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PETROGRAPHIC STUDIES ON THE NASA LUNAR SAMPLE THIN SECTION SET: II. TEXTURAL COMPARISONS OF NASA LUNAR BRECCIA SAMPLES AND VARIOUS COUNTERPARTS FROM THE TERRESTRIAL, CHONDRITIC (NIPR) AND ARTIFICIAL CERAMIC SAMPLES

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ABSTRACT

NASA Lunar Sample Educational Set is a valuable source for planetary petrology education. Using the breccias of the Apollo expedition lunar samples we made cosmopetrographic comparisons between the lunar, the meteoritic, the terrestrial natural brecciated samples and the terrestrial artificial breccia-like ceramic ones. The meteoritic samples were studied from the NIPR Antarctic Meteorite Thin Section Set. From this comparative study the selected counterparts and their formation processes were also concluded.

INTRODUCTION

During the last 10 years Eötvös University received on loan the NASA Lunar Sample Thin Section Educational Set from Johnson Space Center, Houston. We made various new applications on the basis of this valuable set. One main topics was the comparison of extraterrestrial materials and selected thin sections from terrestrial rocks. In this work we also used artificial breccia-like materials for textural comparisons, where the operations in the technology manufacturing sequence give a good descritpion of the transformations of the phases (Bérczi et al., 1997, 1999, 2001). Added textures multiplied and extended the possibilities to form complex concepts: how to constitute complex material maps by starting from counterparts of textural types? (inter-connections, basic physical and textural relations of brecciated and other fragmental rocks, and other compositions from material science, as ceramics, metallurgy).

Here we report about the study on breccias of NASA Lunar Educational Thin Section Set with comparisons to Antarctic meteoritic (NIPR Set), terrestrial natural and artificial breccia-like textures. On the basis of parameters read from lunar, meteoritic and terrestrial textures the counterpart technology or processing sequences were selected.

DEFINITION AND COMPARISON

The nomenclature of the siliciclastic sedimentary rocks contains three main types depending on their grain size range. Above 2 mm sized grains they are classified as breccias and conglomerates. Between 2 and 0.063 mm the siliciclastic sedimentary rocks are sandstones. Below 0.063 mm the sedimentary rocks are mudstones. Among the planetary sedimentary materials and among the artificial materials all these groups occur. These sedimentary rock textures are classified into two textural types depending on the clast-matrix ratio. The clast-supported textures are named as orthobreccias (or orthoconglomerates, for sandstones they are orthosandstones). The matrix-supported textures are named parabreccias (or paraconglomerates, for sandstones they are wackes). The general distinction between the ortho and para cases is at the 15 % matrix content. In this paper we shall use this nomenclature for the artificial ceramic textures, too. We call any kind of the artificial ceramics as "ceramic breccia", regardless of their grain size.

SOLAR SYSTEM BRECCIAS: CHONDRITES AND BRECCIATED BASALTIC ACHONRITES

Various types of brecciation, like the 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 study.

In the the sample collections we compare the chondrites are the most ancient breccias. They accreted in a cosmic sedimentation process, they can be considered accretionary breccias. Even if there is a gradual sequence of brecciated textures among the chondrites, most of the chondrites are parabreccias (except the E-chondrites), because the matrix materials are dominantly more than the 15 % boundary quantity of matrix between the para and ortho textural variants. The E-chondrites essentially consist of chondrules only, without considerable matrix material. In some cases we can observe orthobrecciated textural regions in the type 3 ordinary chondrites, where chondrules frequently touch each other (for example in Mezőmadaras, or in Knyahinya).

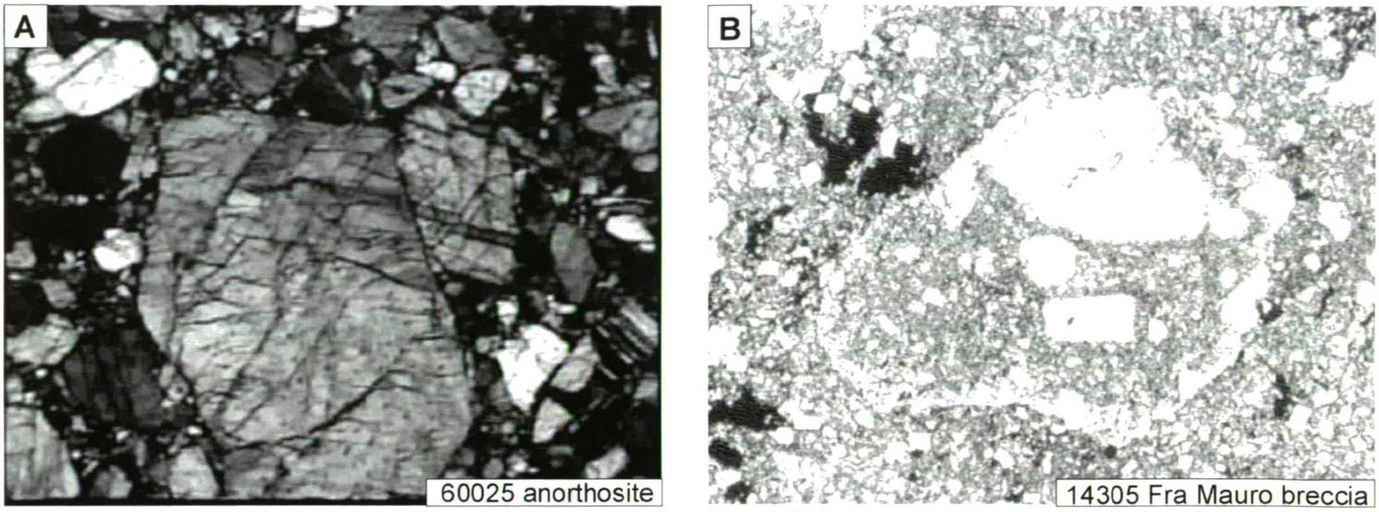

Fig. 1. Apollo 16 crushed anorthosite exhibits orthobreccia texture. The Apollo 14 Fra Mauro breccia has breccia-in-breccia texture.

Two other parent body evolutionary periods may produce brecciated characteristics of the texture of chondrites. In collisions sometimes chondrules broke to fragments, the occurrence of broken chondrules was observed in Y-790448 of NIPR Set, and in Mezőmadaras. Even larger fragments of broken chondrite clasts are also known in C-chondrites, too.

After accretionary period chondrite paernt bodies (asteroids) were heated up by the radionuclides. Thermal metamorphism gradually equilibrated the originally unequilibrated chondritic textures. When metamorphic chondritic rocks were exposed on the surface of the parent body, impacts could break, mix and weld together chondritic fragments with observable different metamorphic type. Brecciated equilibrated chondrite types in Knyahinya shows textural evidences of such breaking and mixing. Moreover, repeated impacts could produce breccia-in-breccia texture which also occurs in chondrites (Cangas de Onis).

On the surface of the most evolved meteorite parent bodies (recently only Vesta is known among them) basaltic achondrites are exposed. Basaltic achondrites also suffered impacts and formed monomict or polymict breccias. The NIPR set achondrite breccias (ALH-77256 - diogenite breccia, Y-7308 - howardite breccia, and Y-74450 - eucrite breccia), have less crushed/mixed parabreccia texture than most lunar breccias probably because smaller number of impact episodes.

LUNAR BRECCIAS IN THE NASA LUNAR SAMPLE THIN SECTION SET

Impacts always formed brecciated rocks and soils on the Moon. Breccias are represented by 4 samples in the set.

Among NASA Lunar samples 60025 anorthosite sample formed by mechanical mixing of cumulate anorthosites (Meyer, 1987). Anorthosite is the only ortho-breccia in the NASA Lunar Set. The 14305 Fra Mauro breccia with breccia-in-breccia texture shows a cycle in the "manufacturing" sequence: the repeated events breaking, mixing by transporting and finally sedimenting and welding together. Many regions of this sample have parabreccia texture (Fig. 1).

The 15299 regolith breccia (parabreccia) is similar to Y-86032 lunar meteorite of the NIPR Set. Glassy matrix marks hot welding. The 65015 impact melt breccia, although poikilitic in many regions, but it has a parabreccia texture (Fig. 2). The 72275 consists of many rock-fragments from

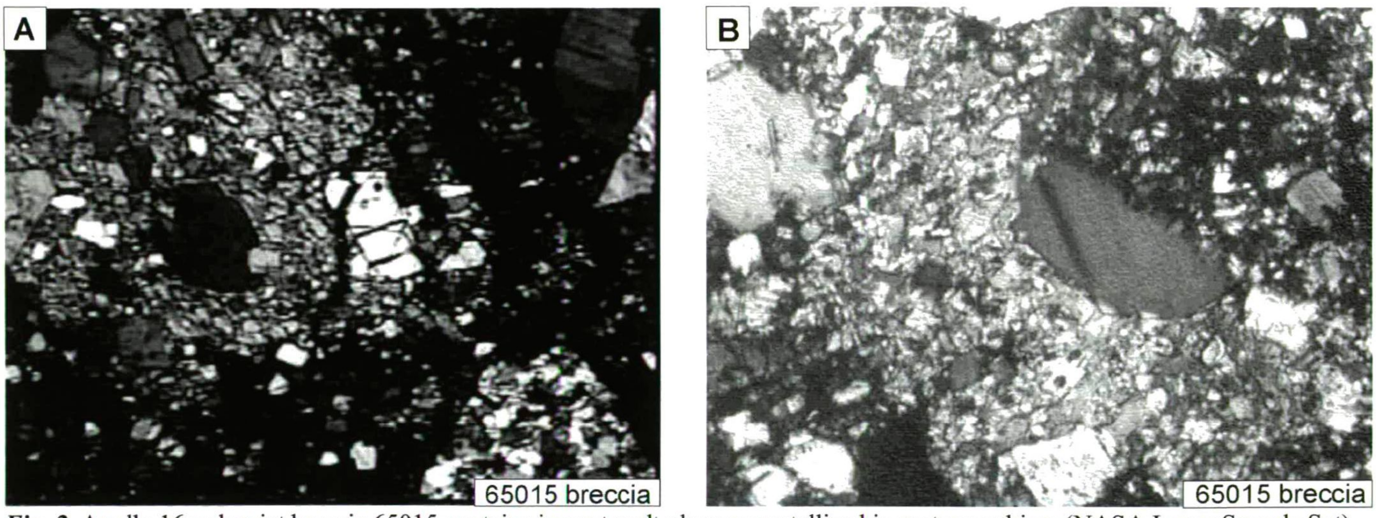

Fig. 2. Apollo 16 polymict breccia 65015 contains impact melt glass recrystallized in metamorphism (NASA Lunar Sample Set).

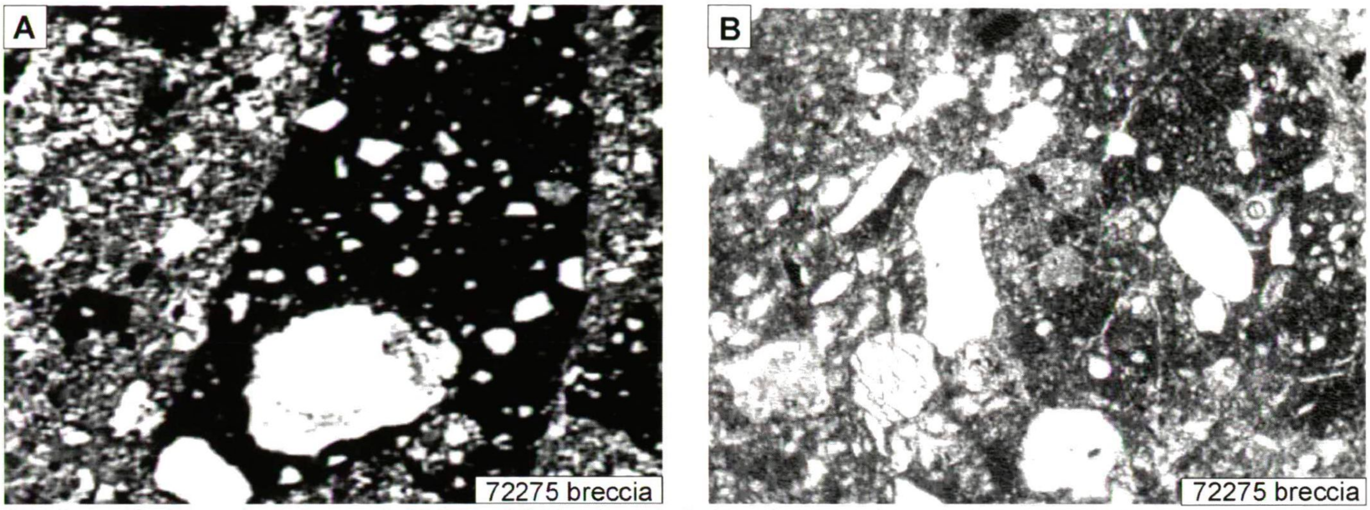

Fig. 3. Apollo 17 parabreccia sample 72275 exhibiting breccia-in-breccia textured regions (NASA Lunar Sample Set).

the lunar highlands. This parabreccia has two parts: the lighter one has lower, the darker side has higher matrix/fragment ratio (Fig. 3).

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 melts and special breccias develop (Fig. 4).

Among terrestrial fragmentary rocks the pyroclastic rocks were sedimented in a hot state and welded together. Broken fragments, clasts, dust were mixed during their transport in the eruption process. One stage event formed their frequently parabreccia like texture, orthobrecciated textures only rarely 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. The pebble conglomerate aggregated in cool state and it has orthobreccia texture.

Artificial breccias by ceramic manufacturing (from the Neolithic and Bronze Age, Hungary)

For ceramic products the manufacturing technology consists of various procedures from mechanical crushing and mixing of the raw materials through forming till the different levels of heatings which fuse the components. The raw materials are: clay plus some fragmentary temper material (frequently broken earlier ceramics). The main manufacturing phases of ceramics did not change since ancient pottery technology, however, temperature of heating increased.

Most modern ceramics have generally parabreccia type textures. However, regions of orthobreccia textures appear in special ceramics. Especially archaeological potteries are interesting for comparisons to brecciated rocks. In ancient manufacturing first natural soil materials, mainly clays were used and plant fragments were added as temper material. Such pottery samples from the neolithic age were found in Bicske and Felsővadász, Hungary (Fig. 5).

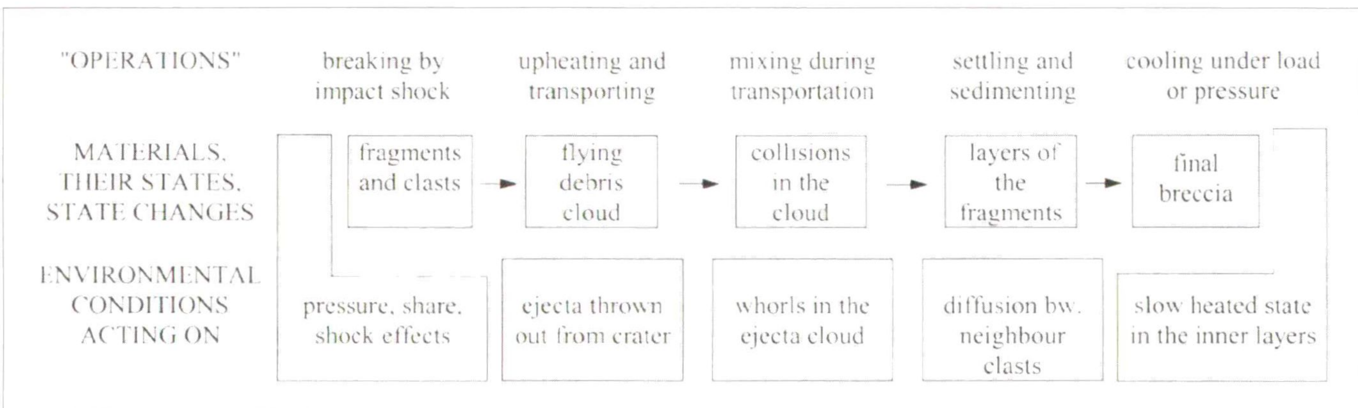

Fig. 4. Main operations in the breccia formation: from breaking, transport and mixing through sedimenting till the slow cooling under the pressure of local superposed layers.

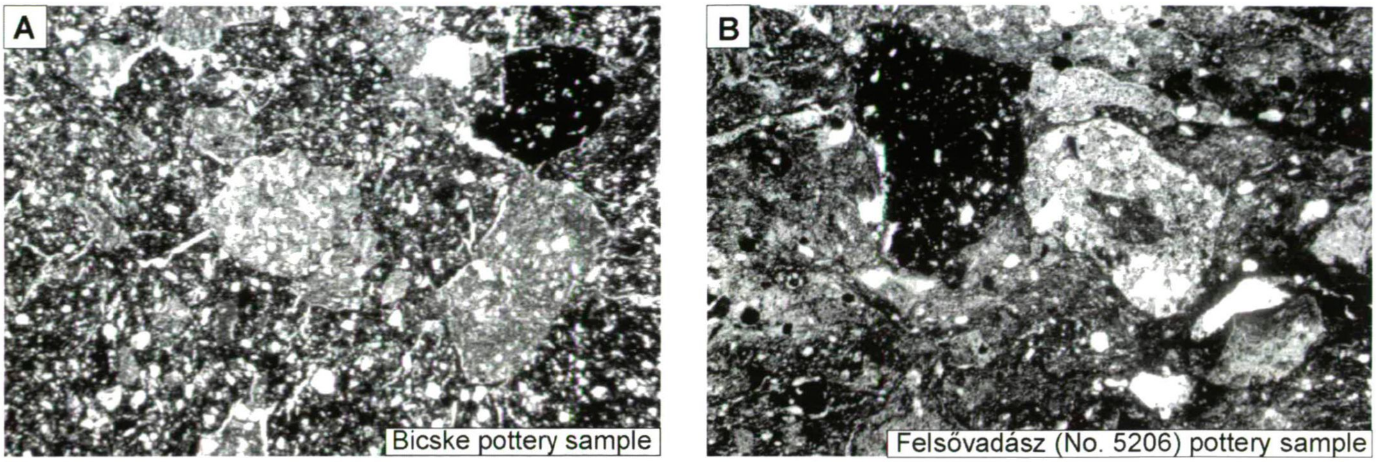

Fig. 5. Two pottery textures with breccia in breccia texture from the neolithic age, Hungary.
(A) Grog clasts in pottery from Bicske-Galagonyás, Neolithic, Sopot-Bicske culture (1 nicol, the shorter side of the photo is 2.22 mm). ***(B)*** Grog and argillecous rock fragments clasts from Felsővadász, Neolithic, Bükk culture (1 nicol, the shorter side of the photo is 2.22 mm).

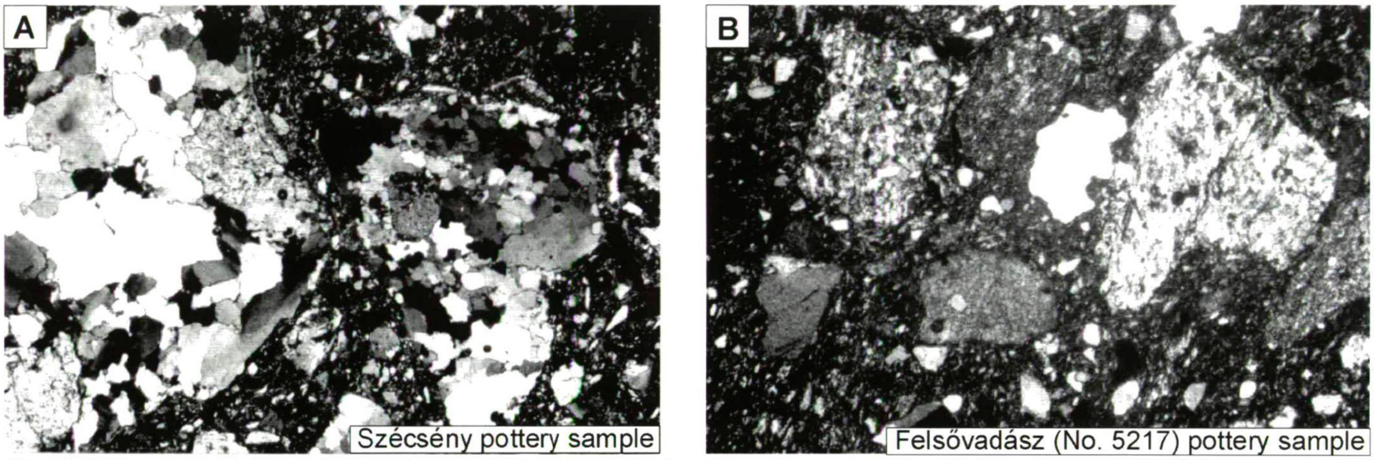

Fig. 6. Old potteries with orthobreccia texture ***(A)*** and with locally grain-supported orthobreccia texture ***(B)*** from Hungarian archaeology. ***(A)*** Large granitoide clasts as a temper in an orthobreccia textured pottery from Szécsény-Ültetés, Neolithic, Zseliz-culture (crossed nicols, the shorter side of the photo is 2.22 mm). ***(B)*** Phillite, micrite, quartzite and quartz fragments in an almost orthobreccia textured pottery from Felsővadász, Bronze age (crossed nicols, the shorter side of the photo is 2.22 mm).

There are ancient orthobrecciated textures like as samples from Szécsény and Felsővadász, Hungary (Fig. 6). Various local rocks were used as temper components int he pottery.

Conclusions

Textural characteristics witness formation processes both for natural and industrial materials. In our study textures of Solar System brecciated rocks and some ancient potteries were studied parallel. Their para- or orthobrecciated textures were implicated by the sequence of the operations which affected the target materials both in Solar System or parent body processes and in industrial ceramic technology procedures. This work continues our efforts to use the cosmic materials as basic planetary materials in comparing them with terrestrial natural samples and industrial processes.

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