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THE POSSIBLE ROLE OF CLAY MINERALOGY IN THE STUDY OF MICROSPHERULES OF COSMIC ORIGIN

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ABSTRACT

In this short review the clay mineralogy of rocks of cosmic or impact origin and of their enclosing sediments are discussed.

In cosmic matter (meteorites, rocks of the Moon) clay minerals, even hydrous layer silicates are extremely rare (very minor amounts in some Apollo 11 lunar samples and in carbonaceous chondrites). The hydrous layer silicate serpentine is relatively abundant in the zone of asteroids and among the satellites of the planets Jupiter and Saturn.

The non-sedimentary, first phase products (suevites) of the Ries impact crater at Nördlingen contain fresh glassy components. Clay mineral formations starts first during the subsequent post-impact sedimentary history. Examples are given from the Miocene crater lake of the Ries structure, the Cretaceous/Tertiary boundary in a peat-forming environment of western North America and marine deposits of the Eastern Alps as well as Jurassic/Cretaceous boundary formations near an impact structure in the Barents Sea.

Mineralogical analysis may contribute to the reconstruction of the conditions of sedimentation, alteration and diagenesis of rocks containing cosmic or impact-derived material. Examples from the study of Hungarian sedimentary formations are given (Anisian of Mecsek Mts., Uppar Cretaceous of Bakony Mts. and Pannonian of the Little Hungarian Plain).

INTRODUCTION

Microspherules are spherical particles of microscopic size found in sedimentary rocks and Recent sediments. They have either glassy silicatic, or magnetic iron-rich composition. They are supposed to be of cosmic origin. Because of their small size they are normally not accessible for traditional determinative methods of mineralogy. These methods, however, including the determination of clay minerals, can help to elucidate the circumstances of the formation of the rocks that contain the particles. The aim of the present short review is to discuss these possibilities.

COSMIC DISTRIBUTION OF CLAY MINERALS

Clay minerals, similarly to the phenomenon of life seem to be restricted to the surface of the planet Earth. As it was stated by SZÁDECZKY-KARDOSS in one of his essays in 1975, "they are known only on the Earth' surface" and from the "preentrance" of terrestrial life

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(p. 163). One exception from this rule can be the surface of the planet Mars. On the basis of measurements of the Viking program BANIN (1980) supposed that "smectite clays are abundant in the soil of Mars". In the IR spectra of the interstellar dust the lines of clay minerals such as chlorite, montmorillonite and serpentinite could be identified (BÉRCZI 1991, Fig. 72).

Clay minerals or even hydrous layer silicates are completely absent or represent extreme rarity in cosmic materials accessible for direct mineralogical measurements. In the Apollo 11 lunar samples only extremely rare di- and trioctahedral phyllosilicates could be detected by electron diffraction study (DREVER et al. 1970) which were not more closely specified. Among the meteorites the carbonaceous chondrites may contain clay minerallline phases. In the Orgueil meteorite minor amounts of "pseudo-chlorite" (ORCEL et al. 1972), in the Allende carbonaceous chondrite intergrown mica and montmorillonite and a serpentine-like phase were found (TOMEOKA, BUSECK 1982a,b).

Contrary to true clay minerals the hydrous layer silicate serpentine is relatively abundant in the Solar System in the zone of asteroids and among the satellites of Jupiter and Saturn. Serpentine constitutes e. g. essential part of the 4 Galilean satellites of Jupiter. Its occurrence is typical in a zone which occupies intermediate position between plantes constituted mainly by silicates, e. g. Earth, Moon, Mars and those containing much water like Jupiter and Saturn. Serpentine may be a constituent of carbonaceous chondrites and is supposed to occur in comets (BÉRCZI 1991).

Microspherules of cosmic origin can remain fresh over verly long periods of time. In glassy microspherules found in Carboniferous of Upper Silesia no water contents could be detected by IR method (MANECKI and SKOWRONSKI 1970). On the other hand, glauconite-bearing microspherules proved to be of diagenetic, not of impact origin in the layers near the Cretaceous/Tertiary boundary at Gubbio, Italy (NASLUND et al. 1986).

THE LACK OF CLAY MINERALS IN IMPACT PRODUCTS

Clay minerals are practically absent in particles and rocks formed from terrestrial material by the effect of impact of cosmic bodies.

Tektites and micro-tektites consist of glassy silicate material which may contain also particles of pure SiO2 glass (lechatelierete) but are devoid of primary crystallites (GLASS 1990). No hydrous devitrification and transformation of the glass into clay minerals could be observed.

The infilling of the impact crater of Ries at Nördlingen, Germany, was extensively studied (FÜCHTBAUER et al. 1977, LEMCKE 1981). The rocks on the basis of the sequence, called suevite, show effects of shock and melting phenomena but no evidence of subsequent clay mineral formation was found. The same is true for the majority of the overlying so called Graded Unit which is most probably the product of the subaeric fall of the cloud of suevite debris produced by the impact. Alteration products of glass such as montmorillonite, zeolites and calcite appear first in the fine-grained groundmass of the upper part of the Graded Unit (JANKOWSKI 1977b, FÜCHTBAUER et al. 1977) introducing a subsequent lacustrine sedimentation in the crater basin.

CLAY MINERALS IN SEDIMENTARY ROCKS CONTAINING IMPACT OR COSMIC MINERAL

There is a great variety of composition of rocks hosting impact-derived material or particles of cosmic origin.

In the lacustrine sequence of the Ries impact crater near Nördlingen, Germany, various sediments are present (SALGER 1977, JANKOWSKI 1977a, 1980, 1981). In the lower part of the sequence glassy detrital material derived from the crater walls predominate in the sediments which has been altered into montmorillonite and zeolites. Diagenetic transformation produced illite from montmorillonite in hypersaline periods of the lake. Detrital clay minerals such as micas, chlorite, kaolinite and montmorillonite derived by weathering of micas, appear only in the upper portion of the sedimentary sequence.

In a distance of about 80 km south from the Ries crater sporadic debris derived from the impact products can be found in the fluviatile layers of the Upper Freshwater Molasse horizon of the Molasse Basin. In the molasse sediments of this zone normal terrigene detrital clay minerals were found (e. g. near Augsburg, see VICZIÁN 1984), no traces of the impact material can be detected. There are, however, restricted bentonite layers in the molasse sequence of the area, the glassy components of which are remarkably synchronous with the Ries event (Ries: 14.7±0.4 Ma, bentonite: 14.4–14.6 Ma). They were connected with the impact event by several authors (GENTNER and WAGNER 1969, see HEROLD 1970 and VOGT 1980). No direct mineralogical evidence supporting this theory was found except the very sporadic occurence of diaplectitic plagioclase glass (?) in the sediments (HARR 1976). Recently, however, the connection of the Bavarian bentonites with the Ries event was questioned and the source area was located to the Carpathian volcanic region (UNGER, NIEMEYER 1985).

The Cretaceous/Tertiary boundary is being extensively studied because the theory of a catastrophic impact event on this boundary is widely accepted.

In the western Interior of North America a few cm thick clay layer represents this boundary (POLLASTRO, BOHOR 1993). It was deposited in a peat-forming environment. The clay minerals differ from those found in marine K/T boundary sequences due to special circumstances of deposition and alteration which prevailed in this region. The layer consists of two subunits depending from the mechanism of the impact: the lower one, called the "melt ejecta layer" underwent kaolinitic alteration of glassy fragments including hollow spherules (microtektites). The upper one, called "fireball layer" has been altered into smectite. These impact-derived layers differ significantly from other clays found in the sequence, namely from tonsteins and detrital shales.

In a marine K/T transition sequence of the Northern Calcareous Alps the boundary clay differs from other clay layers in the sequence. It contains remarkably little quartz and detrital minerals such as plagioclase, micas and chlorite while it is rich in "expandable clays" and kaolinite which are the devitrification products of fine-grained vitric material derived by the impact (PREISINGER et al. 1986, LAHODYNSKY 1994).

The Jurassic/Cretaceous transition beds were studied in a borehole drilled in the Barents Sea which penetrated a marine shelf succession of clay- and siltstones (DYPVIK et al. 1995). The upper part of this sequence above the Early Volgian (=Tithonian) beds contains enhanced quantities of smectite. The authors think that smectite may be the devitrification product of glassy particles derived from the closely located Mjølnir Structure, a possible extraterrestrial impact crater.

In Hungary glassy and magnetic microspherules were found in several stratigraphic horizons ranging from Triassic to Recent sediments (DETRE et al. 1995). The clay minerals of the particular host rocks are not yet known. In some instances, however, clay minerals were investigated from the same stratigraphic formation but from another localities. Even so, some conclusions can be drawn concerning the mode of formation of these samples. A few examples are given here:

One of them is the *Lower Anisian Vöröshegy Dolomite Member in the Mecsek Mts.* (RÁLISCH-FELGENHAUER 1995). In this member there is a transition between two clay mineral associations (VICZIÁN 1993). The lower one is illite+Mg-chlorite+corrensite formed in a restricted basin environment, the upper one is detrital illite typical of shallow marine sedimentation.

In the *Upper Cretaceous of the Bakony Mts.* microspherules were found in alluvial sediments of the non-marine Csehbánya Formation as well as in the Ajka Coal Formation and in the marine Polány Marl Formation (SZARKA 1994, BODROGI 1994, 1995, SIEGL-FARKAS and WAGREICH 1994). According to clay mineral analyses Csehbánya Formation and clastic intercalations of the Ajka Coal Formation are characterised by the detrial association of illite+chlorite (VICZIÁN 1988). The Polány Marl is similar but contains more smectite which is a sign of the open marine conditions of sedimentation (VICZIÁN 1987). The possible contribution of a volcanogenic component (VASKÓ-DÁVID 1994) is not yet clear.

Spherules were found in the *Upper Pannonian* deposits of the borehole Nagylózs 1 in the *Little Hungarian Plain* (SZÖŐR and RÓZSA 1995). No clay minerals analysis was performed from this well. Stratigraphically equivalent sediments from another borehole contain detrital terrigeneous polymineralic clay mineral association of illite+chlorite in the bulk rock and highly expandable illite/smectite in the <2 μm fraction (borehole Szombathely II, VICZIÁN 1990).

It is planned to investigate the mineralogy of the samples themselves which contain spherules in order to study the particular conditions of their formation.

CONCLUSIONS

1. Meteorites and micrometeorites of cosmic origin usually contain no clay minerals, even hydrous layer silicates are rarity. Ejecta produced from terrestrial material by impact of a cosmic body are in most cases of fresh unaltered glassy composition.
2. Diagnostic features of cosmic or impact origin can be detected mainly by morphological or geochemical studies rather than by bulk mineralogical methods.
3. The clay minerals formed later of the cosmic or impact-produced particles reflect the circumstances of sedimentation, alteration and diagenesis of this material. The same is true for sedimentary rocks hosting microspherules or rather particles produced by a cosmic event. Bulk mineralogical methods such as X-ray analysis may contribute to the reconstruction of the geological history of these formations.

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