

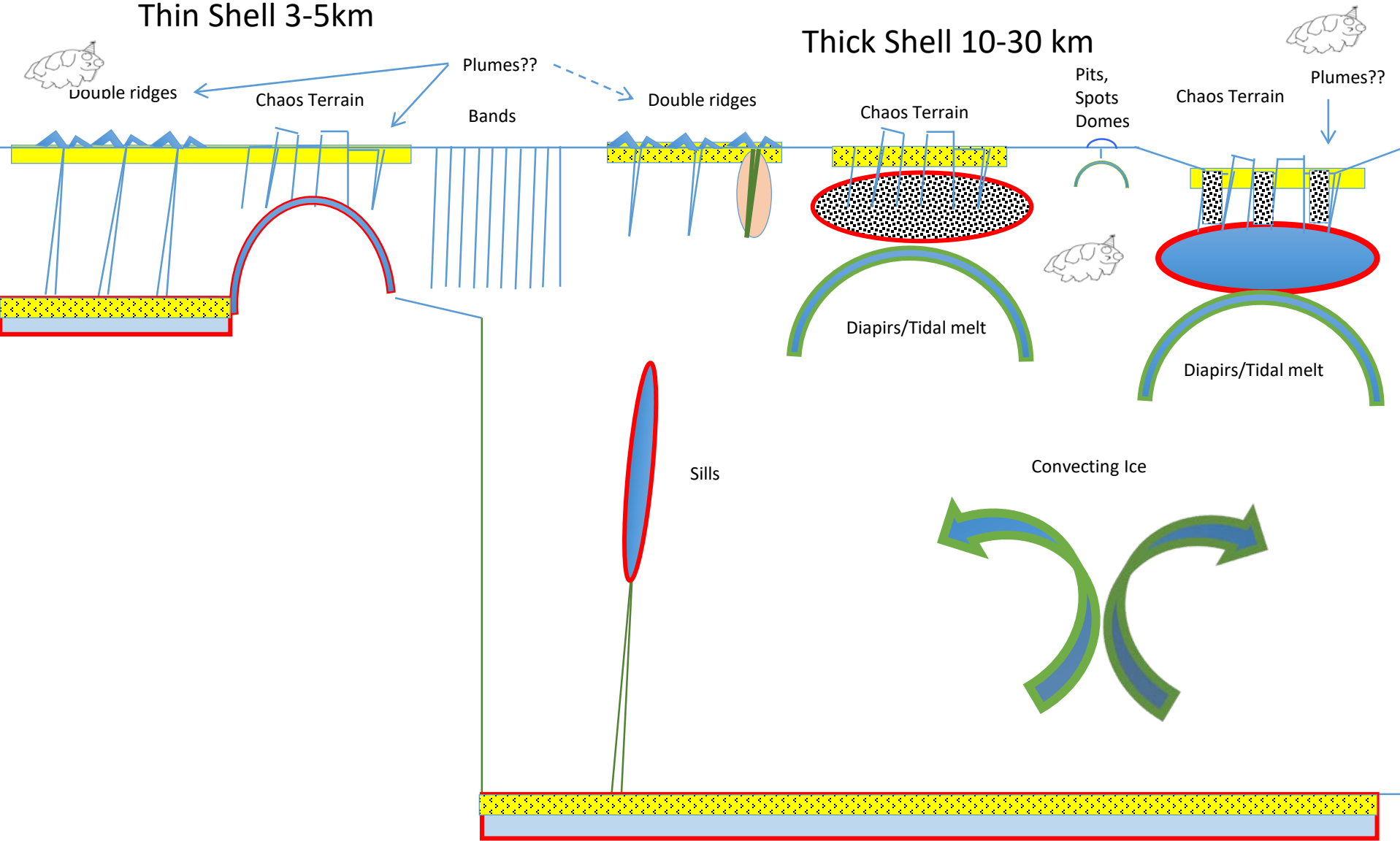
Geophysical/Geological Notes on Planetary Protection for Europa

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Thin Shell 3-5km

Thick Shell 10-30 km



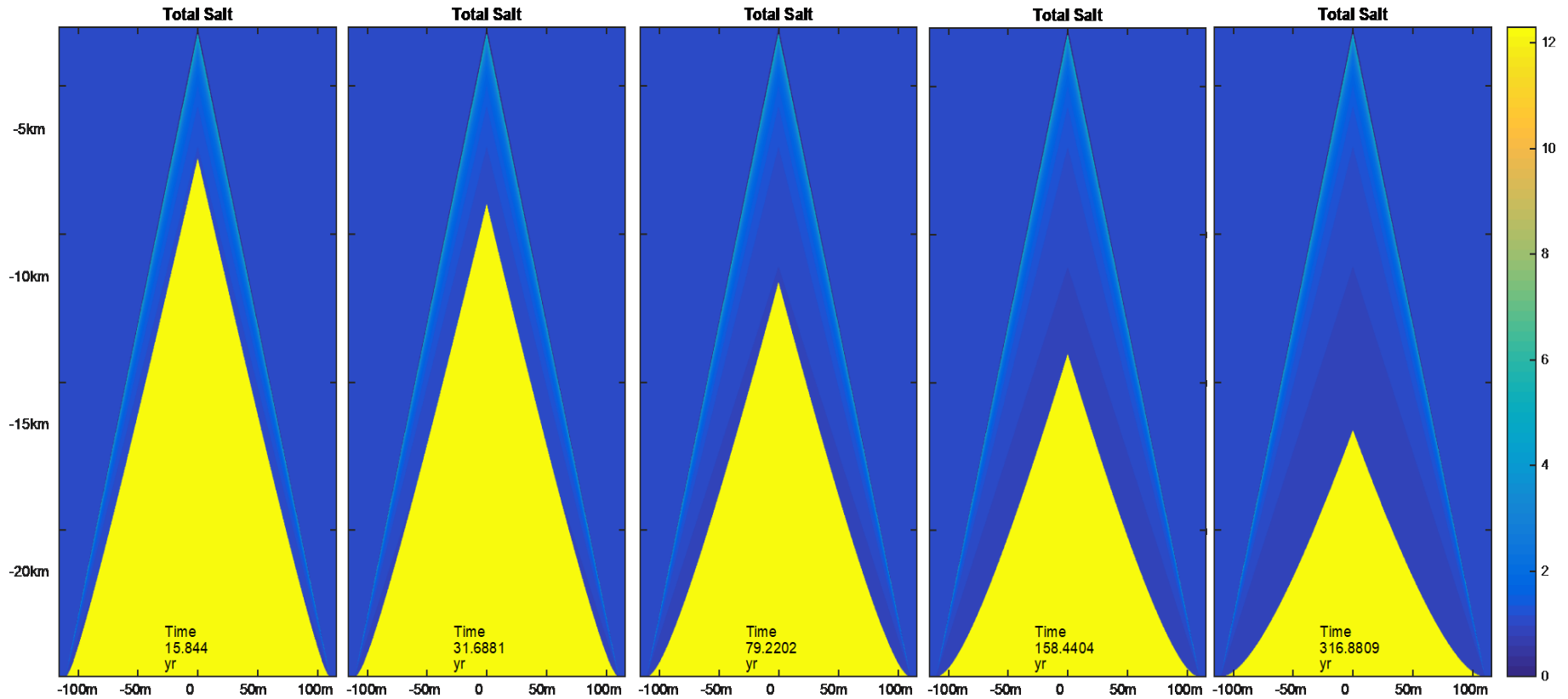
- Biomarkers Possible
- Biomarkers
- Liquid Water
- Brine Zones
- Accreted Ice
- Frictional Heat
- Likely Habitable
- Possibly Habitable

PP Timescales – Chaos

Forthcoming Paper: Schmidt et al 2018

- Surface age:
 - 40-90 Mya
 - ~14% of surface covered in chaos → 0.11 Km²/yr “active”
 - Goes up to .77 Km²/yr if assume whole surface reworked by chaos
 - Probability of impacting an “active area”: 6×10^{-8} - 10^{-9}
 - Surface immediately freezes down to 300m → very low likelihood of hitting anything in contact with a pocket
- Lenses/Chaos:
 - Lifetime: 10^4 - 10^6 years
 - Liquids: ~1200 kg/m³
 - likely very low water activity to form and decreases as it freezes
- Convective/vertical transport timescales:
 - Strongly controlled by density, which means composition
 - 20 km shell, 1200 kg/m³- 10^4 - 10^5 years (Barr & Pappalardo 2004) if/when it gets worked into the ice
- Minimum of 10^4 - 10^5 years for anything in chaos to reach the ocean → kept below activity limits (250K) for that whole time

Refreezing of basal fractures



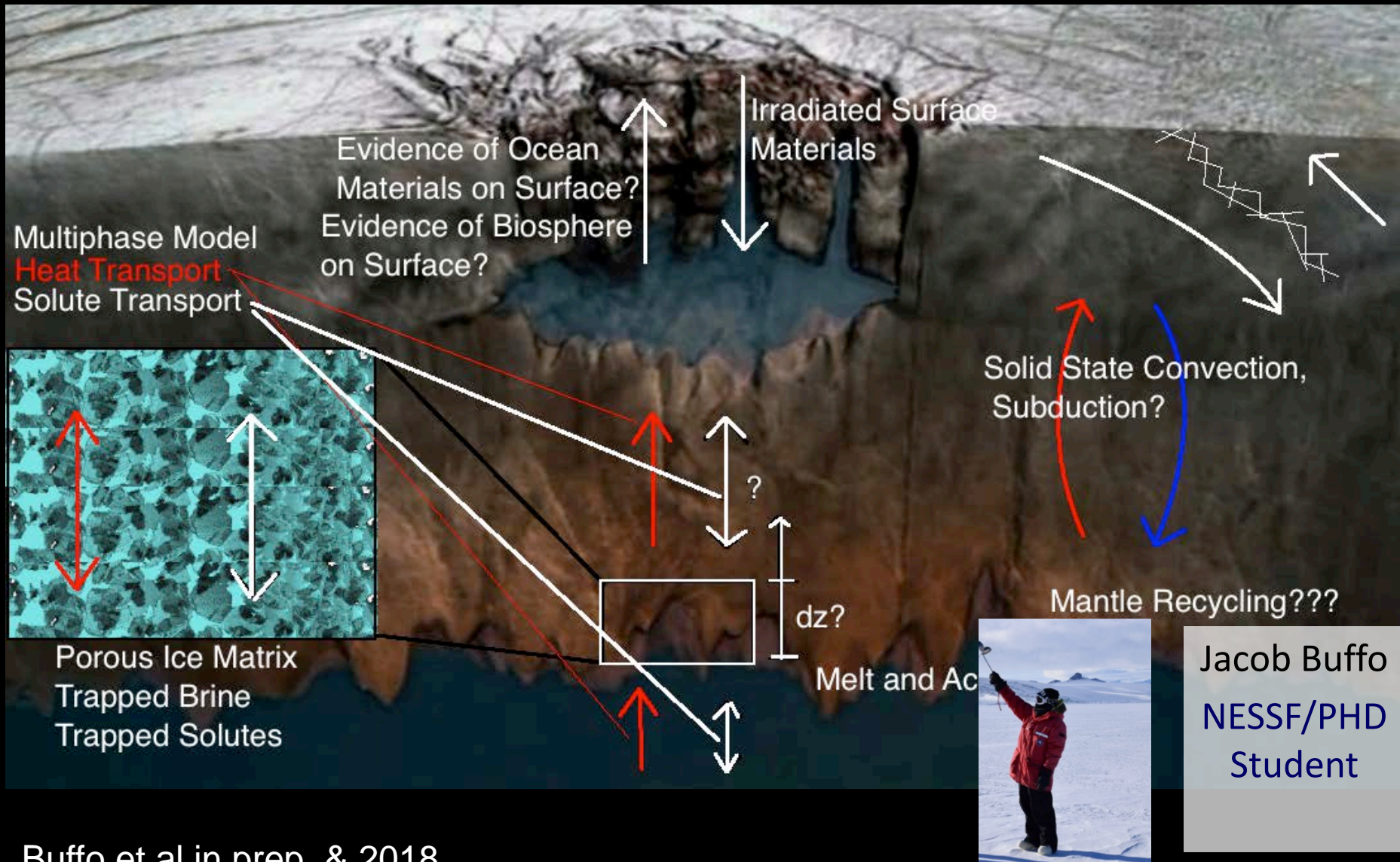
- Freezing of surface water-essentially instantly
- Freezing to 300+m within 1 day

PP Timescales – Fractures

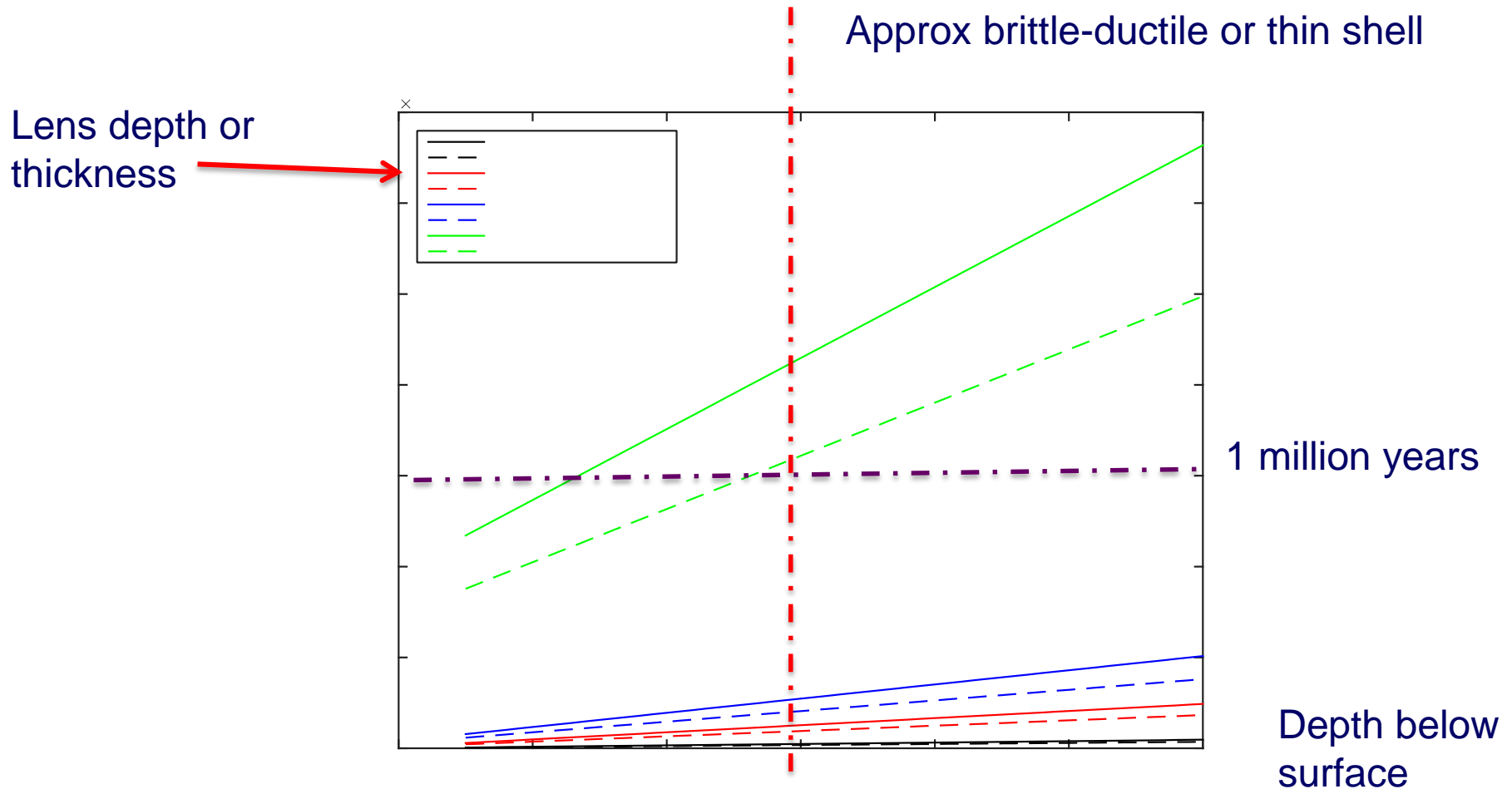
Forthcoming Paper: Schmidt et al 2018/9, Buffo et al 2018/9

- Topography of fractures essentially prevents subsurface contamination
 - troughs are only a few 10's m wide, any opening will be much less than that
 - Not Geysers → “mistifiers”
 - Remember isostasy: water can only come up to ~10% of the surface
 - Any large eruptions (which are not observed) have force that is out not in, won't allow water back down
- Surface age:
 - 40-90 Mya
 - 0.77 km²/yr “active” →
 - Only <30m wide trough
 - Probability of impacting an “active area”: 1×10^{-9} - 10^{-10}
 - Surface immediately freezes down to 300m → very low likelihood of hitting anything
 - Lenses/Chaos:
 - Fracture Lifetime: years to freeze cracks through whole ice shell from 5km (15 years) to 15km (300 yrs)
- Vertical transport timescales: only by burial
 - 1.2 Gyrs (100m burial per 40ma through 3000m ice shell)

Melting inside Europa



Refreezing of water in the ice shell



- Freezing of 100ppt salt water pockets
 - ✧ Conductive vs Multiphysics Reactive Transport Mushy model

Schmidt, Buffo et al in prep, do not reproduce

Further PP Consideration

- Processing by:
 - Radiation
 - Fracture
 - Freezing/Melting
 - Deformation
 - Turbulence
 - Reactions, kelation
 - Dilution-concentration
- Biocidal influence of: Bio Team: C. Carr & A. Pontrefract (MIT),
J. Glass (GT), J. Bowman (Scripps)
 - Radiation
 - Freezing (does prevent activity and stop cell/DNA repair)
 - Low water activity (liquids in the ice shell must be very concentrated)
 - Acidity of shallow liquid?
- We need to define an “exploration timescale”
 - Published work all points in the same direction—1000 years
 - Need to think about Europa “Special Regions” and how to handle these
 - ◇ 1000 years assumes this is the case for all of Europa

Europa PP Findings

- Most conservative (i.e. assume shortest possible timescales and address all possible sources in published work) suggest it is highly improbable to directly contaminate the ocean
- Same approach suggests it is very difficult to contaminate subsurface water reservoirs unless intentionally done
- We need to define an “exploration timescale”
 - Published work all points in the same direction—1000 years
 - Need to think about Europa “Special Regions” and how to handle these
 - 1000 years assumes this is the case for all of Europa