History & Current Inventory of Water on Mars

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Mars Science T^3

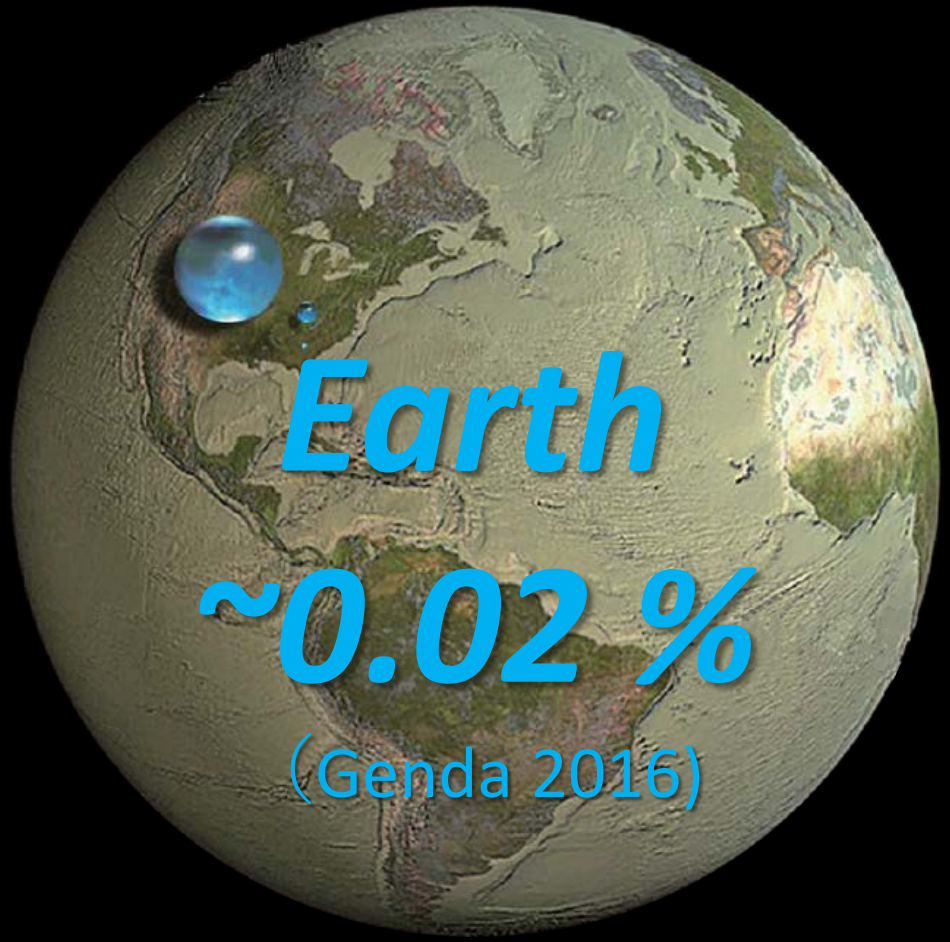
Surface Water Inventory of Mars & Earth

Mars is/was a water-rich planet

Early Mars

~0.01-0.1 %

(Kurokawa+ 2014)



Earth

~0.02 %

(Genda 2016)

東工大研究チームによる火星の水に関する研究

1. **Usui et al. (2012)**
   - 水の起源の解明

2. **Kurokawa et al. (2014, 2016, 2018)**
   - 海・大気の消失過程の解明

3. **Usui et al. (2015)**
   - 失われた海水の貯蔵層の発見

Key Question

火星の水は
Q1. どこからやってきて
Q2. いつ，どのように失われ
Q3. 現在はどこにあるのか

→ 今日の話題：散逸量と貯蔵量の進化

詳細は研究グループのHPを参照

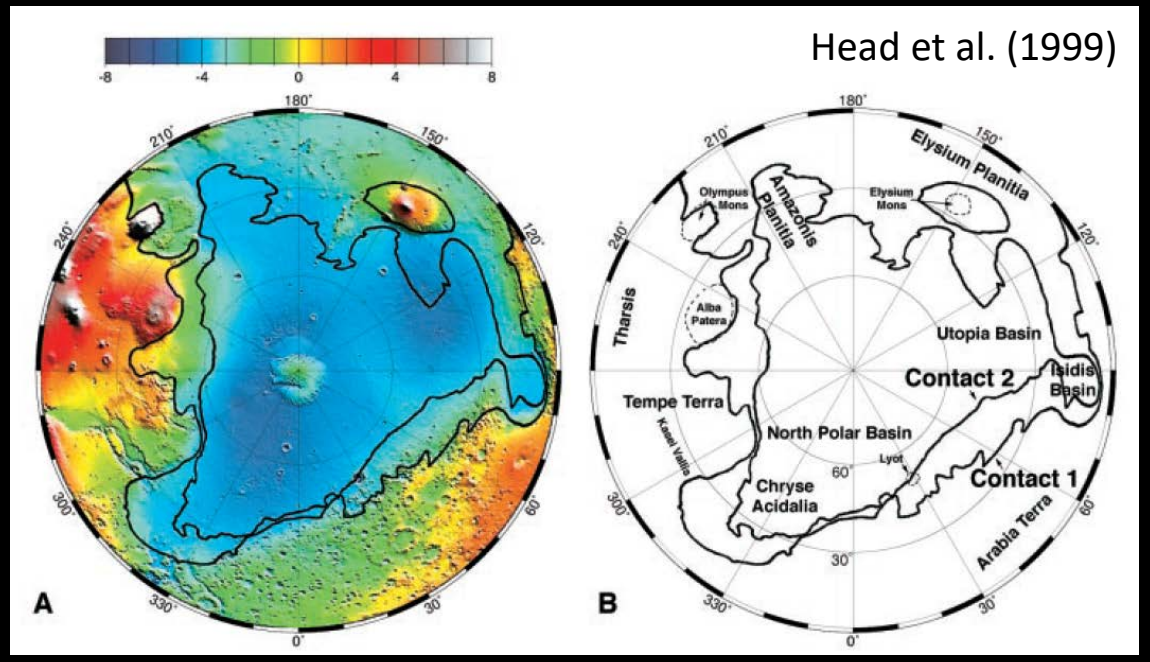
Mars Science Team of Tokyo Tech
<https://sites.google.com/site/marssciencet3/>

ESTIMATE OF SURFACE WATER BUDGET

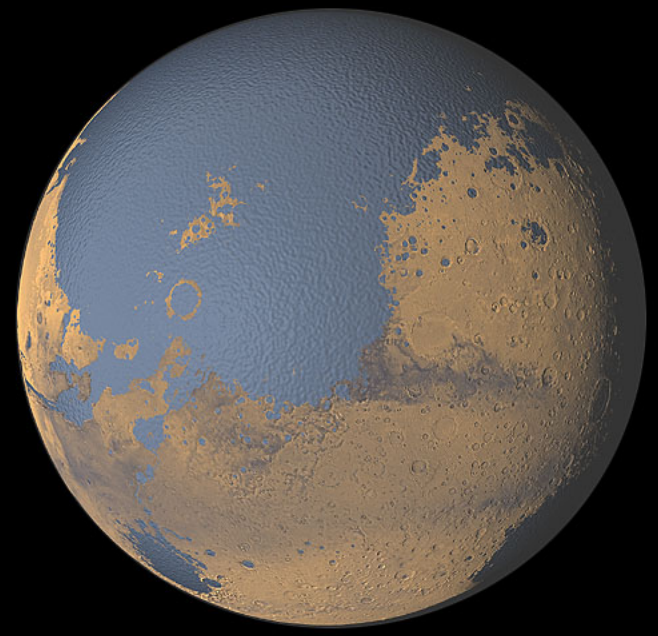
Two-fold issues on geomorphological approaches

- No geological record before ~4.2 Ga (pre-Noachian)
- No constraints on ice and subsurface-water/ice

Putative paleo-ocean shorelines in the northern hemisphere

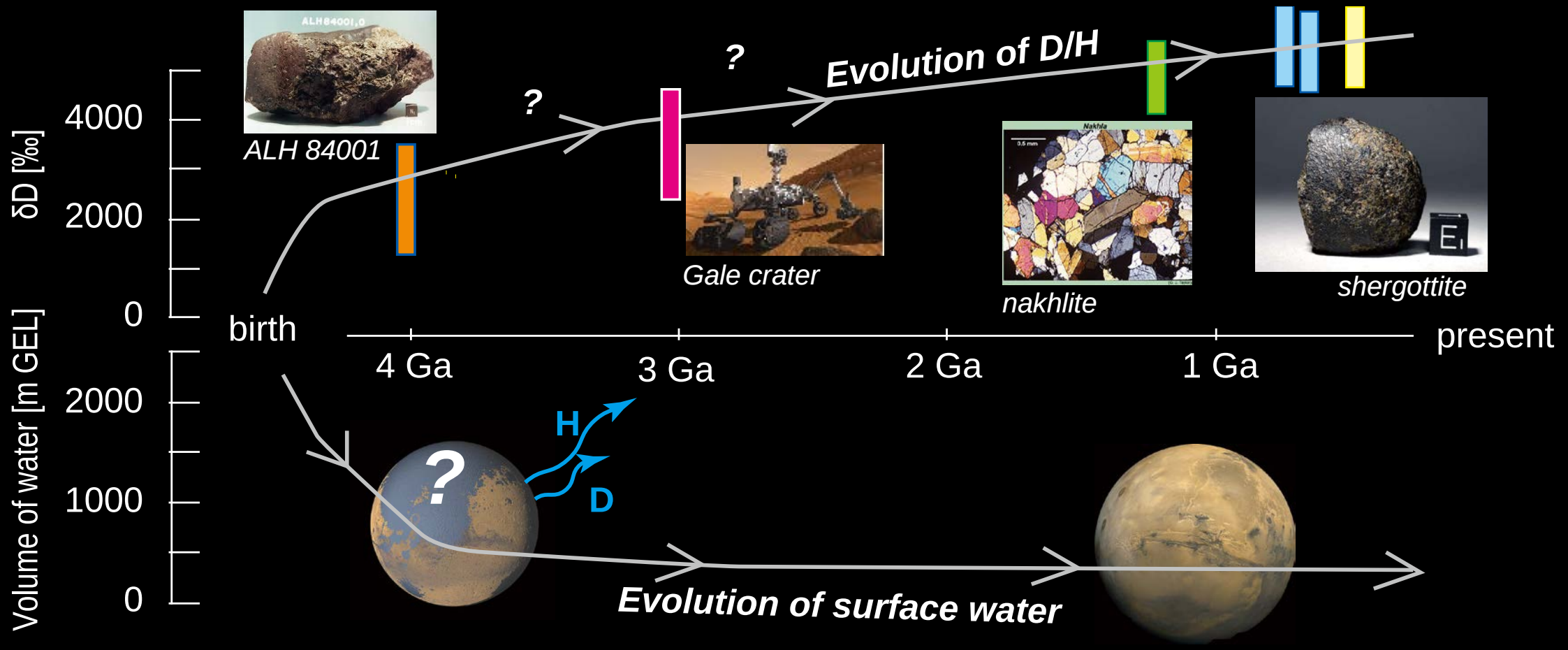


Ocean on Mars in 4 Ga？



OBJECTIVE & OUR STRATEGY

Investigate the evolution of surface water inventory based on hydrogen isotopes in rocks from Mars



SNC (MARTIAN) METEORITE

They are all “igneous”: No sedimentary rocks

Shergottite

Basalt (0.2 – 0.6 Ga)

Nakhlite

Clinopyroxenite (1.3 Ga)

Chassignite

Dunite (1.3 Ga)

MARTIAN METEORITES = IGNEOUS ROCKS

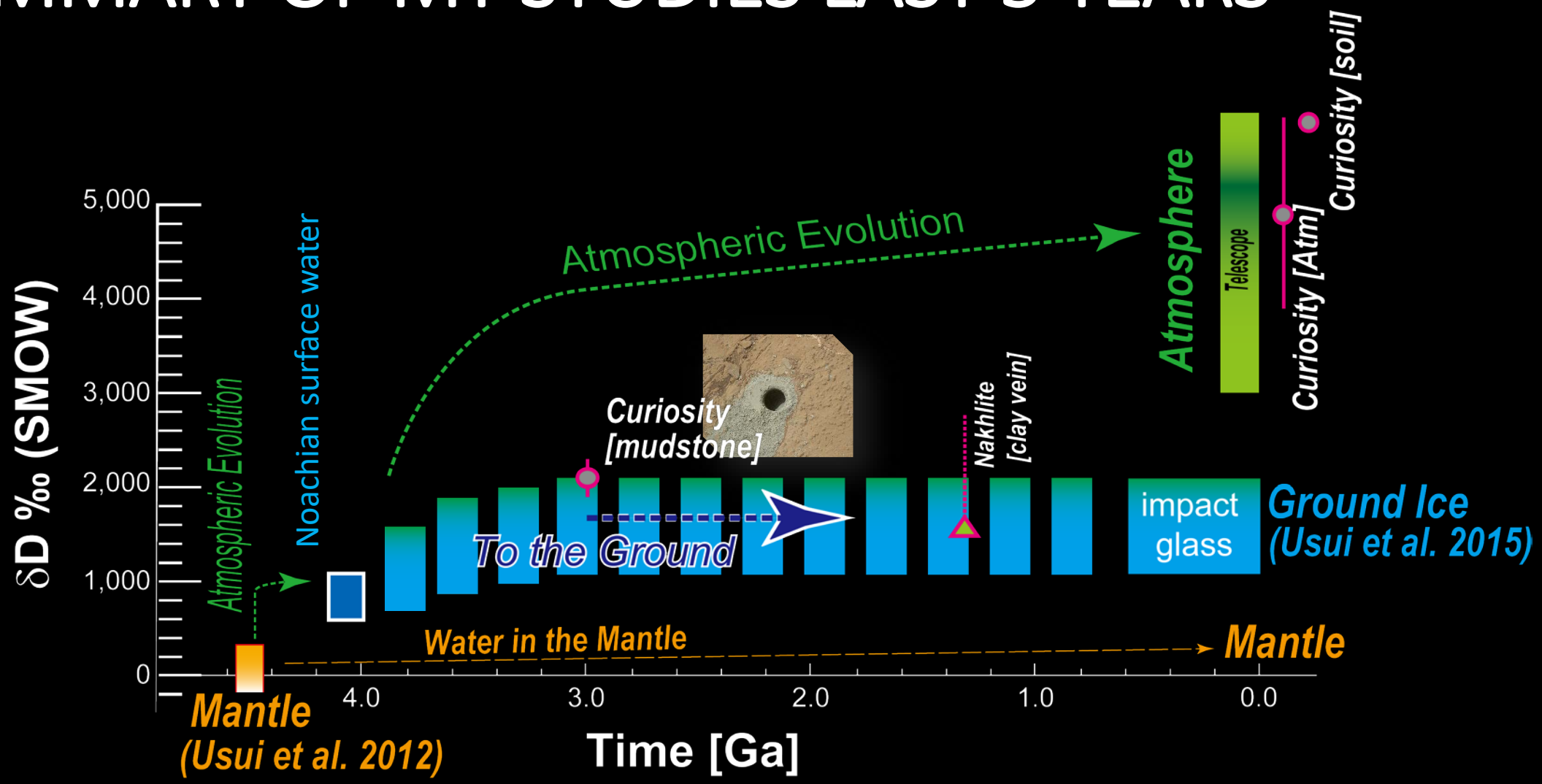
But, have a chance to incorporate surficial components

Y-980459: Martian basalt

Interaction w/ surface components

Hawaii island

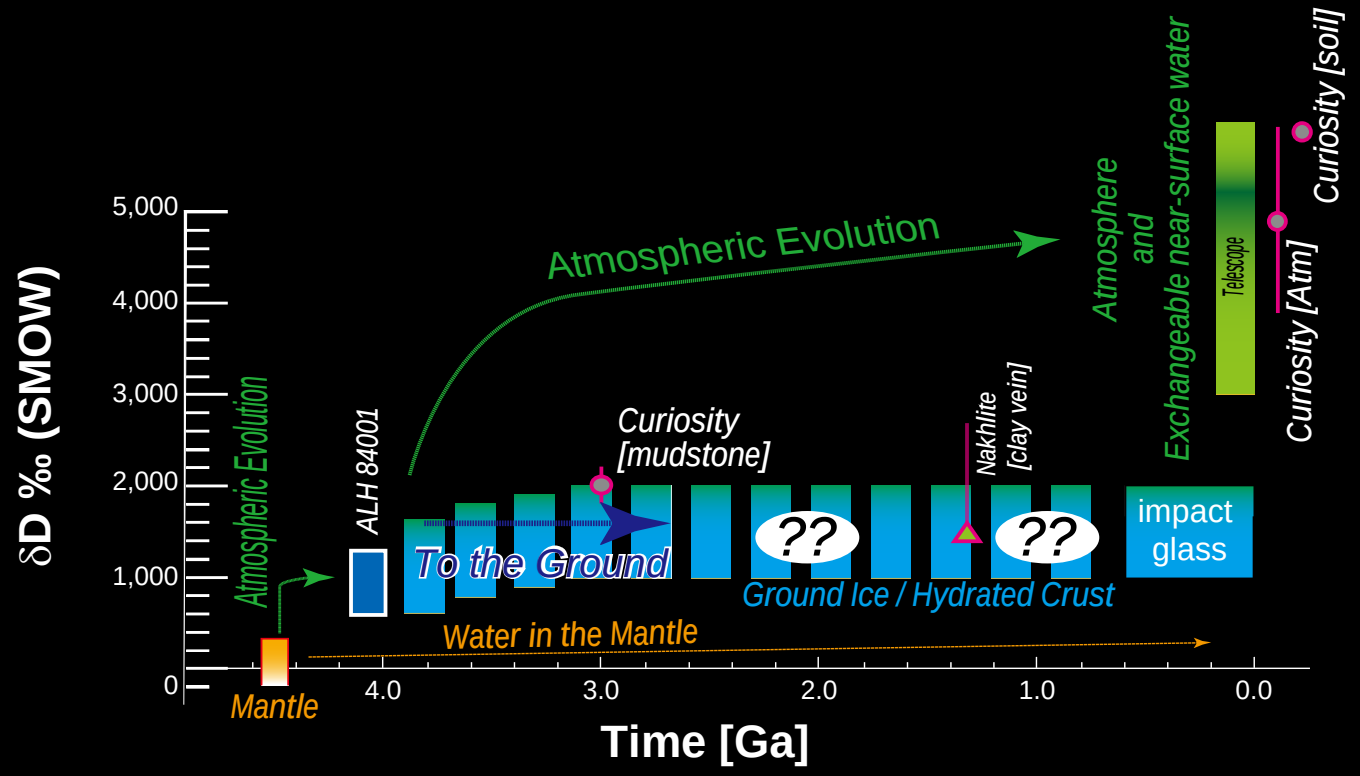
SUMMARY OF MY STUDIES LAST 5 YEARS



Usui et al. 2012, 2015, 2016; Kurokawa et al. 2014, 2016; Hallis et al. 2012; Mahaffy et al. 2015

SUMMARY OF MY STUDIES LAST 5 YEARS

Three distinct water reservoirs on Mars



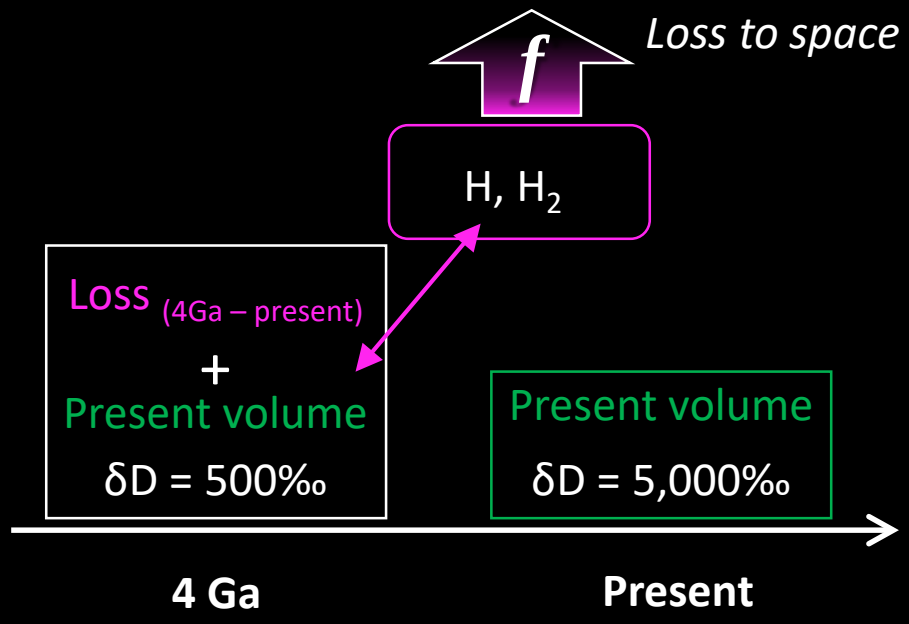
Primordial water in the mantle

Usui et al. 2012, 2015, 2016; Kurokawa et al. 2014, 2016; Hallis et al. 2012; Mahaffy et al. 2015

Water inventory at 4 Ga: *One-reservoir model*

One reservoir model based on D/H ratio provides the volume of water loss

Schematic illustration of one-reservoir hydrogen escape model (Kurokawa et al. 2014 *EPSL*)



Basic equation

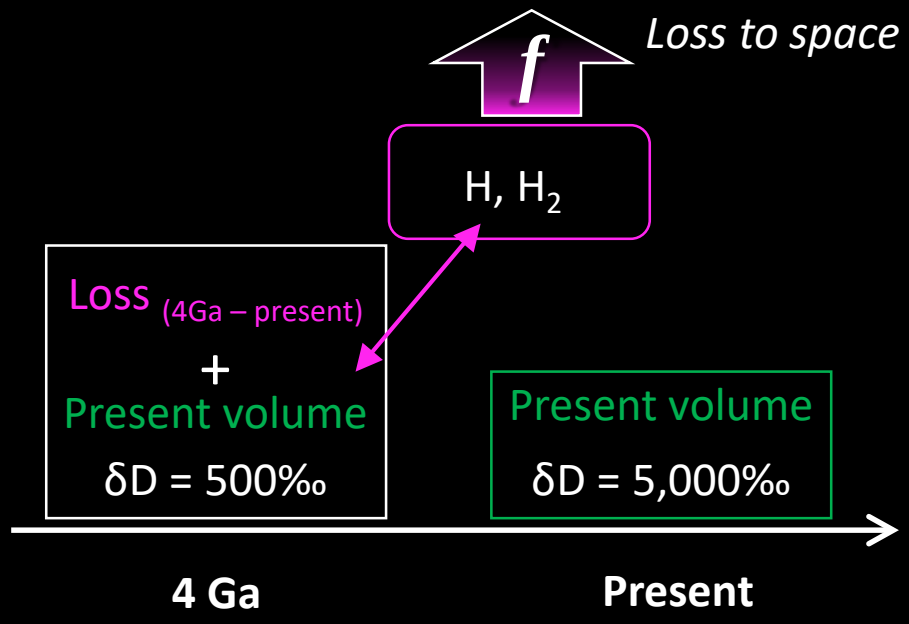
$$L_{1\to 2} = R \cdot \left[\left(\left[\frac{D}{H}\right]_1 \Big/ \left[\frac{D}{H}\right]_2 \right)^{\frac{1}{1-f}} - 1 \right]$$

- L: water loss
- R: water amount
- f: fractionation factor

Water inventory at 4 Ga: *One-reservoir model*

Two atmospheric escape regimes provide a range of realistic *f* values

Schematic illustration of one-reservoir hydrogen escape model (Kurokawa et al. 2014 *EPSL*)



Two cases for atmospheric escape regimes

Case-1: Jeans escape-limited regime

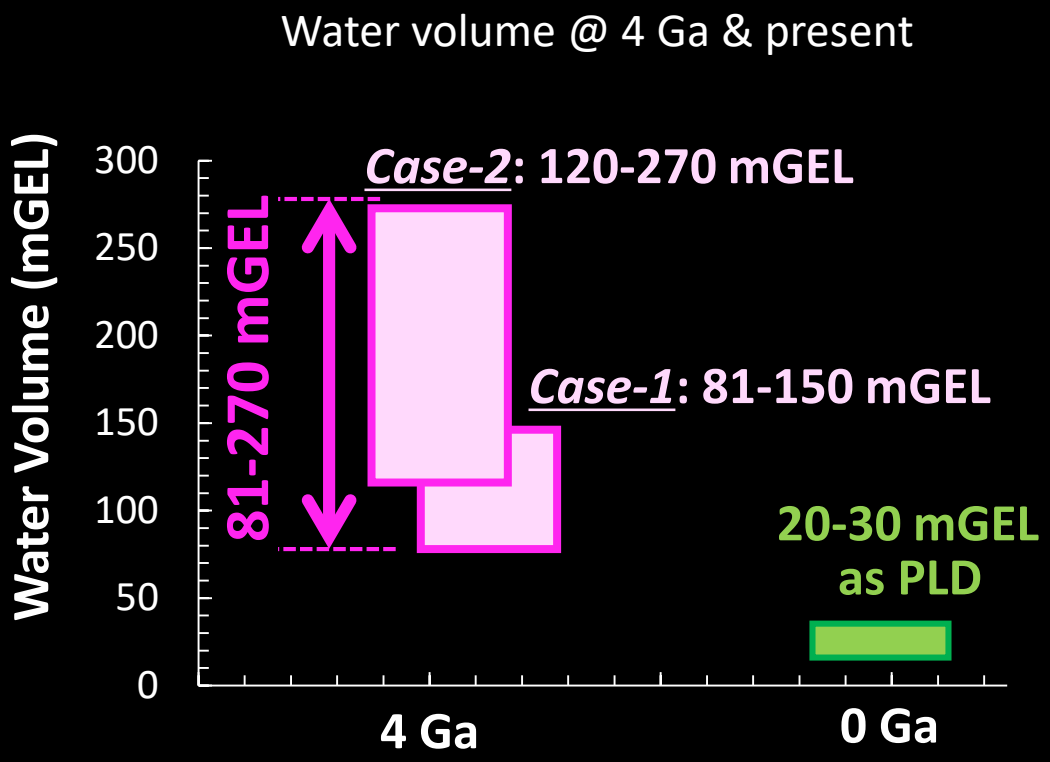
- Min. *f* = 0.016 (Krasnopolsky, 2000)
- represent the current Mars condition

Case-2: Diffusion-limited regime

- Max. *f* = 0.33 (Kurokawa et al. 2016)
- approximate ancient Mars conditions

Water inventory at 4 Ga: *One-reservoir model*

Case-1 & -2 yield the water inventory lower- & upper-bounds at 4 Ga



**GEL = Global Equivalent Layer*

Two cases for atmospheric escape regimes

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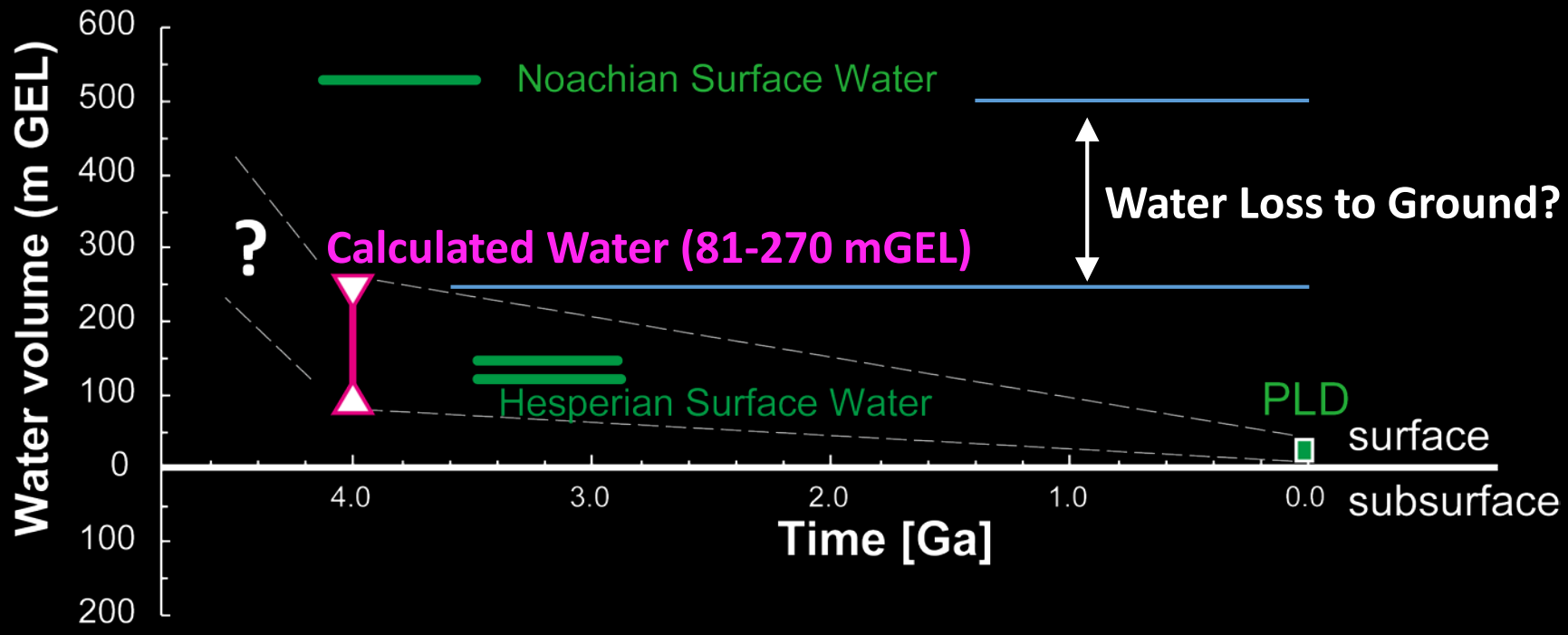
evolution of surface-subsurface water

Calculated water volume ≈ Hesperian ocean << Noachian ocean



evolution of surface-subsurface water

Paleo-”oceans” were probably sourced from the subsurface water

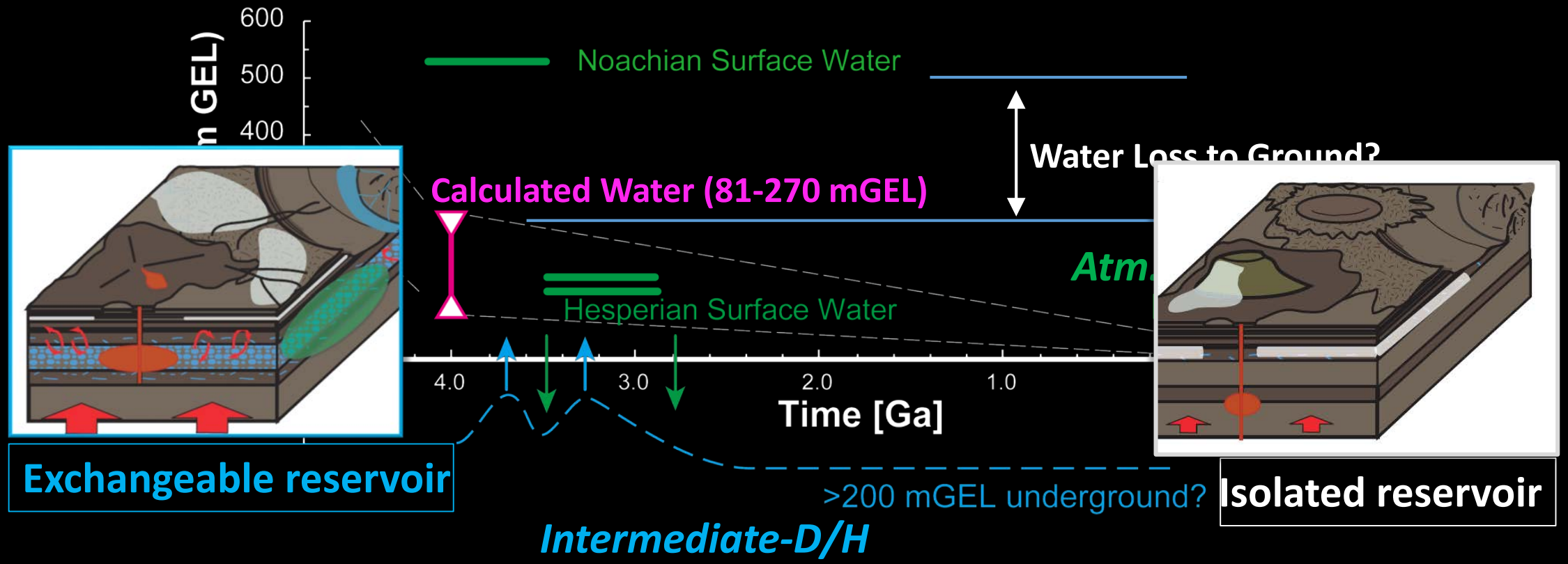
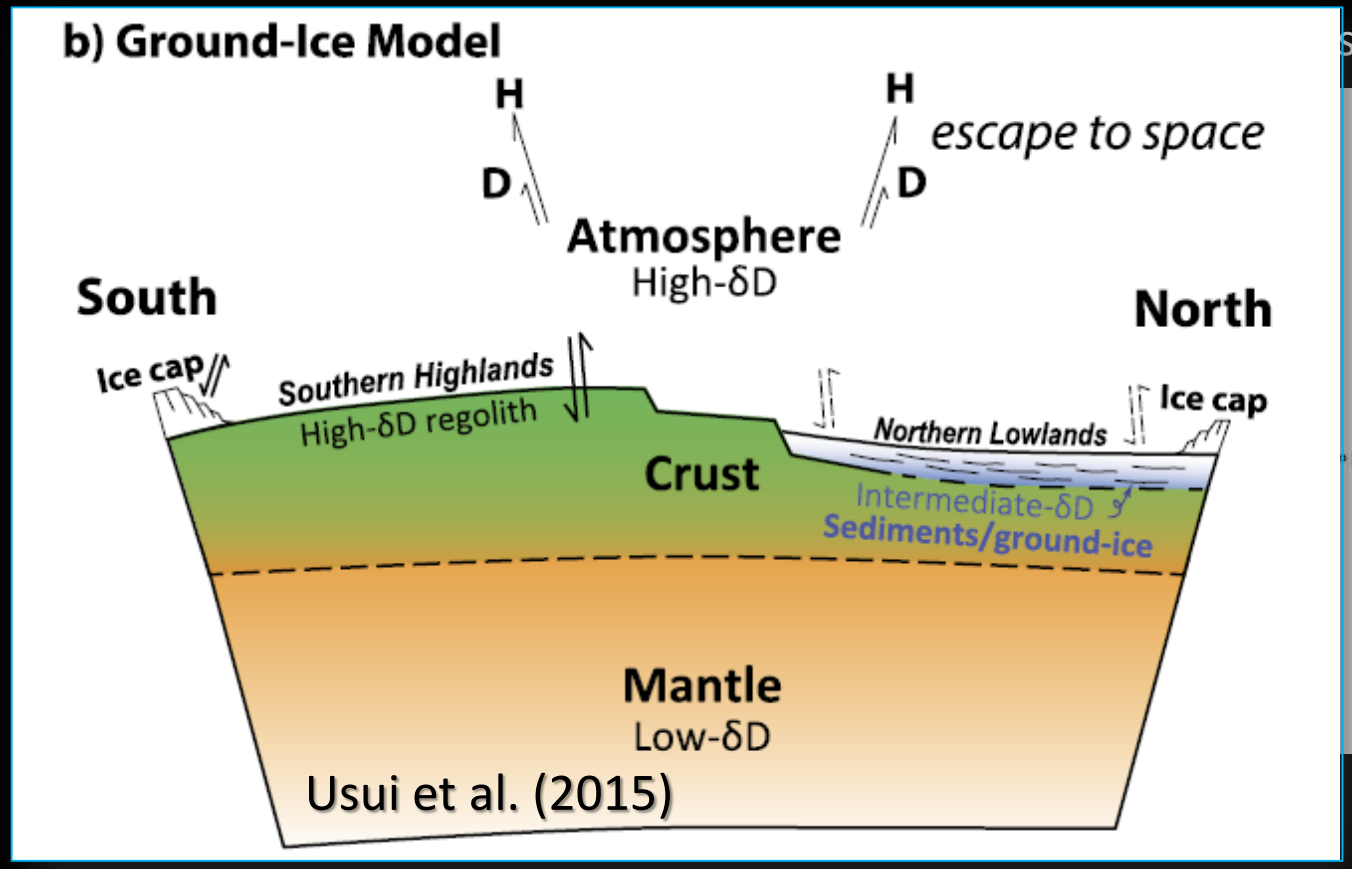


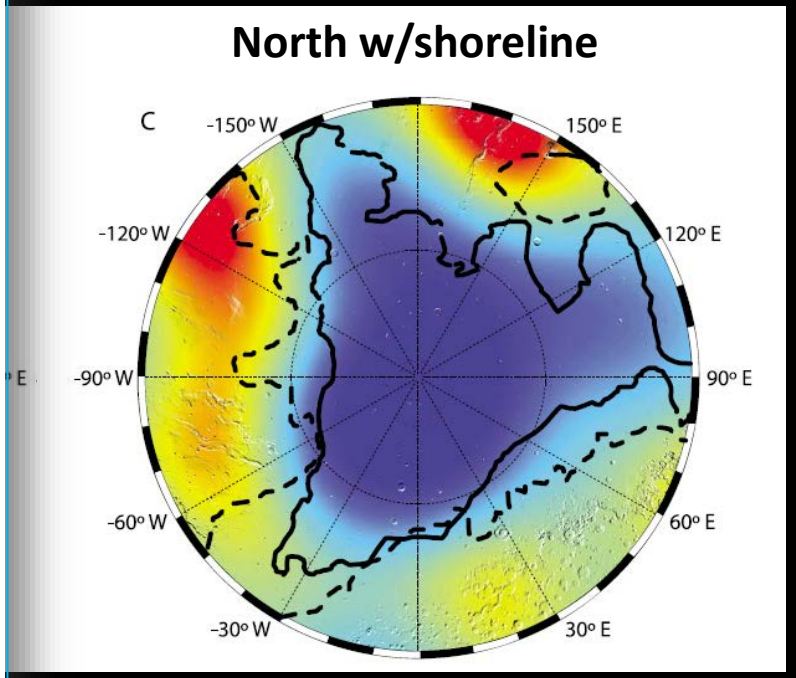
Illustration from Ehlmann et al. (2011)

RADAR SOUNDER OBSERVATION

Possible existence of ground ice in the northern lowlands



s Express (Mouginot et al. 2012)



Conclusions

Based on *in situ* hydrogen isotope analyses of Martian meteorites, my team reported convincing evidence:

- The Martian mantle has retained a primordial hydrogen isotope composition similar to water on Earth
- Using the one-reservoir model (Kurokawa et al. 2014) and our new D/H data (500-1000‰ @4 Ga), we obtained water inventory lower- and upper-bounds (81-270 mGEL) at 4 Ga.
- The calculated range of water inventory at 4 Ga is distinctly lower than the geological estimates based on the volumes of paleo-oceans (e.g., ~550 mGEL [Di Achille & Hynek, 2010]).
- This difference supports our hypothesis (Usui et al. 2015) that a part of Noachian surface water has been sequestered underground over geologic time and is a source of the intermediate D/H reservoir.
- The Hesperian surface water might have been sourced from this subsurface reservoir.