

## QUARTZ DIORITE FROM WATER-EXPLORATORY DRILLING AT BALATONFENYVES

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The water-exploratory hole drilled in 1969 in Balatonfenyves village, Transdanubia, Hungary, reached at 601.0 m depth the pre-Tertiary basement under younger basin sediments, to stop then at 603.0 m in an intrusive magmatic rock, identified macroscopically as of granitoid type, microscopically as quartz diorite, the first rock of this kind ever found in Transdanubia.

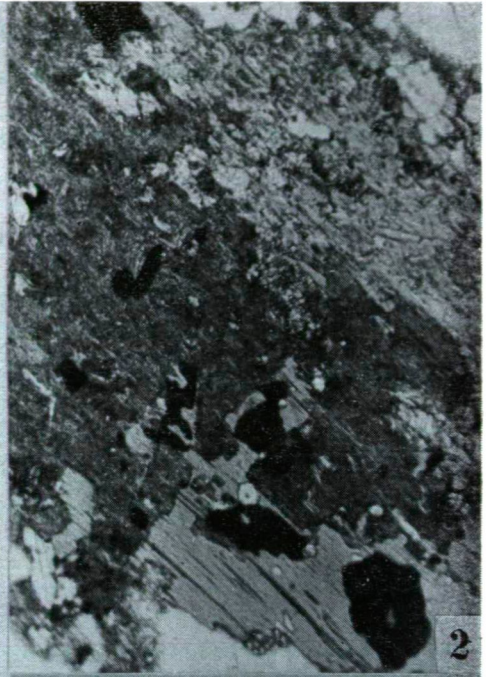
The fresh rock is medium-gray, of medium grain size, showing a holocrystalline texture constituted by euhedral to anhedral grains. Main constituents of its mineralogical composition are intermediate plagioclase, quartz, hornblende, biotite, potash feldspar. Accessories: ilmenite, sphene, apatite, zircon, sporadic magnetite and garnet. Secondary (autohydrated) minerals: grammatite (tremolite), anatase, calcite and some chlorite.

*Volumetric % of the components as found with the integration stage:*

Plagioclase	50.4%
Quartz	21.6
Hornblende— (grammatite)*	10.4
Biotite— (chlorite)*	9.0
Potash feldspar	7.8
Accessories	0.8
	<hr/>
	100.0%

A predominant main constituent of the rock, plagioclase is idiomorphic to hypidiomorphic, with advanced zoning (*Fig. 1*). As a rule, the inner core is of most basic composition, whereas the outer rims are more acidic, though the phenomenon of recurrence is also common. The plagioclase crystals are twinned according to the albite, pericline and Carlsbad laws, complex twins being frequent. Changing in composition even within one crystal, plagioclase can be considered to span the interval between basic oligoclase ( $An_{25}$ ) and labradorite ( $An_{60}$ ). Most common are the crystals showing a composition corresponding to andesine ( $An_{37.5}$ ). No more than some 2% of the crystal individuals are oligoclase; a corresponding composition can often be measured on the outer rims of zoned plagioclases. On the

\* In measurements with the integration stage secondary calcite was included in amphibole group, since calcite is present as a replacement of amphiboles. Chlorite was measured together with biotite.



extinction angles data measured by *Michel-Lévy's* method and on complex twins (combination of Carlsbad and albite twins) it is the value  $An_{42.5}$  that can be considered the subaverage composition of plagioclases.

The mafic minerals are represented by biotite and hornblende. Biotite is fresh, of light to dark brown pleochroism, zircon inclusions being surrounded by pleochroic halo. Hornblende is represented by a green variety. In the majority of the cases it occurs together with an actinolitic alteration product: finely fibrous grammatite crystal aggregates forming large, irregularly outlined patches (*Fig. 2*). The presence of this characteristic Ca-amphibole of the actinolite group is evidenced by the X-ray diffractogram showing a peak of 8.38  $d$  value occurring beside the 8.50 Å reflexion of hornblende and having nearly the same intensity. The formation of grammatite can be explained by the uralitization of an earlier diopsidic pyroxene, by its autohydrothermal alteration. However, the presence of diopsidic pyroxene or diopside in this type can be ascribed to the phenomenon of contamination only. Affected by subsequent  $CO_2$  metasomatism of lower degree, grammatite has been partly carbonatized. Biotite, hornblende and grammatite combine to form crystal groups in the rock, frequently containing apatite inclusions and minute ilmenite-anatase-leucoxene crystals.

In most of the cases, anatase — coupled with leucoxene — can be observed around an ilmenite nucleus and it may be supposed to be an alteration product of sphene, a hypothesis suggested by the sphenic form of the anatase crystals still recognizable in some places. Like the pyroxene seemingly present on account of grammatite, the sphene rimming the ilmenite cores warrants the contaminated character of the rock. The formation of anatase deducible from sphene can be ascribed to autohydration that must have affected the rock.

Quartz and potash feldspar are xenomorphic in the rock. The quartz shows a slightly undulated extinction, submicroscopic inclusions are frequently present.

Potash feldspar is poor, no perthitic intergrowth can be observed to occur. The homogeneity of the mineral is broken by abundant inclusions represented by remnants of plagioclase, hornblende, chlorite, calcite and quartz crystals as well as by larger masses of submicroscopic inclusions (*Fig. 3, 4*). Viewed under the microscope with crossed nicols, even the inclusion-free parts of certain crystals are not entirely homogeneous, showing irregular patches, vein-like features, 0,03—0,1 mm in size, of different extinction. In case of some microscopic patches, at high magnification, some imperfect, polysynthetic twinning hardly recognizable, is manifested. In order to study potash feldspar at closer scrutiny, the authors performed measurements with the universal stage, to determine both the optic angle and optical orientation, varying in dependence on the degree of Al/Si order. In doing so they used a conoscopic method by the aid of producing interference figure of measuring  $2V_\alpha$ . The results allow the authors to conclude that  $2V_\alpha$  varies from crystal to crystal and even within one and the same crystal, the range of variation being comparatively large: 40—47°. The authors have tried to measure optic angle (by

*Fig. 1.* Texture of quartz diorite. X N, 68×.

*Fig. 2.* Hornblende, biotite (lower part) and irregular crystal aggregates of fibrous grammatite. Inclusions: apatite, anatase-, leucoxene (dark). II N, 68×.

*Fig. 3.* Xenomorphic potash feldspar crystals containing numerous inclusions. X N, 28×.

*Fig. 4.* Plagioclase crystal showing resolved and corroded rim. X N, 68×.

the extinction method) even for the minor single patches, still measurable. The value thus obtained has been about  $60^\circ$ . The plane of the optic axes is perpendicular or nearly perpendicular to (010). In according to the optical orientation potash feldspar is monoclinic while the above-mentioned patches within the crystals seem to turn into triclinic symmetry. On the strength of optical properties potash feldspar is of disordered structure or shows some slight to fair degree of Al/Si order which tends to increase in the single microscopic patches. According to the X-ray diffractogram (a powder diagram made of the separated potash feldspar fraction of the rock), the triclinicity of potash feldspar is 0.0. Measured on the basis of the position of the  $(\bar{2}01)$  reflexion by the use of the *Bowen-Tuttle* diagram, the Or content of potash feldspar equals 88%. *Wright's* diagram, based upon  $2\theta$  (060),  $-(204)$ ,  $-(201)$ , yields the same result. In addition, it can be stated that the examined potash feldspar is of low albite content and has its plotted dot between the high sanidine and the maximum microcline. As shown by the chemical analyses of the potash feldspar fraction separated by heavy liquids by means of centrifuging, potash feldspar has the following average composition:  $Or_{88.2}$ ,  $Ab_{11.7}$ ,  $An_{0.1}$ . With *Tuttle's* diagram the average of  $2V\alpha$  yielded a value of about  $Or_{88}$ . According to the above data, the potash feldspar under consideration is a cryptoperthitic orthoclase (even though no definite agreement concerning the nomenclature of potash feldspars could so far be reached). The lack, or low to medium degree, of Al/Si order suggests rapid crystallization, i. e. a rapid cooling down of the system. To determine with higher accuracy the temperature of the unstable crystallization of potash feldspar, known to crystallize for the most part at a pneumatolytic temperature, would be difficult because of the manifold influences involved under the given circumstances: a fact notified also by I. M. SÁENZ [1967]. It is probable, however, that the final crystallization phase of potash feldspar has fallen in the hydrothermal temperature range already. Resolution of the already solid crystals by the pneumatolytic-hydrothermal solutions can be observed even under the microscope (*Fig. 4*). During this process the *Or-Ab + An* ratio may also have been changed with regard to the total of the crystal in some minor patches around the mineral inclusions within the crystal. At the same time, during partial re-resolution a partial re-crystallization of potash feldspar can be supposed to have taken place, a phenomenon confined to the microscopic patches just mentioned. The observed optical divergences of the individual potash feldspar crystals may be explained by the above processes.

Nomenclaturally, in the sense of *Lindgren's* definition, the rock is quartz diorite (tonalite), as the weight % quantity of potash feldspar is  $< 13\frac{1}{3}$ . JOHANNSEN showed the nomenclatural boundary of granodiorite to quartz diorite to lie at 5% potash feldspar. In other words, he assigned to this category those rocks which contain potash feldspar just as an accessory component. Used widely in recent literature, the term tonalite corresponds practically rather *Lindgren's* original definition. Since on the basis of plagioclase present as predominant main component the examined rock is doubtless of dioritic character, it seems to be justified to name it quartz diorite rather than granodiorite.

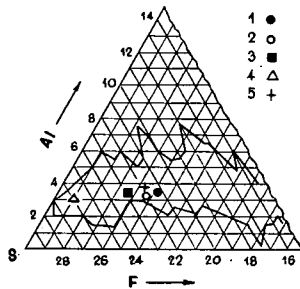
Chemical composition of quartz diorite:

Constituent	Weight percent
SiO <sub>2</sub>	60.04 %
TiO <sub>2</sub>	0.80
Al <sub>2</sub> O <sub>3</sub>	16.91
Fe <sub>2</sub> O <sub>3</sub>	0.88
FeO	5.38
MnO	0.18
MgO	2.10
CaO	5.85
Na <sub>2</sub> O	2.79
K <sub>2</sub> O	2.34
- H <sub>2</sub> O	0.15
+ H <sub>2</sub> O	1.32
CO <sub>2</sub>	1.05
P <sub>2</sub> O <sub>5</sub>	0.10
S	0.08
	99.97 %
- O	0.04 %
	99.93 %

According to *Niggli's* classification, the rock is a Pacific magmatic product of quartz dioritic composition. Placed in *Osann's* triangular diagram, it seems to belong unambiguously to the quartz dioritic magmatic type (*Fig. 5*).

*Niggli's* parameters:

si	al	fm	c	alk	ti	p	k	mg
207.7	34.5	29.3	21.6	14.6	2.1	0.2	0.36	0.37
o	c/fm	co <sub>2</sub>	qz					
0.08	0.74	4.99	49.49					



*Fig. 5.* Dioritic and granitic rock types plotted on the S Al F triangle diagram of *Osann's* system. Legend: 1. Quartz diorite, Balatonfenyves, Hungary; 2. Quartz diorite, average value (from literatur); 3. Granodiorite, average value (from literatur); 4. Granite, Velence Mountain, Hungary, average value (from literatur); 5. Granite, a type close to quartz diorite, Velence Mountain, Hungary (from literatur).

*Niggli's bases:*

$$\begin{array}{lll} Q = 45.7 & L = 41.3 & M = 13.0 \\ \pi = 0.41 & \gamma = 0.05 & \alpha = 4.19 \end{array}$$

Within the earth crust magmatic products of this type occur in form of minor intrusions or as marginal zones of major intrusive masses. The structural relations of its occurrence being unknown, the direct connection of the rock to the Carboniferous granite of the Velence Mountains cannot be confirmed, even though such a connection is quite probable. As stated by Gy. BUDA [1969], who investigated the Velence Mountains granite, in terms of the optic axial angle of the potash feldspar of this post-kinematic orthogranite is a monoclinic variety characterizable by a lower degree of Al/Si order, high temperature of formation, and rather rapid cooling. The crystals are either finely micropertthitic or do not show any pertthitic texture. With its even more advanced disordered structural state and its definitely cryptopertthitic texture, the potash feldspar of the Balatonfenyves quartz diorite may correspond to the marginal zone of the granitic mass.

The chemical and mineralogical compositions of the rock, differing from those of the Velence Mountains granite may be due to contamination of the marginal zone. In case of hybrid magmas of granodioritic — quartz dioritic composition the phenomenon of contamination is a generally accepted fact. The contaminated character of the quartz diorite of Balatonfenyves is evidenced by a peculiar mineral assemblage:

diopside (grammatite) → hornblende → biotite  
ilmenite → titanite → anatase (leucoxene)

The effect of contamination can be characterized by an increase of CaO, FeO and MgO as well as by a decrease of the alkalis and SiO<sub>2</sub>.

Chemical considerations and empirical data suggest that a rock of quartz dioritic composition can be brought about as final product in the case of a granatic melt coming into contact with a country rock of carbonate or basic composition (gabbro, — amphibolite): a process resulting in contamination. For lack of information, it is only with reservations that we can conclude as to which of the processes may have affected the rock under consideration. The presence of diopside admitted on account of grammatite, the comparatively great abundance of anortite molecules in plagioclase and the reductional character ( $O_{Fe} = 0.33$ ) of the rock seem to favour the assumption of a contamination connected with carbonate rocks rather than with basic ones.

A comparison of the trace element data of the rock with the average trace element content of the Velence Mountains granite shows an increase of Mn, Sr, V, Zn by an order of magnitude in the Balatonfenyves quartz diorite.

Let us quote the trace element data of the quartz diorite:

Mn	1 000 ppm	Ce	20 ppm
Cu	25	Zr	120
Pb	6	Sr	230
Ga	10	Rb	52
V	60		
Ti	2 500		
Zn	< 160		
Ni	< 6		

(Results yielded by X-ray fluorescence spectrography)

Co	< 10
Sr	250
Cr	< 2.5
Ba	400
Li	100

(Results yielded  
by quartz-spectro-  
graphy)

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