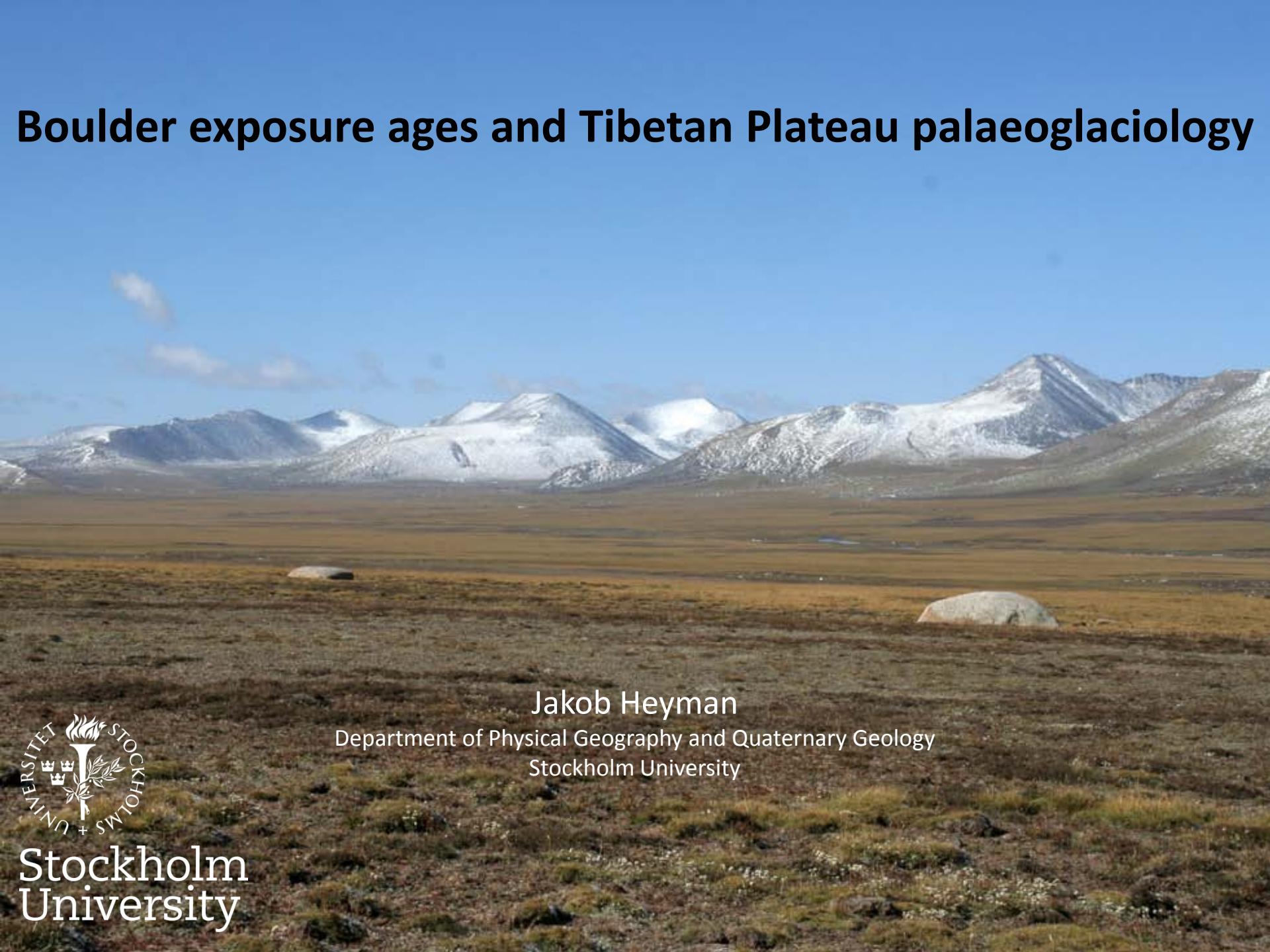


Boulder exposure ages and Tibetan Plateau palaeoglaciology



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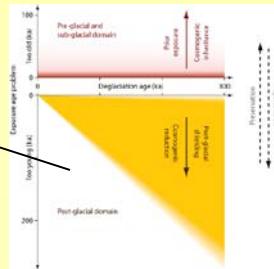
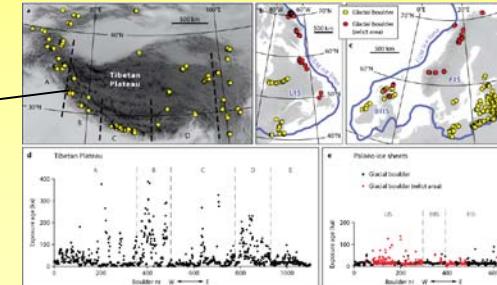
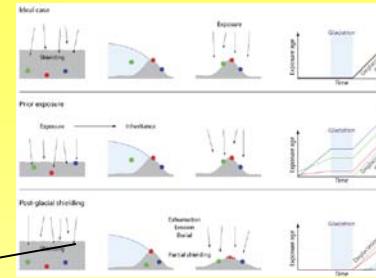
Presentation outline

- Boulder exposure ages

Introduction

Data compilation + modeling

Implications

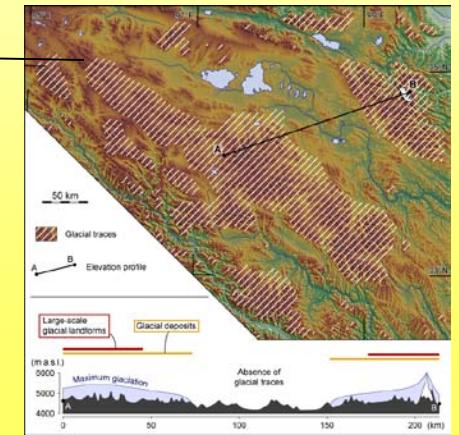
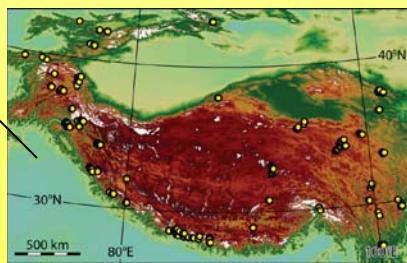
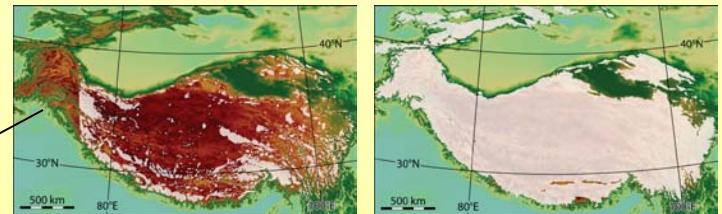


- Tibetan Plateau palaeoglaciology

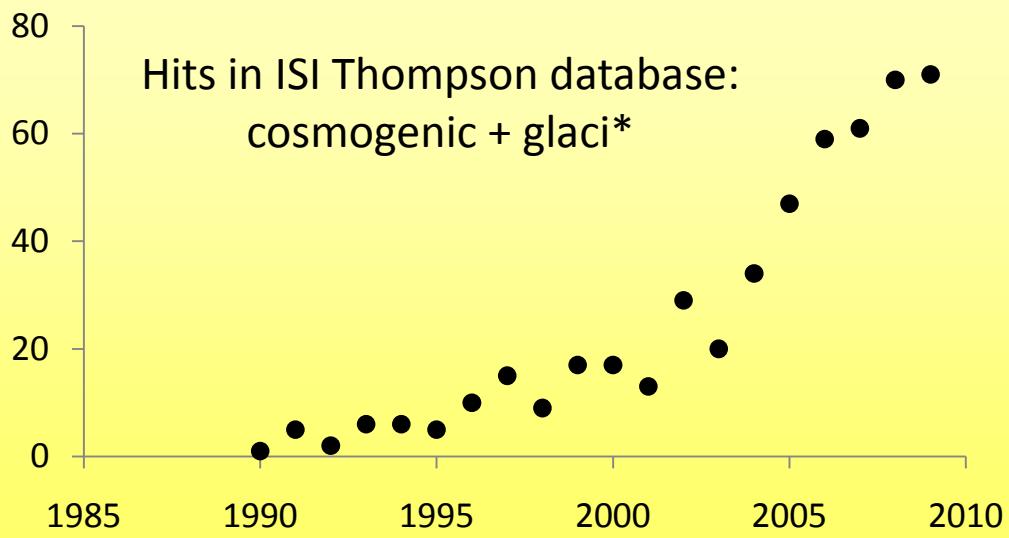
Background – different reconstructions

Bayan Har study area

Plateau-scale glaciation



Exposure dating



Exposure dating

1. Glacial erosion
and deposition



2. Exposure to cosmic rays produces
cosmogenic nuclides (^{10}Be) in quartz



3. Sampling



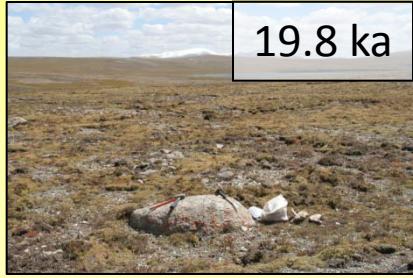
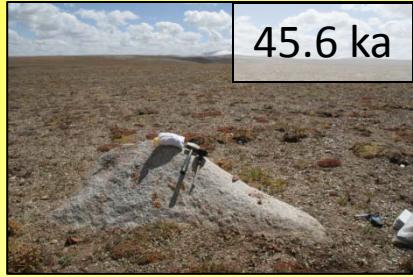
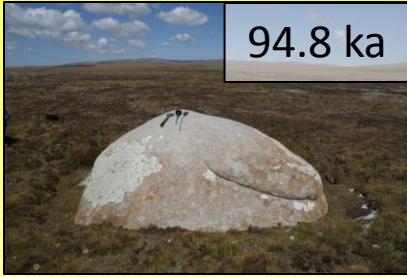
4. Measurement of
cosmogenic nuclide
concentration



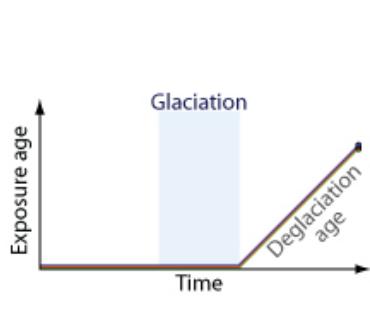
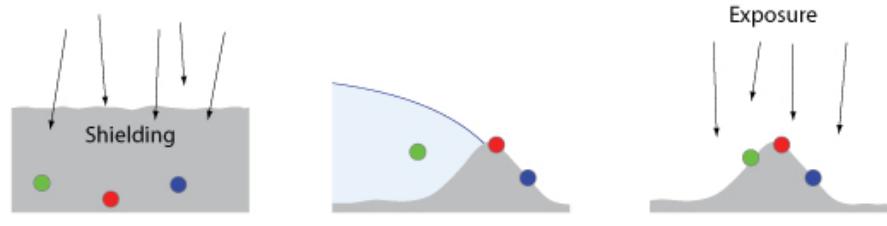
Absolute measurement of
exposure to cosmic rays

The problem

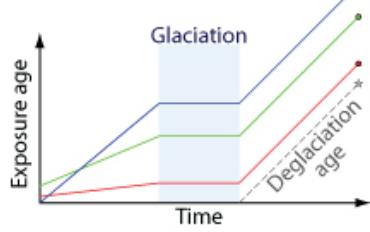
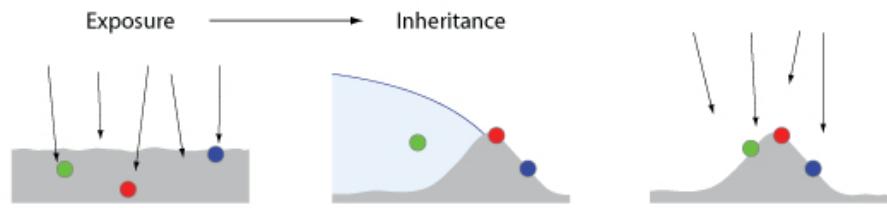
exposure age \neq deglaciation age



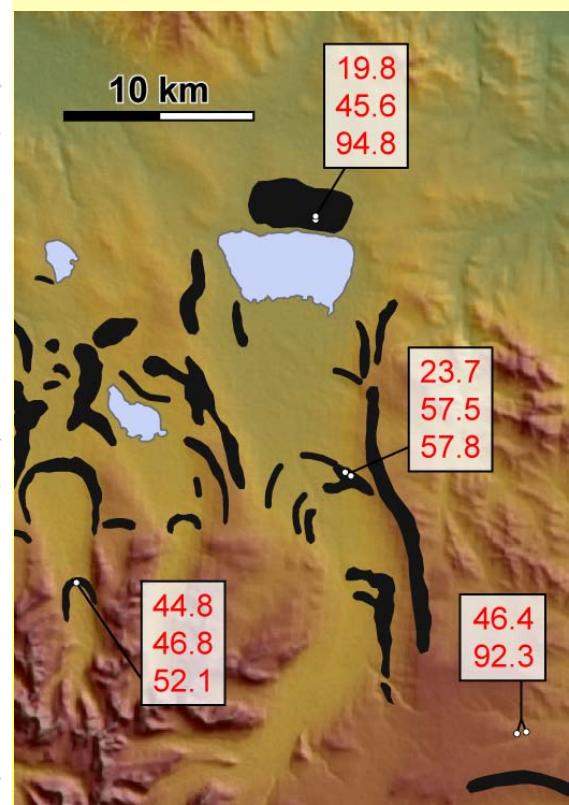
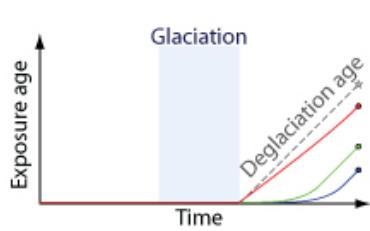
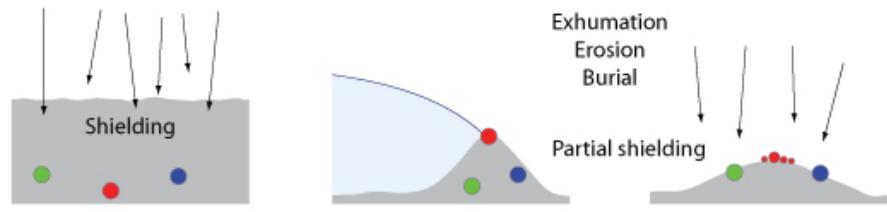
Ideal case



Prior exposure



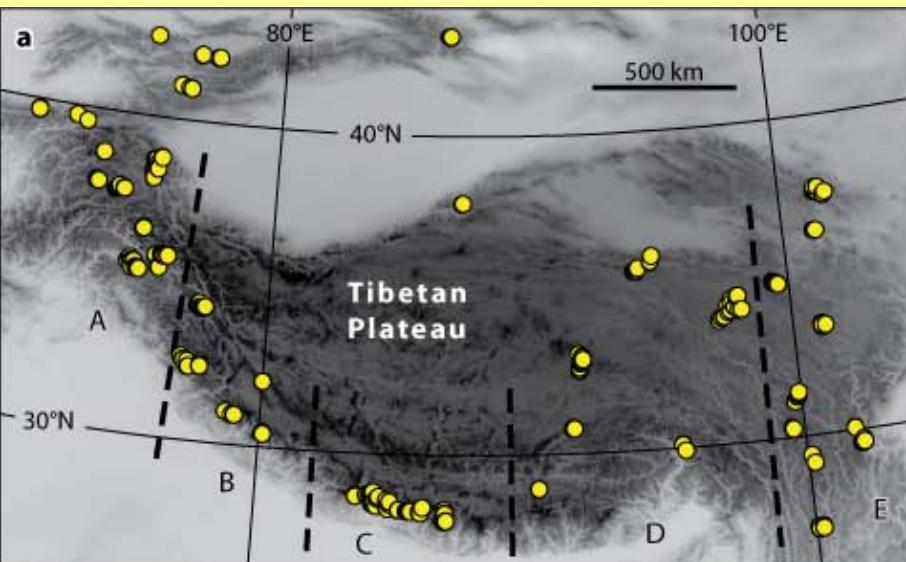
Post-glacial shielding



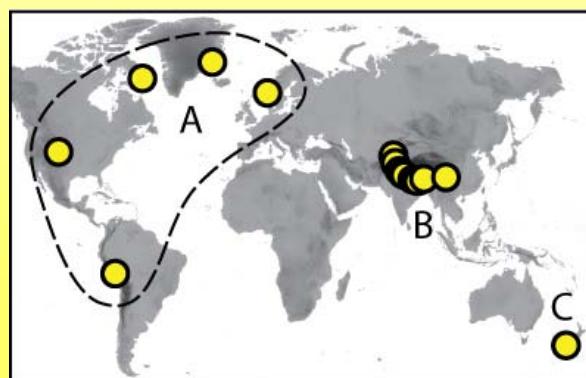
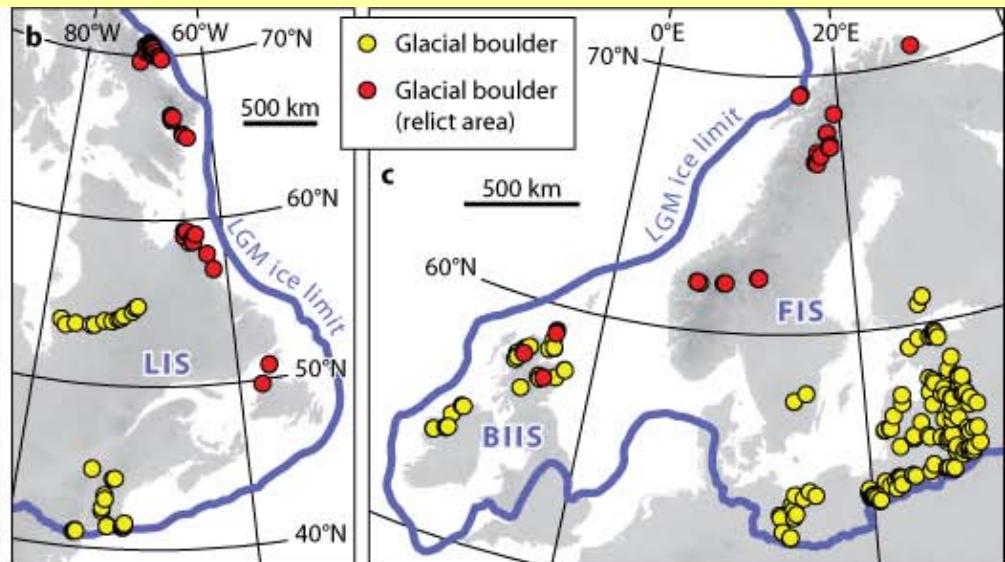
Question: How to interpret widely diverging exposure ages?

Strategy: Meta analysis of large dataset of boulder exposure ages

Tibetan Plateau: 1099 boulders



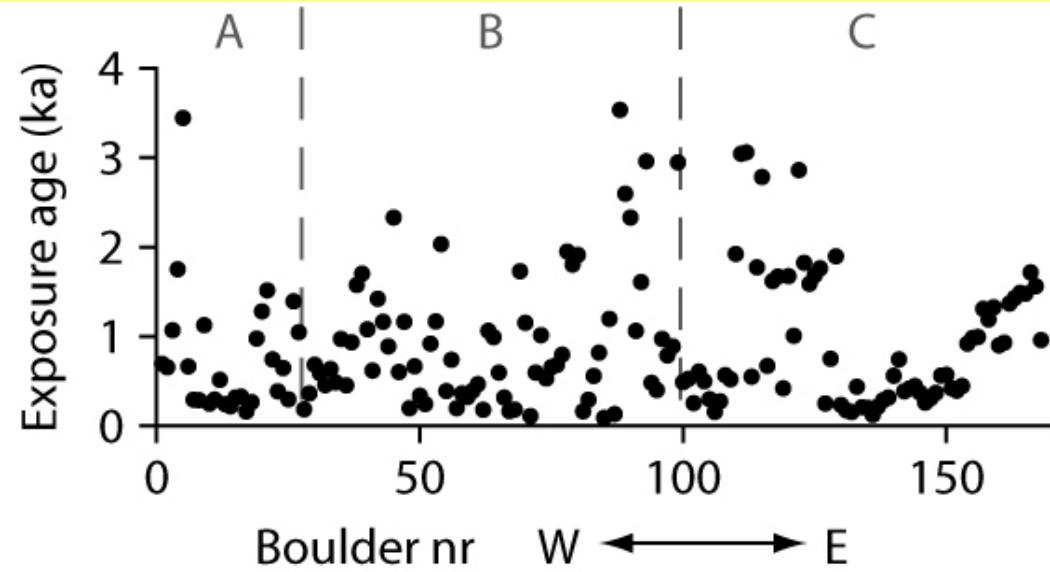
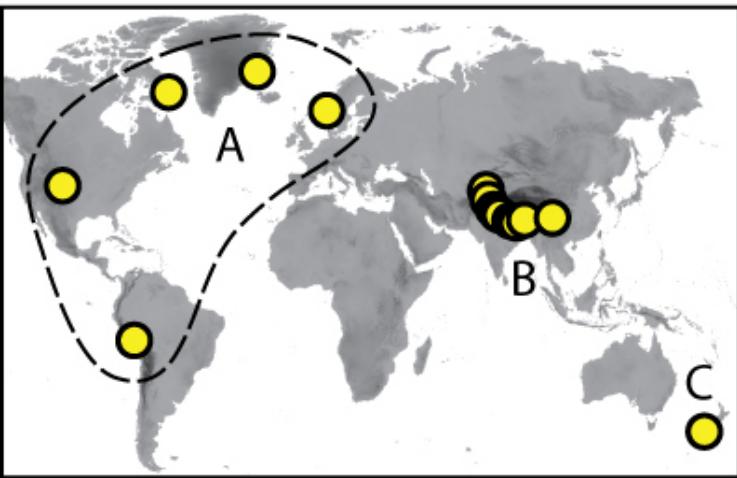
Palaeo-ice sheets: 613 boulders



Present-day and late Holocene glaciers:
168 boulders

Present-day and late Holocene glaciers

168 boulders from 25 glaciers

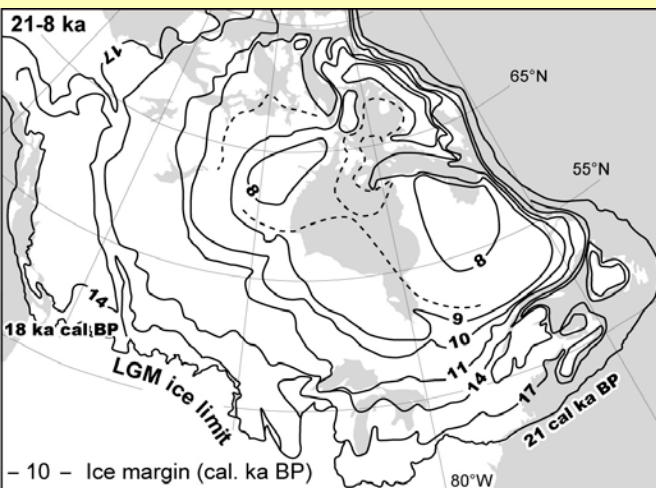
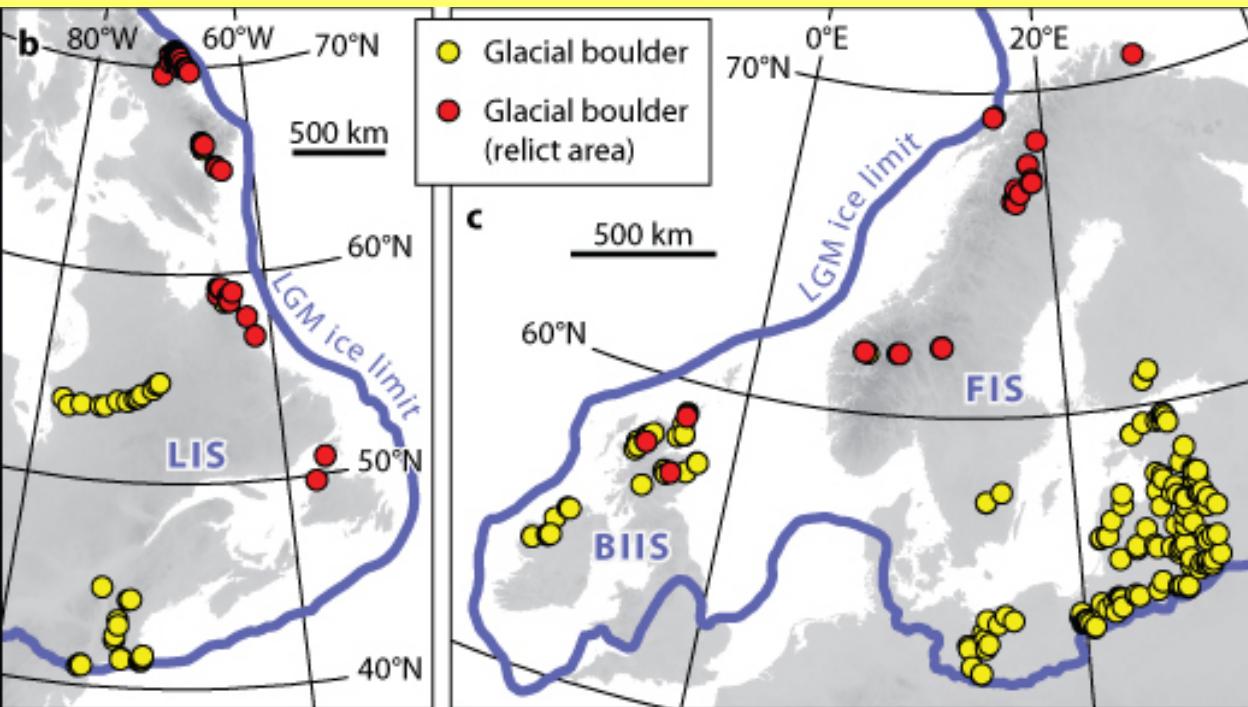


All boulders < 3.5 ka exposure age

No significant prior exposure!

613 exposure age samples (385 non-relict / 228 relict area)

Deglaciation reconstructions

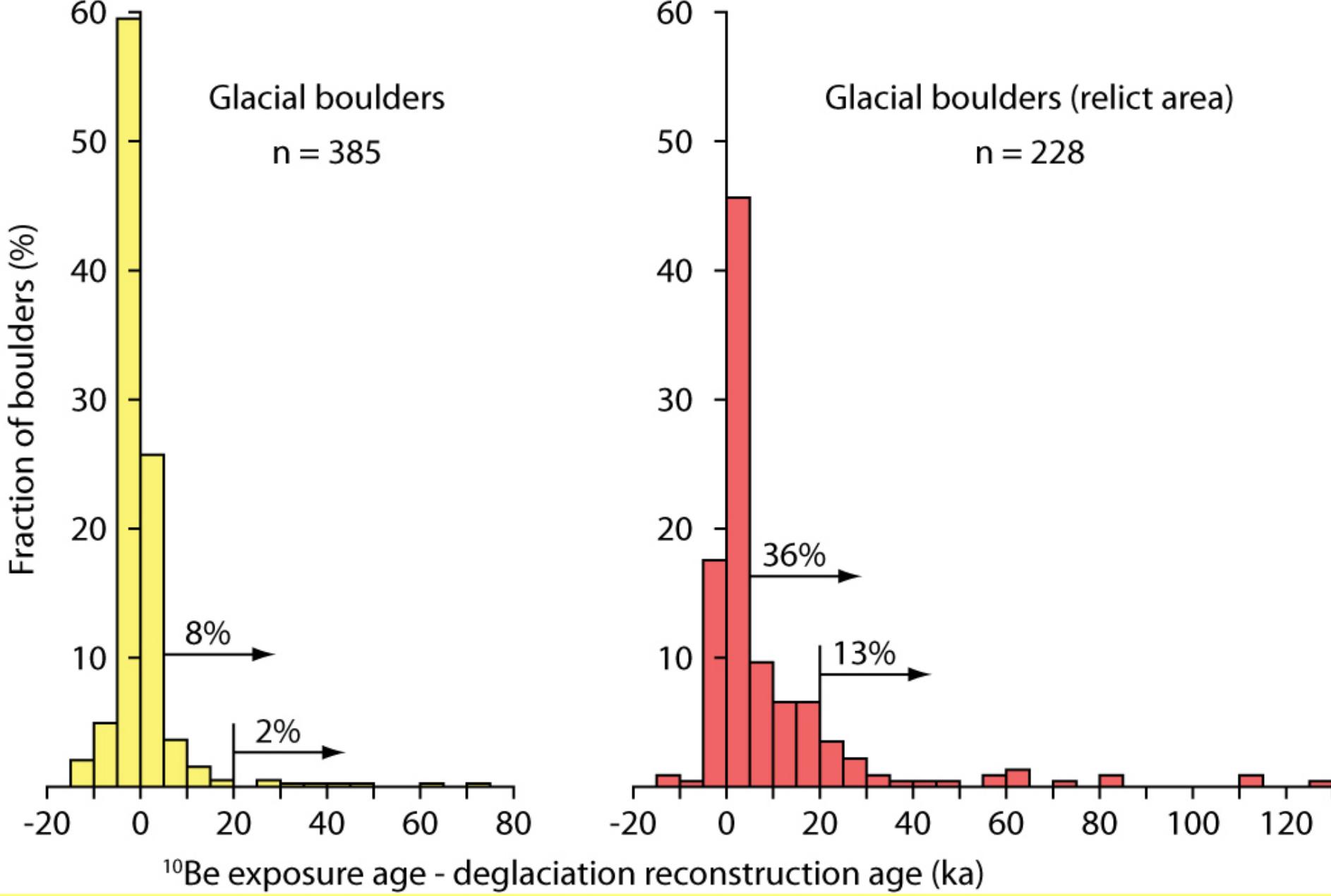


LIS: Kleman et al. / Dyke et al.

Deglaciation reconstructions based on ^{14}C dates

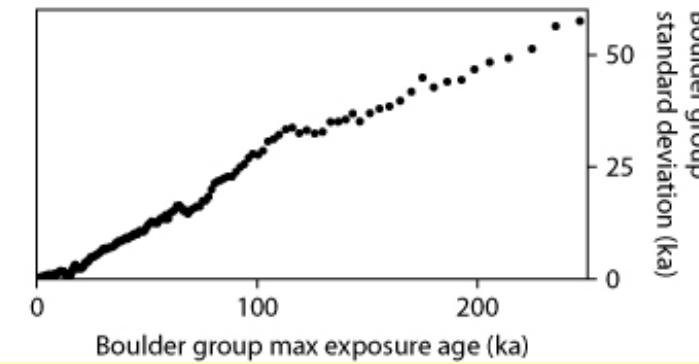
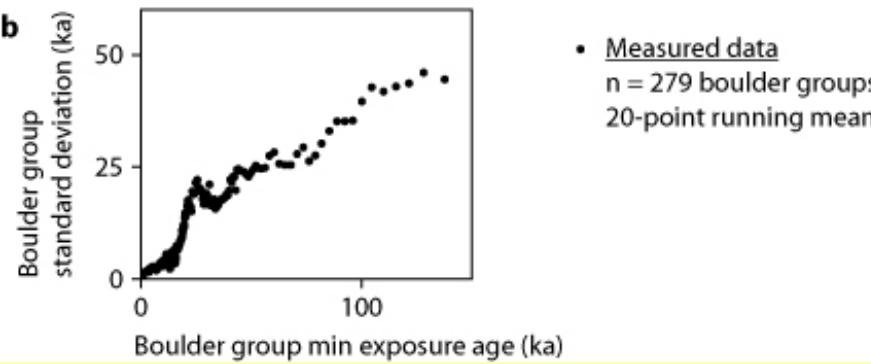
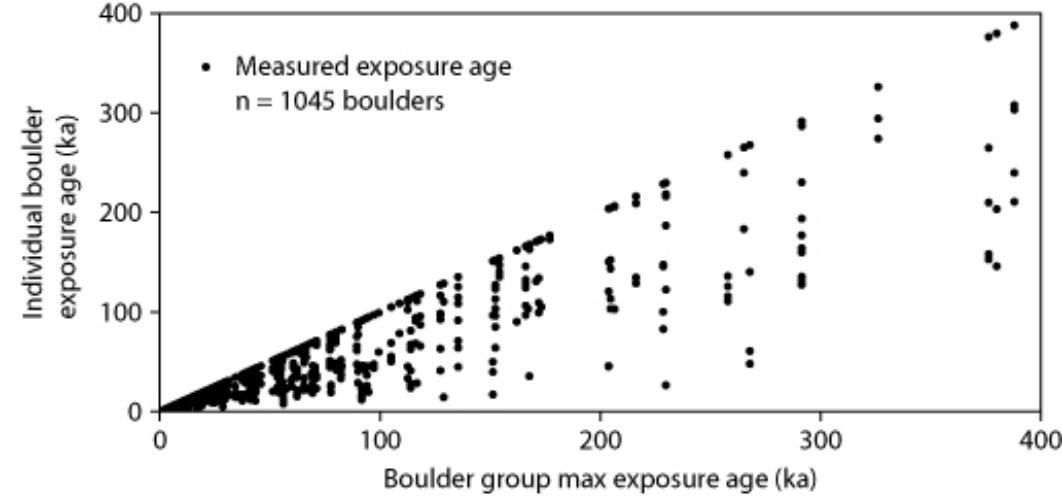
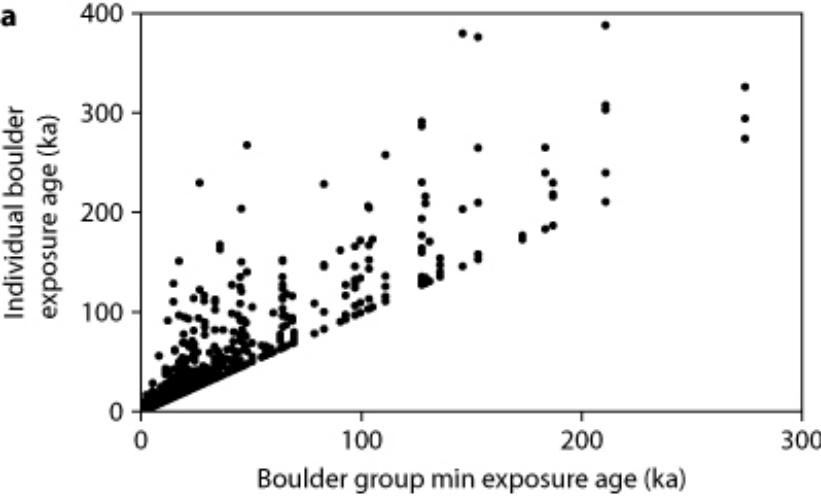


Independent deglaciation ages for comparison with exposure ages



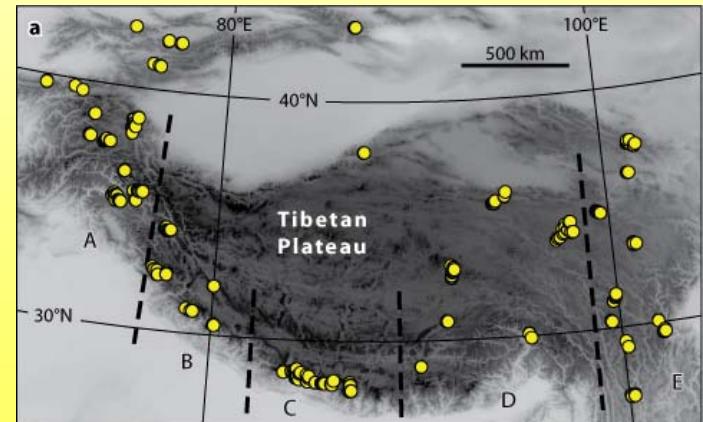
Quantification of exposure age accuracy

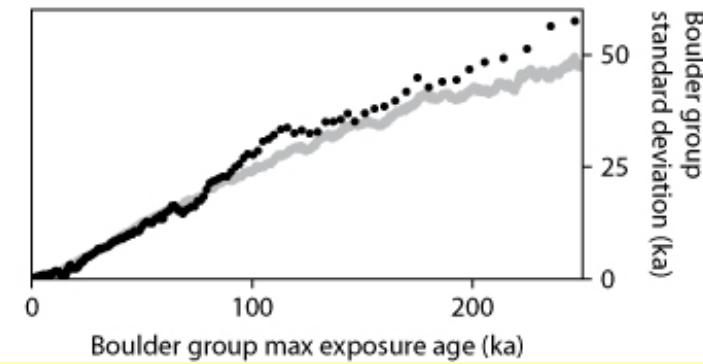
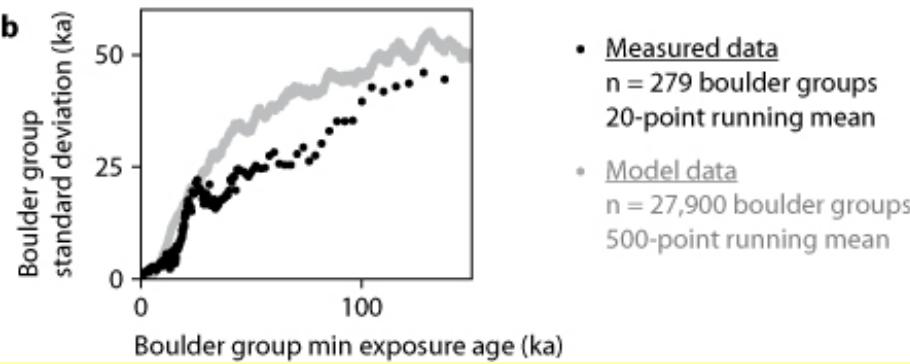
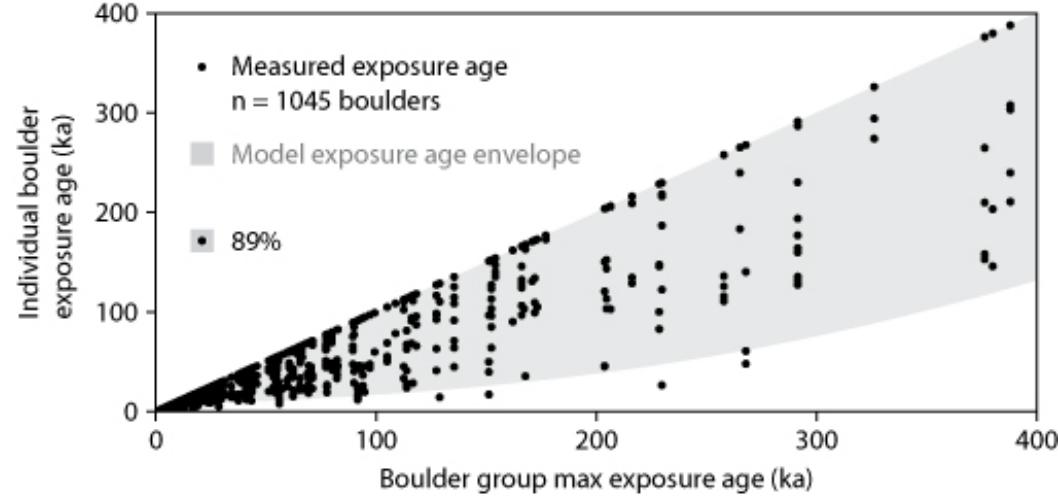
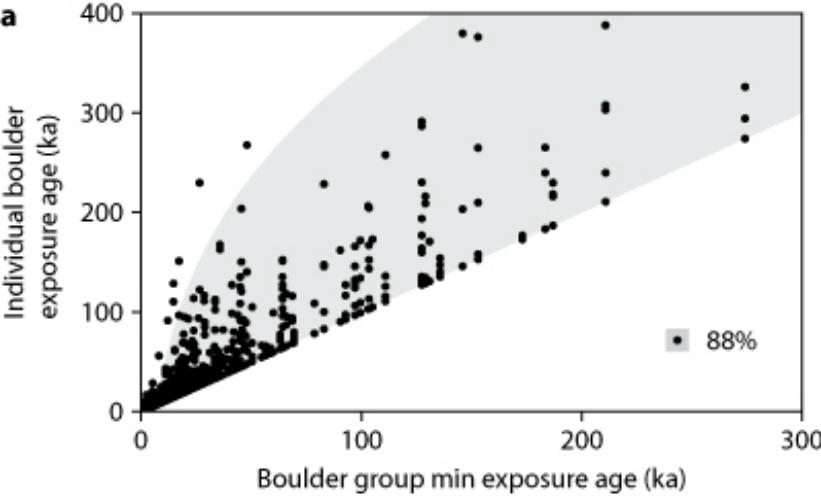
Limited prior exposure



Tibetan Plateau boulder group data:

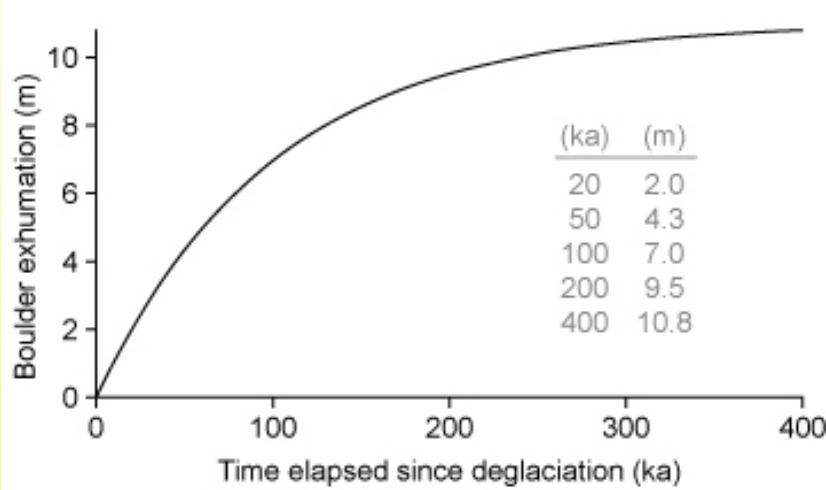
Wide age spread within groups





Can post-glacial shielding explain the age spread?
Monte Carlo simulation with boulder exhumation

**Remarkable conformity between measured data
and output from a very simple model**

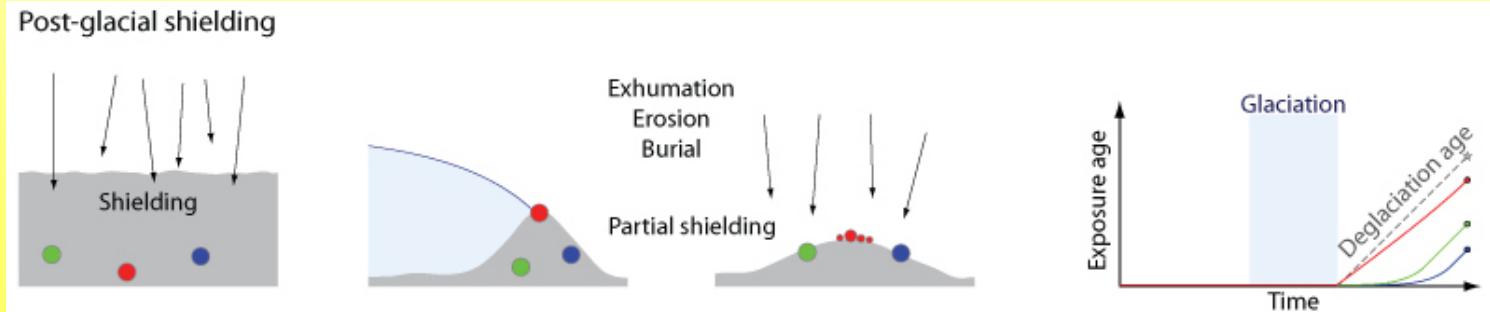
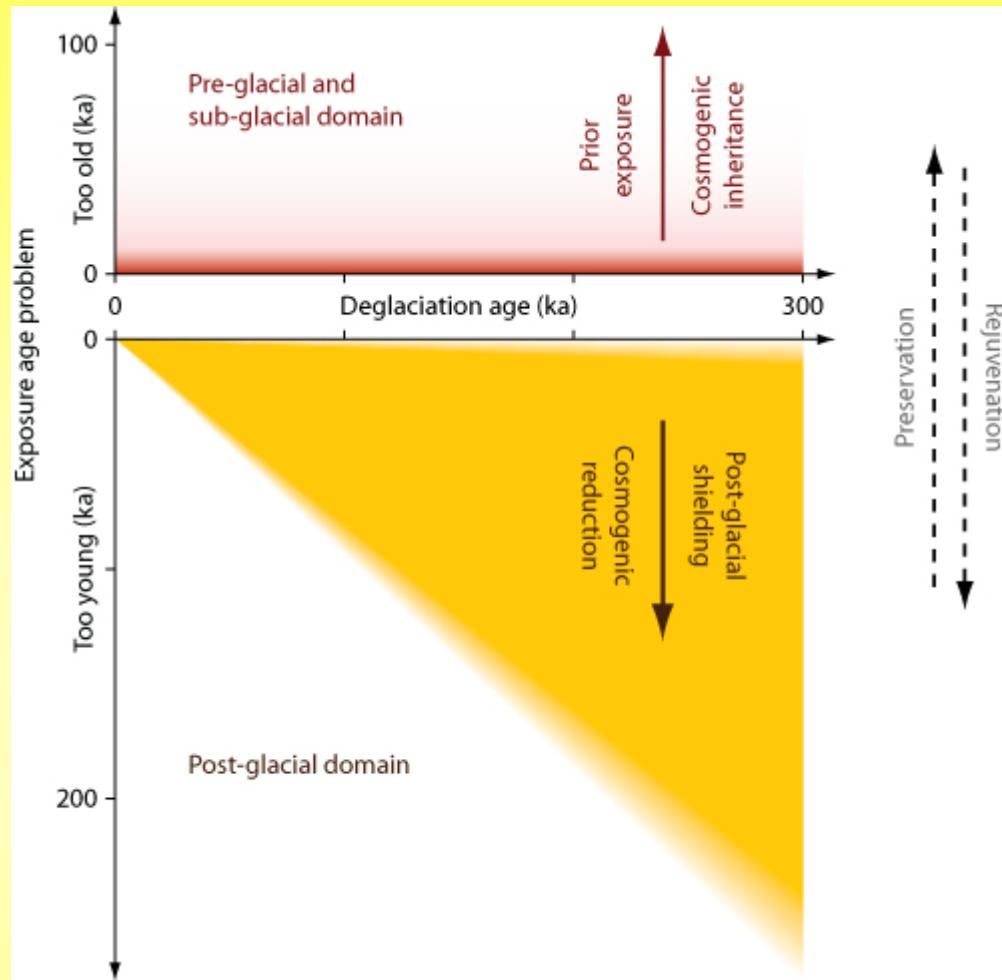


Summary

- Recent glaciers: no prior exposure
- Palaeo-ice sheets: limited prior exposure
- Tibetan Plateau: post-glacial shielding can explain large part of measured data

Post-glacial shielding is more important than prior exposure

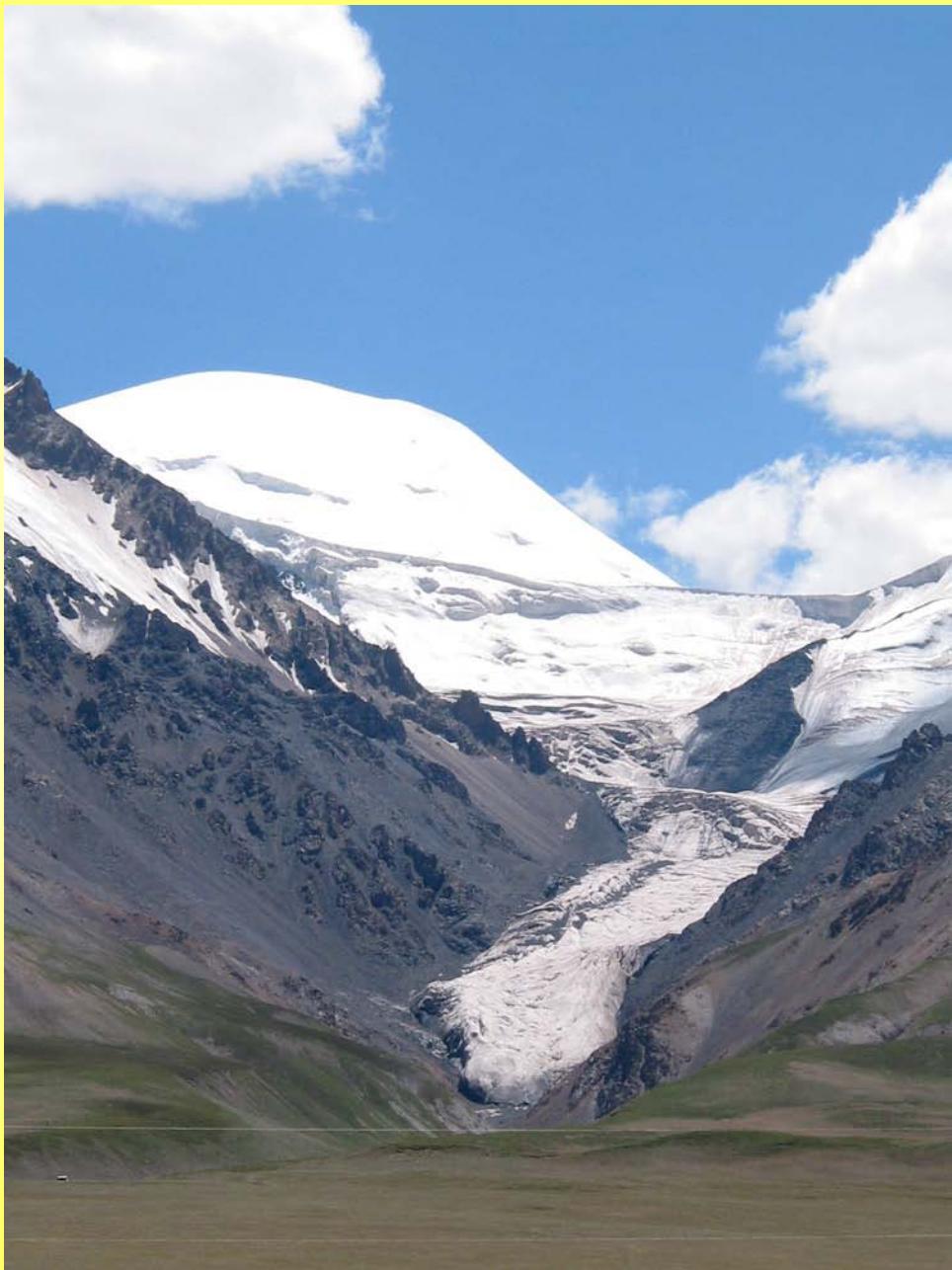
In the absence of other evidence, exposure ages should be viewed as minimum limiting deglaciation ages



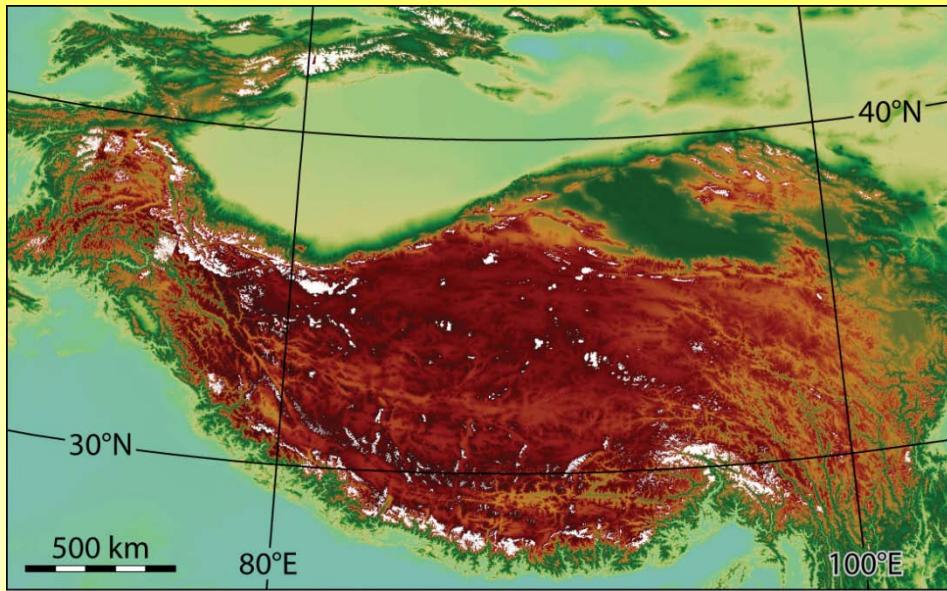
Tibetan Plateau palaeoglaciology

- How extensive have the glaciers been on the Tibetan Plateau?
- When did glaciers advance?
- What has controlled glacier evolution (temperature/precipitation)?

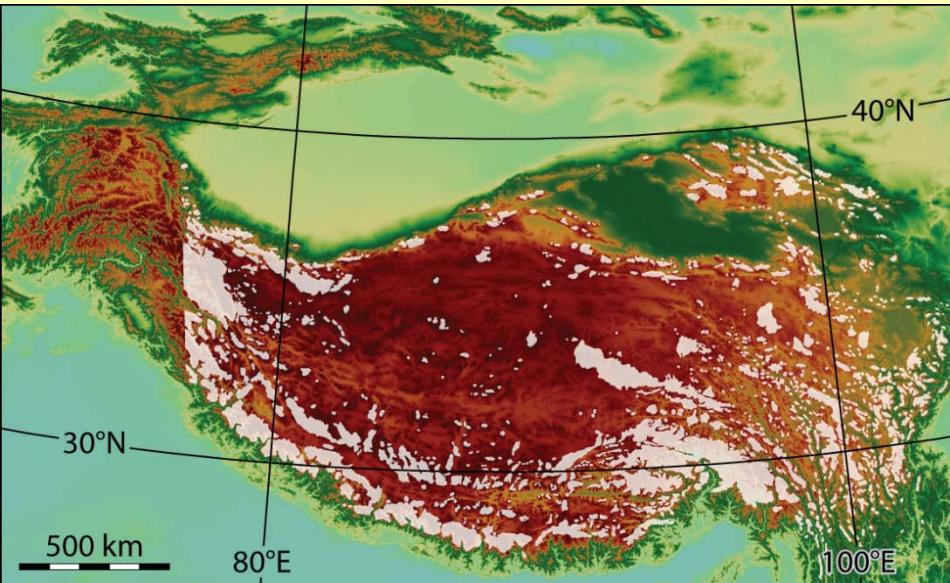
Tibetan Plateau LGM glaciers?



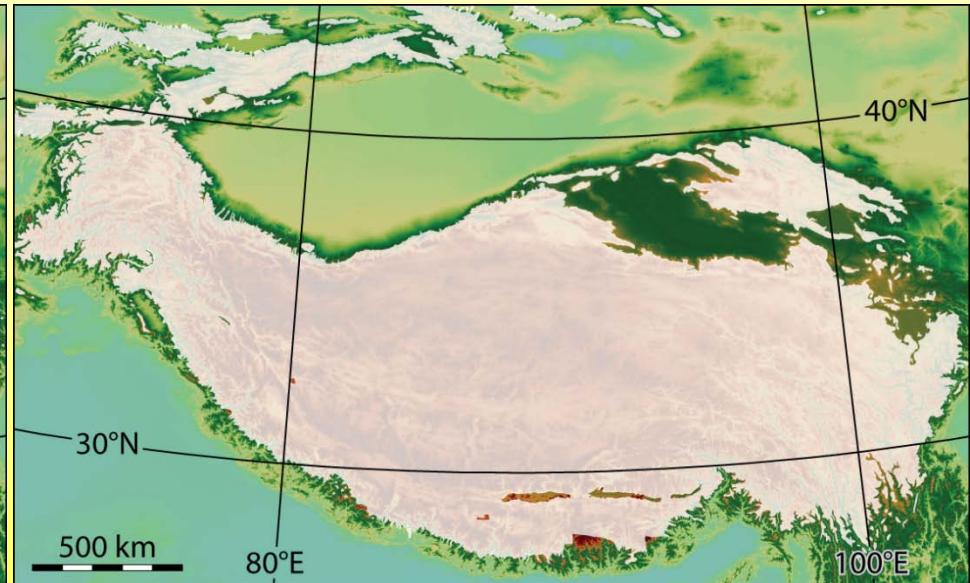
Present-day glaciers (GLIMS glaciers)



Li et al. (1991): Quat. glacier distribution map



Kuhle (2004): plateau-scale ice sheet



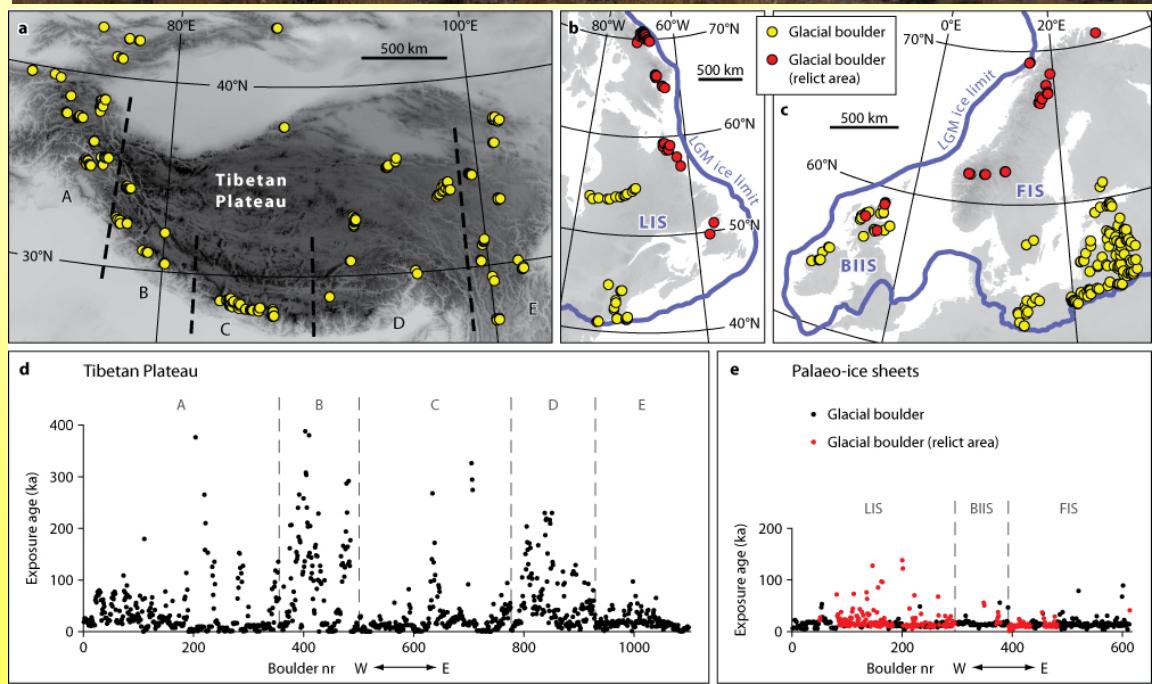
A Tibetan ice sheet?

Major problems:

Complete lack of glacial landforms such as glacial lineation swarms, eskers, ribbed moraines

Extensive areas lack all glacial landforms and sediments

Many cosmogenic exposure ages significantly older than the global LGM

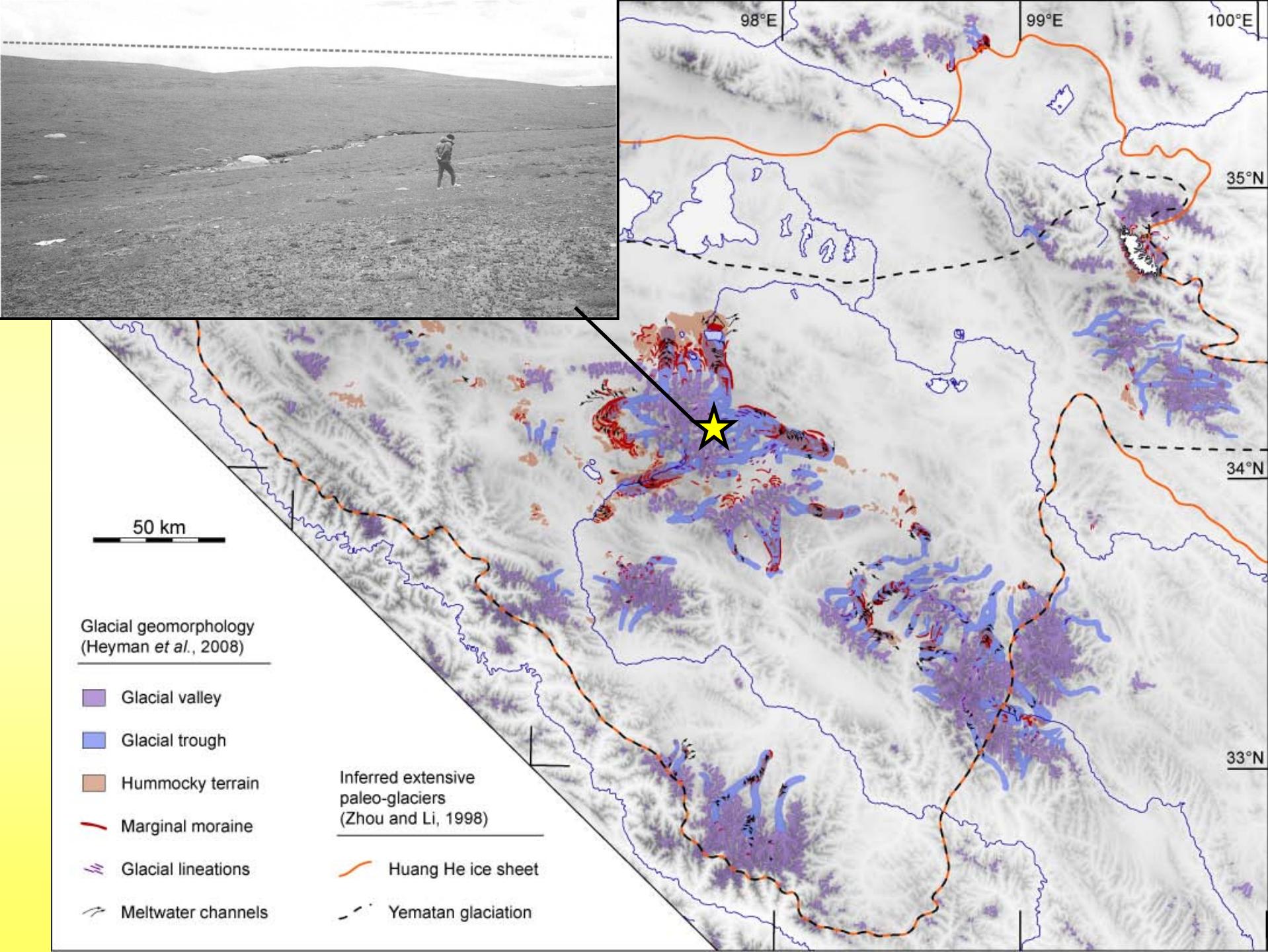


A Tibetan ice sheet?

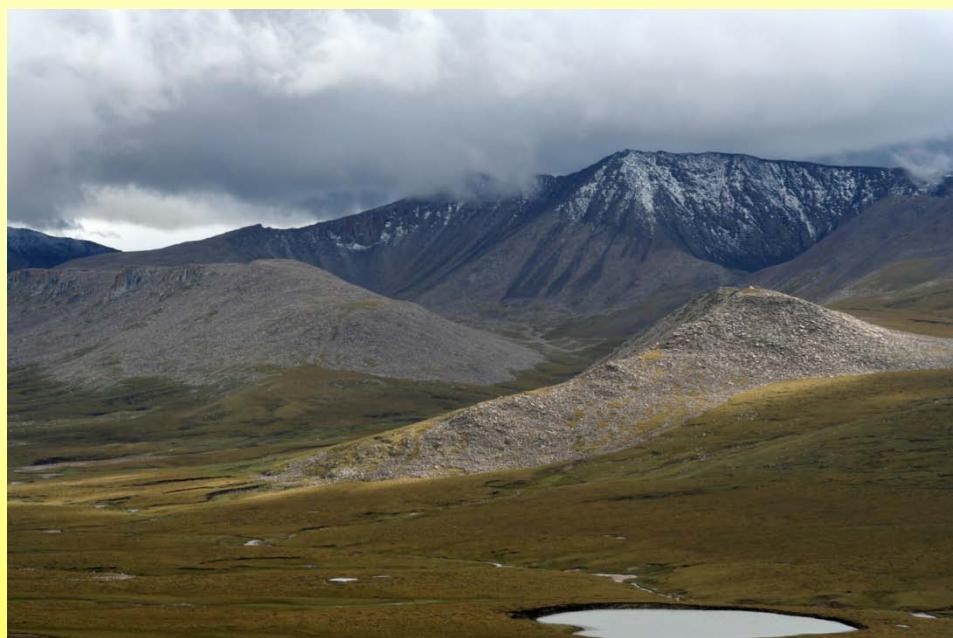


*Fig. 7. Several metres thick till with metre-sized far-travelled granite boulders, in the form of a 1-1.5 m-thick active layer over the permafrost table at 4580 m a.s.l, in Tibet, west of the Animachin ($34^{\circ}11'10''N$ $97^{\circ}46'10''E$; Fig. 1 No 19).
Being 200 km away from any glaciated mountain range, this site is evidence of a complete inland ice coverage (----). Photograph: M. Kuhle.*

From Kuhle (2004), in Ehlers and Gibbard: Quaternary Glaciation, Extent and Chronology Vol III, p. 178



Bayan Har Shan study area



Methodology

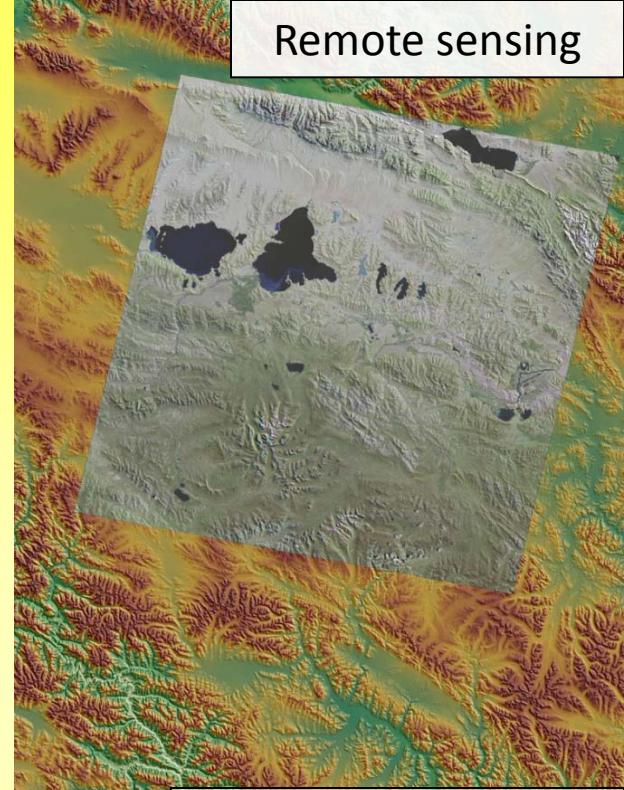
Remote sensing (extensive mapping)

Field investigations (detailed point data)

Glacial dating

Spatial pattern

Glacial chronology



Field investigations

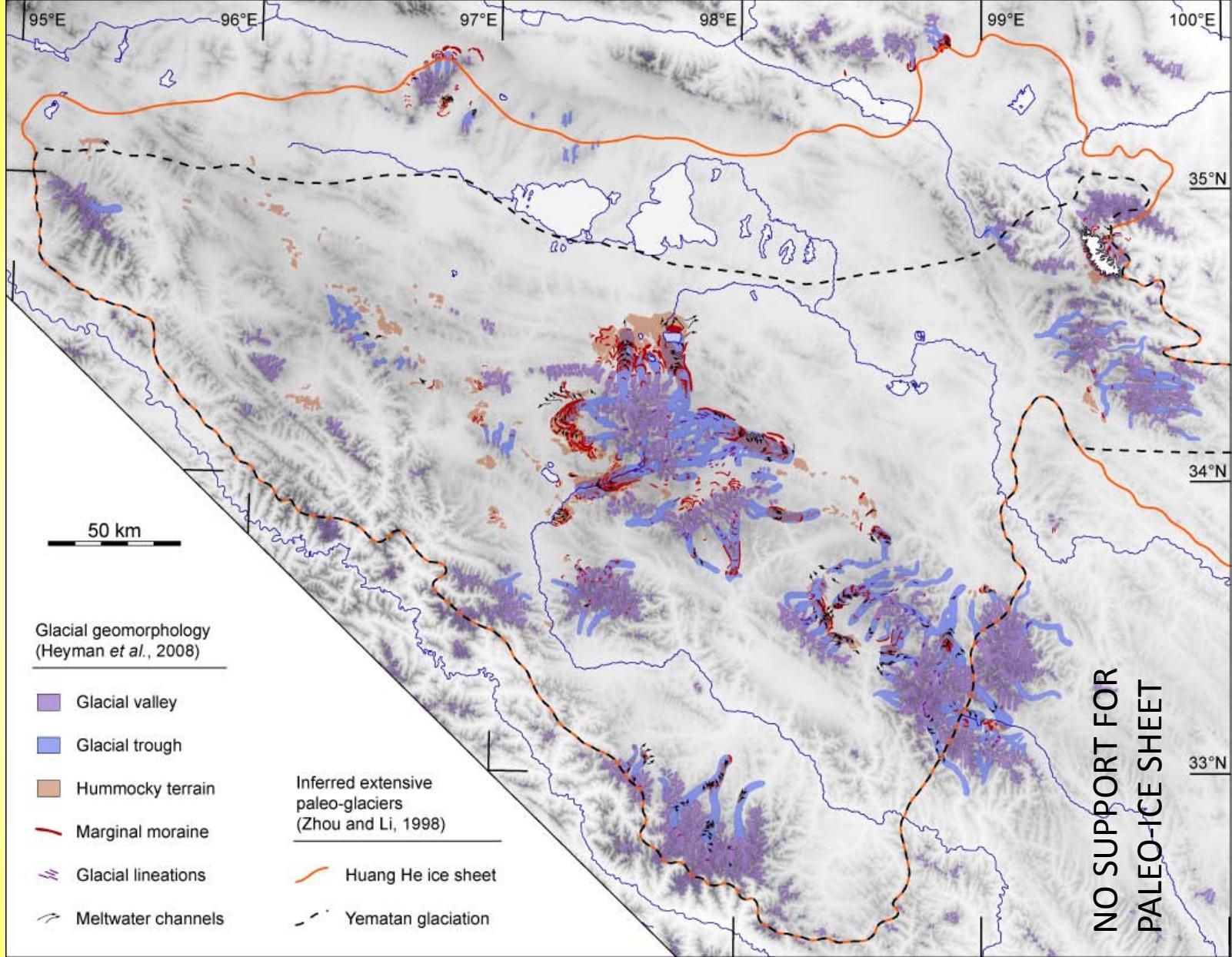


Glacial dating



Remote sensing

(SRTM DEM, Landsat ETM+, Google Earth)



Ample landform record of alpine style glaciations

Absence of paleo-ice sheet landforms (drumlin swarms, eskers, ribbed moraines)

Field investigations

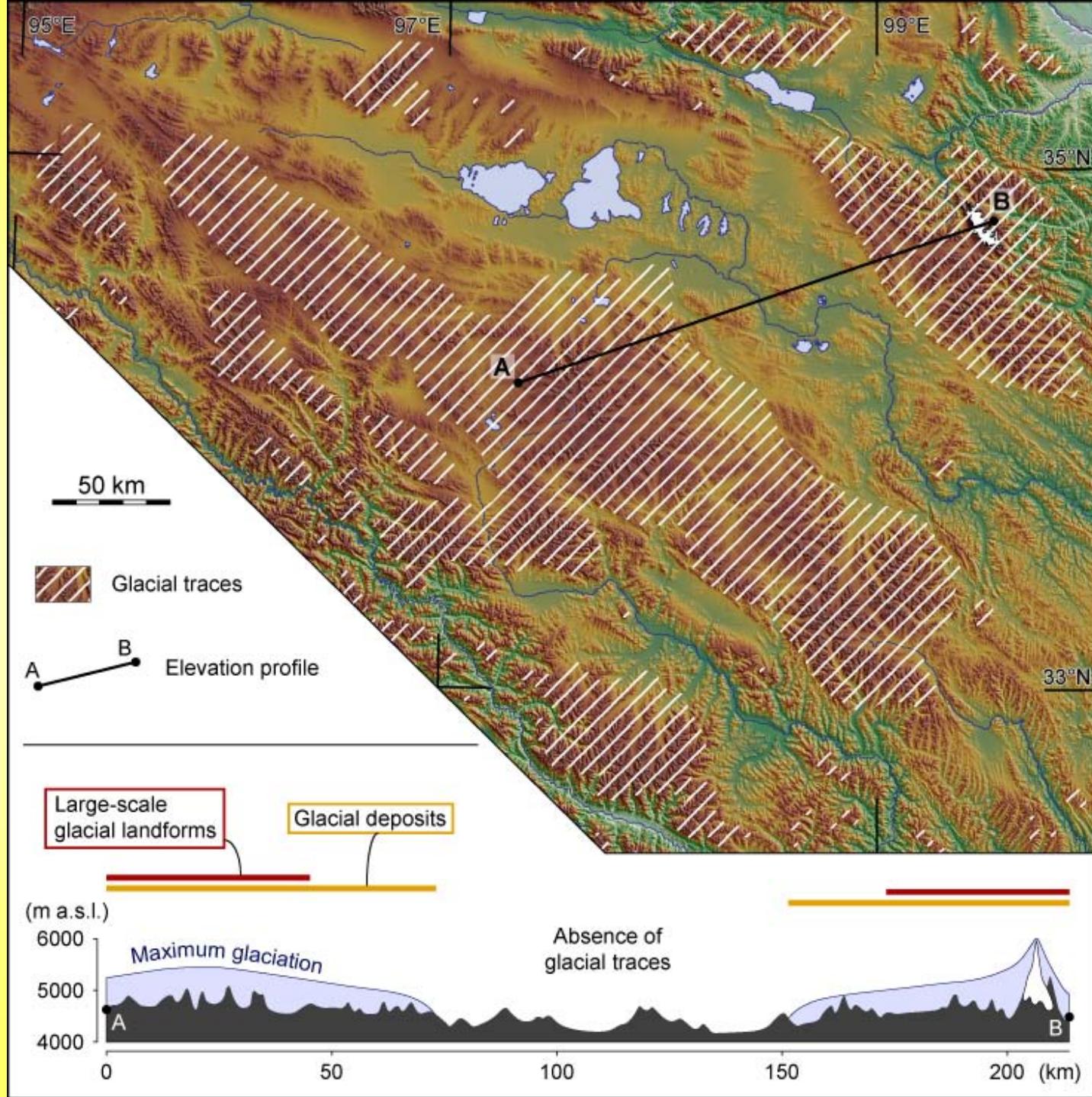


Totally 3 fieldworks (2005-2007)

- Detailed studies of key locations
- Mapping of glacial deposits and areas lacking all glacial evidence



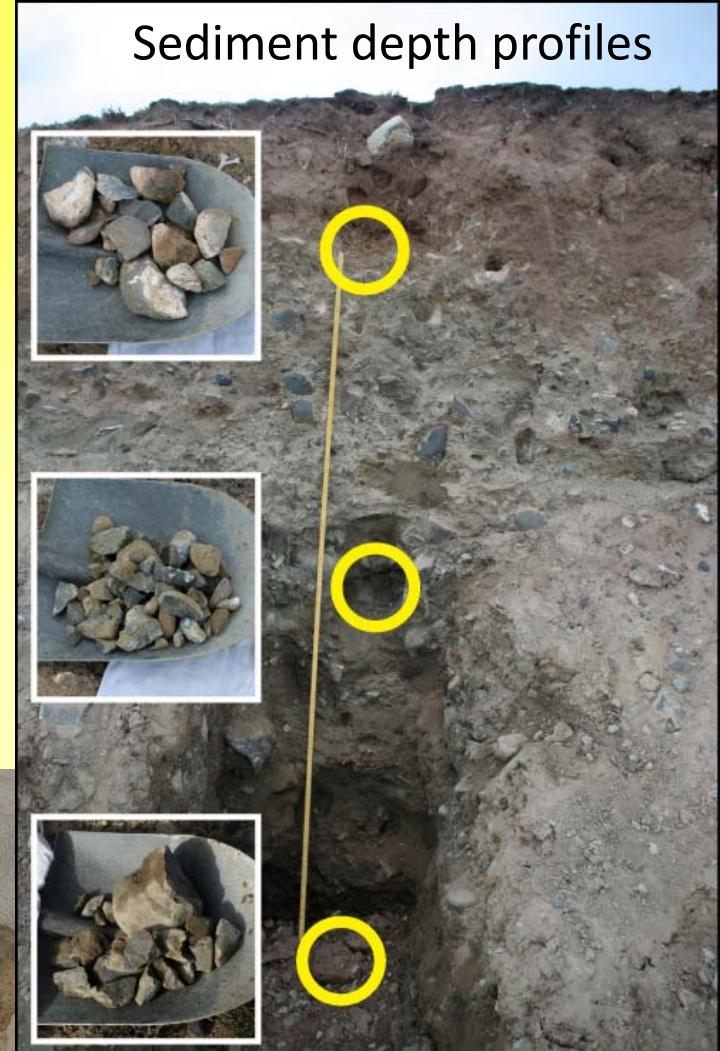
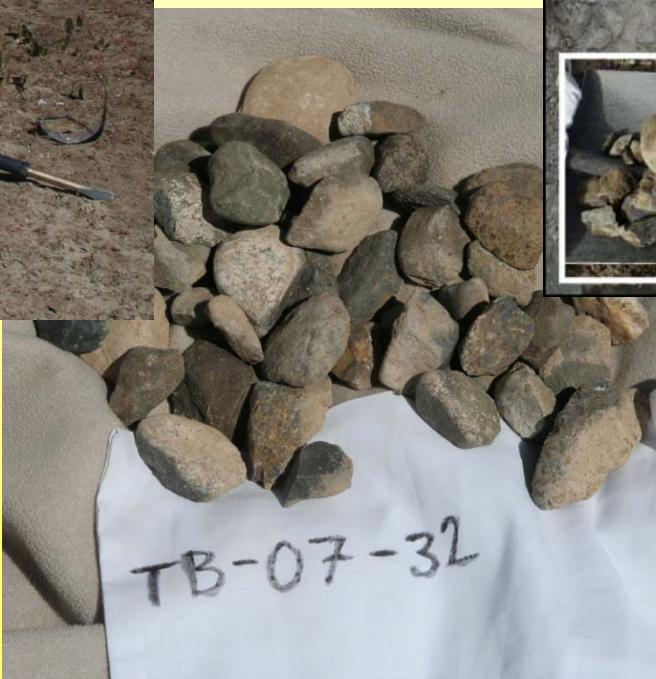
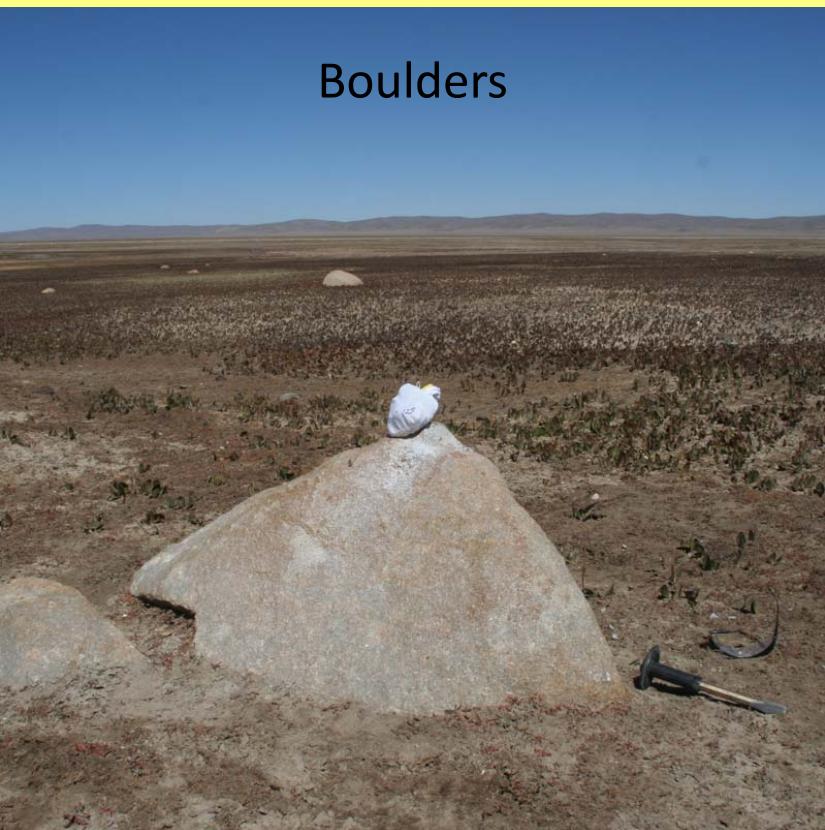
Maximum glaciation – time unknown



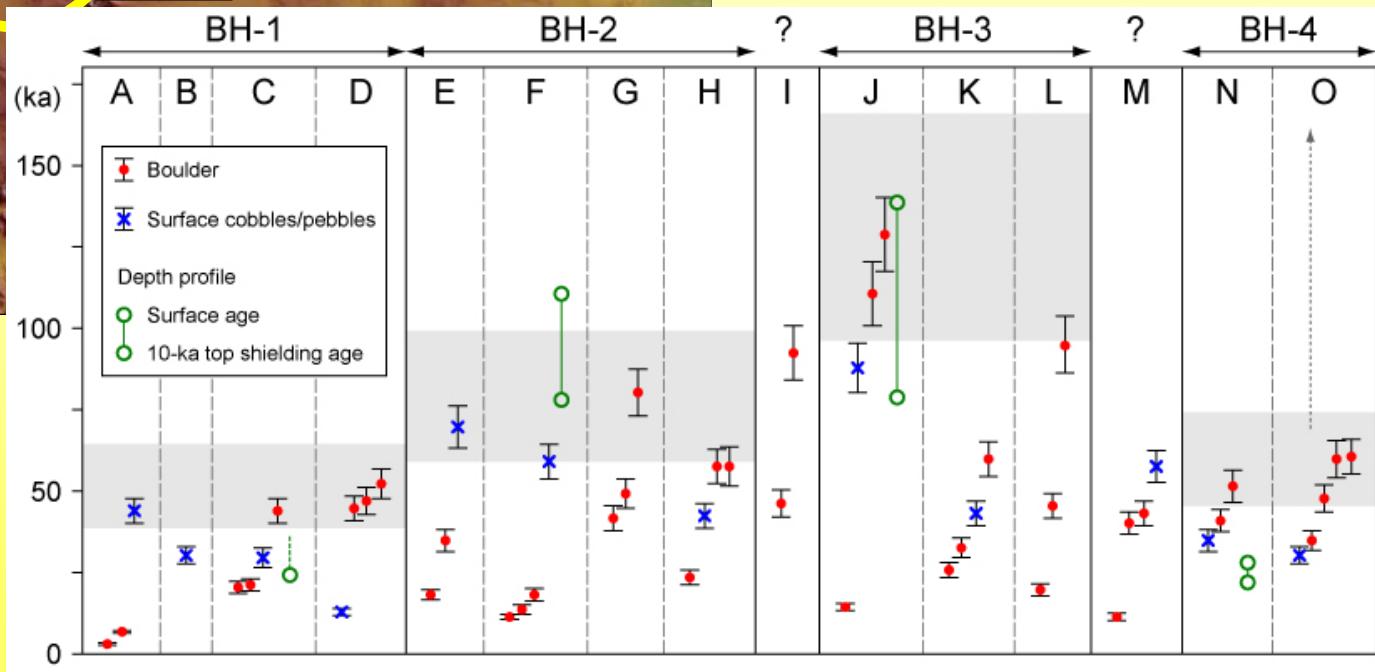
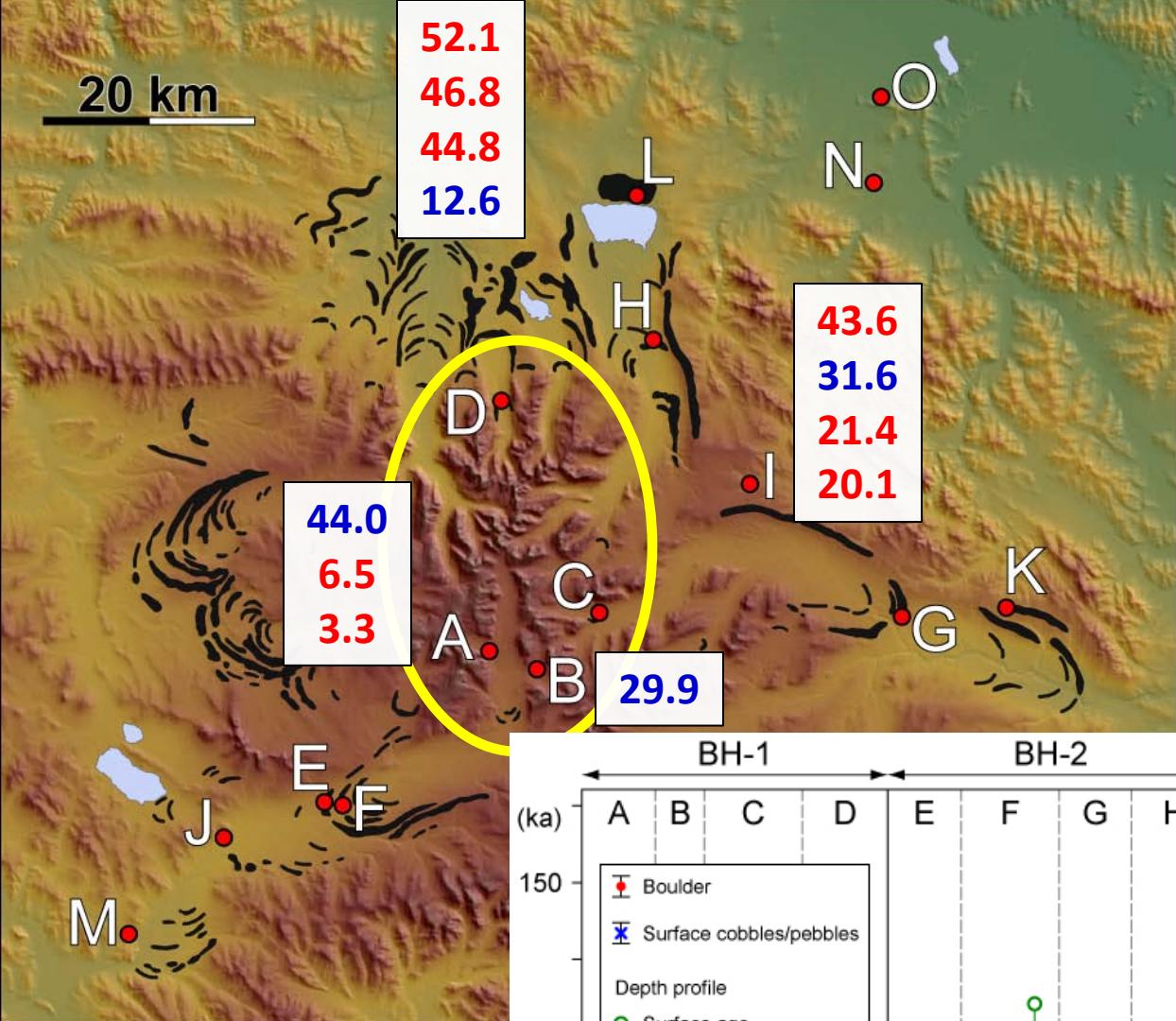
Heyman et al. (2009, JQS)

Cosmogenic exposure dating (^{10}Be):

Boulders



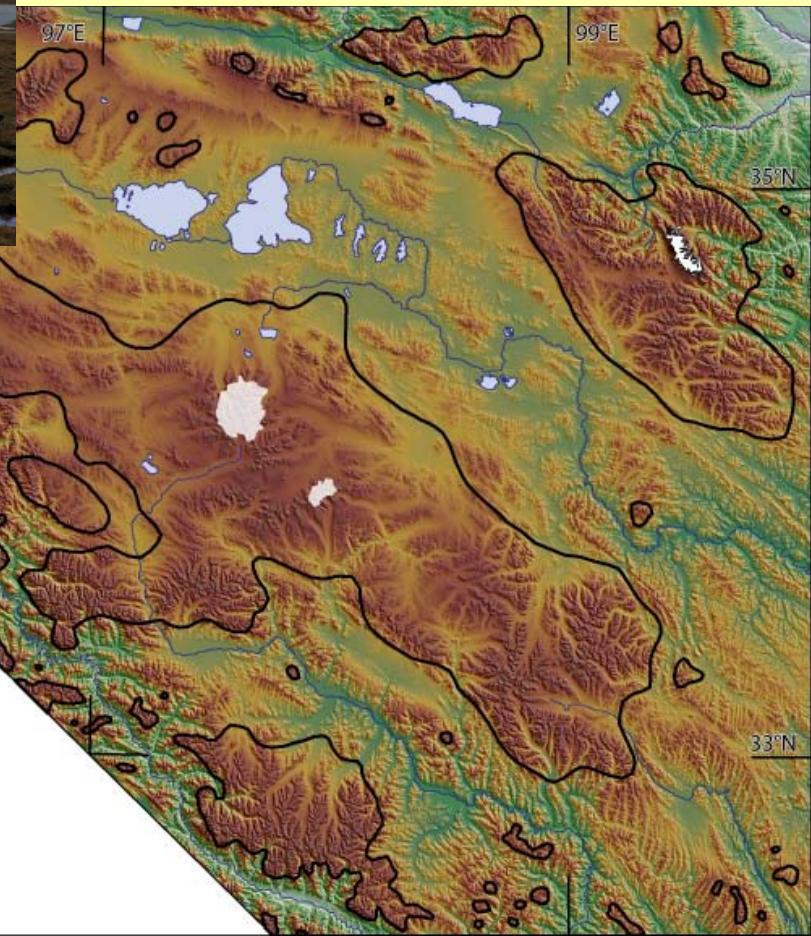
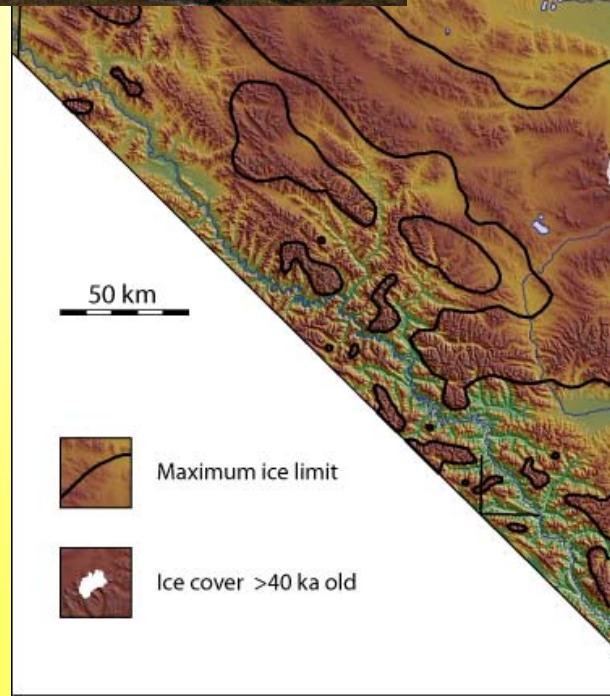
Surface pebbles

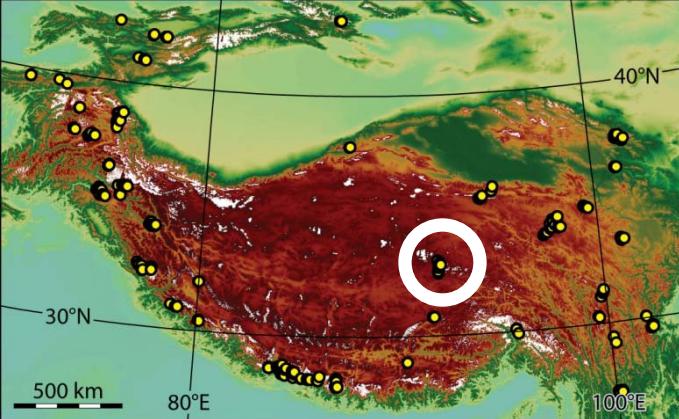




>40 ka

Glacial extent very limited over the last 40 ka (at least)





Tanggula ice-field, Central Tibetan Plateau

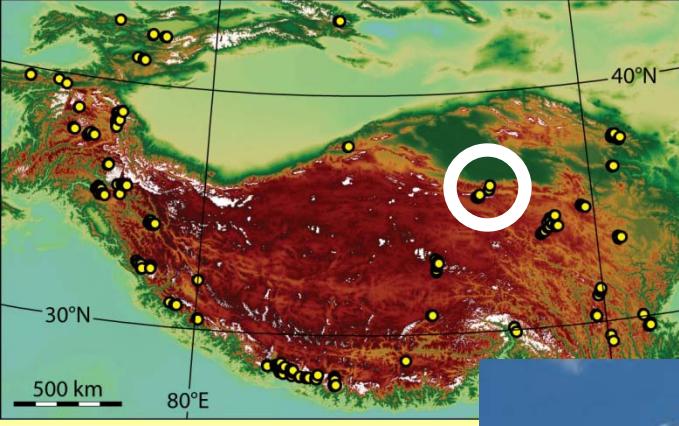
Exposure age data from Schäfer et al. (2002),
Owen et al. (2005), Colgan et al. (2006)



77 ka
71 ka
66 ka
62 ka
47 ka
43 ka

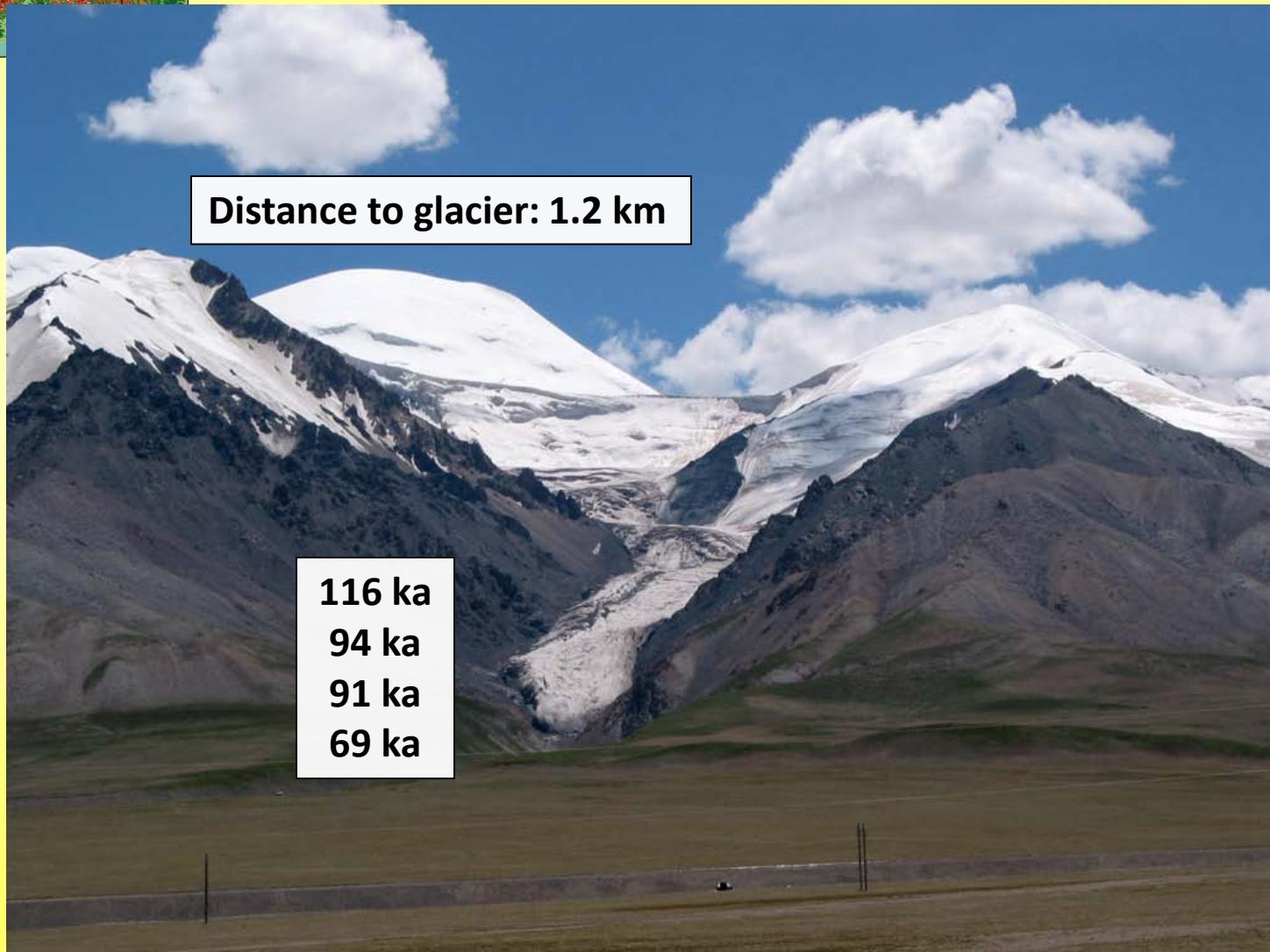
Distance to glacier: 7.8 km

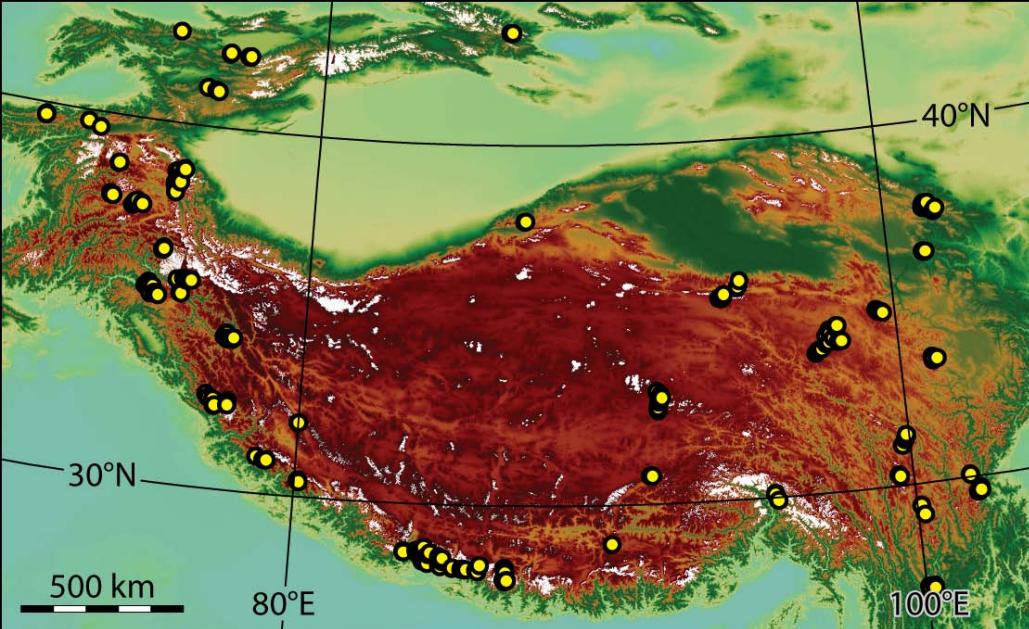
34 ka Distance to glacier: 3.1 km



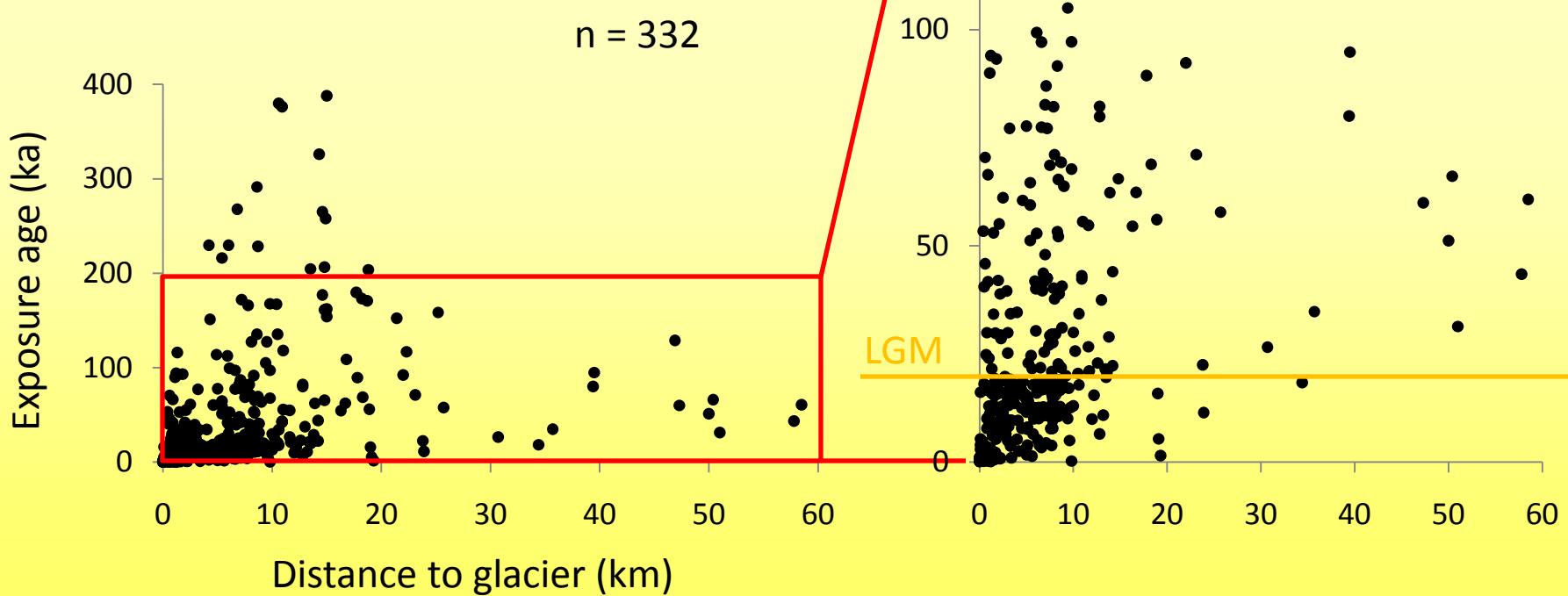
Kunlun ice-field, Northern Tibetan Plateau

Exposure age data from Owen et al. (2006)

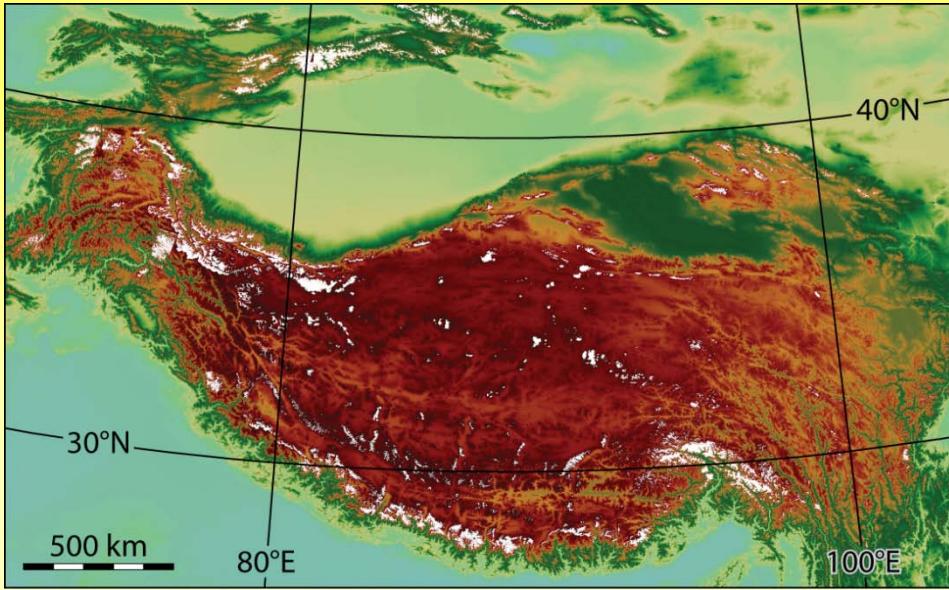




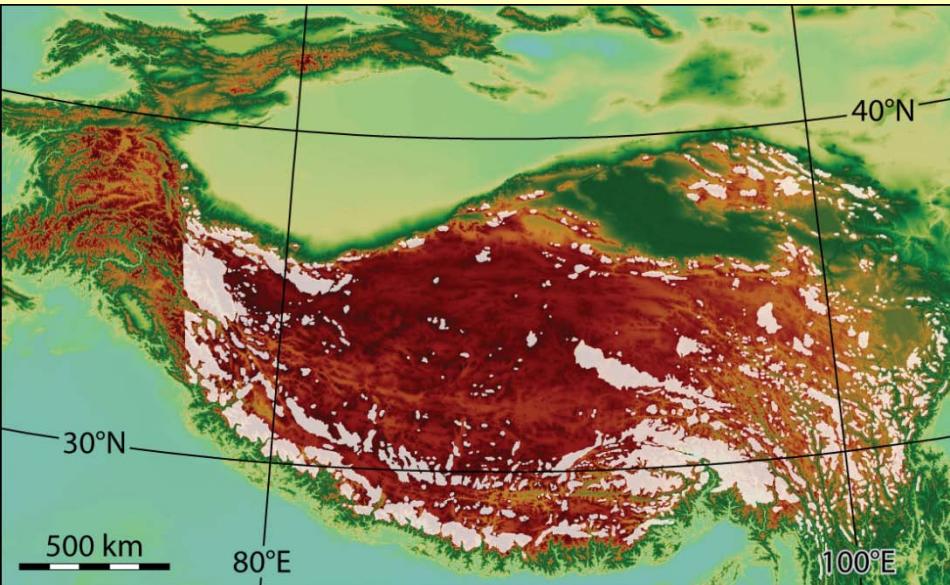
Past glaciers (even the very old) were generally not much larger than today!



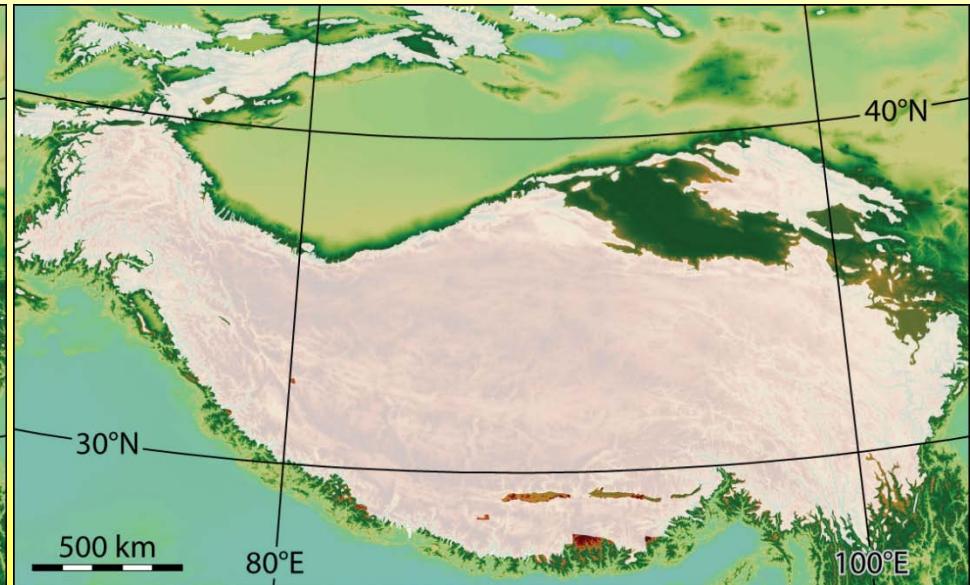
LGM glaciers (and present-day glaciers)



Quaternary glacial maximum (unknown timing)

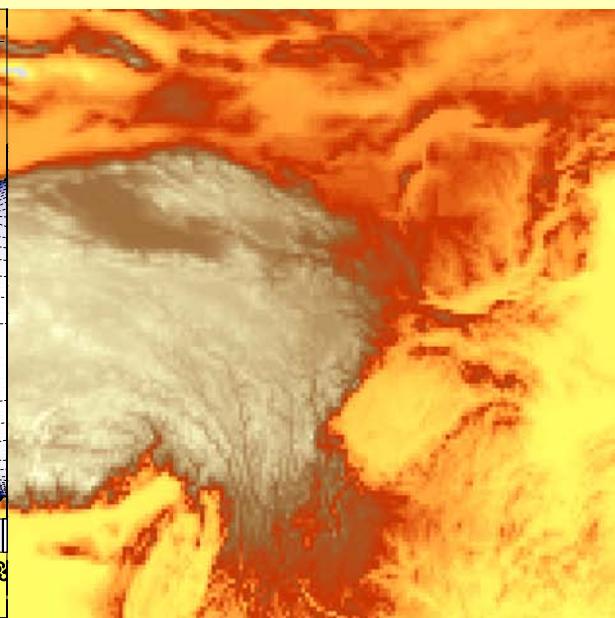
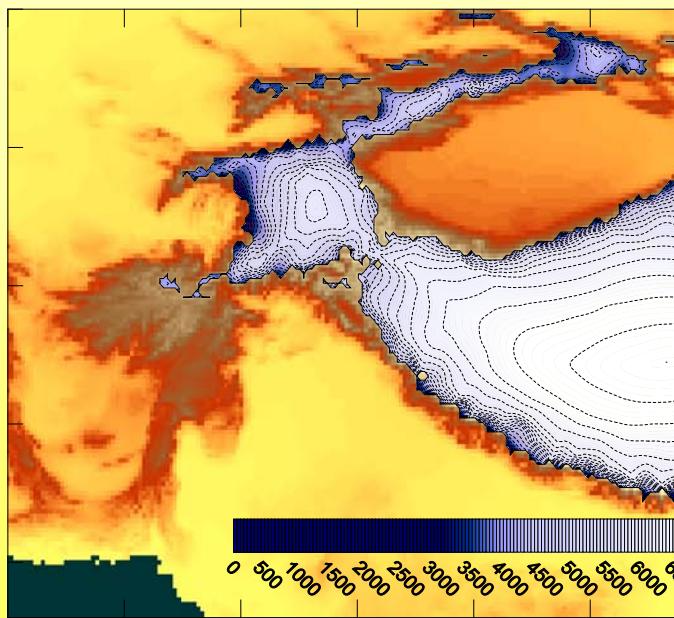
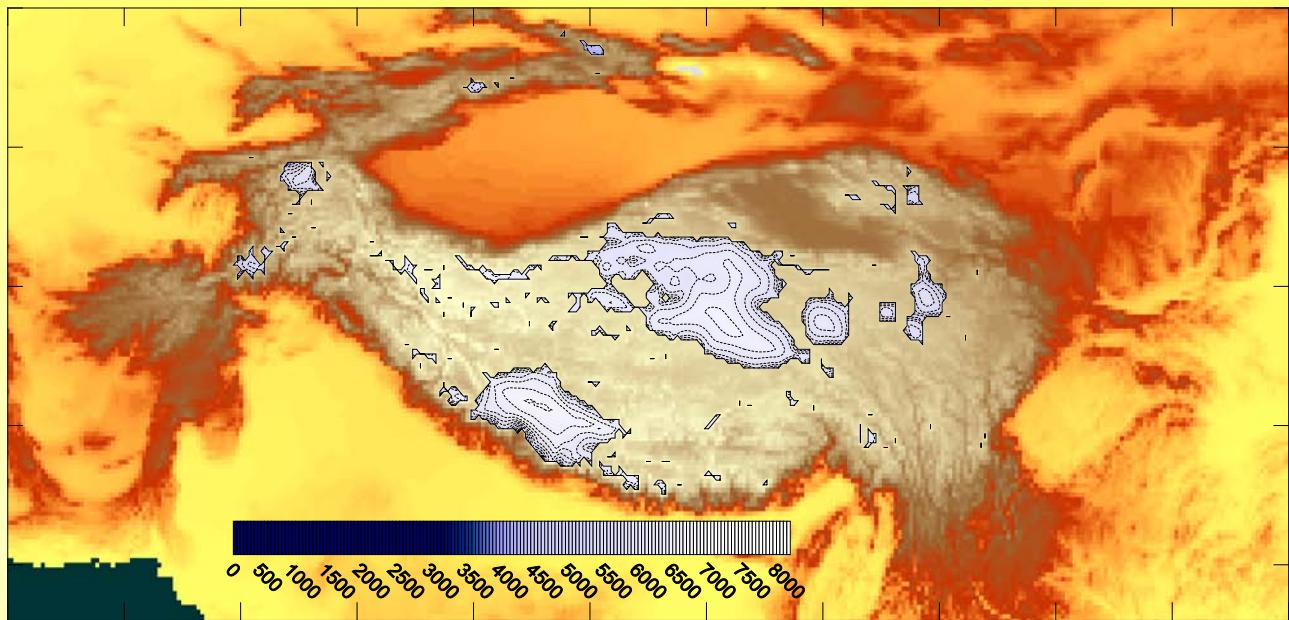


Palaeoglaciology dream



Palaeoclimatic implications?

3D glacier
modelling



Summary



- Glaciers on the Tibetan Plateau have not been much larger than today for a very long period
- Boulder exposure ages typically yield minimum deglacial ages

A photograph of a traditional nomadic camp in a vast, open landscape. In the foreground, two dark-colored yaks are grazing on dry, yellowish-brown grass. One yak has a red and white patterned blanket draped over its back. In the middle ground, there are two large, white, bell-shaped tents with dark blue or black curtains at the entrance. Several people, dressed in traditional colorful clothing, are standing near the tents. A small motorcycle is parked between the two tents. The background features a range of low, brown mountains under a clear blue sky.

Thank you!