Student questions: Gordon Osinski colloquium on "A Cataclysmic Origin of Life?"

12/1/21

The late heavy bombardment is said to have lasted between 20 - 200 million years, this could be considered as a narrow interval of time. How possibly could this short lived event be responsible for life on planets especially when compared to other life evolution theories?

The idea of the late heavy bombardment is being actively debated in the community. Regardless of whether it occurred or not, there was still a significntly higher "background" rate of impacts for the first 0.5 to 1 billion years of Earth's history.

Would hydrothermal phase in craters would be possible on the modern surface of Mars?

Yes, absolutely: if we had a "decent" size impact (e.g., a crater in the 10s km size range) in the northern plains of Mars (where we know there is a substantial amount of ice in the subsurface) then I would expect a hydrothermal system to be created.

Considering how many craters are undoubtedly hidden beneath the oceans, how would you go about trying to study these ocean floor craters?

With difficulty! The major challenge is the cost of sampling these structures – as we need samples to prove they are craters in the first place.

Is there a reason why some areas of the planet have more impacts than other areas?

Absolutely! The major reason is geology. The big concentrations of craters in Australia, Scandinavia, and N. America are because these are the regions of the world with the biggest preserved areas of the ancient Shields or Cratons. Other reasons are that it's hard to spot craters in the tropics, and also the more remote a location is, the lower the likelihood that there are lots of geologists working there.

Talking about the shocked gneiss and the biomass. Have you found any other rocks that show similar biomasses to the gneiss?

We also published a paper on shocked sandstones from the Haughton impact structure, which provided similar results, but with a few twists: Cockell C. S. and Osinski G. R. 2007. Impact-induced impoverishment and transformation of a sandstone habitat for lithophytic microorganisms. *Meteoritics & Planetary Science* 42:11:1985–1993. We now have studies of shocked basalts ongoing so stay tuned!

Are there craters that you haven't been to or haven't had very close look at that you'd eventually like to explore?

Nice question! Definitely on my "impact crater bucket list" are some of the craters in Siberia, Russia, that appear to be well-preserved but that are very remote.

Is it possible that there are endolithic microorganisms on Mars that we haven't yet found?

I think it is entirely a possibility. The only way to really see endoliths in the Arctic is to crack open a rock with a hammer to get a fresh surface and we haven't done that yet on Mars.

Do you currently do any field-work studying volcanically active regions of hydrothermal systems on earth, as analogs for how life might behave in these similar conditions on other planets?

I don't but I'd love to! We do have a paper in review though that was an experiment where we put shocked rocks and impact glasses in so-called cold springs in the Canadian Arctic.

Are these impact-generated hydrothermal systems mainly found in complex craters?

I don't have a definitely answer for this, but this is a subject of ongoing research. My current answer would be mostly: from what we cal tell, most complex craters on Earth formed hydrothermal systems, but there might be a couple of simple craters that also did.

How do the crater impacts form water without extreme heat causing that water to evaporate?

During the early stages of impact-generated hydrothermal systems when temperatures are higher (few hundred degrees), then it is probably steam-dominated. As things cool down, we then have liquid water and temperatures more suitable for life.

Is there any indication that some of the impact craters had sustained hydro/geothermal activity?

Yes. I'm working on a new review of all craters on Earth to determine exactly now many, but I think most complex craters on Earth resulted in at least minor hydrothermal activity.

What evidence do you look for that tells you you're in an impact crater and not some sort of volcanic crater, etc?

The only unequivocal way to determine this is to find evidence for shock metamorphism, so features such as shatter cones and planar deformation features (PDFs). These features are only formed naturally in meteorite impact events.

What are impact deposits?

I assume this is about the map I showed? These are deposits of things such as tektites or spherules that are not within or around a host crater – they have been ejected 100s or even 1000s of km from their host crater. And most of the time, we don't know where the host cratyer is/was.

Would we be able to replicate asteroid/meteor impacts to create life again?

Unfortunately it is REALLY hard to recreate the huge pressures and temperatures generated during impacts in a lab environment, so probably not unfortunately.

Do you think Mars could have sustained life at one point in time?

Yes, I really do think so, and I think impact craters might be some of the best places to look.

What is the possibility of observing an impact live or seeing the effects of a very recent impact on another planet or moon?

There is always the possibility, but an impact on Earth that big is probably not something we really want to witness, right?"

How is hydrothermal alteration maintained/sustained post-impact?

The two major heat sources for hydrothermal systems in impact craters are rock melted by the impact and rocks uplifted from depth to form central uplifts.

Is there a threshold for the size of an impact that could support habitability?

My best guess is craters in the 10s km size range.

How does one date an impact crater?

The primary way is to use radiometric age dating (e.g., U-Pb or Ar-Ar) on rocks melted by the impact; that reset's the age to give the age of the impact. Kip Hodges in SESE is an expert in dating impacts ☺

Are the conditions that favored the formation of montmorillonite clay exclusive to impact craters?

No, montmorillonite clay forms in other settings, but it's interesting that that this is one of the most, probably the most, common clays formed in impact settings.

How likely do you believe it will be that there is an abundance of volatiles (water ice) in the permanently shadowed regions on the moon?

I think it's very likely. We have lots of evidence from lots of different spacecraft for water ice in these permanently shadowed craters.

Where the impact map is empty, meaning there are no records of craters, could the lack of data be from non-communication with the researchers in those areas?

See my answer to one of the other questions, but yes, this is part of the story. I wouldn't say lack of communication, rather, many developing countries don't have government-run geological surveys or active geology mapping occurring.

If a meteor were to induce a hydrothermal vent, would microbes and small life species be able to survive even under the conditions of Mars?

Yes, I absolutely think so.

How long-lived was the hydrothermal system at Ries?

Gernot Arp in this paper suggested 250,000 years: http://dx.doi.org/10.1111/maps.12235.

What is the minimum diameter that a meteorite would need to have in order to have a significant impact on Earth's environment?

We don't really know the answer to this as we haven't been around to witness any big impacts, but we think craters in in the 20-30 km size range start to have global environmental impacts.

Is it theoretically possible to find remnants of mud-like ejecta on craters on planets such as Venus, which are closer to the Sun?

If you mean "fluidized" ejecta, like is present on Mars, probably not as we think volatiles are required.

Would the hydrated silicates found in Isidis indicate the possibility of being a landing site for humans?

Possibly. You can extract H2O from clays, but it's far easier from ground-ice so I think the mid-latitudes, e.g., Arcadia Planitia, are the best places to send humans.

Is it possible that the life was brought from the other extraterrestrial planets by meteorites?

The idea of panspermia that you describe has been around for decades. In theory it is, yes, possible.

How are craters on the moon dated?

If we have samples in the Apollo collection, the same way as craters on Earth (i.e., by dating rocks melted by that impact event). If not, we rely on crater counting, which is not precise.