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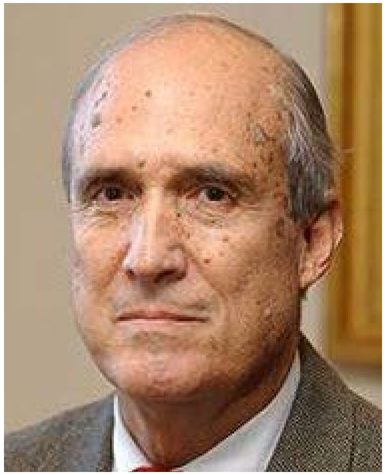
A new negative feedback mechanism for balancing Tibet uplift-driven CO_2 drop: Evidence from Paleogene chemical weathering records in the northern Tibetan Plateau

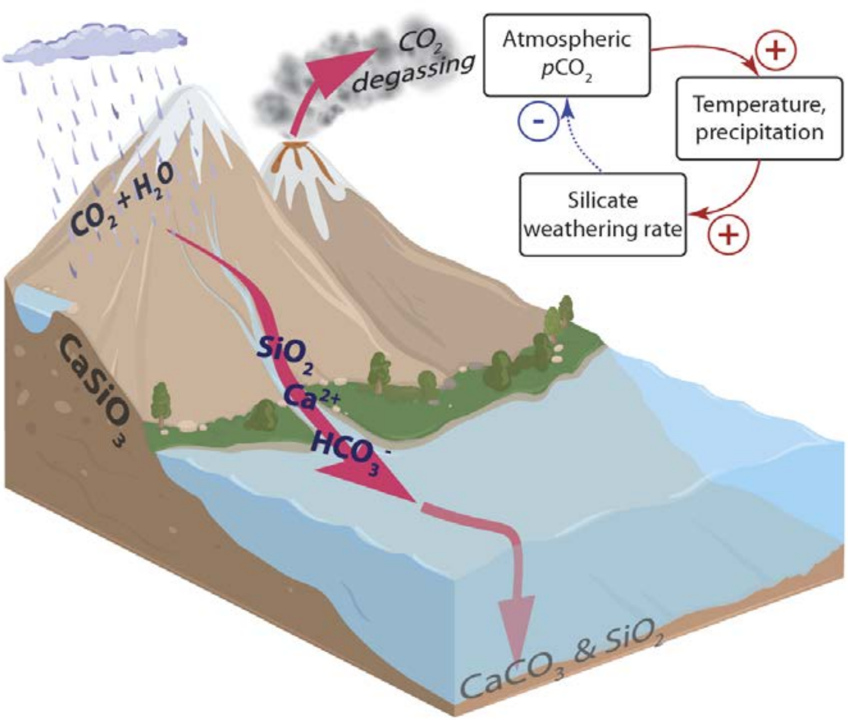
Xiaomin Fang[1], Albert Galy[2], Yibo Yang[1], Weilin Zhang[1], Chengcheng Ye[1], Chunhui Song[3]

1. Institute of Tibetan Plateau Research, CAS
2. CRPG-CNRS-University of Lorraine
3. Lanzhou University

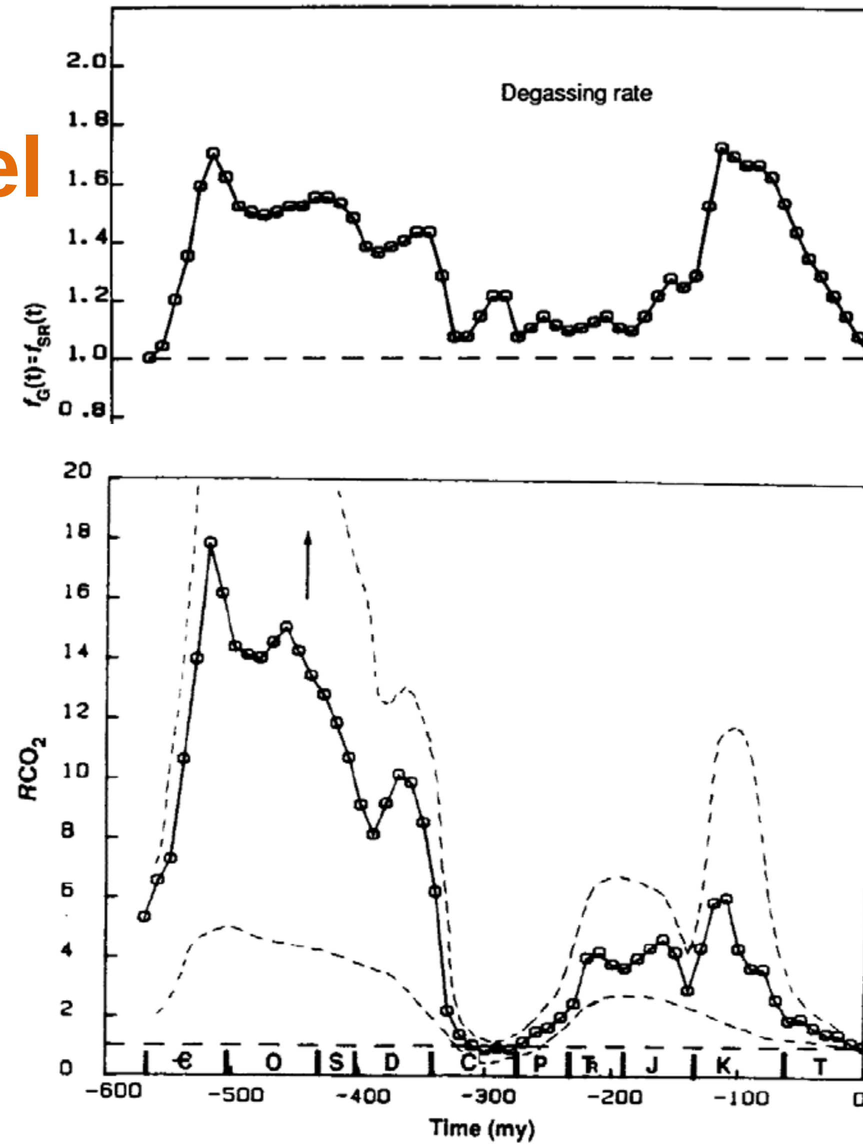
BLAG model



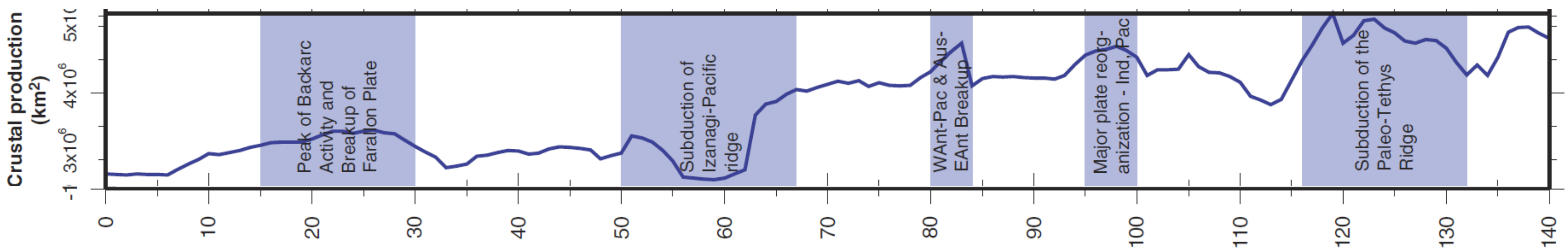
Robert A. Berner



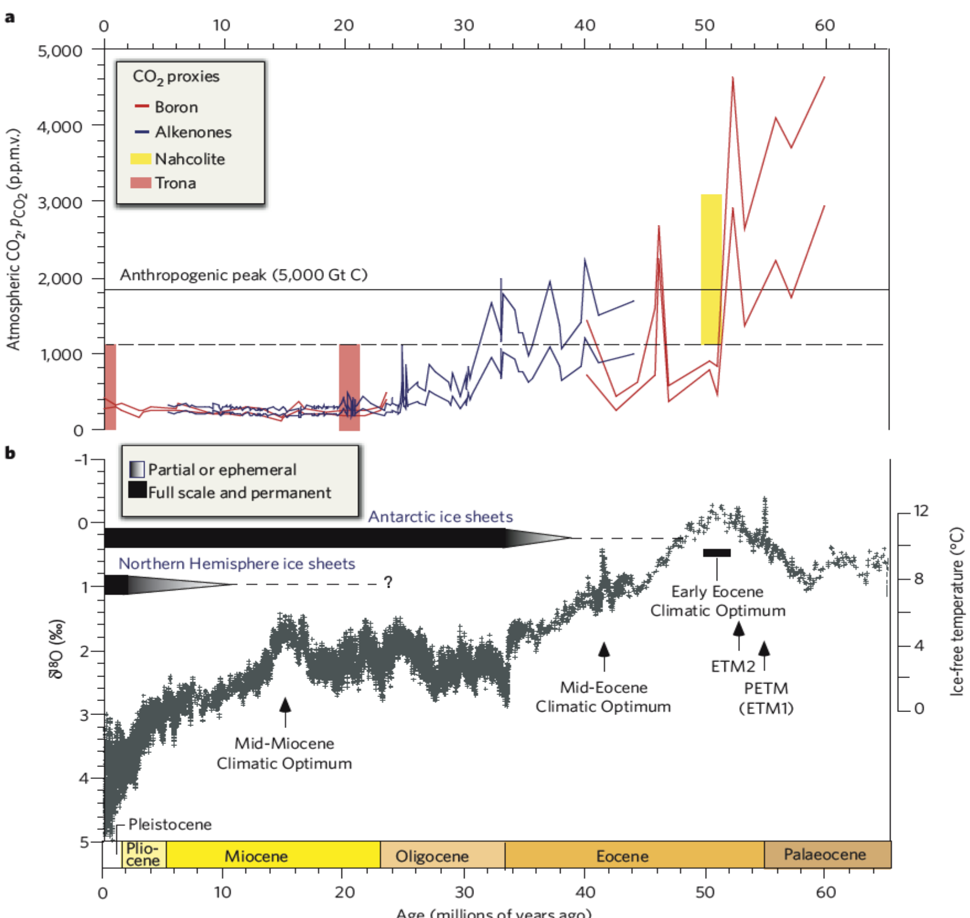
Frings, 2019



Berner, 1990

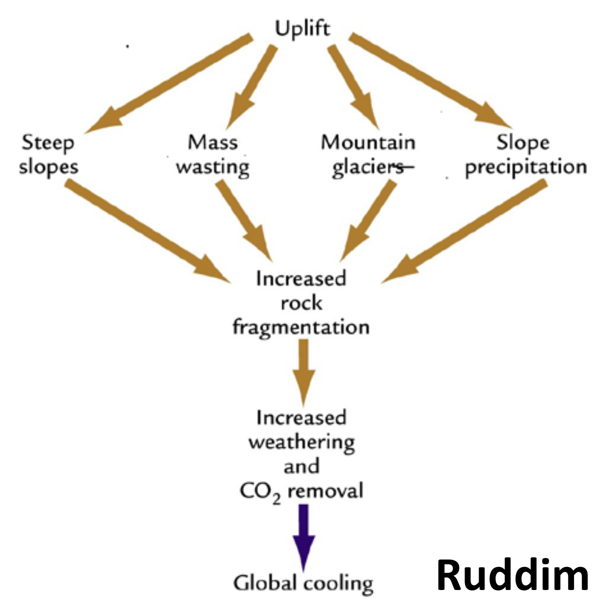


Muller et al., 2008



Uplift-Weathering Hypothesis

Maureen Raymo

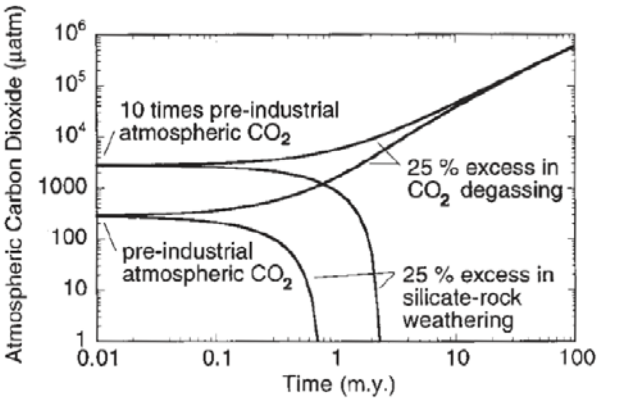


Zachos et al., 2008

Ruddiman, 2008

Negative Feedbacks to maintain geological carbon cycle

The imbalance resulting from accelerated CO_2 consumption and a relatively stable CO_2 input from volcanic degassing during the Cenozoic should have depleted atmospheric CO_2 within a few million years.



Bener and Caldeira， 1997

Therefore, a negative feedback mechanism must have stabilised the carbon cycle.

1 Reduce organic carbon burial (Raymo and Ruddiman, 1992)
2 Enhance reversal weathering and CO_2 release (Raymo and Ruddiman, 1992)
3 Enhance metamorphism degassing (Bickle, 1996)
4 Enhance sulfide weathering and CO_2 release (Torres et al., 2014)
5 Reduce Temperature-regulated weathering (Kump and Arthur, 1997)

- 5.1 Ocean crust basalt (Coogan and Dosso, 2015)
- 5.2 Ocean island basalt (Li et al., 2013)
- 5.3 Continental arc (Lee et al., 2015)
- 5.4 Weatherability (Caves et al., 2016)
- 5.5 Weathering in other regions (Kump and Arthur, 1997)

Working hypothesis

CO_2 consumption increase in tectonically active region (e.g., Himalayas, where erosion rate increases)

⬇

CO_2 decline reduced the degree of silicate alternation in tectonically less active region (where erosion rate is stable)

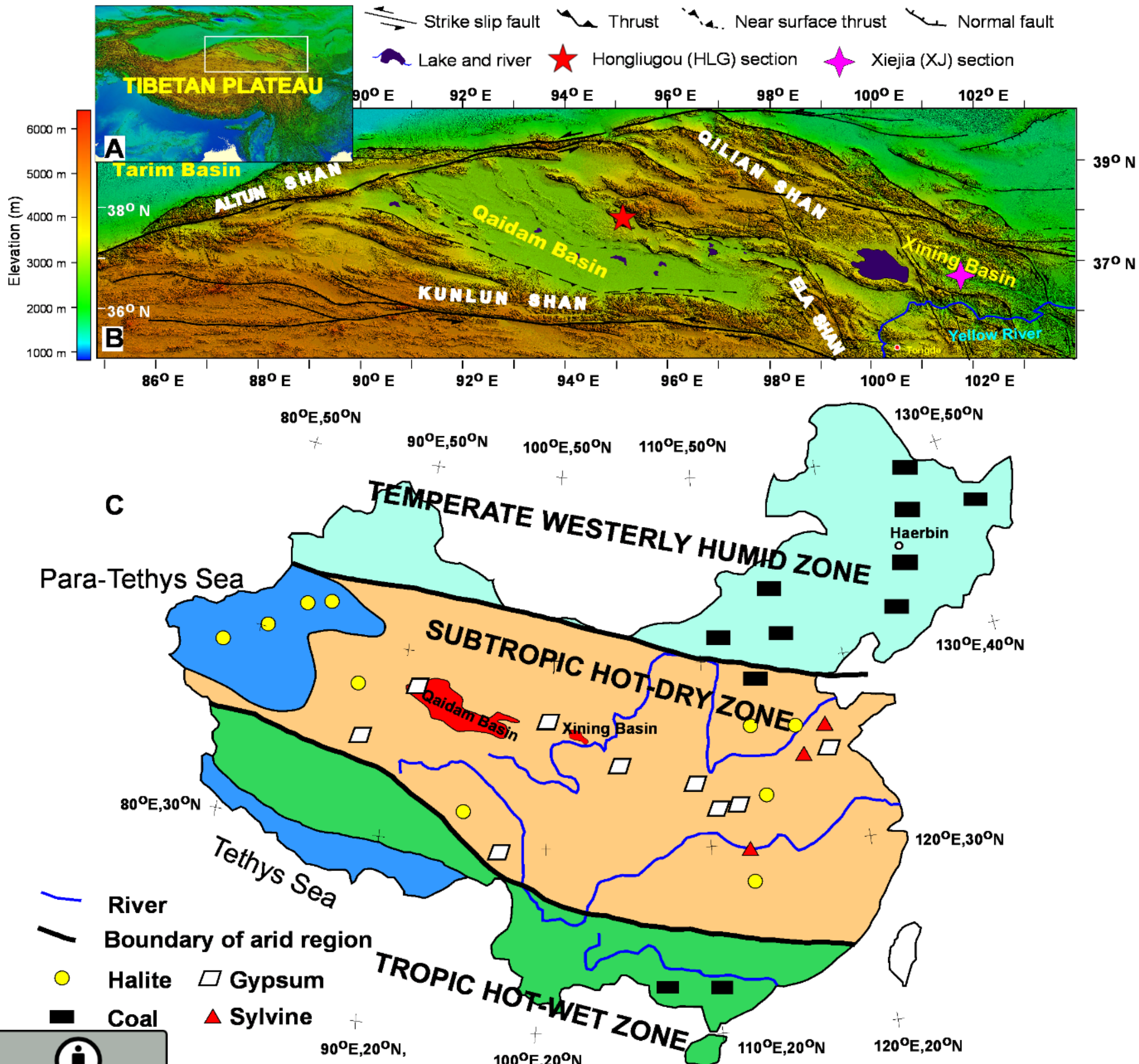
⬇

Decrease in silicate weathering flux and CO2 consumption in tectonically less active region

⬇

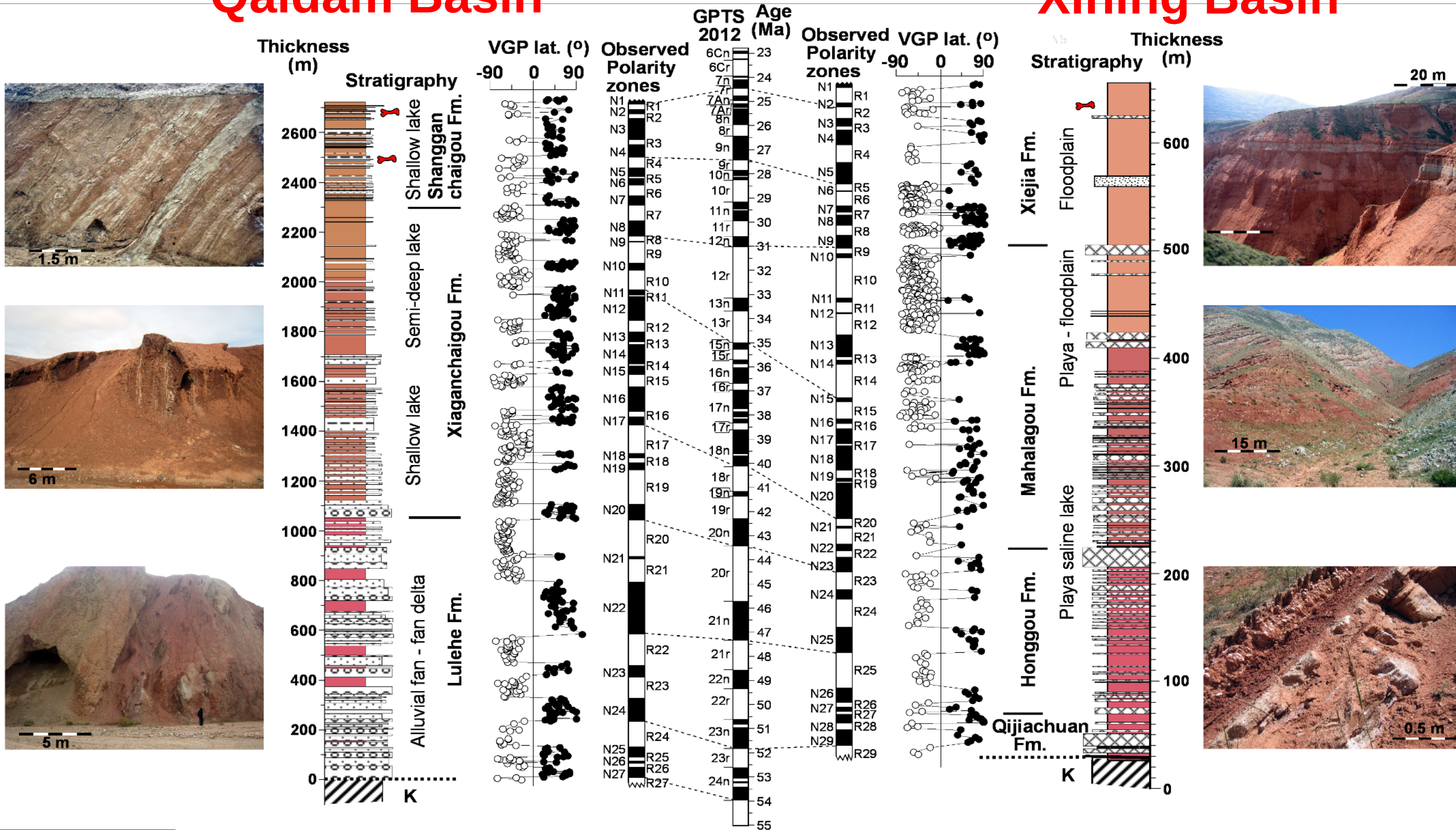
Carbon cycle balanced!!

Study region



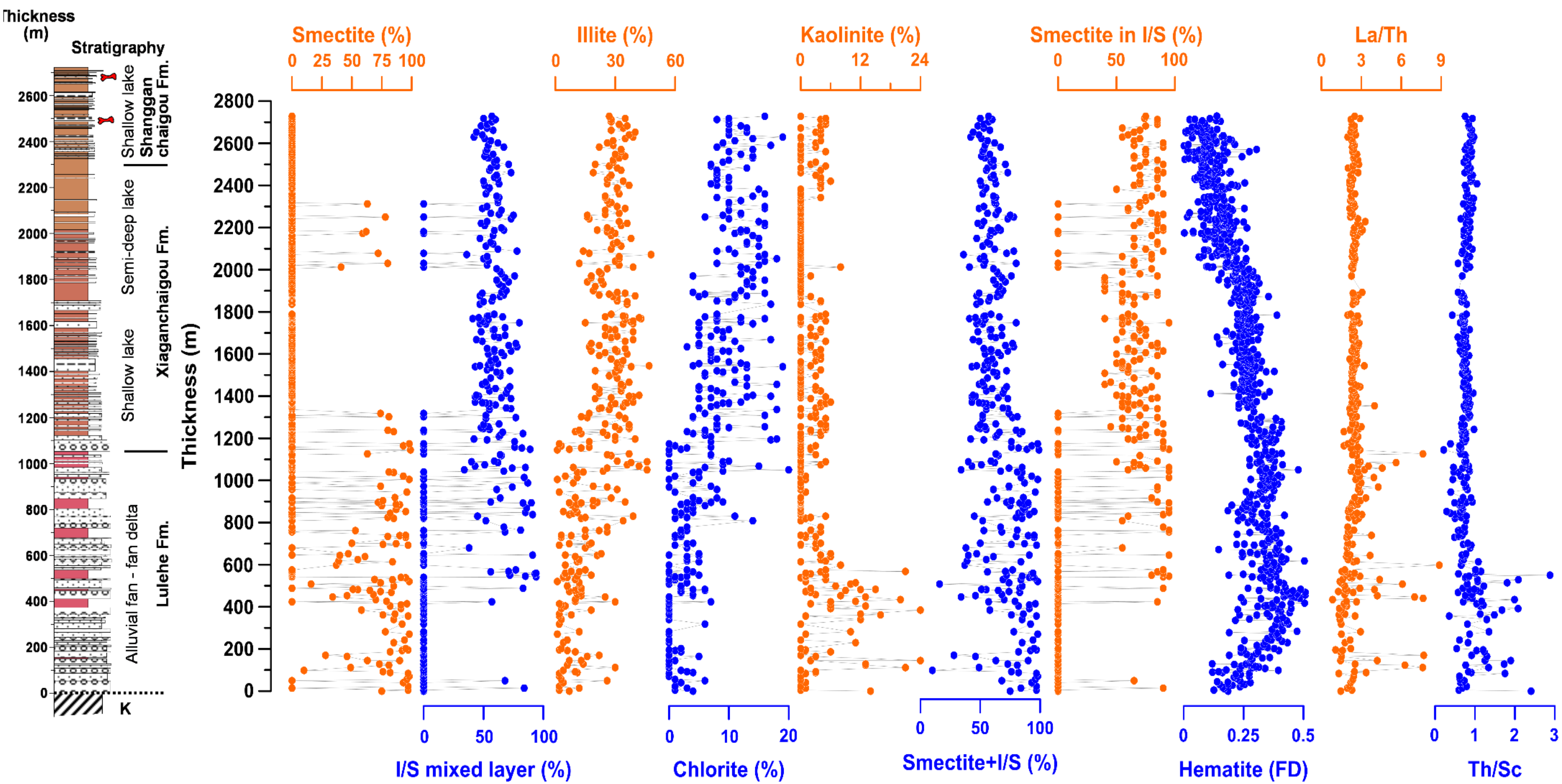
1) During the Paleogene, the northern Tibetan Plateau was a tectonically less active area;
2) The Asian summer monsoon did not reach this region until the beginning of the Neogene

Lithology and Age control

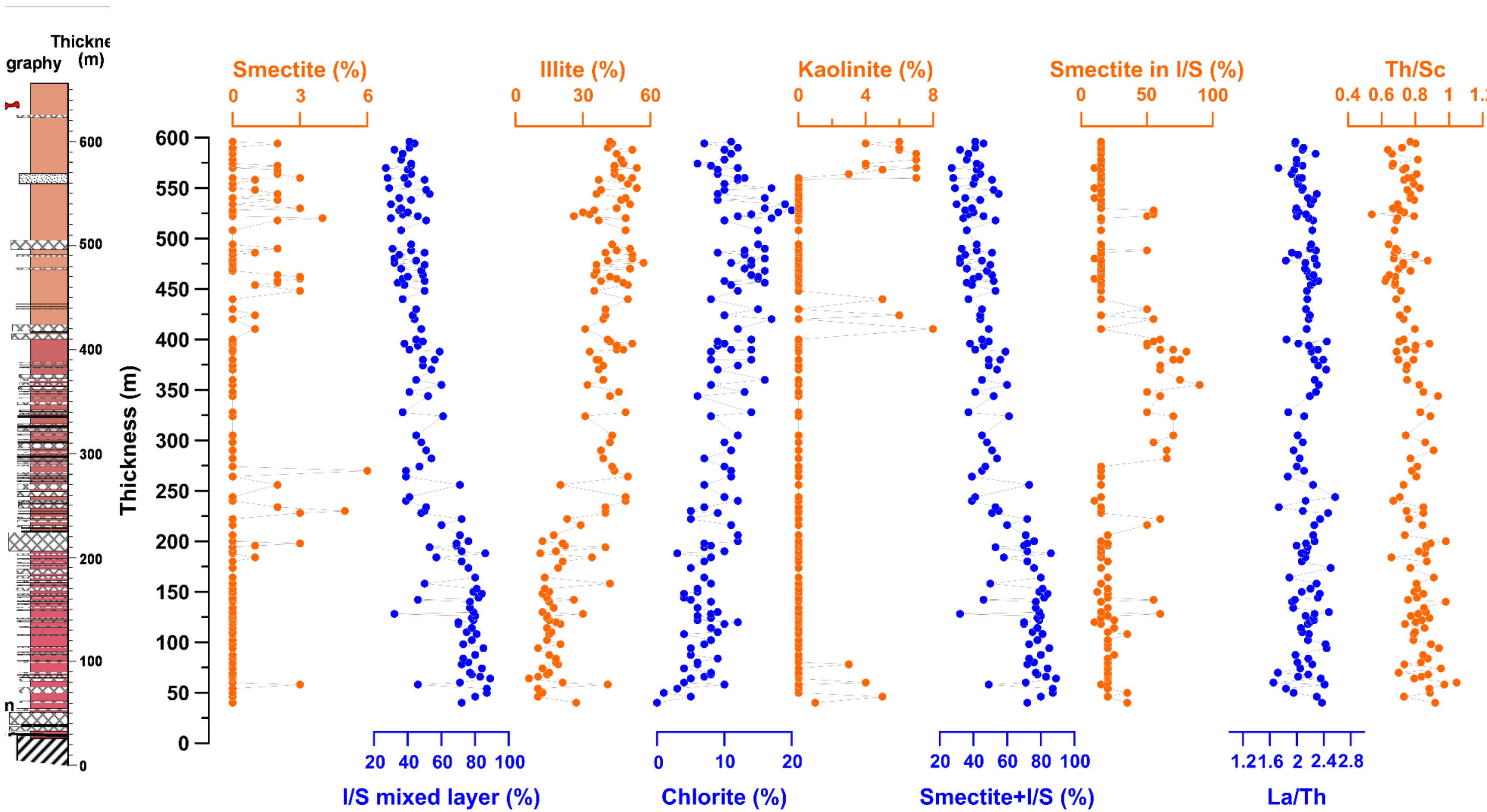


...merate | Sandy conglomerate | Sandstone | Mudstone & siltstone | Muddy limestone | Gypsum & muddy gypsum | Fossil mammal

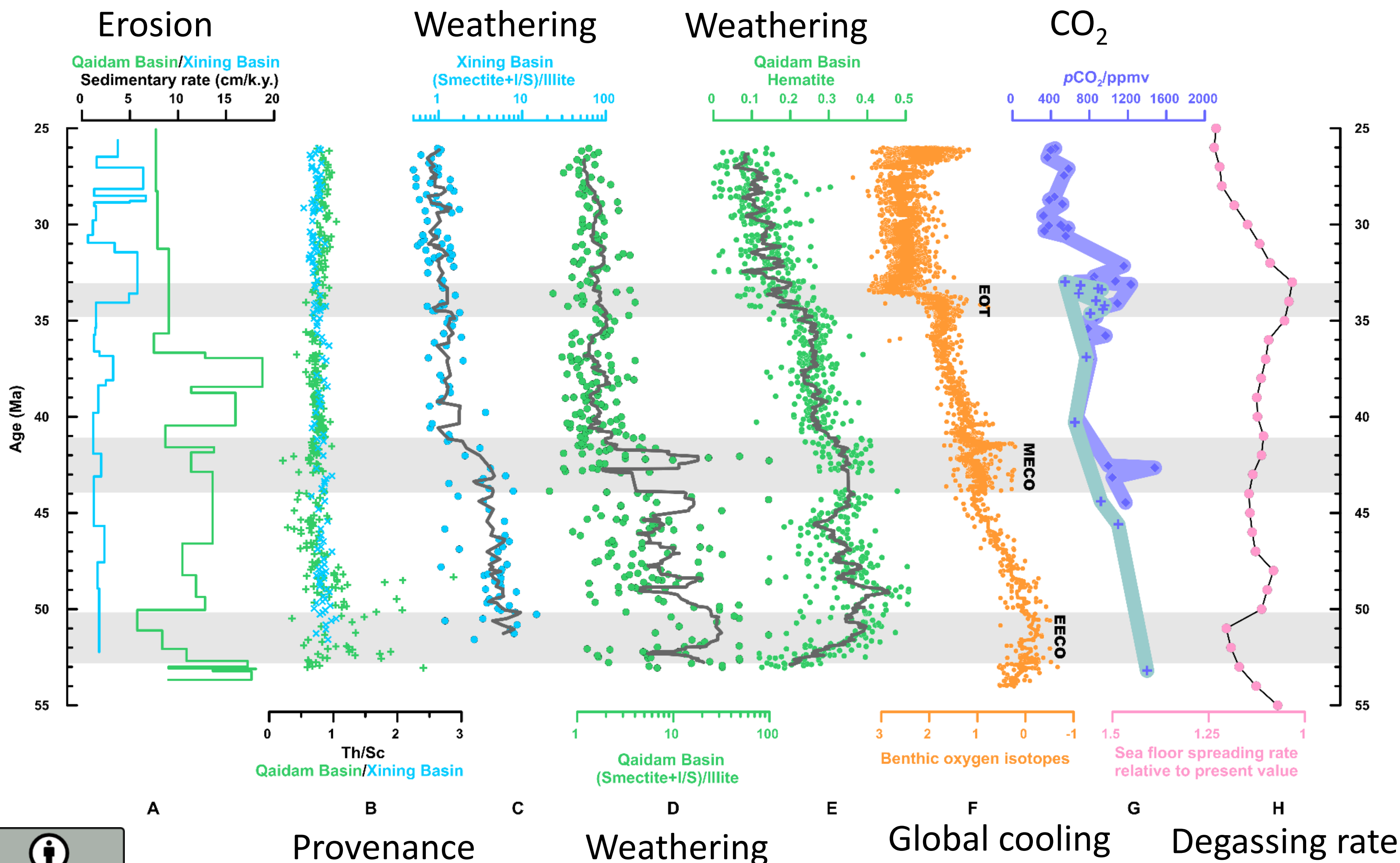
Clay mineral records in Qaidam Basin



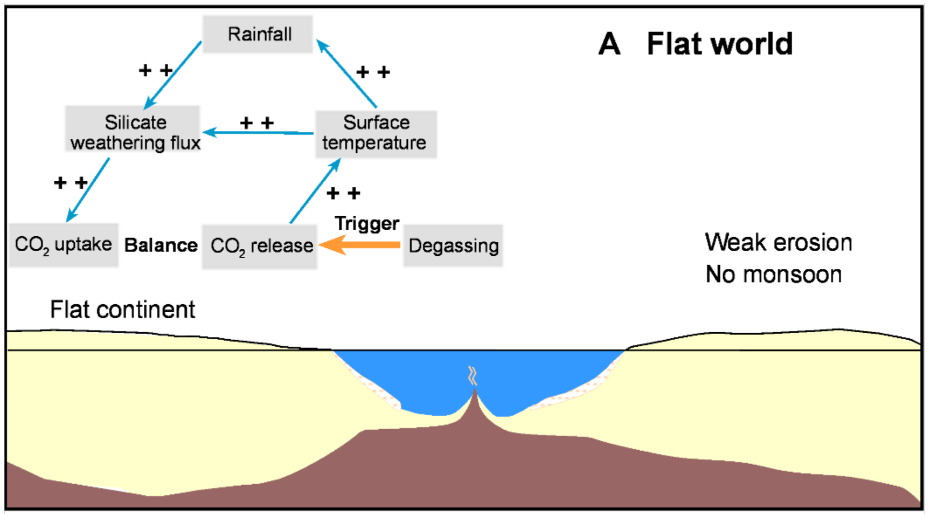
Clay mineral records in Xining Basin

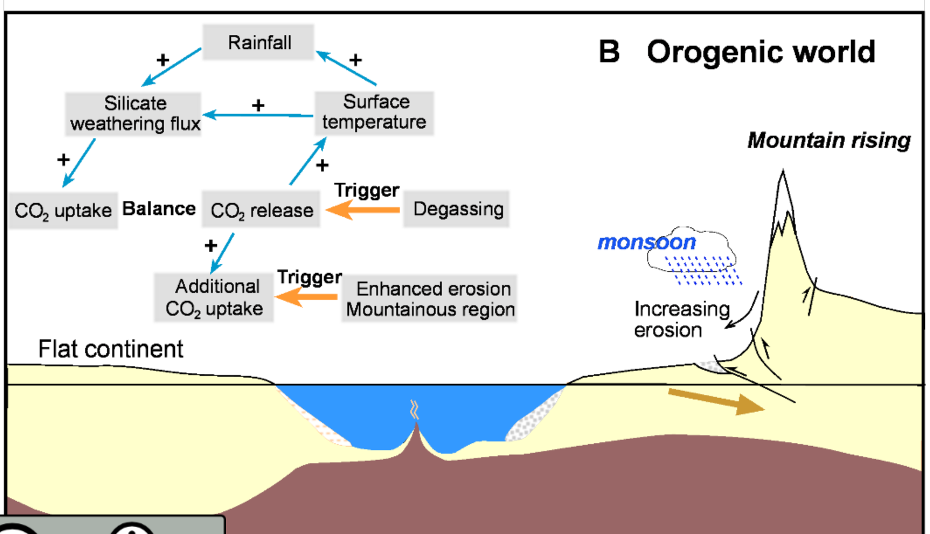


Global cooling regulate silicate weathering intensity in the northern Tibetan Plateau



Conceptual model



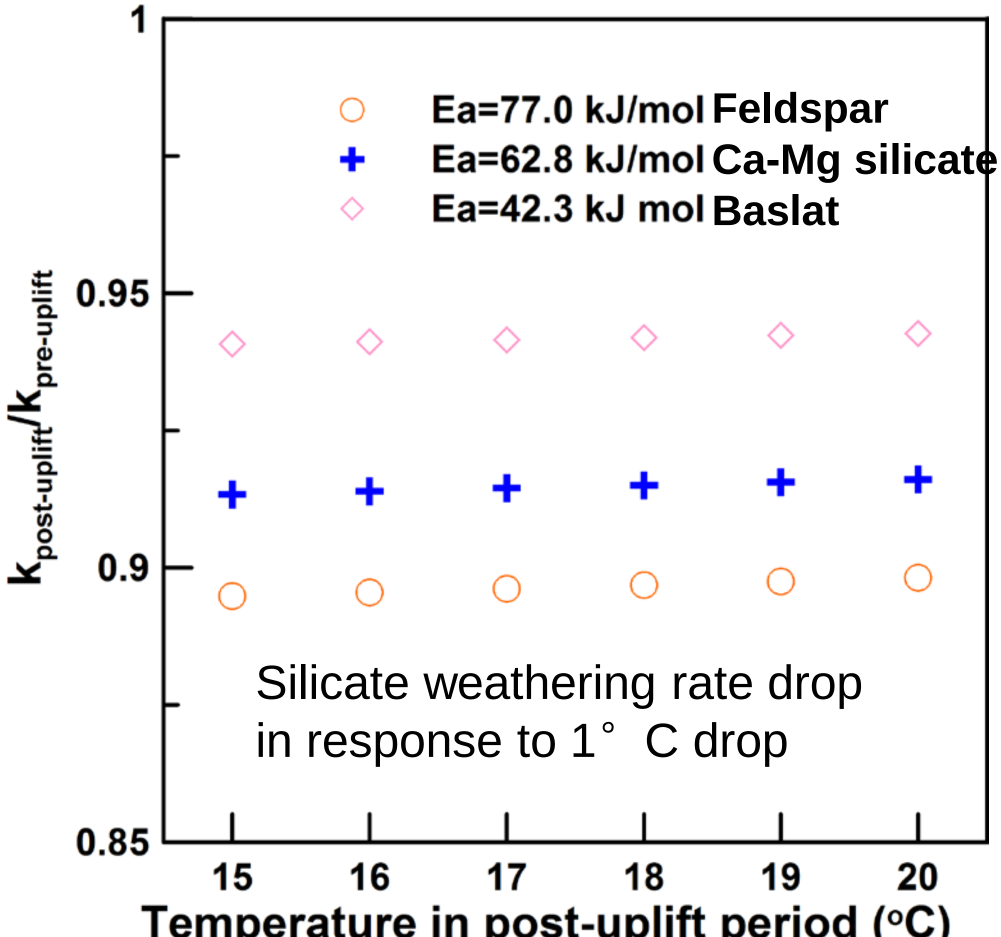


In scenario (A), any increase in degassing flux will lead to an increase in temperature and ultimately will be balanced by nearly the same amount of increase in CO_2 uptake flux through increases in the silicate weathering intensity and thus in the silicate weathering flux.

In scenario (B), given a constant degassing flux, any increase in erosion in orogenic belts will result in an overall increase in the CO_2 uptake flux in orogenic belts. This will be quasi balanced by nearly the same amount of decrease in CO_2 uptake flux in flat tectonically inactive regions through decreases in in the silicate weathering intensity and the silicate weathering flux

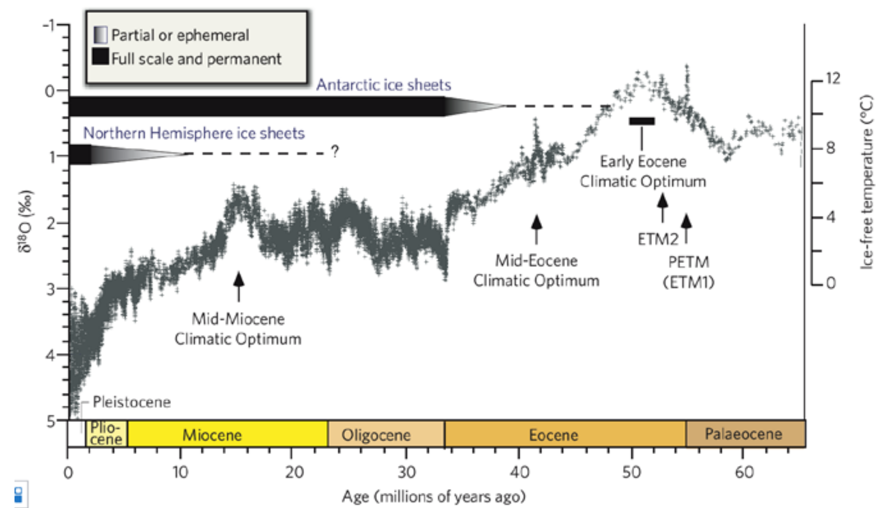
Model test

$$\ln(k_{post\text{-}uplift}/k_{pre\text{-}uplift}) = -Ea/R(1/T_{post\text{-}uplift} - 1/T_{pre\text{-}uplift})$$



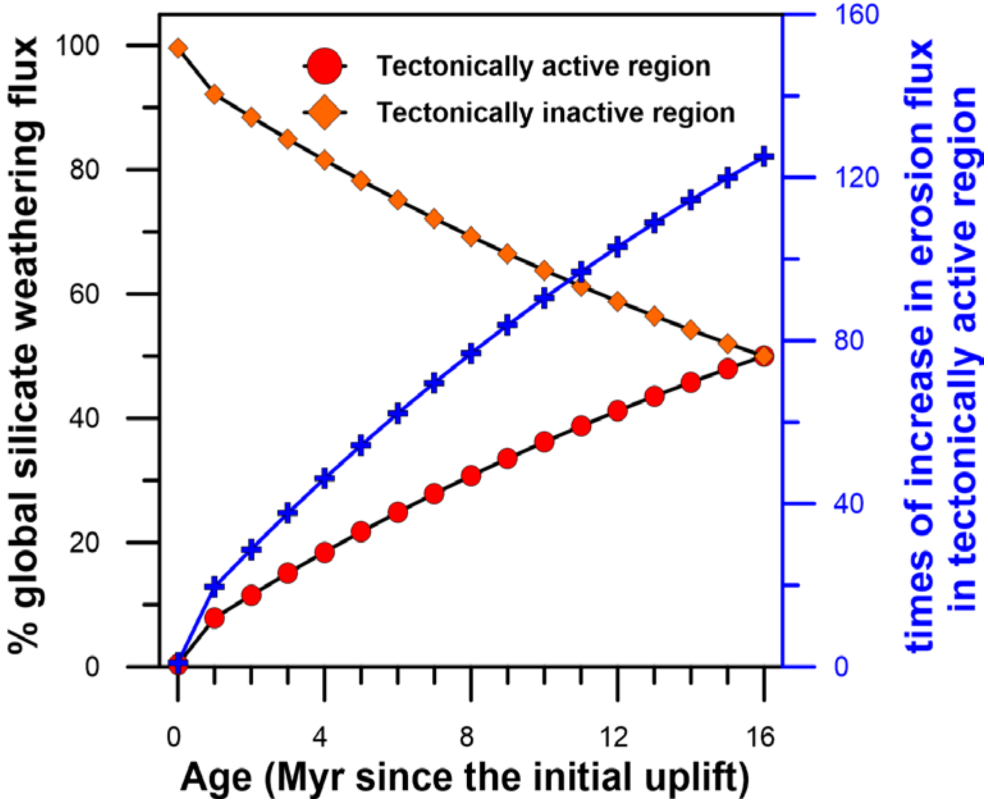
52-36 Ma Temperature drop 7-8 ° C, ~0.44 ° C/Myr

Silicate weathering rate drop 4%/Myr



Zachos et al., 2008

Model test



Pre-uplift：

Area of tectonically inactive region ：99.6%

Area of tectonically active region：0.4%

Uniform erosion flux everywhere, Weathering flux in proportion to area

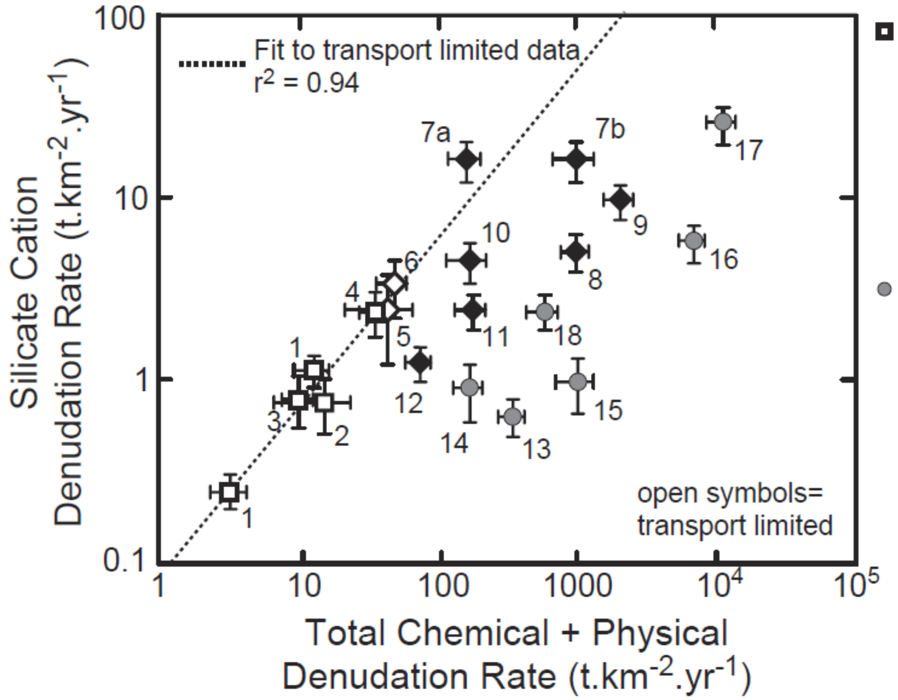
Post-uplift：

Weathering flux drop in tectonically inactive area would be balanced by erosion-induced weathering flux increase in tectonically active region

Result：

Erosion increase in tectonically active region should be >100-fold

Modern observations



Continental Cratons

1. Canadian Shield
2. Siberian Shield
3. African Shield
4. Guyana Shield

Alpine Catchments

13. Colorado Rockies
14. Sierra Nevada
15. Svalbard
16. High Himalaya
17. West Southern Alps
18. Swiss Alps

Submontane Catchments

5. British Columbia
6. Sabah Malaysia
7. Puerto Rico
   a. Long Term Erosion
   b. Modern Day Erosion
8. East Southern Alps
9. Lesser Himalaya
10. Cote d'Ivoire
11. Idaho Batholith
12. Appalachians

West et al., 2005

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Xiaomin Fang[1,2], Albert Galy[3], Yibo Yang[1,2], Weilin Zhang[1,2], Chengcheng Ye[2] and Chunhui Song[4]

[1]CAS Center for Excellence in Tibetan Plateau Earth Sciences, Chinese Academy of Sciences, Beijing 100101, China

[2]Key Laboratory of Continental Collision and Plateau Uplift, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100101, China

[3]Centre de Recherches Pétrographiques et Géochimiques, UMR7358, CNRS, Université de Lorraine, 54500 Nancy, France

[4]School of Earth Sciences & Key Laboratory of Western China's Environmental Systems (MOE), Lanzhou University, Lanzhou 730000, China