Developing Predictive Tools for the Early Environmental Assessment of New Semiconductor Materials

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Collaborators

- Duane Boning, Electrical Engineering & Computer Science
- Ajay Somani, Materials Science
- Phil Gschwend, Civil & Environmental Engineering
- Harry Hemond, Civil & Environmental Engineering
- Katherine Orchard, Chemistry

Evaluating Alternative Process Technologies:

Overall comparison	Al release	Smart cut	Oxide release
Yield (performance)	10% - depends on Cu-Cu bonding and mass transfer of acid	80% - work with oxide bond subjected to CMP oxide	80% subjected to functionality – as layer transfer is yet to be proven
Cost - additional	Cost for depositing Al on Si wafer which means 1.2 X	Cost for H_2 implantation which is 10 X	Oxidation, etch along with one CMP which means 1.2X
Environmental - additional	Illustrated very briefly in table below.		

Somani et al. 2006

Environmental Focus: Life Cycle Analyses, Inventories

Environmental comparison for additional steps	Al release	Smart cut	Oxide release
Energy	50-100 KWH primarily Al sputtering	20-40 KWH primarily H_2 implant	10-20 KWH oxidation, CMP, Photo and etch
Water	Primarily PCW for cooling Al dep./ Wet etch requires DI water	PCW for implantation, CMP and annealing	PCW for oxidation, etching and CMP, DI water for wet etch in 49% HF
Chemical (inputs)	Al, HCl, Ta, Cu	H2, SiH2Cl2, O2, CMP slurry, piranha	SiH2Cl2, O2, CMP slurry, NH4, HF, piranha, photoresist
Chemical (outputs)	$AlCl_3$, HCl, Ta?, Cu?	Oxide CMP waste, oxide dep. exhaust	Oxide CMP waste, oxide and nitride dep. exhaust, HF, SIF4

Somani et al. 2006

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Somani et al. 2006

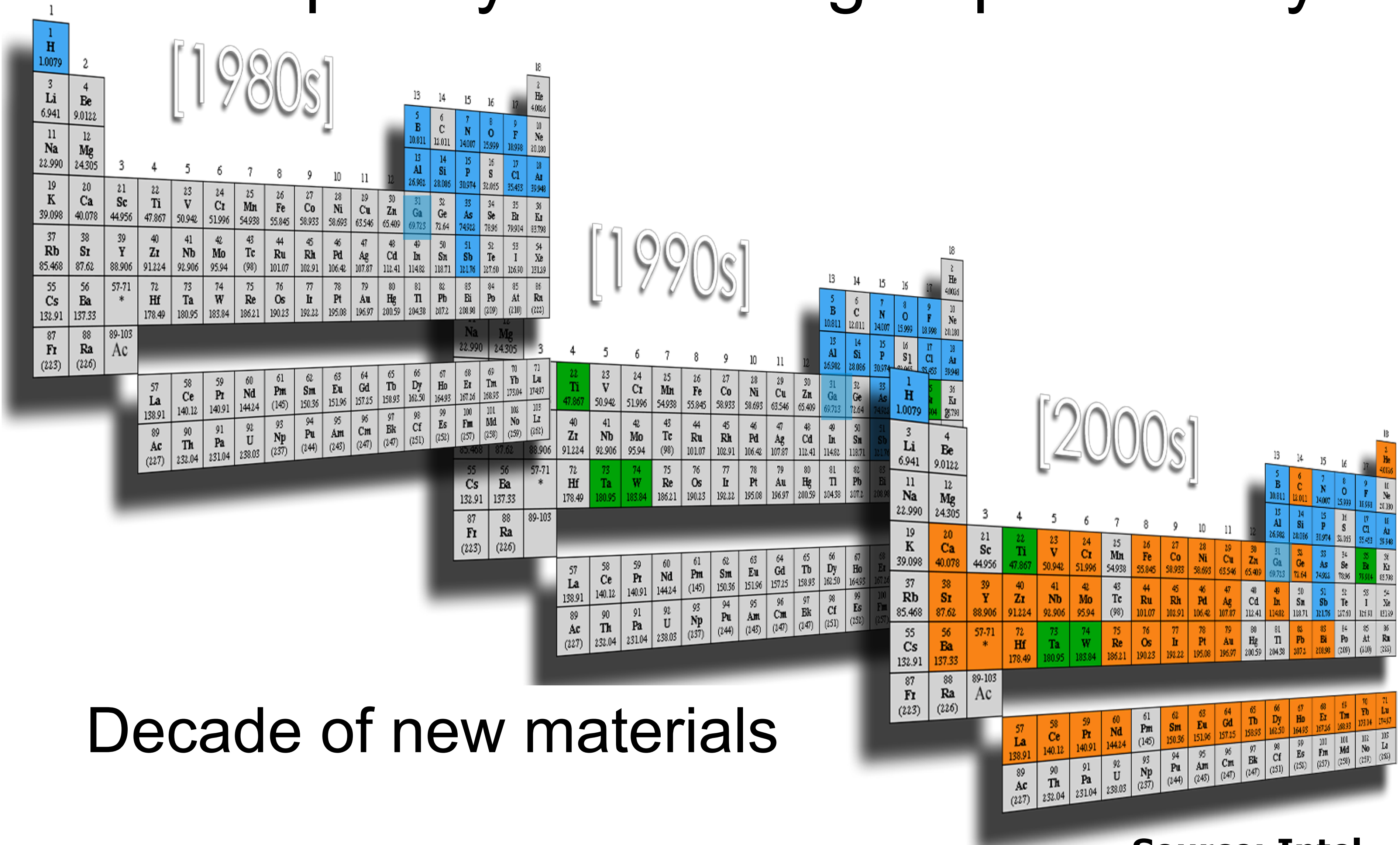
Need to do more than simply minimize

Need to be ANTICIPATORY and SPECIFIC

Ultimate Goal:

- Assess potential materials
  - Do so EARLY in process
  - Do so QUICKLY
  - Do so CHEAPLY

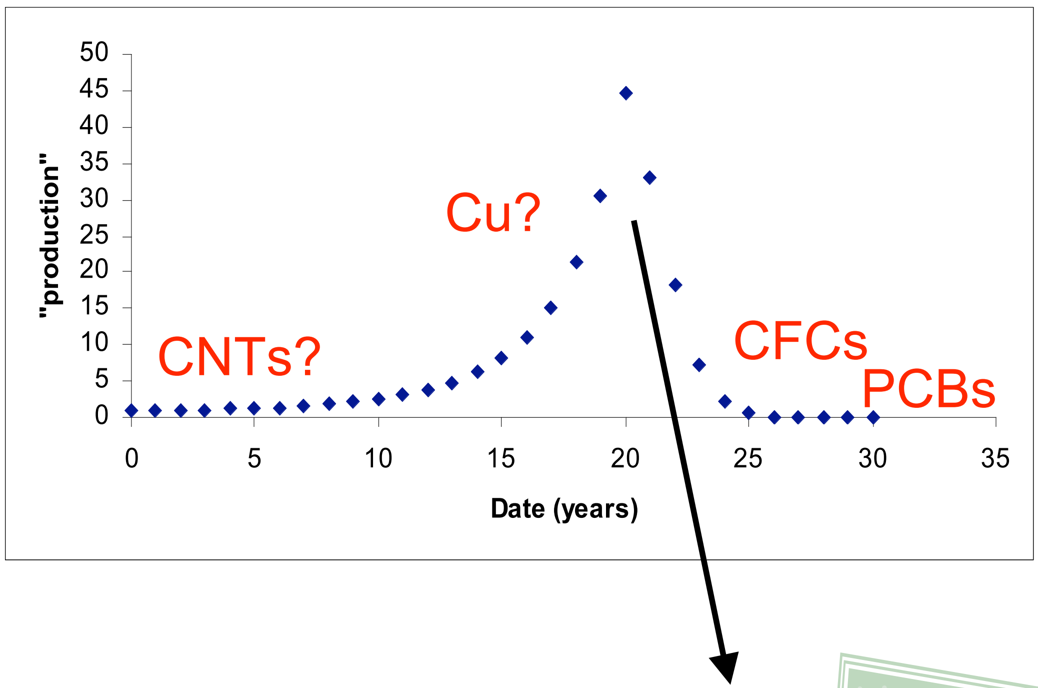
Si Technology:
Complexity Increasing Exponentially



Decade of new materials

Source: Intel

Potential Lifespan of Environmentally Harmful Compounds



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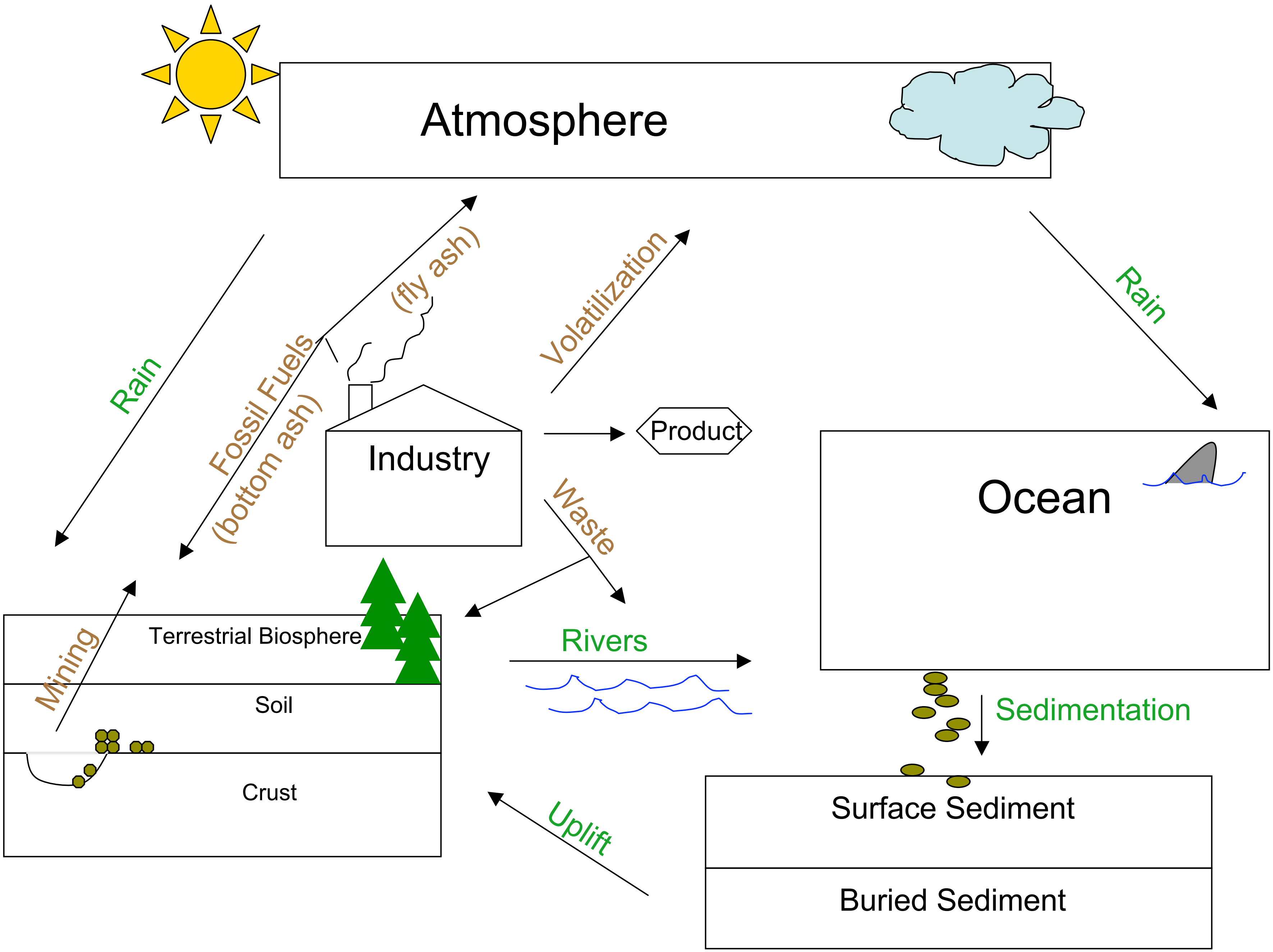
What I’d like to Convey:

Important to think about environmental impacts EARLY!

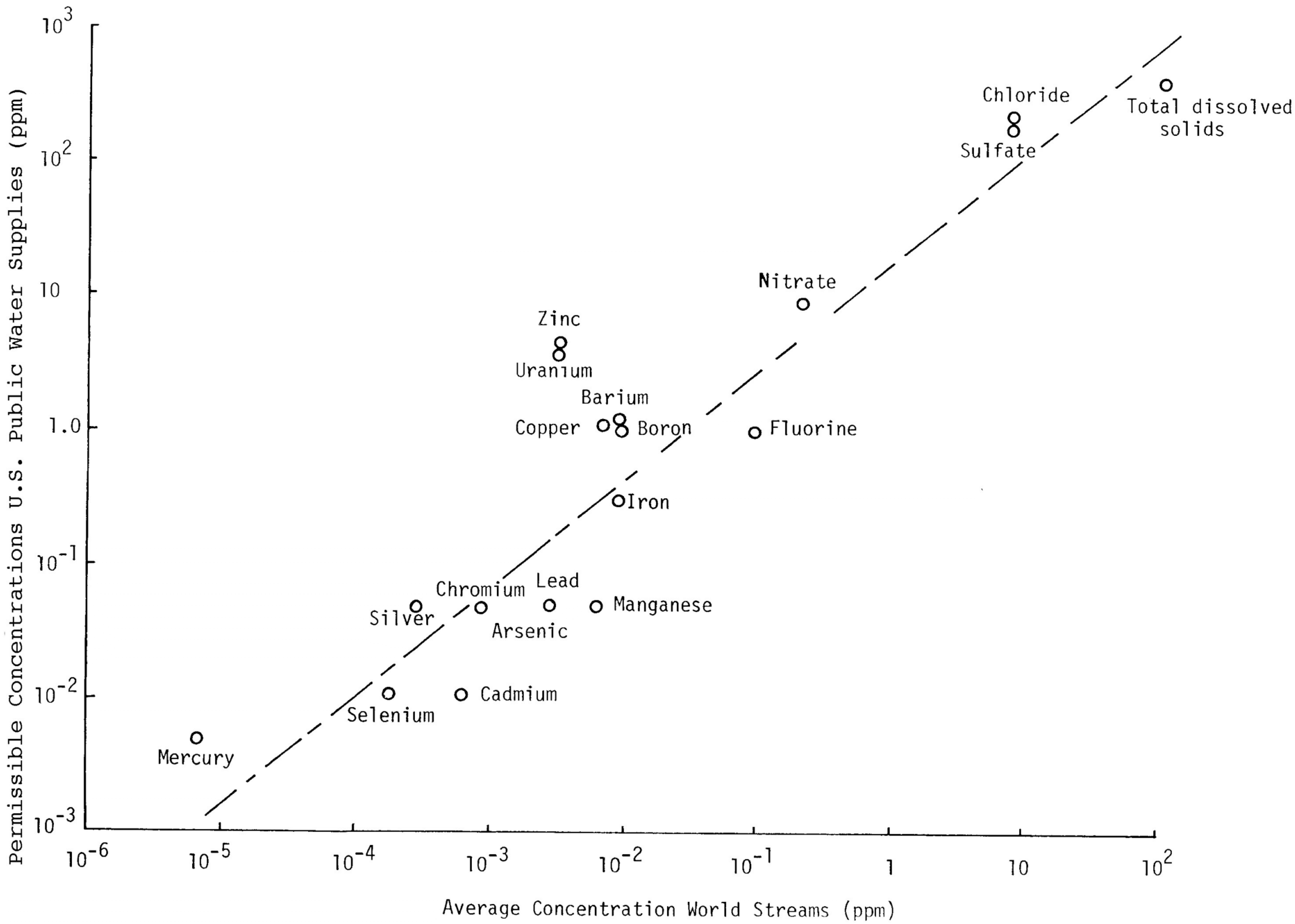
Yes, but… HOW??

» Geochemical Cycles «

Geochemical Cycle

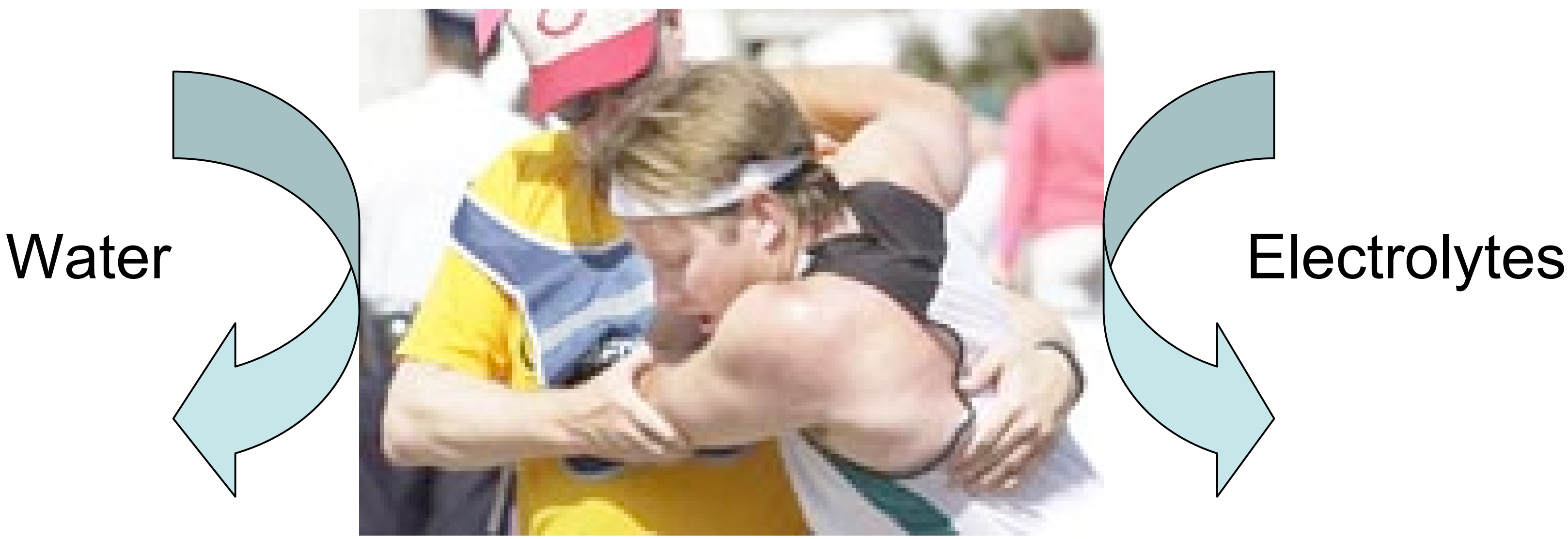


Background Concentrations versus Permissible Limits



from Garrels et al.

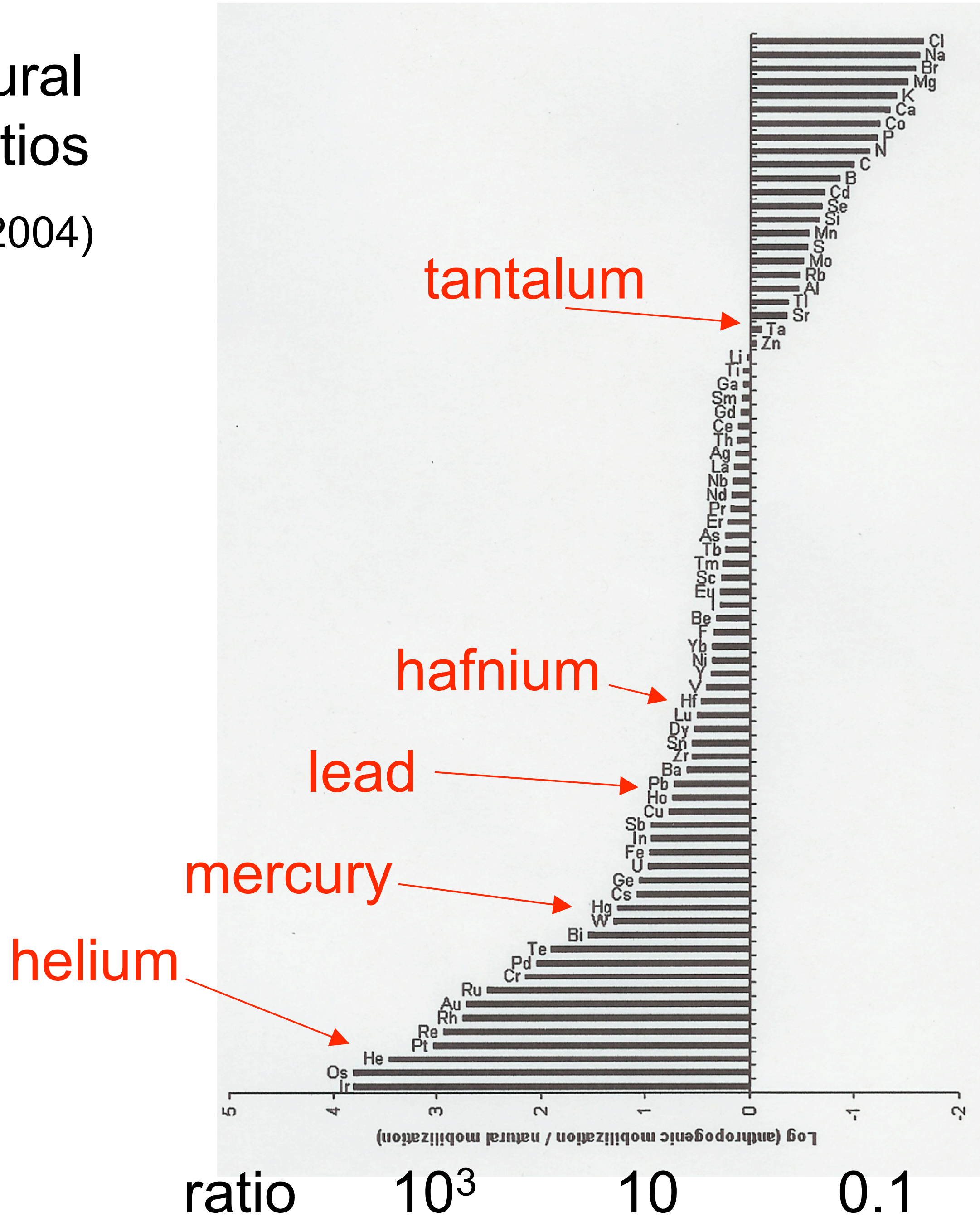
Perturbed Fluxes



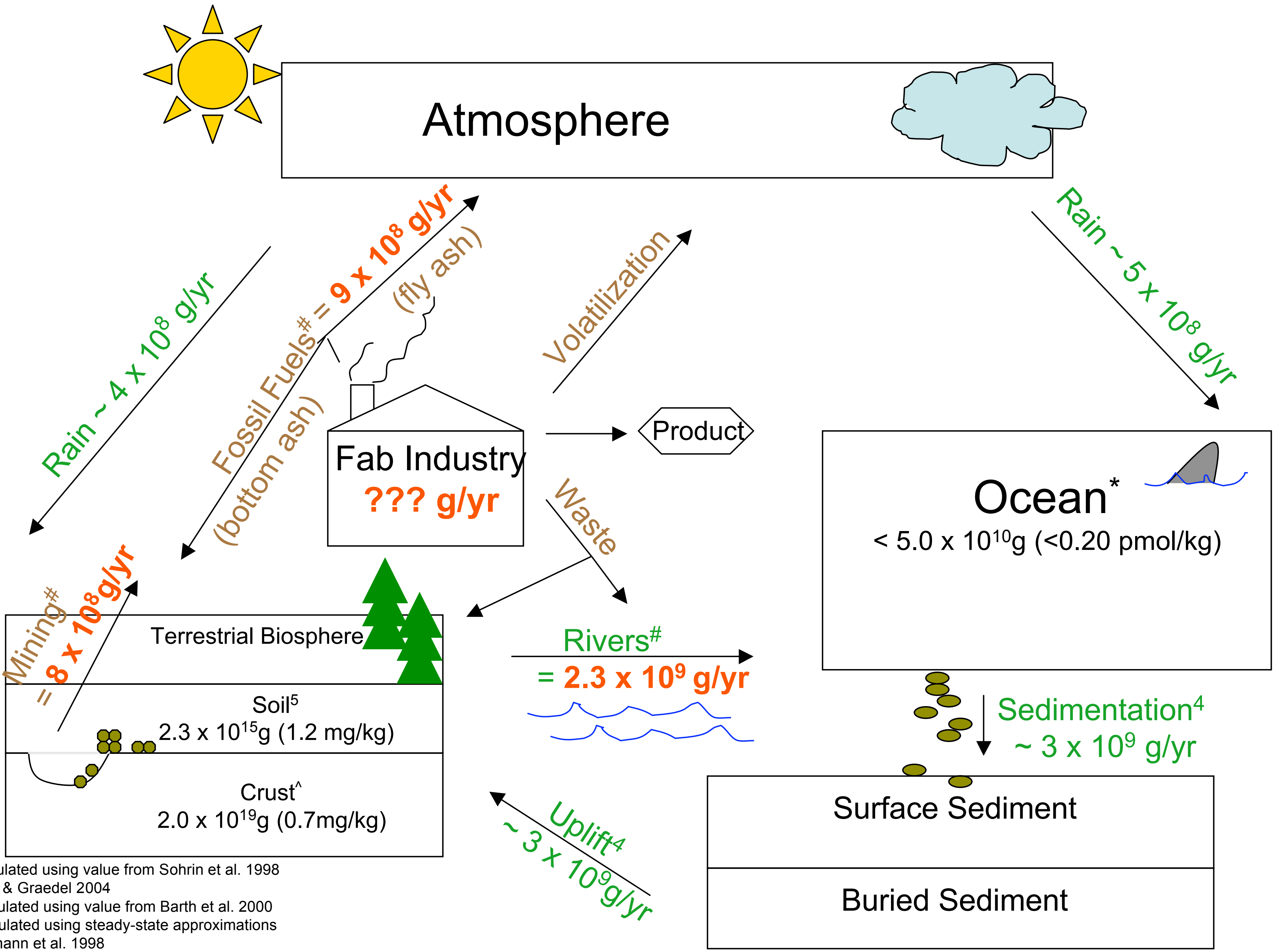
Gary Landers photo from
www.enquirer.com/editions/2000/05/15/collapse.jpg

Human vs. Natural Mobilization Ratios

(Klee and Graedel, 2004)



Global Cycle of Tantalum



*Calculated using value from Sohrin et al. 1998

#Klee & Graedel 2004

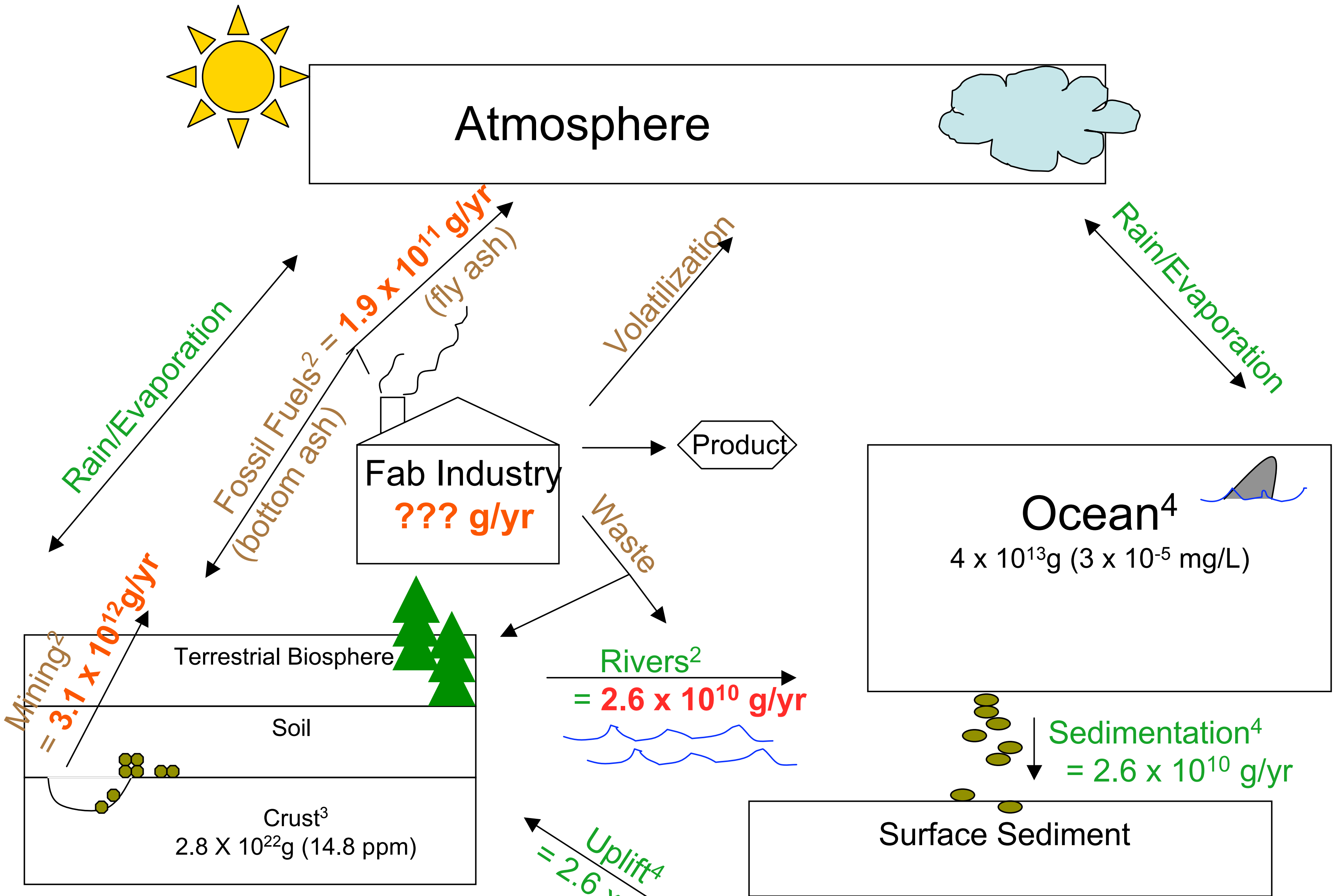
^Calculated using value from Barth et al. 2000

4Calculated using steady-state approximations

5Reimann et al. 1998

Lead as a Case Study…

Global Cycle of Lead



[2]Klee & Graedel 2004
[4]Calculated using steady-state approximations
[3]Wedepohl et al. 1995
[4]CRC Handbook of Chemistry & Physics, 2006

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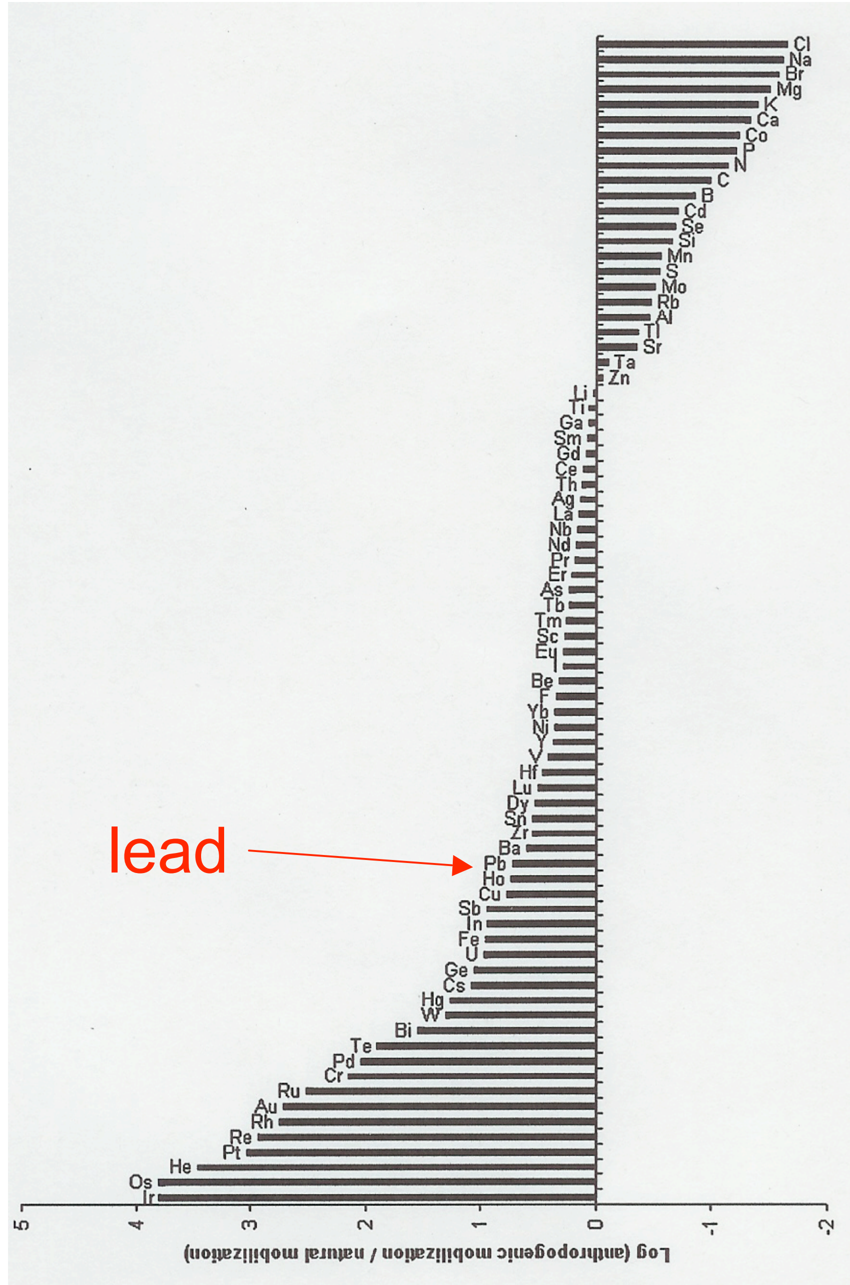
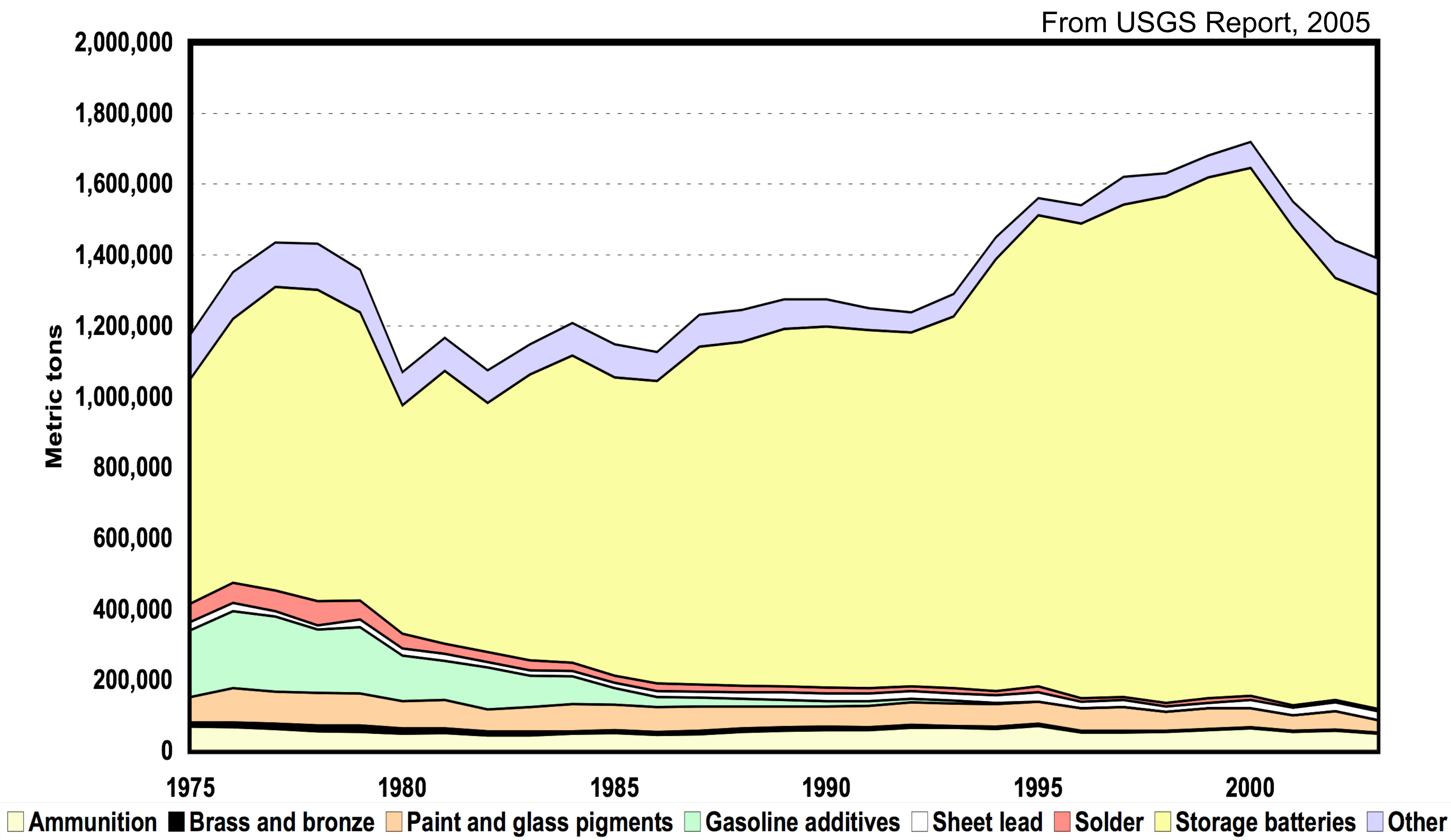


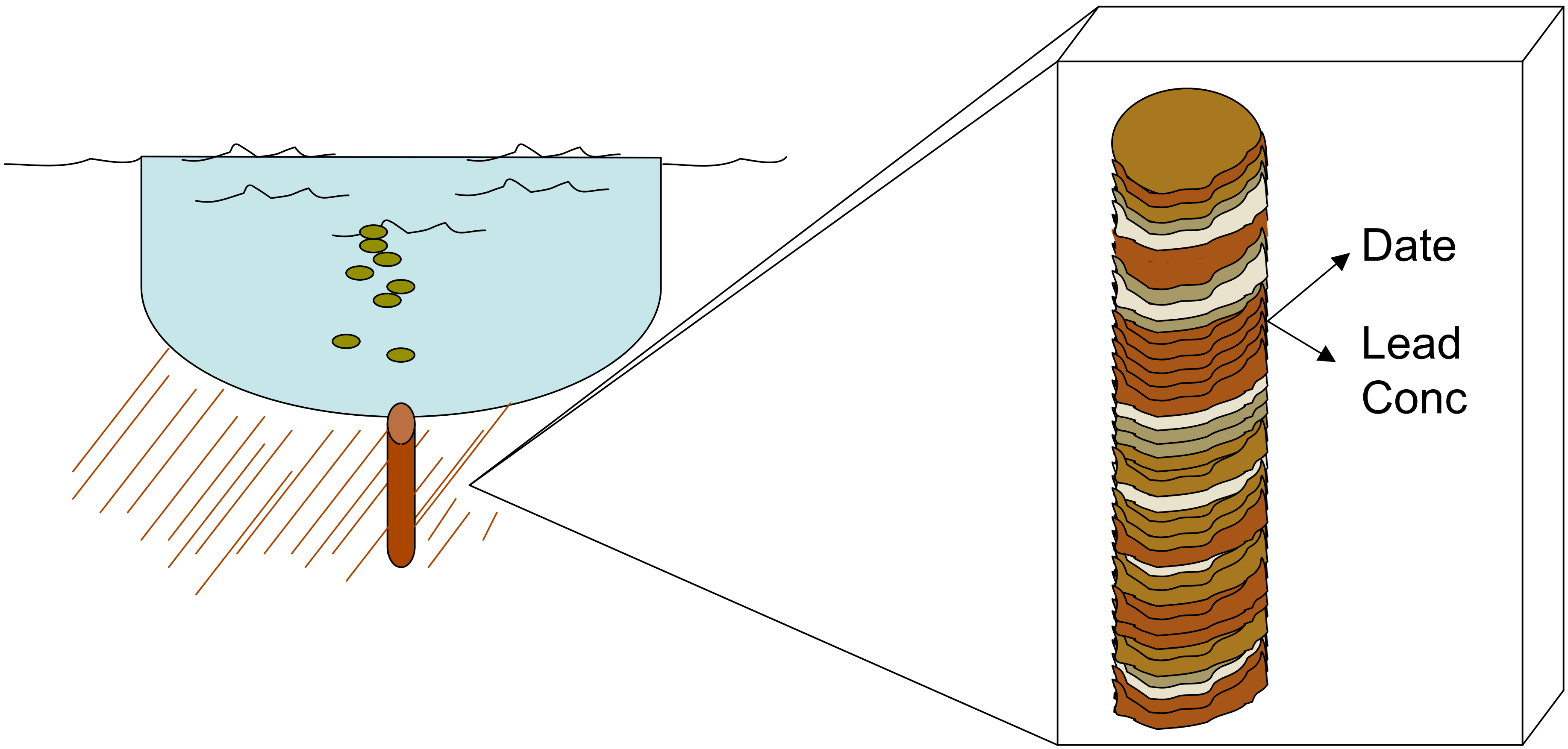
ratio 10^3 10 0.1

End Uses of Lead



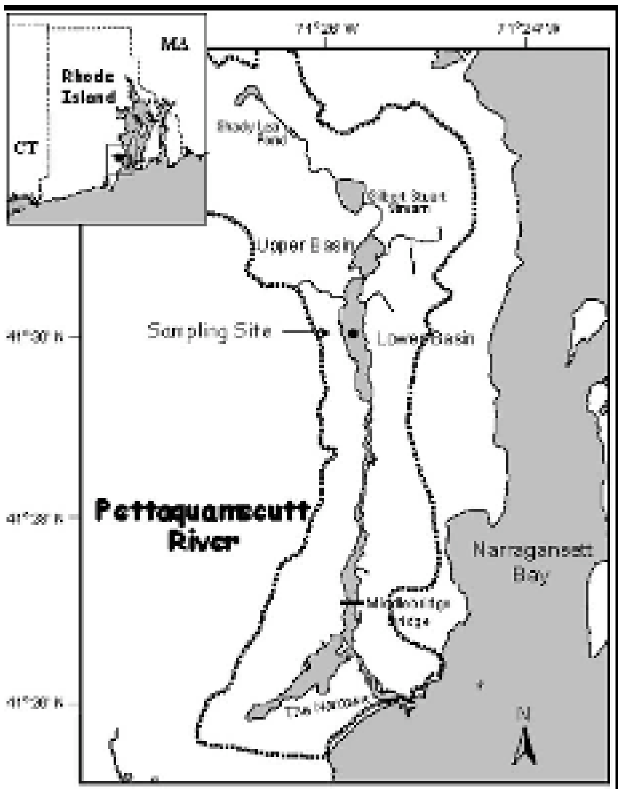
Probing Environmental Media

Sediment Cores



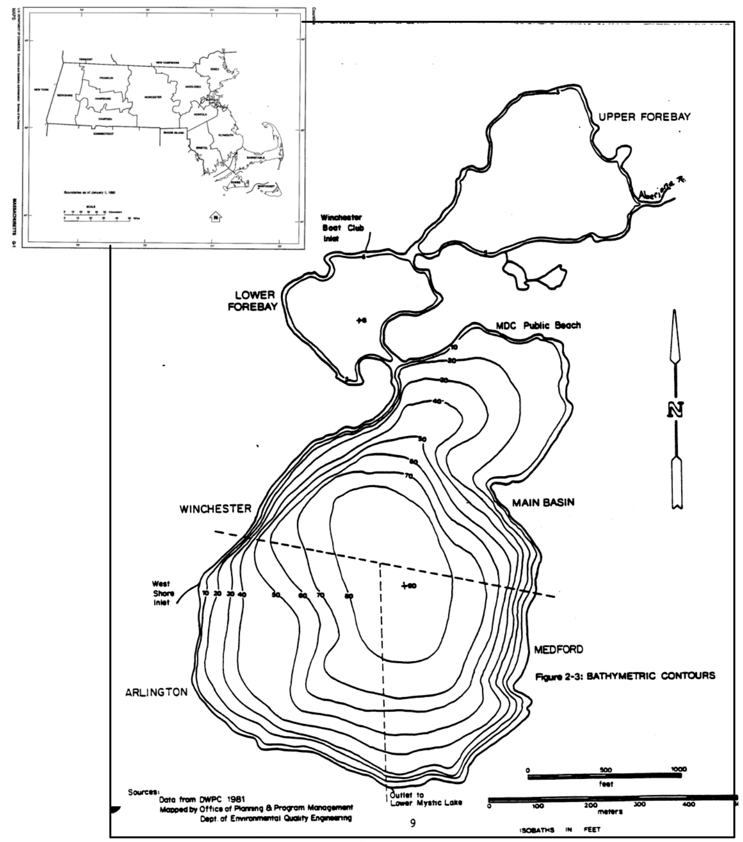
Sediment Core Sites

Pettaquamscutt Estuary, RI

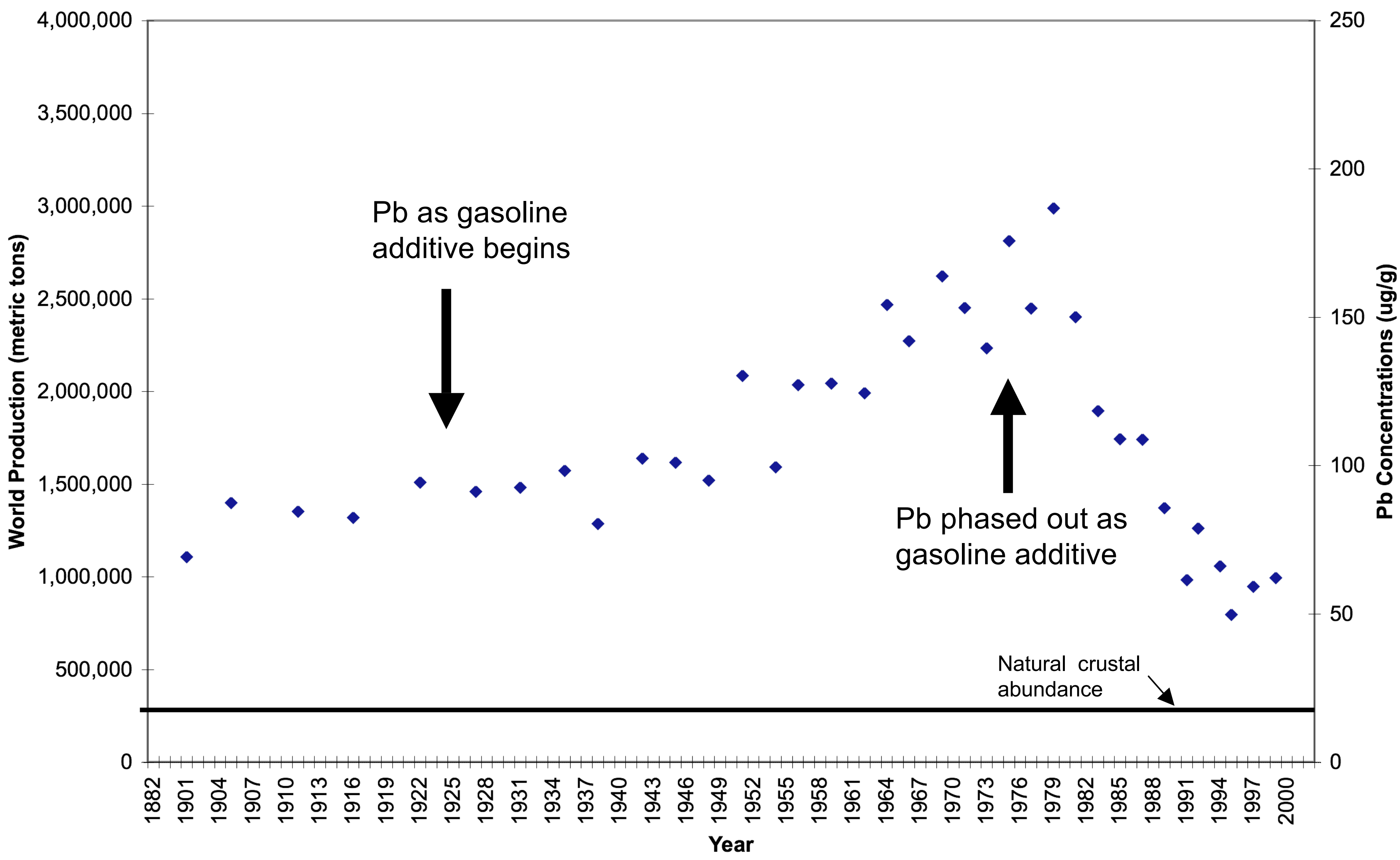


From Lima et al. 2005

Upper Mystic Lake, MA



Pb "availability" as Measured in Sediments of an Isolated Watershed



Pb sediment data from Lima, A. thesis (2004)

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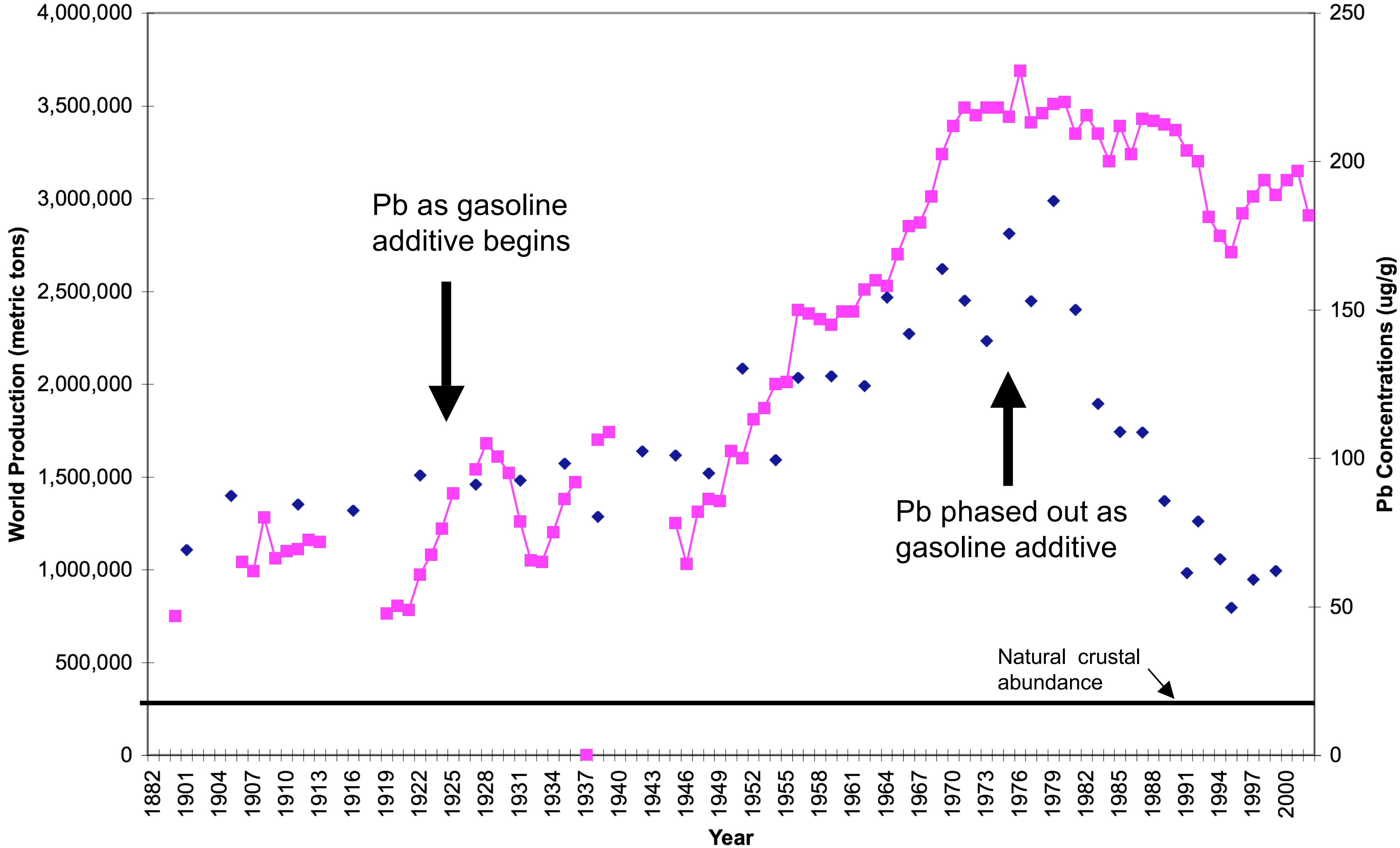

Production data from USGS report (2005)

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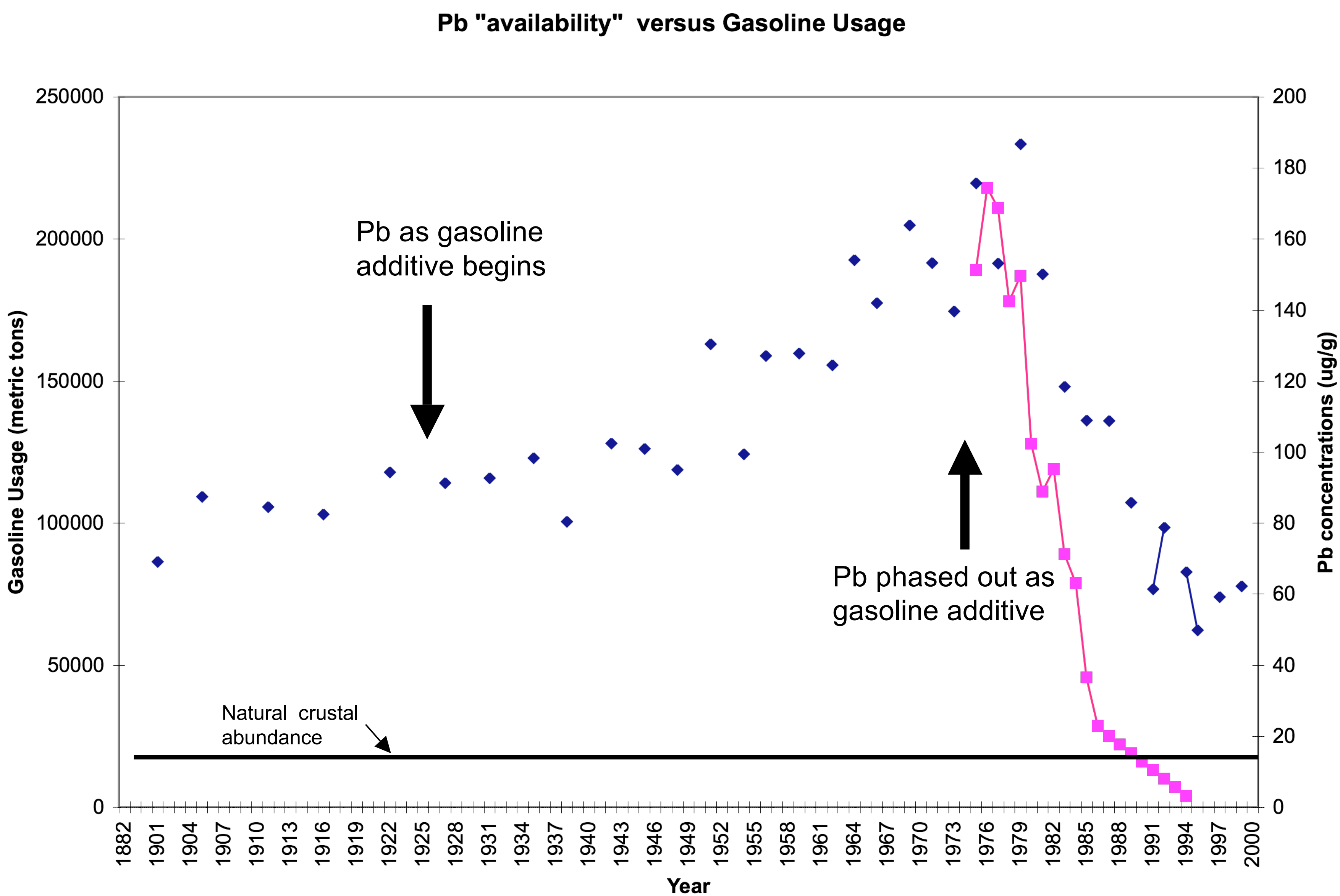

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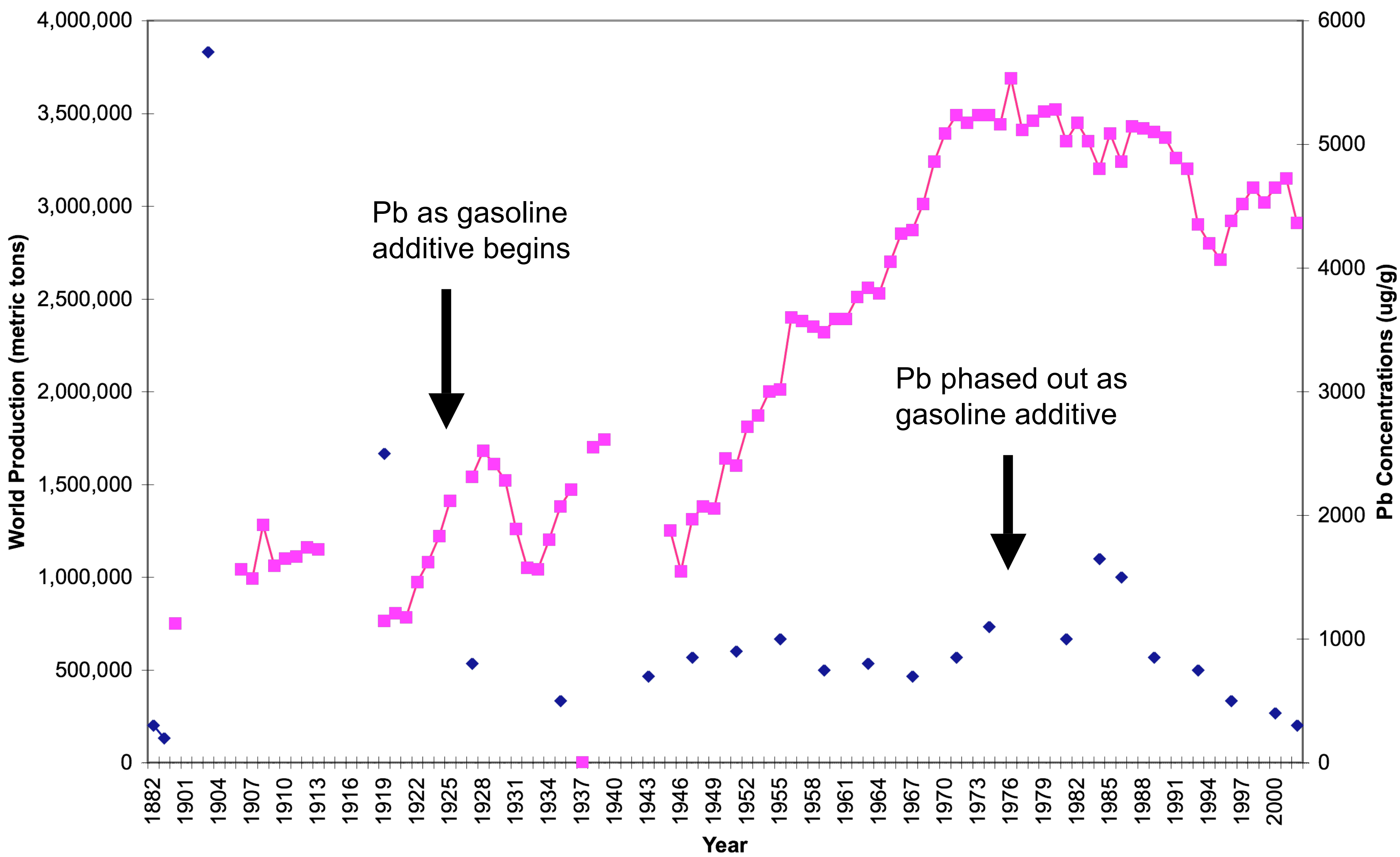
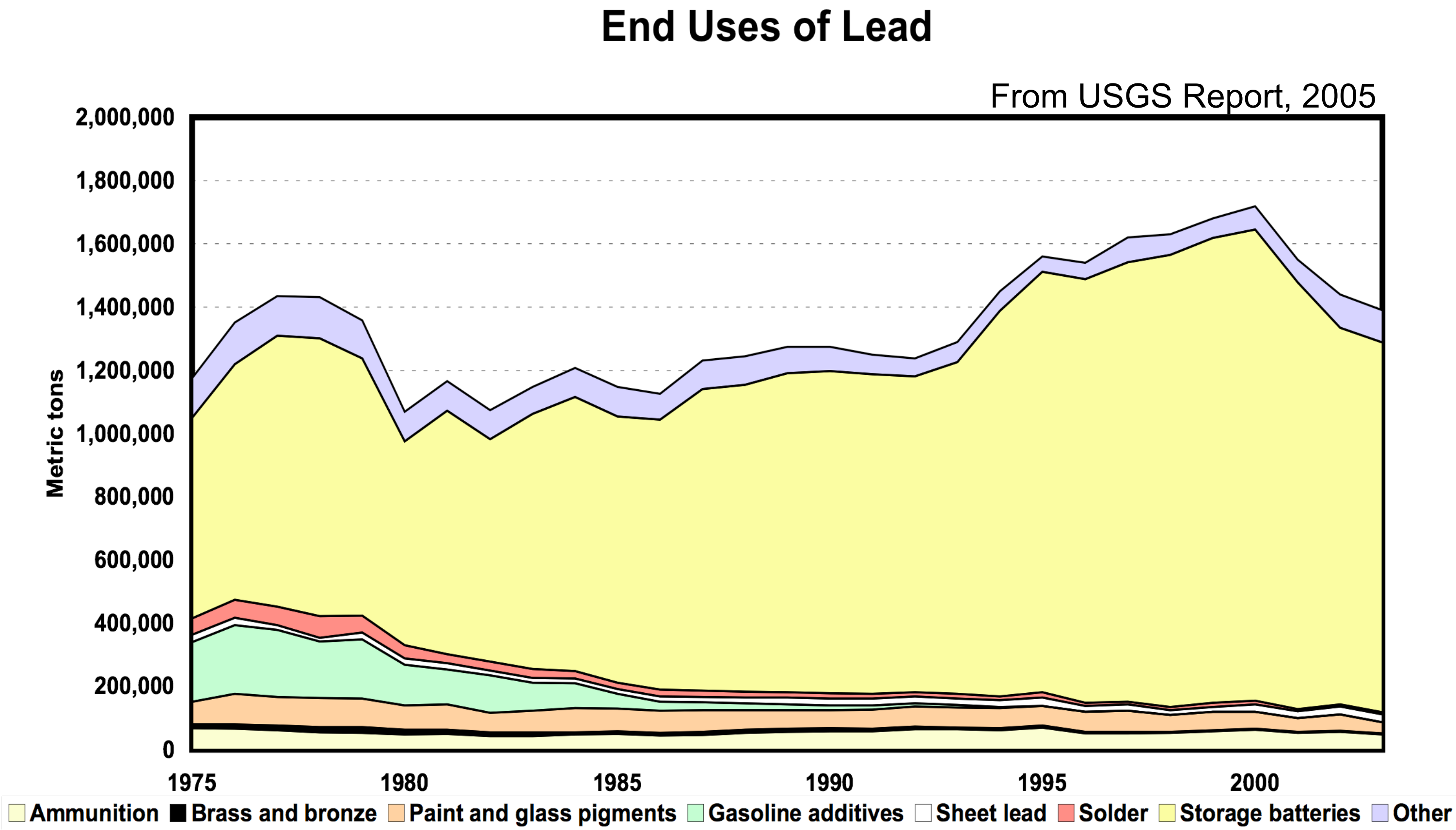


Production data from USGS report (2005)

Pb sediment data from Rauch & Hemond (2003)

What we can learn from lead:



- Local versus Global is important
- End-use is important

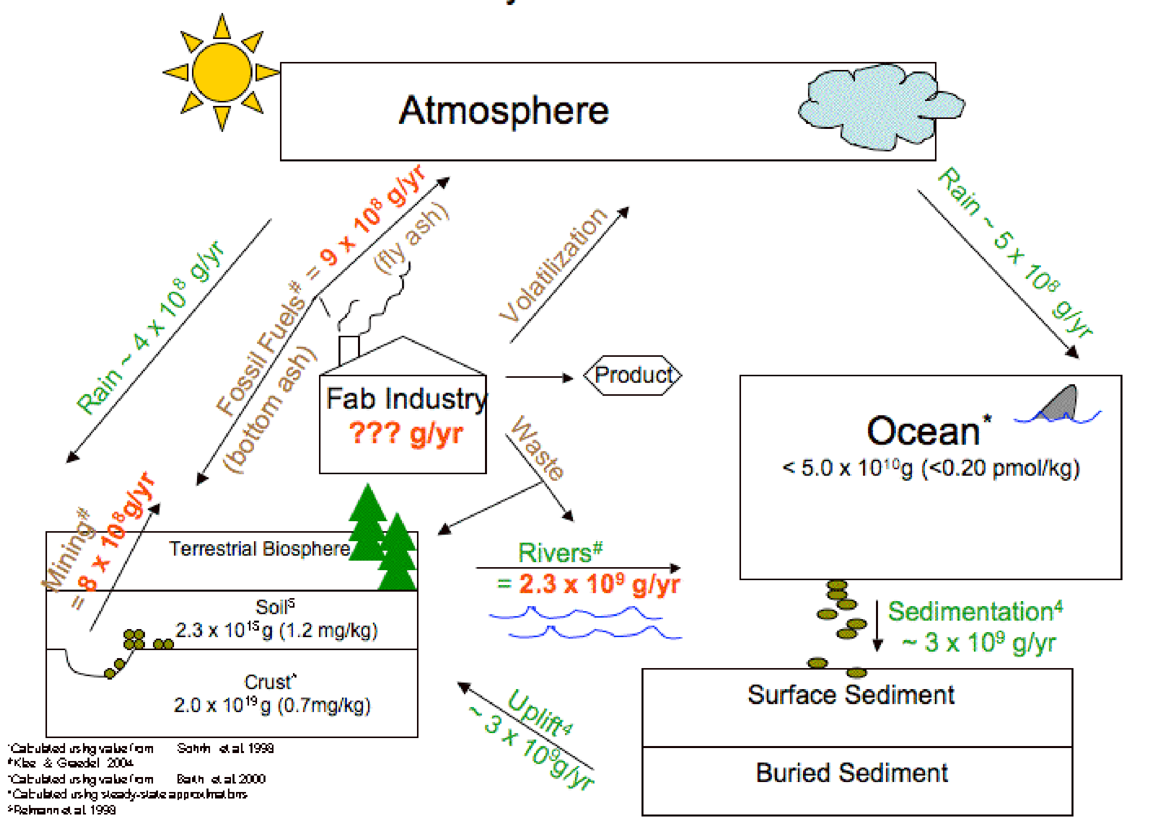
Conclusions:

- We need to think about environmental impacts EARLY
  - First Approximation: Look at Natural versus Anthropogenic Fluxes on local and global scales
  - Second step: Look at end-use on local and global scales
- Ultimate Goal: Provide timely feedback to researchers who are developing new process technologies

Looking Ahead…

- A Current Goal: Predict the concentrations of metals of interest (tantalum, indium, **others?**) in environmental media
  - Use data from environmental measurements

Global Cycle of Tantalum



Looking Ahead…

- A Current Goal: Predict the concentrations of metals of interest (tantalum, indium, **others?**) in environmental media
  - Use data from chemical observations and calculations

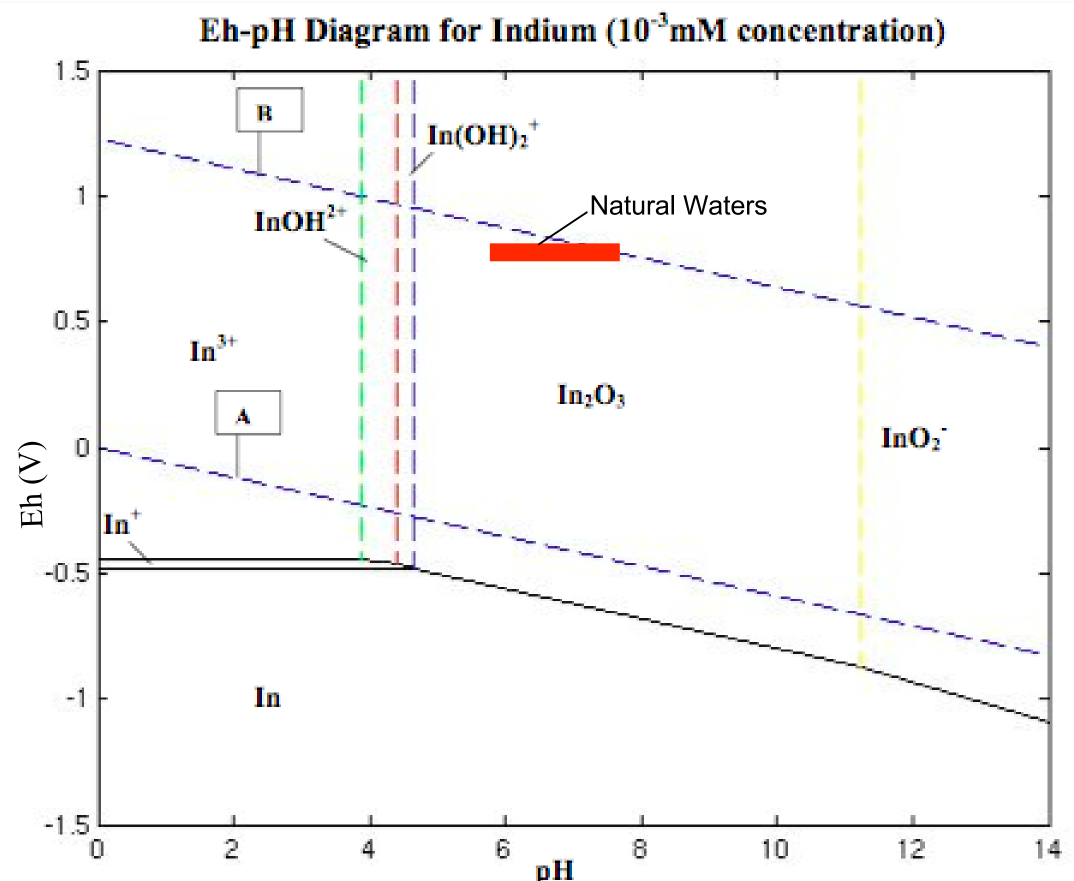
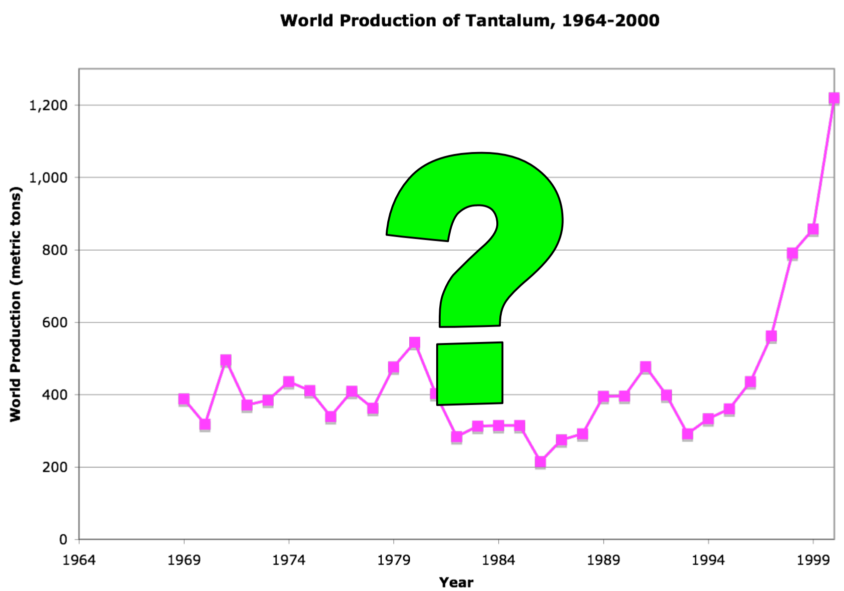
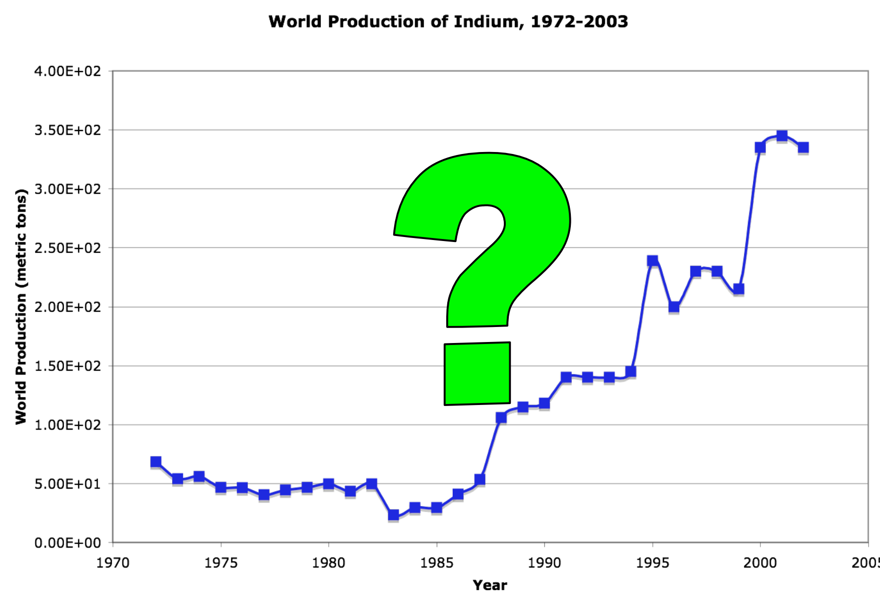


Figure by Katherine Orchard

Looking Ahead…

- A Current Goal: Predict the concentrations of metals of interest (tantalum, indium, **others?**) in environmental media
  - Use Proxy like sediment core to confirm prediction





Data from USGS Report, 2005

Acknowledgments

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- Sarah Boyd, Applied Materials/UCBerkeley