Landscape evolution of the south-eastern Tibetan Plateau – temporal and spatial relationships between glacial and fluvial landforms

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Geophilia_BN

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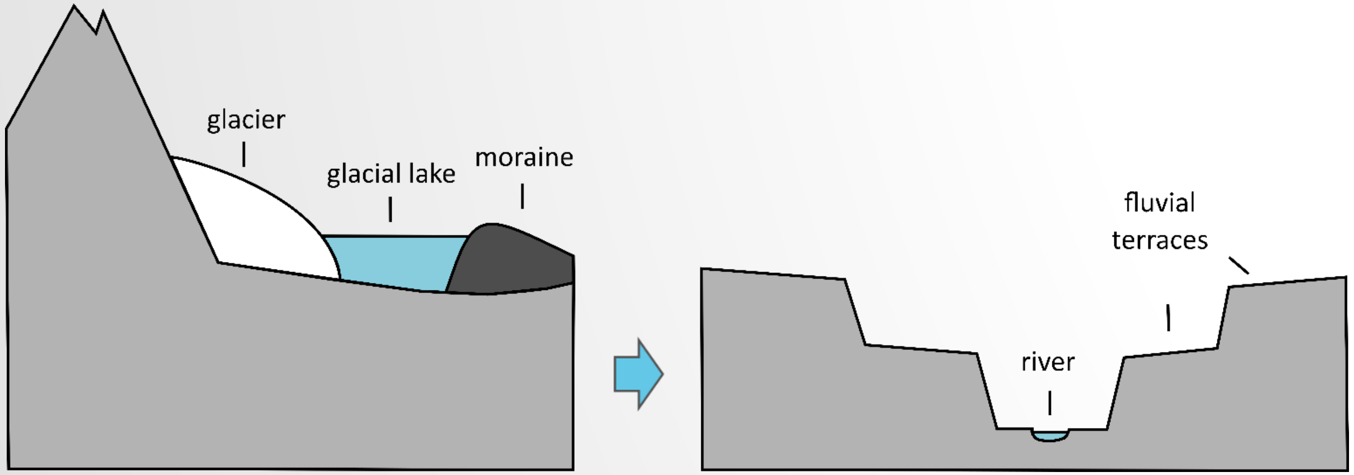
HYPOTHESIS



HYPOTHESIS

formation of river terraces in the Shaluli Shan, south-eastern Tibetan Plateau, is spatially and temporally related to regional glaciations

MOTIVATION

- Process relationships, feedbacks and response times in glacial-fluvial systems and the formation of terraces in (formerly) glaciated, tectonically active regions are challenging to disentangle – dating of key landforms can shed light on landscape evolution
- Extent and timing of glaciations in Tibet are important input for climate models, but challenging to constrain for glaciations older than the last glacial cycle – do extensive terrace deposits like those in the Shaluli Shan show a potential as climate proxies?

Project Aim

Aim

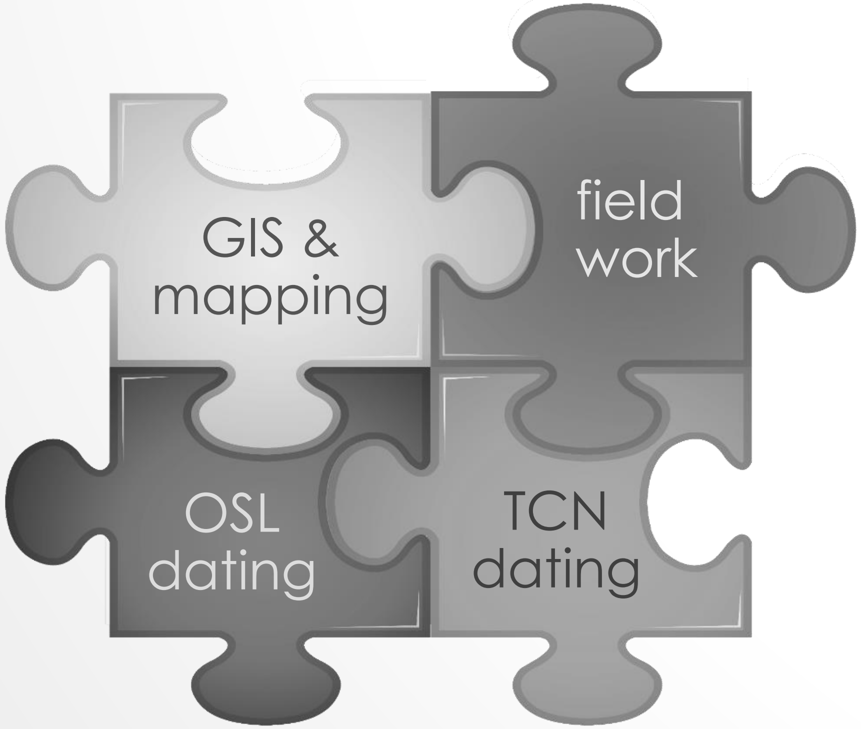
To unravel temporal and spatial relationships between glacial and fluvial landforms by combining geochronological and high-resolution remote sensing techniques

Objectives

- To map glacial and fluvial landforms in the wider region including the research area in unprecedented detail (based on 12 m TanDEM-X topographic data and field observations)
- To conduct field investigations to ground-truth and refine geomorphological mapping
- To sample glacial and fluvial landforms and subsequently date them using Terrestrial Cosmogenic Nuclides (TCN) and Optically Stimulated Luminescence (OSL)
- To propose a conceptual model for landscape evolution with a focus on the relationship between glacial and fluvial processes

METHODOLOGICAL APPROACH

- Geomorphological mapping based on TanDEM-X data (12 m spatial resolution)
- Extraction of terrace surface elevations, terrace gradients, river gradients, and topographic profiles
- GIS-based approach for terrace classification by aggradation period in conjunction with depositonal ages

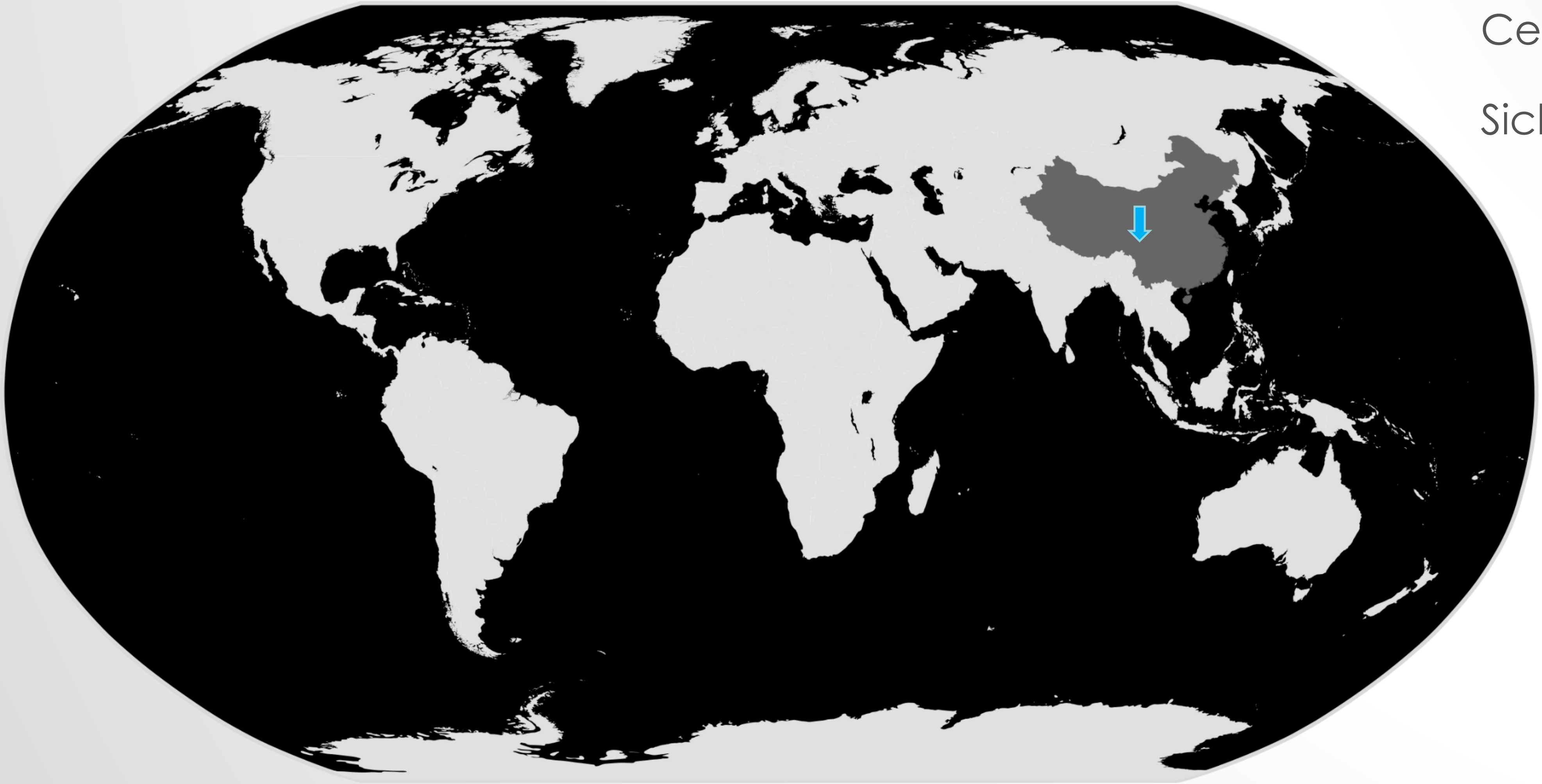


- Ground-truthing of geomorphological mapping
- Direct observations regarding landforms, present-day formative processes, sedimentary records
- Inferences about formation processes of terrace deposits
- Identification and sampling of suitable OSL and TCN targets

- Determination of depositional ages of selected extensive terrace deposits
- pIRIRSL SAR protocol used on 24 feldspar aliquots (ø 1 mm) per sample
- Inference of terrace aggradation periods and comparison with upstream TCN dates from this study and previous publications

- Determination of exposure ages of selected boulders on a sequence of terminal moraines
- Constraining the glacial history of the Litang valley
- Direct comparisons with the terrace IRSL dates downstream

Research Area



Central China

Sichuan Province

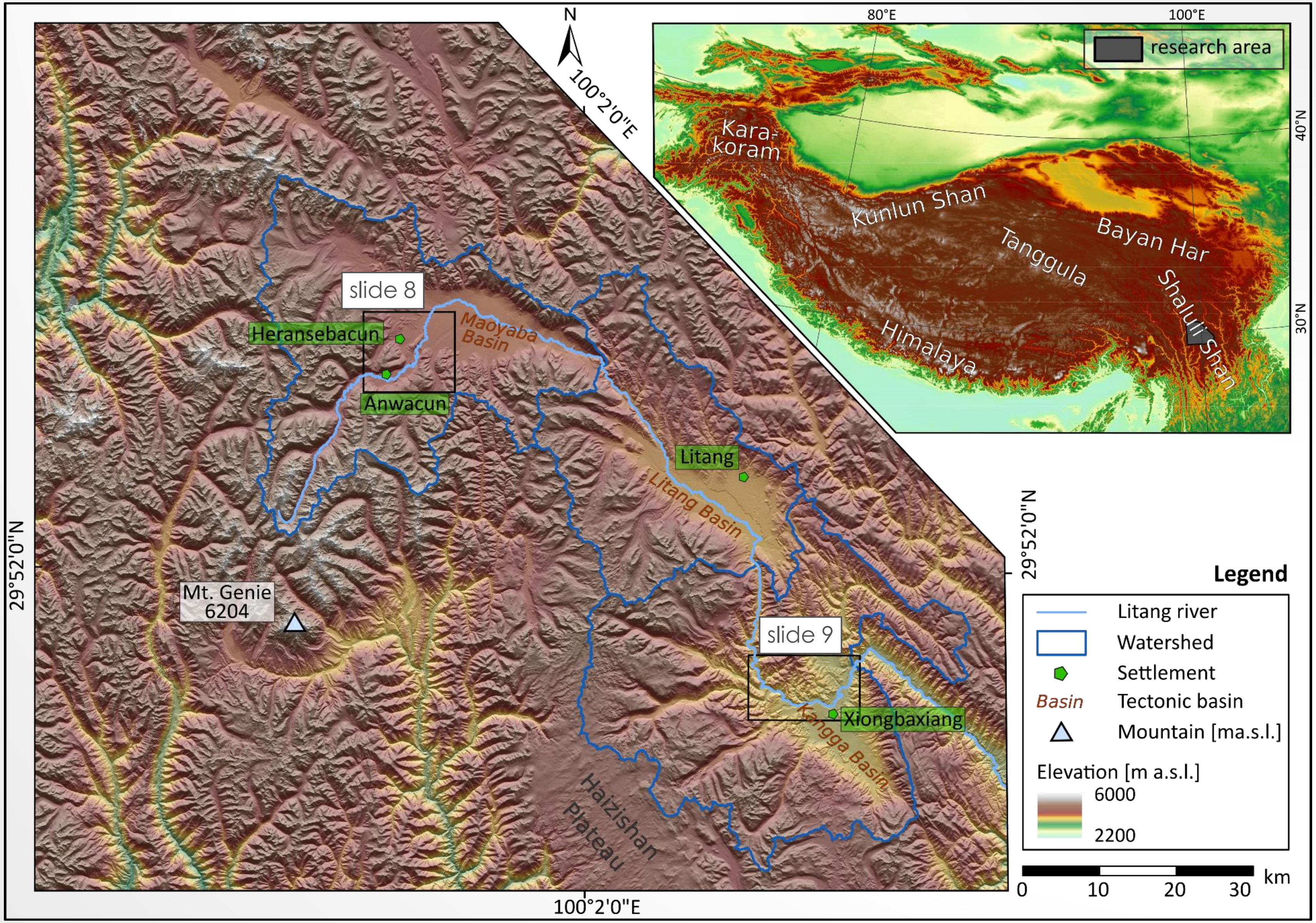
Research Area & Field observations

Traces of landscape evolution

Evidence for former glaciations
- cirques
- U-shaped valleys
- glaciolacustrine deposits
- moraines

Signs of tectonic activity
- ruptures
- landslides
- fault scarps

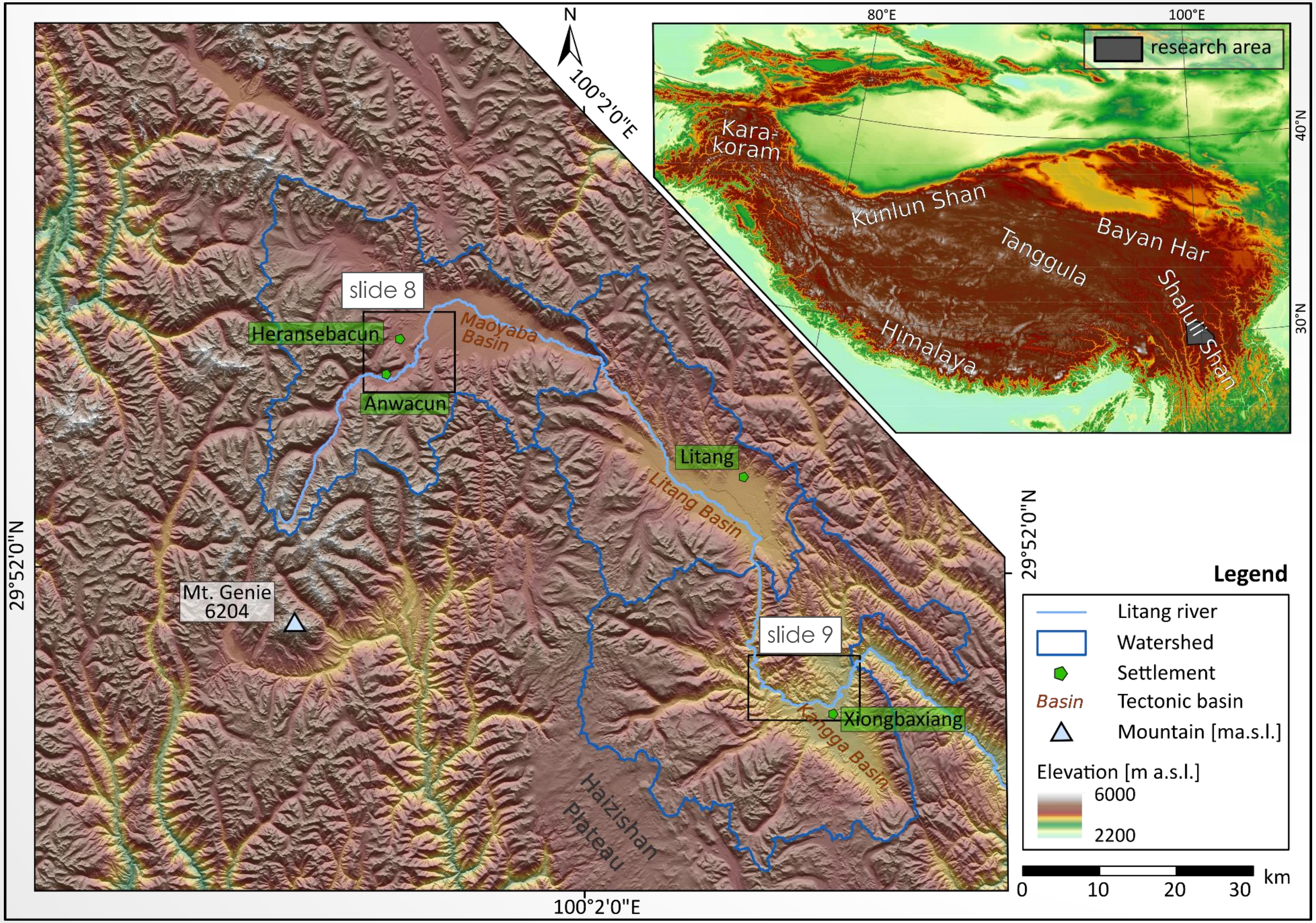
Fluvial imprint
- oxbow lakes
- fluvial and glaciofluvial terraces



Research Area & Field observations

Hypothesis test

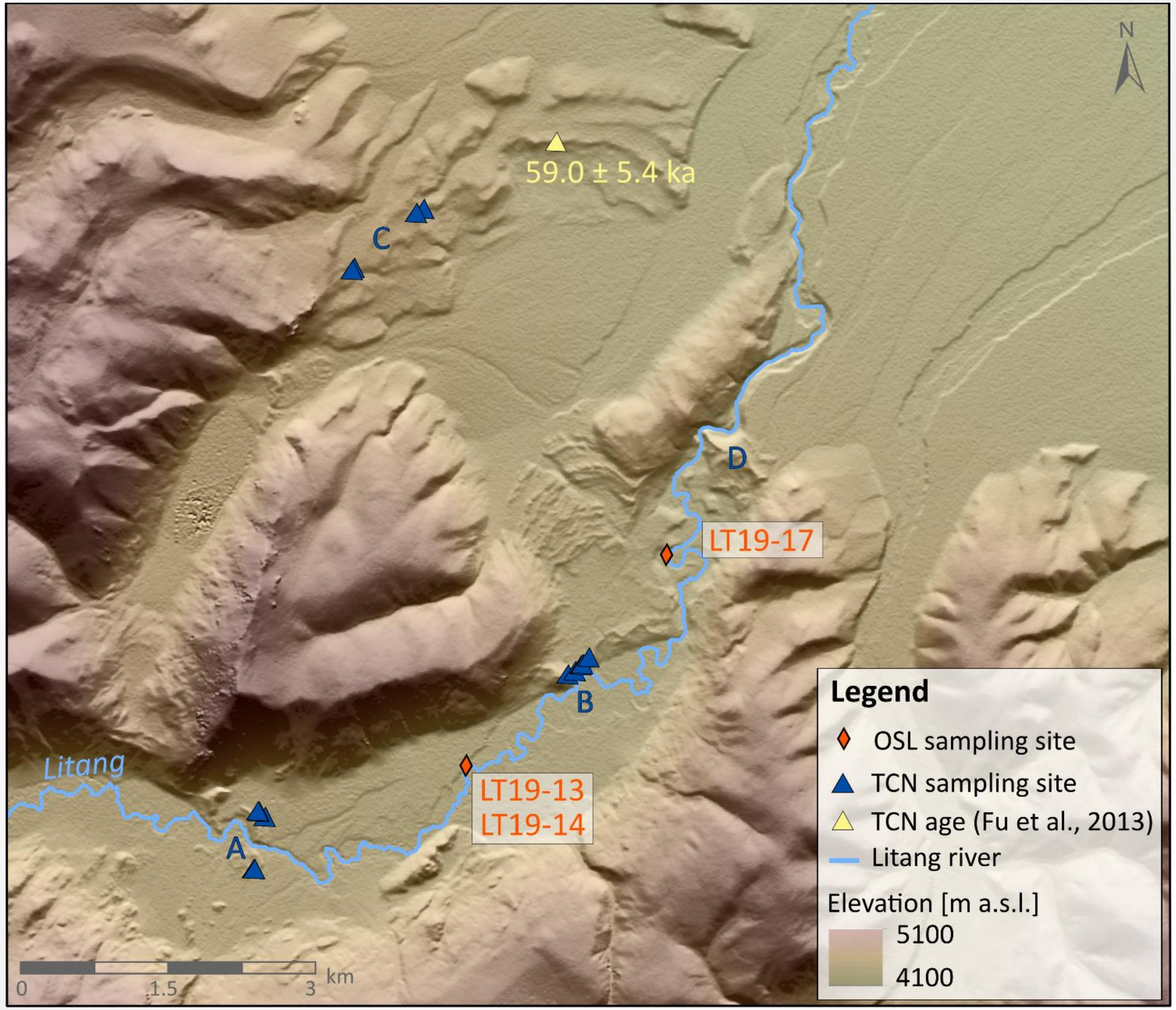
OSL dating of three terrace levels (one in the Maoyaba basin, two in the Kangga basin) located directly downstream of formerly glaciated valleys will show the temporal relationship to headwater glaciation as deduced by TCN ages of moraines



Maoyaba Basin

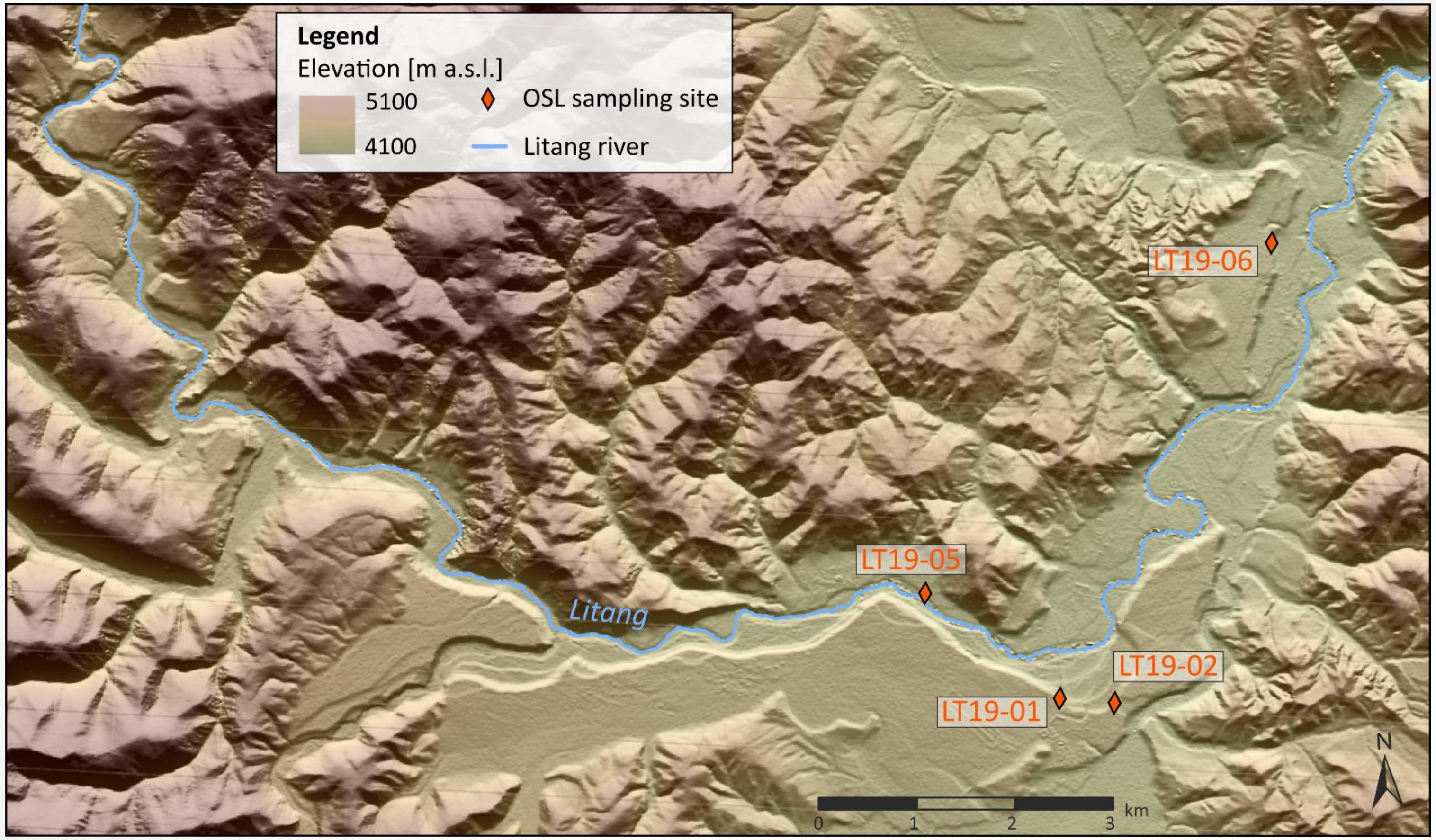
- moraine complexes A, B and C chosen for TCN dating → sequence of glacial extents in the Litang valley
- outermost moraine complex (C) dated to 59.0 ± 5.4 ka (Fu et al. 2013) based on one boulder

- OSL samples obtained from indicated locations
- **LT19-13** and **LT19-14** were sampled from the same section; chosen to determine the age of the terrace level framed by moraine complexes A and B
- **LT19-17** was taken from a glaciolacustrine deposit → found to be saturated

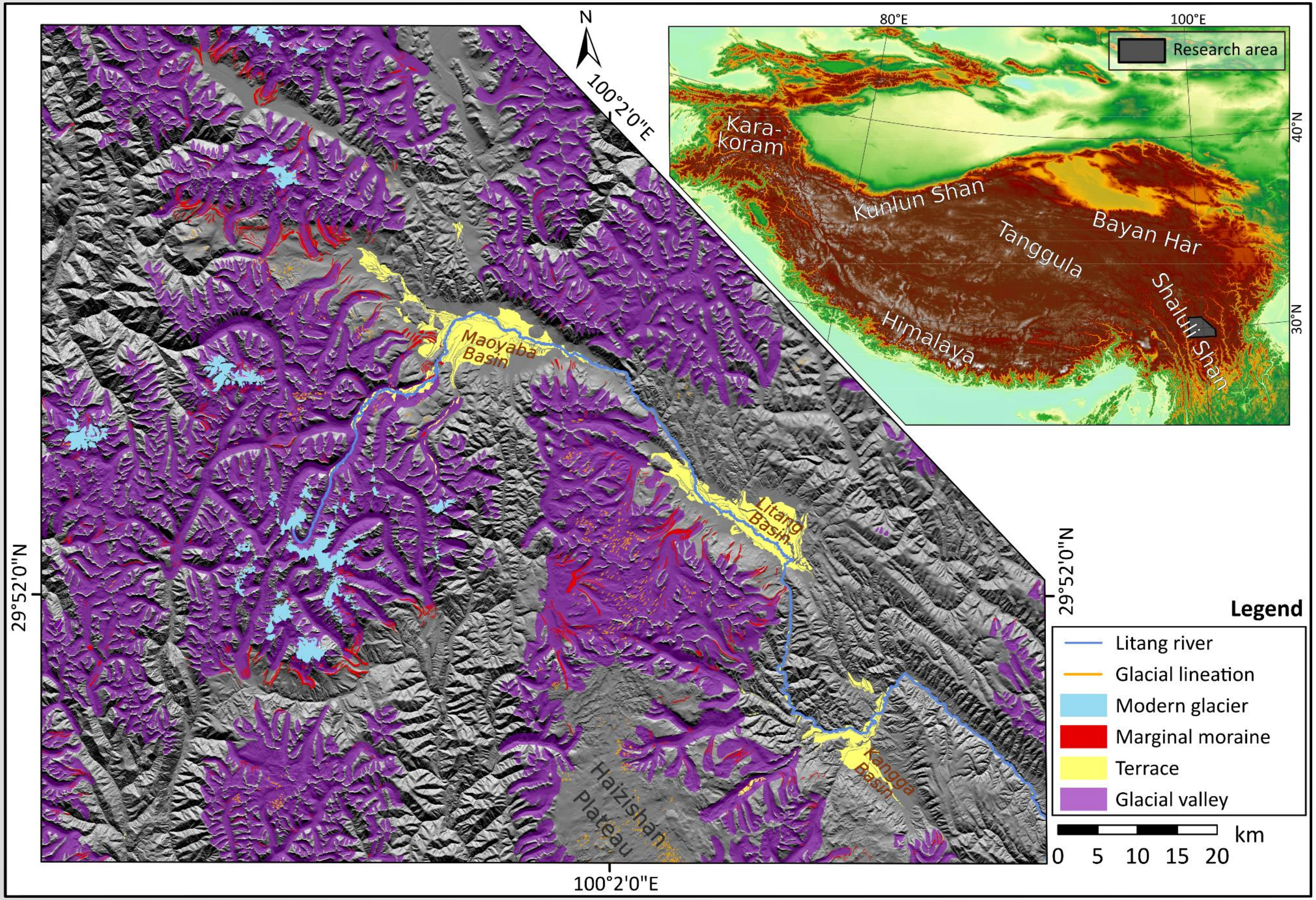


Kangga Basin

- OSL samples obtained from the indicated locations along the Litang river
- Samples **LT19-01**, **LT19-02** and **LT19-06** taken from the most extensive main terrace level
- Xu & Zhou (2009, 2014) have obtained an age range of 16.4 ± 1.4 ka to 45.3 ± 5.6 ka with ESR dating for the main terrace level
- **LT19-05** was taken from a lower, yet extensive terrace level



Results: Geomorphological mapping



Paleoglaciation

43 % of mapping area, based on TanDEM-X/12m

Present-day glaciation

1 % of mapping area currently glaciated
(GLIMS Glacier Database 2018)

Results: IRSL dating

Kangga Basin

sample ID	IR50 Equivalent Dose (CAM) [Gy] [a]	overdispersion (IR50) [%] [a]	g-value (IR50) [b]	Dose rate [Gy/ka] [c]	Burial age IR50, fading-corrected [ka]	Ratio between IR50 and postIR225 ages
LT19-01	247.2 ± 4.0	7.3 ± 1.3	4.3 ± 0.9	4.8 ± 0.1	83.6 ± 12.5	0.8 ± 0.1
LT19-02	244.8 ± 6.0	11.5 ± 1.8	5.3 ± 1.0	4.8 ± 0.1	93.7 ± 21.0	0.8 ± 0.2
LT19-06	248.3 ± 5.9	11.2 ± 1.8	3.4 ± 0.9	5.0 ± 0.2	70.8 ± 10.1	0.6 ± 0.1
LT19-05	100.7 ± 2.7	12.8 ± 1.9	3.2 ± 0.5	5.4 ± 0.2	26.0 ± 2.2	0.5 ± 0.1

Litang valley

sample ID	IR50 Equivalent Dose (CAM) [Gy] [a]	overdispersion (IR50) [%] [a]	g-value (IR50) [b]	Dose rate [Gy/ka] [c]	Burial age (IR50, fading-corrected) [ka]	Ratio between IR50 and postIR150 ages
LT19-13	70.8 ± 0.6	3.2 ± 0.7	3.0 ± 0.5	6.0 ± 0.2	16.0 ± 1.1	0.9 ± 0.1
LT19-14	75.2 ± 0.9	5.1 ± 0.9	3.1 ± 0.5	7.0 ± 0.3	14.5 ± 1.1	0.9 ± 0.1

OSL measurements were conducted following a modified post IRIRSL protocol, using 50 °C and 150°C or 225°C stimulation temperatures (Buylaert et al., 2009; Reimann & Tsukamoto, 2012), on 1 mm aliquots. Results focus on IR50 luminescence signals due to better bleachability, which makes them more informative. For comparison, ratios between final IR50 and post IRSL (225 or 150) ages corrected for fading are provided.

a Calculated using the Central Age Model tool in R (Burow 2020), based on Galbraith et al. (1999) and Galbraith & Roberts (2012)
b Fading correction is performed with the Fading Correction tool in R (Kreutzer 2019), according to Huntley & Lamothe (2001)
c Based on gamma ray spectrometry, calculated in DRAC (Dose Rate and Age Calculator) (Durcan et al. 2015)

Results and discussion: IRSL dating

Terrace formation during late MIS 5 / early MIS 4

78.0 ± 12.3 ka weighted average age for main terrace level (IRSL signals at 50°C for LT19-01, LT19-02 & LT19-06 (dark orange squares); deposition during cooling period (cf. Bridgland & Westaway 2008)

Terrace formation during MIS 2

deposition during glacial phase (in accordance with regional climate proxies and prevailing theories for the formation of climatically controlled terraces in uplifting regions, cf. Starkel 2003, Bridgland & Westaway 2008, Cordiér et al. 2017)

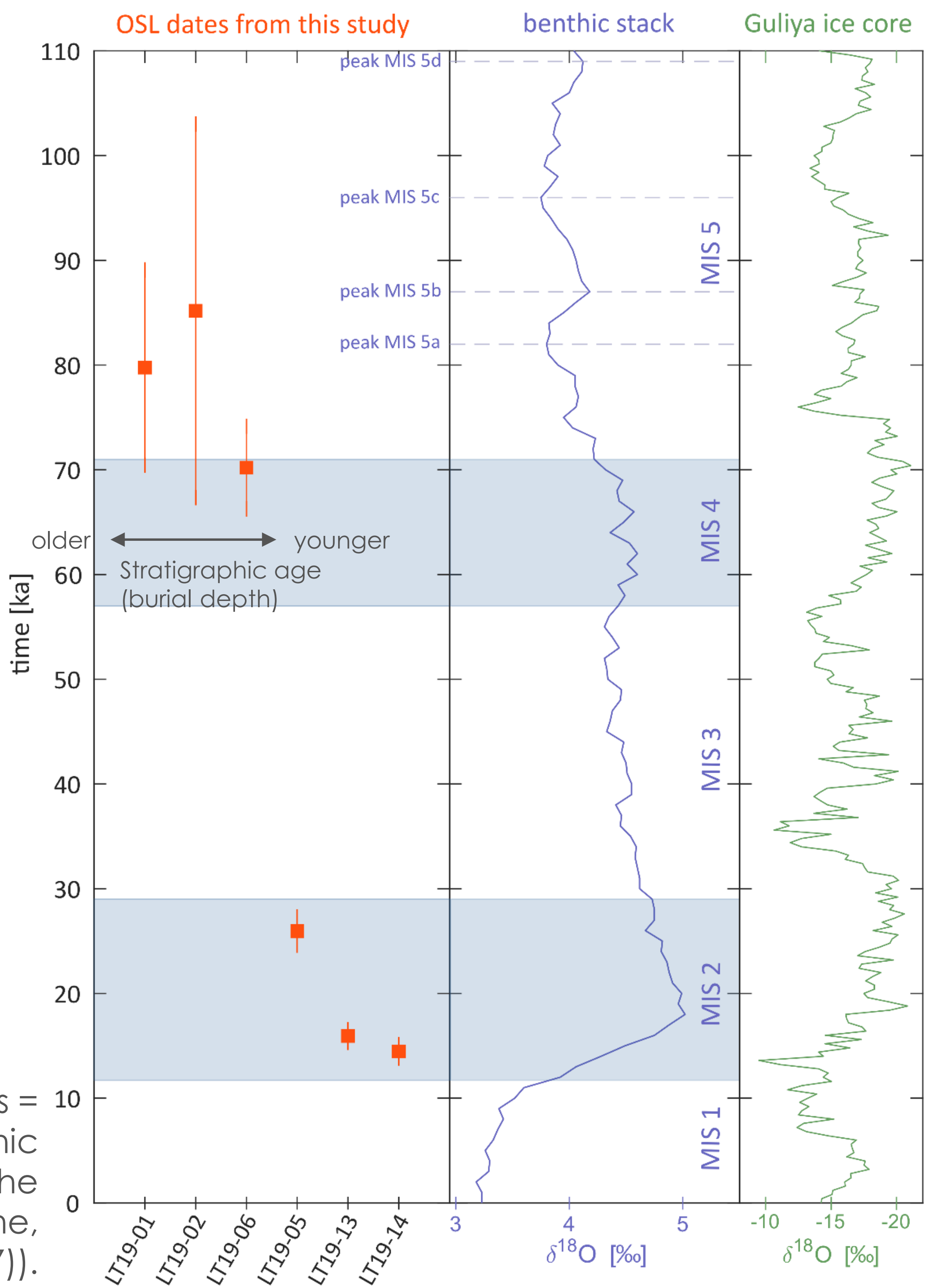


Figure: OSL dates from this study (dark orange squares = IR50 measurements) in comparison with stacked benthic $\delta^{18}O$ records (blue line, Lisiecki & Raymo (2005)), and the $\delta^{18}O$ records from the Guliya ice core (green line, Thompson et al. (1997)).

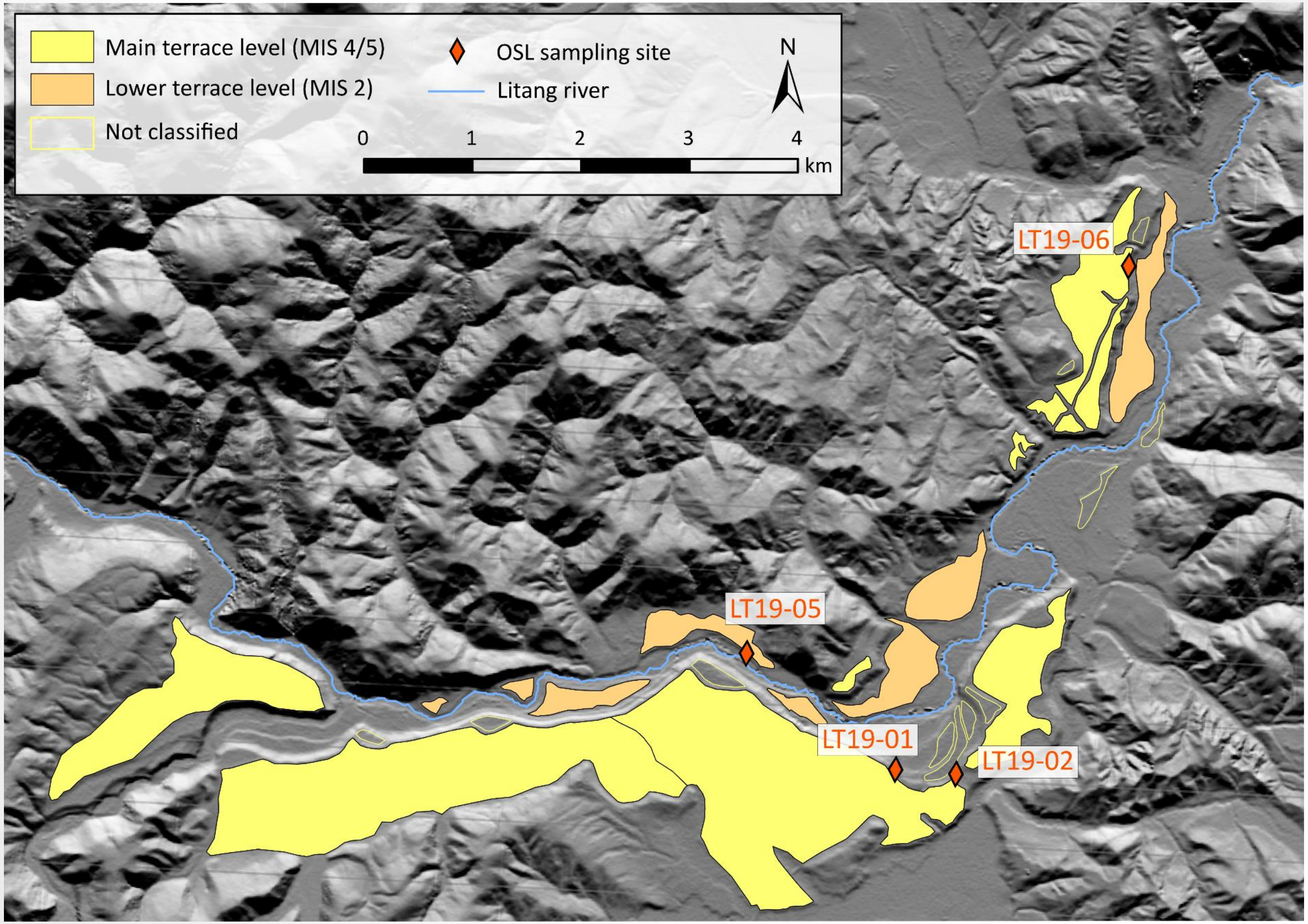
RESULTS AND DISCUSSION: FINAL TERRACE CLASSIFICATION

Criteria

- terrace gradients
- terrace height above river
- cross profiles

Main level
78.0 ± 12.3 ka
late MIS 5a / early MIS 4

lower level
26.0 ± 2.2 ka
MIS 2



Conclusions and Perspectives

- OSL ages on the two younger terrace levels validate the hypothesis of a spatial and temporal relationship between glacial phases and terrace deposition, based on their age correlation with glacial phases and the spatial location of the deposits directly downstream of formerly glaciated valleys.
- The main terrace level can be dated to the end of MIS 5 / start of MIS 4. Based on its age, it can be interpreted as a response of the fluvial system to this transition in climatic conditions.
- TCN dates for direct comparison between upstream moraine sequences and both ice-proximal and downstream ice-distal terraces are being processed.
- These results underline the potential of combined geochronological methods to advance understanding of landscape development.

Hypothesis

formation of river terraces in the research area is spatially and temporally related to regional glaciations

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