AGU Chapman
Oxnard, 2011

Glacial-interglacial weathering in the Himalayan system:
a source to sink approach

Maarten LUPKER[a], Christian FRANCE-LANORD[a], Valier GALY[b],

[a] Centre de Recherches Pétrographiques et Géochimiques (CRPG), BP20, Nancy, FRANCE.
[b] Woods Hole Oceanographic Institution (WHOI), 266 Woods Hole Rd., Woods Hole, Ma. 02543, USA

Contact: mlupker@crpg.cnrs-nancy.fr; cfl@crpg.cnrs-nancy.fr; vgaly@whoi.edu

I - Introduction

Chemical weathering is central in earth surface biogeochemical cycles:

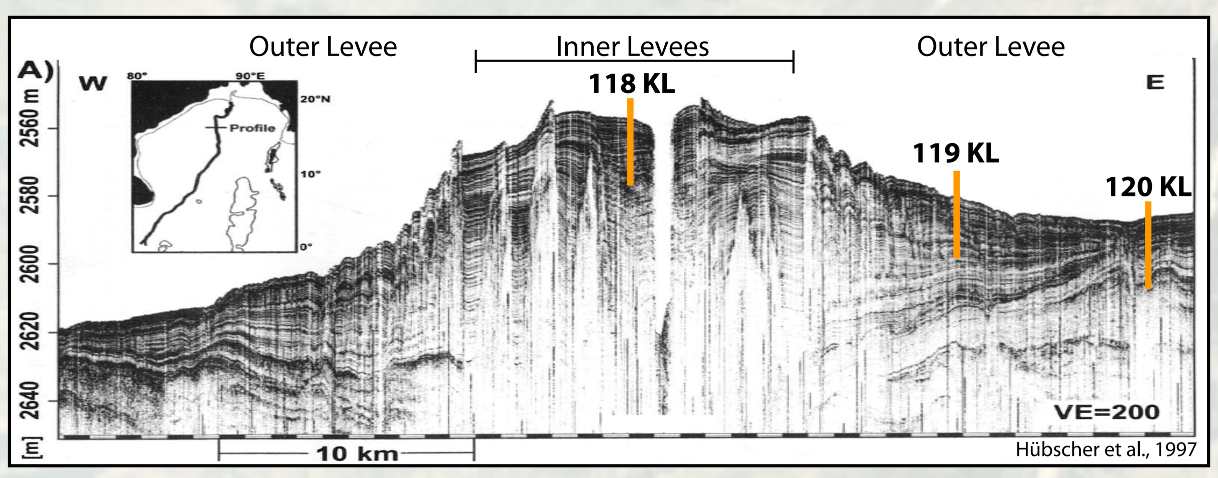
- It is redistributing chemical elements between exogenic reservoirs, which is essential to many organic and inorganic cycles.
- By consuming atmospheric CO_2 and transporting it to the oceans as bicarbonate ions (HCO_3^-) that will eventually precipitate as carbonates, silicate weathering balances (along with biospheric organic carbon burial) mantle and metamorphic CO_2 input into the atmosphere.
- Weathering rates are a function of temperature and runoff and can thus be used as proxy for paleoclimatic or paleogeographic reconstructions.
- Weathering is also part of the evolution of landscape regarding the retroactions existing between physical erosion and chemical weathering.

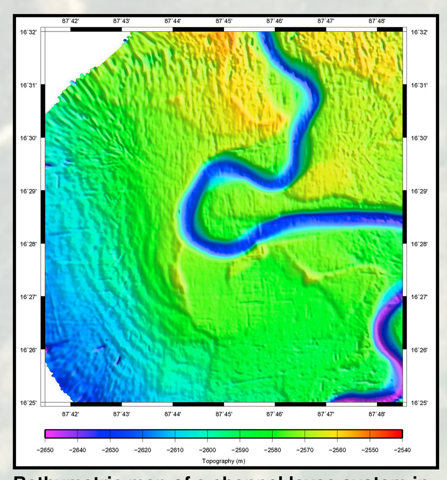
Nevertheless, the exact locus of weathering in a continental scale basin and it's response to changes in external forcing has never been fully addressed. We report the evolution of sediment chemistry with respect to weathering in the modern Ganga-Brahmaputra system and investigate how this signal has varied since Last Glacial Maximum (LGM) using sediment cores from the Bay of Bengal.

II - Samples and methods

Field campaigns were undertaken from 1999 to 2010, mainly during monsoon to cover **all major tributaries of the Ganga and Brahmaputra** in Nepal, India and Bangladesh. In each sampling location and when possible river sediments were sampled at different depth in the channel to document the full chemical variability of the river.

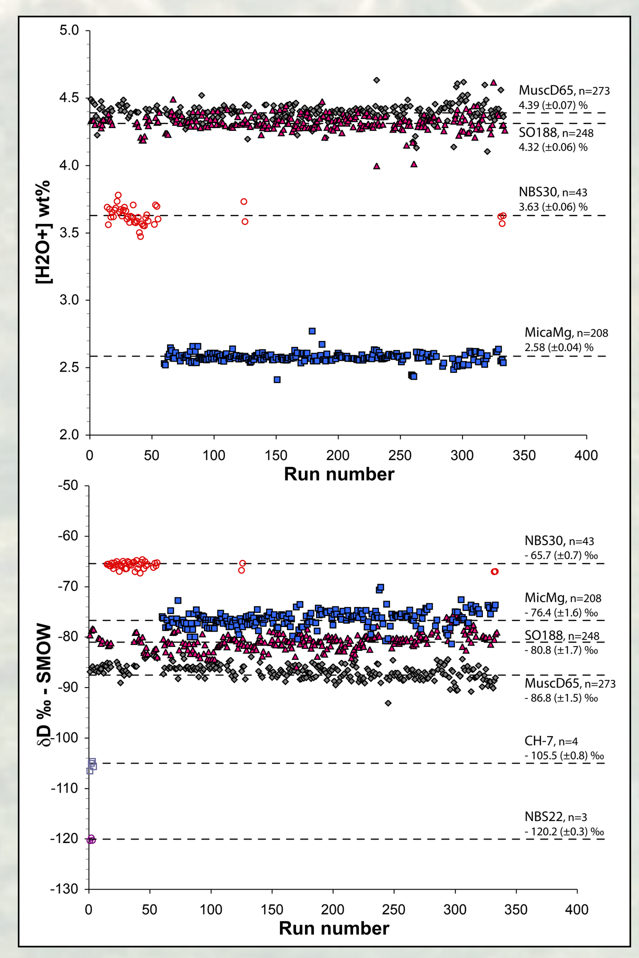
Sediment cores from the Bay of Bengal were recovered during RV-Sonne SO93 cruise and sampled the delta foreset and the active channel levee of GB turbidite system in the Bay of Bengal (Schwenk et al., 2005). The cores were dated using ^{14}C on planktonic foraminifers (Weber et al., 1997). Theses cores recorded Himalayan erosion history from **Last Glacial Maximum (LGM) to present.**





Bathymetric map of a channel levee system in the Bengal Fan (SO188 Cruise Report)

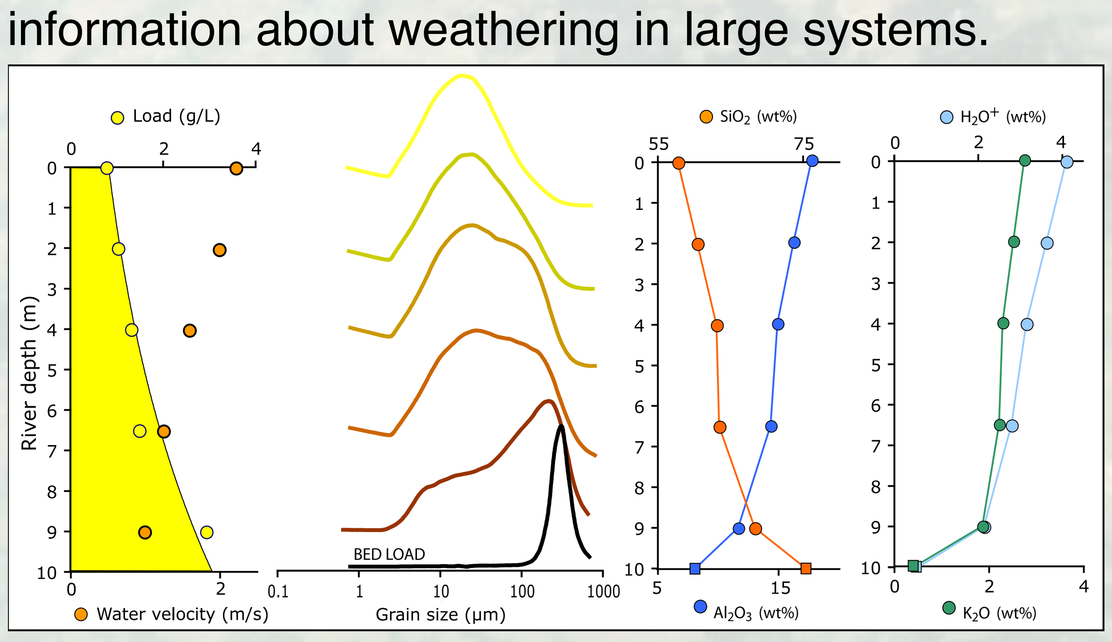
We follow the evolution of Na and K in sediments to trace weathering using a source to sink approach. In addition, we introduce the less conventional **sediment hydration H_2O^+ as complementary weathering tracer** that can be used in the marine environment contrary to Na that is hindered by marine Na. As minerals weather, their structural OH content increases to balance cation release. The D/H isotopic composition of hydroxyls reflects the isotopic composition of water they were formed from and could potentially be used as weathering locus tracing.

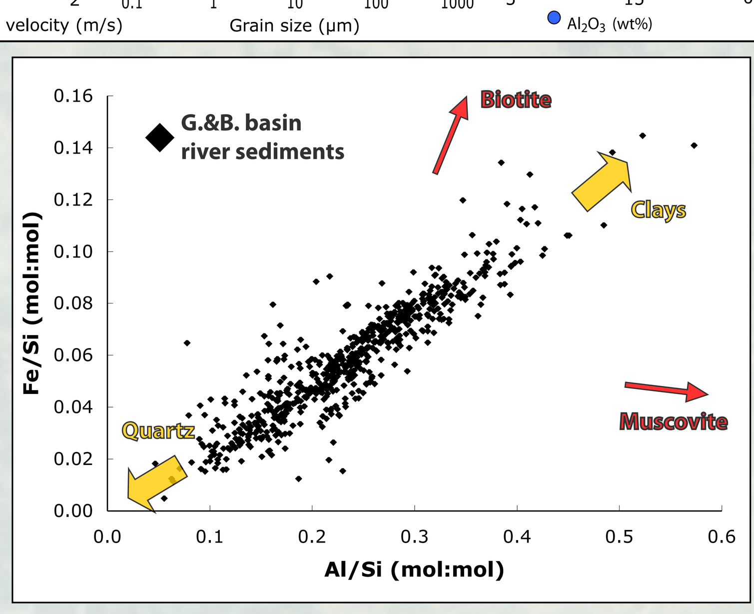


H_2O^+ and D/H were measured on a EA-IRMS. Special care was taken to remove adsorbed, free water before analysis.
Long term absolute reproducibility is 2 ‰ on δD and 0.1% on H_2O^+.

III - Mineral sorting

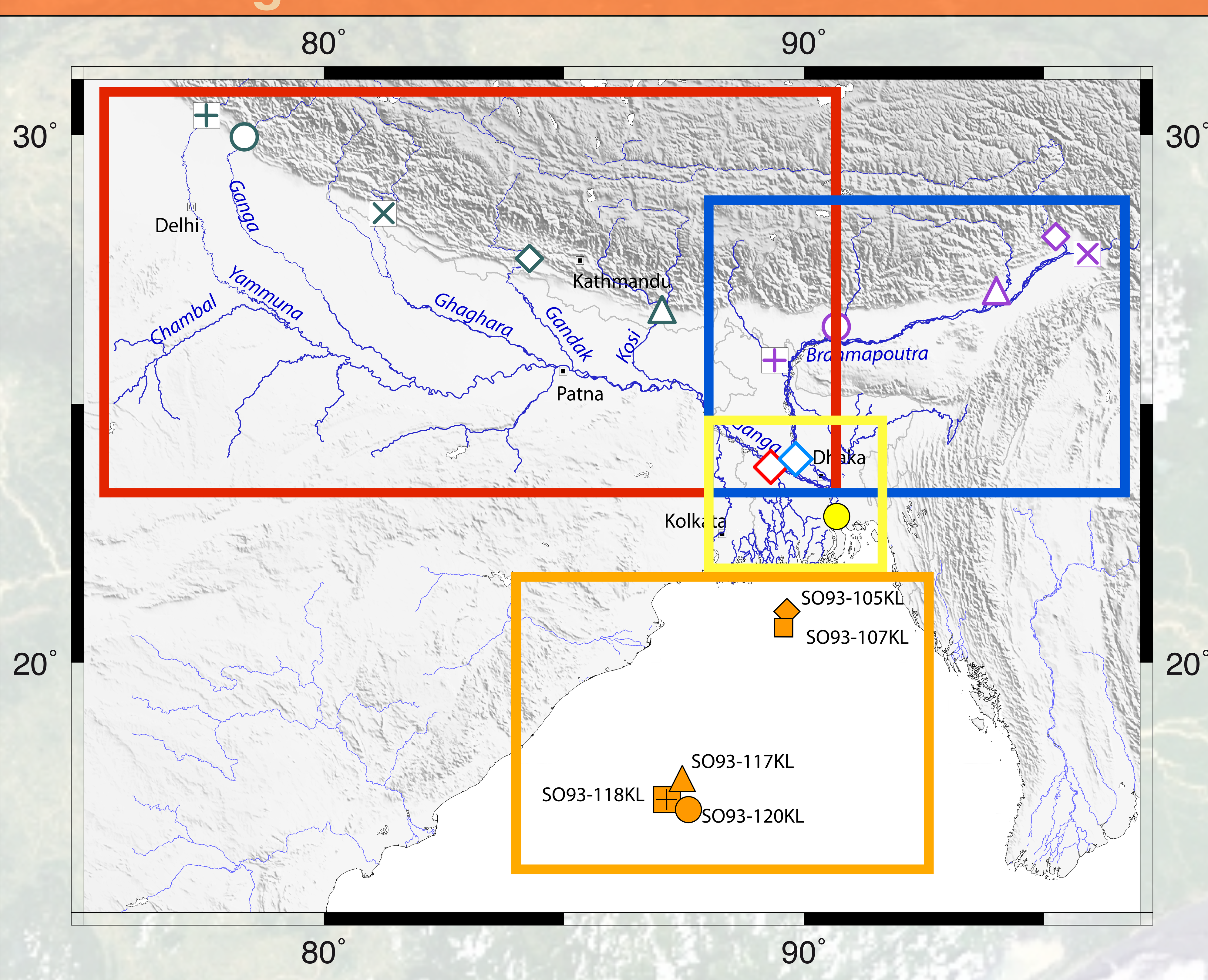
Mineral sorting in the river water column is the **first order control on the chemical composition** of sediments. This effect should be carefully accounted for in order to derive integrated information about weathering in large systems.



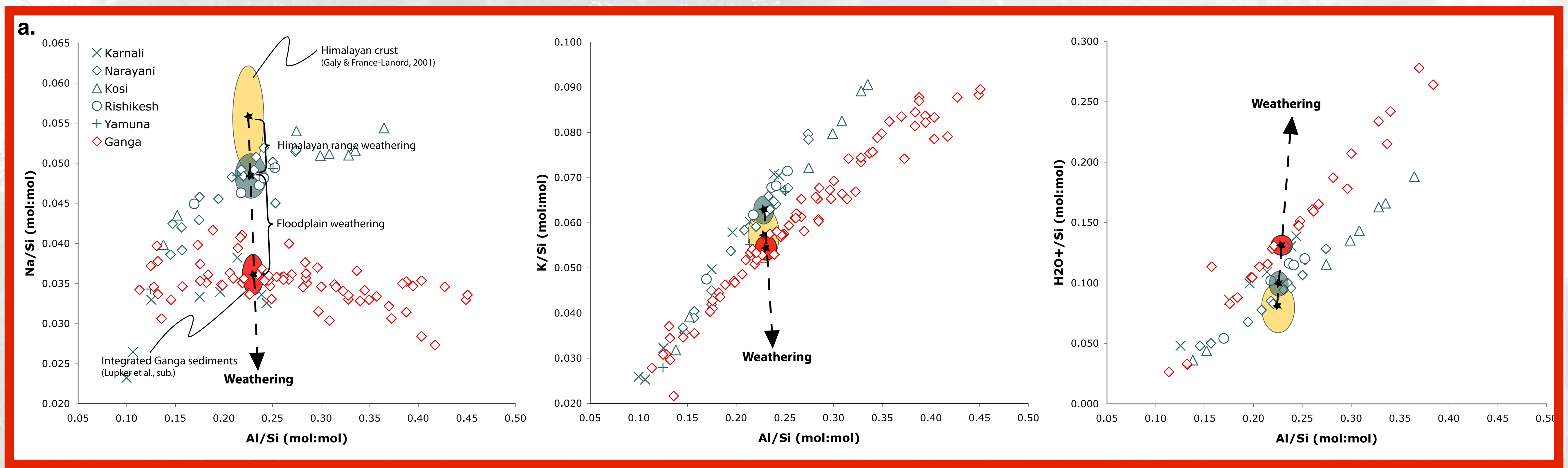


References:
Galy et al., 2008 - *QSR*
Granet et al., 2010 - *GCA*
Hübscher et al., 1997 - *Marine Geology*
Kudrass et al., 2001 - *Geology*
Schwenk et al., 2005 - *Mar. Pet. Geol.*
Weber et al., 1997 - *Geology*

IV - Setting



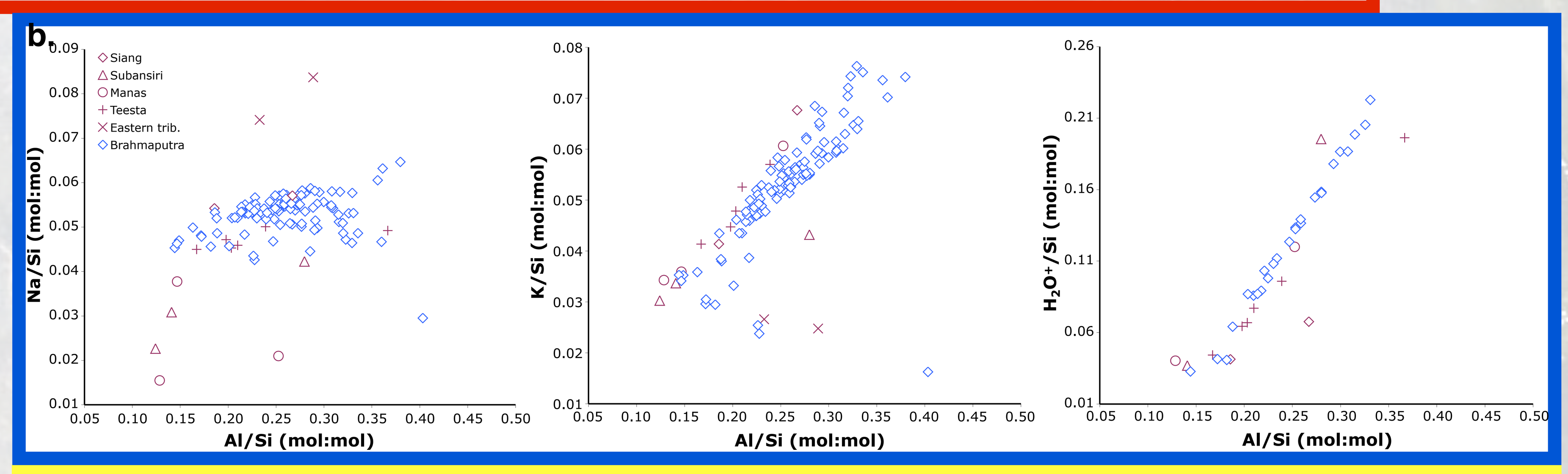
V - Modern Himalayan system weathering

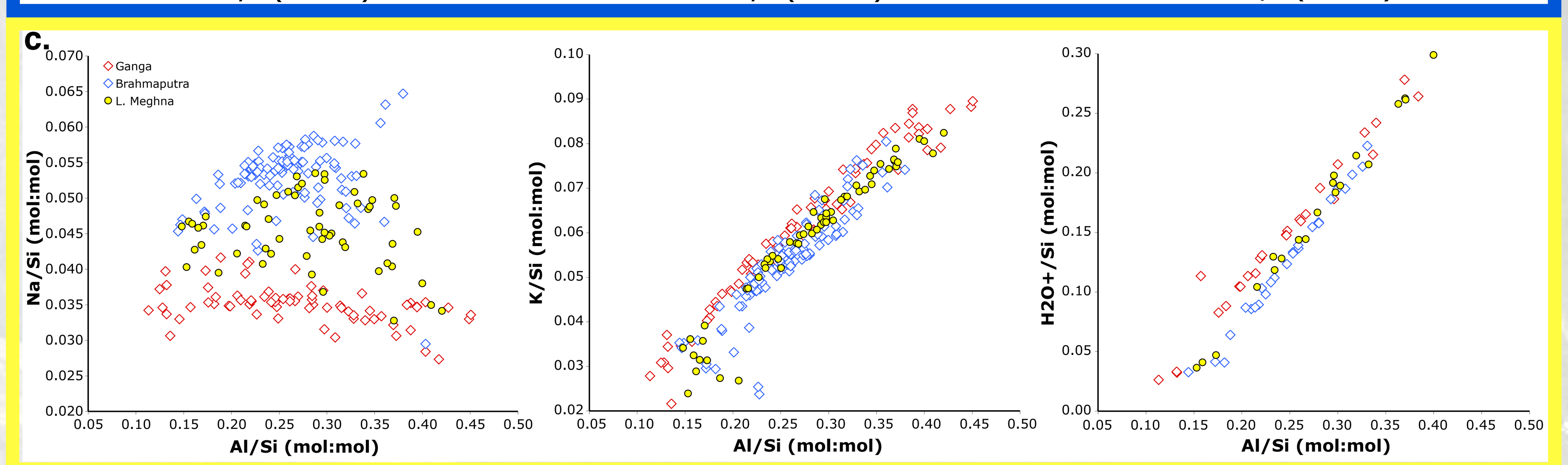


a. Comparing himalayan source rocks (yellow) with sediments sampled at in the main rivers of the front of the Himalayan range (green) and sediments sampled in Bangladesh (red) shows that **weathering mainly occurs in the Gangetic floodplain.**

b. The Brahmaputra watershed was also studied, but the more complex geology of the suture zone prevents the estimation of an average source rock composition. Furthermore highly variable sediment composition among Himalayan tributaries prevents the solving of a basin wide weathering budget.

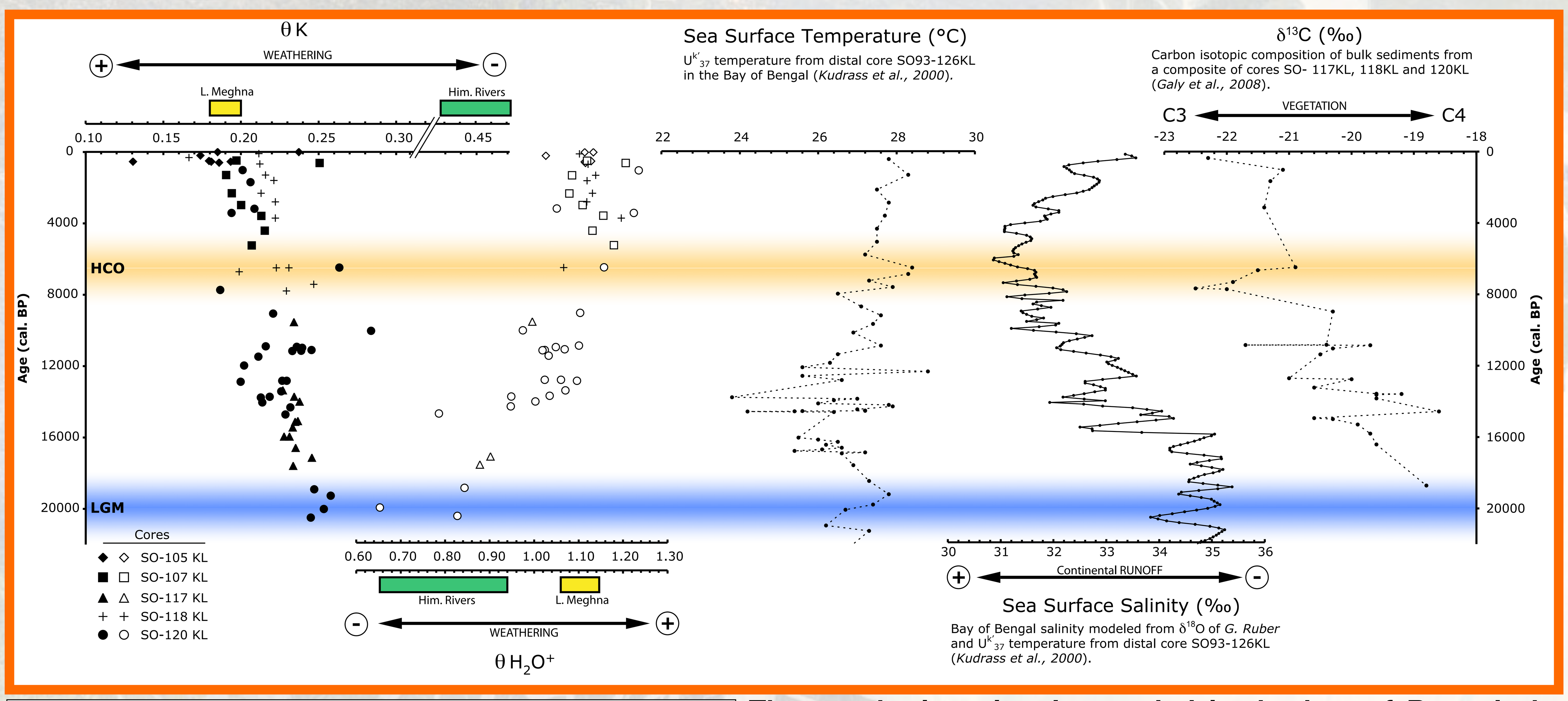
c. The Lower Meghna, after the confluence of the Brahmaputra and Ganga records the mixing signal of the two watersheds.

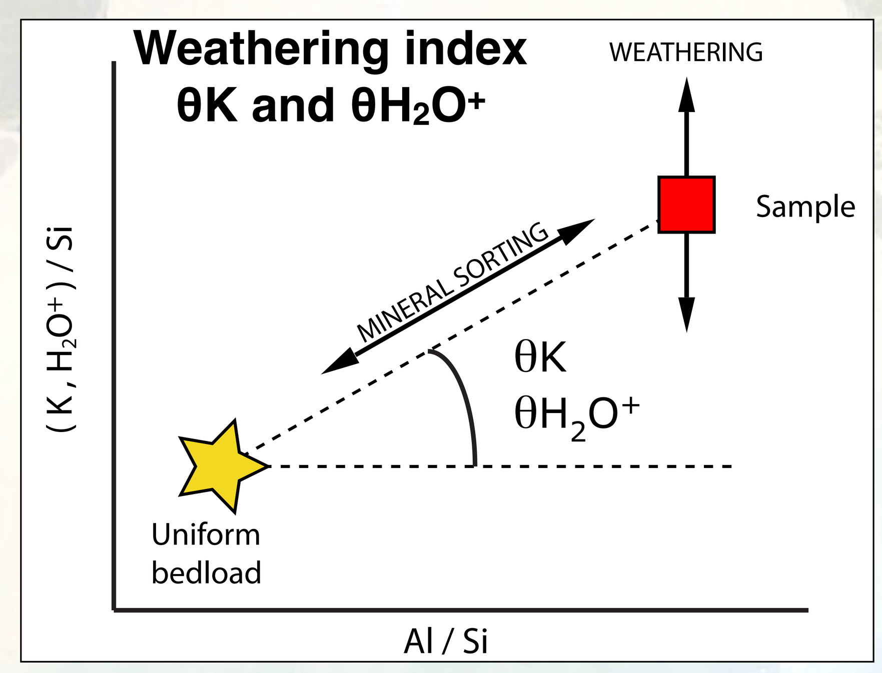


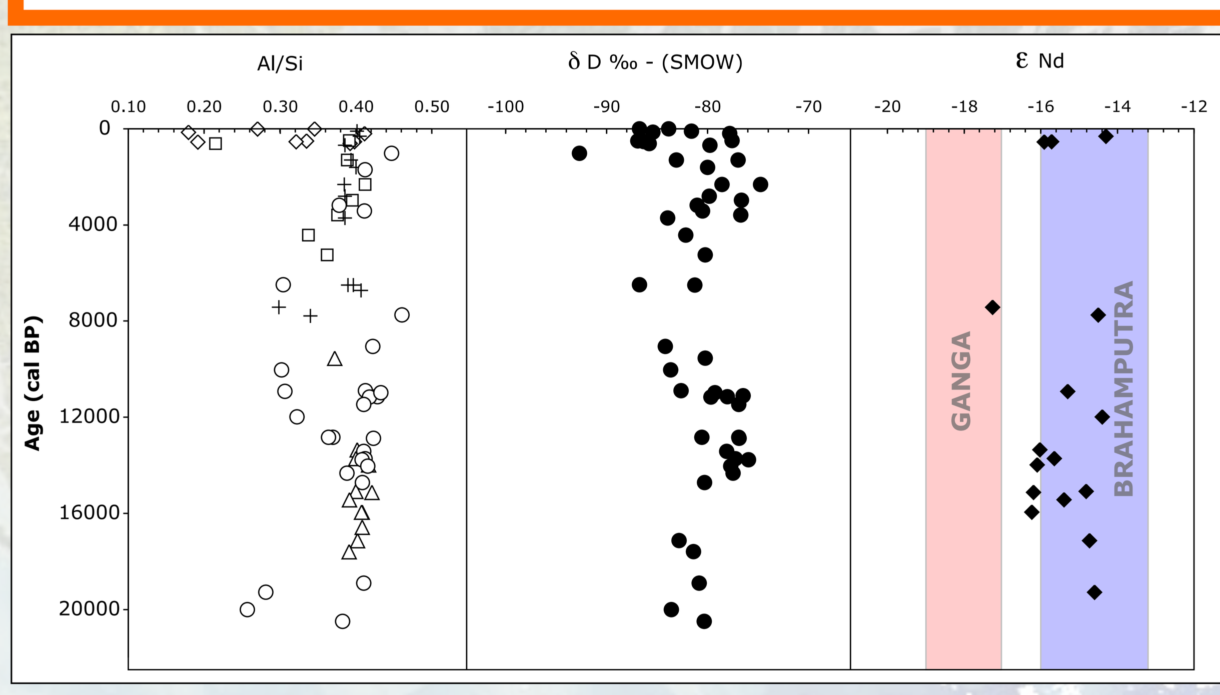


VI - Himalayan system weathering since LGM

A composite record was made from 5 dated cores in the Bay of Bengal and analyzed for K and H_2O^+ to record paleo-weathering of the Himalayan sediments up to the LGM. Mineralogy and grain size have a strong control on K and H_2O^+ content. The sediments are the result of a binary mixing of coarse bed-load and a fine clay fraction. Mineralogical sorting controls the mixing between these two end-members. Weathering, in turn, leads to a decrease in mobile element content (Na, K) and an increase in H_2O^+ while immobile elements (Al, Fe) are not affected which modifies the position of the end-member. Here we use the slope between bedload and the sediment core sample in an (K, H_2O^+)/Si vs Al/Si diagram to derive the reliable weathering signals θK and θ H_2O^+. Normalization to Si prevents artifacts due to variable carbonate content. Na cannot be used in the marine environment.







The weathering signal recorded in the bay of Bengal shows that the Himalayan system has reacted to abrupt climate change upon deglaciation by exporting less weathered sediments.

The observed trends in **θK and θH_2O^+** cannot be explained by changes in the relative contribution of Ganga and Brahmaputra as this would result in a covarying trend in θK and θH_2O^+. Nd isotopes, that are independent of grain size, further support a relatively stable origin of sediments since ca. 20ky.

The isotopic composition of structural hydroxyls does not show any variation during the same period. This is likely due to the high proportion of primary phyllosilicates that dampen the weathering signal carried by secondary OH radicals.

Other proxies show that if sea surface temperature in the Bay of Bengal has changed by only 2°C over this period, discharge deduced from salinity anomalies has peaked during the Holocene Climatic Optimum and is higher today than during LGM (Kudrass et al., 2000). The vegetation in the floodplain has also changed with a decrease in C4 vegetation type *i.e.* grasslands (Galy et al., 2008).

VII - Conclusions

- **The Ganga basin shows that the weathering of Himalayan sediments is more intensive in the floodplain than in the Himalayan catchments.** This points out that in this system, erosion and weathering are spatially decoupled. This can be linked to the short residence time of sediments in the Himalayan catchments were sediments are transferred rapidly to the plain. Downstream, exchange of sediments with the floodplain increases the average residence time in the system (Granet et al., 2010) which could promotes weathering.
- **A large scale basin such as the GB is not completely buffered with respect to rapid environmental changes such as glacials-interlacials.** It is thus possible to retrieve valuable information on short time scale changes occurring within these large basins stored in the detrital sedimentary record.
- **During the LGM, exported Himalayan sediments where less weathered than modern sediments.** As only limited weathering occurs in the Himalayan catchments as suggested by the modern Ganga plain data, a decrease in weathering is most probably due to a change in the floodplain behavior. A low base level combined with a weaker monsoon could possibly limit the ability of rivers to exchange sediments with their floodplain. The sediments are thus transferred much faster and have undergone less weathering than in the present day system.