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Meteorite and meteoroid: New comprehensive definitions

Alan E. RUBIN[1*] and Jeffrey N. GROSSMAN[2]

[1]Institute of Geophysics and Planetary Physics, University of California, Los Angeles, California 90095–1567, USA
[2]U.S. Geological Survey, 954 National Center, Reston, Virginia 20192, USA
*Corresponding author. E-mail: aerubin@ucla.edu

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Abstract–Meteorites have traditionally been defined as solid objects that have fallen to Earth from space. This definition, however, is no longer adequate. In recent decades, man-made objects have fallen to Earth from space, meteorites have been identified on the Moon and Mars, and small interplanetary objects have impacted orbiting spacecraft. Taking these facts and other potential complications into consideration, we offer new comprehensive definitions of the terms "meteorite," "meteoroid," and their smaller counterparts: A *meteoroid* is a 10-μm to 1-m-size natural solid object moving in interplanetary space. A *micrometeoroid* is a meteoroid 10 μm to 2 mm in size. A *meteorite* is a natural, solid object larger than 10 μm in size, derived from a celestial body, that was transported by natural means from the body on which it formed to a region outside the dominant gravitational influence of that body and that later collided with a natural or artificial body larger than itself (even if it is the same body from which it was launched). Weathering and other secondary processes do not affect an object's status as a meteorite as long as something recognizable remains of its original minerals or structure. An object loses its status as a meteorite if it is incorporated into a larger rock that becomes a meteorite itself. A *micrometeorite* is a meteorite between 10 μm and 2 mm in size.

Meteorite–"a solid substance or body falling from the high regions of the atmosphere" (Craig 1849); "[a] mass of stone and iron that ha[s] been directly observed to have fallen down to the Earth's surface" (translated from Cohen 1894); "[a] solid bod[y] which came to the earth from space" (Farrington 1915); "A mass of solid matter, too small to be considered an asteroid; either traveling through space as an unattached unit, or having landed on the earth and still retaining its identity" (Nininger 1933); "[a meteoroid] which has reached the surface of the Earth without being vaporized" (1958 International Astronomical Union (IAU) definition, quoted by Millman 1961); "a solid body which has arrived on the Earth from outer space" (Mason 1962); "[a] solid bod[y] which reach[es] the Earth (or the Moon, Mars, etc.) from interplanetary space and [is] large enough to survive passage through the Earth's (or Mars', etc.) atmosphere" (Gomes and Keil 1980); "[a meteoroid] that survive[s] passage through the atmosphere and fall[s] to earth" (Burke 1986); "a recovered fragment of a meteoroid that has survived transit through the earth's atmosphere" (McSween 1987); "[a] solid bod[y] of extraterrestrial material that penetrate[s] the atmosphere and reach[es] the Earth's surface" (Krot et al. 2003).

INTRODUCTION

Since Chladni (1794) published *On the Origin of the Pallas Iron and Others Similar to it, and on Some Associated Natural Phenomena* and made plausible the hypothesis that rocks could fall from the sky, the definition of the word *meteorite* has remained essentially unchanged, as reflected in the ten quotations given above. Nearly all modern reference works use a similar definition. Meteorites are almost always defined to be solid bodies that have fallen through the Earth's atmosphere and landed on the Earth's surface.

Nineteenth-century definitions tend to leave open the origin of the falling material, whereas later definitions specify that the material came from space.

Many recent definitions of *meteorite*, including the one adopted by the International Astronomical Union (IAU), specify that meteorites originated as meteoroids. The latter term was defined by the IAU as "a solid object moving in interplanetary space, of a size considerably smaller than an asteroid and considerably larger than an atom or molecule" (Millman 1961). Beech and Steel (1995) suggested modifying this definition to include only natural objects in the size range 100 μm to 10 m. Because modern usage frequently ties these two terms together, with meteoroids forming the pre-impact precursors of meteorites, it is imperative that the definitions be consistent.

With the advent of the Space Age and the discovery of new sources of extraterrestrial material, it is clear that most existing definitions of the term *meteorite* are too restrictive. Indeed, there are already three objects recognized by the Meteoritical Society's Committee on Meteorite Nomenclature (NomCom) that violate most traditional definitions of *meteorite* (with the exception of the one given in Gomes and Keil 1980) because they were not found on Earth's surface. Two millimeter-size chondrites discovered among samples returned from the Moon during the Apollo missions have been described and named as meteorites: Bench Crater (McSween 1976; Zolensky et al. 1996) and Hadley Rille (Haggerty 1972; Grossman 1997; Rubin 1997). A IAB-complex iron identified on the surface of Mars by the Opportunity rover was recently given a formal meteorite name: Meridiani Planum (Connolly et al. 2006; Schröder et al. 2008). The existence of these objects, combined with other probable meteorites from the Moon and Mars that have not yet been formally named (as well as other conceivable examples), has led us to re-examine the term *meteorite* and the related term *meteoroid* in a search for precise, comprehensive definitions.

The NomCom is responsible for approving a unique name for every properly described meteorite. Meteorites are traditionally named for a geographic feature in the vicinity of the place where they were found. Thus, any change in the definition of *meteorite* will have practical consequences for how they are named.

PROBLEMS WITH THE DEFINITIONS OF *METEORITE* AND *METEOROID*

Where Do Meteorites Occur?

Meteorites are Not Restricted to Earth

The discoveries of the Bench Crater carbonaceous chondrite and Hadley Rille enstatite chondrite among returned lunar samples and the identification of the Meridiani Planum iron on Mars demonstrate that foreign objects, analogous to meteorites found on Earth, can arrive intact on the surfaces of other planetary bodies. The literature designations of these objects as meteorites have been widely accepted in the meteorite research community. The two meteorites found on the Moon were not derived from objects that produced meteors, a phenomenon that requires the presence of an atmosphere.[1] Although the words *meteor* and *meteorite* share a common Greek root meaning "high in the air," there is no reason to link these terms in a modern definition by requiring meteorites to have produced meteors during an atmospheric transit.

If the chondrites found on the Moon or irons found on Mars are considered meteorites, then it is reasonable that a comprehensive definition of *meteorite* would allow for their presence on other planets as well as airless bodies such as asteroids and comets, or the natural satellites of any of these bodies. Thus, the first refinement needed for a comprehensive definition of *meteorite* is:

> Meteorites can occur on any celestial body, not just Earth.

Meteoroids may Hit Spacecraft and Other Artificial Targets

Another difficult situation arises when considering projectiles that strike a spacecraft. For example, publications reporting on the Long Duration Exposure Facility (LDEF), which was exposed to interplanetary space in low Earth orbit for 5.75 years, generally used the term *meteoroid* (not *meteorite*) to describe both the small impactors and the resulting particulate debris that was collected (e.g., Clark 1984). However, as pointed out by Beech and Youngblood (1994), according to existing definitions, meteoroids are defined as objects moving in interplanetary space and meteorites are defined as objects that have reached Earth. Neither definition seems to apply to material that has struck a spacecraft: that material is no longer in interplanetary space as an independent body, nor has it reached Earth or any other celestial body. One could quibble over whether a platform in orbit around the Earth is simply an extension of Earth's surface, but it is also easy to imagine a situation where an object hits a spacecraft in orbit around the Sun or traveling with sufficient velocity to escape the solar system altogether. Beech and Youngblood (1994) indicated that either a new

[1]Following common usage, we define meteor as the light phenomenon produced by the passage of an object through an atmosphere that heats the surrounding gas to incandescence.

definition is needed for the term *meteorite* or a new term needs to be created to cover material that hits a spacecraft.

The essential characteristic of a meteorite is that it represents material that comes from one place and survives an accretionary impact someplace else. In addition, the essential characteristic of a meteoroid is its independent existence as a solid object in interplanetary space. The most straightforward way to retain these characteristics is to allow the definition of *meteorite* to cover material that accretes to man-made objects. Returning to the LDEF example, we would prefer to say that *meteoroids* impacted the facility and that some of this material survived as small *meteorites*, which further refines the definition:

> Meteorites can arrive on man-made objects or other artifacts.

We note that this revision to the definition of *meteorite* also covers other situations that could be considered gray areas, where an object never actually hits the Earth's surface. This potentially includes impacts into cars, airplanes, boats, buildings, and other man-made structures. (Such impactors have recently been termed "hammers" by meteorite dealers and collectors.) Non-man-made structures (e.g., beaver dams, termite mounds, bird bowers) and even alien spacecraft would also be covered by this revision.

The Problem of Meteorites within Meteorites (within Meteorites…)

Foreign clasts found in ordinary-chondrite regolith breccias and howardites almost certainly originated as projectiles that collided with the parent asteroids of their hosts. Prominent examples include H-chondrite clasts in the LL chondrite, St. Mesmin (Dodd 1974), an LL5 clast in the H chondrite, Dimmitt (Rubin et al. 1983), and CM clasts in the Kapoeta howardite (e.g., Zolensky et al. 1996). Although we know of no precedent for using the term *meteorite* to describe individual foreign clasts inside chondrite and achondrite breccias, it seems clear that some of these clasts could once have been properly called "asteroidal meteorites."[2] However, we *do not* recommend using this term for describing xenoliths in specimens from individual meteorites. Complex breccias such as the Kaidun meteorite are known in which the bulk of the specimen is composed of millimeter-size clasts of diverse asteroidal and, conceivably, planetary origins (Zolensky and Ivanov 2003). In Kaidun and other meteorite breccias, the clasts themselves may be breccias containing material derived from diverse sources. Brecciation is common among chondrites and achondrites and it is not always easy to determine which clasts may be locally derived and which may be foreign (i.e., meteoritic) (Scott et al. 1985). These facts would make it difficult to decide which clasts are worthy of the name *meteorite*. There would also be a nightmare of nomenclature if one tried to give each potential meteorite in a complex, polymict breccia a unique name.

Consequently, we recommend that the term *meteorite* be reserved for objects that have experienced an accretion event, not for any of the constituents or clasts within those objects. In other words, an object should lose its nomenclatural status as a meteorite when it and the material into which it has been incorporated together become a projectile and accrete as a meteorite to another body. For example, the CM chondritic clasts in the Kapoeta achondrite should not be considered meteorites because they occur within a meteorite that hit the Earth. However, if a spacecraft were to go to asteroid 4 Vesta (if that is, in fact, the parent body of HED achondrites like Kapoeta) and collect CM chondrite fragments from the regolith, these could be considered asteroidal meteorites. Although samples returned from a future mission to the Kaidun breccia's parent body would pose the same issues of classification and nomenclature that were described above, the situation would be analogous to samples recovered from the Moon; each foreign projectile fragment would deserve to be called a meteorite. We leave this as a nomenclature problem for the future.

Another refinement needed for a comprehensive definition of *meteorite* is therefore:

> Clasts within meteorites should not be called meteorites.

The Nature of Meteoritic Material

Existing definitions vary in their descriptions of what types of material meteorites represent. Three terms used commonly in literature definitions to define meteoritic material are *solids*, *extraterrestrial materials*, and *meteoroids*.

Most definitions of *meteorite* state that the material must be a solid or a meteoroid, which are equivalent if one uses the simple IAU definition of *meteoroid* as "a solid object moving in interplanetary space." The word

[2]Wide-spread use mandates that the terms lunar meteorites and martian meteorites be reserved for meteorites derived from the Moon and Mars, respectively, not from meteorites found on the Moon or Mars. Similarly, the terms *mercurian meteorites*, *venusian (or venerian) meteorites* and *terrestrial (or terran) meteorites* would designate rocks from Mercury, Venus and the Earth that became meteorites. In this case, the term asteroidal meteorite indicates that the CM clasts originated on another asteroid.

solid, if unaccompanied by a modifier, is problematic because it allows for the existence of man-made meteorites. Once Sputnik 1 was launched on October 4, 1957, it became inevitable that man-made solid objects would one day fall to Earth. Two spectacular examples of this were the debris from the U.S. Skylab space station, which fell across the southeastern Indian Ocean on July 11, 1979, and the nuclear reactor of the Soviet Cosmos-1402 satellite, which fell in the South Atlantic Ocean on February 7, 1983. Most researchers and collectors would probably not accept surviving fragments of these artificial satellites as genuine meteorites. Thus, the word *solid* is not sufficient to define what kinds of materials can be meteorites, nor is the word *meteoroid* as defined by the IAU.

The Krot et al. (2003) definition of *meteorite* specifies that the material must have an extraterrestrial origin. Although this succeeds in limiting meteorites to non-anthropogenic material, it is too restrictive. First of all, it allows the rather unlikely, but conceivable, situation where a crashed alien spacecraft would be considered a meteorite. (In the novel *The war of the worlds* [Wells 1898], the crash-landed Martian spacecraft were first thought to be meteorites.) More importantly, however, there is a plausible situation in which the word *extraterrestrial* clearly fails as part of a comprehensive definition. This concerns the potential existence of terrestrial (or terran) meteorites. High-energy impacts on the Earth could propel some ejecta to velocities greater than that necessary for escape. If such a rock were to land on the Moon, for example, it should properly be considered a terrestrial meteorite (e.g., Armstrong et al. 2002; Crawford et al. 2008). Because of this possibility, meteorites cannot be limited to extraterrestrial material.

It follows that the definition of *meteorite* must include only natural materials, including (but not necessarily limited to) silicate and non-silicate minerals, mineraloids, organic matter, amorphous material, metal and ice, without regard to whether this material is asteroidal, planetary, cometary, derived from a natural satellite, or originating outside the solar system. Use of the term *meteoroid* in the sense of Beech and Steel (1995) to describe the precursors of meteorites is acceptable because these workers restricted the definition of *meteoroid* to include only natural solid objects. Beech and Steel discussed the possibility that objects termed *meteoroids* could be derived from comets as well as asteroids; meteoroids simply represent the collection of objects too small to be easily detected from Earth. We would extend their discussion to acknowledge the possibility that meteoroids could be derived from any of the natural bodies of the solar system, and that some could conceivably be from natural bodies originating outside our solar system. This usage bars artificial objects from being called meteorites and allows for the possible existence of terrestrial meteorites on other astronomical bodies. Thus, the revised definition of *meteorite* should have the constraint:

> Meteorites are natural solid objects that spent time in interplanetary space.

The Transport of Meteorites

One potential situation that could complicate our definition of *meteorite* is one in which ‘‘meteorites’’ might be created intentionally. In the novel, *The Moon is a harsh mistress* (Heinlein 1966), revolutionary ‘‘loonies’’ use an electronic catapult to hurl moon rocks at Earth. It is also conceivable that astronauts traveling back home from Mars with a collection of martian rocks could jettison a large boulder from their spacecraft along a trajectory that would cause it to fall to Earth. Interesting as it might be to examine the fusion crust of such a rock or prized as the boulder's remnants might be to collectors, these materials would probably be regarded by researchers as artificial meteorites, not the genuine article. This thought experiment suggests another restriction in a new comprehensive definition of *meteorite*:

> Meteorites must be transported by natural means.

There are a number of conceivable, natural transport processes that can lead to the formation of natural solid objects in interplanetary space, and ultimately to meteorites. Meteorite precursor objects may be primary bodies that were never part of larger objects and thus were never launched from a larger body. Alternatively, they may have been ejected from larger parent bodies by collisions, or been derived from landslides on low-gravity bodies or by shedding of material from the equator of a rapidly spinning object.

The Sizes of Meteorites and Meteoroids

Meteoroids in interplanetary space and meteorites found on Earth and other bodies span a wide size range. The IAU definition of *meteoroid* vaguely limits these objects to those smaller than asteroids but larger than atoms or molecules. Beech and Steel (1995) suggested modifying this definition to include only objects in the range 100 μm to 10 m. Their logic was that objects smaller than 100 μm were unlikely to produce meteors during atmospheric passage and should be considered dust, whereas 10 m was close to the minimum size of astronomically detectable objects that could be called asteroids.

However, object 2008 TC_3, which dropped fragments of the anomalous ureilite Almahata Sitta in northern Sudan on October 7, 2008, was considered to be an asteroid (Jenniskens et al. 2009) despite the fact that its diameter was 4.1 ± 0.3 m. The term *micrometeoroid* has also been used for decades (e.g., Shapiro 1963); Love and Brownlee (1991) applied it to meteoroids in the size range of 10 μm to 1 mm, although in practice the term is most often applied to objects smaller than approximately 100 μm. These size ranges need to be modified.

Similar terms are used to describe meteoritic material in different size ranges. The largest known meteorite is the 60 metric-ton Hoba iron, which has dimensions of approximately 3 × 3 × 1 m (Grady 2000). The smallest object named as a meteorite by the NomCom is Yamato 8333; this weighs 12 mg (Yanai and Kojima 1995) and corresponds to a particle diameter of approximately 2 mm. There are several unclassified objects in the Yamato collection that are even smaller. The term *micrometeorites* has been applied to tiny meteorites that have been found on Earth; these are typically smaller than 500 μm in diameter (e.g., Engrand and Maurette 1998), but recent collections in Antarctica have produced micrometeorites as large as 2 mm in diameter (Rochette et al. 2008). Very small particles of meteoritic material, frequently ≤1 μm, are usually called *cosmic dust* or *interplanetary dust particles* (IDPs). Micrometeorites and particles of dust can be quite numerous in many terrestrial collections and are therefore not individually named by the NomCom.

Thus, a similar portfolio of terms is used to describe both meteorites and meteoroids. *Interplanetary dust* is used to describe tiny particles, regardless of whether they have accreted to a larger body or still exist as independent particles in space. The prefix *micro*- is applied to objects coarser than dust but below approximately 0.1–1 mm in size. The unmodified words *meteorites* and *meteoroids* are used to describe objects up to several meters in diameter. These terms are useful and suggest that the same size ranges should be used whether one is referring to objects in interplanetary space or objects that have accreted as meteorites. But what size ranges are the most appropriate for both meteorites and meteoroids?

For the purposes of this paper, we define the upper limit of particle size that should be considered dust as 10 μm, following Love and Brownlee (1991). Beech and Steel (1995) chose 100 μm as the upper limit on micrometeorite and micrometeoroid size because, as stated above, particles smaller that this were considered unlikely to cause a meteor during passage through the Earth's atmosphere. We reject this value for several reasons. We have already argued that meteorites can accrete to airless bodies, which suggests that there is no reason to limit meteorites to objects that once produced a meteor. Moreover, because meteorites can fall through atmospheres around other celestial bodies (e.g., Mars, Venus, Titan), the size of the smallest accreting meteoroids that cause meteors will probably vary with atmospheric density and composition and the celestial body's escape velocity.

There are more practical reasons that can be used to select the best upper size cutoff for micrometeorites and micrometeoroids. Meteorites have long been recognized as rare, special kinds of rocks. The practice of naming individual meteorites after the places where they were found is based on this special status. Generally, to receive a name, a meteorite must be well classified and large enough to provide material for curation and research. Much of the material that forms meteorites in the inner solar system is relatively coarse grained. Many chondrites and nearly all achondrites and iron-rich meteorites have mineral grain sizes that exceed 100 μm. Although in many cases it is possible to classify small particles of meteoritic material at least tentatively, this process is greatly hindered when the particle size is significantly smaller than the parental rock's grain size. To allow for proper classification, 2 mm is a more useful size cutoff than 100 μm. In addition, the number of objects that accrete to the Earth (and other bodies) varies exponentially with the inverse of mass (e.g., Brown 1960, 1961; Huss 1990; Bland et al. 1996). Single expeditions to recover micrometeorites have found thousands of particles in the sub-millimeter size range (Rochette et al. 2008), but very few that exceed 2 mm. The 2 mm divide also seems to form an approximate break between the smallest objects that have historically been called meteorites and the largest objects called micrometeorites. This leads to additional refinements to our definitions:

> Micrometeorites are meteorites smaller than 2 mm in diameter; micrometeoroids are meteoroids smaller than 2 mm in diameter; objects smaller than 10 μm are dust particles.

By this definition, IDPs are particles smaller than 10 μm. We are not proposing a lower size limit for IDPs.

Before it impacted the Earth, object 2008 TC_3 was approximately 4 m across and was officially classified as an asteroid (Jenniskens et al. 2009). It is likely that when smaller interplanetary objects are observed telescopically, they will also be called asteroids, even if they are of sub-meter size. Thus, the boundary between meteoroids and asteroids is soft and will only shrink with improved observational capabilities. For the purposes of the present paper, we adopt 1 m as the minimum asteroid size. We thus differ from Beech and Steel (1995) who suggested a 10 m cutoff between meteoroids and asteroids.

The Relationship between Meteorites and Meteoroids

It is tempting to include in our definition of *meteorite* a statement that meteorites originate as meteoroids, which, using our modified definition are *natural solid objects moving in space, with a size less that 1 m, but larger than 10 μm*; this was done in previous definitions such as that of McSween (1987). However, because the Hoba iron meteorite is larger than 1 m across, it represents a fragment of an asteroid, not a meteoroid, under our definition of *meteoroid*. If a mass of iron 12 m in diameter deriving from an asteroidal core were to be found on Earth or another celestial body, it would almost certainly be called a meteorite, despite the fact that it was too large to have originated as a meteoroid even under the Beech and Steel (1995) definition. In addition, the Canyon Diablo iron meteorites associated with the Barringer (Meteor) Crater in Arizona, are fragments of an impacting asteroid that was several tens of meters in diameter (e.g., Roddy et al. 1980); the Morokweng chondrite may be a fragment of a kilometer-size asteroid that created the >70 km Morokweng crater in South Africa (Maier et al. 2006).

Comets, particularly Jupiter-family comets (JFCs), could also produce meteorites. A small fraction of JFCs evolve into near-Earth objects (Levison and Duncan 1997) and could impact main-belt asteroids at relatively low velocities (approximately 5 km s^{-1}) (Campins and Swindle 1998). Meteorites could also be derived from moons around planetary bodies. Lunar meteorites are well known on Earth, and meteorites derived from Phobos may impact Mars, especially after the orbit of Phobos decays sufficiently (e.g., Bills et al. 2005).

We see no simple way out of this semantic dilemma, so we add the refinement:

> Meteorites are created by the impacts of meteoroids or larger natural bodies.

Additional Complications

Fragments of Meteorites

Meteorite showers result from the fragmentation of a meteoroid (or larger body) in the atmosphere. In the case of the L6 chondrite Holbrook, about 14,000 individual stones fell (Grady 2000). Each of these stones is considered a meteorite, paired with the others that fell at the same time. A meteorite can break apart when it collides with the surface of a body or it can fragment at a later time due to mechanical and chemical weathering. Each fragment of a meteorite is itself considered a meteorite, paired with the other objects that fell during the same event.

Degraded Meteorites

Weathering and other secondary processes on the body to which a meteorite accretes can greatly alter meteoritic material. Chondritic material has been found embedded in terrestrial sedimentary rocks in Sweden (e.g., Thorslund and Wickman 1981; Schmitz et al. 2001). Other than the minor phase chromite (and tiny inclusions within chromite), the primary minerals in these extraterrestrial objects have been replaced by secondary phases. Despite this extensive alteration, some of these rocks (e.g., Brunflo) contain well-preserved chondrule pseudomorphs. Iron meteorites can be severely weathered at the Earth's surface, forming a substance known as *meteorite shale* (Leonard 1951) in which the original metal has been completely oxidized; nevertheless, this material can still preserve remnants of a Widmanstätten structure. The NomCom considers these types of materials to be *relict meteorites*, defined as "highly altered materials that may have a meteoritic origin. . .which are dominantly ($>95\%$) composed of secondary minerals formed on the body on which the object was found" (Meteoritical Society, 2006). Many relict meteorites have received formal meteorite names in recent years. We support the use of this terminology and would further revise our definition as follows:

> An object is a meteorite as long as there is something recognizable remaining either of the original minerals or the original structure.

We assert that objects that are completely melted during atmospheric transit or weathered to the point of complete destruction of all minerals and structures should not be called meteorites. This would include cosmic spherules (reviewed by Taylor and Brownlee 1991), ice meteorites that melted, and bits of what appear to be separated fusion crust from larger meteorites (eight of which have received formal meteorite names from the NomCom as relict meteorites, incorrectly in our opinion). A report of possibly meteoritic material in sediments near the Cretaceous/Tertiary boundary (Kyte 1998) presents a borderline case. No primary minerals remain in this object although the textures of secondary minerals are suggestive of some kind of primary chondritic structure.

Meteorites accreted by their own parent body

We now consider whether it is possible for an object to become a meteorite on the same celestial body from which it was derived. For example, if ejecta from a terrestrial impact crater lands back on Earth, can it be considered a meteorite? Tektites are widely held to be glass objects produced by large impacts on Earth. Australite buttons were launched on sub-orbital ballistic trajectories from their parent crater and quenched into glass; they were partly remelted on the way down when they encountered denser portions of the atmosphere (e.g., Taylor 1961 and references therein). Most researchers would likely agree that these objects should not be considered meteorites. However, if terrestrial ejecta reached the Moon, we have argued that it should be considered a terrestrial meteorite. The critical difference is that the hypothetical material in the latter case escaped the dominant gravitational influence of Earth, whereas tektites did not.

Material launched from a celestial body that achieves an independent orbit around the Sun or some other celestial body, and which eventually is re-accreted by the original body, should be considered a meteorite. The difficulty, of course, would be in proving that this had happened, but a terrestrial rock that had been exposed to cosmic rays and had a well-developed fusion crust should be considered a possible terrestrial meteorite. In a related context, Gladman and Coffey (2009) calculated that large fractions of material ejected from Mercury by impacts achieve independent orbits around the Sun and are re-accreted by Mercury only after several million years. Any of this material that survived re-accretion could be considered a meteorite.

The next refinement of the definition of *meteorite* is then:

> An object that lands on its own parent body is a meteorite if it previously escaped the dominant gravitational influence of that body.

Relative sizes

As a final clarification, we suggest that:

> An object should be considered a meteorite only if it accretes to a body larger than itself.

REVISED DEFINITIONS OF *METEORITE* AND *METEOROID*

From the discussion above, new definitions of *meteorite* and *meteoroid* are proposed:

Meteoroid: A 10 μm to 1-meter-size natural solid object moving in interplanetary space. Meteoroids may be primary objects or derived by the fragmentation of larger celestial bodies, not limited to asteroids.

Micrometeoroid: A meteoroid between 10 μm and 2 mm in size.

Meteorite: A natural solid object larger than 10 μm in size, derived from a celestial body, that was transported by natural means from the body on which it formed to a region outside the dominant gravitational influence of that body, and that later collided with a natural or artificial body larger than itself (even if it is the same body from which it was launched). Weathering processes do not affect an object's status as a meteorite as long as something recognizable remains of its original minerals or structure. An object loses its status as a meteorite if it is incorporated into a larger rock that becomes a meteorite itself.

Micrometeorite: A meteorite between 10 μm and 2 mm in size.

Interplanetary dust particle (IDP): A particle smaller than 10 μm in size moving in interplanetary space. If such particles subsequently accrete to larger natural or artificial bodies, they are still called IDPs.

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