METEOR IMPACTS AS A SEISMIC SOURCE ON MARS N. A. Teanby[1], J. Wookey[1], [1]School of Earth Sciences, University of Bristol, UK (n.teanby@bristol.ac.uk).

Introduction: There is currently great interest in missions to Mars that include a surface geophysics element (for example the recently proposed INSIGHT NASA Discovery Mission). The most important instrument on such a mission would be the seismometer as this would allow us to greatly increase our understanding of Mars' internal structure and seismic activity. At present the only constraints we have on the maritan interior come from measurements of the moment of inertia, gravitational potential, tidal dissipation, and geochemical inferences deduced from martian meteorites. This severely limits our understanding of Mars' structure and formation and a wide range of internal models are able to fit the available constraints. As demonstrated on Earth, the most powerful way of constraining internal structure is seismology.

However, for a seismic study to be effective, a seismic source is required with enough energy to be detected globally and provide seismic waves that travel through the deep mantle and core. Potential seismic sources include faulting due to release of thermal and topographic stresses (Mars has no active tectonics at present) or meteorite impacts. Here we focus on the use of meteorite impacts, which have the advantage that source locations may be constrained by observations of new impact craters from orbit. This is beneficial, especially in the early stages of seismic exploration where only a single instrument is likely to be deployed, and would provide the simplest way to determining internal structure.

A previous study by [1] based on scaling the Apollo impact results from the Moon, estimated that around 20 globally detectable impacts should be detectable each year. However, we now have a much better understanding of the present day martian meteorite impact rates, internal models, and seismic waveform modeling. This allows us to update these estimates and determine if meteorite impacts do indeed provide a viable source for the seismic exploration of Mars [2].

New impacts: Orbital imaging has recently allowed the detection of many newly formed impact craters. For example, [3] detected 20 new impact craters by comparing MOC images over a seven year period. Subsequently [4] has detected over 100 new craters using a combination of CTX and HiRISE data from MRO. These new craters show that detecting new impact craters from orbit is viable and could provide a possible seismic source. The new observations also allow us to constrain the current impact rate and constrain extrapolations of cratering isochrons [5] to present day rates.

Mars Internal Model: To model seismic waveforms within Mars' interior we require the velocity and attenuation as a function of radius. For velocity we use model A from [6]. Attenuation Q is difficult to measure, but can be estimated from the tidal dissipation of Phobos [7]. We use a globally averaged value of Q of 261 (for S-waves), which is also comparable to that of the Earth.

Method: To model seismic wave propagation through Mars we require a way to convert a given observed impact crater diameter into an equivalent seismic moment. This involves three stages.

First the crater diameter must be converted into an equivalent impact energy. To do this we used data compiled from laboratory and field impact experiments and explosive analogues. This compilation allowed us to determine a power law relation between crater diameter and impactor energy (Fig. 1).

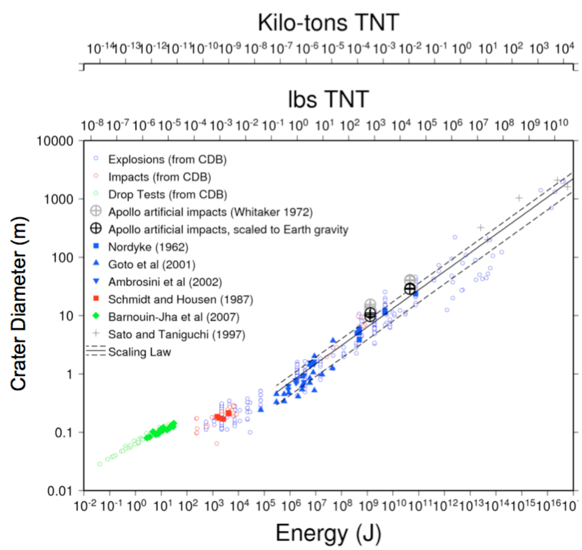

Fig. 1: Crater diameter as a function of impact energy compiled from laboratory and field studies.

Second, the proportion of impact energy converted into seismic waves – the seismic efficiency – must be known. This is the most uncertain part of the analysis and measured values of seismic efficiency vary from 10^{-2}-10^{-6}. We adopt a value of $2x10^{-5}$, which is consistent with most of the data, but includes a large factor of 10 error.

Third, seismic energy must be converted into a seismic moment. This was accomplished using a compilation of high frequency measurements of seismic events from both microseismic and teleseismic studies.

A given impact crater size can now be converted into and equivalent seismic moment – albeit with a large errorbar.

High frequency (8Hz) seismograms were generated for an impact source with an equivalent seismic moment of 10^{14}Nm (~300m crater diameter). These seismograms could then be scaled for any impact crater size – giving the seismic amplitude as function of source-receiver offset.

Results: By combining the updated yearly isochron of cratering rate [5] with our overall conversion relation from crater diameter to seismic moment, we were able to determine the meteorite induced seismicity. This results in a total moment release of 10^{13}-10^{14} Nm per year.

This is seismically quite weak. Assuming reasonable noise levels for current instrument designs only allows the global detection of impacts with an equivalent seismic moment of 10^{13}Nm (~100m diameter crater) or more (Fig 2). This translates into one globally detectable impact event every 30 years. However, the errorbars on this figure are very large – perhaps as high as a factor of 100 – even so globally detectable meteorite impacts seem like an unreliable seismic source for studying the deep interior. A far more viable source is faulting, which is estimated to release 10^{18}Nm per year [8], over 10^4 times as much as our estimate of meteor impacts.

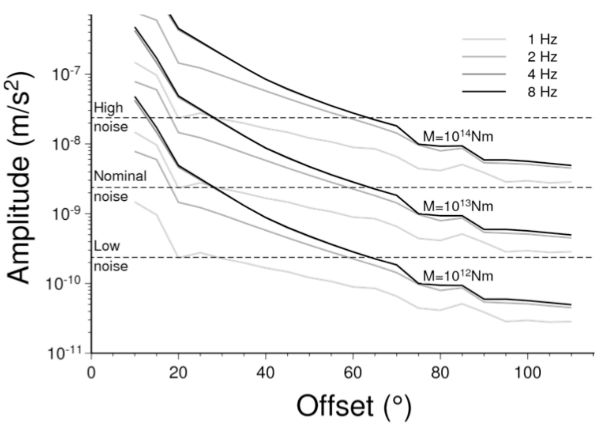

Fig. 2: Maximum amplitude of the first arrival from impact events with an equivalent seismic moment (M) of 10^{12}, 10^{13}, and 10^{14}Nm. Dashed horizontal lines show the expected noise levels of martian seismometers. To be detectable on global scales (>60° from source) requires a seismic moment of at least 10^{13}Nm.

Finally, although large globally detectable impacts are likely to be rare, small local impacts are much more likely to be detected because attenuation is much reduced by the shorter path lengths through Mars and small impact events occur much more frequently than larger ones. Local impacts may thus provide an effective way of studying regional structure. However, the only truly reliable way to determine the potential for exploting meteorite induced seismicity on Mars is to send a seismometer there. Hopefully, over the coming decade, such a mission will be realized. Seismic measurements on Mars would not only have implications for understanding internal structure, but also allow the impact rate to be accurately determined in a very cost effective way. This would have wide ranging implications for martian surface chronology as well as the deep interior.

References:

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