

Oxygen Isotope and Sr/Ca Analysis of Uplifted Coral Terraces around Taiwan for Paleoclimate Reconstruction

Project Background

Coral reefs are among the most valuable natural archives for reconstructing past marine environments and climate variability. Reef-building corals produce aragonite skeletons that record the physical and chemical conditions of the surrounding seawater during growth. Geochemical proxies preserved in coral skeletons, particularly oxygen isotopes ($\delta^{18}\text{O}$) and trace element ratios such as Sr/Ca, are widely used to reconstruct past sea surface temperatures and hydrological changes. The oxygen isotopic composition ($\delta^{18}\text{O}$) of coral aragonite reflects both seawater temperature and the isotopic composition of seawater, which is influenced by rainfall, evaporation, and freshwater input. Meanwhile, the Sr/Ca ratio in coral skeletons is temperature dependent and can serve as an independent proxy for sea surface temperature. Combining these two proxies allows researchers to better interpret past ocean conditions and climate variability.

Taiwan is located near the northern boundary of the Coral Triangle, a global center of marine biodiversity. The island also hosts numerous uplifted coral reef terraces, which formed during past sea-level highstands and were later raised above sea level due to tectonic uplift. These uplifted corals preserve valuable records of past marine environments, making them ideal materials for paleoclimate research. Despite Taiwan's strategic location in the western Pacific Ocean—where the Kuroshio Current, East Asian monsoon, and tropical ocean circulation interact—paleoclimate studies based on fossil corals remain limited. Investigating the geochemical composition of uplifted corals around Taiwan can provide important insights into past oceanographic conditions and climate variability in this region.

Project Objectives

1. To analyze oxygen isotope ($\delta^{18}\text{O}$) compositions in uplifted coral skeletons around Taiwan.
2. To measure Sr/Ca ratios in coral samples and estimate past sea surface temperature conditions.
3. To evaluate the preservation state of fossil coral skeletons to ensure reliable geochemical signals.
4. To compare geochemical results with modern oceanographic data in order to interpret past marine environments.

Research Methods

Sample Preparation--Collected coral samples will be cut into slabs along the growth axis using a diamond saw. The slabs will be cleaned and examined under a microscope to identify growth bands and ensure that the coral skeleton has not undergone significant alteration.

Micro-sampling--Powder samples will be obtained along the coral growth bands using a micro-drill. This allows sampling of the coral skeleton at regular intervals to represent past environmental conditions during coral growth.

Oxygen Isotope Analysis--The powdered coral samples will be analyzed using stable isotope ratio mass spectrometry (IRMS) to measure the $\delta^{18}\text{O}$ values. These values will provide information about past seawater temperature and hydrological conditions.

Sr/Ca Elemental Analysis--The Mg and Ca concentrations of the coral powders will be measured using ICP-OES or ICP-MS. The Sr/Ca ratios will be calculated and used to estimate past sea surface temperatures.

Data Analysis--The $\delta^{18}\text{O}$ and Sr/Ca results will be compared and interpreted together to reconstruct past marine environmental conditions. The results will also be compared with modern oceanographic data for interpretation.

Expected Outcomes

- A geochemical dataset of oxygen isotope ($\delta^{18}\text{O}$) values and Sr/Ca ratios from uplifted corals around Taiwan.
- Preliminary estimates of past sea surface temperatures during coral growth periods.
- Improved understanding of the paleoenvironmental conditions of Taiwan's coastal waters.
- Identification of well-preserved coral samples suitable for future high-resolution paleoclimate studies.

What Will Be Learned from This Project

1. Coral reef geology and paleoceanography, including how coral skeletons record past environmental conditions.
2. Field sampling techniques for coral and coastal geological materials.
3. Laboratory techniques for preparing carbonate samples and conducting geochemical analyses.
4. Stable isotope and trace element geochemistry, including how $\delta^{18}\text{O}$ and Sr/Ca proxies are used to reconstruct past climates.
5. Scientific data interpretation and visualization, including comparing geochemical data with environmental datasets.
6. Scientific communication skills, including preparing research reports and presenting research results.

台灣上升珊瑚台地之氧同位素與 Sr/Ca 古氣候分析研究

研究背景

珊瑚礁是重建古海洋環境與氣候變化的重要自然紀錄之一。造礁珊瑚在生長過程中會形成碳酸鈣（文石）骨骼，其化學組成會記錄當時海水的物理與化學條件。其中，**氧同位素（ $\delta^{18}\text{O}$ ）與微量元素比例（如 Sr/Ca）**是重建過去海表溫度與海洋環境變化的重要地球化學指標。

珊瑚骨骼中的氧同位素組成同時受到海水溫度與海水同位素組成的影響，而海水同位素組成又與降雨、蒸發與淡水輸入等水文條件相關。另一方面，Sr/Ca 比值則與海水溫度呈現密切關係，可作為重建古海表溫度的獨立指標。透過結合 $\delta^{18}\text{O}$ 與 Sr/Ca 兩種地球化學代理指標，可以更準確地解析過去海洋環境與氣候變化。

台灣位於全球海洋生物多樣性最高的區域之一——珊瑚金三角（Coral Triangle）北緣，周圍海域擁有豐富的珊瑚礁生態系。此外，台灣部分沿岸地區受到構造抬升作用影響，形成隆起珊瑚礁階地（uplifted coral terraces）。這些隆起珊瑚原本形成於過去海平面較高時期，之後因地殼抬升而暴露於海平面之上，因此保存了良好的古海洋環境資訊。

由於台灣位於西太平洋暖池、黑潮洋流以及東亞季風系統交會區域，對區域海洋循環與氣候變化具有重要指標意義。然而，目前利用隆起珊瑚進行高解析度古海洋環境研究的資料仍相對有限。因此，本研究希望透過氧同位素與 Sr/Ca 分析，探討台灣周圍海域過去的海洋環境變化。

研究目的

1. 分析台灣隆起珊瑚骨骼中的氧同位素（ $\delta^{18}\text{O}$ ）組成。
2. 測量珊瑚樣品中的 Sr/Ca 比值，並推估過去海表溫度變化。
3. 評估隆起珊瑚骨骼的保存狀態與成岩作用影響。
4. 將地球化學分析結果與現代海洋環境資料進行比較，以解釋過去海洋環境條件。

研究方法

樣品切割與前處理

採集之珊瑚樣品將沿著生長軸（growth axis）**切割成珊瑚薄板（slabs），並進行清洗與乾燥。之後利用顯微鏡觀察珊瑚骨骼結構，以確認其保存狀態並辨識生長帶。

微量取樣

利用**微型鑽取設備（micro-drill）**沿著珊瑚生長帶進行取樣，取得碳酸鈣粉末樣品。這些樣品可代表珊瑚生長期間不同時間點的環境條件。

氧同位素分析

珊瑚粉末樣品將利用**穩定同位素質譜儀（IRMS）**進行氧同位素分析，測定 $\delta^{18}\text{O}$ 值。透過分析結果可推估過去海水溫度與水文環境變化。

Sr/Ca 元素分析

珊瑚樣品中的鎂與鈣濃度將利用感應耦合電漿發射光譜儀（ICP-OES）或 ICP-MS 進行測定，並計算 Sr/Ca 比值。Sr/Ca 比值可用於推估珊瑚生長時期的海表溫度。

資料分析與解釋

將整合 $\delta^{18}\text{O}$ 與 Sr/Ca 分析結果，並與現代海洋資料（如海表溫度、降雨與海洋循環資料）進行比較，以重建過去海洋環境變化。

預期成果

1. 建立台灣隆起珊瑚的氧同位素與 Sr/Ca 地球化學資料庫。
2. 推估珊瑚生長時期的古海表溫度變化。
3. 提供台灣周邊海域古海洋環境變遷的重要證據。
4. 篩選出保存良好的珊瑚樣品，作為未來高解析度古氣候研究的重要材料。

執行本研究可學習之能力

1. 珊瑚礁地質與古海洋學基礎知識--了解珊瑚骨骼如何記錄過去海洋環境與氣候變化。
2. 採樣技術--學習珊瑚樣品採集與地質調查方法。
3. 地球化學實驗技術--碳酸鹽樣品前處理、微量取樣與儀器分析。
4. 穩定同位素與微量元素分析概念--理解 $\delta^{18}\text{O}$ 與 Sr/Ca 在古氣候研究中的應用。
5. 科學資料分析與解釋能力--學習如何整合實驗數據並解釋環境變化。
6. 科學報告與研究成果表達能力--撰寫研究報告並進行口頭或海報發表。