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THE SIGNIFICANCE OF GEOETHICS IN PLANETARY PROTECTION AND SPACE RESEARCH

Special introduction

The **Příbram meteorite** fall[a,b] on April 7, **1959** was the first scientifically observed meteorite fall. The associated bolide was captured by the photographic cameras of the double-station meteor observation program initiated and led by the Czech astronomer, **Zdeněk Ceplecha** (born **1929**), who also analyzed all the available data and predicted the location of the meteorites. To date there have been only 9 cases where a meteorite dropping bolide was observed instrumentally, so that the trajectory and the orbit could be determined precisely and – at the same time – the meteorite was recovered. A special conference in Prague in May 2009[c] has been devoted not only to celebrating the anniversaries, but also to offer a forum to discuss recent achievements in this field and future programs.

Application of geoethics

Thanks to various observational programs and modeling efforts the understanding of bolides and associated phenomena (mainly meteorites) has increased dramatically over the past 50 years. This development brings **new juristic and ethical problems**, e.g. in the sphere of scientific integrity, methodological procedures and protecting meteorites for scientific and museistic research. Therefore, ideas of geoethics can be extended to the study of astromaterials and, in general, to planetary protection and to the space research.

Since the foundation of **astrogeology** (alternatively known as planetary geology) by Dr. Eugene M. Shoemaker in 1963, there has been a real scientific and conceptual extrapolation to Space of the classical geological topics (e.g. study of terrestrial analogies), which is marking the objectives and roadmaps of the planetary missions[1,2]. However, geology is an evolving, living discipline, which is interrelated with other areas and fields of knowledge, and the new emerging aspects from its connections also have potential applications to such scenario beyond our planet. This is the case of geoethics.

A first contribution regarding these aspects, linking geoethical issues and meteorites, **and specifically focused on the study of bolides and meteorite falls,** was presented in Prague in May 2009 at the above mentioned international conference. But meteorites are only the first step and the significance of geoethics goes further…

Although various definitions and uses of the term “geoethics” have been proposed, it is important to note that the concept of geoethics was presented for the first time, in 1991, linking ethics and geology, and involving theoretical and practical aspects in a broad sense[3]. At present, space agencies, through the well-established planetary protection requirements[4], are committed to exploring space preventing all types of biological contamination, and preserving the planetary conditions mainly considering biological and bioethical issues[5].

Here, we propose to take into account the significance of the geoethical issues in Planetary and Space Research *"sensu lato",* emphasizing the connotation, advantages and interdisciplinary approach of their original definition, and incorporating them as a fundamental part of planetary geology studies. It should widen the classical concept of Planetary Protection (**including scientific integrity issues**), bearing in mind, besides the organics-bearing perspective, the abiotic nature and all features of the planetary bodies and their planetary geodiversity[6,7].

The following aspects are much more connected with the "abiotic world":

I.- The scientific study of **bolides and meteorites** as well as the **terrestrial areas affected by their impacts or influence** (e.g. impact structures, mineralogical and geochemical anomalies):

A) Regarding meteorite collectors or suppliers:
Geoethical problems are more related with lack of knowledge and clear illegalities.
1.- Illegal trafficking of meteorites.
2.- Intention of hustling and fraudulent manoeuvres, regarding authenticity and/or the source area of the "find".
3.- Spurious interests to artificially increase the chrematistic value of the meteorite specimens to call the attention of Museums or scientific institutions by the false or deceitful indication that "they witnessed a fall event" → fall versus find. (e.g. → to buy a meteorite and alleging that it is a find or fall related with a bolide previously observed).

B) Regarding geoscientists and host institutions:
Problems are more related with mistakes, bad scientific practice or even ethical misconduct.
1.- To give credibility, without unequivocal verification, from scientists, museistic and scientific institutions, to questionable sources of meteorite specimens (mainly in the sense of finds vs. falls) or about any other previously defined aspects (see left column).
2.- Erroneous or intentional confusion between the concepts of meteorite "falls" and "finds" and the terms "bolides" and "meteorites", provoking misunderstanding.
3.- Geoethical issues related with the correct study (scientific integrity) and preservation (geological heritage) of unique geological structures (craters) and other features originated by meteorite impacts.

II.- The scientific study of the **abiotic nature** and all features of the planetary bodies and their **planetary geodiversity (including terrestrial analogs)**:

A) Regarding meteorites (for their own features)
Meteorites are not only crucial pieces of the "Solar System Geodiversity" (they come from the asteroids, Mars and the Moon), but also they built and influenced the Earth systems:
Meteorites are unique samples which:

1) yield clues about the Earth and Solar System formation;
2) played a major role in the geo/bio co-evolution of our planet (large impacts), and
3) which could also be potentially involved in the origin of life, as carriers of water, carbon and other astrobiologically significant compounds.

Therefore, given their unique nature and significance, geoethical issues need to be considered regarding both scientific studies and methodological and analytical protocols.

Specifically regarding meteorites it is important to take into account an old (but significant) UNESCO's Recommendation.

B) Regarding planetary exploration – Planetary Geodiversity and Planetary Protection issues (e.g, Moon, Mars)
It is important to preserve, considering geoethical issues, the planetary environments, and their great variety of geological outcrops (e.g. Martian outcrops of El Capitan (jarosite-hematite) or Cape St. Mary (cross bedding), in a similar way that the concept of Geodiversity is taken into account in our own planet. Geodiversity warrants the status of a geological paradigm, incorporating in its definition all the variety of rocks, minerals and landforms and the processes which have formed these features throughout geological time (Gray, 2003; IUCN, 2008).

Planetary protection is the term given to the practice of protecting solar system bodies (i.e., planets, moons, comets, and asteroids) from contamination by Earth life, and protecting Earth from possible life forms that may be returned from other solar system bodies.
Therefore, in accordance with our proposal, the classical concept of Planetary Protection in space missions **should be extended to include further geological and geoethical requirements** (in addition to the biological and bioethical), in order to prevent: 1) all types of "inorganic contamination" (e.g. hydrazine contamination; neoformation of minerals) and 2) the destruction or alteration of geological outcrops of special interest.

Regarding planetary geodiversity:
Also, Geoethical issues should be taken into account for the development of some extremely interesting and new initiatives related with Planetary Parks

C) Regarding terrestrial analogs
The preservation and appropriate study, following well-defined scientific, methodological and geoethical protocols, of some selected terrestrial analogs (e.g Rio Tinto and Jaroso areas, Spain) is crucial for the unambiguous definition of bio and geomarkers which can be used in planetary missions.

III.- Other potential museistic, geoconservation (**and even cultural**) issues regarding legal regulation and procedural protocols related with extraterrestrial materials (e.g. meteorites, Lunar samples):
The scientific singularity and/or historical significance of some meteorites and extraterrestrial samples may also require an special protocol and museistic treatment for their correct preservation and exhibition in which cultural aspects are also extremely important.

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