# Decoupling between fluvial aggradation-incision and paleo-denudation rates during the last glacial cycle, Crete, Greece

**R. Ott**, D. Scherler, M. D'Arcy, K. Wegmann, S. Ivy-Ochs, R. Pope, M. Christl, V. Vockenhuber

# What is the impact of glacial cylces on erosion?

- Debate in mountainous regions:

LETTER

doi:10.1038/nature12877

**Worldwide acceleration of mountain erosion under a cooling climate**

Frédéric Herman[1,2], Diane Seward[3], Pierre G. Valla[1,2], Andrew Carter[4], Barry Kohn[5], Sean D. Willett[2] & Todd A. Ehlers[6]

LETTER

https://doi.org/10.1038/s41586-018-0260-6

**Spatial correlation bias in late-Cenozoic erosion histories derived from thermochronology**

Taylor F. Schildgen[1,2,6]*, Pieter A. van der Beek[3,6], Hugh D. Sinclair[4] & Rasmus C. Thiede[2,5]

- What happened in fluvial regions?
  - Few paleo-denudation studies, disparate results…
- Did cooling at mid-latitudes intensify physical erosion and cause higher denudation rates?

# Can we use river terraces as climate archives?

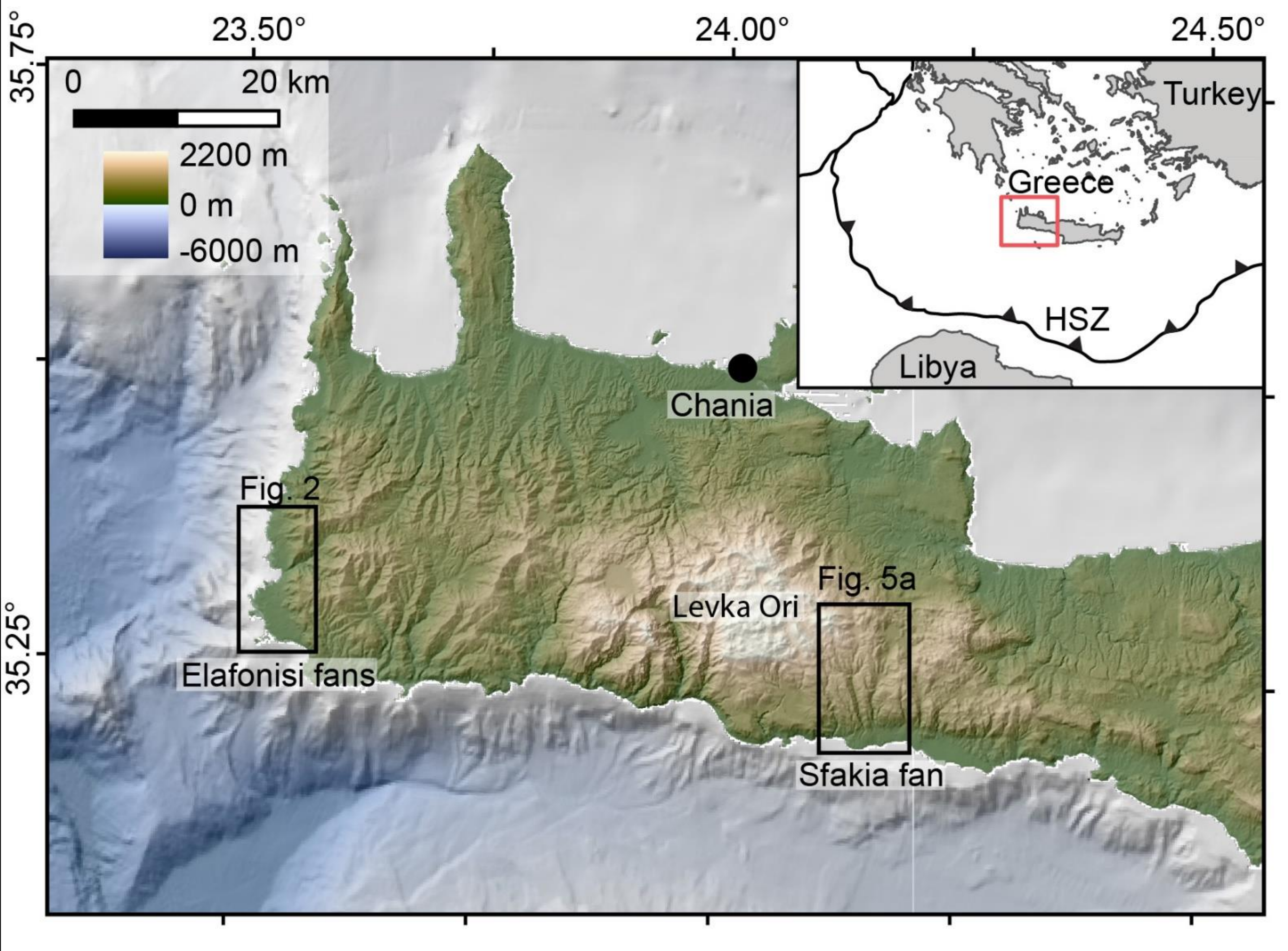
- Many studies relate river terrace formation to climate

**BUT:**

Do terraces record sediment production OR hydroclimate variations?

**combined aggradation-incison data**
**&**
**paleo-denudation rates required**

# Overview, Crete, Greece



# Archives on Crete - Elafonisi

**not mapped**

**no geochronology available**

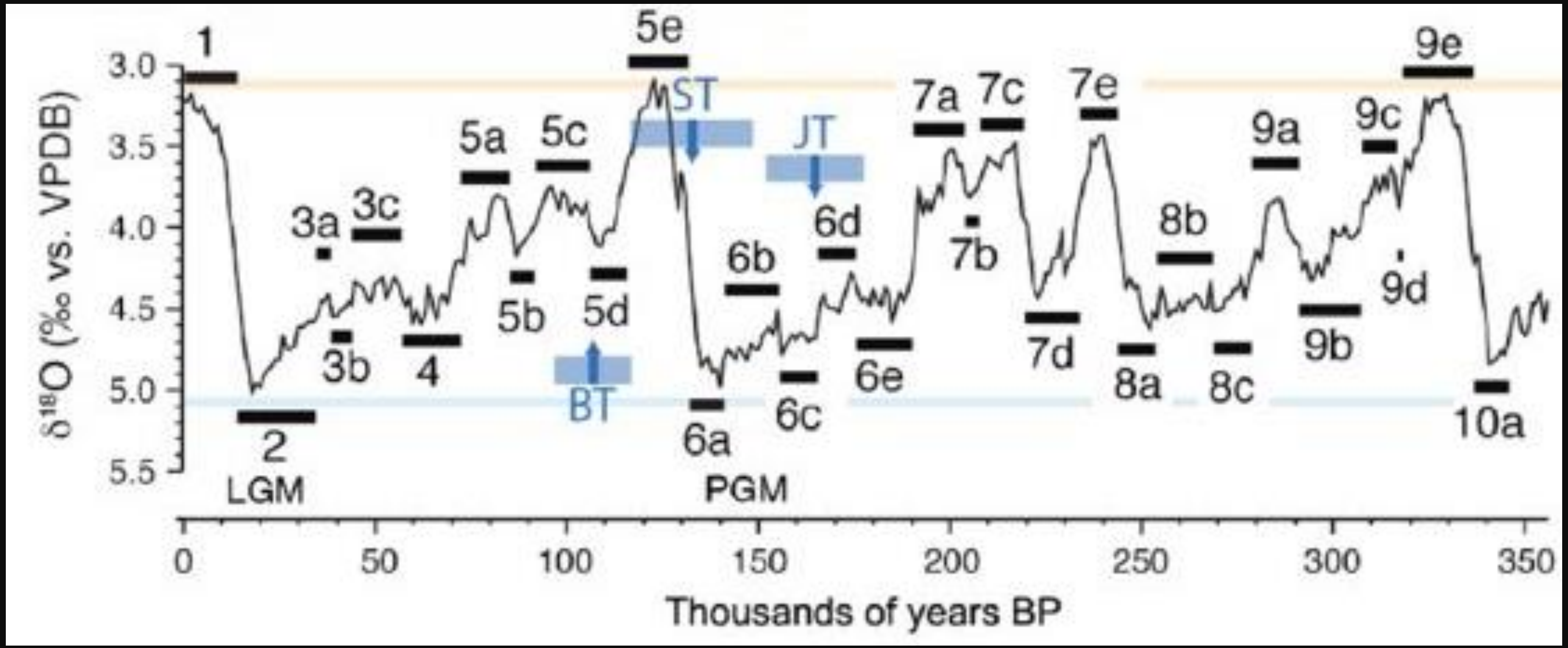
# Archives on Crete - Sfakia

**mapped**

**31 OSL & U-series ages**

**Integrates over full last glacial cycle**

# Marine Isotope Stages (MIS)




**warm stages – interstadials & interglacials – uneven numbers – MIS 1,3,5**

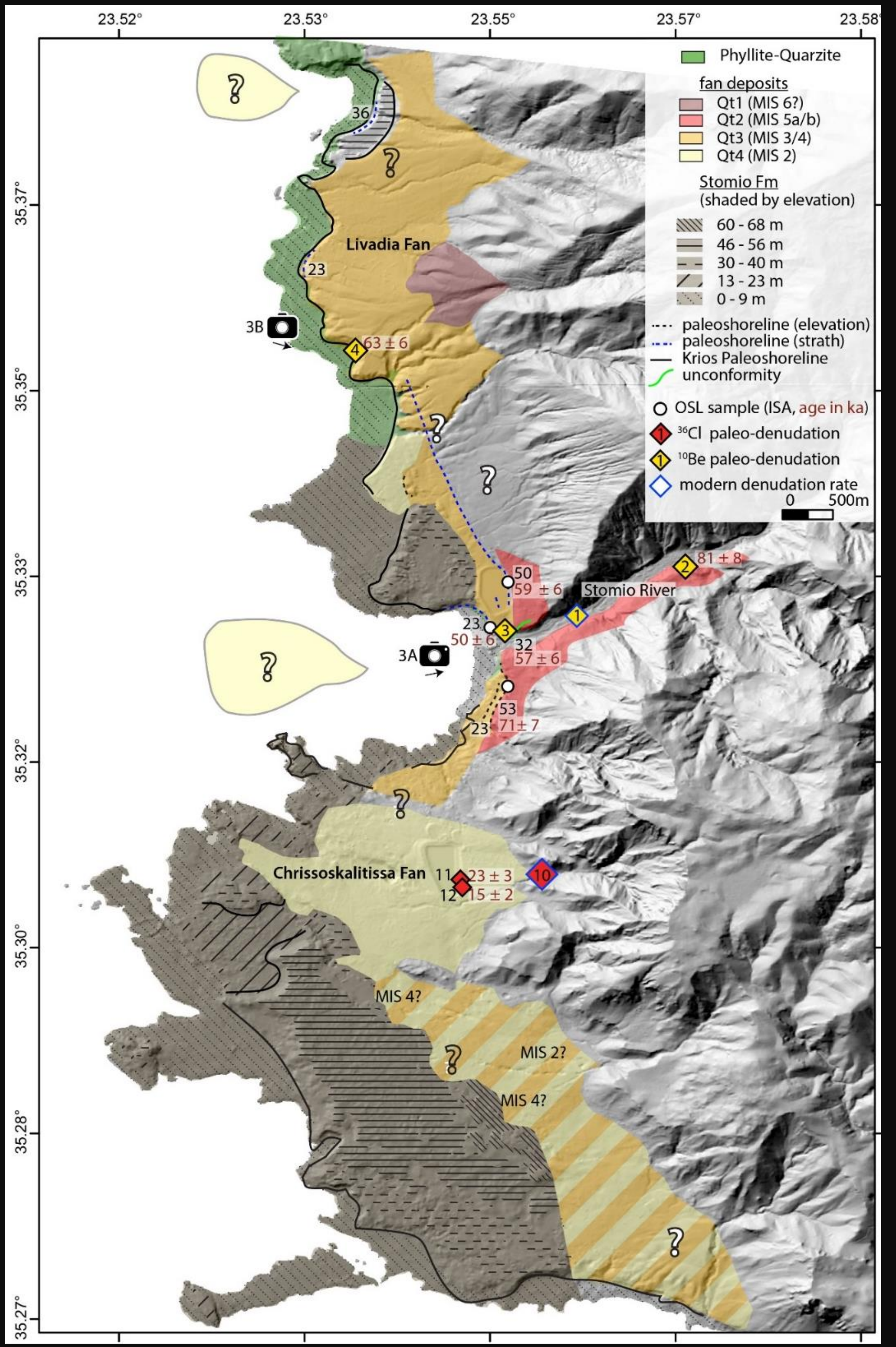
**cold stages – stadials – even numbers – MIS 2,4,6**

# Mapping Elafonisi

- 4 Quaternary units
- numerous paleoshorelines
- alluvial units inset to each other

- 8 OSL samples
- 1 radiocarbon age

- 2 samples for modern denudation
- 5 paleo-denudation samples (2 $^{36}Cl$, 3 $^{10}Be$)

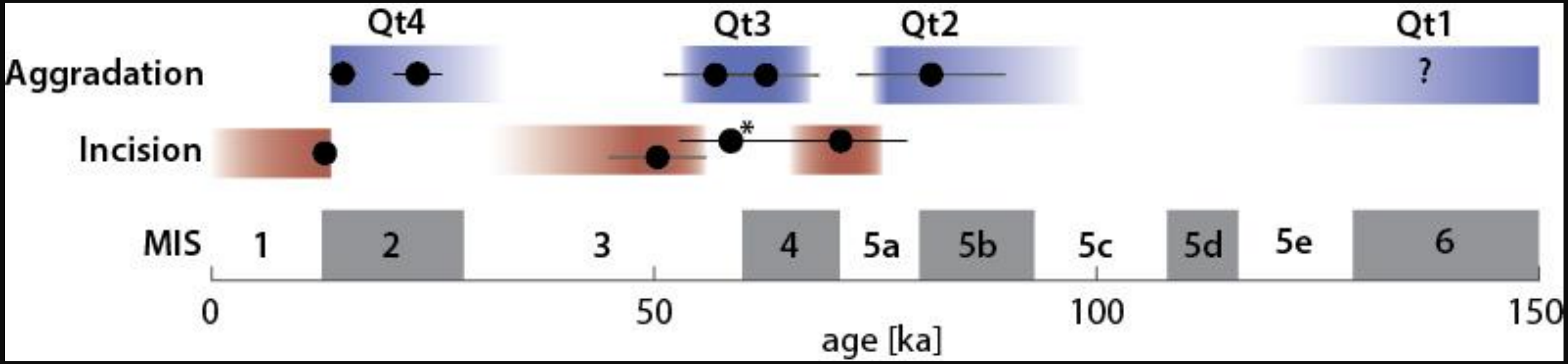


# Elafonisi


A
81.3 ± 8.4
Qt2
Qt2
Qt3
56.9 ± 5.9
Gypsum
50.4 ± 5.5
Gypsum
B
Qt1
Qt3
Qt3
62.7 ± 6.0 ka
Phyllite-Quartzite
Phyllite-Quartzite
sea level
C
D
E
paleobeach
gypsum
F
Qt1
81.3 ± 8.4 ka
channel fill
G
13 m
13.06-13.28 ka
14.8 ± 1.5 ka
23.3 ± 2.8 ka

# Aggradation – Incision - Elafonisi

- alluvation mostly during cold stages
  - despite low eustatic sevel!
- incision during warm stages

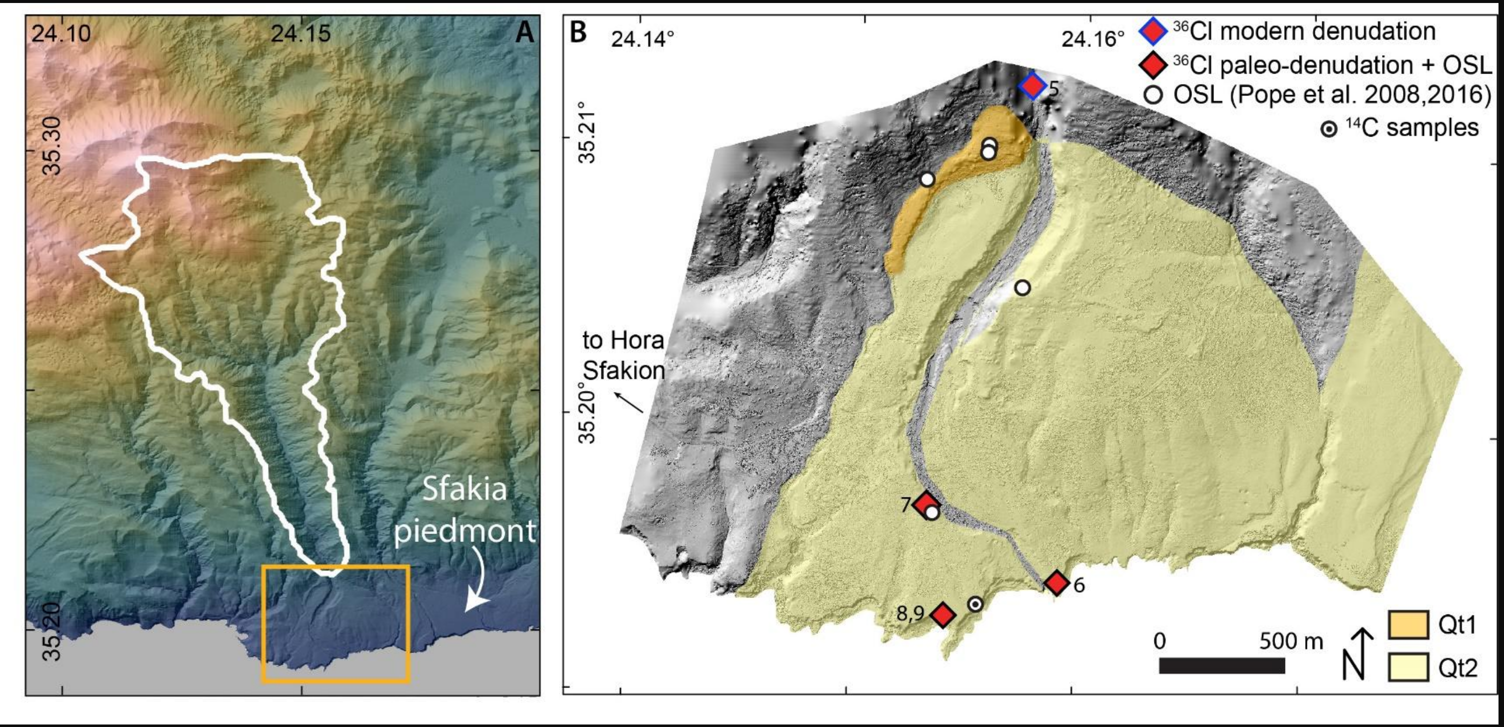


# Sfakia fan

- 2 Quaternary units
- alluvial units inset to each other

- 24 OSL ages (published)
- 7 U-series ages (published)
- 9 new radiocarbon ages

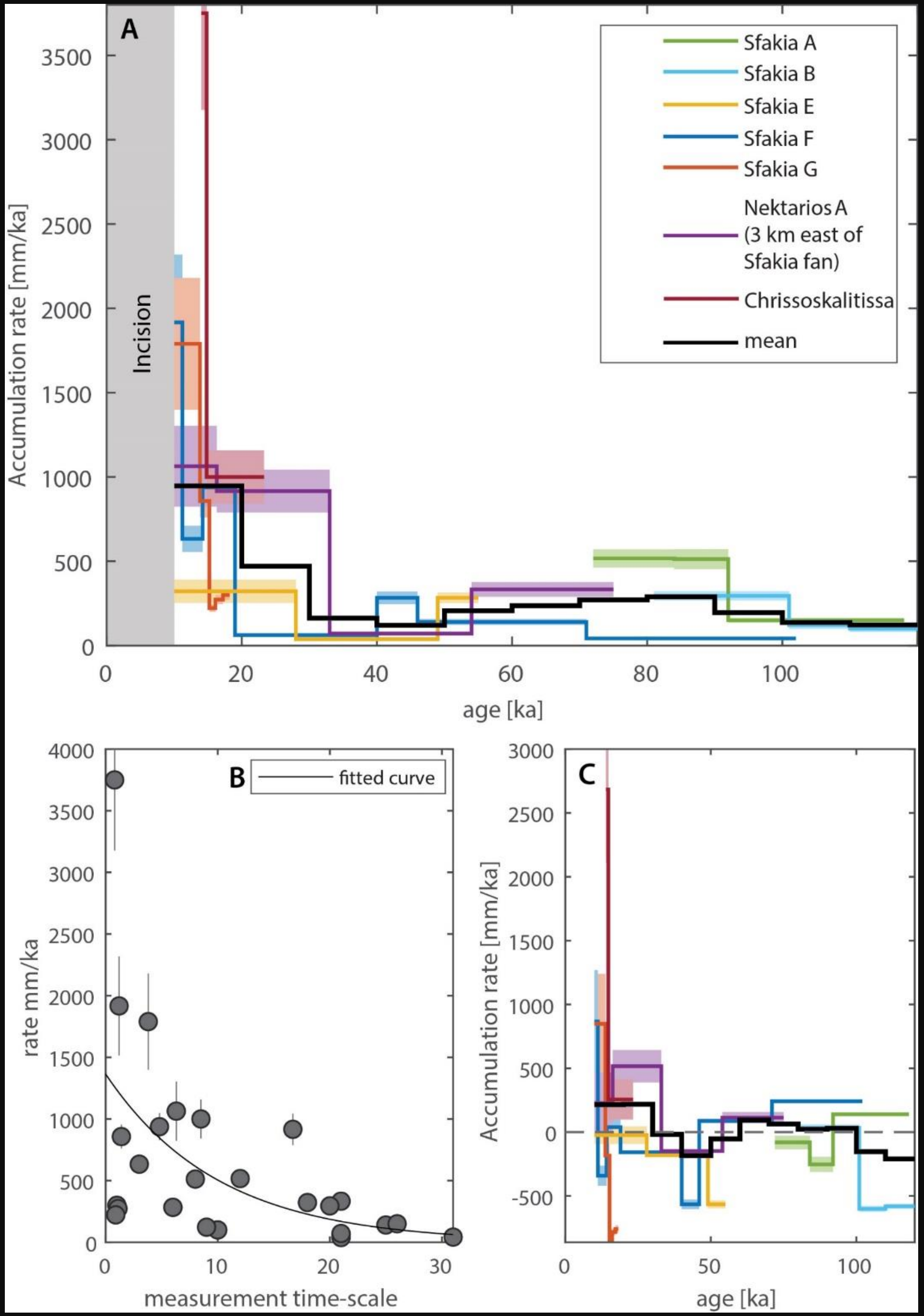
- 1 samples for modern denudation
- 4 paleo-denudation samples ($^{10}Be$ & $^{36}Cl$)



# Sfakia – field pics

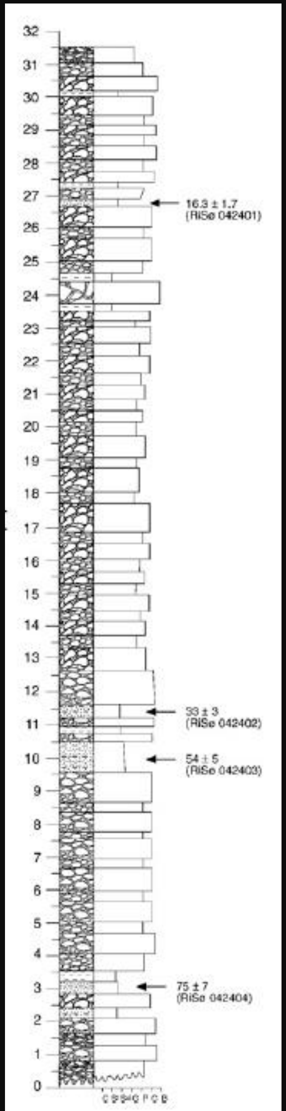
# Sfakia fan – aggradation rates

- fastest aggradation at end of MIS 2
- major incision during MIS 1
    - despite high sea level!
- Sadler-effect correction
- high relative aggradation during MIS 2 & 4
- analogous to Elafonisi fan



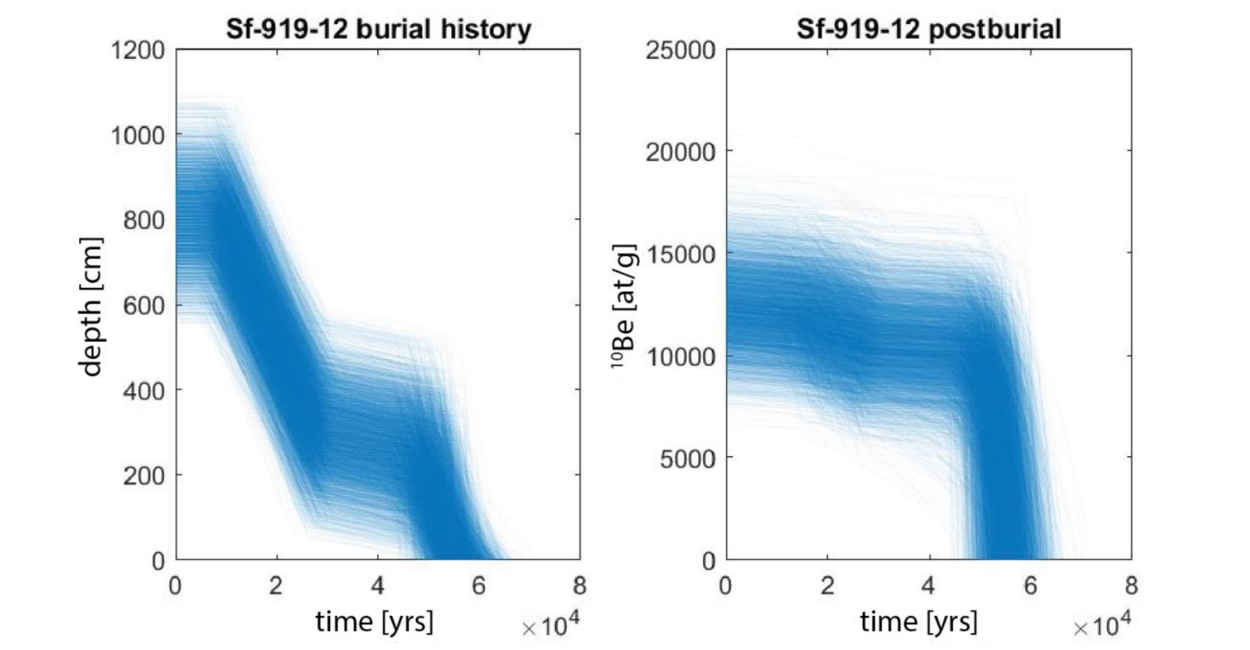
# Postburial production of nuclides

- End of deposition
  - Beginning of incision
  - Date of top of sequence
- Some sequences with several dated layers
- PostPro = Monte Carlo routine to estimate postburial production
  - Integrated in CRONUScalc v2.1
  - Avalailable at https://github.com/Richard-Ott
- Random sampling of „synthetic“ burial histories
  - Integration of postburial production through time
  - Linear aggradation between ages of known age



# Postburial production

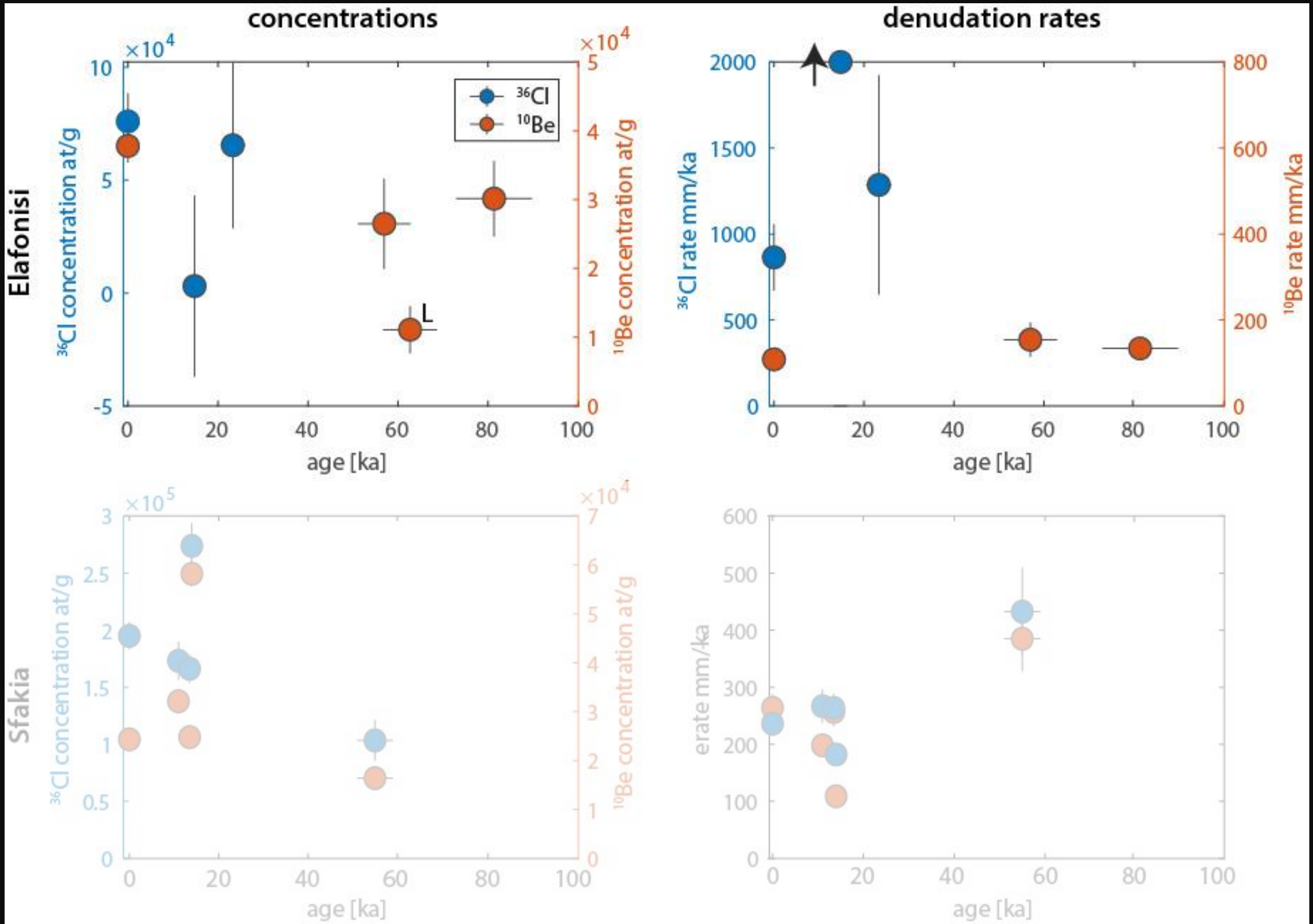
- 5000 MC simulations per sample
- Uncertainties: depth of layers, layer ages, production rates
- For most samples postburial < 30% of total
  - Some 36Cl samples problematic due to high [Cl]



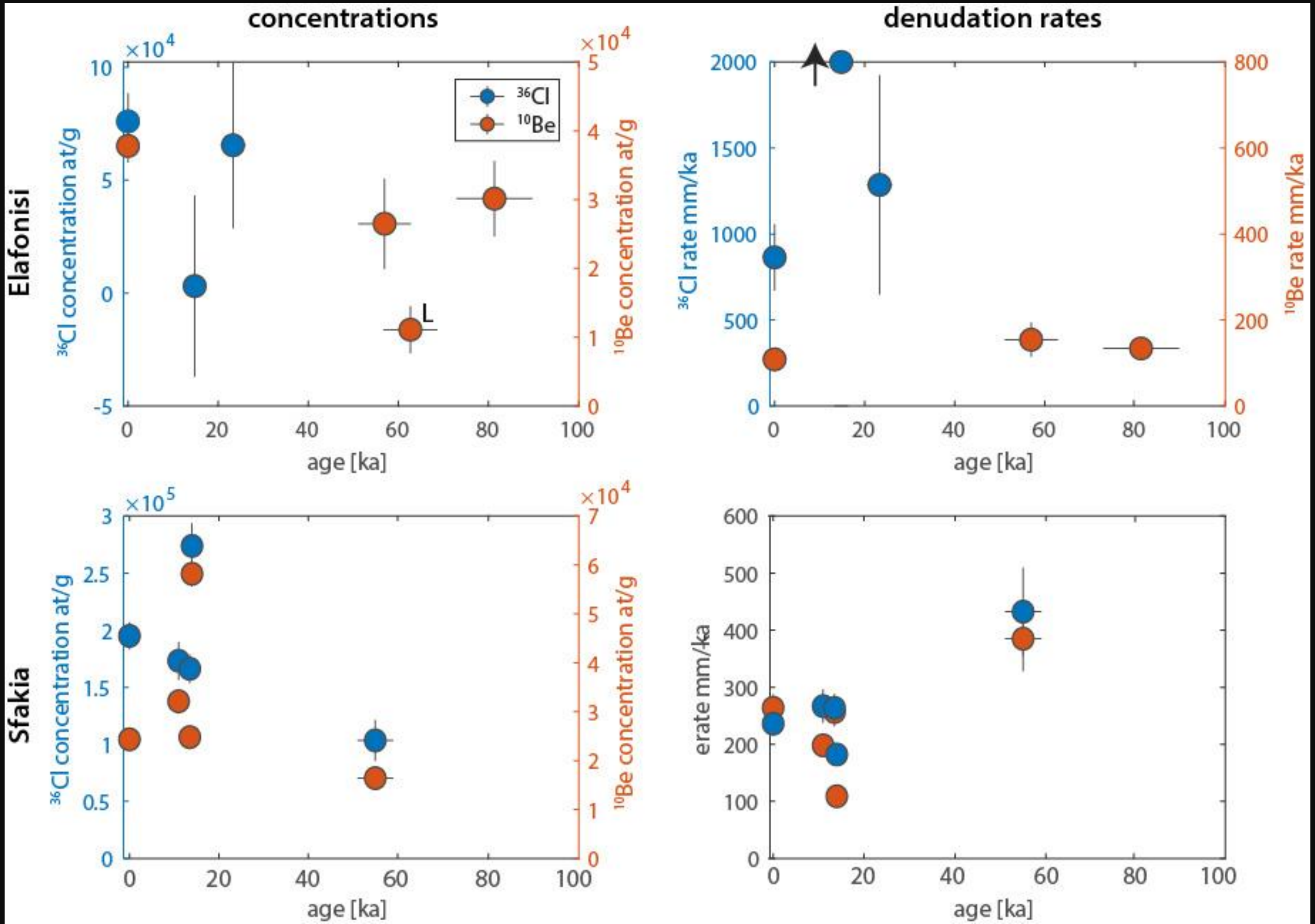
# paleo-denudation calculation

Elafonisi:

- High uncertainties due to [Cl]
- Roughly constant rates for 10Be



# paleo-denudation calculation



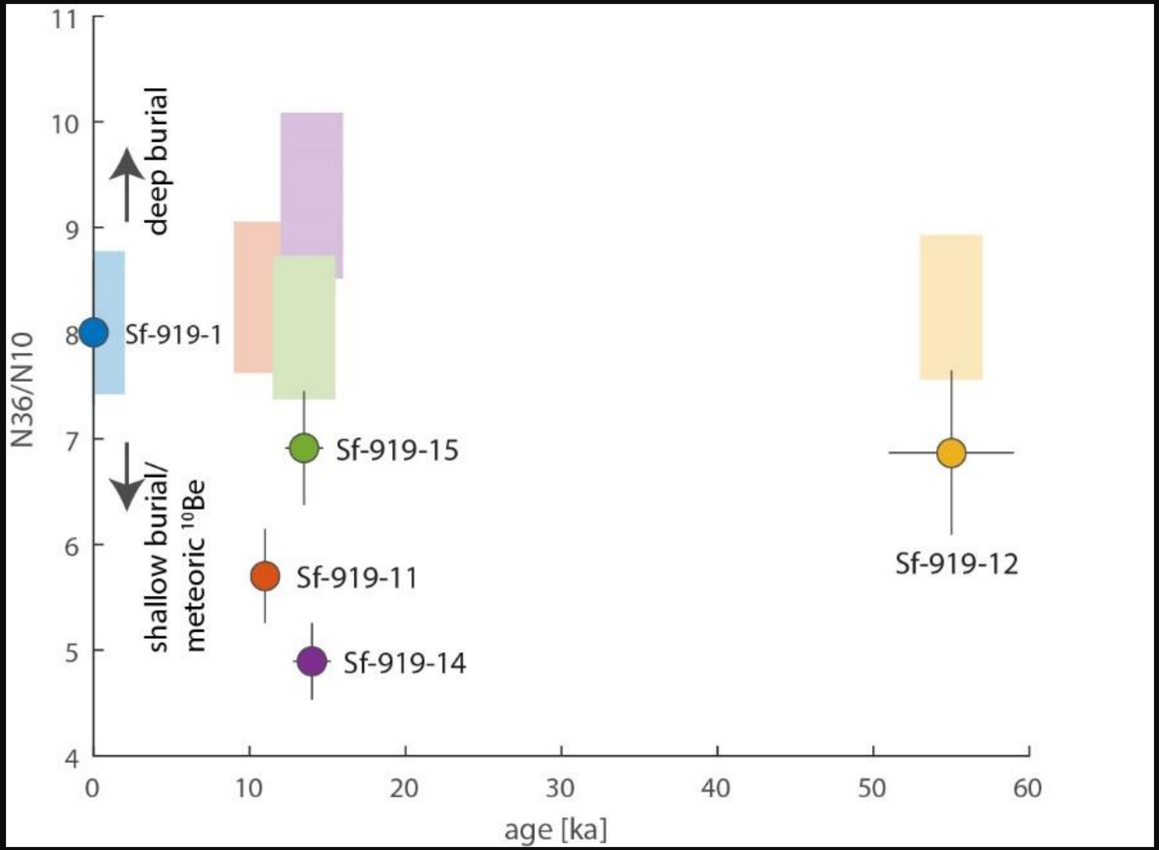

Sfakia:

- 10Be-rate < 36Cl-rate
- Similar rates through time, except MIS4

# $^{36}Cl$-$^{10}Be$ ratios

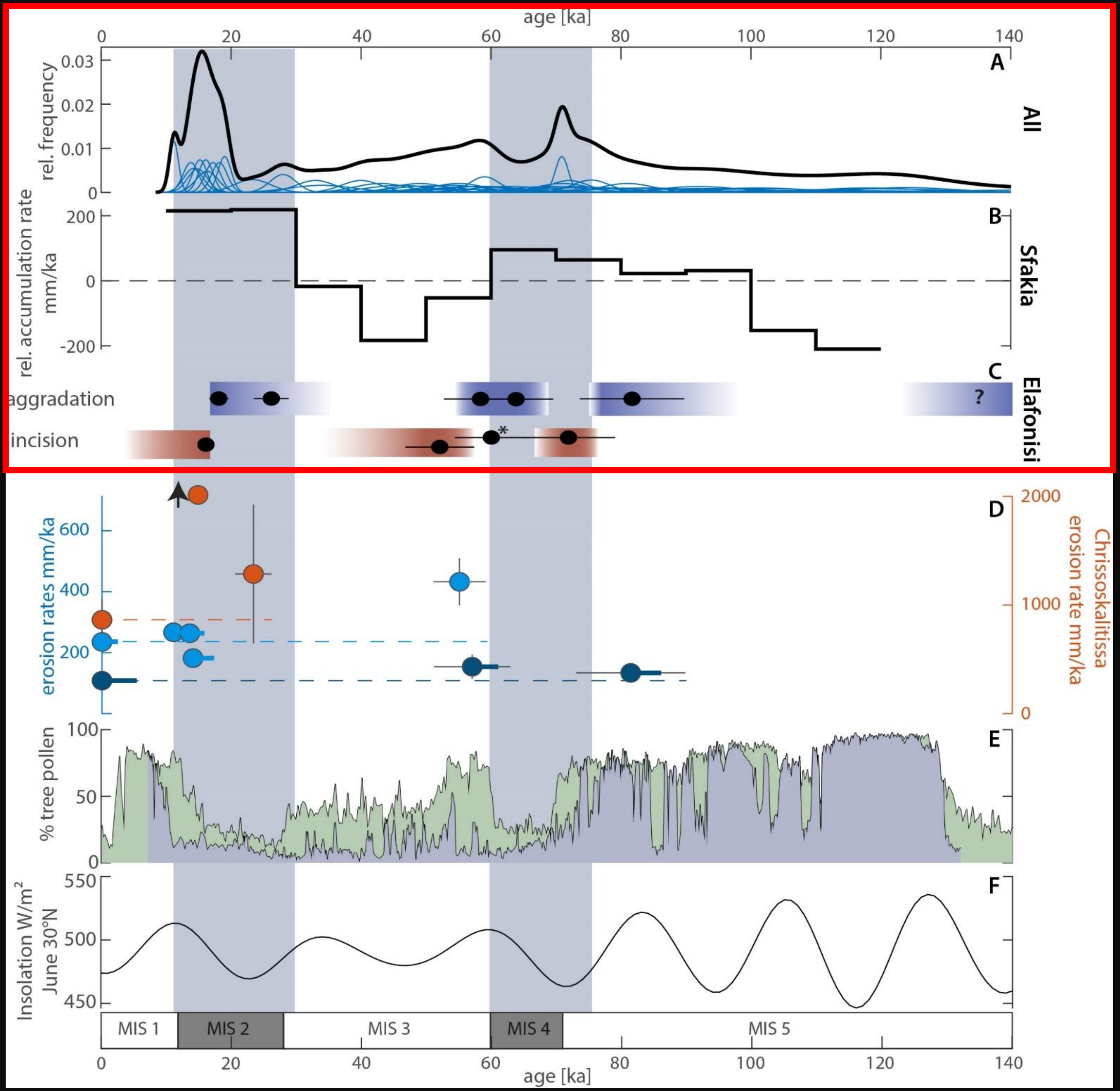
- Steady denudation predicts ratios ~ 8
  - Sample dependent!
- Most samples have too low ratio
- Independent burial constraints exclude long shallow burial

- $^{10}Be$ concentrations too high due to insufficient meteoric $^{10}Be$ removal



# Synthesis

- Aggradation-incision controlled by climate
- Cycles in tune with vegetation
- Near-steady denudation
- Potential basin size buffering



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- Aggradation-incision controlled by climate
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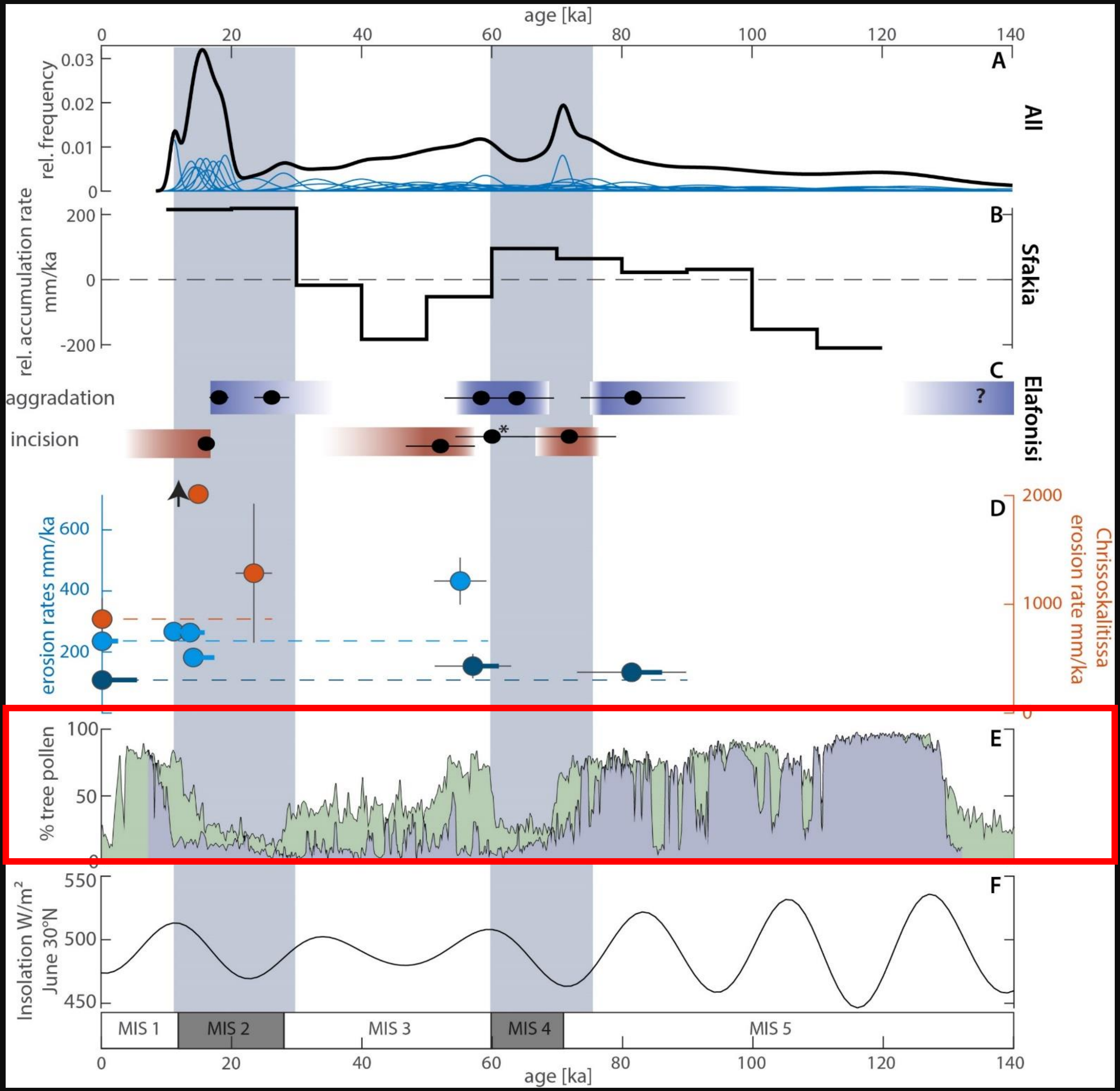

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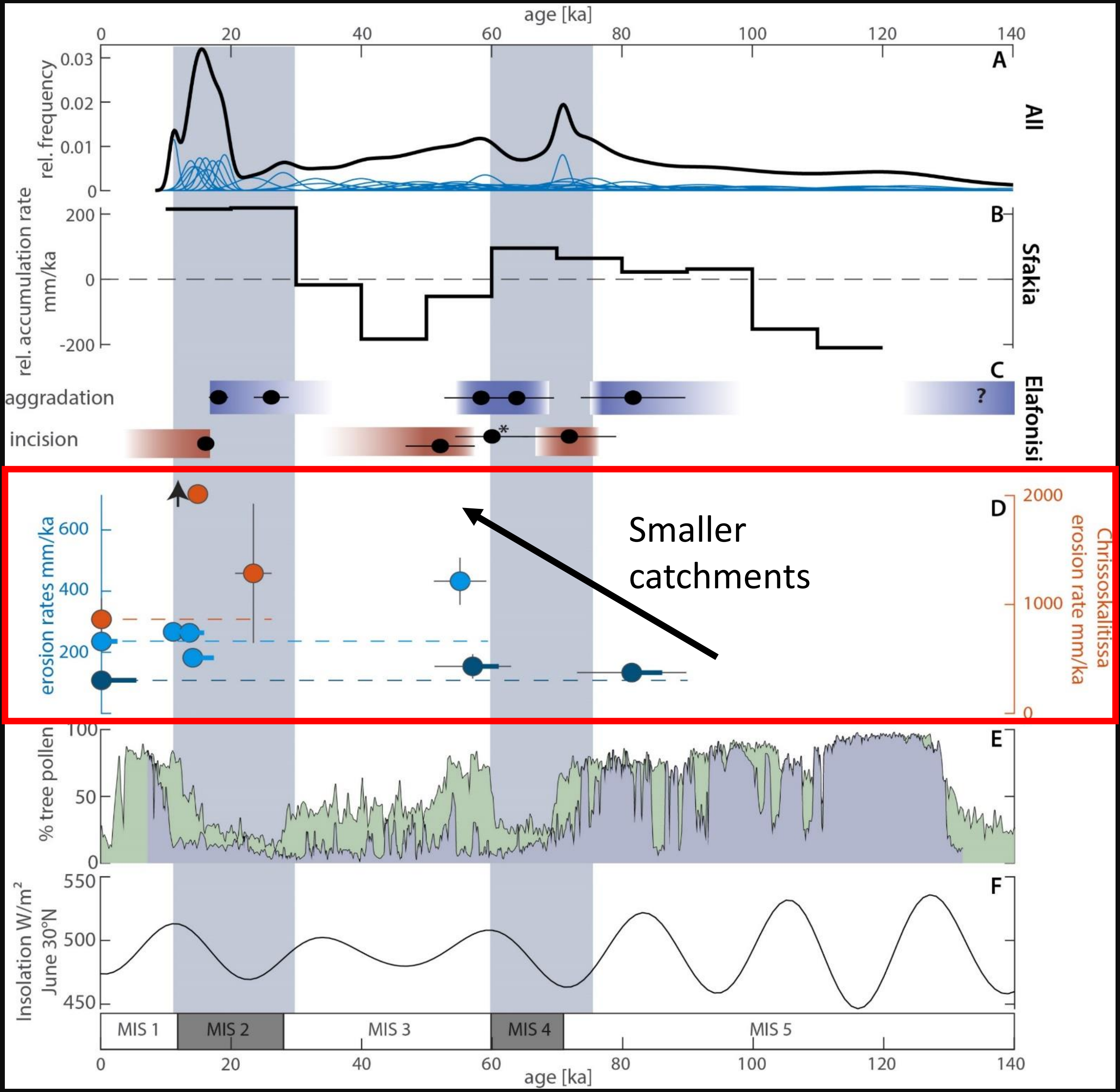

# Climate-denudation-sediment interactions

- No clear evidence for increased denudational supply from hillslopes
  - Vegetation stabilizing sediment during warm stages
  - Release of sediment pulses during cold stages?

- Channel aggradation-incision mostly controlled by hydroclimate
  - Transport-limited streams
  - Limited influence of sea-level & tectonics
  - Fans and river terraces record mostly hydroclimate

- Implies low sensitivity of denudation in fluvial landscapes to climate change, but high sensitivity of sediment transport