指導教授：
葉孟宛教授、米泓生教授 Prof. Meng-Wan Yeh & Horng-Sheng Mii

Investigating the Influence of Seawater Temperature on Oyster Shell Chambering Using Oxygen Isotope and Sr/Ca Analysis

Project Background

Oysters are important filter-feeding organisms in coastal ecosystems. Their shells are primarily composed of calcium carbonate and grow through a process of biomineralization that incorporates chemical signals from the surrounding seawater. As a result, oyster shells can serve as valuable archives of environmental conditions during their growth. One distinctive microstructural feature observed in oyster shells is chambering, which refers to the formation of voids or chambers within the shell layers due to interruptions in biomineralization. Earlier studies linked oyster shell chambering to organotin pollution, particularly tributyltin (TBT). However, chambered oyster shells continue to be observed even decades after the global ban of TBT, suggesting that other environmental factors may also play an important role in controlling this phenomenon. Recent studies suggest that seawater temperature may influence oyster physiology and biomineralization processes. Elevated or rapidly fluctuating temperatures can disrupt shell formation, potentially leading to irregular calcification and the formation of chambered structures. Understanding the relationship between temperature stress and shell chambering is therefore important for evaluating the impact of climate change on marine organisms.

Geochemical proxies preserved in carbonate shells provide a useful tool for reconstructing environmental conditions. In particular, oxygen isotope composition ($\delta^{18}O$) and Sr/Ca ratios are widely used indicators of seawater temperature. The $\delta^{18}O$ values of carbonate shells generally decrease with increasing temperature, while Sr/Ca ratios often increase with higher temperatures. By analyzing these geochemical proxies in oyster shells, it is possible to estimate the seawater temperature conditions during shell formation. This project aims to investigate the relationship between seawater temperature and oyster shell chambering by combining shell microstructure observations with oxygen isotope and Sr/Ca geochemical analyses.

Project Objectives

1. To analyze the oxygen isotope composition ($\delta^{18}O$) of oyster shells showing chambering.

2. To measure Sr/Ca ratios in oyster shells as an independent proxy for seawater temperature.
3. To compare the geochemical signatures of oyster shells with different degrees of chambering.
4. To evaluate whether seawater temperature is a key environmental factor controlling oyster shell chambering.

Research Methods

3.1 Oyster Sample Collection

Oyster shell samples will be collected from coastal environments in Taiwan, including both:

- Cultured oysters
- Wild oysters

Samples will be classified into two groups based on shell structure:

- Shells with visible chambering
- Shells without chambering

3.2 Shell Microstructure Observation

Oyster shells will be cut and polished to expose internal shell structures. Microscopic observation will be used to identify and document:

- Number of chambers
- Chamber size
- Spatial distribution of chambers within the shell

Image analysis software may be used to quantify chambering intensity.

3.3 Micro-sampling

Carbonate powder will be obtained from selected shell layers using a micro-drill system. These samples will represent specific growth intervals of the oyster shell.

3.4 Oxygen Isotope Analysis

The carbonate powder will be analyzed for oxygen isotopes ($\delta^{18}O$) using Isotope Ratio Mass Spectrometry (IRMS). The $\delta^{18}O$ values will be used to estimate seawater temperature conditions during shell formation.

3.5 Sr/Ca Elemental Analysis

Magnesium and calcium concentrations will be measured using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) or ICP-MS. Sr/Ca ratios will then be calculated and used as an additional temperature proxy.

3.6 Data Analysis

The following datasets will be integrated for analysis:

- $\delta^{18}O$ values
- Sr/Ca ratios
- Degree of shell chambering

Expected Outcomes

1. A dataset of oxygen isotope and Sr/Ca geochemical signatures from oyster shells.
2. Preliminary estimates of seawater temperature conditions during shell formation.
3. A better understanding of the relationship between temperature stress and oyster shell chambering.
4. Evaluation of whether shell chambering could serve as a potential biological indicator of temperature stress in coastal environments.

What Will You Learn from This Project

Through this research project, students will gain knowledge and practical skills in several areas of marine and environmental science, including:

1. Marine biomineralization and shell formation processes--Understanding how oyster shells record environmental information.
2. Shell microstructure analysis--Learning how to identify and characterize chambering features.
3. Geochemical laboratory techniques--Including carbonate sample preparation, micro-sampling, and analytical procedures.
4. Stable isotope and trace element geochemistry--Understanding how $\delta^{18}O$ and Sr/Ca proxies are used to reconstruct temperature conditions.
5. Scientific data interpretation--Integrating geochemical data with environmental variables.
6. Scientific communication skills--Preparing research reports and presenting research findings.

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利用氧同位素與 Sr/Ca 分析探討海水溫度對牡蠣殼腔室化（Chambering）的影響

研究背景

牡蠣（Oysters）是沿海生態系中重要的濾食性雙殼類生物，其殼體主要由碳酸鈣組成，在生長過程中會記錄海水環境條件的變化，因此可作為研究海洋環境的重要生物地球化學載體。在牡蠣殼的微觀結構中，常可觀察到一種稱為**腔室化（chambering）**的現象，即殼體在生長過程中出現不連續沉積，形成空腔結構。過去研究曾將此現象與有機錫污染（如 tributyltin, TBT）聯繫在一起，但即使在 TBT 被禁止使用多年後，牡蠣殼腔室化現象仍然普遍存在，顯示其形成機制可能與其他環境因素有關。近年研究指出，海水溫度變化可能影響牡蠣的生理活動與生物礦化過程（biomineralization）。當海水溫度過高或快速變動時，可能導致碳酸鈣沉積效率降低，進而產生殼體沉積中斷或腔室化結構。因此，探討海水溫度與牡蠣殼腔室化之間的關係，對於理解海洋生物對氣候變遷的反應具有重要意義。牡蠣殼中的氧同位素（$\delta^{18}O$）與 Sr/Ca 元素比值可作為重建海水溫度的重要地球化學指標。$\delta^{18}O$ 與海水溫度呈現反向關係，而 Sr/Ca 比值則通常隨溫度升高而增加。透過分析這些地球化學訊號，可以推估牡蠣生長時期的海水溫度條件。本研究計畫將利用牡蠣殼的氧同位素與 Sr/Ca 分析，探討海水溫度變化與牡蠣殼腔室化形成之間的關係，以評估牡蠣殼腔室化是否可作為海洋溫度壓力的指標。

研究目的

本研究計畫主要目的包括：

1. 分析具有腔室化結構的牡蠣殼之氧同位素（$\delta^{18}O$）組成，以推估牡蠣生長時期的海水溫度。
2. 測量牡蠣殼中的 Sr/Ca 比值，作為海水溫度的獨立指標。
3. 比較具有不同腔室化程度的牡蠣殼，其地球化學溫度指標之差異。
4. 探討海水溫度是否為控制牡蠣殼腔室化的重要環境因素。

研究方法

殼體結構觀察與分類--利用影像分析軟體進行定量分析。

微量取樣--利用微型鑽取設備（micro-drill）從牡蠣殼不同部位取得碳酸鈣粉末，用於地球化學分析。

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氧同位素分析

碳酸鈣粉末將利用穩定同位素質譜儀（IRMS）測量 $\delta^{18}O$ 值。由於 $\delta^{18}O$ 與海水溫度具有已知的分餾關係，可用於推估牡蠣生長時期的海水溫度。

Sr/Ca 元素分析--樣品中的 Mg 與 Ca 濃度將利用 ICP-OES 或 ICP-MS 進行測量，並計算 Sr/Ca 比值。Sr/Ca 比值將作為海水溫度的另一項獨立指標。

資料分析--：

- $\delta^{18}O$ 結果
- Sr/Ca 比值
- 腔室化程度

預期成果

1. 建立牡蠣殼氧同位素與 Sr/Ca 溫度指標資料。
2. 了解不同腔室化程度的牡蠣殼，其地球化學溫度訊號差異。
3. 評估海水溫度對牡蠣殼生物礦化過程的影響。
4. 探討牡蠣殼腔室化是否可作為海洋溫度壓力的生物指標。

執行本研究可學習之能力

1. 海洋生物礦化與海洋環境科學知識--了解牡蠣殼如何記錄海水溫度訊息。
2. 樣品觀察與結構分析技術--學習辨識牡蠣殼腔室化結構。
3. 地球化學實驗技術--包括碳酸鹽樣品處理、微量取樣與儀器分析。
4. 穩定同位素與微量元素地球化學概念--理解 $\delta^{18}O$ 與 Sr/Ca 在溫度重建中的應用。
5. 科學數據分析與環境解釋能力--學習如何將實驗結果與海洋環境資料結合。
6. 科學研究與成果表達能力--撰寫研究報告並進行研究成果發表。