2014 GSA Annual Meeting in Vancouver, British Columbia

# HYDROGEOMORPHOLOGIC ARCHITECTURE AND DISTRIBUTION CHARACTERISTICS OF EARLIER EPIKARST CARBONATE RESERVOIRS IN MIDDLE-LOWER ORDOVICIAN IN TAZHONG OIL FILED, TARIM BASIN

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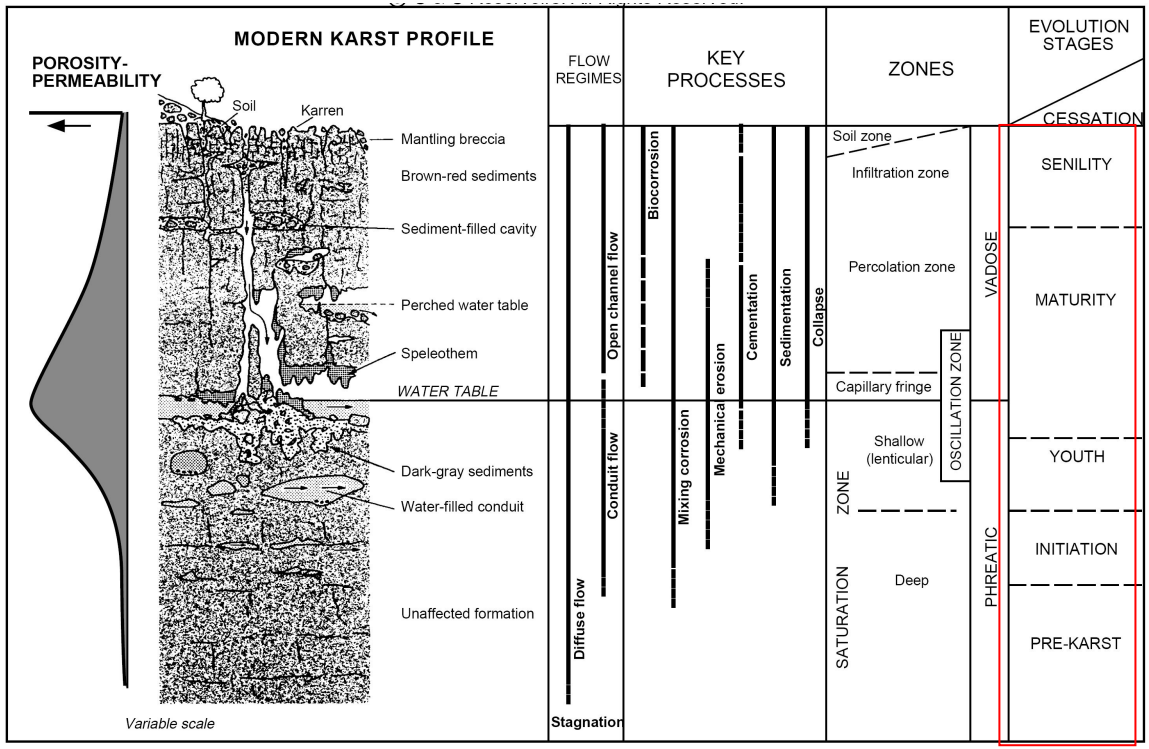
**19 October 2014**

# Outline

- Introduction
- Geological setting
- Hydrogeomorphologic architecture
- Reservoir distribution characteristics
- Discussion
- Conclusion

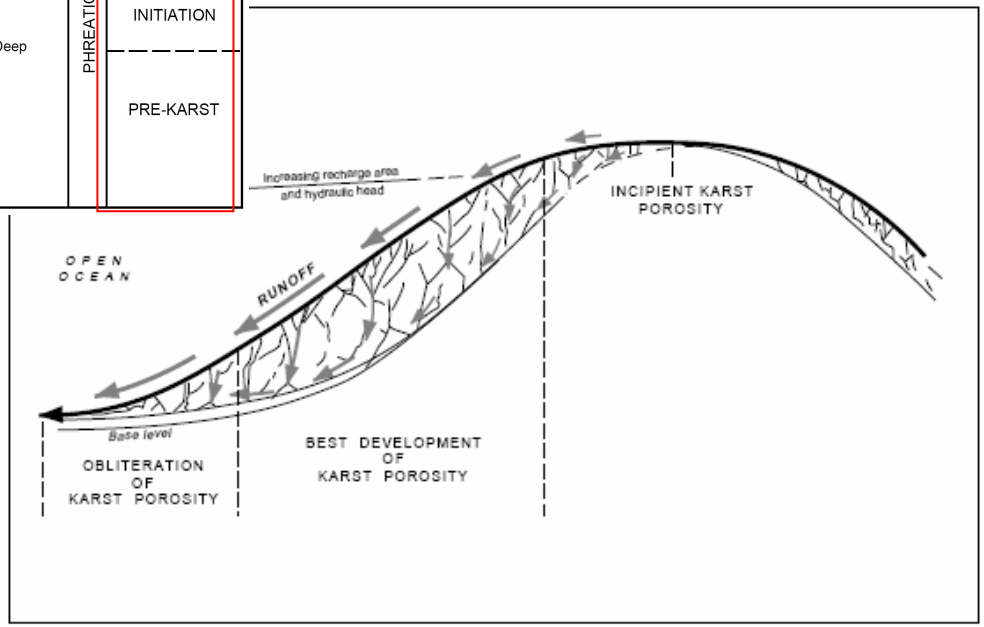
# Introduction

## Carbonate Reservoir Model(C&C,1998)

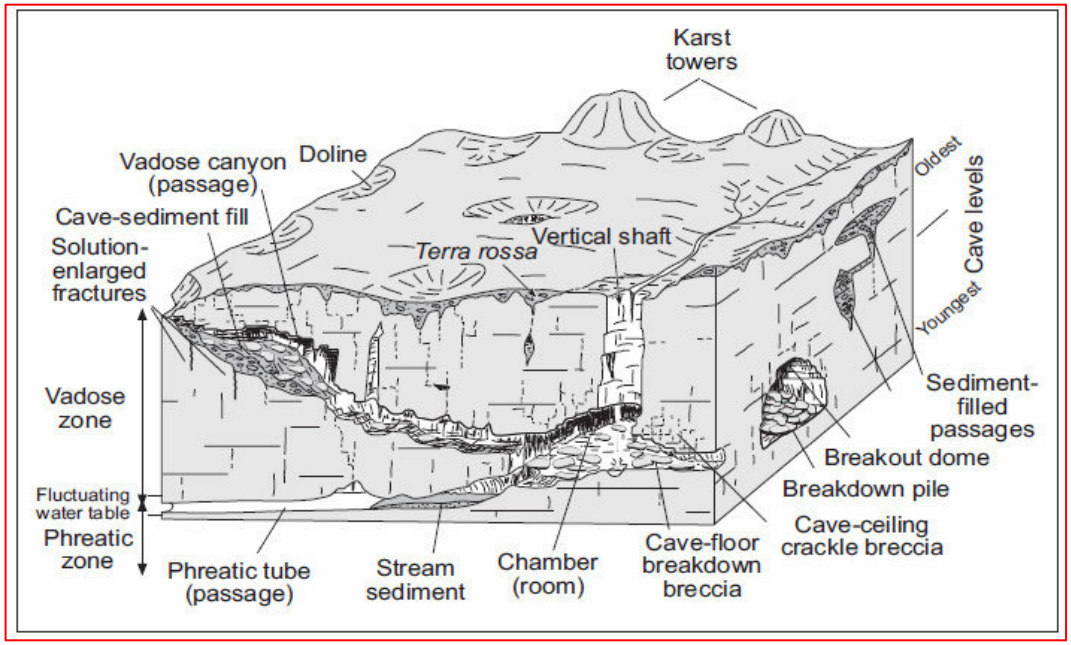



**Vertical megakarst profile showing stages of evolution and their relationship to porosity-permeability**

**Epikarst development model, Flank control on development of karst porosity**

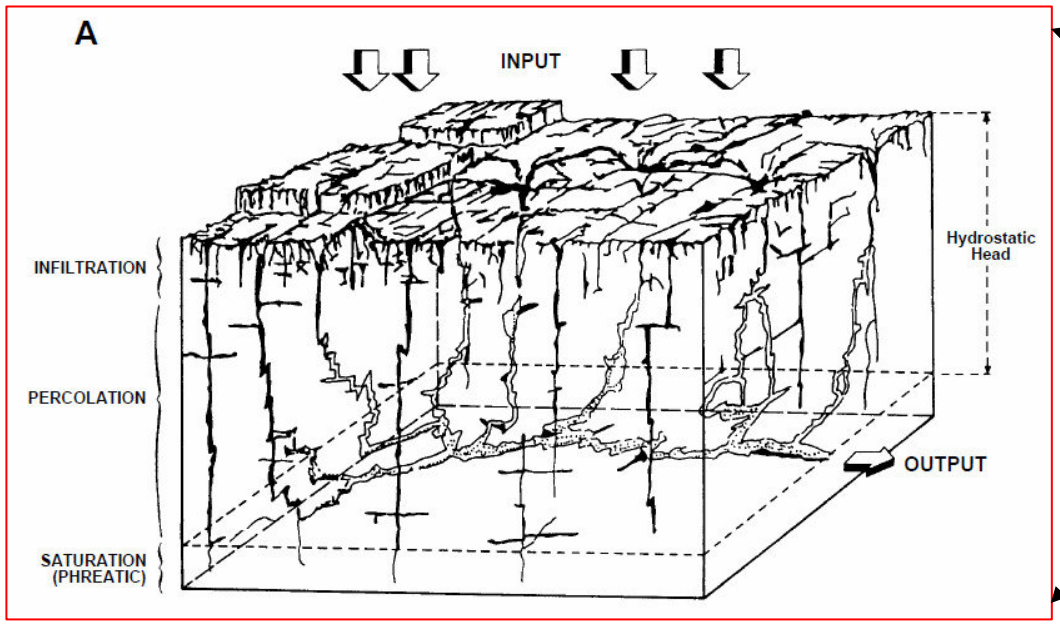


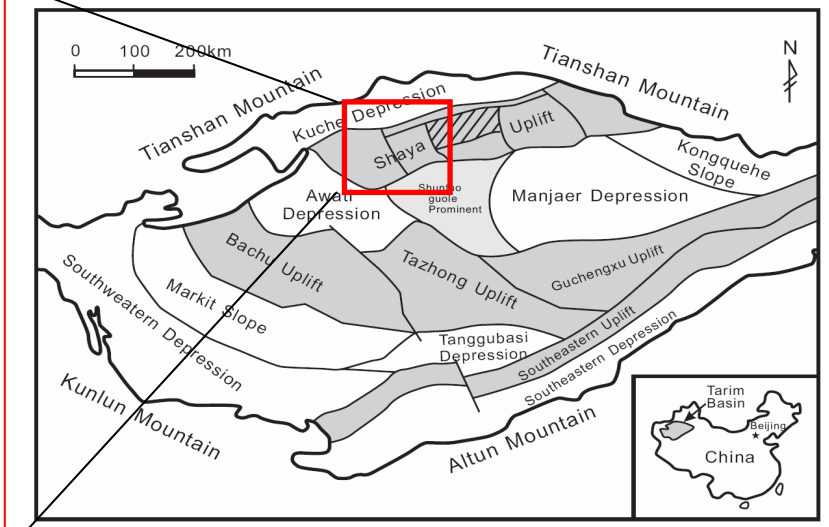
Ellenburger Reservoir
Permian Basin
Loucks et al.,1999




Ordovician Reservoir in Tahe Oil Field
Tarim Basin
Jiao Fangzheng et al.,2008

**Block diagram of a near-surface modern karst system**




**Karst caves distribution model in the early Hercynian period**

# What is the karst condition of Tazhong Oil field? Same ?
# What are the reservoir distribution characteristics?

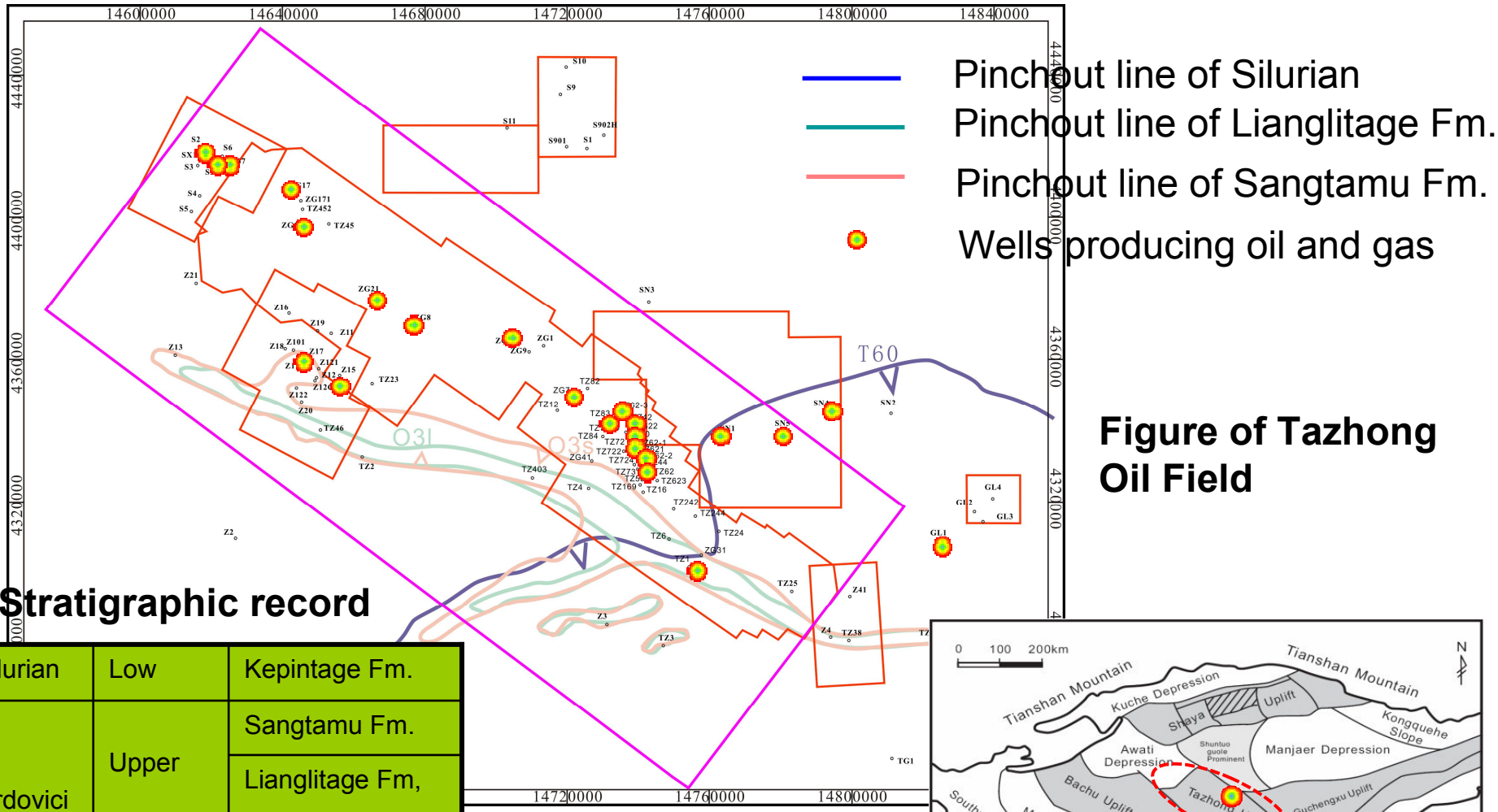
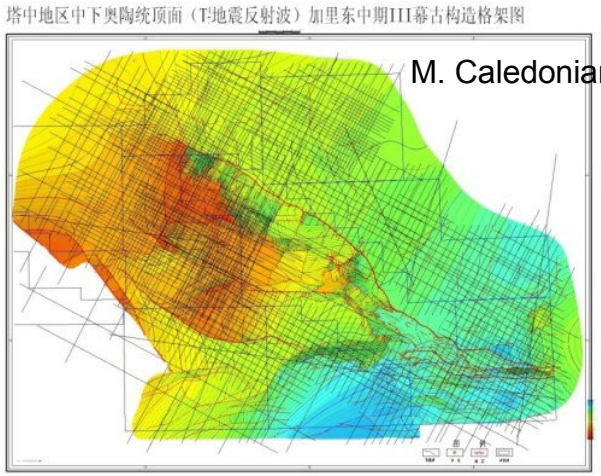


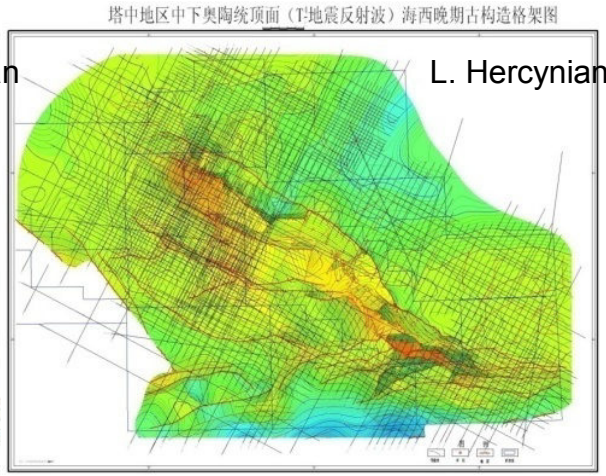

**Figure of Tazhong Oil Field**

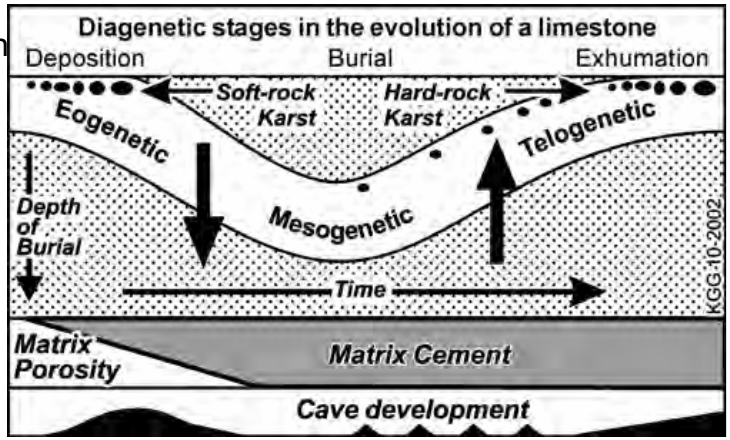
## Stratigraphic record

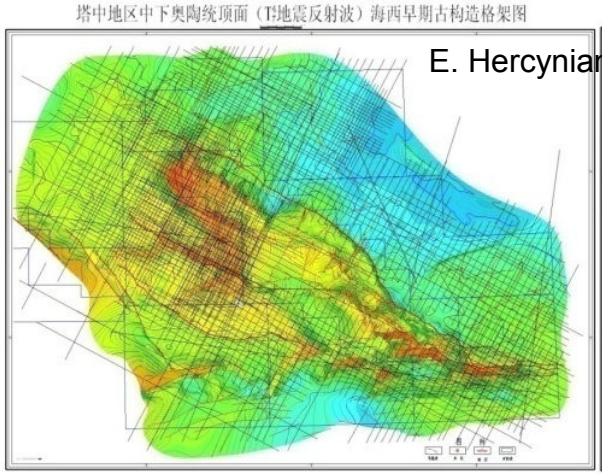
| | | |
|---|---|---|
| Silurian | Low | Kepintage Fm. |
| Ordovician | Upper | Sangtamu Fm. |
| | | Lianglitage Fm, |
| | Middle - Lower | Yingshan Fm. |
| | | Penglaiba Fm. |

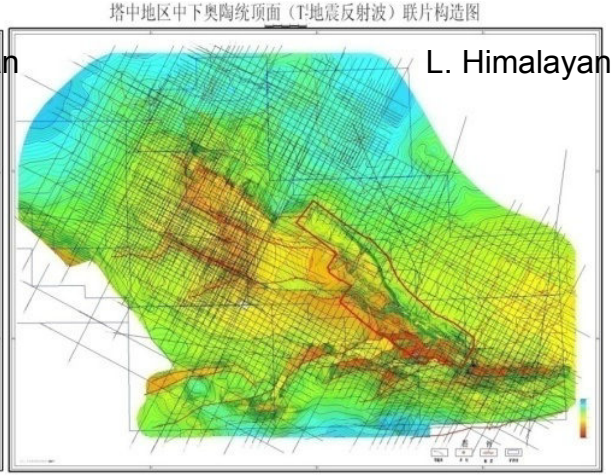
# Geological setting




**Diagenetic stages in the evolution of a limestone and of its karst. Black dots indicate possible cave formation.**
**(Choquette & Pray, 1970)**

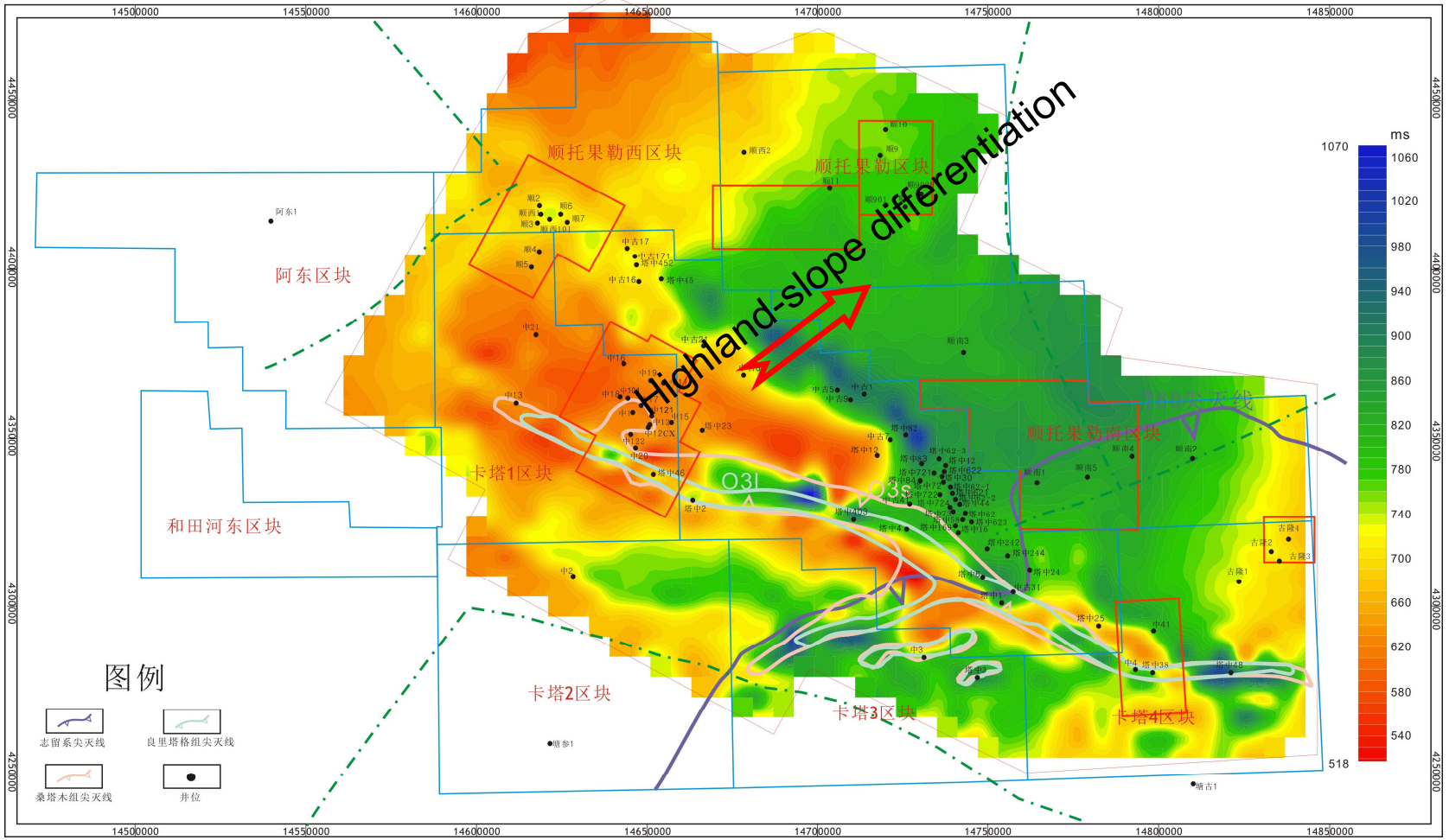
**The Palaeo-structure high (T74) of Tazhong uplift(Chen Honghan, 2012)**

**It is a little different from the classic definition.**
**The uplift and erosion returns the limestone to the surface immediately**
**Thus, its limestone is soft rock rather than hard rock.**

# Hydrogeomorphologic architecture

## Paleo-geomorphology

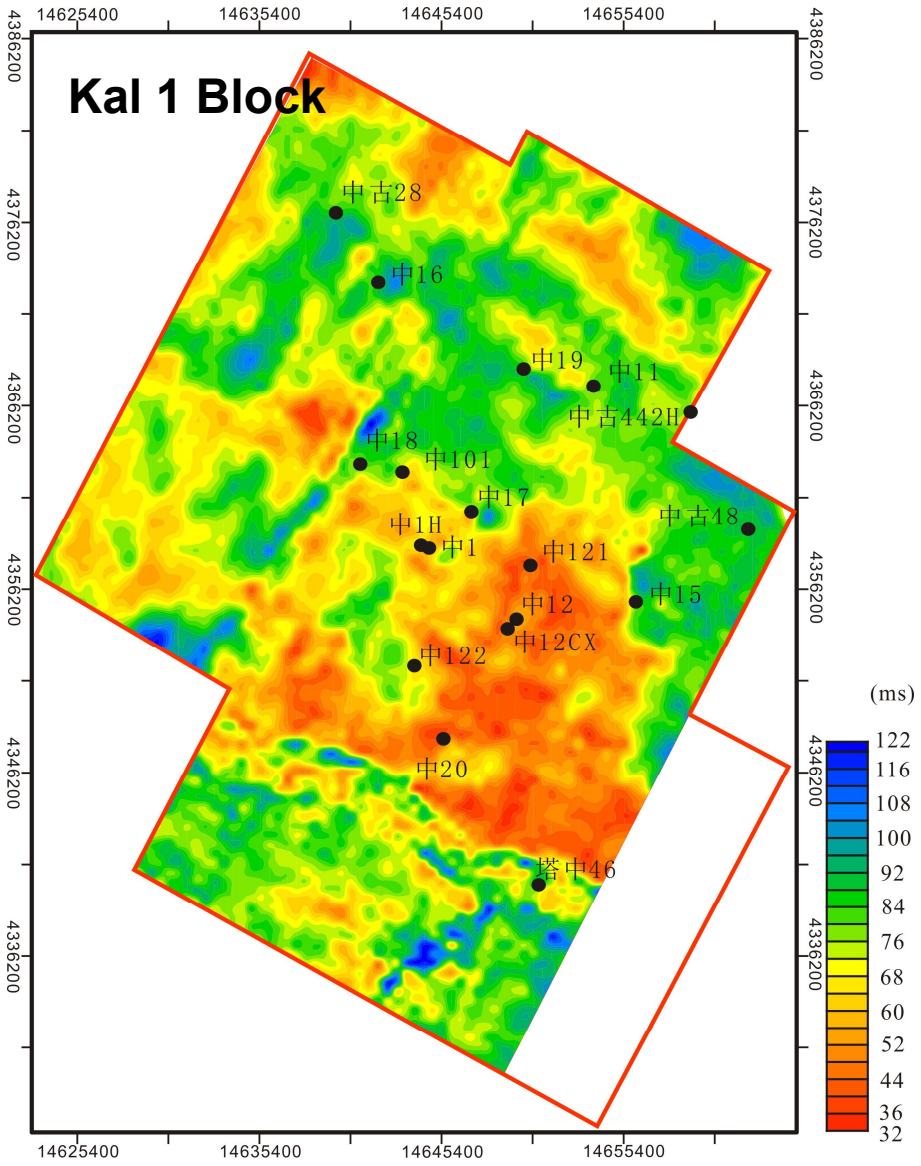
Both the 2D and 3D seismic data indicate that the terrain of the whole Middle-Lower Ordovician is flat and the relief amplitude is small



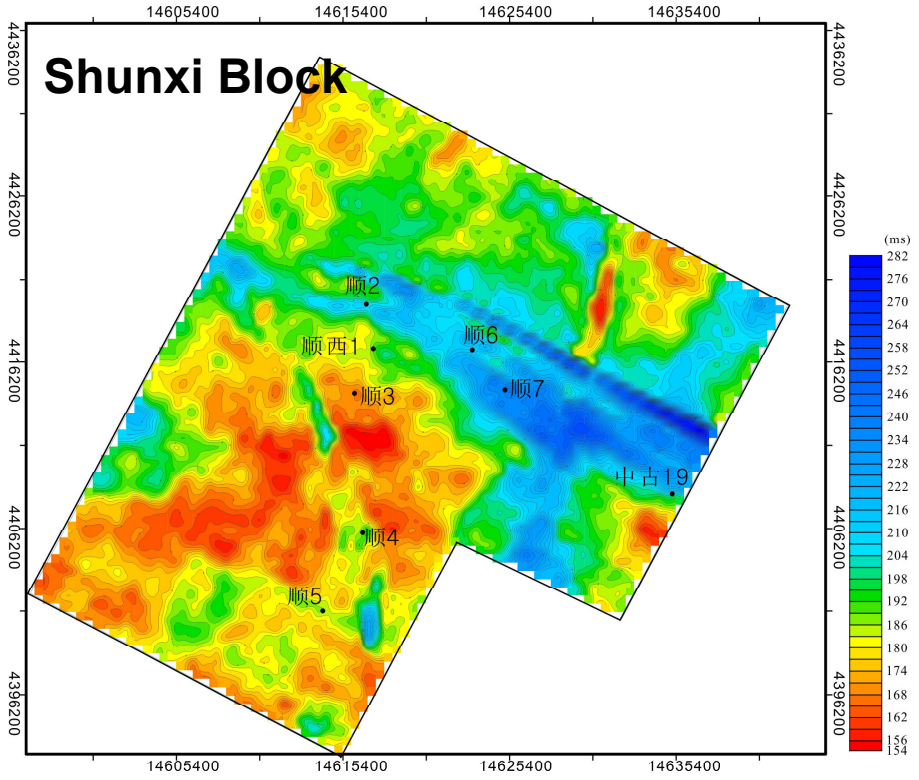

**2D Paleo-morphological Figure of Yingshan Fm. $T_8^0$-$T_7^4$ (Yingshan and Penglaiba Fm.)**

# Hydrogeomorphologic architecture

Paleo-geomorphology




**Karst Paleo-morphological Figure of Yingshan Fm. （T78-T74）**
(Data from 3D regions)

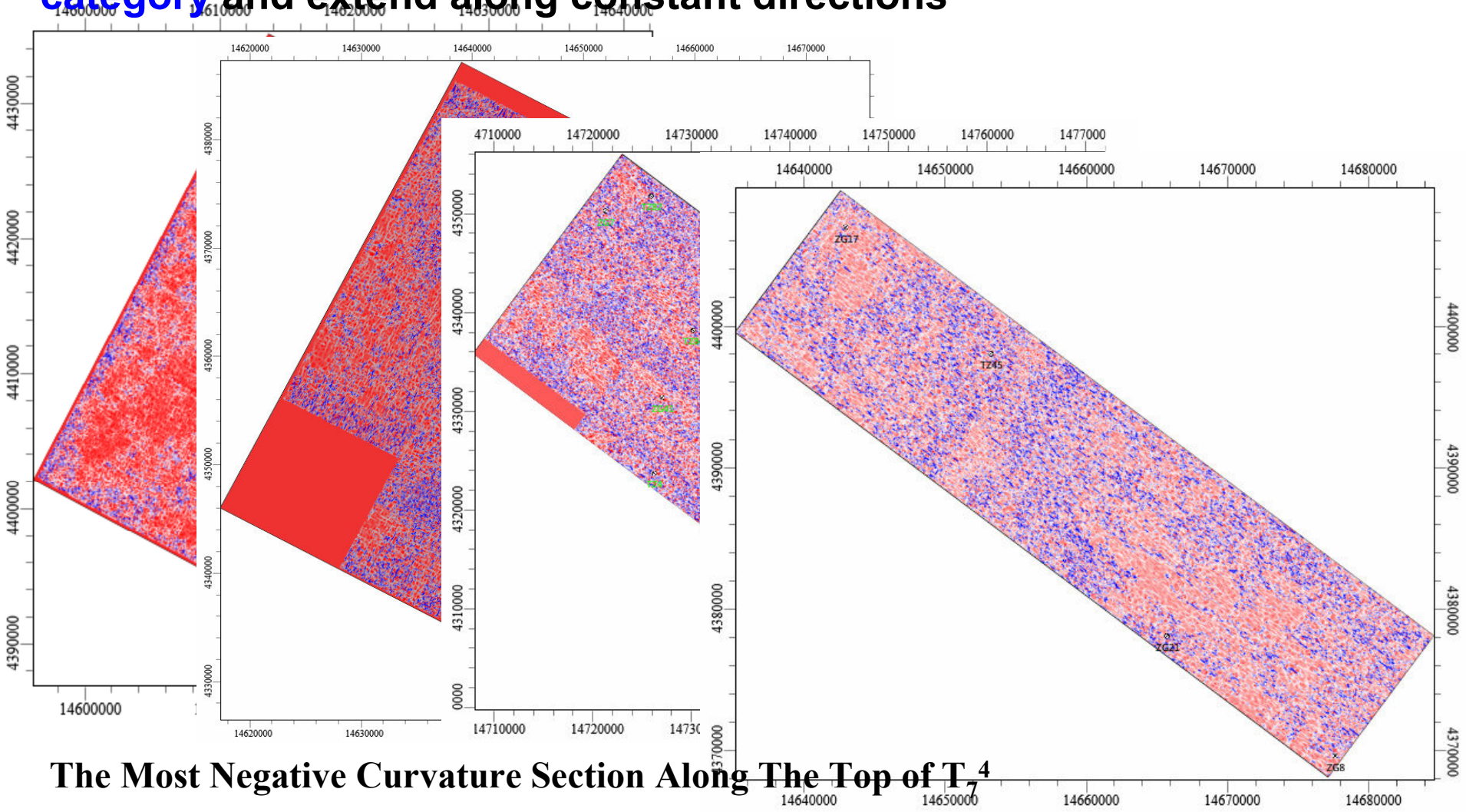



**Amplitude differfence of Landscape in Shunxin and Kal 1 blocks is 30-40ms**

# Hydrogeomorphologic architecture

Paleo-geomorphology

1)The erosion and collapse of landform is weak, 2)Fissure and karren develop well, 3)Fissure and karren are the main paleo-geomorphology category and extend along constant directions




The Most Negative Curvature Section Along The Top of $T_7^4$

# Hydrogeomorphologic architecture

Paleo-geomorphology



1) Karren in Malham Cove, Yorkshire , US( left) , 2) clint and crike (right) (Ford, 2006)

Clint in Northwest of Burren, Ireland (left)
Karren in Curacao Coastal zone, Netherlands (right)

# Hydrogeomorphologic architecture

Paleo-geomorphology

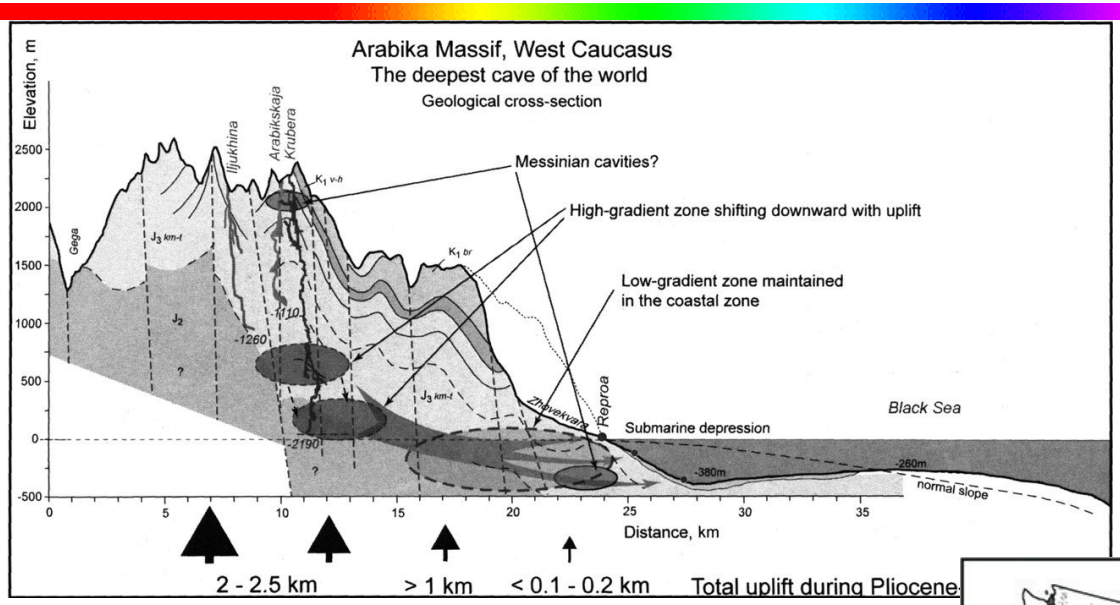
**The Karren assemblages vary a lot, but the angle of slope changes from small to medium.**

| | The bearing surface | | | |
|---|---|---|---|---|
| Karren assemblages | Its altitude (m) | Angle of slope | Development environment | Denudation of rock |
| Grikekarren–rinnenkarren | 1,600–1,800 | Small, medium | Under soil, or bedding plane surface, where is bordered by soil | Total bed |
| Rinnenkarren–grikekarren | 1,600–2,100 | Medium | Under soil, or bedding plane bordered by soil or at the boundary of beds | Surface of bedding planes, or total bed |
| Rinnenkarren–pit | 1,800–2,100 | Small, medium | Surface of bedding planes | Cavity development |
| Rinnen karren–grike | 1,800–2,100 | Medium | Surface of bedding planes | Cavity development, surface of bedding planes |
| Wall karren–schichtfugen-karren | 1,600–2,100 | Great | Bed head | Regression of the surface of the bed heads |
| Pit–grikekarren | 1,600–2,100 | Small, medium | At the lower margin of bedding planes surfaces | Shortening of bedding planes surfaces |

(Veress，2003)

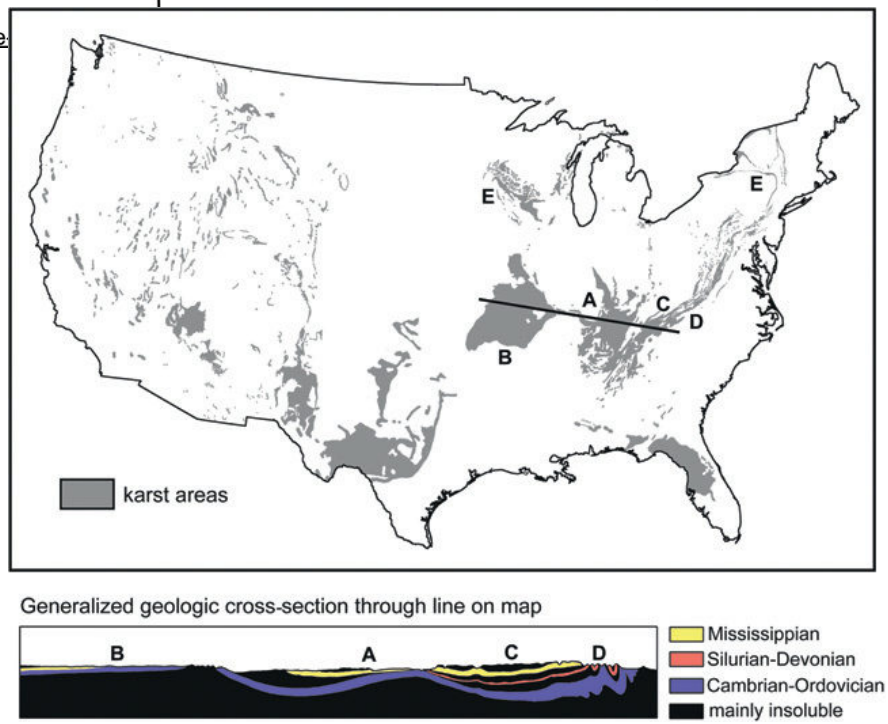
# Hydrogeomorphologic architecture

Paleo-geomorphology




**Krubera Cave in connection with recent uplift of the Caucasus range. ( Klimchouk et al., 2009.)**

**Map of karst regions of the 48 conterminous United States**




**Two karst landform types**

REGIONS OF HIGH RELIEF

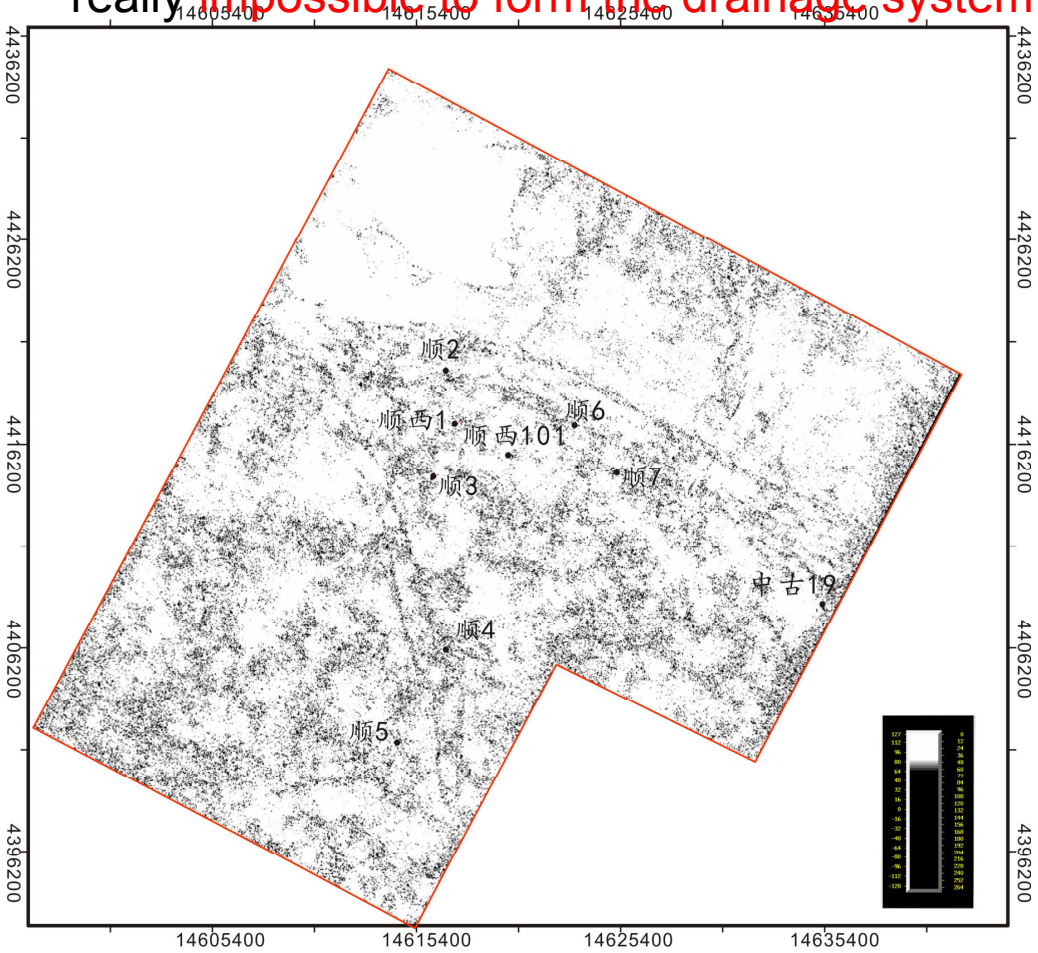
REGIONS OF MODERATE RELIEF

**——The karst landform type of Tazhong is identified to be later**

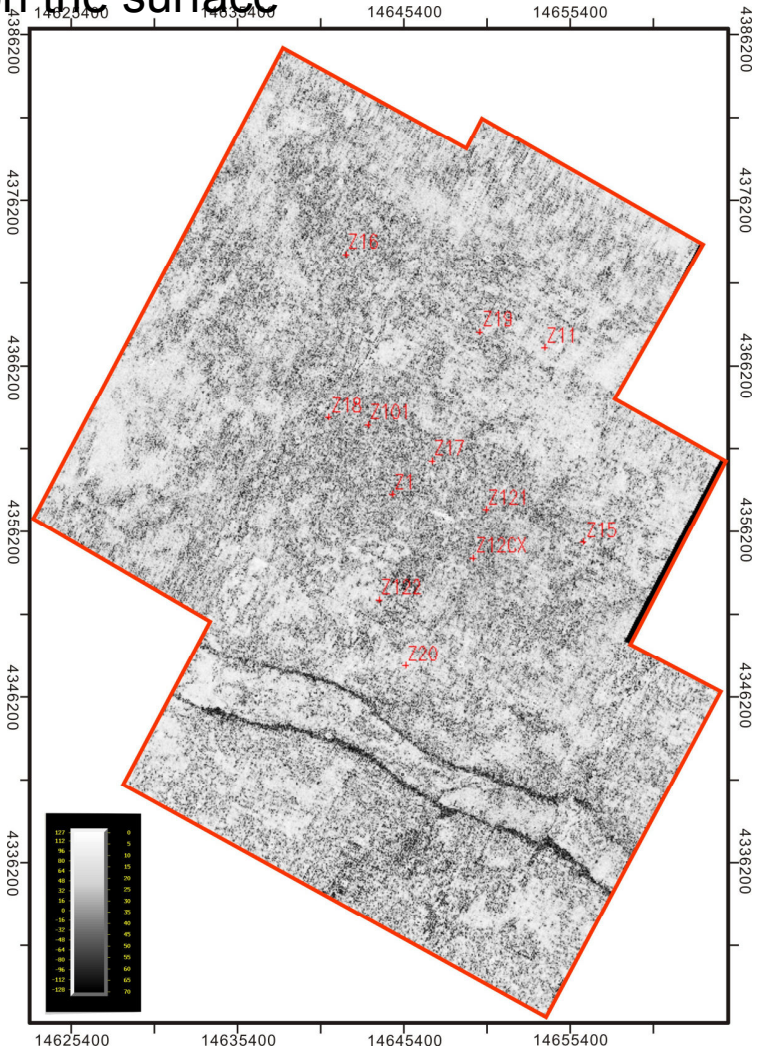
# Hydrogeomorphologic architecture



**Without surface drainage pattern**: The surface flow pattern has been generally restricted to the paleo-geomorphic landform and tends to be diffuse , and it is really impossible to form the drainage system on the surface




Coherence attribute of $T_7^4$_10-40ms in Shunxi region

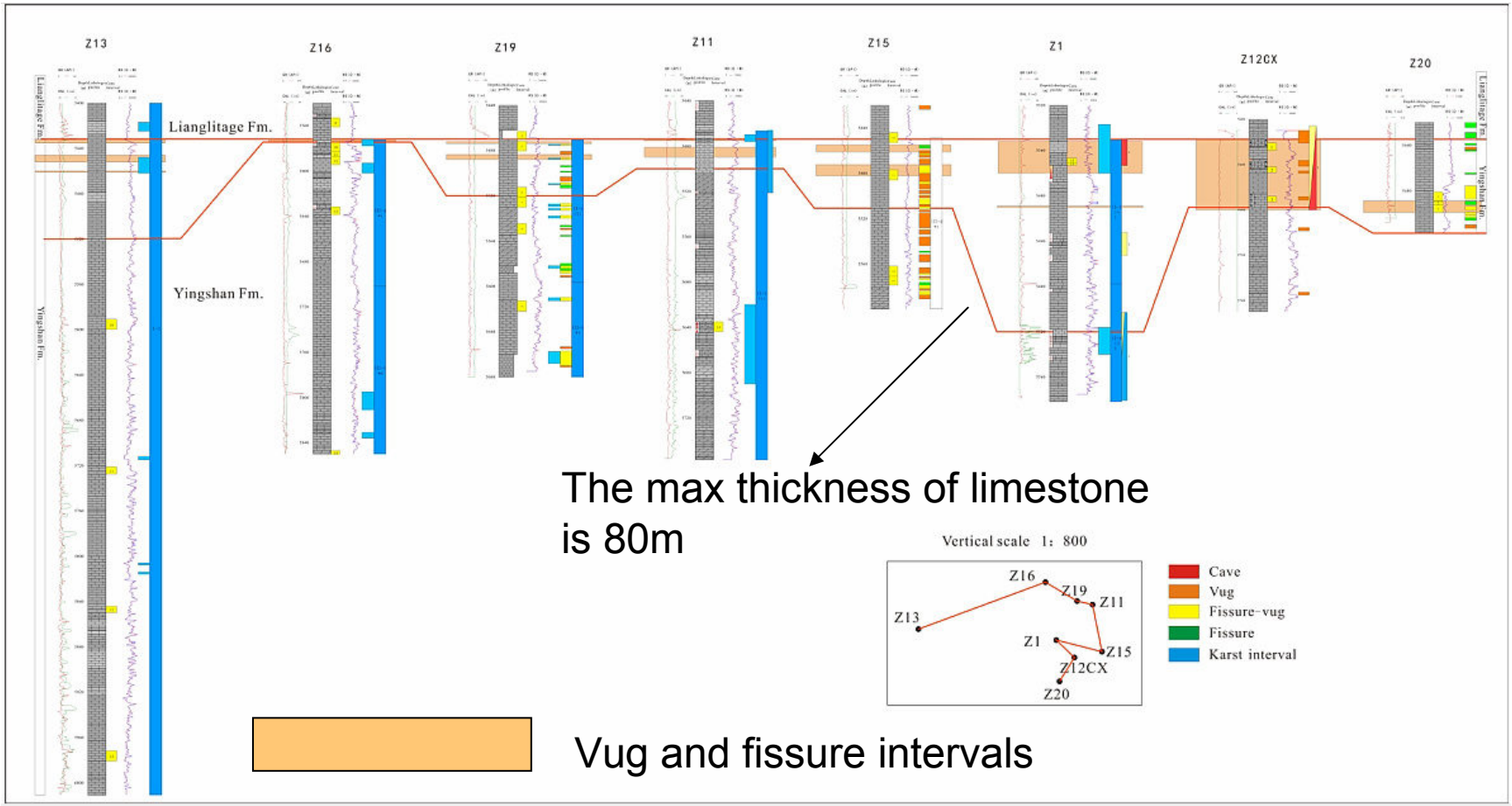



Coherence attribute of T74_10-40ms in Ka 1 region

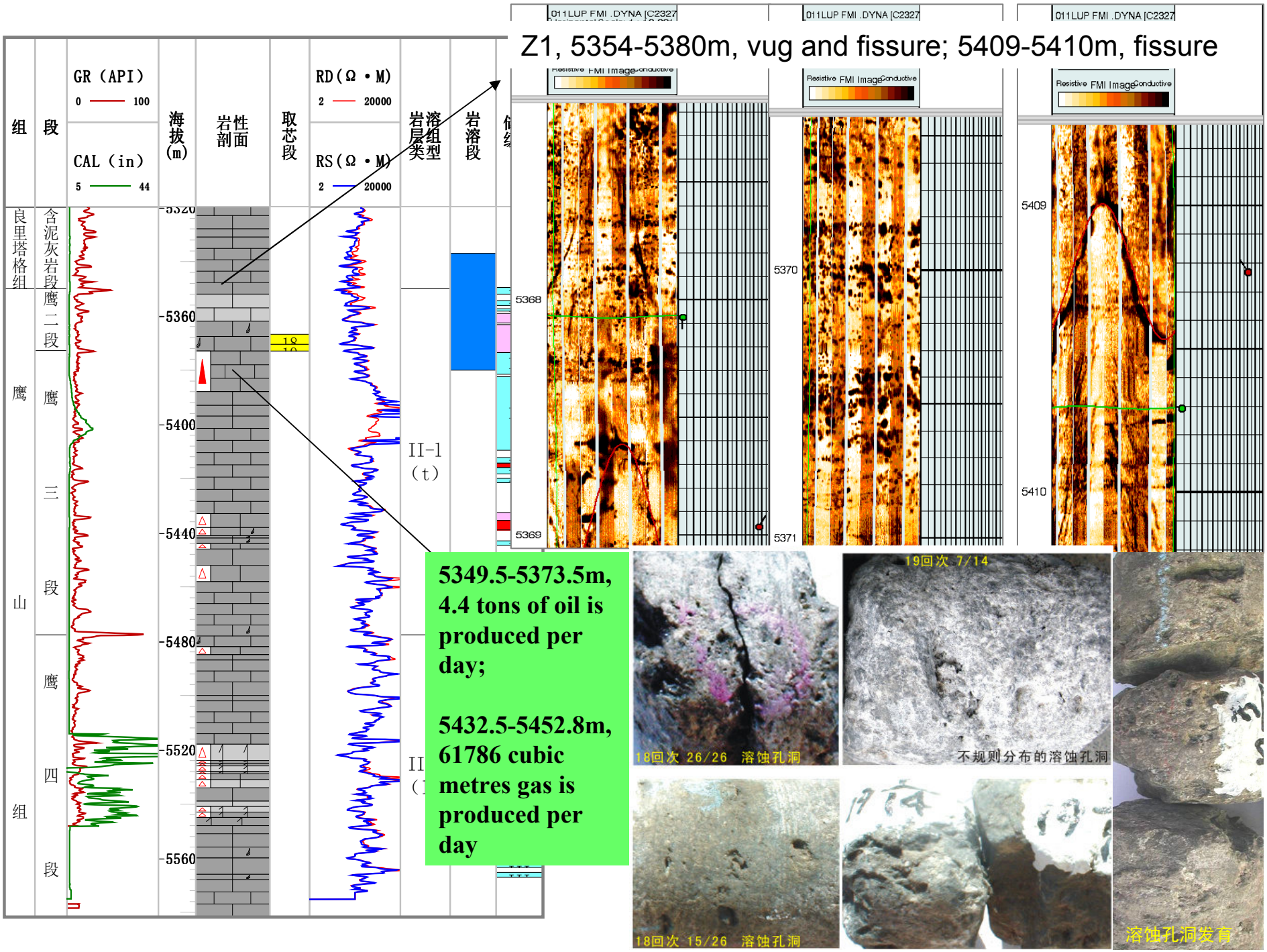
# Reservoir distribution characteristics

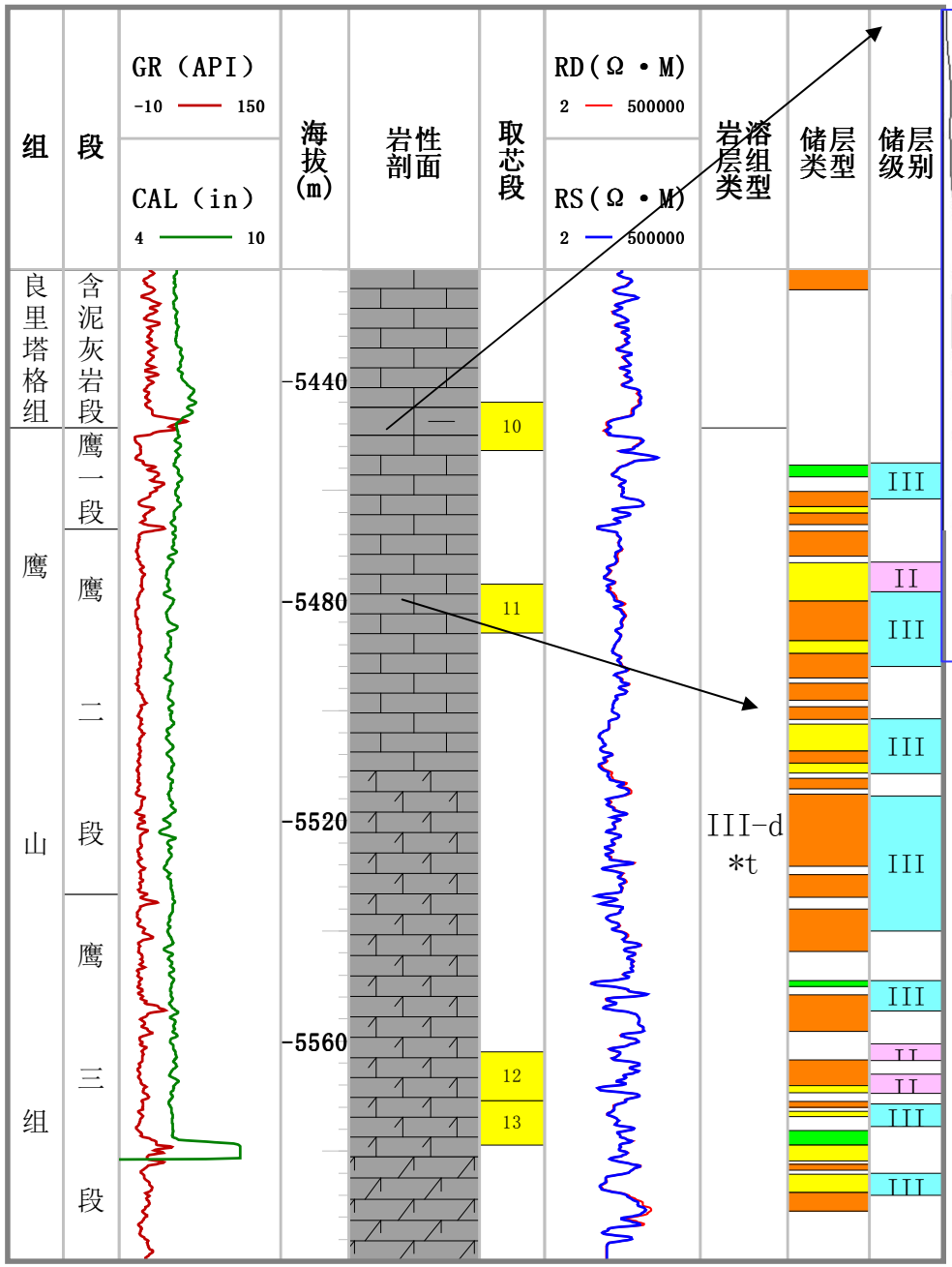
## Vertical Distribution

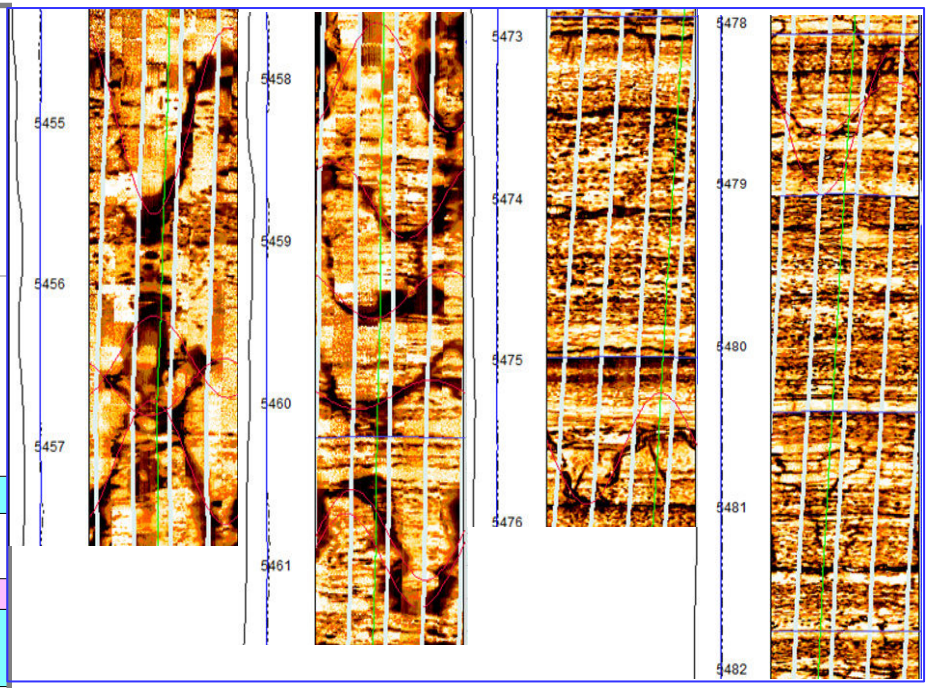
1.A set of vug and fissure is identified near the unconformity surface( $T_7^4$) by imaging logging, which is the broad reservoir category



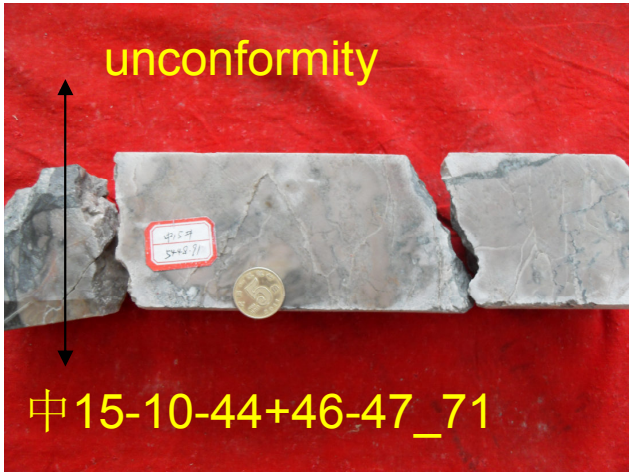

Correlation Profile of solution vugs on the top of Yingshan Fm. Z13-Z16-Z19-Z11-Z15-Z1-Z12CX-Z20

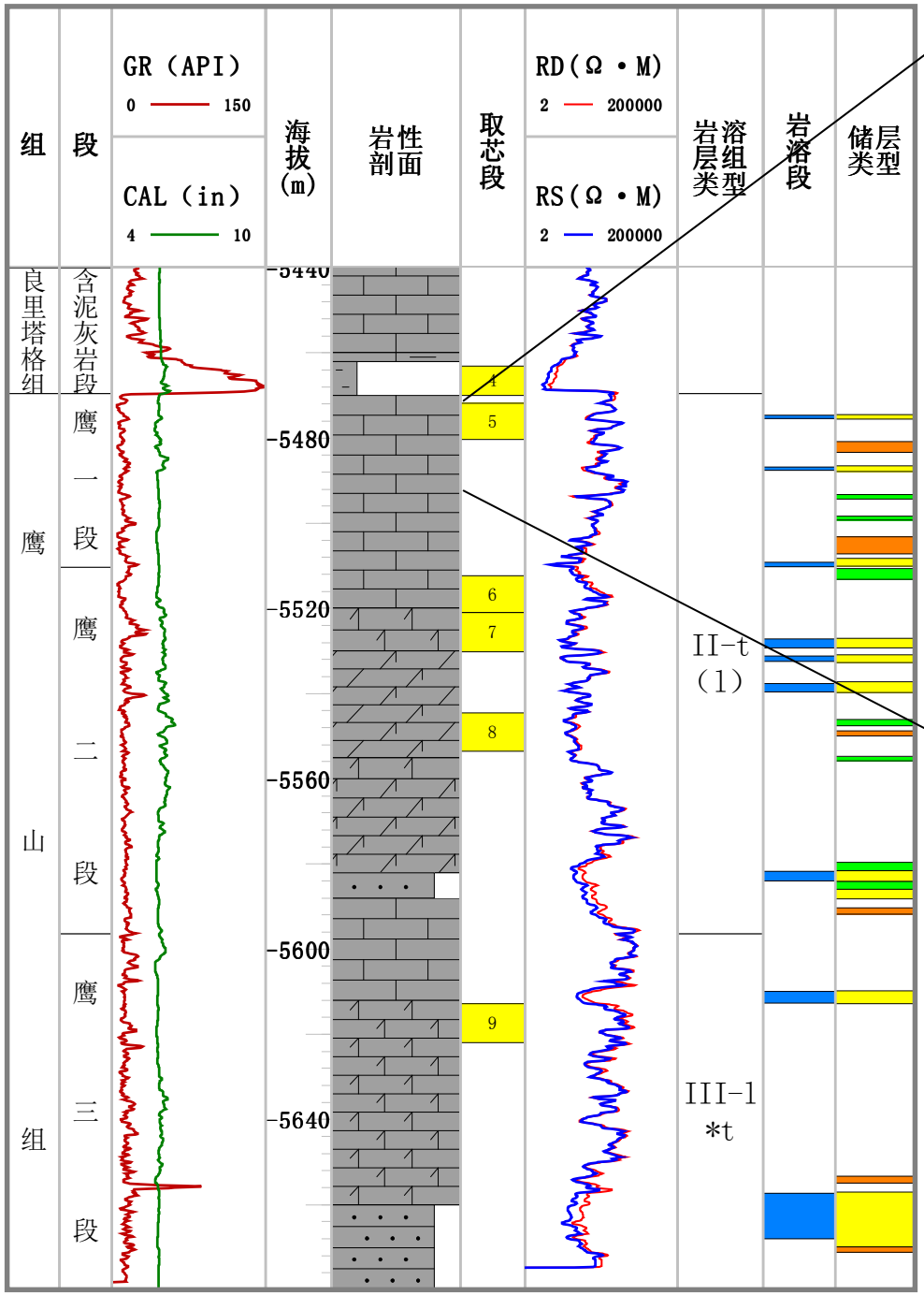

Z1, 5354-5380m, vug and fissure; 5409-5410m, fissure
组
段
GR (API)
0
100
CAL (in)
5
44
海拔(m)
岩性剖面
取芯段
RD(Ω·M)
2
20000
RS(Ω·M)
2
20000
岩溶层组类型
岩溶段
良里塔格组
鹰山组
含泥灰岩段
鹰二段
鹰三段
鹰四段
-5360
-5400
-5440
-5480
-5520
-5560
II-1 (t)
5368
5369
5370
5371
5409
5410
5349.5-5373.5m, 4.4 tons of oil is produced per day;
5432.5-5452.8m, 61786 cubic metres gas is produced per day
18回次 26/26 溶蚀孔洞
19回次 7/14
不规则分布的溶蚀孔洞
18回次 15/26 溶蚀孔洞
溶蚀孔洞发育

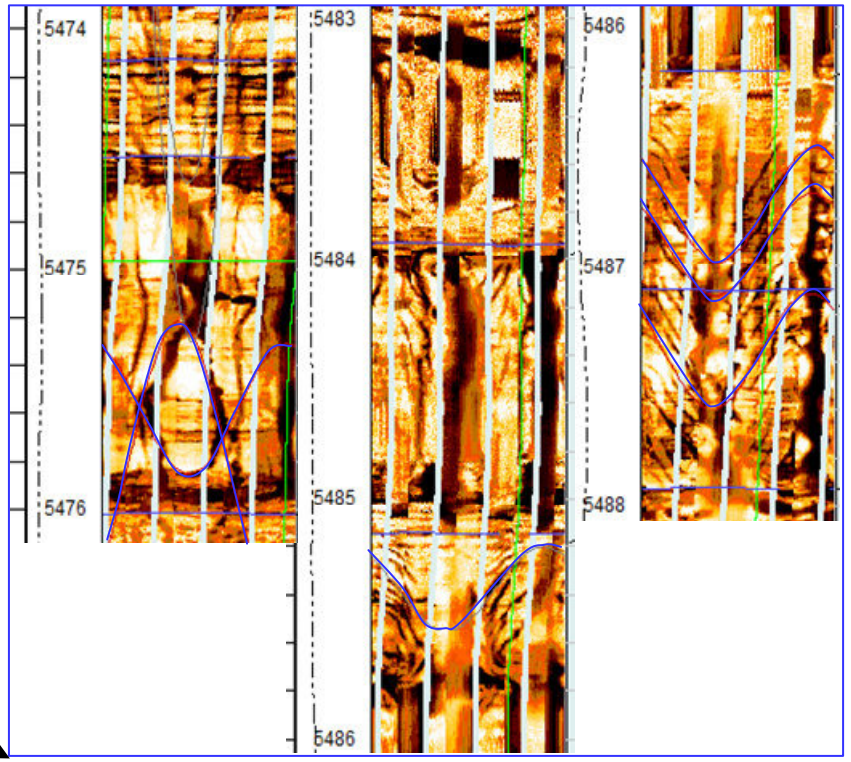



Z15, 5455-5461m、5473-5482m, vug and fissure, vug develops along fissure in vertical direction





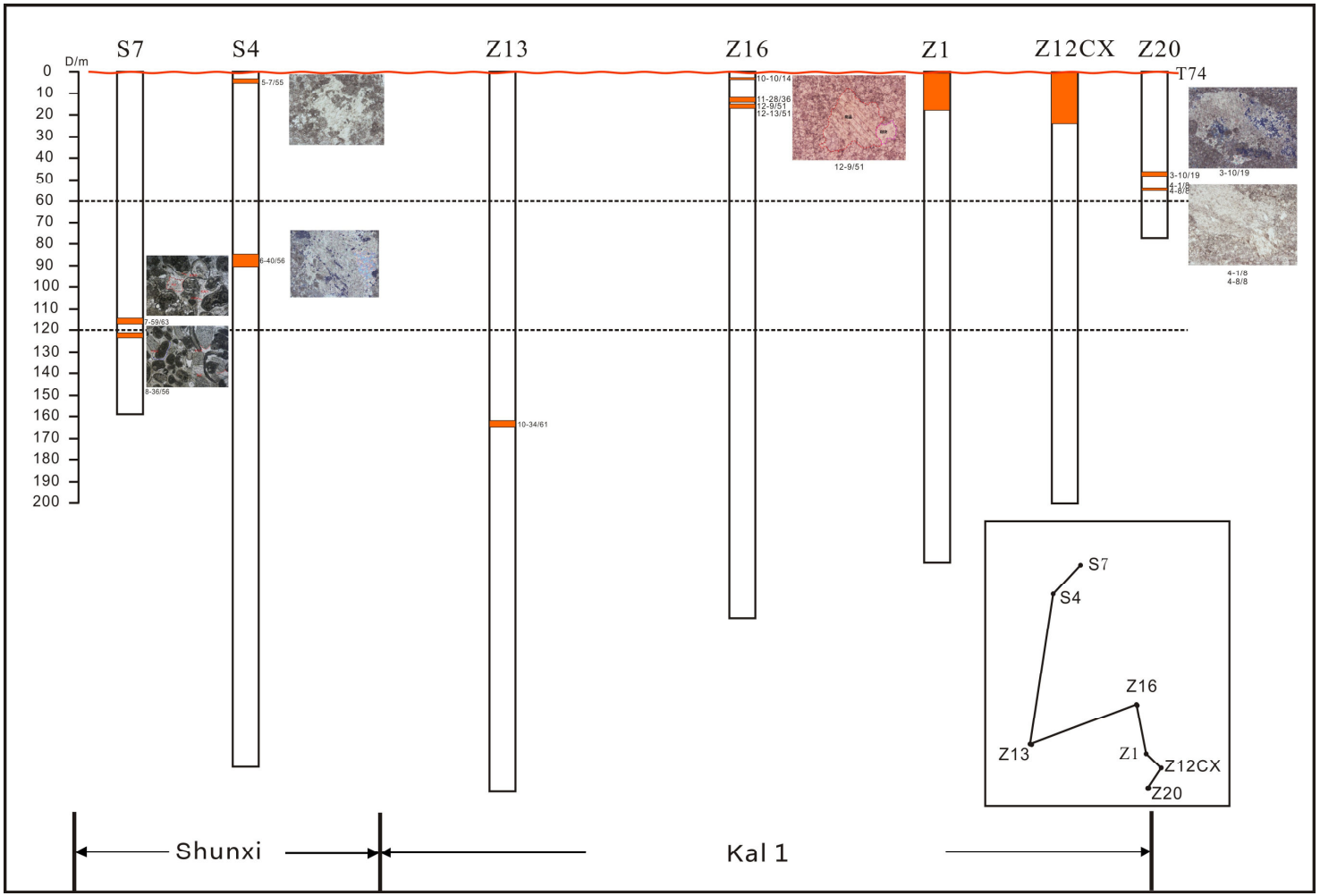

Z19, 5474-5476,5483-5488m, vug and Fissure

Z19, 4_62/72，core, unconformity

# Reservoir distribution characteristics

## Vertical Distribution

**2.Epikarst reservoir mainly develops in the region 0-120m away from unconformity**




**Vertical distribution of epikarst reservoir in Yingshan Fm.(data from core and thin sections)**

# Reservoir distribution characteristics

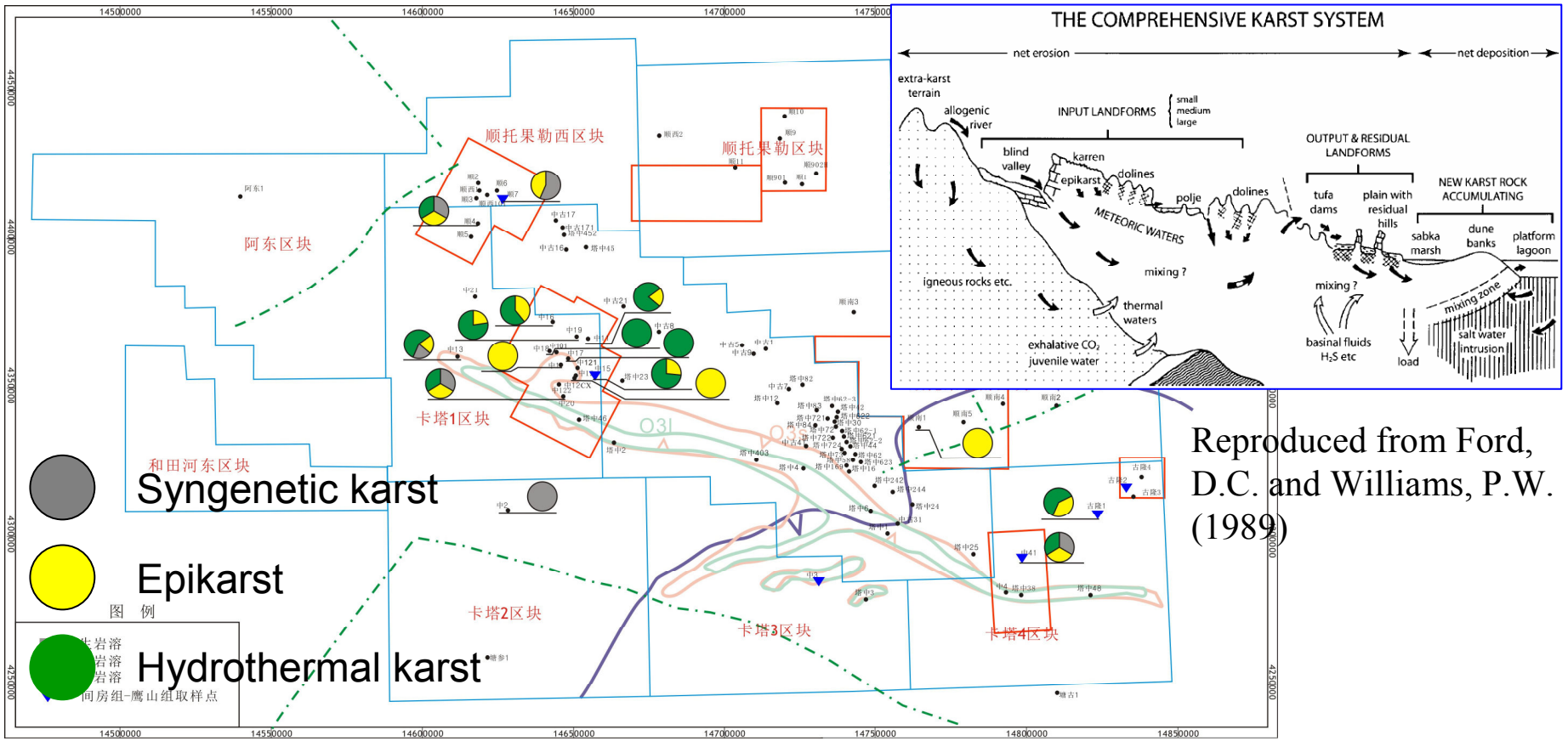
Horizontal Distribution

## 3.Horizontal distribution characteristics of epikarst reservoir

1）The distribution is universal

2）Horizontal distribution features vary in different regions

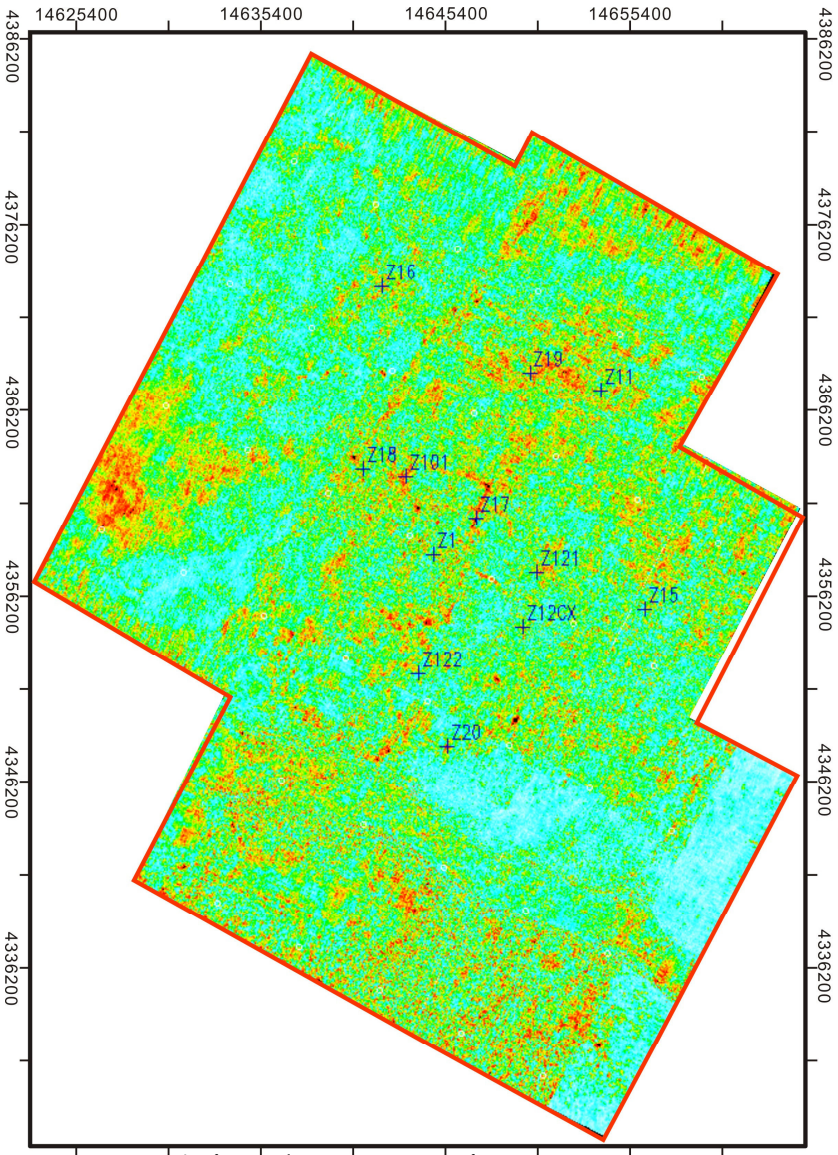
3）Epikarst reservoir develops better near the Pinchout line and the genesis of reservoir becomes complex when be far away from Pinchout line

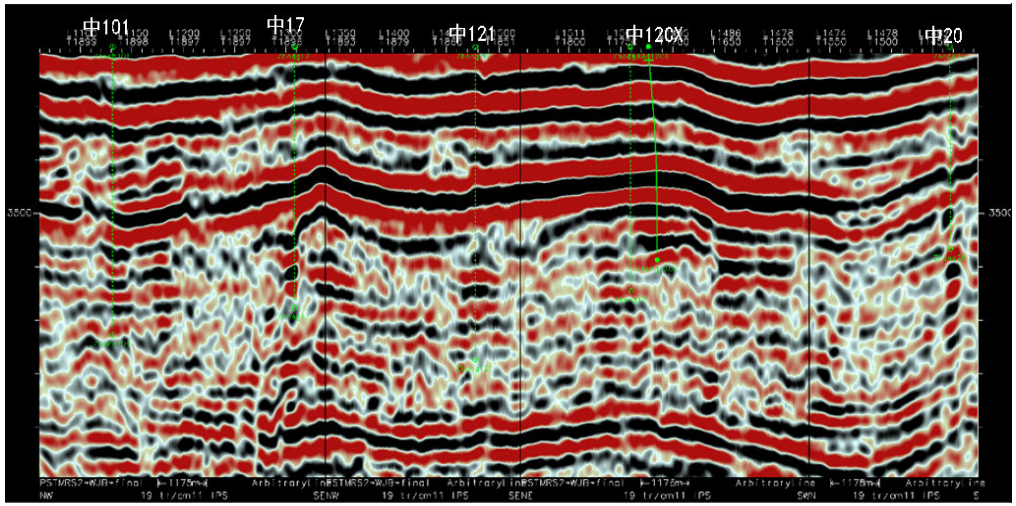



Reproduced from Ford, D.C. and Williams, P.W. (1989)

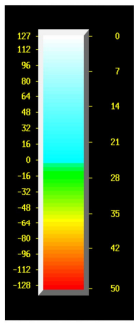
**The distribution of different genesis reservoir in Tazhong Oil field**

# Reservoir distribution characteristics




**4."short plate" or "beaded" reflection are the primary seismic reflection characteristics**

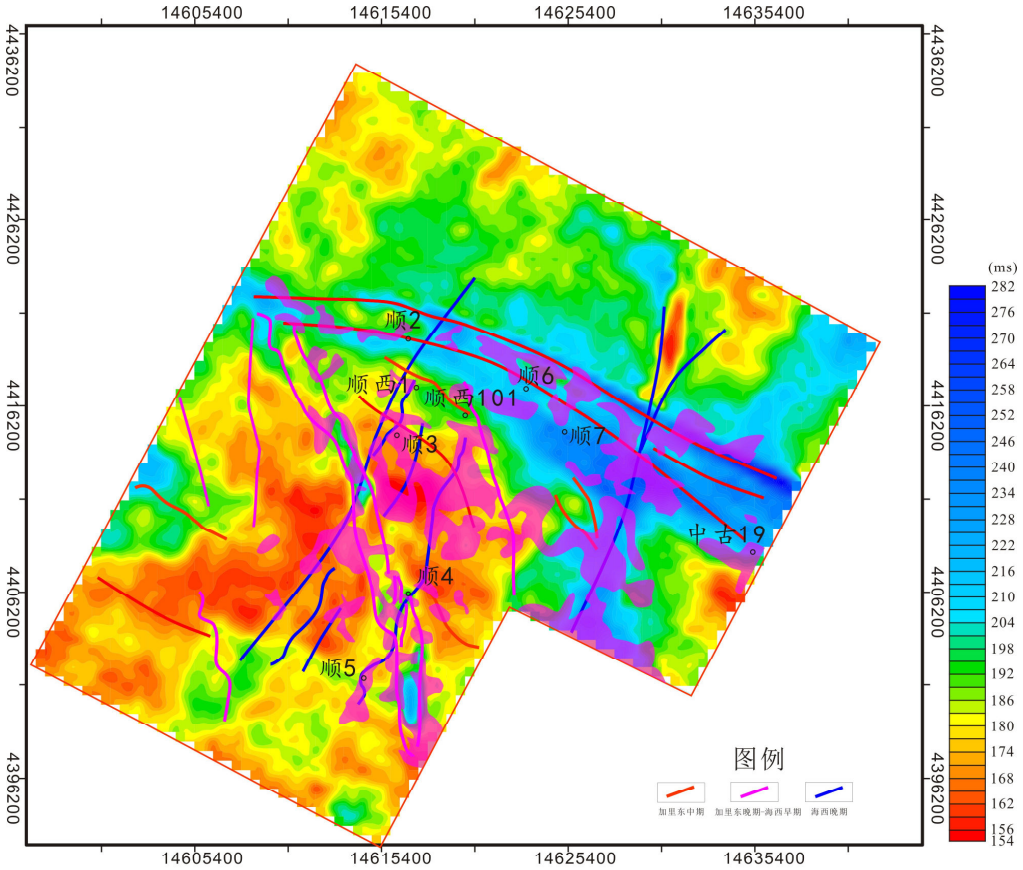


Average Absolute Amplitude Anomaly distributes as line in NEE direction

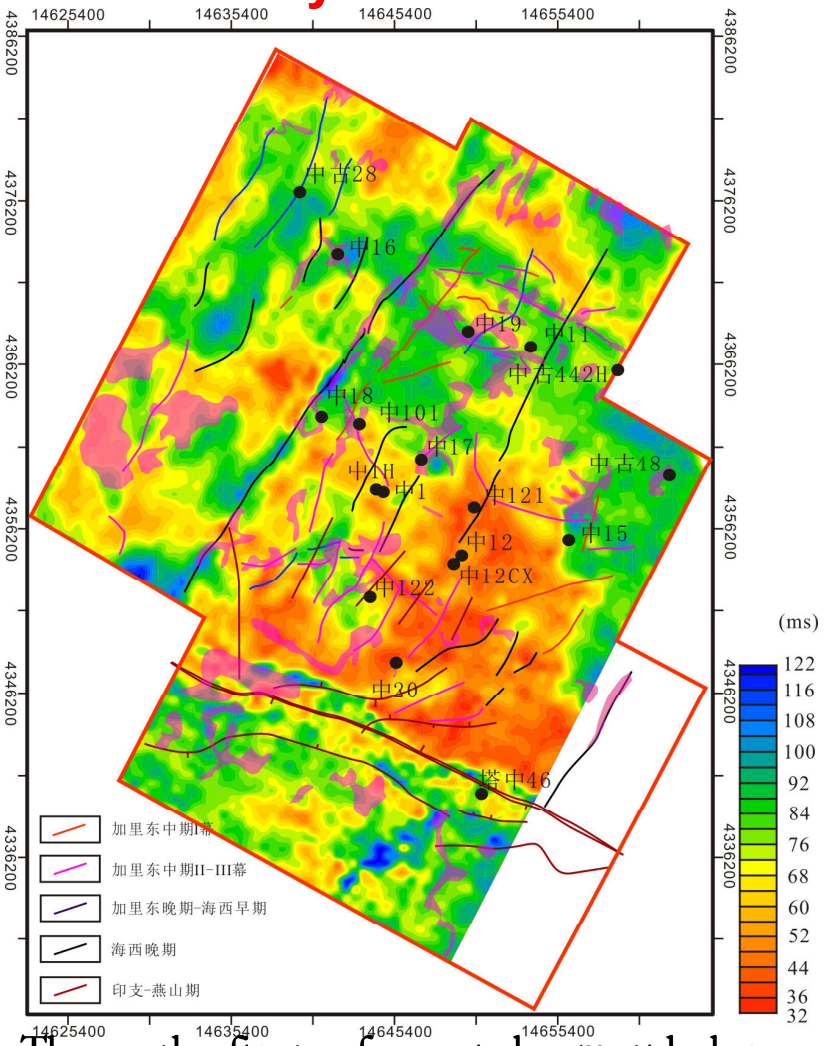
Horizontal distribution prediction of cave in Yingshan Fm. in Kal 1 block ($T_7^4$_0-100ms Average Absolute Amplitude)

# Reservoir distribution characteristics

**5.The differentiation of reservoir distribution in different landform is not obvious, but the underlying reservoirs are intimately related to fissures and faults**




The overlay figure of cave, paleo-morphology and fault system in Shunxi Block

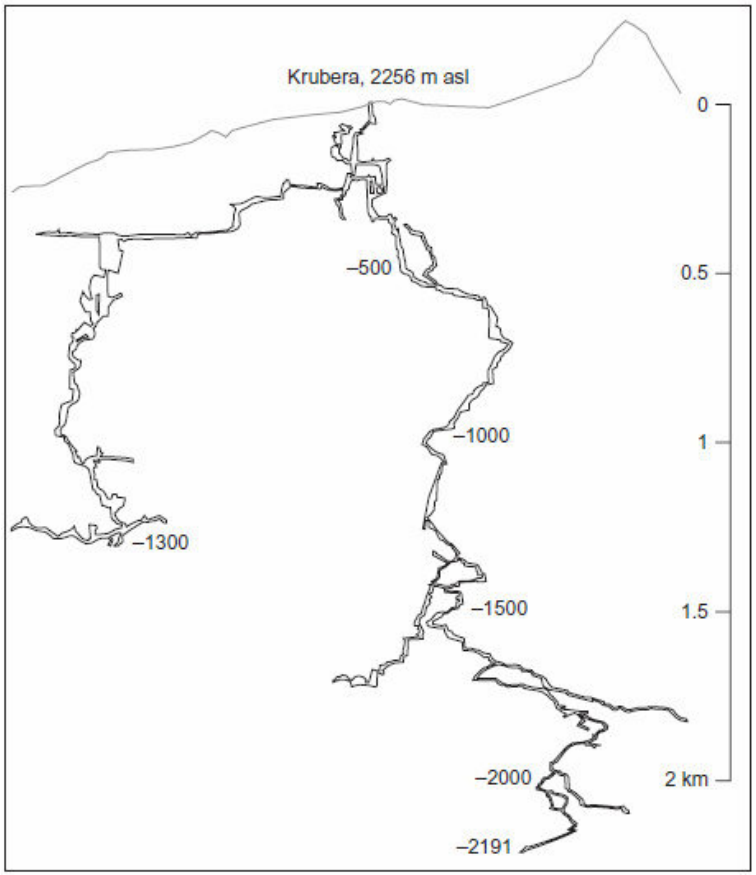



The overlay figure of cave, paleo-morphology and fault system in Kal 1 Block

# Disscusion

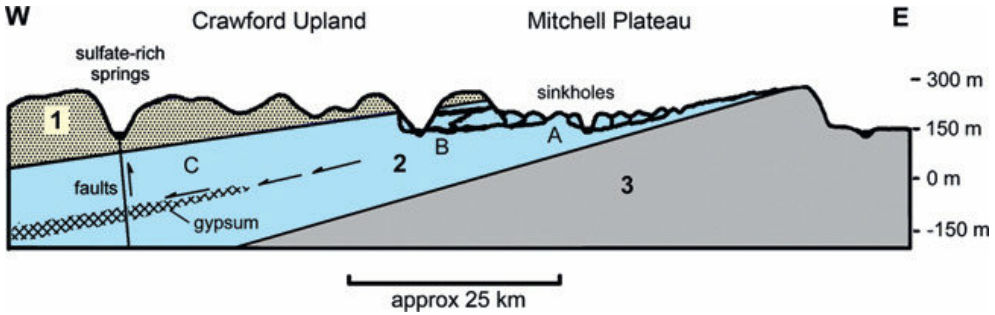
## The difference between high and moderate relief regions

### High relief regions

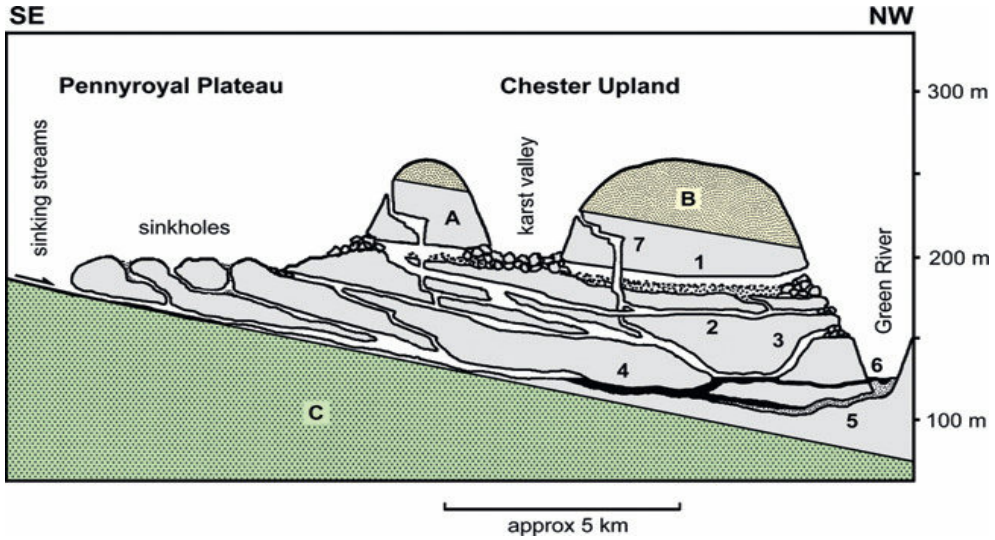



**Krubera Cave in connection with recent uplift of the Caucasus range**

### Moderate relief regions



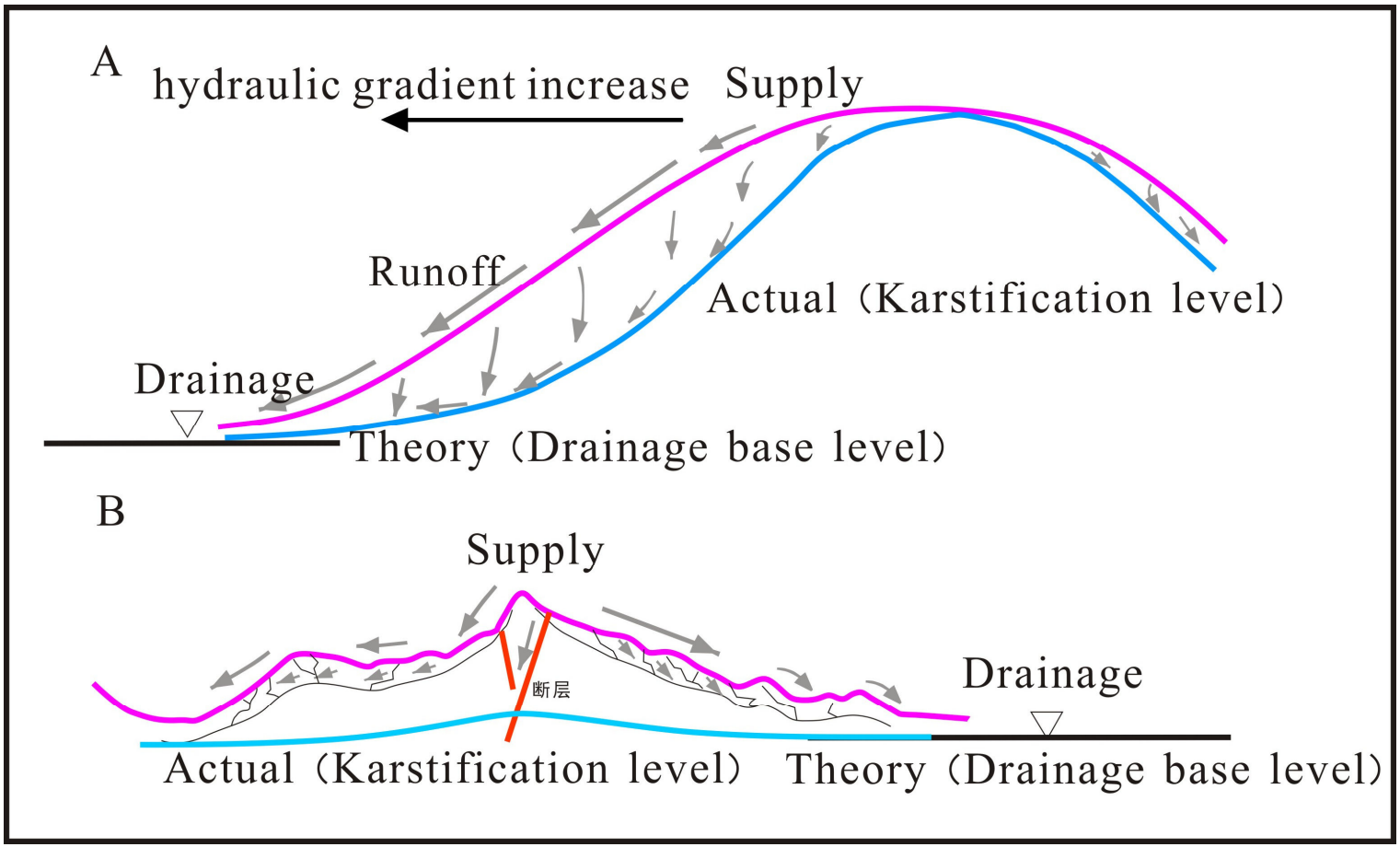

**Cross-section through the karst area of southern Indiana**




**Idealized profile through the Mammoth Cave System, Kentucky**

# Disscusion

## The difference between high and moderate relief regions




**Karst reservoir development model figure in moderate relief regions**

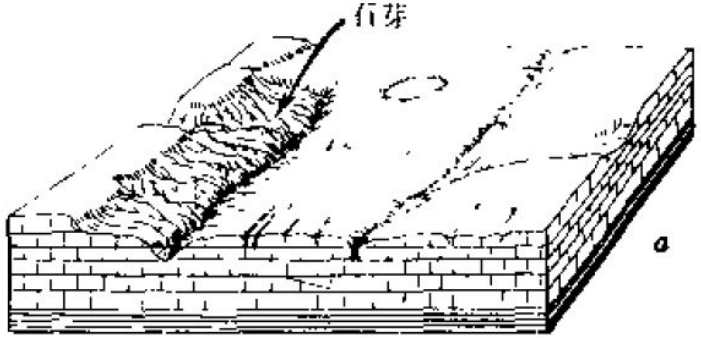
# Disscusion

## Karstification evolution stage

| Paleomorphology | Hydrology |
|---|---|
| Karren, channeling karren | Without surface drainage system;<br>Without uniform water table |

**Initiation**

| Paleomorphology | Hydrology |
|---|---|
| Clints、channeling karren、doline, sink hole | Obvious surface drainage system;<br>Without uniform water table<br>With the enlarge of fissure, isolate caves develop |




**Youth**

| | |
|---|---|
| Fengcong、fenglin、karst depression、sink hole、dry valley、blind valley | Integrated drive system<br>Isolate caves ——Cave system |
| | Surfece drainage system、Subsurface drainage system<br>Collapse |


**Maturity**

# Conclusion

1.The slope of karst terrain in research area is flat and the slope of surface is small, and surface drainage system does not form

2.Karren is the most obvious geomorphic category, including cracks and fissures along some constant directions

3.Fissures and vugs are the main reservoir categories, which controlled by the fault system distribution.

4.Fissure-Spose patter karst model is the product of the unique hydrogeomorphologic architecture (Without surface drainage pattern) , which reflecting the feature in the initiation period

***Thank You Very Much!***