Late-Pleistocene geomorphological and geochronological history of the former Patagonian Ice-Sheet in north-eastern Patagonia (43°S)

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BSG British Society for Geomorphology · E3 DTP Edinburgh, Earth and Environment Doctoral Training Partnership · NERC Science of the Environment · CROWD SCIENCE · QRA Quaternary Research Association · SAGES Scottish Alliance for Geoscience, Environment and Society · The University of Edinburgh School of GeoSciences · SUERC Scottish Universities Environmental Research Centre

❖ Field/study site

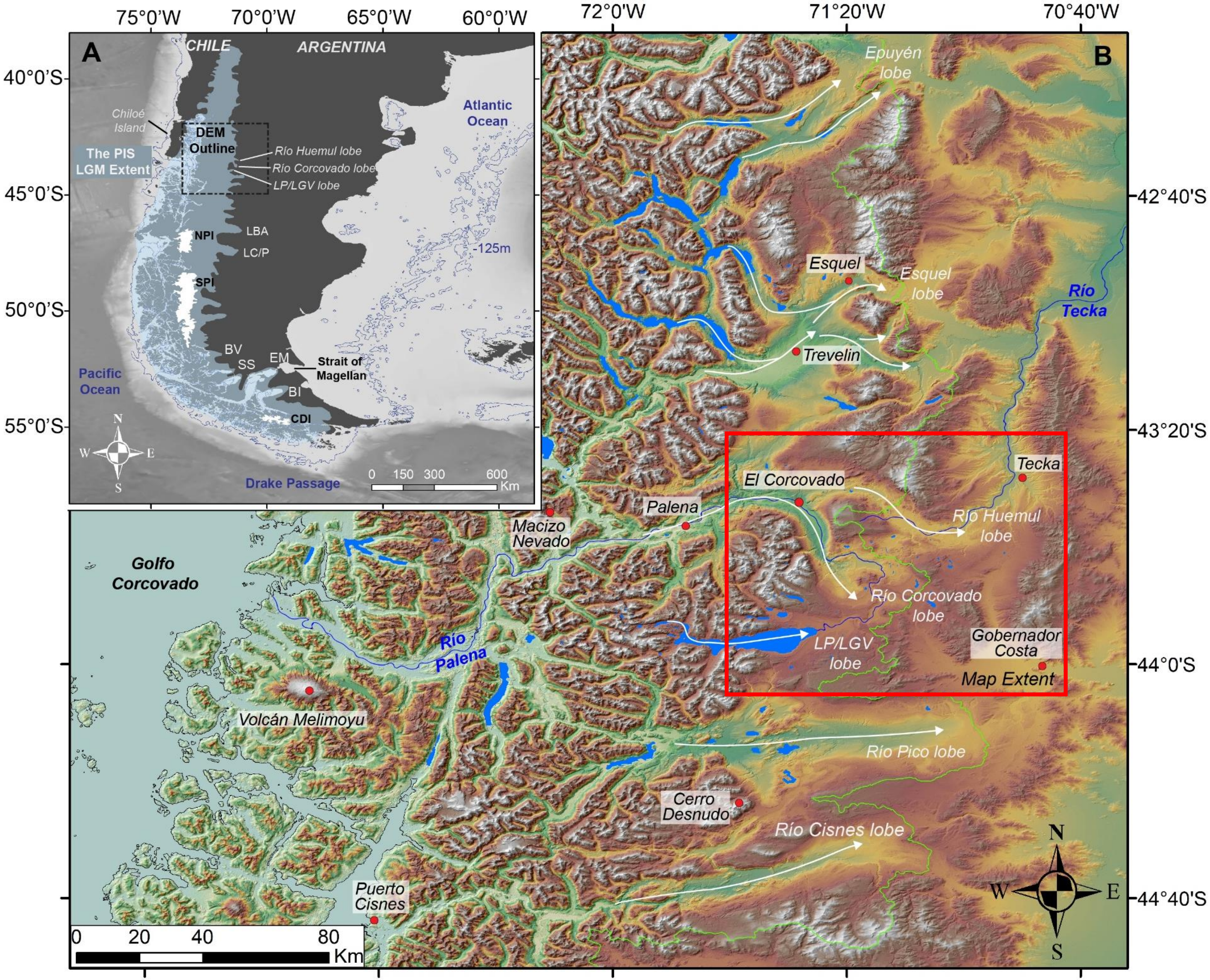
- The largely unstudied northeastern sector of the former Patagonian Ice Sheet (PIS) (43°S; 71°W)

- A valley system (red box) formely host to:

  -The Río Corcovado outlet glacier
  -The Río Huemul outlet glacier
  -The Lago Palena/General Vintter outlet glacier

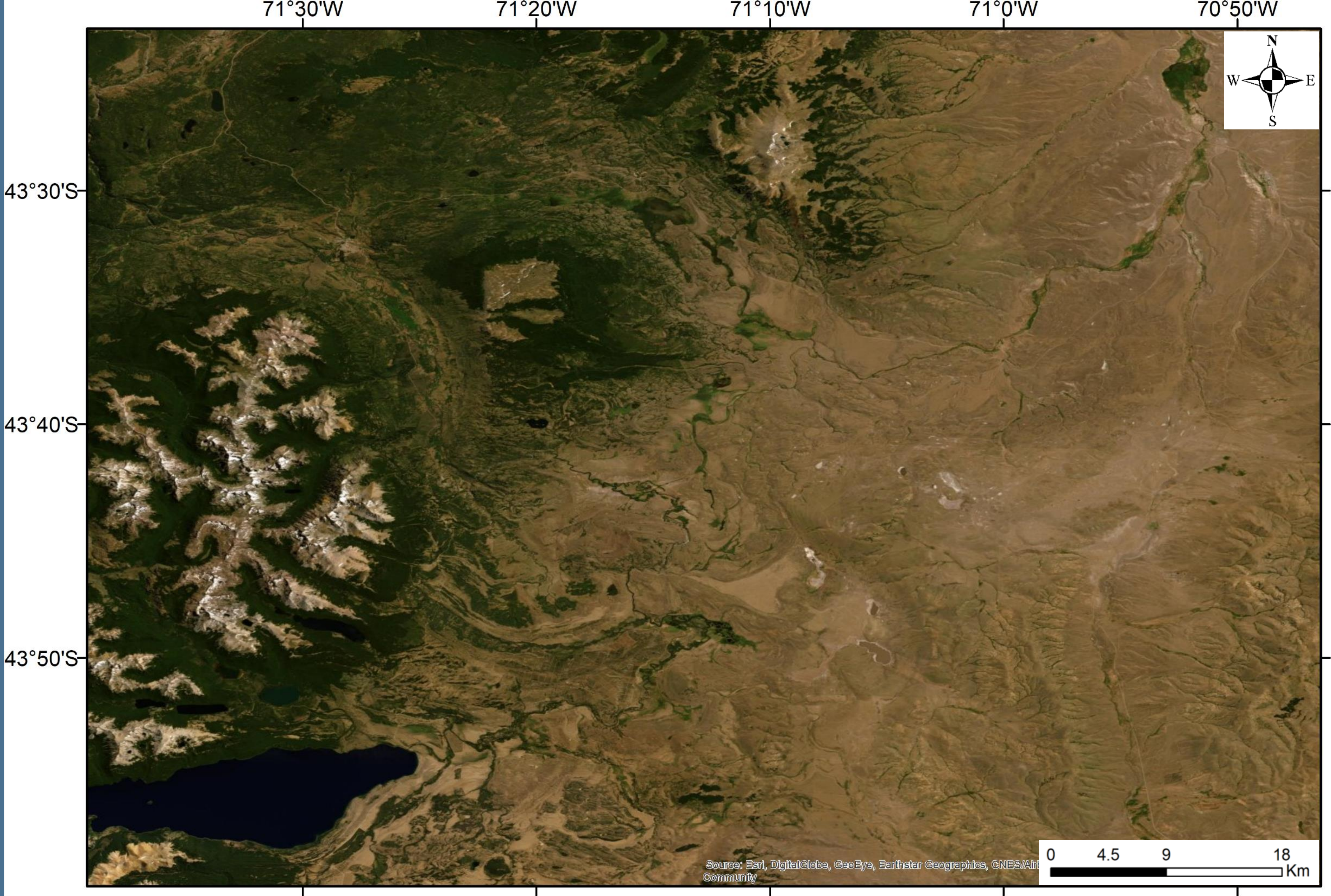
- No previous glacier-scale glacial geomorphological mapping

- No previous direct glacier chronology



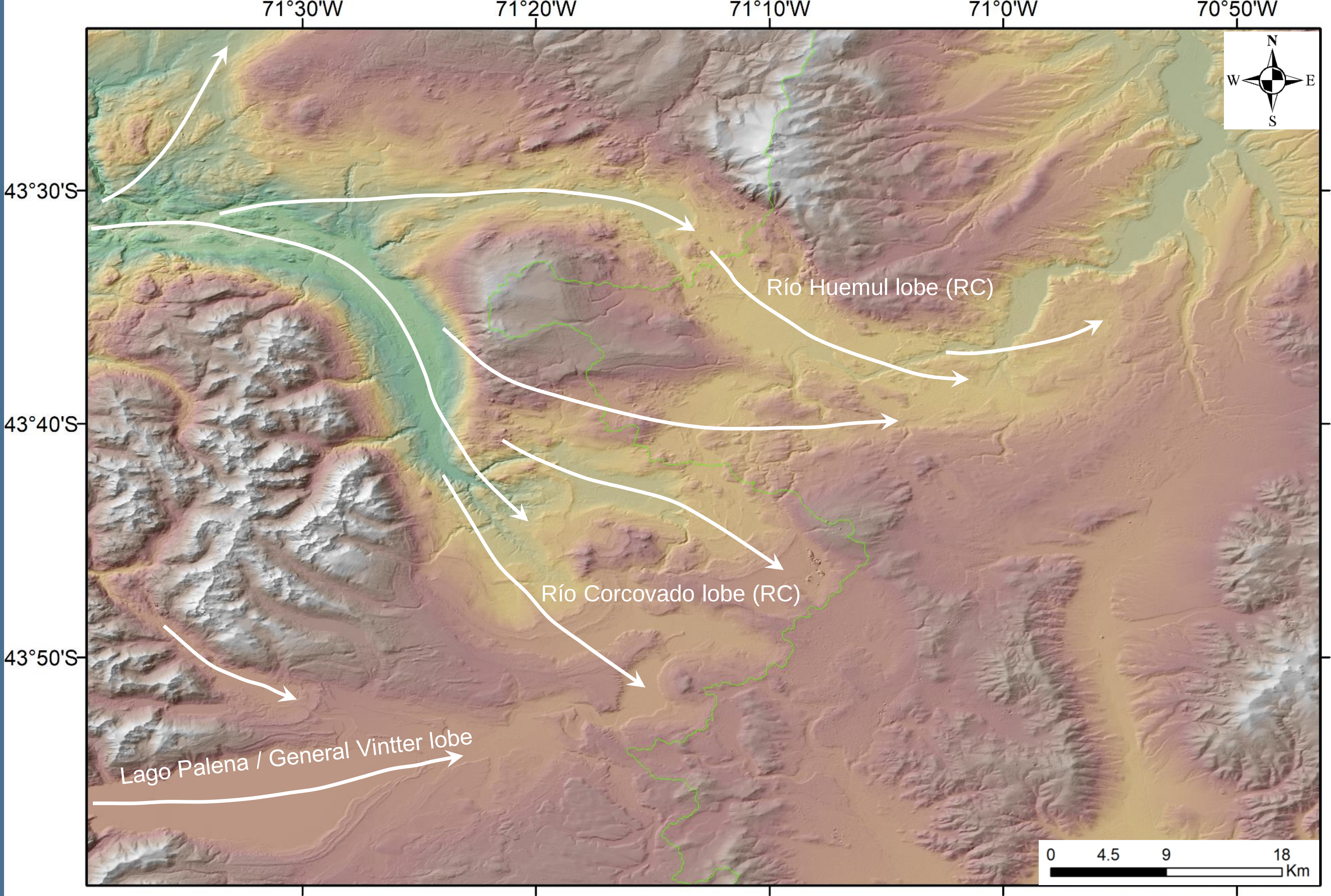
❖ Mapping

- Imagery: (digital globe)



❖ Mapping

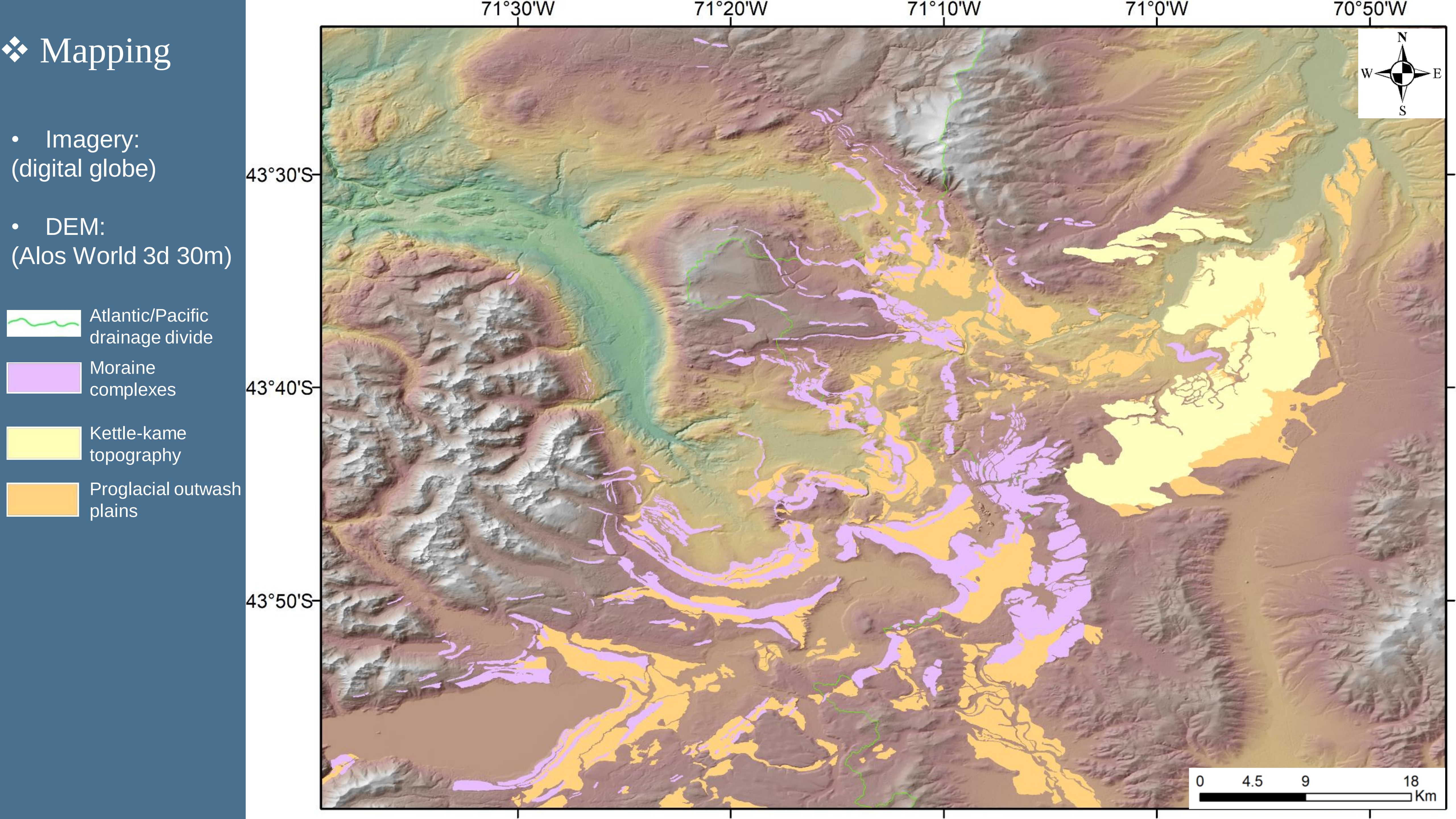
- Imagery: (digital globe)
- DEM: (Alos World 3d 30m)



❖ Mapping

- Imagery:
(digital globe)

- DEM:
(Alos World 3d 30m)



❖ Mapping

- Imagery:
(digital globe)

- DEM:
(Alos World 3d 30m)

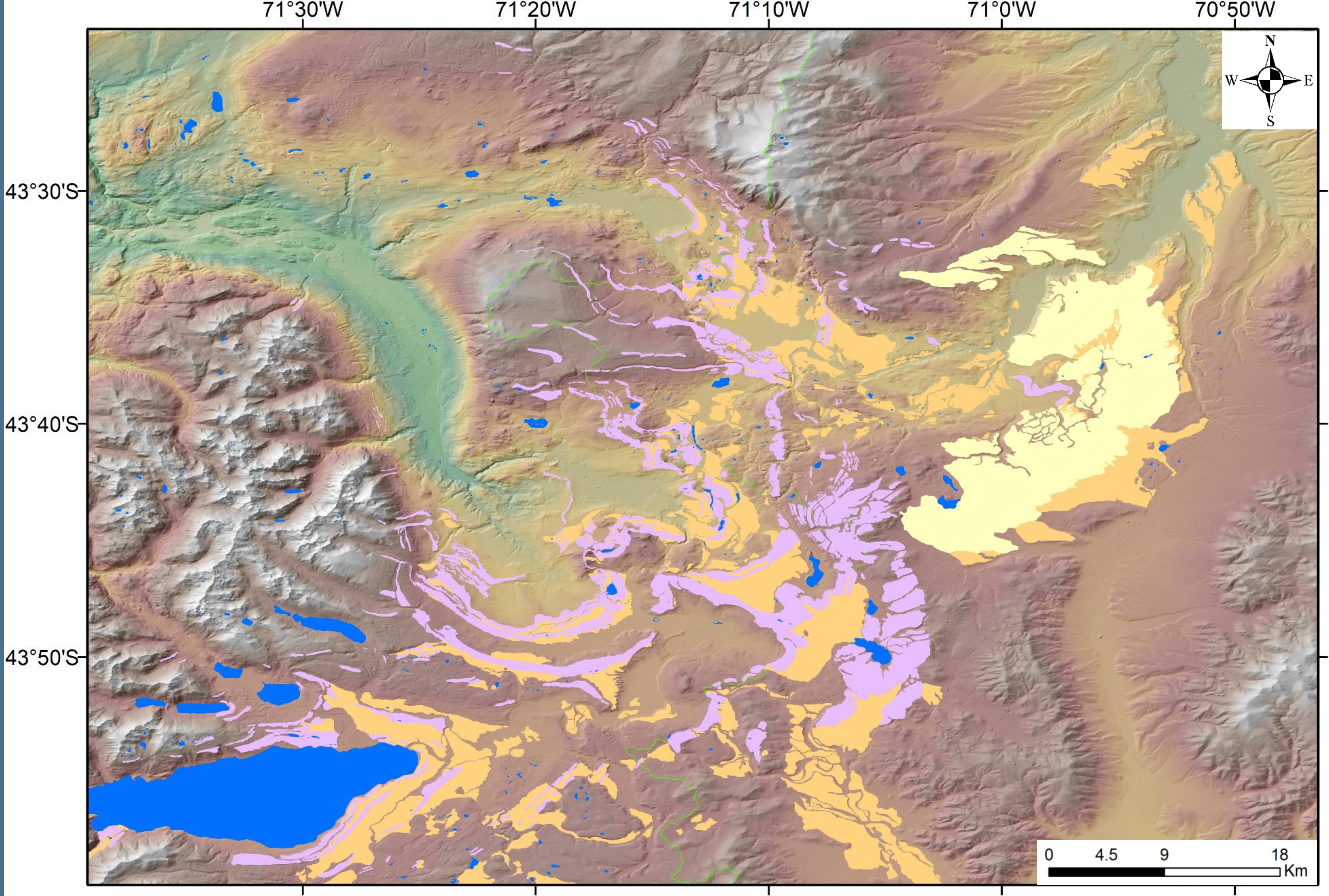
Atlantic/Pacific drainage divide

Moraine complexes

Kettle-kame topography

Proglacial outwash plains

Lakes / water bodies



❖ Mapping

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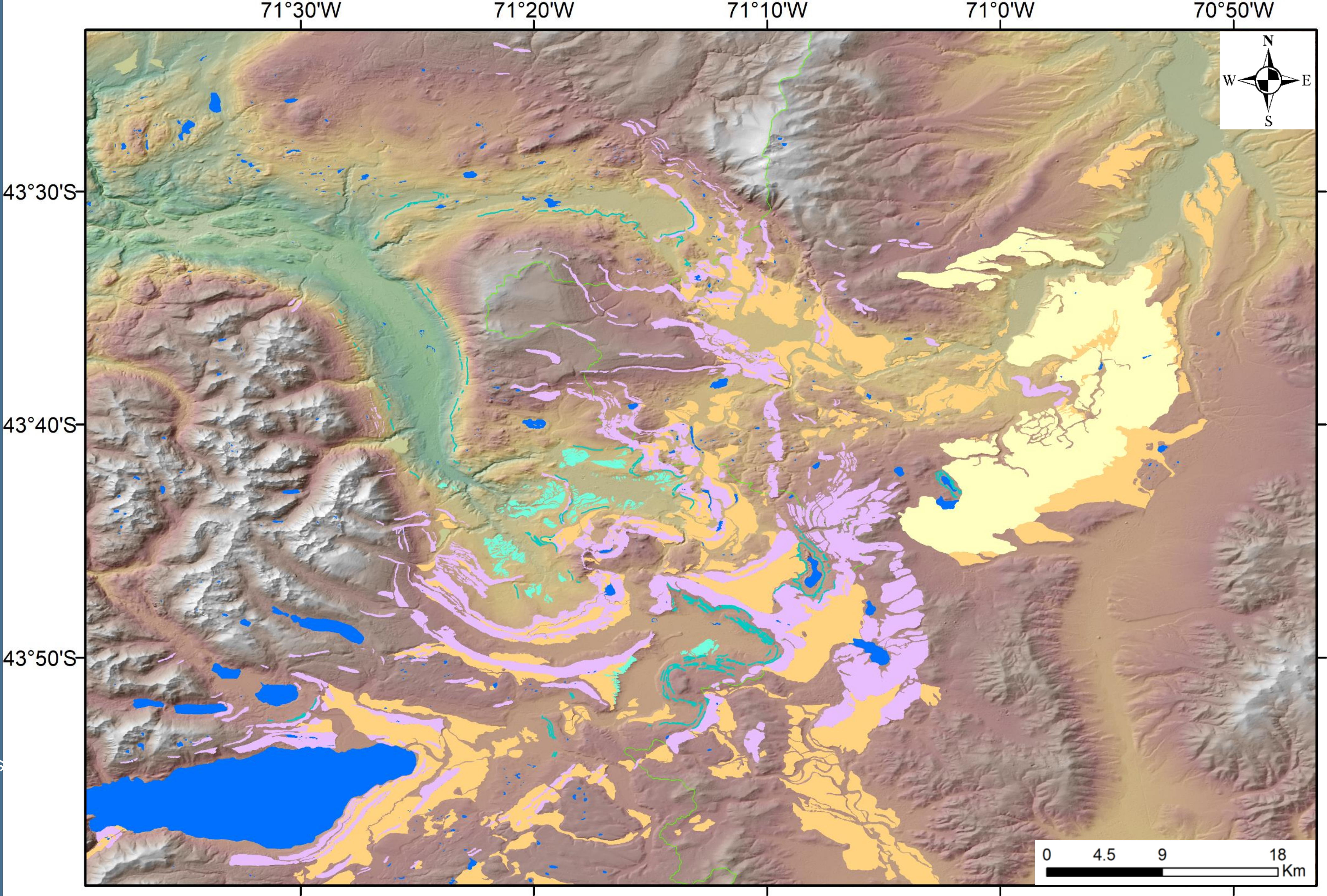
Palaeo-shorelines

Glaciolacustrine sediment exposures



❖ Mapping

- Imagery:
(digital globe)

- DEM:
(Alos World 3d 30m)

Atlantic/Pacific drainage divide

Moraine complexes

Kettle-kame topography

Proglacial outwash plains

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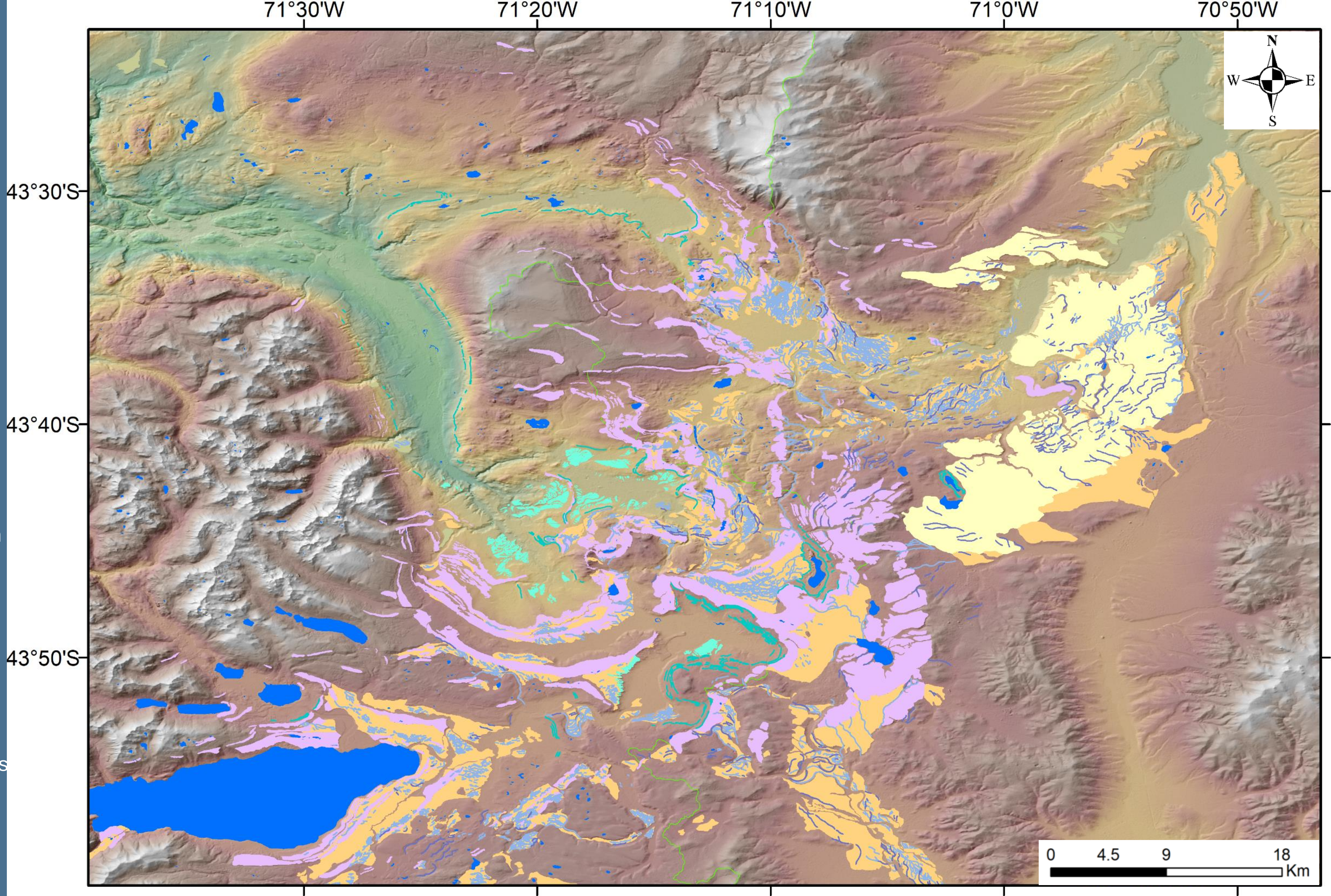
Glaciolacustrine sediment exposures

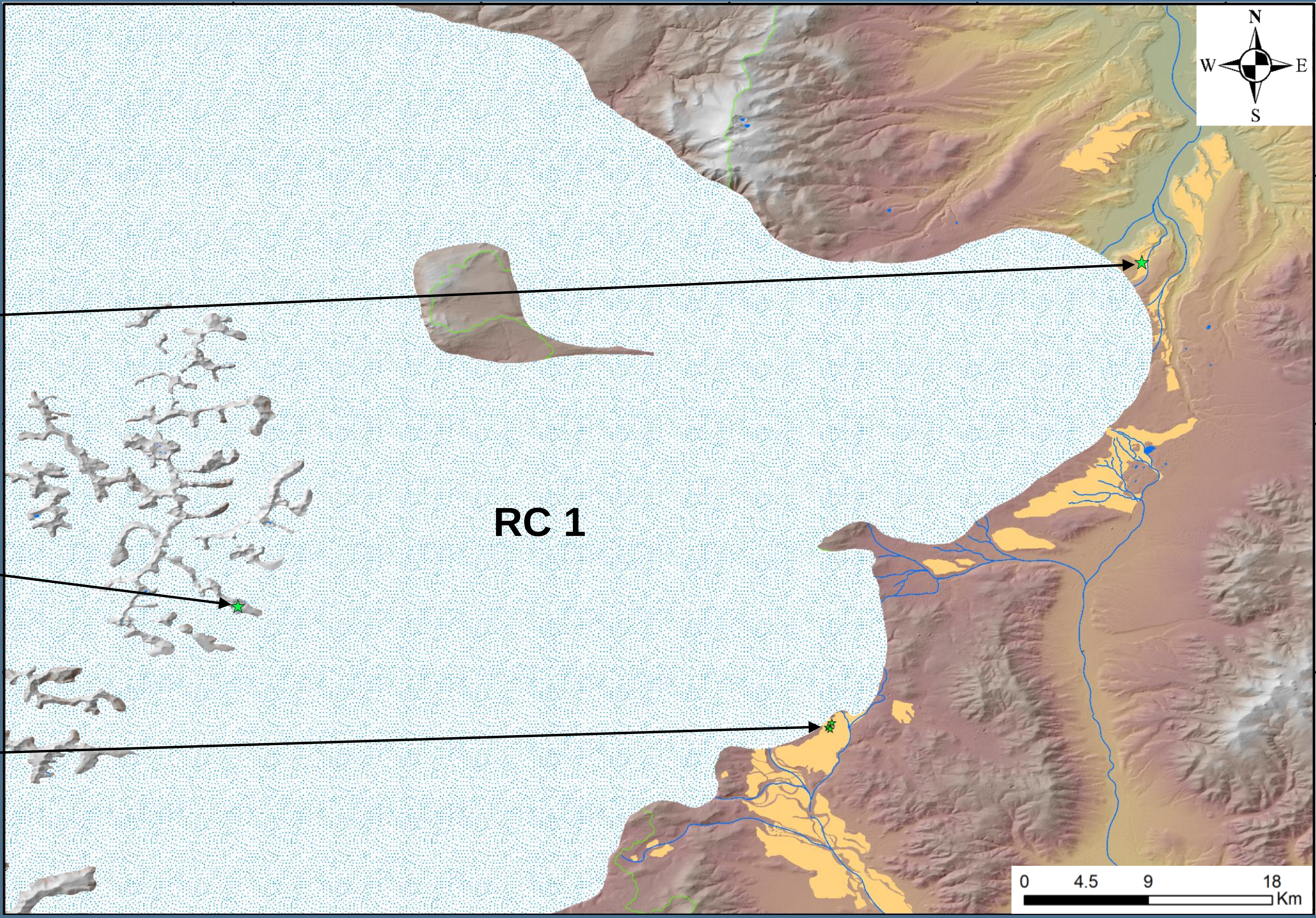
Meltwater channels >30 m width (top) <30 m (bottom)



❖ Geochronology

- 10Be surface exposure dating
- Sample Lithologies: Granite, Quartzite

RHS09 RHS10 RHS12 RHS13 RHS15	**RC1 advance**	Awaiting ages (COVID delay) 5 surface outwash cobbles
RCS58 RCS68 RCS69	**RC1 advance**	Awaiting ages (COVID delay) 3 mountain-ridge boulders
RC20-12 RC20-13 RC20-14 RC20-15 RC20-16 RC20-17	**RC1 advance**	Funding requested 6 surface outwash cobbles



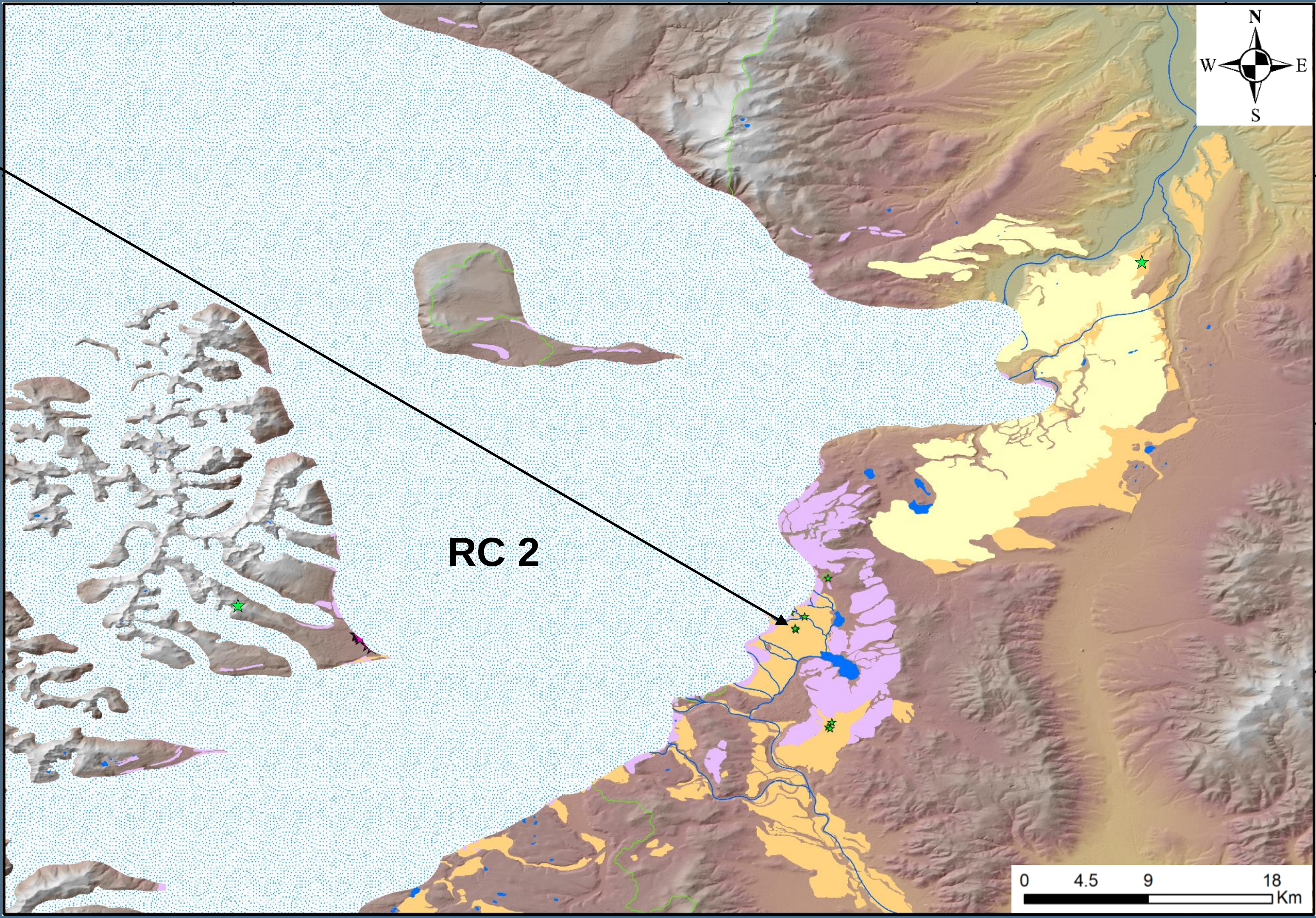
Note: apart from confidently mapped moraine limits, glacier model limits and elevations are inferred

- Estimated age: MIS 6-8 ?

❖ Geochronology

RC20-02	RC20-03	**RC2 advance/Still-stand**
RC20-04	RC20-05	
RC20-10	RC20-11	Funding requested
RC20-06	RC20-07	
RC20-19	RC20-20	6 moraine boulders
RC20-21	RC20-22	+6 surface outwash cobbles
RC20-01		+1 surface bedrock sample

- Estimated age: MIS 3/4 ?



Note: apart from confidently mapped moraine limits, glacier model limits and elevations are inferred

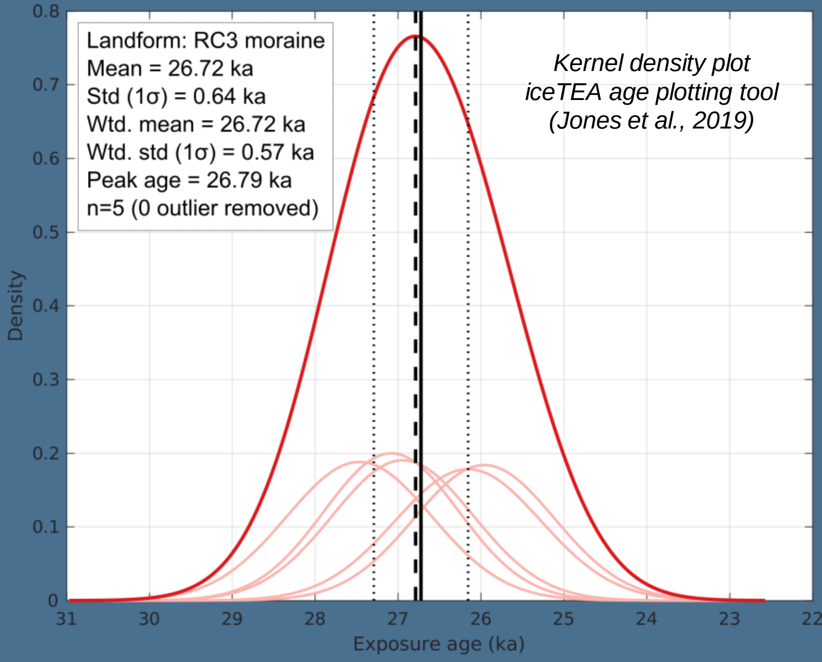
❖ Geochronology

RCS21: 26.2 ± 0.9 (2.3)
RCS23: 26.9 ± 0.8 (2.4)
RCS25: 27.1 ± 0.8 (2.4)
RCS27: 25.9 ± 0.9 (2.3)
RCS28: 27.5 ± 0.9 (2.4)
RCS24: ? (awaiting)

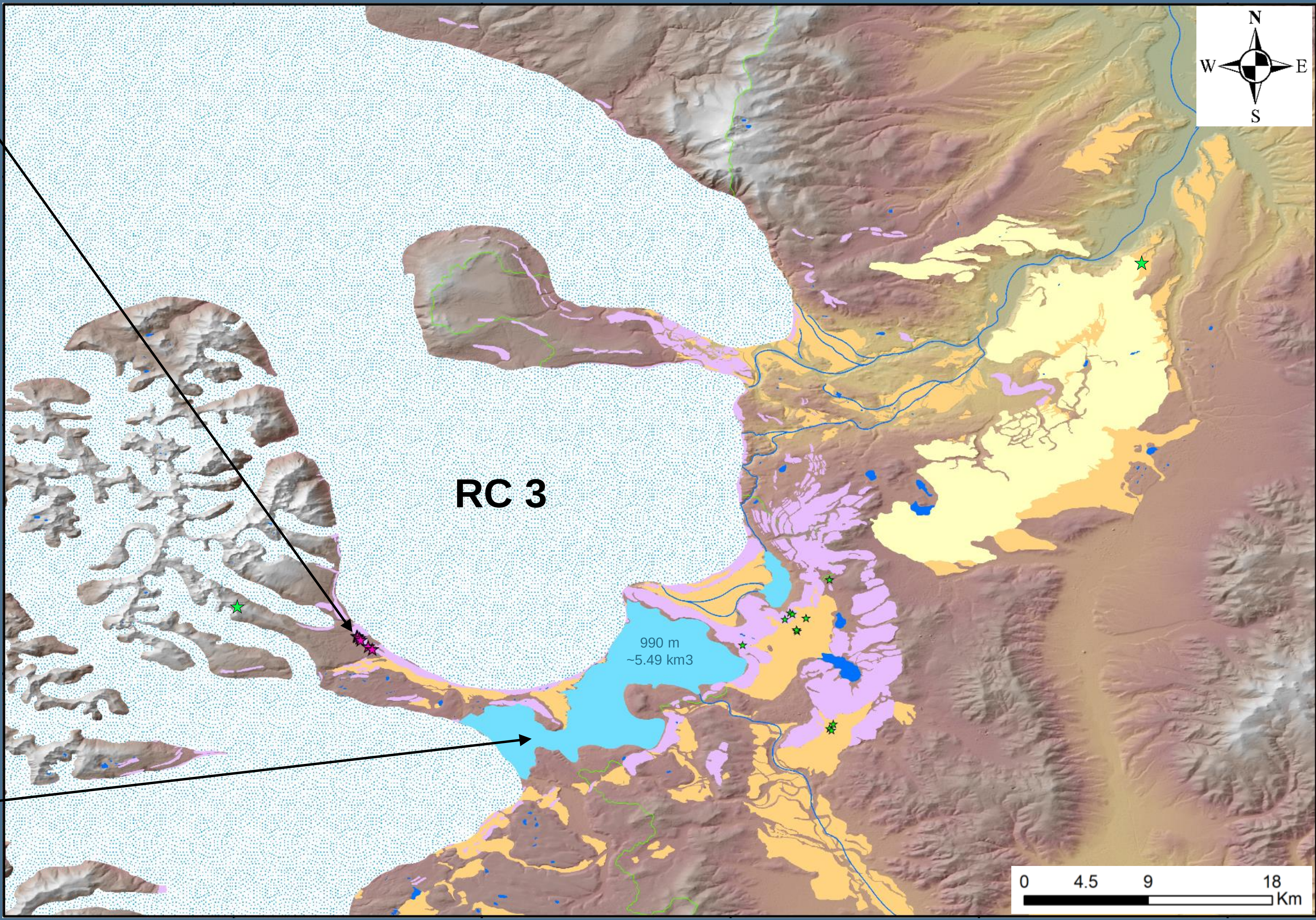
RC3 advance/Still-stand

26.7 ± 0.64 (2.2) ka

6 moraine boulders



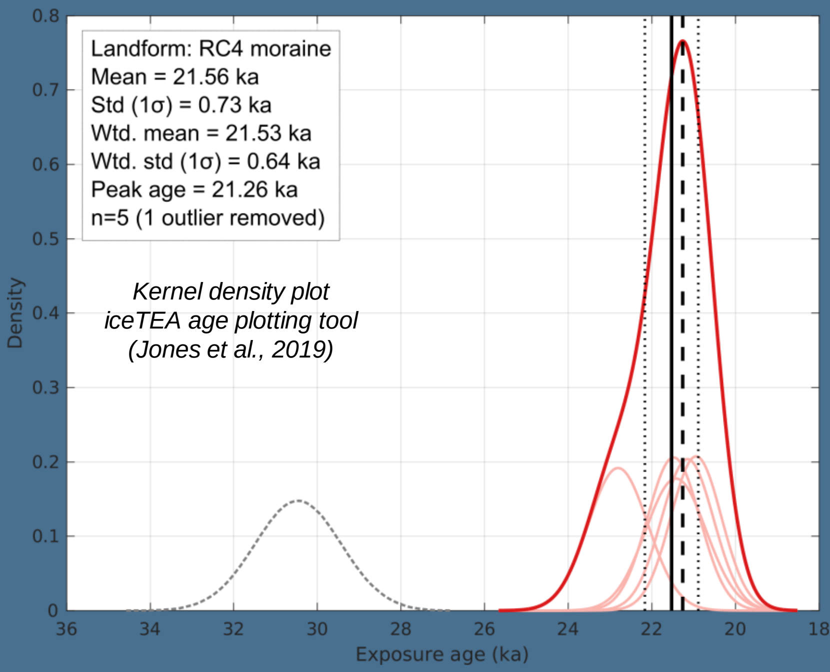
- 1st lake phase:
  - Lake level: 990 m asl
  - Lake volume: ~5.49 km3
  - Formed at around 26.8 ka?

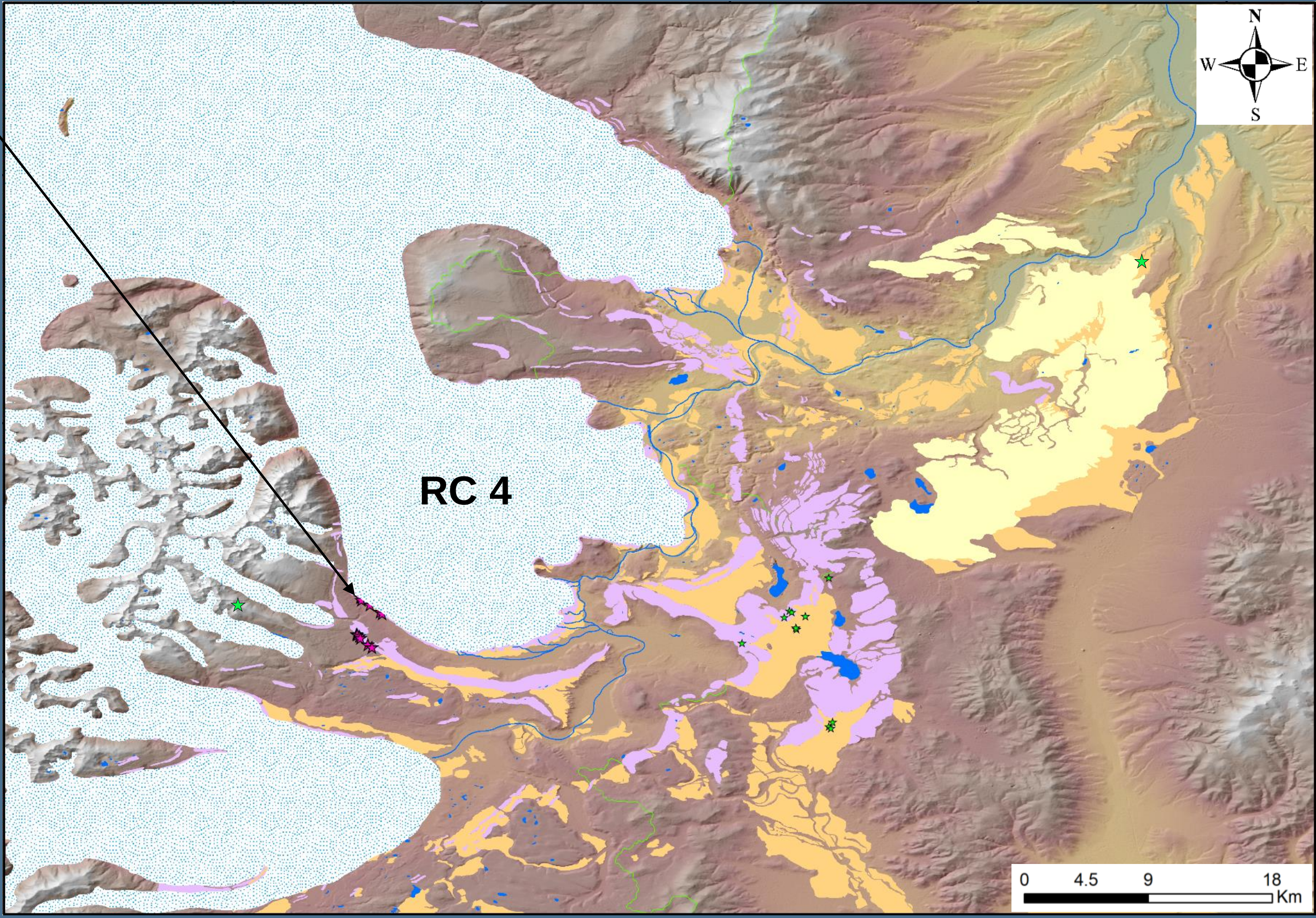


Age calculation: CRONUS-Earth online calculator v3 (Balco et al., 2008). No erosion is assumed, and no correction for vegetation and/or snow shielding is applied
Production rate: Central Patagonia production rate (Kaplan et al., 2011- 50°S) obtained from the ICE-D online database (http://calibration.ice-d.org/).
Scaling model: Lm: time dependent version of Lal (1991) and Stone (2000). Outliers are pruned based solely on stratigraphy: age of adjacent moraines.

❖ Geochronology

~~RCS13: 30.5 ± 1.0 (2.7)~~	**RC4 advance/Still-stand**
RCS15: 20.9 ± 0.6 (1.8)	
RCS16: 21.5 ± 0.6 (1.9)	**21.5 ± 0.73 (1.8) ka**
RCS17: 21.4 ± 0.7 (1.9)	
RCS51: 22.8 ± 0.7 (2.0)	6 moraine boulders
RCS52: 21.1 ± 0.6 (1.8)	





- Time elapsed since RC3: 5 thousand years

Age calculation: CRONUS-Earth online calculator v3 (Balco et al., 2008). No erosion is assumed, and no correction for vegetation and/or snow shielding is applied
Production rate: Central Patagonia production rate (Kaplan et al., 2011- 50°S) obtained from the ICE-D online database (http://calibration.ice-d.org/).
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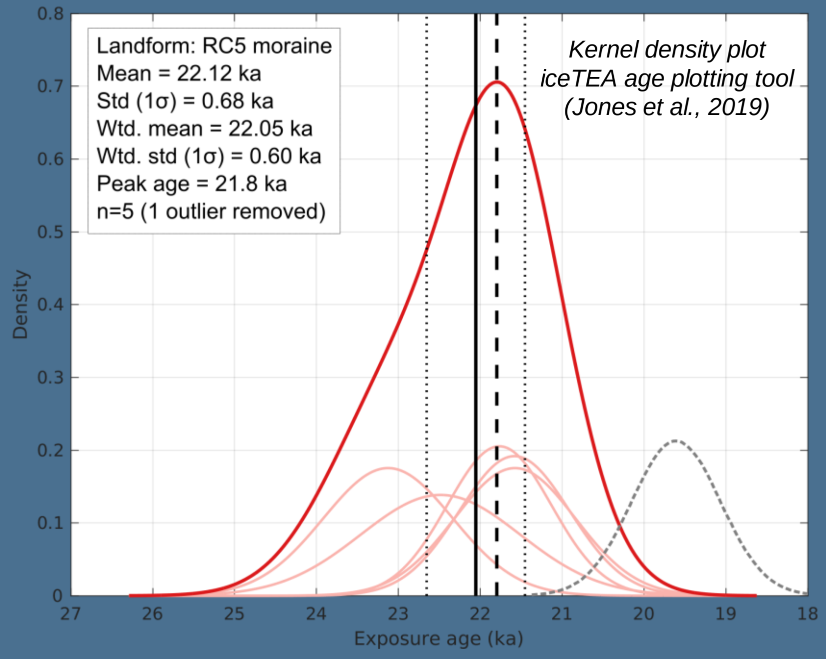
❖ Geochronology

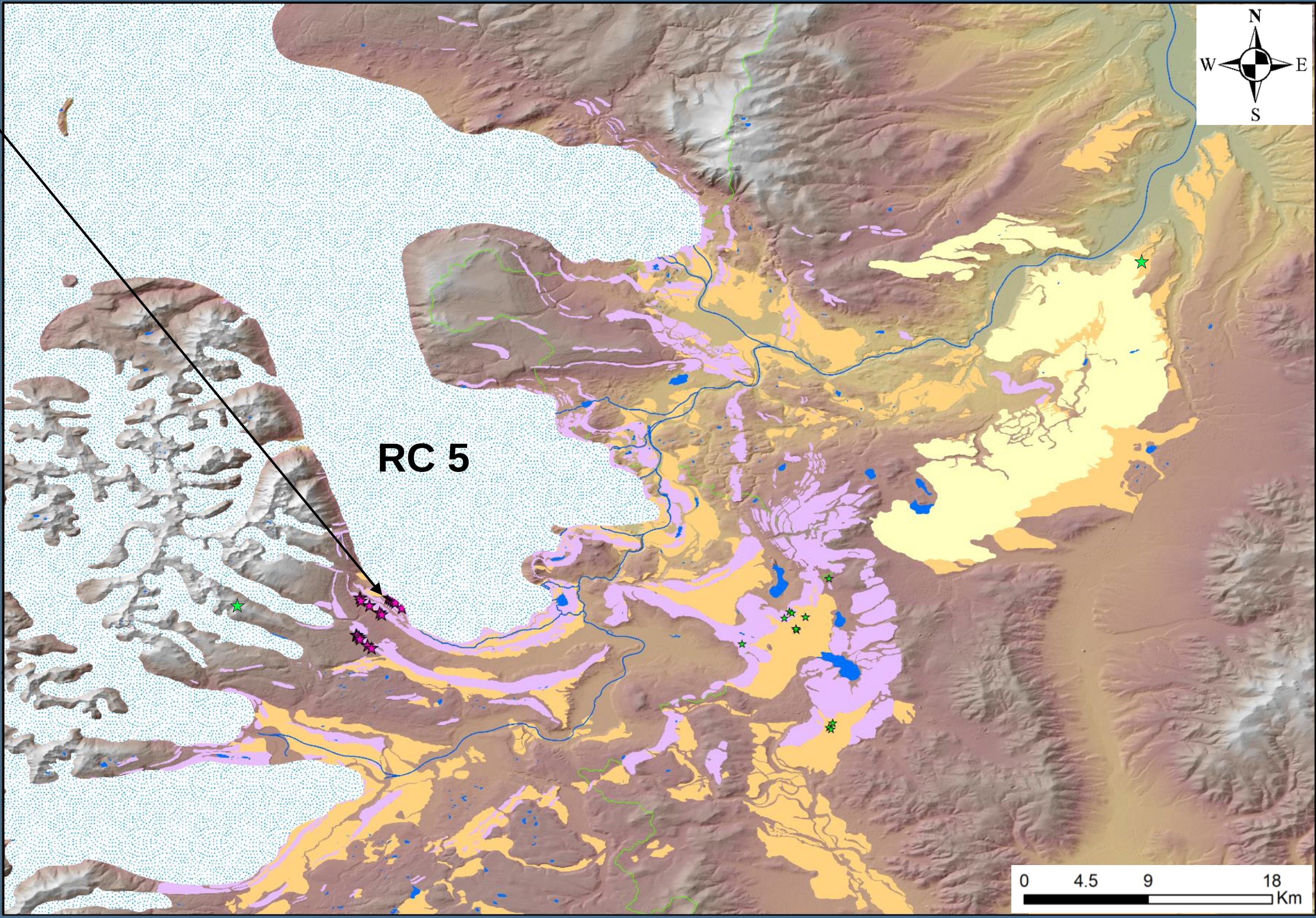
RCS38: 22.5 ± 1.0 (2.1)
RCS40: 21.8 ± 0.6 (1.9)
RCS41: 21.6 ± 0.7 (1.9)
~~RCS42: 19.6 ± 0.6 (1.7)~~
RCS43: 21.6 ± 0.7 (1.9)
RCS44: 23.1 ± 0.8 (2.1)

RC5 advance/Still-stand

22.1 ± 0.68 (1.9) ka

6 moraine boulders





- RC4 & RC5 are time-synchronous within dating uncertainty.

Age calculation: CRONUS-Earth online calculator v3 (Balco et al., 2008). No erosion is assumed, and no correction for vegetation and/or snow shielding is applied
Production rate: Central Patagonia production rate (Kaplan et al., 2011- 50°S) obtained from the ICE-D online database (http://calibration.ice-d.org/).
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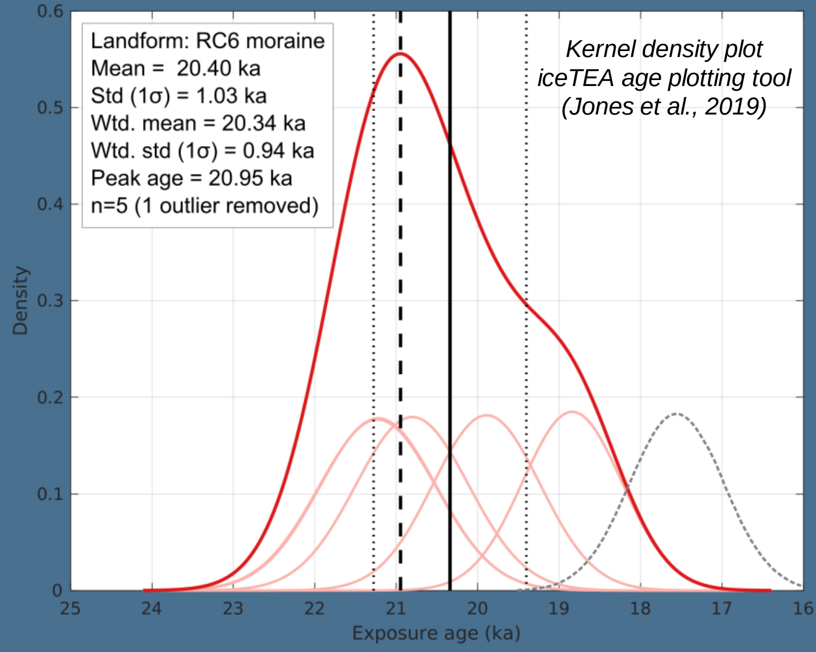
❖ Geochronology

RCS30: 20.8 ± 0.7 (1.8)
RCS31: 18.8 ± 0.6 (1.7)
~~RCS32: 17.5 ± 0.6 (1.5)~~
RCS33: 19.9 ± 0.7 (1.8)
RCS34: 21.2 ± 0.7 (1.9)
RCS36: 21.2 ± 0.7 (1.9)

RC6 advance/Still-stand

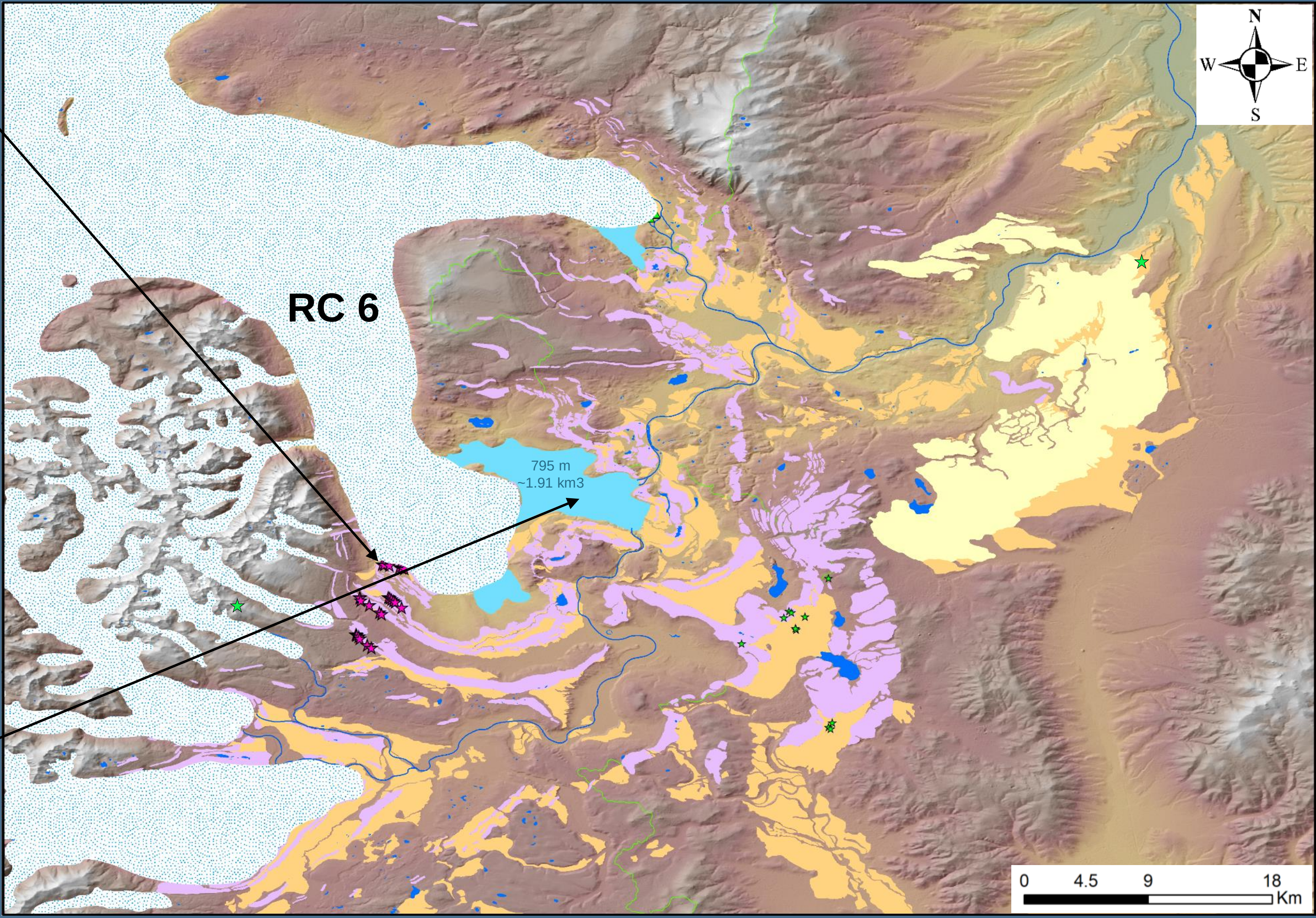
20.4 ± 1.03 (1.7) ka

6 moraine boulders



- 2nd lake phase:

- Lake level: 795 m asl
- Lake volume: ~1.91 km3
- Formed between ~21.8 & ~20.4 ka



Age calculation: CRONUS-Earth online calculator v3 (Balco et al., 2008). No erosion is assumed, and no correction for vegetation and/or snow shielding is applied
Production rate: Central Patagonia production rate (Kaplan et al., 2011- 50°S) obtained from the ICE-D online database (http://calibration.ice-d.org/).
Scaling model: Lm: time dependent version of Lal (1991) and Stone (2000). Outliers are pruned based solely on stratigraphy: age of adjacent moraines.

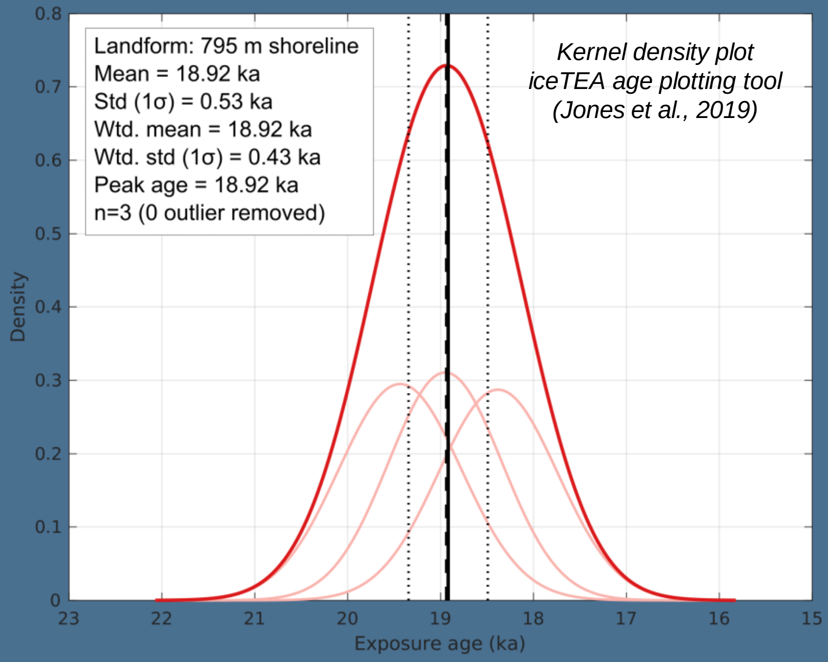
❖ Geochronology

RHS02: 18.4 ± 0.6 (1.6)
RHS03: 18.9 ± 0.6 (1.7)
RHS04: 19.4 ± 0.7 (1.7)

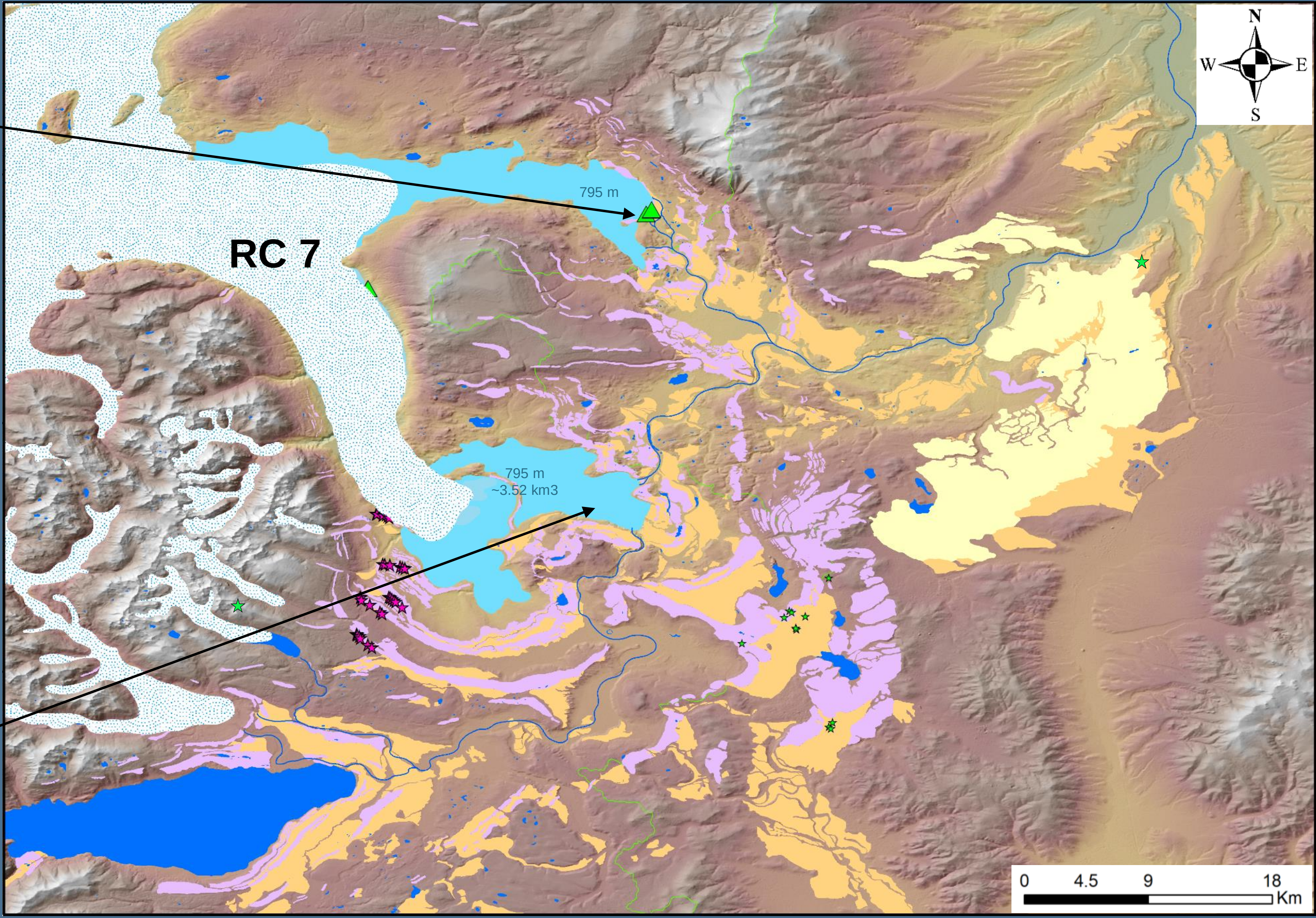
795 m palaeoshoreline

18.9 ± 0.4 (1.6) ka

3 surface cobbles



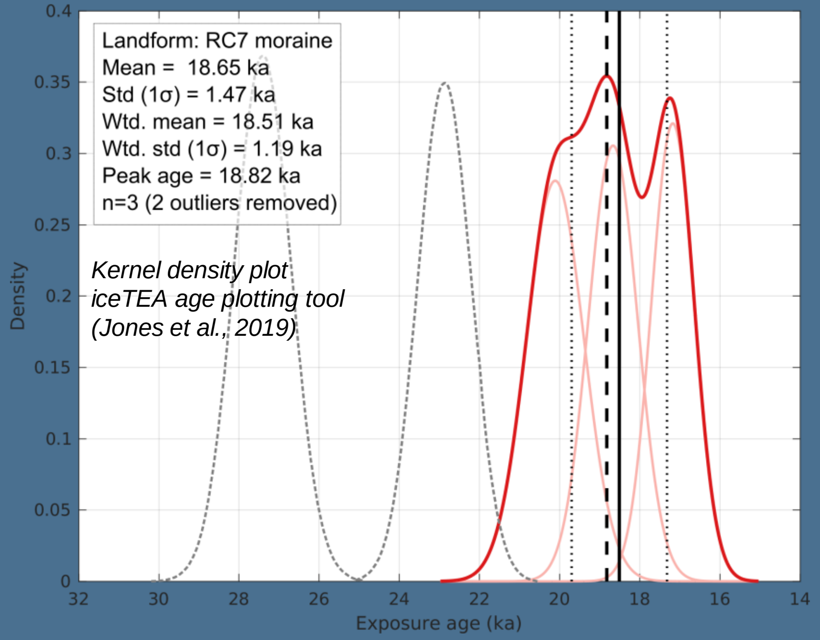
- 2nd Lake phase:
  - Lake level: 795 m asl
  - Lake volume: ~3.52 km3

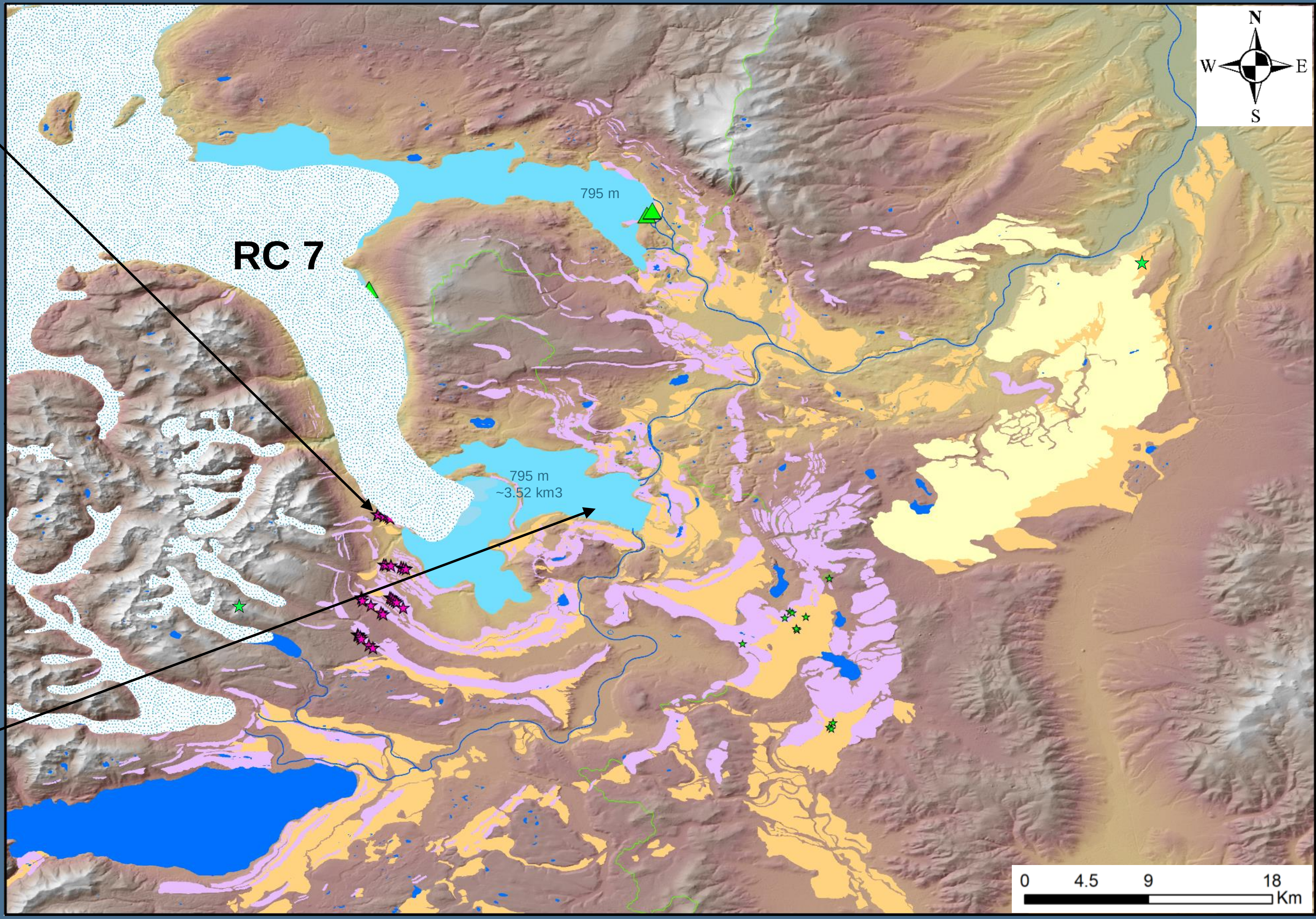


Age calculation: CRONUS-Earth online calculator v3 (Balco et al., 2008). No erosion is assumed, and no correction for vegetation and/or snow shielding is applied
Production rate: Central Patagonia production rate (Kaplan et al., 2011- 50°S) obtained from the ICE-D online database (http://calibration.ice-d.org/).
Scaling model: Lm: time dependent version of Lal (1991) and Stone (2000). Outliers are pruned based solely on stratigraphy: age of adjacent moraines.

❖ Geochronology

RCS07: 17.2 ± 0.5 (1.5)	**RC7 advance/Still-stand**
RCS08: 20.1 ± 0.7 (1.8)	
~~RCS09: 27.4 ± 0.7 (2.4~~)	**18.6 ± 1.19 (2.1) ka**
RCS11: 18.7 ± 0.6 (1.7)	
~~RCS12: 22.9 ± 0.7 (2.0)~~	6 moraine boulders
RC20-29: (awaiting)	





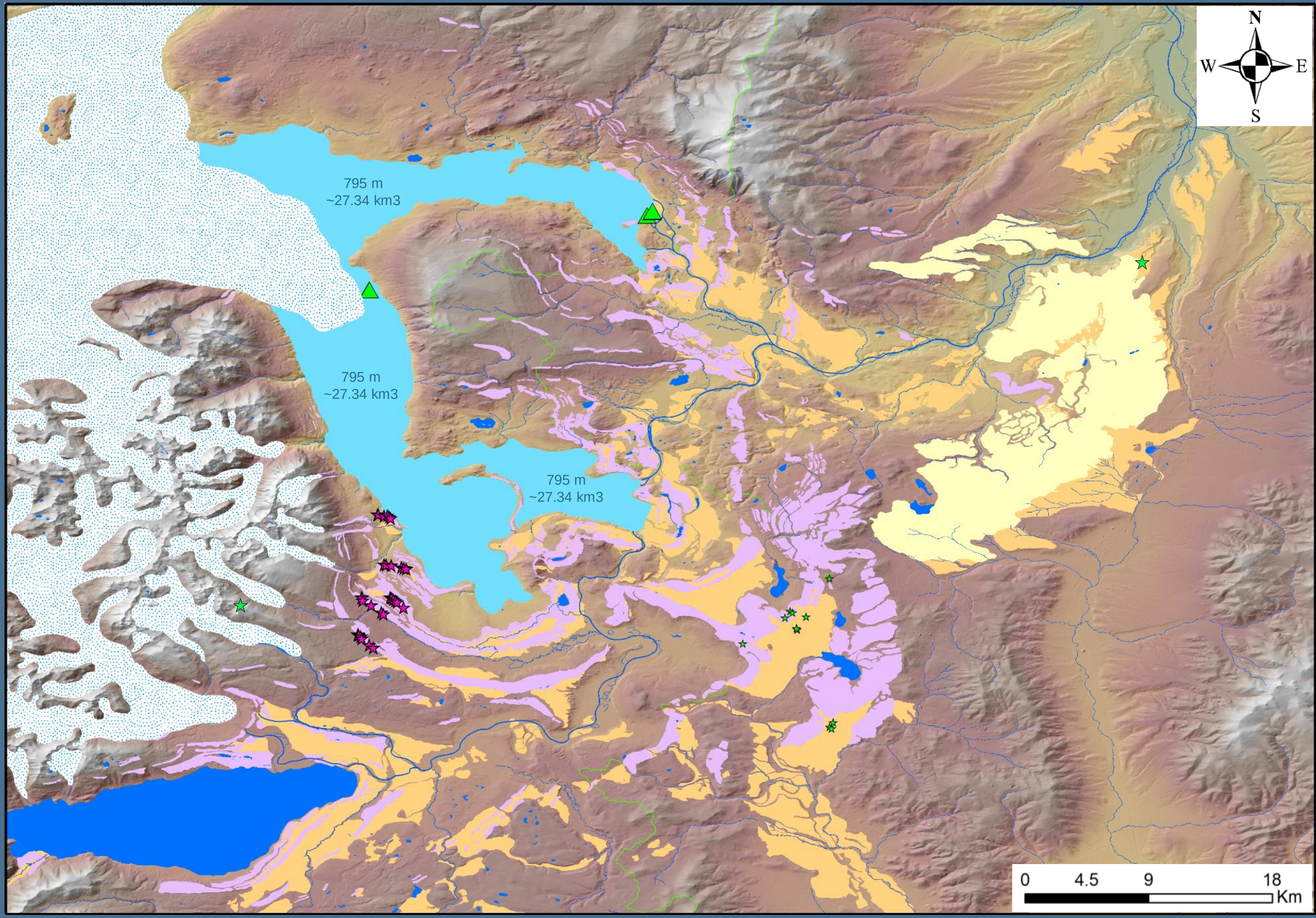
- 2nd Lake phase:
  - Lake level: 795 m asl
  - Lake volume: ~3.52 km3

Age calculation: CRONUS-Earth online calculator v3 (Balco et al., 2008)
Production rate: Central Patagonia production rate (Kaplan et al., 2011- 50°S) obtained from the ICE-D online database (http://calibration.ice-d.org/).
Scaling model: Lm: time dependent version of Lal (1991) and Stone (2000)

❖ Geochronology

- ~18.6 ka marks the potential onset of local deglaciation: and the progressive retreat of RC glacier's calving front

- 2nd Lake phase:
  - Lake level: 795 m asl
  - Lake volume: ~27.34 km3

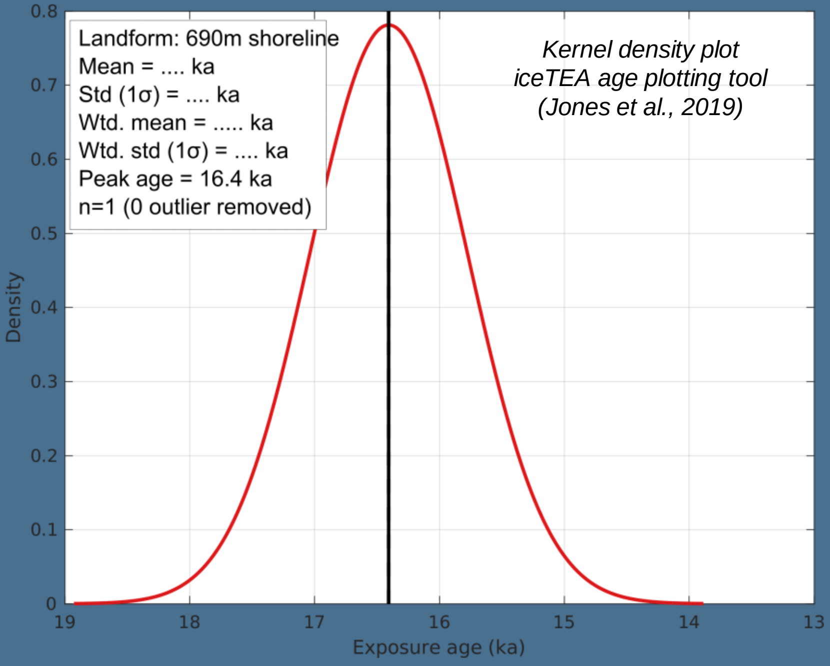


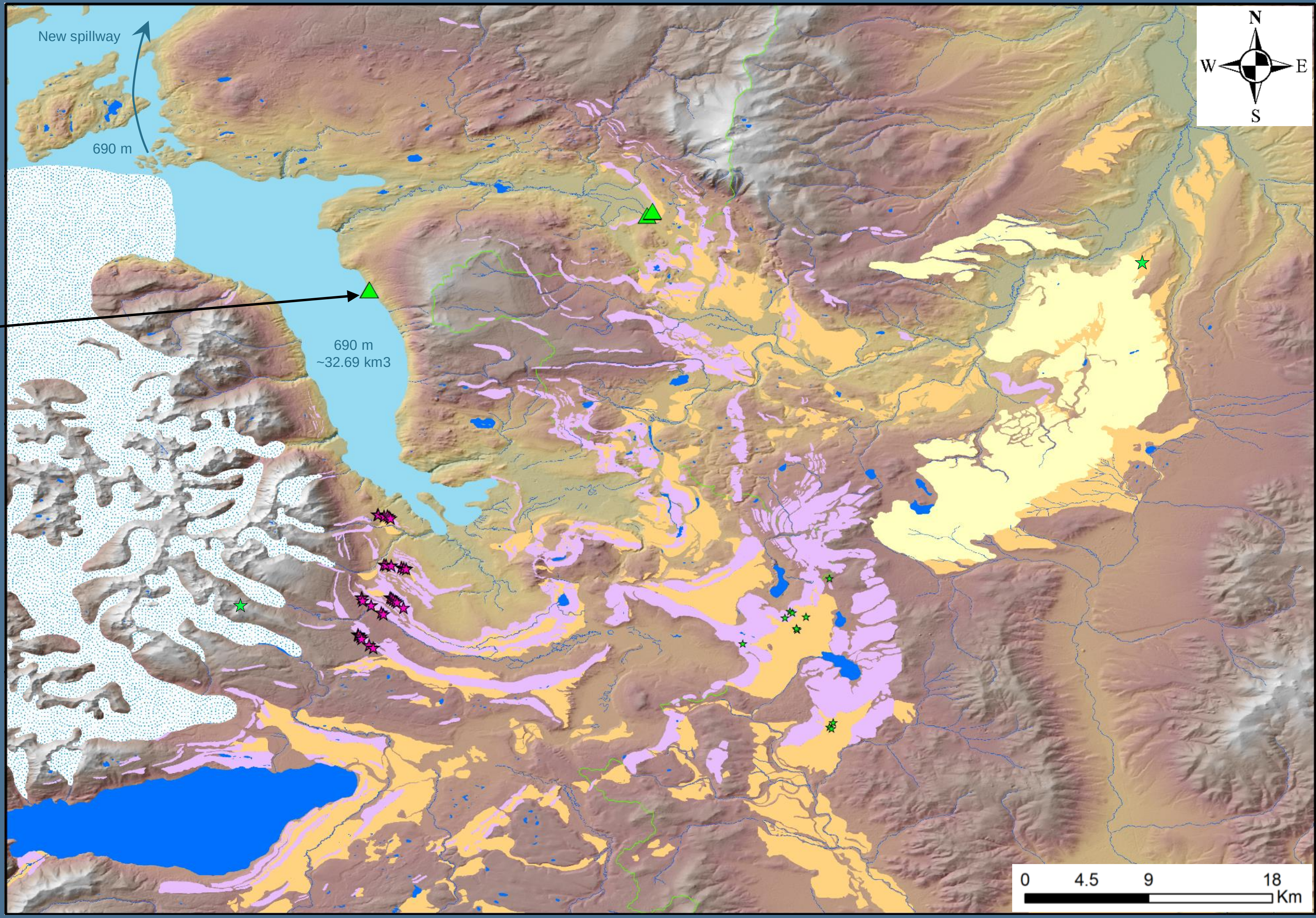
❖ Geochronology

- Further retreat causes northern valley (Río Frío) ice-dam to be breached: proglacial lake lowers by ~100 m:
  - 3rd lake phase
  - Lake level: 690 m
  - Lake volume: ~32.69 km3

RCS05: 16.4 ± 0.6 (1.5)
RCS03: ? (awaiting)
RCS04: ? (awaiting)

690 m palaeoshoreline
16.4 ± 0.6 (1.5) ka
3 surface cobbles





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RCS05: 16.4 ± 0.6 (1.5)
RCS03: ? (awaiting)
RCS04: ? (awaiting)

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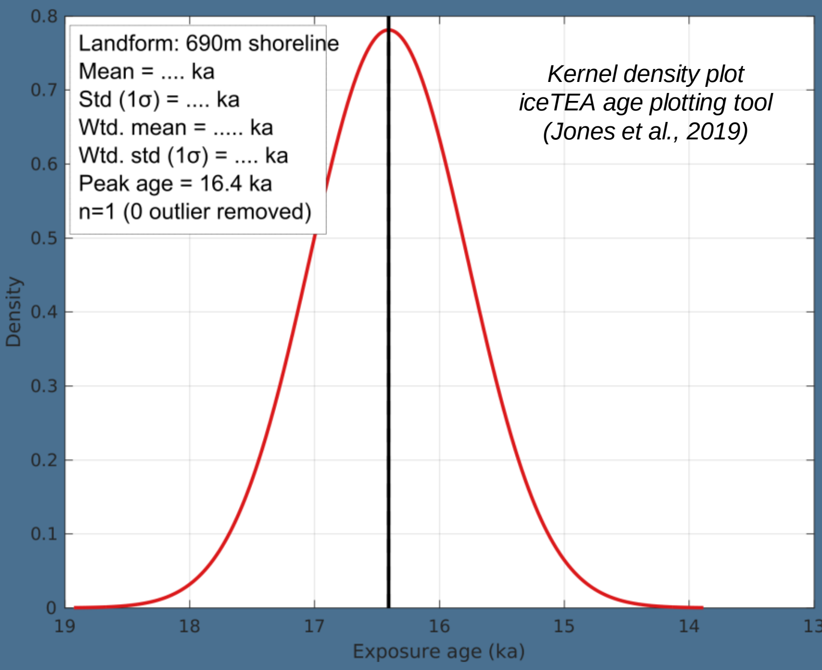
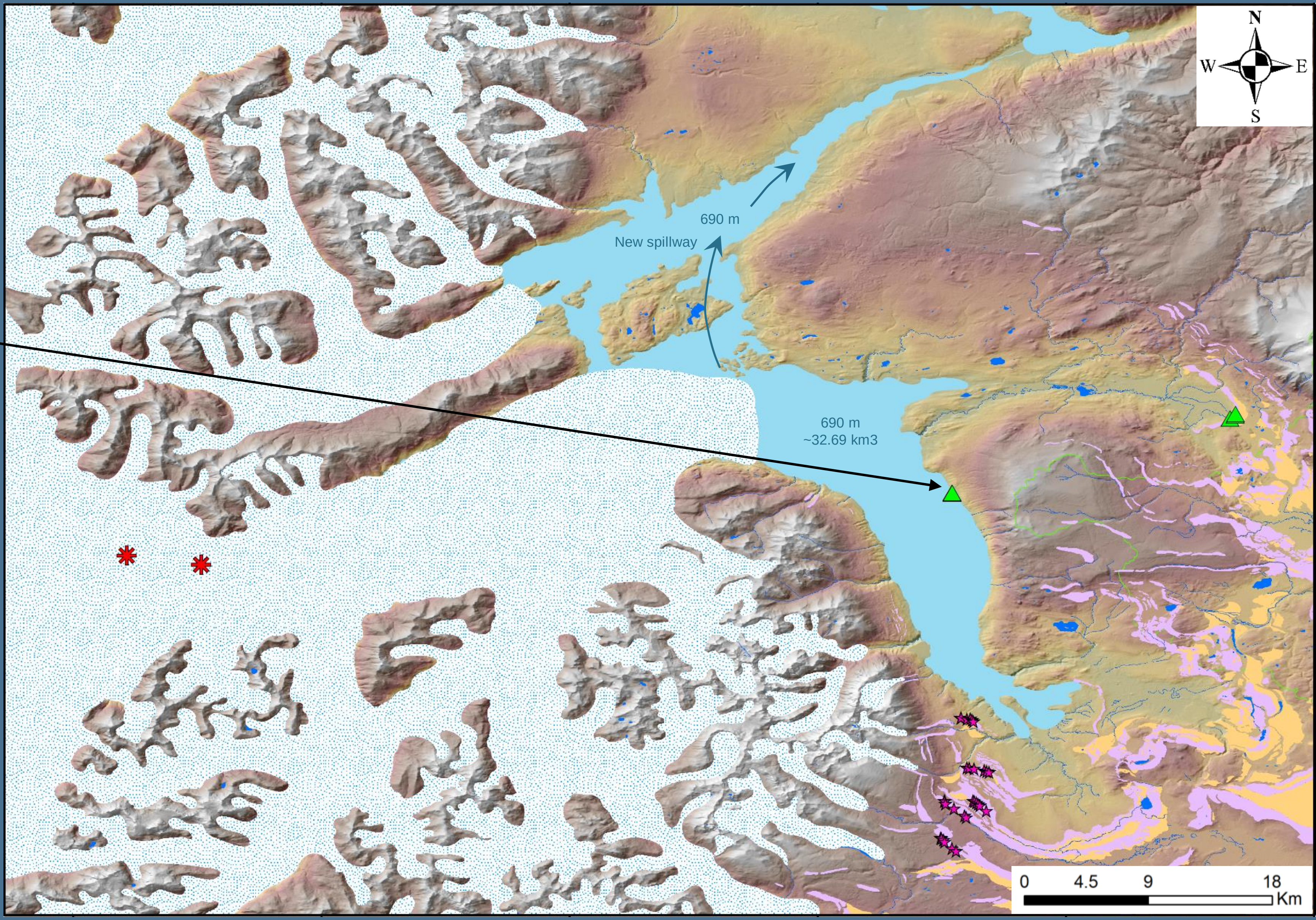
16.4 ± 0.6 (1.5) ka
3 surface cobbles





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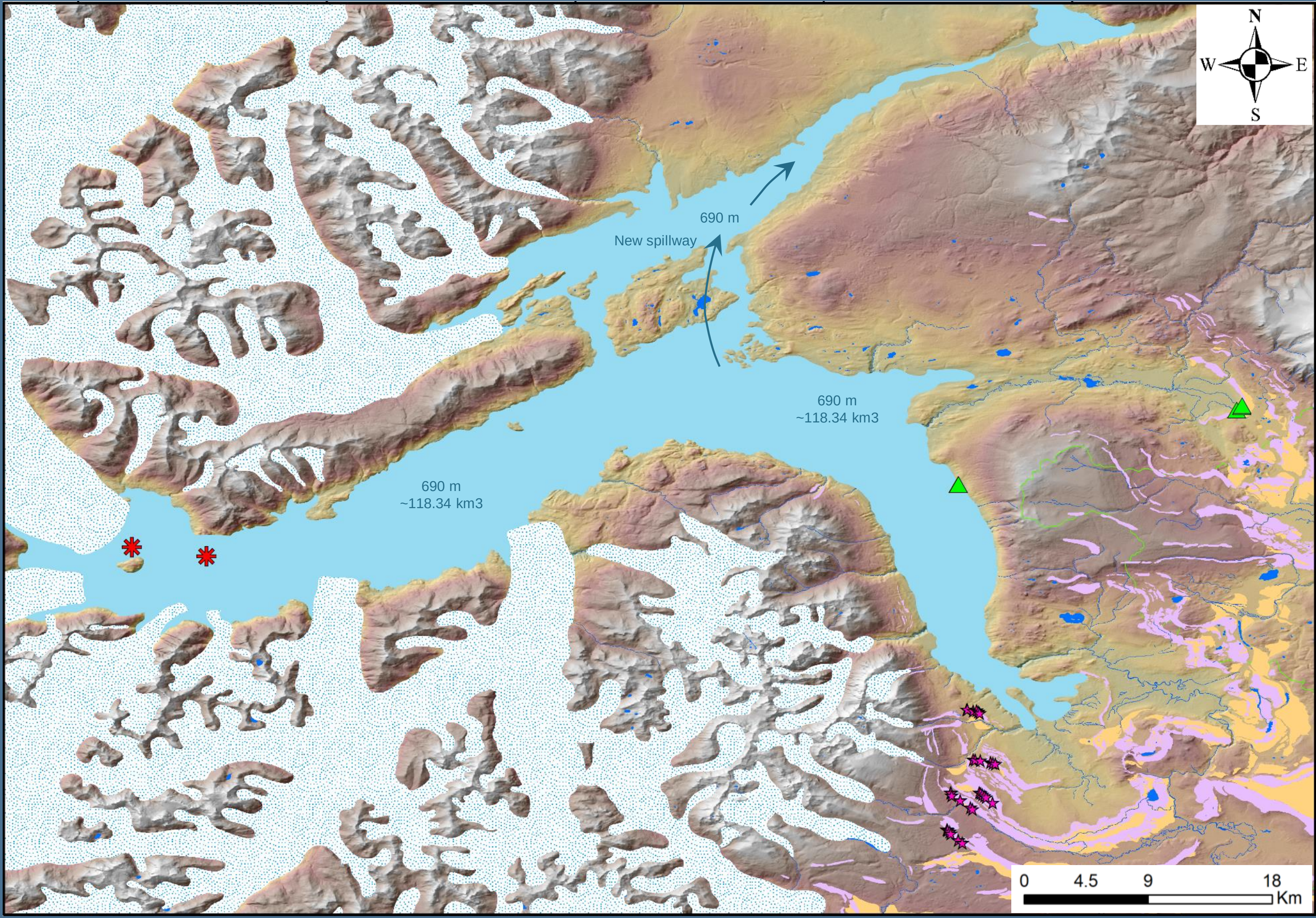
❖ Geochronology

- Further retreat causes northern valley (Río Frío) ice-dam to be breached: proglacial lake lowers by ~100 m:
  - 3rd lake phase
  - Lake level: 690 m
  - Lake volume: ~118.34 km3

- Rapid subsequent retreat of the PIS leads to ice-sheet desintegration

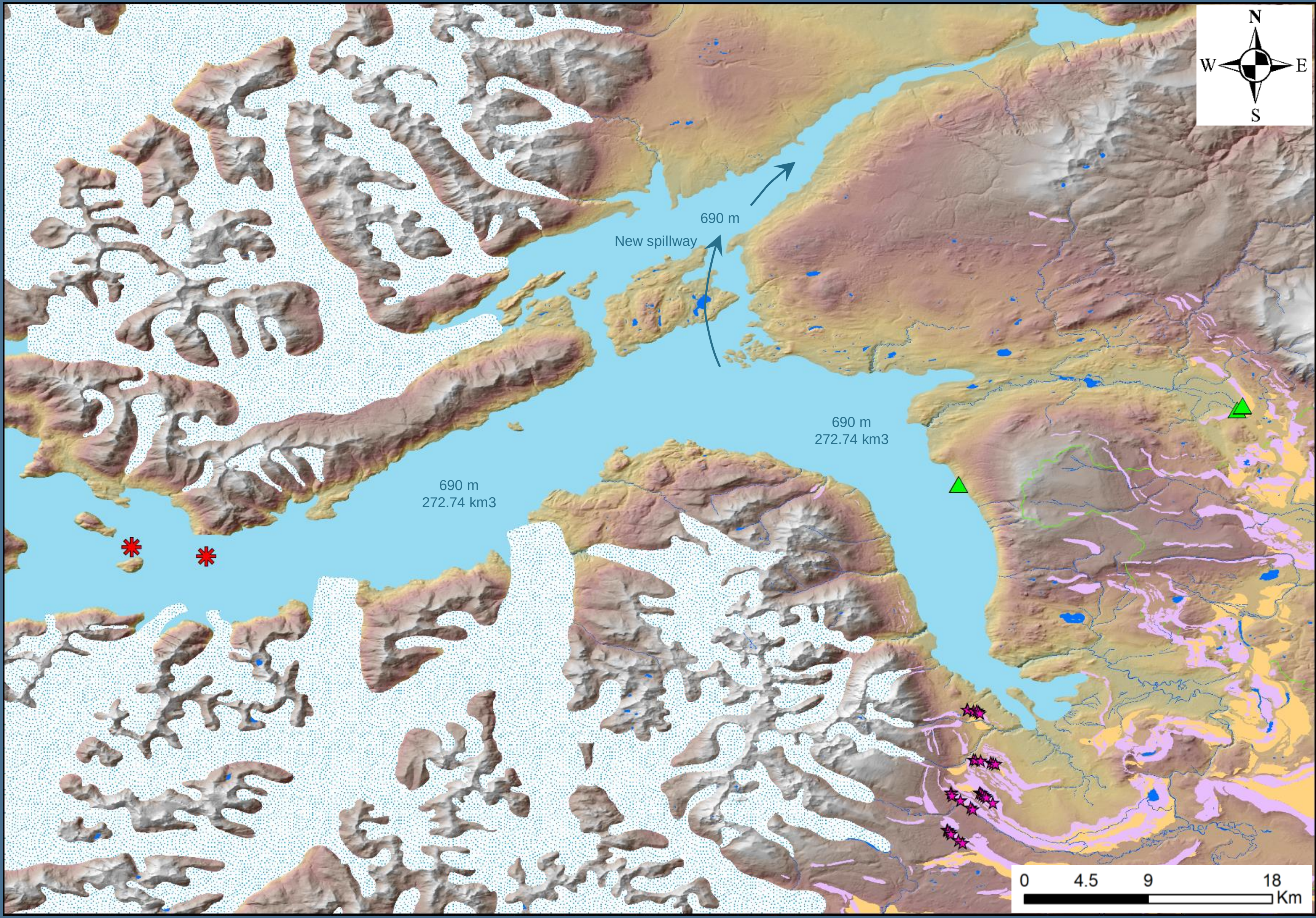


❖ Geochronology

- Further retreat causes northern valley (Río Frío) ice-dam to be breached: proglacial lake lowers by ~100 m:
  - 3rd lake phase
  - Lake level: 690 m
  - Lake volume: ~272.74 km3

- Rapid subsequent retreat of the PIS leads to ice-sheet desintegration

- 690 m proglacial lake expands towards the west



❖ Geochronology

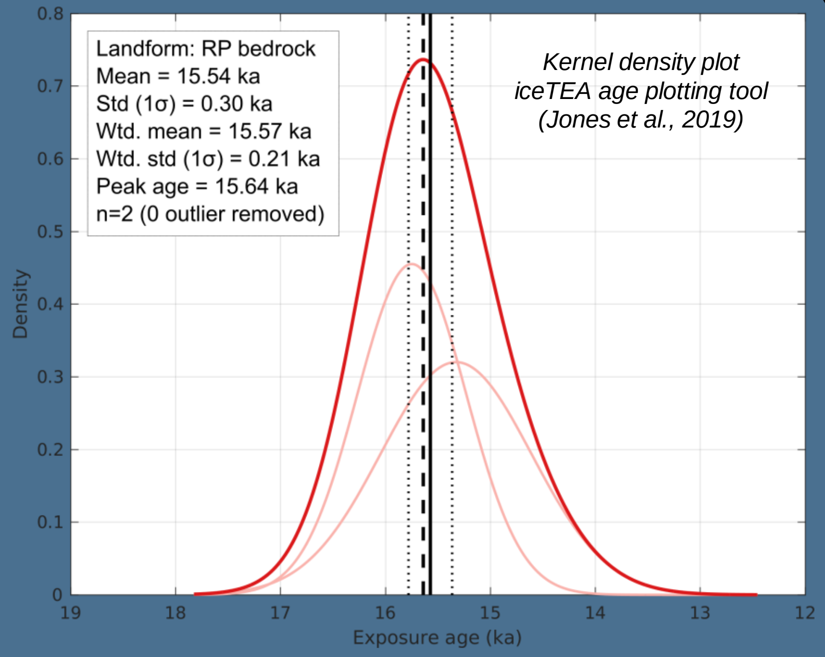
- The PIS ice-dam is breached, proglacial lake drains to the Pacific: Atlantic/Pacific drainage reversal

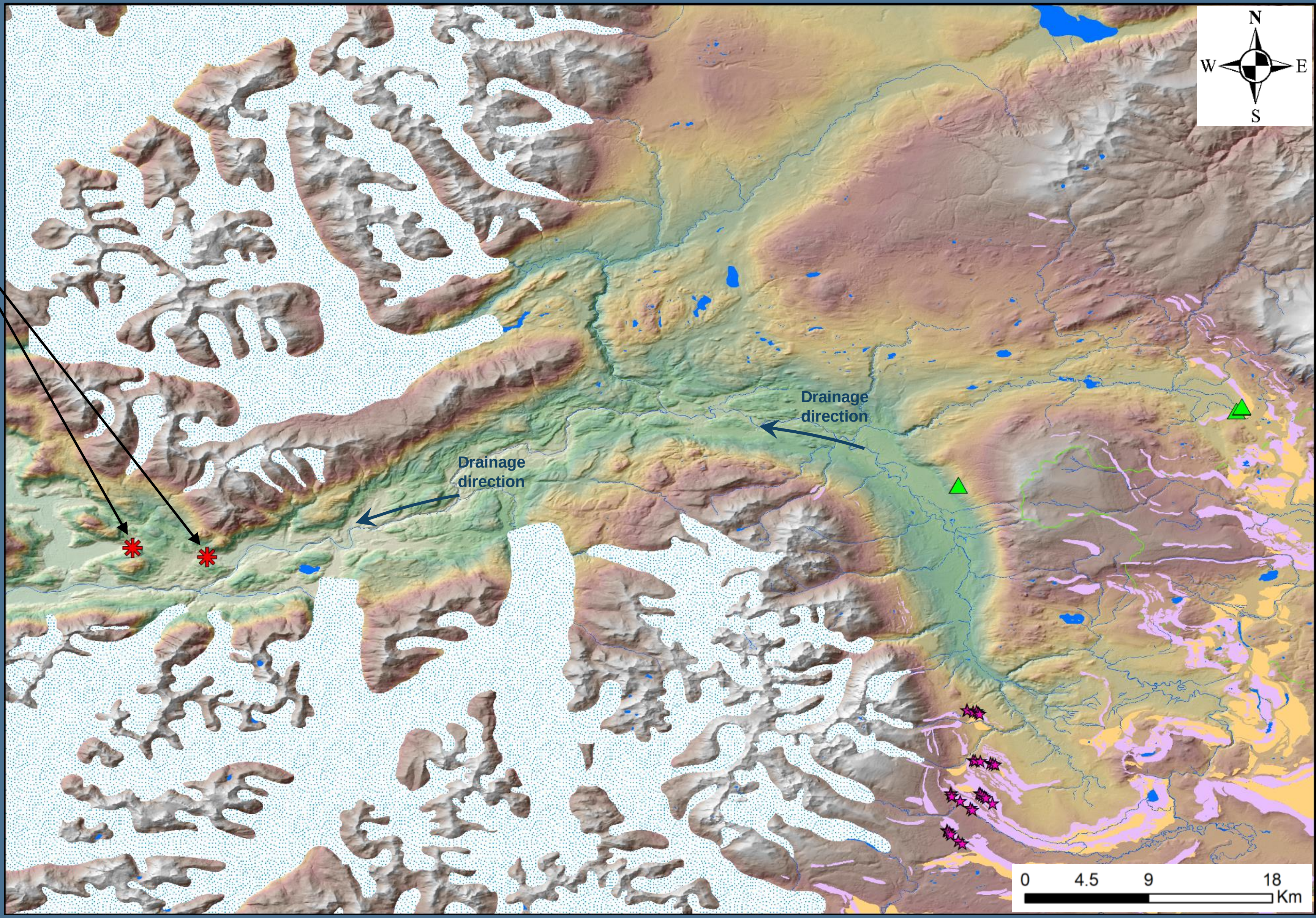
A/P drainage reversal

RPS01: 15.6 ± 0.7 (1.5)
RPS02: 15.9 ± 0.5 (1.4)

15.5 ± 0.3 (1.4) ka

2 surface bedrock samples





- Time elapsed since lake lowering to 690 m: ~6 hundred years

Age calculation: CRONUS-Earth online calculator v3 (Balco et al., 2008). No erosion is assumed, and no correction for vegetation and/or snow shielding is applied
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❖ Conclusion:

1) This work represents the first detailed geomorphological and geochronological reconstruction for this sector of the former Patagonian Ice Sheet (PIS) (43°S; 71°W).

2) Results are preliminary at this stage: and we are awaiting for additional data to discuss our resulting geochronological reconstruction and propose a detailed palaeoclimate reconstruction.

3) However, our data seems to suggest a local LGM occurring during MIS 2, and spanning a full precessional cycle in summer insolation intensity (at 44°S). This is in agreement with glacier reconstructions from the Chilean lake district (Denton *et al*., 1999; Moreno *et al*., 2015, 41-42°S) and New Zealand's Southern Alps (Doughty et al., 2015).

4) However we require more ages from older (RC2 – last glacial cycle?) advances to propose a latitudinal asynchrony in the timing of Patagonian Ice Sheet expansion during the last glacial cycle, as recent studies from central and southern Patagonia have found the local LGM to date to MIS 3 (Darvill et al., 2015: Garcia et al., 2018).

5) Our results also seem to suggest that northeastern PIS outlet glaciers expanded into LGM limits until around ~18.5 ka, after which T1 was initiated; thus at the time of, and possibly in response to; Heinrich Stadial 1. Outlet glaciers seemed to remain fairly close to their LGM limits until ~16.5 ka, after which retreat acceleration and rapid PIS disintegration took place, leading to interglacial conditions and the drainage of a large proglacial lake system into the Pacific by ~15,8 ka. This pattern of deglaciation agrees with high-resolution varve chronologies from central Patagonia (Bendle et al 2019)

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