RIMFAX GROUND PENETRATING RADAR MODELLING: IMAGING THE SUBSURFACE OF THE JEZERO WESTERN DELTA.

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Introduction: Ground penetrating radar (GPR) has proven successful in near-surface imaging for stratigraphic analysis [1]. Radar facies, corresponding to patterns and geometries in the radargram, are specific for different sedimentary formations. The stratigraphy of the Jezero Western Delta (JWD) is among the key targets at the Mars 2020 landing site. RIMFAX, the GPR instrument onboard the Mars 2020 rover [2] will be conducting radar soundings as the rover drives across the Martian surface. Designed to image subsurface features down to 10 meters or more, it is expected that bedding and stratigraphic relationships can be put into context of surface observations.

This study presents the potential of GPR modelling in JWD, where surface observations of the delta successions are related to what RIMFAX will be able to image below. Initial results show how different sedimentary formations can be identified in the GPR data by their characteristic radar facies. The presented subsurface structures and dielectric properties are part of a preliminary model, based on published studies and experience from field tests in similar geological environments. Furthermore, the modelling framework presented could also be valuable for assisting interpretation of radargrams during rover operation.

GPR Modelling: This study focuses on the deep operation mode of RIMFAX [2], where the frequency bandwidth extends from 150 MHz to 600 MHz. Measurements are done every 10 cm along the drive path. RIMFAX employs a Frequency Modulated Continuous Wave (FMCW) which sweeps through the bandwidth. However, to prevent very large computations the modelling was conducted with a single wavelet matching the frequency content of the FMCW.

This work presents the capabilities of conducting finite difference time domain (FDTD) modelling on a regional scale while incorporating surface observations at their true location into the subsurface model. Construction of the geological model was conducted with the software BGS Groundhog Desktop GSIS [3]. The numerical calculations were carried out with gprMax [4], a recognized software for simulating GPR performance in various media that implements Yee's FDTD algorithm [4] to solve Maxwell's equations.

Transect RFX_JWD: A 2 km long transect was selected spanning from the Light Toned Floor unit (LTF), across the lower parts of the delta and upwards onto the delta succession, see Fig. 1. The transect crosses several sedimentary facies along its path. Building on published JWD studies [6, 7, 8, 9, 10], surface features were extrapolated into the ground populating the subsurface model.

Following the findings of [11], dielectric properties were assigned to units based on assumed density and bulk composition of dry rocks. Studies into dielectrics of Martian rocks shows dependency on frequency as well as temperature, e.g. [12, 13]. However, in this initial model the dielectric relaxation was assumed negligible in the frequency range under investigation, similar to other studies [14, 15].

Results: Initial modelling results show that characteristic radar facies of point-bars and channel fills of delta plain, foresets and bottomsets of delta front and prodelta, are identified along the transect. See annotations in Fig. 2. The profile is displayed to a depth of 10 m below the surface, as each trace of 200 ns was depth converted employing a constant velocity of 0.1 m/ns.

In the northern part of the transect, an erosional boundary is modelled at the base of a meandering river system and its cross-cutting sections of point-bar

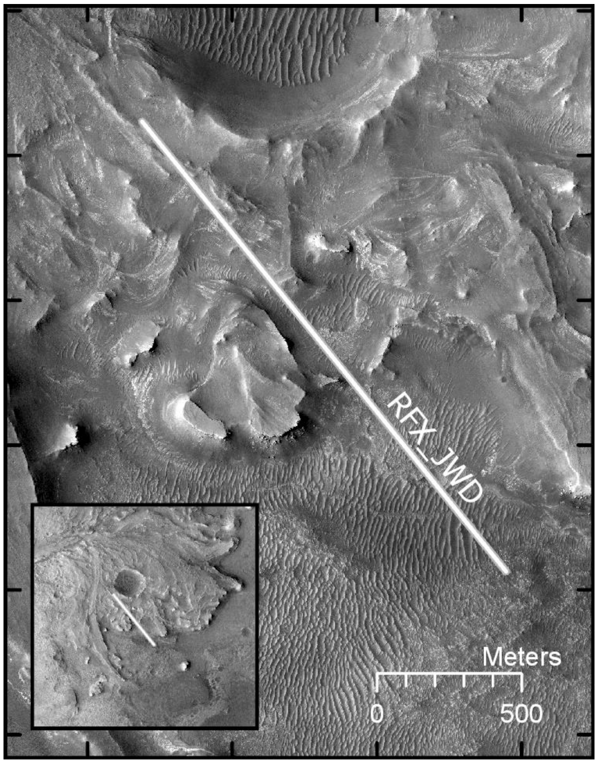

Fig. 1: Line RFX_JWD displayed on top of mosaics of HiRISE and CTX images [16].

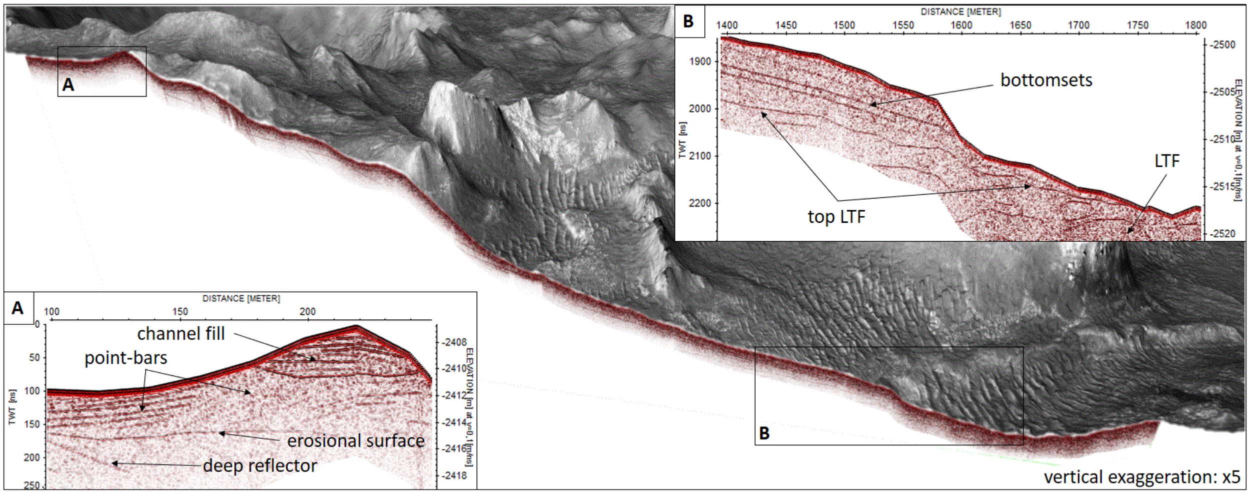

Fig. 2: Initial modelling results along line RFX_JWD, displayed together with a mosaic of HiRISE images draped over a HiRISE-derived stereo DEM [16]. Distinct radar facies are visible in the zoomed-in 2D-windows A and B.

deposits. Layering in the original delta succession below can also be recognized (e.g. "deep reflector" in Fig.2-A). The inverted channels are modelled with semi-horizontal layers, giving a distinct appearance in the radargram.

Bed geometry and dip in both foresets and point-bars are key features that can indicate the depositional settings, e.g. [17, 18]. This will be studied during operation on Mars. In the modelled transect variation in dip is visible in the cross-cutting sections of point-bar deposits. The effect of apparent dip is also prominent, as beds can appear semi-horizontal in the radargram when dipping in a cross-track direction.

Stratigraphically below the JWD succession lies the LTF, where several theories of formation have been proposed [10]. During operation on Mars, these theories can be assessed by comparing modelling results with real measurements. In the present study LTF was modelled as a brecciated volcanic unit rich in carbonate, similar to [19]. The interface between the horizontally layered prodelta and the more chaotic reflection pattern of the LTF appears clearly in Fig.2.

Future Work: Subsurface models will gradually be made more elaborate by further comparison to GPR field studies at terrestrial locations geologically comparable to JWD. This includes investigations into detectability of relevant stratigraphic geometries and into dielectric properties of comparable units. Attention will also be given to quantifying penetration depth and electromagnetic loss due to attenuation and scattering.

In turn, the modelling framework can be employed to assess detection of features like water ice and bound water in rocks, as well as underground cavities and mineralization zones.

Parallel ongoing research is also dedicated to how the physical and technical aspects of RIMFAX's antenna, FMCW radar signal and system dynamic range are best incorporated into the FDTD software.

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