Characterization of Carbonate Fracture-Cavity Reservoirs in Tahe Oilfield, Tarim Basin, China*

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Abstract

The Tahe Oil Field is a typical carbonate fracture-cavity reservoir in the Shayan Uplift of northern Tarim Basin, western China. Caves and fractures are the main reservoir space. The reservoir is very heterogeneous and therefore difficult to characterize quantitatively. In this article, taking Tahe block 4 and block 7 as examples, we present a systematic method to characterize the carbonate fracture-cavity reservoir.

Based on cores, outcrops, logging data, seismic data and dynamic data, we classified the reservoir into caves, pores, large scale fractures and small scale fractures. Then we analyzed the connectivity of reservoirs based on dynamic data, defined the boundary of the fracture-cavity reservoir and divided it into different units. Block 4 is divided into 8 units, and block 7 into 5 units.

The cave is the most important storage space of this fracture-cavity reservoir. Taking the typical units as an example, in order to describe the internal architecture of caves in detail, we divided the caves into pipe caves, isolated caves, and doline caves based on the genetic mechanism and size. Then the size and shape, internal filling characteristics, mutual relationships and communication status of pipe caves, isolated caves, shafts, corridors, pores, large fractures and small fractures are characterized in detail, integrating static data and dynamic data for further refinement of the fractures and caves. On the basis of architectural anatomy, the pattern of fracture and water surface both controlling facies distribution and the pattern of water surface mainly controlling facies distribution are summarized. Combined with the fracture-cavity fabric geometry constraint parameter and different fabric configurations of different elements, the patterns are used to assist in establishing a facies model which can used as guidance in karst facies modeling.

For the single well, the standards of the filling type and the filling degree of caves are established quantitatively with cores calibrating logs. The quantitative characterization method of property parameter in different fracture-cavity units is setup based on different filling characteristics, and the parameter distribution and controlling factors are revealed. The filling characteristic of caves under different karst background is different, leading to distribution of property parameters which can used in guidance of property modeling.

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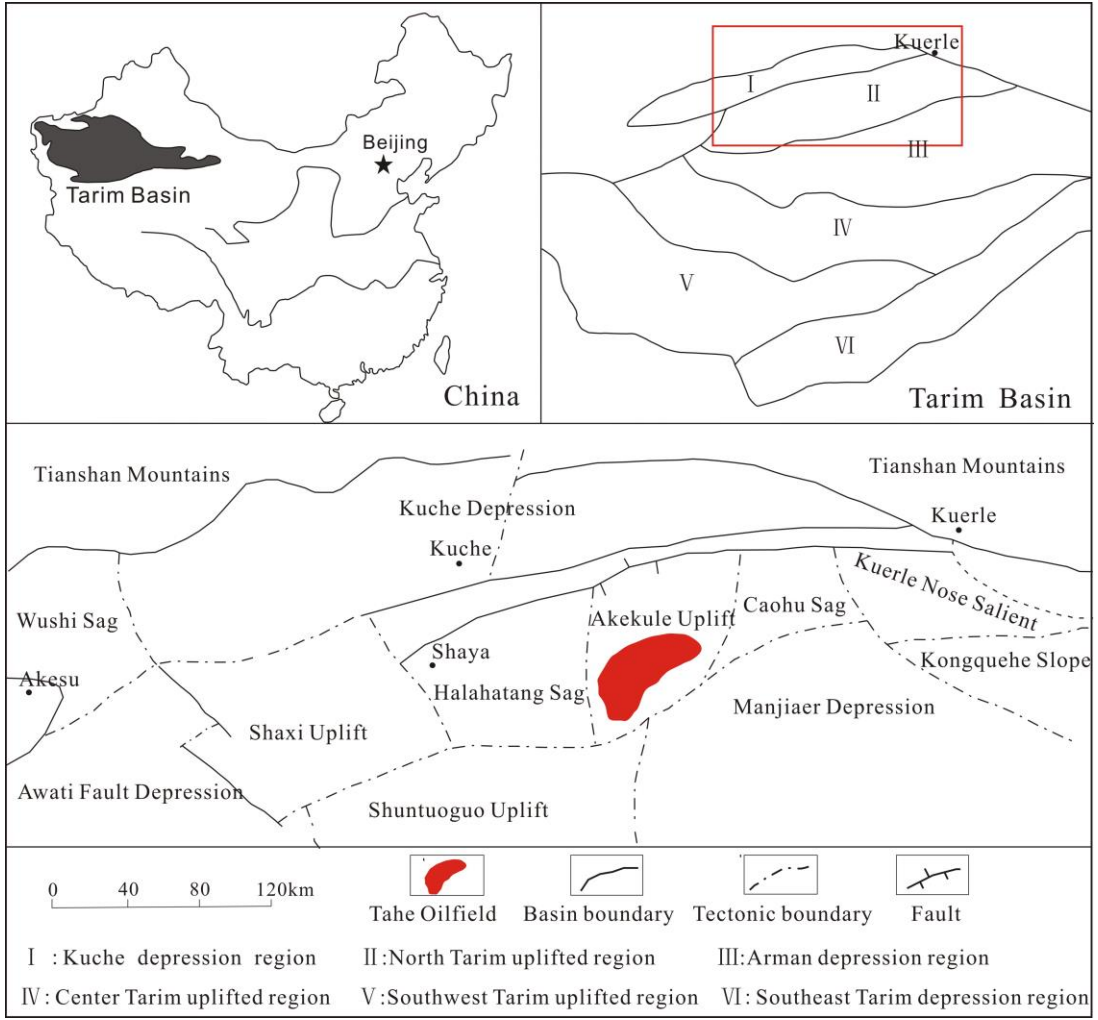
Contents

- **Introduction**
- **Data**
- **Research Analysis and Results**
- **Conclusions**

Location map

- **Tahe oilfield is located in the north flank of shaya uplift in Tarim basin**
- **The uplift experienced Caledonian period, Hercynian, Indosinian, Yanshan and Himalayan period.**
- **The late Caledonian period and the early Hercynian period are the main period.**
- **Ordovician is the main oil-bearing formation and a typical fracture-cavity reservoir.**



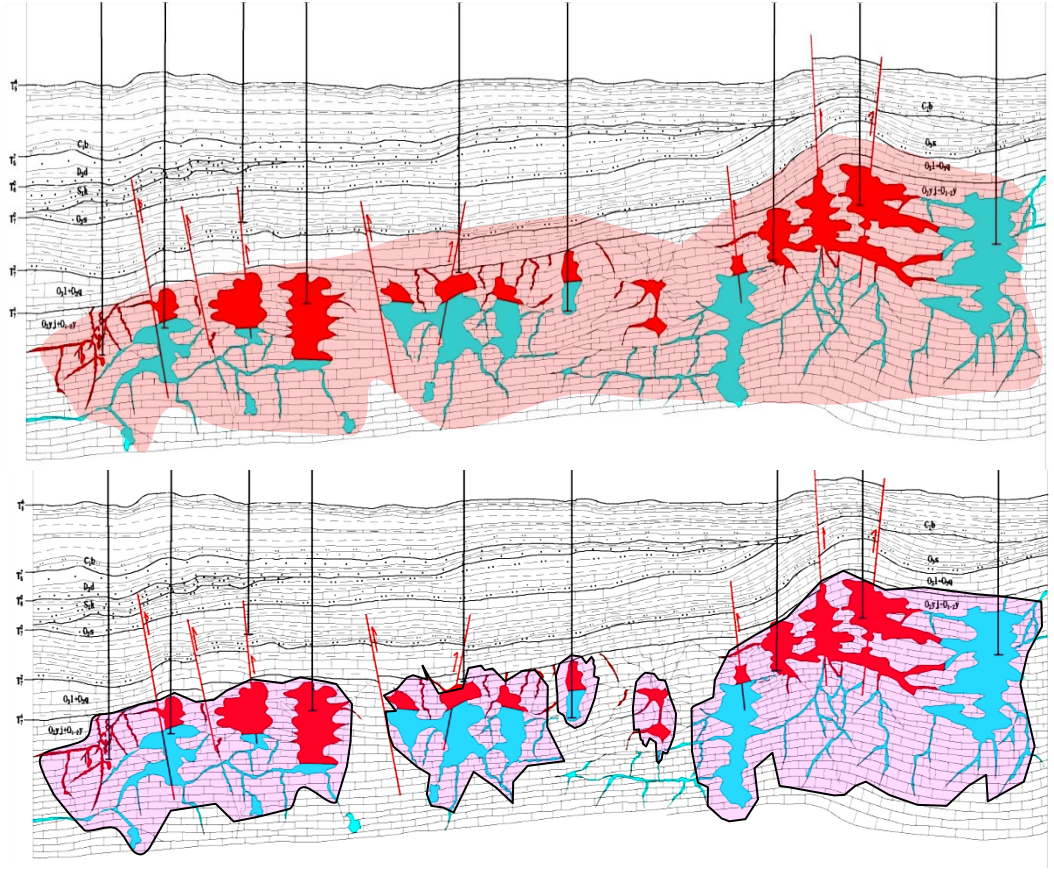
Introduction

Fracture-cavity Reservoir is special type of reservoir, different from clastic reservoir

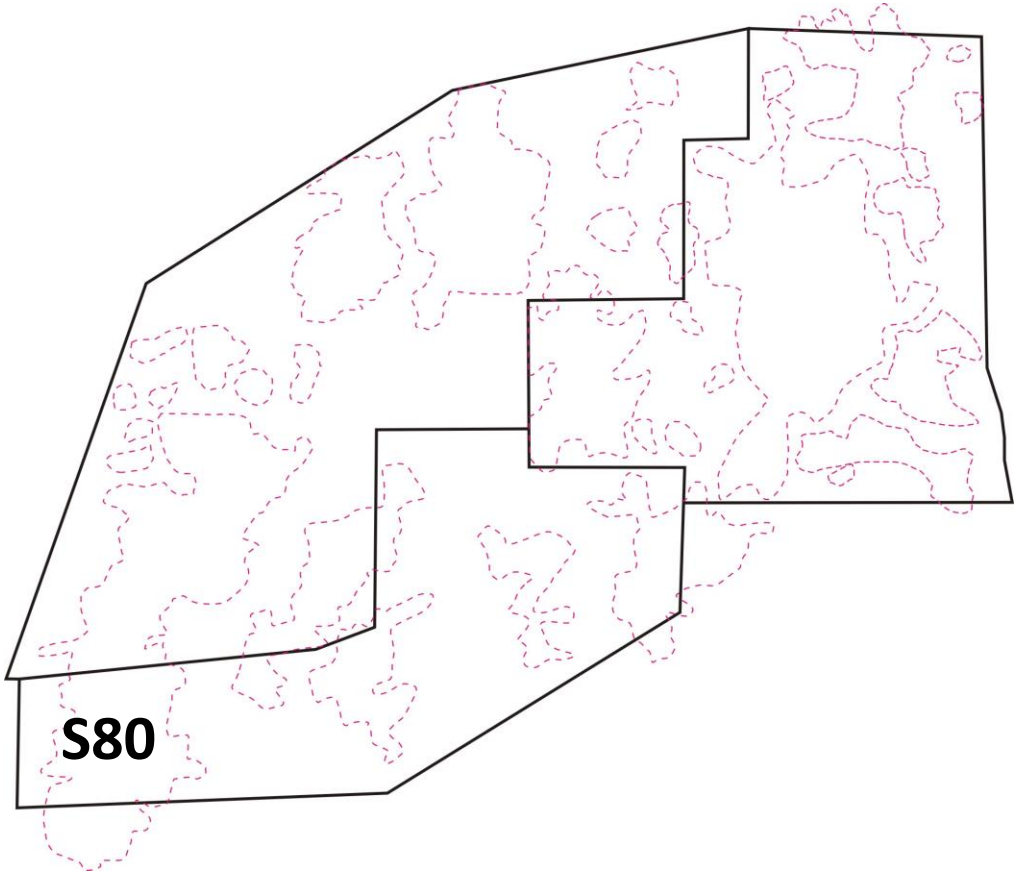
- **Fracture-cavity system**
- **Fracture-cavity unit**

•Caves and fractures are the main reservoir space and seepage passage.

•The reservoir shape and size varies greatly, and the distribution is unique.



Introduction



Introduction

Research objectives

- **To characterize the reservoir architectural elements (caves, fractures, internal fillings, etc.) of Fracture-cavity Reservoirs**

- **To build a Geological modeling (structural, facies & property modeling).**

Contents

- Introduction
- Data
- Research Analysis and Results
- Conclusions

Data

❖Seismic data:

A 3D seismic data covering S80 area (research area) with a total coverage of about 44 km^2 length were used

❖Wire line logs:

Some logs such as GR, SP, Resistivity, Density, Neutron and Sonic were integrated together in order to recognize the different reservoir architectural elements

❖ Core data:

6 wells has a conventional core of 4-inches diameter with a total length of 227.61 m

❖Modern karst and analogous outcrop data

14 survey locations and 17 outcrop sections

Contents

- Introduction
- Data
- Research Analysis and Results
- Conclusions

Modern karst

- various forms of caves


Huanglong cave in Zhangjiajie


Xiaozai in Fengjie,China


Chichen itza in Mexico


Tianxing in wulong,china

Analogous outcrop

- **Isolated caves**

  Controlled by water surfaces, pipe caves extend horizontally.

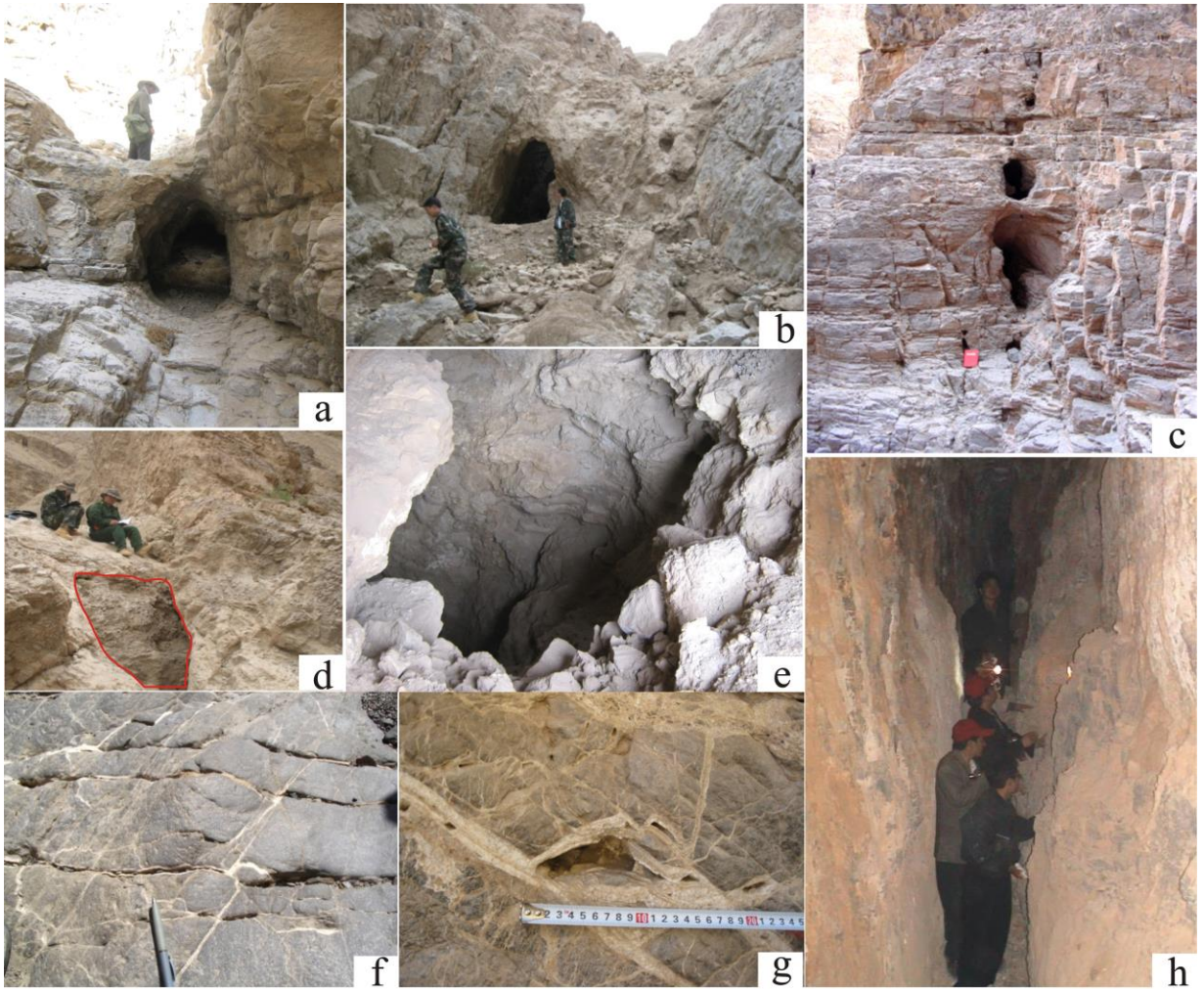
- **Underground rivers**

  Affected by vertical corrosion controlled by the fault and collapsed, isolated caves are approximate ellipsoid.

- **Doline caves**

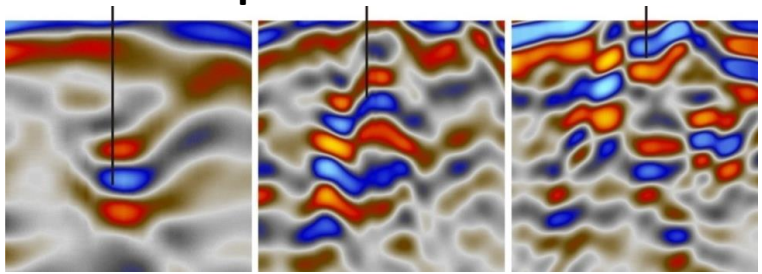
  developed vertically

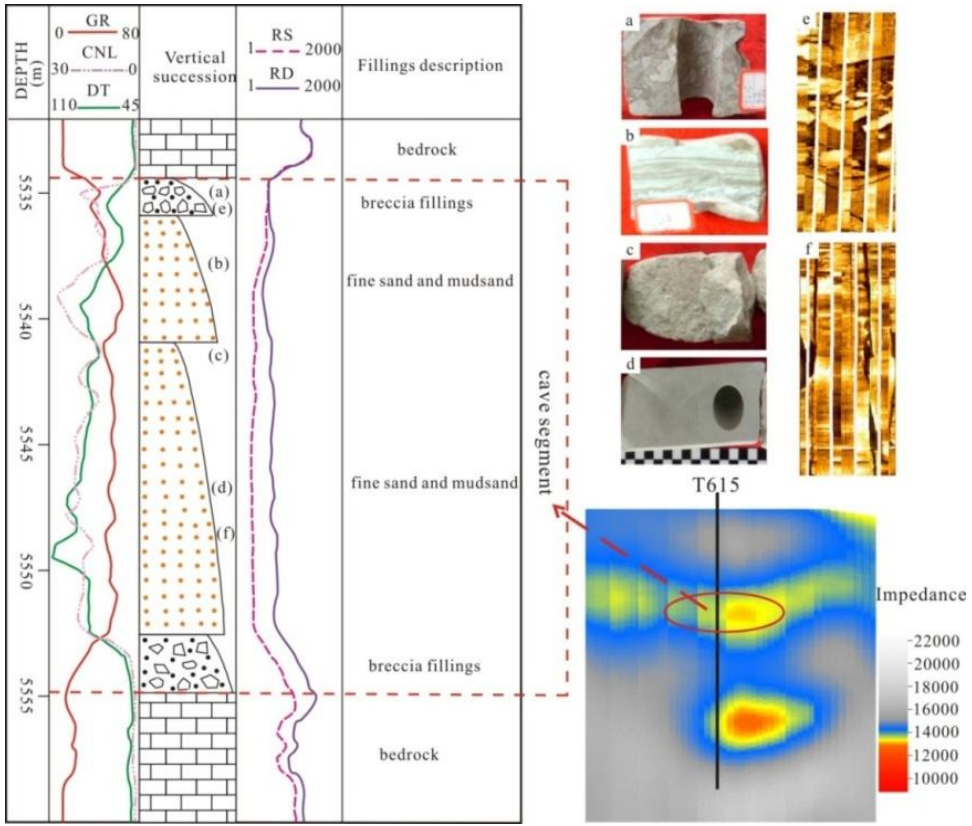
- **Fault and fractures**



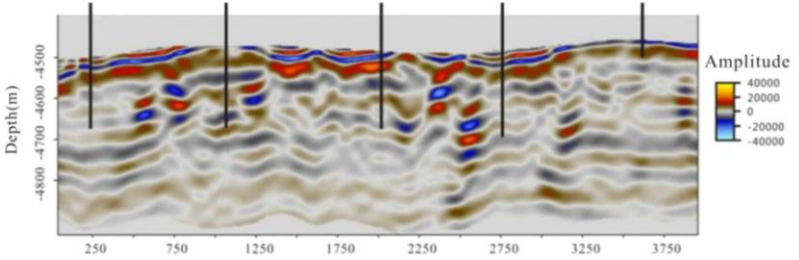
Identification of karst facies

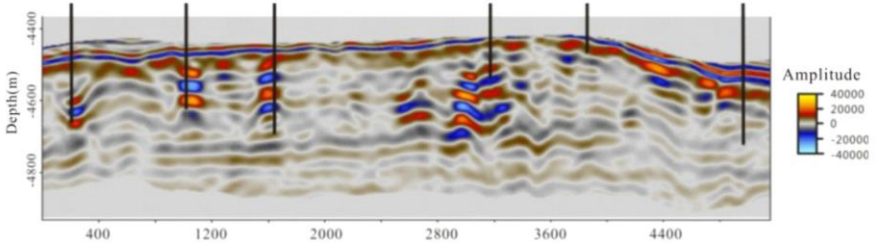
- **Well drilling：** emptying, mud loss, or very low drillling time
- **Well logging：** obviously decreased resistivity value, great difference of the size of deep and shallow resistivity, obviously increased Neutron porosity and Acoustic time amplitude
- **Core data：** sand, mudsand, breccia or calcite fillings
- **Seismic data：** beaded reflection and low values of impedance

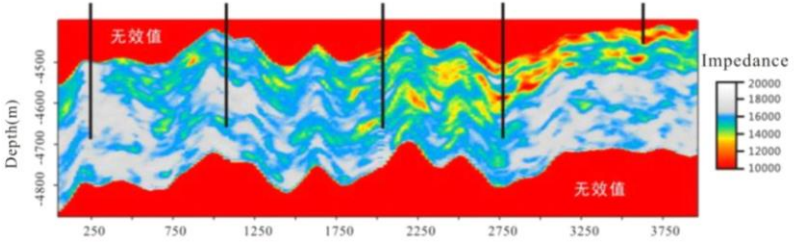


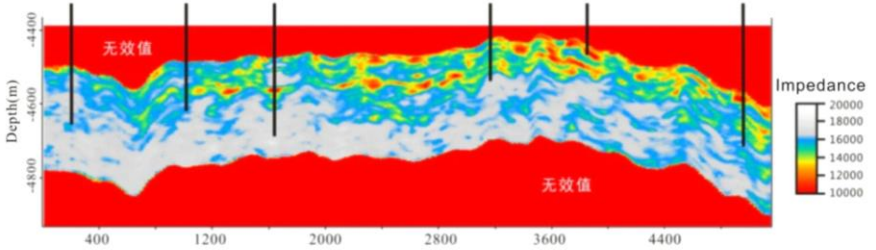


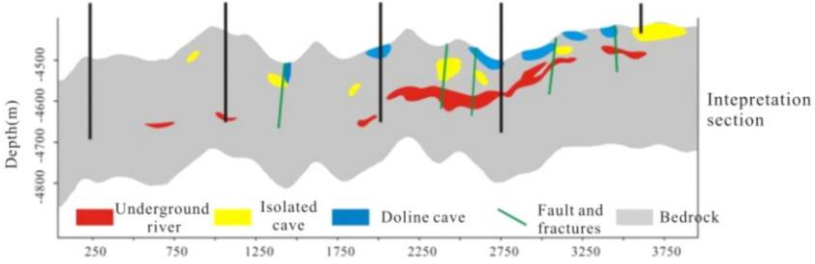
Multi-section prediction

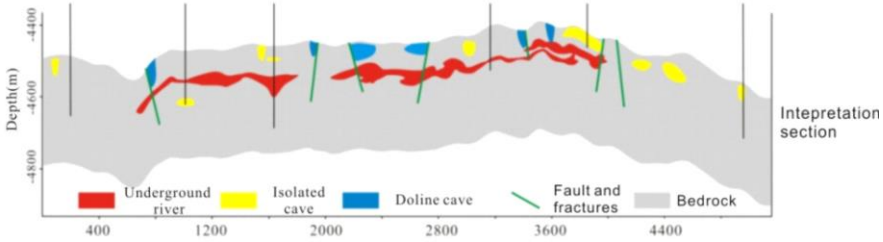






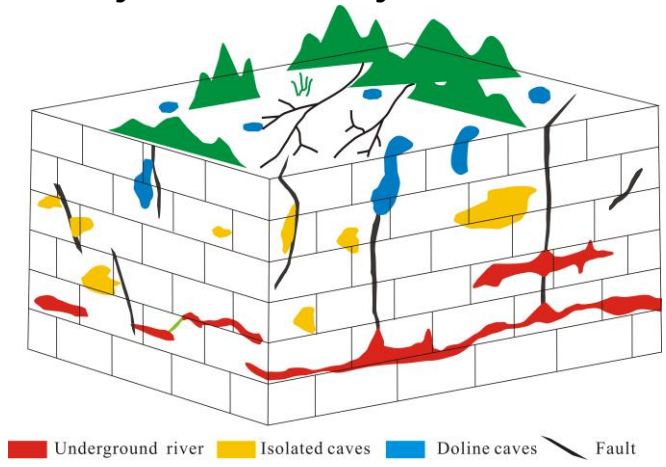


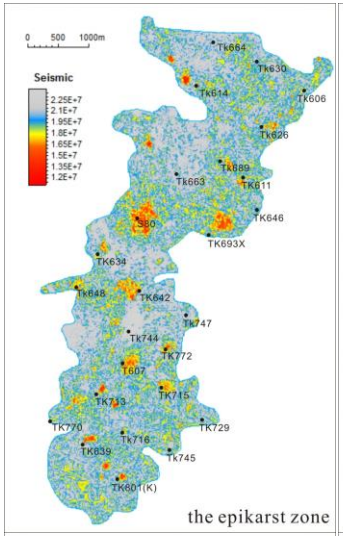


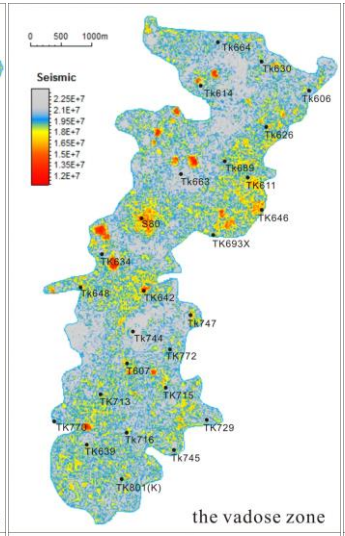


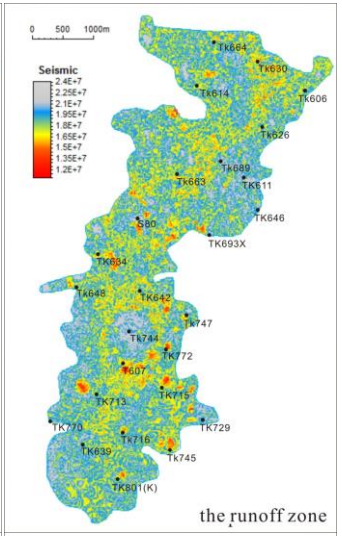
Plane composition

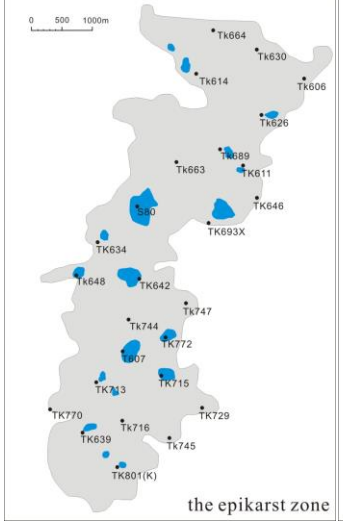
- **The epikarst zone, mainly develop doline caves, the vertical karst forms with thickness greater than the length and width.**
- **The vadose zone, mainly develop discrete caves, oval-shaped irregularly.**
- **The runoff zone, mainly develop underground river caves with good continuity horizontally.**

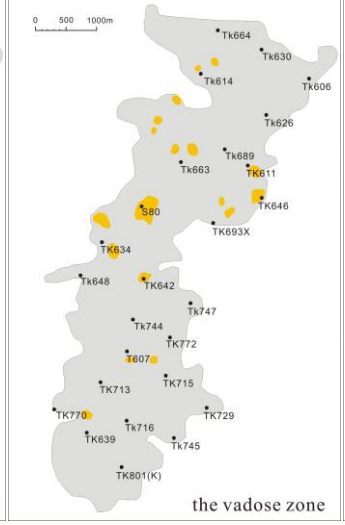


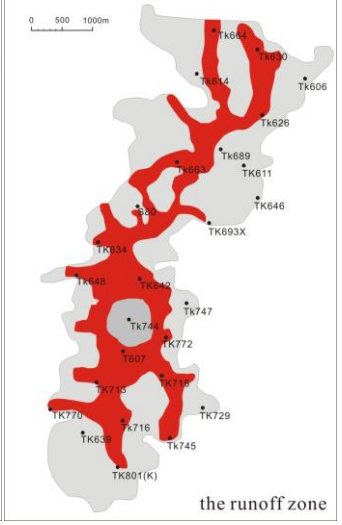






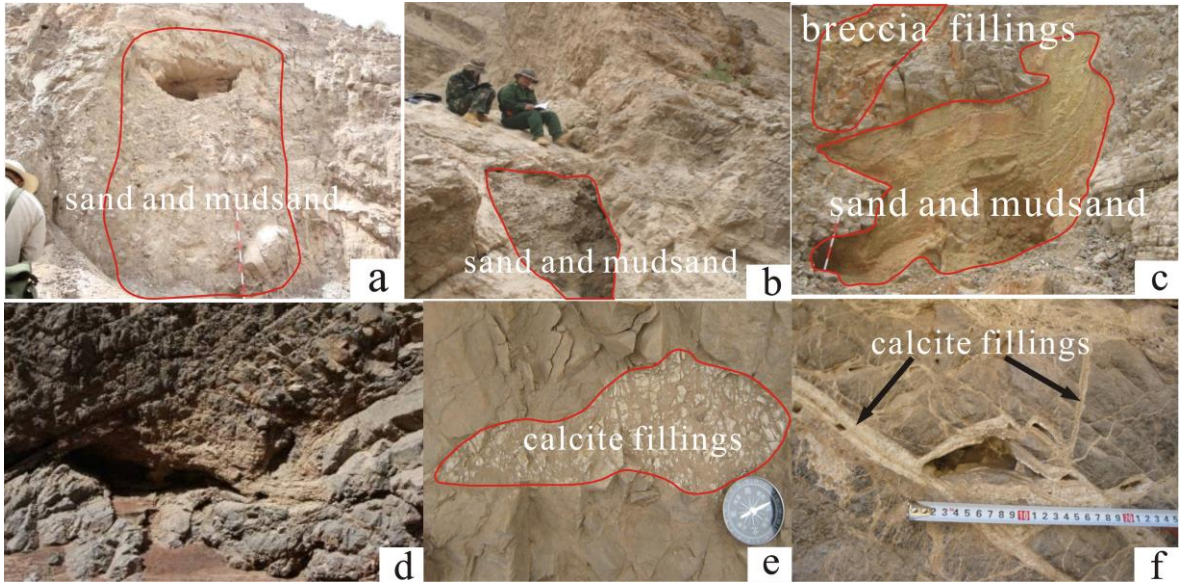


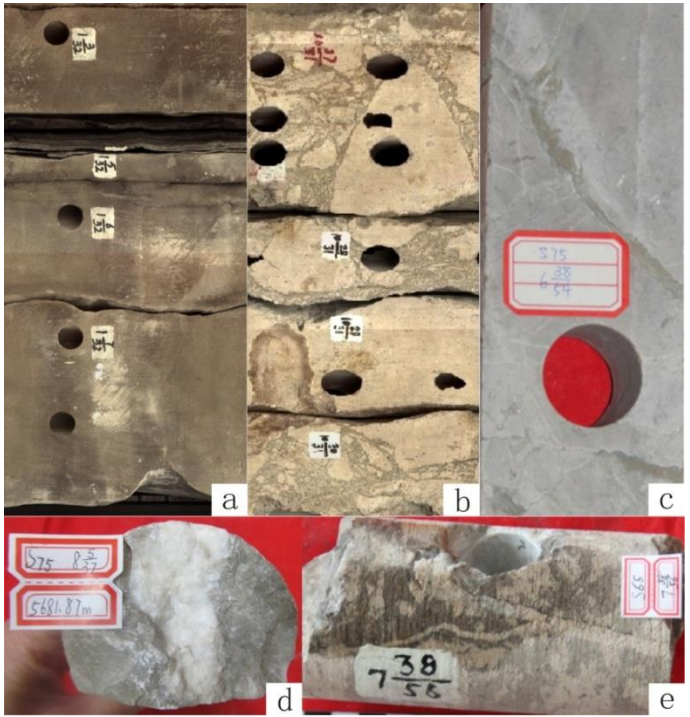




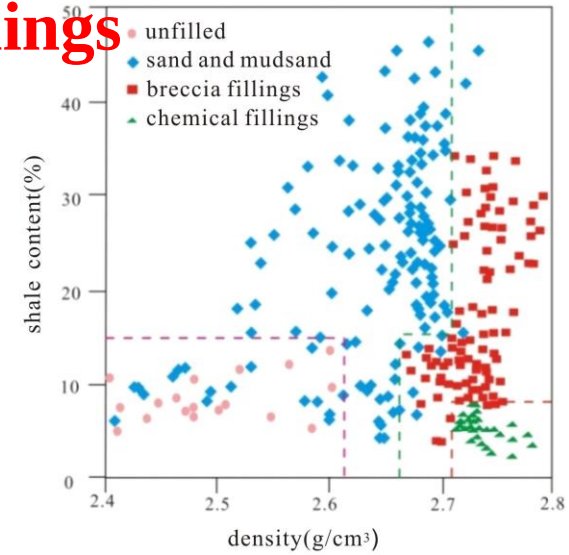
The types of fillings

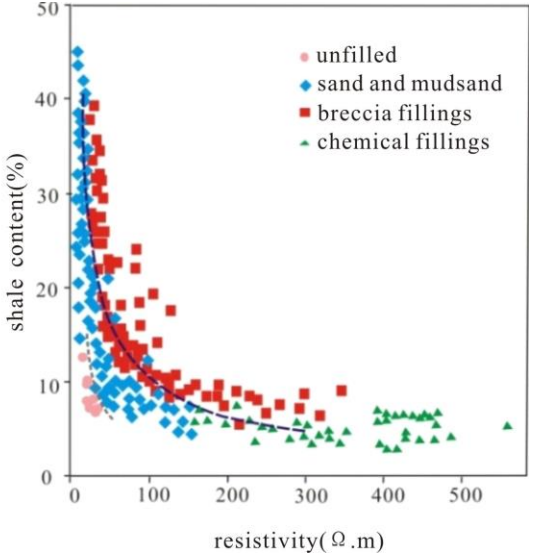
- **Sand and mudsand:** The product of allogenic water transport and deposition,parallel bedding and cross bedding can be found.
- **Breccia fillings:** Collapse in situ, the composition is consistent with the bedrock, poor sorting and rounded
- **Chemical fillings:** mainly calcite





The identification of fillings

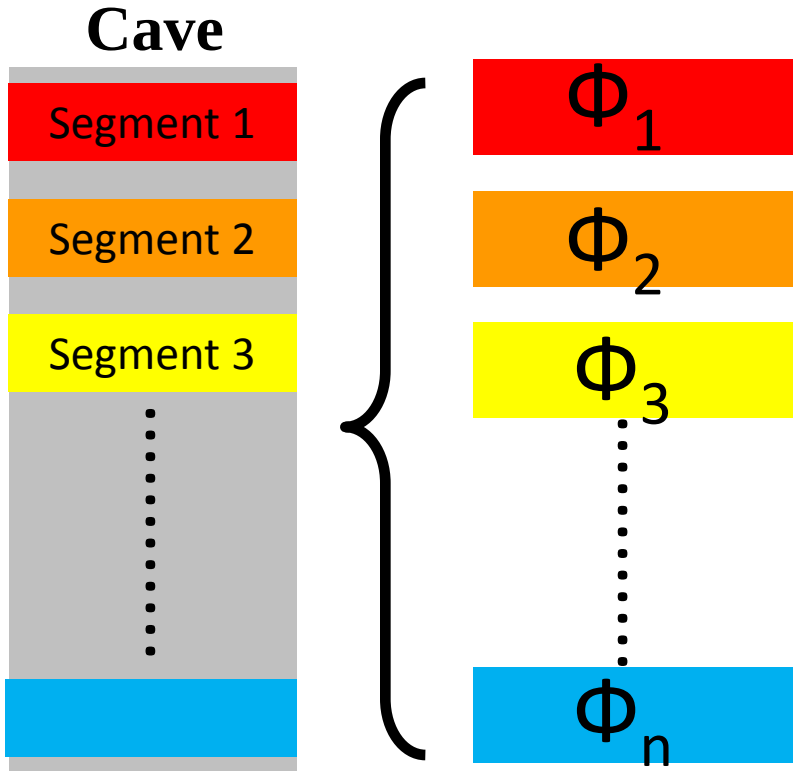




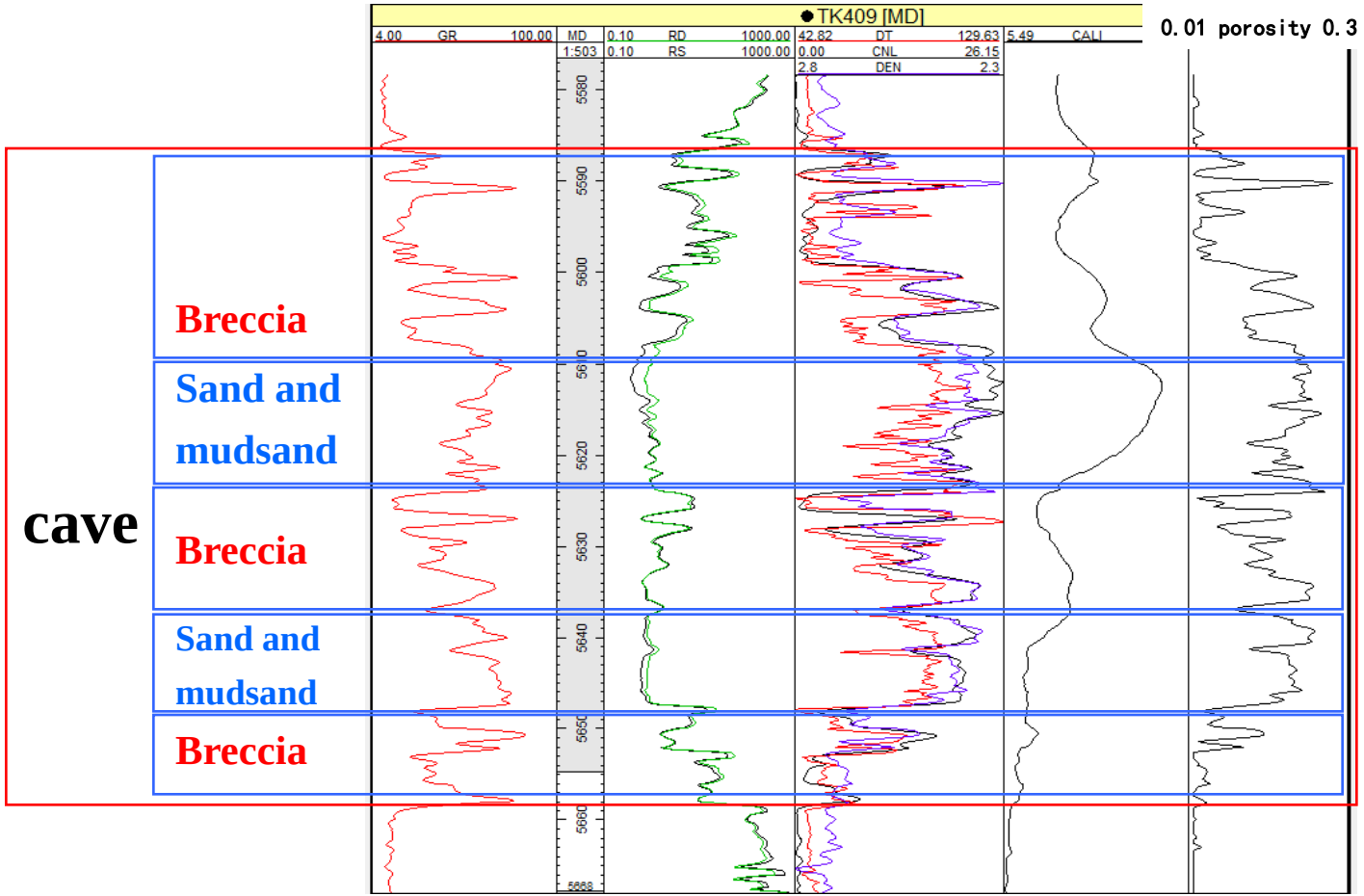
Fillings	GR	CAL	RS	RD	AC	DEN	CNL
Sand and mudsand	>30	5.6-9.2	< 200	<100	>55	<2.7	>8
Breccia fillings	5-30	5.6-9.2	200-400	100-600	40-55	2.2-2.8	0-8
Chemical fillings	5-15	5.6-8.5	300-400	200-700	45-65	2.1-2.9	0-8

The interpretation of porosity based on fillings

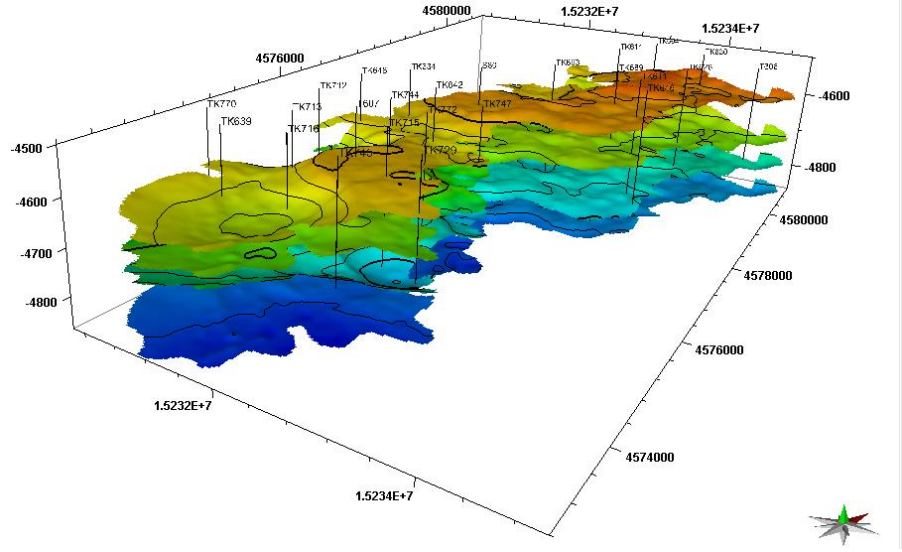
- **Breccia fillings**
  $\Phi = 51.263 * \rho_b + 2.3057 * \Delta t - 264.56$
- **Sand and mudsand**
  $\Phi = 0.624 * \Delta t - 0.086 * Vsh$
- **Chemical fillings**
  $\Phi = 46.332 * \rho_b + 1.863 * \Delta t - 176.34$

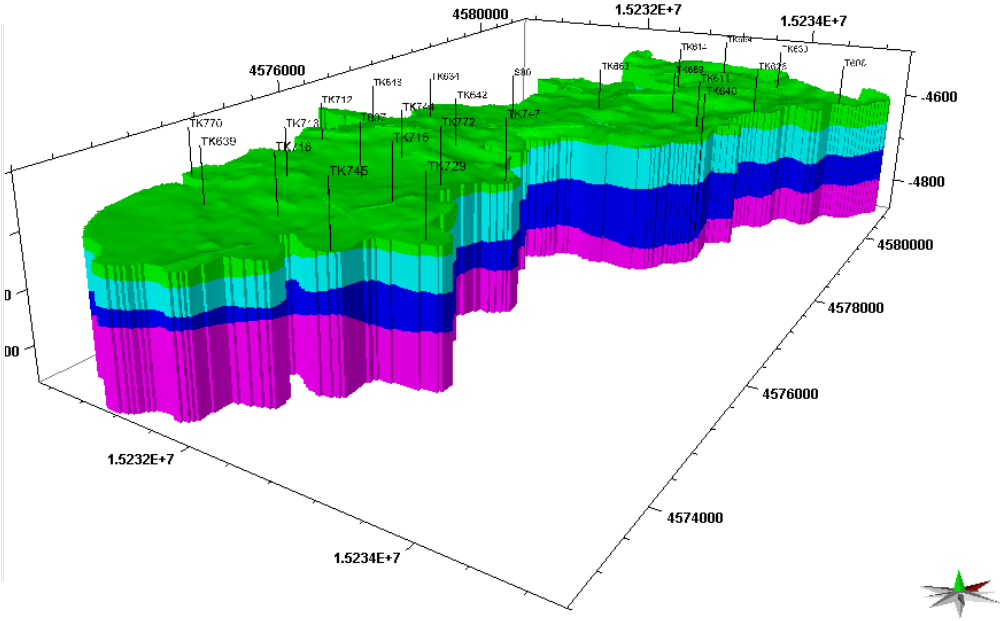


The interpretation of porosity based on fillings

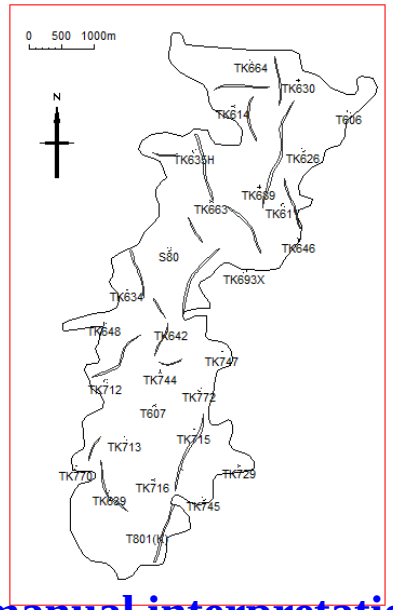


Structural modeling

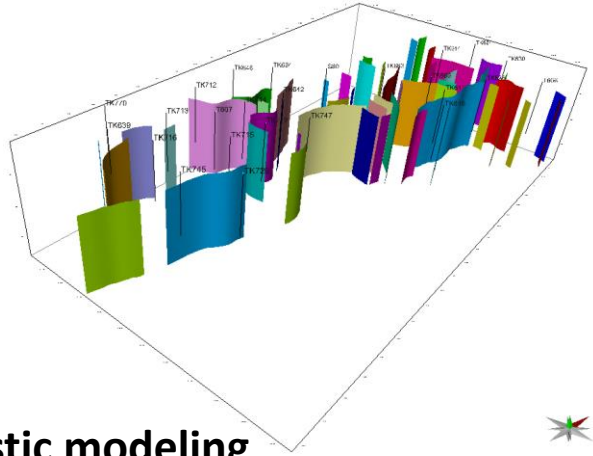




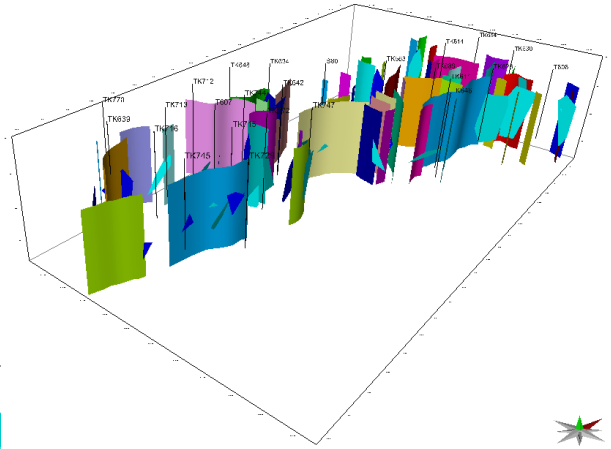
Fracture modeling

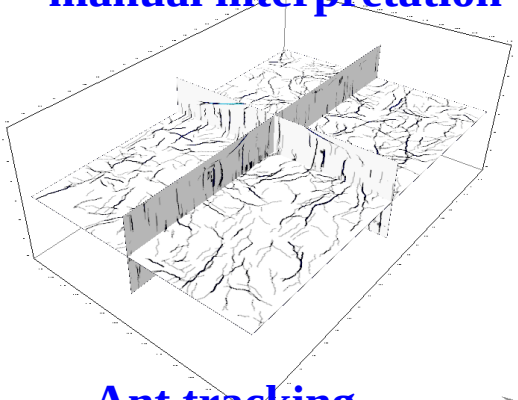


manual interpretation

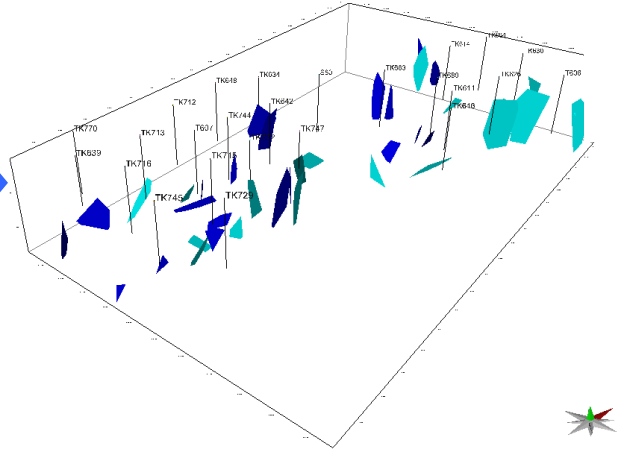


Deterministic modeling

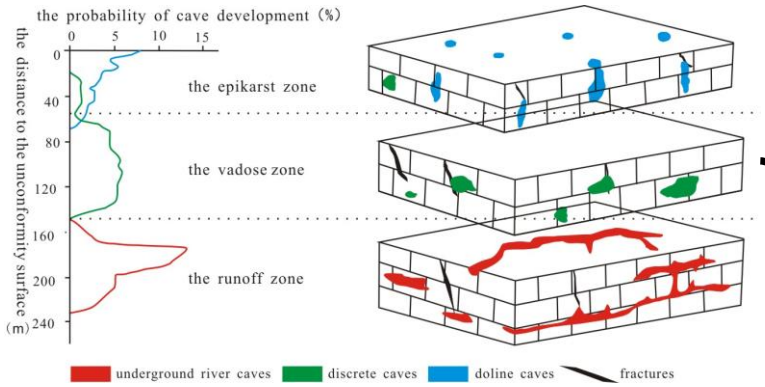




Ant tracking



Cave modeling



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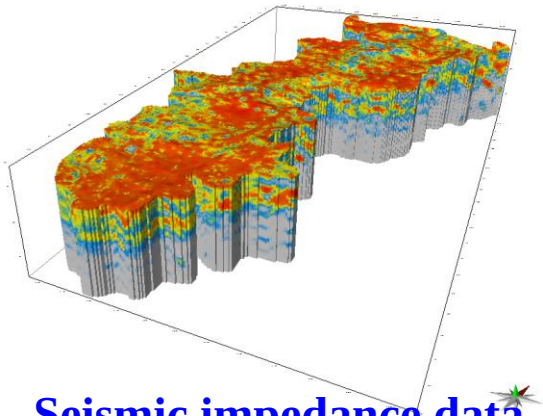
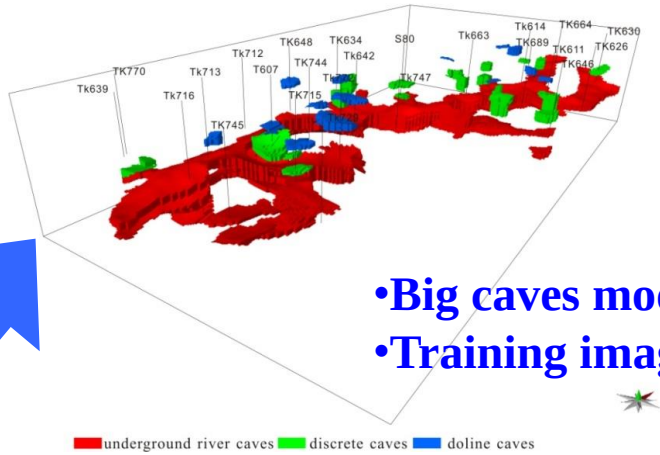
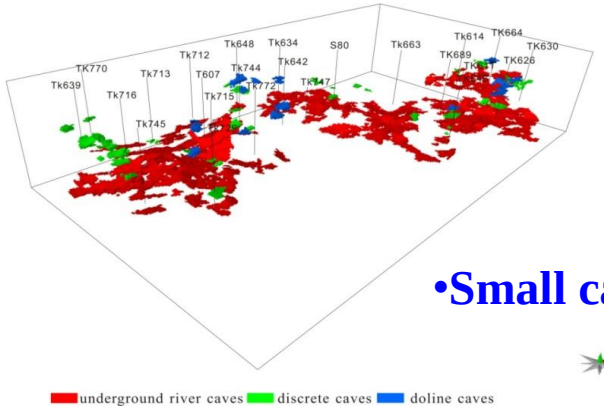


Seismic impedance data



- Big caves model
- Training images for mps

Multi-point simulation



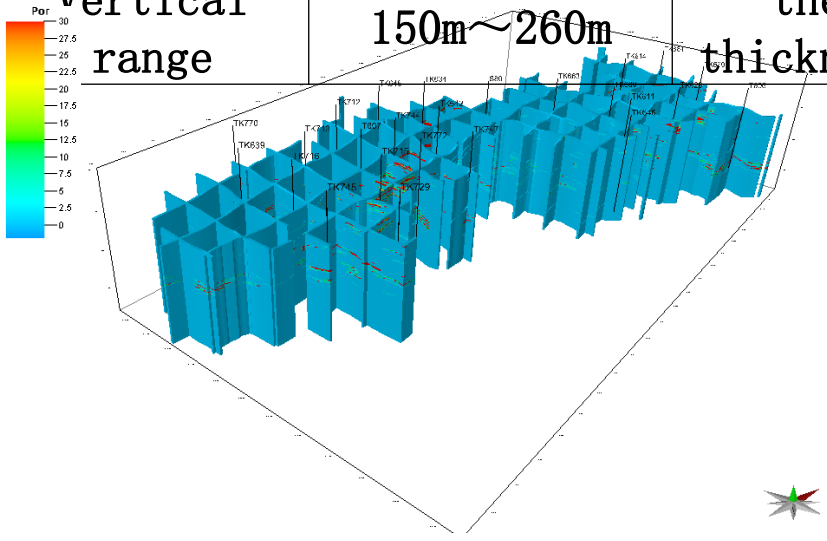
- Small cave model

Porosity modeling

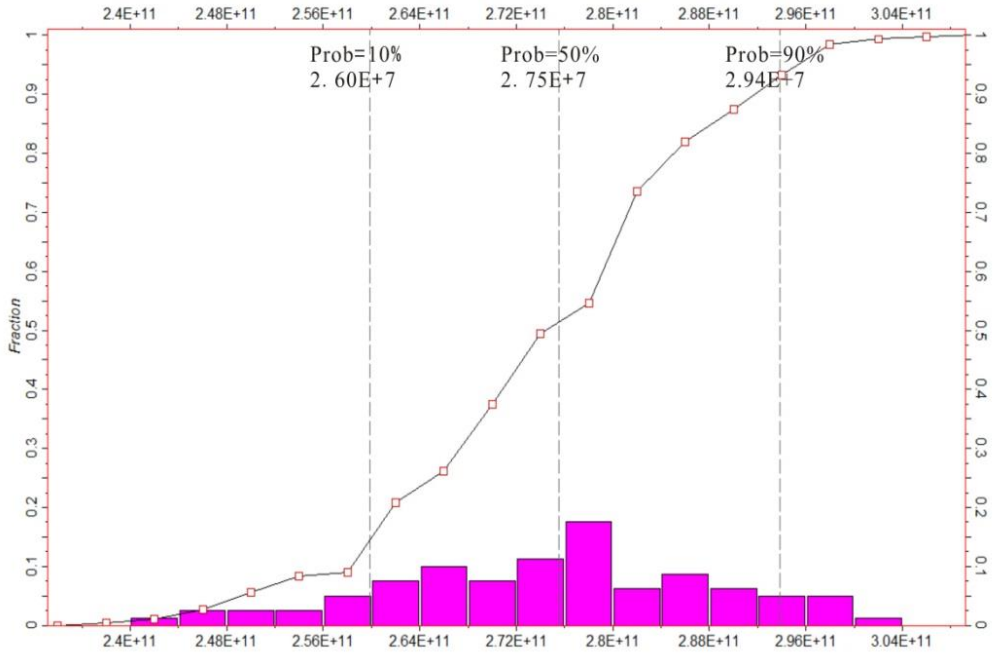
The semivariogram(underground river)		
Major direction	NNE、NNW	the trend of underground
Major range	600m～4000m	the length
Minor range	50m～120m	the wide
Vertical range	10m～30m	the thickness

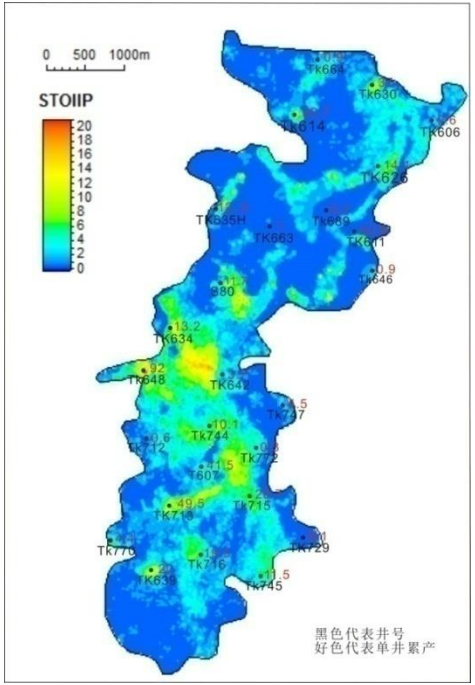
The semivariogram(isolated caves)		
Major direction	-----	----
Major range	160m～400m	the length
Minor range	100m～200m	the wide
Vertical range	70m～50m	the thickness

The semivariogram(doline caves)		
Major direction	-----	----
Major range	100m～170m	the length
Minor range	80m～120m	the wide
Vertical range	150m～260m	the thickness



Reserve calculation





Contents

- Introduction
- Data & Method
- Research Analysis and Results
- Conclusions

Conclusions

- **According to the modern karst and analogous outcrop,we defined the effective reservoir as isolated cave, underground river, doline cave and fracture.**
- **Using “point-line-surface” multidirectional interaction, integrating cores, logging and seismic data,we identified different caves and summarized the karst pattern of fracture-cavity reservoirs in Tahe oilfield.**
- **On the basis of the outcrop and cores, we set up the criterion of identification of fillings ,and then we build the calculate formula based on different fillings.**
- **we build the cave models using deterministic method and the multi-point simulation. And the fracture model is built using deterministic method based on manual interpretation and ant tracking respectively.**
- **According to the size and shape of different karst facies ,we set up the parameters of semivariogram and established the porosity model**