Jet Propulsion Laboratory
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Laboratory studies of dissolution geology on Saturn's moon Titan

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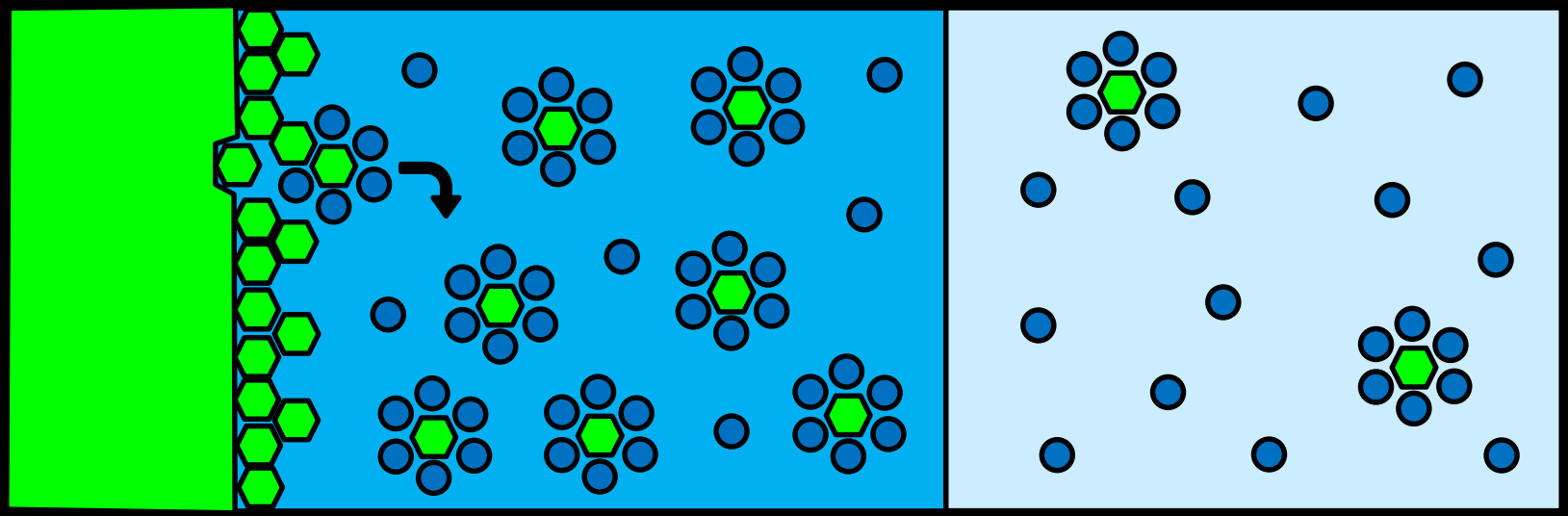
Karst as a molecular process



Solvent penetration
Dissolution
Weakening
Removal of insoluble materials

Karst landscape development

Pitting → Sinkholes → Polygonal karst →Tower or cone karst

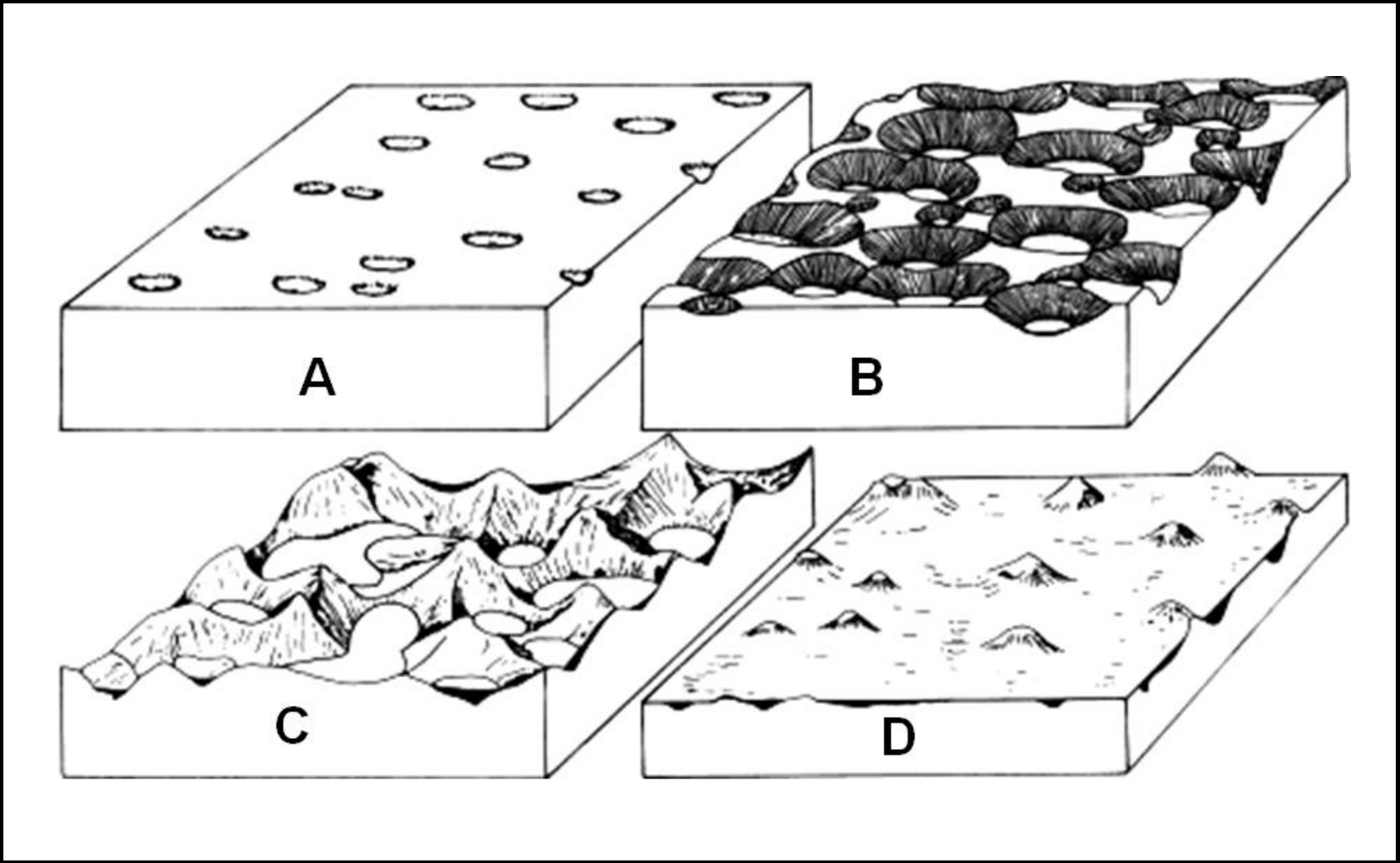
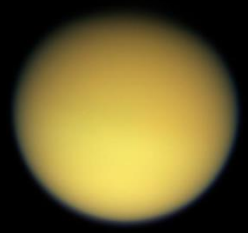


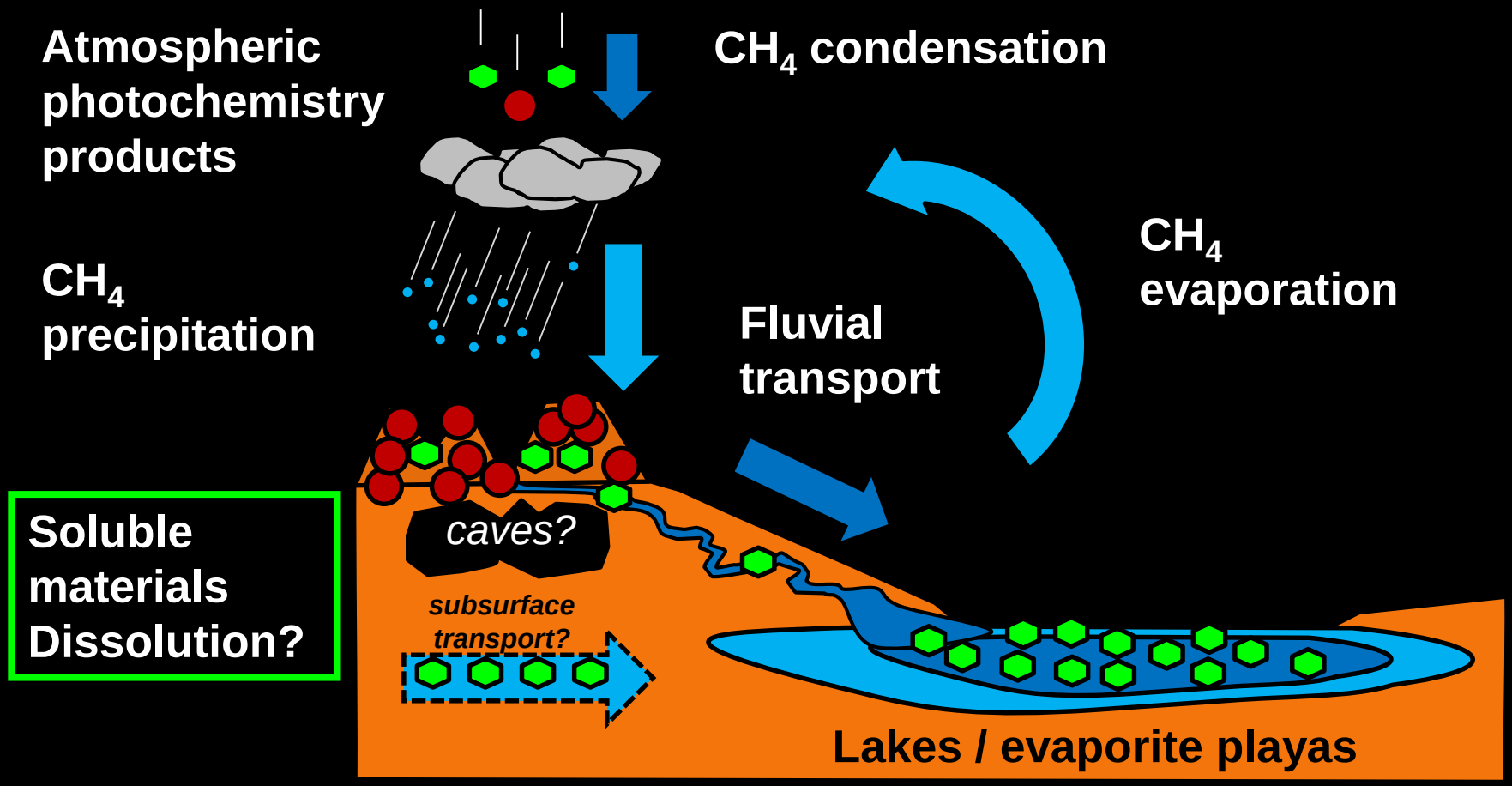
Figure from: Ford and Williams, Karst Hydrogeology and Geomorphology, 2007. Wiley. (Fig 9.63)

Fluids and materials



	Earth	Titan
Fluids	H_2O	Methane (CH_4) / N_2 Ethane (C_2H_6) Propane (C_3H_8)
Materials	Halite (NaCl) Gypsum ($NaSO_4$) Limestone ($CaCO_3$) Dolomite ($CaMg(CO_3)_2$) Quartz (SiO_2)	Ethylene (C_2H_4) *n*-Butane (C_4H_{10}) Vinyl acetylene (C_4H_4) 1,3-Butadiene (C_4H_6) Benzene (C_6H_6) Acrylonitrile (CH_2CHCN) Acetonitrile (CH_3CN) Cyanoacetylene (HCCCN)

Titan Organic Cycle
Organics and CH_4

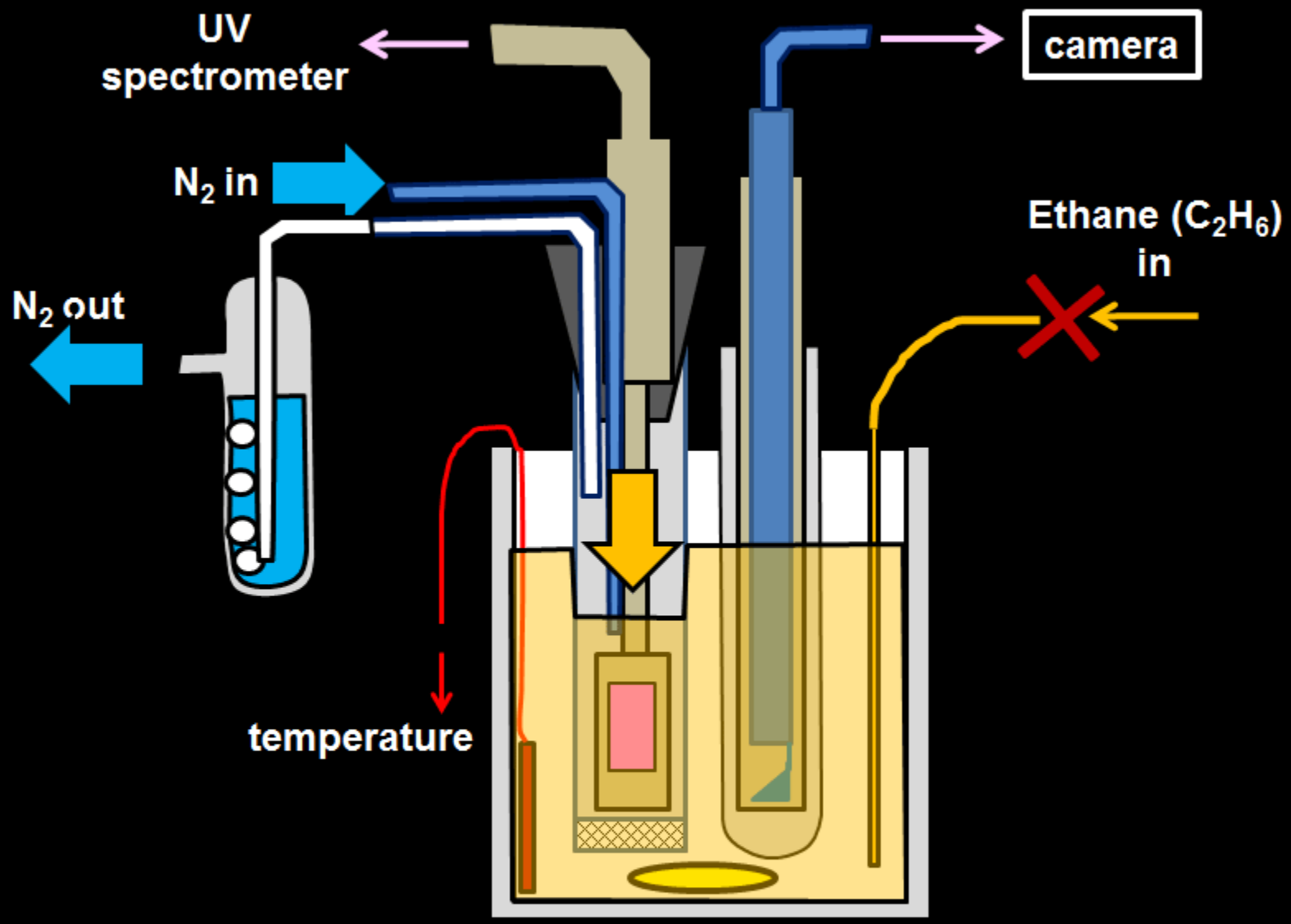


Malaska et al., Workshop on the Habitability of Icy Worlds (2014), Abstract 4020.

Cryogenic dissolution studies

Malaska and Hodyss, LPSC 44 (2013), Abstract 2744.

(Image credit Mike Malaska)

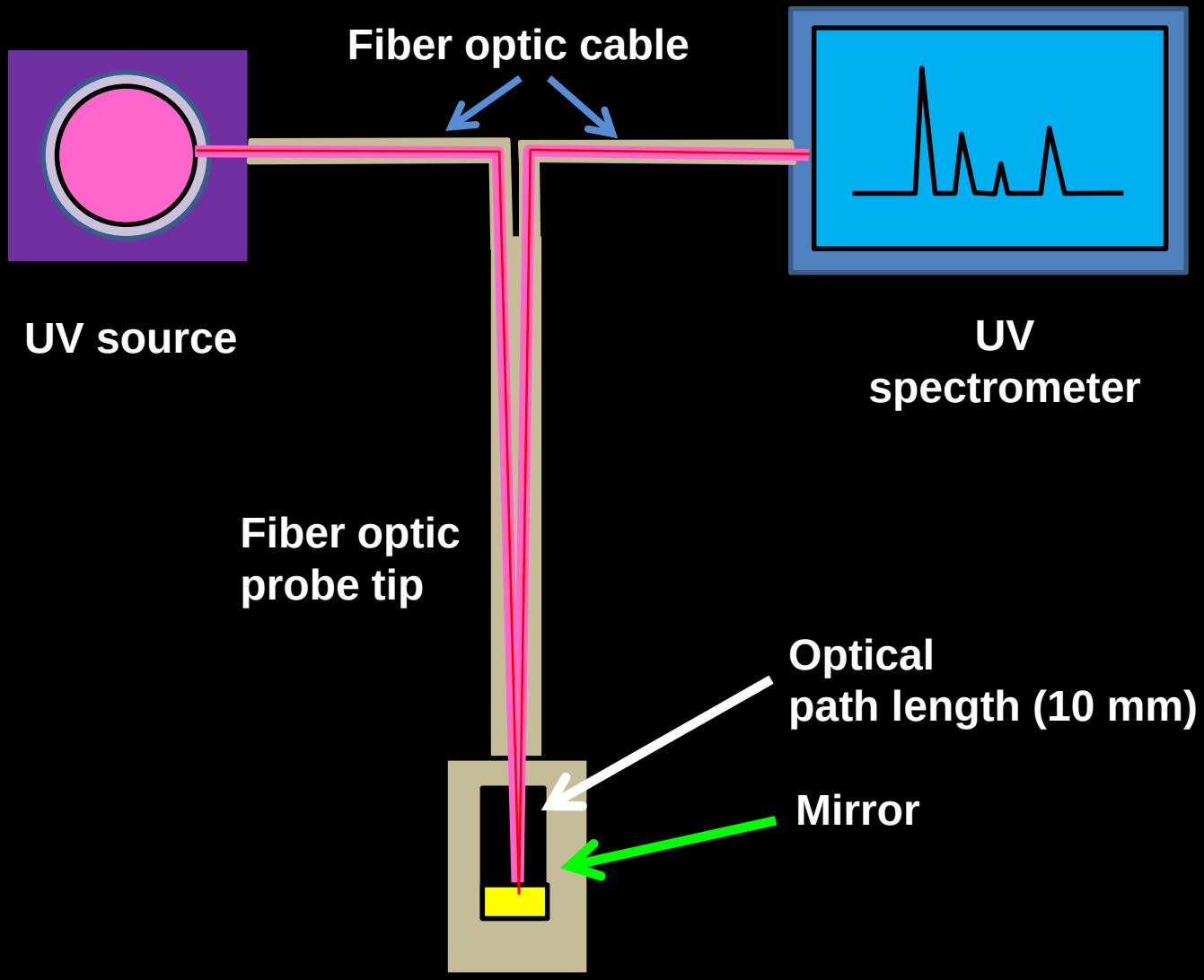


Flush and Fill

Filter tube
+ UV probe

Malaska and Hodyss, Icarus 242 (2014), 74-81.

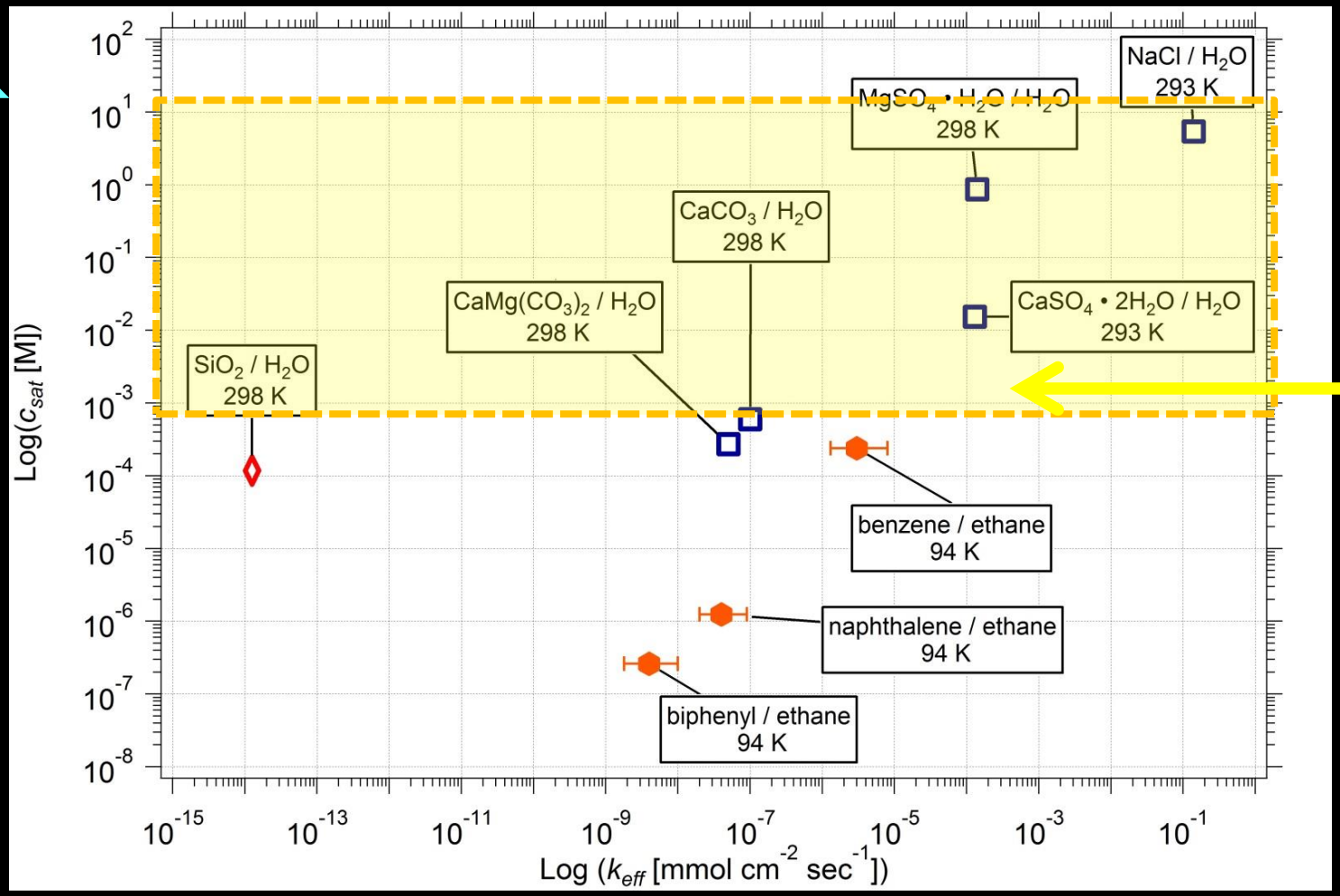
UV probe optical path



Malaska and Hodyss, Icarus 242 (2014), 74-81.

Titan materials geologically soluble

Titan molecules vs. terrestrial karst materials



Estimated ranges for ethylene, acetylene, *n*-butane, propyne CO_2, vinyl acetylene (C_4H_4) and butadiene in 77% CH_4/N_2

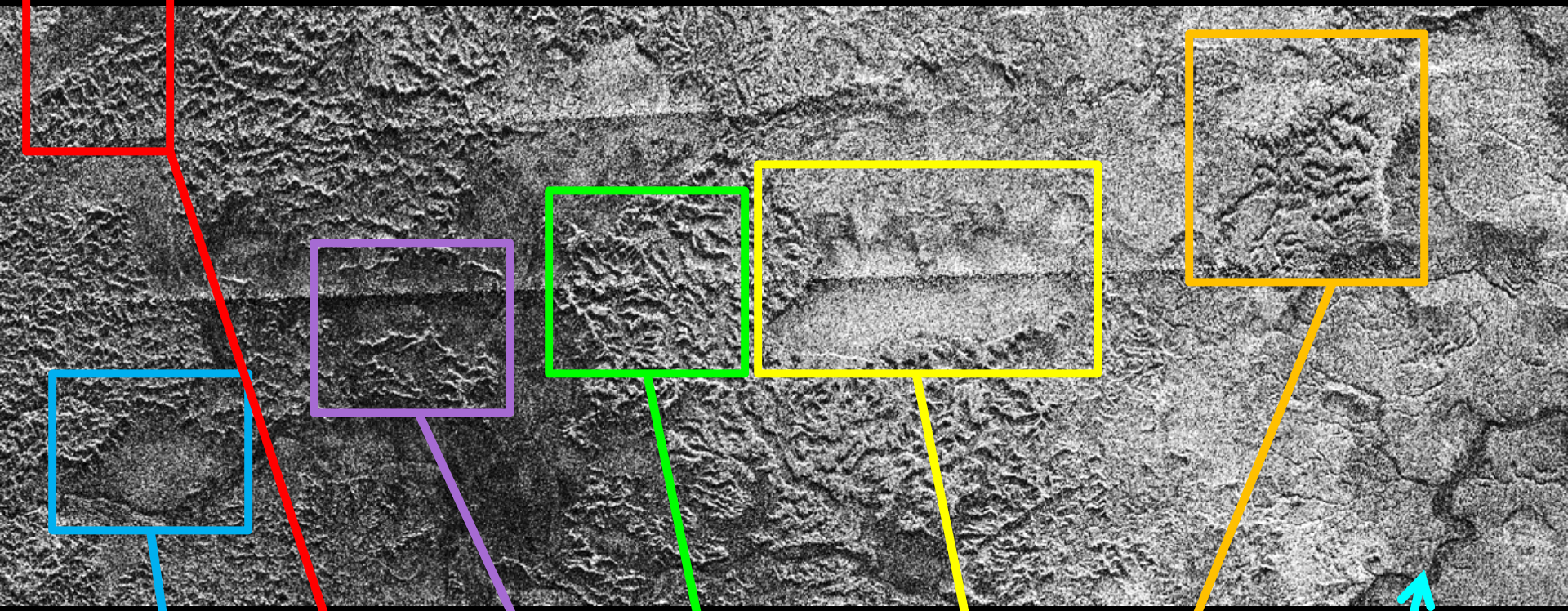
solubility

dissolution rate

Malaska and Hodyss, Icarus 242 (2014), 74-81.; estimates from Cornet et al., JGR Planets (2015).

Geomorphological evidence for dissolution geology on Titan

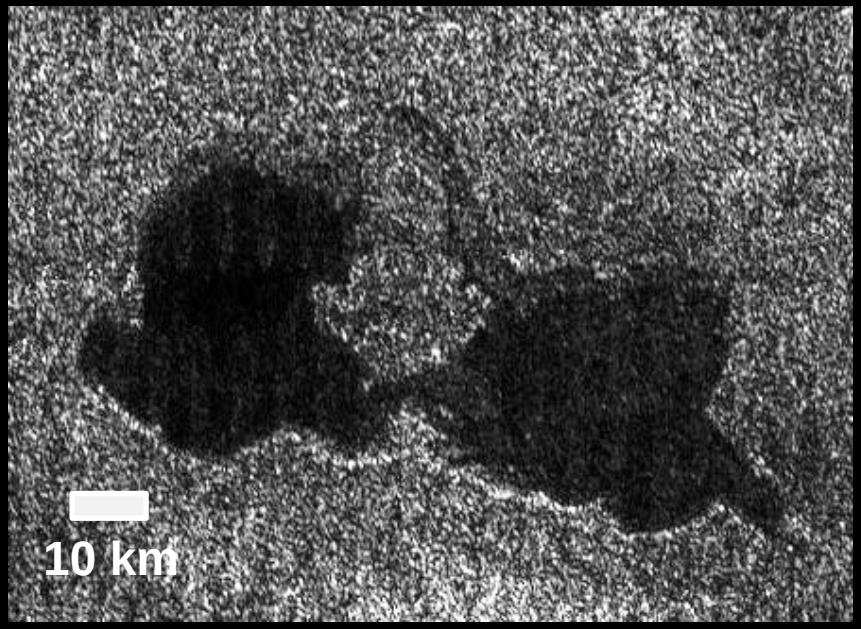
Karst-like features near Sikun Labyrinthus, Titan [77.9 S, 29.8 W]



Titan similarities to Earth sinkhole lakes

SAR RADAR image of hydrocarbon karst-like lake on Titan

Titan

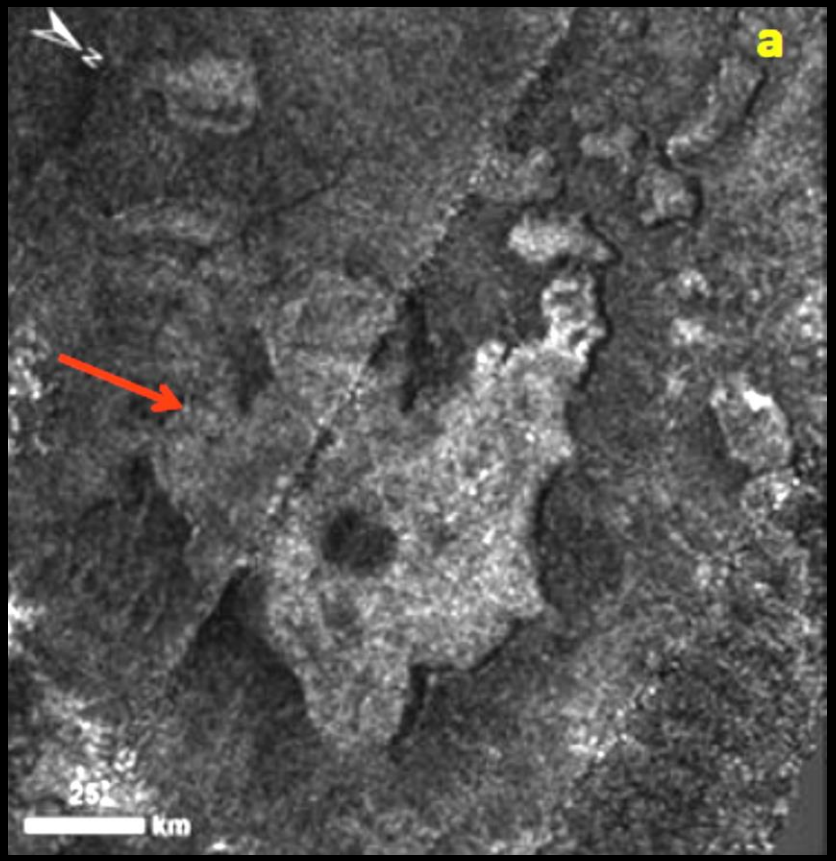


Abaya Lacus
"Kissing Lakes" T16 SAR
Titan [73ºN, 47ºW]

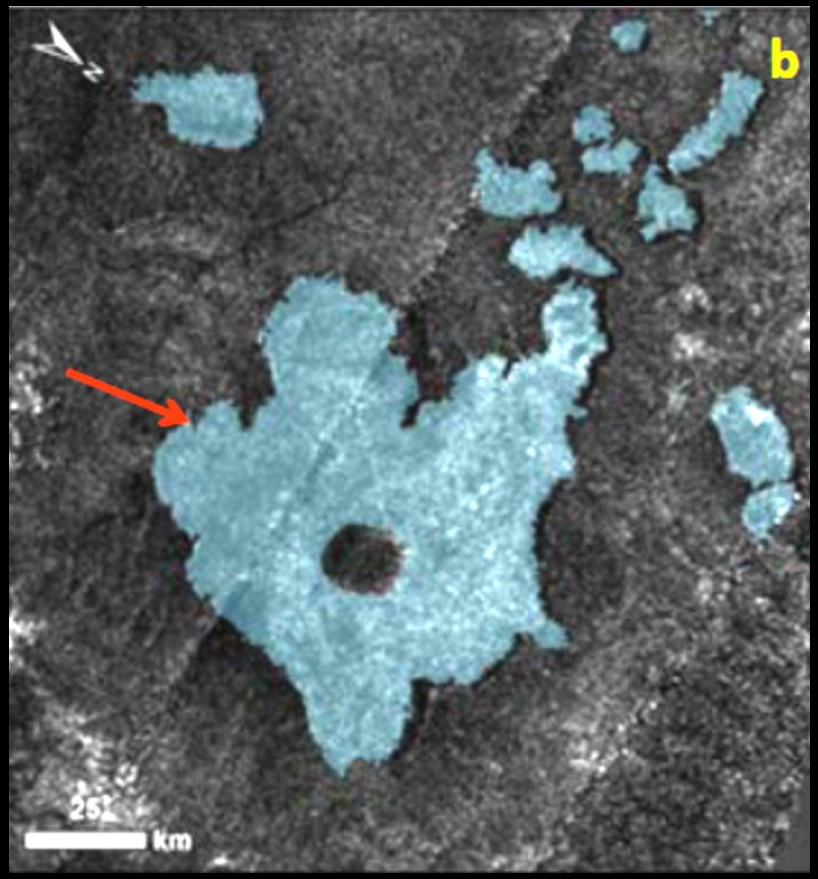
Earth

Lazy Lagoon in a gypsum plain,
Bottomless Lakes State Park, NM
Earth [33.3ºN, 104.3ºW]
(Google Earth image)

Flat-floored empty lakes displaying scarp retreat



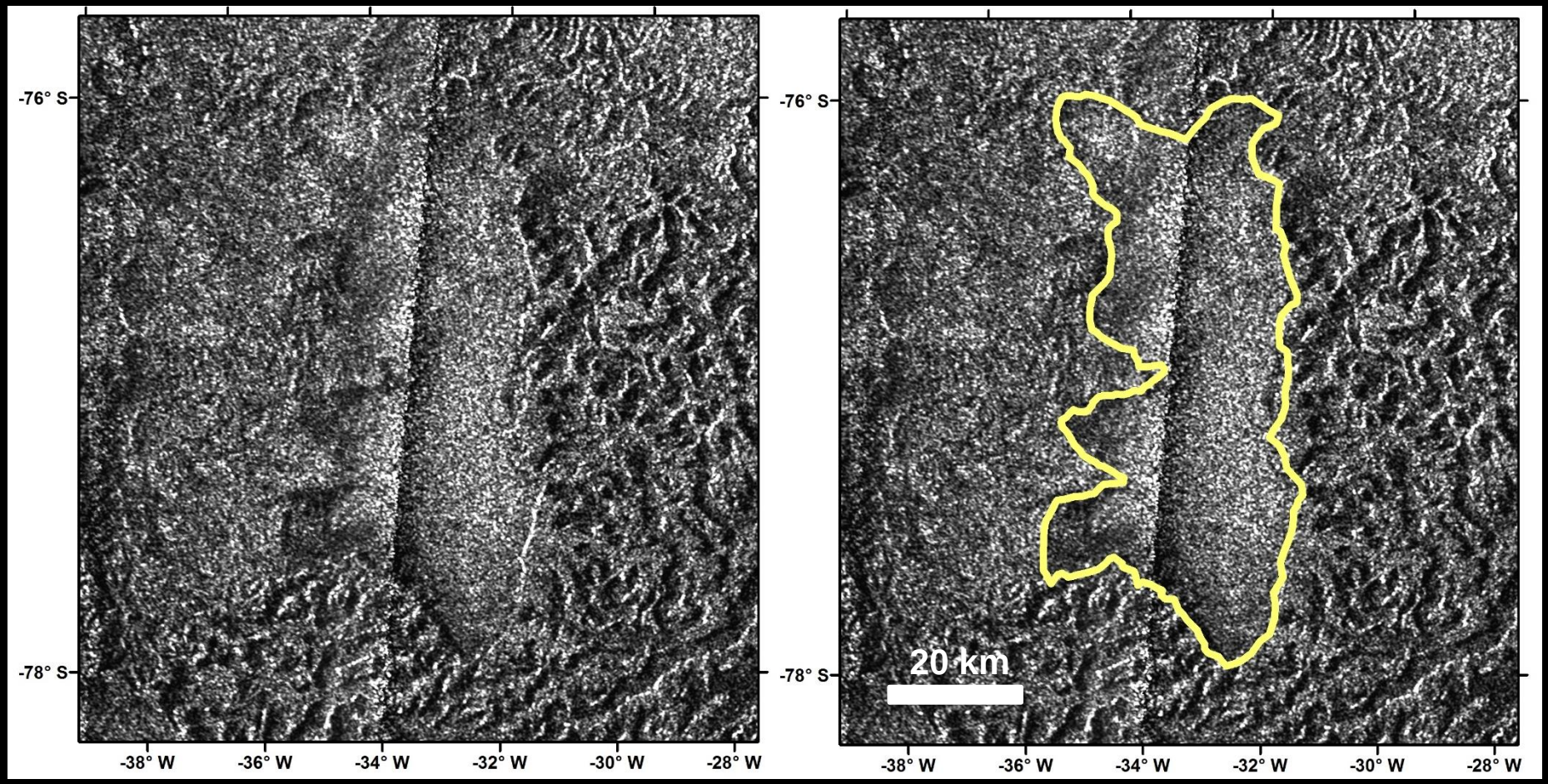
Unnamed lacuna, (80°S, 120°W)



(annotated)

Birch et al., Icarus 2016, in press. (source for figure above)
Michaelides et al., Icarus 170 (2016) 57-66.

Veliko Lacuna, Titan

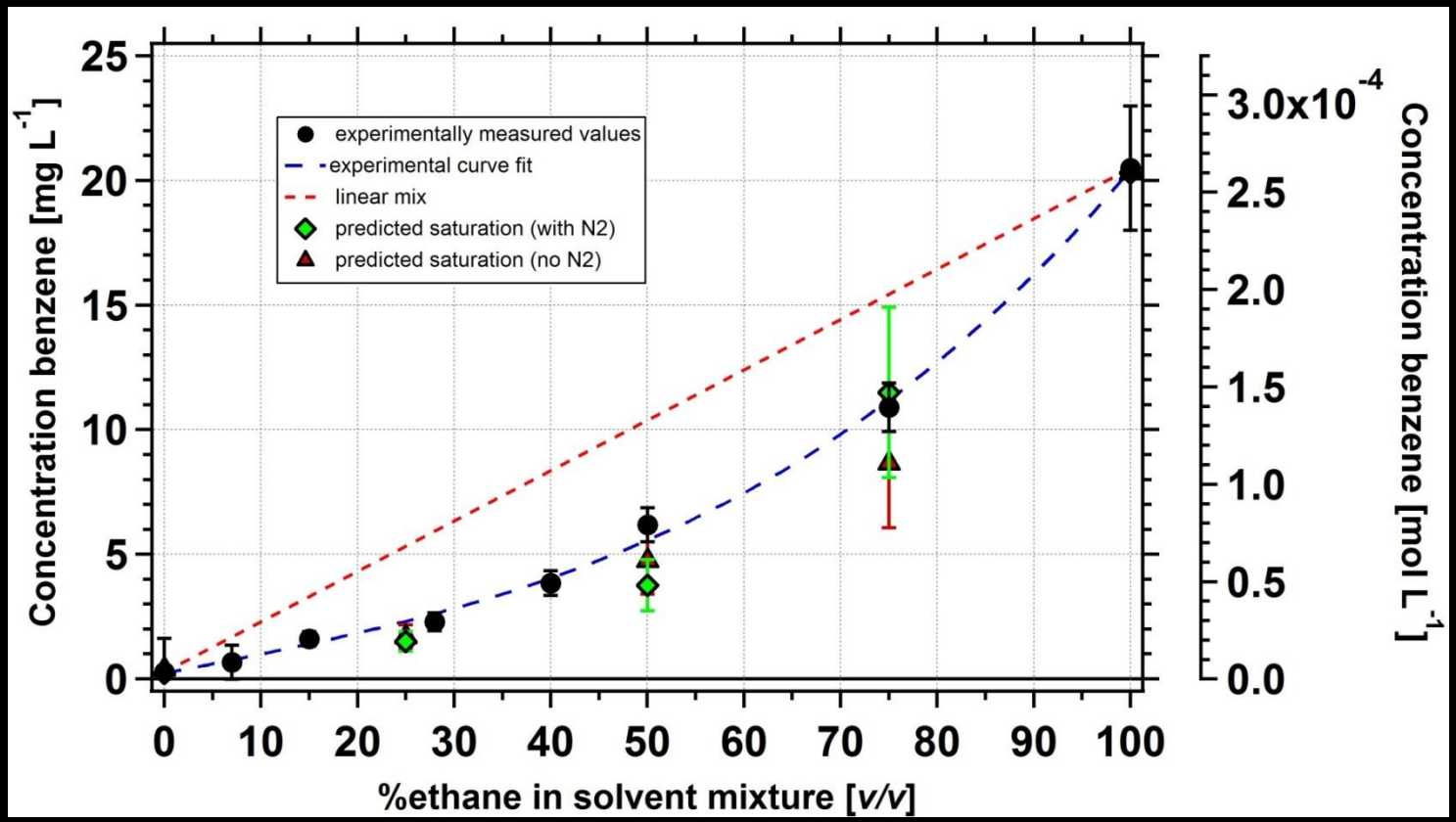


Veliko Lacuna, T39 SAR, [77°S, 33°W], Titan

(annotated)

Malaska et al., LPSC 41 (2011), Abstract 1544.

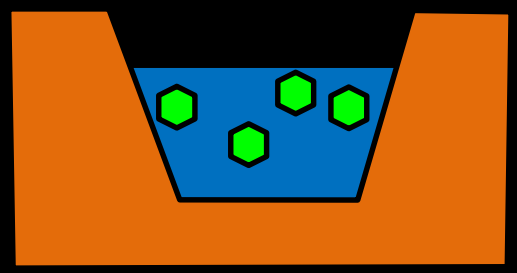
Benzene dissolution curve in mixed methane-ethane solvents



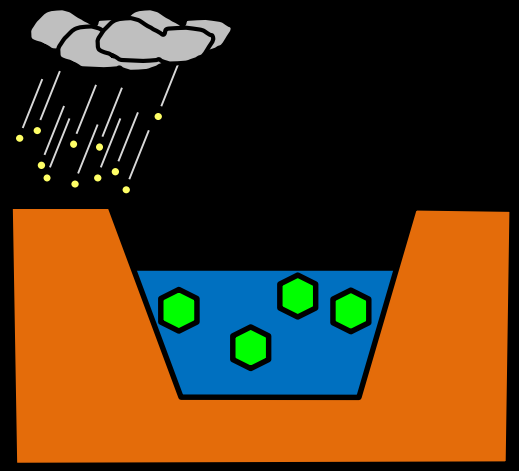
Solubility increases in ethane

Malaska et al., in preparation

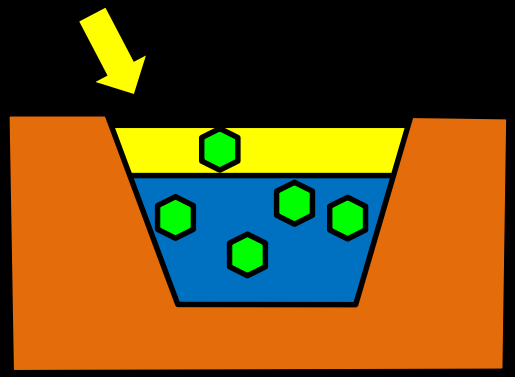
Funky Titan dissolution mechanism



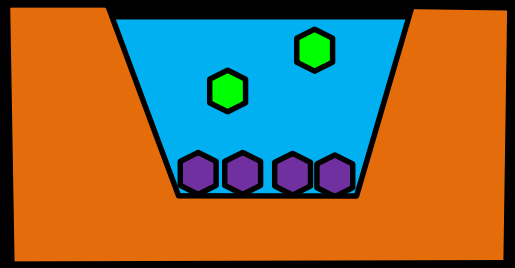
1) Solute-saturated ethane-containing lake fluids.



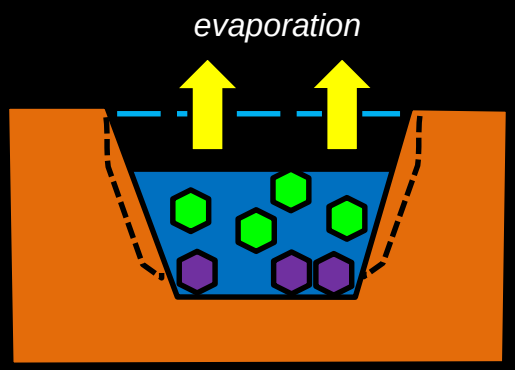
2) Methane-rich rainfall.



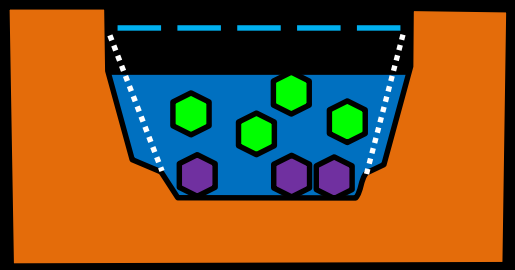
3) Influx of saturated methane-rich runoff. Transient layering.



4) Fluids mix. Solubility decreases. Chemical precipitation across bottom.

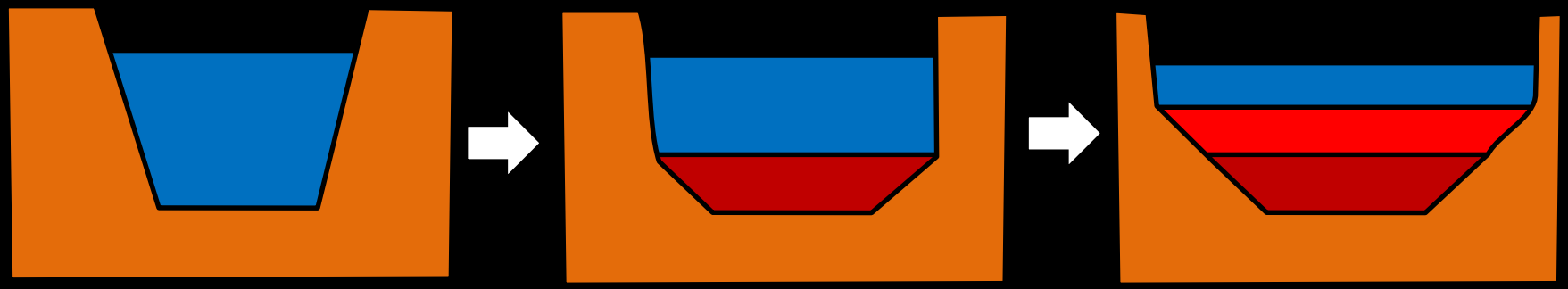


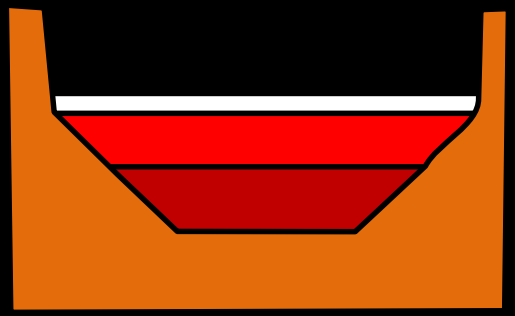
5) Evaporation removes methane. Lake fluids become more ethane-rich.



6) Fluids become aggressive. Widens lake through dissolution of sides.

Evolution of a Titan lake to flat-floored high-backscatter depression





Final drying (or base level lowering) of ethane phase leaves evaporite surface[1]

Steep-sided flat-floored lake with high backscatter bottom

[1] Michaelides et al., Icarus 170 (2016) 57-66.

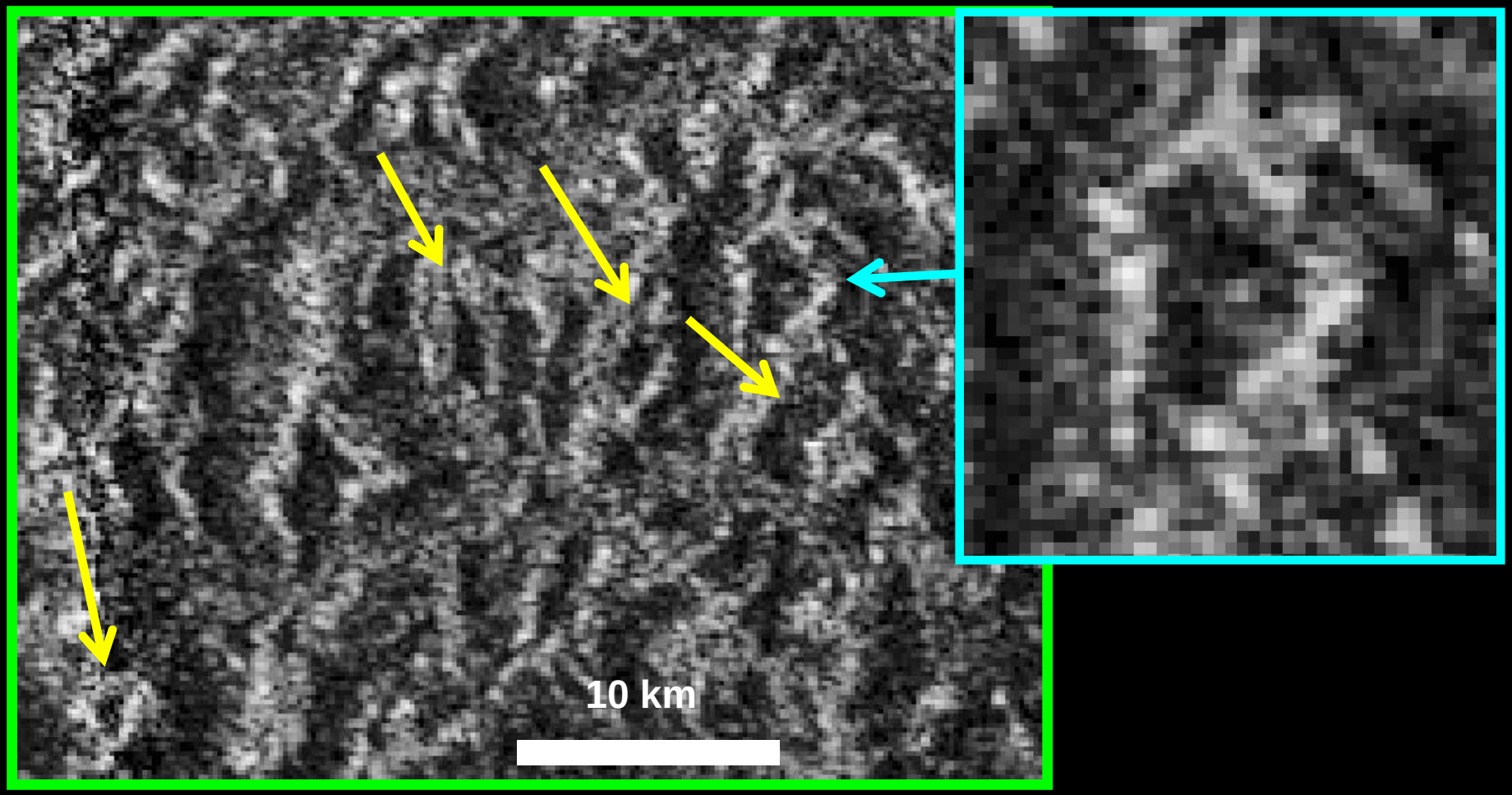
Titan Karst – cryogenic hydrocarbons can dissolve local geological materials

Like Earth, but with more flavors

Purnululu National Park, NSW Australia Image credit: Philip Griffin

Closed valleys diagnostic for karst

Sikun Labyrinthus, Titan

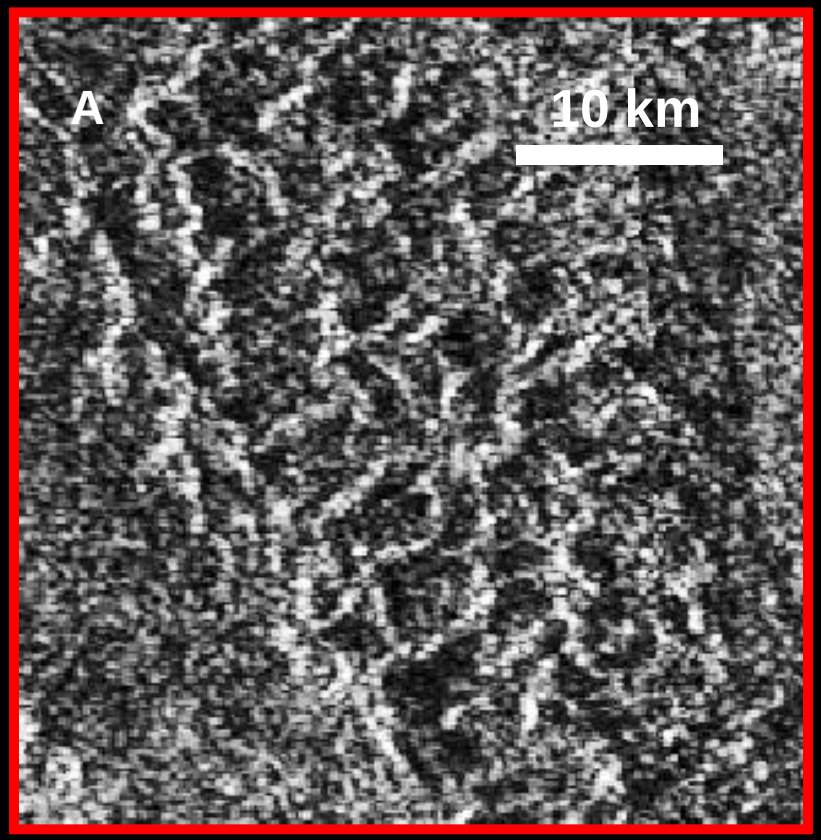


"Karst is always developed when dolines are found and so they can be considered index landforms of karst…" [1]

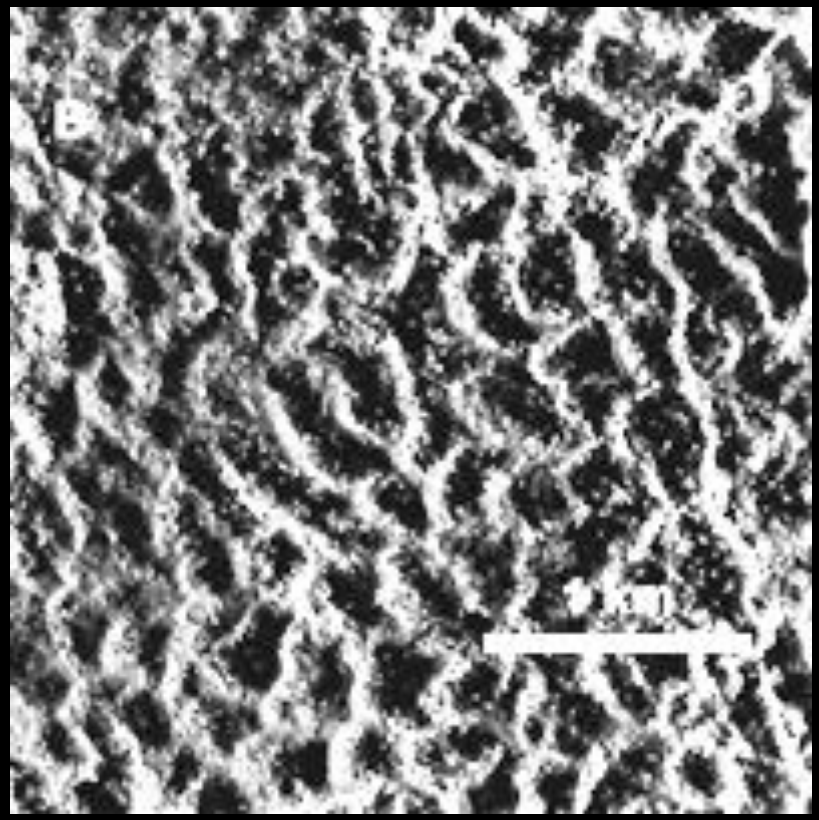
[1] Ford, D. and Williams, P. "Karst Hydrology and Geomorphology" (2007), Wiley, Chichester, Great Britain.

Polygonal Karst-like terrain on Titan

Closed valleys
Structural control of valleys



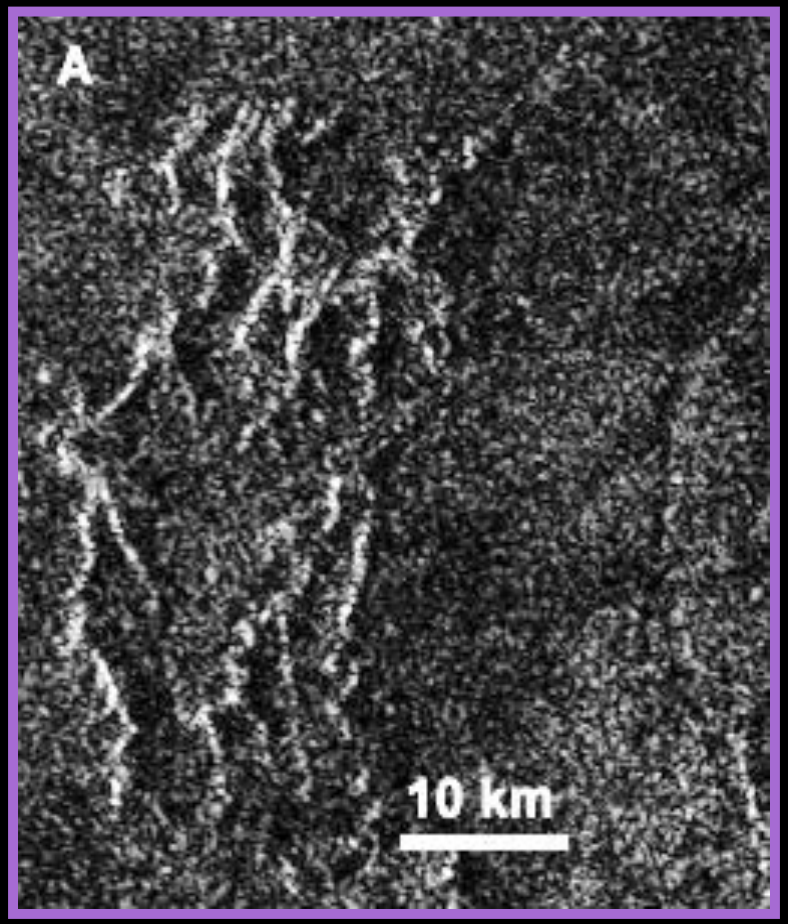
Polygonal Karst-like terrain,
Sikun Labyrinthus region,
Titan [77.9°S, 28.9°W]



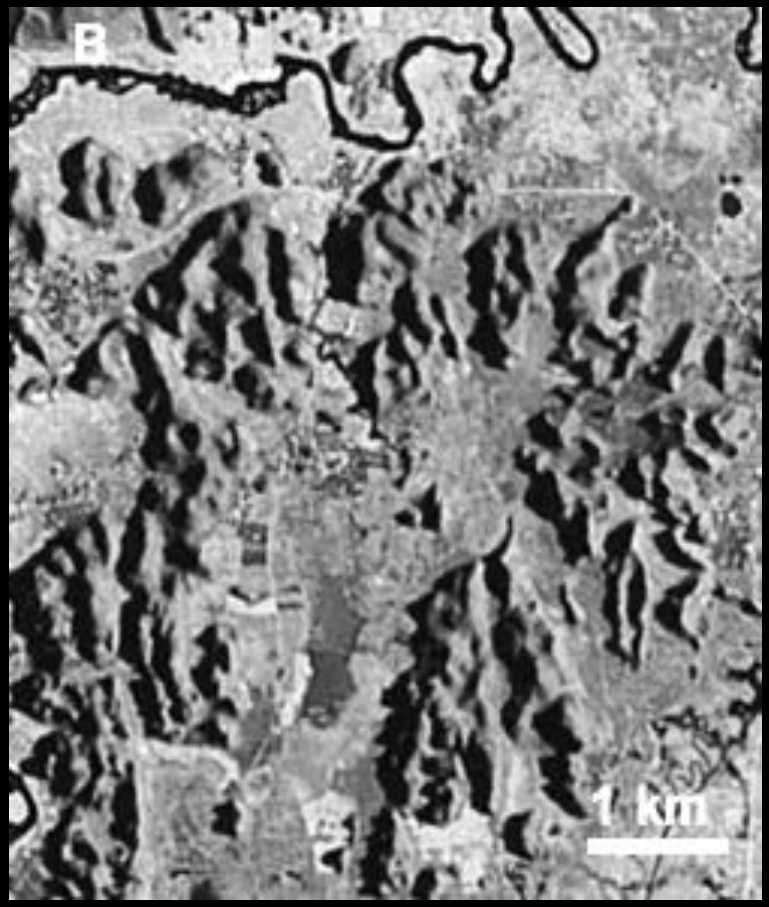
Polygonal Karst,
Darai Hills, Papua New Guinea,
Earth [6.8°S, 143.3°E]
(figure reproduced from [1])

[1] Williams, GSA Bulletin 82 (1972) 761-796.

Tower Karst[1]-like terrain on Titan



Tower Karst-like terrain,
Sikun Labyrinthus region,
Titan [77.9ºS, 28.9ºW]



Tower Karst, Tanpaixiang,
Guangxi Province, China
Earth [23.4ºN, 108.8ºE]
(Google Earth image)

[1] U.S. EPA. "A Lexicon of Cave and Karst Terminology with Special Reference to Environmental Karst Hydrology" (2002 Edition). U.S. EPA/600/R-02/003, 2002.

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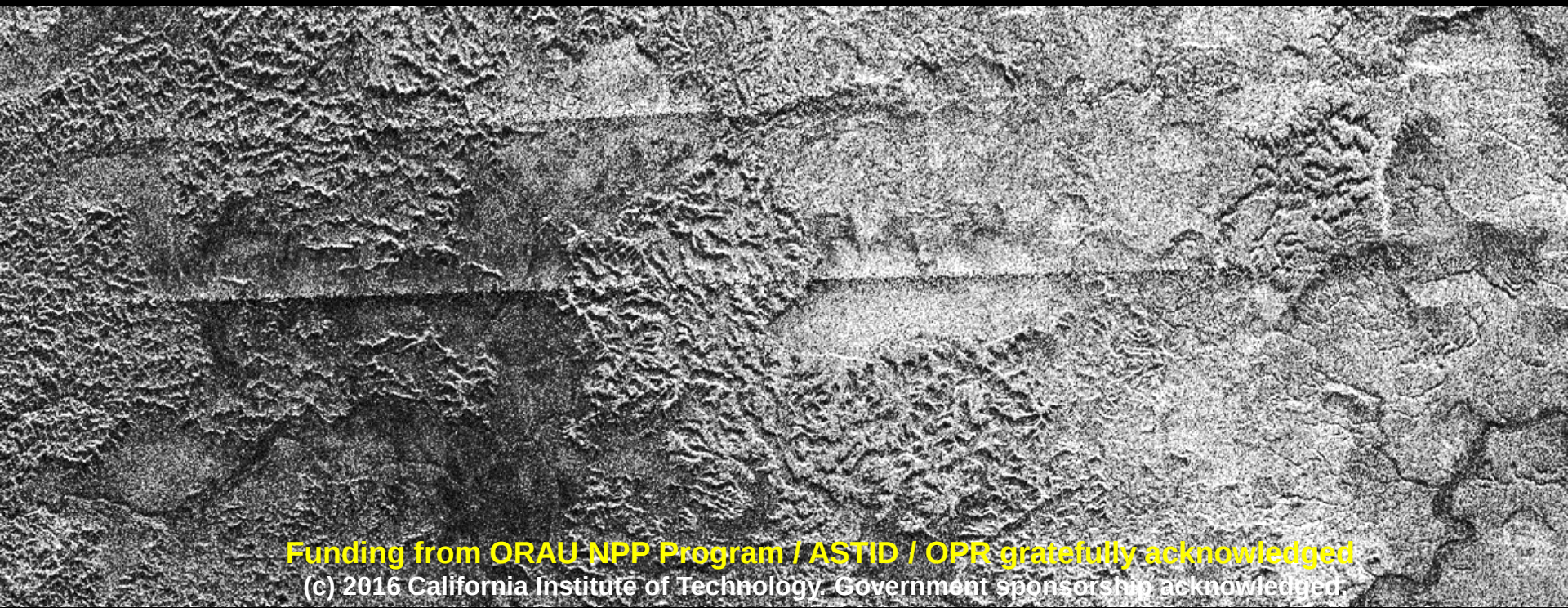

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(c) 2016 California Institute of Technology. Government sponsorship acknowledged.