Geomorphological and sedimentary archives of deglaciation and Holocene climate in James Ross Archipelago

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Supervisor: doc. Mgr.
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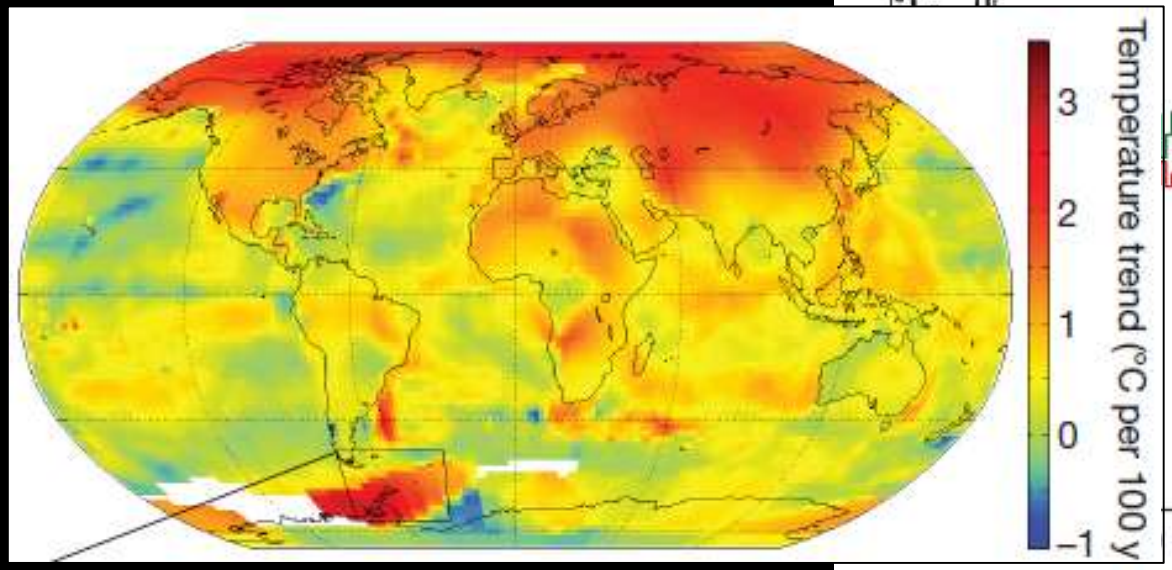
Geography seminar,
Brno, 17 April 2019

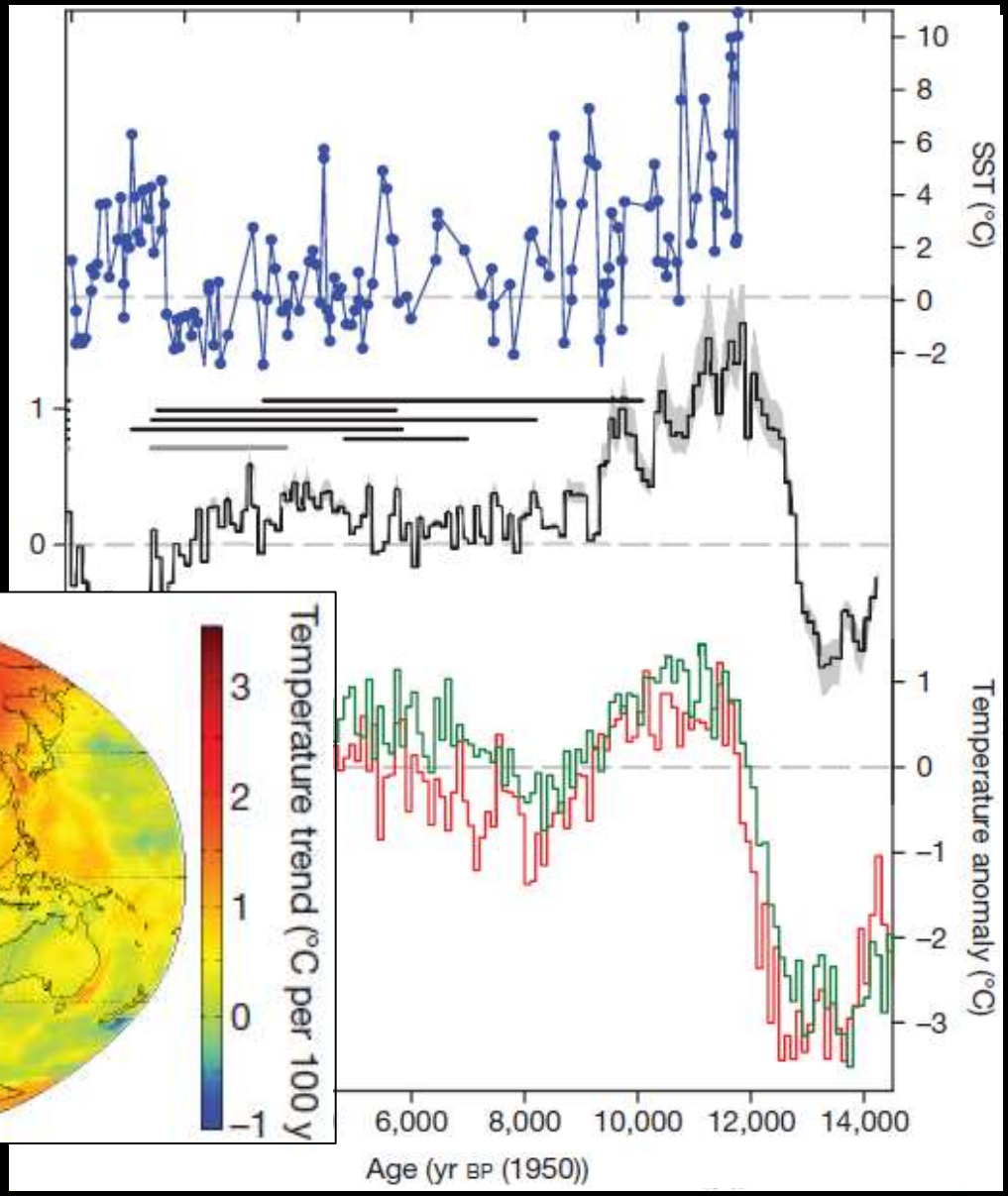
PhD research project:

Pattern and timing of the last deglaciation in the James Ross Archipelago as a response to palaeoclimatic evolution of the Antarctic Peninsula

- Framework question: How did Antarctic Peninsula Ice Sheet (APIS) react to post-LGM and Holocene climatic changes?
- Contribution to sea level rise of 3 m since LGM (APIS alone)
- Ice cores, lacustrine and marine sediments record palaeoclimate around AP
- Rapid warming since AD 1950 in AP region (temporarily halted in the last 15 years, e.g. Oliva et al. 2017)

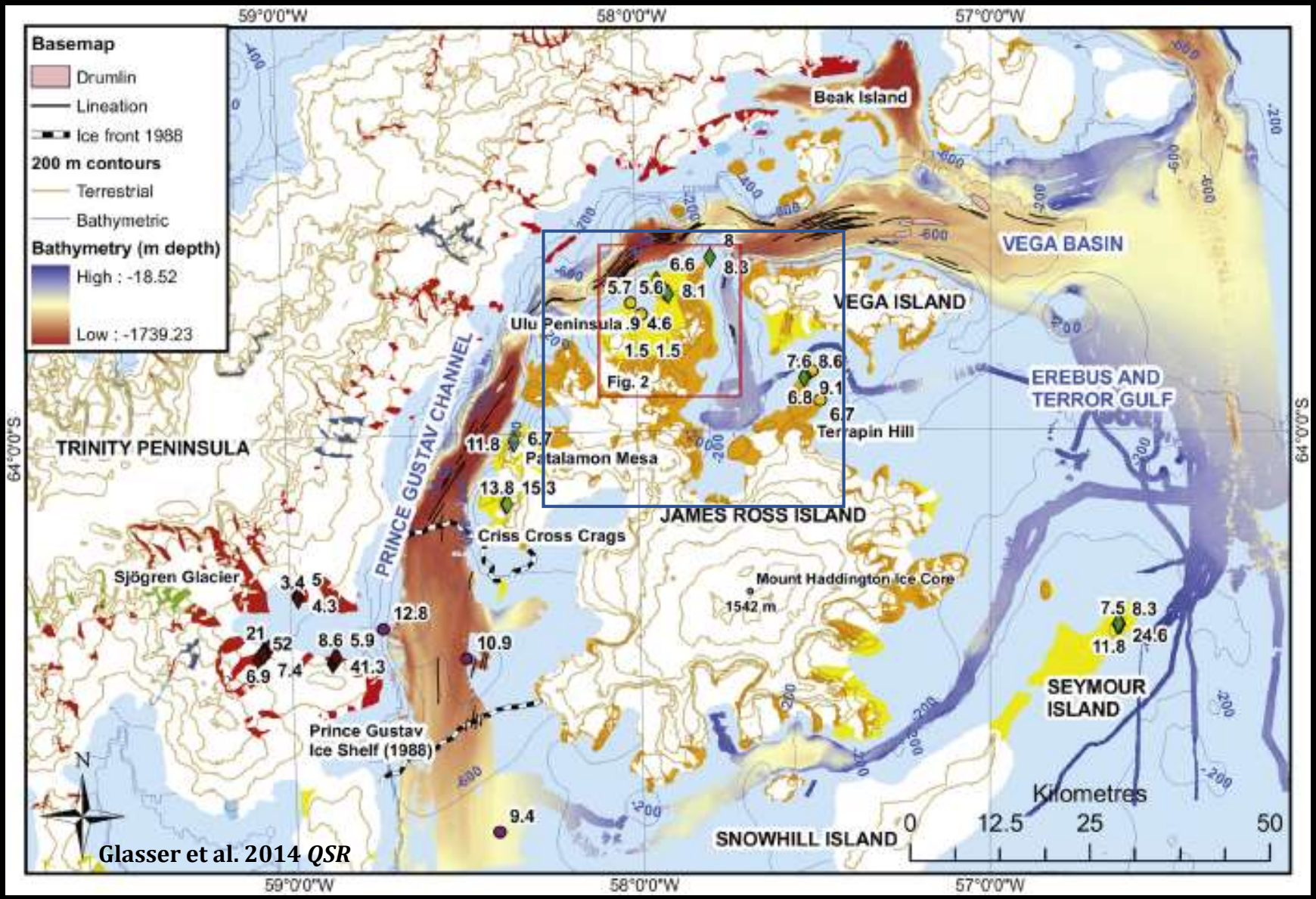


Instrumental measurement for past 50 yrs



PhD project – Objectives:

- -1) TCN dating of granite erratics to constrain timing of the post-LGM deglaciation
- 2) Geomorphological mapping
- -3) Combine palaeolimnology and glacial geomorphology and eliminate inconsistencies
- 3) Reconstruction of the palaeoclimate based on lake sedimentary records.



Geomorphological evidence of past glaciation

Antarctic Science page 1 of 20 (*2019*) © Antarctic Science Ltd 2019 doi:10.1017/S0954102019000178

Lacustrine systems of Clearwater Mesa (James Ross Island, north-eastern Antarctic Peninsula): geomorphological setting and limnological characterization

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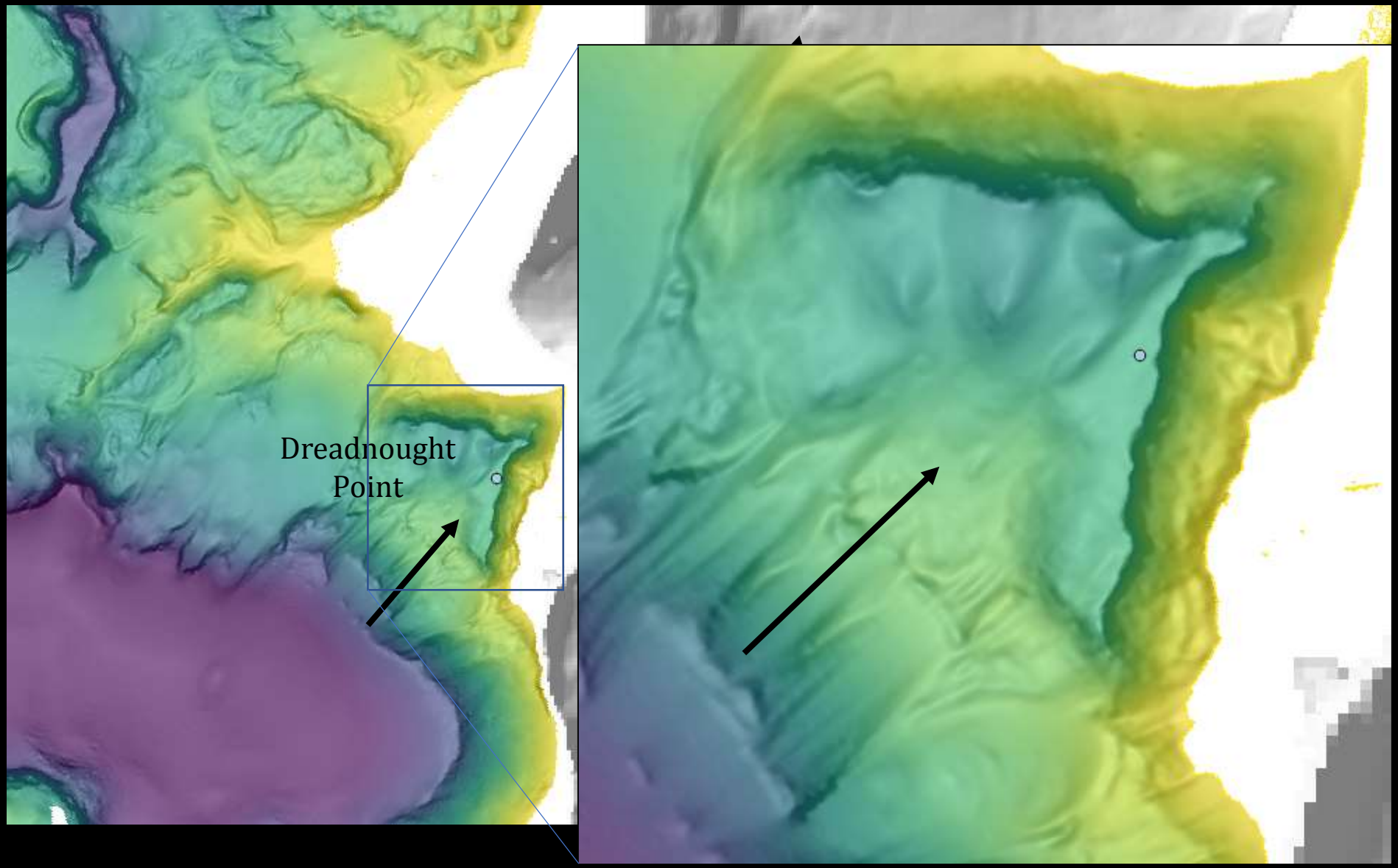
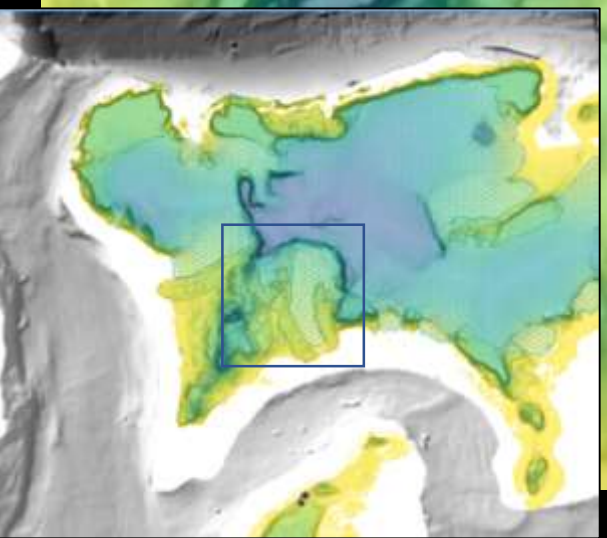
- Glacigennic assemblage: erratic boulders, striation, glacial erratic-rich/-poor drift
- Geomorphological mapping of JRA using REMA DEM (On Clearwater Mesa together with limnological survey of local ca. 70 lakes



- Direction of ice flow – Lineation (MSGL, Crag-and-tails), material provenance
- Agreement between terrestrial (REMA) and bathymetric data –> high confidence



Lateral and frontal moraine ridges of rejuvenated glacier, Cape Lamb, Vega Is.

Polygenetic landscape – Glacial, Periglacial and Paraglacial

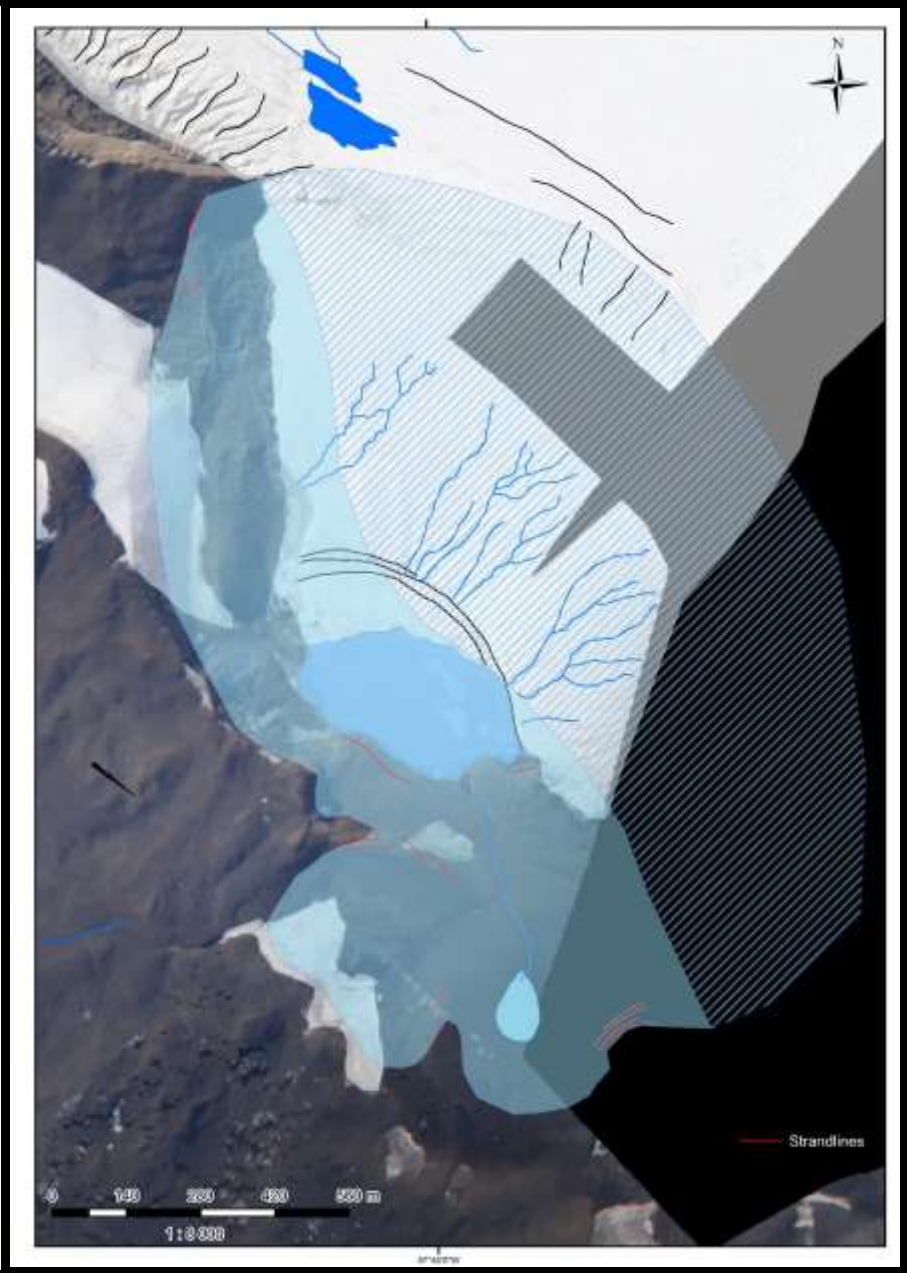
- Recent landscape changes in terminoglacial areas: a dry fluvial valley downcut by an ice-marginal (lateral) meltwater stream
- Glacial erratic-poor drift (=degraded moraine) covers the glacier forfield and dams the lakes

Lakes Rosa and Malvina; Haddington Ice Cap to the right

Lacustrine strandlines (palaeoshorelines) – a series of horizontal topographic steps a few or up to 60 m above present lake levels in case of Lake Florencia

Ice-contact (terminoglacial) Lake Florencia

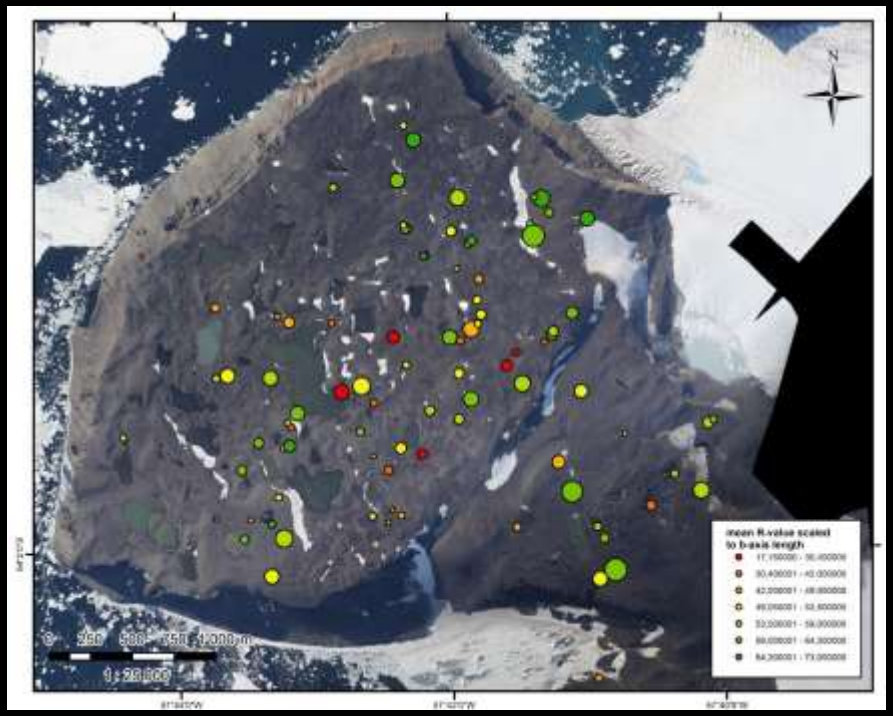
Lakes Cecilia and Florencia



- Lacustrine strandlines indicated on the sketch map. Reconstructed extent of the palaeolake Florencia. The probable lake area was 0.5-2 km^2. The lake level and the damming outlet glacier were ~60 m higher.

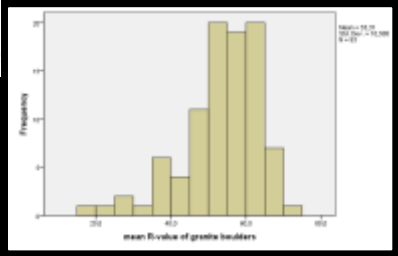
Surface exposure dating of erratic boulders

- A) Relative dating: measurement of rock hardness and degree of weathering using Schmidt hammer:
  - Wide range of R-values: the most weathered boulders <40, less weathered 50-60, boulders with developed desert varnish >60 (complicating relative dating as long-term wind abrasion causes rock surface hardening)
  - Spatial distribution of erratics: more weathered boulders in central part, no boulders near CWM's western edge, where palaeo-ice stream was flowing



Clearwater Mesa, a locality on James Ross Island with more than 50 lakes and around 90 granite erratic boulders (b-axis > 0.5 m). Material from 18 rock surfaces sampled for TCN dating

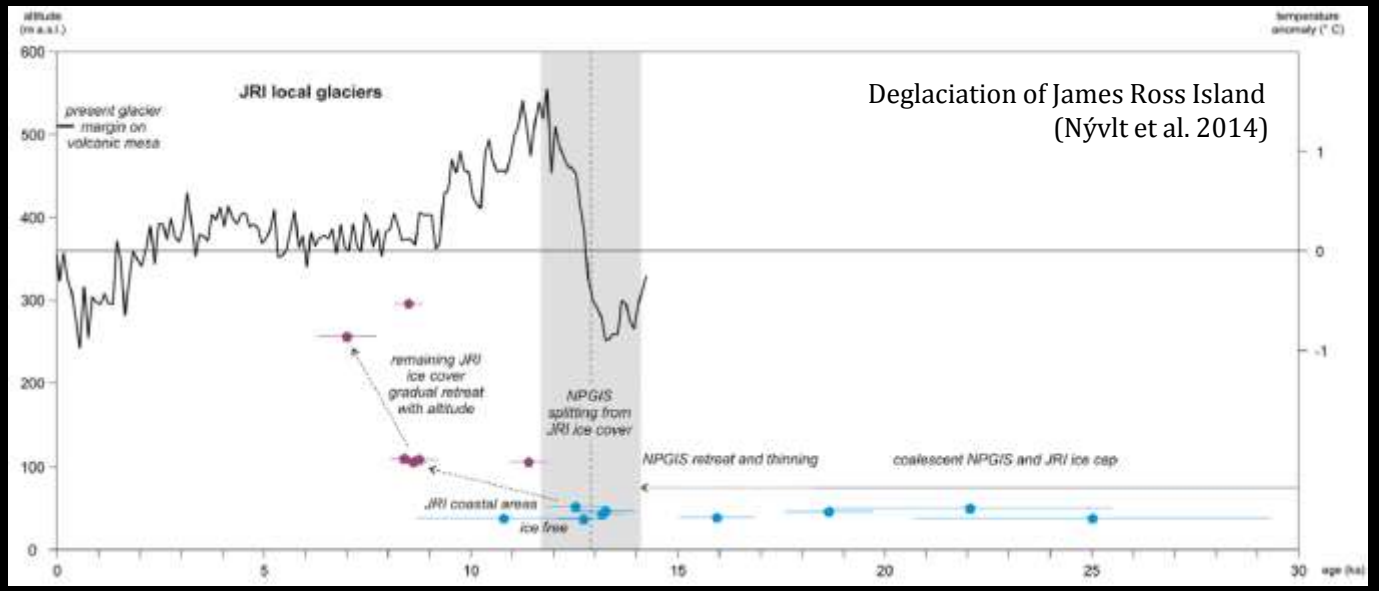
Glacial striation on granitic boulder



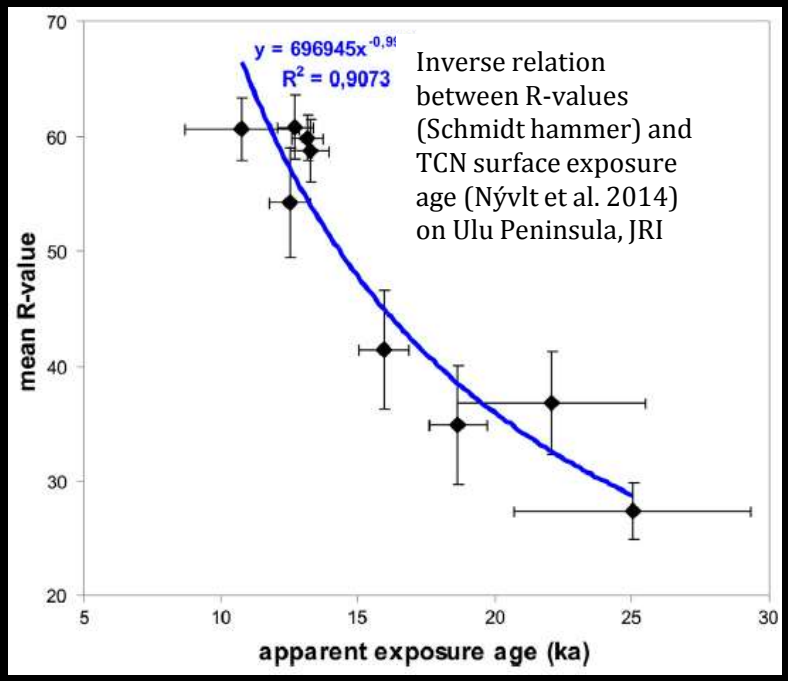
Histogram of R-values

Where next? – TCN dating

- Extraction of purified fine-grained quartz minerals
- Accelerator mass spectrometry measurement of ^{10}Be and ^{26}Al (^{3}He) TCN concentrations
- Calculation of ^{10}Be spallation production induced by cosmic rays and age of exposure



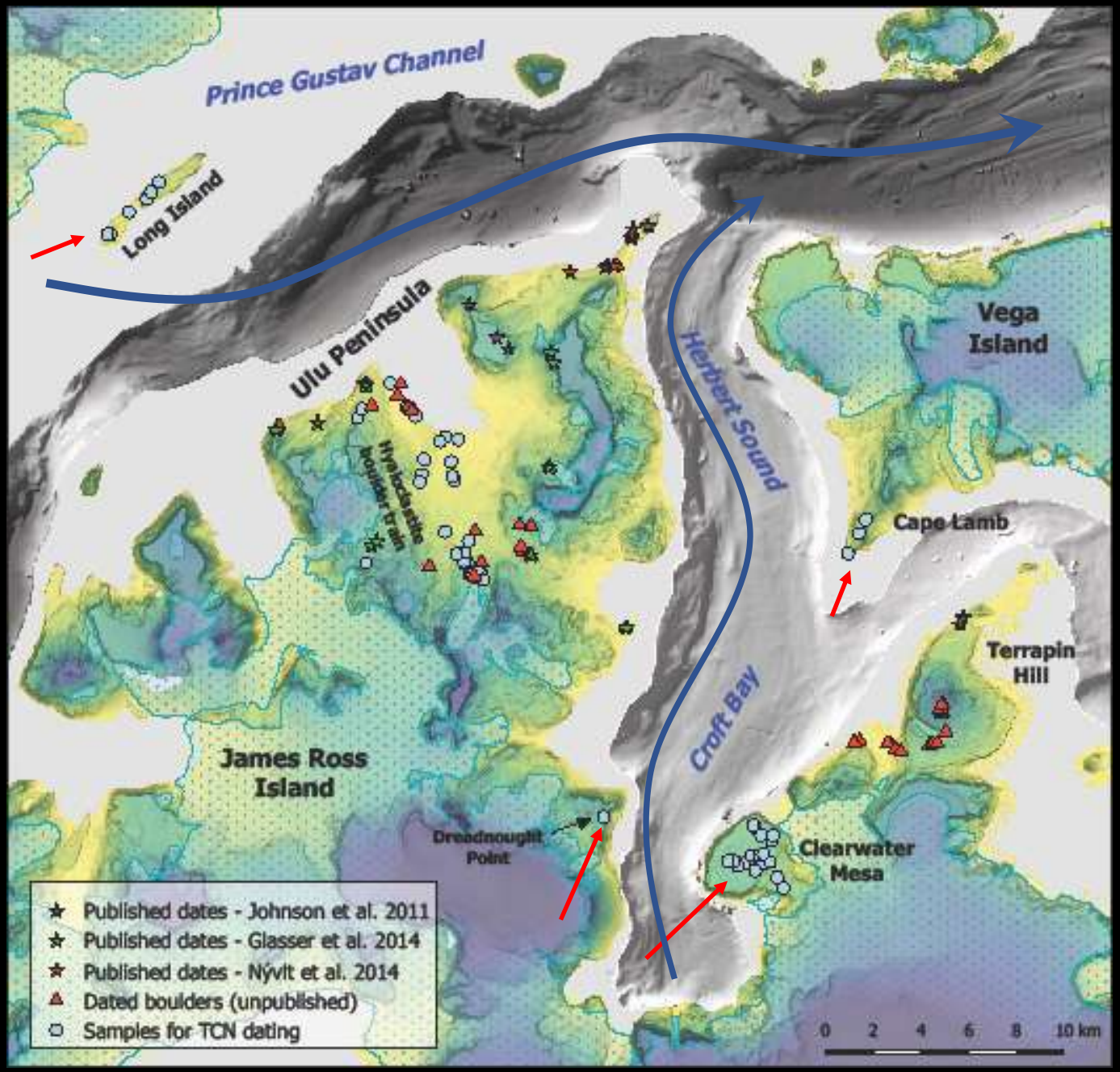
Deglaciation of James Ross Island (Nývlt et al. 2014)



Inverse relation between R-values (Schmidt hammer) and TCN surface exposure age (Nývlt et al. 2014) on Ulu Peninsula, JRI

AMS facilities at Scottish Universities Environmental Research Centre (SUERC), East Kilbride, UK.

TCN analysis might be alternatively performed at ASTER AMS facility, Aix-en-Provence, France.



Location of erratic boulder samples for TCN dating

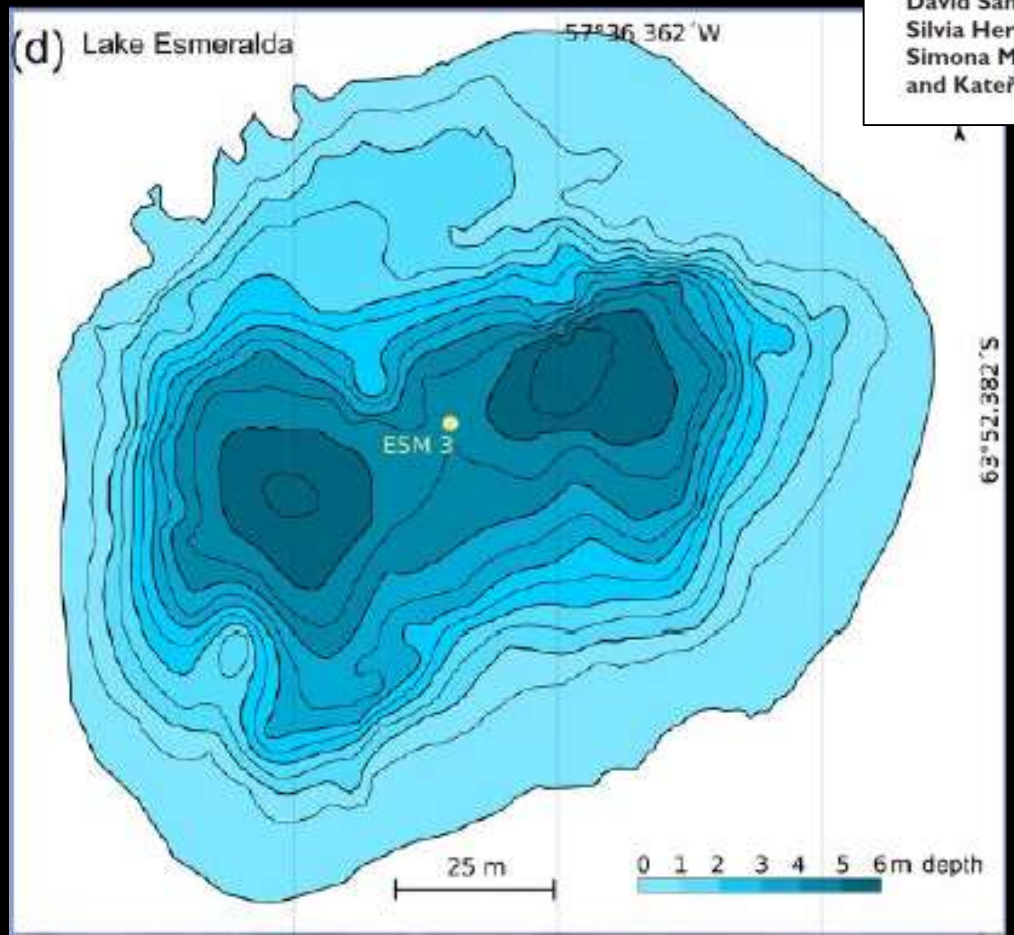
- Clearwater Mesa (2016)
- Cape Lamb (2017)
- Long Island and Dreadnought Point (2019)
- Already dated samples (from D. Nývlt and Bethan J. Davies) – Terrapin Hill, Ulu Peninsula

Sampling on Long Island (Acknowledgement – Michal Břežný)

Sedimentary evidence: Palaeolimnology

- Lake Esmeralda – meromictic, acidic lake located on Cape Lamb, Vega Is.
- Underlying bedrock: Cretaceous sandstones, Tertiary basalts and hyaloclastite breccias; small catchment - river piracy in the past?
- Max. depth ca. 6 m, sediment thickness ca. 2 m

Palaeolimnological research – Analyses of Lake Esmeralda sediment



Research Paper

Late-Holocene palaeoenvironmental changes at Lake Esmeralda (Vega Island, Antarctic Peninsula) based on a multi-proxy analysis of laminated lake sediment

The Holocene
1–20
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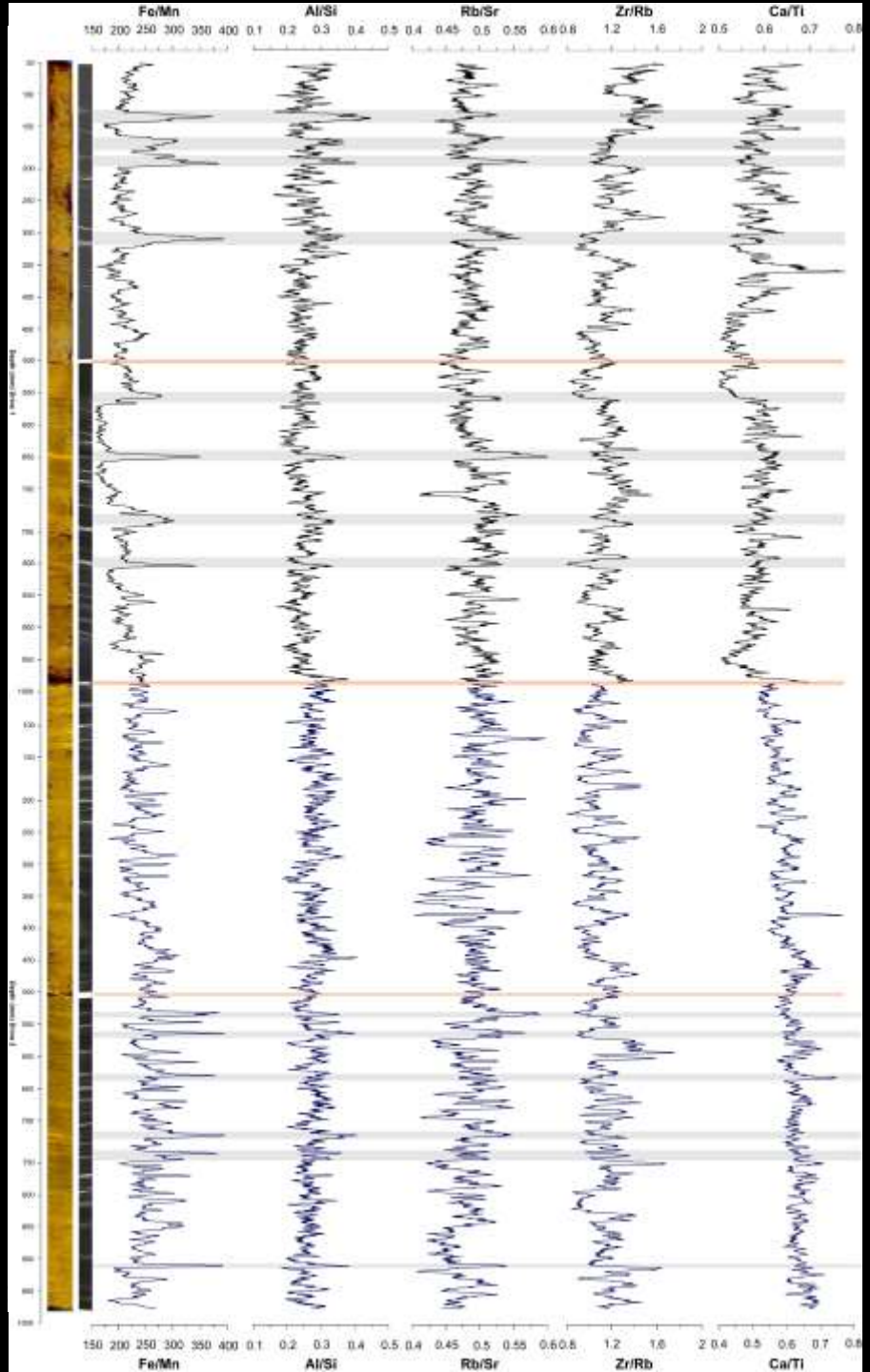
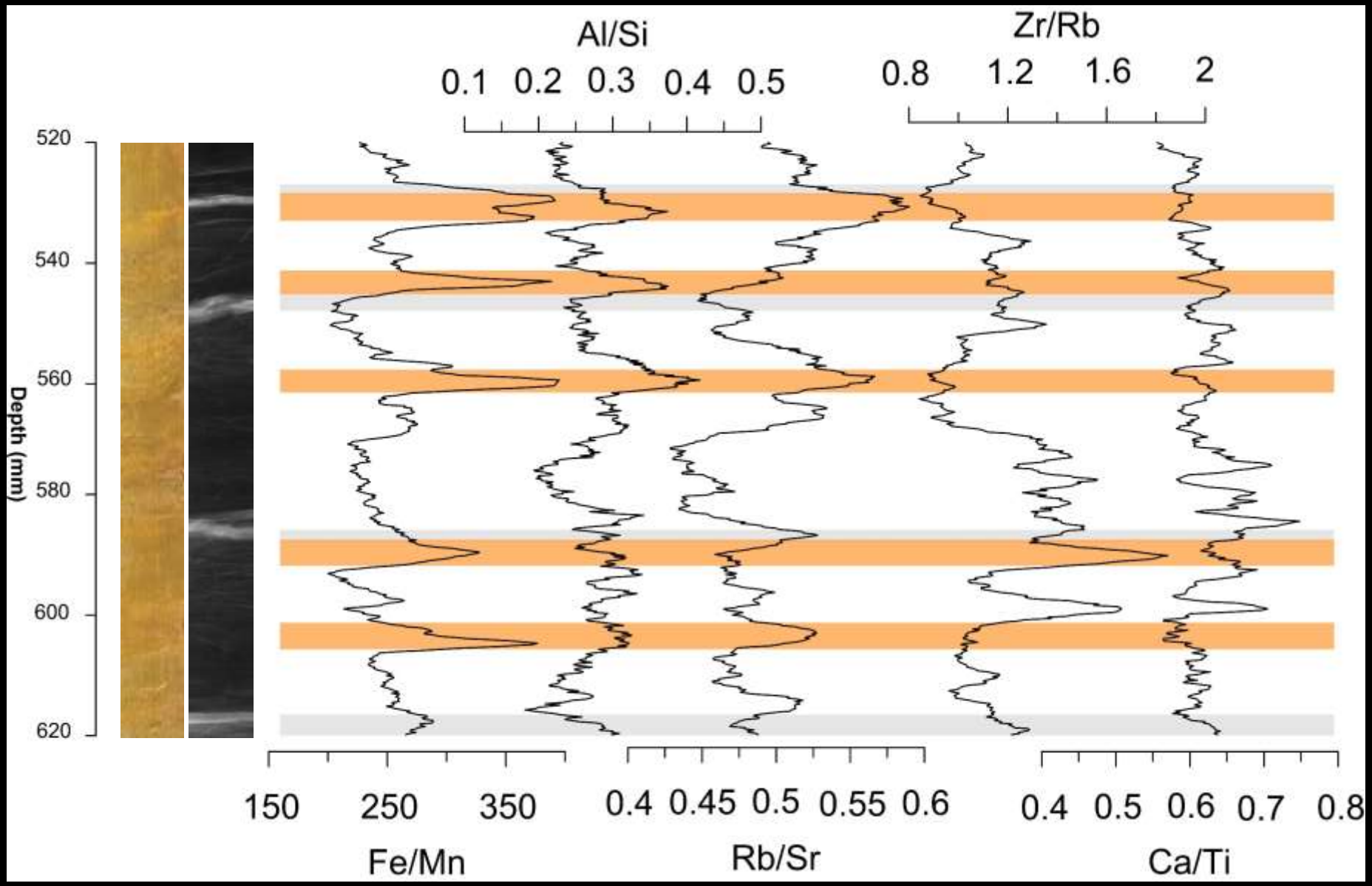
- Analyses:
  - magnetic susceptibility
  - grain size
  - organic and XRF geochemistry
  - XRD
  - biological proxies (diatoms, pigments)
- High-resolution scanning of lamination (most probably varves) and detection of tephra was performed in the Palaeolimnological lab at Aberystwyth University - µXRF scanner ITRAX for sub-millimetre scale geochemical analysis and tephrochronology
- Challenging dating! ->

Formation of laminae

- Macroscopically and geochemically, distinct alternation of dense sedimentary matter with less dense, dark organic layers
- Clastic input, aeolian influx (sea spray?), autochtonnous bioproductivity
- 2 cores analysed:
  - ESM3 – cut in 1-cm steps
  - ESM4 – continuous scanning
- Fe/Mn ratio points to sudden changes in redox condititions
- Not perfect match between geochemically and sedimentologically defined laminae, and between cores (170 x 100 layers in ESM 3 and 4)



Geochemical fingerprinting – µXRF scanning



Geochronology:

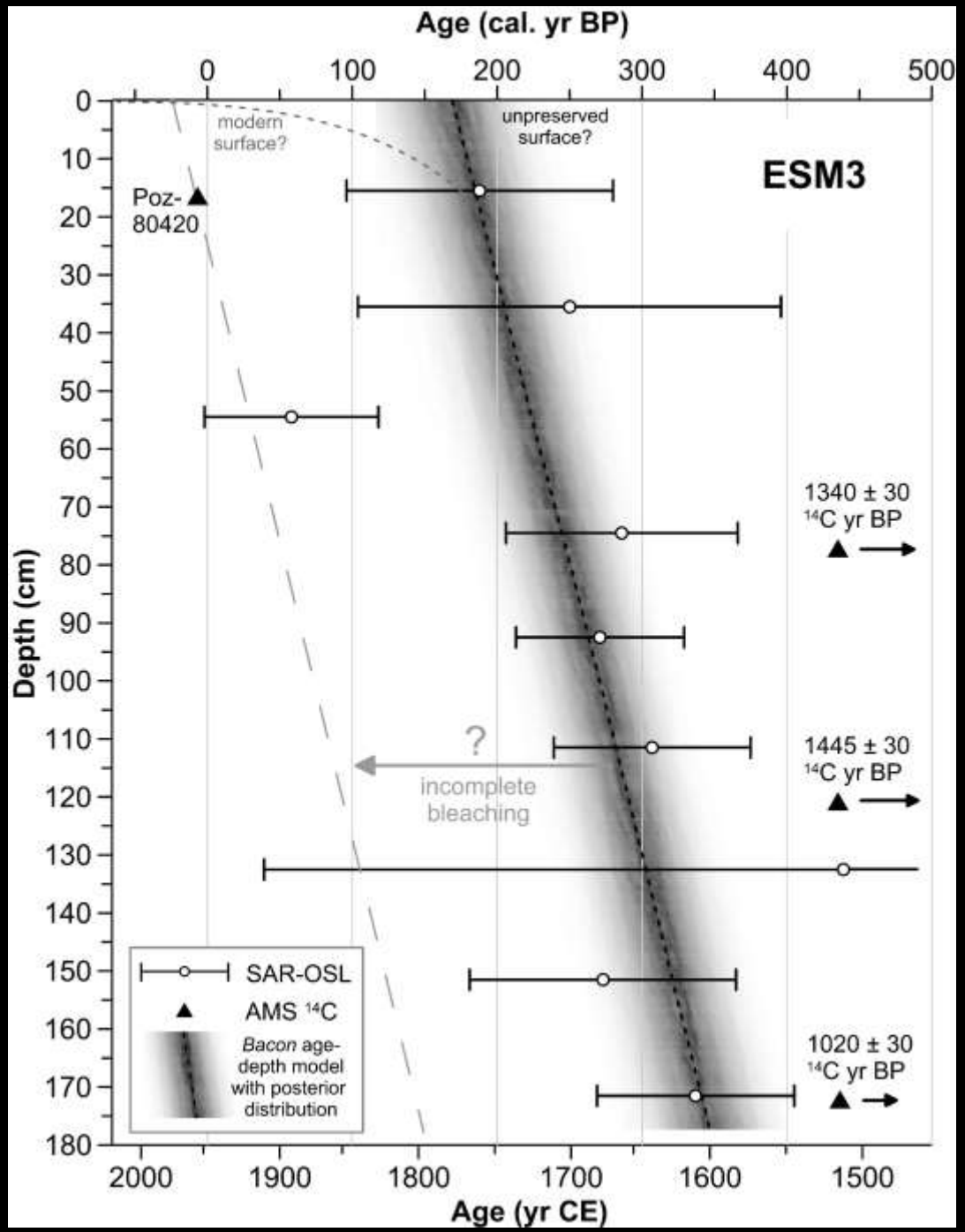
- Irurzun et al. (2017) – 14C dating suggests Holocene age (>10 ka BP)
- Our ^{14}C dating - aquatic moss macroremains - displaying age reversals, but Late Holocene age (1-1.5 ka BP)

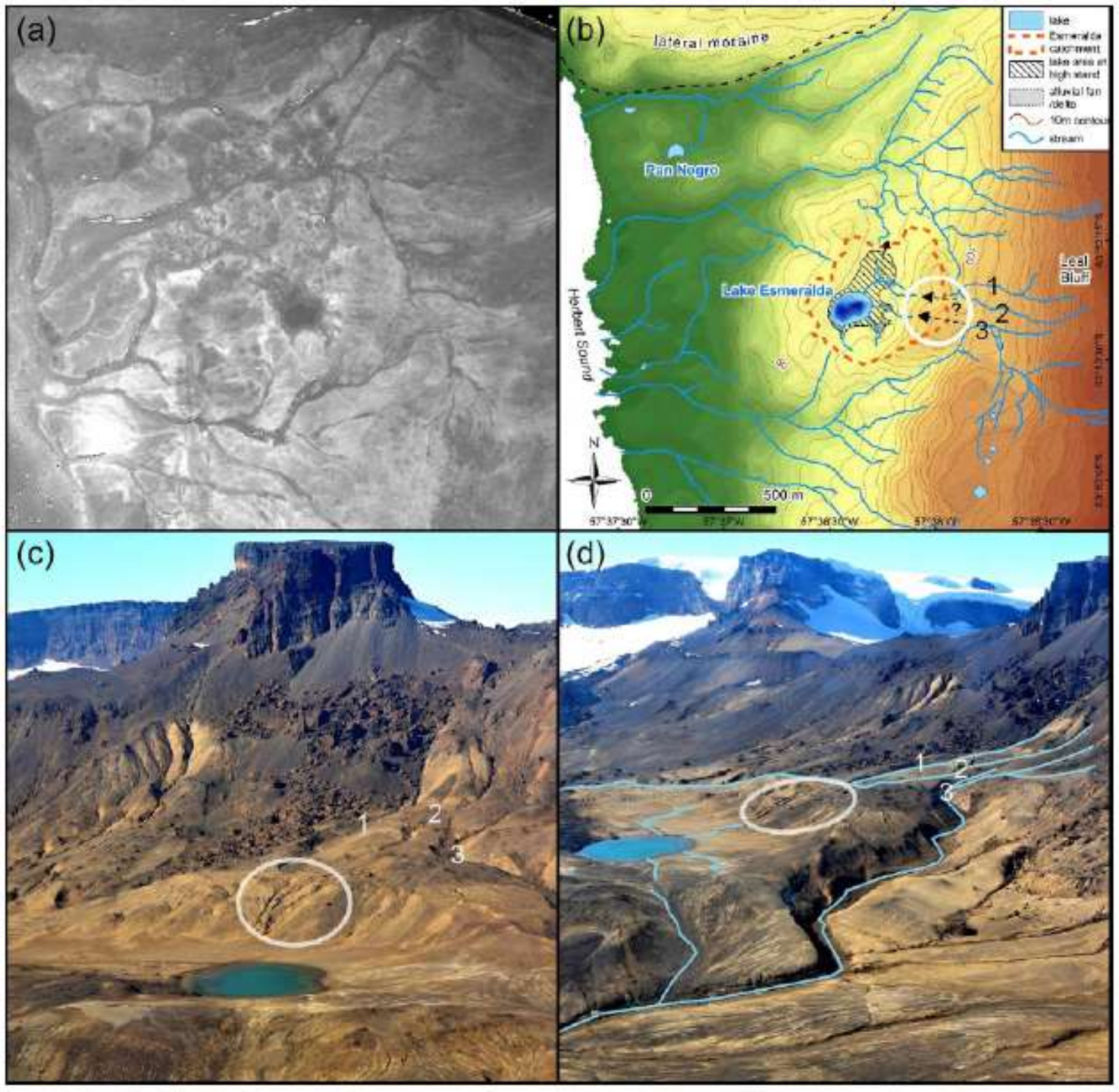
OSL dating at SUERC:

- SAR-OSL dating of fine sand quartz and polymineral fractions - in Visible and IR spectrum
- Dose rates - thick-source β counting and high-resolution γ spectrometry
- Weighted or robust mean of D_E as the most appropriate for calculation of apparent age (Abanico plot)
- Results: very young ages, in range 50–450 yrs BP - generally increasing with depth, most often 180-350 yrs BP

-> supports our ^{14}C ages and annual formation of laminae

- Bacon age-depth modelling in R
- However, incomplete bleaching possible – shift of the whole chronology towards younger age?





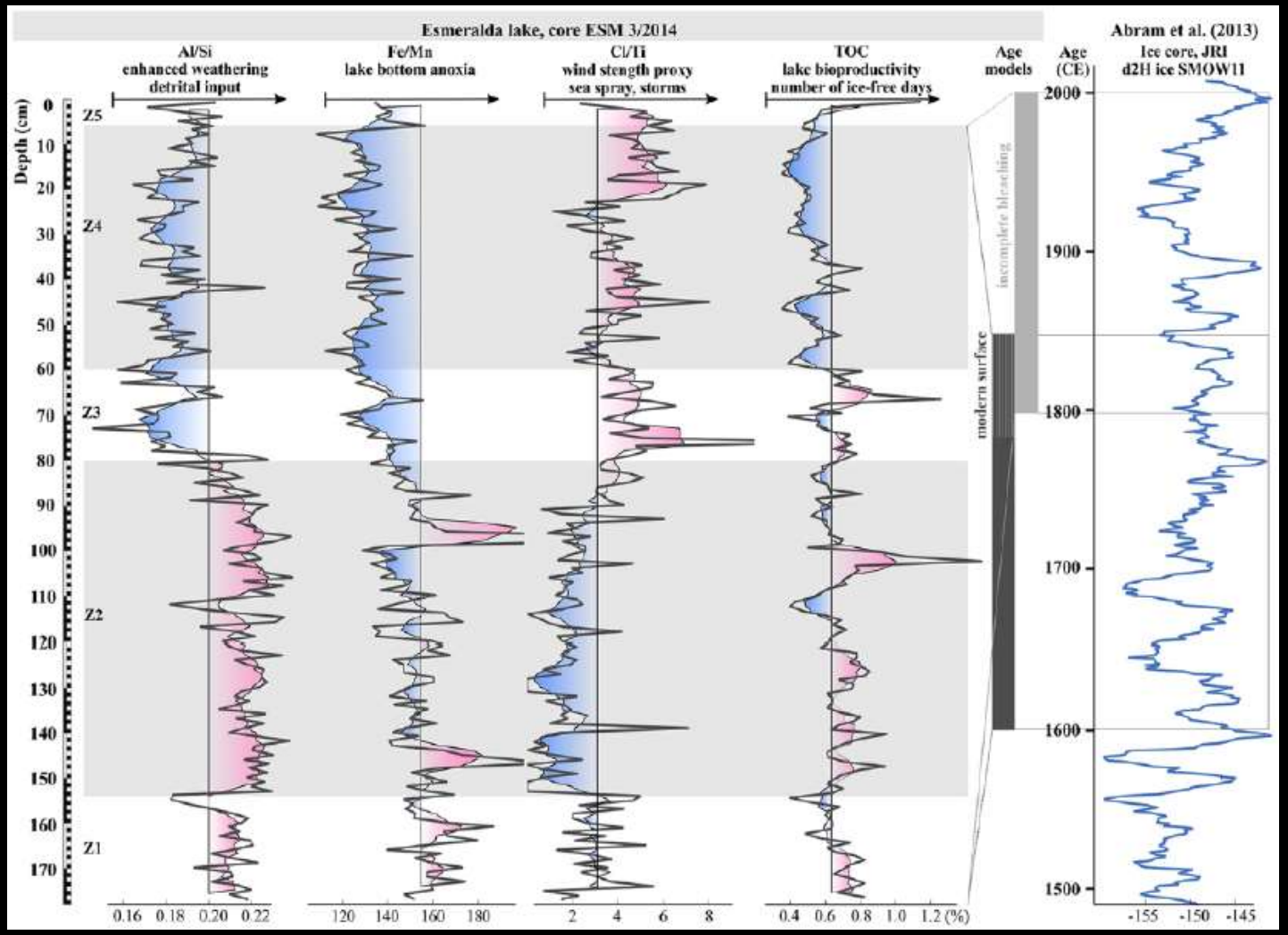
Catchment changes

- Stream piracy as a culprit in cessation of sediment delivery
- One or more streams captured during and at the end of the sedimentary record
- Past lake extent and location of deltas/alluvial fans

Palaeoenvironmental inferences from Lake Esmeralda

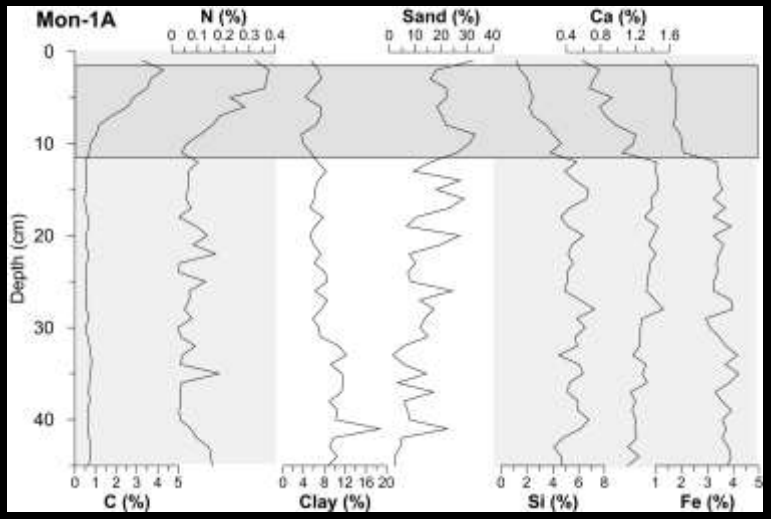
- Extremely high accumulation rates enabled subdecadal temporal resolution
- Lake level high stand and highest bioproductivity in ca. 17th century CE
- 18th century – lower bioproductivity, sedimentation rate and weathering intensity, coldest period? Followed by rapid warming

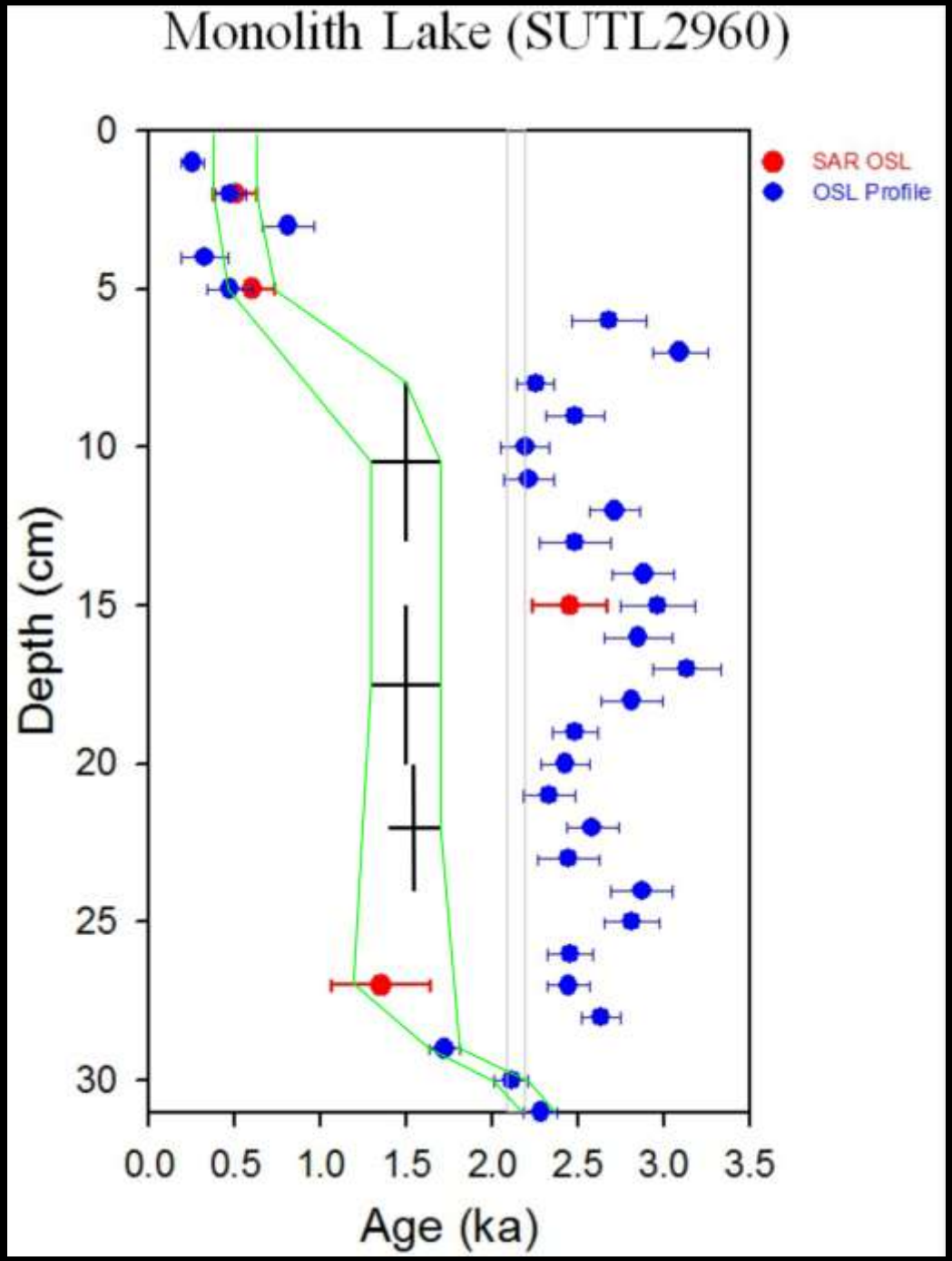
- End of accumulation at 1780 AD – river piracy and termination of sediment influx in the lake basin
- Comparison with ice core from Mt. Haddington
- Follow-up: Multi-proxy analysis of new continuous core where mXRF scanning was performed



Search for other sedimentary archives in JRI Archipelago

- Monolith Lake, JRI – OSL dating in progress: large residual of luminiscence signal in middle part of the profile – probably insufficient zeroing of paraglacially mobilised material or glacier wasting around 1.5 ka BP – overlying better resetted sediment in the lowermost unit
- Lake Anonima? Hidden Lake?





Publications:

Published/Accepted:

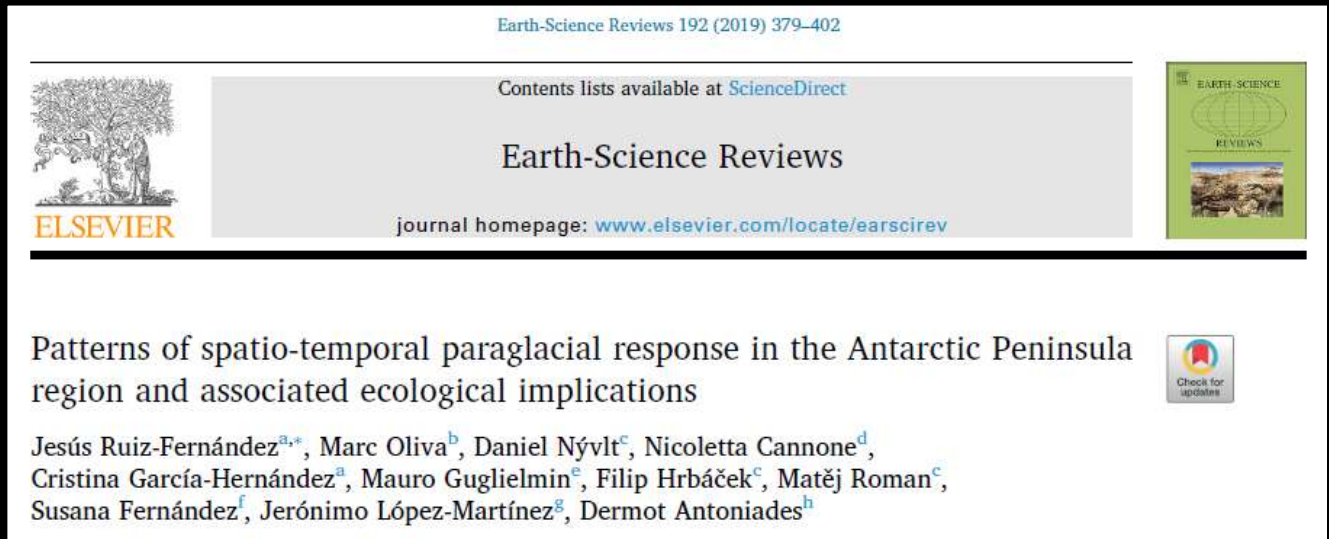
- Roman et al. (2019): Lacustrine systems of Clearwater Mesa, James Ross Island, north-eastern Antarctic Peninsula: geomorphological setting and limnological characterization. *Antarctic Science*
- Píšková et al. (2019): Late-Holocene palaeoenvironmental changes at Lake Esmeralda (Vega Island, Antarctic Peninsula) based on a multi-proxy analysis of lake sediment. *The Holocene*
- Ruiz-Fernández et al. (2019): Patterns of spatio-temporal paraglacial response in the Antarctic Peninsula region and associated ecological implications. *Earth-Science Reviews*

Under review:

- Roman, M., Chattová, B., Lehejček, J., Tejnecký, V., Polická, P., Němeček, K., Houška, J., Nývlt, D. (under review): Integrated multi-proxy study of Late Holocene environmental changes from two infilled lakes in the Kobbefjord area, Southwestern Greenland. Submitted for publication in *Journal of Paleolimnology*
- Kopalová. K., Soukup, J., Kohler, T.J., Roman, M., Coria, S.H., Vignoni, P.A., Lecomte, K.L., Nedbalová, L., Nývlt, D., Lirio J.M. (under review): Habitat controls on lake and pond diatom communities of Clearwater Mesa, James Ross Island, Maritime Antarctica. Submitted for publication in *Polar Biology*

In preparation:

- Glacial geomorphological mapping of Herbert Sound and adjacent areas, James Ross Archipelago (using REMA DEM and bathymetric data)
- TCN dating of glacial erratics in James Ross Archipelago



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Patterns of spatio-temporal paraglacial response in the Antarctic Peninsula region and associated ecological implications

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Conclusions and outlooks

- Geomorphological and sedimentary evidence complements each other – obviates the problems of obliteration/incomplete preservation of the palaeoenvironmental records
- My PhD project synthetises glacial geological and palaeolimnological data in novel way
- Research of the cryosphere imperative as human impact on the Earth system will increase ever more in the 21st century.

Thanks for your attention!

Milky Way from J.G.Mendel station