
| $TiO_2$ | 0,79 | 0,55 | 1,10 | 0,65 | 0,86 | 0,80 | 0,80 |
| $Al_2O_3$ | 17,50 | 17,22 | 16,44 | 16,65 | 16,72 | 15,95 | 16,50 |
| $Fe_2O_3$ | 3,72 | 2,43 | 1,66 | 2,11 | 3,01 | 2,34 | 1,07 |
| FeO | 3,31 | 3,07 | 4,22 | 2,96 | 3,26 | 2,75 | 3,99 |
| MnO | 0,17 | 0,11 | 0,12 | 0,07 | 0,07 | 0,07 | 0,09 |
| MgO | 3,64 | 3,55 | 5,04 | 4,40 | 4,30 | 3,90 | 3,70 |
| CaO | 6,70 | 6,68 | 7,70 | 7,60 | 5,64 | 6,40 | 7,30 |
| $Na_2O$ | 3,62 | 2,40 | 2,68 | 2,52 | 2,36 | 2,28 | 1,96 |
| $K_2O$ | 2,01 | 1,89 | 1,08 | 1,68 | 1,82 | 1,83 | 2,09 |
| $H_2O^-$ | 0,83 | 0,81 | 0,28 | 1,18 | 0,57 | 1,16 | 1,06 |
| $H_2O^+$ | | 1,28 | 1,29 | | 0,91 | | |
| $P_2O_5$ | 0,25 | 0,16 | — | 0,10 | 0,10 | 0,10 | 0,13 |
| $CO_2$ | — | 0,03 | 0,16 | 0,20 | 0,17 | 0,09 | 0,20 |
| Total | 99,54 | 100,19 | 99,15 | 100,12 | 99,82 | 100,07 | 100,19 |

* Corrected data get from the explanations to the geologic map "M-34-XXXIV. Sátoraljaújhely, 1966".

As this question is to be solved recently too, the chemism of the rocks is compared to the VINOGRADOV's average (Table 3) remarking, that the higher $SiO_2$ content of our rocks is not in contradiciton to the andesite character (i.e. taking the classical definitions into consideration until a new, more exact system would not be developed). The author is of the opinion, that even the rhyodacite and dacite categories ($SiO_2$-content is 65—69% and 60—65% respectively) could not show any solution to this problem to be solved possibly by comprehensive statistical investigations only.

The $SiO_2$-content of 60,01 % does not involve an increase of the alcalies and a decrease of the CaO-content. Moreover the latter showed a slight increase in some rocks while the alkali content mostly decreased as compared to the VINOGRADOV-average. The MgO content is also higher than the international average. This phenomenon is in accordance with the more basic character of the original magma. Estimating the NIGGLI's *si-al-alc-fm-c* values and plotting them in the differentiation diagram *(Fig. 5)*, it can be stated, that parallel to the increase of the *si*-volume there is a slight and interrupted increase of *the alc* and *al* values; while the *fm* value — inspite the extremly high value from Magostér — shows a decreasing trend. The *al* and *alc* values vary parallel to one another, while the *fm* and *c* values alternate opposite to each other. On the basis of the *si-al-alc-c-fm-k-mg* values (Table 4) the rocks involved belong to the NIGGLI's leucogabbroidic type of magma.

TABLE 4

*Si, al, fm, c, alk, k, mg and Q, L, M values by* NIGGLI *of the Sarmatian pyroxene-andesites*

| | *si* | *al* | *fm* | *c* | *alk* | *k* | *mg* | *Q* | *L* | *M* |
|---|---|---|---|---|---|---|---|---|---|---|
| Acidic pyroxene-andesite Kéked, Szurokhegy | 171,2 | 28,8 | 36,9 | 24,6 | 9,7 | 0,20 | 0,61 | 45,0 | 33,7 | 21,3 |
| Acidic pyroxene-andesite Pányok, quarry | 188,0 | 30,7 | 33,2 | 25,4 | 10,7 | 0,29 | 0,62 | 49,4 | 35,7 | 14,8 |
| Acidic pyroxene-andesite Telkibánya, Magos-tér | 195,7 | 32,0 | 37,2 | 19,7 | 11,1 | 0,33 | 0,56 | 48,7 | 33,4 | 17,8 |
| Acidic pyroxene-andesite Pányok, Nagy-hegy | 212,0 | 31,9 | 33,5 | 23,3 | 11,3 | 0,35 | 0,58 | 52,0 | 32,2 | 15,8 |
| Foliated pyroxene-andesite Telkibánya, Hosszúkő | 201,2 | 31,8 | 31,9 | 25,6 | 10,7 | 0,40 | 0,57 | 50,0 | 33,4 | 16,6 |

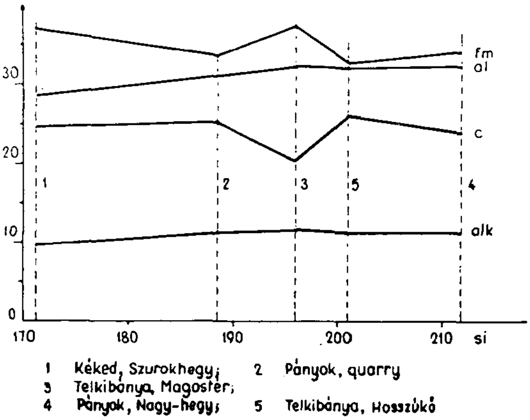



*Fig. 5.* The acidic pyroxene-andesite (1—4) and the foliated pyroxene-andesite (5) in the differentiational diagram by NIGGLI.

## CONCLUSIONS

The first generation plagioclase crystals and larger hypersthenes, forming knots connecting to plagioclases and abundant in longitudinal clefts as well as containing $MgSiO_3$ of 51—52 mol% are considered as the first crystallized compoments of the acidic pyroxene-andesite. This hypothesis is corroborated by the very rounded, resorbed shape of the plagioclase crystals as well as by the fact that the uralitic alteration of the hypersthene is more emphasized than that of the other pyroxenes. Similar phenomena have been described by PANTÓ, GY. [1970] from the Börzsöny Mts. (North-Hungary), stating that "by the increase of the instability of the pyroxenes the plagioclase crystals were eroded by the environmental conditions necessary for forming uralite".

According to BOLAND, J. N.—AL DUBA-EGGLETON, A. [1974] clinoenstatite is formed from orthopyroxene by lamellae more abundant in $Ca^{2+}$ and $Fe^{2+}$ ions than the orthopyroxene and interbedding into the latter parallel to its (100) plane. This mixed phase, however, is metastable in the temperature range of 800—1000 °C according to the experiments carried out by the authors listed above. The superflous Ca- and Fe-content of the clinoenstatite lamellae parallel to the (100) plane diffuse with a simultaneous intake of energy, while the late clinoenstatite lamellae are transformed into enstatite.

The author is forced by reasons of several types to compare the phenomenon described above to the more advanced uralitization experienced in the case of the hypersthene crystals of the first generation:

*1.* The orthopyroxenes of the pyroxene-andesite of Hosszúkő having a fairly uniform composition and refering to a more rapid ascending mechanism, are of clinohypersthene character and uralitization could not be observed in the rock.

*2.* The first generation hypersthenes of the acidic pyroxene andesites are dominated by vertical clefts being generally absent in the second generation hypersthenes. It may be therefore assumed that the vertical clefts could be correlated to the lamellae parallel to the (100) plane and more abundant in Ca and Fe. The first hypersthenes of the rock contained or contain until now lamellae more abundant in Ca and Fe and parallel to the (100) plane. During the formation of these minerals an additional ascending period of the magma may have taken place pushing the melt into an upper magma chamber with lower temperature, where the conditions were favourable even for forming amphiboles.

According to WITTELS, M. [1952] [in ILKEY-PERLAKI, E. 1961] the amphibole-pyroxene transformation could be pigeon-holed to the temperature range of 600—1000 °C, i.e. the two phases could be observed together within this temperature range. Being the clinopyroxene lamellae abundant in Ca and Fe metastable between 800—1000 °C, it should be assumed that they survived in the orthopyroxenes of quickly cooling rocks only. Though the formation conditions of the mineral involved is not given by BOLAND, J. N. *et al.* [1974] the hypersthenes of the quickly solidified andesite in Hosszúkő showing an oblique extinction of 5—10° refer to the conditions mentioned above.

Consequently in the temperature range of 800—1000 °C Ca and Fe diffusion and uralite formation should be taken into consideration as well. Thus, the alteration of orthopyroxenes could be accounted for a part of the Ca necessary for forming amphibole; naturally in addition to the Ca-quantity supplied by feldspar-resorption mentioned also by PANTÓ, GY. [1970]. Our former assumptions seem to be corroborated also by the fact, that the uralitization proceeds parallel to the longitudinal clefts of the hypersthene.

In addition to the intake of $OH^-$, the uralitization of the hypersthene crystals would take place by diffusion of Ca- and Fe-ions along longitudinal cleavages and by material and structural transformations at first time in the inner cavity and along transversal cleavages as well — according to the facts listed in this study so far. In contradiction to the equations described by ASKLUND [1925], STEWART [1947] [in PANTÓ, Gy. 1970] Si-addition is considered as improbable. For the orthopyroxene

$[(Mg, Fe)_2Si_2O_6] \rightarrow$ actinolite $[Ca_2(Mg, Fe)_5\ Si_8\ O_{22}(OH)_2]$ transformation 4 molecules of orthopyroxene would be necessary providing quantum sufficit of Si, but in this case — reckoning with $OH^-$ addition too — an excess of $3(Mg, Fe)^{2+}$ and $2O^{2-}$ should be formed. Thus the released $Fe^{2+}$ ion would be oxidized by an increase of the oxidation-reduction potential caused by the released $O^{2-}$, which, after having united with $H^+$, incorporated into the uralite.

On the other side, orthopyroxenes showing higher $MgSiO_3$-content than the older ones would be formed by the released Mg-ions increasing the Mg-content of the remnant melt. These orthorhombic pyroxenes, having an composition abundant in $MgSiO_3$, would be considered as the second generation marking the hypersthene-bronzite boundary. The $FeSiO_3$-content of the pyroxene would decrease, as the Fe-ions having attained a higher degree of oxidation, would be useless for forming orthopyroxenes. Thus a solution is given to the formation of first generation hypersthene of lower $MgSiO_3$ content (i.e. of lower compound-potential) prior to the formation of bronzite. The foliated pyroxene-andesite of Hosszúkő does not contain orthopyroxenes of second generation.

The $Fe^{3+}$ content of the acidic pyroxene-andesite produced by the increased oxidation-reduction potential appears in form of hematite. The fact that the foliated pyroxene-andesite in Hosszúkő having no hematite is characterized by an $Fe_2O_3$: :FeO ratio of 1,07:3,99, while the same parameters in the acidic pyroxene-andesite from the Pányok-quarry and from Nagy-hegy are 2,11:2,96; 2,34:2,75 respectively, is in accordance with the author's statements .The total of the two Fe-oxides in the different rocks are almost the same.

For a comprehensive evidence of the explanation outlined above by thorough investigations elucidating even the quantitative relation between the first and second generations of the orthopyroxenes are among others to be carried out.

The formation of orthopyroxenes more abundant in Mg-ions has taken place simultaneously to the uralitization in the same magma chamber of the acidic pyroxene-andesite. With the proceeding of the uralitization their margines have become more abundant in Mg and even pigeonitization has taken place by Ca-addition. In this environment showing relative low $Fe^{2+}$ content, a Ca-rich type of diopside i.e. en-diopside phase has been found. This period of quiescence is reflected by the pyroxene-knots composed of monoclinic pyroxenes mostly. After this second "stopover" the acidic pyroxene-andesite has solidified quickly in the area involved. This "frozen" state refering to a quick final cooling is reflected by the pigeonite [Pantó, G. 1964]. In the rocks of Hasdát-völgy showing marks of a thicker cover, even the alteration of the uralite can be observed. It transformed into chlorite, and the Ca-content released is fixed by small apatite needles in the centre of uralite and chlorite pseudomorphoses after pyroxenes.

In the foliated pyroxene-andesite characterized by more rapid ascension, the uralitization has not taken place. The only generation of the orthopyroxenes is the hypersthene of clino-character; and in presence of enough $Fe^{2+}$ augite has formed, representing the monoclinic pyroxenes.

The pyroxene-andesites have involved inclusions consisting mainly quartz originating from the basement complex.

This fact accounts the more acidic character of the pyroxene-andesites attained likely in the crust. Originally, on the basis of their chemical composition the andesite could be pigeon-holed to the leucogabbroidic type of rocks defined by Niggli. Their more basic character is also corroborated by the presence of minerals such hypersthene, bronzite, diopside and endiopside, though the latter three minerals could not have formed in the foliated pyroxene-andesite as a result of the more rapid ascension of the magma.

## ACKNOWLEDGEMENT

The author is indebted to PROF. MRS. VILMA SZÉKY-FUX for her kind helping during this work and for reading the manuscript critically as well.

## REFERENCES

AHRENS, L. H. [1954]: Element Distribution in Igneous Rocks — VII. A reconnaissance of the distribution of $SiO_2$ in granitic and basaltic rocks. — Geochim. Cosmochim. Acta **28**, pp. 271—290.

BOLAND, J. N., AL DUBA, EGGLETON, A. [1974]: Kinetic and Microstructural Studies of Magnesium-Rich Orthopyroxenes. — Journ. Geol., **82**, 4. pp. 507—514.

DEER, W. A., HOWIE, R. A., ZUSSMANN, J. [1963]: Rock Forming Minerals 2, Chain Silicates. pp. 125—130. London.

GYARMATI, P. [1961]: Problems of the Classification of Volcanic rocks, as Revealed by Examples from the Tokaj Mountains, Northeastern Hungary. — Földt. Közl., **91**, pp. 374—381.

HERRMANN, M. [1952]: Pétrographie et pétrochimie des rhyolites et des andésites du sud Telkibánya — Földt. Közl., **82**, pp. 349—367.

ILKEY–PERLAKI, E. [1961]: Altérations hypo- et métavolcaniques au contact des roches volcaniques, selon des esemples du contact d'andésite avec le tuf rhyolithique dans les Montagnes de Tokaj. — Földt. Közl., **91**, pp. 382—390.

KUBOVICS, I. [1968]: Kőzetmikroszkópia — Budapest, 367 p. In Hungarian.

KUBOVICS, I., PANTÓ, GY. [1970]: Vulkanológiai vizsgálatok a Mátrában és a Börzsönyben. — Budapest. pp. 161—302. In Hungarian.

LIFFA, A. [1953]: Géologie et petrographie des environs de Telkibánya. — Ann. Inst. Geol. Publ. Hung. **41**. 3. 70 p. Budapest.

M-34-XXXIV. Sátoraljaújhely. (1966). — Magyarázó Magyarország 200 000-es földtani térképsorozatához. Budapest. 199 p. In Hungarian.

NIGGLI, P. [1936]: Die Magmentypen. — Schweizerische Min. Petrogr. Mitt., **16**, pp. 335—399.

RÖSLER, H. J., LANGE, H. [1965]: Geochemische Tabellen. — Leipzig, pp. 186—199.

SZABÓ, J. [1867]: Tokaj—Hegyalja és környékének földtani viszonyai. — Math. Term. Közl. **4**. pp. 226—303. Budapest. — In Hungarian.

SZÁDECZKY, GY. [1897]: Das nordwestlich von Sátoralja-Újhely zwischen Ruda-bányácska liegende Gebiet in geologischer und petrographischer Hinsicht. — Földt. Közl., **27**, pp. 349—385.

SZÁDECZKY—KARDOSS, E. [1968]: A föld szerkezete és fejlődése. — Budapest, pp. 147—157. In Hungarian.

SZÉKY-FUX, V. [1970]: Telkibánya ércesedése és kárpáti kapcsolatai. — Budapest, pp. 38—104. In Hungarian.

SZTRÓKAY, K. I., GRASSELLY, GY., NEMECZ, E., KISS, J. [1970]: Ásványtani praktikum. — Budapest, pp. 189—207. In Hungarian.

*Manuscript received, June 16, 1975*

MÁRTA NÉMETH
Institute of Geology and
Palaeontology
Attila József University
H—6722 Szeged, Egyetem u., 2, Hungary