Middle Permian Coarse-Crystalline Dolostone Reservoirs in the Northwest Sichuan Basin (SW China): Their Formation and Evolution*

Liyin Pan[1]

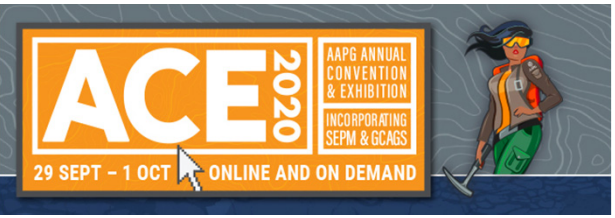
Search and Discovery Article #11352 (2021)**
Posted February 8, 2021

*Adapted from oral presentation accepted for the 2020 AAPG Annual Convention and Exhibition online meeting, September 29 – October 1, 2020.
 DOI:10.1306/11352Pan2020

[1]PetroChina Hangzhou Research Institute of Geology, Hangzhou, China (panly_hz@petrochina.com.cn)

Abstract

The Middle Permian dolostones in the northwest Sichuan Basin (Southwest China) represent significant exploration targets in recent years because commercial natural gas accumulations have been discovered therein. These coarse-crystalline dolostones, previously interpreted as hydrothermal dolomite (HTD) related to the end-Middle-Permian Emeishan Large Igneous Province (ELIP) volcanism, were selected for a combination of *in situ* U-Pb dating, clumped isotope (Δ_{47}) thermometry, as well as carbon, oxygen, strontium isotope ($\delta^{13}C$, $\delta^{18}O$ and $^{87}Sr/^{86}Sr$) and trace element analyses, with an attempt to correlate their formation and evolution to the geodynamic evolution of Sichuan Basin, thus better understanding the distribution of reservoir geobodies in the subsurface. The U-Pb ages of the replacive dolomites (240 to 233.8Ma) were significantly younger than the eruption of ELIP volcanism (~263 to 258Ma) implying that dolomitization was probably unrelated to this magmatic event as previously assumed. Instead, these younger ages point to a Middle to Late Triassic dolomitization event that was probably linked to the Late Triassic compression of the Northern Longmenshan Fold-Thrust Belt (LFTB). Integrated U-Pb ages and Δ_{47} thermometry, together with C-O-Sr isotope and trace element geochemistry, indicate that these coarse-crystalline replacive dolomites were formed at burial (~2.5 to 2.8km) by hot (100~120 ºC) fluids that were derived from Middle Permian or younger seawater, and a later stage (~13 to 6.8Ma) saddle dolomite cements were precipitated from a hydrothermal fluid with elevated $^{87}Sr/^{86}Sr$ during the Cenozoic deformation of the Northern LFTB. Vugs and intercrystalline pores in the Middle Permian dolostones were interpreted to be inherited from the precursory limestones that had experienced meteoric leaching during the Late Permian uplift. This study demonstrates the potential of combined *in situ* U-Pb geochronology, Δ_{47}, thermometry, as well as isotopic and trace element geochemistry for better understanding the formation and evolution of ancient dolostone reservoirs.



Middle Permian Coarse-Crystalline Dolostone Reservoirs in the Northwest Sichuan Basin (SW China): Their Formation and Evolution

Liyin Pan

(panly_hz@petrochina.com.cn)

PetroChina Hangzhou Research Institute of Geology

CNPC Key Laboratory of Carbonate Reservoirs

Outline

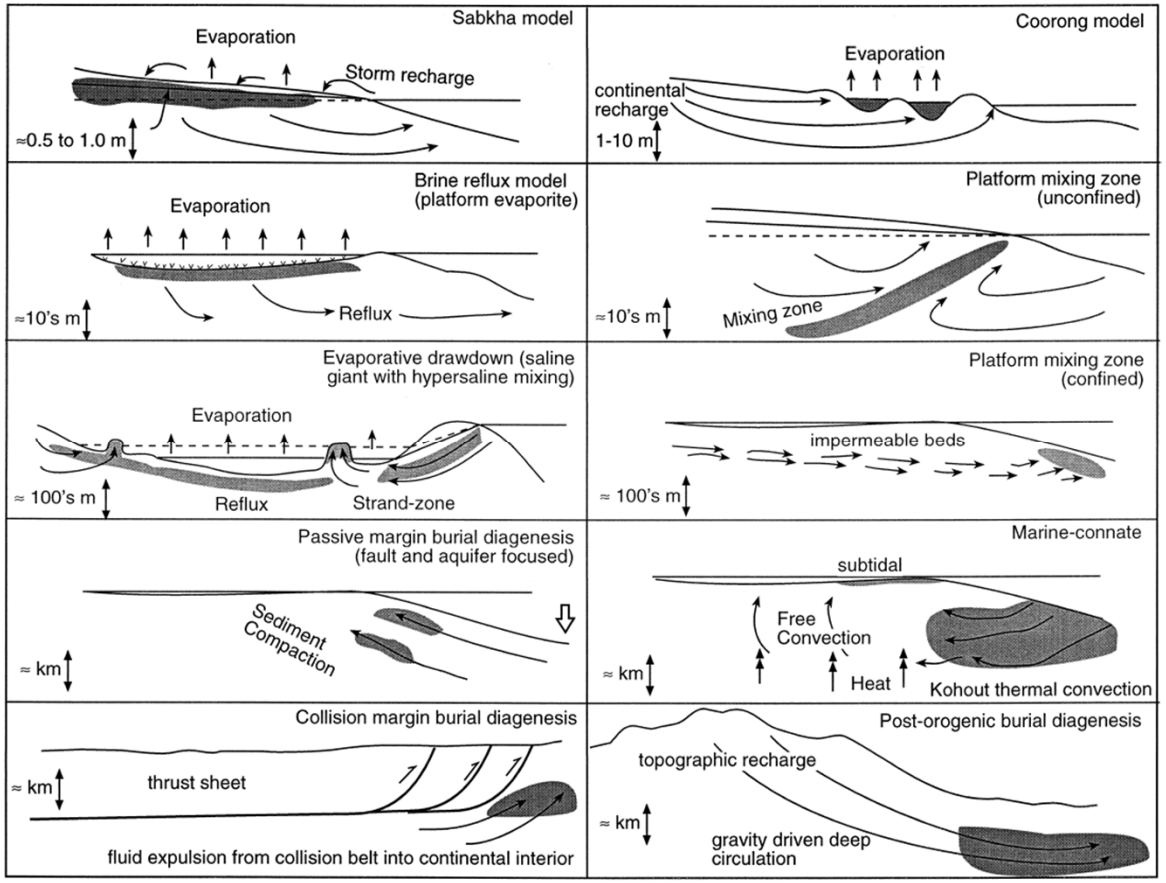
- **Introduction and geologic setting**
- **Formation and evolution of Middle Permian dolostones**
- **Conclusions**

Introduction

Despite intensive research for more than 200 years, the origin of dolomites is still full of controversy.

The Dolomites, where dolomite was discovered in 1791.

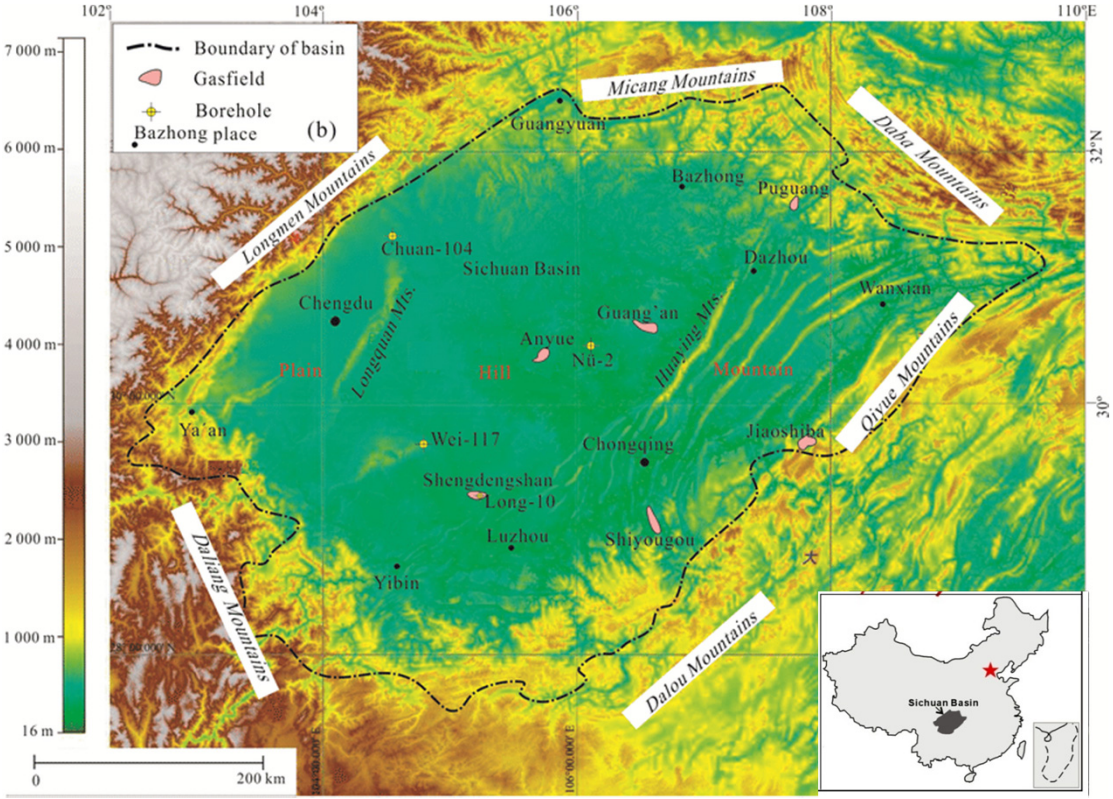
Deodat de Dolomieu (1750-1801)



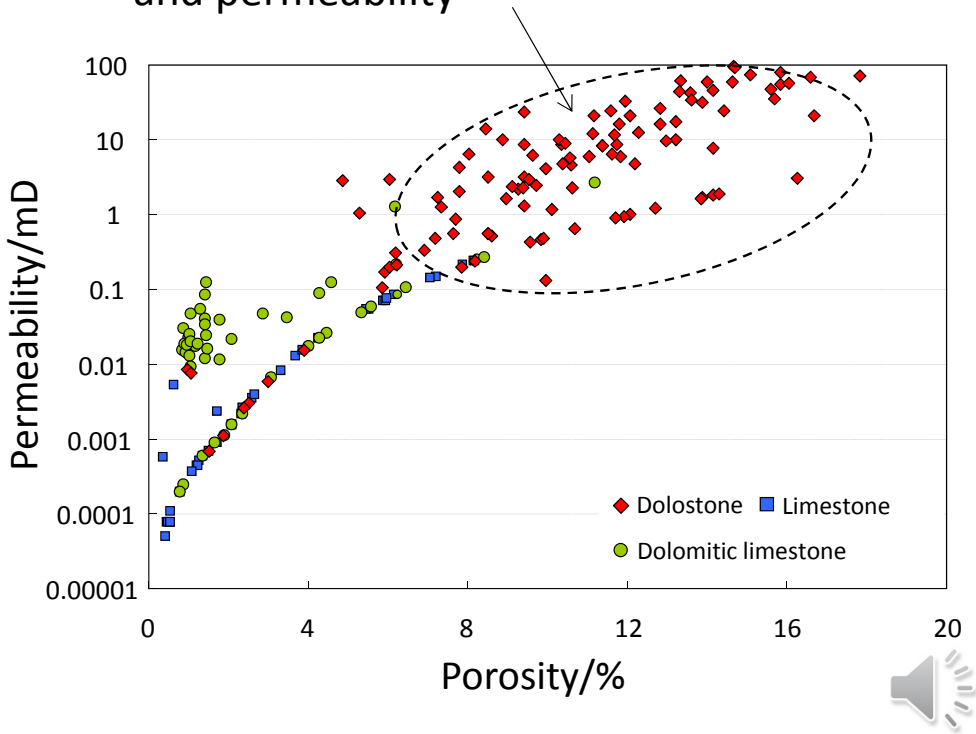
Various dolomitization models (Warren, 2000)

Introduction

- Dolostones are of economic significance because they often form hydrocarbon reservoir rocks
- In Sichuan Basin, one of the most largest petroleum provinces in China, >85% reservoir rocks are hosted in dolomite sequence

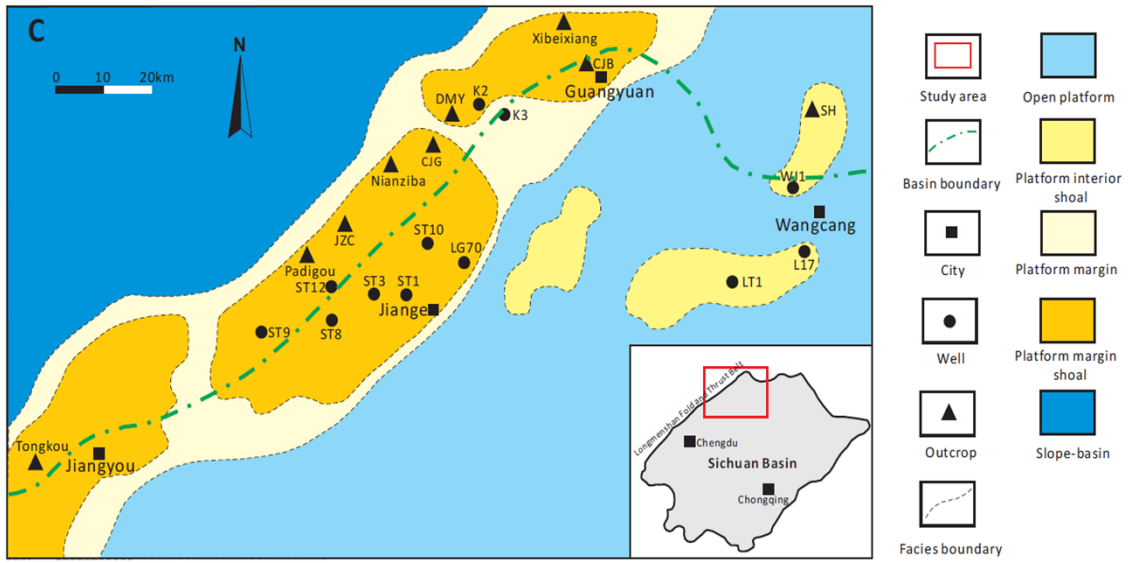


Dolostone in Sichuan Basin: higher porosity and permeability

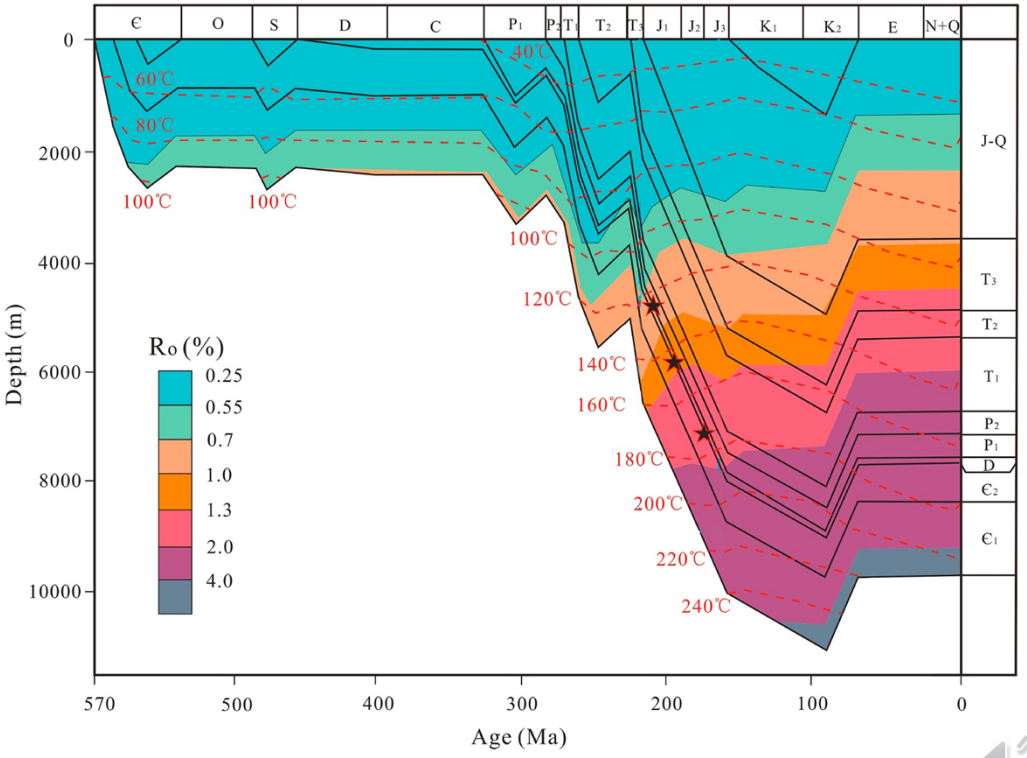


Introduction

- Middle Permian carbonates in NW Sichuan Basin represent the recent favorable exploration target, in which commercial natural gas accumulation has been discovered
- These shallow-water carbonates are deep-buried (7,000~8,000m) and have been affected by dolomitization; the formation and evolution of these dolomite reservoirs attract attention



Paleographic map of the study area during Middle Permian (Guan et al., 2018)

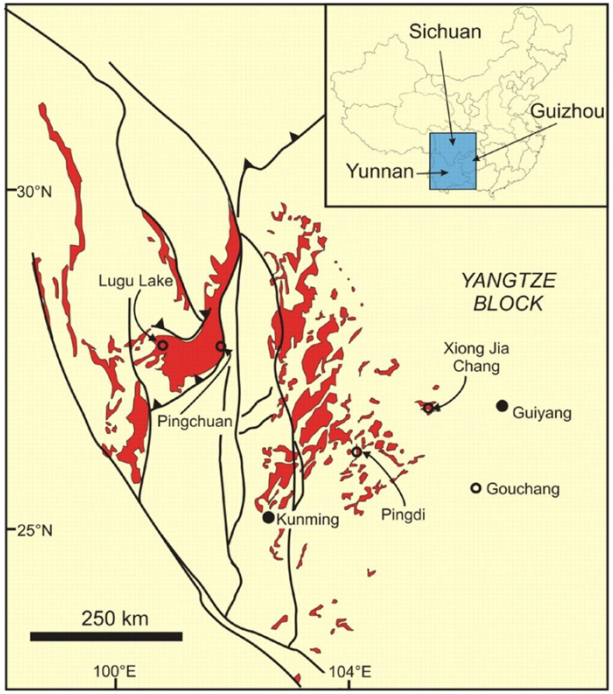


Burial-thermal history of well ST3 in NW Sichuan Basin (Li et al., 2019)

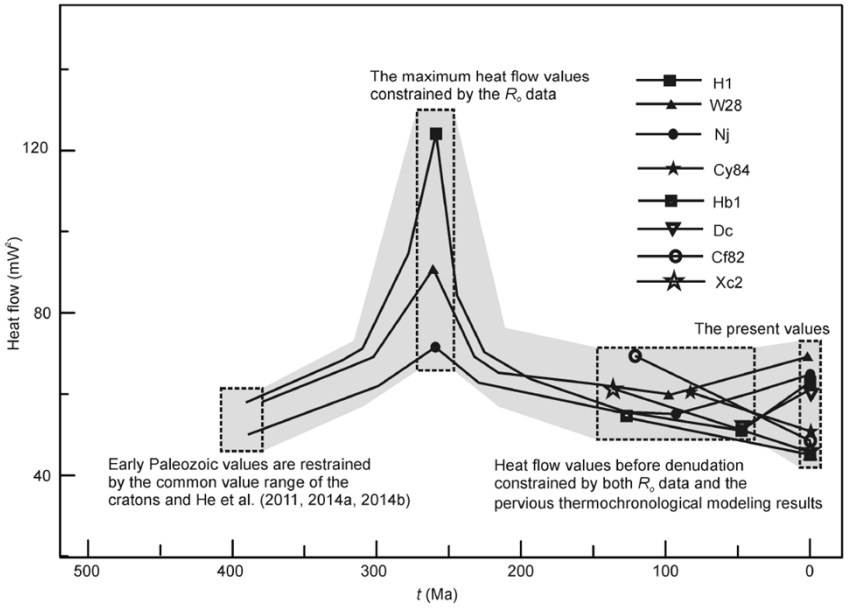
Geologic events that may affect dolomite reservoir formation and evolution

#1. End-Middle-Permian (~260Ma) volcanism (known as Emeishan Large Igneous Province)

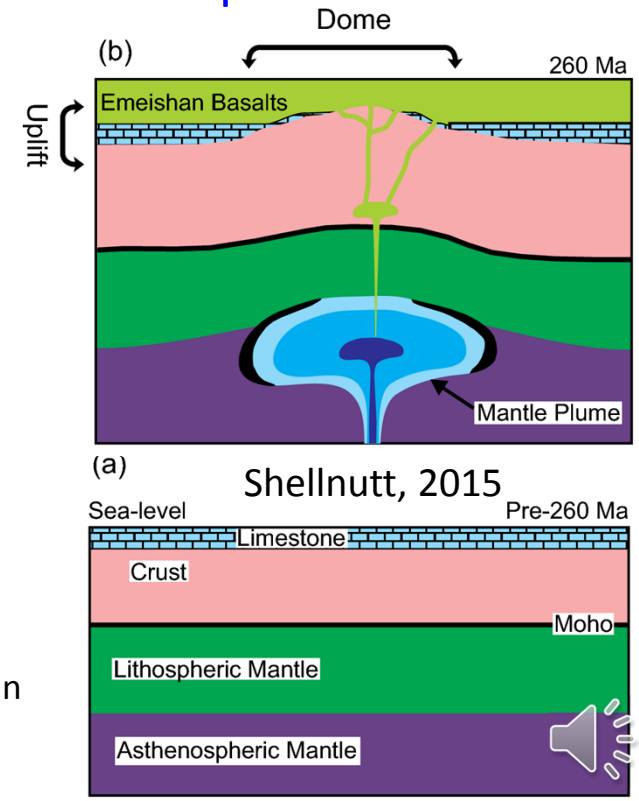
- Recorded by the extensive flooded basalts overlying the Middle Permian carbonates in Sichuan, Yunnan and Guizhou Provinces of SW China
- Had caused regional high thermal regime and plume-induced dome and uplift



Distribution of Emeihan basalts (Ali et al., 2004)



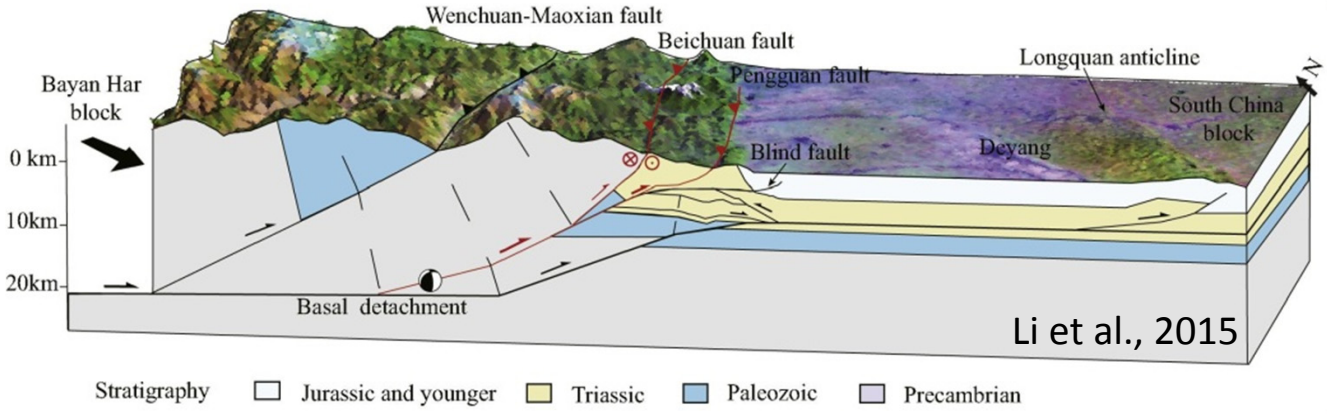
Heat flow history of selected boreholes of Sichuan Basin (based on vitrinite reflectance and thermal modeling; Zhu et al., 2016)

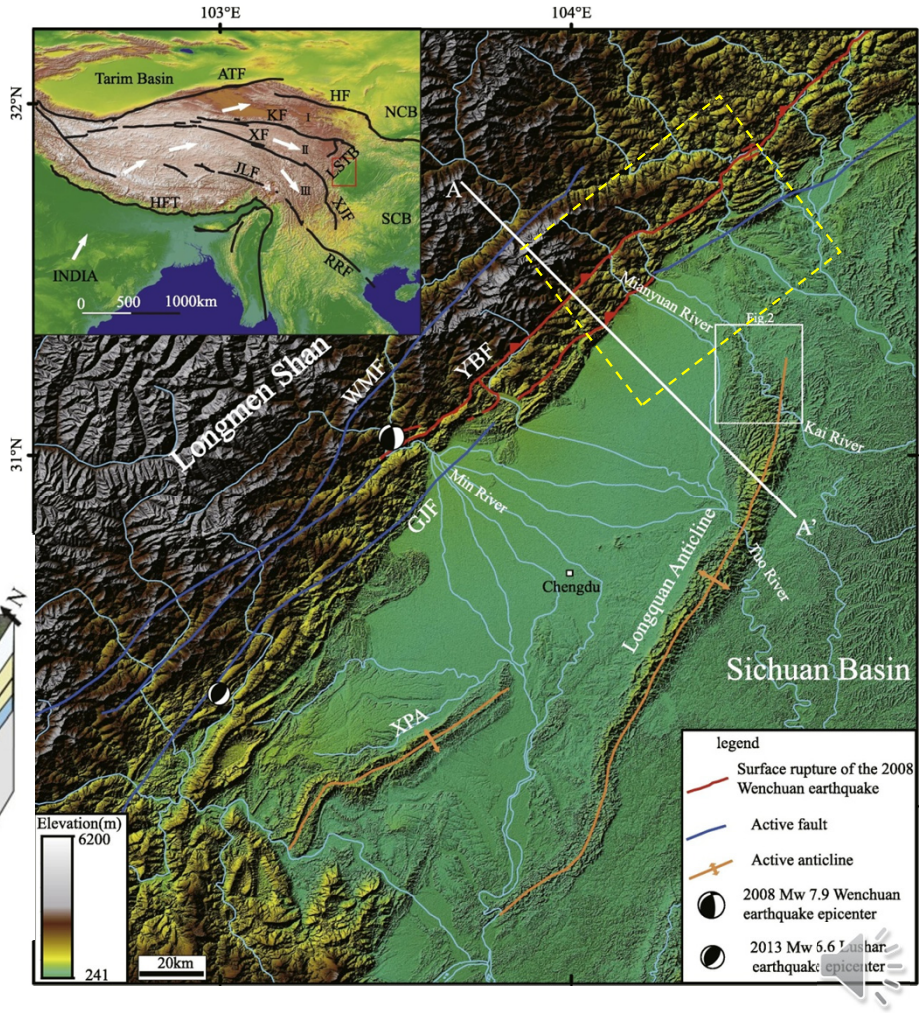


Geologic events that may affect dolomite reservoir formation and evolution

#2. Evolution of Longmenshan Fold-Thrust Belt

- An orogeny belt that borders Sichuan Basin and Tibet Plateau
- Formed in late Triassic and experienced two major deformation in Late Triassic and Cenozoic
- Potentially had caused tectonic-driven fluid flows





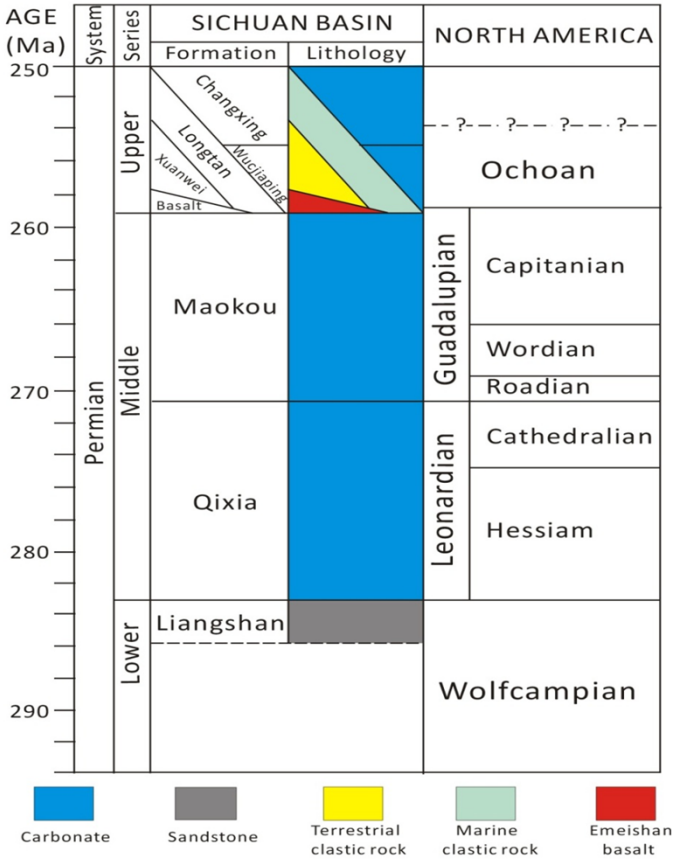
Previous Study

- Various dolomitization models have been proposed
- Recent studies led to the hypothesis that dolomitization could be related to the end-Middle-Permian volcanism

--Volcanic eruption immediately after the deposition of Middle Permian carbonates

--Higher fluid inclusion temperatures dolomites than the burial-induced temperature

--Highly radiogenic $^{87}Sr/^{86}Sr$ values of dolomites



Objective

#1. To test the volcanism-related dolomite model by carbonate U-Pb dating

#2. To establish the possible link between diagenetic alteration and tectonic evolution

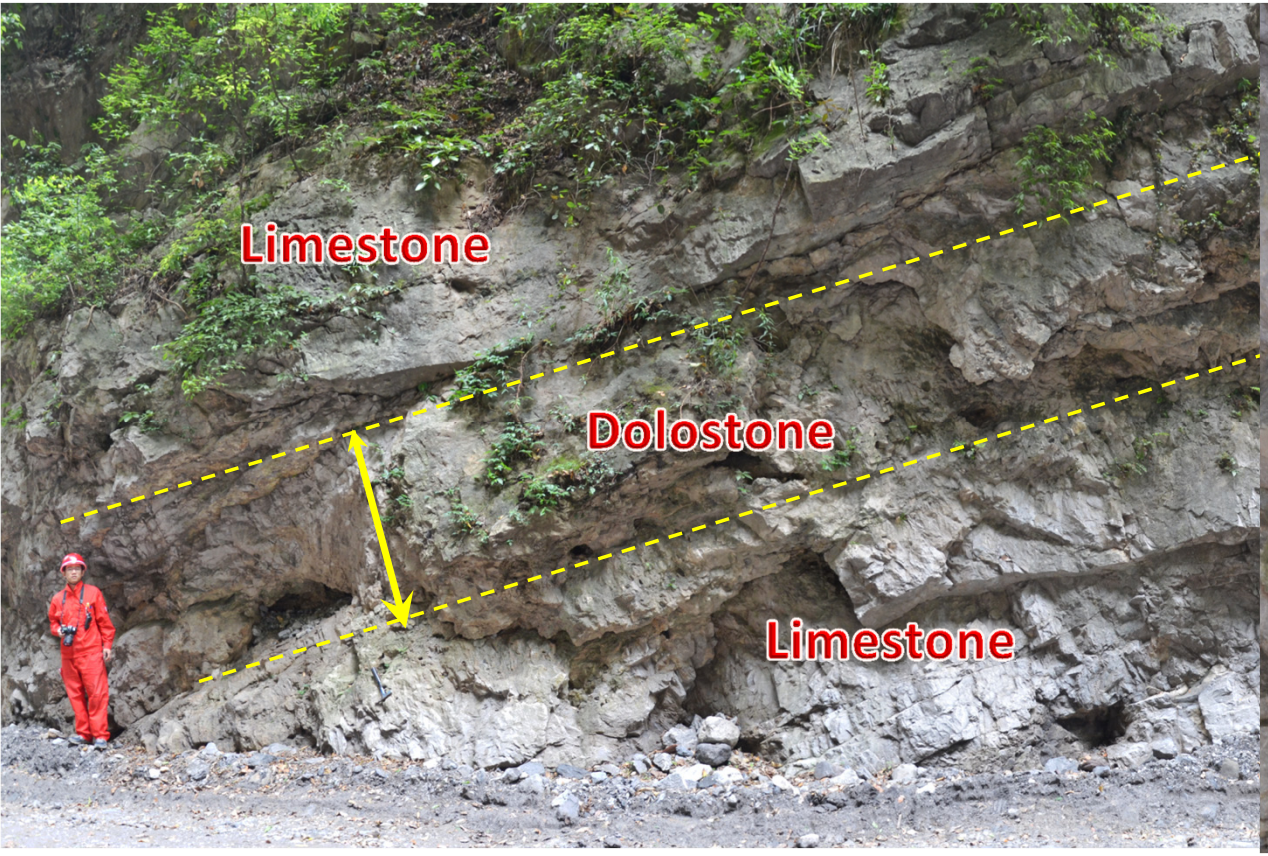
Outline

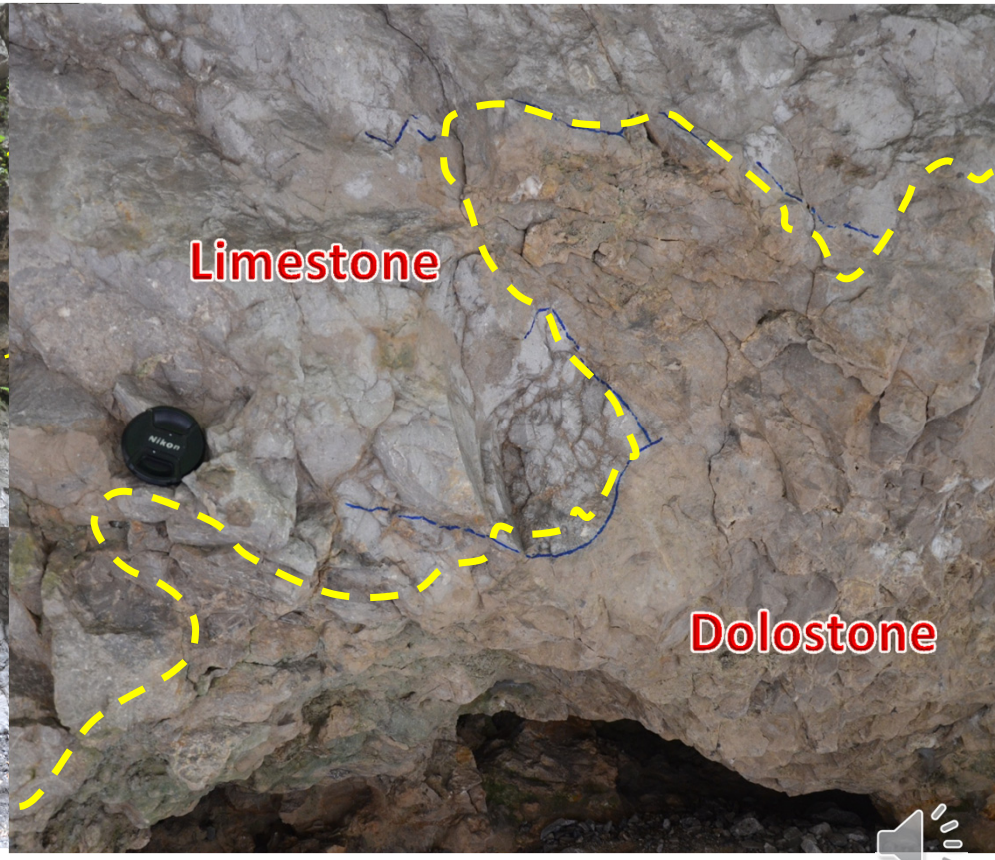
- **Introduction and geologic setting**
- **Formation and evolution of the Middle Permian dolostones**
- **Conclusions**

Formation and evolution of Middle Permian dolostones

Field observation

Dolostones are commonly stratiform, with irregular dolomitization front

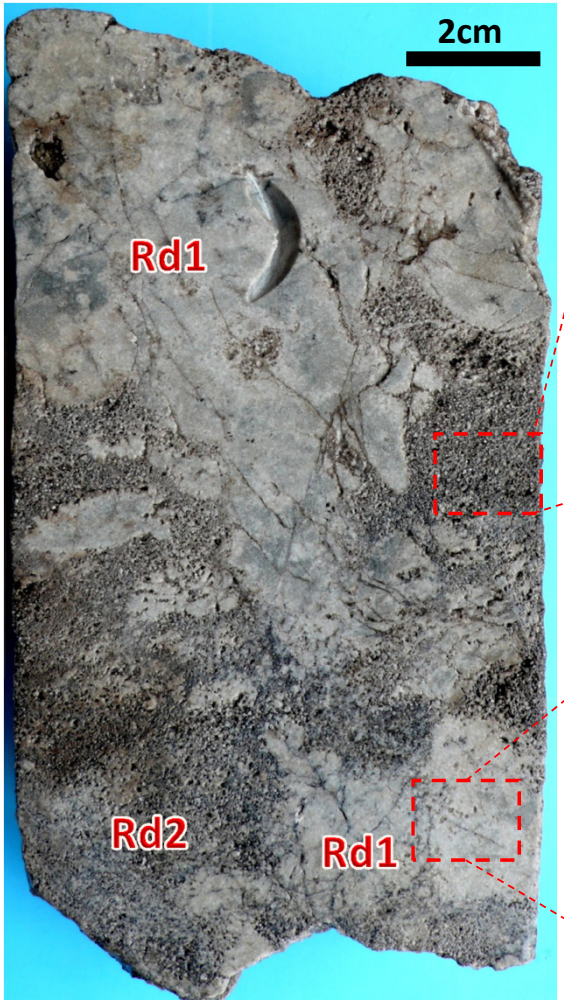


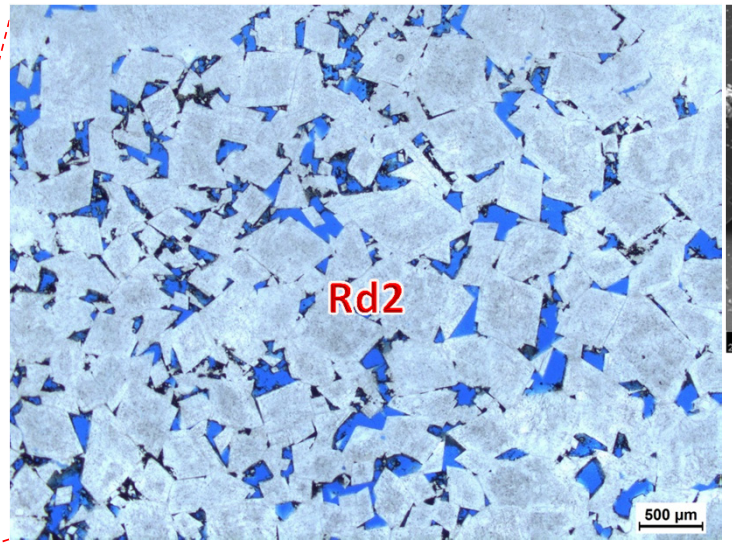


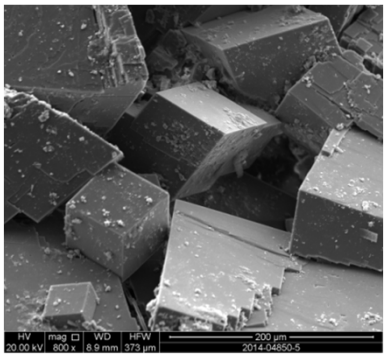
Formation and evolution of Middle Permian dolostones

Petrography

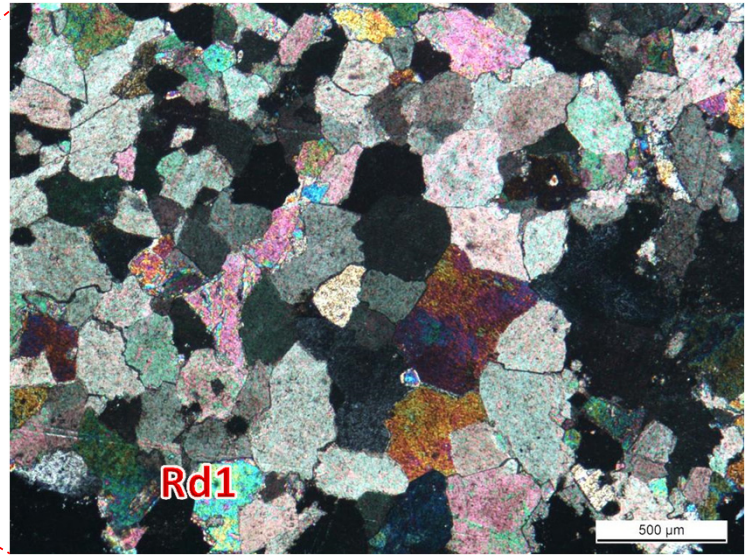
Reveal two closely associated replacive dolomites







High intercrystalline porosity

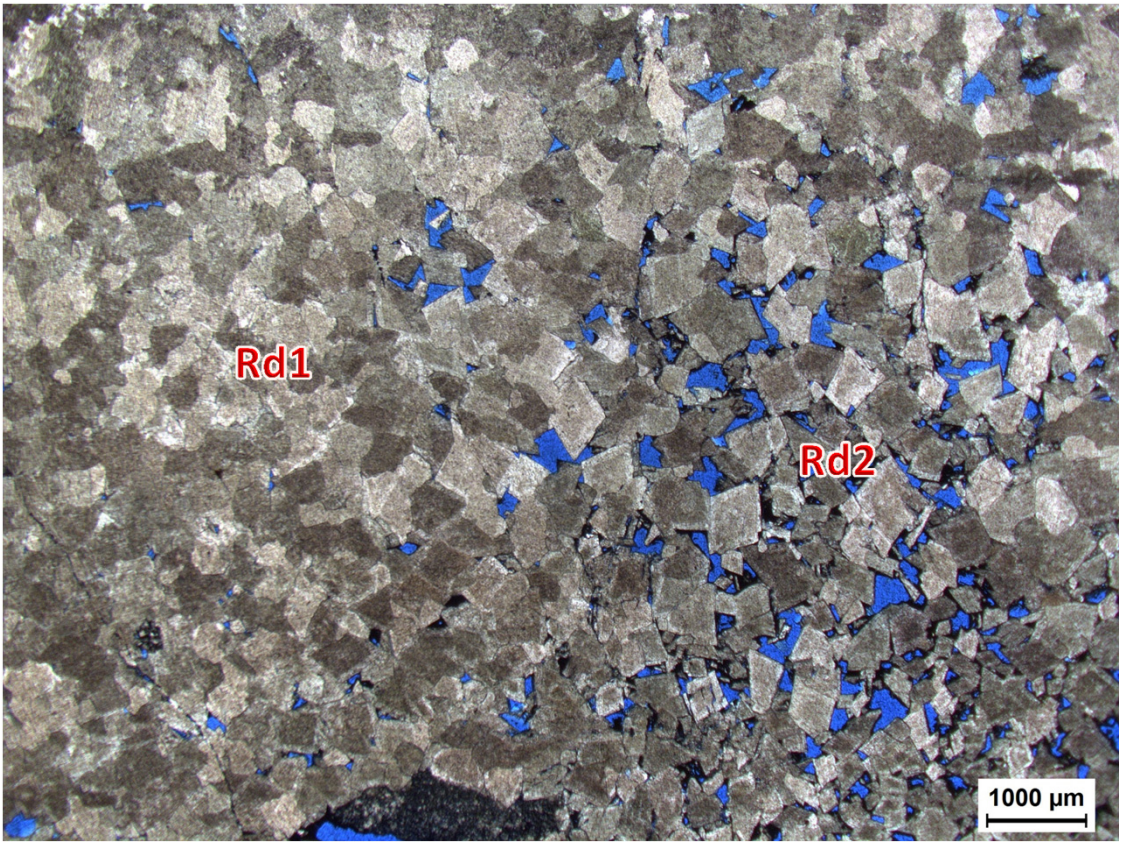


No porosity

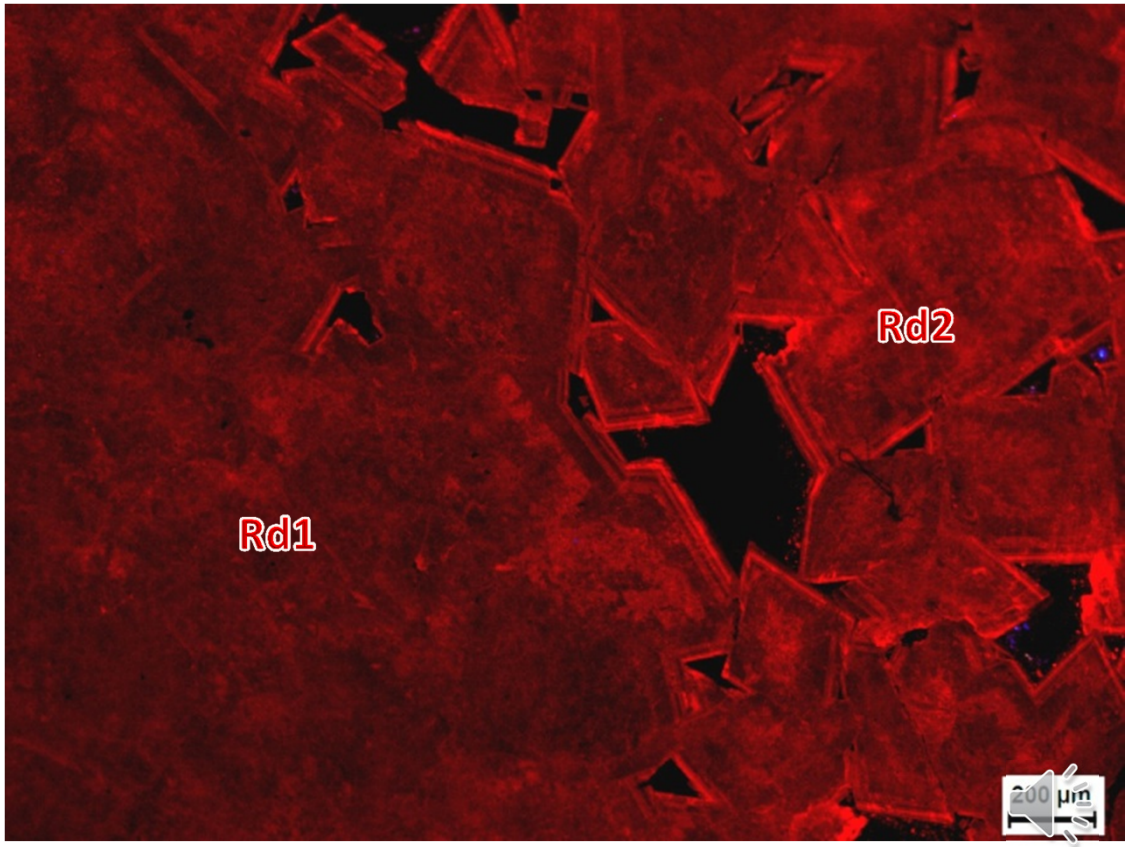
Formation and evolution of Middle Permian dolostones

Petrography

Gradual transition of Rd1 and Rd2 dolomites



Similar CL of Rd1 and Rd2 dolomites



Formation and evolution of Middle Permian dolostones

Petrography

Paragenetic sequence

Rd1/Rd2: replacive dolomite

⇩

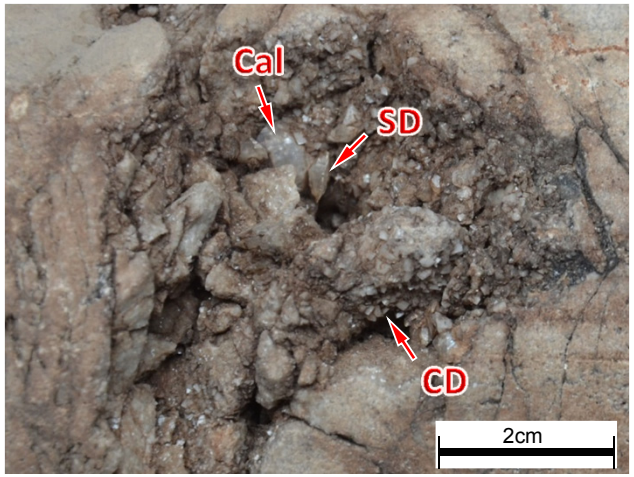
CD: Euhedral dolomite cement

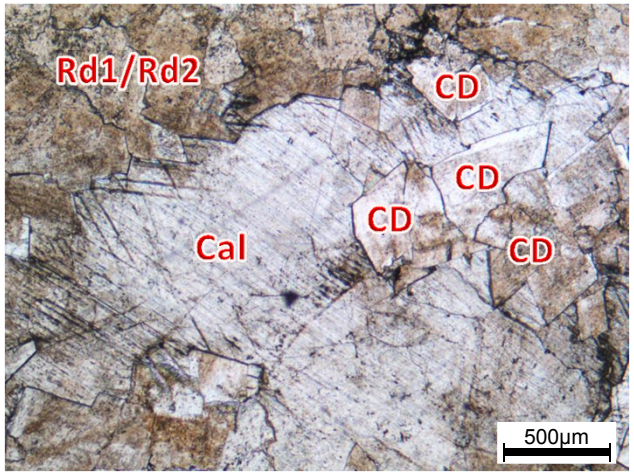
⇩

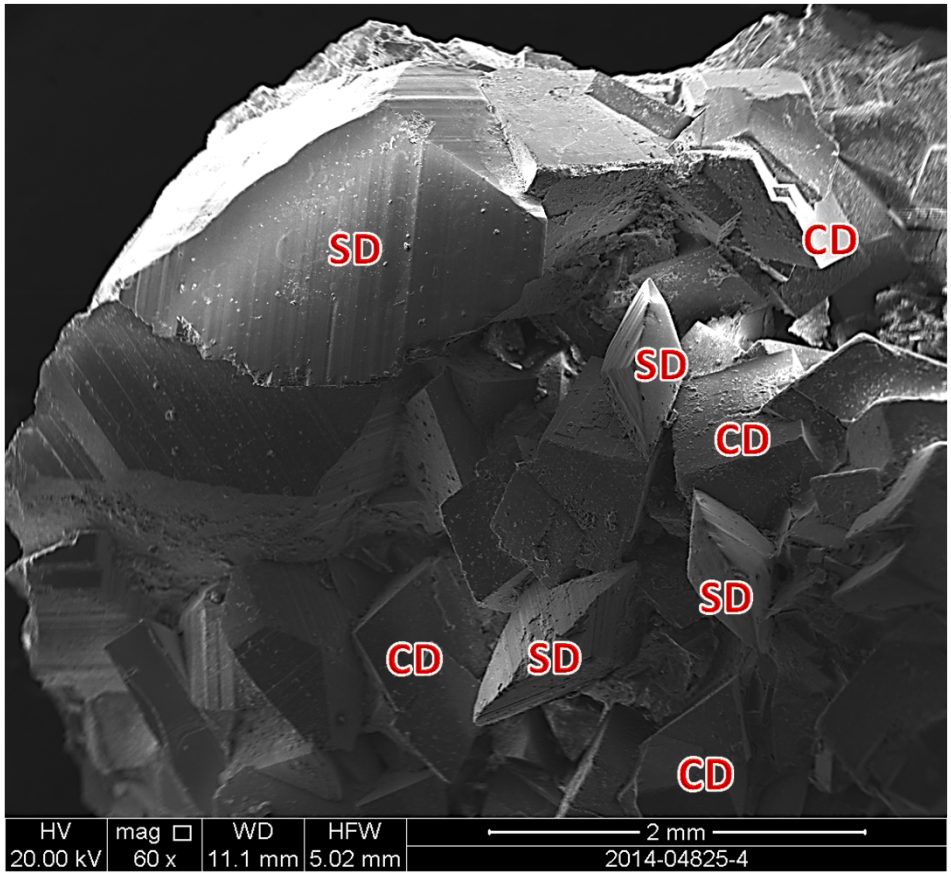
Cal: blocky calcite cement

⇩

SD: saddle dolomite cement



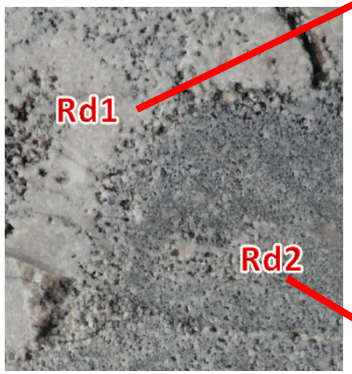


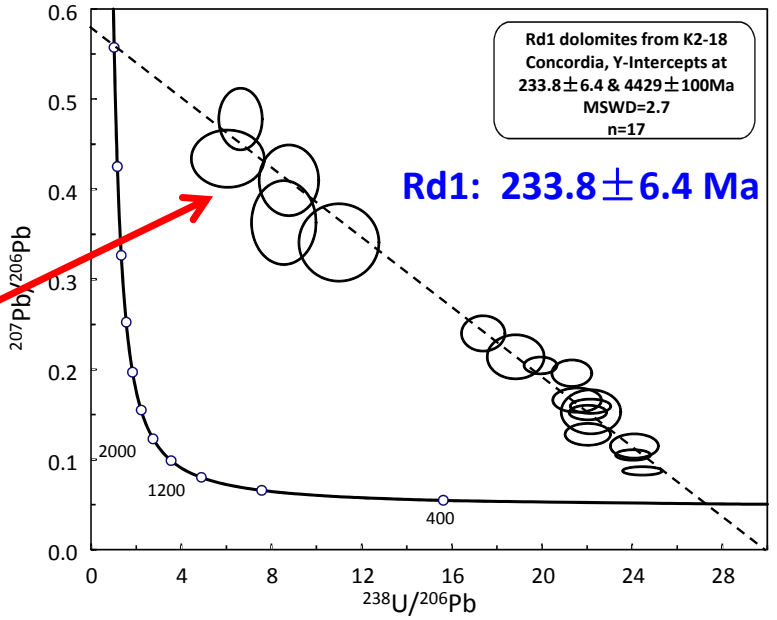


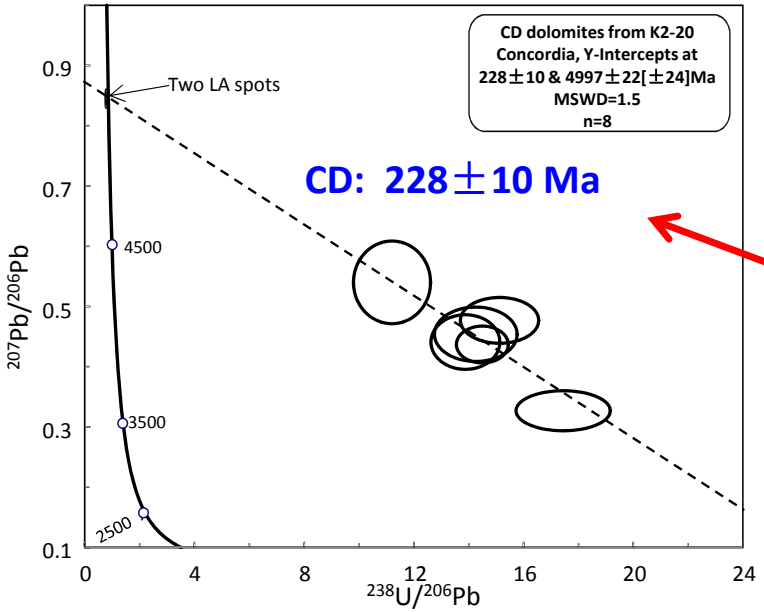
Formation and evolution of Middle Permian dolostones

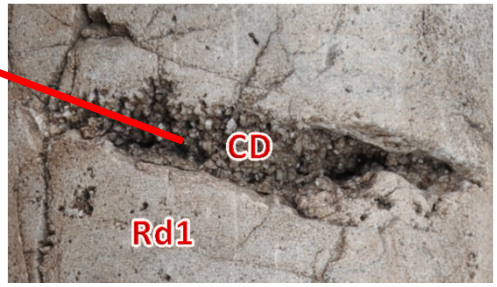
Rd1, Rd2 and CD share the overlapping ages that indicate a Late Triassic dolomitization process

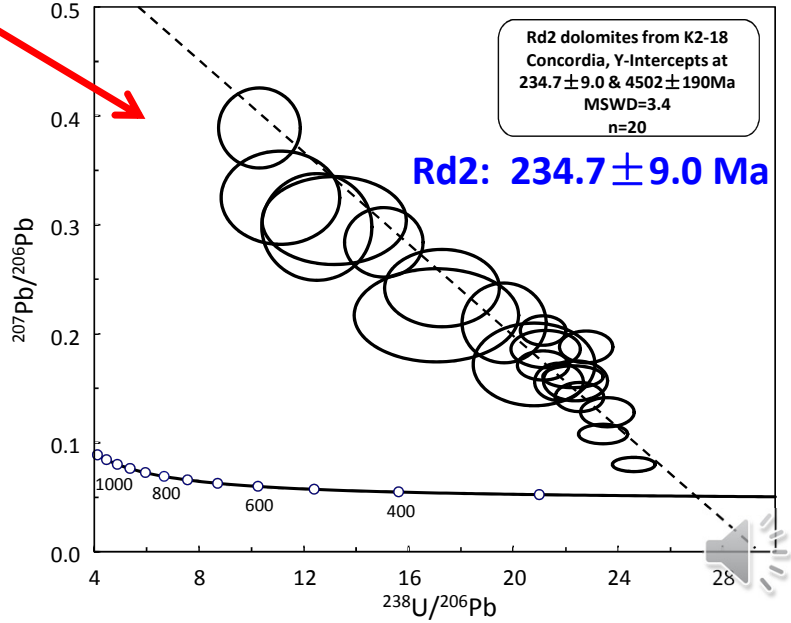
U-Pb ages







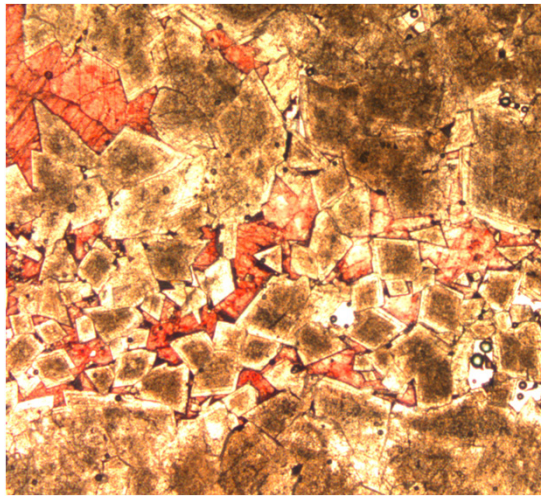


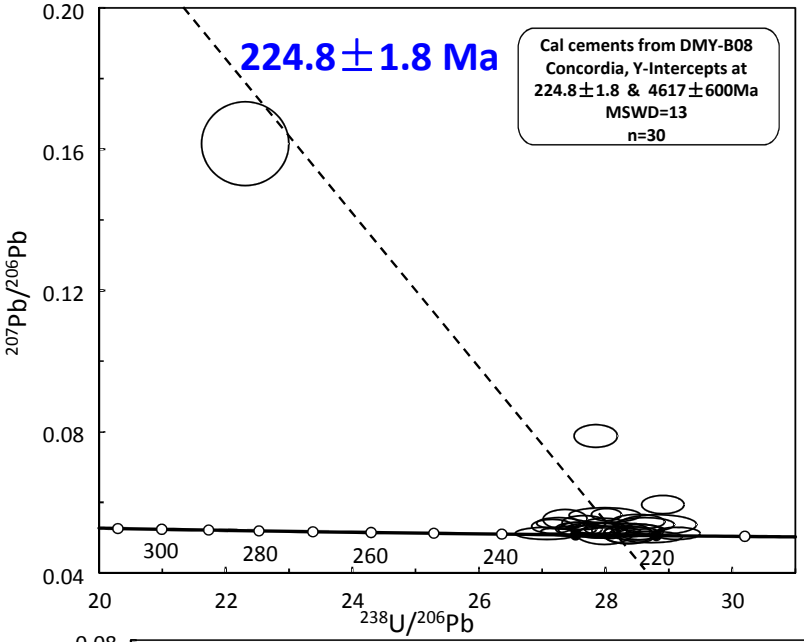


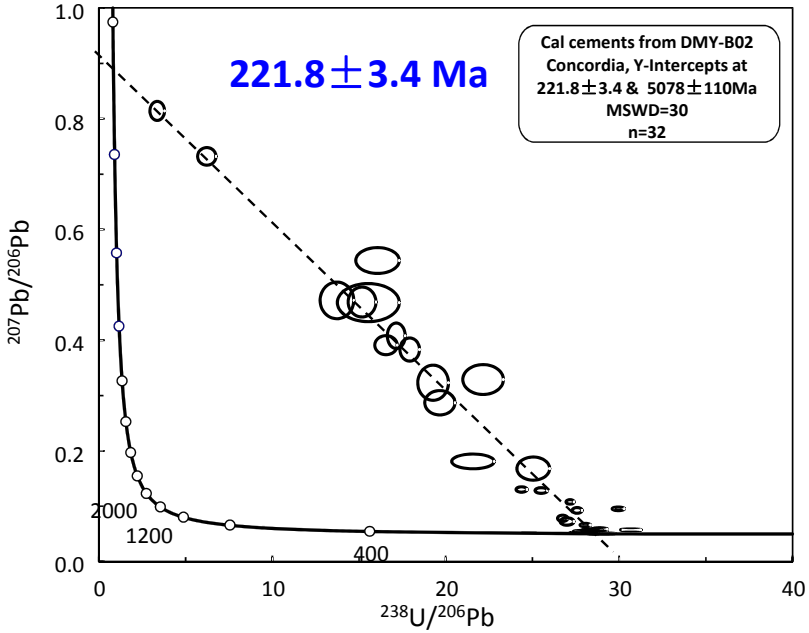
Formation and evolution of Middle Permian dolostones

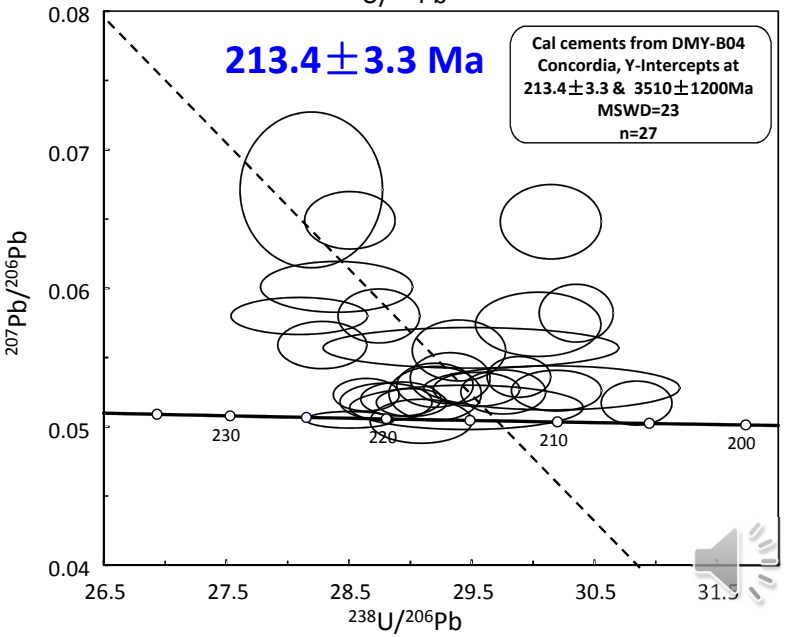
U-Pb ages

Calcite cements are a bit younger than the replacive dolomites, but still indicate precipitation during the Late Triassic





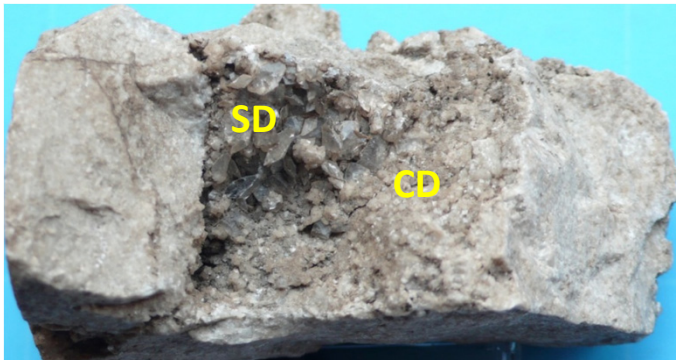


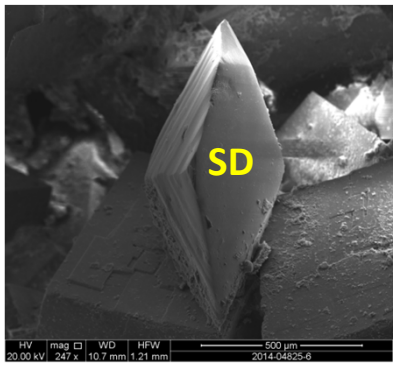


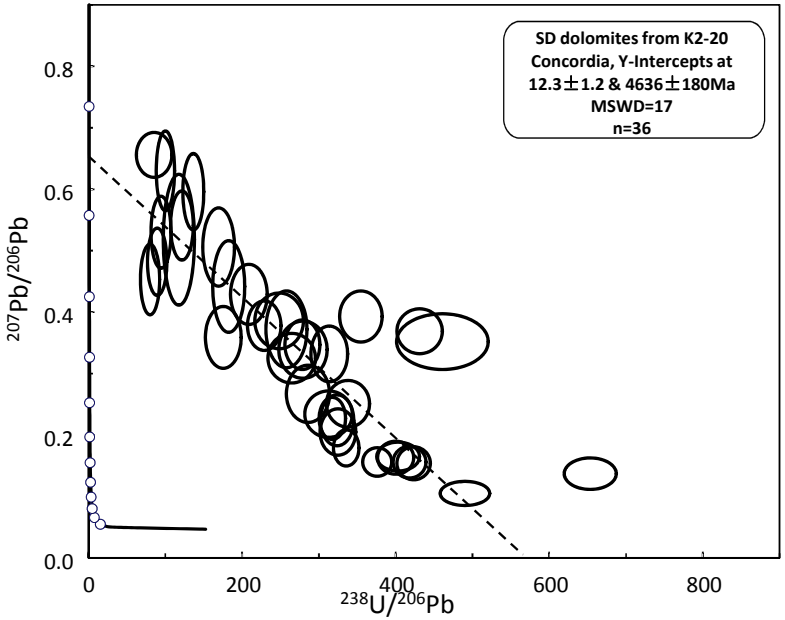
Formation and evolution of Middle Permian dolostones

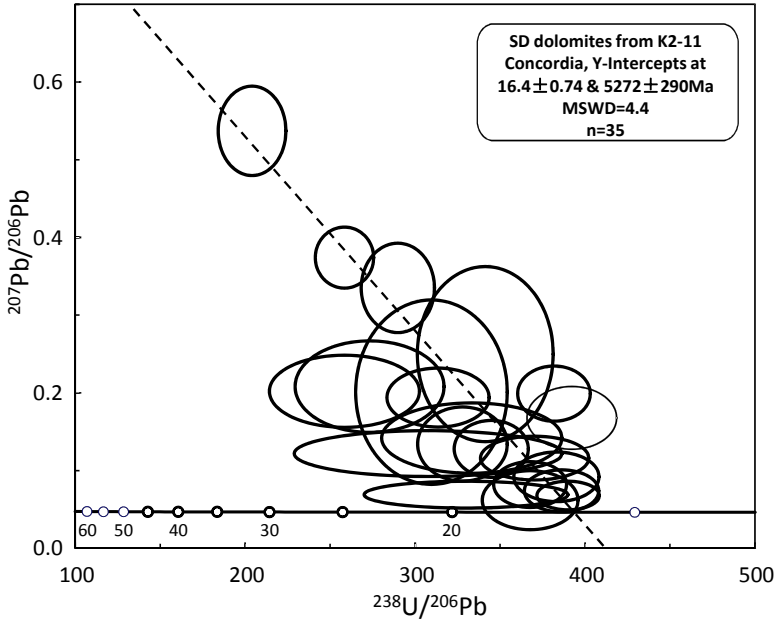
U-Pb ages

Saddle dolomite cements are significantly younger than any other diagenetic phases, and indicate a Miocene precipitation event





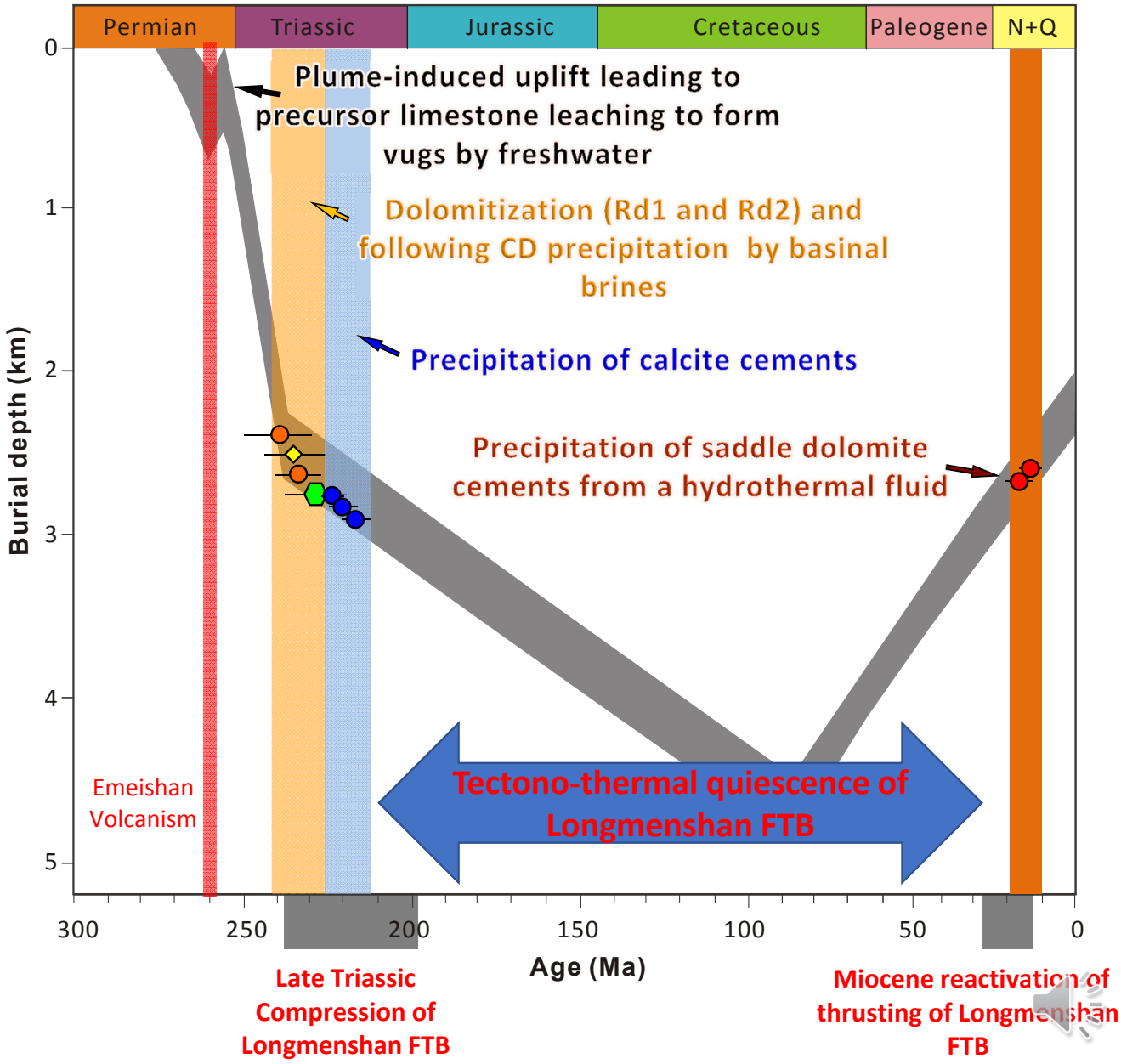




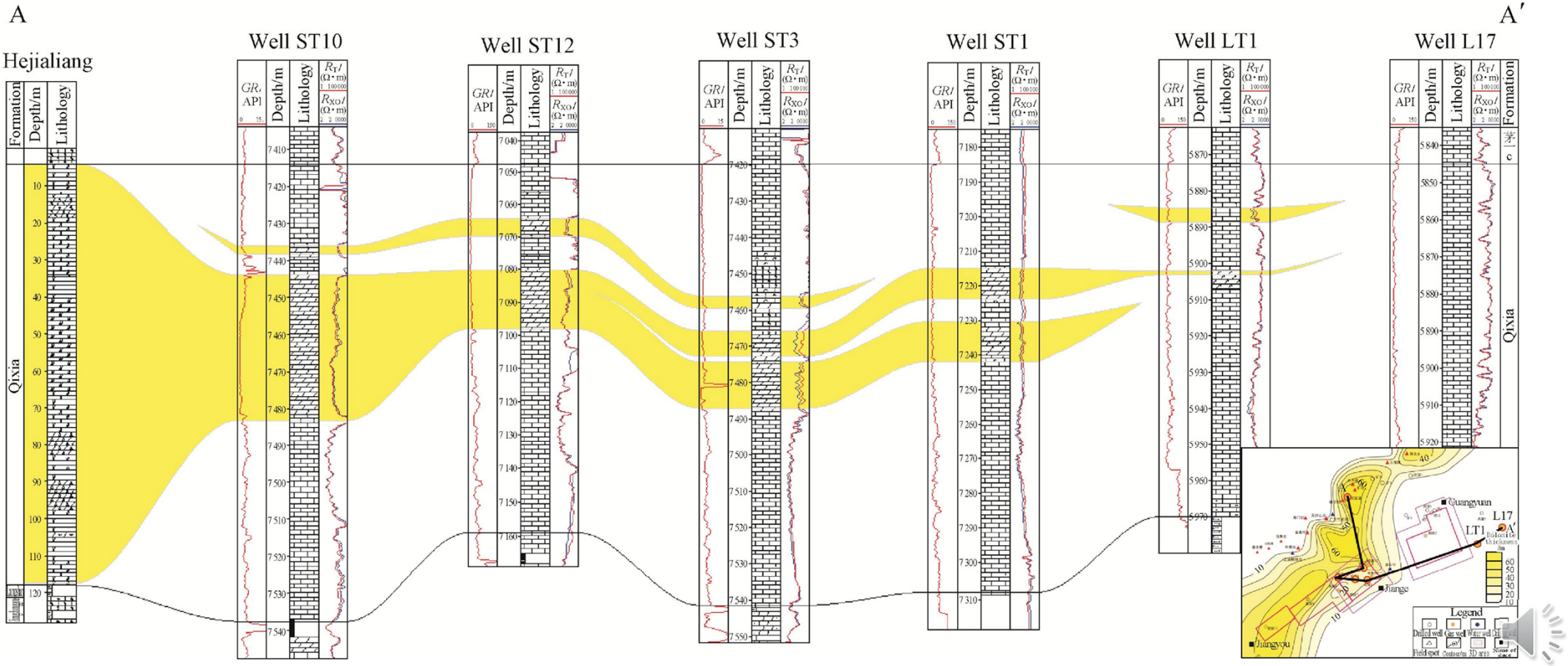
Implication of U-Pb ages

- Late diagenetic alteration only took place during tectonic events

- Dolomitization could be related to the compressional deformation of Longmenshan FTB, rather than Emeishan Volcanism

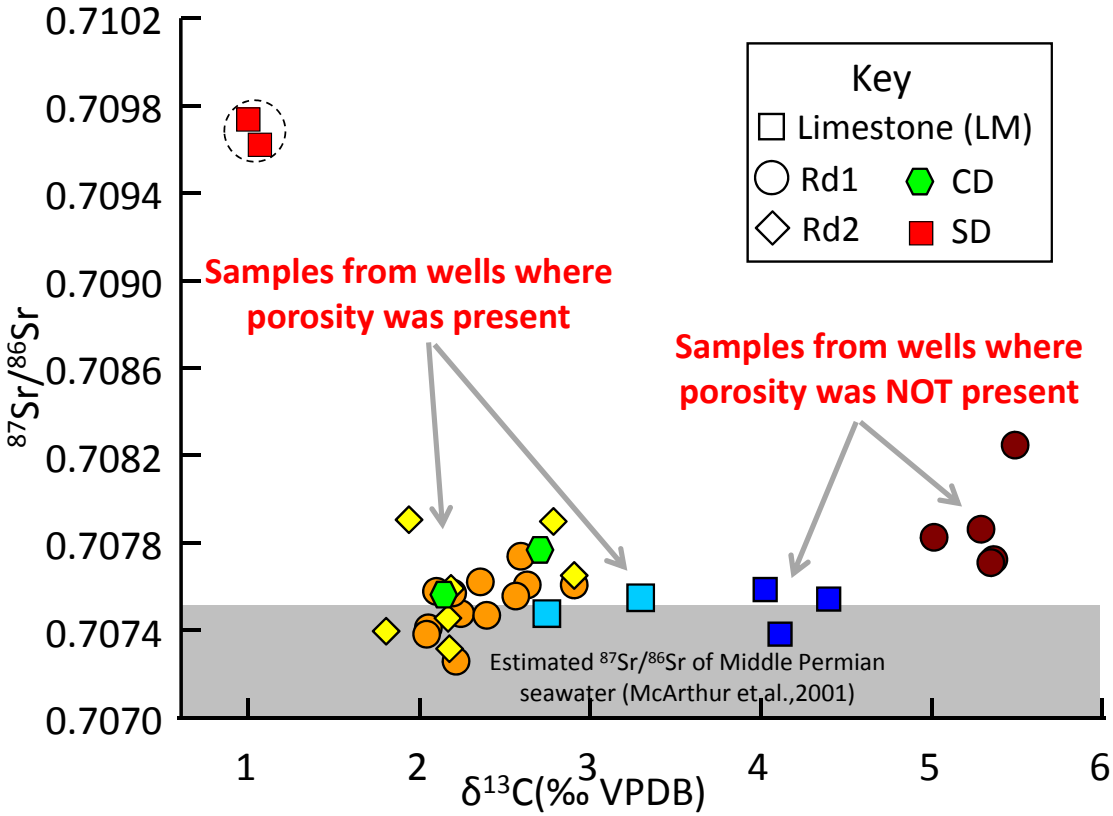


The thinning trend of dolostones from the Longmenshan Front to Sichuan Basin imply an eastward flow of dolomitizing fluids from the orogenic belt to the basin, supporting the tectonically driven dolomite model.

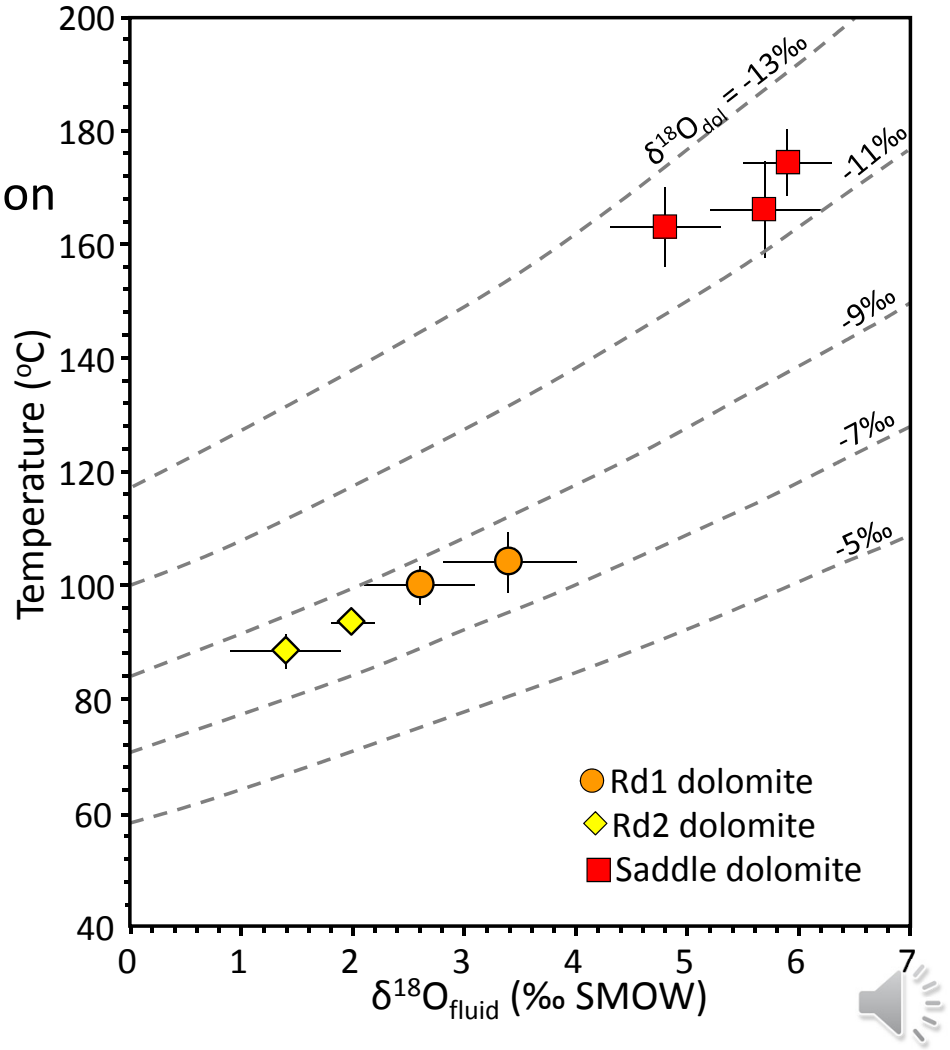


Formation and evolution of Middle Permian dolostones

- A hot basinal brine in Late Triassic, leading to replacive dolomitization and subsequent CD and Cal cementation
- A hydrothermal fluid in Miocene leading to SD cementation



Clumped and stable isotopic geochemistry reveal two major episodes of fluid flow



Conclusions

- Formation of the Middle Permian dolostones in NW Sichuan Basin does not appear to be related to the Emeishan volcanic event. The U-Pb ages indicate that they were likely formed in the compressional regime of the Longmenshan orogenic belt since the Triassic

- Dolomite diagenetic evolution was affected by two major episodes of fluid flow in Late Triassic and Cenozoic, both of which were likely tectonically driven

- Late diagenetic alteration of these dolostones only took place during tectonic events. Tectonically driven fluid flow events have had the greatest impact on late diagenetic history

Thanks for your attention!