Hypotheses for Near-Surface Exchange of Methane on Mars

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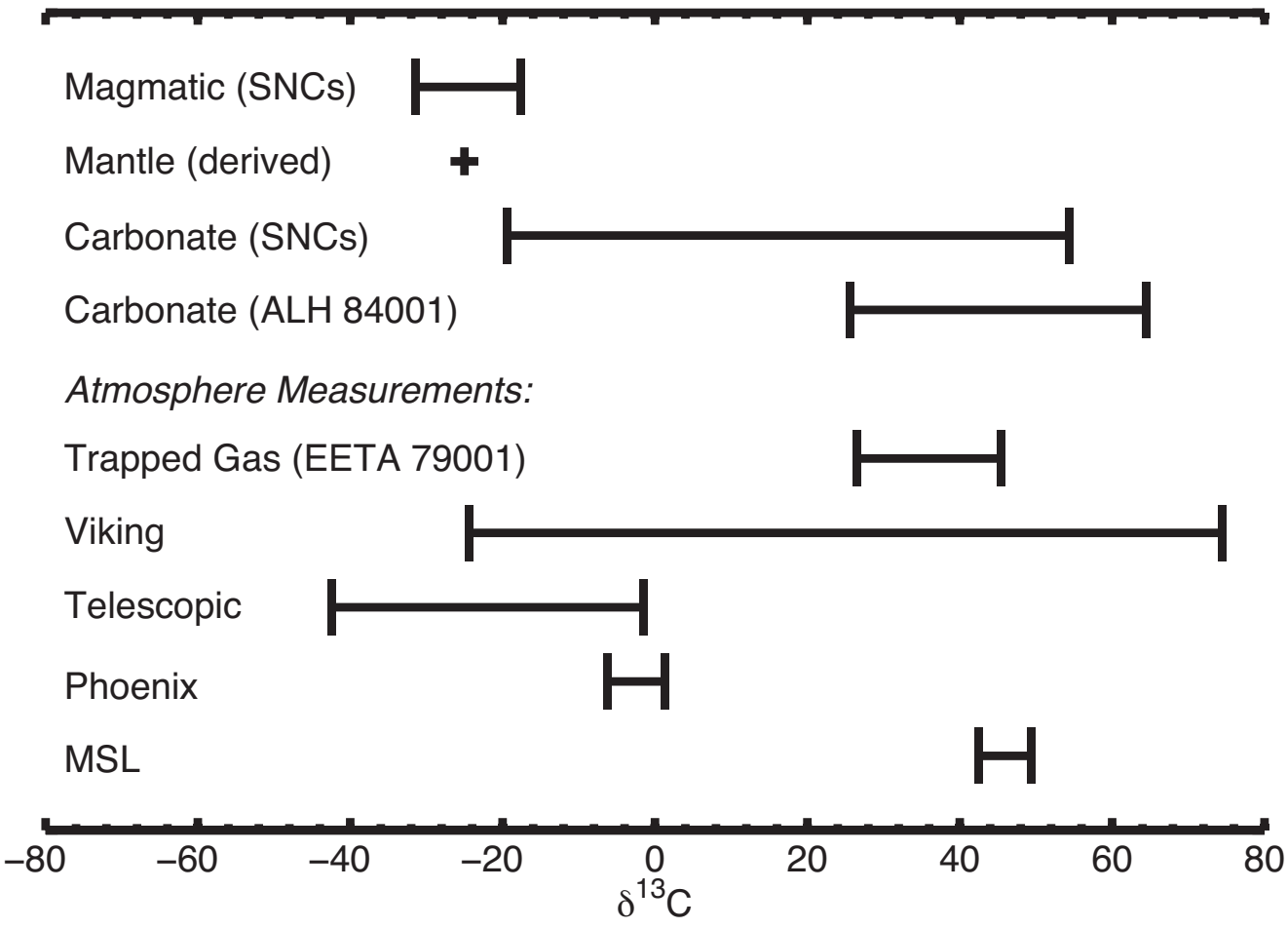
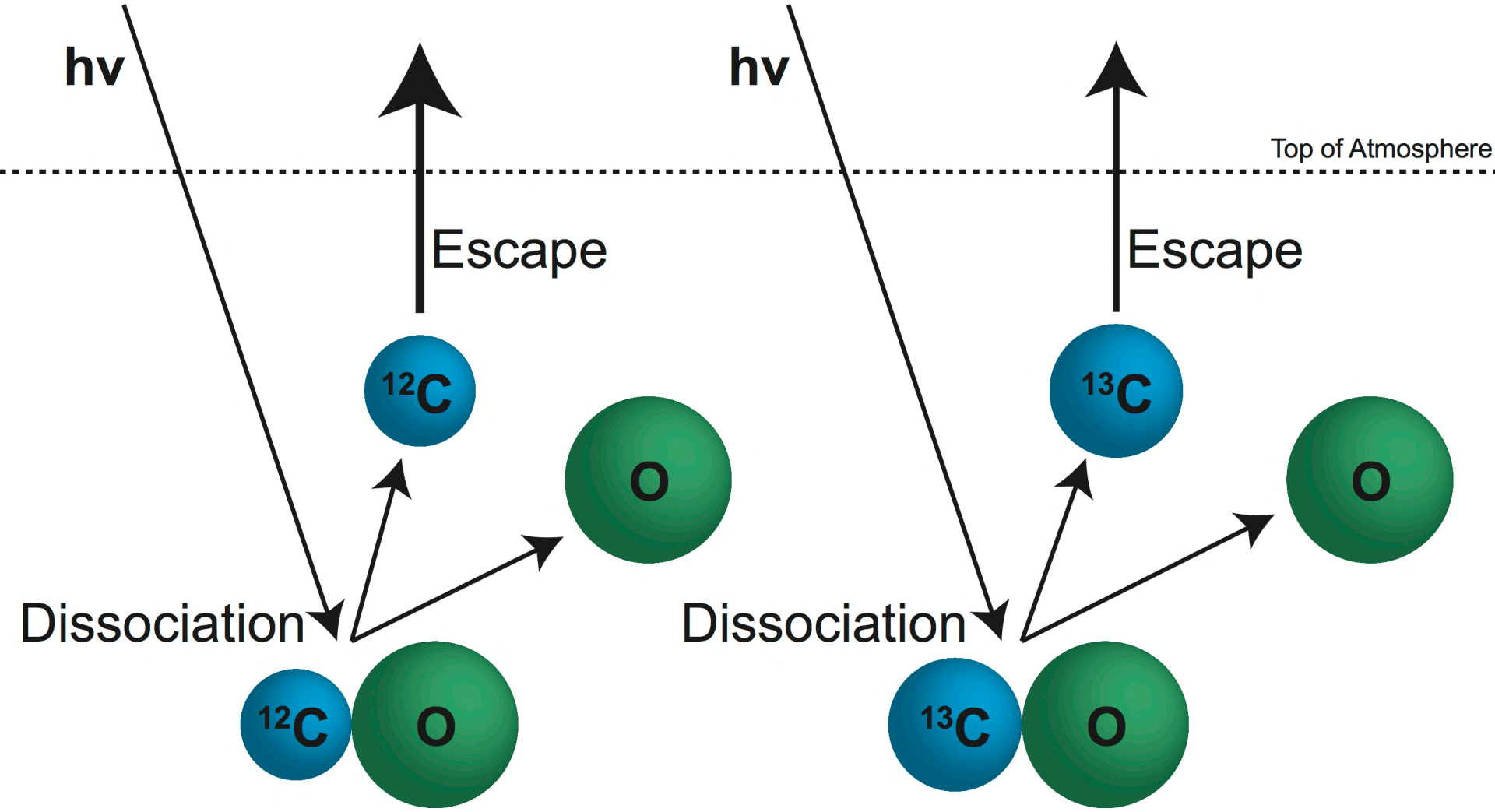
Evidence of Profound Evolution of Mars Atmosphere



$$\delta^{13}\mathrm{C} \equiv \frac{^{13}\mathrm{C}/^{12}\mathrm{C} - (^{13}\mathrm{C}/^{12}\mathrm{C})_{\mathrm{standard}}}{(^{13}\mathrm{C}/^{12}\mathrm{C})_{\mathrm{standard}}} \times 1000$$

Hu et al. 2015c

Carbon Escape via CO Photodissociation



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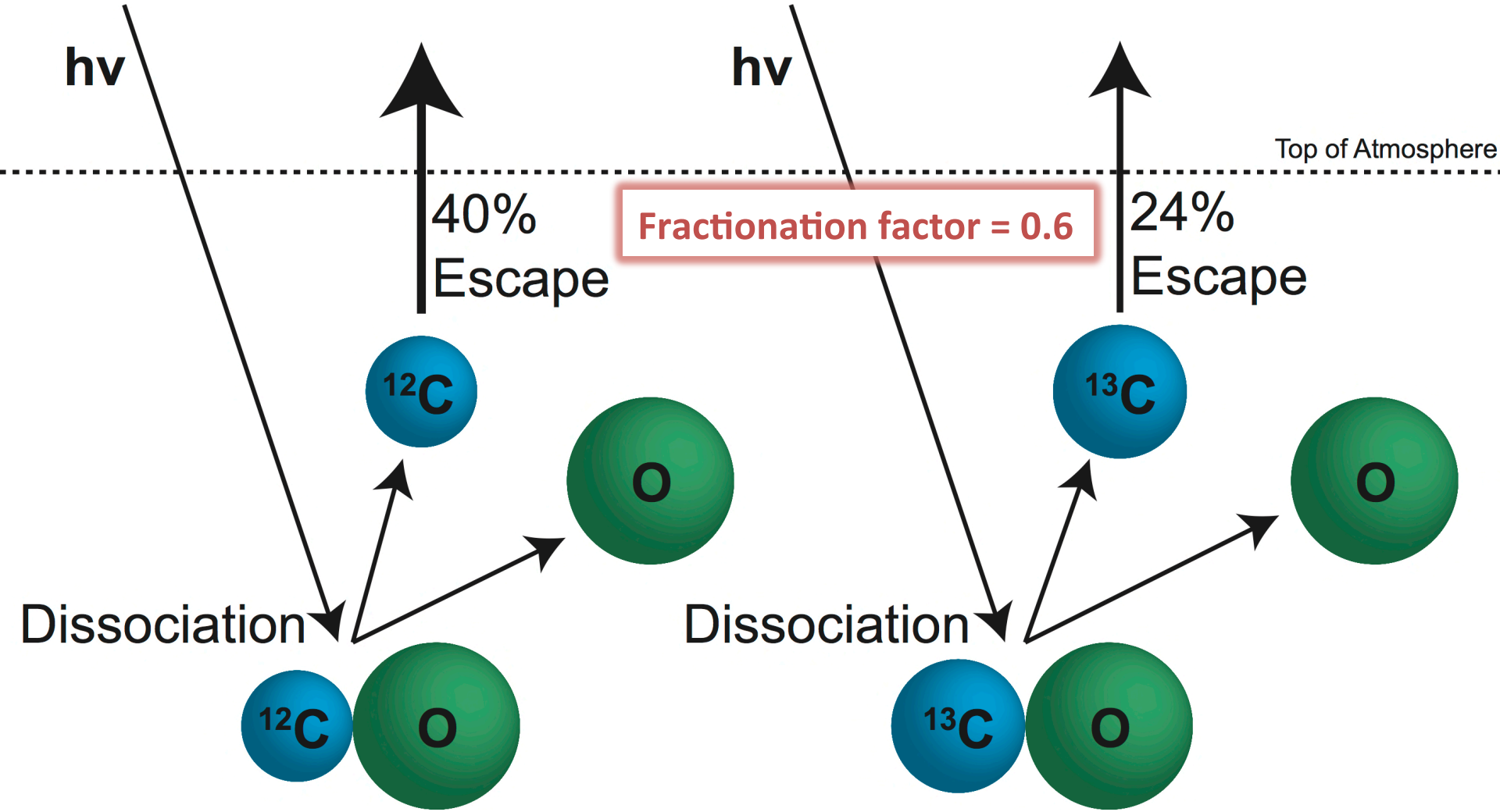

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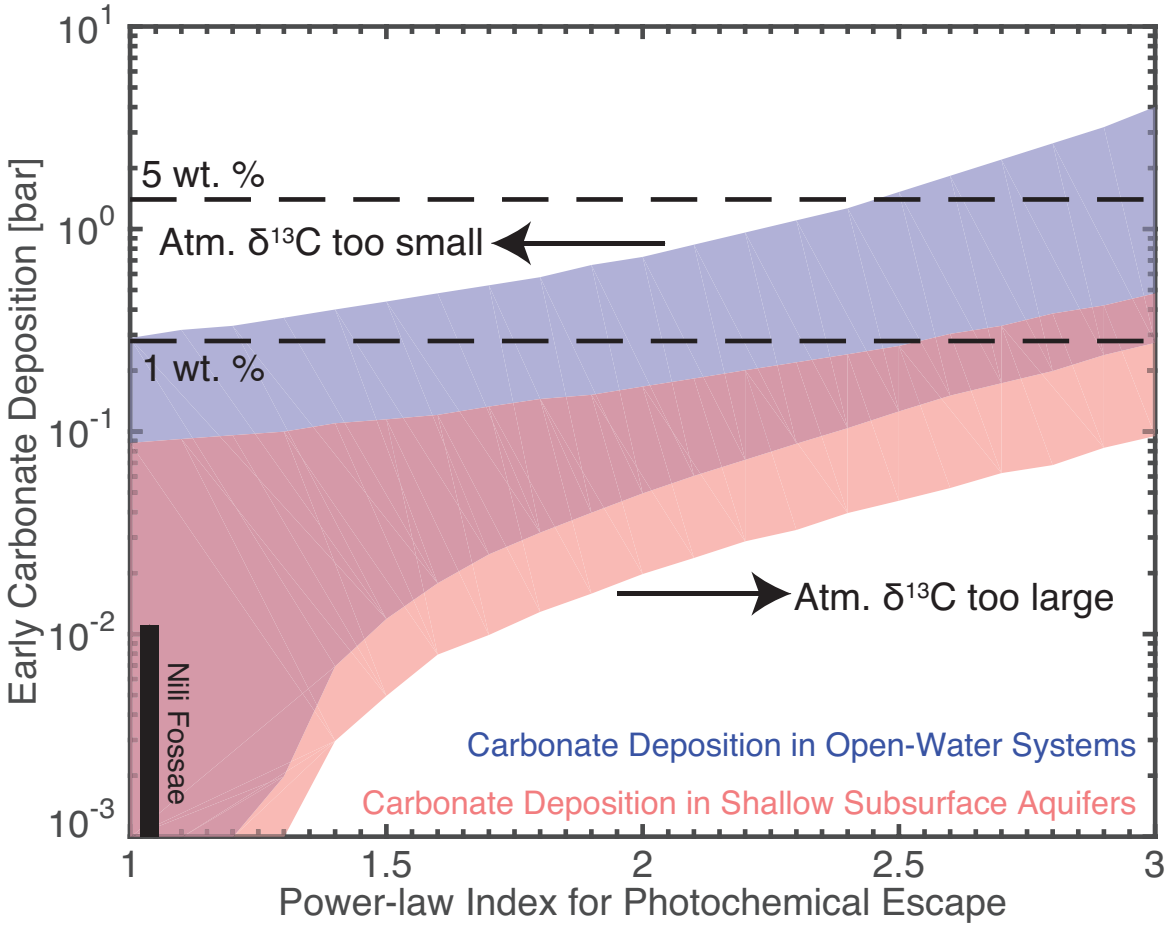
Carbonate Formation vs. Escape

Massive escape is not required by the isotopic data

The upper bound of carbonate formation is 0.5 bar, unless most carbonate formed in open-water systems



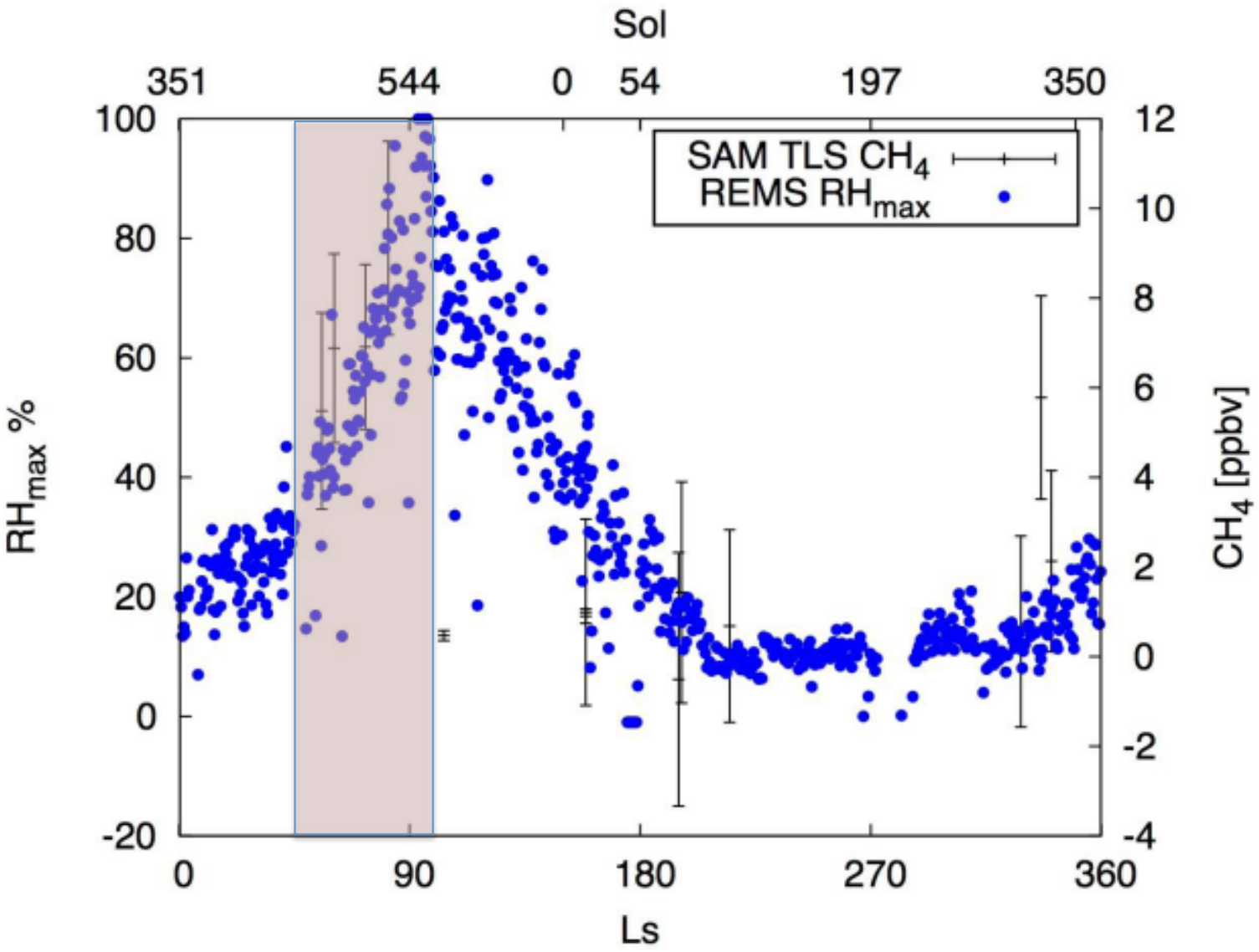
Hu et al. 2015c

Not Only Carbon …

Isotopic Ratio	Mars Value	Relative to
$\delta^{13}C$ in CO_2	46 per mil	VPDB
δD in H_2O	5880 per mil	Earth Ocean (VSMOW)
$\delta^{18}O$ in CO_2	48 per mil	Earth Ocean (VSMOW)
$\delta^{15}N$ in N_2	572 per mil	Earth Atmosphere
$\delta^{38}Ar$	310 per mil	Sun

Mahaffy et al. 2013; Webster et al. 2013; Wong et al. 2013; Atreya et al. 2013

MSL/TLS Measurements of Methane



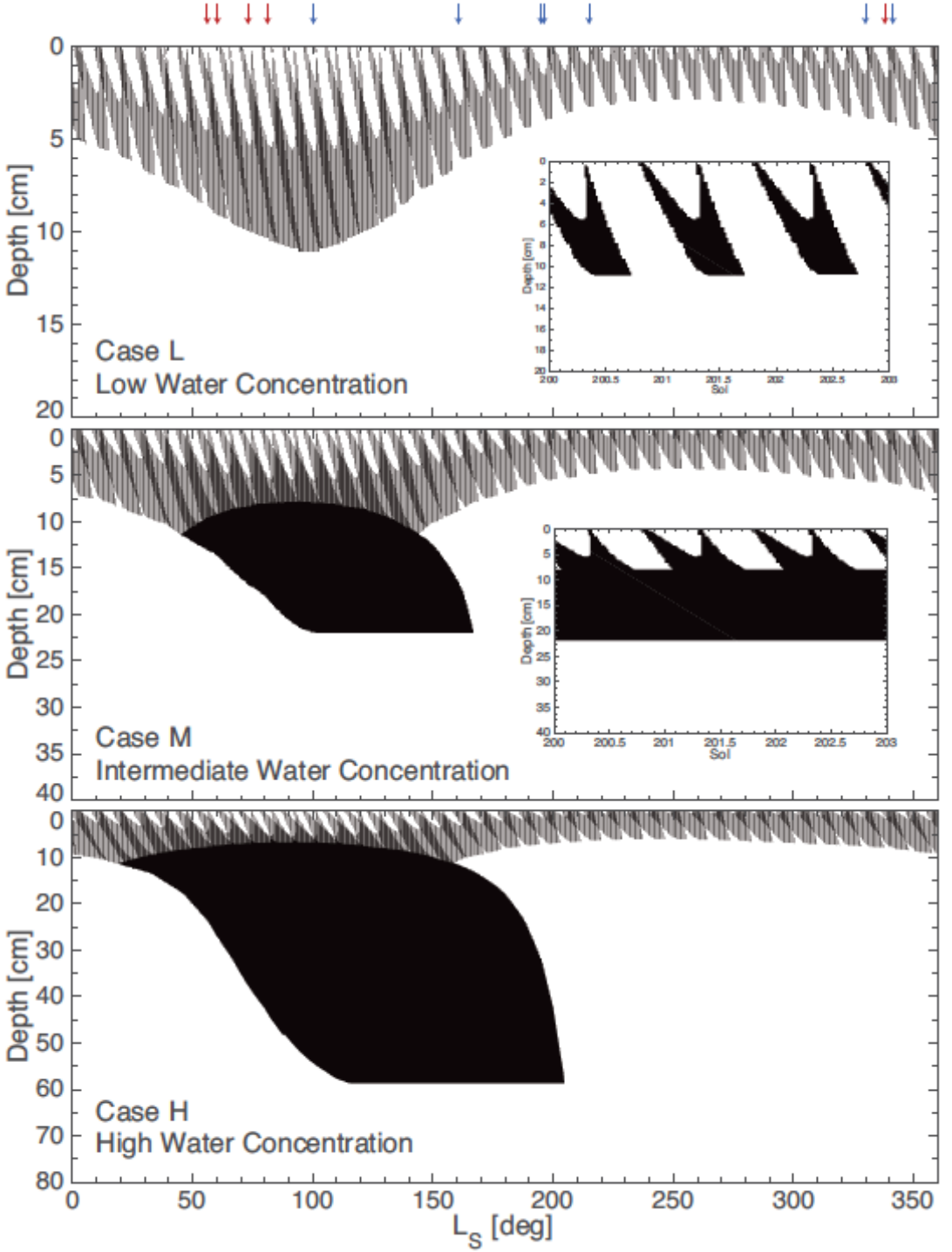
Webster et al. 2015

Deliquescence of Perchlorate in the Subsurface

MSL/REMS data are used as the upper boundary condition to derive the subsurface temperature and humidity profiles

Deliquescence occurs in the top 5 – 15 cm of soil, on a daily basis (Case L, consistent with Martin-Torres et al. 2015)

Persisting liquid solution could occur below ~10 cm depth staring from L_S~50^o



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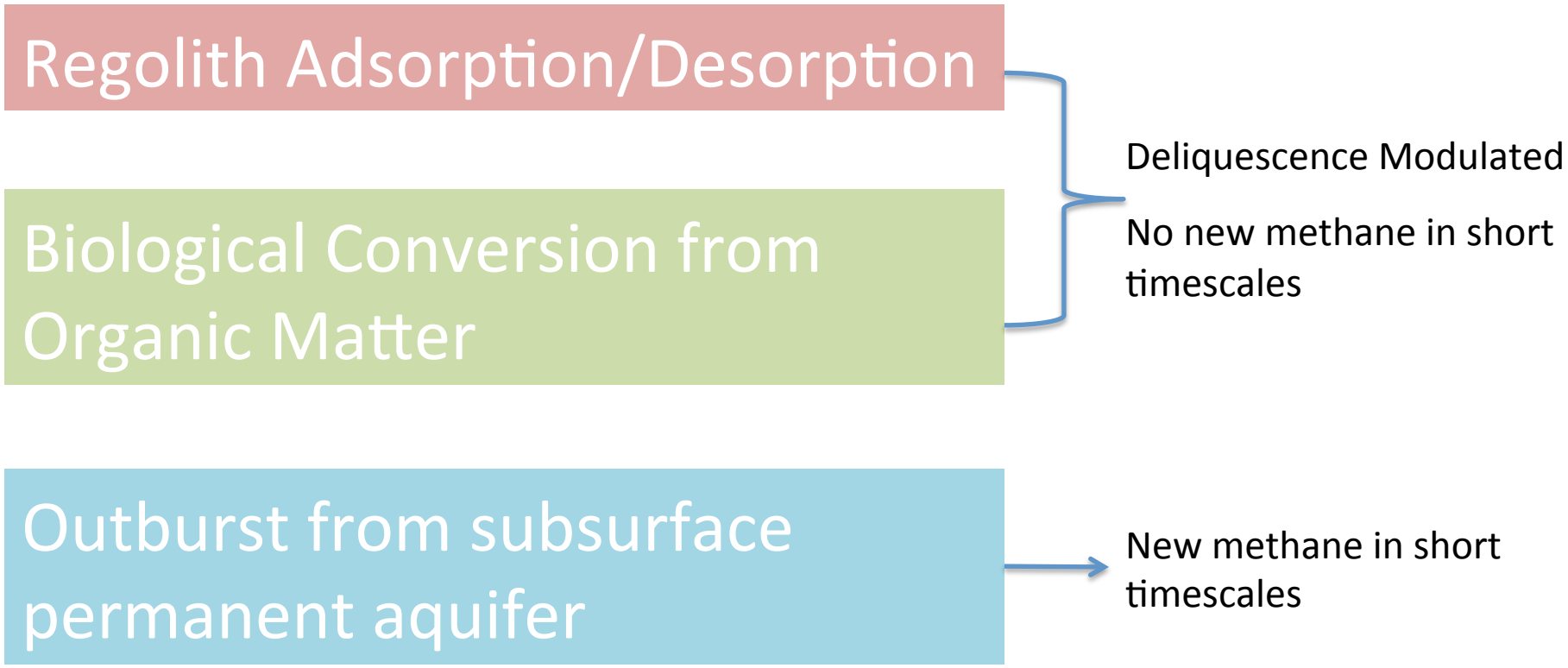
Three Hypotheses



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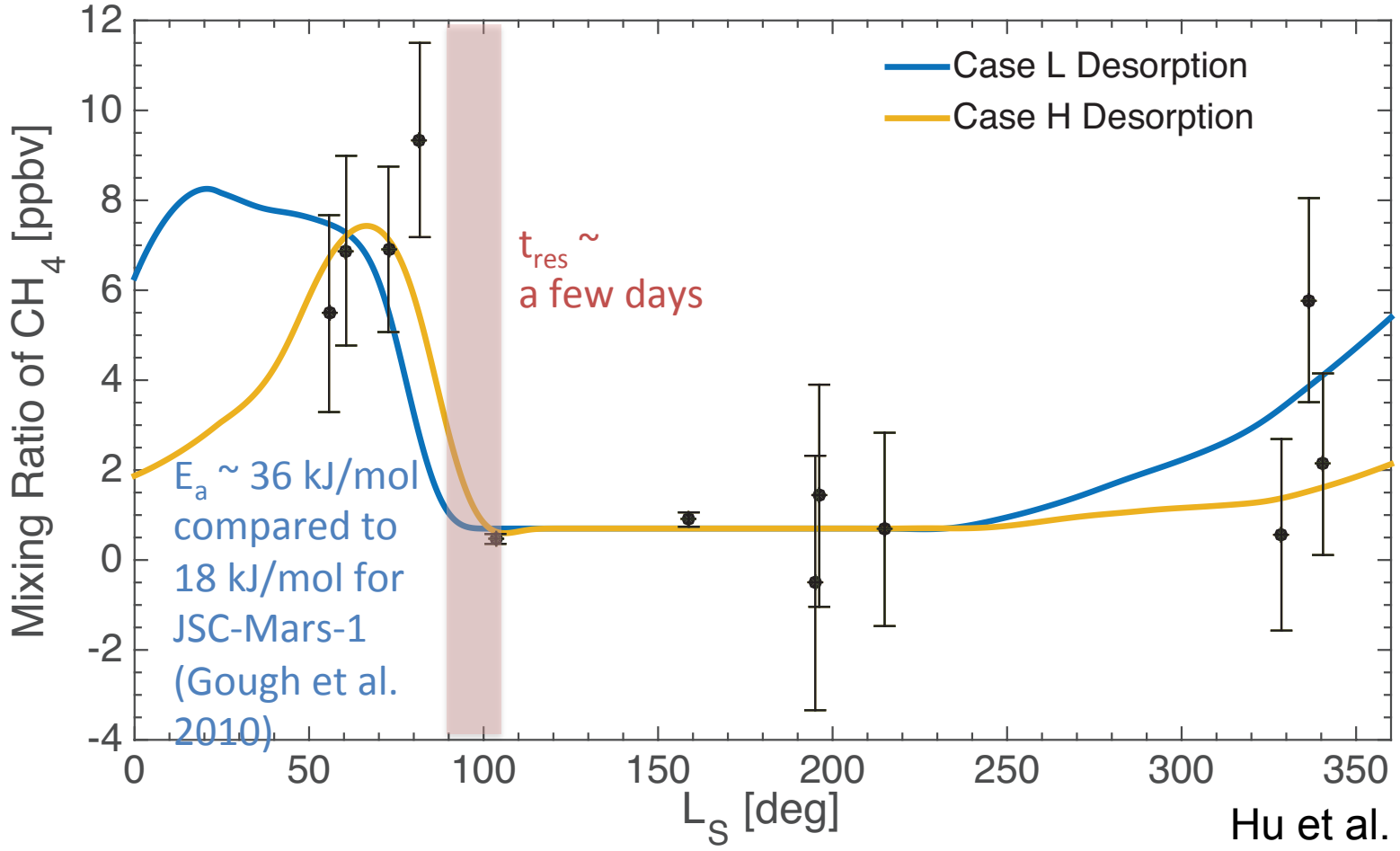
Regolith Adsorption and Desorption

Assumes methane normally adsorbed by the regolith, and deliquescence deactivates adsorption sites and releases methane into the atmosphere

The adsorption energy and methane's atmospheric residence time are two "free" parameters to fit the observation



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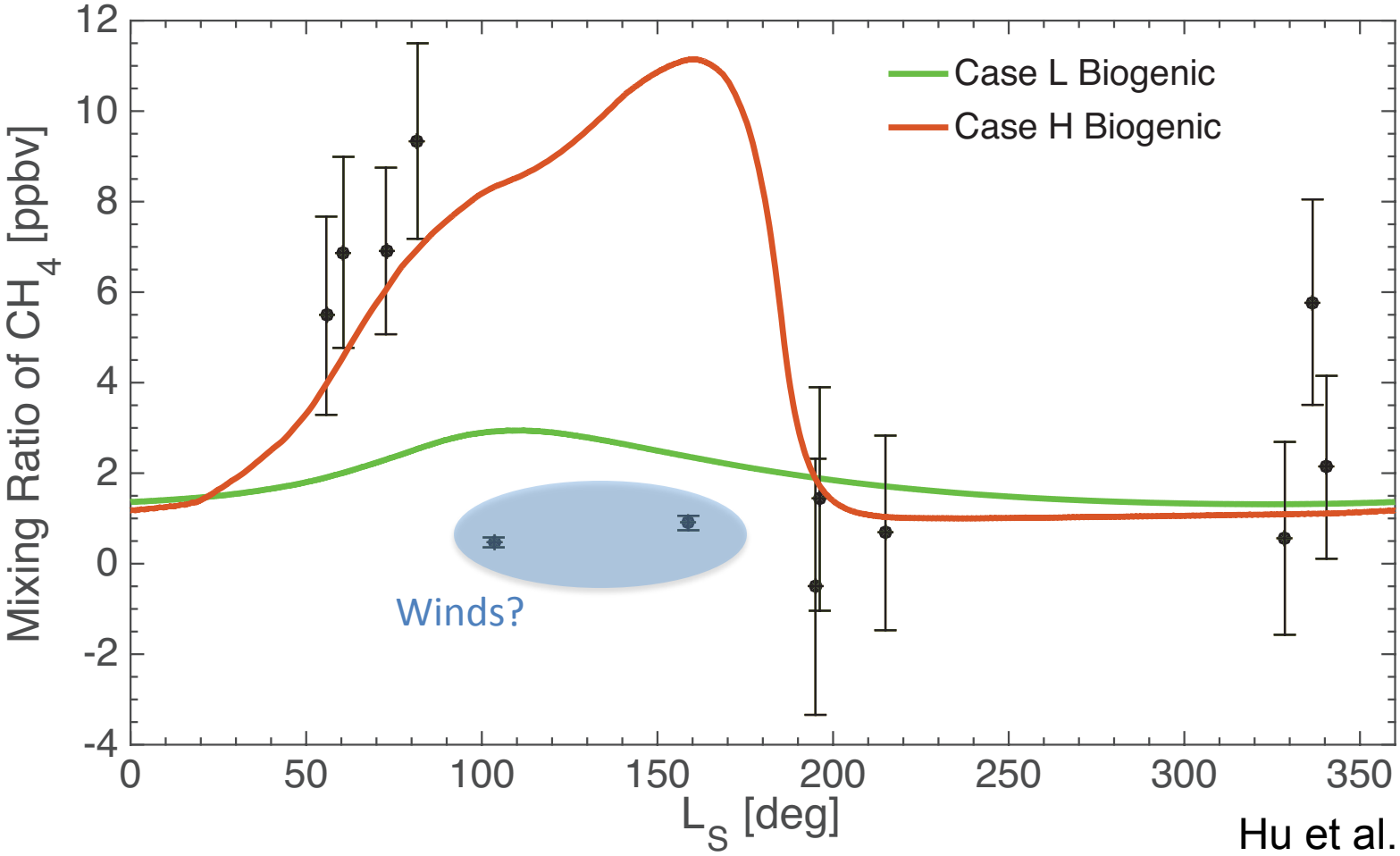
Biological Conversion from Organic Matter

Assumes yeast-like methanogens become active with liquid solution resulted from deliquescence, having Earth-like temperature dependency on the conversion efficiency



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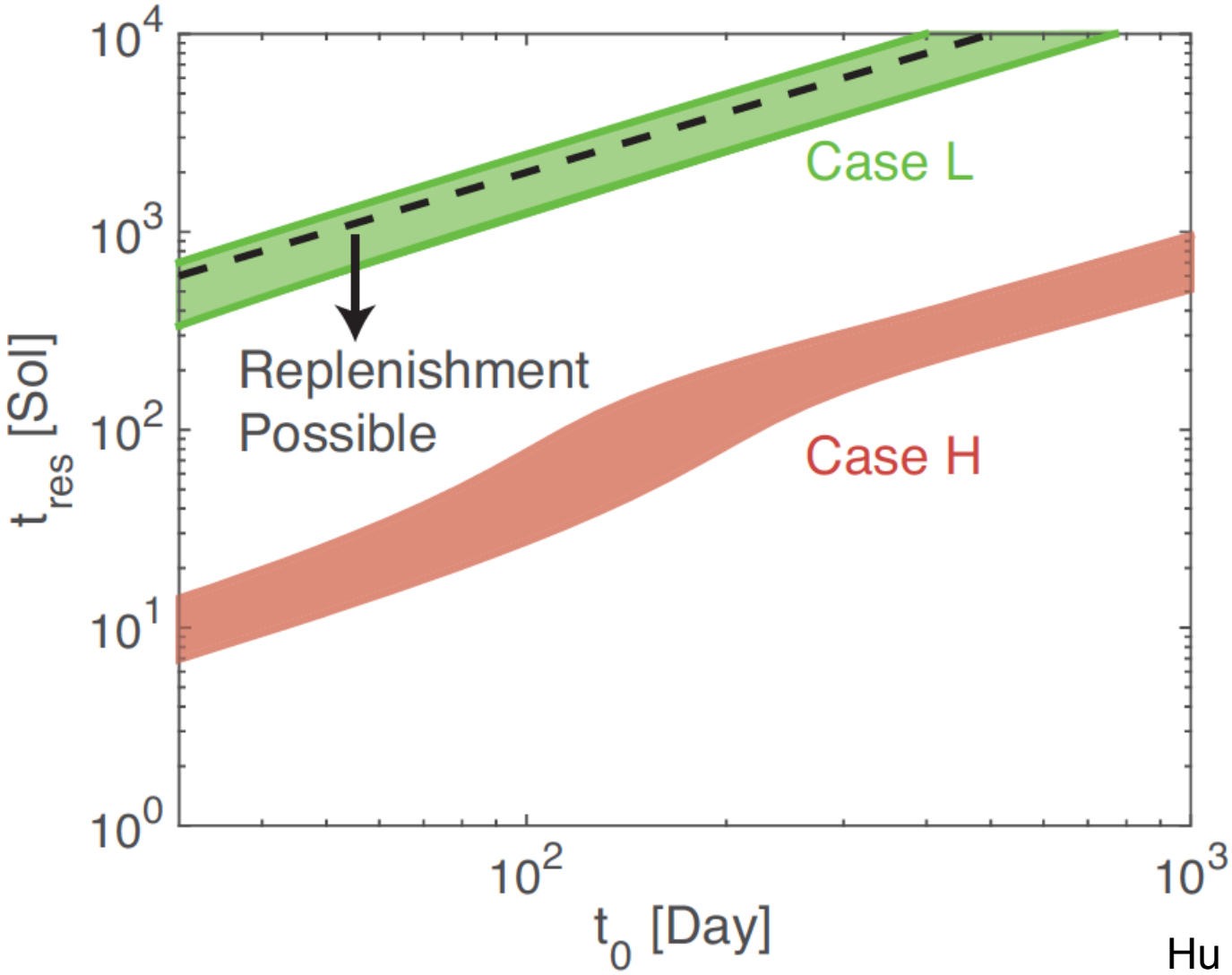
Biological Conversion from Organic Matter

Replenishing the organic matter reservoir in the soil is possible



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Outburst from Subsurface Permanent Aquifer

A subsurface permanent aquifer may exist at a depth of 5 km at Gale Crater

This aquifer must be partially sealed by an ice or clathrate layer to produce the methane burst

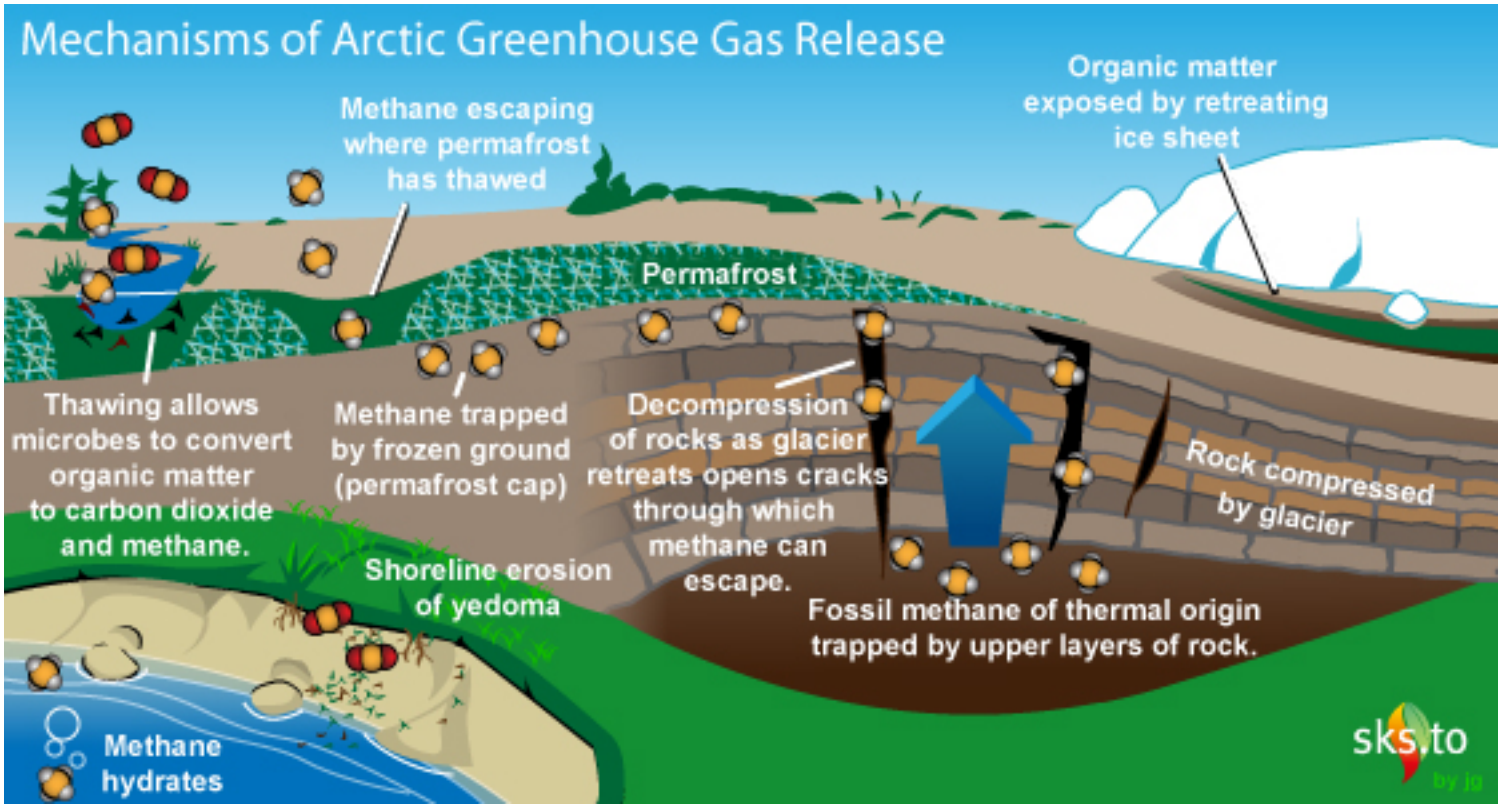

Figure from Anthony et al. 2012

Outburst from Subsurface Permanent Aquifer

If 7 ppb of methane is added to the atmosphere globally each season L_S~50^o – 90^o over the past 3 billion years

-> 140 mbar of CO_2 is accumulated in the atmosphere

-> 8.4E-3 mol/g of C_6H_5Cl is accumulated in the top 1 km of soil

The source must be local

Hu et al. 2016

Summary and Prospect