EXPLORING SEDIMENTOLOGICAL EVIDENCE OF AN ANCIENT OCEAN ON MARS. Y. Iijima[1], K. Goto[2], K. Minoura[1], G. Komatsu[3], F. Imamura[4], [1]Dept. of Earth Science, Tohoku Univ. (6-3, Aramaki Aza Aoba, Sendai, Miyagi 980-8578, Japan; a8sb5005@s.tohoku.ac.jp, minoura@m.tohoku.ac.jp), [2] Planetary Exploration Research Center, Chiba Institute of Technology (2-17-1 Tsudanuma, Narashino, 275-0016 Chiba, Japan; kgoto@perc.it-chiba.ac.jp), [3]IRSPS, Univ. G.d'Annunzio (Viale Pindaro, 42 65127 Pescara, Italy; goro@irsps.unich.it), [4]Disaster Control Research Center, Graduate School of Engineering, Tohoku Univ. (Aoba 06, Sendai, Miyagi 980-8579, Japan; Imamura@tsunami2.civil.tohoku.ac.jp)

Introduction: Whether there was an ocean on Mars is fundamental question when discussing the past environment of the planet [e.g. 1]. The ancient ocean hypothesis was first proposed in the late 1980s based on geomorphological evidence interpreted in Viking orbiter images. The spatial resolution of the images at that time was, however, very low (~100 m) and detailed observation was difficult. From 1990s to early 2000s, high-resolution images (~10 m) were acquired, but observation was still limited to identifying geomorphological features [2]. Since the late 2000s, an approx. 30-cm resolution HiRISE images enable us much more detailed sedimentological observations [3], such as boulders.

Discussing evidence of an ocean from sedimentological point of view may provide new clues of its past existence. However, on Mars, sedimentological characteristics of the ocean may differ from that of the Earth because of lack of a tidal activity, which is a large factor characterizing terrestrial shorelines [4]. One phenomenon that is in common to Mars and the Earth as well and that can leave sedimentological traces on the surface of the planets is meteorite impact into oceans and consequent generation of large tsunami waves [4, 5, 6]. In order to propose candidate localities to find sedimentological evidence of the impact-generated tsunami, we conducted numerical modeling for tsunami propagation and inundation.

Impact-generated tsunami on Mars: The estimated number of meteorite impact into the Martian ocean is 0 to 160 in the case of Contact 1 shoreline, and 1 to 1200 in case of Contact 2 shoreline [7]. Up until now, more than 10 candidate marine target craters have been proposed [8]. Such impacts might have generated large tsunami waves on Mars [5], and left sedimentological features around the shorelines [4].

In order to assess effects of the impact-generated tsunami on the Martian ocean, we conducted numerical simulation using the MOLA topographic data as shown in Fig. 1. Simulations are based on the nonlinear long wave theory, and a leap-frog scheme was used. We assumed 34 craters on the ocean (Fig. 2), crater diameters are assumed to be 10 km and 50 km, respectively, and water level and velocity of the tsunami were calculated. Contact 1 (-1500 m) and Contact 2 (-3702 m) were assumed as two shoreline levels.

Impact-generated tsunami can be classified into three types; shock wave, rim wave, and receding-rushing wave [5]. Shock waves are generated when meteorite penetrates the atmosphere, whereas rim waves are generated in front of the ejecta curtain. Receding-rushing waves are generated when ocean water flows into the crater cavity and the water flows out from the cavity. In this study, we assumed only receding-rushing wave, because it has probably the most significant effects along the shorelines because of its wave period longer than the other types of waves [5].

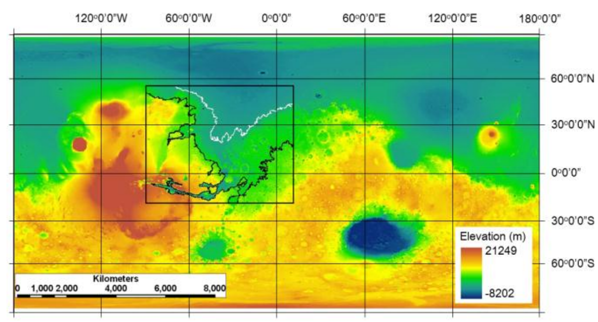

Figure 1: A map showing the topographic data used for the simulation. Black and white lines indicate the Contact 1 and Contact 2 shorelines, respectively.

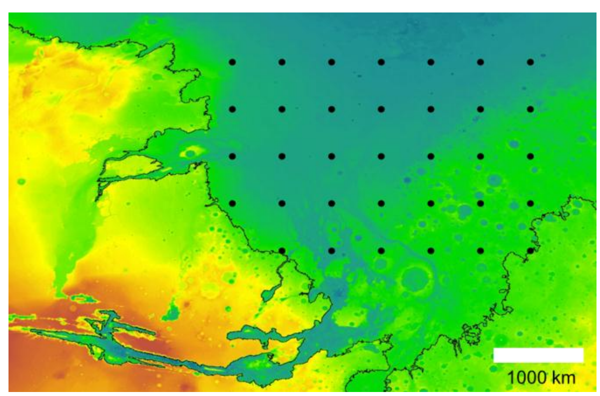

Figure 2: A map showing the location of assumed craters. Black solid line indicates the Contact 1 shoreline.

Results: Fig. 3 shows one of the numerical results, which indicates the maximum velocity at each grid after 50 hour calculation. The location of the crater is shown as the black dot. Velocities are low at the deep sea region (0 to 2 m/s) but are high at around the crater and the shoreline (4 to 12 m/s). Numerical results of other cases are generally consistent with these features. Therefore, the tsunami effects are mostly strong around the crater and the shoreline, which should be the candidate places to explore the sedimentological evidence of the tsunami.

Tsunami sedimentation and erosion on Mars?: Our results are useful in identifying adequate places where the influence of the tsunami was strong. There are three types of sedimentological processes that leave possible traces of the tsunami along shorelines; erosion, sedimentation, and movement of boulders [9, 10]. However, erosional processes of the tsunami and their consequent landforms are poorly understood even on Earth. Sedimentation of tsunami deposits on land is generally less than a few tens of centimeters in thickness on Earth and is difficult to find on Mars using satellite imageries. On the other hand, tsunami deposits on the sea floor are sometimes very thick and widely distributed [9]. However, it is also uncertain whether such deposits can be identified from satellite imageries.

In contrast, distribution of meters-scale boulders (Fig. 4), which are originally generated by the impact as ejecta, could be detected by high-resolution satellite images such as HiRISE [11]. Studies on the movement of boulders by tsunami have been well conducted on Earth [10]. It is interesting to note that the current velocity calculated along the shoreline (~12 m/s) is high enough to move meters-scale long boulders (~4 m/s for movement of 4~5 m long boulders) on Mars. Therefore, although boulders may be originally deposited concentrically around impact craters, they might have been reworked by tsunami wave currents if the ocean existed for certain periods as suggested by Ormö J. et al. [7]. Thus, we propose that the reworked boulder deposits may be the best candidates as the sedimentological feature of tsunami using the currently available datasets on Mars.

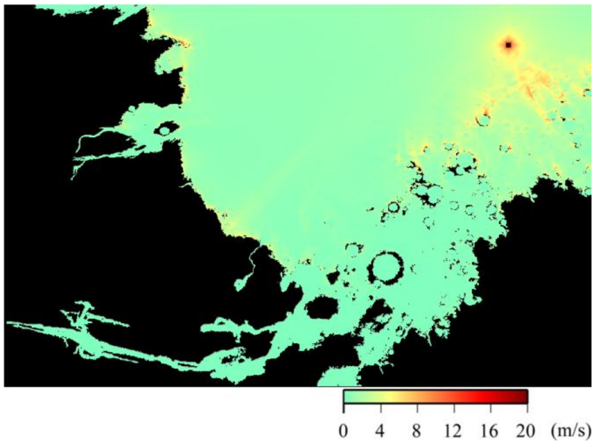

Figure 3: Maximum velocities at each grid. The black area indicates land. The black dot indicates the location of the assumed crater. Diameter of the crater is 50 km.

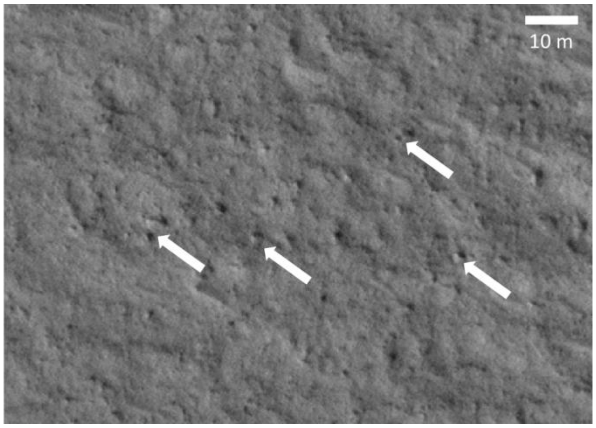

Figure 4: Meters-scale boulders (indicated by white arrows) on the surface of Mars (PSP_003842_1935).

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