DRAINAGE PATTERNS OF TERRESTRIAL COMPLEX METEORITE CRATERS: A HYDROGEOLOGICAL OVERVIEW. K. Mihályi[1], A. Gucsik[2], J. Szabó[1], [1]University of Debrecen, Department of Physical Geography and Geoinformatics, H-4010, Debrecen, P.O. Box 9., Hungary (e-mail: k.mihalyi@freemail.hu), [2]Max Planck Institute for Chemistry, Department of Geochemistry, Joh.-J.-Becherweg 27., Mainz, D-55128, Germany

Introduction: Drainage patterns of a landscape can show the geological structures (surface or even the subsurface structures) and directions of the slopes. The consequences between drainage patterns and the geological features are known since the 1960's [2-and references therein], which can be useful in the meteorite crater researches. Distributions of the impact structures are also important because of their relationship to the age and the geological history of a given surface. The purpose of this study is to summarize the main hydrogeological properties of the terrestrial impact structures. Furthermore, it is also aimed to demonstrate whether or not geomorphological and hydrogeological features of an impact structure can aid to recognize or identify meteorite crater, even if it is geologically or tectonically modified.

Experimental procedure: Keys (for Popigai, Manicouagan and Mistasin structures): *light blue parts* were cut through the rim (headwarding segments). *Dark blue parts:* rivers, which are primarily flows outside of the crater rims, but captured by headwarding (light blue) segments (so now they flows into the basin). *Green:* downflow of the basin (also by headward erosion). *White and black:* drainages of the inner basin, outer rim slopes or determined by other features (see the text). Keys for Vredefort: see text under Fig. 4. All maps are in northern direction. *d:* diameter of the crater; *m. y.:* age in million years.

Results: The following chapter briefly summarizes some typical examples of the well-known terrestrial impact structures and their drainage patterns (Figs. 1-5.).

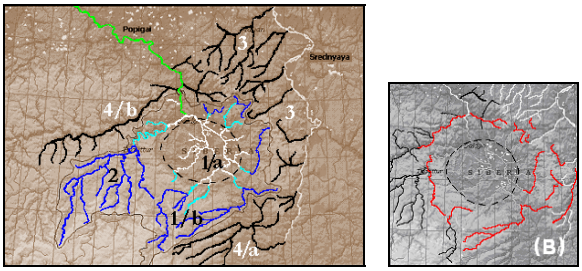

Figure 1. Popigai meteorite crater *(Russia, Siberia, age: 36 m. y.* [3]*, d: 100 km* [3]*, area of the map on the left side: 280×132 km).* ***(1/a):*** *centripetal (convergent) drainage of the inner basin (basin is marked with rugged line both maps).* ***(1/b):*** *parallel drainage cut thruogh the rim (by headward erosion), there may be occurence of captures.* ***(2):*** *subparallel-dendritic drainage system connect to the basin by headward erosion (and captures) from the northwestern rim of the basin.* ***(3):*** *radial drainage with dendritic tributaries flows from the outer slopes of the eastern rims into river Shrednyaya.* ***(4/a-4/b):*** *4/a has parallel consequent streams, while 4/b is a pinnate-like pattern. They are determined by the outer slopes. Downflow of the impact system is on the northern part of the crater (river Popigai). Red coloured, arcuate streams (map B) shows river segments of the same rivers as the brown map on the left side, but streams were coloured red only by stream directions (arcuate streams), which are now shows the rims. Rugged inner line is the basin, light brown line is the divide (between the black and the coloured river systems).*

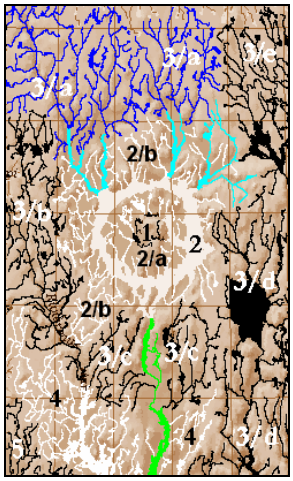

Figure 2. Manicouagan meteorite crater *(Canada, age 214 m. y.* [3]*, d: 100 km,* [3]*, map area: 280×190 km)* ***(1):*** *rivers flow around the central peak (Mount Babel).* ***(2):*** *annular ring (around the inner, impact origin shield* [1] *– René Levasseur isl.) according to selective erosion, filled with water, called Lake Manicouagan.* ***(2/a):*** *radial rivers of the inner, shield-island.* ***(2/b):*** *centripetal rivers flows from the inner walls of the crater into the annular lake. At the western parts of the 2/b area (between 2 and 3/b) the drainages became deranged.* ***(3/a-e):*** *river systems runs around the 2/b areas, but separated with divides from it. 3/a: dendritic pattern; 3/b: deranged; 3/c: radial or nearly parallel; 3/d: dendritic and deranged patterns in connection with a lake (black) southeastern to the crater; 3/e: similar pattern to 3/a, but separated from it by divide (there is only one meeting point).* ***(4):*** *deranged patterns with lakes.* ***(5):***

these river patterns (left corner at the bottom) are similar to 4, but separated from it with divide. According to the deranged patterns, divides in some areas are uncertain or disconnected.

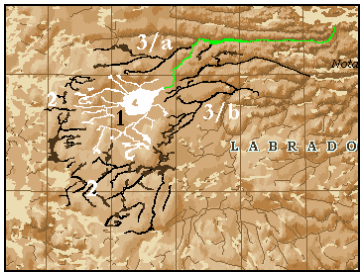

Figure 3. Mistasin meteorite crater *(Canada, age: 36 m. y.* [3], *d: 28 km* [3], *map area: 170×125 km). The shape of the structure is determined by ice* [4-and references therein]*: eastward moving glaciers heavily deformed and eroded the crater. River patterns of the structure.* ***(1):*** *the inner lake (Mistasin) according to eastward ice movements, was elongated in eastern direction. Convergent rivers flowing into the lake shows, that the basin is larger than the lake.* ***(2):*** *deranged pattern of the outer slopes of the western and southern rims. Headwardings and captures are lack.* ***(3/a-3/b):*** *parallel rivers probably determined by the remnants of the rim. Drain river of the crater flows eastward in a preformed valley.*

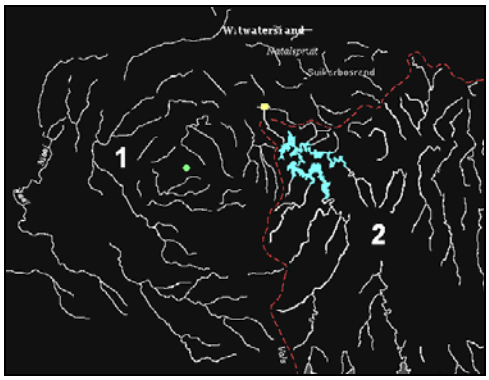

Figure 4. Vredefort impact structure *(South Africa, age 2023 m. y.* [3], *d: 300 km* [3], *map area: 310×220 km): the Vredefort impact structure is interesting, according to its deep erosion* [1]*: what now can be seen is the concentric structure of the basement. The green dot shows the central region of the structure (Vredefort Dome). Drainage patterns:* ***(1)****: Around the dome can be seen the arcuate stream segments of its rivers.* ***(2)****: East from the dome there is a lake (Lake Wilge – blue coloured), which captured about third part of the rivers (divide marked with red rugged line), but even in this region of the Vredefort structure can be recognize the arcuate river segments (this is similar to the process of river-epigenesis), determined by the impact generated, arcuated geological features. Yellow square shows the meeting point of the two river systems.*

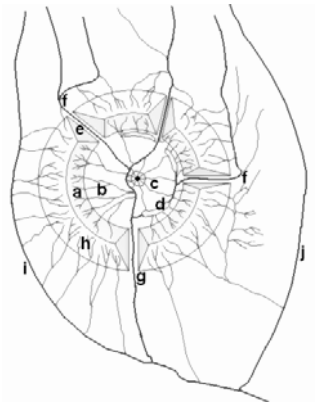

Figure 5. Idealized sketch of possible drainage patterns of meteorite craters with their positions and examples, which is a scheme for fluvial erosion of impact craters. *Keys:* ***a*** *– centripetal-dendritic or convergent streams of the inner slopes of the rim wall (for example: Mistasin, Manicouagan, Popigai).* ***b*** *– centripetal, convergent or parallel steams of the basin (Mistasin, Acraman).* ***c*** *– radial pattern, if there is a central uplift (black point at the center, Manicouagan).* ***d*** *– annular lakes or arcuate stream segments (or both) may occur, where the outward slopes of the central uplift or basin and the inward slopes of the inner rim-walls meets (Siljan, Manicouagan, Charlevoix).* ***e*** *– streams cut through the rim with headward erosion and pirate rivers by capture* ***(f)*** *(Ries, Charlevoix, Popigai, Siljan).* ***g*** *– drain or downflow river of the basin comes of by cut through the rim with headward erosion (Manicouagan, Ries, Popigai, Siljan).* ***h*** *– rivers flow outward the rims can collect by an (sometimes) arcuate river* ***(i)*** *(Popigai).* ***j*** *– rivers with arcuate drainage and weak connections with the crater-influenced rivers (Ries).*

Discussion and Conclusion: These four impact structures (as many others) and the idealized sketch (with the examples) shows, that meteorite craters may have remarkable drainage patterns according to their geological or geomorphological features, even if they were modified during the geological ages. These river patterns (or the circular-annular lakes) can show the arcuate or concentric structures of a given surface. Recognizing these features can be the first steps in the way of finding undiscovered meteorite craters or understanding crater erosion.

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References: [1] Dressler, B. O., Reimold, W. U. (2001) *Earth-Sci. Rev., 56*, 218-219, 227-228. [2] Twidale, C. R. (2004) *Earth-Sci. Rev., 67*, 160-161, 173-188. [3] Spray, J. (PASSC director): Earth Impact Database (EID), website: http://www.unb.ca/passc/ImpactDatabase/index.html
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