Estimating carbon dioxide flux from coal mining discharge portals in the bituminous coal field region of Pennsylvania

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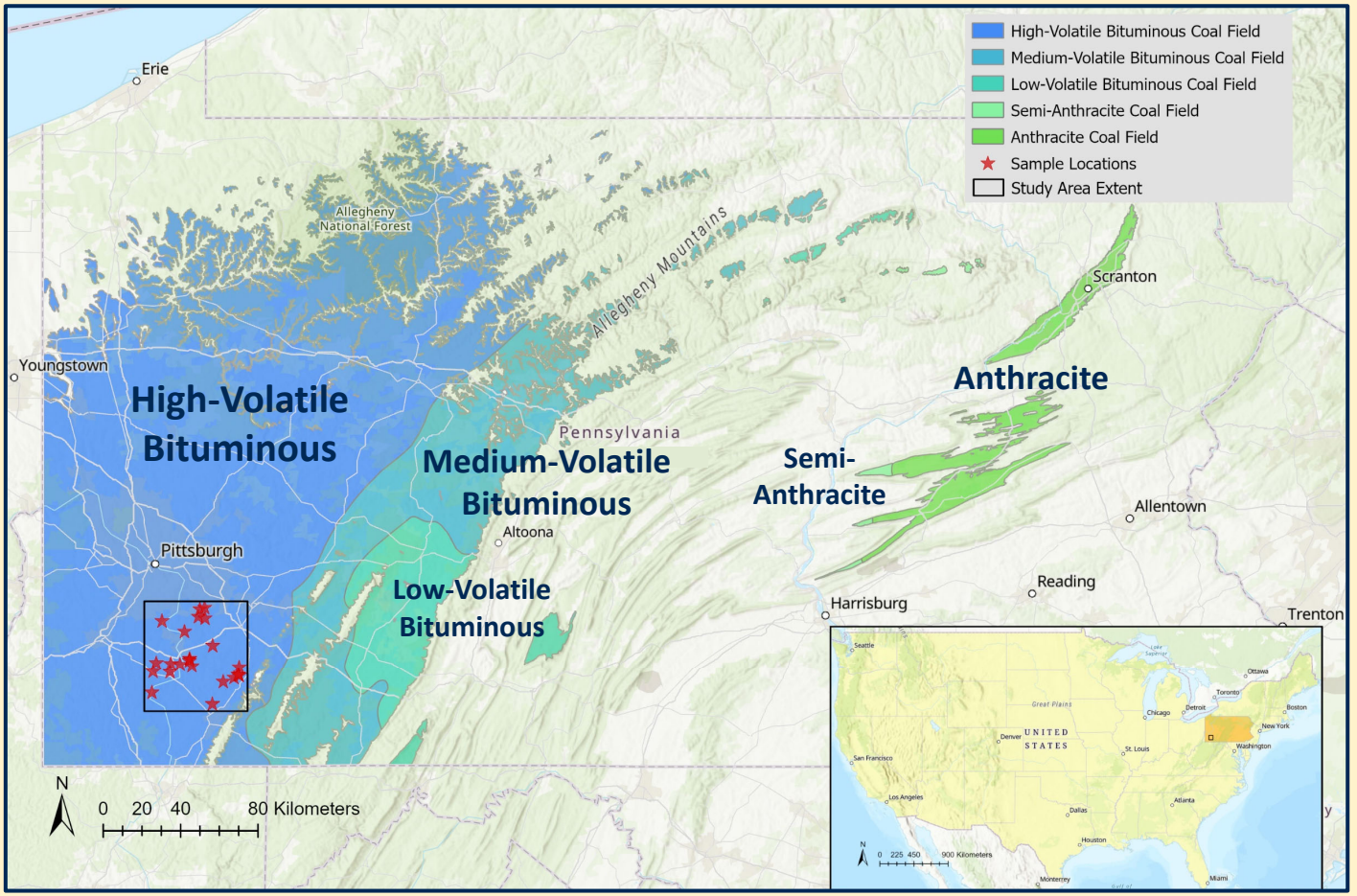
Distribution of Coal Fields in Pennsylvania



(PA Department of Conservation and Natural Resources (DCNR), 2021)

Coal Mine Drainage (CMD) in Pennsylvania

- Mining for coal exposes rock to water and oxygen
- Estimated that **5-trillion gallons** of water are contained within flooded Pittsburgh coal seam mines in PA (Donovan & Leavitt, 2004)
- PA has 138,400 km (**86,000 mi**) of streams

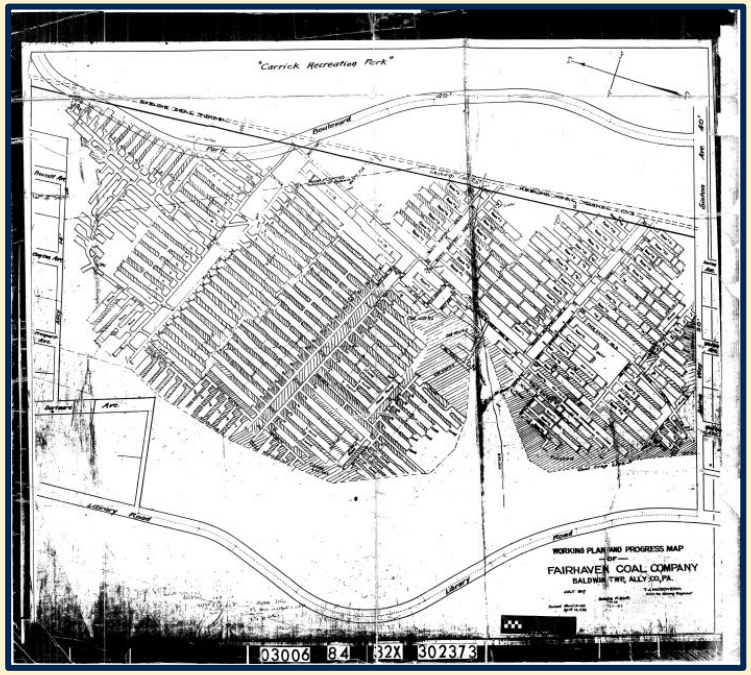
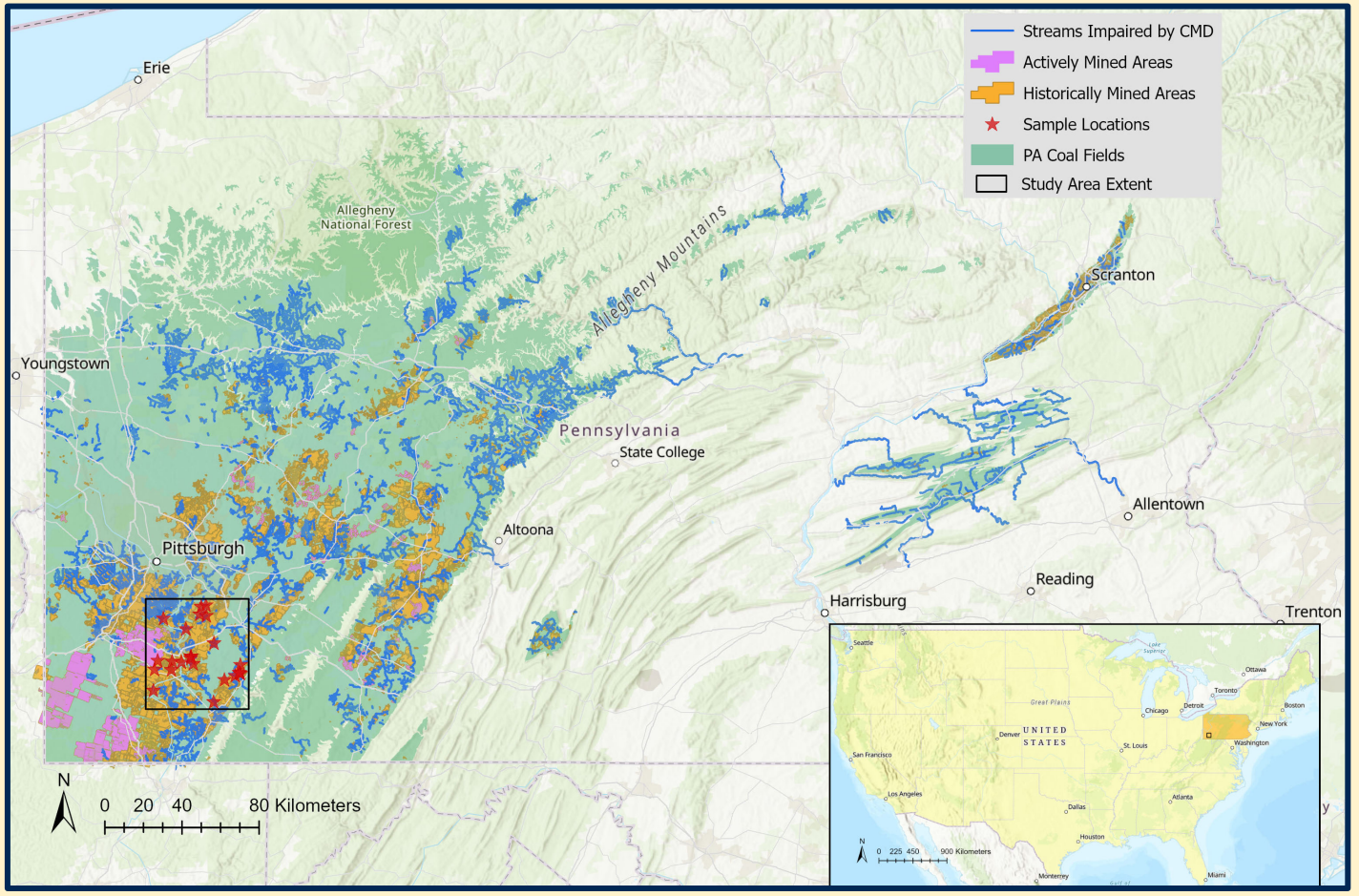


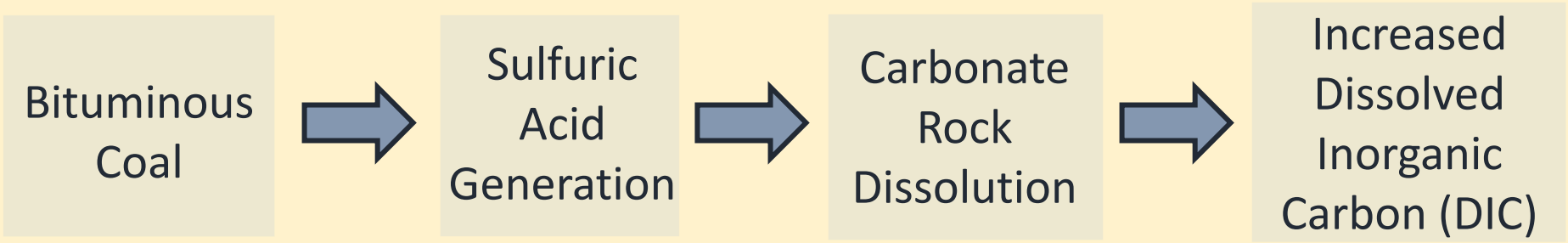
Photo Source: http://wiki.carrick-overbrook.org/Coal_Mine_Maps

Impaired Streams from CMD in relation to Mined Areas



(PA DCNR, 2021; PA Department of Environmental Protection (DEP), 2023c; 2023d)

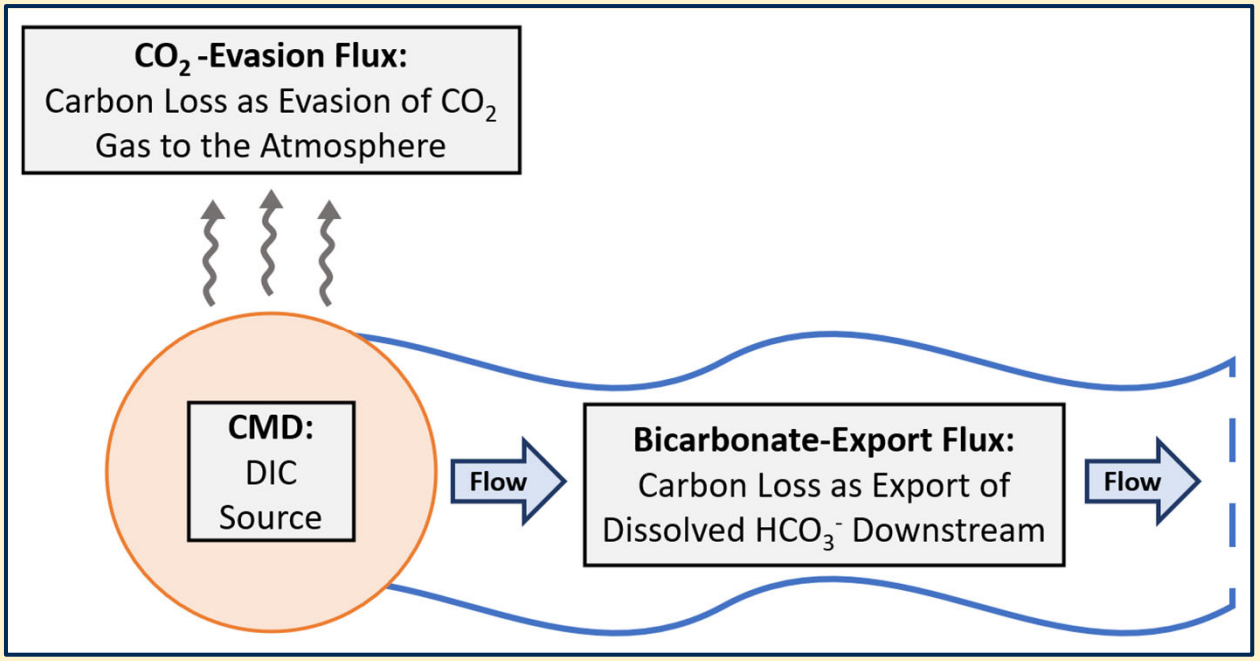
The Role of CMD in Carbon Dioxide (CO_2) Release



Sulfuric acid drives the dissolution of **geologically bound carbon** in carbonate rocks to the atmosphere

DIC loss occurs as two major fluxes in CMD systems:

CO_2-Evasion Flux & Bicarbonate-Export Flux



Planar View of a CMD Source

Project Purpose & Objectives

- **Purpose:** Collect data about carbon flux from CMD portals in the study area to make inferences about the flux over the bituminous coal field region of PA
- **Objectives:**
  - Evaluate regional variability
  - Quantify total fluxes of loss of DIC
  - Compare estimates for the region to other studies

Study Area & Timeline

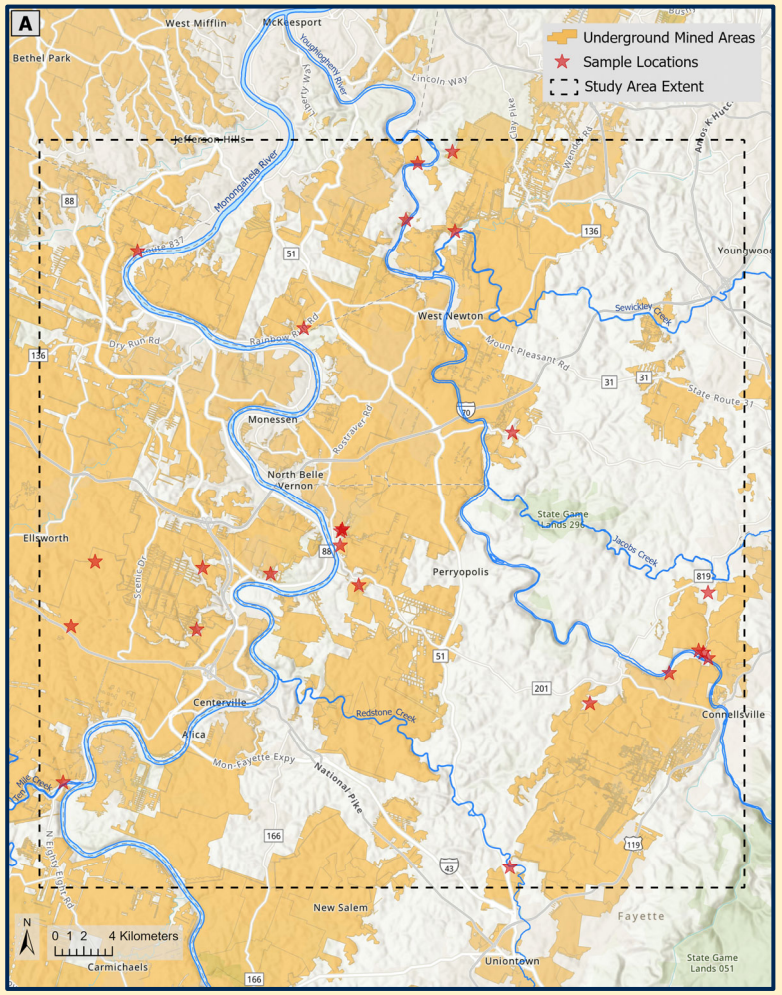
June 2023 – January 2024

- 25 locations sampled once
- Gorby Run (LR00) sampled monthly for 5 months

Discharge Pipes

Ground Seeps

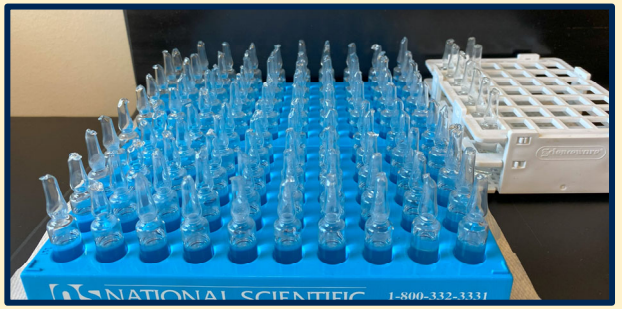
Mine Portal Entrances



(PA DEP, 2023c; The Pennsylvania State University, 1996)

CO_2 & DIC Sampling Method

- Cleaned soda (or pop) bottles were used
- **DIC process:**
  - Hydrochloric acid (HCl) used to convert all DIC into dissolved CO_2
  - Measure dissolved CO_2 concentration
  - Correct for temperature
  - Calculate DIC from temperature-corrected CO_2

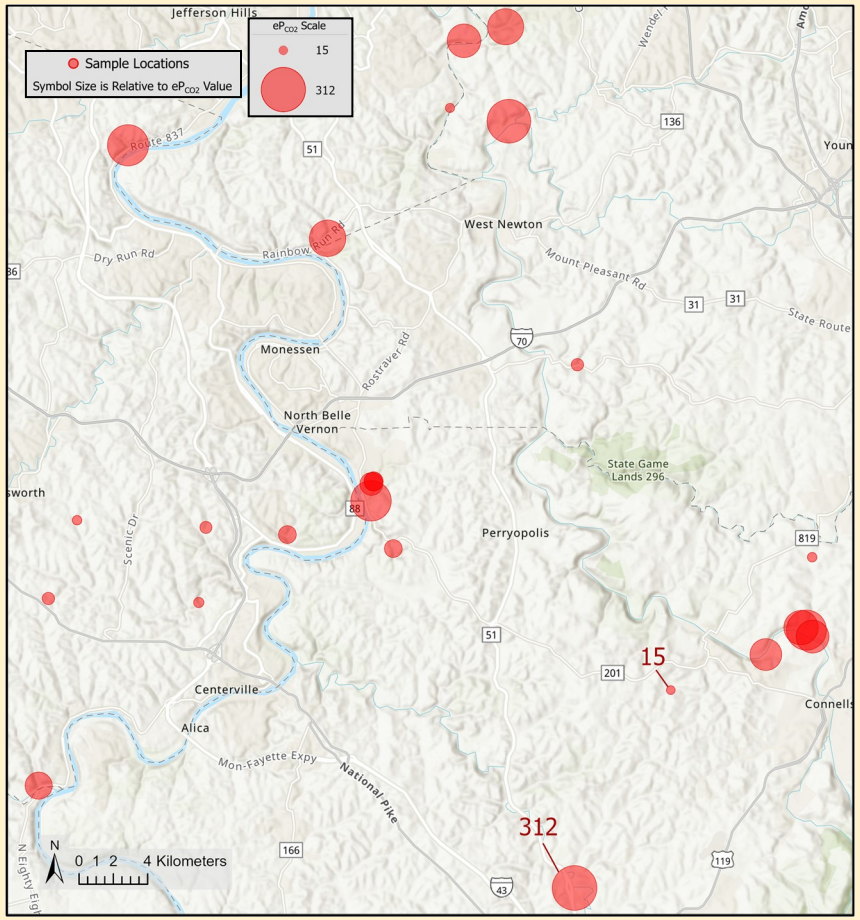


Methods modified from Vesper & Edenborn (2012) and Vesper et al. (2024)

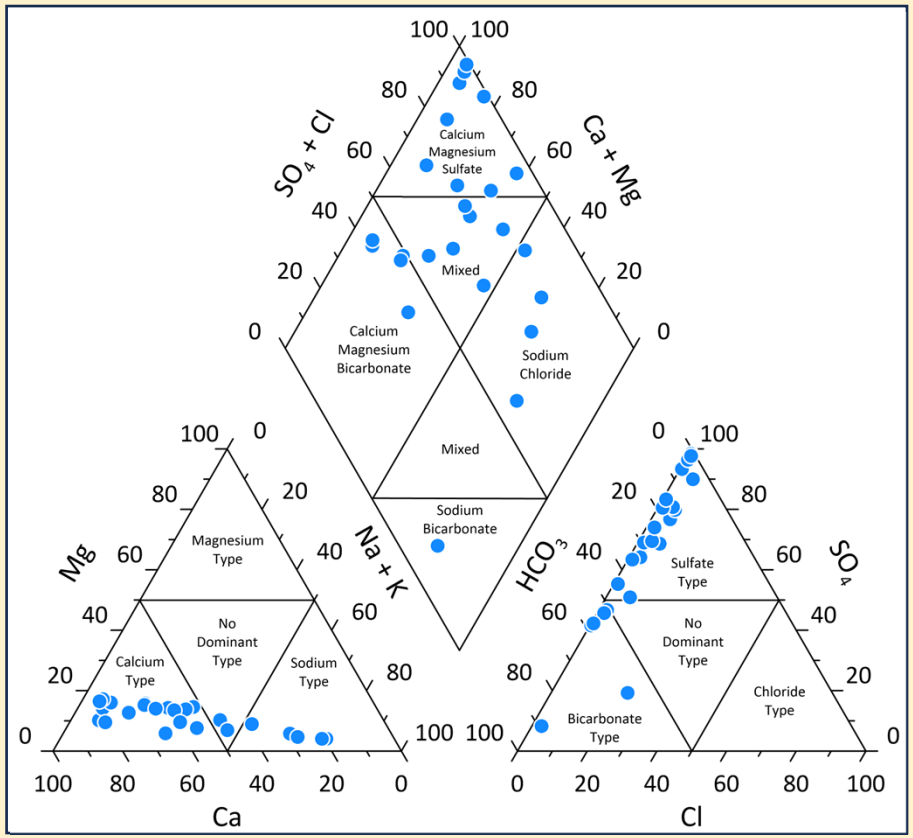
CO_2 & DIC Variability

- **CO_2 Range:** 0.3 – 5.8 mM
- **DIC Range:** 0.8 – 15.3 mM
- **Enhanced Partial Pressure of CO_2 (eP_{CO2}) Range:** 15 – 312
  - CO_2 concentrations of the samples are this many times greater than expected at atmospheric equilibrium

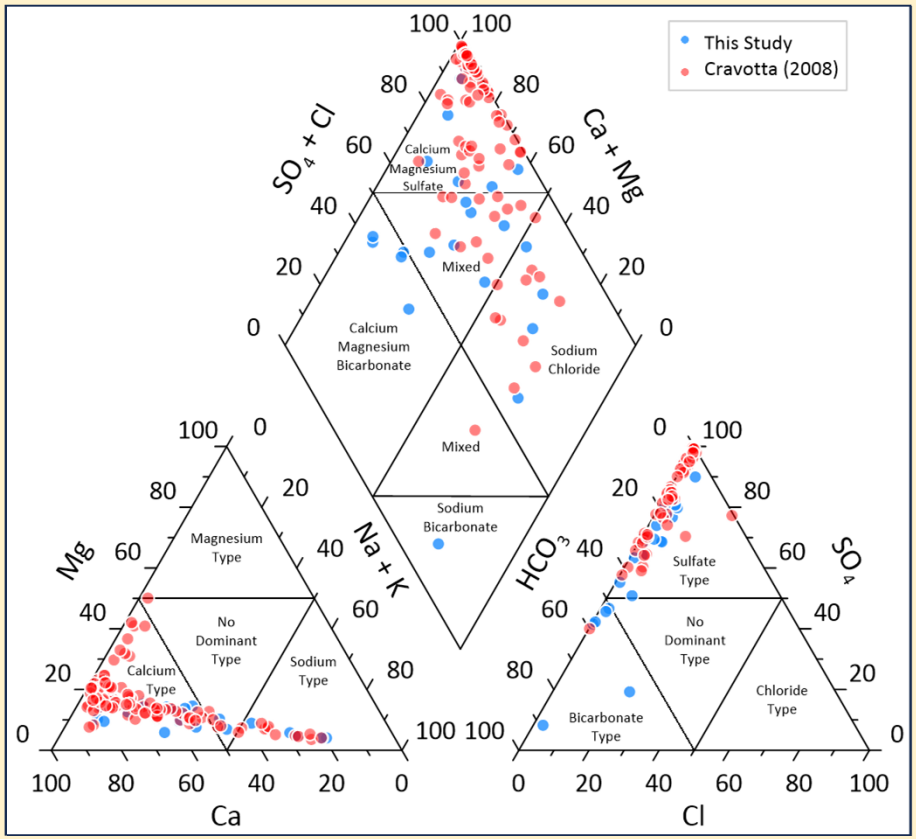
    (420 ppmv from National Oceanic and Atmospheric Administration (NOAA), 2023)



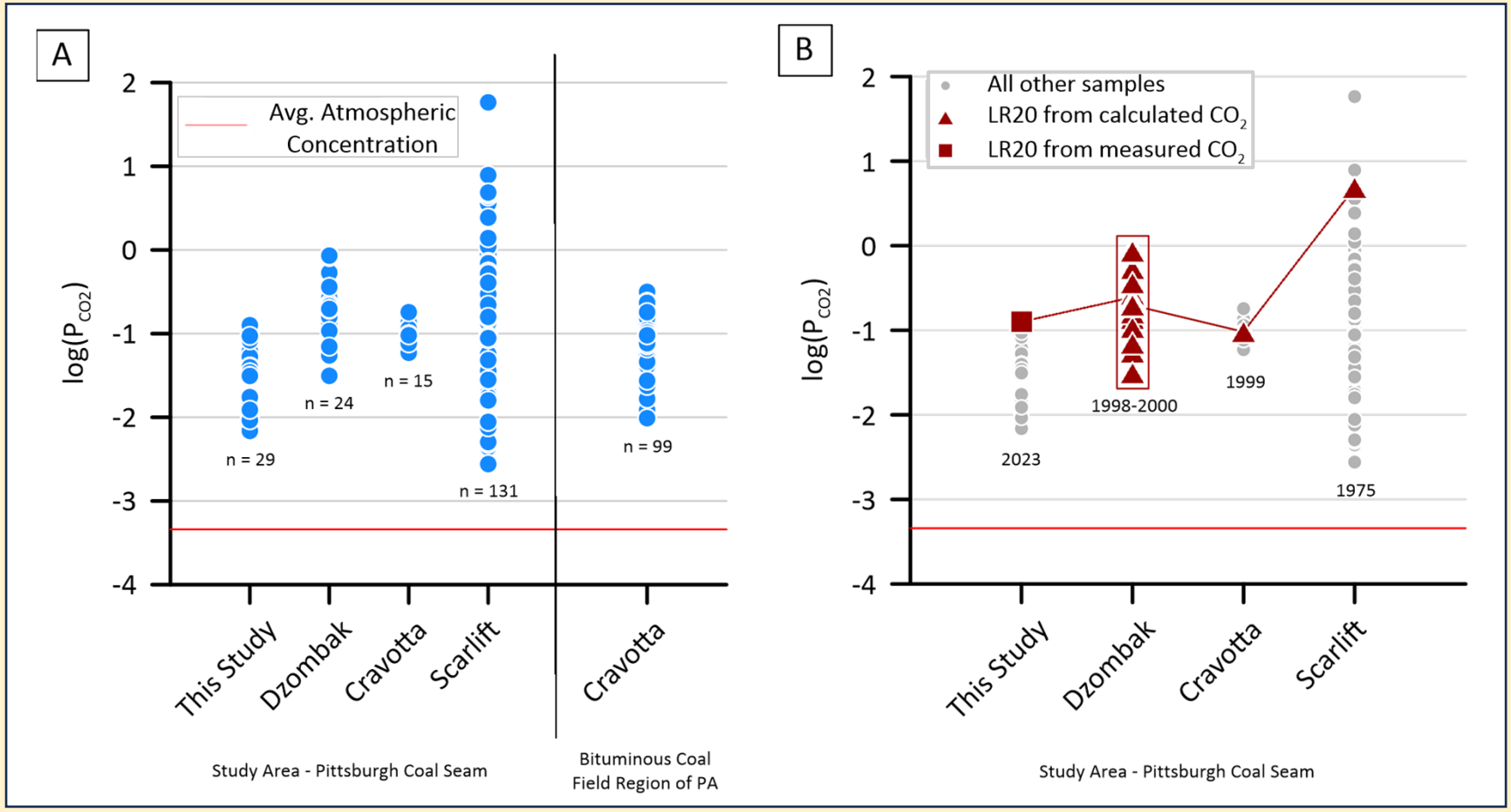
This Study's Study Area



This Study's Study Area + Cravotta (2008)'s Bituminous Coal Field Region of PA



Study Area Variability



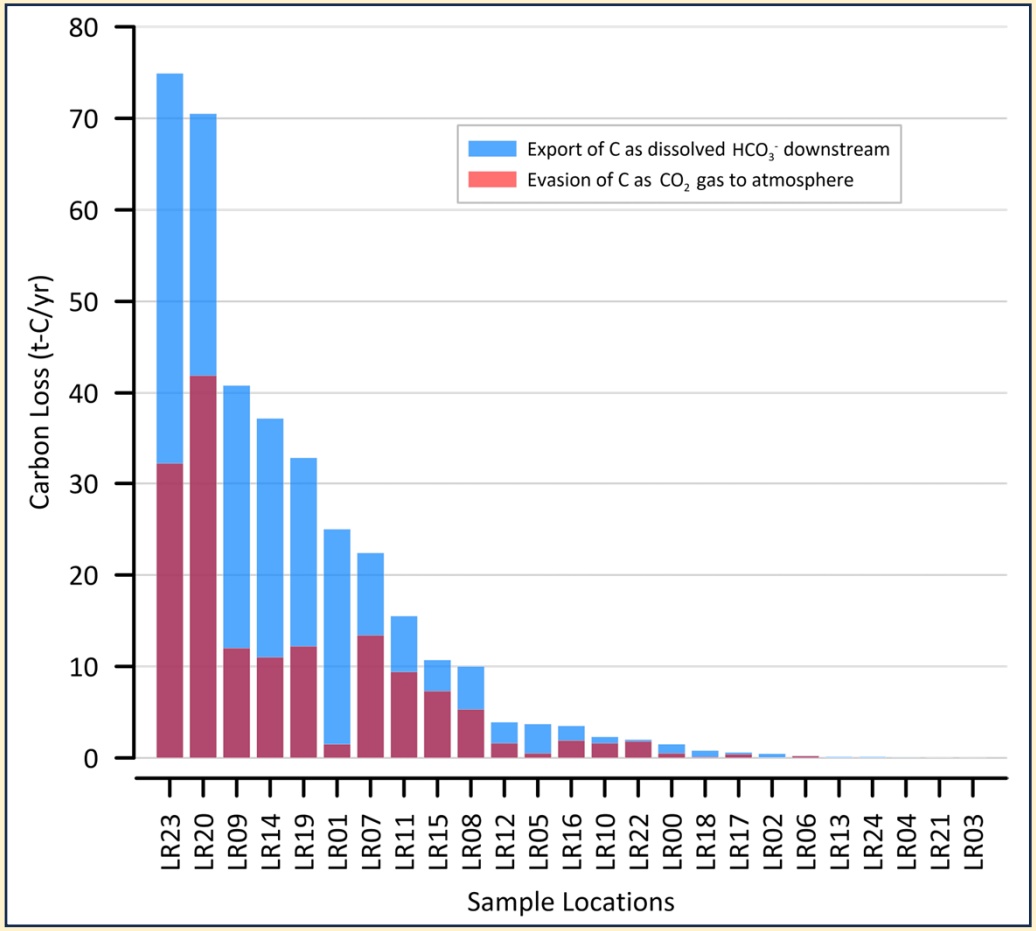
Flux Variability

Average CO_2-Evasion:

23 t-CO_2/year or 6 t-C/year

Average Bicarbonate-Export:

8 t-C/year



Total Flux Comparison

Region	CO_2-Evasion Flux ($t\text{-}CO_2$/year)	CO_2-Evasion Flux (t-C/year)	Bicarbonate-Export Flux (t-C/year)
Study Area Total	570	160	200
Bituminous Coal Field Region of PA Total	14,300	3,900	5,200

Note: Study area is 4% of the total area of bituminous coal field region of PA

Flux Comparison: PA Coal-Fired Power Plants

	PA Coal-Fired Power Plants	
	Minimum Average Flux	Average Flux of All Plants
CO_2 Flux (Mt-CO_2/year)	0.23	1.86
Percentage Comparison of Study Area Total CO_2 Flux (0.00057 Mt- CO_2/year) to PA Power Plants	0.25%	0.03%
Percentage Comparison of Bituminous Coal Field Region of PA Total CO_2 Flux (0.014 Mt- CO_2/year) to PA Power Plants	6.2%	0.77%

Note: PA power plant data is from 2022, where the smallest power plant flux was the average from Pixelle Specialty Solutions and the average is from available data for eleven power plants (U.S. EPA, 2023)

Limitations: Over- or Under- estimation ?

- Lack of data quantifying distribution of CMD locations across PA
- Sample inaccessibility or no point source of CMD
  - Exs: wetlands, outcrop seeps, private property, & physical inaccessibility
  - About an additional 35 locations in the study area fell into these categories
- Measurement variability based on CMD type
  - i.e. seep, pipe, mine entrance
- Temporal or seasonal variability was not fully addressed in flux estimates

Summary

- Predominately carbonate-sulfate system
  - Consistent with observations from other studies
- Dissolved CO_2 and carbon fluxes vary across the study area
  - eP_{CO2} values ranged from 15 – 312 times greater than the atmosphere
- Average fluxes for the study area were 6 t-C/year for CO_2 evasion and 8 t-C/year for bicarbonate export
- The flux estimates are very approximate and may be biased high or biased low

Thank you!

MS Thesis Committee Members:

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