WHERE ARE ALL THE TERRESTRIAL METEORITES?

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Meteorites clearly can reach Earth from the Moon and from Mars, launched by larger impacts. This raises the inevitable question: can solid debris be ejected from Earth by large impacts, to return subsequently, survive re-entry, and be recognized as a meteorite?

Recognition: Meteorites launched from Earth will not be recognizable from lithology or geochemistry. The only diagnostic feature would be a fusion crust formed during re-entry, but this will not develop on many sedimentary rocks [1]. The Antarctic collection programmes are the best prospect for recognizing a fusion-crusted terrestrial meteorite but no candidate has yet been reported. Might this absence be significant and not merely chance?

Residence times in Space and on Earth: CRE ages for Lunar meteorites [2] are typically <<1Ma, which suggests that ejected terrestrial debris will have comparably short space residence times. In geological terms return may be almost synchronous with the impact launch event. Maximum terrestrial residence times of achondrites are <1Ma [3]. Combined space and terrestrial residence times of a terrestrial meteorite, probably <1 Ma, require a launching impact within the last few hundred ka for there to be any prospect of such a meteorite being recognized at the surface.

Launch conditions: Minimum crater diameters necessary to achieve significant dispersal of Lunar and Martian material into space are 0.4km and 3km respectively. Scaling-up to Earth-based parameters suggests a minimum crater diameter of ~25km, even before the effects of atmospheric drag on Earth-launched projectiles is considered. Spallation may launch solid material at high velocities from a narrow and very shallow zone around the impact site [4], with vapourisation of volatiles in the target rock perhaps providing further acceleration. To escape Earth's gravity requires launch velocities perhaps 75% of impact velocity, which exceeds most published estimates [5] and questions the potential existence of terrestrial meteorites. For the high shock pressures associated with a suitably large Earth impact, any potential meteoroids will be small, probably <20cm [6], with obvious implications for survival during re-entry. The shallow location of the spallation zone has significant implications for recognizing 'terrestrial' meteorites. The target lithologies for many large impacts were sedimentary (e.g. limestone for the Chicxulub, Manicouagan and Ries sites). Fusion crusts would not form on such lithologies and hence it would be effectively impossible to identify them as having re-entered the atmosphere as a meteorite.

Conclusions: A fusion crust is the only feature by which a terrestrially derived meteorite might be recognised. None have yet been reported. Minimum crater diameter of ~25km and combined space and terrestrial residence times of <1Ma for potential Earth-derived meteorites precludes the existence of any at the surface today; a crater of such size and recency is unlikely to have been overlooked by impact hunters scouring Google Earth. Ancient terrestrial meteorites might be sought in strata that slightly post-date major impacts in the geologic past.

References: [1] Brandstätter, F. et al. 2008. *Planetary and Space Science* 56:976-984. [2] Eugster, O. et al. 2006. Meteorites and the Early Solar System II. pp. 829-851. [3] Jull, A. J. T. 2006. Meteorites and the Early Solar System II. pp. 889-905. [4] Melosh, H.J. 1984. *Icarus* 59:234-260. [5] Wells, L. E. et al. 2003. *Icarus* 162:38-46. [6] Nyquist, L. E. 2001. *Space Science Reviews* 96:105-164.