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Weathering signals in Lake Baikal and its tributaries

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Silicate weathering and the long-term carbon cycle

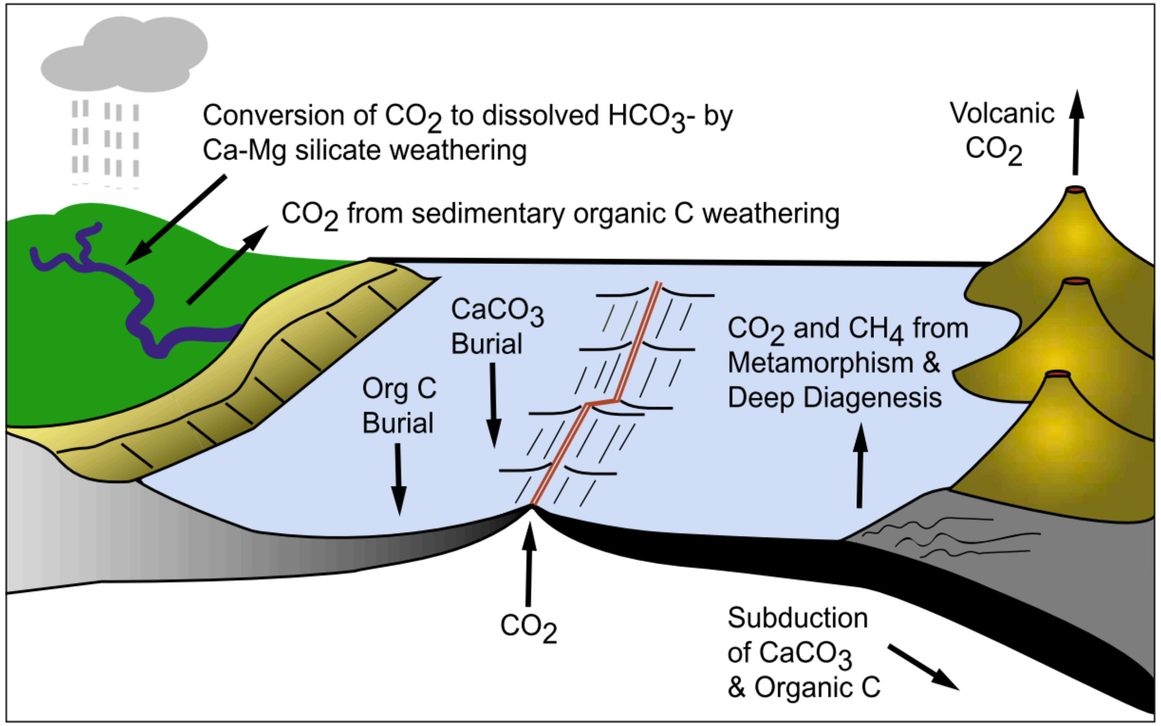

Figure 1: Illustration of the long-term carbon cycle and involved carbon fluxes (Berner, 1999).

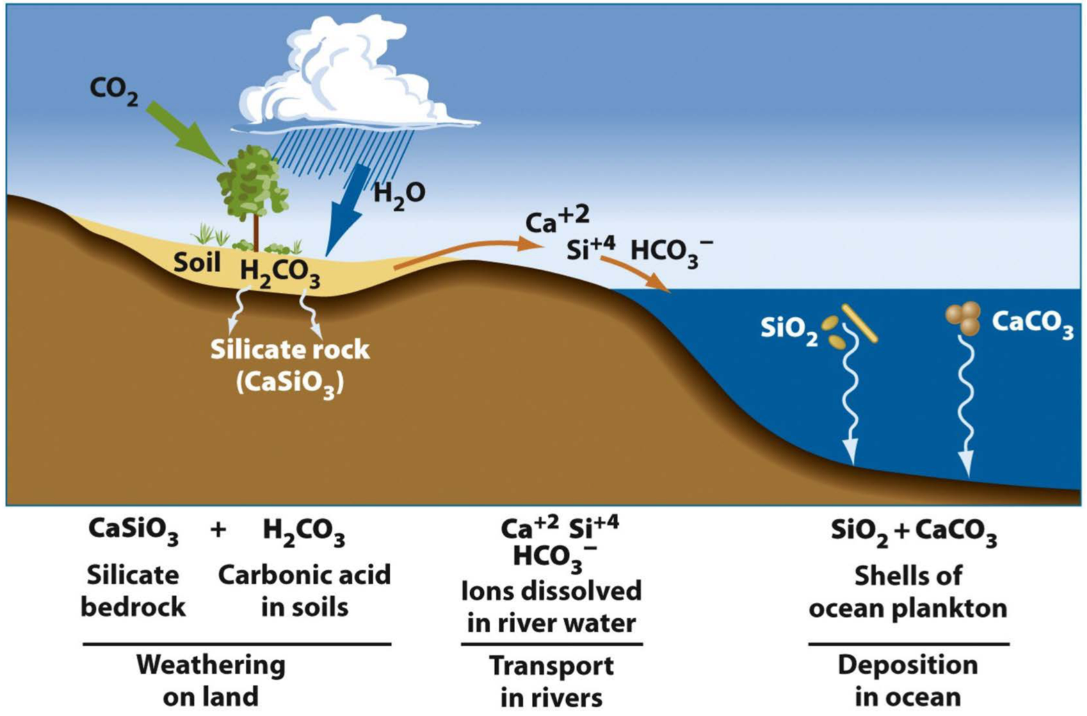

Figure 2: Schematic showing removal of atmospheric CO_2 through silicate weathering (Ruddiman, 2008).

The long-term carbon cycle refers to carbon fluxes between surface earth reservoirs and the lithosphere. Over long time scales (> several 100 kyrs), small imbalances in these fluxes can result in substantial changes of atmospheric CO_2 concentrations. One of the processes removing CO_2 from the atmosphere is the weathering of silicate rocks. We are interested in the relationship between climate and silicate weathering now and in the past, particularly in the context of past climate changes.

Lake Baikal as a promising site to study variation of silicate rock weathering in both space and time:

- Size and age: 20% of global freshwater, 30-40 Ma old
- Periodic glaciations
- Long, continuous sediment cores (dating back as much as 12 Ma)
- Geology of the catchment is dominated by granitoid rocks

(Colman, 1998; Karabanov et al., 1998; Williams et al., 2001; Karabanov et al., 2004; Zakharova et al., 2005 ; Sherstyankin et al., 2006; Fagel et al., 2007; Troitskaya et al., 2015; Panizzo et al., 2017)

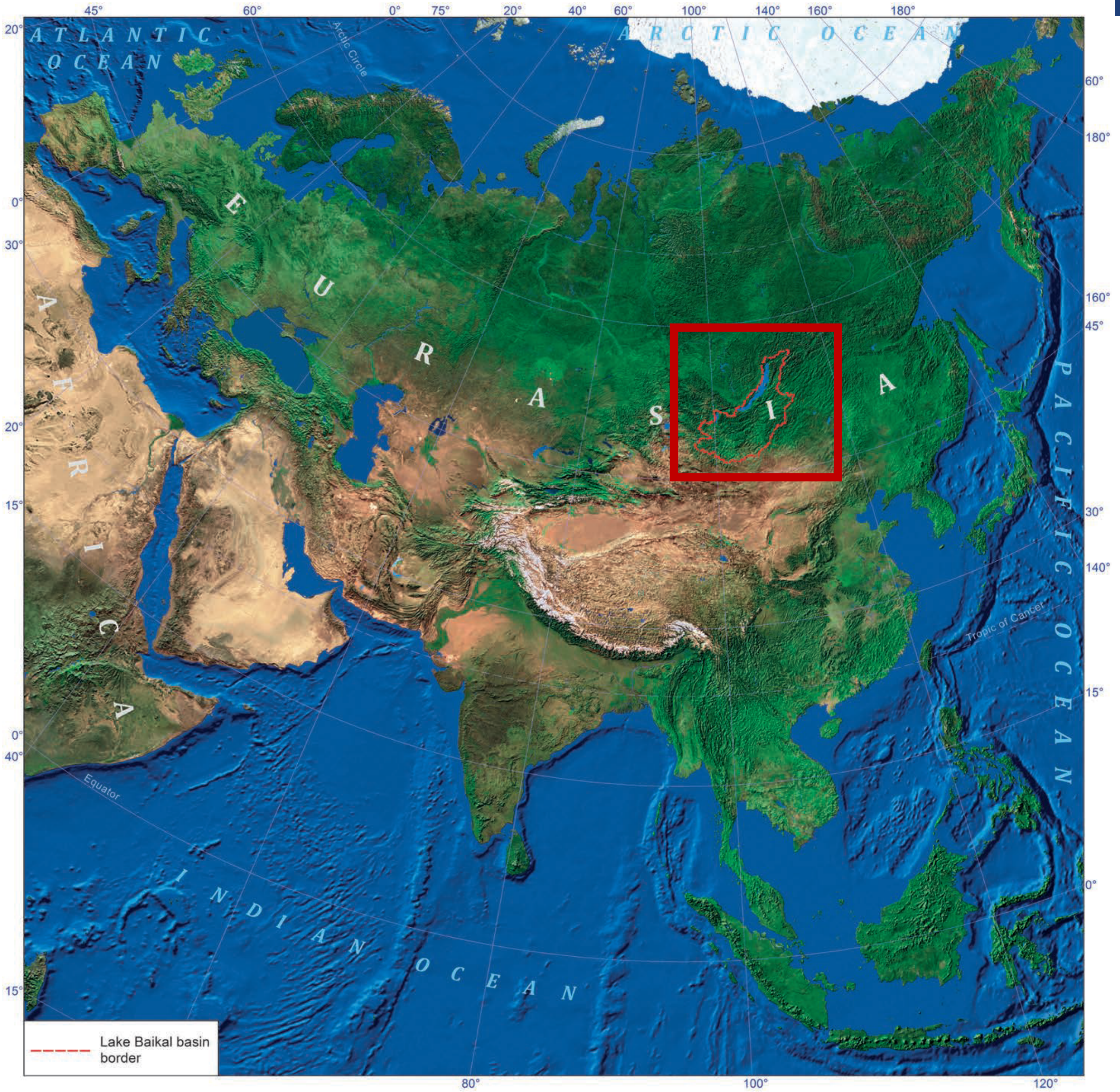

Figure 3: The location of Lake Baikal (Tulokhonov et al., 2015).

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Aim of this study

- To assess weathering processes at Lake Baikal in both space and time:
  - To constrain the present-day budget of the lake with respect to radiogenic weathering tracers (Nd, Pb, and Sr) and meteoric $^{10}Be/^{9}Be$ isotope ratios.
  - To assess current weathering fluxes, compiling and comparing different estimates of denudation and (physical/chemical) erosion rates throughout the Lake Baikal basin in relation to hydrological, climatic and geomorphological conditions.
  - In future work, to use sedimentary records to extend this understanding into the past (i.e. reconstruct the response of silicate weathering to changing climate in the past).

Intro to Lake Baikal

River flow (82%) provides the majority of water input to the lake (groundwater 5%, precipitation 13%; Colman, 1998).

The majority of riverine discharge occurs in summer (82% in May- September; Seal & Shanks, 1998). Samples were taken in August.

The rivers sampled in this study represent ~79% of total riverine inputs and provide a reasonable estimate of total inputs (Sklyarova et al., 2017).

The water residence time in the lake is 300-400 yrs (Falkner et al., 1997), the deep water renewal time is about ˜10 yrs (Falkner et al., 1991; Weiss et al., 1991).

Lake Baikal is subdivided into a northern, central, and southern basin by two submarine ridges.

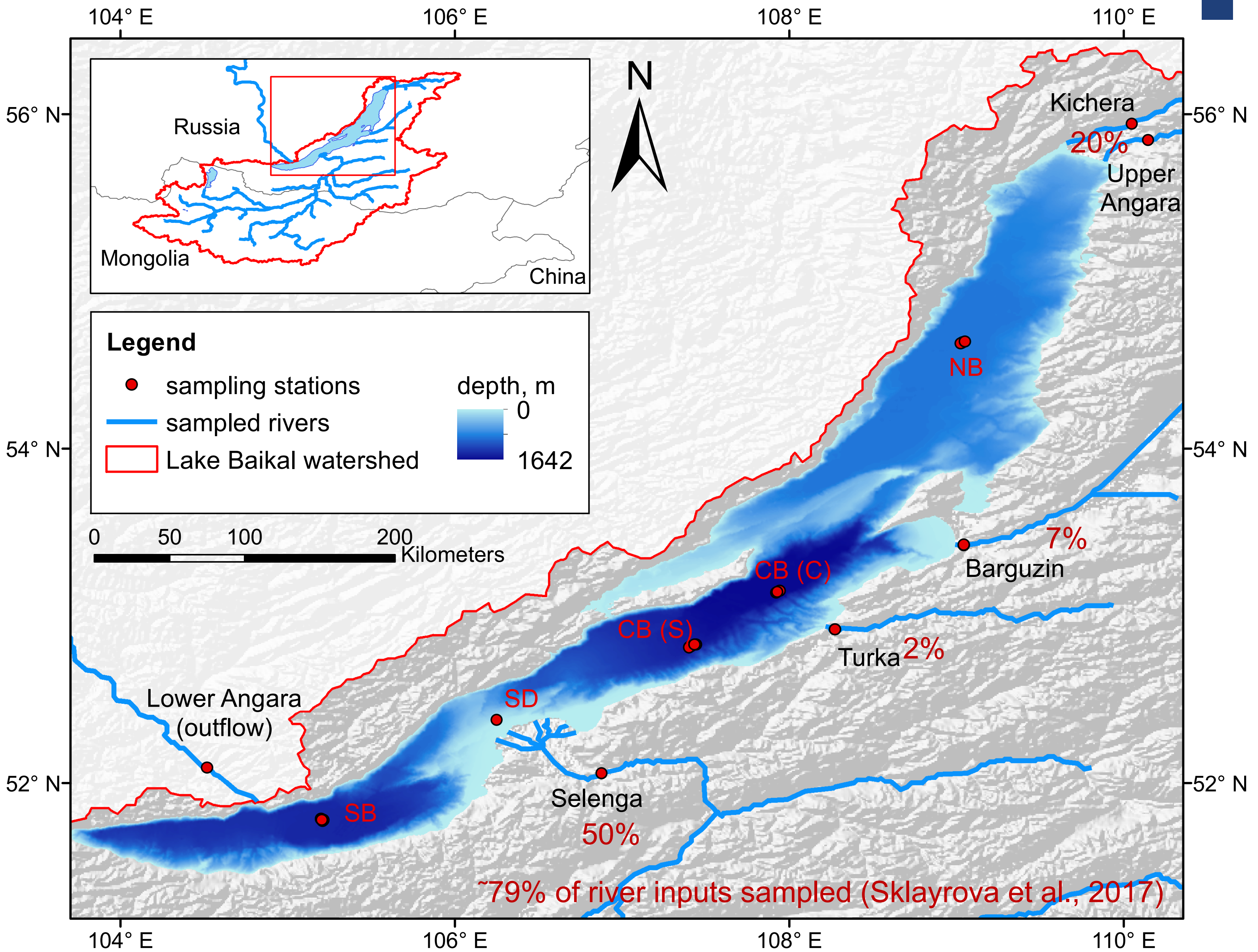

Figure 4: Sample locations at Lake Baikal. Red numbers refer to each river's contribution to total water discharge into the lake.

Sr budgets and isotopes

The residence time (lake inventory divided by input flux) of Sr in the lake is 330 yrs, which agrees reasonable well with a previous estimate of 370 yrs (Falkner et al, 1997).

As a consequence, Sr isotopes in the lake are well mixed and have a uniform distribution.

With respect to future paleo-work, every core location in the lake likely records changes to the chemistry of the whole lake.

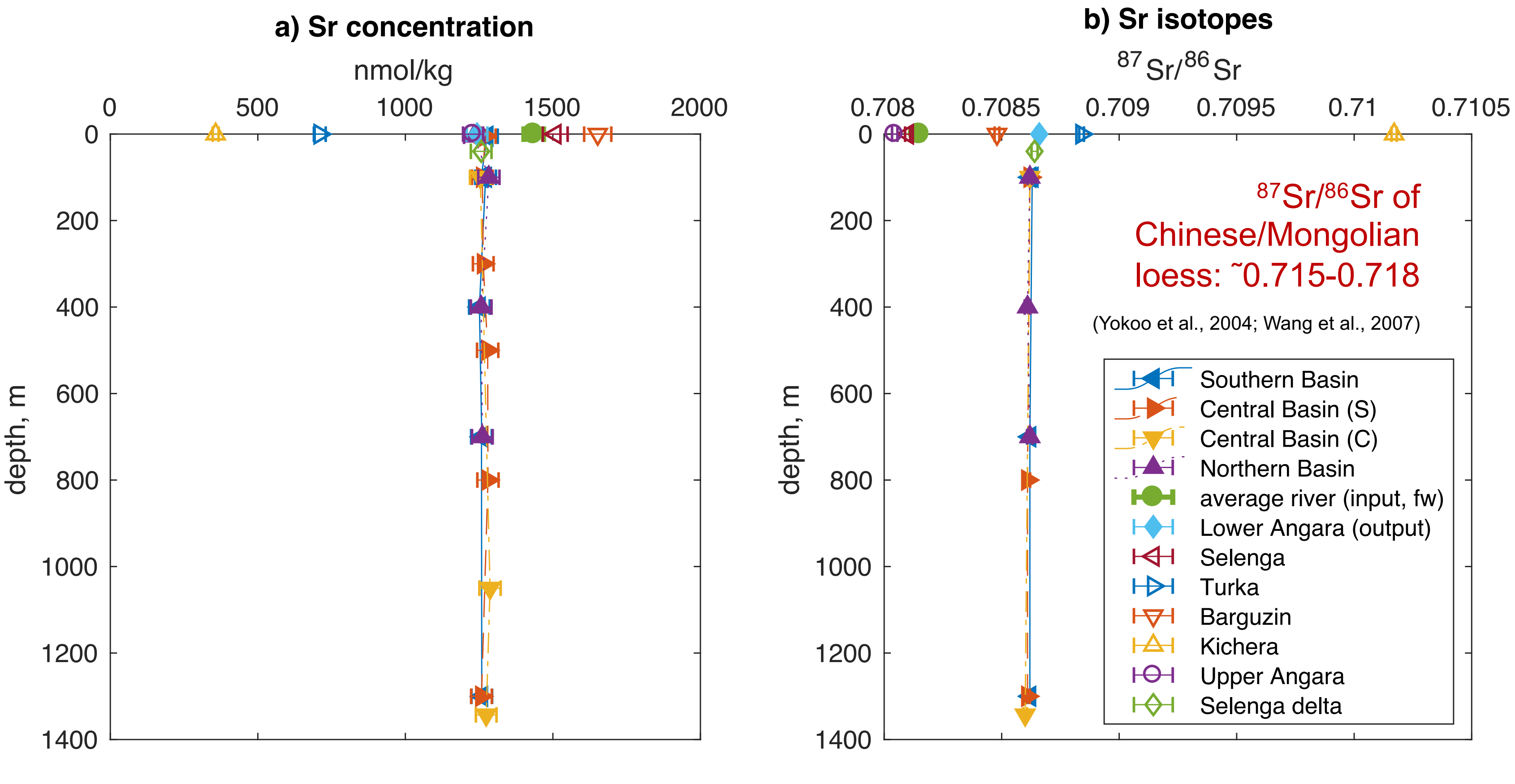

Figure 5: Sr concentrations and isotopes in Lake Baikal and its tributaries.

Nd budgets and isotopes

Nd concentrations are much lower in the lake than in river inflows (~99% seems to be removed at the river-lake interface). The residence time of Nd in the lake is only 5 years. Since the ionic strength of the lake is similar to the rivers (slightly lower), this drop in concentration is most likely due to pH-induced changes in dissolved-adsorbed partitioning, consistent with correlations between Nd concentrations and pH in rivers generally (Deberdt et al., 2002) .

As a consequence, Nd isotopes in the lake are not well mixed. The northern Basin, which has Archean rocks in its catchment (Persits et al., 2007), has a markedly less radiogenic composition.

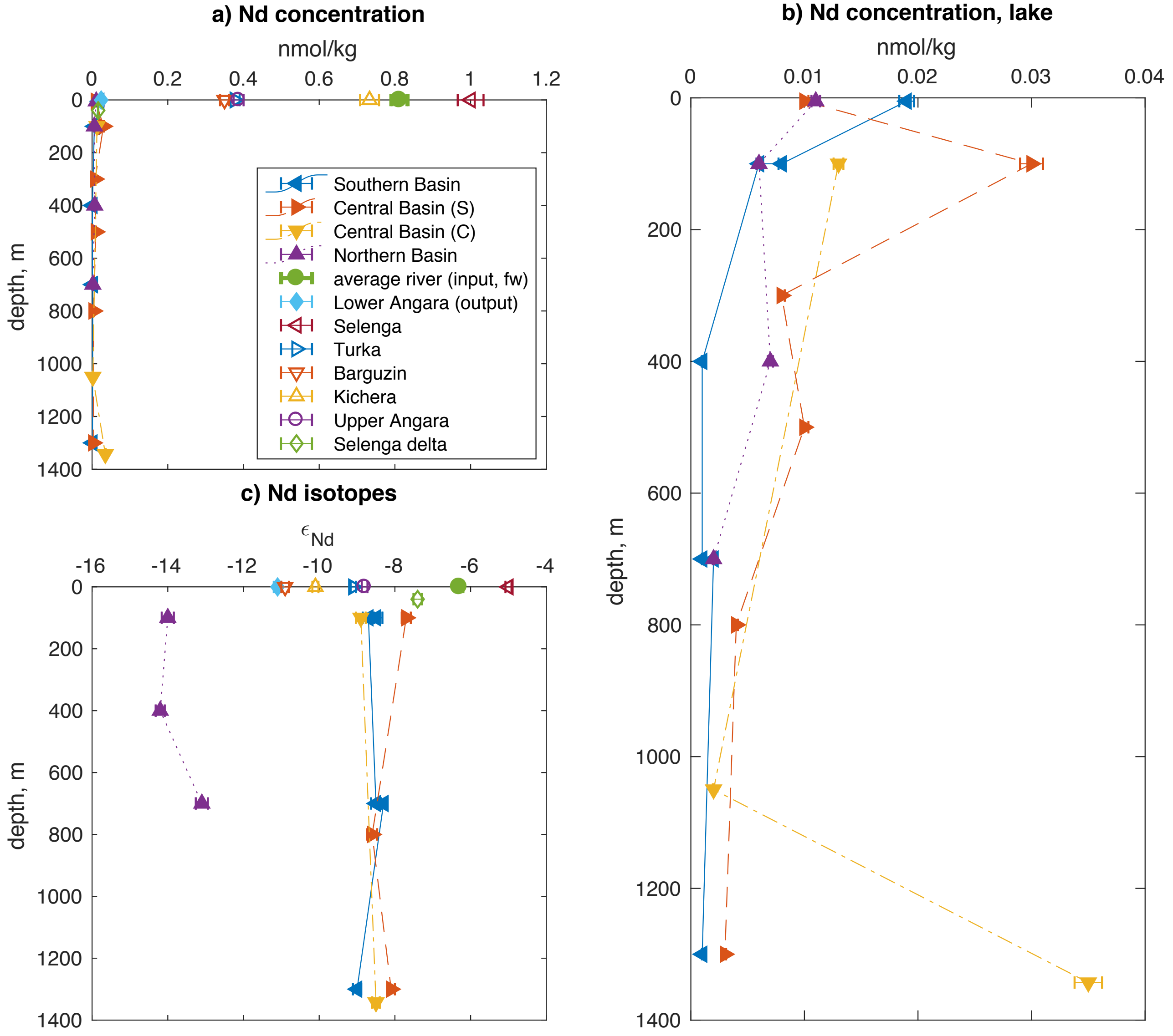

Figure 6: Nd concentrations and isotopes in Lake Baikal and its tributaries.

Nd budgets and isotopes

Due to the short residence time and resulting heterogenous isotopic composition of the lake, any sediment core most likely records changes to the local water composition (e.g. of the respective basin).

In the context of future paleo studies, this is also an opportunity: sediment cores close to the different inputs can resolve weathering changes in individual river catchments.

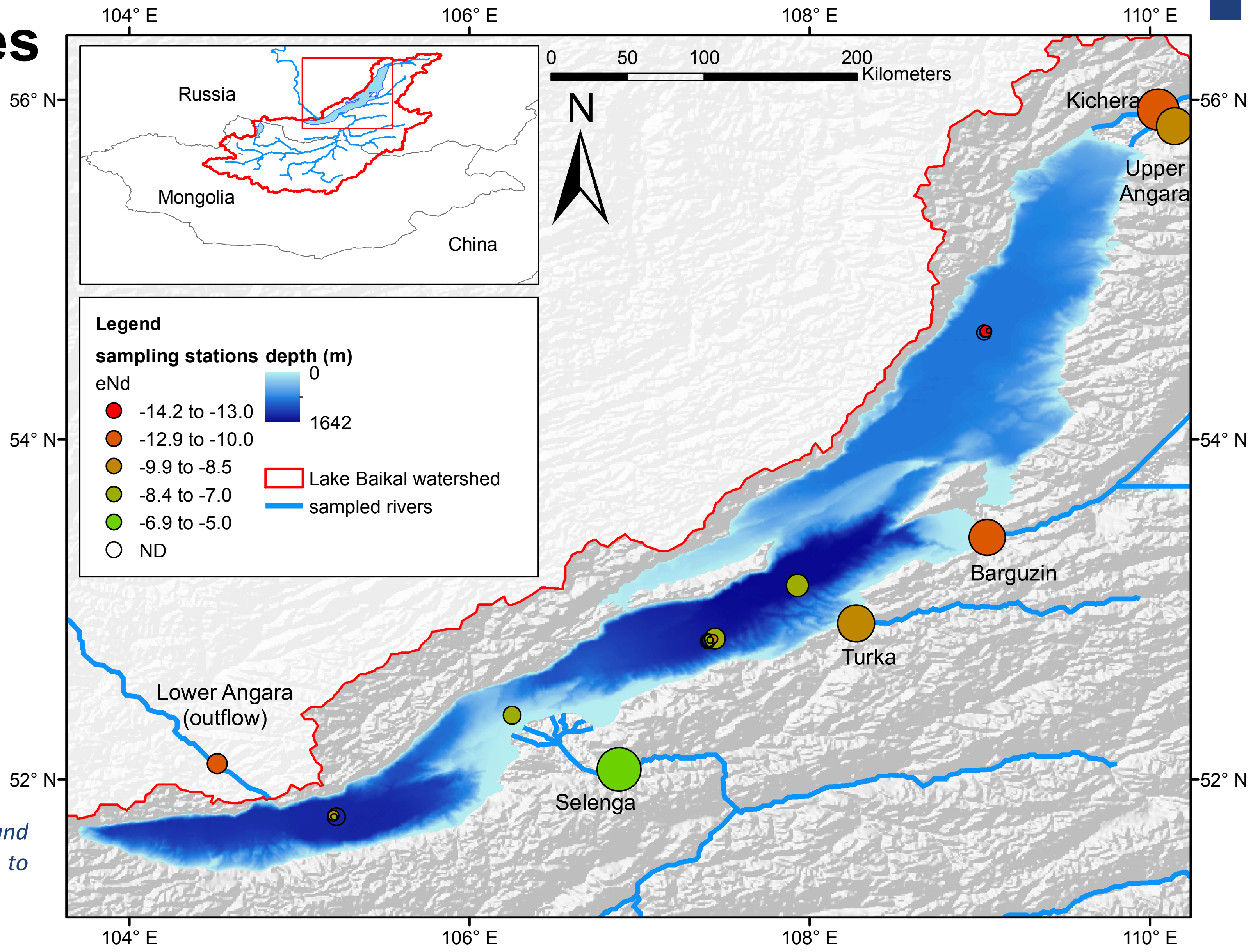

Figure 7: Neodymium concentrations and isotopes in Lake Baikal and its tributaries. The marker size for each station is proportional to log([Nd]), the color refers to its isotope composition.

Be budgets and isotopes

Similar to Nd, Be concentrations in the lake are much lower than in the rivers. The residence time is about 20 years.

The lake has higher $^{10}Be/^{9}Be$ ratios than the rivers, which probably indicates that precipitation and dust are significant sources of ^{10}Be to the lake.

There appears to be a difference in isotope composition between the different basins.

Pb concentrations are higher in the lake than the rivers. The isotope composition points towards pollution (e.g. from gasoline) as the source.

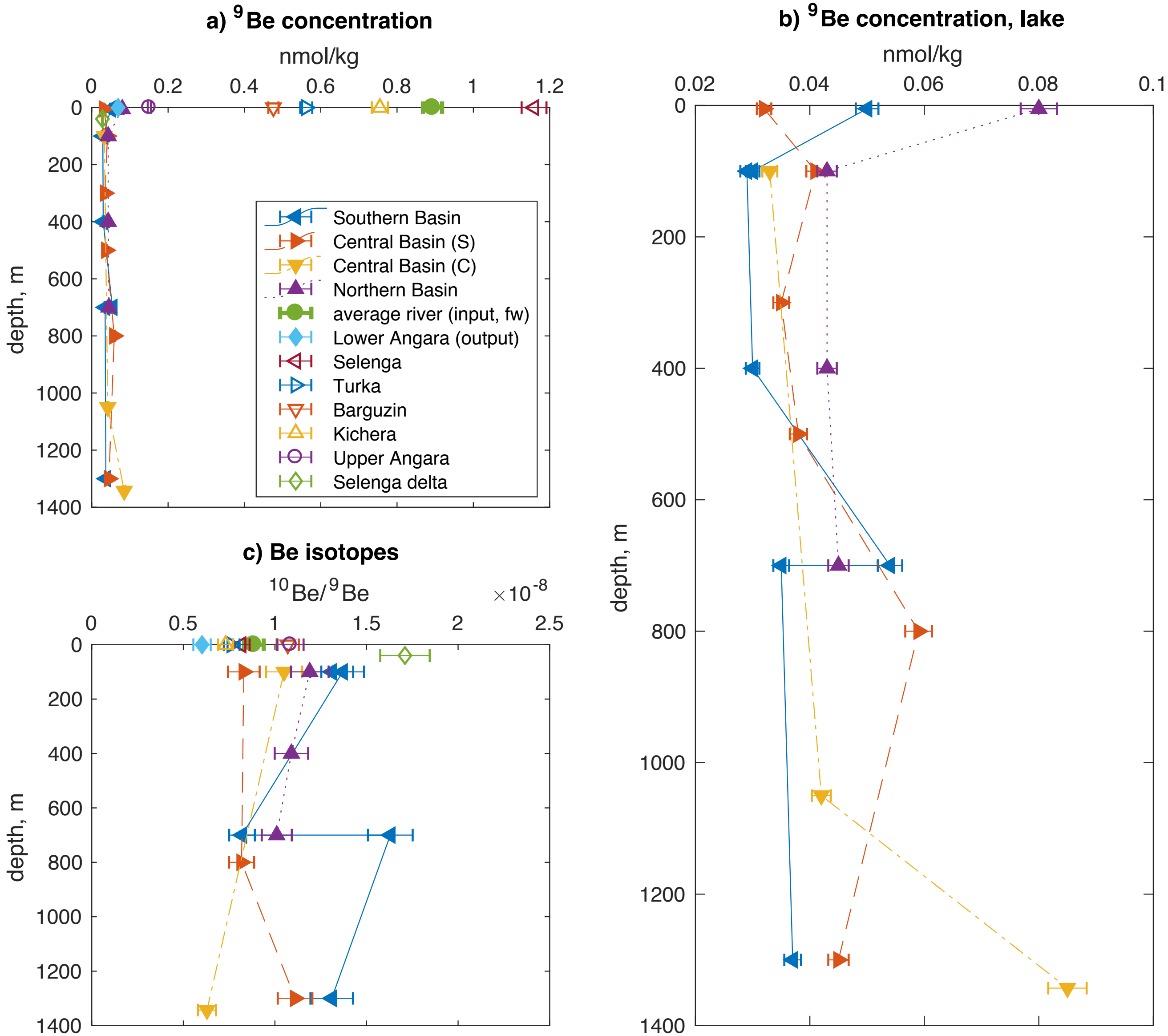

Figure 8: Be concentrations and isotopes in Lake Baikal and its tributaries.

Modern weathering fluxes

- Here, we compare 4 different estimates for denudation/weathering/erosion rates:
  1. Denudation rates (D_10/9Be) calculated from dissolved meteoric $^{10}Be/^{9}Be$ ratios according to von Blanckenburg et al. (2012):

$$\left(\frac{^{10}\mathrm{Be}}{^{9}\mathrm{Be}}\right)_{\mathrm{reac}} = \left(\frac{^{10}\mathrm{Be}}{^{9}\mathrm{Be}}\right)_{\mathrm{diss}} = \frac{F_{\mathrm{met}}^{^{10}\mathrm{Be}}}{D * [^{9}\mathrm{Be}]_{\mathrm{parent}} * (f_{\mathrm{reac}}^{^{9}\mathrm{Be}} + f_{\mathrm{diss}}^{^{9}\mathrm{Be}})} \quad (9)$$

  2. Chemical erosion/weathering rates (E_chem) calculated from total dissolved solid concentrations and water discharge data.

  3. Physical erosion rates from:
     I. Suspended sediment concentrations measured in this study combined with discharge data (E_phys).
     II. Because the above approach probably underestimates sediment flux, in not accounting for bedload, we also combine sediment flux estimates for the whole Baikal catchment (Granina, 1997) with water discharge data to derive a Lake Baikal wide physical erosion rate (lake E_phys).

Modern weathering fluxes

These are preliminary results/interpretations.

$^{10}Be/^{9}Be$ derived denudation rates are highest for the Selenga river, and decrease towards the North, although catchments there have steeper average slopes. At the same time permafrost soils occur predominantly in the North – do they slow denudation?

In contrast, chemical weathering fluxes are higher in the North (Kichera estimate uncertain, no reliable estimate for discharge). Glaciers mostly occur in the North of the Lake Baikal catchment (and reached lake level during the last ice age; Karabanov et al., 1998). High chemical weathering fluxes due to weathering of glacially produced fine sediments?

Physical erosion rates are very low compared to $^{10}Be/^{9}Be$ derived denudation rates, particularly for the Selenga. Storage of suspended matter and sediments along the fluvial transport cascade?

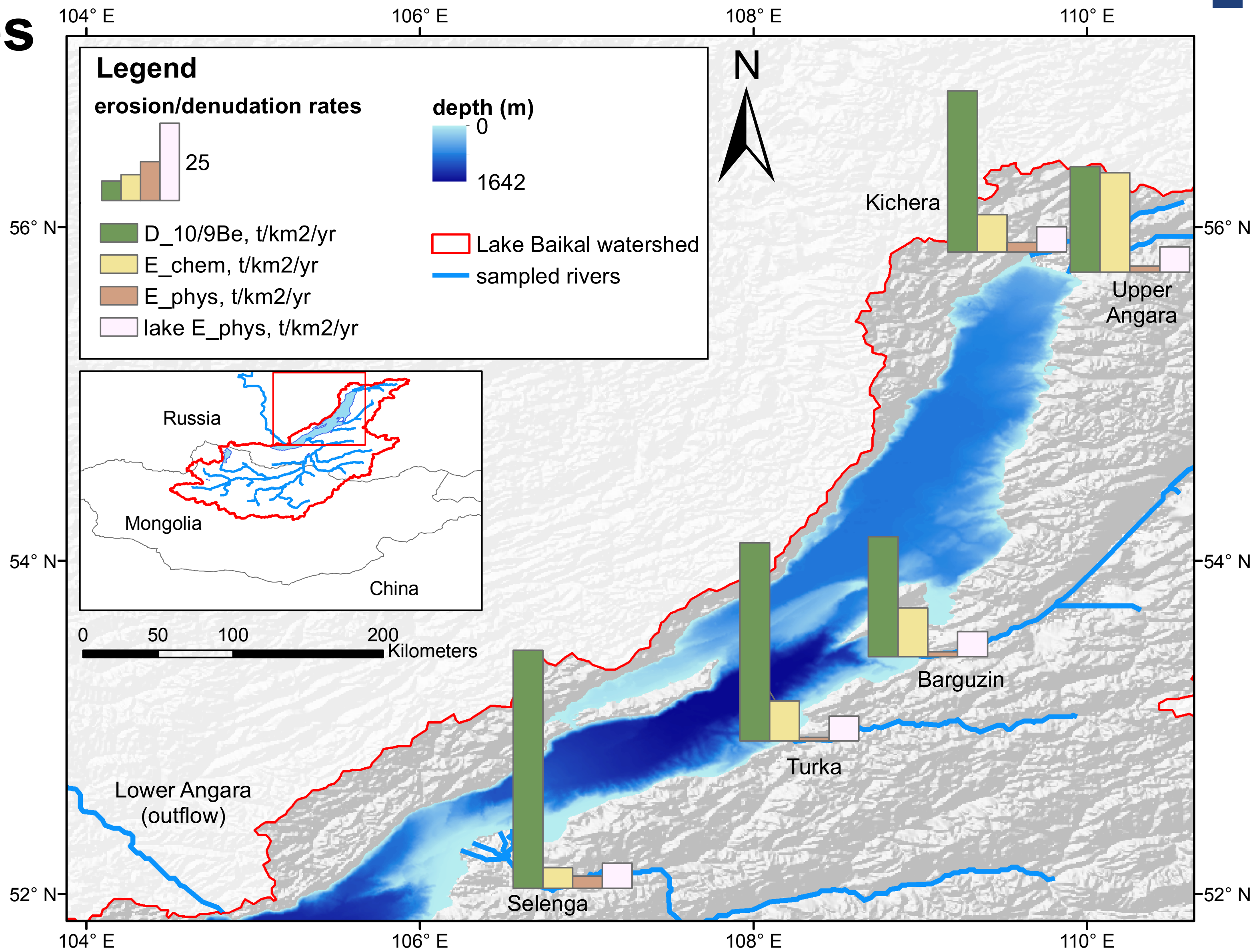

Figure 9: Estimates of denudation and erosion rates for the sampled rivers.

Thank you very much for your attention.

- If you have any questions don't hesitate to contact me during the Q&A session or via e-mail.

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