

Impacts do NOT initiate volcanic eruptions!

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A theme that runs through many papers on meteorite impact is the idea that large impacts can induce volcanic eruptions. This idea probably got its start in pre-Apollo days when early observers of the moon noted the common occurrence of dark material—usually supposed to be lava—filling the nearside impact basins. A logical inference is that this is a genetic association: The impacts caused lava to upwell in the biggest craters after they had formed, eventually filling them. Samples returned from the moon by the Apollo missions showed that the mare basalts are considerably younger (up to about 1Gyr) than the basins in which they lie. Any presumption of a genetic association of impacts and volcanism on the moon must thus be deemed questionable. It seems more likely that the large nearside basins were merely the lowest spots on the moon's surface at the time that the lunar interior warmed to the point where basaltic partial melts formed in its mantle, and that the rising lava simply flowed to the lowest points. At most, this rising lava might have flowed up impact-induced fractures in the lunar crust.

Nevertheless, the idea that impacts may initiate volcanic eruptions on Earth or even the Moon has been vetted many times in recent years. We examine the conditions under which impacts can produce extra melt in their vicinity, focusing on the process of decompression melting. We show that extra melting may occur due to an unusually high geothermal gradient that enhances the normal process of shock melting and thus increases the total volume of melt produced. Nevertheless, except for the case of an extremely high geothermal gradient or a fortuitous impact on an already-erupting volcano or magmatic province, we find that impact-induced volcanism is very unlikely to be important on the Earth, Moon or any other planet in the solar system.

Fig. 1.

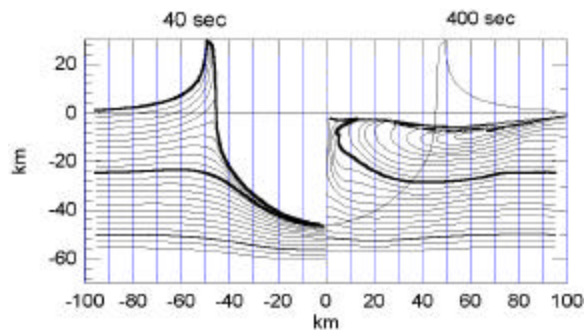
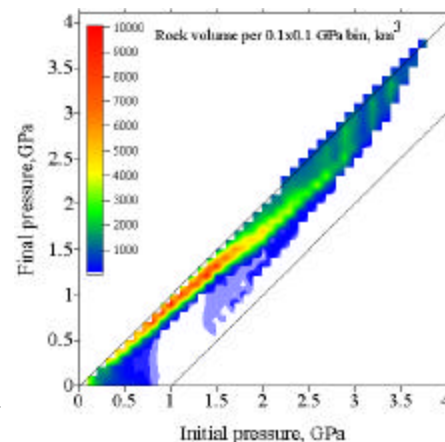


Fig. 2 →



We numerically modeled the impact of an asteroid with a diameter of 20 km striking at 15 km s^{-1} . The impact ultimately creates a 250 to 300 km diameter crater with approximately $10,000 \text{ km}^3$ of impact melt. We model the target as ANEOS dunite with a melting curve similar to mantle peridotite. The transient cavity has a maximum depth of 45 km. However, the crater collapses almost flat and the pressure field returns almost to the initial lithostat. All target material uplifted during crater collapse is inspected to determine the pressure difference (release) between the initial and final state. The uplifted volume of $400,000 \text{ km}^3$ is divided into $0.1 \times 0.1 \text{ GPa}$ bins to show where we have the maximum pressure release. Fig. 2 illustrates that even for this enormous crater (maximum transient cavity volume of $200,000 \text{ km}^3$) most material experiences a release of less than 0.5 GPa during uplift from a depth of $\sim 30 \text{ km}$ to the near-surface. Even a near-surface thermal gradient of 30 K km^{-1} is not enough to put mantle material above the peridotite solidus. Hence to provoke an eruption impact craters must be (i) larger than $\sim 250 \text{ km}$ or (ii) occur in a region where nearly molten material is delivered to a depth above $\sim 20 \text{ km}$. The area and time of existence of such a hot spot is small (area $< 10\%$ of Earth's surface, time of cooling $\sim 0.1 \text{ Gyr}$). The impact of a large asteroid into a hot spot is possible but highly improbable. If such an event has ever happened, it can not be treated as a regular geologic process.