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# Mapping and Dating of Recent Ice-Rich Deposits on Alba Mons, Mars

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## 1 - INTRODUCTION

There are three main reservoirs of water ice on present day Mars: i) the two polar caps [1], ii) the Latitude Dependant Mantle, continuous from the mid-latitudes to the poles [2] and iii) various morphologies of debris covered glaciers [3]. By studying these ice-rich materials we can enrich our knowledge of the past climate of Mars and better understand the distribution of resources for future human exploration.

Impact craters are ideal locations to observe these debris-covered glaciers, thanks to their steep slopes which facilitate their deposition and preservation. Sinha and Vijayan (2017) studied the volcanic region of Alba Mons located at mid-latitudes which is a favourable area for ice-rich deposits. They observed north-facing deposits on crater slopes and dated them between 10 and 100 Ma. Schiff et al. (2022) studied the texture of similar deposits on the slopes of the Alba Mons caldera. They observed an ice-rich mantle above them, interpreted as younger and showing a "hummocky" texture with very few superimposed craters.

Our study focuses on the morphology, the spatial distribution and the dating of these upper deposits (UDs) within the entire Alba Mons region (Fig.1), using as a basis the list of north-pole facing deposits mapped by Sinha and Vijayan (2017). We used CTX data to recognise the UD types using their distinctive surface texture.

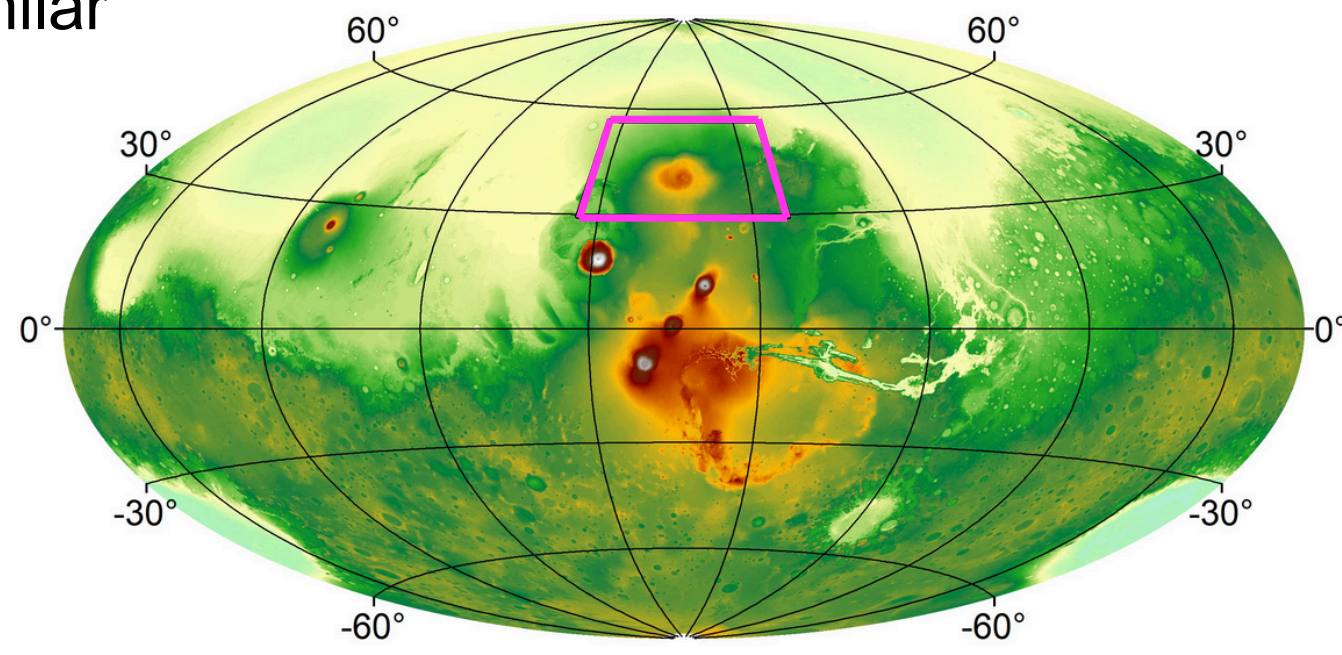


Figure 1 : Global topographic map (MOLA) centred on Alba Mons with our study area outlined by a pink frame.

## 2 - MORPHOLOGY OF UPPER DEPOSITS

Our exploration of the Alba Mons region led us to define two types of UD morphologies. Type 1 is characterized by a steep lobate termination on the crater floor (Fig. 2a-c). Type 2 is characterized by a flatter concave termination which lies over a more cratered lower deposit (LD) (Fig. 2d-f). Type 1 and 2 are found in craters of any diameter.

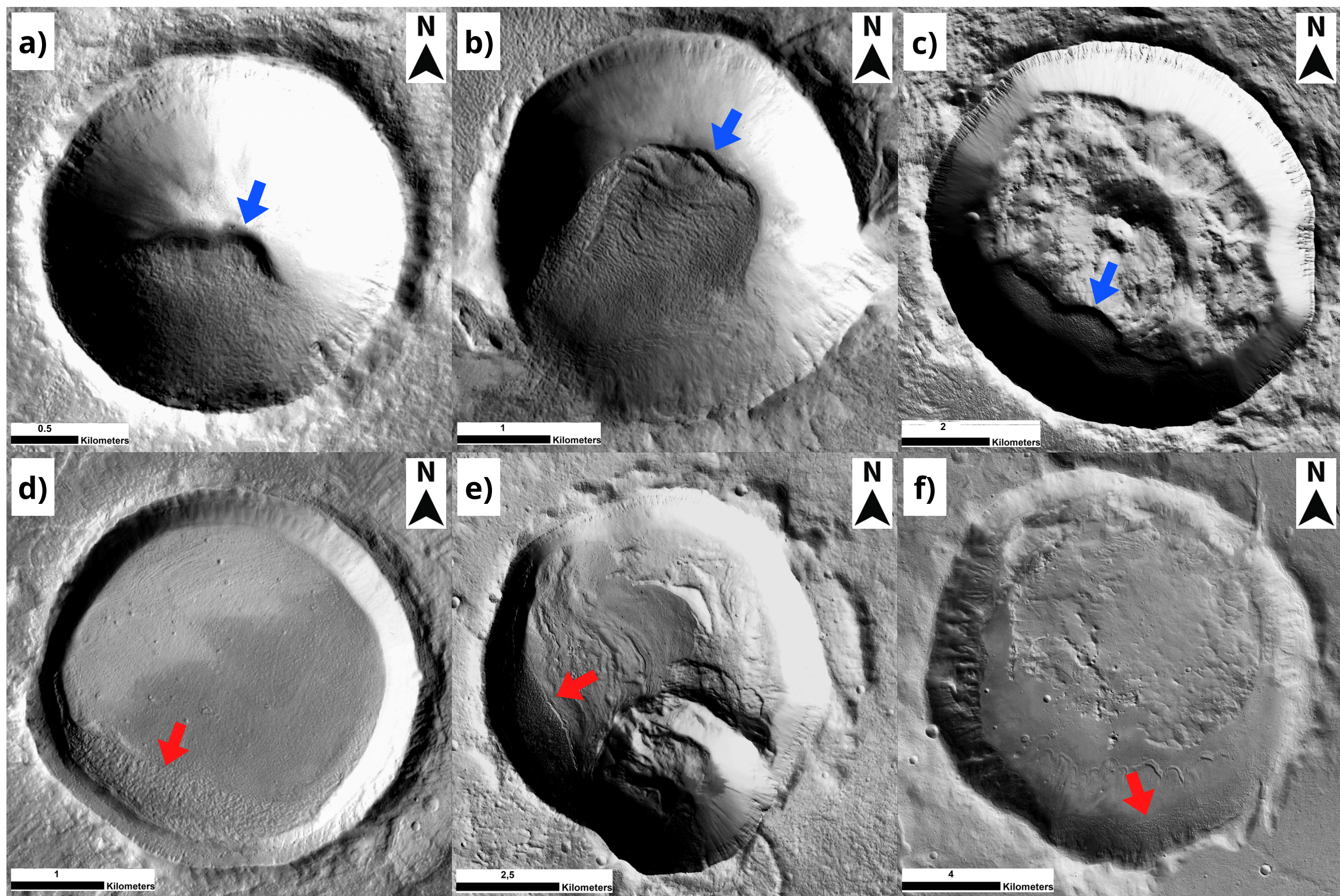


Figure 2 : CTX images showing craters with UD types. a-c) Craters with a type 1 UD showing a steep lobate termination (blue arrow) on the crater floor (92°36'W 42°50'N, 111°9'W 44°58'N, 119°14'W 43°2'N). d-f) Craters with a type 2 UD showing a flatter concave termination (red arrow) above a LD with a higher crater density (108°6'W 36°50'N, 123°41'W 44°57'N, 85°9'W 37°17'N). Sunlight is from the left in all images.

## 3 - SPATIAL DISTRIBUTION OF UPPER DEPOSITS

UDs are mostly located at high altitudes compared to other debris-covered glaciers as mapped by Levy et al. (2014). Type 1 UD types are concentrated between 40° and 50° and on the southeast flank of Alba Mons. Type 2 UD types have a more scattered distribution over the whole latitude range (30° to 50°).

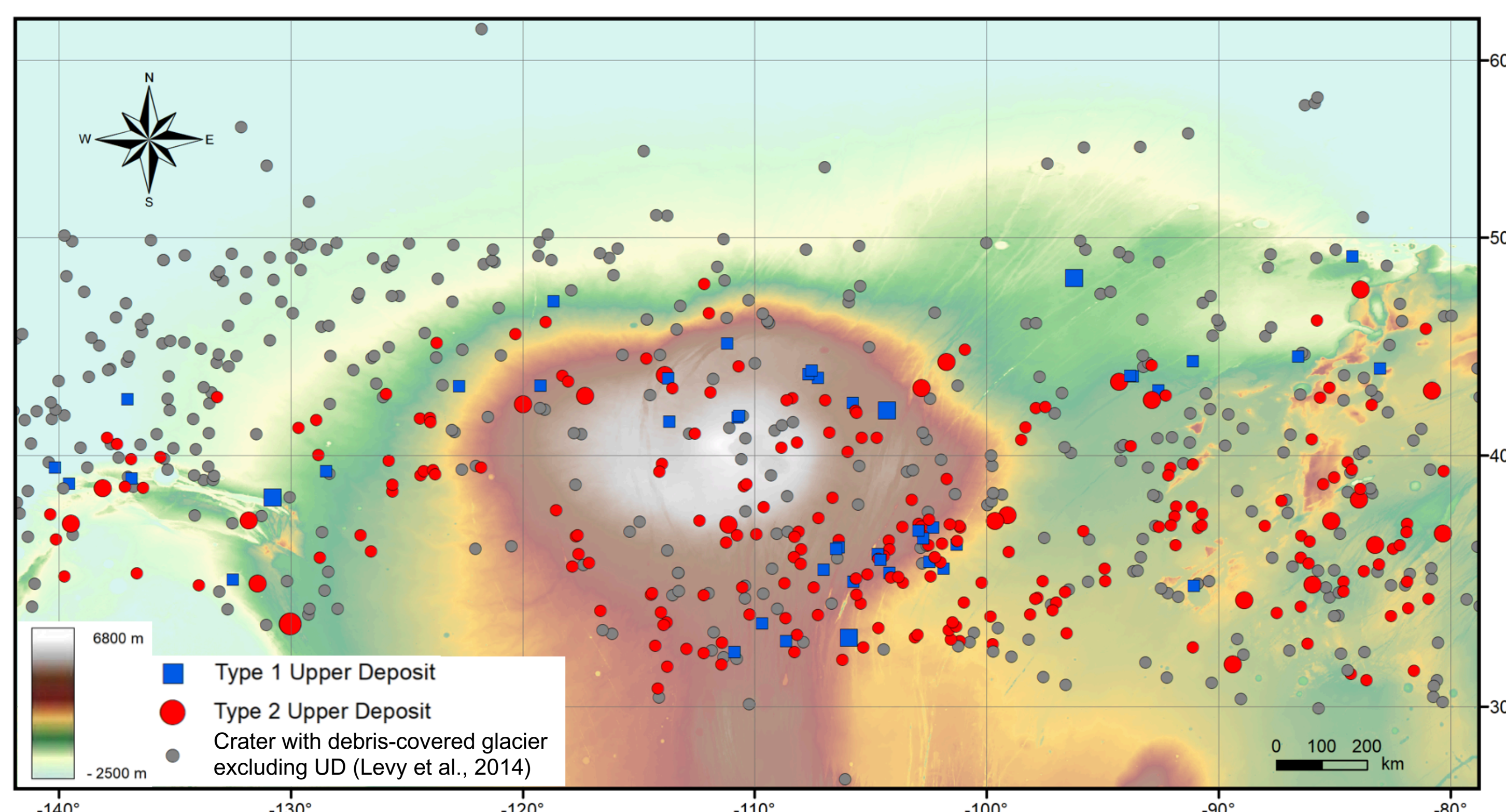


Figure 3 : Map of the spatial distribution of UD types. Global topographic map (MOLA) as basemap.

## 4 - DATING THE UPPER DEPOSITS

We measured the Crater Size-Frequency Distributions (CSFDs) of superimposed craters on UD types where suitable images were available. We used CraterTools and CraterStats with the Hartmann & Daubar (2016) chronology system (Fig. 4). Only two UD types have HiRISE data and we obtained respectively two ages : 4.5 (±2) Ma and 8.8 (±4) Ma. We also used CSFD of the host craters themselves to provide age brackets for the major regional events (Fig. 6).

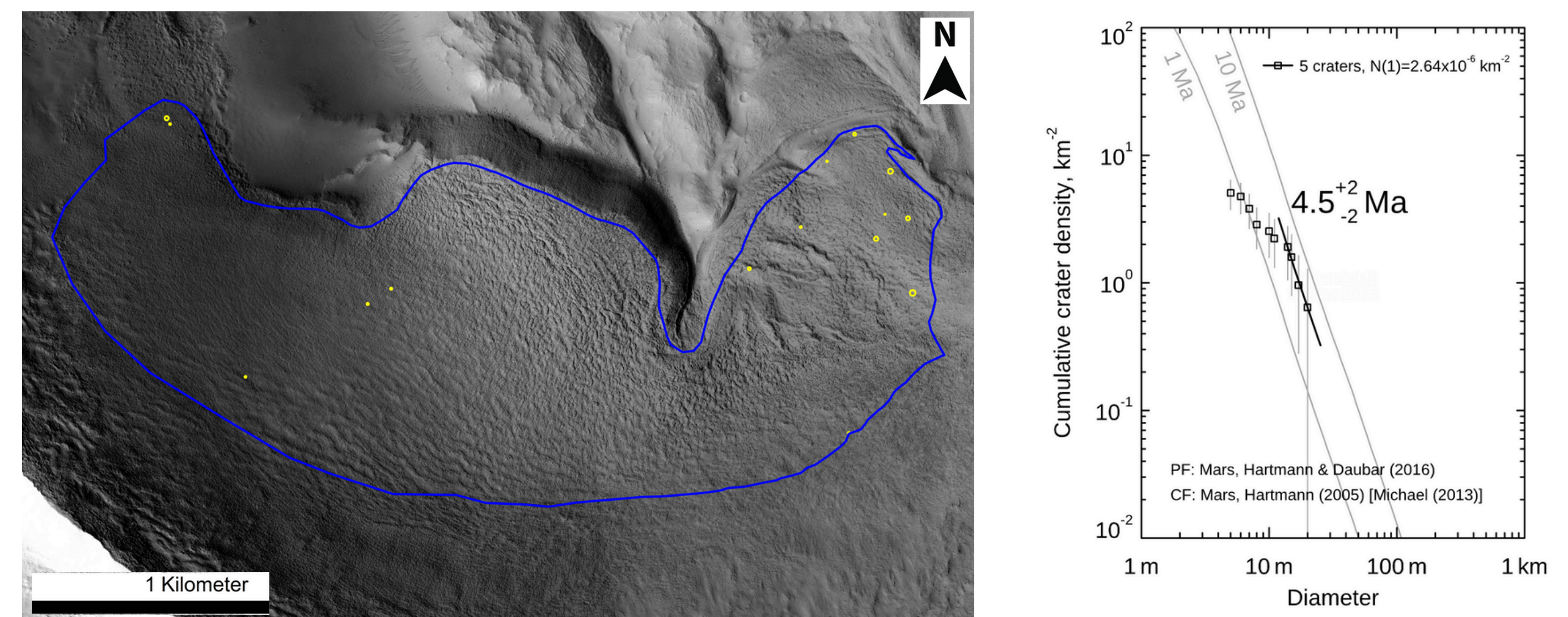


Figure 4 : Left, HiRISE image (ESP\_016727\_2270) of a type 1 UD with its superimposed craters (yellow) and the area analyzed (blue). Right, results from the CSFD analysis.

## 5 - COMPARISON WITH A GENERAL CIRCULATION MODEL

Madeleine et al. (2009) made a map of the accumulation of water-ice in the northern hemisphere during the northern winter, with a obliquity parameter of 35°. In our study area, ice is deposited in these conditions (Fig. 5a). Then, they made a map of the surface water-ice budget which shows a "hotspot" on the southeast part of our study area (Fig. 5b). Further, Laskar et al. (2004) simulated the past obliquity of the planet and obtained an average obliquity of 35° during the period which corresponds to the ages that we obtained for UD types (4.5 and 8.8 Ma) (Fig. 5c). Hence, the climate model results are consistent with our observations.

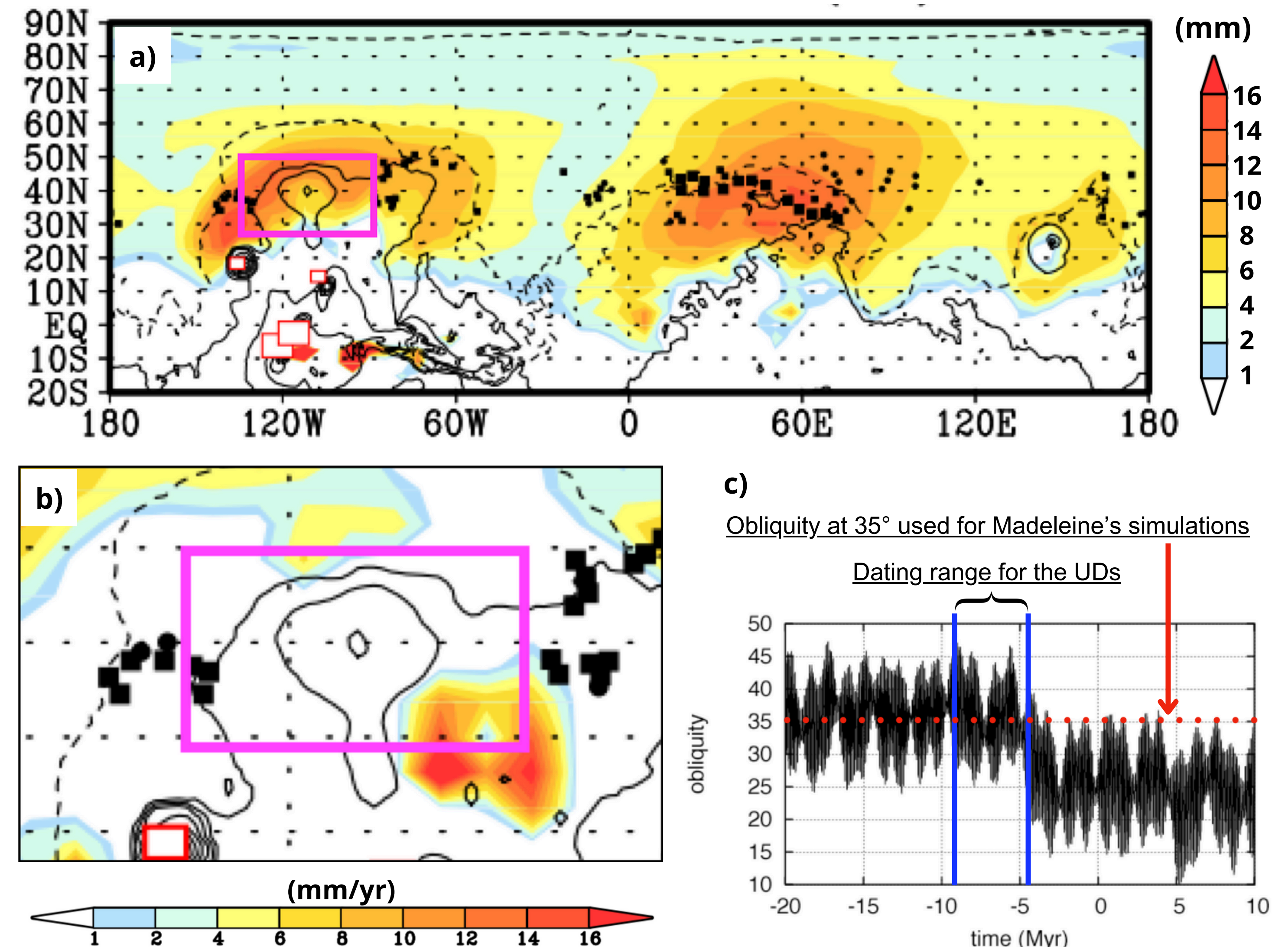


Figure 5 : a) Map of Winter accumulation (mm) predicted by the General Circulation Model of Mars at 35° obliquity from Madeleine et al. (2009) over a map by Squyres (1979). Our study area is shown with a pink frame. b) Zoom of the surface water-ice budget map from Madeleine et al. (2009), with the same parameters as in panel a). c) Simulation of the past obliquity of Mars from Laskar et al. (2004).

## 6 - CONCLUSION

We characterized 2 types of UD types with different morphologies and spatial distributions. Our dating results suggest that we have 2 different glaciation phases represented by LD types and UD types, with a recent glaciation during the very late Amazonian (4.5 - 8.8 Ma) for UD types (Fig.6). To explain the presence of two different types of UD types, we propose two potential hypotheses :

- Type 1 UD types are within young craters that were formed after the glaciation responsible for LD types and are located mostly in higher latitudes and on the southeast flank of Alba Mons because these are expected to be preferential deposition zones [7].
- Type 2 UD types entirely cover lower deposits and the larger coverage is linked to the preferential deposition zones identified by Madeleine et al. (2009). Lower deposits dated by Sinha & Vijayan (2017) (10-100 Ma) were deposited within young craters.

In this study, we identified a regionally unique pattern left by at least two recent phases of glaciation. The most recent phase occurred around 5 Ma when Mars shifted to a lower mean obliquity. Our results provide additional constraints for climate model simulations and reveal the presence of low latitude near-surface ice that could be a potential resource for future human exploration.

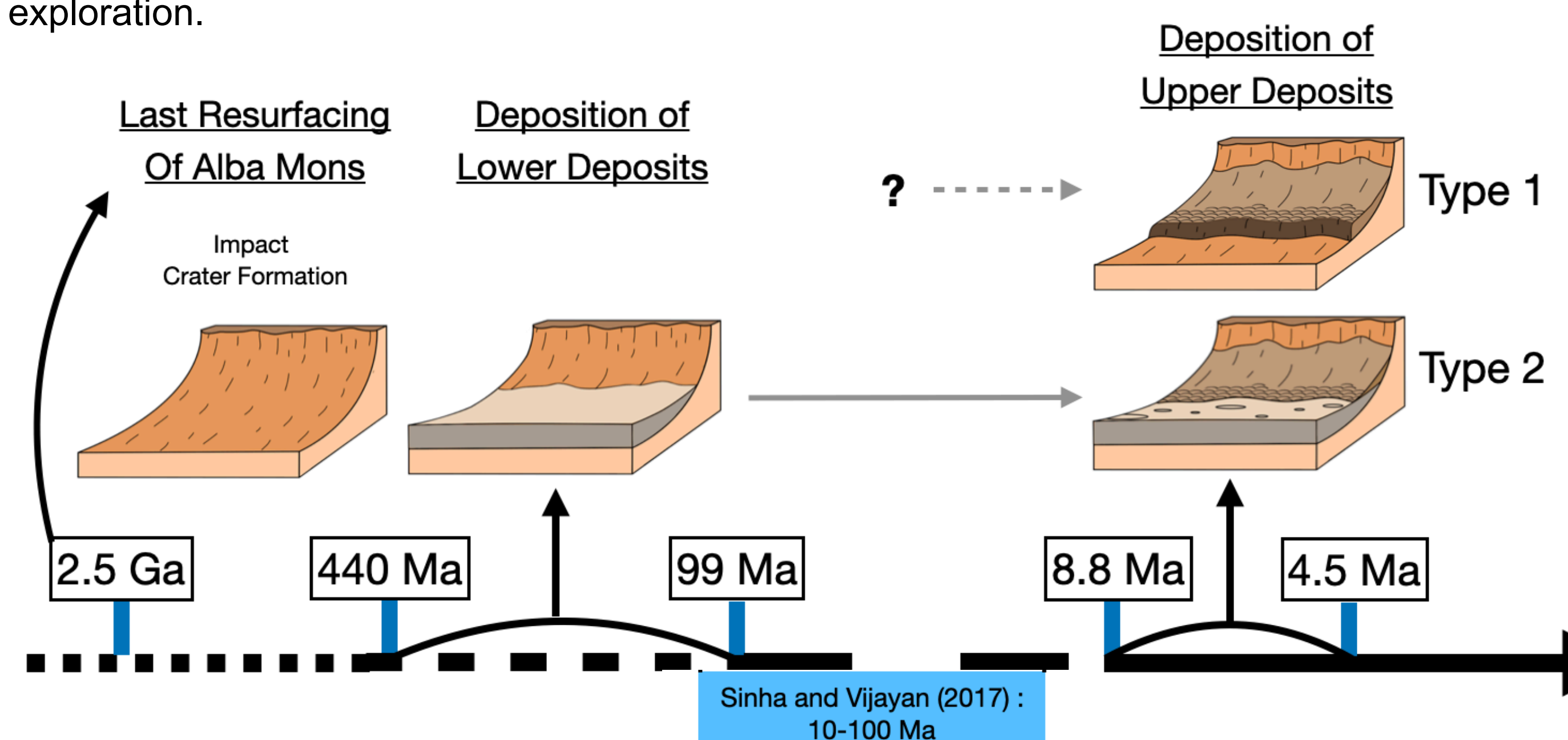


Figure 6 : Timeline of key events from our study which led to the deposition of the two types of Upper Deposits.