

Stable carbon and oxygen isotopic composition in carbonate nodules from alluvial soils and their implications for paleoclimate in Taiwan

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Carbonate nodules in Taiwan

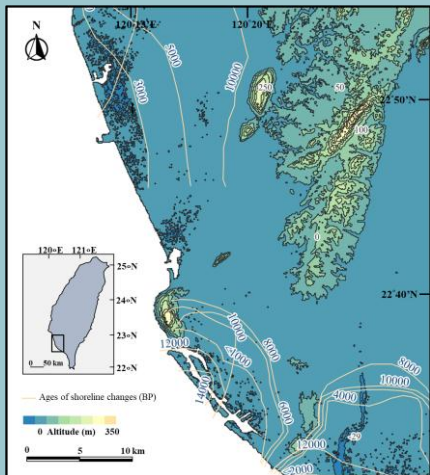


Carbonate nodules distribution in Taiwan

- Distributed in the southwestern alluvial plains
- Impacted by marine transgressive and regressive processes during the Holocene
- The soil developed stably after marine regression

The modern humid climate may not be favorable to the precipitation of carbonates.

Research framework



Alluvial plains in southwestern Taiwan

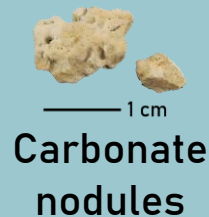
Pedogenesis

Different ages of soil formation



Chronosequence soils

Calcification



Carbonate nodules

Paleoclimate

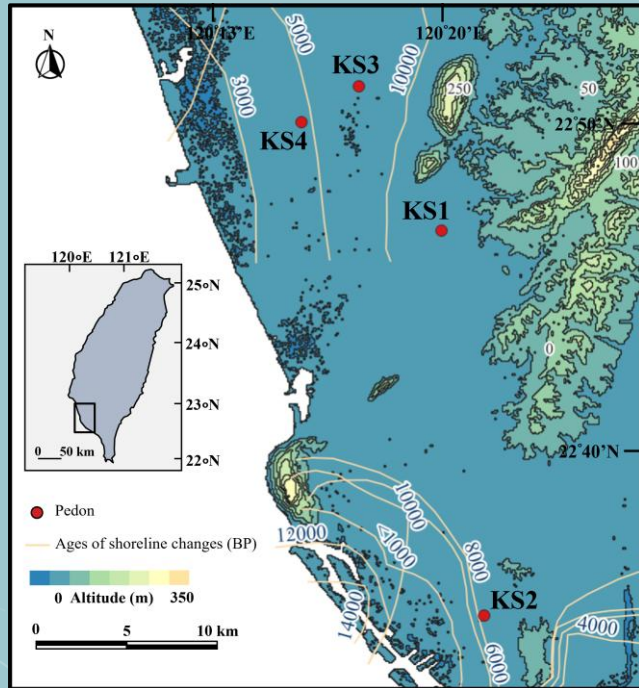
reflect

- Stable C isotope → vegetation (C3/C4 plant)
- Stable O isotope → mean annual temperature (MAT)
- Geochemical climofunction- mean annual precipitation (MAP)
- Radiocarbon dating (^{14}C) → ages of formation

Objectives

- (1) To elucidate the formation of soil carbonate nodules on the alluvial plains of southwestern Taiwan.
- (2) To reconstruct the vegetation types and temperature during the formation of carbonate nodules by stable carbon and oxygen isotopes.

Studied area



Pedon	Age of soil formation (year BP) ^a
KS1	10,000
KS2	8000
KS3	5000
KS4	3000

- Ustic moisture regime
- Hyperthermic temperature regime
- Mean annual precipitation: 1829 mm yr⁻¹
- Potential evaporation: 1419 mm yr⁻¹
- Mean annual temperature: 24.7° C

^a determined by performing radiocarbon dating on drill cores (Chen and Yang, 2012).

Soil profiles and carbonate nodules

← Chronosequence soil

10000 year BP
Inceptic Haplustalf



8000 year BP
Ultic Haplustalf



5000 year BP
Ultic Haplustalf



3000 year BP
Kanhaplic Haplustalf



Analysis of carbonate nodules

- **Stable carbon & oxygen isotopes**
 - **Automated carbonate preparation device (Kiel IV Carbonate Device) and an isotope ratio mass spectrometry (IRMS)**
- **Radiocarbon dating**
 - **Accelerator mass spectrometry (AMS)**

Calculation

- Abundance of C4 plants

- $C4 (\%) = [(\delta^{13}C_{sample} - \delta^{13}C_{C3}) / (\delta^{13}C_{C4} - \delta^{13}C_{C3})] \times 100\%$

- Climofunctions

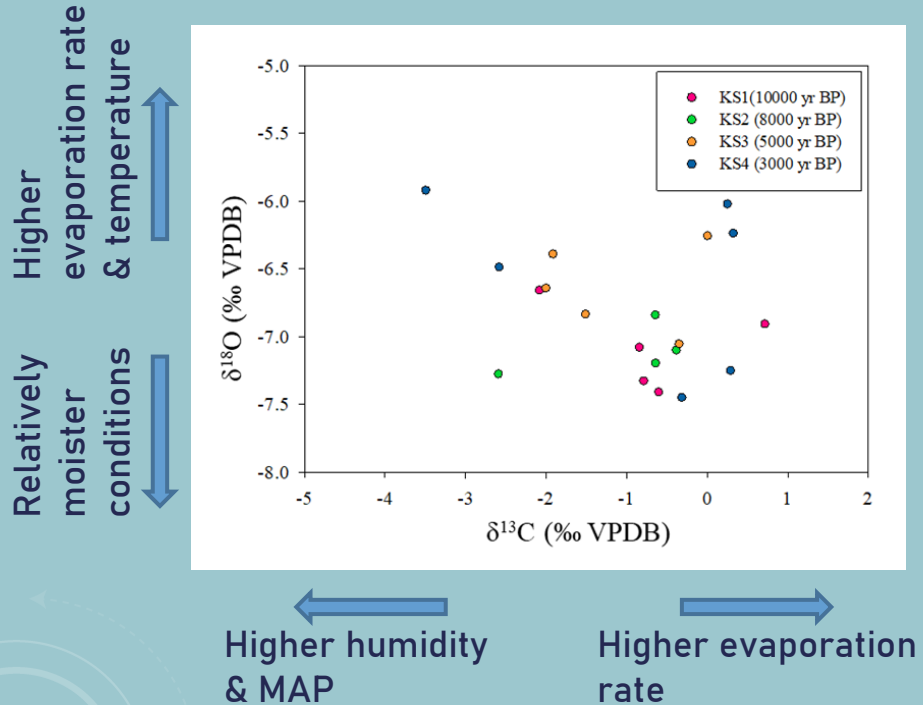
- $mean\ annual\ temperature\ (MAT, \text{°C}) = (1.1415 \times \delta^{18}O_{sample}) + 20.805$
(Hyland and Sheldon, 2013)

- $mean\ annual\ precipitation\ (MAP, \text{mm yr}^{-1}) = 221 e^{0.0197(CIA-K)}$

- $CIA - K = \frac{Al_2O_3}{Al_2O_3 + CaO + Na_2O} \times 100$

(Sheldon et al., 2002)

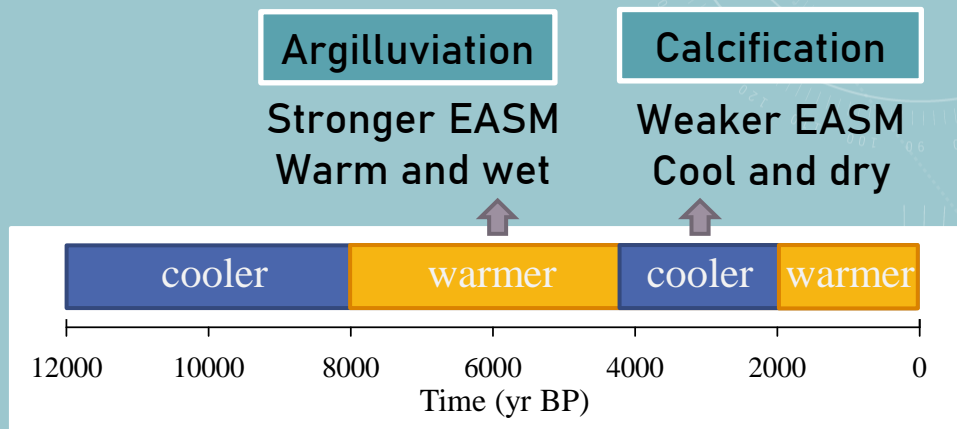
Stable carbon and oxygen isotopic composition



- Isotopes indicated seasonal dry-wet alternation
- $\delta^{13}\text{C}$: mixed C3-C4 vegetation
- $\delta^{18}\text{O}$: cooler than the present
- C4 plants may have acted as pioneer plants, adapting to the harsh conditions during the early stage following marine regression in the study area.

Radiocarbon ages & climofunctions

- Climofunctions:
 - MAT: 12.3-14.0° C
 - MAP: 1036 to 1342 mm yr⁻¹
- Radiocarbon age: 4063 yr BP to 690 yr BP
- This time frame was drier and cooler than the present, which can correspond to the formation of carbonate nodules in the studied area.
- Weaker East Asian Summer Monsoon (EASM)



According to the pollen record in southern Taiwan (Lee and Liew, 2010).

Conclusions

- The stable carbon isotopes in carbonate nodules reflect a vegetation that consisted of a mixture of C3 and C4 plants, with a predominance of C4 species.
- The climate during the time frame of the formation of carbonate nodules was drier and cooler than the present.

Limitations

- The reconstructed MAP values are interpreted as relative trends rather than absolute values.
- The potential effects of other pedogenic processes during this time frame cannot be excluded and are considered a source of uncertainty in this study.