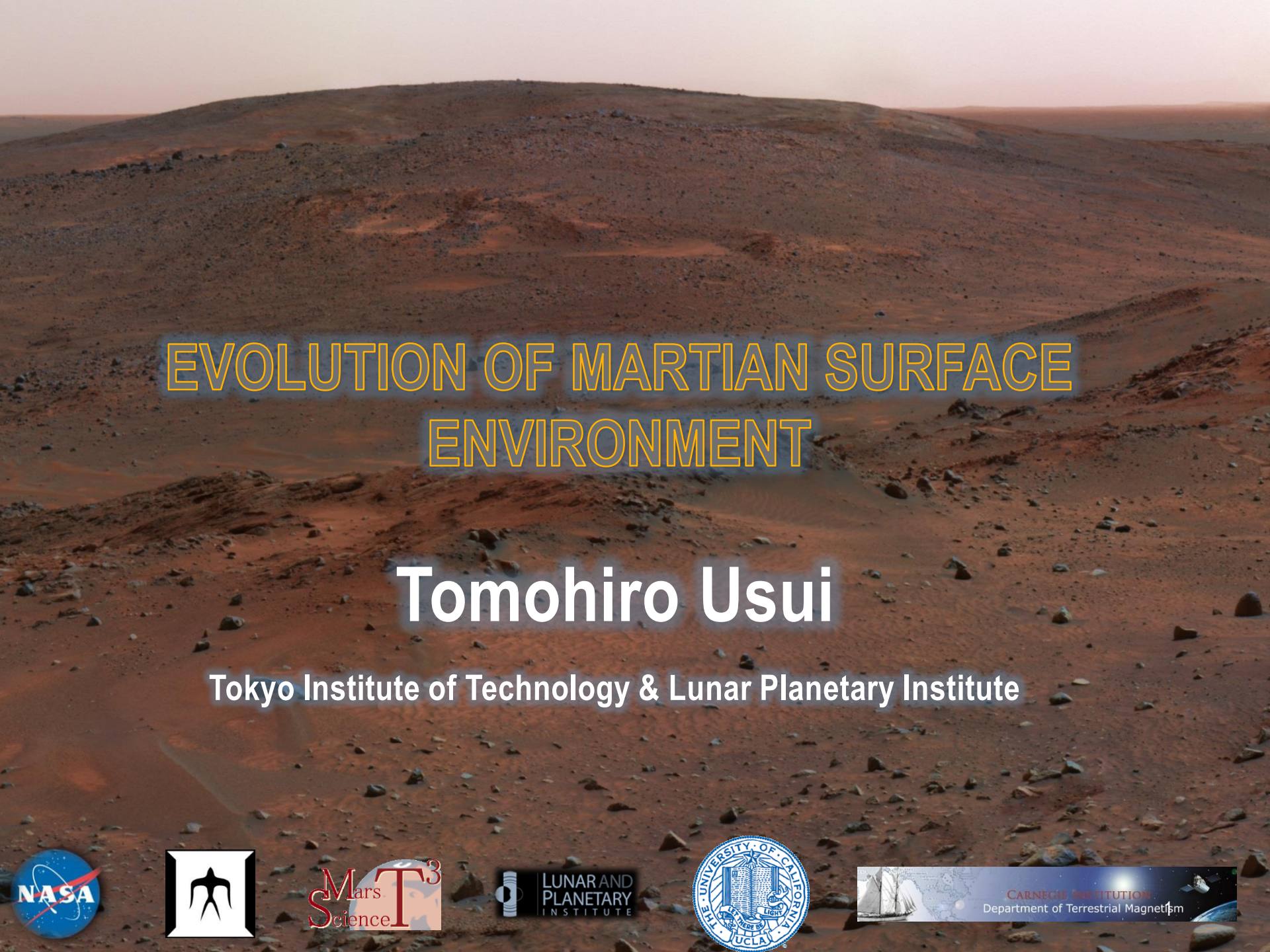


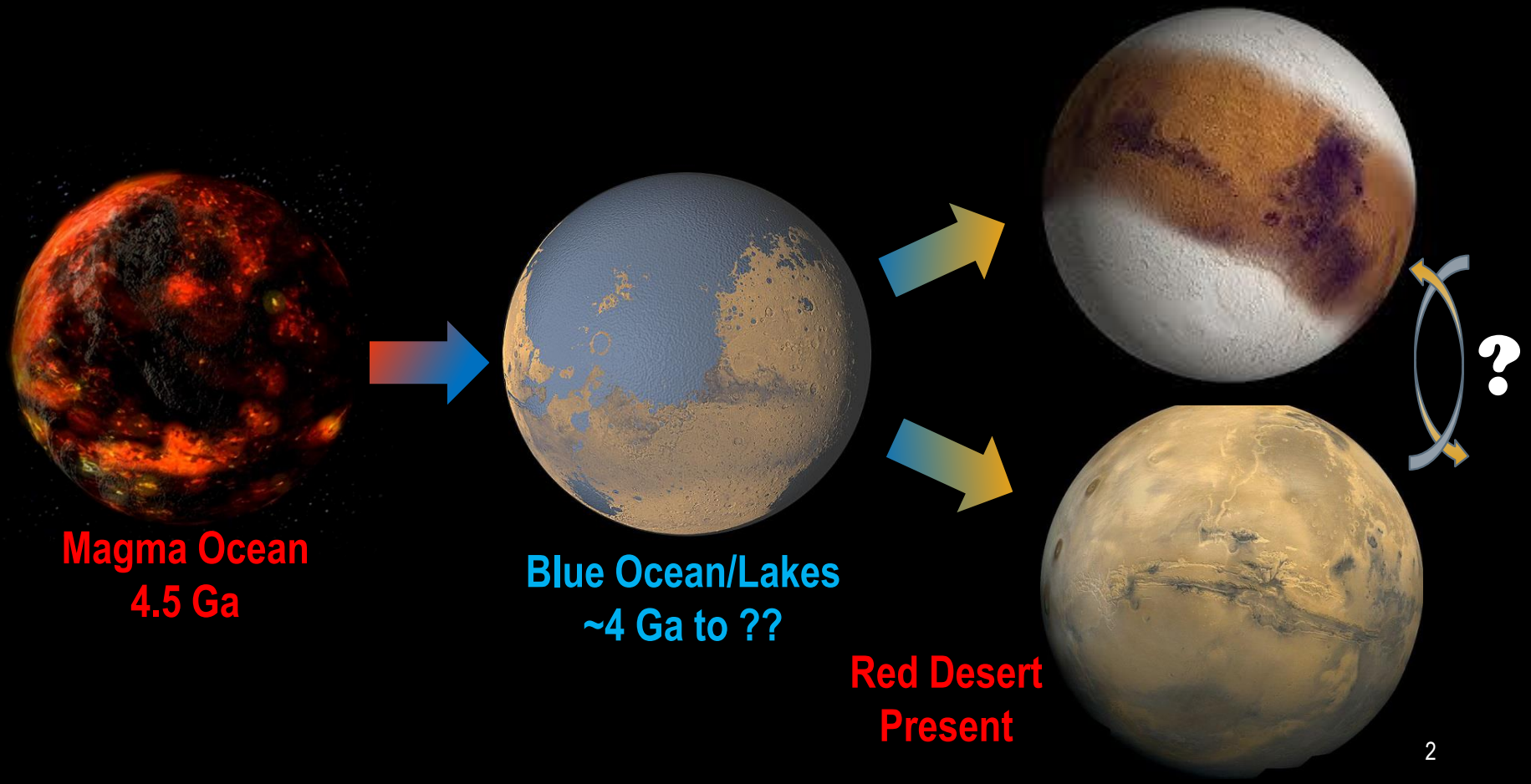
EVOLUTION OF MARTIAN SURFACE ENVIRONMENT

Tomohiro Usui

Tokyo Institute of Technology & Lunar Planetary Institute

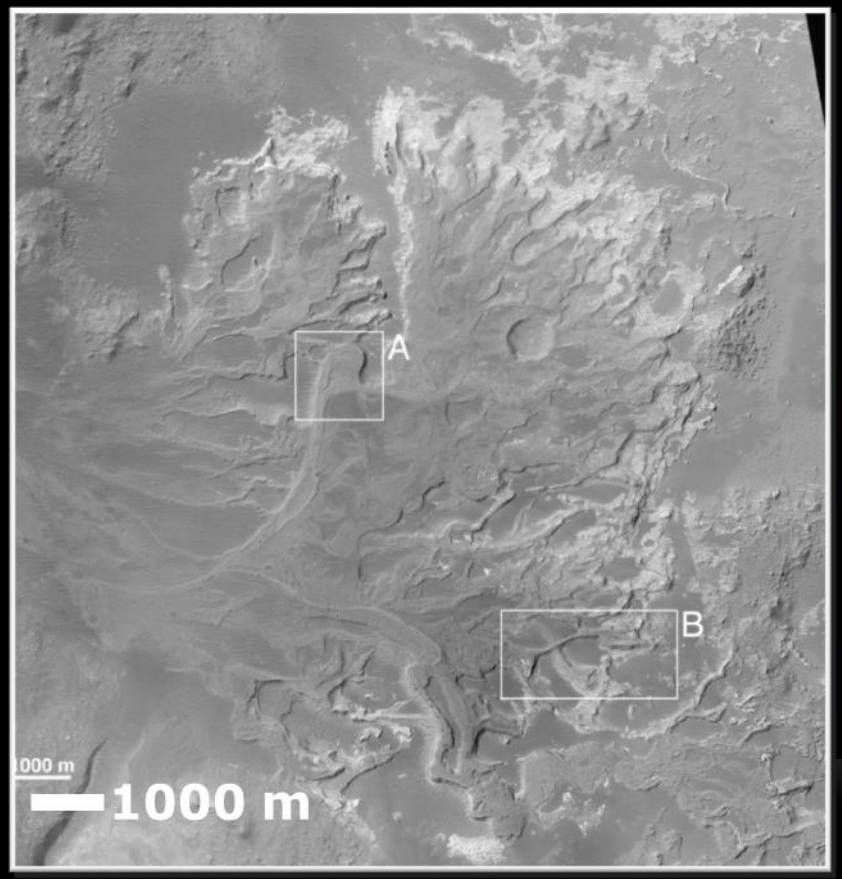
BLUE, RED & WHITE MARS

- Dramatic climate change through the history…



GEOLOGIC RECORD: *Morphology*

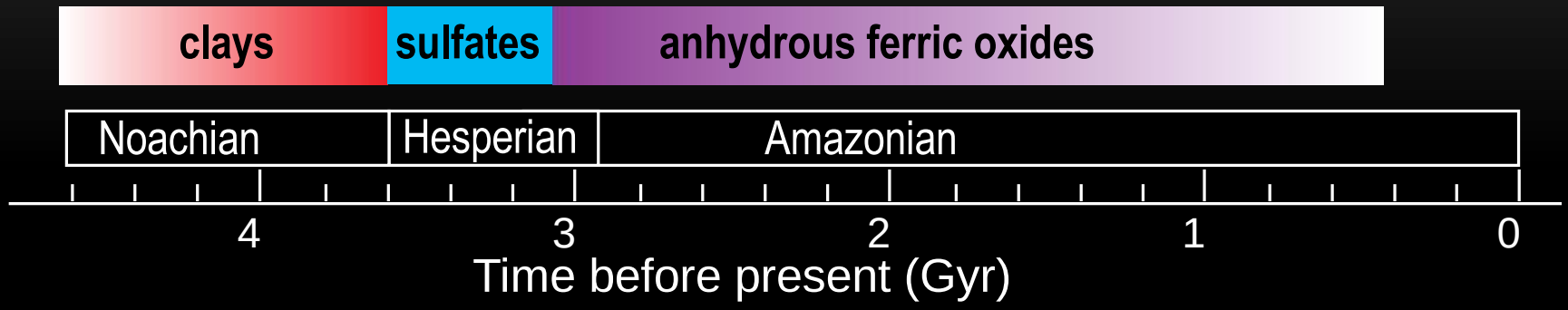
Fluvial Activity



By Mars Global Surveyor

By Mars Reconnaissance Orbitor

GEOLOGIC RECORD: *Mineralogy*



Red: clays, blue: sulfates, yellow: other hydrated minerals (Not ID)

By OMEGA/Mars Express [*Bibring et al.* 2006]

GEOLOGICAL & GEOCHEMICAL APPROACHES

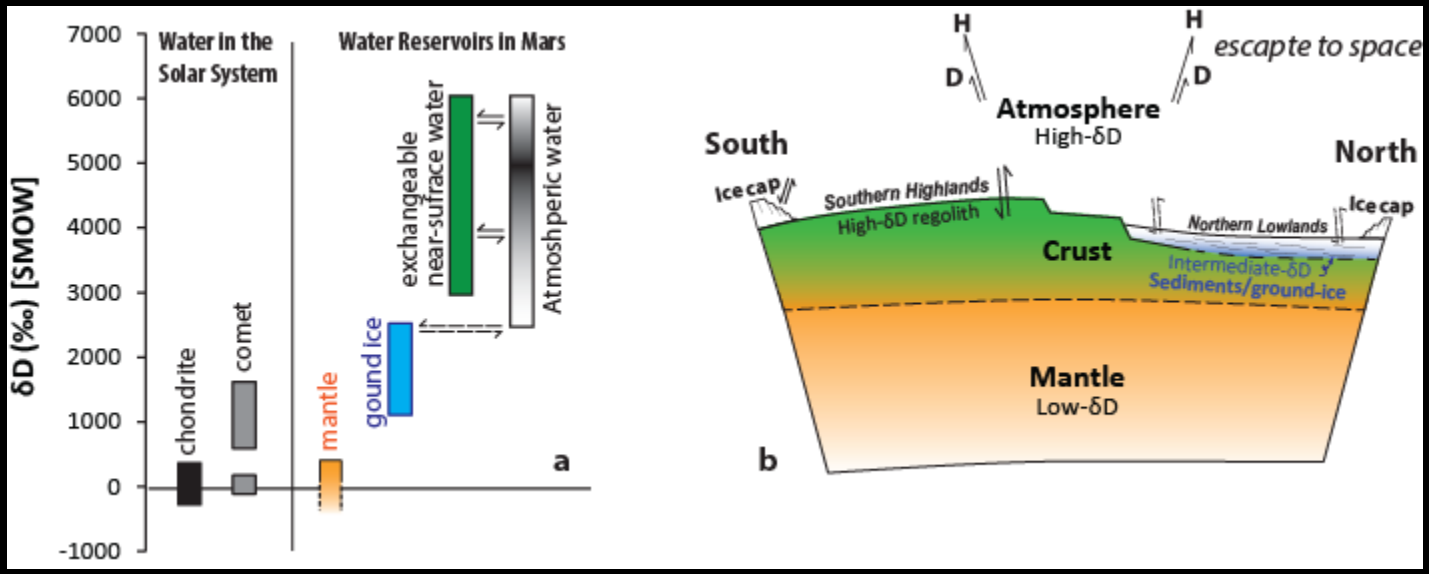
- **Unfold "integrated" historical records in rocks**
- **Mars is only the planet for which we have rocks samples!**

Young basalts: ~0.2-0.6 Ga

Old cumulate : 4.1 Ga, w/ surface alteration

EVIDENCE FROM HYDROGEN ISOTOPES IN METEORITES FOR MASSIVE GROUND ICE ON MARS

Tomohiro Usui et al. (submitted)



ATMOSPHERIC EVOLUTION & D/H RESERVOIRS

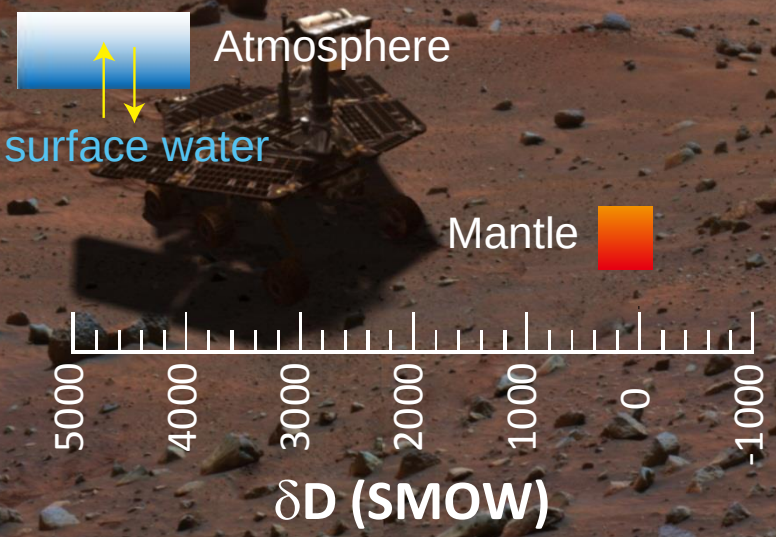
Significant D/H fractionation among martian volatile reservoirs

Atmospheric composition

isotope	Δ [terrestrial]	Lost to space
D/H	**~5**	**60-74 %**
$^{38}Ar/^{36}Ar$	1.3	50-90 %
$^{13}C/^{12}C$	1.05-1.07	50-90 %
$^{15}N/^{14}N$	1.7	90 %
$^{18}O/^{16}O$	1.025	25-50 %

Jakosky & Phillips [2001]

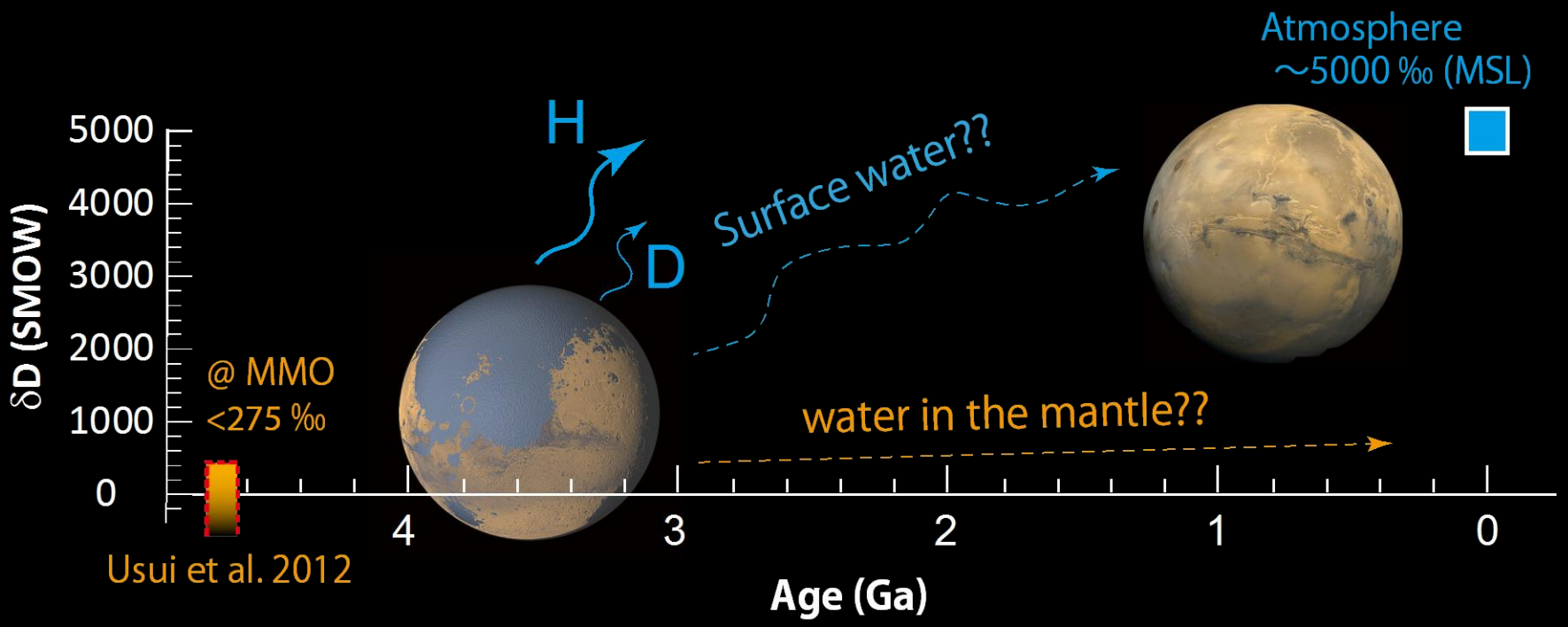
D/H reservoirs on Mars



Modified after Usui et al. [2012]

MY STRATEGY & APPROACHES

- Constrain the histories of martian hydrosphere/atmosphere by tracing the evolution of hydrogen isotopic compositions recorded by martian meteorites



SAMPLES: ***Martian basalts***

Martian basaltic meteorites

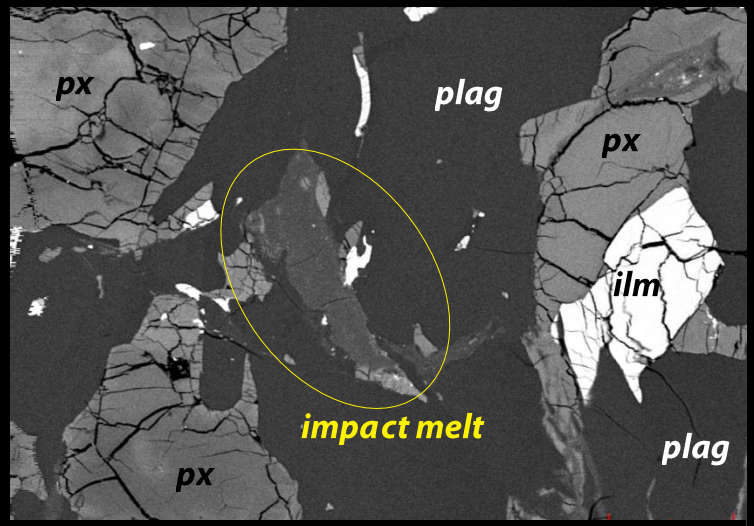
Interaction w/ surface components

Hawaii island

TARGETS: impact melt & Melt inclusion

Impact melt

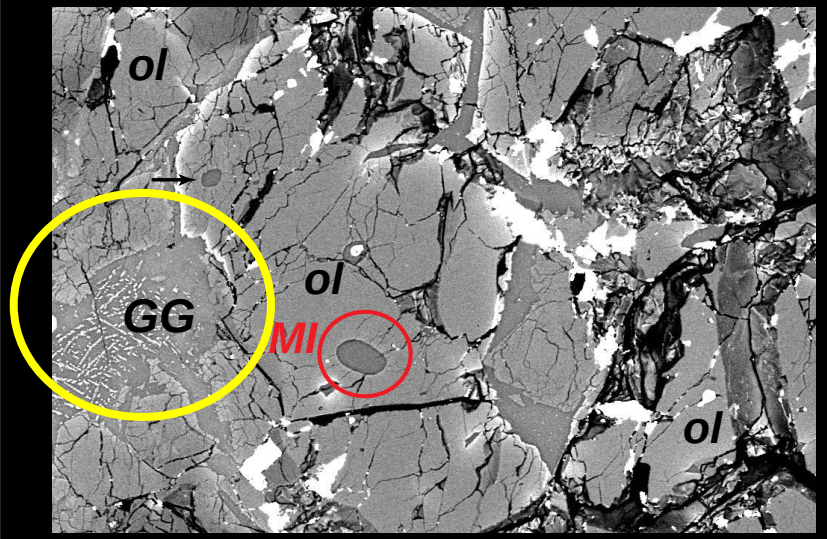
- Post-erupted volatiles
- Surficial and/or atmospheric volatile reservoirs



BSE image of EETA79001

Melt inclusion

- Pre-erupted volatiles
- Magmatic waters in the deep mantle/crust

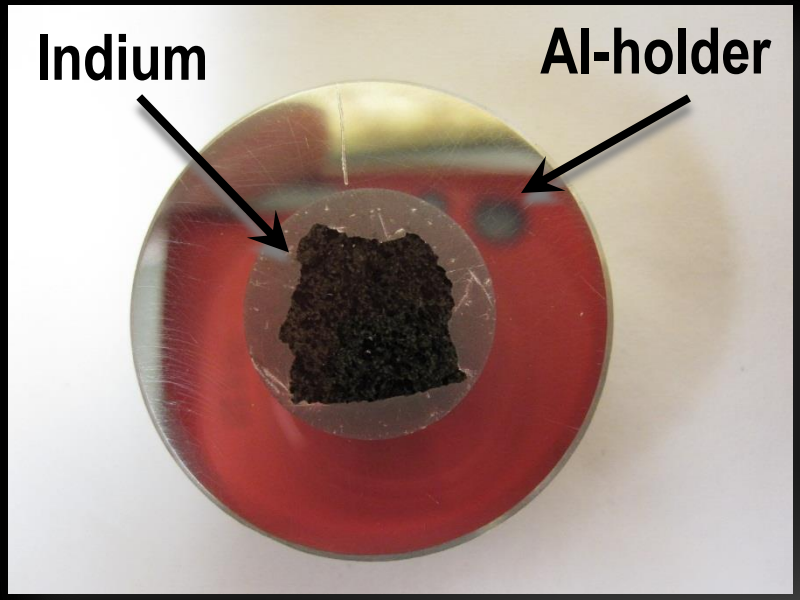


BSE image of Y980459

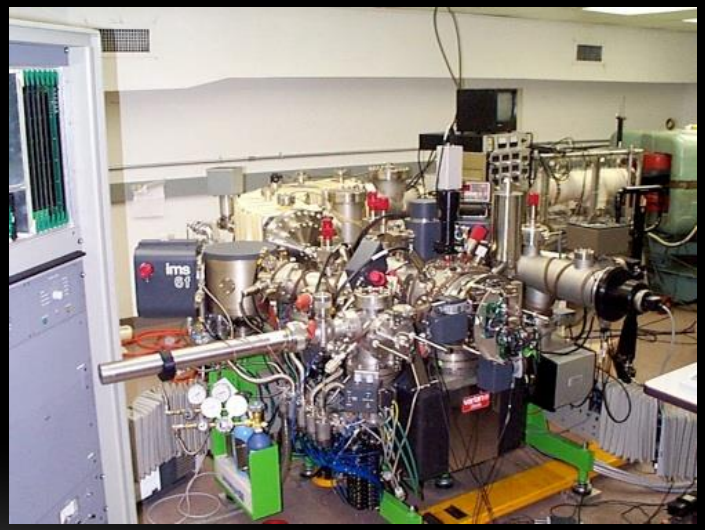
LOW-CONTAMINATION, *IN-SITU* ANALYSIS

SIMS: Secondary Ion Mass Spectrometry

- Embedded in **liquid indium** while under vacuum



- Analysis under high-vacuum condition （<8x10^{-10} torr)

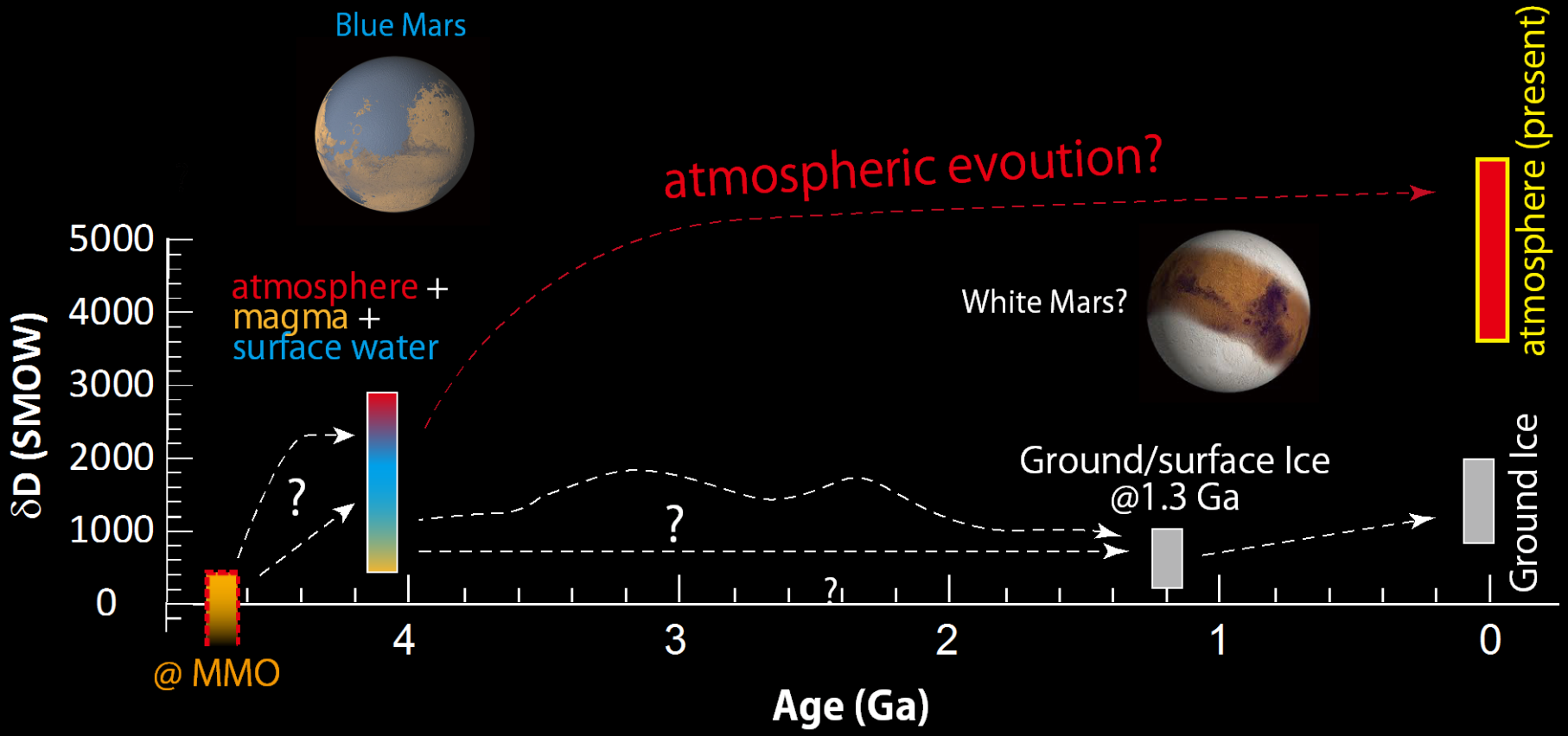


Cameca-6f at DTM, CIW

ISOTOPIC RESULTS

- **Two distinct water-ice reservoirs on present Mars:**

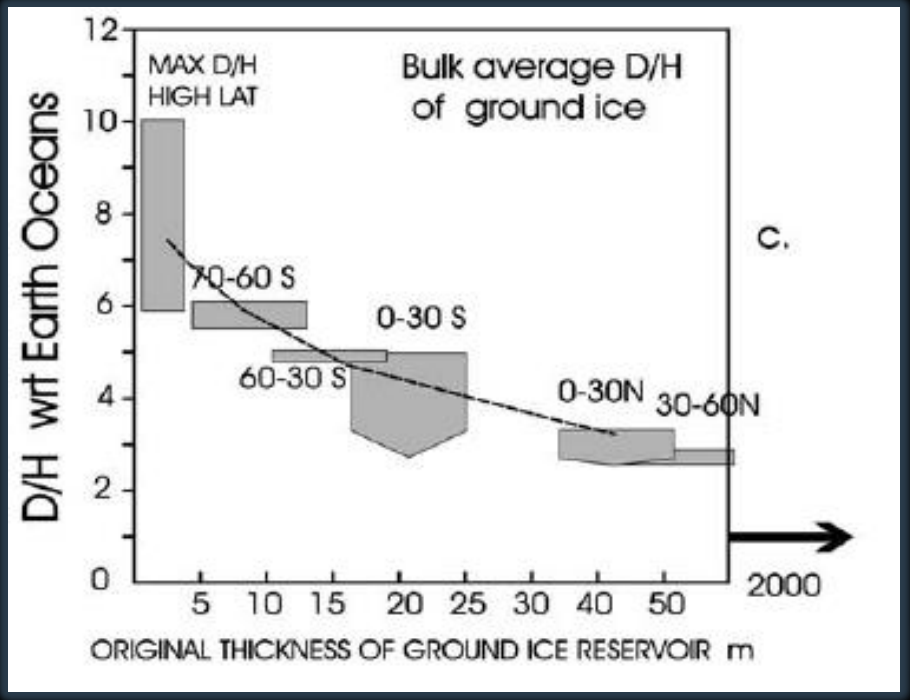
  Atmosphere & **Surface/Sub-surface Ice**



Usui et al. (2012, submitted), Kurokawa et al. (submitted)

NON-ATMOSPHERIC, INTERMEDIATE D/H WATER RESERVOIR

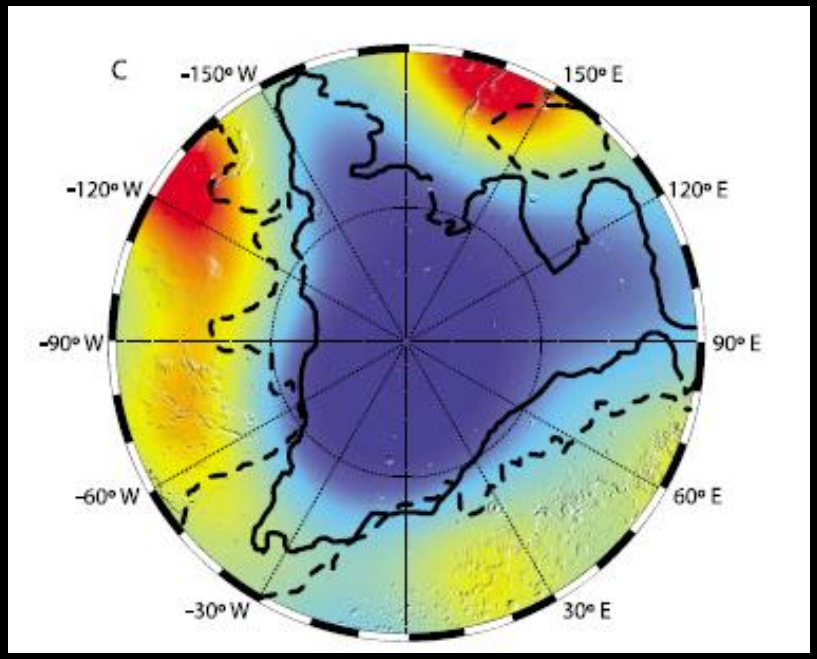
- **Massive ground ice:** Thickness of >30 m can preserve a δD value of <2000 ‰ over a geological extended period of time (~3×10^9 year)

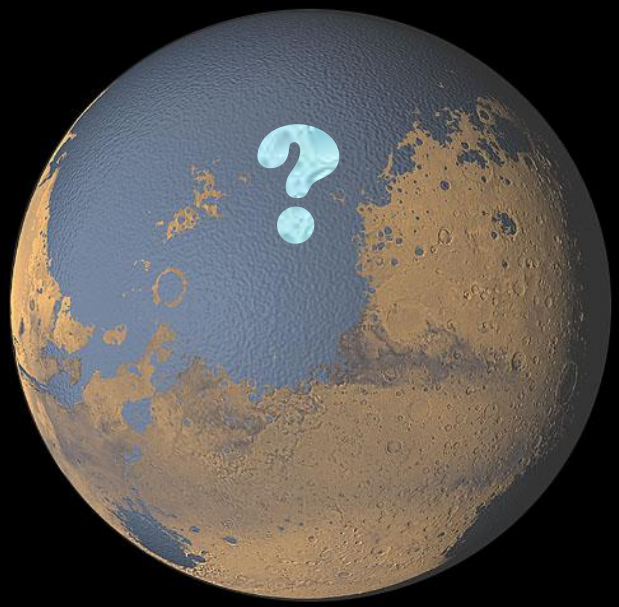


Fisher et al. (2008)

RADAR SOUNDER OBSERVATION

- **Presence (?) of sub-surface ice in the northern lowlands**
  - Low dielectric constant (ε = ~3) indicate pure water-ice





Dielectric map near the N-pole by Mars Express
Mouginot et al. (2012)

CONCLUSIONS

- Mars has experienced the dramatic climate changes: from wet & warm to cold & dry.

- The historical evolution of martian surface environments are recorded in rocks (meteorites) as geologic/geochemical signs.

- Hydrogen isotope analyses of martian meteorites provide evidence for the existence of massive ground-ice that has existed relatively intact over geologic time.