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Origin of cratering features on meteorites surface

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ABSTRACT

Cratering features are observed on the surface of planetary bodies and on their moon's surface, small size cratering features are observed on the surface of moons, asteroids, meteoroids and meteorites. To investigate in detail the formation or the cause or origin of small size cratering features on the surface of meteorites, five iron meteorites namely Sikhote Alline – 1 No., Campo-del-cielo – 2 No., unknown iron meteorites – 3 Nos and a stony meteorite Chelyabinsk were undertaken with respect to earth rocks. From the studies conducted, it is concluded that the cratering features observed on meteorites are from the time our present solar system came into existence, it may either be pre solar dust, present solar dust or possibility of heavy bombardment by fragments of super nova explosion. This paper reports or documents a detail study to search the cause or origin of small size cratering features on meteorite surface, which is one of the most important characteristic features in recognizing a meteorite from a terrestrial rock.

Keywords—*Meteorites, Meteoroids, Asteroids, Cratering features, Small size craters*

1. INTRODUCTION

Meteorites are supposed to be the oldest remnants of our solar system. It is not known whether they are the remnants of earlier solar system or present solar system. They have been studied from the ancient times and were worshipped as gods. In some temples they have been kept as deities and worshipped. Some materials have been made and kept as weapons for protection against enemies which were held only by kings. Meteorite studies have been carried throughout the world to find their origin or their formation and the formation of our solar system and finally the earth origin. Each meteorite fallen on the earth surface has been studied in detail. Meteorites are the richest source of information with regards to the formations of our solar system and the formation of our planet. Cratering features are of two types the larger ones are seen on the surface of planetary bodies and their satellites or their moons, the smaller ones are seen on the surface of meteorites/ meteoroids and asteroids etc. Also craters are of two types 1) Meteorite impact craters formed by impact of extraterrestrial bodies on the planetary body's surface and their moons. 2) Volcanic craters formed by volcanic eruption seen on the earth surface, satellite of the earth, i.e., moon, surface of Mars, surface of Io (Jupiter's moon) etc.

1.1 Previous work carried on meteorites

Based on bulk and mineral chemical composition and oxygen isotopic composition, Kaprada is classified as L Chondrite[1]. The unusual Sulfide minerals in the highly reduced enstatite meteorites are unstable at the earth's surface and can produce an assortment of secondary minerals upon weathering[2]. In addition to the major carbon-bearing phases, large excursions in isotopic composition indicate the presence of interstellar grains within Tagish Lake[3]. Several iron meteorites have been recovered from deposits of a considerable geological age[4]. The shape of the meteorite can give the history of descent to Earth, how it travelled through the atmosphere. The shape indicates if the meteorite was rotating or not, if it broke apart high in the atmosphere or just before reaching the Earth's surface[5]. From the moment a meteorite arrives on the earth, interaction with the terrestrial environment begins to alter it[6]. Due to the high temperature of the shockwave of compressed air that reaches a temperature of several thousand degrees, the surface of the body melts boils and evaporates[7]. Meteorites impact is, in principle, a simple process in which a large object strikes an even larger one at very high velocity, locally releasing a huge amount of energy[8]. The most puzzling mineralogical aspects are the very low temperature phases[9].

2. SCOPE OF WORK

To study the cratering features on meteorite surface and to search their origin with respect to earth rocks.

2.1 Observations

Iron meteorites have metallic luster, figure 1-4, 6 and 7. There are some small cratering features seen on the surface, figure 1-8, 16. Regmaglypts or finger print type of features is seen, figure 2,3,6,7. Burnt marks are usually seen on stony meteorites, but very

rarely seen on iron meteorites, which are known as fusion crust, figure 3,7,16. The surface features of meteorite shows that there are some cratering features. The surface feature of the earth rocks do not show any of these cratering features. These features are not observed on earth rocks or terrestrial rocks.

2.2 Experiments

Images of the meteorites under study were taken along with the earth rocks. Their physical parameters like density, dimensions, their luster, size, shape, etc. and their originality has been discussed in detail by Jadhav and Mali[10]

From the images, cratering features on meteorites figure 1-8 and figure 16. Earth rocks where no cratering features observed, figures 9-15, craters on the earth, figure 18 Lonar crater and craters on the moon figure 17 (a) and (b).

3. RESULTS AND DISCUSSIONS

Cratering features have been observed on meteorites. Large crater formation features have been observed on the rocky planets i.e., Mercury, Mars, Earth (figure 18) etc., satellites like moon [figure 17 (a) and (b)] etc. Small size crater formation features have been observed on the satellites and asteroids and much smaller size cratering features has been observed only on the meteoroids/meteorites. These features are the characteristic features on meteorites surface. These features are not attained when the meteorites come directly on the earth surface, but it is postulated that the cratering features, which the meteoroids and meteorites (figure 1-8, 16), attained was, at the time, before they solidified into hard mass, similar to the features on the surface of planets and satellites, when they also solidified forming the crust, during this period, different types and sizes of rocks and minute particles frequently bombarded or attacked on meteoroids and meteorites existing in space. These components may be in a hotter state at the time of impact and hence may have impacted on meteorites causing cratering features which is prominent seen on their surface. When formation of any process takes place, debris of the process is left behind. From this it can be inferred that the meteorites or asteroids may not be the fragments of a huge planet as suggested by some researchers, but they are considered as the debris of the pre solar system dust or present solar system dust, or it is possible that the meteoroids / meteorites or asteroids may be the leftover or remnants of our earlier solar system. The formation of asteroidal belt between Mars and Jupiter where only rocks of rocky planets remained or exist, itself shows that these asteroids or meteoroids, being a fragmented parts of bigger asteroids existing in asteroidal belt, are not the fragmented parts of any bigger planet, because the rocks on the earth surface or any planetary body's surface in the solar system, if observed do not show any cratering features, no such features are ever observed on the earth rocks or even for that matter rocks on the moon and mercury surface will show any cratering features, which suggests that the cratering features of smaller size is only prominently seen on meteoroids / meteorites and asteroids. Since planets and satellites are huge bodies, cratering features of larger size are best observed on their surfaces, Mercury surface if observed is found to be heavily cratered and also the moon's surface [figure 17 (a) and (b)]), but the craters are not seen on the rocks existing on their surface. The two features i.e., the regmaglypt and fusion crust are only seen after the meteorite lands on the surface of the earth. Regmaglypt feature (finger print type region) usually can be seen on iron meteorites, but the fusion crust (burnt marks) is usually observed on stony meteorites. It can be said that cratering feature originated from the time these minor bodies came into existence and hence it is the birth mark on their surface. Iron meteorites (figure 1-8), rarely shows cratering features, because during their entry into the atmosphere of the earth, they get burnt and due to their being metallic in nature and good conductor of heat, can be melted and their shape may change, during this process, if any cratering feature exist on their surface are likely to be destroyed, but the stony meteorites (figure 16), definitely shows these cratering features even after landing on the earth surface, which suggest that these stony meteorites possibly may be the oldest material or components or, the remnants / leftovers or debris of the solar system or earlier solar system or of super nova explosion. Smaller size cratering features are mostly seen on stony meteorites, it is due to high content of silica (SiO_2). SiO_2 is heat resistant and hence protects the meteorite from heat. Hence the surface features are usually preserved i.e., not destroyed, whereas the iron meteorites being of metallic nature, contains SiO_2 in lesser percentage, iron meteorites being good conductor of heat are likely to be melted and their surface features are likely to be changed. But not every meteorite may show cratering features. There are meteorites where cratering features are not observed or are absent, there are meteorites where only one or two craters may be observed. It is possible that these types of meteorites on whose surface no cratering features are observed may not be affected by micro dust existing at that time in the solar system. From the size of the craters formed on these minor bodies, the approximate size of the particles existence can be known, also from the numbers of the craters formed on the surface of these minor bodies, the approximate micro dust existence in the solar system can be known, although it may never be known the amount or the quantity of micro dust existence, but it may at least give an approximate quantity of the micro dust existence in the solar system. Also, the quantity of cratering features formed on meteorites can give us information about the existence of their place in the asteroidal belt, whether their place was on the outer side or inner side, because the outer side meteorites are likely to be affected more than the inner side. During that period instability of spheres (planetary bodies) may have caused chaos and hence inner planets are found to be affected more than the outer planets. From the numbers of craters formed on meteorites two types of studies can be conducted. 1) The quantity of craters on meteorites, its place in the asteroidal belt can be known. 2) The size of the particles forming the crater can be known accurately. Usually on the earth surface, the craters formation by meteorites may not give accurate information about the size of the meteorite, due to weathering and climatic conditions and changes in the earth surface due to geological events, but on meteorite surface, usually no changes takes place, hence the true nature of the particle can be known accurately. The meteorites somewhat reflect the features of rocky planets.

Cratering features have been observed on minor bodies, planetary bodies, but craters formed on planetary bodies are larger ones, whereas the craters formed on minor bodies i.e., on asteroids, meteoroids and meteorites are smaller ones. It is also to be stated that no cratering features has been observed on comets, it is because, the surface features of meteorites and the surface features of comets are totally different, i.e., the surface of meteorites is hard and solid, whereas the surface features of a comet are somewhat similar to spongy type. If solar debris hits the surface of a comet, due to its spongy type nature it may penetrate below surface, where crater features are likely to be covered by dust particles or ice particles and which may not be observed, or it is possible that

the comets are composed of dust particles and ice particles and being at far ends of the solar system, the solar debris may not have reached that part where these objects are in large numbers and hence may not show cratering features. It is assumed or postulated that the comets may be the remnants of Gas giants, or the debris of gas giants or left-over materials of the outer planets, because the possibility of their features somewhat reflects or represent the features of the gas giants.

When meteoroids or space rocks comes in contact with the earth, it has to go or pass through gravitational force, and atmospheric layers, and finally if it has escaped the gravitational force and atmospheric layers, then it straight away lands on the earth surface, making a depression or a crater, while entry through the atmosphere, it has to first pass through thin layer of atmosphere and then through thick layers of atmosphere, where most of the gases, dust, aerosols, water vapor etc., are present. All these are likely to change or affect the meteorite outer surface features, while in its journey through earth's atmosphere, right up to the landing on the surface, forming a crater. Hence through its journey, it may be affected and the surface features are likely to be destroyed. Also their physical properties and chemical compositions are also likely to be changed. The cratering features on meteoroids, meteorites are very prominent, much prominent than the regmaglypt and fusion crust, because when the meteoroids in space comes in contact with the earth's atmosphere, if it survives after the entry through the atmosphere, then only regmaglypt and fusion crust will be observed, but cratering features is observed even if the meteoroids, meteorites or space rocks are in space. Hence one can conclude how important this feature is.

The cratering features are best observed on the surface of moon / Mercury and minor bodies due to absence of any atmosphere and hence the surface features are usually not destroyed, whereas earth has atmosphere, where it is likely that these features may be destroyed and even if the meteorites falls on the earth surface forming a crater, it may eventually be destroyed in due course of time due to weathering and climatic conditions existing on earth. But there are also craters which are not of meteorite origin, but of volcanic origin. Volcanic origin craters can be observed only on planetary bodies (Earth, Mars, Mercury, Venus, and their satellites, Moon, Io (One of Jupiter's moons) etc., where in the interior of these planetary bodies heat phenomena if it exists can give rise to volcanic eruption forming volcanic craters. In the absence of any heat phenomena in the interior of meteoroids, asteroids and meteorites, volcanic activity is absent due to which no volcanic craters can be formed because they are formed of one single compact solid mass. On the earth bombardment of meteorites are rare, due to the moon, also the earth has atmosphere, where the meteoroids when come in contact with the earth's atmosphere, due to friction and the speed of meteoroids, they are burnt in the air, but some meteoroids escape the burning process and straight away lands on the surface, which are known as meteorites, and these meteorites form craters known as meteorite impact craters. As per the studies carried out by some researchers on meteorites, according to them many micro meteorites or meteoric dust falls on the earth every day. Since the earth is covered by 71% water, large amount of these micro meteorites and meteoric dust lands in the sea and oceans. Hence from the time water came on the earth, many micro meteorites and meteoric dust may have been deposited at the bottom of the sea or oceans from the time immemorial.

Cratering features of smaller size are mostly observed on minor bodies e.g., meteoroids / meteorites. These surface features are characteristic features/peculiarity of meteorites. These features are not observed on any terrestrial rocks except on very rare occasion. Larger cratering features are observed on the moon, mercury, satellites of outer planets surface etc. Even after the impact of these minor bodies on the Earth' surface, these features remain as it is, i.e., do not get destroyed. In other words, it can be said that the cratering features of smaller size on minor bodies are the birth marks on their surface, which is not easily wiped out or easily destroyed.

When meteorites of large size impact on earth, forming craters, though the rocks may get affected or shattered, but the surface of these rocks will not show cratering features similar to cratering features observed on meteoroids and meteorites because these rocks are solid in nature. Any impact on these rocks will fragment the rocks or shatter the rocks into pieces but no craters will ever be formed. But there are some exceptions to this rule. Rocks of larger size i.e., volcanic rocks, where this rule may not be applicable e.g., Logancha Crater in U.S.S.R. which is formed on Basaltic rock, Lonar Crater, Maharashtra, India formed on basaltic rock. But the basaltic rocks formed are not of a single compact piece of rock, but it is a formation of flows at different intervals. There is no such rock observed, so huge that it can form into a single piece, and if exist, then cratering features are not observed. This is one of the peculiarity of meteorites. Hence while saying cratering features on minor bodies, it means that a single piece of rock where cratering features are observed. Formation of cratering features especially small size craters on extra-terrestrial rocks is not only of prime importance in recognition of meteorites from terrestrial rocks, but also it can give us valuable information about the existence of micro dust in the solar system and these dust can provide us detail and vital information about the existence of interstellar dust particles in the solar system and where these type of interstellar dust are segregated on a large scale, or can be found in large quantities. It can be postulated that at the time, the solar system were taking its shape or the planets, their satellites and minor bodies forming into a solid surface, they may have been super nova explosion near our solar system, where the fragmented, rocks or dust may have travelled with great speeds and may have hit the asteroids, meteoroids/meteorites, which is why these features are seen. It is also possible that some components of super nova explosion may be present in the asteroidal belt. The study of the surface feature of meteorites, having craters of smaller size can be helpful in knowing, the crater's diameter, the depth of the crater and the age factor, when was these craters formed, will help us to know more about the formation of our solar system and about these fragmented rocks, are they really the debris of our solar system, or the remnants of our earlier solar system or the remnants of the super nova explosion, which segregated in large quantities between Mars and Jupiter. What are they exactly remnants of? It cannot be the fragmented parts of any planetary body. The remnants of super nova explosion near our solar system can be known due to large and small size crater formations on inner planets. In the whole solar system Mercury and moon are the only celestial spheres, found to be heavily cratered. This may be possible due to heavy bombardment of the particles coming from super nova explosion with great speeds bombarding heavily on these two celestial spheres, because before the moon could be the satellite of the earth it is postulated that the moon was near the sun and also mercury. Hence their surface features

show craters of large and small size. It is also possible that bombardment by solar dust or solar micro particles which originated from solar debris, similar to sand blasting, in one way it can be said of etching, roughing the surface of planetary bodies by eroding (erosion), can also be the reason.

Micro cratering or cratering features observed on asteroids, meteoroids/meteorites can give us valuable information about the micro dust existence in the solar system, the birth of these dust particles, their age factor i.e., when were these micro cratering features formed, because just before solidification of the meteoroids/meteorites, these process of constant bombardment must have taken place, which means at that time, the speed of the particles must have been high. If after solidification of the asteroids, meteoroids/meteorites and bombardment of smaller particles would take place, then it would fragment the asteroids meteoroids/meteorites into much smaller pieces which has not happened, or it is also possible that even after solidification, if any terrestrial rocks smaller or bigger, than the meteoroids would hit, then instead of fragmenting the meteoroids into much smaller components, the smaller particles after hitting would return back without forming any crater. Hence it can be inferred that, the bombardment of space dust or dust particles was at its highest peak at the time, before solidification of these debris or rocks i.e., the asteroids, meteoroids/meteorites. The size of the cratering feature also differs. From the measurements of the size and the depth of the cratering feature, the dust particle size can be known. Since they are independent bodies and are not related to any planetary bodies.

If considered that meteorites are the fragmented parts of a planet existing between Mars and Jupiter, due to collision with another celestial body fragmented and the fragmented parts spread between Mars and Jupiter. If this is the theory of asteroids formation, the minor bodies birth or formation, then how Cl and CM carbonaceous chondrites can be the oldest of the meteorites, if these components were a part of a larger planetary body? Then the chondrites of carbonaceous origin of Cl and CM was the surface part of a rock of that planetary body, which cooled quicker than the other rocky parts, but then how come the features of cratering observed, it is not possible. If chondrites of carbonaceous nature of Cl and CM assumed to be the oldest of the meteorites then the cratering features would not have been observed, and if any collision with other minor bodies would directly fragment the rocks of chondrite origin not forming a single cratering features. On a larger planetary body this is possible, but minor bodies, this may not be possible and hence, the theory of asteroids, meteoroids / meteorites being of planetary origin cannot be possible. No rocks on any planetary body even after fragmentation of the planet may show surface features of craters formation. This is the fact. Hence the only possibility of cratering features observed on the surface of meteorites, meteoroids and asteroids can be related to the origin of our solar system.

From the detail studies carried out on Tagish Lake meteorite by Brown et al., it has been shown that the elemental composition of CI, CM- chondrite nature of stony meteorite, and the Tagish Lake meteorite resemble very closely to the solar elemental composition value[3]. This clearly shows that the meteorites especially the CI and CM and carbonaceous types of chondrites, are the oldest meteorites, which means these minor bodies existed at the time of formation of the solar system or it is also likely that they existed earlier than our present solar system, pointing out that these components are not fragments of any planetary body explosion, and hence their studies in every respect is carried out very seriously. These minor body components did not take part in the formation of any planetary body formation, but remained independent and because of this; today we are able to frame models of our solar system formation. If these minor bodies formed into one single planet, then we would never know about the history of our solar system. It is because of these minor bodies or space rocks that today we are able to frame the model of our solar system and also with the help of these small pieces of extra terrestrial rocks, we may one day try to search the origin of our planet earth and the origin of our solar system. How did our solar system come into existence? What is the role of these minor bodies in the solar system? Etc.

If considered that these minor bodies are fragmented part of a planetary body, then because the fragmented part of a planet existing between Mars and Jupiter shattered or exploded would not give the detail information about our solar system formation, and the cratering features would not have been observed on any rocks of that fragmented planet. But detail studies are carried out because meteorites are considered as the debris, remnants or leftover of the solar system or earlier solar system or may be, the fragments spread through explosion of a Super Nova near our solar system, and hence it can give us valuable information about how our solar system came into existence, what were the components that made these celestial objects circle around the sun etc., many questions related to our solar system and our planet earth can be found by studying meteorites seriously and in detail. Also the cratering features seen on the meteorites surface can be considered as their birth marks, which show that they are not the rocks of a fragmented planet. Hence meteorites cannot be considered a fragmented part of any planet, but they are the debris leftovers or remnants of the earlier solar system or present solar system and hence detail studies are being carried out to find many unanswerable questions related to our solar system and also of our earth. There are independent bodies totally different and not related to any planet whatsoever. If considered that meteoroids/meteorites and asteroids are fragments of a shattered planetary body, then during the formation of our solar system, where are the debris of the solar system? Or where is the debris of earlier solar system? Or where are the remnants of super nova explosion? No satisfactory explanation or answer can be found. Hence these fragmented rocks existing between Mars and Jupiter cannot be the parts of a shattered planetary body, but are the debris of our solar system or either it may be the debris of earlier solar system or may be the remnants of super nova explosion, which may have exploded near our solar system, the particles of this explosion may have travelled with very high speeds piercing with great speeds on meteoroids/meteorites or asteroids surface for which these cratering features are observed. The cratering features on asteroids/meteoroids/meteorites are reflection of those events occurrence at the initial stage of formation of our solar system. Any system after formation leaves debris, leftover etc., is it the dust or debris of solar system or solar dust left behind after formation of our solar system, or is it pre solar dust?

During the formation of planetary bodies, some of the material or debris or leftover material did not go to form planets. Is this the material that was left, segregated away from the sun as rocky planets having high density stayed near the sun? The meteorites also

having high density than the terrestrial rocks can also be considered as staying on the borders of rocky planets is what we call them as meteorites/meteoroids or asteroids, as per research conducted on meteorites, the iron meteorites are found to be similar to core of rocky planets, the stony irons are found to be similar to mantle and stony meteorites are found to be similar to crust of the rocky planets, it is natural then that the debris or remnants of the rocky planets are found on the border of the rocky planets, which is between Mars and Jupiter. Hence meteorites cannot be considered fragmented part of any planetary body, but are totally independent bodies with a single compact solid mass. The minute particles or solar dust bombarded with great speeds on the meteoroids, meteorites or asteroids like a sand blasting or like hit and run. These particles made craters on meteorites, but the meteorites were not able to hold these particles due to lack of gravity on their surfaces, after colliding with meteorites and forming craters, they escaped into space. These are the only possibilities of explaining the cratering features observed on asteroids, meteoroids and meteorites. Cratering features on meteorites if any may be related to formation of our solar system whether past or present, but they are the debris of presolar dust or solar dust and this is the fact.

The bombardment of high speed particles of micro level on space rocks (asteroids / meteoroids/meteorites) at the initial stage causing smaller depressions or craters known as mini craters or micro craters is possible only if super nova explosion have occurred near our solar system, where the particles of this explosion traveled with highs speed bombarding on the surface of space rocks, which is similar to sand blasting or like hit and run. Since asteroids, meteoroids or meteorites do not possess gravity these solar particles or solar dust did'nt remain on the meteorites surface similar to planetary bodies because planets have gravity. Some of the well-known meteorite impact craters on the earth surface. [1] Arizona Meteorite impact crater, [2] Lonar meteorite impact crater, [3] Chicxulub meteorite impact crater, Yucatan, Mexico.

3.1 Conclusion

From the images in figures 1 – 8 and 16 of meteorites, the observation of surface features, small cratering features observed which are not found on terrestrial rocks. Images in figures 9 – 15 of rocks of the earth where cratering features are not observed and the images of the moon's surface [figure 17 (a) and (b)], where the surface shows cratering features and figure 16 image showing crater on planetary surface i.e., earth. From the discussion, it is very clear that cratering feature is a characteristic surface feature of asteroids / meteoroids / meteorites (minor bodies), and has been formed from the time the solar system came into existence and these rocks of extra terrestrial origin, being bombarded constantly by very minute particles (much smaller than these minor bodies), on these asteroids / meteoroids / meteorites, which gave rise to cratering features on minor bodies of extra terrestrial nature, which are observed today. The planetary bodies also show bombardment by larger asteroids on their surface, but the cratering features on meteorites surface suggest that during cooling period i.e., before solidification heavy bombardments by micro dust or micro micrometeorites or space rocks of smaller size must have occurred and this is possible only if near our earlier solar system formation, super nova explosion may have occurred these smaller size particles may be in a hotter state at that time and hence could have formed minor craters on meteoroids and meteorites before the meteorites solidified, similar to sand blasting where the components of this explosion were flung far off with great speeds, impacting on the planetary bodies, their satellites, asteroids / meteoroids / meteorites. Since the planetary body surface is large, it is not possible to observe it because the cooling time for planetary bodies may have taken more time than the minor bodies and hence are observed on their surface which is characteristic feature. Also due to the large size of the planetary bodies with respect to minor bodies, their surface features were not affected on a large scale, but minor bodies being smaller in size may have cooled faster than the planetary bodies being of single compact mass, the minor depressions or craters remained after cooling as it is seen till date. The features of cratering are the reflectance of that event. The above-mentioned events are the three possibilities for giving rise to minor crater formations on the minor bodies.

Studying these features is of prime importance because it will help to build a model about our earlier solar system formation, the role of these minor bodies and the existence of micro level dust particles, whether they are of interstellar origin or solar system origin. Cratering features observed on meteorites, meteoroids and asteroids are not observed on any rocks of terrestrial nature or terrestrial origin.

From these studies it can be concluded that the cratering features of smaller size observed on asteroids, meteoroids/meteorites especially on stony meteorites, suggest that meteoroids/ meteorites are independent bodies, not related to any planetary bodies, they are the dust/debris or remnants of the present or may be earlier solar system or may be the remnant of interstellar dust particles existed before the formation of planetary bodies, or the remnant of Super Nova explosion. Hence their surface feature study in every respect is very important.

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APPENDIX

Fig. 1: Iron meteorite, small cratering features are observed on their surface

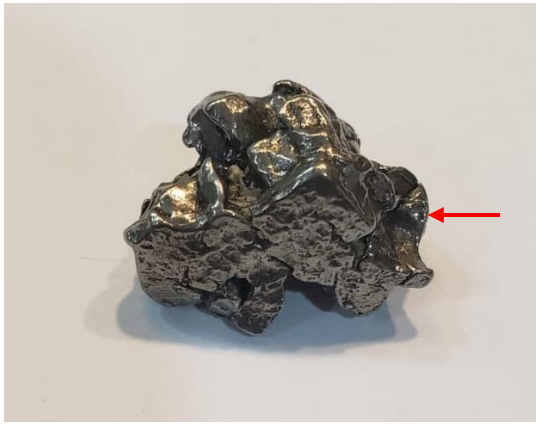


Fig. 2: Iron meteorite, where cratering features of small size is observed

Fig. 3: Iron meteorite, small cratering features observed on their surface

Fig. 4: Iron meteorite showing small cratering features on their surface shown by arrow

Fig. 5: Iron meteorite showing cratering features of smaller size on the surface.

Fig. 6: Iron meteorite showing cratering features of smaller size on the surface.

Fig. 7: Iron meteorite showing cratering features Of smaller size on the surface shown by arrow

Fig. 8: Iron meteorite showing cratering features of smaller size on the surface shown by arrow

Fig. 9: Earth rock, no cratering feature observed on the surface

Fig. 10: Hematite (Earth Rock). Cratering features not observed on their surface

Fig. 11: Magnetite (Earth Rock). Cratering features not observed on their surface

Fig. 12: Earth rock no cratering features observed on the surface

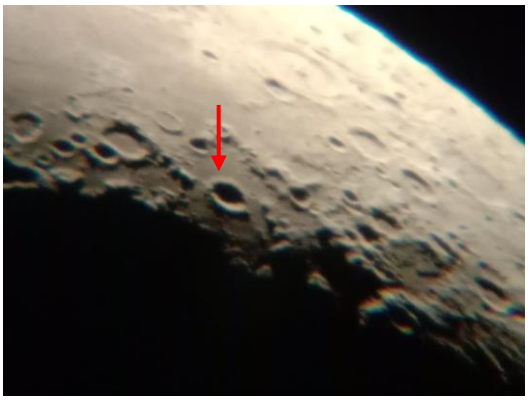
Fig. 13: Earth rock, no cratering features observed on the surface

Fig. 14: Magnetite (Earth Rock). Cratering features not observed on their surface

Fig. 15: Magnetite (Earth Rock). Cratering features not observed on their surface

Fig. 16: Craters seen on stony meteorite Chelyabinsk. Small size craters can be observed

(a)



(b)

Fig. 17: (a) and (b) Moon's surface showing craters of large and small sizes. Photos taken by Mr. Asish Kumar Sahu of Raurkela, Odisha, on C sky 8" Dobsonian reflecting telescope. Craters shown by arrow

Fig. 18: Meteorite impact crater on the earth surface, Lonar, Maharashtra, India. Photo by Mr. Gabriel Francis

