HOW WE USED NASA LUNAR SET IN PLANETARY MATERIAL SCIENCE ANALOG STUDIES ON LUNAR BASALTS AND BRECCIAS WITH INDUSTRIAL MATERIALS OF STEELS AND CERAMICS.

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Introduction: Analog studies play important role in space materials education. Various aspects of analogies are used in our courses. In this year two main rock types of NASA Lunar Set were used in analog studies in respect of processes and textures with selected industrial material samples. For breccias and basalts on the lunar side, ceramics and steels were found as analogs on the industrial side. Their processing steps were identified on the basis of their textures both in lunar and in industrial groups of materials.

Samples: In our studies we used the following samples: NASA Lunar Set: A) **Breccias**: 14305 - breccia-in-breccia texture; 15299 - regolith (para)-breccia, 65015 - impact melt (para)-breccia, poikilitic; 72275 - para-breccia, 60025 - mechanical mixing of cumulate anorthosites, ortho-breccia; B) **Basalts**: 74220 - fast cooling rate, lava fountain droplet [1]; 68501 – clasts in breccia, variolitic, 72275 - spherulitic-variolitic clast in breccia; 14305 - intergranular type clasts in breccia; 72275 - subophitic clast in breccia; 12002 - porphyritic sample; 70017 - ophitic sample; 12005 - poikilitic sample (basalts are in cooling rate sequence). The comparative samples from manufacturing industry. **Ceramics**: Bi-cske-sample (pottery), Felsővadász-sample (pot.), Szécsény-sample (pot.), and Szarvas-Sample (pot.) **Steels**: perlite-sample, bainite-sample, martensite-sample.

Ceramics and breccias: For industrial materials the sequence of the main steps of operations were followed in textural formation (breaking, crushing, transporting, mixing, recycling and final welding or heating).

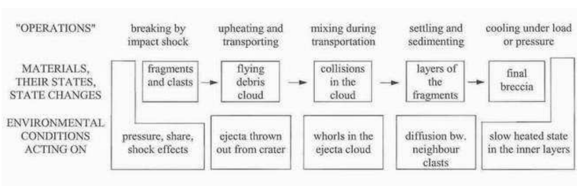
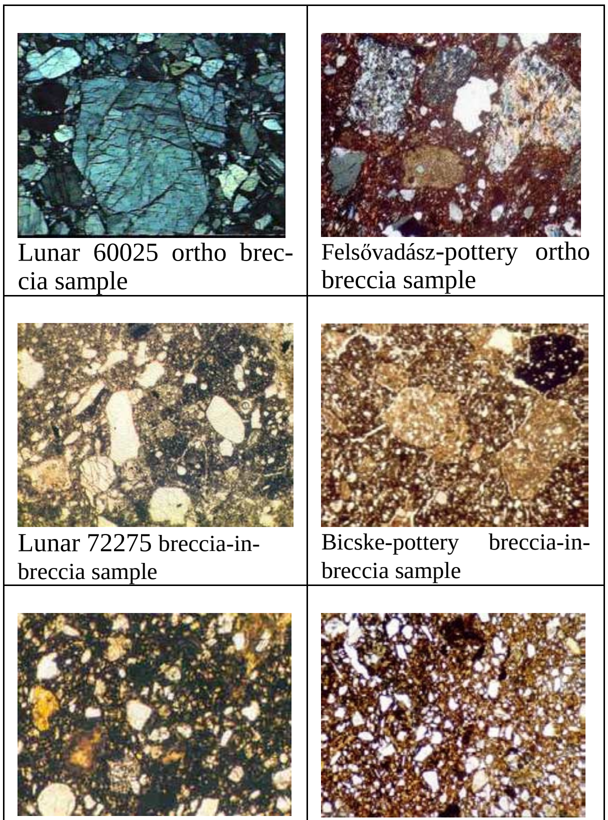


Fig. 1. When an impact rearrange fragments and clasts, and it forms a final fragmental brecciated material, then the steps of transformations are analog in many respects with those of the ceramic industry manufacturing process.

Impacts always formed brecciated rocks and soils on the Moon. It is interesting to compare the main events during an impact process and in a ceramic manufacturing technology. Impact crush the target rocks, heat up them and during the ejecting process fragmented materials are mixed and collisionally fragmented again. In the ejecta blanket sedimentation process begins the long term cooling and welding together process. Lower layers are under the pressure of the superposed layers. Some parts of the impact and target material melt and special breccias develop.



Lunar 60025 ortho breccia sample	Felsővadász-pottery ortho breccia sample
Lunar 72275 breccia-in-breccia sample	Bicske-pottery breccia-in-breccia sample
Lunar 15299 regolith breccia	Endrőd-fine grained pottery

Fig. 2. The ortho breccia texture (upper row) and the breccia in breccia texture (lower row) in lunar breccia and in a pottery ceramics sample.

Basalts and steels - cooling rate: Analog study for lunar basalts made it possible to arrange them in cooling rate sequence. However, for industrial materials the hardening in the steel industrial textures form a sequence of the main steps of operations also according to the cooling rate of the heated steel samples. We can follow both the process and the textures formed in the TTT diagrams.

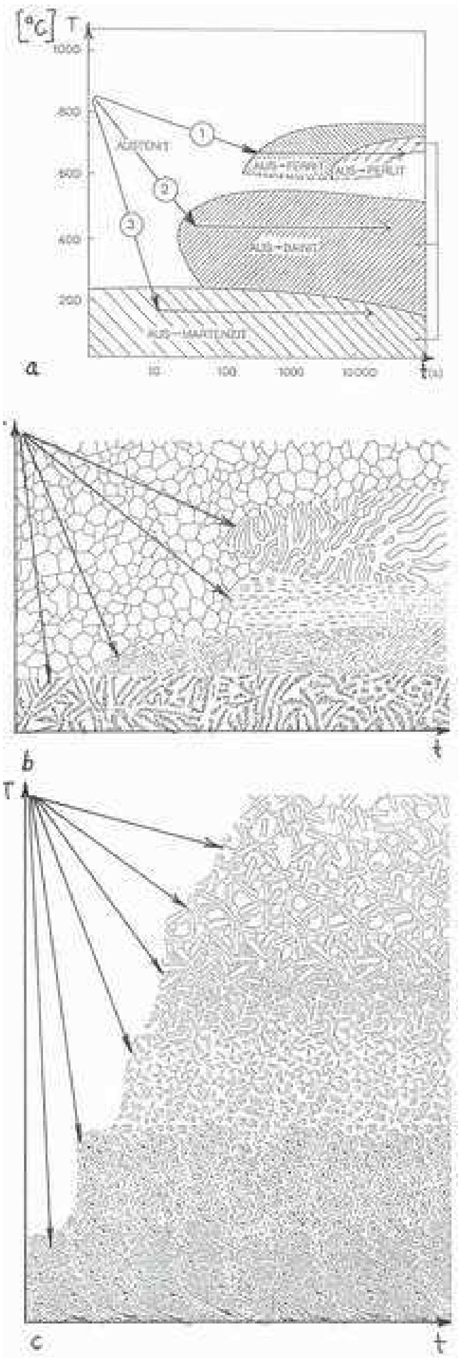


Fig. 3. Comparison of textural analogs between steels produced by hardening via heating and cooling (in solid state) with various cooling rates and basalt-textures also produced by decreasing cooling rates, (however from a molten state). The "C-rurves" of steels (a) are followed by their main textural regions in the T (temperature)-T (time) transformation diagram (b) and the corresponding basaltic textural field with lines of cooling rates.

Discussion: Materials from nature and from manufacturing has common and distinct characteristics. One of their main characteristic is their texture and formation process. The relations between formation process and the produced textural variants are better known for industrial materials. But natural processes are also "mapped" and the relation are summarized in "material maps" like TTT, pT, cT and many other diagrams. If students learn planetary and industry materials parallel, then 1) they have exciting insight to far and exotic topics, 2) they get acquainted with planetary processes and manufacturing processes parallel 3) they get acquainted material maps both with microscope studying textures and their forming parameters, 4) functions may be deduced from the relations between textures and manufacturing steps. This way lunar sample analog studies with industrial counterparts sugest them recognition of steps in formation of other complex material systems and this will initiate their own experiments and studies on more complex materials, too.

Summary: In our analog studies NASA lunar samples were compared with the petrography-manufacturing technology conclusions on their formation processes and textures. This work focuses a valuable type of use of the NASA Lunar Set in planetary materials education.

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