X-RAY MEASUREMENTS OF TERRESTRIAL CONCRETIONS AS ANALOGUES OF MARTIAN CONCRETIONS "BLUEBERRIES" FROM MERIDIANI PLANUM. N. Zalewska[1], L. Czechowski [1,2] , E. Borowska[3], [1]Space Science Center PAS, ul. Bartycka 18 A, 00-716 Warszawa, Poland, [2]University of Warsaw, Faculty of Physics, Institute of Geophysics, ul. Pasteura 5, 02-093 Warszawa, Poland, [3]The College of Inter-Faculty Individual Studies in Mathematics and Natural Sciences (MISMaP), University of Warsaw, Banacha 2C, 02-097 Warsaw, Poland

Introduction: We undertook to study the analogues of Martian concretions discovered by the Opportunity rover in the Meridiani Planum [1].

Some terrestrial concretions may be analogs of Martian concretions "blueberries". They could have arisen in a similar sedimentation environment as some terrestrial concretions. Therefore, it is important to determine which Earth concretions are analogs of Martian concretions and under what conditions they were formed. [2], [3], [4].

For our research, as an analogs we chose: 1.Utah concretions from the Dakota Formation (Cretaceous period), Fig.1,3; 2.Utah Navajo Formation concretions (Jurassic), Fig.5; 3.Romanian „Trovants"- gigantic concretions up to 4.5 meters in diameter (Miocene-Neogene) Fig.7.

In many publications, scientists emphasize that these concretions were formed by water [5], [6]. Their chemical mineralization is quite complex because the water that migrates through the porous sandstones is responsible for the crystallization of these formations thanks to the dissolved chemical compounds. There is a repeated mineralization and demineralization, and therefore the chemical composition of concretions in different regions of the world may differ despite the identical origin of their formation [7], [8], [9].

Methodology: Measurements were made using X-ray spectroscopy with energy dispersion -EDS on a Bruker spectrometer. The samples were analyzed in their entirety without fragmentation. As a result of the analysis, we obtained a spectrum of elements that make up the concretion minerals. Magnification pictures of the internal structure of the concretions were taken on a Sigma UP Zeiss microscope

Results: We used for measurements: 1. Concretions of the Cretaceous sandstone of the Dakota Formation in Utah: two types of concretions from this formation - dark and light - were analyzed. As a result of this analysis, it turned out that: dark concretions has quartz grains cemented by calcium and manganese minerals Fig1,2. In contrast to dark, light concretions leached with secondary mineralization of barium sulphate (barite $BaSO_4$) Fig.3,4.

2. Moqui Marbles [11], hematite, goethite concretions, from the Navajo Sandstone of southeast Utah, which microscopic magnification describes that consolidated quartz grains with mineralization in addition to iron oxides, copper and tin minerals are tightly packed Fig.5,6. It is very interesting that in addition to iron, copper and weak tin have been found. These elements can be in the form of stannite.

3. Romanian Trovants concretions. We can notice that quartz grain cementation is primarily calcium minerals, and there are much smaller consolidation than the Utah concretions Fig. 7,8.

Discussion: These studies show that concretions can have a wide range of mineralization. A common feature of discussed concretions is a similar ferric sulphate mineralization. Therefore we consider that Martian concretions and those from Utah probably have formed in a similar environment and water is responsible for their formation [2], [11].

In response to the copper found in concretions there are places in Utah where Dacota concretions are mineralized with copper compounds (malachite, azurite) and take a green-blue color [7].

If Martian concretions were formed in a similar way to terrestrial ones, it is possible that they also contain copper and other metals that may be useful as mineral resources on Mars.

The conditions for the origin of Martian concretions are still unknown. They could have arisen in a similar sedimentation environment as some terrestrial concretions [10].

Therefore, it is important to determine which terestrial concretions are analogs of Martian concretions and under what conditions they were formed. This would significantly enrich knowledge about the conditions prevailing on Mars during the formation of Martian concretions, and would be an important evidence for the presence of liquid water in the history of the red planet [1], [2].

These are only preliminary studies. We plan further measurements to determine the precise mineralization of terrestrial and spectral research on Martian concretions.

Acknowledgments: Special thanks to G. Kaproń from the Faculty of Geology of the Warsaw University for the EDS measurements.

References: [1] Chan, M., et al., (2005) *GSA Today*, 15, 8, 4-10. [2] Fan, Ch., et al., (2010) *Planet. Space Sci*., 58, 401–410. [3] Busigny, V., and Dauphas, N., (2007) *Earth and Planet. Sci. Let.,* 254, 272–287. [4] Potter, S., and Chan, M., (2011) *Geofluids.* [5] Parry, W., (2011) *Sediment. Geol*., 233, 53-68. [6] Chan, M., et al., (2007) *Geofluids*, 7, 1–13. [7] Mika, K., et al.,

(2018) *Geofluids of Utah,* 47, 197-219. [8] Di Bella, M., et al., (2021) *Minerals*, 11, 460, 1-18. [9] Ray, D., et al., (2021) *Planet. Space Sci.*, 197, 105163. [10] Klingelhofer, G., et al., (2004) *Science*, 306, 1740-1745. [11] Potter, S. et al., (2011) *Earth & Planet. Sci. Lett*. 301, 444–456

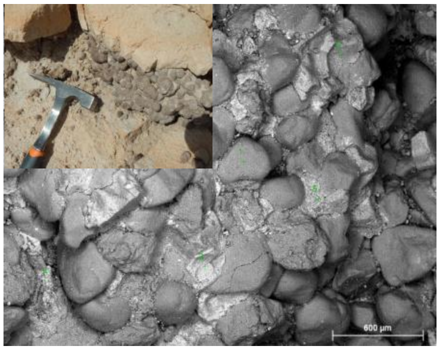

Fig.1. Utah dark concretion from Dakota Formation - quartz grains cemented by calcium and manganese minerals. Microscope Sigma VP Zeiss. Top square - A layer of Cretaceous sandstone from the Dakota Formation in Utah with dark cemented concretions.

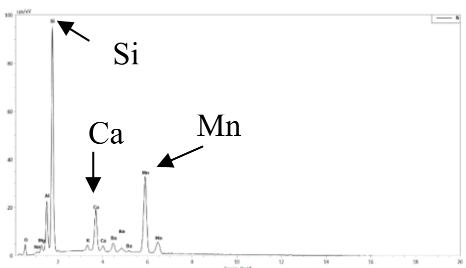

Fig.2. Data from detector EDS Bruker, X Flash 6I10.

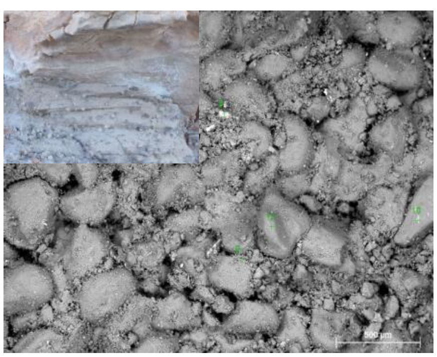

Fig.3. Utah light concretion from Dakota Formation - concretion leached with secondary mineralization of barium sulphate – (barite). Microscope Sigma VP Zeiss. Top square - A layer of Utah cretaceous sandstone from the Dakota Formation with concretion leached with secondary mineralization.

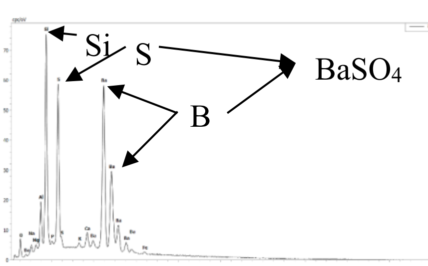

Fig.4 Data from detector EDS Bruker, X Flash 6I10.

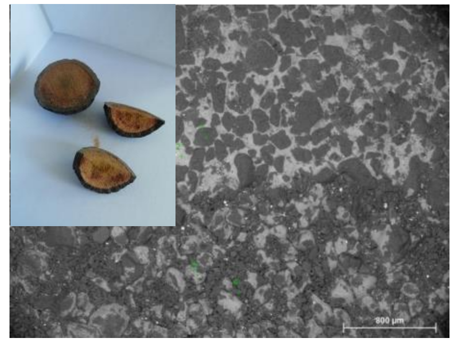

Fig.5. „Moqui Marbles", hematite, goethite concretions, from the Navajo Sandstone of southeast Utah. Tightly packed, consolidated quartz grains with mineralization in addition to iron oxides, copper and tin minerals. Microscope Sigma VP Zeiss. Top square- A cut Moqui Marble.

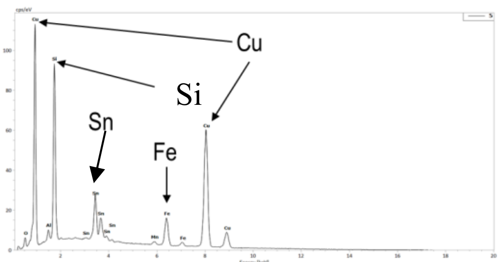

Fig.6. Data from detector EDS Bruker, X Flash 6I10.

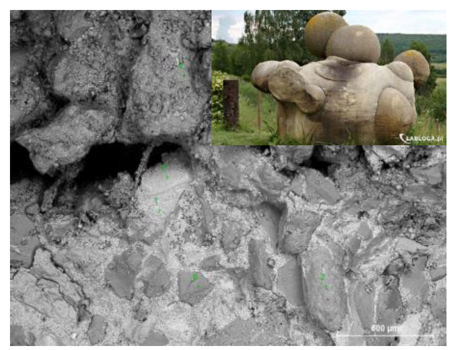

Fig.7. "Trovants" from Romania the sandstones of Costesti village. There are a type of sandstone concretion, up to 4.5 meters in diameter. The quartz grains cementation is primarily by calcium minerals. Microscope Sigma VP Zeiss. Top square- Romanian gigantic concretions „Trovants". Image credit: https://www.geologyin.com/2018/04/the-mysterious-living-stones-of-romania.html

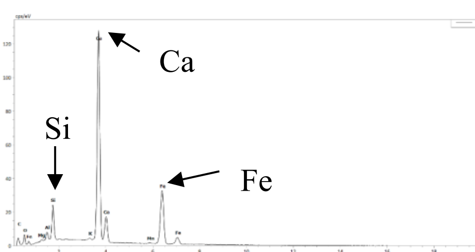

Fig.8. Data from detector EDS Bruker, X Flash 6I10.