Lecture

Planetary Surface Processes

Objectives

• Stages of impact process
• Diagnostic indicators for an impact crater
• Complicating factors in using impact cratering record as chronometers
• Fluvial processes and aeolian processes

Notes

• What is impact cratering? What happens to the impactor and the target during the impact process?

Impact cratering is the process of formation of craters on the surfaces of solid planetary bodies through hypervelocity impacts. Impact structures may range in size from millimeters (such as microcraters found on lunar samples and man-made satellites) to thousands of kilometers (such as multi-ringed basins found on the far-side of the Moon – Orientale Basin, and on one of Jupiter’s moon, Callisto – Valhalla Basin). Between the two extremes, there are simple craters (such as Meteor Crater or Barringer Crater in Arizona) and Complex craters (such as Chicxulub on the Yucatan peninsula of Mexico).

The impact process includes the contact and compression stage (lasts for less than one second in all but the largest impacts), the excavation stage (lasts for a few or tens of seconds), and the modification stage (normally completed within 15 minutes).

During the contact and compression stage, the impactor plunges into the target and is decelerated. The target is compressed and accelerated. The initial crater is formed. Both the impactor and the target are subject to pressures greater than 100 GPa, and temperatures high enough to cause vaporization or melting.

During the excavation stage, materials move outwards (upwards at upper levels, and downwards at lower levels). The crater is expanded to produce a bowl-shaped transient cavity. Excavated material is ejected over the surrounding terrain (impact ejecta).

During the modification stage, debris cascades down the walls to form a layer of fragmented materials in the base of the crater (breccia lens). In larger craters, slump terraces may form on the walls of transient cavity, as it collapses under gravity. In addition, central peaks may form on the floor as material beneath the impact structure rebounds.

Others effect of the impact process may include tsunamis if an impactor hits the Earth’s ocean, loss of materials to space if ejecta acquire escape velocity, forest fires if re-entering ejecta significantly heats up the atmosphere.

• How can we tell that a crater is formed by impact process instead of volcanism?

Impact is a highly unusual process, involving exotic materials, and extreme pressure and temperature conditions. This give rise to a set of diagnostic indicators of impact, both local to the impact site, and in more distant settings such as a impact layer in an otherwise normal sequence of rocks.

• Shock waves causes phase transition and produce a variety of microstructure in minerals

  Graphite to Diamond
  Quartz to Coesite or Stishovite
Planar deformation features in Quartz

- Shock waves causes metamorphism in rocks; 
  Shatter cores, Suevite, etc.
- Shock waves produce impact glass (tektites);
- Actual fragments of the impactor may be found in some small impacts;
- Geochemical signatures of the impactor may be incorporated in the melt or ejecta.

- What are the complicating factors in using the impact cratering record as a planetary surface chronometer??

It has been observed that older surfaces show more craters. Therefore, the number of craters on a surface can be used as an indicator for its age. There are several complicating factors in measure the age of a planetary surface based on crater counting.
- Density of craters (number of craters per unit area) is affected by impact flux (the number of impacting bodies hitting a given area in a given time) and size distribution, which may change with time and vary from place to place.
- Density of craters is affected by the nature of the target, which may changes with time and vary from place to place.
- Density of craters only give the relative age. The absolute age needs to be calibrated by other method such as radiometric dating.

- What processes can modify the appearance of planetary surfaces?

The processes that have significantly reshaped planetary surfaces are
- plate tectonics on Earth
- volcanism and impact cratering on other planetary bodies
- fluvial and aeolian processes on Earth and Mars.

Fluvial and Aeolian process refer to the erosion, transport, and deposition of material due to the action of the water and wind, respectively, at or near the surface of a planetary body.