ON THE SYSTEM OF IGNEOUS ROCKS

(Abstract, preprint.)

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1. An exact classification of rocks is based on quantitative determinations. "Classifications" according to one of the characteristics of the rocks, e.g. arrangement according to the chemical or to the mineralogical composition represents a nomenclatoric delimitation. True classification of the igneous rocks is complex and includes quantitative arrangements according to the chemical and the mineralogical composition and to different textural characteristics. Textural characteristics of the igneous rocks include the microtextural (:rock fabrics), the macrotextural (:size and shape of the igneous body), the megatextural (:position in the rock association of the igneous complex area) and the geotextural pecularities (:position in the comagmatic petrographic provinces, i.e. the role in the Earth's evolution). Quantitative or semiquantitative determinations of these characteristics are already possible, thus the problem of the complex classification of igneous rocks may be approached.

The main trends of the changes in the chemical composition are mostly determined by mega- and geotextural factors: a) basic and ultrabasic orogenic and anorogenic upper mantle igneous activity, b) acid synorogenic crustal plutonic activity, c) intermediate, late and postorogenic mantle volcanism hybridised by the crust, d) cratogenic alkali magmatism of the sheets.

The main physical features -- mineralogical composition and petrofabrics -- depend by given chemical composition chiefly on the temperature relations during the crystallization. Temperature relations are determined by the type of the igneous body and by the position of the rock sample within the crust and the igneous body. The type of igneous body on the other hand, depends on mega and geotextural factors. Hence the mineralogical composition and the petrofabric -- named in this paper together the igneous rock facies -- are connected with all the higher textural factors.

Practically igneous rock facies is determined by petrographic methods and the geological informations included in these data are already evaluable. The quantitative determination of the igneous rock facies renders possible the elucidating of macro--mega--geotextural relations by rock specimens of small outcrops and deep borings.

In order of the exactitude and reliability of quantitative determinations the first level of igneous rock classification is the chemical composition, the next one is the igneous rock facies and the last levels are the macro- geotextural relations: the type of igneous body, the igneous complex and the petrographic province.

The proposed classification of igneous rocks assignes the place of rock types in the realm of igneous chemical composition, igneous rock facies and rock bodies. (In this sense the igneous rock types -- described by more than 1000 rock names -- mean statistically homogeneous parts of igneous masses.) Obviously the complex classification of igneous rocks represents their genetic system, too. It yields an exact basis for connecting petrography to geology, even geochemistry to geophysics.

2. The most complete classification of the chemistry of igneous rocks -- given by P. Niggli and C. Burri -- comprises 179 "magma types". Magma types do not include local hybride alterations of igneous rocks. Using the classification of magma types for igneous rocks the hybrides, e.g. korunditic, carbonatic and peraciditic types delimited already in an older classification by P. Niggli must be added to this classification, too.

3. The igneous rock facies, as second level of the system, may be described quantitatively by microtextural diagrams which connect the mineralogical composition and the granulometric distribution in a grain

size frequency percent scheme (fig.1).

In this diagram the quantitative mineralogical composition is shown by rectangles. One side of it represents the volume percent of the mineral species, the other its grain size extensions. (Smaller rectangles inside the former may indicate different grain size concentration maximums of the mineral species in question.)

The most important feature of the rock fabric is the granulometric distribution of the rock forming grains. The grain sizes are characterized by the maximum diameter of the grains as seen in the microscope. (The description of the quick determination method of the granulometric distribution is given by the author in Acta Geologica 11, 1967.) The granulometric distribution is represented in the microtextural diagram by cumulative granulometric curve. Strong anisometry of crystals is represented by a second curve showing the distribution of their smaller diameters as seen in the microscope.

Chorismitic rocks with mesotextural inhomogenity of mineralogical and even granulometric composition are represented by twin or triplet microtextural diagrams.

4. Mineralogical composition and granulometric distribution of a rock serie having identical chemical composition changes mostly in function of the rate of cooling of the magma. Sanidine, zoned plagioclase, clinopyroxene are formed if the cooling was relatively fast during the temperature interval of crystallization. In contrary, perthite or two feldspar, uniform plagioclase crystalls and orthopyroxenes are formed by slow rate of cooling. Degree of triclinity of feldspars may show the temperature interval of crystallization. The sequence of pyroxene-amphibole-biotite indicates increasing vapor pressure and relatively slow rate of cooling at decreasing temperature.

The granulometric curves of igneous rocks formed from completely molten magma are controlled by the cooling curves of the crystallization interval, those formed from partly molten (embryonic) magma chiefly by the heating curves (fig.2).

The quotient of the temperature interval (D) and the length of the time of crystallization (t), i.e. the average rate of cooling (c) is about an inverse ratio to the grade of crystallinity (K).

$$\frac{D}{t} = c = \frac{A}{K};\ K = A\frac{t}{}$$

(A is the factor of proportionality.) The grade of crystallinity may be expressed by the median of the granulometric curve.

Average rate of cooling and grade of crystallinity are, however, not unambigious values. The relation between the grain size and cooling is expressed more exactly by the complete granulometric and the complete cooling curves.

The cooling curve is mainly a function of a) the shape factor determined by the thickness and mass of the magma body, b) the temperature difference between the magma and the surroundings and c) the distance of the sample from the border of the igneous body.

The shape factor of a simple volcanic body is determined mainly by its shortest diameter, e.g. in the case of a simple sheet by its thickness. In composite sheets the shape factor equals the quotient $\Sigma v / \Sigma t$, where Σv: total thickness of the sheet, Σt : sum of the time intervals between the single lava flows. In subvolcanic and plutonic bodies the whole mass of the body is to be considered, too.

The temperature difference between the intruding magma and the surroundings is -- by known geothermal gradient -- a measure of the depth of crystallization. The incipient temperature of magma may be estimated on the basis of the chemical composition. Hence the temperature of the surroundings and -- by known geothermal gradient -- the depth of crystallization may be evaluated by the granulometric curve. In consequence of the heating effect of former intruding magma masses the geothermal gradient increases in the same igneous body with the duration of the intrusion.

The connection of the grain size curves with the cooling curves for intermediate (andesitic-dioritic) composition of a normal low orthomagmatic volatile content is shown by fig. 2. There are represented 10 ·s of grain size curves, corresponding to distinct grades of crystallinity. The grain size curves corresponding to a given cooling curve of more viscous magmas than the normal dioritic are shifted towards the left, whereas those of basic and volatile rich magmas towards the right.

5. On the basis of the micro- and mesotextural diagram and chemical analysises 12 types of igneous rock bodies and 3 series of rock types for all body types, i.e. 36 igneous rock facies may be preliminarly separated (fig.3).

Rock bodies characterized by special mesotextures (chorismites) and by heating curves instead of cooling curves are the migmatite complexes, the basic rock bodies with "Schlieren" textures, and many parts of the cauldron subsidences containing (mostly extreme) alkaline rocks.

The 3 chief series of rock types in the igneous bodies are the followings: 1. the average dry orthomagmatic type, 2. the dry orthomagmatic rim rock type (R) and 3. the volatile rich hypo- and metamagmatic rock type (V) often developed, too, only as rim rock. The dry rim rock type represents the chilled margin described mostly as separate rock type under special names and differs from the average dry orthomagmatic rock type by an about one grade lower crystallinity. The hypo- and metamagmatic type differs from the former chiefly by the appearance of low grade "metamorphic" hydrous minerals. They indicate a high vapour pressure during the crystallization at lower temperatures, below 450--600^{o} C.

Obviously in the nature more rock type series than 3 exist. This is shown by the different mineralogical composition of rock types in the same magma type and igneous rock facies. Especially the series of hypo- and metamagmatic rocks -- neglected formerly as "not fresh" products -- must be enlarged to discerne the different hydrosilicate, silica, carbonate, complex etc. rock types. The aim of this first outline is, however, only the arrangement of older rock names.

6. The complex system of igneous rocks is outlined preliminarly

in 3 tables, according to the 3 magma type series stated by Niggli. It contains the rock names as described in the "Spezielle Petrographie der Eruptivgesteine" of Tröger, 1935, ordered chemically according to the 183 Niggli-Burri magma types and to the 36 complex igneous rock facies as defined above. (Here is presented only one sheet of these tables. This does not show the synonimic rock names belonging to the same magma type and the same rock facies and containing essentially the same mineralogical composition, because in this sheet the diagrams of the mineralogical composition are omitted.)

The rock names applied by Tröger do not correspond always to the names of the magma types given by Niggli-Burri. E.g. missurite by Tröger appears not in the missuritic but in the kajanitic magma type, and melteigite not in the melteigic but in the turjaitic magma type.

This first outline of the complex classification provides 183 x 36 = 6588 categories of igneous rock types. The number of the known rock types is, however, only about 1000 without the new types of hypo- and endometamagmatites. Obviously the 183 magma types are not equivalent, many of them derive from other magma types by special processes of the igneous rock facies formation. Such derivative magma types are principally represented merely by one or two related igneous rock facies. The system renders possible to evaluate the primary and the derivative magma types.

About the half of the magma types occur in the whole sequence of plutonic, hypabyssic-subvolcanic and volcanic bodies. Nine of them are represented by an especially great number of rock names. They are obviously the most general and the "primary" magma types". Here belong the aplitgranitic, dioritic, gabbrodioritic, peridotitic, alkaligranitic, foyaitic, essexitic and essexitgabbroic magma types. The plottings of their chemical composition appear mostly in the corner centres of the field of igneous rocks (fig.4). They seem to represent the main types of the mentioned 4 genetic groups of the igneous rocks: upper mantle magmatism (peridotitic, gabbroidic, essexitgabbroidic magma types), synorogenic deep crust plutonism (aplitgranitic and alkaligranitic magma types), serorogenic hybrid volcanism (dioritic and gabbrodioritic magma types) and alkali rock serie (essexitic and foyaitic magma types).

In sharp contrast to these frequent types there are many magma types represented -- often even by more rock types -- in only one or two related types of rock bodies, presumably the derivative ones.

Merely as volcanic lava rocks occur 13 magma types, e.g. the adamellitic, peleéitic, hawaiitic, mugearitic, jumillitic ones. They are characterized by relatively great si and low alk values in the si - alk diagrams (fig. 4) and mostly by high k values.

Only plutonic dyke rocks form 11 magma types, among them the Na-rapakivitic, syenite-granitic, orbitic, groruditic ones. These are characterized by relatively low si, high alk and low k values.

More than 10 magma types occur only in cauldron subsidences, e.g. the urtitic, the montmouthitic and the tawitic magma types. They are all characterized by extremely high alk and mostly low k values.

More than 20 magma types appear merely in basic complex stocks with Schlieren-texture. These are characterized mostly by low si and alk but by high fm values, i.e. they represent basic rocks.

Magma types occuring only as ± deep plutons without volcanic bodies are partly acid ones characterized by relatively low alk values, e.g. the rapakiwitic, moyitic, farsunditic, opdalitic types.

7. This distribution of rock bodies among the magma types indicates that the chemical composition of the igneous rocks are controlled by mega- and geotextural factors — e.g. by the orogenic or anorogenic processes — only in the great outlines. The periferic derivatives from the main magma types seem to be controlled macrotexturally by the character of the igneous body.

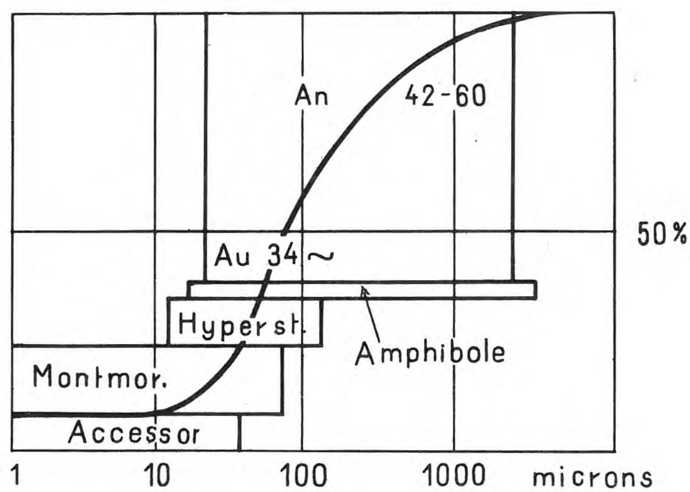
It is admitted that the evolution of these derivative magma types is mostly the result of transvaporization. This is shown e.g. by the great neogenic stratovolcano of the Cserhát and Mátra Mts (Hungary). Here the orthomagmatic rocks are chiefly dioritic, but advancing from the deeper dykes towards the lava sheets, the si content of the rock increases. The most frequent magma type of the lava sheets is the tonalitic one.

Hypo- and endometamagmatic rocks of the same igneous complex -- occuring mainly as laccolithes -- have mostly the same tonalitic character, though the mineral association is quite different from that of the corresponding orthomagmatic rocks. Obviously the change in the chemistry concerning the non-volatile elements of the uprising magma is the same in the ortho- and hypomagmatic rocks. The magmatic evolution is due in both cases chiefly to solutions deriving from the country rocks. Volatiles are retained in closed laccolithic bodies, therefore their rock is developed as hydrous hypomagmatic type. On the contrary, in the open lava-sheets volatiles are delivered, the rock develops as orthomagmatite.

The tonalitic magma type formed in this way differs from the deeper dioritic one chiefly by the higher si, al and k and by the lower fm Niggli values. Hence the components solved by the transvaporizing volatiles are -- at least in the Mátra Mts -- mostly potassic alumosilicates.

The heavy ionic content of the hypomagmatic rock types is often higher than that of the orthomagmatic rock types. These ore forming ions seem to be increasingly leached out from the surroundings, at the high vapor pressure characterizing the crystallization of the hypomagmatic rocks. From the released hydrous volatile excess they crystallize at decreasing vapor pressure and temperature, forming hydrothermal ore bodies.

8. The discussion of the complex genetic classification of igneous rocks on international scale and the ranging of the rocks of the different continents and oceans according to a genetic system supplies a method for the systematic comparative study of igneous rock and ore interrelations and ore prospection.



An
42-60
50%
Au 34 ~
Hyperst.
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Montmor.
Accessor
1
10
100
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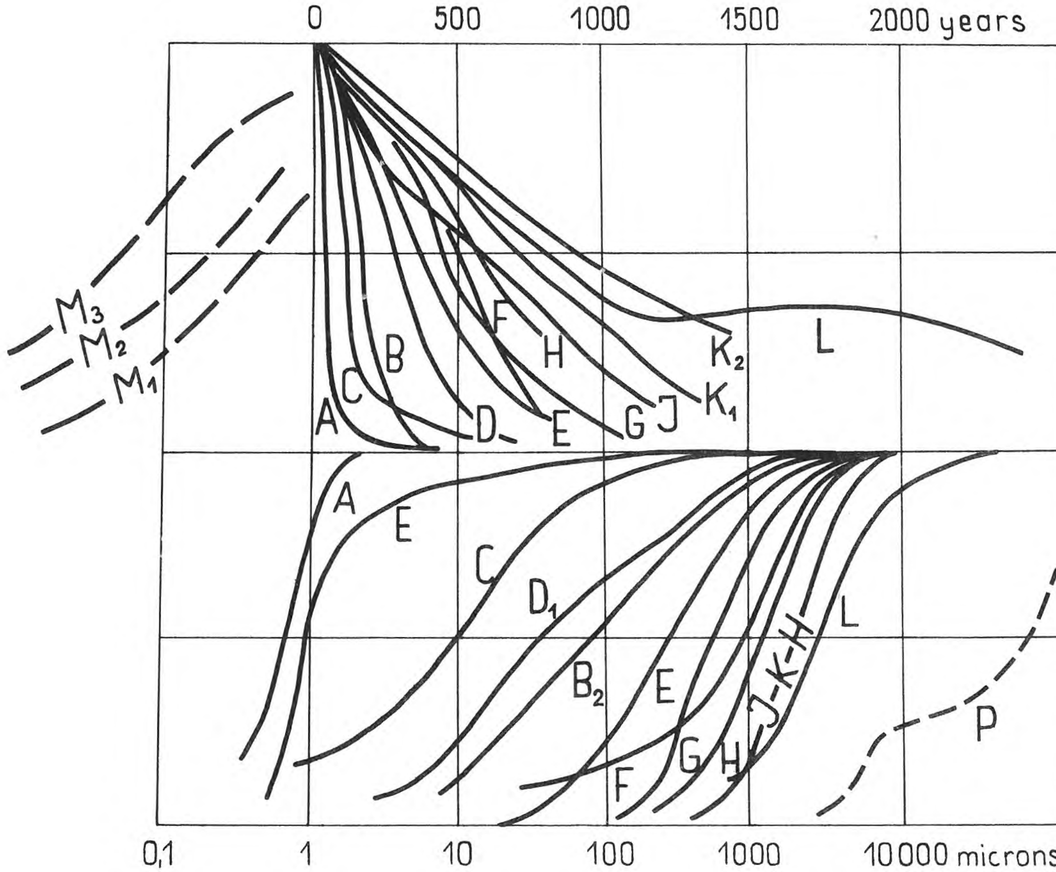
microns


0
500
1000
1500
2000 years
50%
M3
M2
M1
A
C
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D
F
E
H
G
J
K2
K1
L
A
E
C
D1
B2
E
J-K-H
L
F
G
H
P
0,1
1
10
100
1000
10000 microns

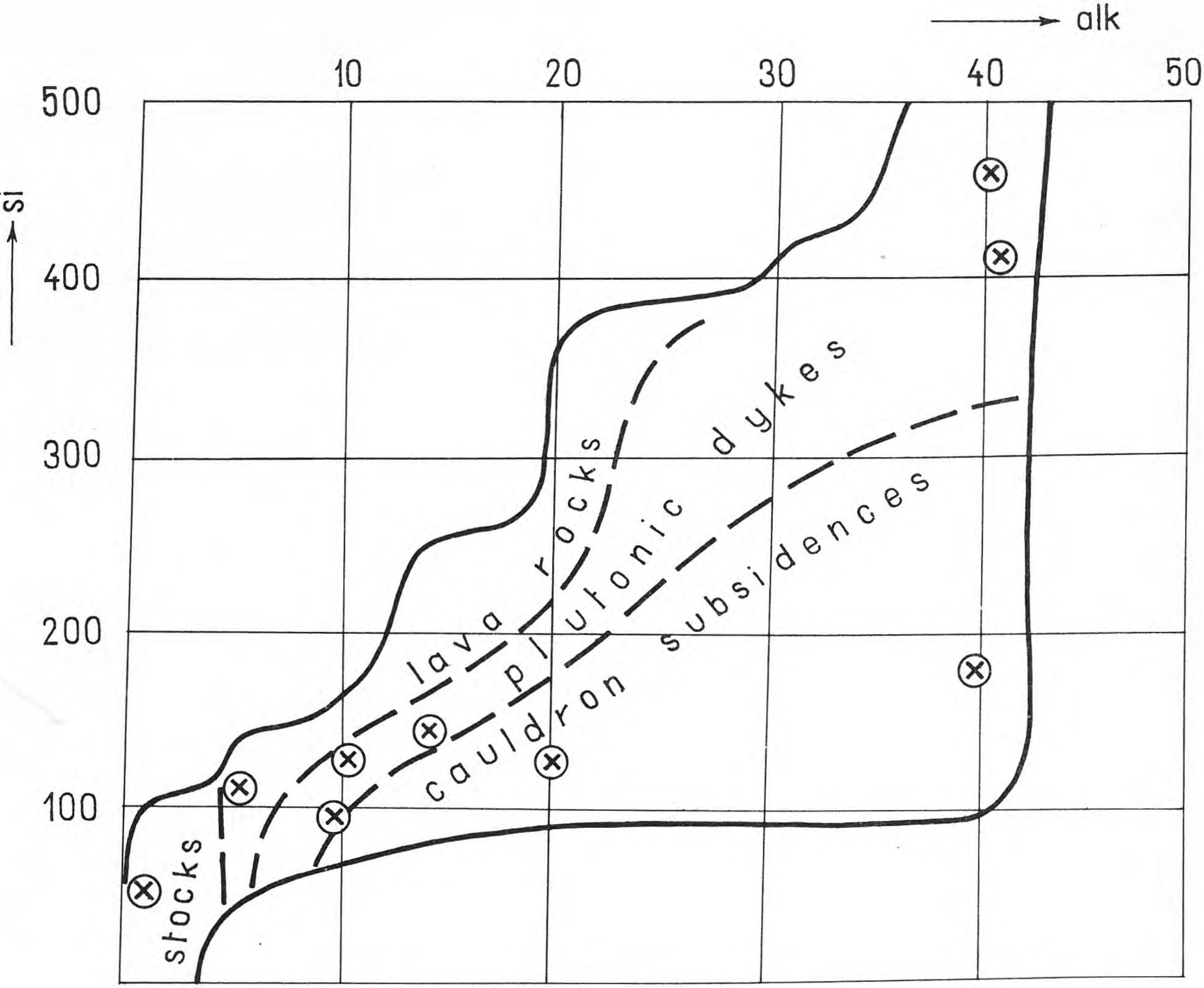
fig. 3.

Igneous rock facies and rock bodies

A - M : granulometric type, V : volatile rich minerals

s = "schlieren texture, g = gravity stratification, z = zoned plagioclase,
d = depth minerals

	Rock type series		
	Orthomagmatic average	Orthomagmatic rim	Hypo- and metamagmatic
Small lava flow	C	A	-
Great lava flow	D - E - F (z)	B	V
Subvolcanic dyke	D - E - F (z)	C - D (z)	V
Plutonic dyke (Pegmatites)	G - H (P)	E - G	V
Laccolith, sill	E (z)	D (z)	V
Lopolith	K (g)	G	
Hypabiyssic stock	H - J (z)	L (z)	V
Basic "Schlieren" stock	M_3 (s)		
Cauldron subsidence	M_1 (s)		
Migmatitic complex	M_2 (s)		
Deep pluton	K	L	(V)
Metamorphic abyssites	K (d)	(d)	



⊗ the 9 most frequent magmatypes