Environmental Consequences of Big Nasty Impacts on the Early Earth

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The geological record of the Archean Earth is spattered with impact spherules from a dozen or so major cosmic collisions involving Earth and asteroids or comets (Lowe, Byerly 1986, 2015). Extrapolation of the documented deposits suggests that most of these impacts were as big or bigger than the Chicxulub event that famously ended the reign of the thunder lizards. As the Archean impacts were greater, the environmental effects were also greater.

The number and magnitude of the impacts is bounded by the lunar record. There are no lunar craters bigger than Chicxulub that date to Earth's mid-to-late Archean. Chance dictates that Earth experienced no more than ~10 impacts bigger than Chicxulub between 2.5 Ga and 3.5 Ga, the biggest of which were ~30-100X more energetic, comparable to the Orientale impact on the Moon ($1x10^{26}$ J).

To quantify the thermal consequences of big impacts on old Earth, we model the global flow of energy from the impact into the environment. The model presumes that a significant fraction of the impact energy goes into ejecta that interact with the atmosphere. Much of this energy is initially in rock vapor, melt, and high speed particles. (i) The upper atmosphere is heated by ejecta as they reenter the atmosphere. The mix of hot air, rock vapor, and hot silicates cools by thermal radiation. Rock raindrops fall out as the upper atmosphere cools. (ii) The energy balance of the lower atmosphere is set by radiative exchange with the upper atmosphere and with the surface, and by evaporation of seawater. Susequent cooling is governed by condensation of water vapor. (iii) The oceans are heated by thermal radiation and rock rain and cooled by evaporation. Surface waters become hot and salty; if a deep ocean remains it is relatively cool. Subsequently water vapor condenses to replenish the oceans with hot fresh water (how fresh depending on continental weathering, which might be rather rapid under the circumstances). (iv) The surface temperature of dry land is presumed to be the same as the lower atmosphere. A thermal wave propagates into the land at a rate set by conduction.

Impacts not greatly larger than Chicxulub can raise the surface temperature by tens, hundreds, or even thousands of degrees, and evaporate meters to hundreds of meters of water. The biggest should have vitrified exposed dry land. More results are for the talk, as here we have run out of space.