

Enceladus' Hydrothermal Activity

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acknowledged.

Plume Gas Composition

H_2O	$90 \pm 1 \text{ \%mol}$
CO_2	$5.3 \pm 0.1 \text{ \%mol}$
H_2CO	$0.31 \pm 0.1 \text{ \%mol}$
CH_3OH	$0.015 \pm 0.006 \text{ \%mol}$
H_2S	$0.0021 \pm 0.001 \text{ \%mol}$
^{40}Ar	$0.031 \pm 0.003 \text{ \%mol}$
NH_3	$0.82 \pm 0.02 \text{ \%mol}$
N_2	$<1.1 \text{ \%mol}^*$
CH_4	$0.91 \pm 0.05 \text{ \%mol}$
C_2H_2	$0.33 \pm 0.2 \text{ \%mol}$
C_3H_6	$0.14 \pm 0.03 \text{ \%mol}$
C_4H_8	$0.023 \pm 0.003 \text{ \%mol}$

Plus 16 other species.

* N_2 Inferred from a combination of INMS and UVIS data

Waite, J., et al. (2009), Liquid water on Enceladus from observations of ammonia and ^{40}Ar in the plume, *Nature*, 460, 487-490.

Plume Particles (Dust)

H₂O **Predominant component**

Na⁺ **Abundant**

K⁺ **~0.5 to 1 % of Na⁺**

(H₂O)Na⁺

(NaOH)Na⁺

(NaCl)Na⁺

(NaOH)₂Na⁺

(NaOH)(NaCl)Na⁺

(Na₂CO₃)Na⁺

(NaCl)₂Na⁺

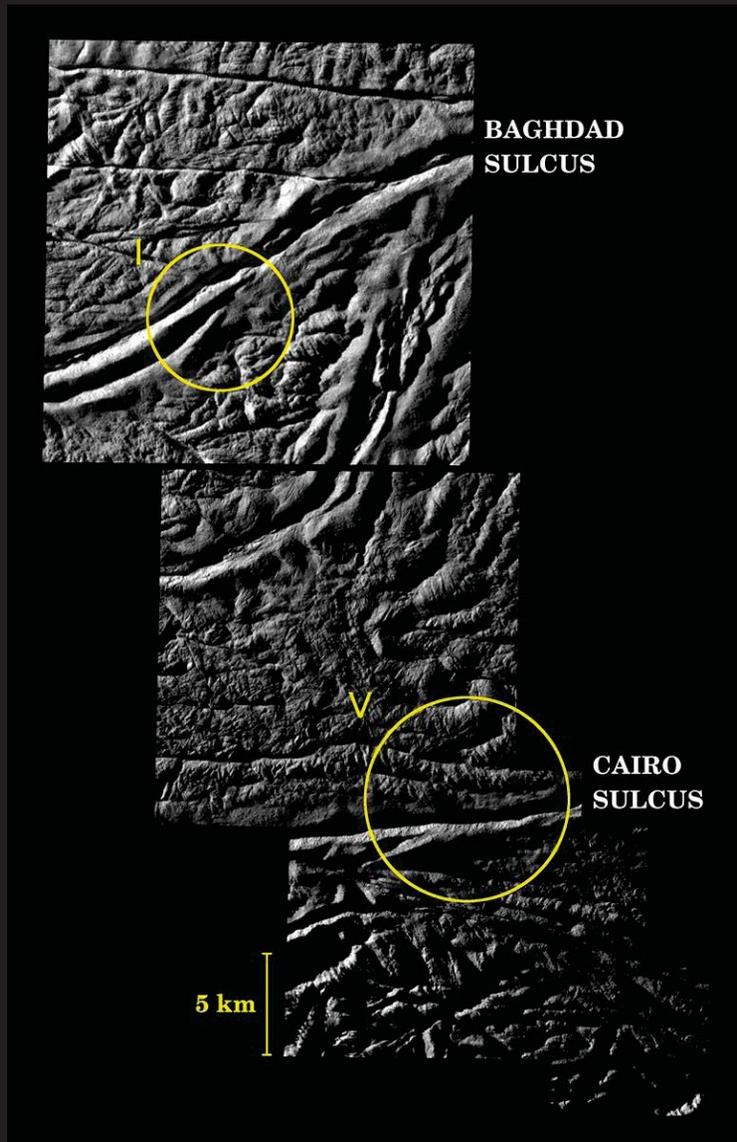
(NaOH)₃Na⁺

Plus other species.



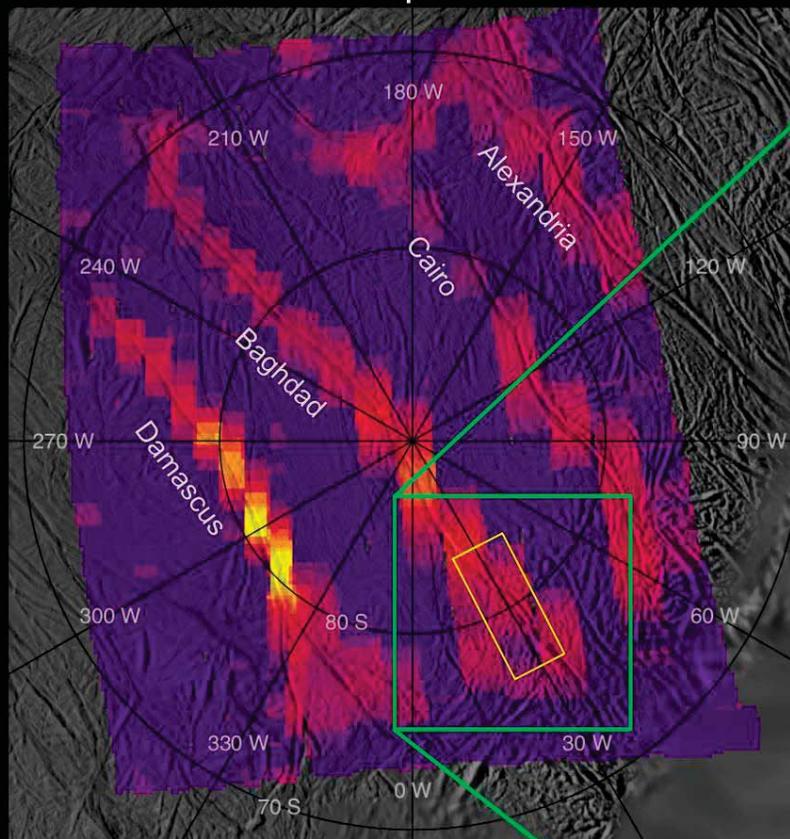
Postberg, F., et al. (2009), Sodium salts in E-ring ice grains from an ocean below the surface of Enceladus, *Nature*, 459, 1098-1101.

Enceladus Plume Sources

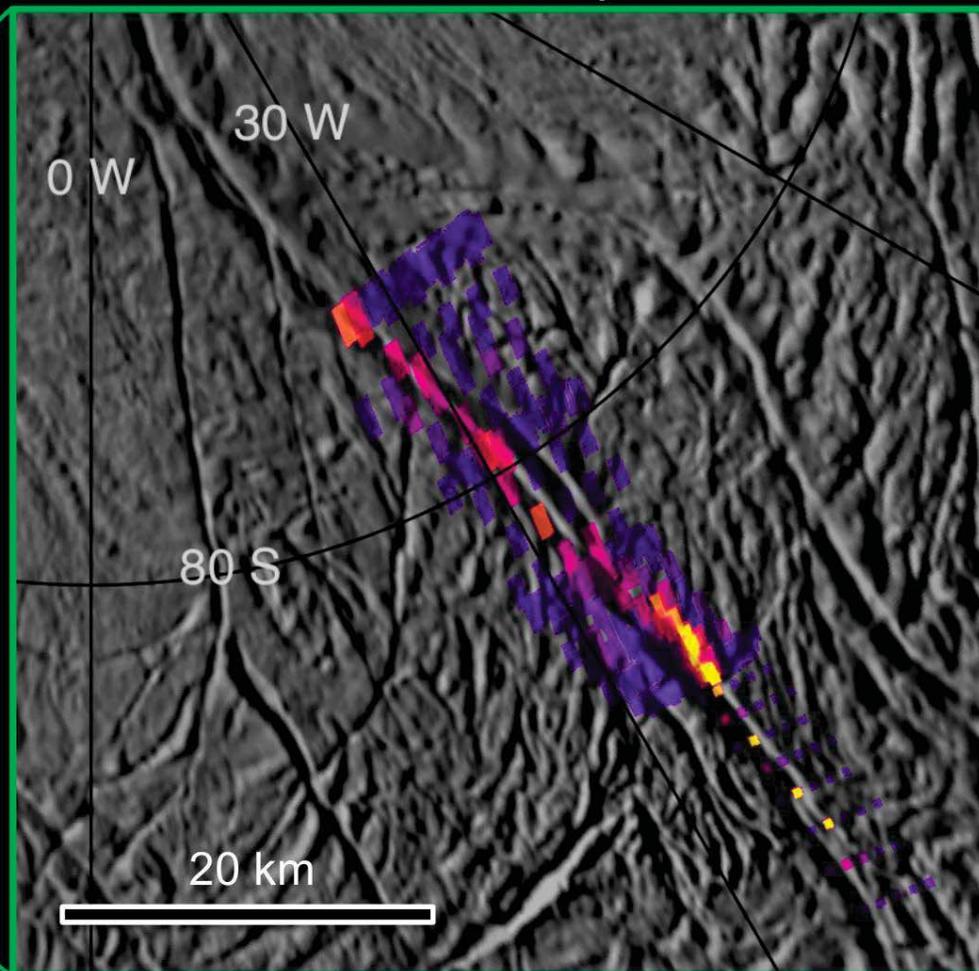


- High resolution images of south polar tiger stripes taken near closest approach during the Aug. 11, 2008 flyby.
- South polar "tiger stripe" fractures, or sulci, are source of moon's icy jets.
- Fractures are about 300 meters (980 feet) deep, with V-shaped inner walls.
- Yellow circles indicate plume locations.
- Finely-fractured terrain littered with blocks of ice tens of meters in size and larger surrounds the fractures.
- Best resolution is 14.5 meters/pixel.

March 2008 CIRS map

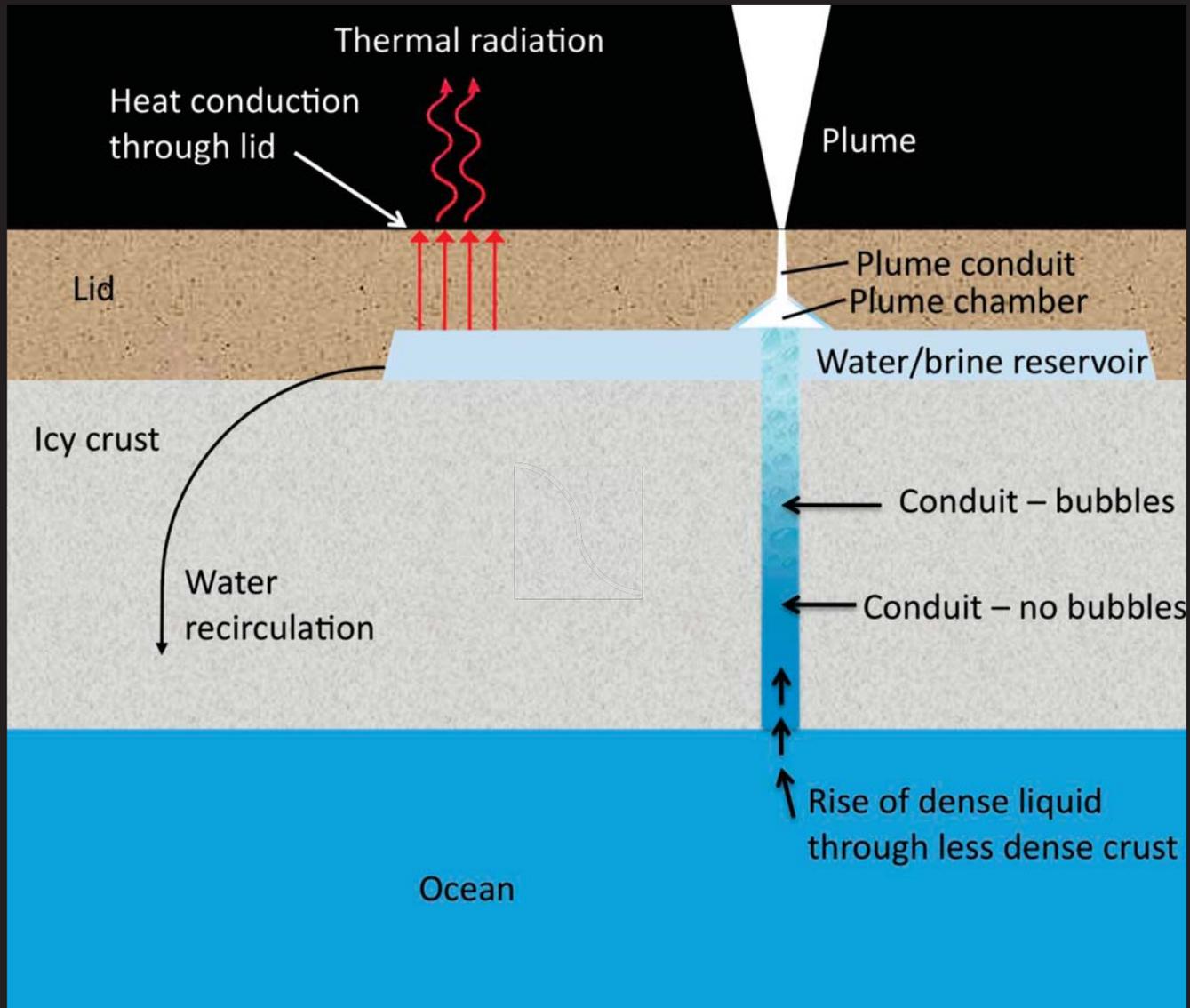


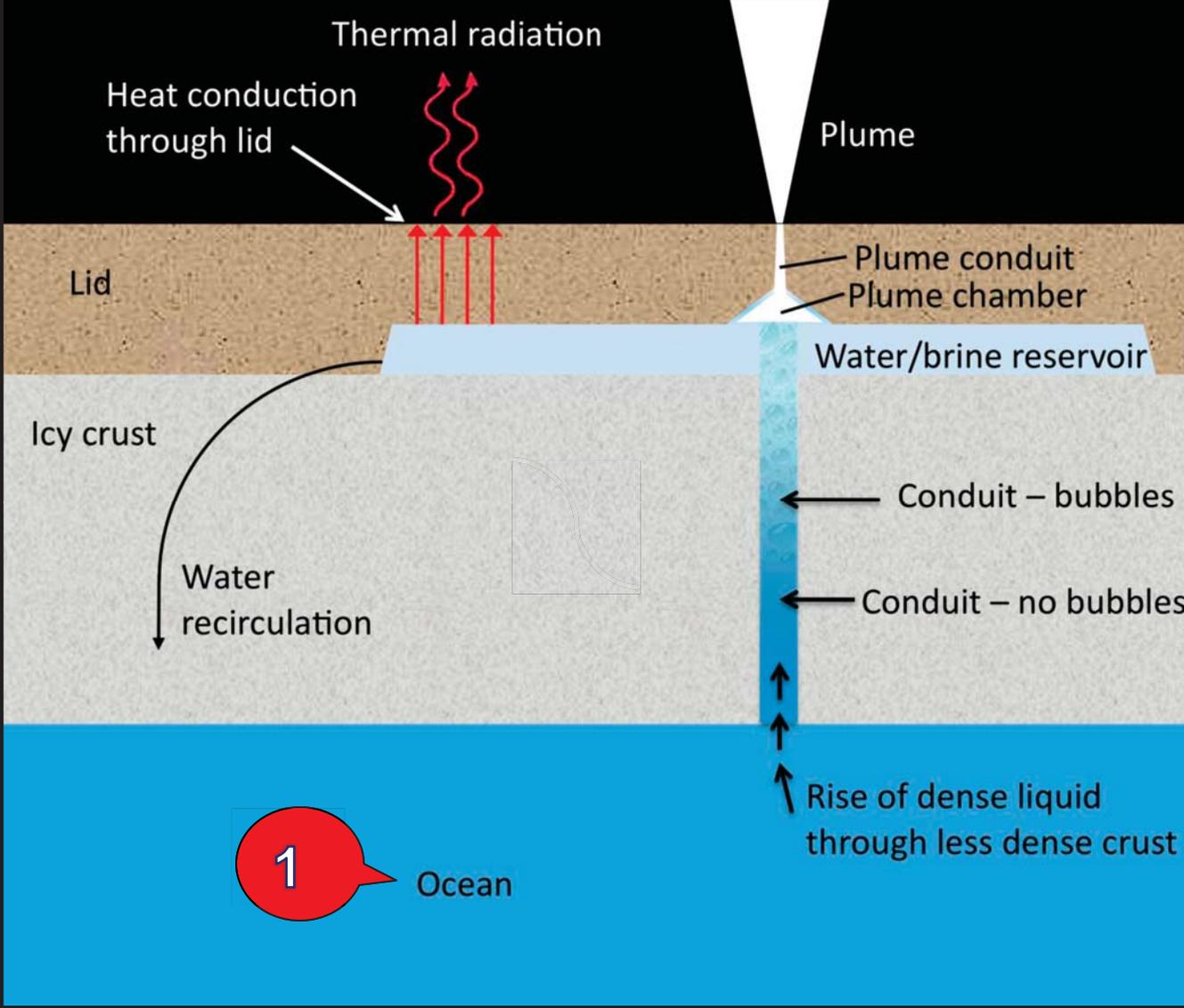
November 2009 CIRS map



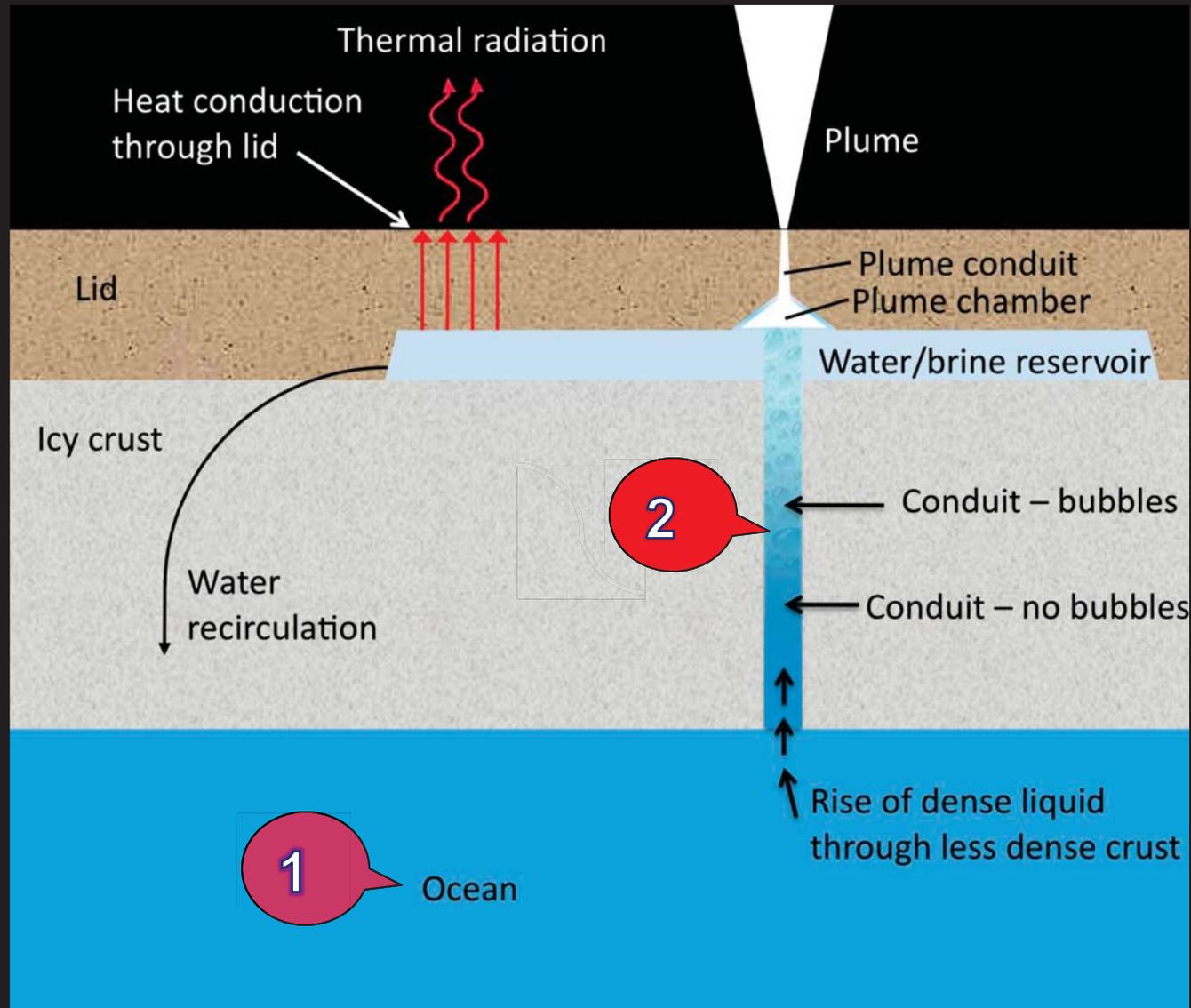
Heat flow >15 GW

$T_{max} \sim 180 \text{ K}$

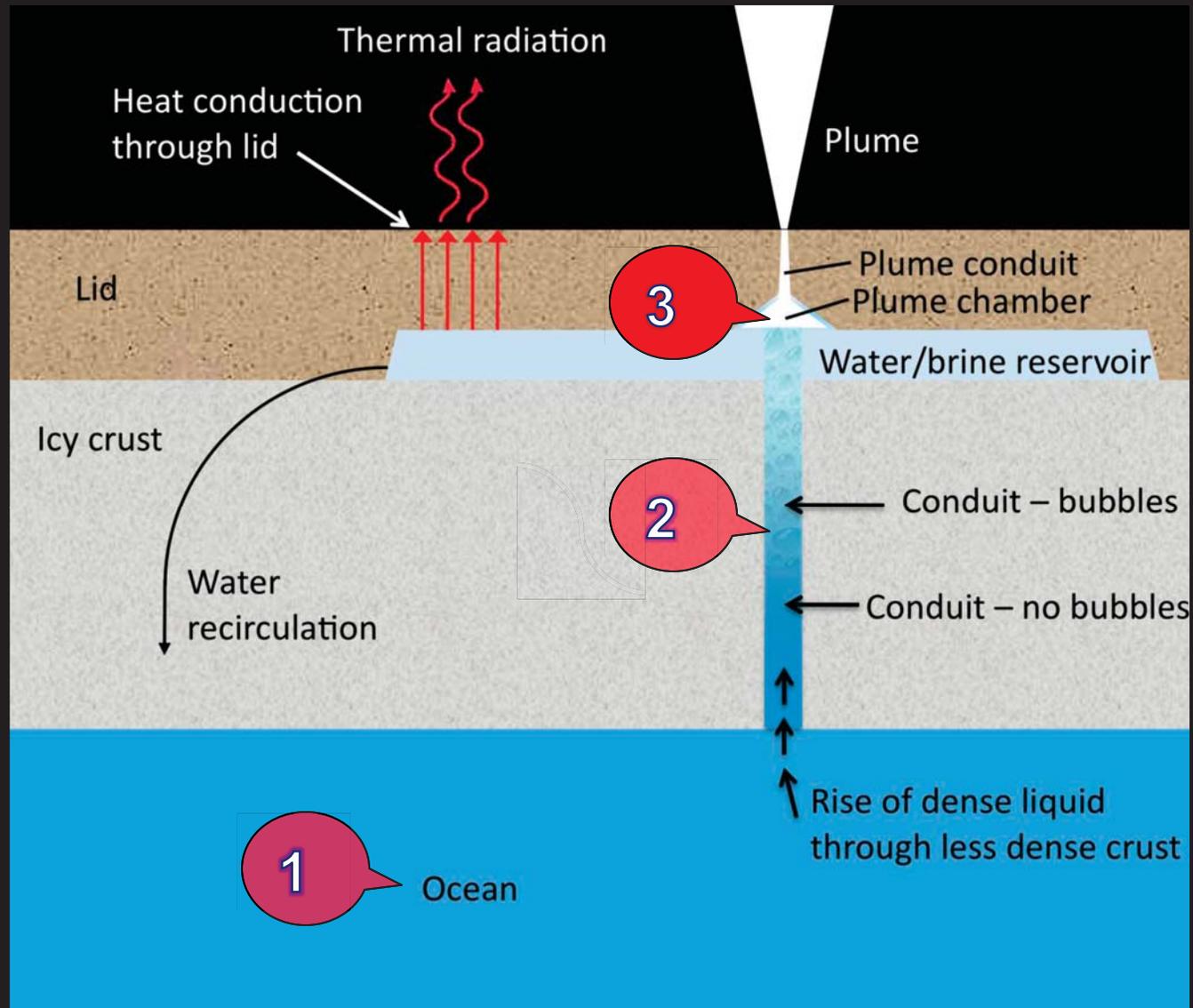




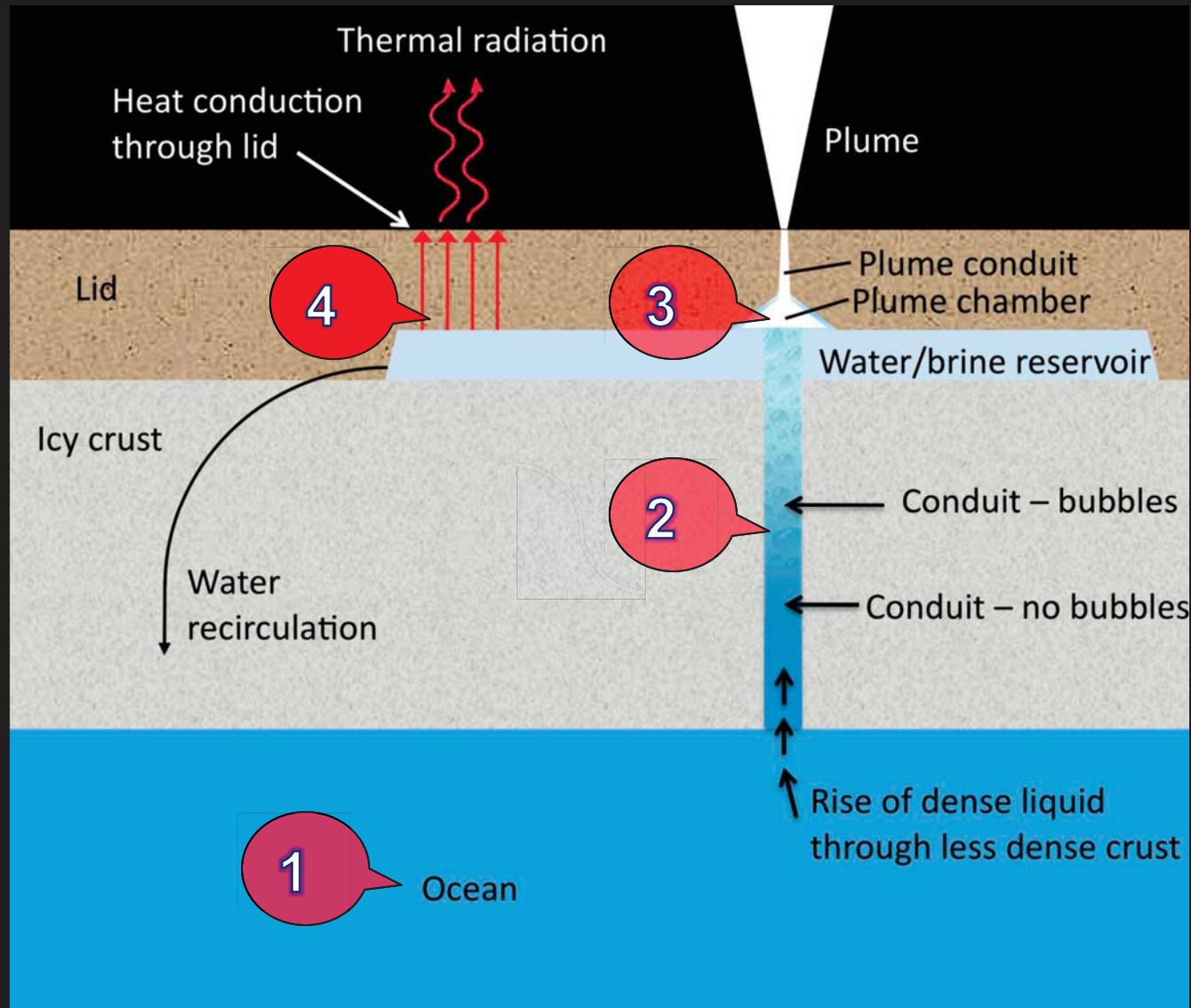
Gas charged ocean



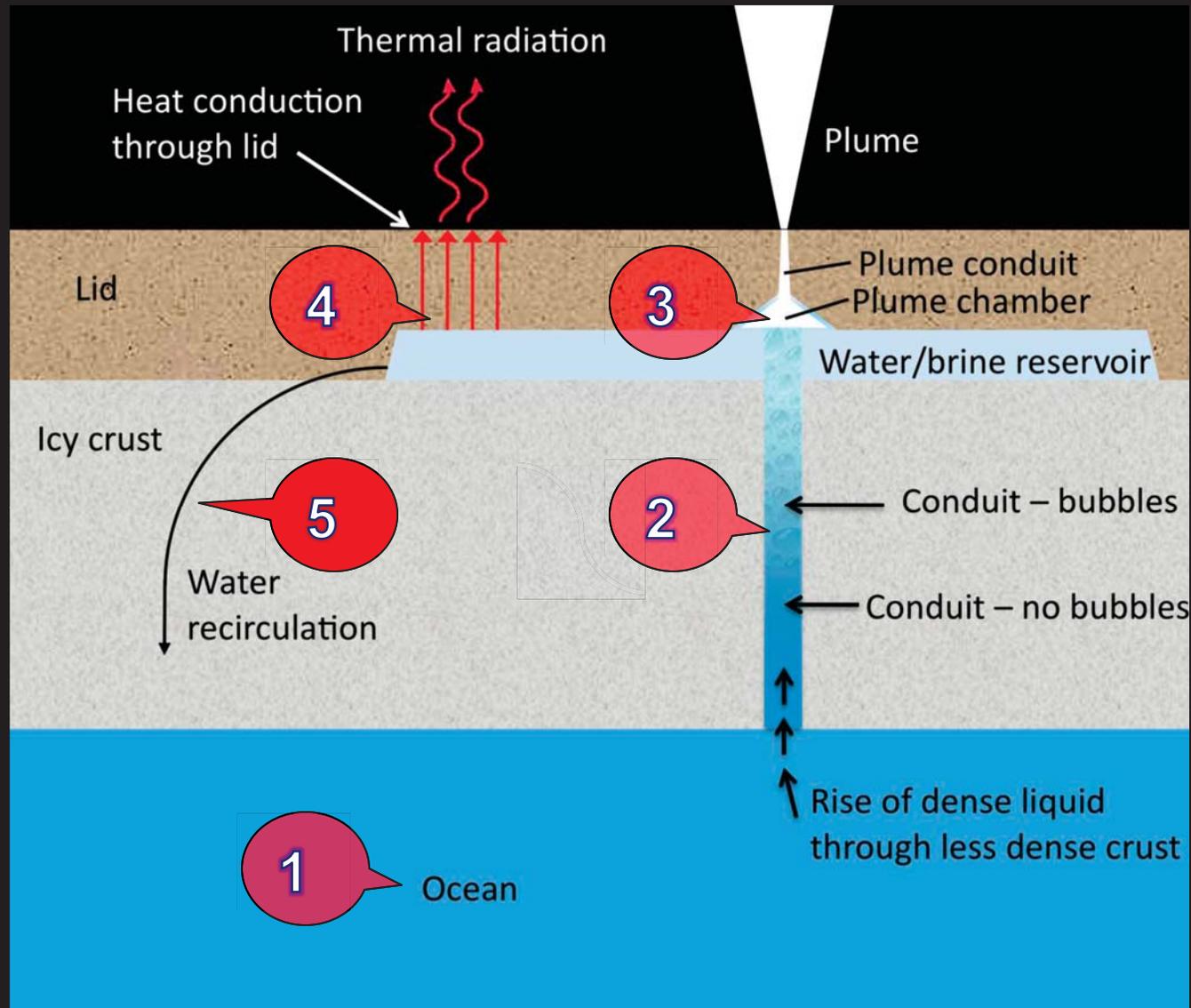
Gas comes out of solution



Heat and chemicals supplied to plume chambers



Heat conducted through ice lid



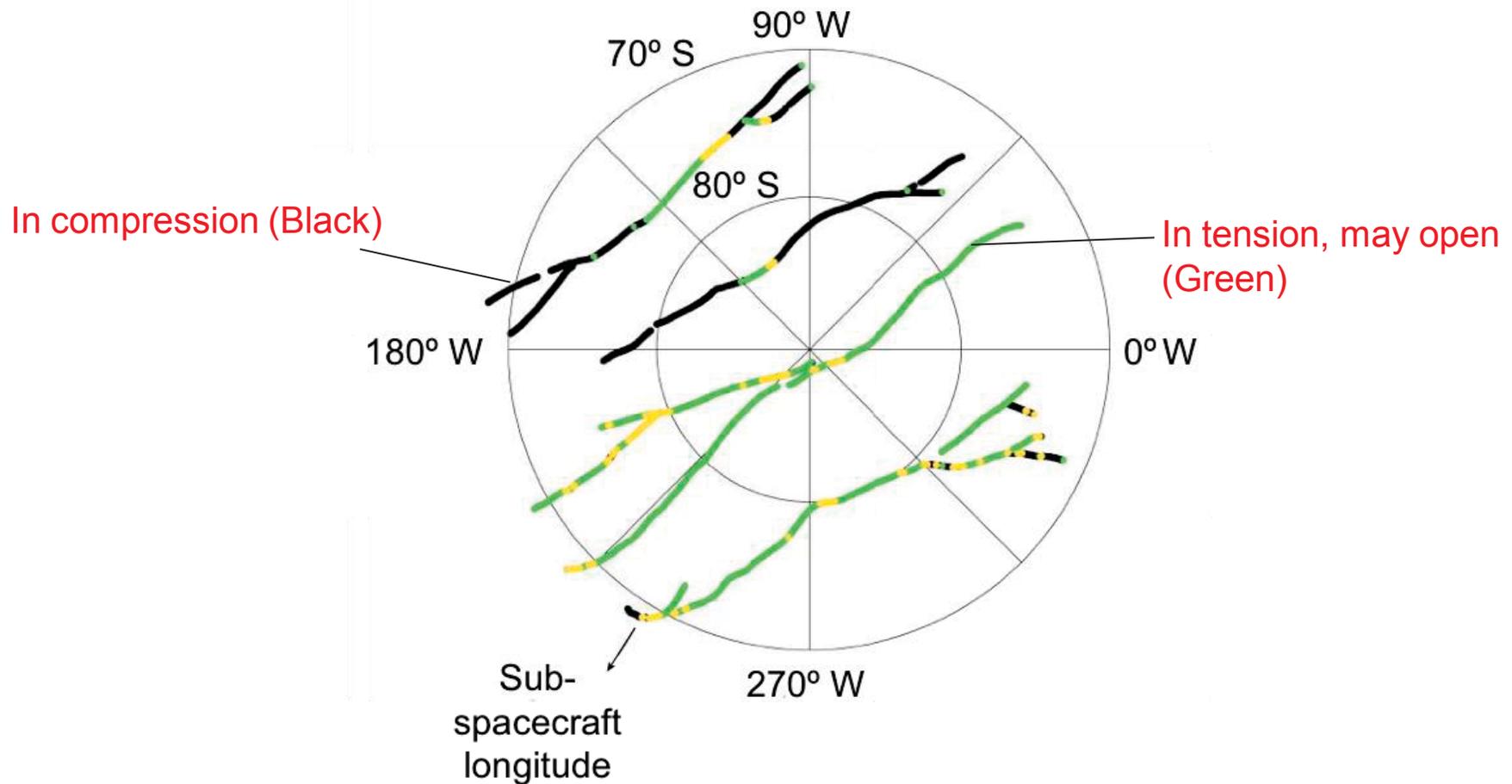
Water returns to ocean via cracks in the ice

How is this process initiated?

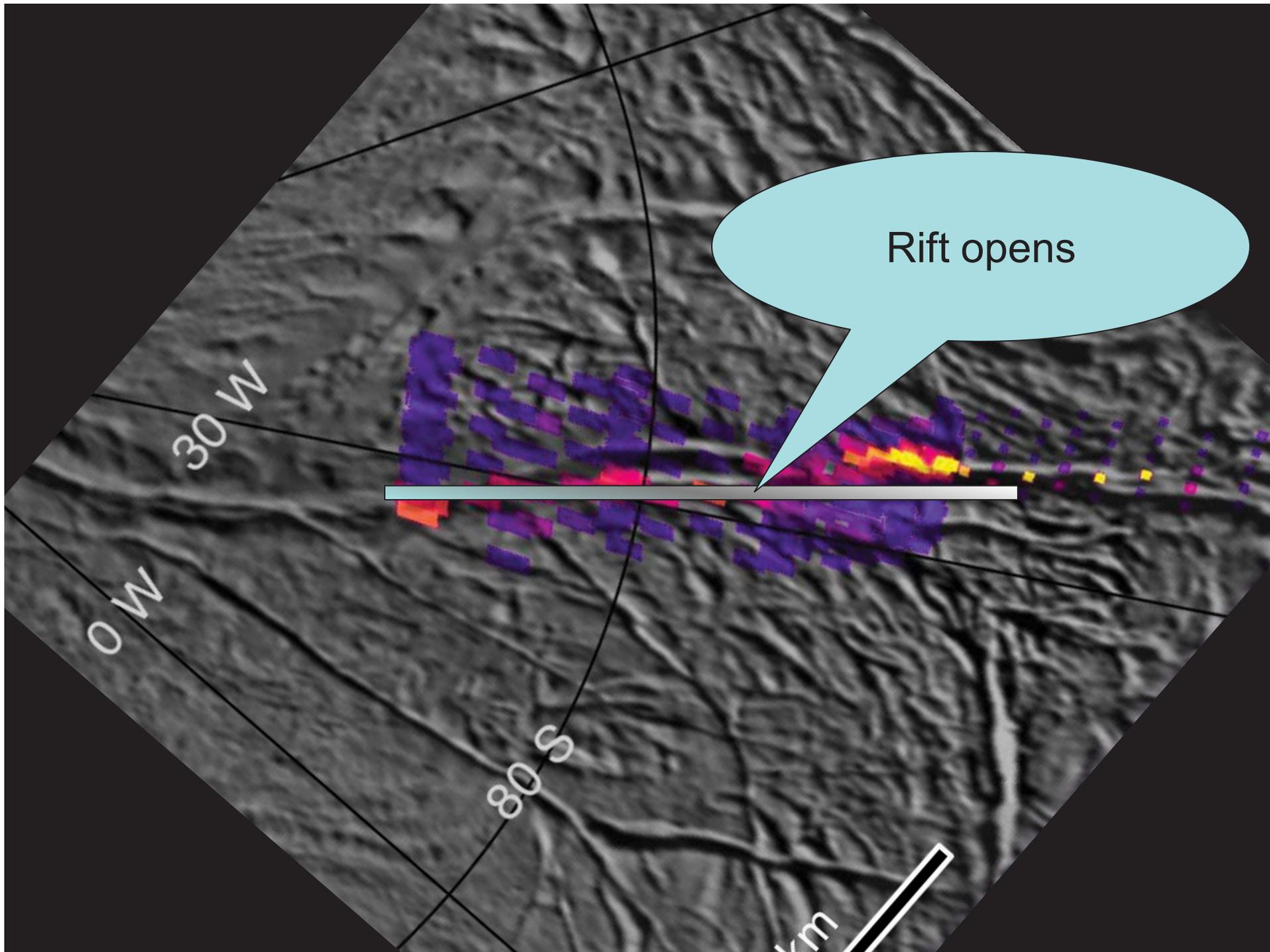
Hurford et al. (2007)

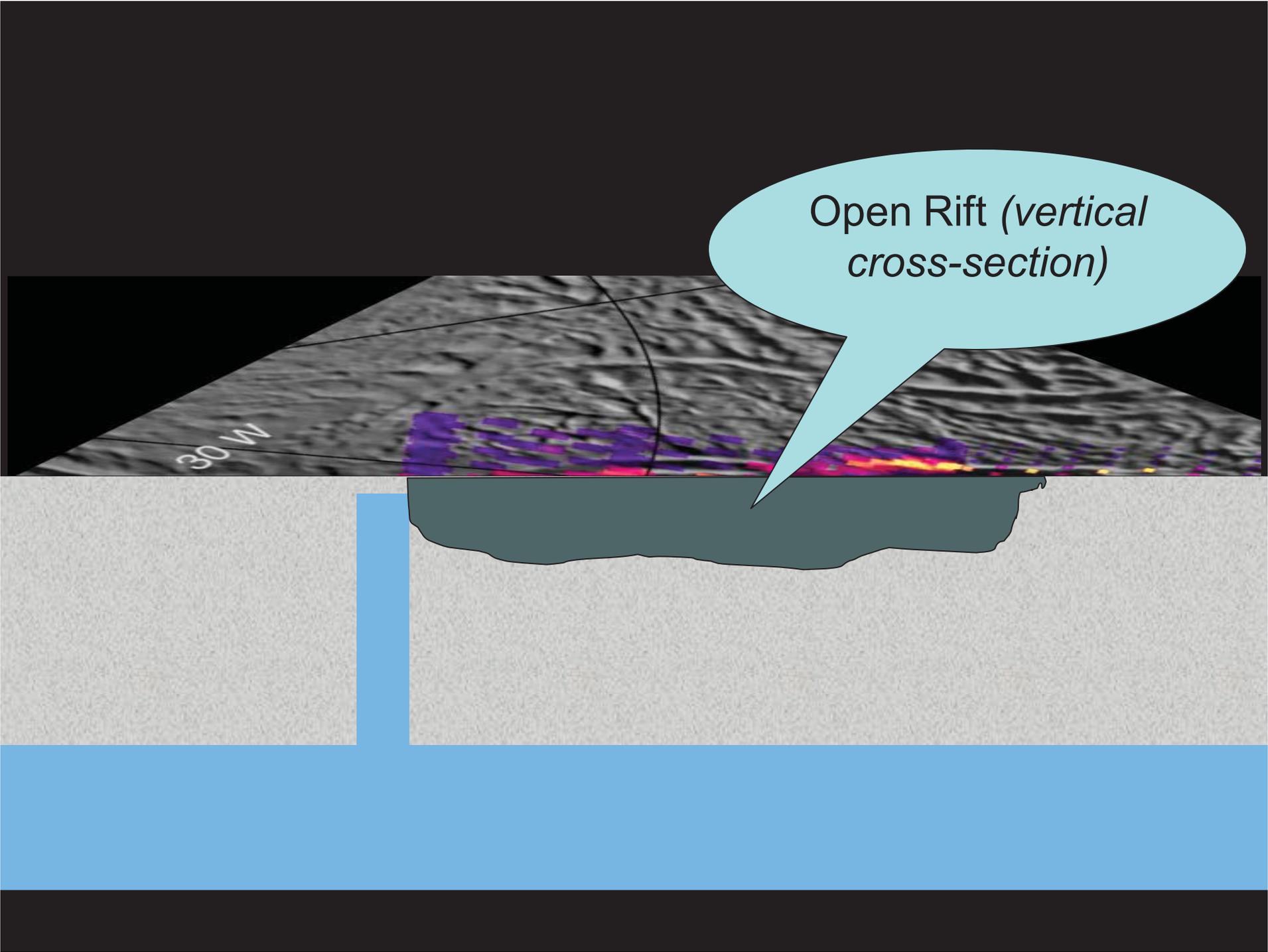
Tidally controlled periodic openings of rifts on Enceladus

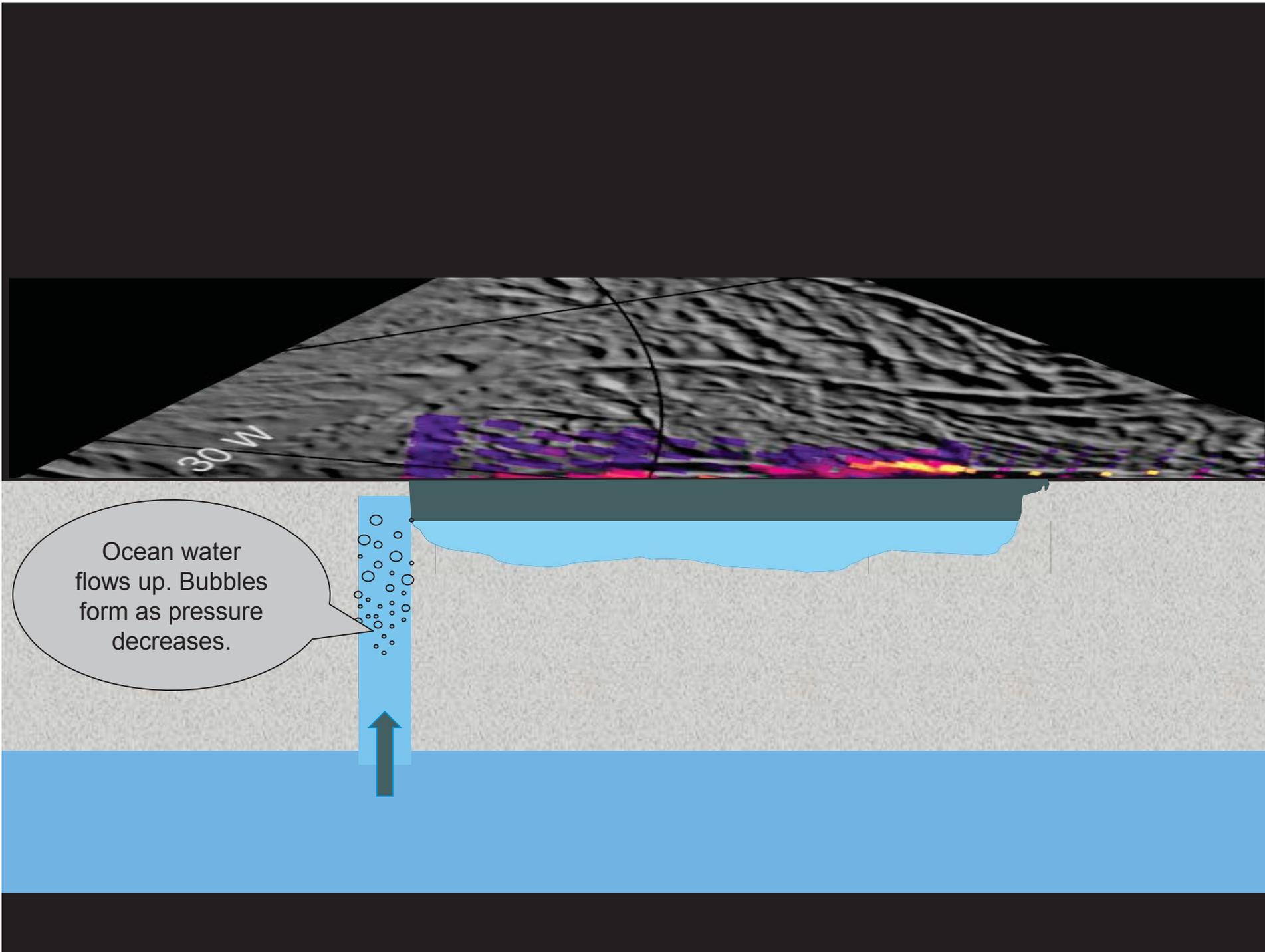
The stress state across the tiger stripe rifts, for 24 April 2007



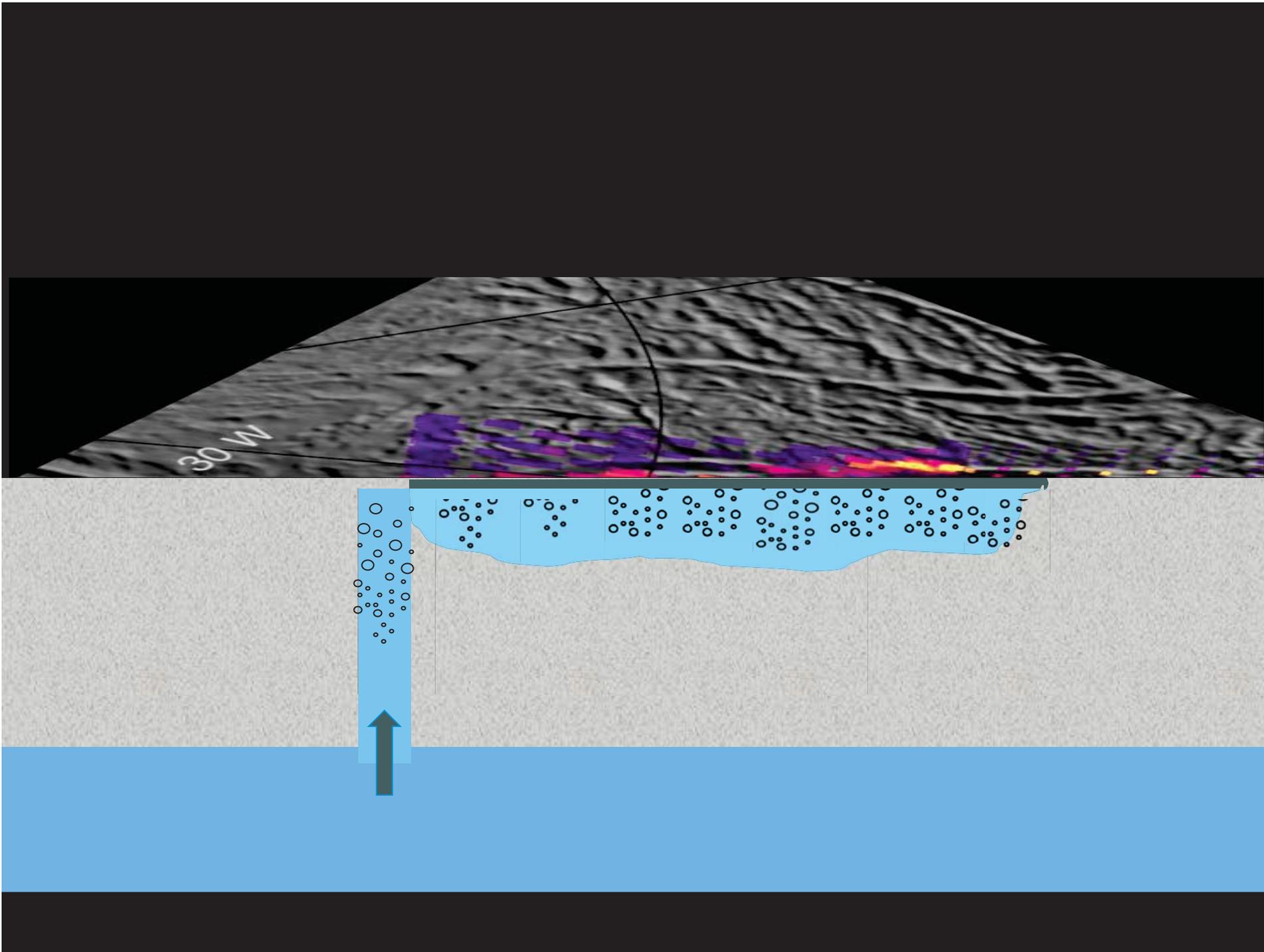
Our modification: some openings fill with water

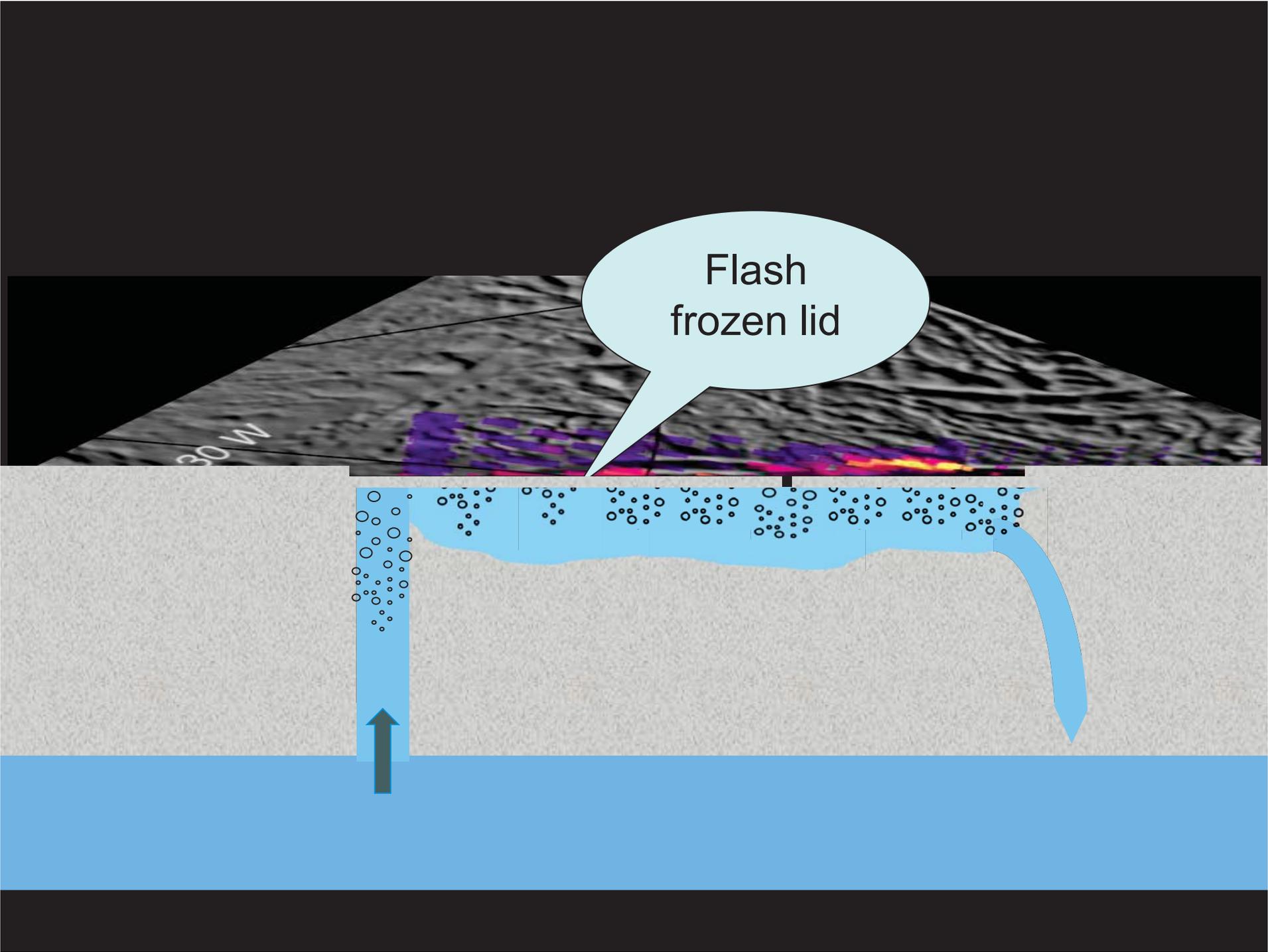






Ocean water flows up. Bubbles form as pressure decreases.

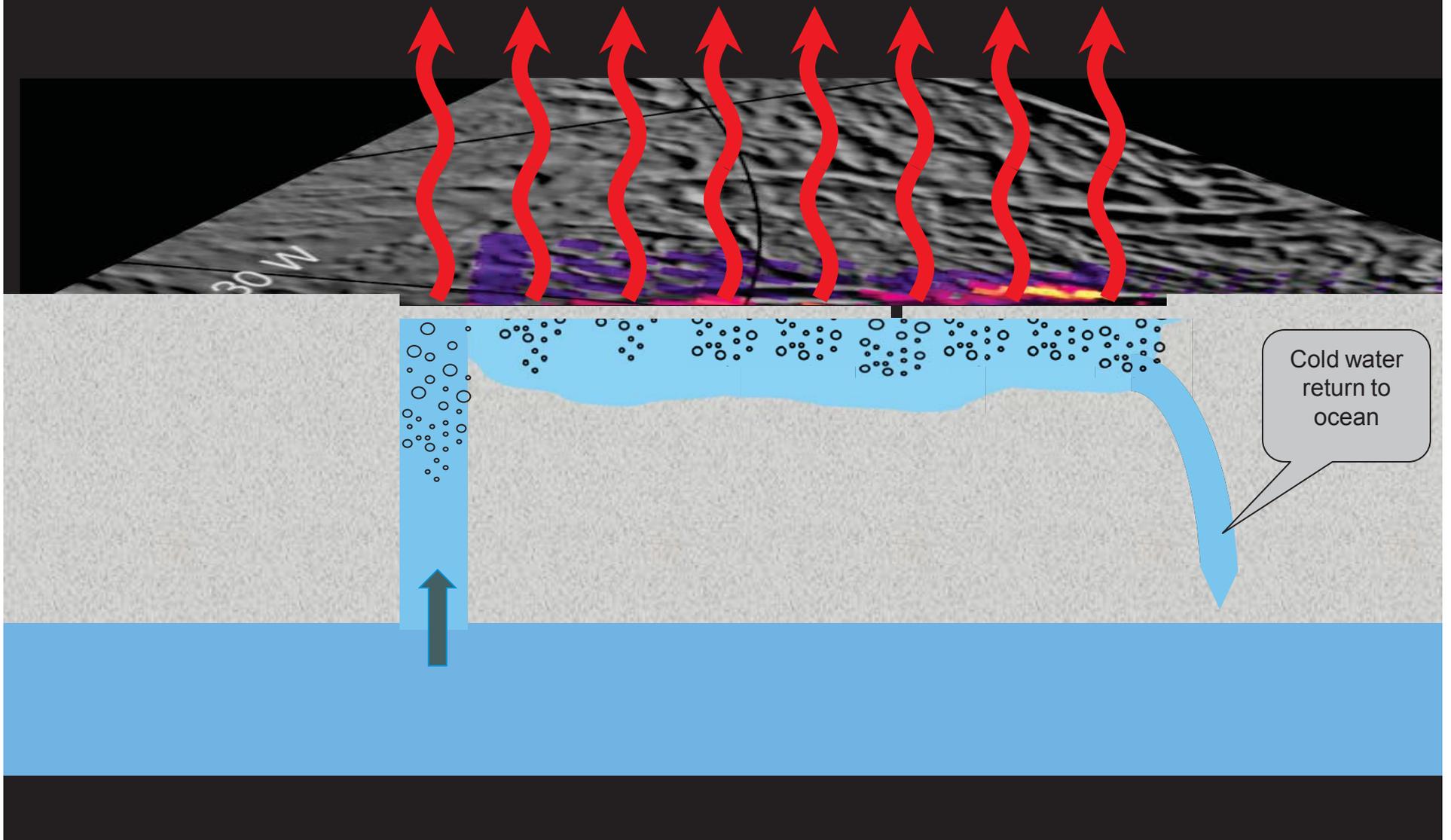


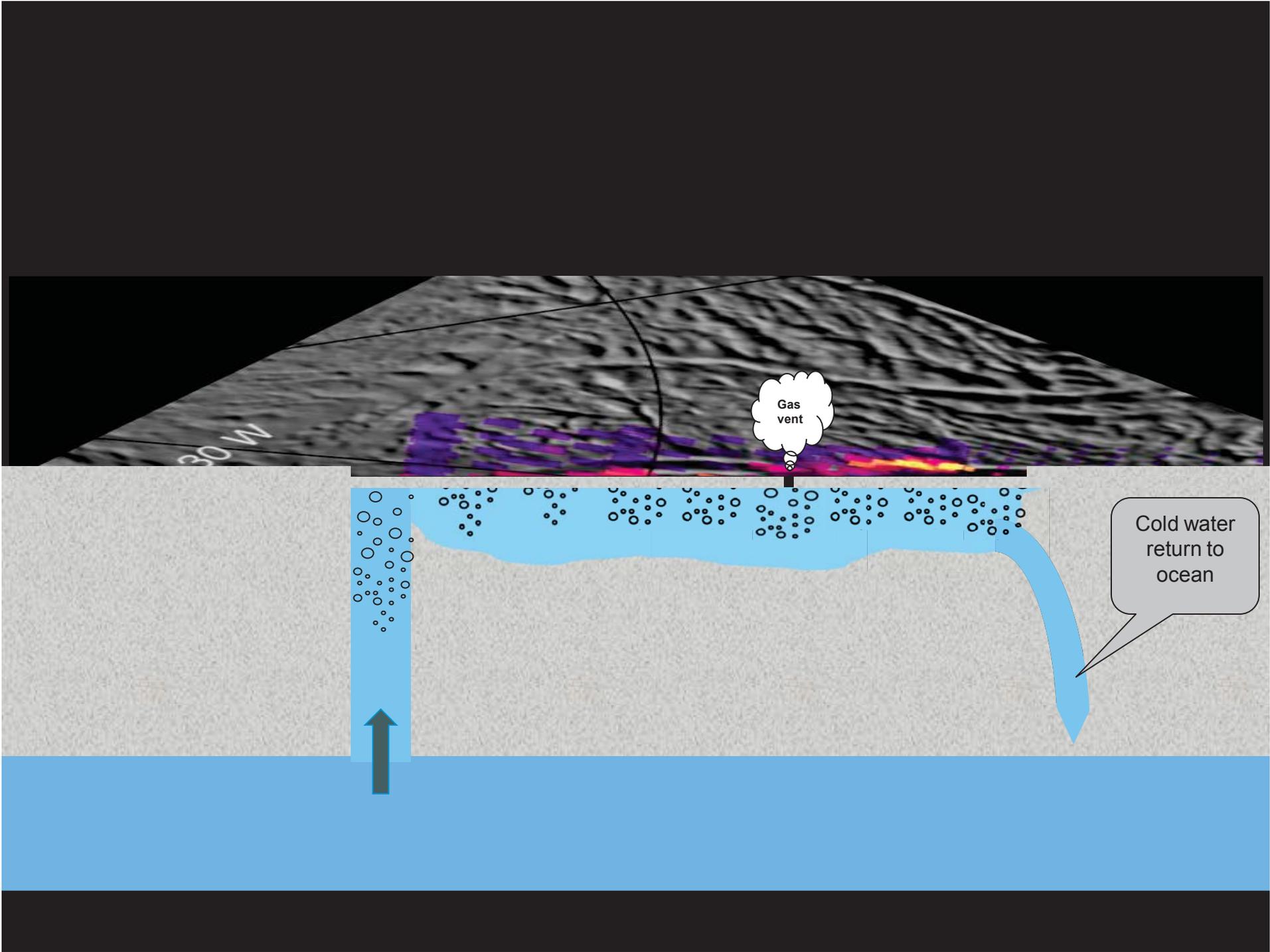


Flash
frozen lid



Thermal Emission





Conclusions

- Ocean water circulation supplies the observed heat flow and chemicals.
- Found a mechanism that starts the circulation of ocean water.

Acknowledgements

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