HOW WE USED NASA LUNAR SET IN PLANETARY AND MATERIAL SCIENCE STUDIES: COMPARISON OF BRECCIAS FROM MOON, EARTH, ASTEROIDS AND ANCIENT CERAMICS BY TEXTURES AND PROCESSES.

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Abstract: Breccias from the NASA Lunar Set, NIPR Antarctic meteorite set, chondritic meteorites from Hungary, terrestrial rock samples and ceramic industrial samples were compared, their processing steps were concluded in our comparative planetary petrography course. Various types of brecciation: early solar nebula mixing and accretion (chondrites), surface impacts (chondrite parent body, lunar, basaltic achondritic), pyroclastic ejection (terrestrial), and repeated reworking (lunar, ancient ceramics) were studied, and the sequence of the main steps of operations (breaking, crushing, transporting, mixing, recycling and final welding or heating) were compared and petrography/technology conclusions were deduced in this course.

Introduction: Because of impacts on planetary surfaces, on asteroidal bodies, also by transportation and mixing of the broken debris, bracciated materials occur frequently among Solar System materials. For these materials we can identify common textural description principles and operations during their formational processes: from the source region of the textural units, through their mixing events and on their way of transportation to the place of sedimentation, till the final fusing the formational operations of these materials has many similar characteristics. Terefore they can be described with a common technological sequence (manufacturing) generally known in ceramics industry.

Samples: In our studies we used the following samples:

NASA Lunar Set: 14305, 15299, 65015, 72275, 60025;

NIPR Antarctic Set: Y-86032 (Lunar regolith breccia), ALH-78113 (aubrite br.), ALH-77256 (diogenite br.), Y-7308 (howardite br.), Y-74450 (eucrite br.), Y-790448 (LL3 chondrite), Y-691 (EH3 chondrite), Y-86751 (CV3);

Chondrites: Mezömadaras (L3), Knyahinya (L5/6), Kaba (CV3), Mócs (L5);

Terrestrial rocks: volcanoclastics: basalt-lapilli, Szentbékkálla (Pannonian-/Pleisztocene), pebble conglomerate of Carboniferous is embedded in the pebble congolmerate of the Mecsek Mts. (L. and M. Miocene) embedded.

Ancient ceramics of Szarvas, Endröd (early neolithic, Körös Culture), Szécsény (middle neolithic, Zseliz Culture).

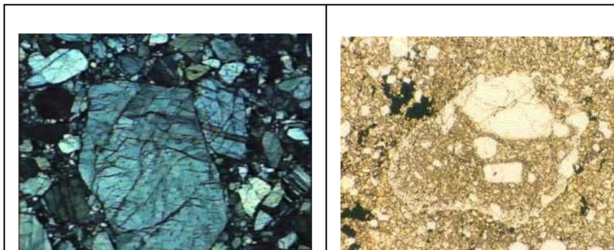
Main breccia-textures Definitions of breccia textures distinguish two main types: para and ortho-breccias. Parabreccias are matrix-supported: the larger grains "flow" in the matrix. Ortho-breccias are grain-supported and matrix fills the regions between the grains. Breccia-in-breccia textures refer textures with fractal type grain size hierarchy. In the descripitons we used these characteristics and the breaking, crushing, transporting, mixing, welding or heating stages in the formation process. Grain size distributions, the modality and the sorted nature of the clasts were also measured in this study.

Chondrites Chondrites were probably accreted in a cosmic sedimentation process [1], they can be considered accretionary breccias. More chondrites are para-breccias (with more matrix, chondrules are surrounded with them, Kaba, Y-86751) then ortho-breccias, where chondrules frequently touch each other (Mezömadaras, Knyahinya). Two periods may produce other characteristics of the brecciated texture for chondrites. During chondrite accretion stage chondrule breaking by collision is proved by the occurrence of broken chondrules (Y-790448, Mezömadaras) [2,3]. Other broken chondrite constituents are also known in chondrites. The other period is the stage when rocks were exhibited on the surface of the parent body, and impacts could break, mix and weld together chondritic pieces with different metamorphic type. Brecciated chondrite Knyahinya shows textural evidences of such breaking and mixing. It is also known that breccia-in-breccia texture occurs in chondrites (Cangas de Onis, [4]).

Achondritres: Basaltic achondritic rocks of the differentiated asteroidal bodies are exposured on the surface: the suffered impacts formed monomict or polymict breccias. The NIPR set achondrite breccias (ALH-77256 (diogenite br.), Y-7308 (howardite br.), Y-74450 (eucrite br.), have less crushed/mixed para-breccia texture than most lunar breccias probably because smaller number of impact episodes.

NASA Lunar samples:

60025 anorthosite sample formed by mechanical mixing of cumulate anorthosites [5,6]. Anorthosites are the only ortho-breccias in the NASA Lunar Set. (Fig. 1A.)



60025 anorthosite | 14305 Fra Mauro breccia

Fig. 1. Apollo 16 crushed anorthosite and Apollo 14 Fra Mauro breccia with breccia-in-breccia texture. (NASA Lunar Sample set thin section photograph.)

14305 Fra Mauro Breccia with breccia-in-breccia texture shows a cycle in the "manufacturing" sequence: the repeated events breaking and welding together. Many regions have para-breccia texture. (Fig. 1B.)

15299 Regolith breccia (para-breccia) is similar to Y-86032 lunar meteorite. Glassy matrix marks hot welding.

65015 Impact melt breccia, although poikilitic in many regions, but it has a para-breccia texture (Fig. 2.)

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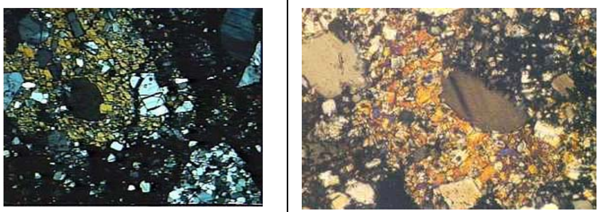
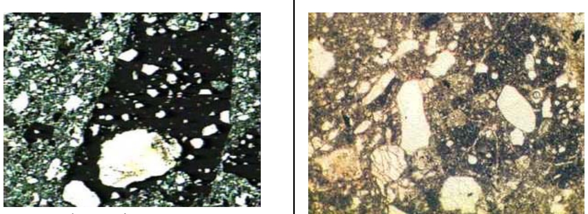


65015 breccia | 65015 breccia

Fig. 2. Apollo 16 polymict breccia: impact melt glass recrystallized in metamorphism (poikilitic region) [7]. (NASA Lunar Sample set thin section photograph.)

72275 consists of many rock-fragments from the lunar highlands. This para-breccia has two parts: the lighter one has lower, the darker side has higher matrix/fragment ratio (Fig.3.)

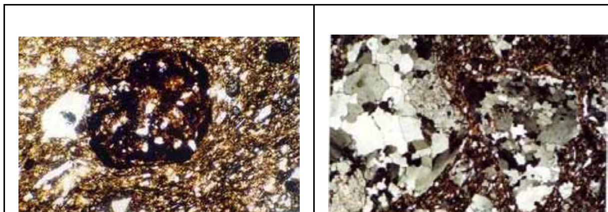


72275 breccia | 72275 breccia

Fig. 3. Apollo 17 para-breccia which shows breccia-in-breccia regions. (NASA Lunar Sample set thin section photograph).

Terrestrial fragmentary rocks: Pyroclastic rocks were sedimented in a hot state and welded together. Broken fragments wer formed during their transport to the eruption place. One stage event formed their frequently para-breccia like texture, but ortho-brecciated textures also occur (Szentbékkálla, Balaton Highlands, Hungary).

Some sedimentary rock textures exhibit good counterparts for comparisons with the fragmentary aggregated textures we study. In pebble-conglomerates from L. and M. Miocene of Mecsek Mts. Southern Hungary we can find also pebble conglomerates from the Carboniferous. Although the transport mechanism is different from the impact or volcanic type ones, the breccia-in-breccia texture is exhibited in these textures. This is an ortho-breccia. It aggregated in cool state.



Szarvas-Endröd ceramics | Szécsény ceramics

Fig. 4. Terrestrial ceramics. A. Breccia-in-breccia like texture in the Szarvas-Endröd ceramics. B. Locally grain-supported (ortho) breccia of an ancient ceramics from Szécsény.

Ceramics: Manufacturing technology consists of mechanical crushing and mixing of the raw materials: clay plus some fragmentary temper material (frequently broken earlier ceramics). Final heating fuses the components. Ceramics have generally para-breccia type textures (ortho-breccia textures appear in special ceramics locally in the fabrics, as our find is among archaeological neolithic ceramics from Hungary) [8,9].

Szarvas-Endröd ceramics: in a para-breccia texture we can find large grains, fragments of previous broken ceramics. Sometimes the repeated use of the old material results in breccia-in-breccia texture in ancient ceramics (Fig. 4A.)

Szécsény ceramics: ortho-breccia like texture, where quartz grains form the grain-supported skeleton. (Fig. 4B.)

Comparisons, conclusions, benefits for technology students: Textural characteristics witness formation processes both for natural and industrial materials. In our course we studied textures and the sequence of the operations were mapped for the samples of Solar System materials and industrial technology materials. As in the earlier year at TTT diagram comparisons for cooling melts of planetary and industrial materials, the work was fascianting for students and helped to recognize the comparable effects between natural and technogical processes. This course was not only for planetary science students but for technology students, who has larger background on industrial materials and manufacturing. It was recognized by students that such comparative petrographic study has mutual benefit: possibility to see wider range of formation processes then in the disciplinary studies (only geology and only industry).

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