中国石油大學(华东)
CHINA UNIVERSITY OF PETROLEUM

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Characteristics of sodium carbonate- bearing rhythms and paleoclimate variations in closed evaporate basin: the case of the Early Permian Fengcheng Formation in the Mahu Sag, Junggar Basin in northwestern China

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Outline

1. Geological background

2. Characteristics of sodium carbonate- bearing rhythms

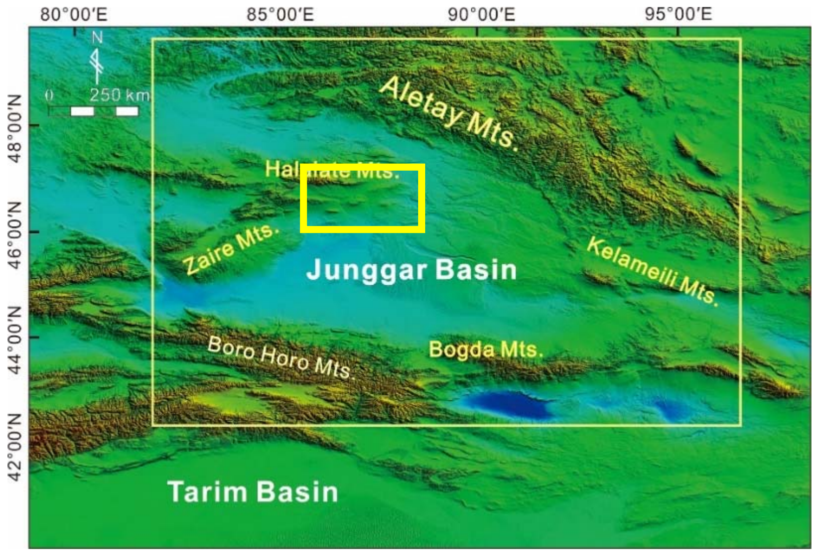
3. Paleoclimate variations and genetic mechanism of rhythms

4. Summary

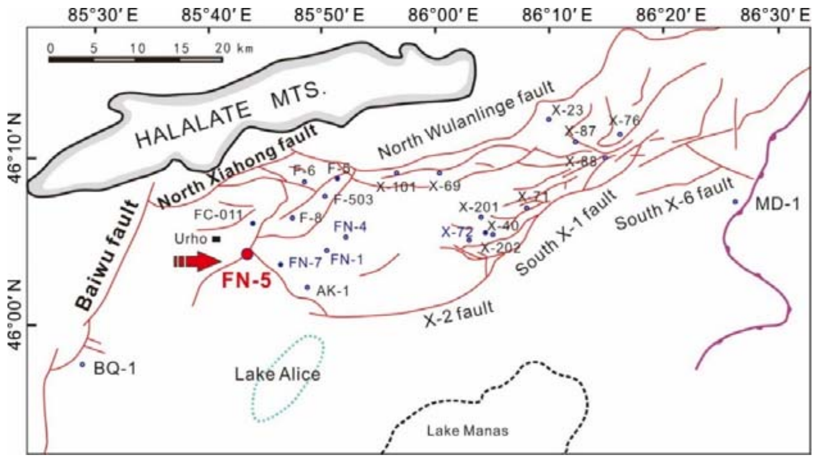
1. Geological background

✓1.1 Tectonic Setting and palepgeography

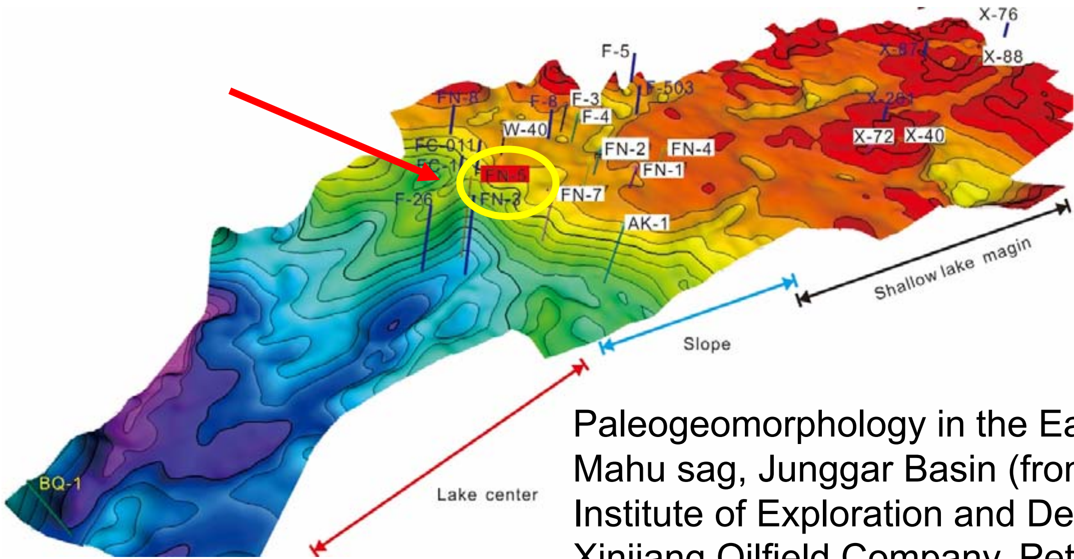
- ***Location of the Junggar Basin:*** *northwest China.*
- ***Location of the Mahu Sag:*** *northwest Junggar Basin.*
- ***Basin type:*** *foreland basin in compressive tectonic activities.*
- ***Faults:*** *Multiple stages of tectonic movements results in a complicated NEE-SWW fault-fold belt.*
- ***Target strata:*** *The early Permian Fengcheng Formation.*
- ***Buried depth:*** *3000m to 5000m*



Location of the Junggar Basin the Mahu Sag



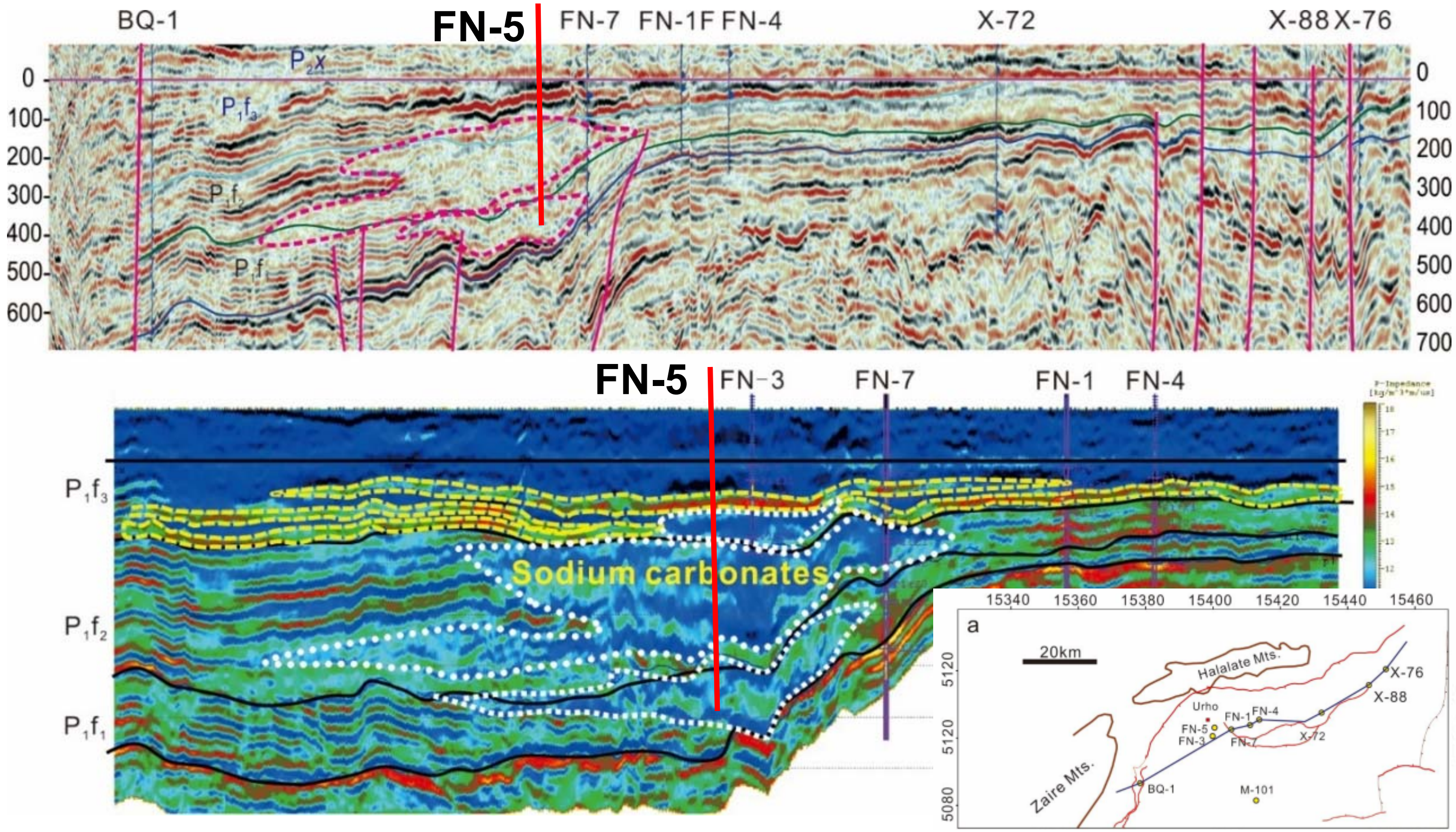
Main drills, faults, and the location of the well FN-5



Paleogeomorphology in the Early Permian Mahu sag, Junggar Basin (from the Research Institute of Exploration and Development, Xinjiang Oilfield Company, Petro China)

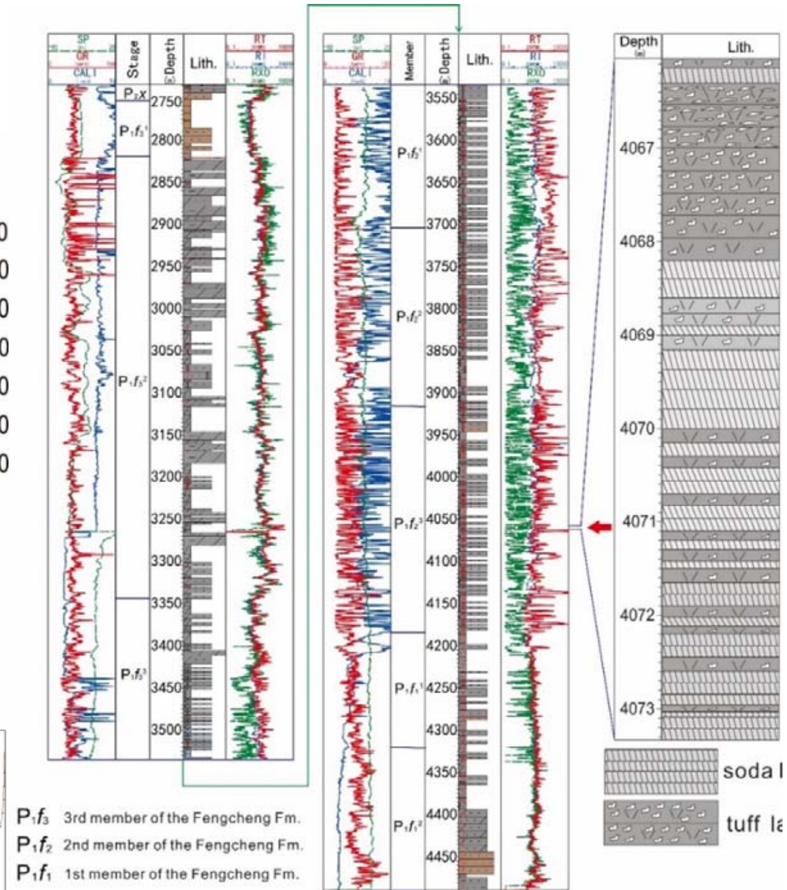
✓1.2 Stratigraphy and distribution of sodium carbonates

- The early Permian Mahu Sag was an evaporate lake and huge thickness of evaporites occurred in the Fengcheng Formation.



Seismic profile and inversion profile, and distribution of sodium carbonates

High resistivity on the Rt curve



Stratigraphic column and the Rt curve characteristics of the FN-5 well

Outline

1. ***Geological background***
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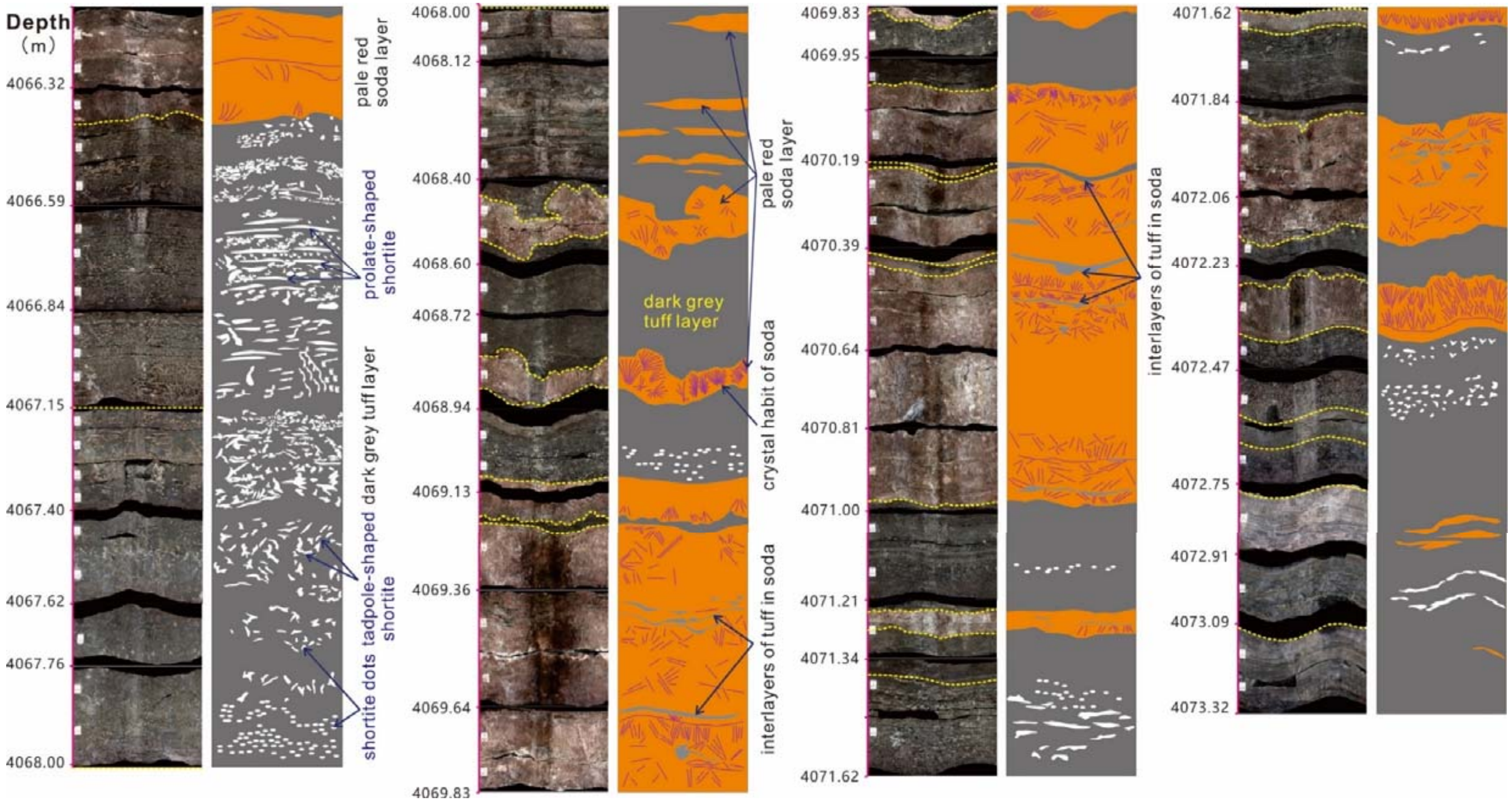
4. ***Summary***

2. Characteristics of sodium carbonate- bearing rhythms

✓2.1 Characteristics of sodium carbonates-bearing rhythms

- **Two fundamental lithofacies**: light- colored soda, dark- colored tuff.
- Soda layers alternated with tuff layers frequently.
- Most single layer are **less than 1m thick**.
- **Sodium carbonate minerals** in the light-colored soda layers occurred as bedded layers, in which the directions of crystal growths are visible.
- **Shortite** in the dark-colored tuff layers occurred as white bands, dots, and tadpole-shaped features.



Scanned images of the studied core and geological sketch map of the relationship among the shortite, soda, and tuff matrix.

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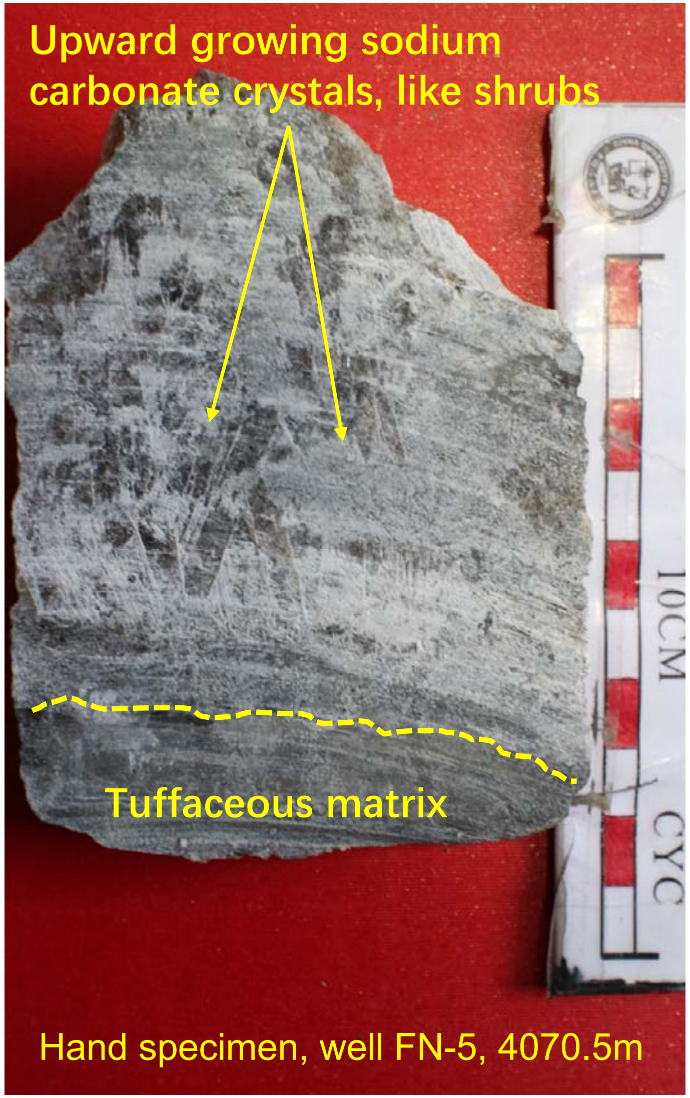
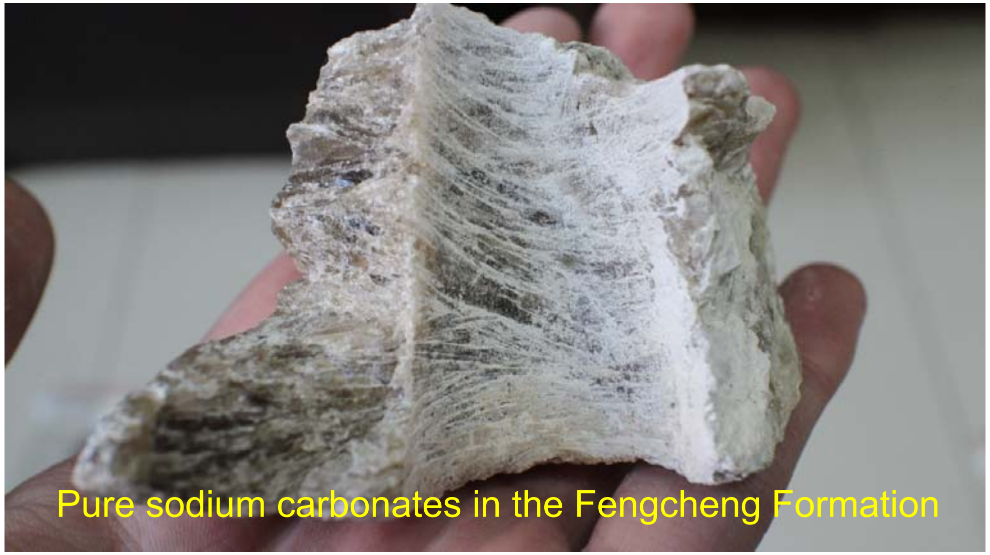
2. Characteristics of sodium carbonate- bearing rhythms



Hand specimen, well FN-5, 4070.5m

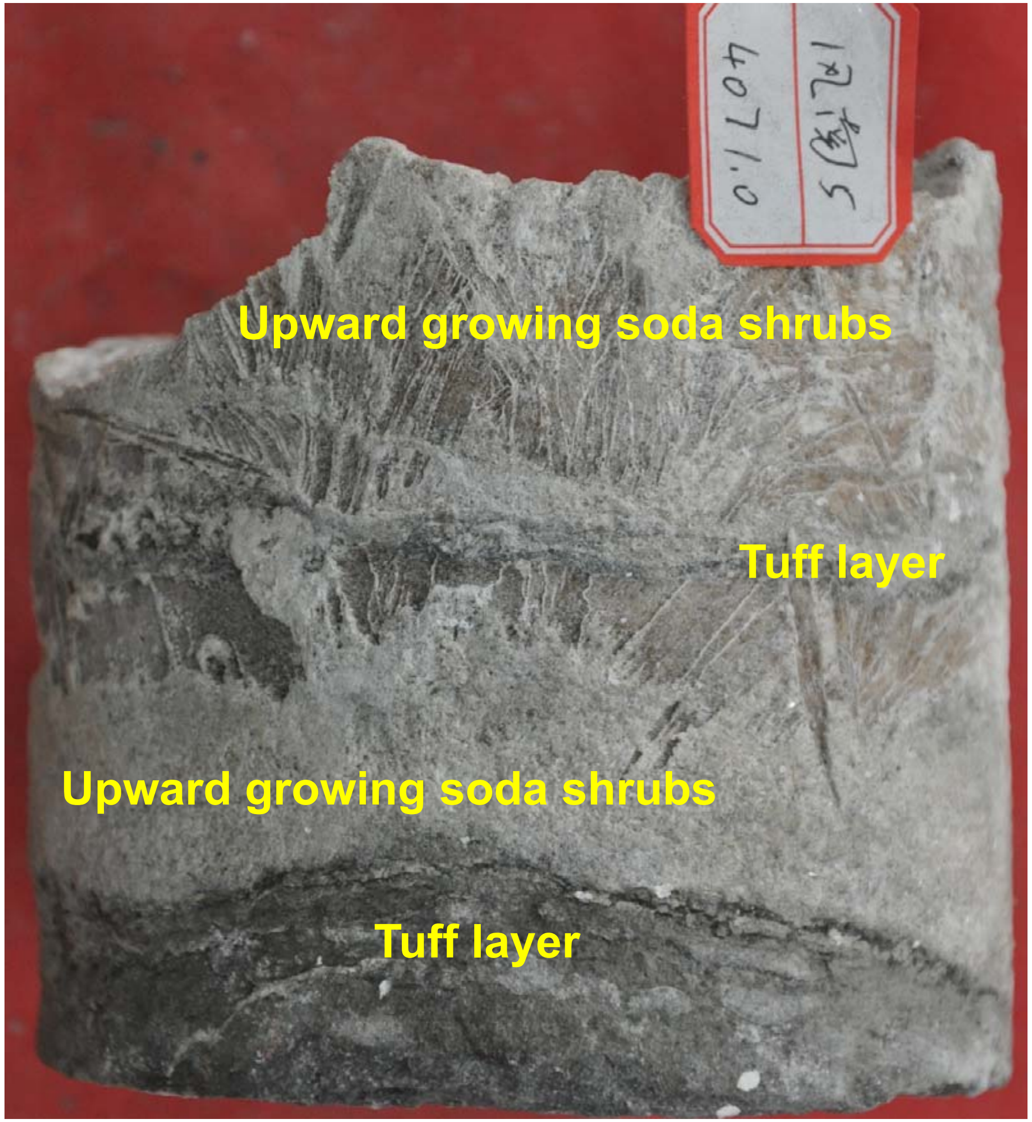
✓2.2 Characteristics of soda (Na_2CO_2 and $NaHCO_3$)

- ***Mineral morphology:*** *idiomorphic.*
- ***Occurrence pattern:*** *grow upward on the tuff layer like shrubs.*
- ***Optical property:*** *fine.*



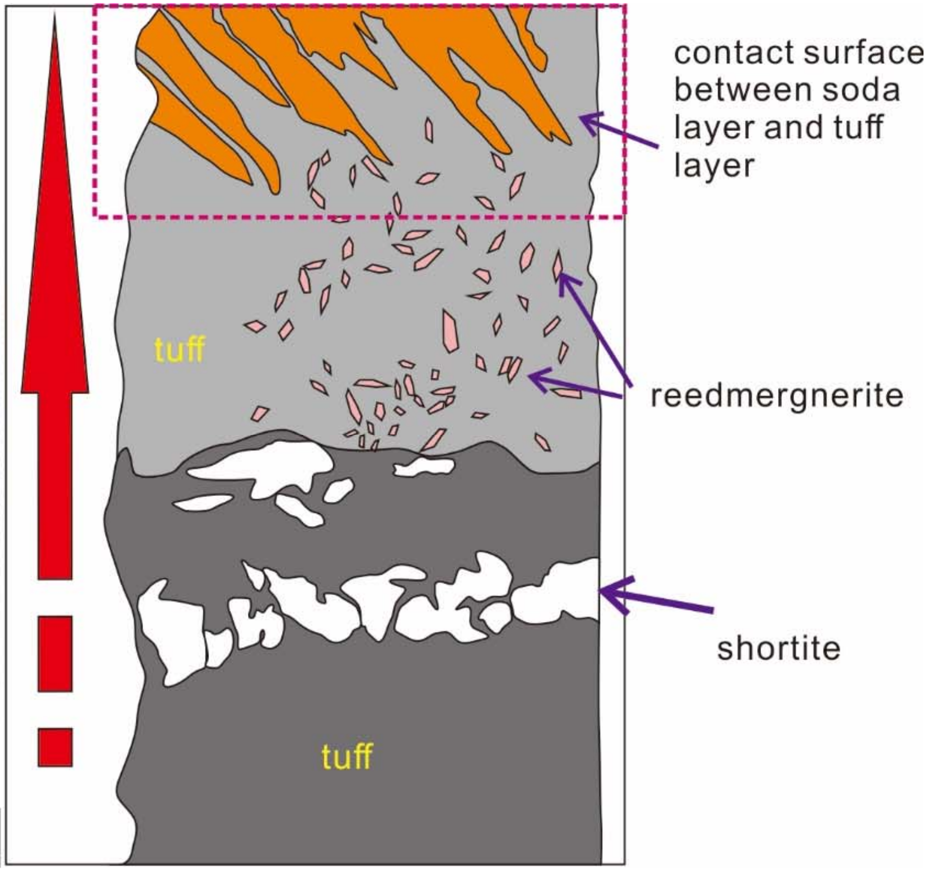
Pure sodium carbonates in the Fengcheng Formation

2. Characteristics of sodium carbonate- bearing rhythms

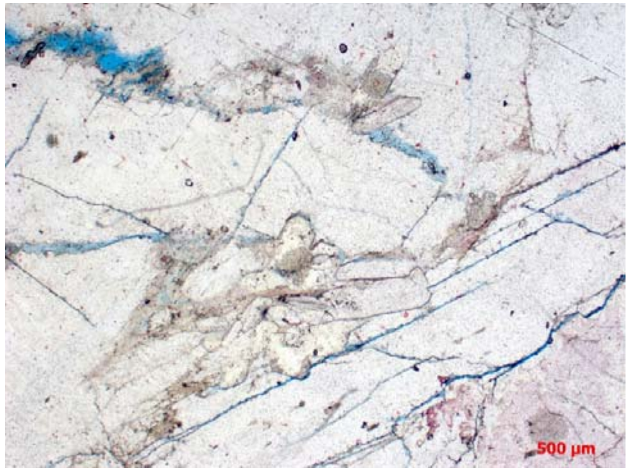


2. Characteristics of sodium carbonate- bearing rhythms

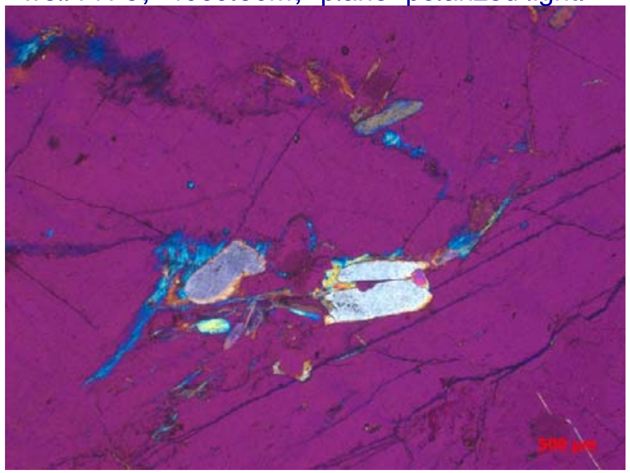
sodium carbonate minerals **embedded into the tuff** matrix like blades and **stabilized the crystals**, and then **grew upward**.



Macro photography of thin section:The contact surface between soda layer and tuff layer is not even



Sodium carbonate crystals under microscope, well FN-5, 4069.36m, plane- polarized light.

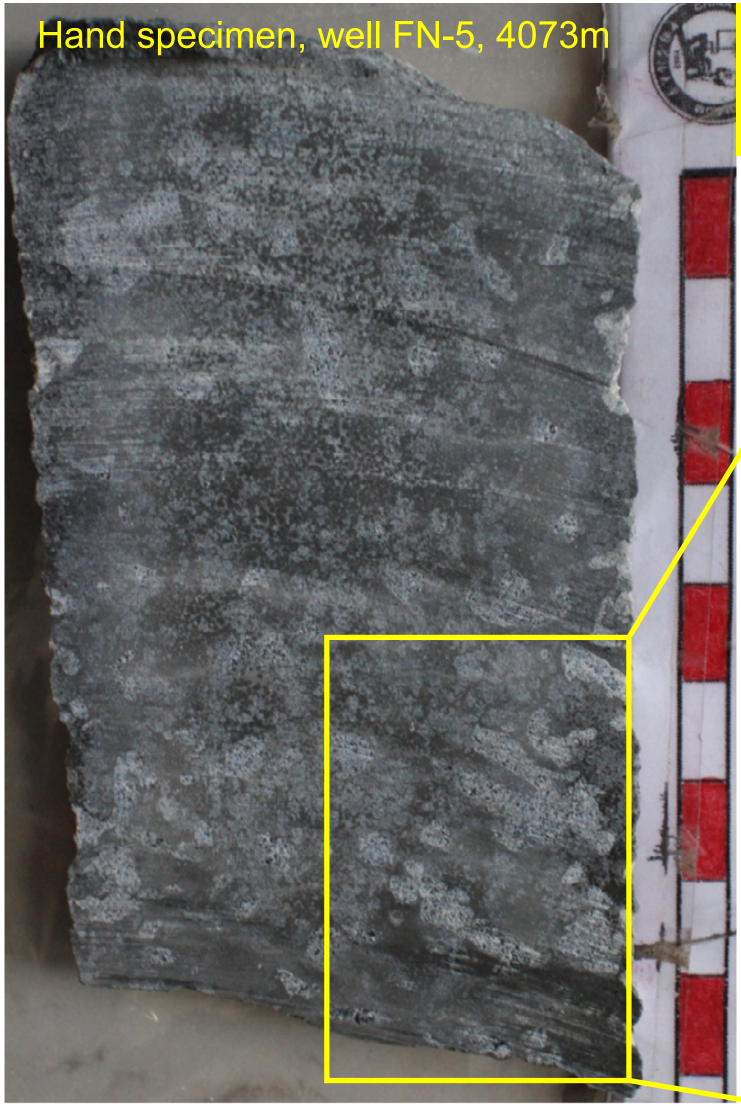


Sodium carbonate crystals under microscope, well FN-5, 4069.36m, cross- polarized light with gypsum plate.

2. Characteristics of sodium carbonate- bearing rhythms

View of shortite in hand specimens

Hand specimen, well FN-5, 4073m

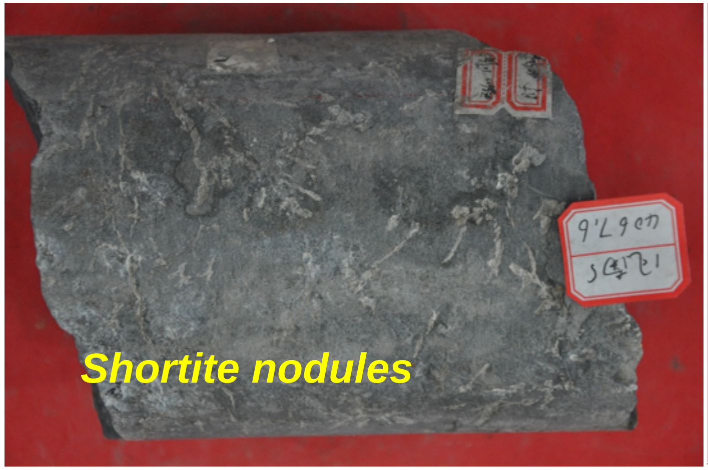


✓2.3 Characteristics of shortite (chemical fomular: $Na_2Ca_2(CO_3)_3$)

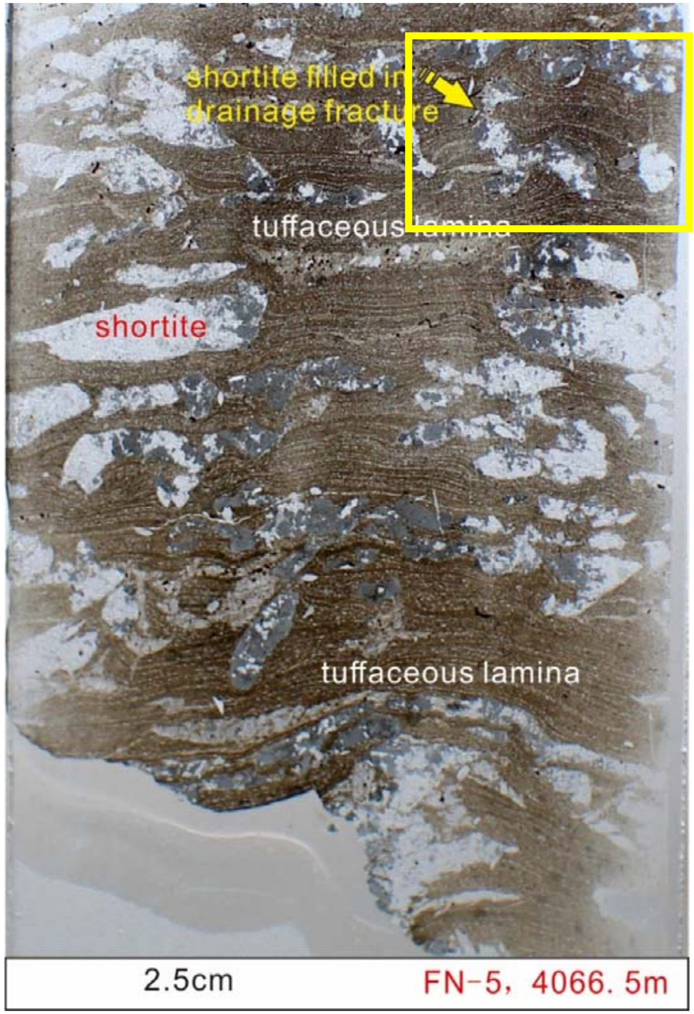
- ***Mineral morphology:*** *amorphous, occurred as bands, dots, tadpole shapes, drainage veins cutting through the tuff lamina.*
- ***Formation time:*** *precipitated after tuffaceous matrix deposited.*

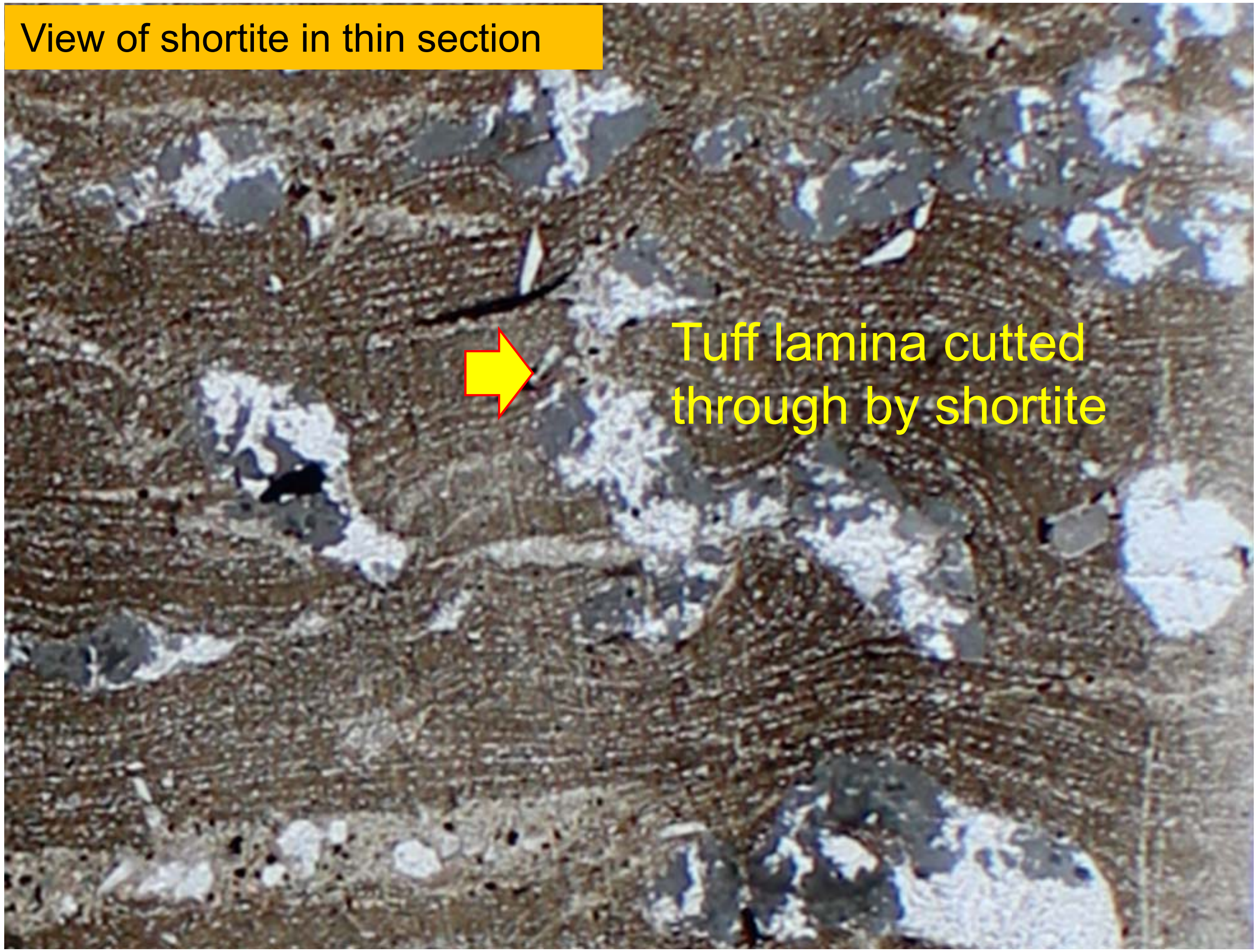
2. Characteristics of sodium carbonate- bearing rhythms

View of shortite in hand specimens



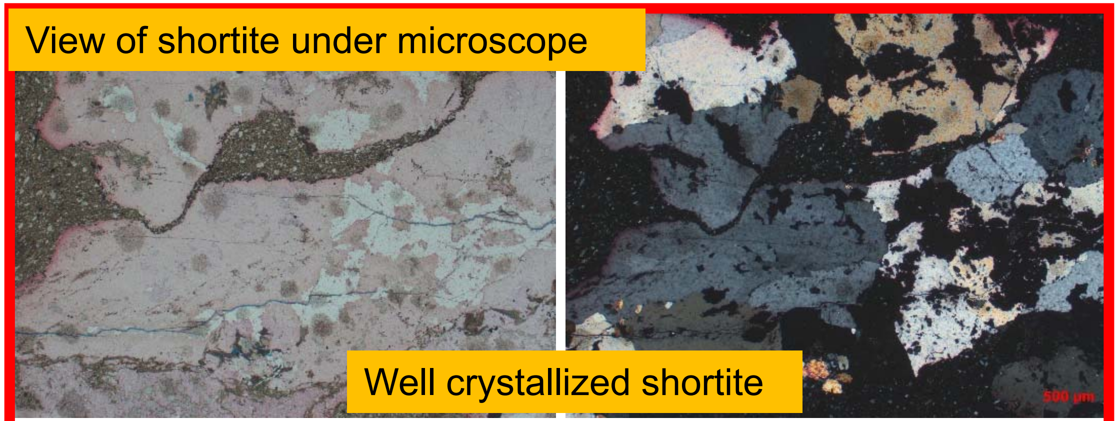
2. Characteristics of sodium carbonate- bearing rhythms





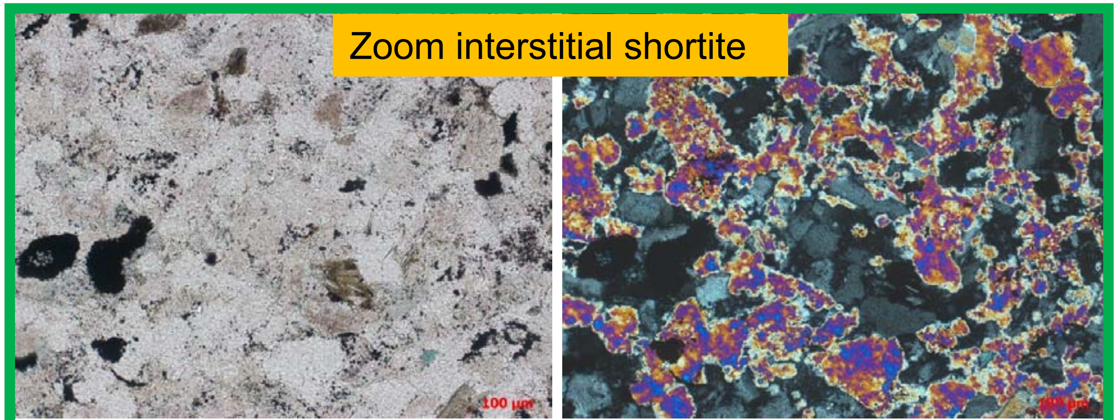
Macro photograph of thin section of shortite-bearing tuffaceous rocks and the lamina were cutted by shortite

2. Characteristics of sodium carbonate- bearing rhythms

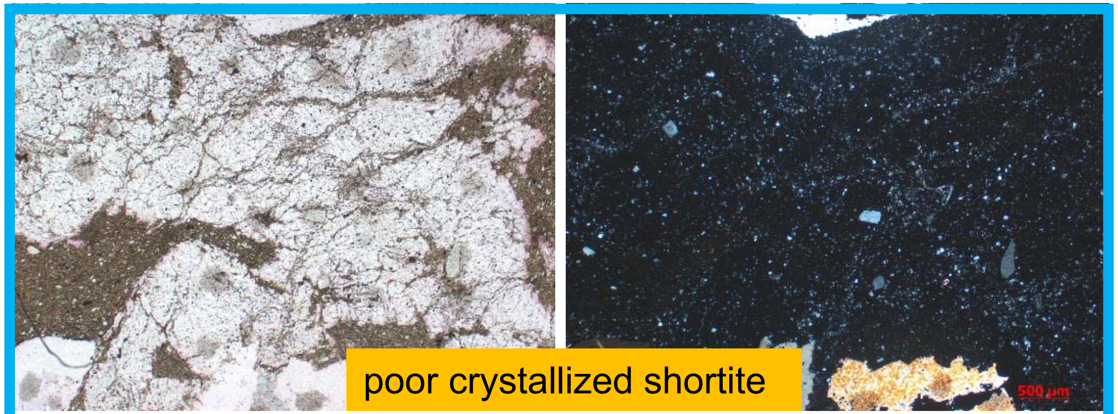


Shortite can be dyed into pink, the same as calcite, well FN-5, 4066.52m, plane- polarized light.

Characteristics of shortite under cross- polarized light, well FN-5, 4066.52m.

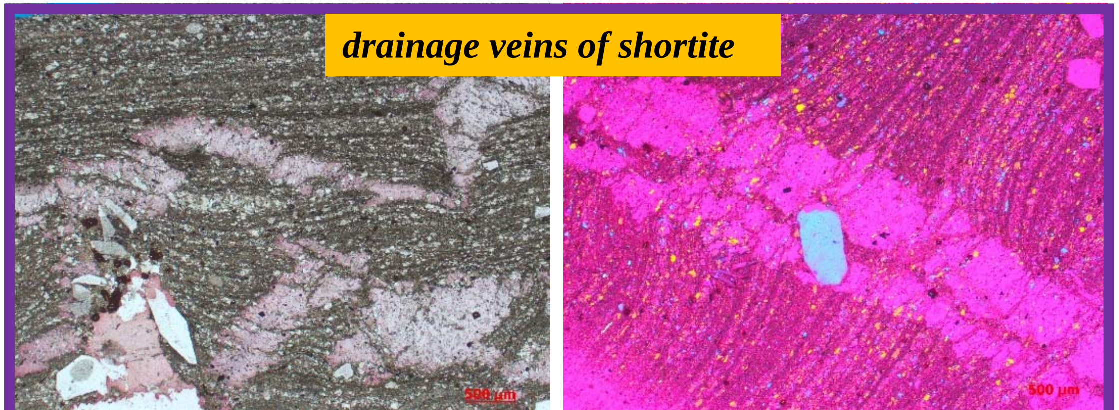


shortite precipitated interstitial in the diagenetic stage, well FN-5, 4068.64m.



Poor crystallized internitial shortite , under plane- polarized light, well FN-5, 4066.52m.

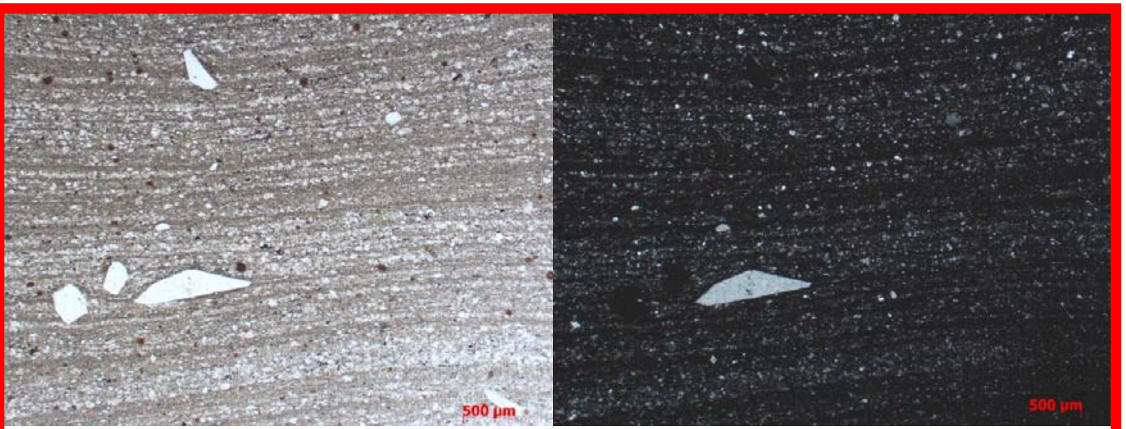
Characteristics of shortite under cross- polarized light, well FN-5, 4066.52m.



Tuff lamina cutted by shortite, plane- polarized light, well FN-5, 4067.94m.

Tuff lamina cutted by shortite, cross- polarized light with gypsum plate, well FN-5, 4067.94m.

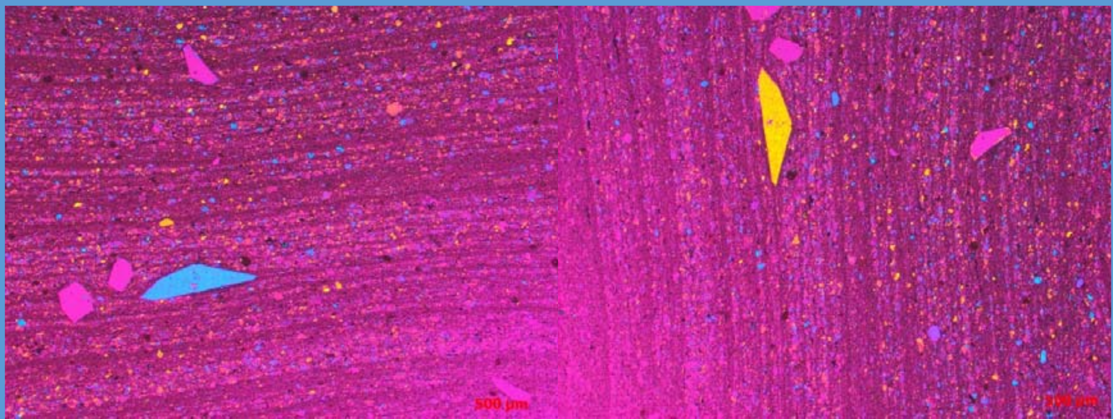
2. Characteristics of sodium carbonate- bearing rhythms



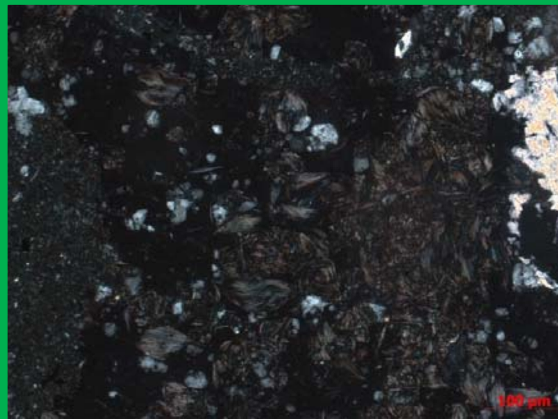
Fine-grained taffaceous laminae and the reedmergnerites are paralleled to these laminae, well FN-5, 4067.94m

✓2.4 Characteristics of tuffaceous matrix (mainly aluminosilicate minerals)

- ◆ *Low clay minerals content.*
- ◆ *Abundant fine- grained feldspars.*
- ◆ *Rich in acid extrusive debris and pyrites.*
- ◆ *Reedmergnerites paralleled to the sedimentary tuff laminae*



Characteristics of tuffaceous laminae, low clay minerals contents, well FN-5，4067.94m.



Acid extrusive debris, well FN-5，4072.66m.

Pyrite generated from volcano eruptions, well FN-5，4072.66m.

Outline

1. ***Geological background***
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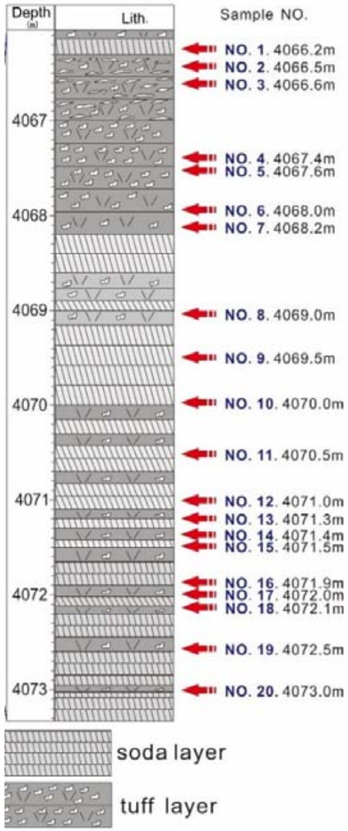
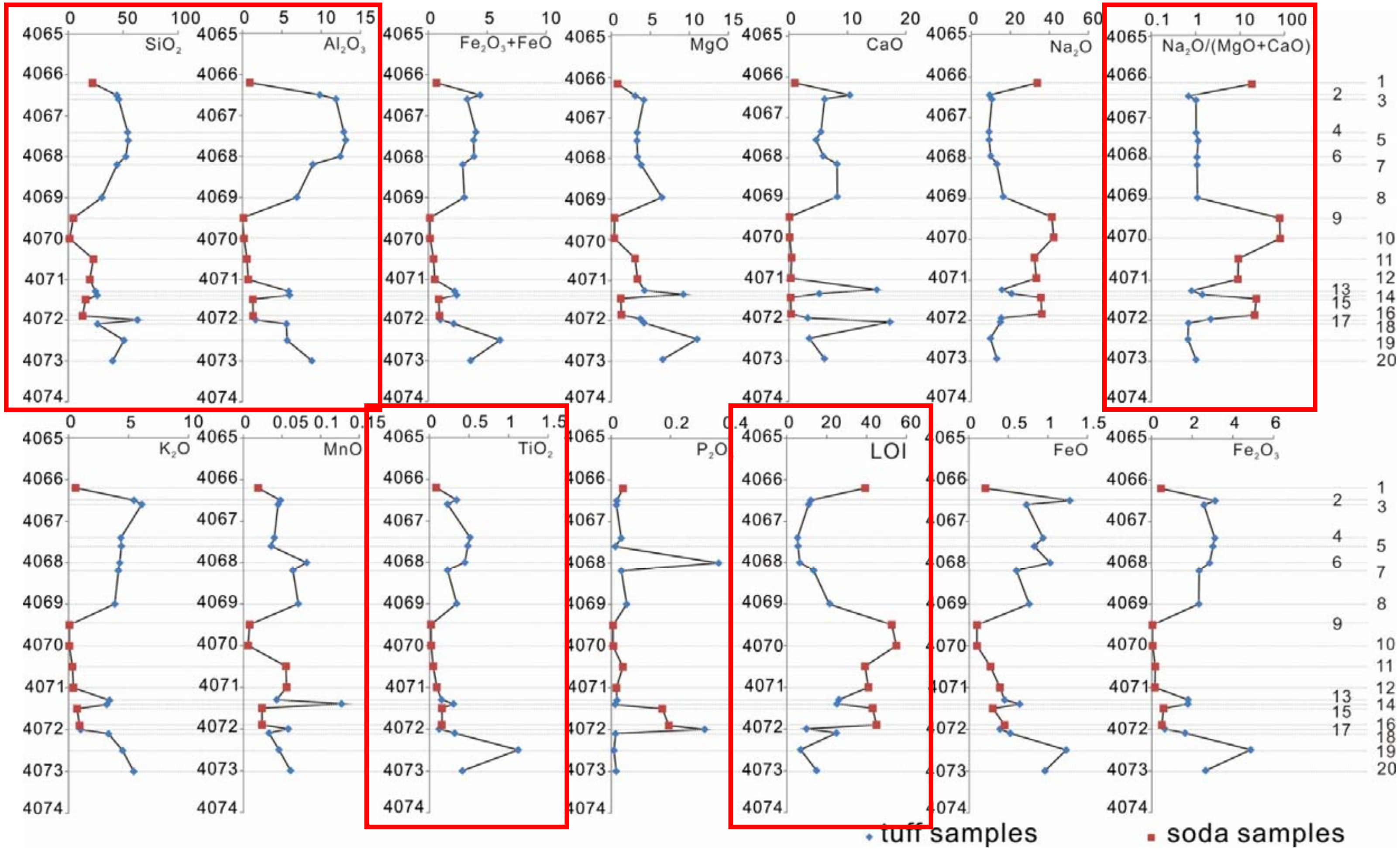
4. ***Summary***

3. Paleoclimate variations and genetic mechanism of rhythms

✓3.1 Major elements and implications for sedimentary processes



7 soda samples
13 tuff samples



Content distribution of major elements in the vertical section

3. Paleoclimate variations and genetic mechanism of rhythms

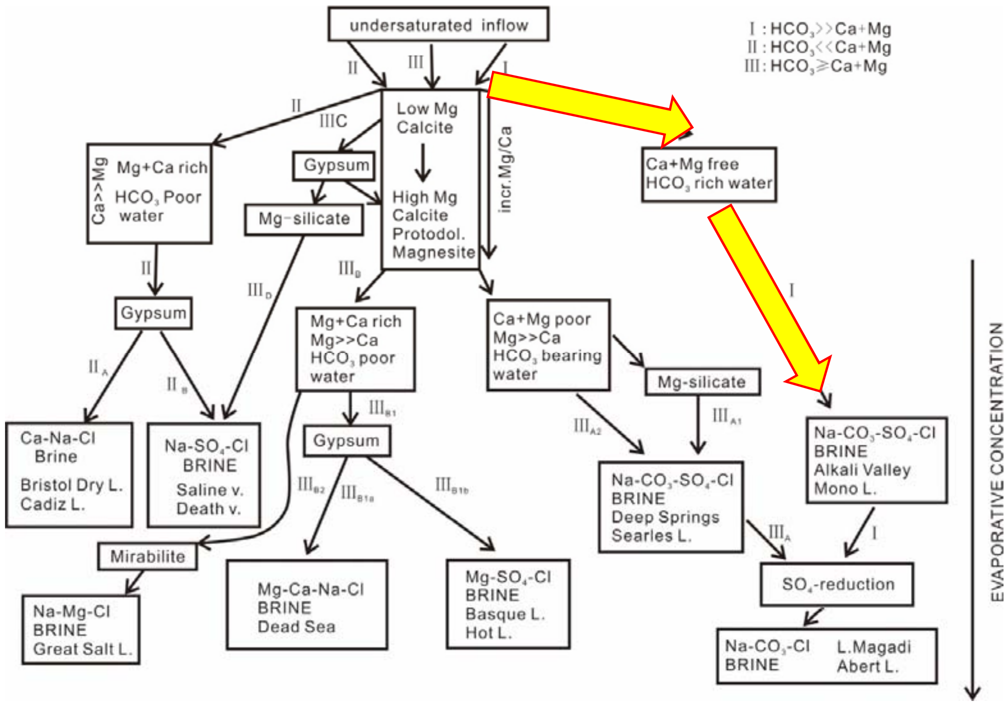
The brines were diluted by inflows, humid, more Ca, Mg inputted

Evaporation, arid, few inflows

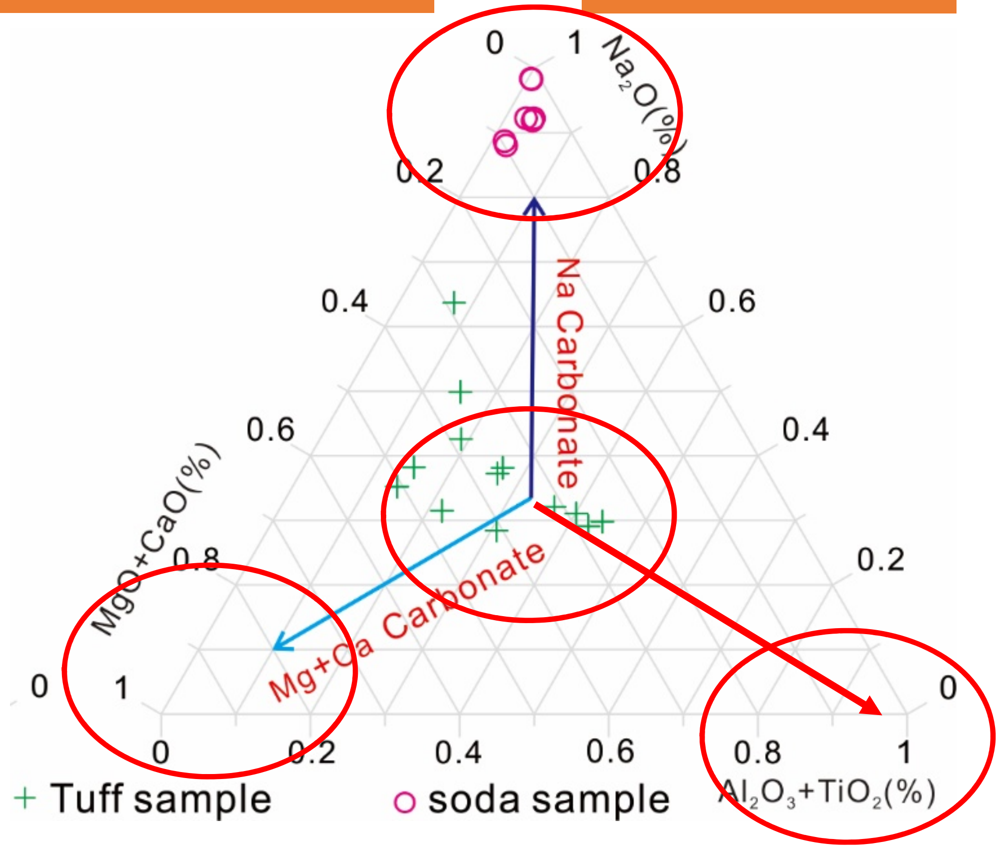
Ca-Mg carbonate

Ca-Mg, Na transitional carbonate

Na carbonate



Brine evolution flow diagram and resulting brines, together with examples of salt lakes (Eugster, 1980)

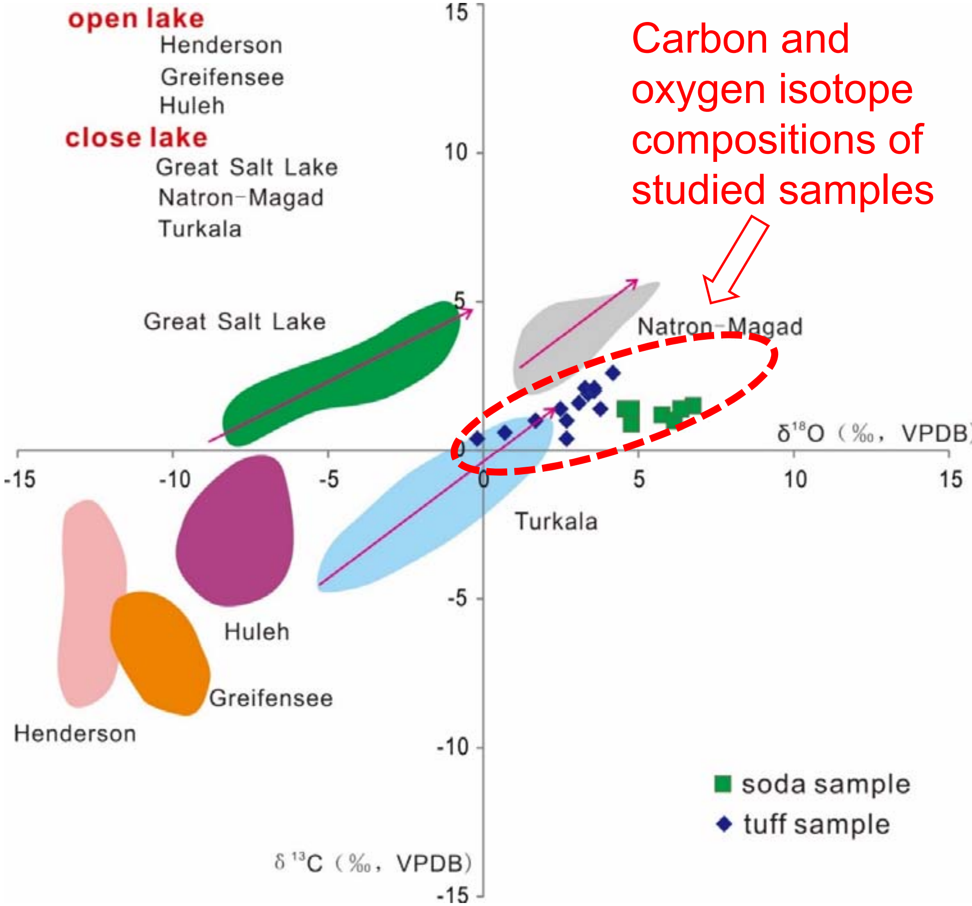


Na_2O- $(CaO+MgO)$-$(Al_2O_3+TiO_2)$ triangle map

3. Paleoclimate variations and genetic mechanism of rhythms

✓3.2 Carbon and oxygen isotopes and implications for sedimentary environments

- **The positive correlation between δ^{13}C‰ and δ^{18}O‰ indicate hydrologically closed basin (Li and Liu, 1997; Liu et al., 2001)**
- We take the carbonates as primary carbonates, and their carbon and oxygen isotope compositions can reflect sedimentary environments.
- The positive correlation between δ^{13}C‰ and δ^{18}O‰ measured from authigenic carbonate minerals in the studied core section indicated that the Mahu Sag **was hydrologically closed** when the sodium carbonate- bearing strata formed.
- The closed hydrological system can enhance the climate fluctuations controls on the sedimentary records.

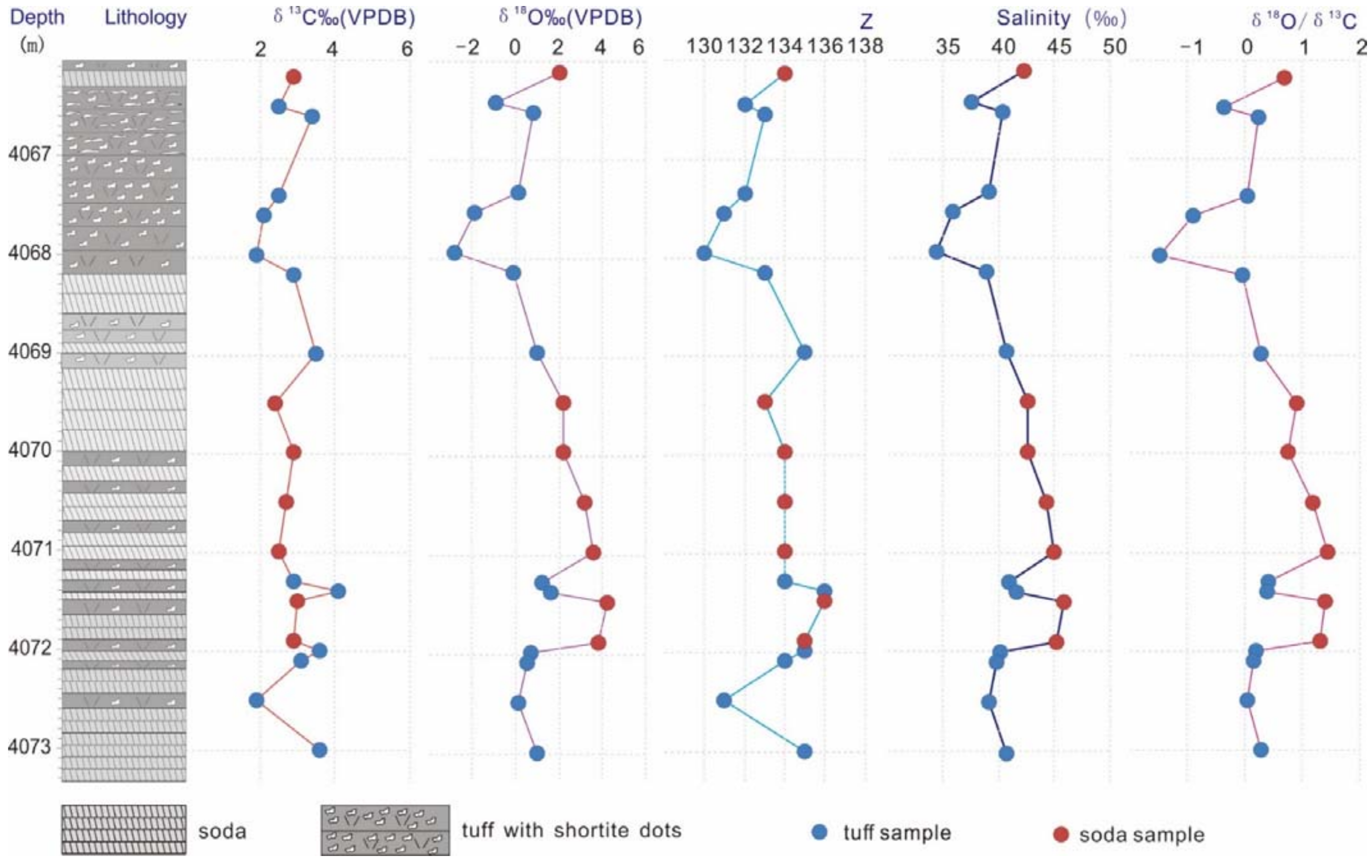


The correlations of carbon and oxygen isotope compositions

3. Paleoclimate variations and genetic mechanism of rhythms

The salinities varied frequently and hydrologically closed condition enhanced the climate influences on the salinities

- **High $\delta^{13}C$‰ (VPDB) values:** The $\delta^{13}C$‰ (VPDB) values in the core section exhibited a positive trend from a minimum of 1.9% to a maximum of 4.1% with an average of 2.87%, which matches the distribution range of modern authigenic carbonates in evaporate environments.
- **High $\delta^{18}O$‰(VPDB) values:** The $\delta^{18}O$‰ (VPDB) values ranged from a minimum of -2.8% to a maximum of 4.2% with an average of 1.13%.
- **High Z values:** the Z value ranged from a minimum of 130 to a maximum of 136 with an average of 133.65, which was much high than the boundary value of 120.
- **High salinities:** The salinities that were calculated from $\delta^{18}O$‰ (VPDB) were got by the equation: S= ($\delta^{18}O$‰+21.2)/0.61 (Lu et al., 2012), and the results were also much higher than that of seawater



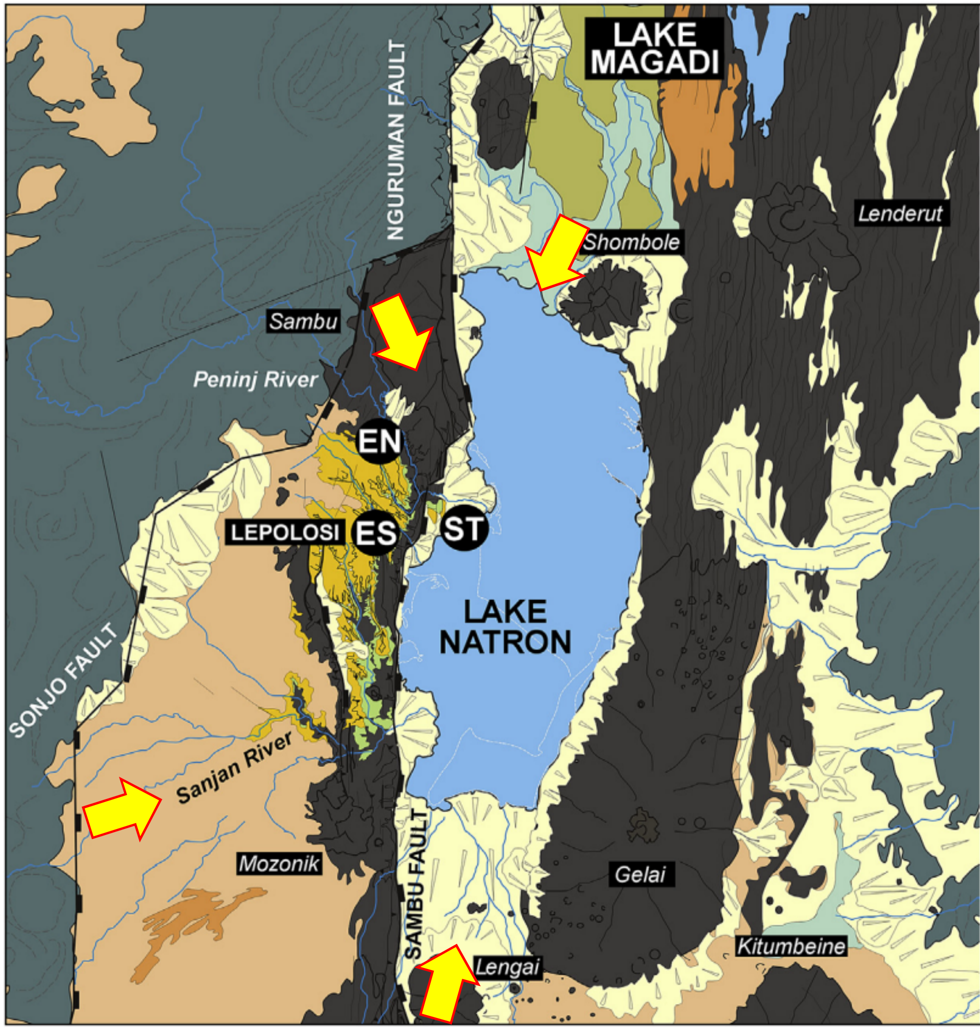
Content distribution of carbon isotopes, oxygen isotopes, Z values, salinity values in the vertical section.

3. Paleoclimate variations and genetic mechanism of rhythms

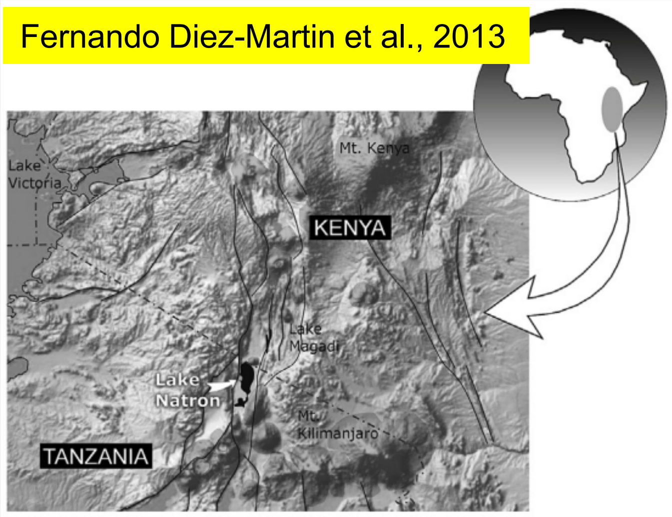
✓3.3 Analogy of modern soda lake----Lake Natron in Tanzania

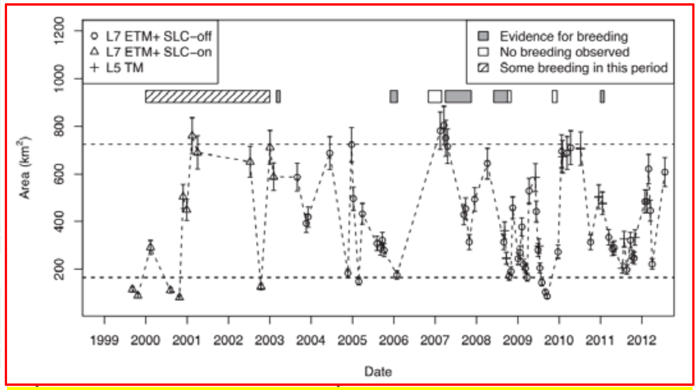
- Hydrologically closed;
- Volcanic ash/sand distributed around the lake;
- Climate arid and varied frequently and the extent of the lake changed periodically.

EROSIVE ESCARPMENT
MAIN FAULT (> 200 m)
LONGITUDINAL DUNE
MARSH
FLOODPLAIN
VOLCANIC ASH/SAND
ALLUVIAL FAN/DELTA
MOINIK FORMATION
HUMBU FORMATION
VOLCANIC
PRECAMBRIAN BASEMENT



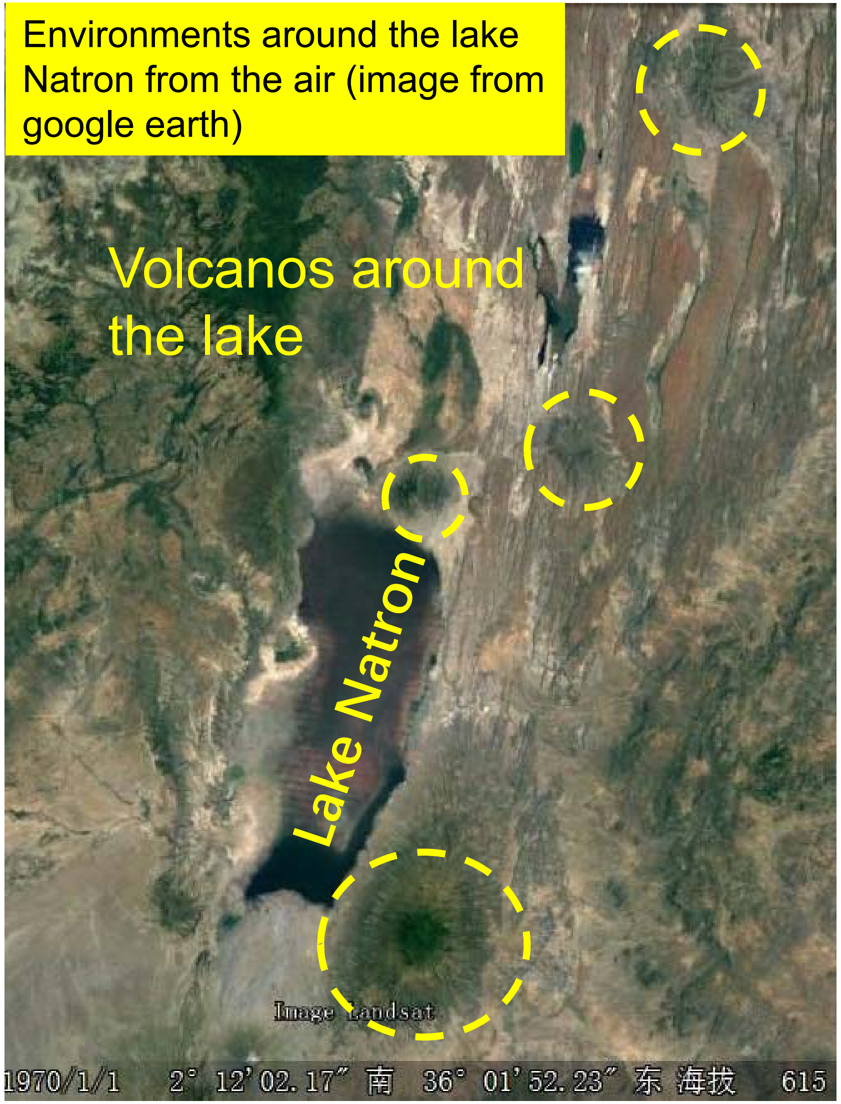
Fernando Diez-Martin et al., 2013





Tebbs et al., 2013

3. Paleoclimate variations and genetic mechanism of rhythms



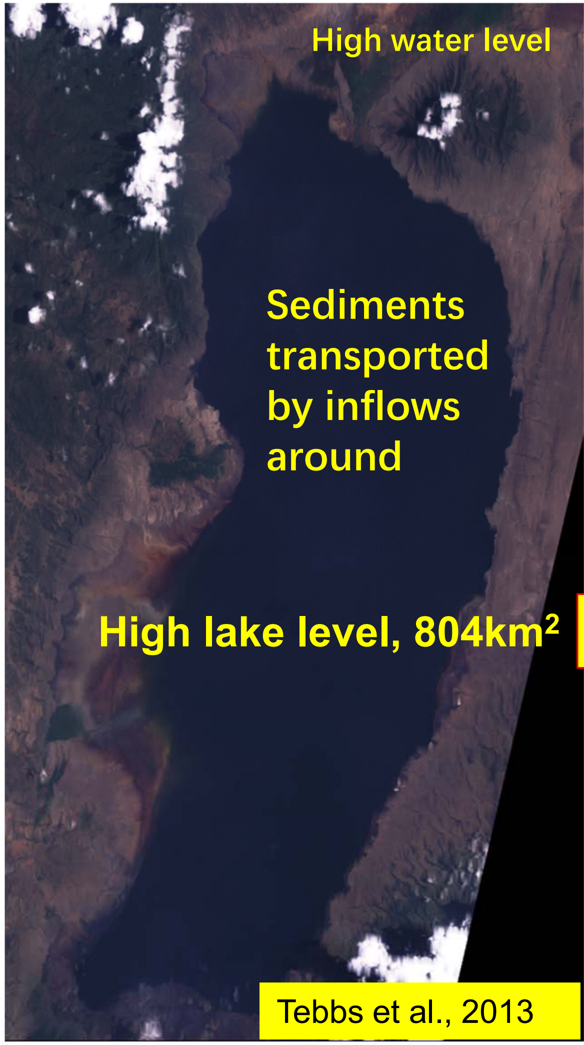


Fig. 5. Maximum extent of Lake Natron, 804 km^2, 2007-03-19, NASA Landsat ETM+ image true colour composite image.

VS

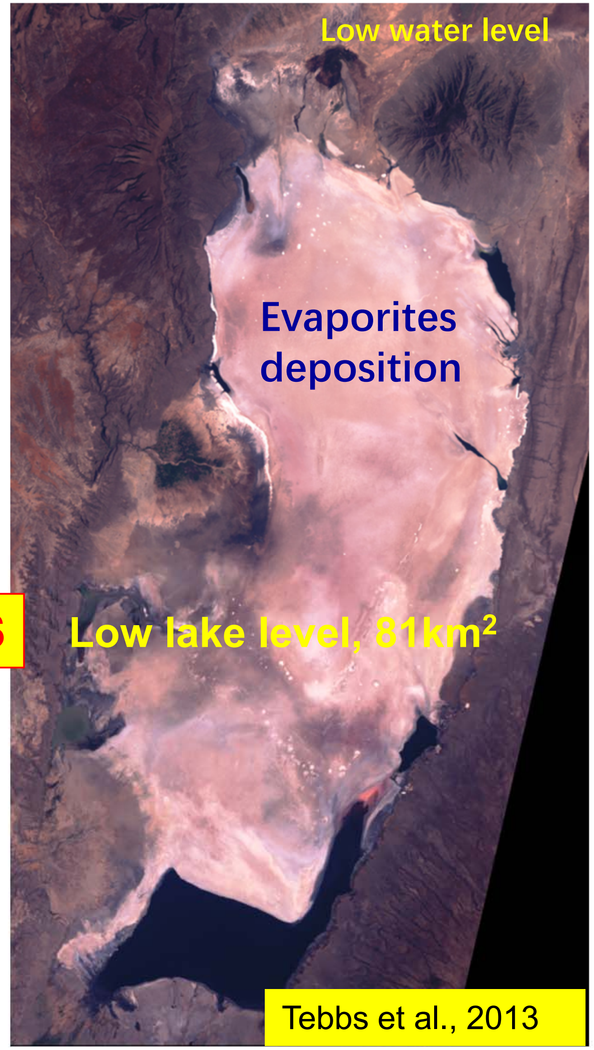
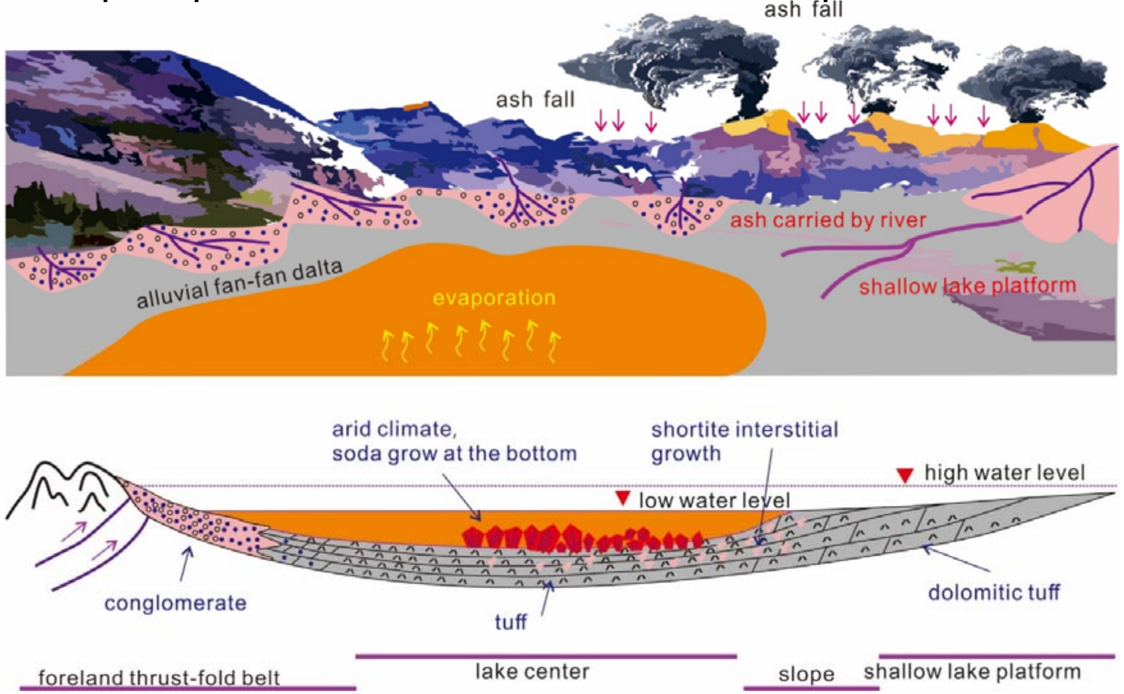


Fig. 6. Minimum extent of Lake Natron, 81 km^2, 2000-10-25, NASA Landsat ETM+ image true colour composite image.

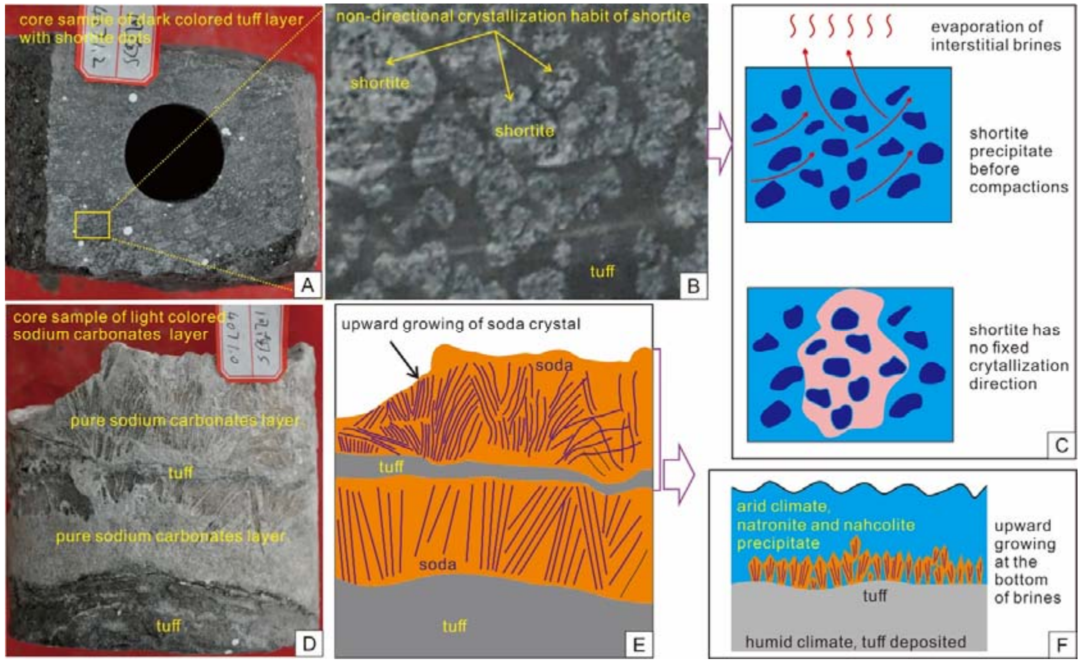
3. Paleoclimate variations and genetic mechanism of rhythms

✓3.4 Genetic mechanism model of sodium carbonate- bearing rhythms

- Hydrologically closed basin.
- The fine-grained sediments in the depositional center mainly came form volcano eruptions.
- Climate variations controlled the evaporates precipitation alternated with the ash deposition.
- Pure sodium carbonates grew at the bottom of the brine when salinities increase and few aluminosilicate minerals imputed.
- Most of shotite precipitated diagenetically interstitial after aluminosilicate minerals deposited when the paleoclimate turned humid.



Model for carbonate precipitation and associated tuff and coarse clastic sediment deposition during the Early Permian in the Mahu Sag.



model for pure sodium carbonates and shortite precipitation.

Outline

1. Geological background

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4. Summary

Summary

1. Most shortite formed diagenetically before the compaction and lithification of the tuff layers, while soda grew on the bottom of the brine.
2. Volcanic eruptions provided most of fine-grained sediments, while not the products from bedrocks weathering.
3. The Mahu Sag was a hydrologically closed basin. The climate fluctuations controlled the lake's expansions and contractions and inflows around the Mahu Sag, and controlled the formation of rhythms.

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Thank you

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