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Something more than boulders: A geological comment on the nomenclature of megaclasts on extraterrestrial bodies

Delia E. Bruno[a], Dmitry A. Ruban[b,c,*]

[a] Water Research Institute, National Research Council (CNR-IRSA), Via F. De Blasio 5, 70125 Bari, Italy
[b] Southern Federal University, 23-ja linija Street 43, Rostov-na-Donu 344019, Russia
[c] P.O. Box 7333, Rostov-na-Donu 344056, Russia

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ABSTRACT

Large clasts are common on extraterrestrial bodies, and these are traditionally termed “blocks” and “boulders”. These two terms can easily raise confusion, however, because they are used in a sense that differs from geological definitions. Several classifications of large clasts are currently in use in the Earth sciences, and they differ only in detail. They restrict the size of boulders to 1–4 m; larger particles are called "megaclasts". The analysis of the published information on large clasts on planet satellites, asteroids, and comets imply that the particles often described as "boulders" actually are megaclasts; boulders, as the term is used in the Earth sciences, are too small to be detected given the limited resolution of most images obtained. It were therefore scientifically preferable if the established geological literature were applied in the modern planetary and space research. It appears sensible to distinguish boulders from megaclasts; the latter comprise bodies that might be subdivided granulometrically into blocks, megablocks, and superblocks. It is also shown that the abundance of megaclasts on extraterrestrial bodies may itself be beneficial for our understanding of such particles, which are rare on Earth.

1. Introduction

Outstanding achievements in the exploration of the Solar System have been recorded since the Sumerian and Assiro-Babylonian cultures, about 2000 years ago, when the cosmic objects were studied for early civilizations needs. Talete of Mileto (624 a.C.), a Greek philosopher, was the first whose whose intuitions led to astronomical hypotheses. Further, observations and then investigations led to major discoveries in the Universe. However, modern planetary and space research employs a lot of knowledge obtained from the Earth.

During the past decades, the development of what can be termed provisionally "planetary geology" (Tanaka and Hartmann, 2012; de Pater and Lissauer, 2015) increased our insight into the age, morphology and structure of extraterrestrial bodies. Some analogies with the Earth have been noted, above all for the nearest planets, their satellites, and some asteroids. It is well demonstrated that the approaches used for geological investigations on Earth can be applied with equal success in studies of other cosmic bodies. A typical example can be found in the work of Pondrelli et al. (2008), who recognized deltaic facies in the Eberswalde crater on Mars. It is worth to add that morphological evidence of fluvial and fluvial-like landforms have been recorded on the surfaces of the inner planets and on some of their satellites (Baker et al., 2015) and also crater size, debris flows, and gullies have been studied in detail (Krishna and Kumar, 2016).

Considering that much of this research has dealt with morphological and structural features, the widespread distribution of large clasts (called "blocks" and "boulders") on extraterrestrial bodies has received close attention (e.g., Lee et al., 1986; Michikami et al., 2008). These large clasts have evident analogues on the Earth's surface (Fig. 1). Recently, the successful *Rosetta* mission to comet 67P/Churyumov-Gerasimenko and its flyby asteroid 21 Lutetia has obtained evidence that has increased the interest in both the morphology of these bodies and their "sedimentary cover" (Küppers et al., 2012; Auger et al., 2015; Pajola et al., 2015). Such research requires the use of proper terminology for description of the different clasts constituting this cover.

With regard to the success of extraterrestrial geology (exogeology), it is logical to consider the suitability of the Earth-based clastic rock nomenclature for extraterrestrial bodies. This option has been expressed already, particularly, by the developers of one classification (Blair and McPherson, 1999) and was practically employed by Miyamoto et al. (2007). However, it is evident that these and other classifications are not used widely in the modern planetary and space research. The main objective of the present paper is to discuss the terminology that should be applied to large clasts defined provisionally

* Corresponding author at: Southern Federal University, 23-ja linija Street 43, Rostov-na-Donu 344019, Russia.
E-mail addresses: delia.bruno@ba.irsa.cnr.it (D.E. Bruno), ruban-d@mail.ru (D.A. Ruban).

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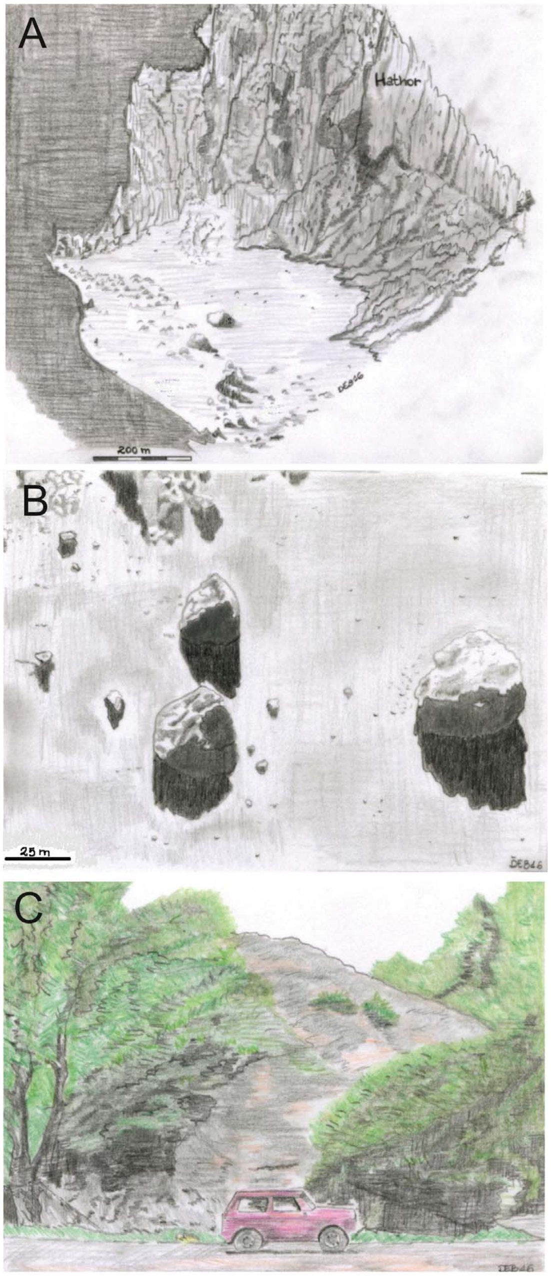

Fig. 1. Examples of extraterrestrial and terrestrial "large clasts" (artist representation by D.E.B.). 67P/Churyumov-Gerasimenko comet: A – the famous view of "large clasts" at the foot of the Hathor cliff (based on Fig. 11a from Pajola et al. (2015)), B – mass wasting in the Imhotep region (based on Fig. 15a from Auger et al. (2015)). Earth: C – the so-called "Maiden's Stone" in the Caucasus (based on Fig. 5b from Lubova et al. (2013)).

as block and boulders on extraterrestrial bodies in the light of the Earth-based nomenclature.

2. Theory: megaclast classifications

Clastic sedimentary rocks are widespread in the geological record of the Earth. The development of their classification was critical to the development of sedimentology as an individual discipline. The Udden-Wentworth grain-size classification, proposed more than a century ago (Udden, 1898; Wentworth, 1922), is still widely used and accepted (e.g.,Boggs, 2006; Nichols, 2009; Tucker, 2011). According to this scheme, all clasts (particles) larger than 256 mm (~0.25 m) in size are boulders (cf.Dutro et al., 1989). Other classifications used in sedimentological, soil, and geotechnical research place the lower size of boulders in the 60–200 mm range (UIFPA, 1961). In the planetary and spaces sciences, boulders are understood as apparently intact rocks or rock fragments lying on a surface, regardless of emplacement mechanisms (e.g., Krishna and Kumar, 2016). However, such a simple definition is less useful for geologists, especially those dealing with tsunami- and storm-formed deposits where clasts measured by meters and even dozens of meters are common. As a result, several classification systems emphasizing these larger clasts have been proposed since the end-1990s. These classifications can be divided into two "branches". The majority of the systems have arisen from the Udden-Wentworth classification. The alternative point of view is rooted in the ideas of the Russian school of sedimentology (Logvinenko, 1980; Shvanov, 1998). This alternative view is based on different scaling of clast size. For instance, sand particles are 0.1–1 mm in size, not 0.0625–2.0 mm as in the case of the Udden-Wentworth classification.

The Udden-Wentworth scheme's derivatives differ. The most famous of them was developed by Blair and McPherson (1999), who limited the biggest size of boulders to 4 m and proposed four new classes for larger clasts (Table 1). Their classification provides exact names for clasts as large as 100 km in diameter (see also Blair and McPherson (2009)). Blott and Pye (2012)proposed another classification system for large clasts. Their system limited the biggest size of boulders by 2 m and defined all larger clasts as megaclasts (Table 1). Terry and Goff (2014) adopted new names for the same size classes, proposed initially by Blair and McPherson (1999). The term "megaclast" was reserved for all clasts larger than 4 m (Table 1). A comparison of these schemes (Table 1) shows clear differences, but it also shows that the only smallest large clasts are defined as boulders.

Ruban et al. (2013), see also Lubova et al. (2013), Ruban (2015) extended the traditional Russian classification. They limited boulders to 0.1–1.0 m, called larger clasts "megaclasts", and subdivided megaclasts into blocks and megablocks (Table 1). This classification system is essentially similar to the proposals of Blair and McPherson (1999), Blott and Pye (2012), and Terry and Goff (2014), viz. in that it restricts the size of boulders and includes megaclasts.

Generally, large clasts can be effectively classified with the available

Table 1
Different classifications of large clasts (grades, i.e., subdivision of classes, are not considered because these appear to be less important for planetary and space science).

Based on the Udden-Wentworth classification principles							Based on the traditions of Russian sedimentology		
Blair and McPherson (1999)		Blott and Pye (2012)		Terry and Goff (2014)			Ruban et al. (2013)[*,**]		
Class of clasts	Size (m)	Class of clasts	Size (m)	Class of clasts		Size (m)	Class of clasts		Size (m)
megalith	33600–107500	megaclast	> 2.048	megaclast	macrolith	33600–107500	megaclast	megablock	> 10
monolith	1048.6–33600				mesolith	1048.6–33600			
slab (megablock[***])	65.5–1048.6				macroboulder	65.5–1048.6		block	1–10
block	4.096–65.5				mesoboulder	4.096–65.5			
boulder	0.256–4.096	boulder	0.064–2.048	boulder		0.256–4.096	boulder		0.1–1

[*] this classification offers both the Russian and the English terminology.
[**] see also discussions in Lubova et al. (2013) and Ruban (2015).
[***] as updated by Blair and McPherson (2009).