Chemical weathering in the Fly River system

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MARGINS

NSF

TIMS FACILITY AT BOSTON UNIVERSITY

MARGINS Source ~ to ~ Sink

OK TEDI MINING

What is the role of *chemical* weathering in a 2S2 system?

Silicate minerals + water + CO_2 →

clay minerals + Fe-oxides + cations/nutrients (Si, K, Ca, P) + neutralized CO_2

-Sediment production (soil, fracture enhancement)
-Affects composition of sediment load
-Contributes to consumption of atmospheric CO_2

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High surface area contributes to organic carbon burial offshore

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clay minerals + **Fe-oxides** + cations/nutrients (Si, K, Ca, P) + neutralized CO_2

Catalyst for early diagenetic remineralization of organic carbon

What is the role of *chemical* weathering in a 2S2 system?

Silicate minerals + water + CO_2 →

clay minerals + Fe-oxides + **cations/nutrients (Si, K, Ca, P)** + neutralized CO_2

Contributes to enhanced productivity offshore

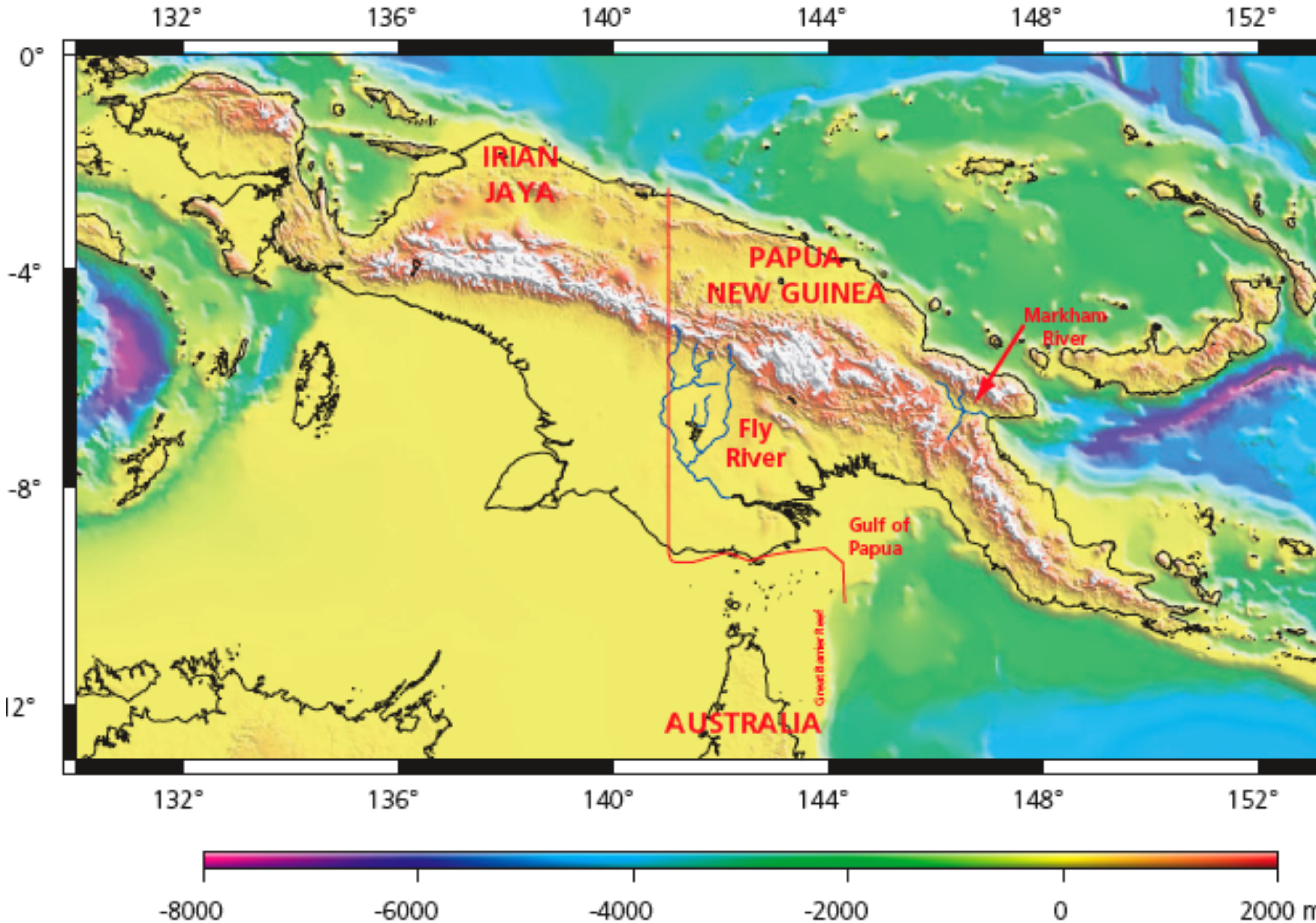
What is the role of *chemical* weathering in a 2S2 system?

Silicate minerals + water + CO_2 →

clay minerals + Fe-oxides + cations/nutrients (Si, K, Ca, P) + **neutralized CO_2**

Alkalinity (HCO_3^-) combines with Ca to produce $CaCO_3$ sediment, represents THE sink for solid-Earth CO_2 emissions.

GULF OF PAPUA FOCUS SITE



Global Sediment Yield (area normalized fluxes)

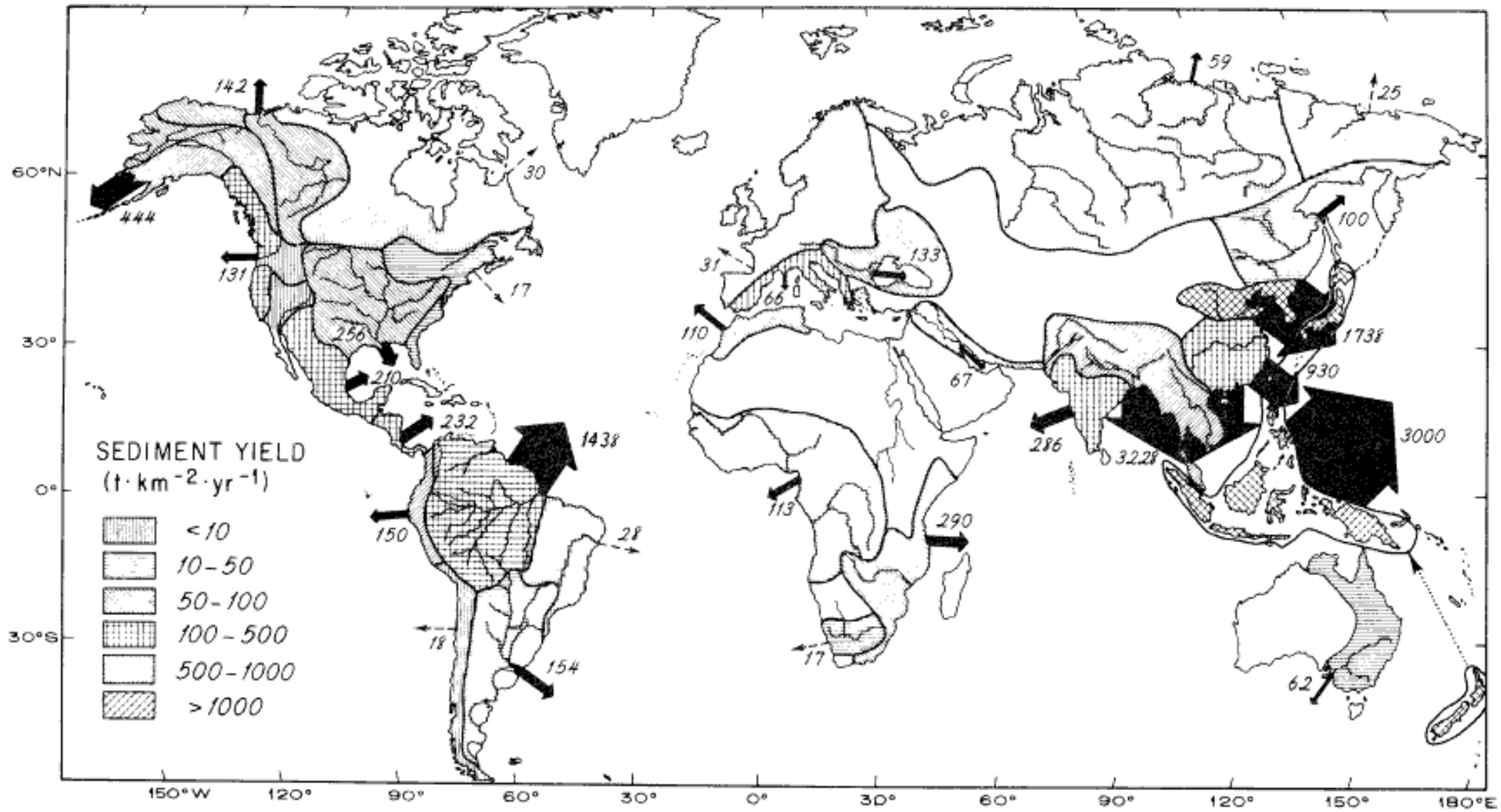
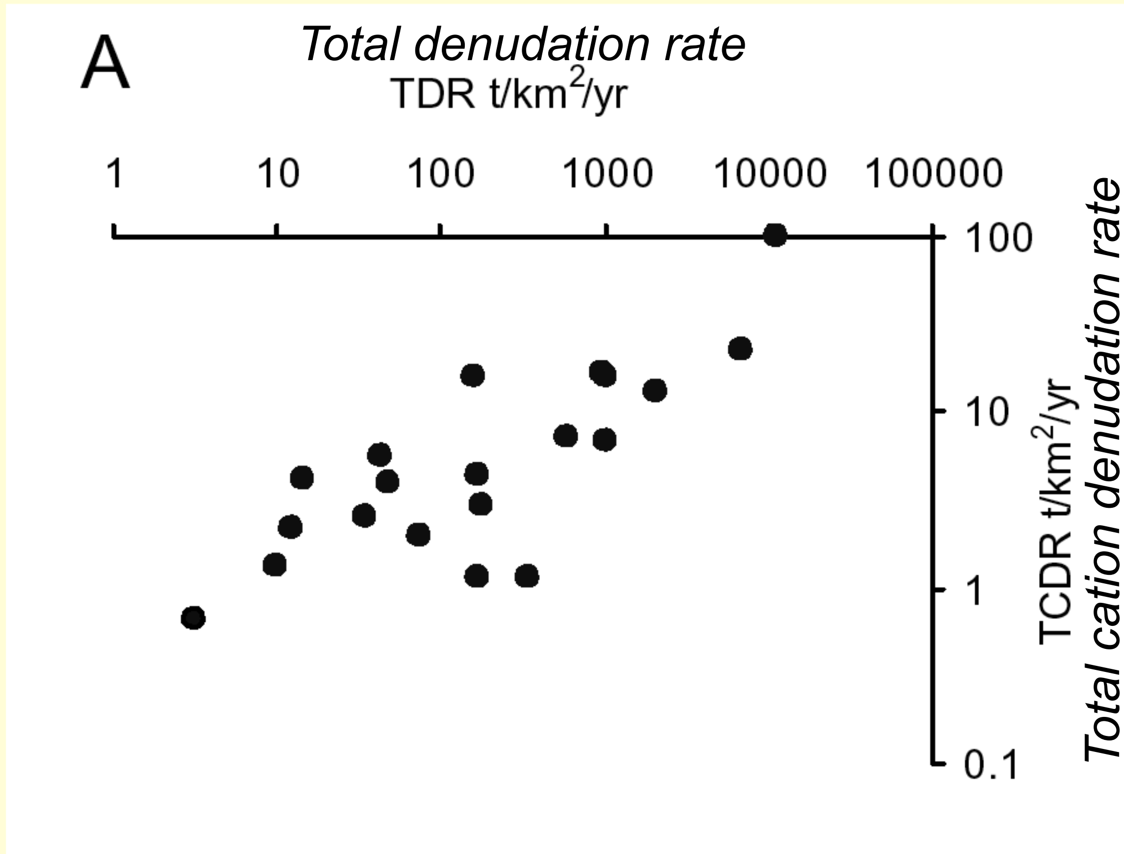


FIG. 4.—Annual discharge of suspended sediment from various drainage basins of the world; width of arrows corresponds to relative discharge. Numbers refer to average annual input in millions of tons. Direction of arrows does not indicate direction of sediment movement. The sediment yields and major rivers of the various basins also are shown; open patterns indicate essentially no discharge to the ocean.

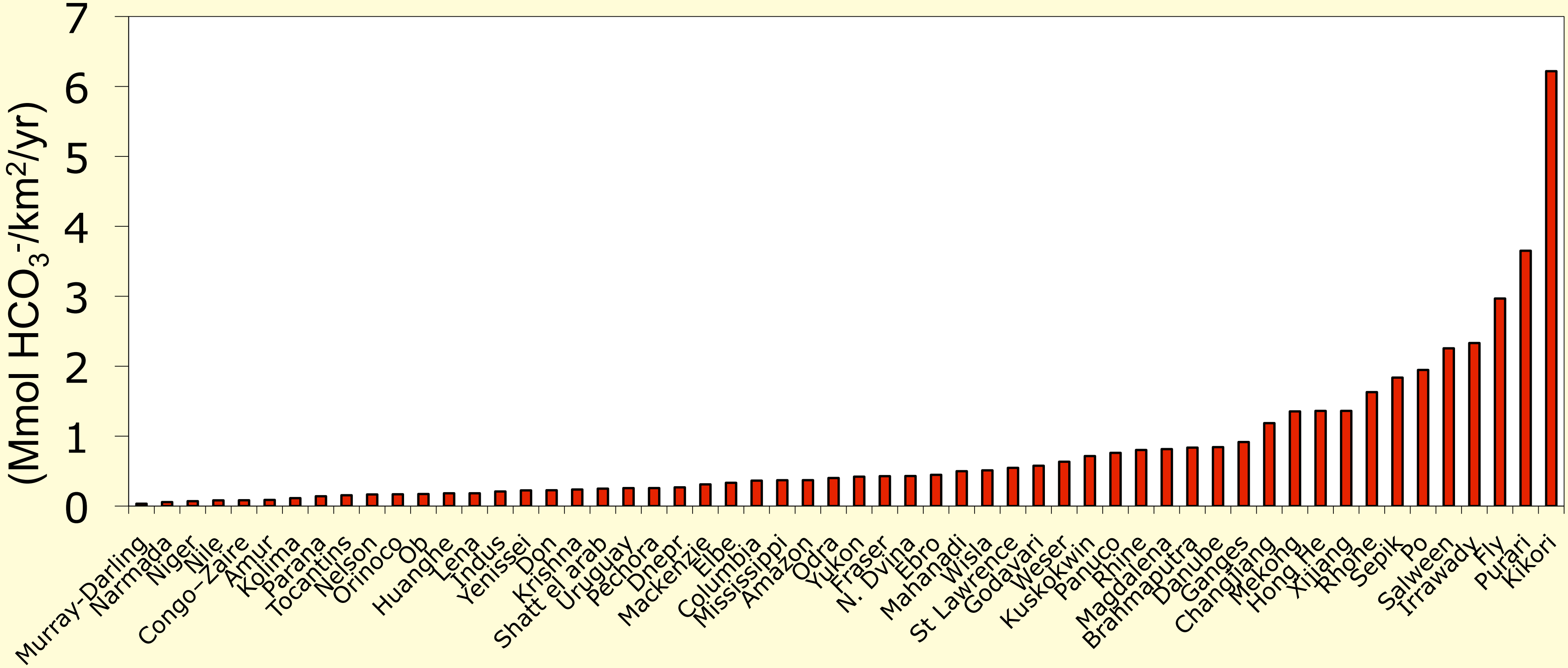
Milliman and Meade, 1983

Weathering scales to erosion

- West et al. (2005) compilation of small catchment data

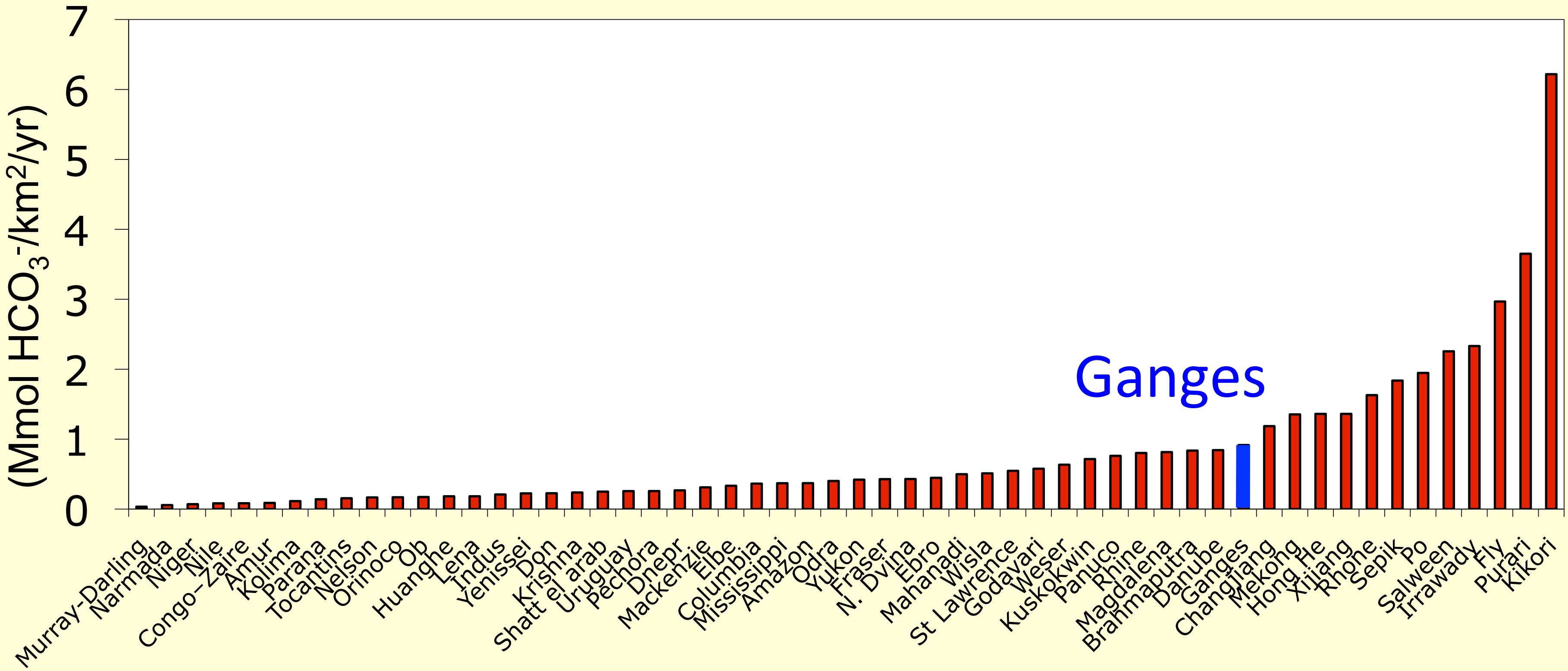


“Alkalinity Yield” (area-normalized fluxes) of World Rivers



Data from Gaillardet et al., 1999; Meybeck and Ragu 1995 GEMS/GLORI compilation

"Alkalinity Yield" (area-normalized fluxes) of World Rivers



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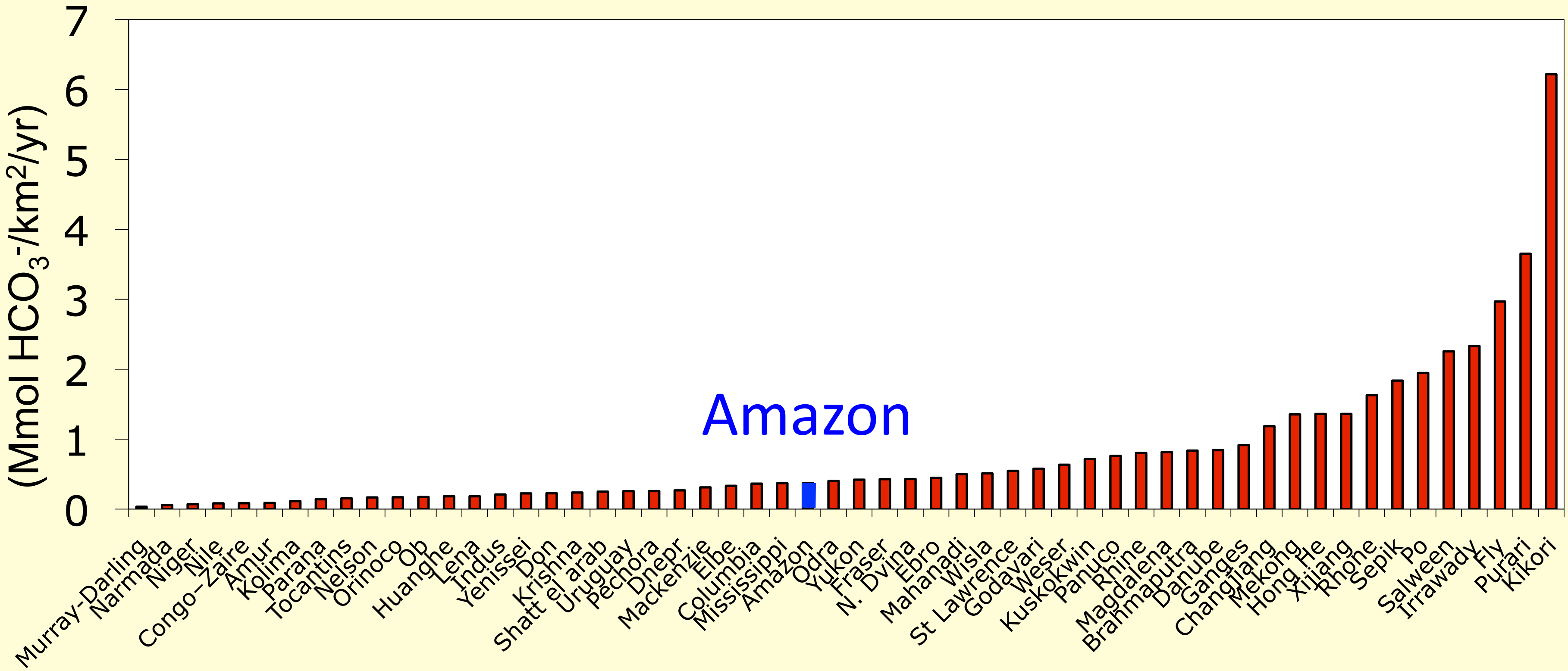

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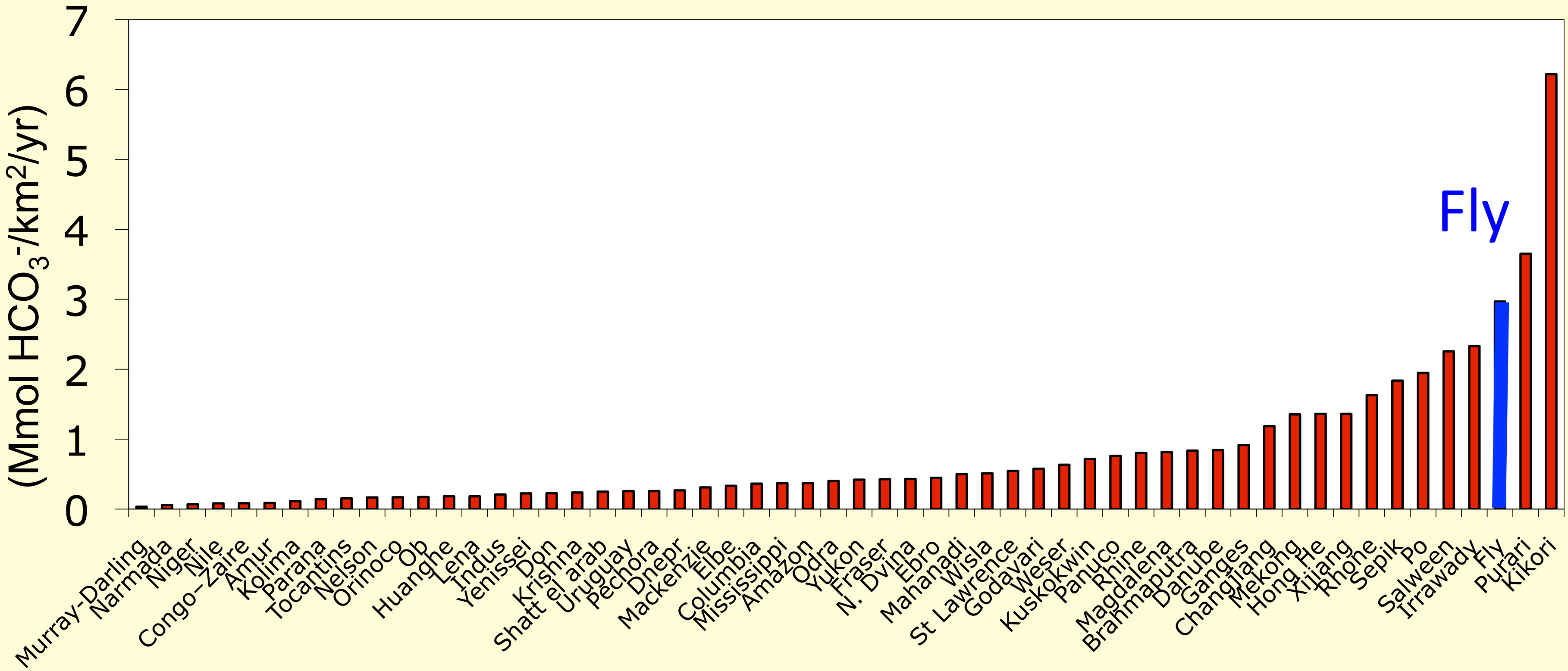

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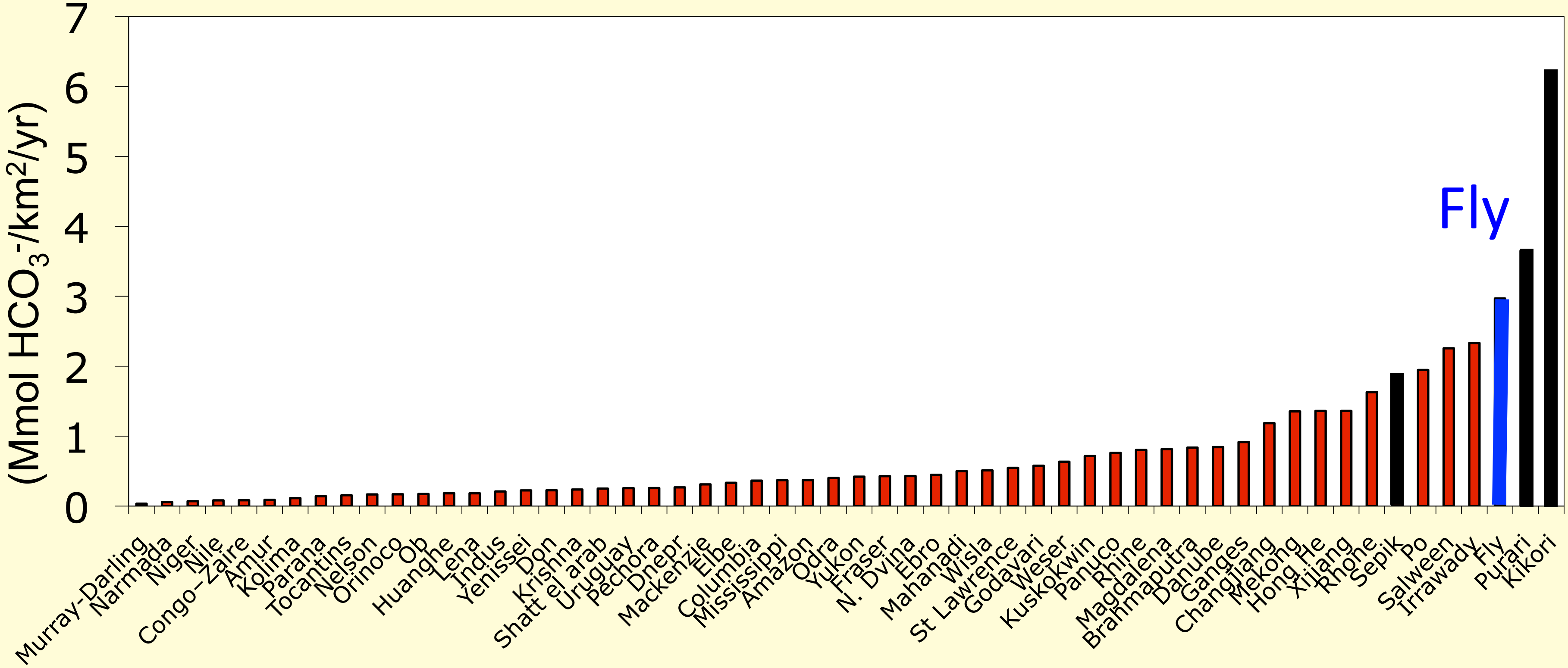
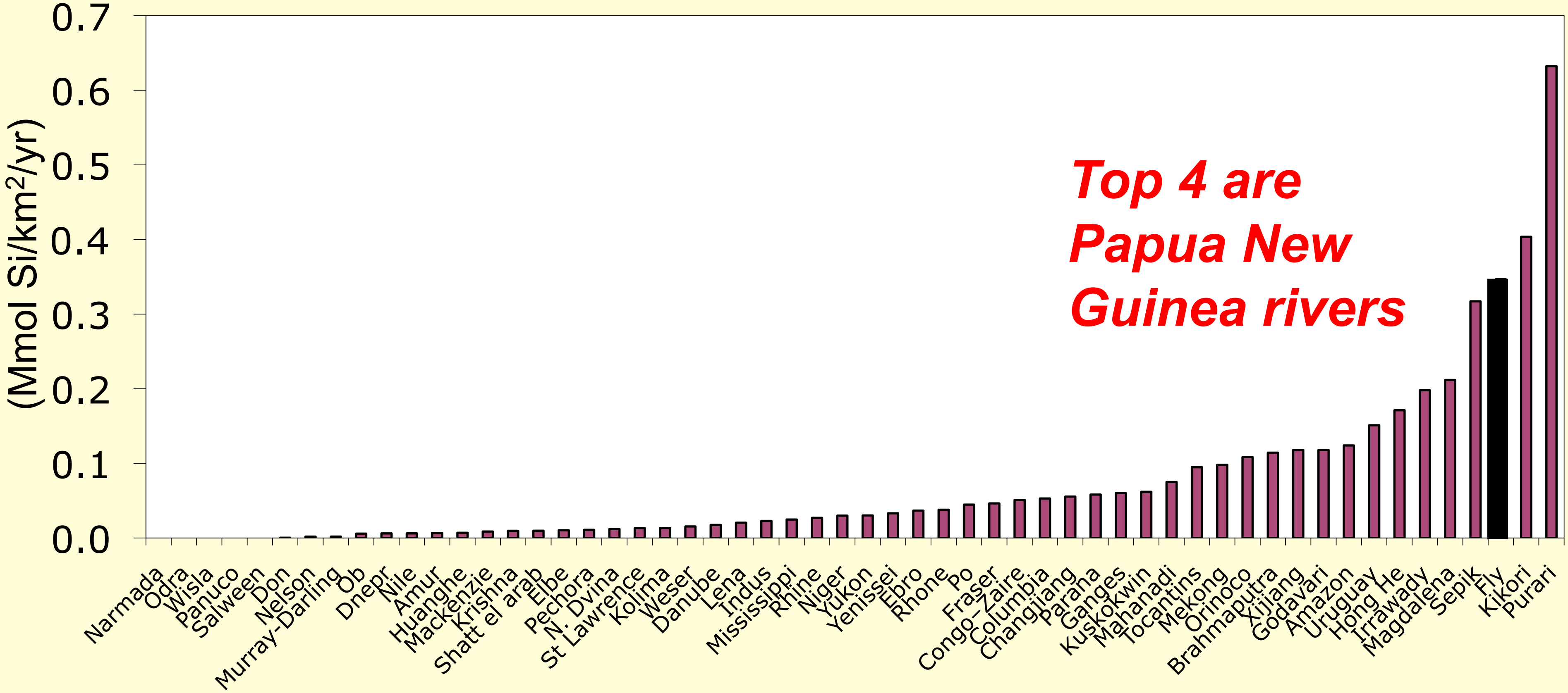


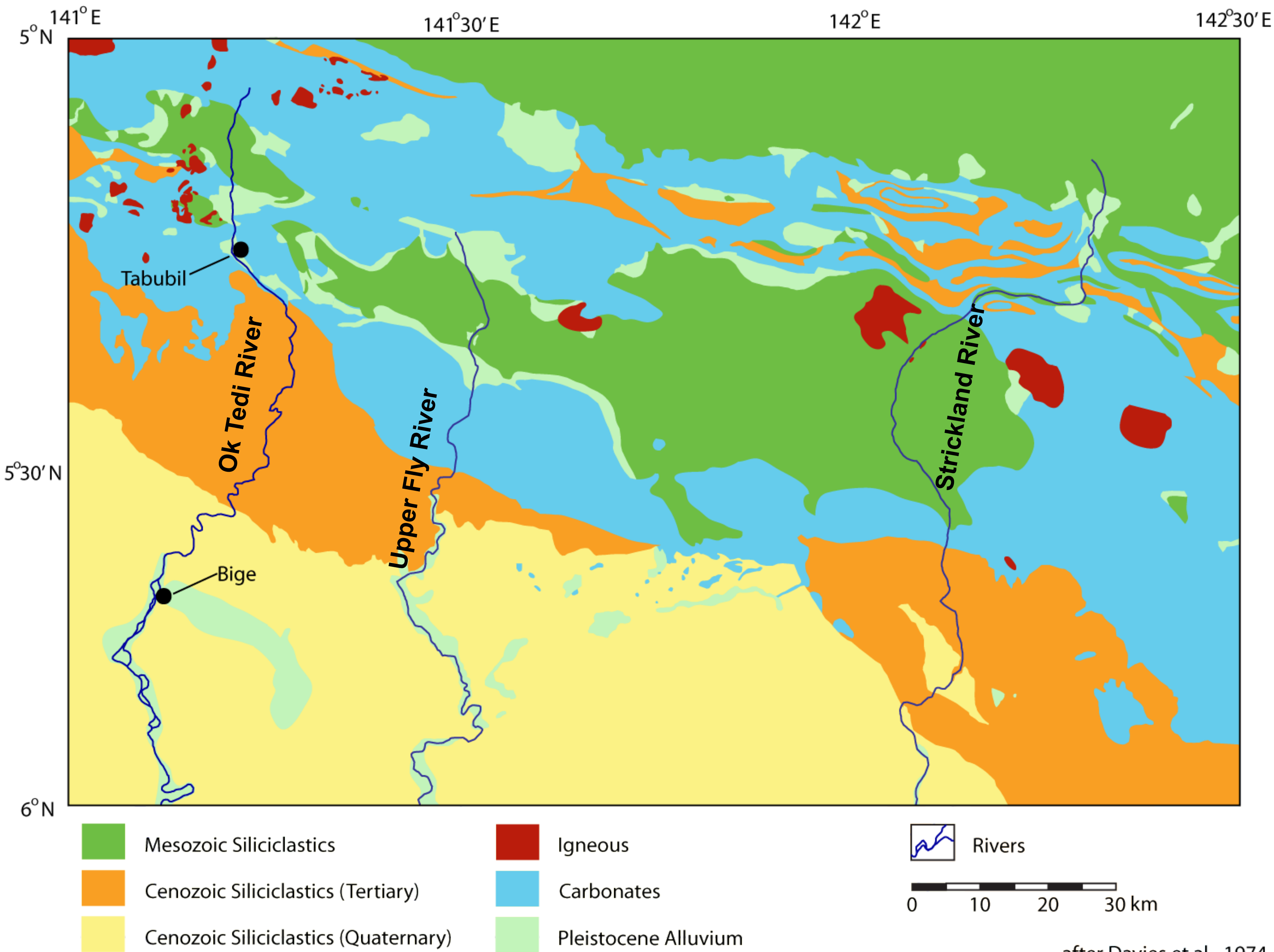
Data from Gaillardet et al., 1999; Meybeck and Ragu 1995 GEMS/GLORI compilation

“Silica Yield” (area-normalized fluxes) of World Rivers



Data from Gaillardet et al., 1999; Meybeck and Ragu 1995 GEMS/GLORI compilation

Bedrock of the Fly River Basin – The Source



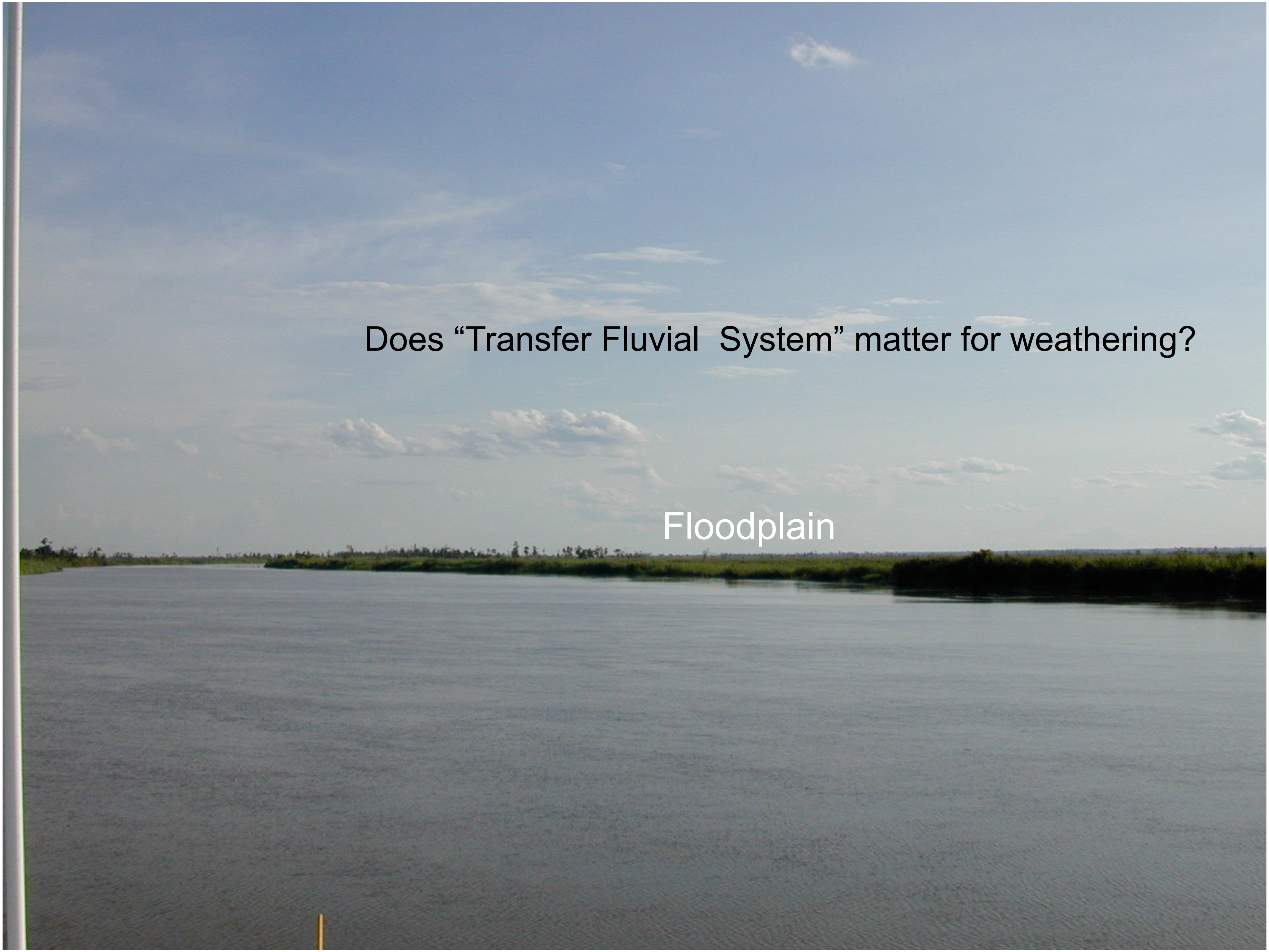
after Davies et al., 1974


Mountainous uplands
“Transitional” low relief hills



Poorly developed upland soils

Well developed soils on ridgetop in transitional zone


Does “Transfer Fluvial System” matter for weathering?
Floodplain

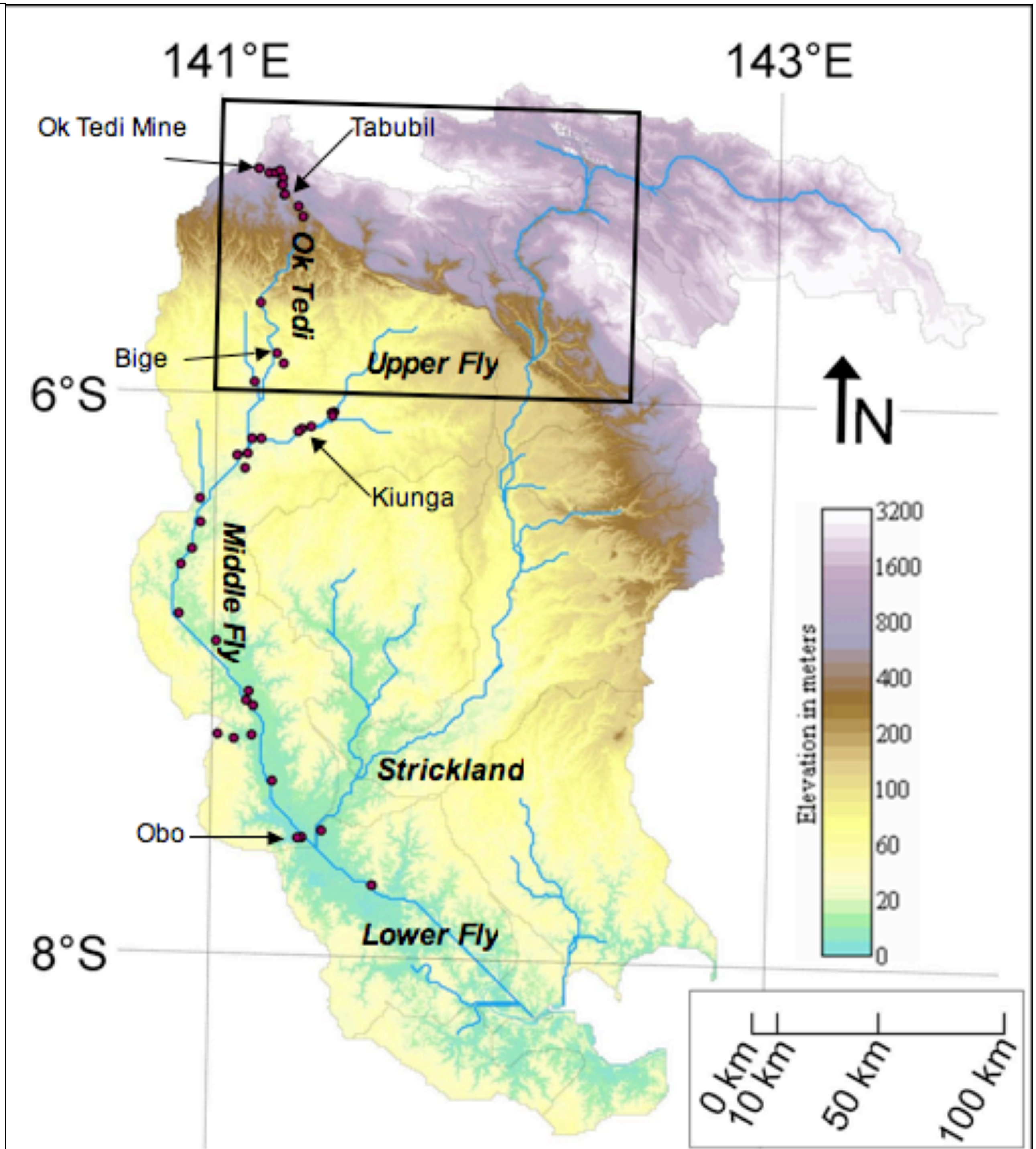

Active Floodplain Sedimentation and storage


"Relict Floodplain" Pleistocene Terraces

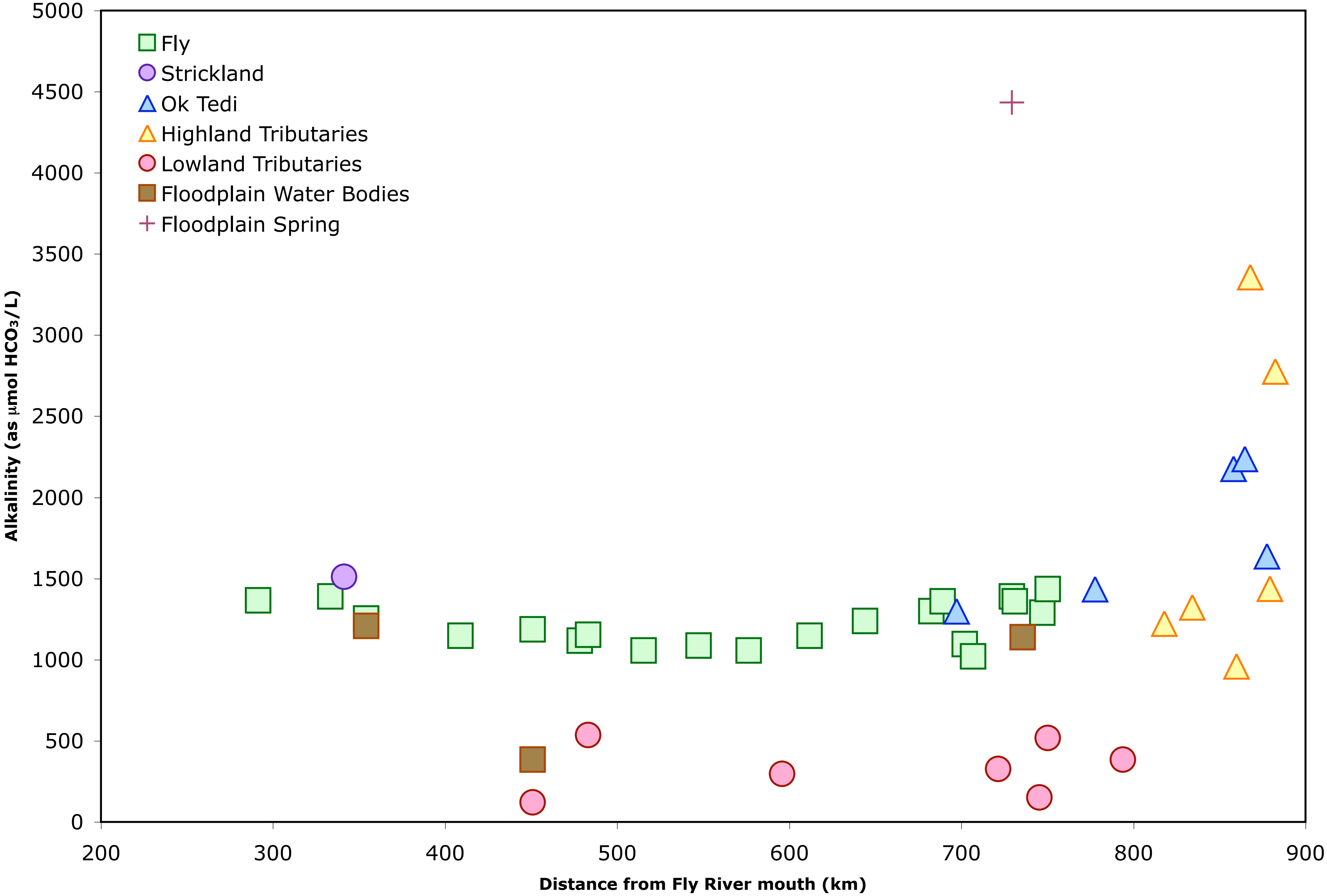

Mining (Cu-Au) has increased sediment flux
~3-5 fold on Middle Fly (since 1985)
And ~15% on Strickland (since early 90’s)

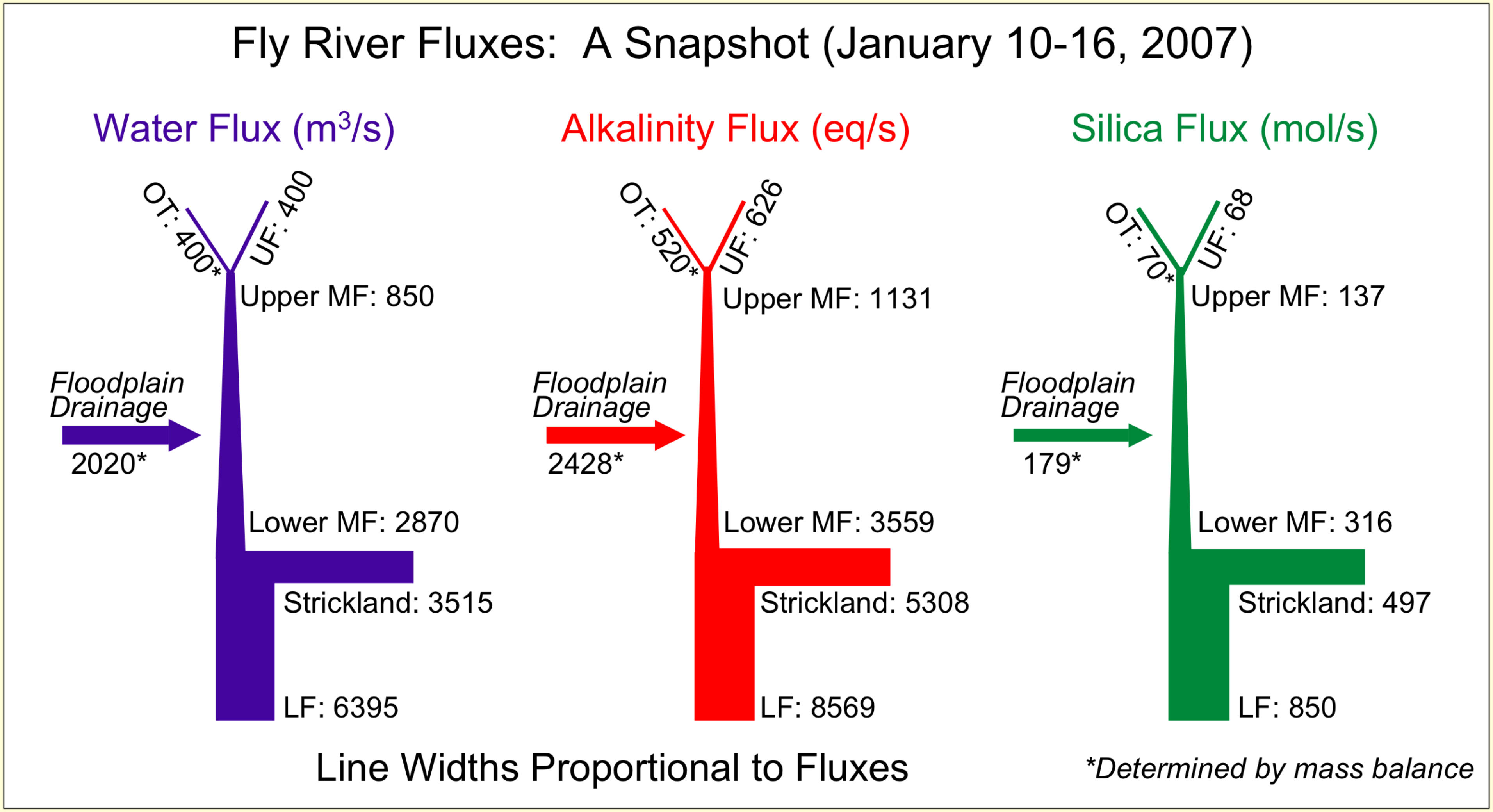
The Fly River

- January 2007 sample collection and discharge survey



Solute Chemistry: Alkalinity (as HCO_3^-)



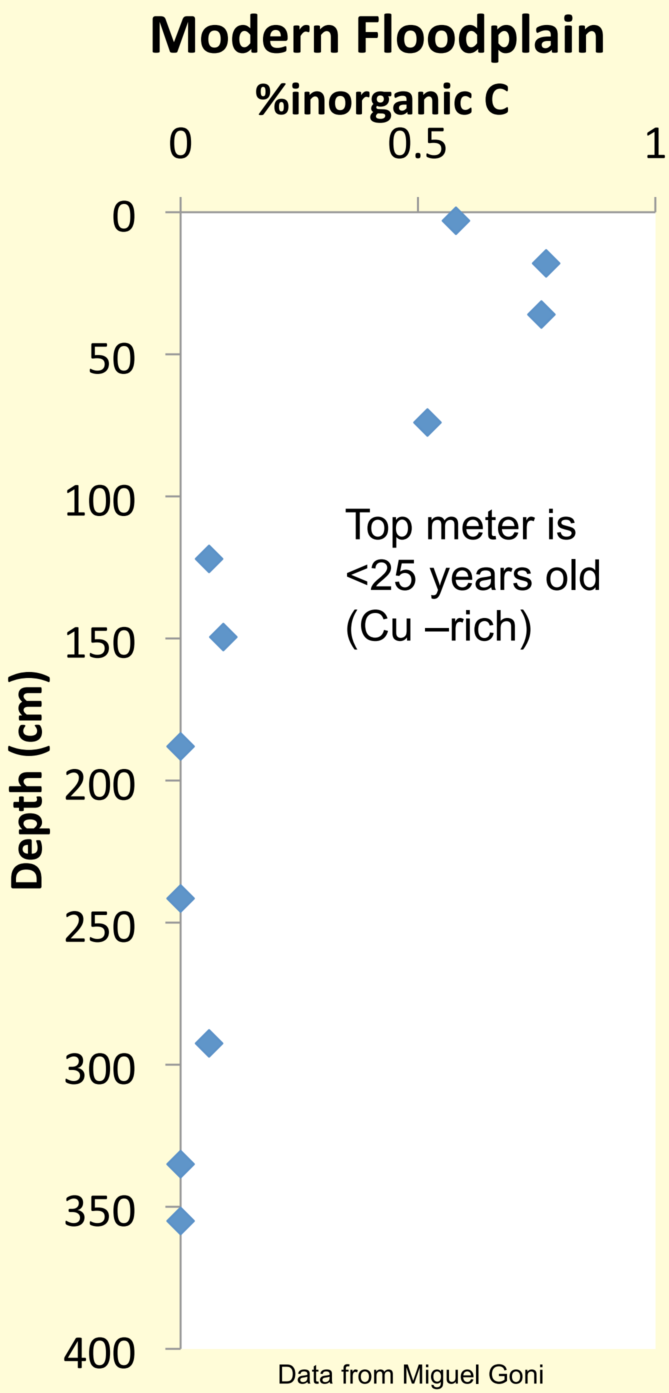


Do increases in solute fluxes across Middle Fly floodplain reach reflect new weathering inputs?

Floodplain Weathering

	Upper Middle Fly (D'Albertis)	Lower Middle Fly (Everill)	Floodplain Spring
Si (µmol/L)	161	110	254
Alk (meq/L)	1330	1240	4430
Alk/Si (eq/mol)	8.3	11.3	17.4

Increase in Alk/Si across floodplain likely reflects new weathering input of carbonates .


Modern Floodplain
%inorganic C
0
0.5
1
Depth (cm)
0
50
100
150
200
250
300
350
400
Top meter is
<25 years old
(Cu –rich)
Data from Miguel Goni

Alkalinity & Weathering – Balancing solid earth's CO_2 emission

- Weathering reactions neutralize CO_2 to produce alkalinity.

  Silicate Weathering:

  $CaSiO_3 + 3H_2O + 2CO_2 = Ca^{2+} + 2HCO_3^- + H_4SiO_4$

  Carbonate Weathering:

  $CaCO_3 + H_2O + CO_2 = Ca^{2+} + 2HCO_3^-$

- Carbonate *precipitation* consumes alkalinity and releases CO_2.

  Carbonate Precipitation:

  $Ca^{2+} + 2HCO_3^- = CaCO_3 + H_2O + CO_2$

What Determines Solute Composition?

- Inverse Method: For any element X_i, where F_n represents the fraction of Na derived from endmember n:

$$1)\quad \frac{X_i}{Na}_{sample} = F_{silicate} * \frac{X_i}{Na}_{silicate} + F_{carbonate} * \frac{X_i}{Na}_{carbonate} + F_{rain} * \frac{X_i}{Na}_{rain} + F_{mine} * \frac{X_i}{Na}_{mine}$$

$$2)\quad F_{silicate} + F_{carbonate} + F_{rain} + F_{mine} = 100\%$$

$$3)\quad 0\% \leq F_{silicate}, F_{carbonate}, F_{rain}, F_{mine} \leq 100\%$$

Measured

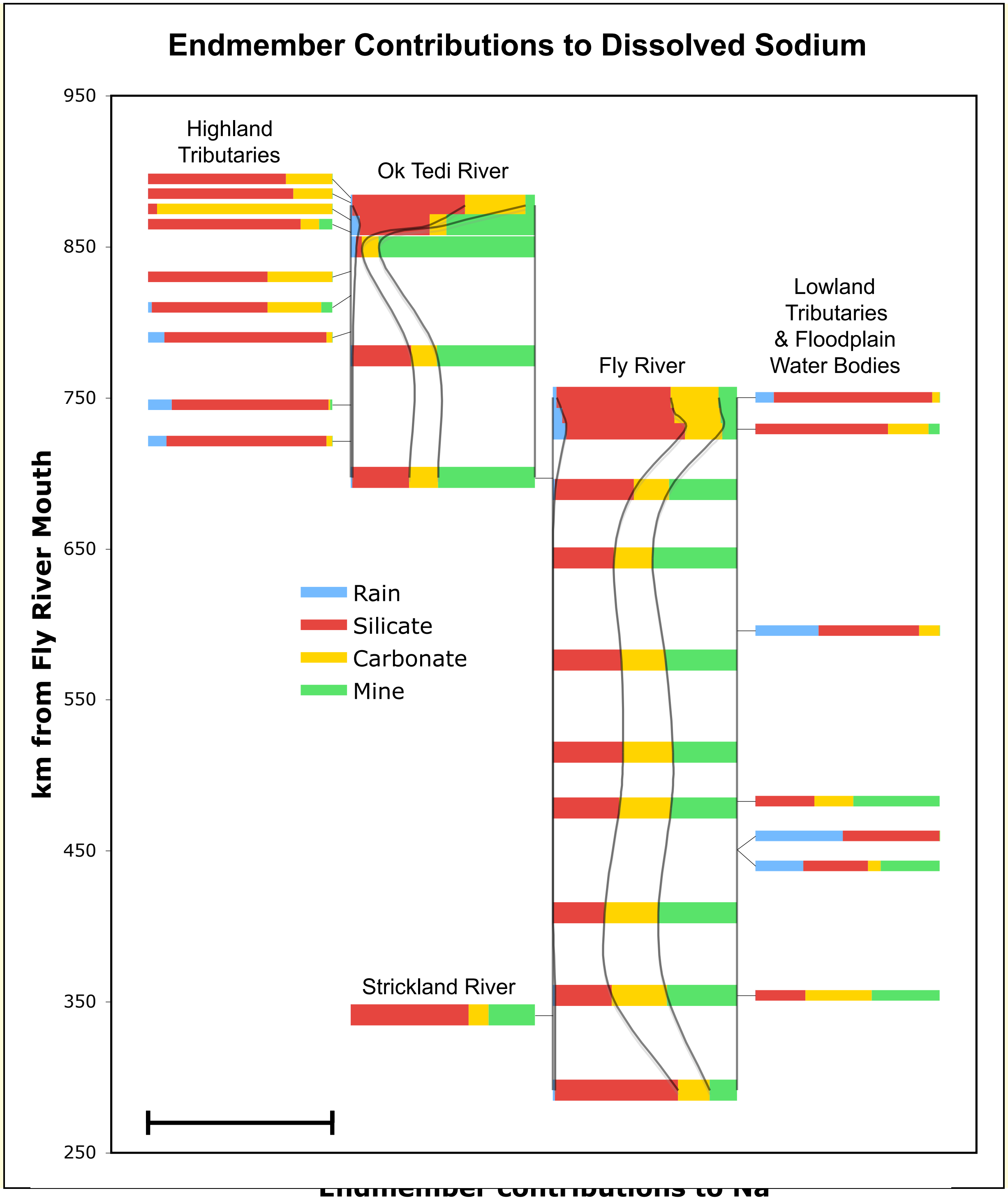
Estimated

Unknown

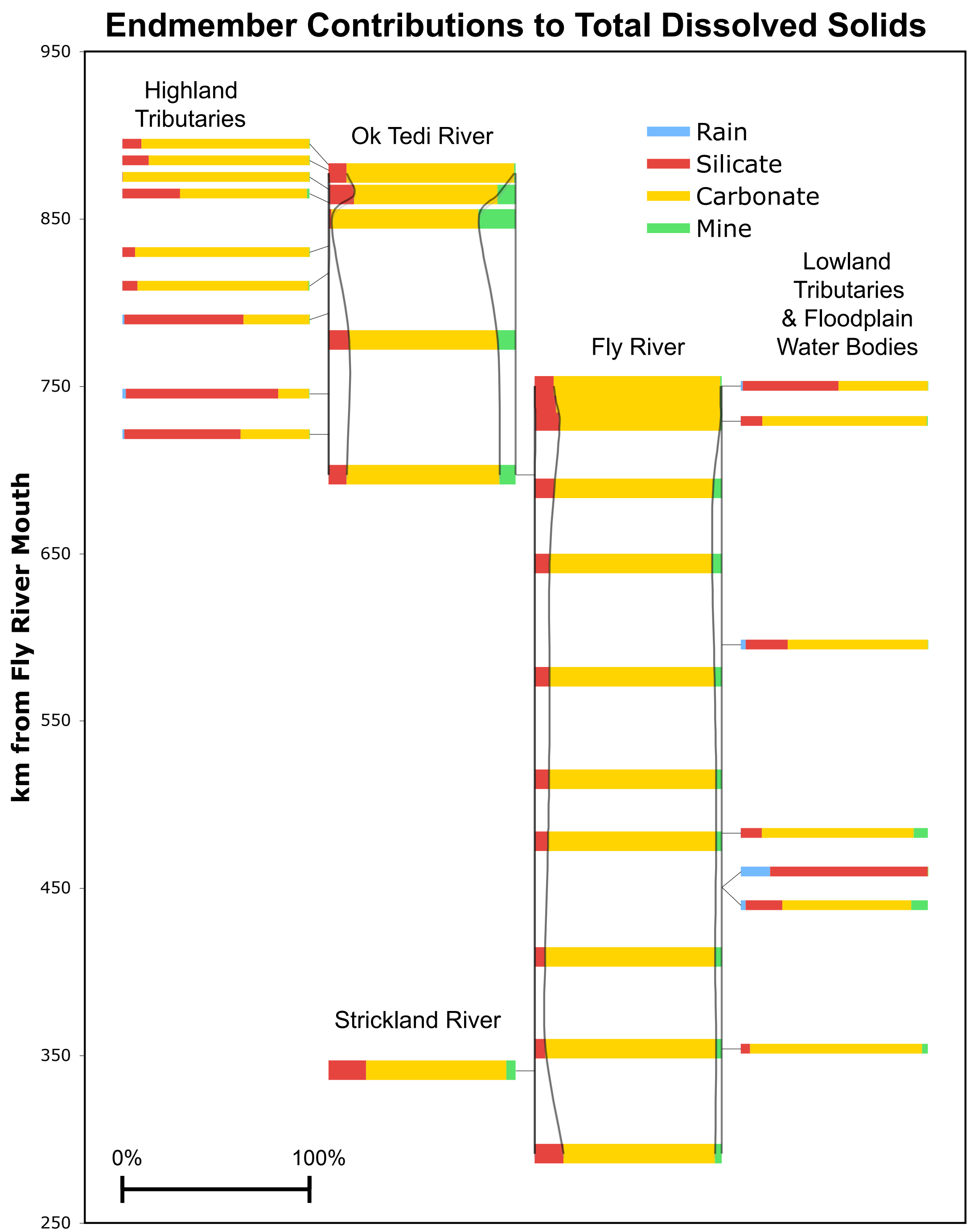
The Inverse Method (after Allegre and Lewin, 1989)

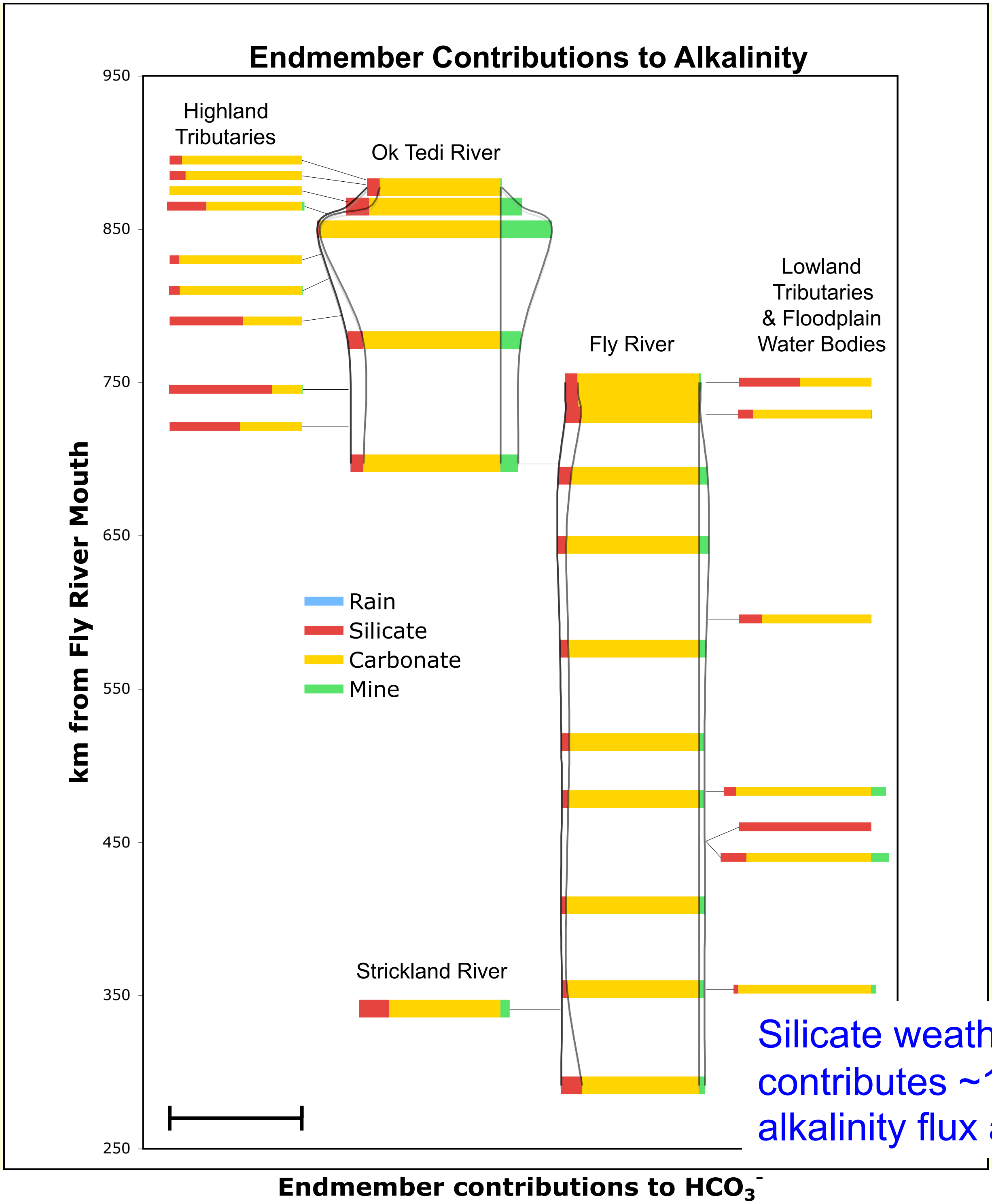
- Simultaneously solve equations for optimal set of F_n while tuning sample and endmember X_i/Na within prescribed uncertainty
  - X_i = Cl, Ca, Mg, K, $^{87}Sr/^{86}Sr$, HCO_3^-, Si and SO_4

- Inverse model solves for the endmember contributions to river water while refining our estimates of endmember compositions



Endmember Contributions to Dissolved Sodium
950
850
750
650
550
450
350
250
km from Fly River Mouth
Highland Tributaries
Ok Tedi River
Fly River
Lowland Tributaries & Floodplain Water Bodies
Strickland River
Rain
Silicate
Carbonate
Mine
Endmember contributions to Na


Endmember Contributions to Total Dissolved Solids
km from Fly River Mouth
950
850
750
650
550
450
350
250
Highland
Tributaries
Ok Tedi River
Fly River
Lowland
Tributaries
& Floodplain
Water Bodies
Strickland River
Rain
Silicate
Carbonate
Mine
0%
100%



Silicate weathering contributes ~12% of alkalinity flux at Lower Fly.

Long-term CO_2 sinks in Fly River system

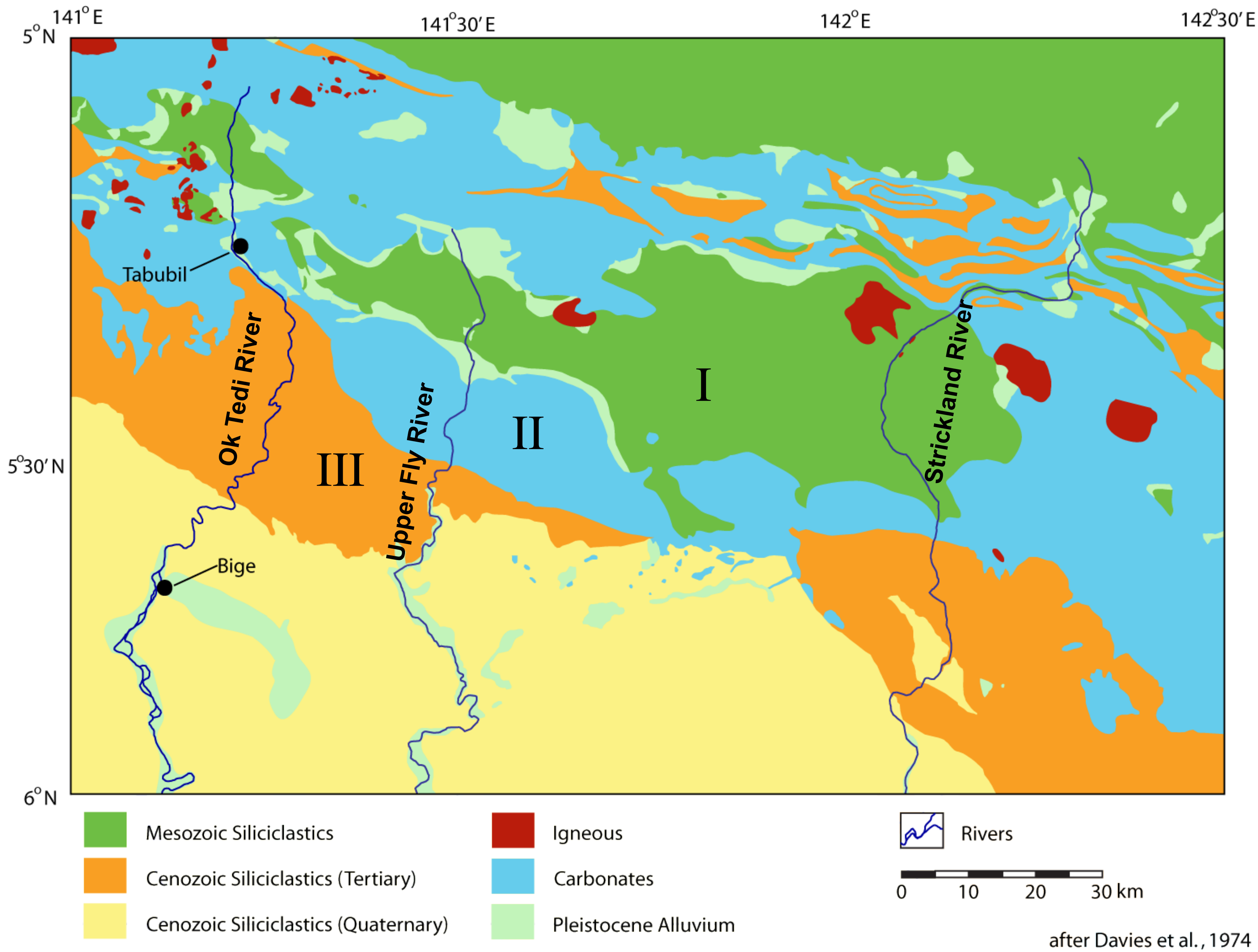
- CO_2 Sink from silicate weathering:
  $3.4 – 4.3 * 10^{10}$ mol C/y

  (90% of this comes from the Strickland)

- CO_2 sink from organic carbon burial:
  $1.7 – 4.5 * 10^{10}$ mol C/y (Miguel's number)

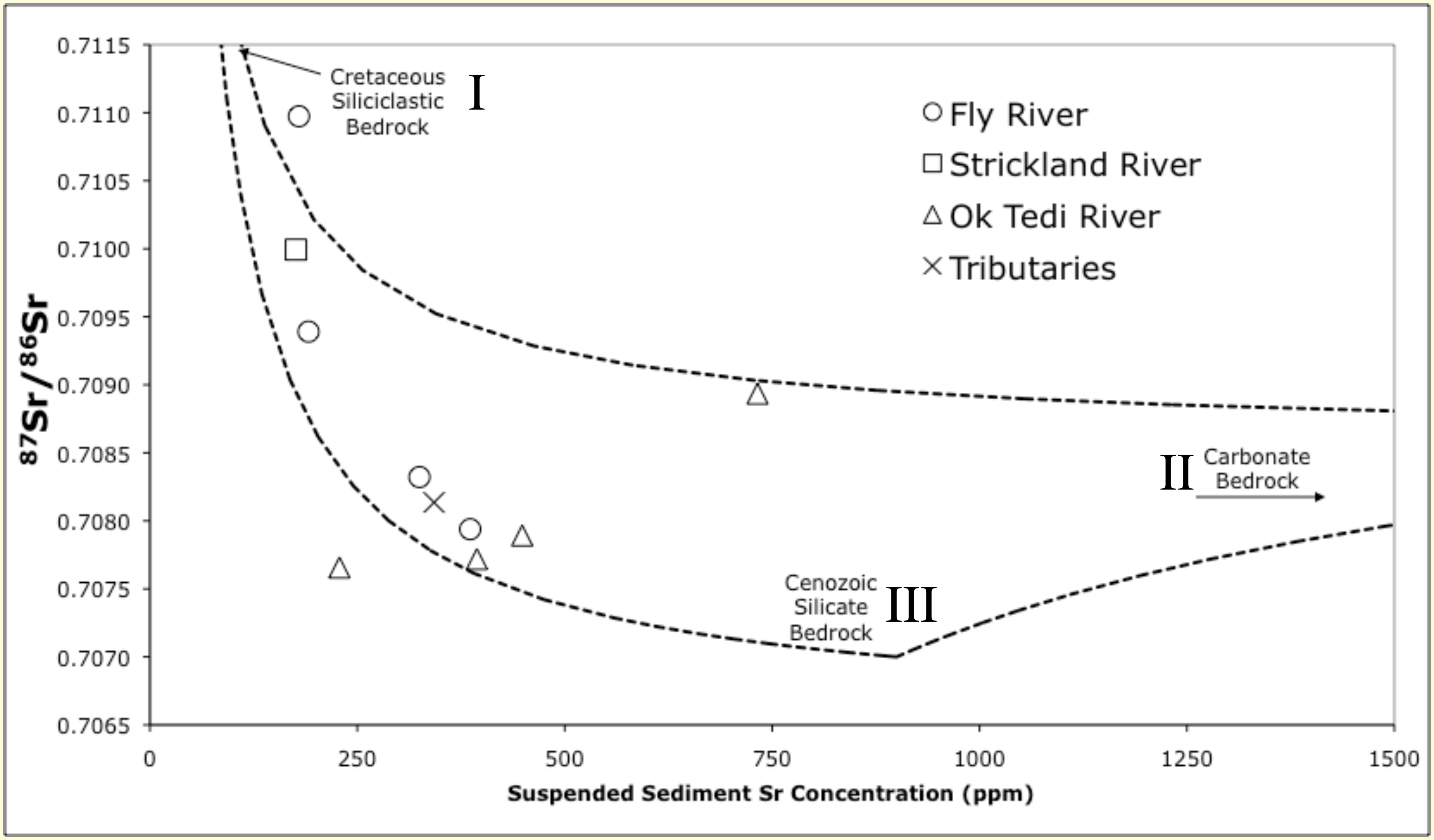
The two majors sinks equal magnitude here. Other rivers?

Bedrock of the Fly River Basin

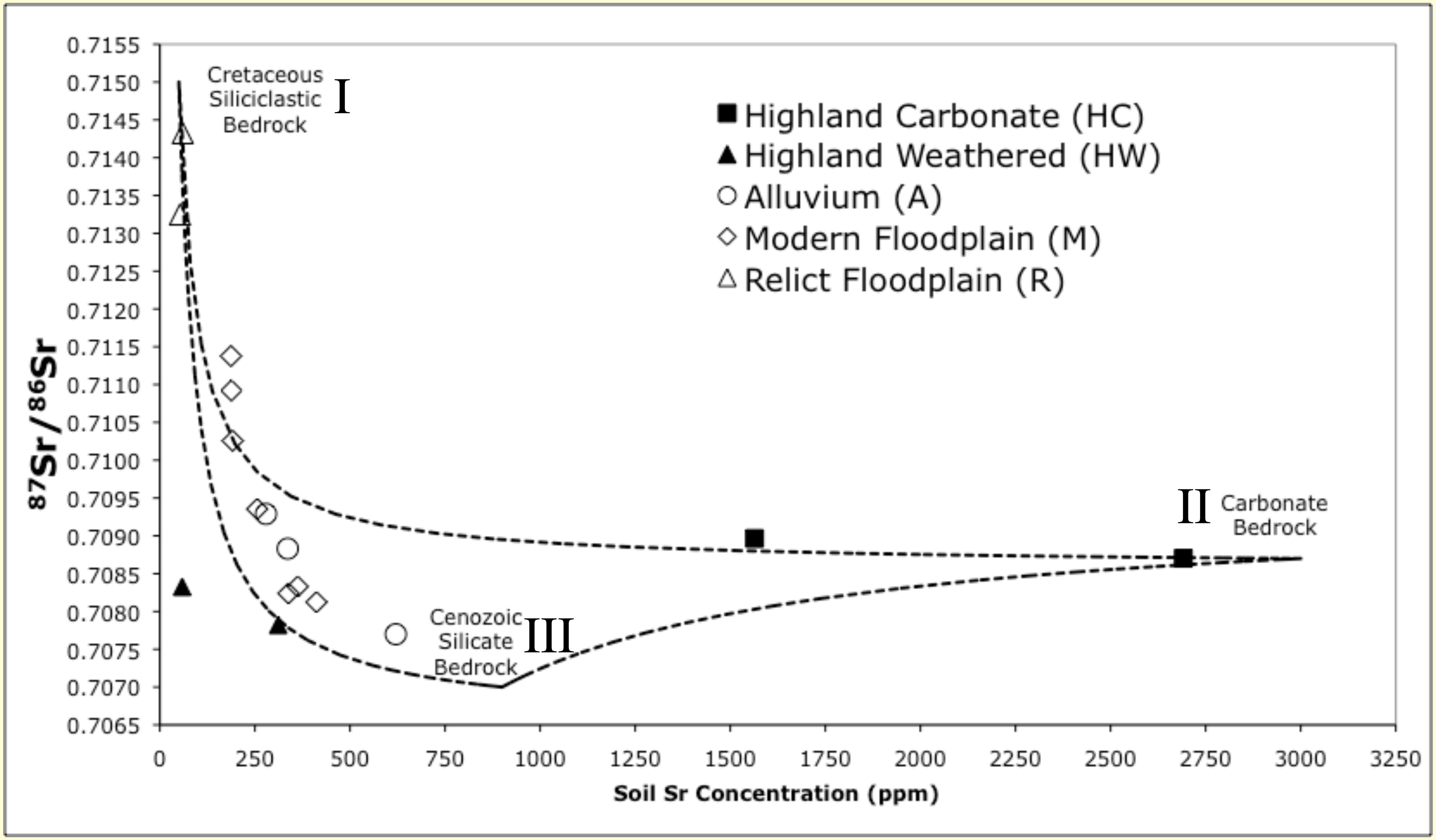


after Davies et al., 1974

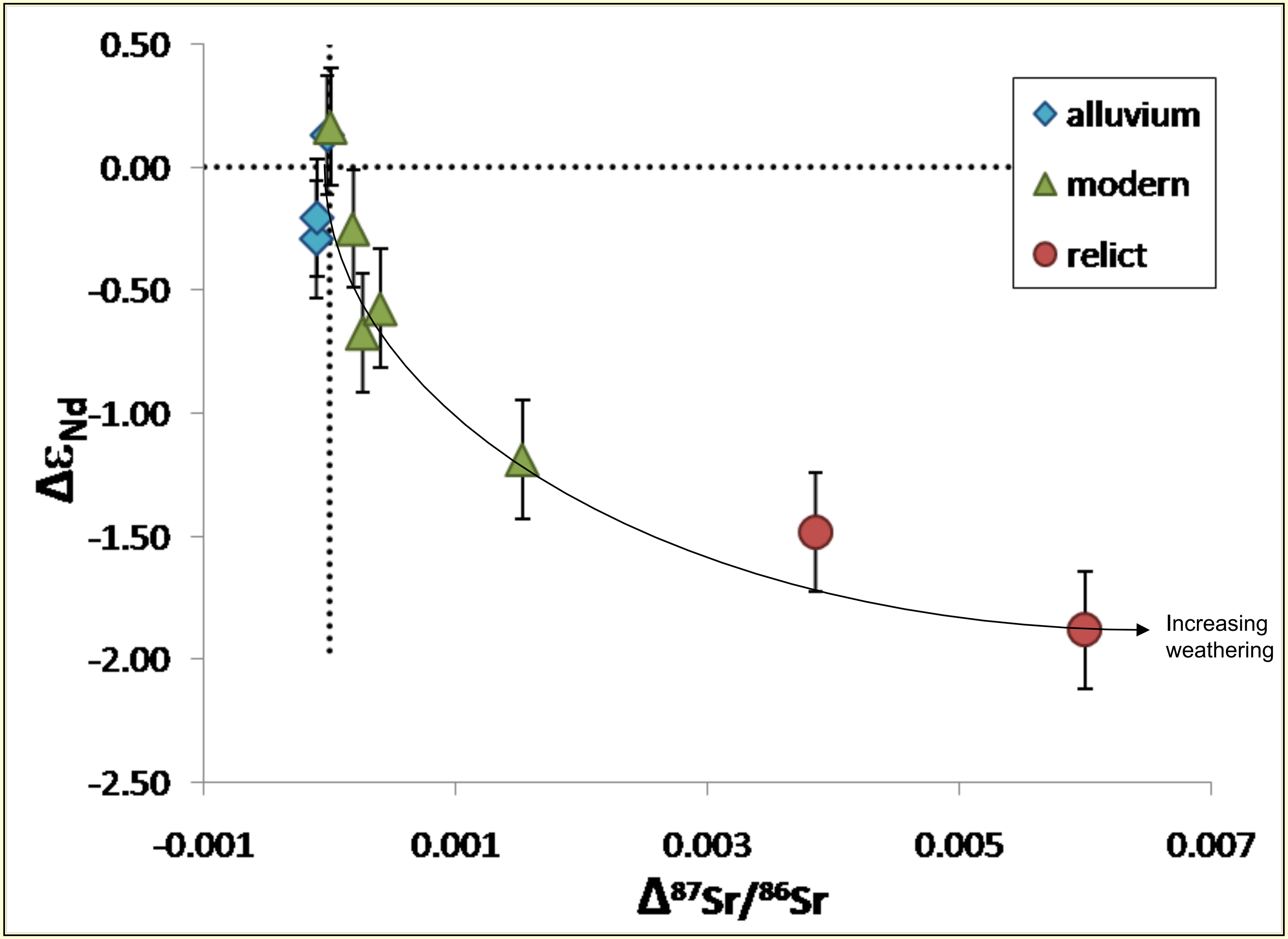
Suspended Sediment



Soils and Floodplain Sediment



Sr and Nd isotopes of Floodplain materials



Δ = soil - suspended sediment

Major Results

- The overall chemistry of the Fly and its major tributaries is controlled by weathering in the highlands (but weathering continues in the lowlands)
- Impact of chemical weathering on sediment delivered to the delta may be minor
- Chemical weathering rate about 13.8 Mt/y, about one sixth of natural physical denudation rate.
- Alkalinity flux is dominated by Carbonate Dissolution, but Silicate contribution is significant (particularly in the Strickland sub-basin)
- CO_2 consumption by silicate weathering is comparable to organic carbon burial