Quantifying Background Erosion Rates in Cuba Using Cosmogenic Nuclides

A thesis proposal by Mae Kate Campbell

Committee Members:
Paul Bierman, Advisor
Gillian Galford
John Hughes

Outline

- Research Goal
- Introduction to Project and Broader Importance
- Background
  - Land Use History of Cuba
  - Use of Cosmogenic Nuclides for Determining Erosion Rates
- Objectives
- Methods
- Summary
- Timeline

Research Goal

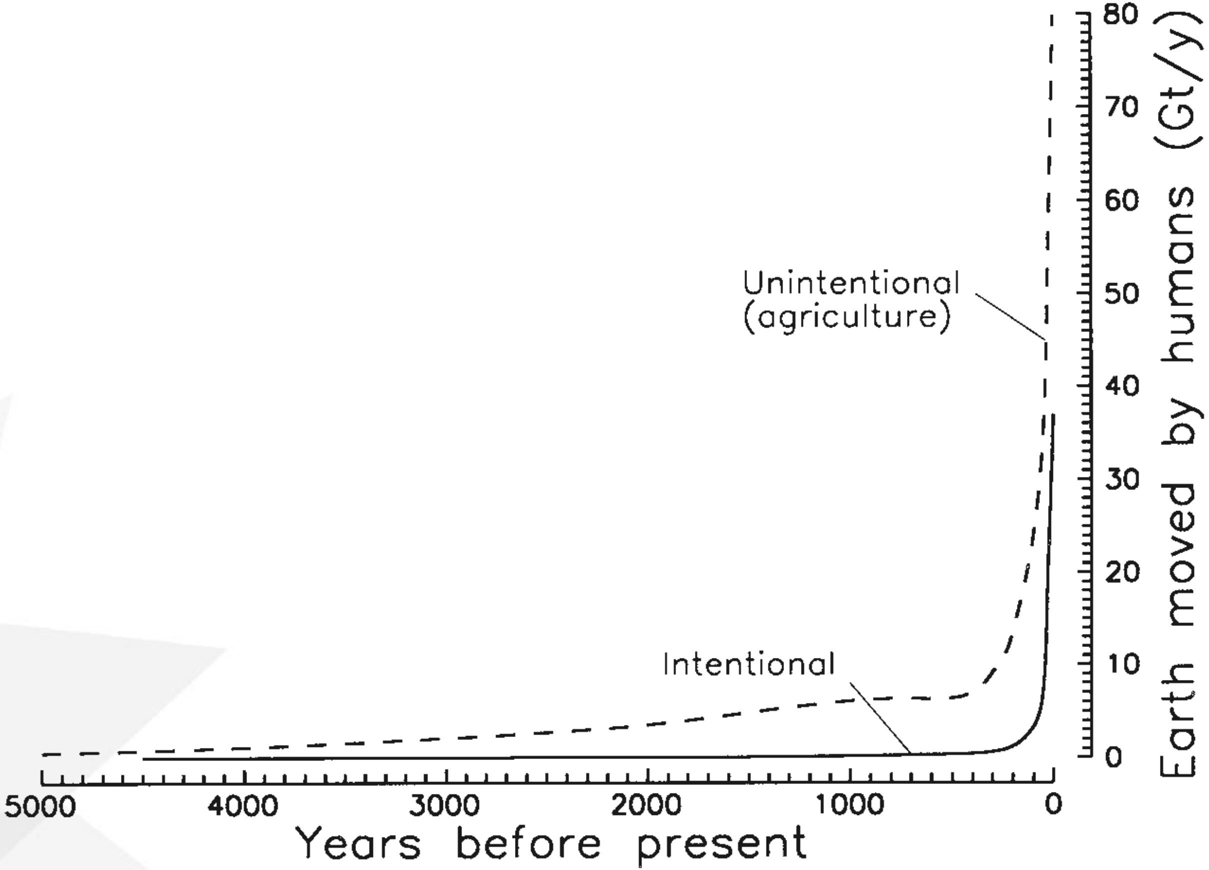
My thesis research is focused on characterizing the background rates of erosion in Cuba using cosmogenic nuclide measurements

Introduction: Understanding Erosion

- Soil erosion is a global issue impacting food production, water quality, and ecosystem health (Montgomery, 2000)

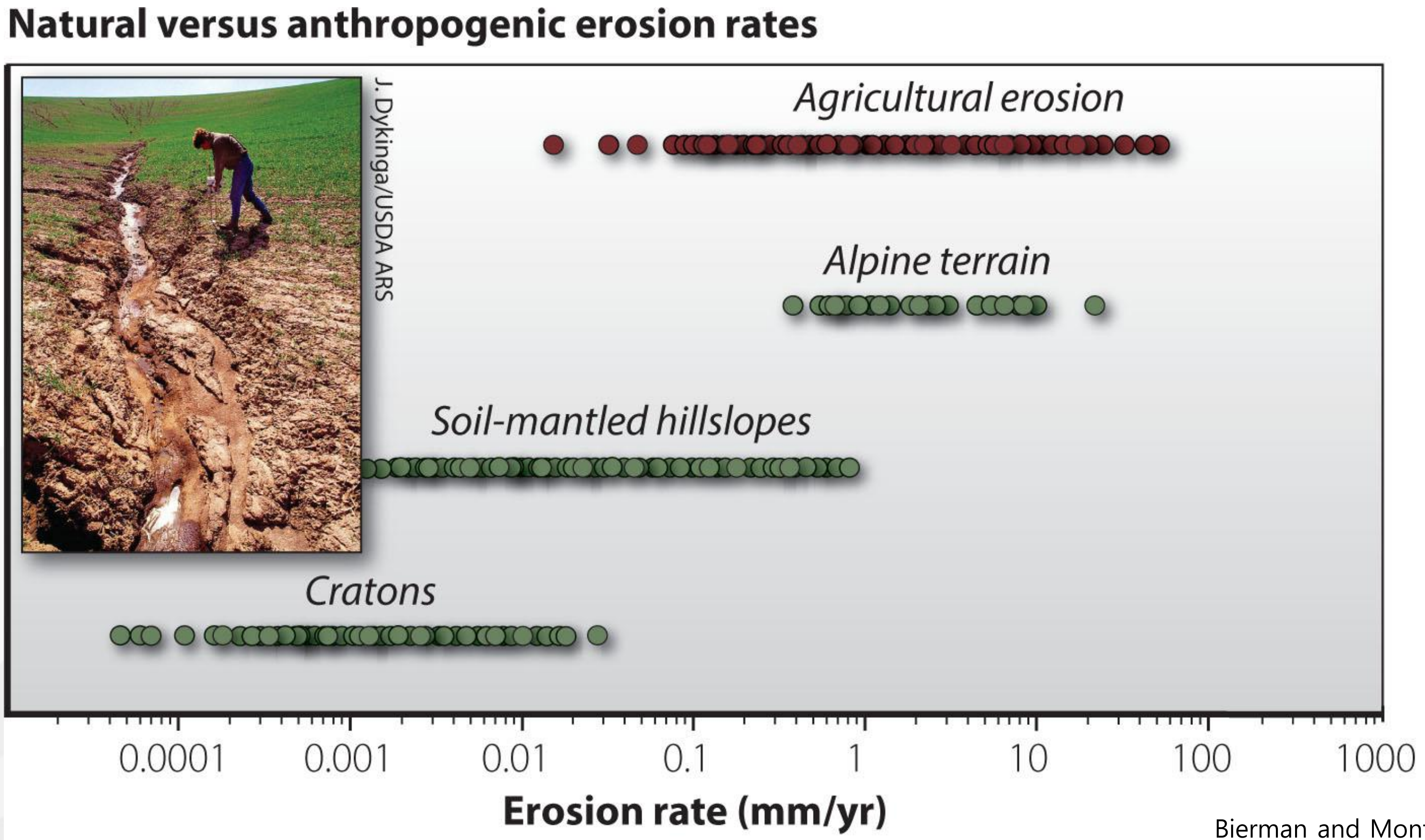
- Natural process, accelerated by human actions

Introduction: Human Induced-Erosion



Hooke, 2000

Introduction: Human vs Natural Rates of Erosion



Bierman and Montgomery, 2013

Introduction: Human vs Natural Rates of Erosion

- Soil compaction from farm machinery, frequent tilling, and leaving fields without cover crops contribute to these high erosion rates from agriculture (Montgomery, 2007)

- ~100,000 km^2 of arable land become unproductive each year (Dotterweich, 2013)

Introduction: Sustainable Agriculture

PBS

DTN Progressive Farmer

Background: Land Use History of Cuba

Maps-Cuba.com

- 15th century, an estimated 95% of Cuba was forested (CITMA, 1998)
- Slash and burn agriculture for colonial sugarcane production
- By the end of the 18th century, Cuba was producing 25% of the *world* supply of sugar (Houck, 2000)

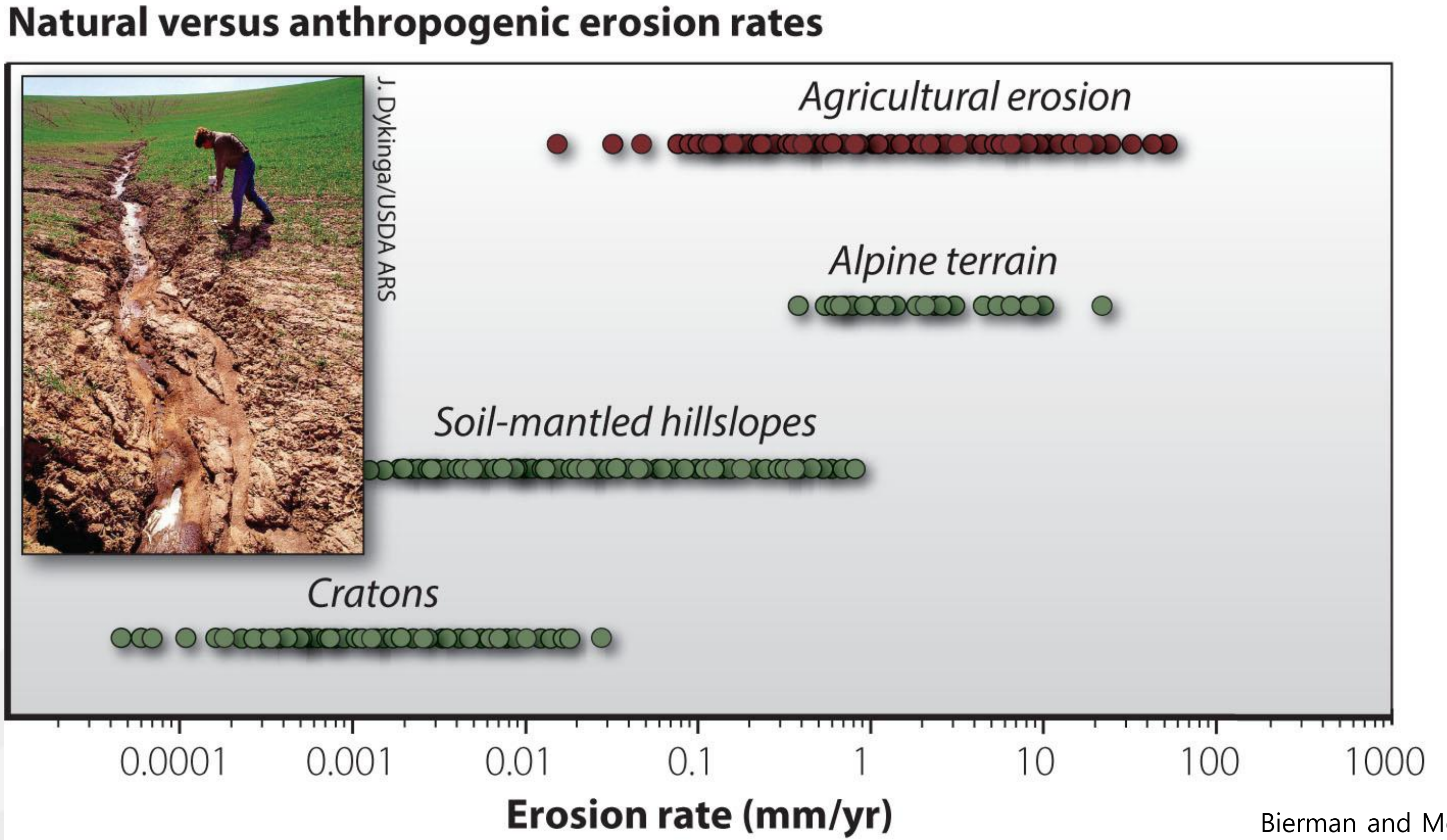
Background: Land Use History of Cuba

- 1959-1989: Highly mechanized industrial sugarcane production
  - More artificial fertilizer and tractors per land area than the US
- 75% of the land area of Cuba was affected by erosion, salinity, acidification, drainage problems, or a combination (CITMA, 1998)
- Forested land was reduced to only 14% (CITMA, 1998)

Background: Land Use History of Cuba

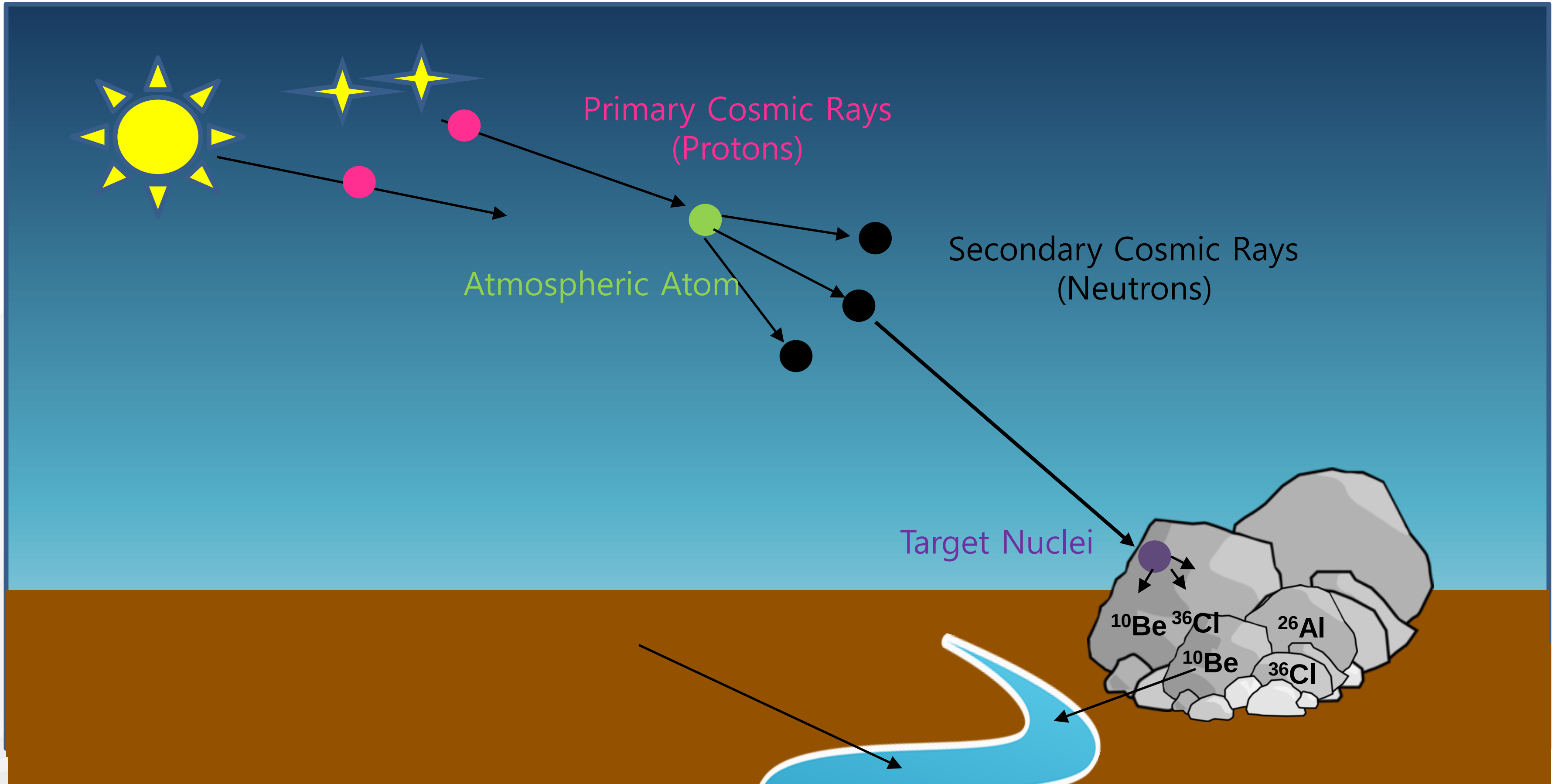
- Caloric consumption fell by as much as an estimated 50% (Enriquez, 2000)
- Rapid conversion from industrial agriculture to soil-conserving, organic agriculture featuring minimal soil tillage, replacing tractors with draft animals, the use of cover crops, and more.

Background: Measuring Erosion

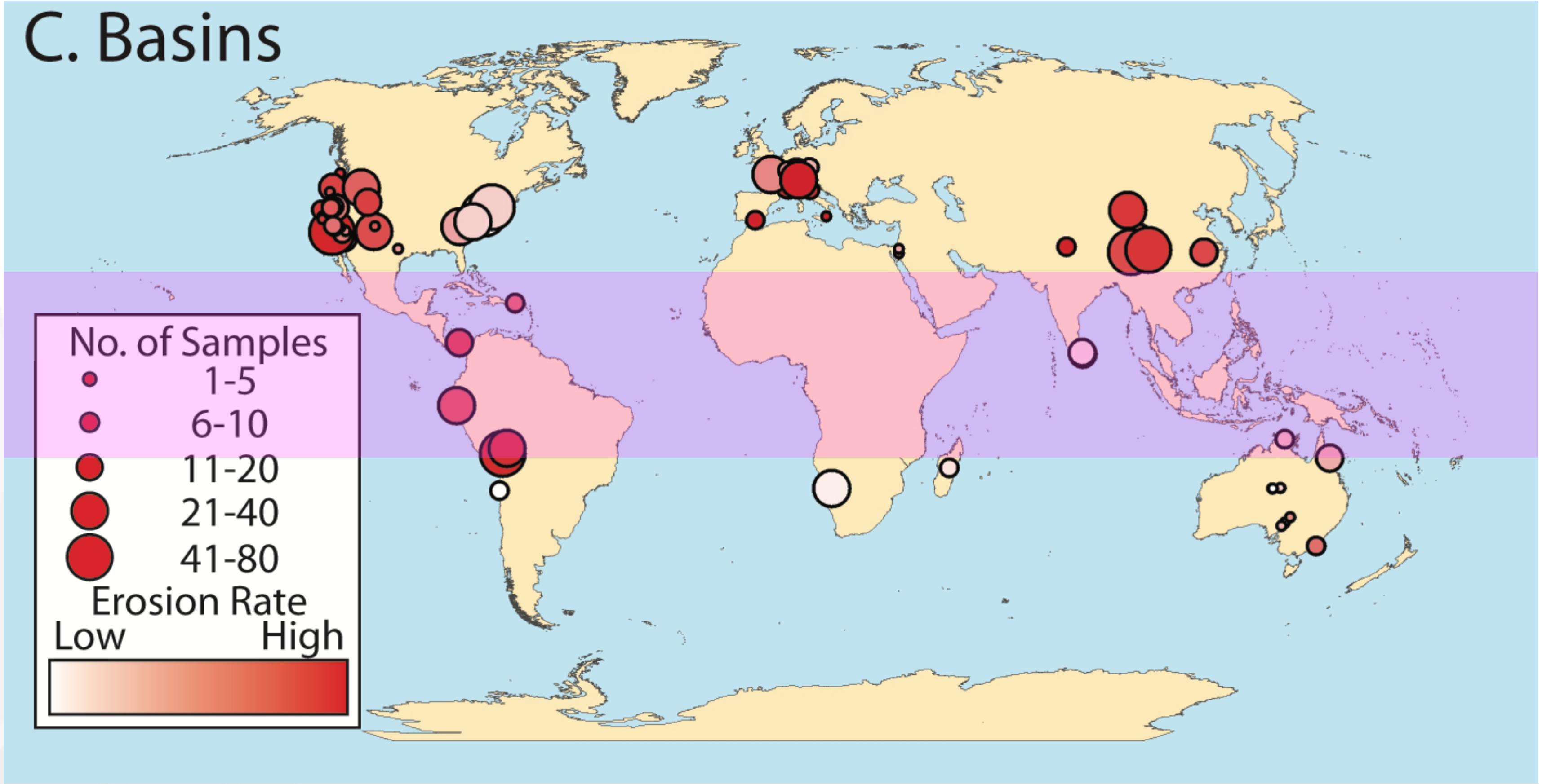


Bierman and Montgomery, 2013

Background: Cosmogenic Nuclides

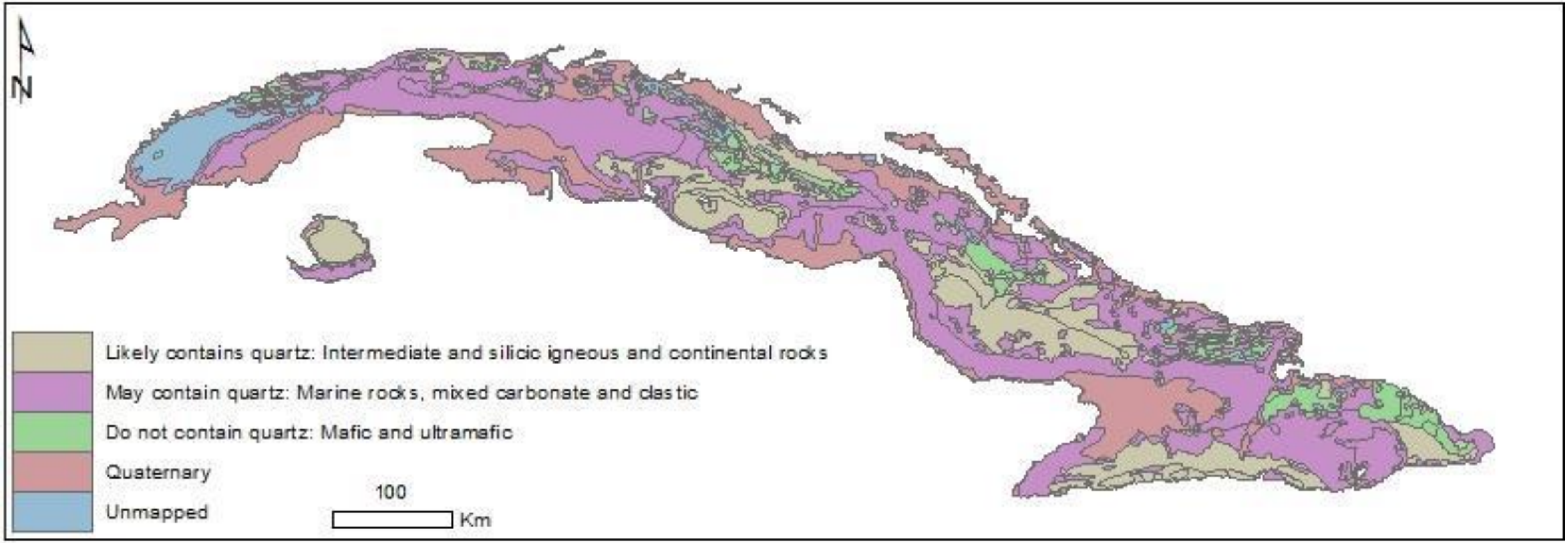


Background: ^{10}Be Erosion Rates from Quartz



Portenga and Bierman, 2011

Measuring Erosion in Quartz-Poor Terrains



Schmidt and Bierman, 2017

Objectives

1. Refine a method for extracting the cosmogenic nuclide ^{26}Al from carbonate sediments

2. Determine the production rate of ^{26}Al in carbonate rocks near my study area

3. Measure background erosion rates in Cuba using the cosmogenic nuclides ^{10}Be, ^{26}Al, and ^{36}Cl

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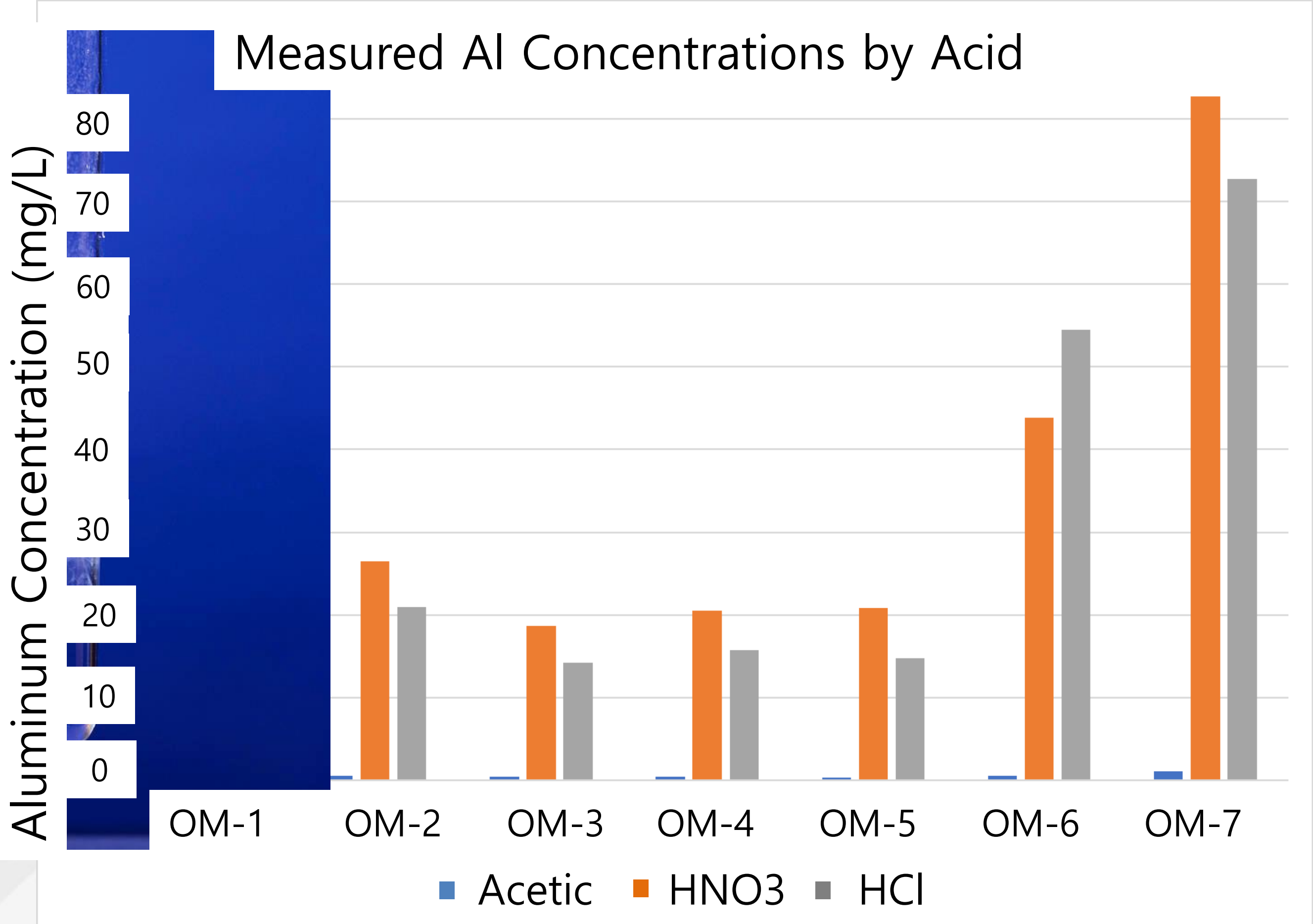
^{26}Al Method Refinement



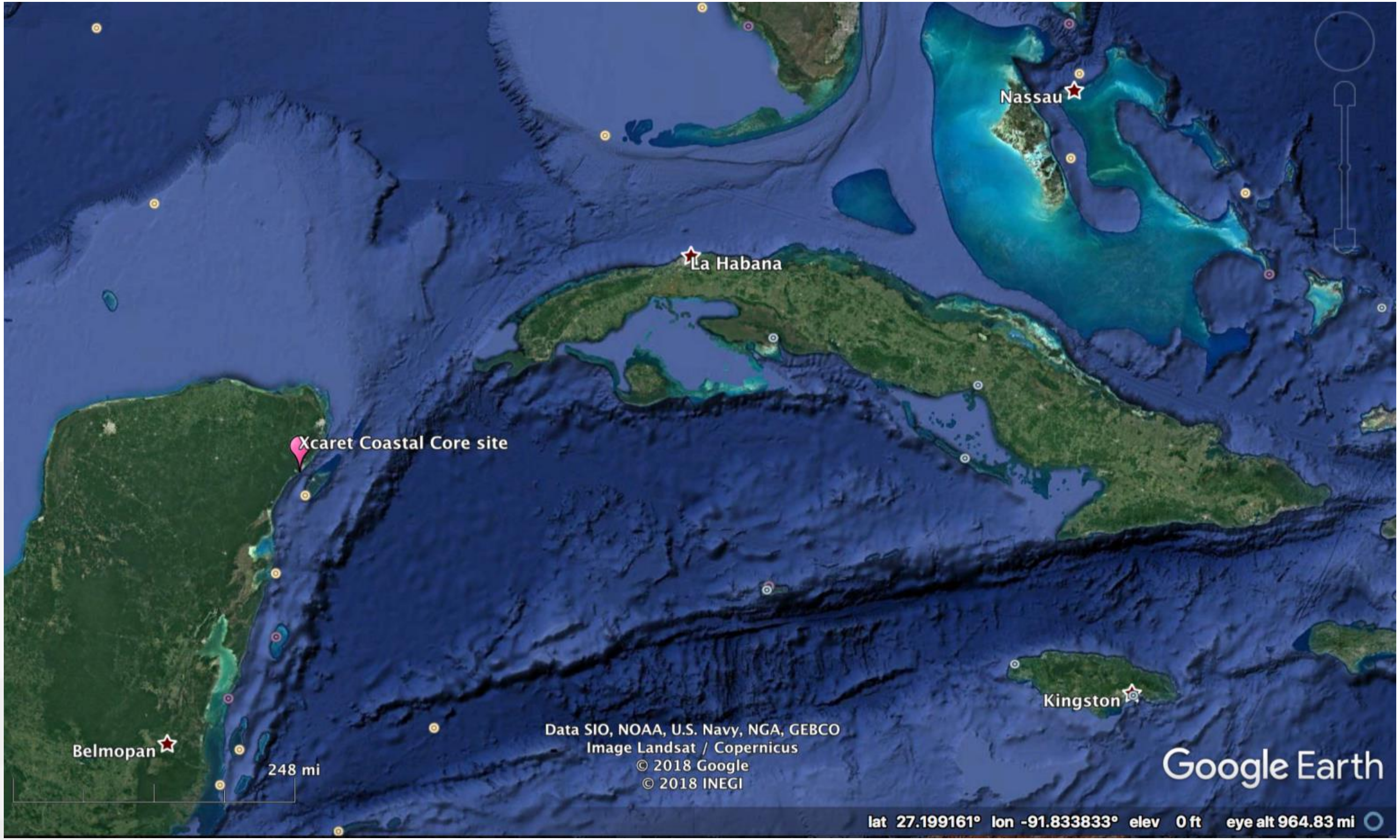
minerals

an affect

Current ^{26}Al Extraction Method

1. Dissolve sediment in acetic acid, react for 24-48 hours on a shaker table
2. Centrifuge to separate solution and residue, quantify initial Al yields using ICP-OES
3. Neutralize solution to between pH 6-8 to precipitate Al gels, centrifuge to separate
4. Reacidify aluminum gels, column chemistry to completely isolate Al
5. Dry and burn resulting Al, mix with binder, pack onto cathodes for AMS measurement

^{26}Al Production Rate Calibration



^{26}Al Production Rate Calibration

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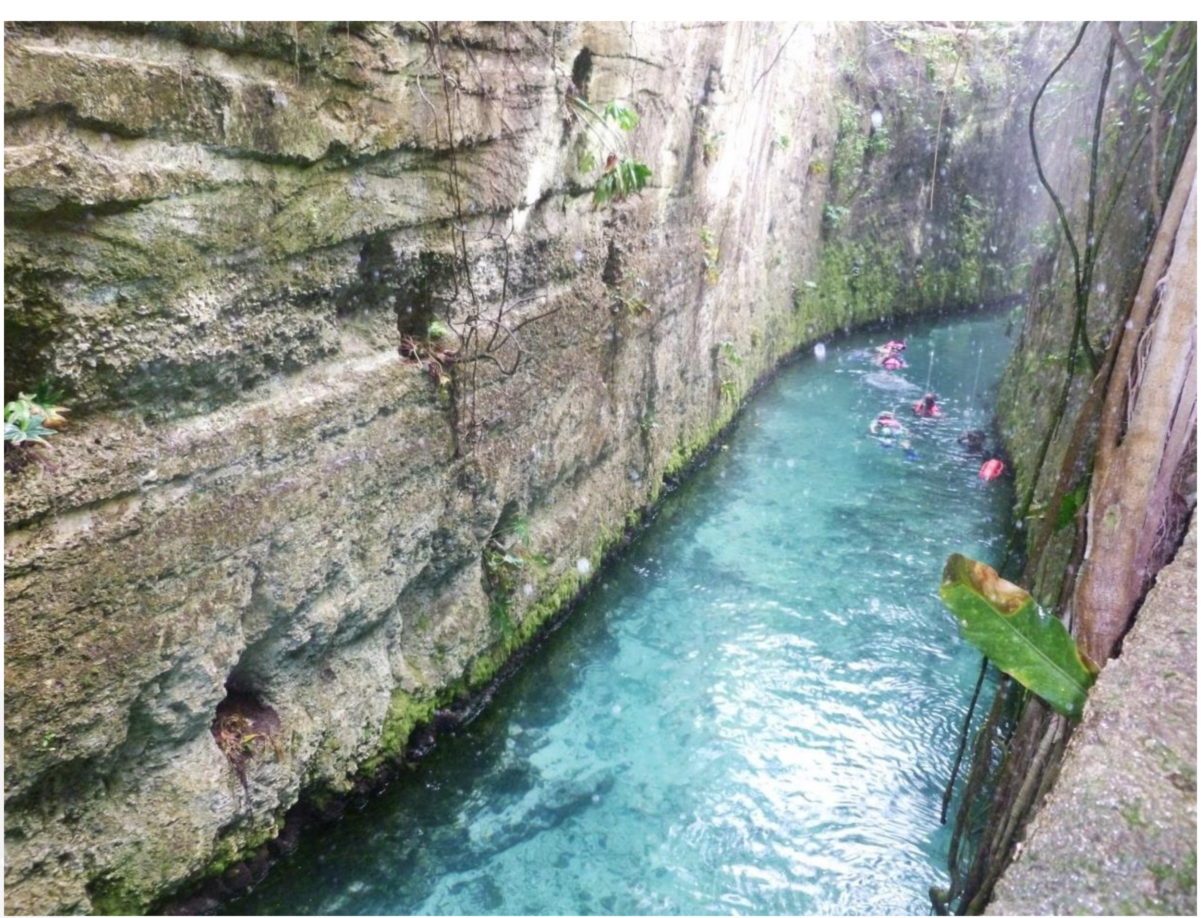
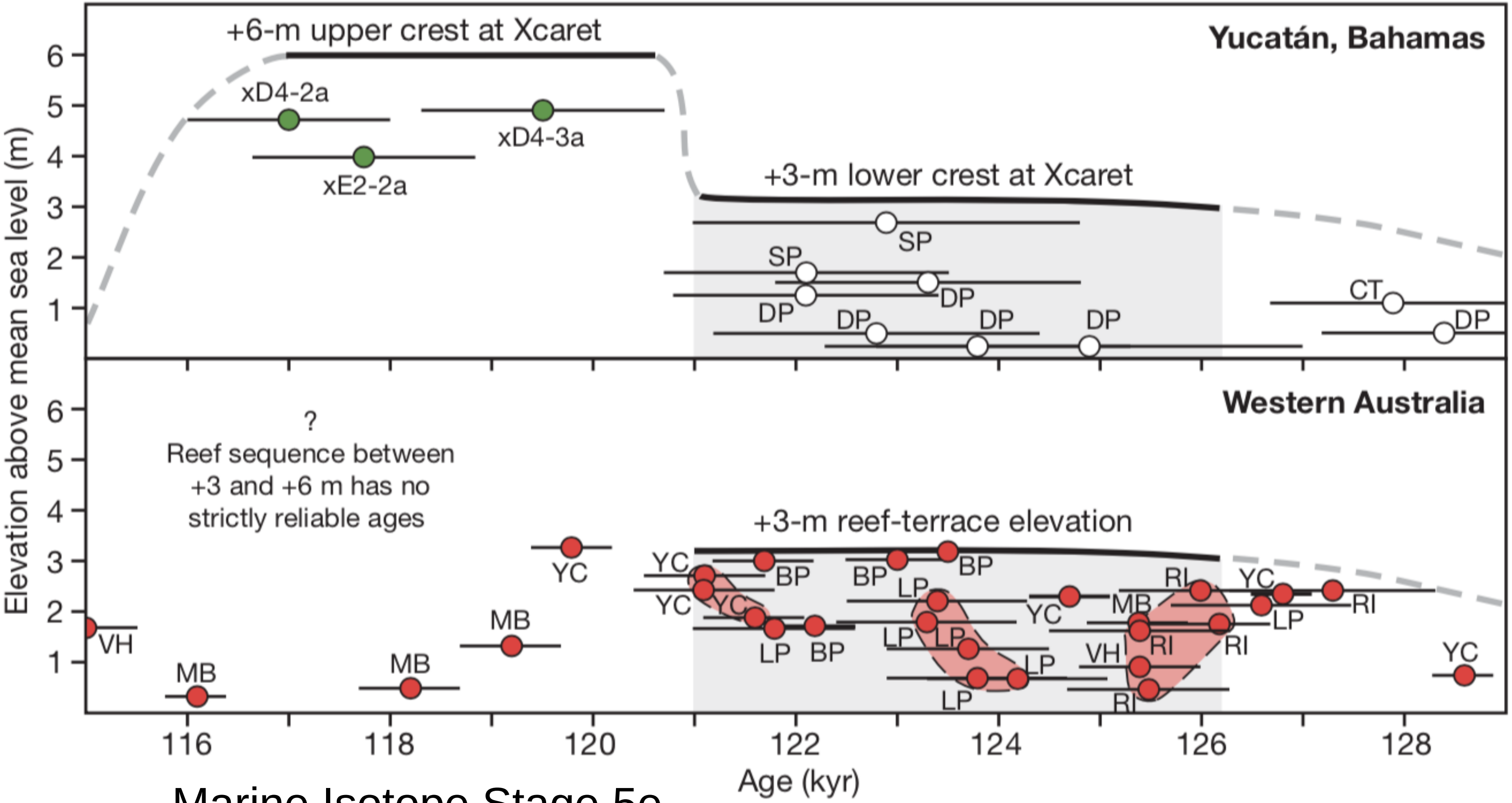


AWOL Americans

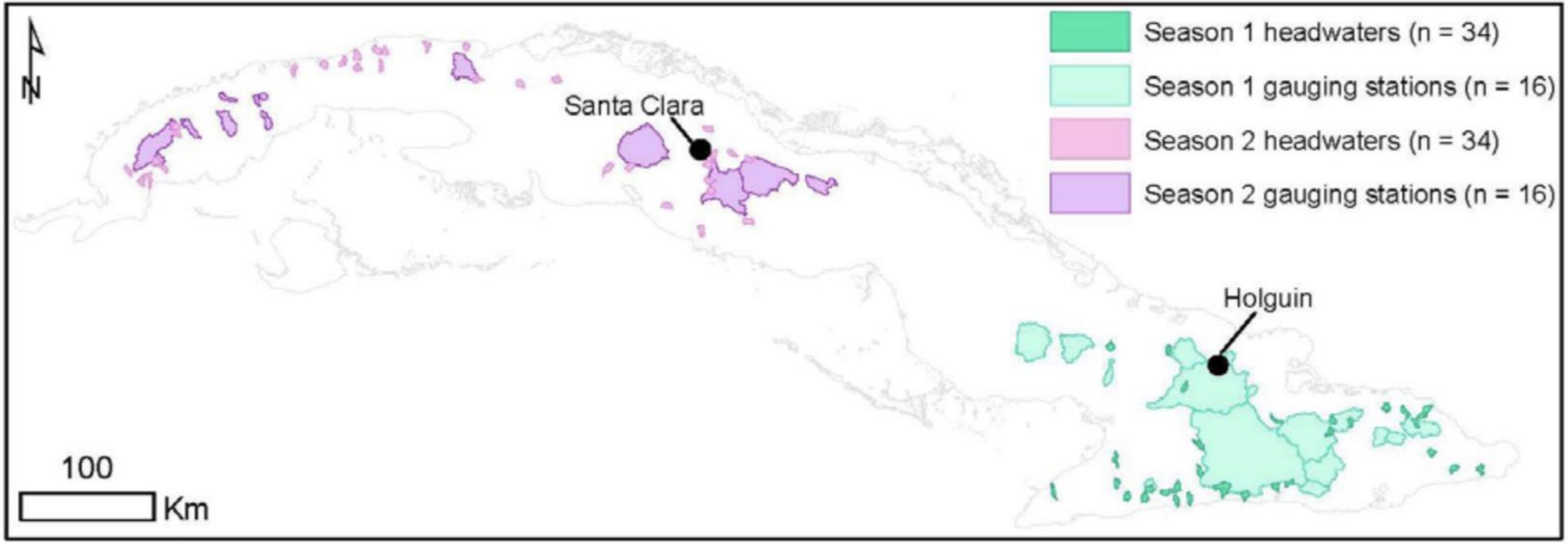
^{26}Al Production Rate Calibration



Marine Isotope Stage 5e

Blanchon et al., 2009

Field Sampling Plan



Hypothesis: Sediment yield >>> Background Rates of Erosion

Summary

- I will use ^{26}Al, ^{10}Be, and ^{36}Cl to constrain background erosion rates in Cuba
- The background erosion rates I measure will be compared to modern records of erosion from sediment-yield data
- I will work to refine a method for extracting ^{26}Al from carbonate sediments
- I will calibrate production rates of ^{26}Al in a carbonate core near our study area

Timeline

Timeframe	Goals
Summer 2018	• Continue ^{26}Al method development • Test method on carbonate core • Extract and measure ^{36}Cl in carbonate core • Begin writing intro and methods • First field visit to Cuba
Fall 2018	• Begin processing samples from first field visit • Complete 2 additional field visits to Cuba • More sample processing • Begin data analysis • Begin writing methods and result/discussion
Spring 2019	• Process remaining samples • Continued data analysis • Present progress report
Summer 2019	• Finish data analysis • Finish writing • Prepare for defense in early fall

Topics I Need to Learn/Do More About

- Aluminum chemistry
- ^{26}Al and ^{36}Cl production systematics
- How to navigate the Cuban government
- Geomorphic processes in tropical areas
- Agricultural impacts in tropical areas

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Questions?

Assumptions in Determining Erosion Rates from Cosmogenic Nuclides

1. “The rate of erosion is constant but not necessarily spatially uniform
2. The basin is in isotopic steady state
3. Sampled sediment is spatially and temporally representative of all sediment leaving the basin, i.e. it is well mixed
4. Mass loss from the basin is occurring primarily by surface lowering
5. The mineral selected for isotopic analysis is uniformly distributed through the basin”

- Bierman and Steig, 1996

Half Lives of Isotopes of Interest

Isotope	Half Life (years)
^{10}Be	1.387×10^{6}
^{26}Al	7.17×10^{5}
^{36}Cl	3.01×10^{5}

Cosmogenic Nuclide Production Pathways

- **Spallation** – Secondary cosmic rays collide with target nuclei and knock off protons and neutrons

- **Neutron Capture** – Secondary cosmic rays (neutrons) slow down e nough that they are captured by target nuclei

- **Muon Reactions**
    - Negative muons get captured by an atom's electron cloud, decay, and neutralize a proton
    - Fast muons produce gamma photons that produce secondary neutrons from nuclei, which produce cosmogenic nuclides
        - Important at depth

Dunai and Lifton, 2014