HOW WE USED NASA LUNAR SET IN PLANETARY AND MATERIAL SCIENCE STUDIES: FROM BASALTIC TTT-DIAGRAMS OF LUNAR BASALTS TO CELLULAR AUTOMATA TRANSFORMATIONS OF TEXTURES.

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ABSTRACT

We made a study and a course of the NASA Lunar Educational Thin Section Set with comparisons of parameters read from lunar textures, terrestrial pillow lava textures and industrial materials. TTT diagram of basalts (using also basaltic clasts from breccias and soil samples), from different paragenetic sequences, textural characteristics, estimated cooling rates was constructed and some materials of corresponding technologies (cooling rates, industrial TTT diagrams of hardening steel and forming industrial textures) were also compared. Silicate grain relations of the fabric were modeled by cellular automata description.

INTRODUCTION

Many studies on basaltic textural types of the NASA lunar samples, from paragenetic sequence, grain size, crystal morphology, and their systematic relation with the cooling rates in the magma body were studied earlier [1, 2]. In our course we first studied how these parameters can be concluded from the textural sequence of gradually coarser fabrics of basaltic samples with greater depth in an undisturbed magma layer: from the surface edge toward the deeper layers. Both textural types, crystal morphology, were used in a cellular automata description to deduce paragenetic sequences for different lunar basalt types of the NASA Lunar Set (in a 8-10 meters thick lunar basaltic flow [1-5]), and finally their tentative TTT diagrams (correspondence of cooling rates and textural gradual changes) were constructed.

In the second part of the course we compared basaltic samples of the lunar set, with some similar Carpathian Basin basalts and gabbros of which basalts we selected an ophiolitic textural series of the Darnó Hill, Heves C., Hungary [7]. where a continuous sequence of textures was found parallel with the lunar samples [3]. (The following thin sections were used from NASA set: 74220, orange soil; 68501, clasts in soil s.; 14305, clasts in breccia; 72275, clasts in breccia; 12002 porphyritic s.; 70017, poikilitic s.; 12005 poikilitic s.)

DESCRIPTION OF PETROLOGIC TEXTURAL TRANSITIONS BY CELLULAR AUTOMATA

We can formulate descriptions of textural analyses by cell-mosaic automata model. It helps to reconstruct the sequence of discrete changes in a cell-mosaic system. The model is formulated on two hierarchy levels: One level is that of minerals (that of cellular one) and that of the texture (global one). The "flow-chart" of the cell-automata mosaic's is composed from two parts: A) that of the structure and initial conditions of the cellular background, and B) that of the transitional functions. [6] Both parts form a pair of approach on a local and a global one.

The cell-automata mosaic model has advantages coming from the separability of local and global picture. One is the feedback possibility between the local and global characteristics [8]. Such style of descriptions of sequence of crystallization of 70017 high Ti basalt texture was made in the paragenetic sequence. From this we reconstructed a tentative TTT diagram. This texture solidifies between 1250 and 950 C, contains the textural fabrics of a sequence, with the cooling rates from glassy quenching 1000 C/min. rate till 0.5-0.05 C/hr.

TEXTURAL SEQUENCE OF BASALTIC SAMPLES AND CLASTS IN NASA LUNAR EDUCATIONAL SET

On the basis of the sequence of terrestrial textures we estimated (interpolated) the place (probable original depth) of the lunar set textures in a lunar basaltic lava flow. We also used literature data for cooling rates. The samples in a sequence starting from the greatest cooling rate are:

74220 The "highest" position (the greatest cooling rate) had the orange soil spherules in the **74220,** because their ejection as a lava fountain ([6],[9],[11]) had glass quenching cca. 1000 C/min. cooling rate [12].

68501 Variolitic clast. (We remember from earlier loans, that in NASA Lunar set No. 6. 72275,509 breccia contained a larger vitrophyric-variolitic clast. 72275 is the thin section with the largest surface in the lunar set). Recent (No. 4.) set contains a clast with spherulitic-variolitic texture among the soil grains of **68501.** This clast had second highest cooling rate in our sequence (tentatively: some hundred degrees Celsius per day).

12002 This Apollo 12 porphyritic sample **12002** represents slower initial cooling rate for the large olivine grains and higher cooling rate (wide range) for the surrounding (variolitic) laths of clinopyroxenes and plagioclase feldspars[12]). In a revised model cooling rates may vary from some degrees Celsius to 2000 C/hour [18].

14305 The breccia **14305** contains intergranular type clasts, such representing the third texture in the cooling rate sequence (tentatively: hundred degrees Celsius per week)

72275 The subophitic clast of **72275,**128 breccia represents an even slower cooling. Over breccias all three basaltic samples represent well crystallized beautiful specimens.

70017 This poikilitic sample of **70017** has paragenetic sequence similar to A-11 High Ti- basalts [2] [15], rich occurrence of sector zoned clinopyroxenes. The rich population of ilmenites make dark the thin section: this ilmenite rich specimen has a counterpart near to Darnó Hill (at Szarvaskő), in a gabbro with high ilmenite cont. bw. 8-10 % wt.)

12005 The Apollo 12 poikilitic **12005** sample had the slowest cooling, so this specimen closes our cooling rate series. It contains large, zoned pyroxene oikocrystals with embedded idiomorphic (euhedral) olivine grains of chadacrysts [12].

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TERRESTRIAL COUNTERPART TEXTURES: AN OPHIOLITIC SEQUENCE OF DARNO HILL

In the Darnó Hill (basalts and microgabbros) textural sequence of an ophiolite can be found. From the outer edge high cooling rate textures to the bottom of the lava layer (or to the center of a pillow lava "sphere") the following textures represent this series: spherulitic, variolitic, intersertal, intergranular, subophitic, ophitic, poikilitic. [7]. Although important details are different in a terrestrial flow and in a lunar flow (chemical compositions, - e.g. 74220 and 12002 are picritic basalts [5], [10], [16]. - water content can change paragenetic sequence of crystallization for plagioclase feldspar and pyroxene), the main textural characteristics determined by cooling rates remains important basis for comparisons and TTT diagrams.

COOLING RATES FOR LUNAR AND TERRESTRIAL BASALTS AND TENTATIVE TTT DIAGRAM FOR THE LUNAR BASALTS

On the basis of experimental determination of the cooling rates and also from TEM measurements of clinopyroxenes both cooling rate sequences and TTT-diagrams were studied and determined [1], [3], [13-15]. The lunar basalt layer was 8-10 meter thick [13] [15]. This thickness is larger, but comparable to pillow lava units as terrestrial pairs.

A pillow lava cools during 2 days, but 8-10 meters thick lunar layers cooled for months or years in their inner regions. In a pillow lava textural sequence only the intergranular texture could be reached because of the quick cooling and smaller lava body size. In the lunar basalt case all textural types in our sequence could be reached. The corresponding cooling rates were given by [3] as 3 C/min. for a vitrophyric, 30 C/hr for a coarser vitrophyric and 3 C/day for a porphyritic Apollo 15 sample. Data of a pillow lava are in table 1. as follows: [7, 17]

textural type	cooling rate	depth in a pillow lava	length of cooling time
glassy	45000 - 1800 C / min.	1 centimeter	1 min.
spherolitic	22000 - 1000 C / min.	some centimeters	some minutes
variolitic	1000 - 200 C / min.	decimeter	10 minutes - 0,5 hour
intersertal	200 - 30 C / min.	some decimeters	0,5 - 2 hours
intergranular	0,5C / min.	central region of pill.l.	1 - 2 days

SUMMARY

We studied and constructed 1) from lunar basaltic textural characteristics via cellular automata modeling paragenetic and cooling rate sequences, 2) a tentative TTT-diagram of lunar basalts (lava flows), we 3) compared lunar textural layers to that of a terrestrial pillow lava textural layers and 4) we compared basaltic TTT diagrams to steel industrial [19] TTT diagrams. In this work role of textural studies of unusual materials for studies of industrial ones were also emphasized. This way studies of planetary materials has a spin-of direction in space science education. Another space science educational outreach of this program was the application of the cellular automata type description to textural transformations [20-24].

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