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Introduction: The comparison Earth Mars Moon from a seismological point of view is possible today with the NASA-Insight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) mission on Mars. Since its deployment at the surface of the red planet, the seismometer SEIS (Seismic Experiment for Interior Structure) recorded hundreds of Very High Frequency (1.5 – 15Hz; VF) small magnitude seismic events [1, 2]. They are characterized by two temporally separated arrivals with a gradual beginning, a broad maximum and a very long decay [3,4]. These basic observations suggest that the VF events are generated by the long-range propagation of seismic P and S waves in a heterogeneous crust [5]. In this work, we propose to use seismic coda analysis to explore the properties of Martian crust and to provide a Earth-Mars-Moon attenuation proprieties comparison.

Dataset: Seismic data used for this study are ground displacement records of VF events from SEIS-VBB sensors with sample rates of 20 samples per second (sps). They were collected as part of the NASA InSight [6] Mission to Mars using SEIS (Seismic Experiment for Interior Structure) seismometer [7] They can be downloaded from the IRIS Data Management Center website (https://www.iris.edu/hq/sis/insight).

Methodology: In this work, we employ basic multiple-scattering concepts to examine and to compare the energetic characteristics of the Earth, Martian and Lunar crust. We measured the delay-time (that we define as the rising time from the direct S-wave onset t_s to the time arrival of the maximum of energy t_{max}) and the coda quality factor (that characterizes the rate of decay of the seismogram envelopes) Q_c.

Results: We performed a fit of the frequency dependence of Q_c using a parameterisation of the form $Q_c = Q_0 f^n$ on 8 VF events. Based on linear least-squares applied to the logarithm of Q_c (see fig.1), we obtain a value of Q_0 between 600-700 and $n \approx 1$ in the [2.5 Hz - 7.5 Hz] range with $\alpha = 1\ (red)\ and\ 0\ (orange)$. The change of α impacts the value of Q_0 (10%) but not the value of n. The results with α = 1 [8] and 0 [9] will be compared to the results on Earth and the Moon respectively. The quasi-linear frequency increase of Q_c seen on VF events suggests that the coda decay is governed by a frequency independent attenuation time. In the case of the regional earthquakes on Earth, the frequency dependence of Q_c is radically different between tectonic areas and shields. Q_0 varies from 100 to 400 in tectonic areas (blue) [e.g. 10] and from 600 to 1000 in shields areas (green) [e.g. 11], where the frequency exponent n is equal to 1 and 0.1-0.5 respectively. Furthermore, Q_c appears to saturate at high-frequency on Earth and only exceptionally exceeds 3000 at 20 Hz. No such saturation is seen in the VF events data. [12] report coda Q_c values of 2400 at 0.5 Hz and possibly as large as 10000 at 7 Hz on the Moon (gray). This result suggests that Q_0 is a factor of 2 to 4 larger than on Mars when the frequency exponent n is more likely in the range of 0.4 – 0.6. To summarize, our measurements indicate that Q_c on Mars is lower than on the Moon but higher than on Earth. The unique combination of high Q_0 with a frequency exponent n =1 also distinguishes very clearly Mars from the Earth.

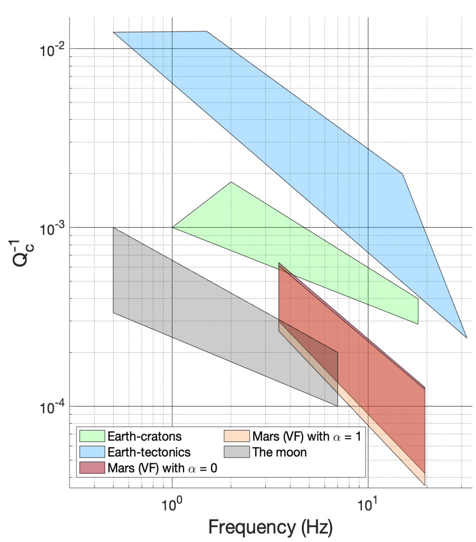

Fig.1: Coda attenuation Q_c^{-1} as a function of the frequency for the Earth-cratons regions (green), the Earth-tectonics regions (bleu), the Moon (gray) and Mars ($\alpha = 0$ in red and $\alpha = 1\ in\ orange$).

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