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Essay 6

Age Dating Using Craters

During the formation of the solar system, a thick disk of dust and ice spiraled chaotically around our newly formed sun. Over the course of billions of years, vast portions of this disk gravitationally coalesced into the planetary bodies we see today: Earth, the Moon, Mars, Europa, Ceres, and Enceladus to name a few. Because these bodies had formed, though, did not mean that the once chaotic disk was no more. An uncountable number of rocks and ice ranging in size from minute dust to kilometers in diameter still littered the space in between the larger planetary bodies, many of which end up impacting them. The craters these impacts leave behind can be used to determine the age of the planetary bodies' surface (Note: Age dating craters does not determine the age of the entire planetary body. It only measures the amount of time since that portion of the surface experienced a major change that altered or removed evidence of preexisting craters[1]). Older surfaces will be more heavily cratered while younger surfaces will be less heavily cratered. If the rate of cratering is known, one can then determine how old the surface is. This method has been very successful at dating planetary surfaces, though it is not perfect. How reliable is this method, what are the uncertainties and how might they be resolved?

According to Williams et al.,[2] some uncertainties are: "variations in impactor flux… atmospheric passage… secondary cratering… crater modification… [and] statistical and observational biases" to name a few. Variations in impactor flux questions how consistent cratering events occur. Impactor rate has been assumed to be constant over the past 3 billion years, but this is not totally certain.[2] Atmospheric passage is how impactors are affected by the planetary body's atmosphere as it passes through it. Smaller objects that enter atmospheres are more likely to be destroyed and thus will not be present in the crater-record. This would decrease the amount of craters a surface has, making it appear younger than it may be. Opposite to atmospheric passage is secondary cratering - the craters produced by a primary impactor's ejecta. This will increase the apparent amount of craters on a surface, making it appear older. Crater modification is how surface craters are affected, over time, by factors such as "erosion, deposition, and terrain diffusion." Smaller diameter craters are much more heavily influenced by this uncertainty. This also makes craters not necessarily correspond to formation age, but other processes and events on the surface instead[2]. Statistical and observational biases include: measuring young planetary surfaces which may have too few craters to accurately date them; small "areas of interest" which may not accurately represent the true age of the surface (though, how would one know for sure that it is not representative of the true age?); and the incident angle of images which affect the detectability of craters[2].

I believe that some of the uncertainties can be scientifically or mathematically accounted for while some others are inherent mysteries that do not have solutions. For example, Antonenko et al.[3] determined the optimal incident angle for detecting craters is between ~58° to ~77°. If a surface has too few craters to get an accurate age, "Poisson statistics can still provide time-

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[1] https://courses.lumenlearning.com/astronomy/chapter/dating-planetary-surfaces/

[2] https://onlinelibrary.wiley.com/doi/full/10.1111/maps.12924

[3] https://www.lpi.usra.edu/meetings/lpsc2013/pdf/2705.pdf

resolved probability" such that an accurate age can be inferred. Secondary cratering could be modeled and simulated in high-end computers, however all the correct information about the impactor (mass, velocity, density, impact angle) would be needed for a truly accurate simulation. A point of uncertainty that may never be resolved is the rate of collisions within the solar system. It can be assumed that it has been constant over the past 3 billion years, but what about before that, or what about periods of time where rates drastically increased (like the late heavy bombardment of earth) or decreased. This is something that cannot be easily uncovered, so educated guesses must be made.

Overall, there are many uncertainties that are inherent to age dating using craters, however much of these uncertainties can be accounted for using statistics, and scientific predictions and inferences making age dating a relatively reliable and successful method.