3D Modeling of the Paleocave Reservoir in Tahe Oil Field, China*

Ma Xiaoqiang[1], Hou Jiagen[1], Liu Yuming[1], and Zhao Bin[1]

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[1]College of Geosciences, China University of Petroleum, Beijing, China (xiaoqiang_ma@sina.com)

Abstract

Paleokarst fractured-vuggy reservoirs are a type of non-stratified reservoir which has been modified intensely. Considerable development of pores, caves, fractures and severe heterogeneity are the prominent features of this type of reservoir, and the fractured-vuggy unit is the elementary characteristic allowing production. It is very difficult to build a precise model for paleokarst fractured-vuggy reservoirs. The Ordovician reservoir of the Tahe Oilfield, located on the north upwelling region of Tarim Basin, is a representative paleokarst fractured-vuggy reservoir. An effective workflow has been proposed to map the 3D modeling of such reservoirs.

In the hierarchical framework of planar compartmentalization of karst paleogeomorphy and vertical division in the karst zone, obeying the developmental pattern of paleokarst for guidance and importing the thought of "facies-controlled modeling", we obtained abundant identification data of the reservoir by integrating cores, well-logs (including image-logs) and rock physics. By combining the physical properties, the identification data could be transformed to the "reservoir facies" data, then the method of collaborative stochastic simulation under dual restraints from "reservoir facies" and optimized seismic attributes (e.g. wave impedance, etc.) was adopted to develop a reservoir-scale 3D model of the Tahe Oil Field paleokarst fractured-vuggy reservoir. For the internal fabric of fractured-vuggy units, we managed to obtain training images via the integrated study on outcrop and seismic facies to characterize complex spatial structure and geometric shape, then made use of the training images to build a more accurate reservoir model by multiple-point statistics. The synthetic display of two different scale models gives a more detailed characterization of the paleokarst reservoir, and our method of modeling for paleokarst fractured-vuggy reservoirs may offer a direction to other similar targets.

Reference

Loucks, R.G., 1999, Paleocave carbonate reservoirs: Orgins, burial-depth modifications, spatial complexity, and reservoir implications: AAPG Bulletin, v. 83/11, p. 1795-1834.

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Ma Xiaoqiang

25 April 2012

Co-authors: Hou Jiagen, Liu Yuming, Zhao Bin

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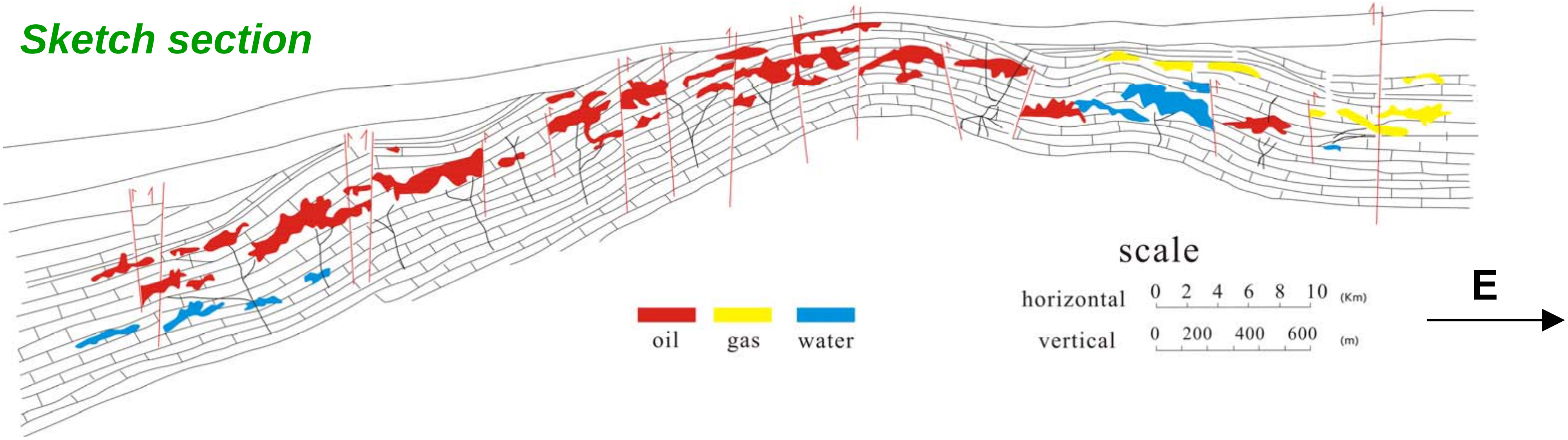
Sketch section

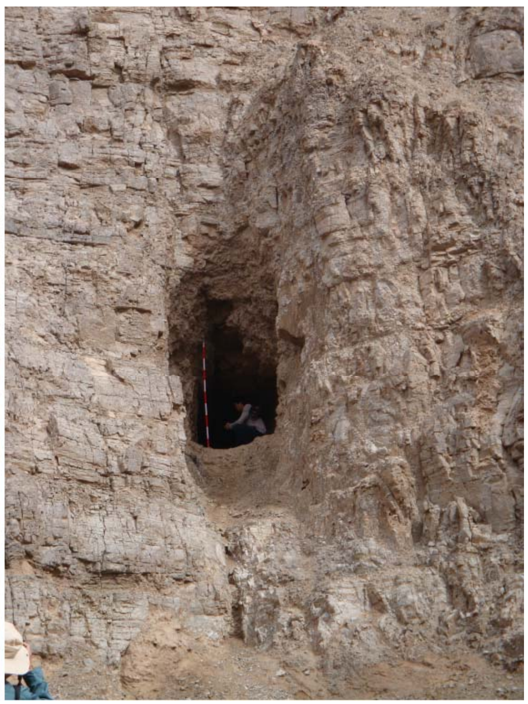


- ➔ **Reformed by Karstification**
- ➔ **Severe Heterogeneity**
- ➔ **Multi-scale**

1、Introduction

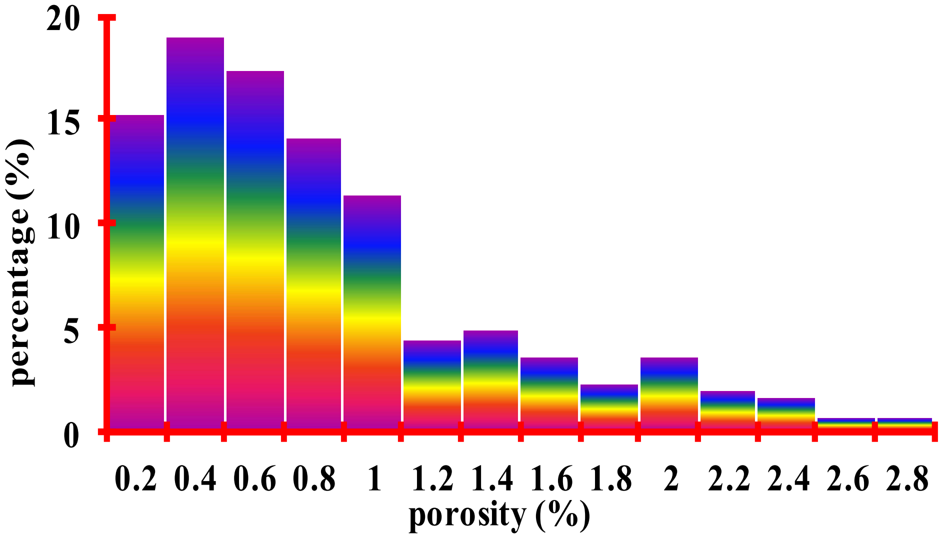
Outcrops

Paleocaves



North of Tarim basin

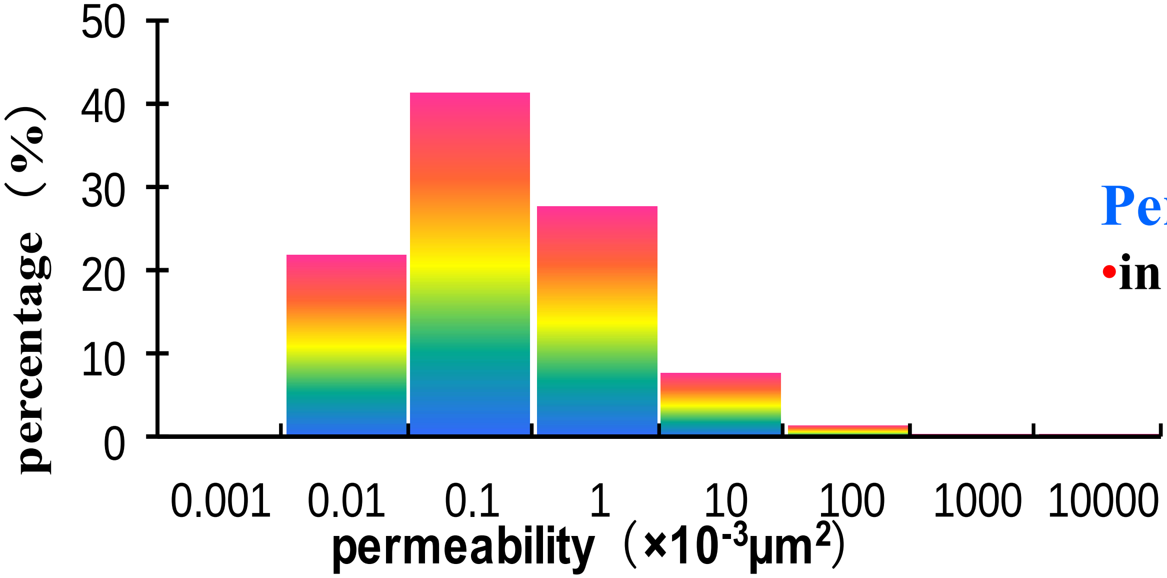
1、Introduction



Porosity

- in the region of 0.01 ~ 10.8%
- the average is 0.92%
- the samples which porosity is less than 1% accounted for 67.6%

(from 4740 pieces of samples)



Permeability

- in the region of $0.001\text{-}5052\times10^{-3}\mu m^2$

(from 4391 pieces of samples)

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2、Analysis

Key question:

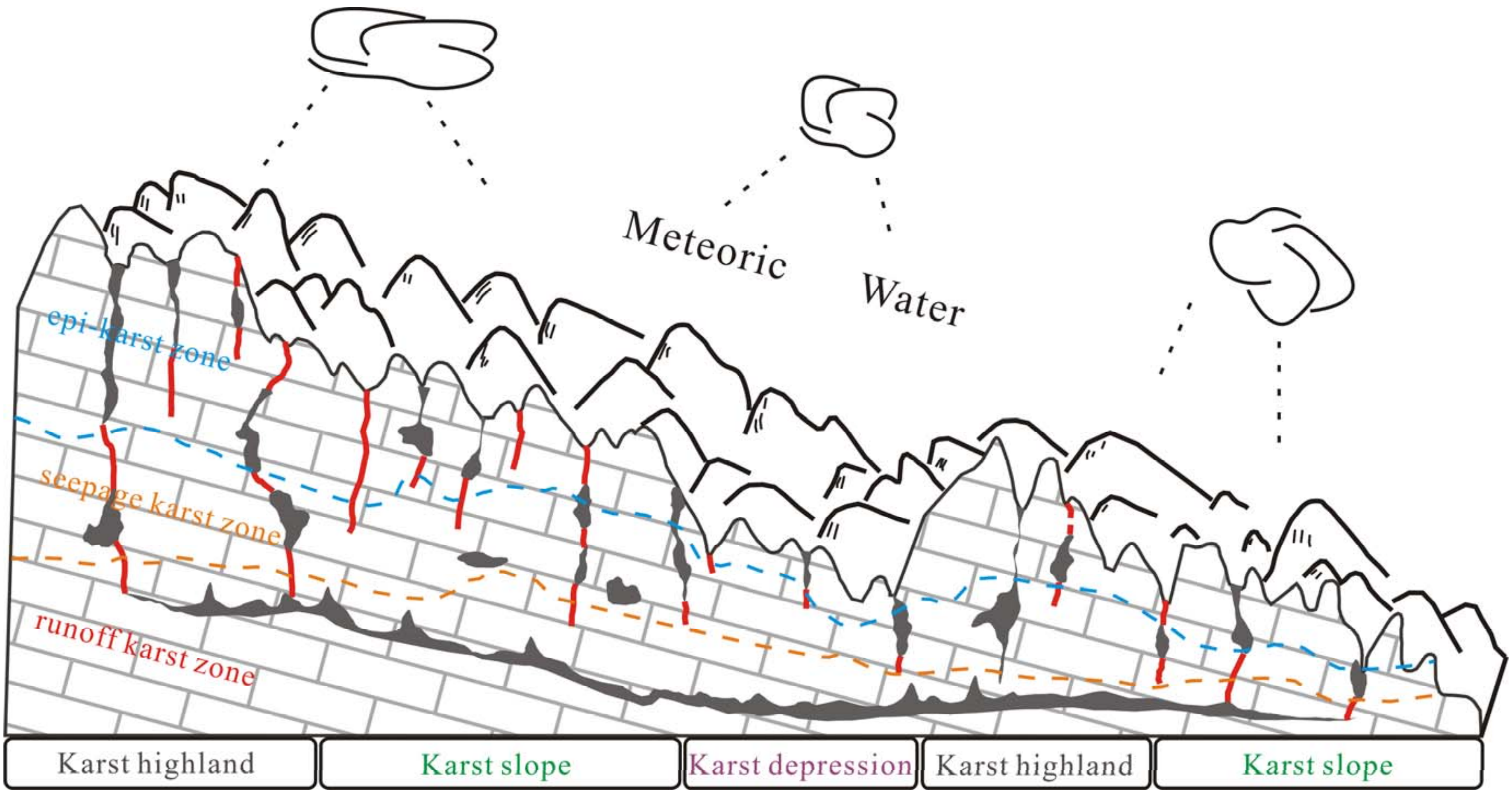
❋ Control of Stochastic Simulation

What should we do ?

Karstification & Geophysics

2、Analysis

2.1 Karstification



Characteristic of karstcave development

2、Analysis

2.1 Karstification

Activity of Karst water

High land → slope → depression

Epi-karst zone → seepage karst zone → runoff karst zone

Cave development and productivity in different paleogeomorphic area

	Cave quantity in drilling	Cave thickness (m)	well		Cumulative recovery	
			Amount	Percentage	Amount ($\times 10^4$t)	Percentage
High land	70	0.3-70	30	38%	427	63%
slope	90	0.37-72	44	55%	244	36%
Depression	14	1-19	5	7%	2	1%

2、Analysis

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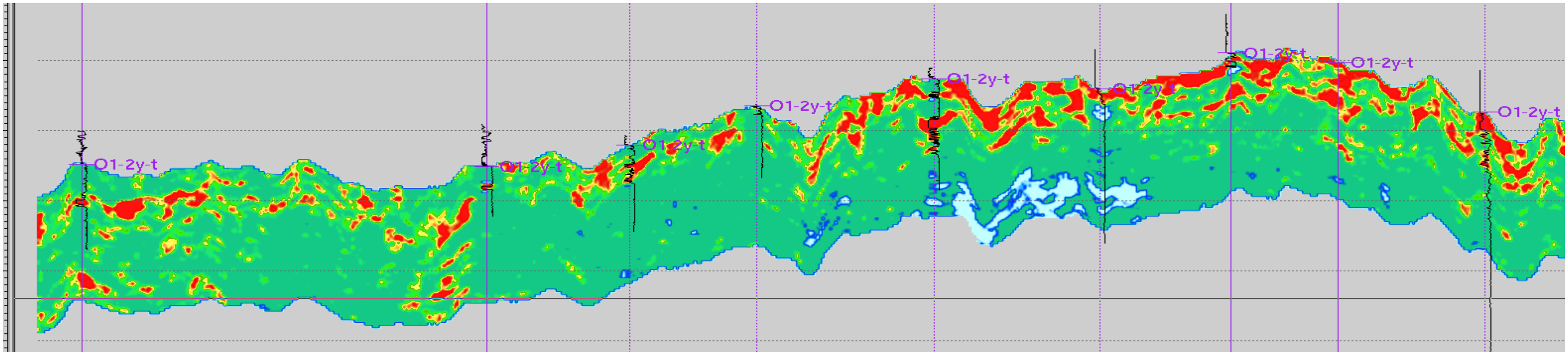
2.2 Geophysics

1）P-impedance

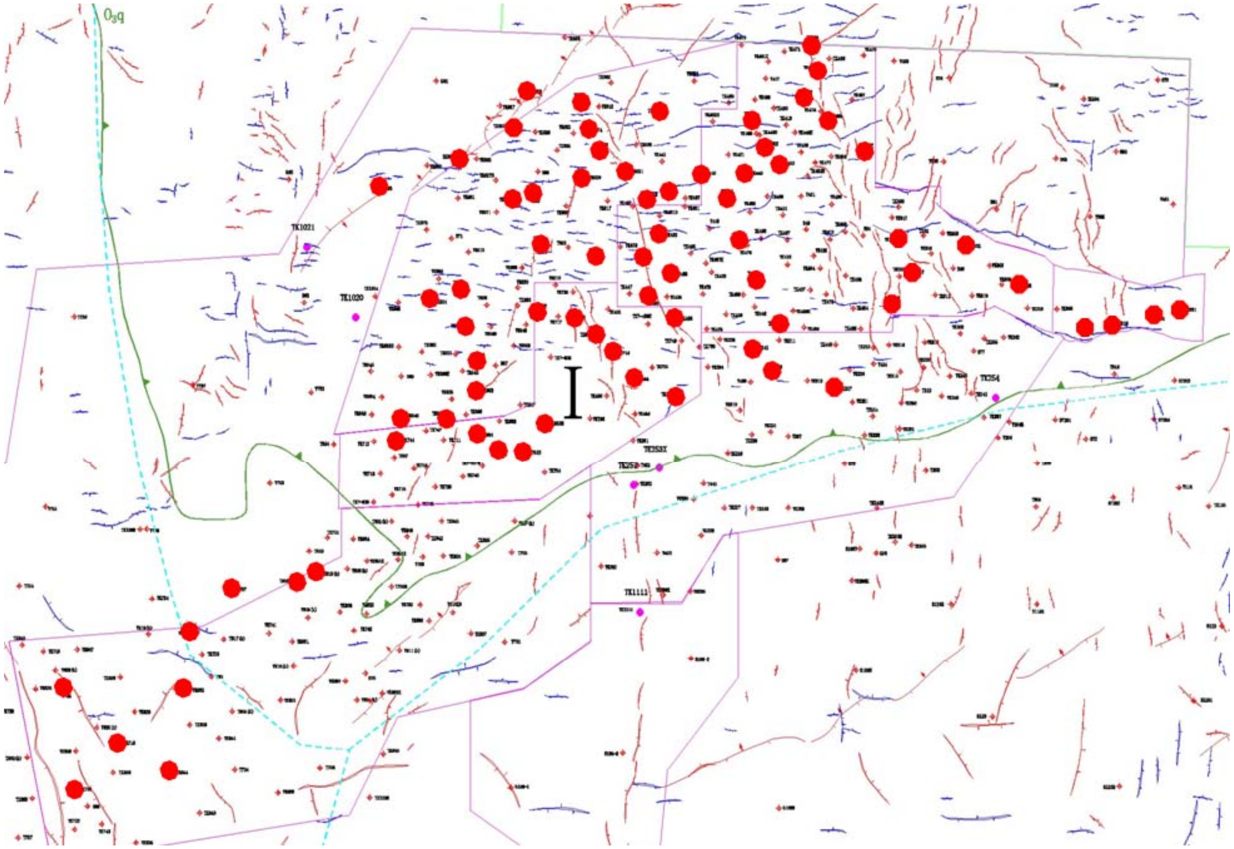


- ➔**Most of impedance responsed by caves are lower than 16000 g/cm^3·m/s**
- ➔**More than 87% caves in well 10000 g/cm^3·m/s - 16000 g/cm^3·m/s**

2、Analysis

2.2 Geophysics

2）Coherence



Faults → cave

● **Well of mudloss or drilling pipe fall down**

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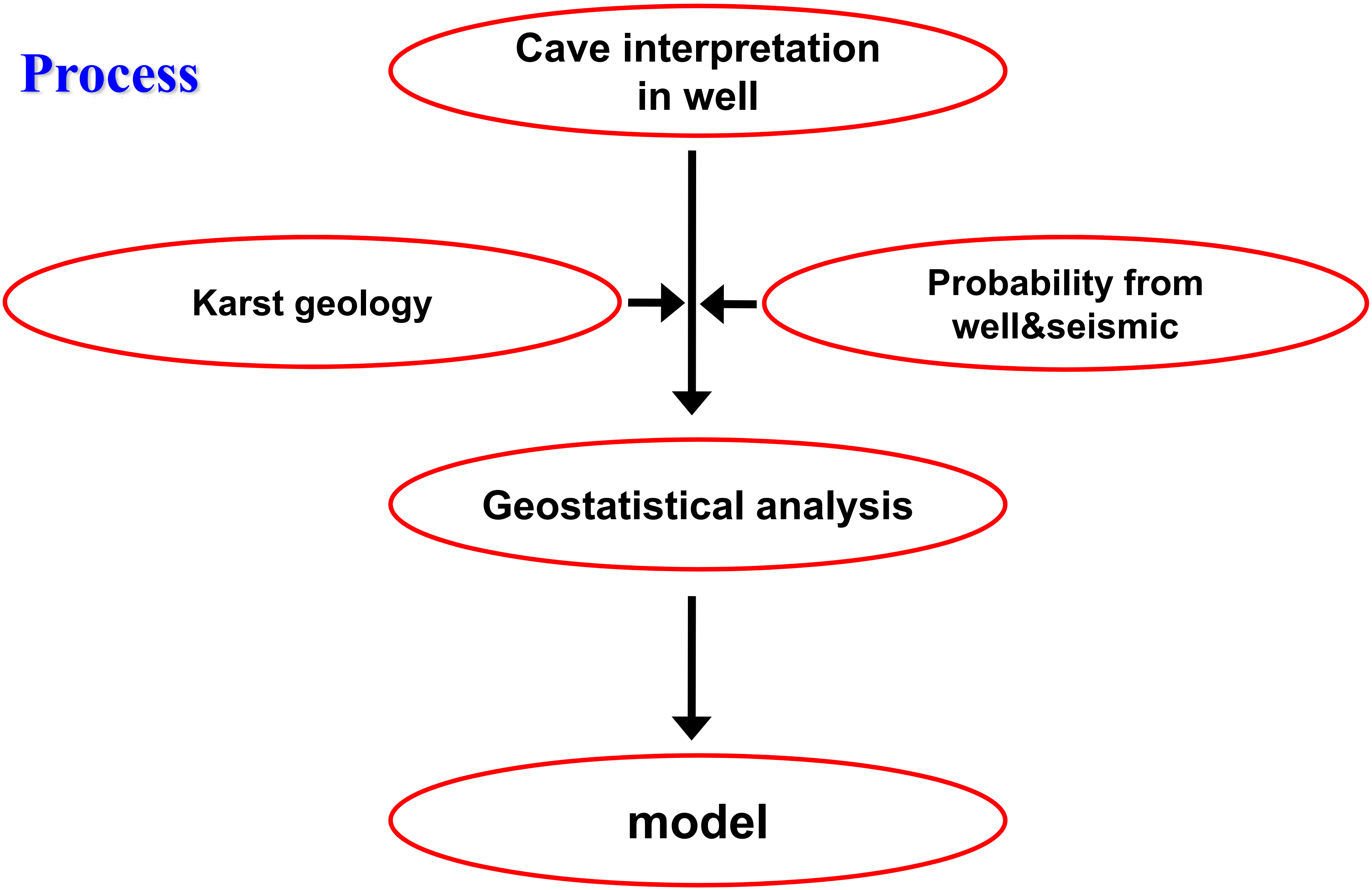
3、Modeling

Process



3、Modeling

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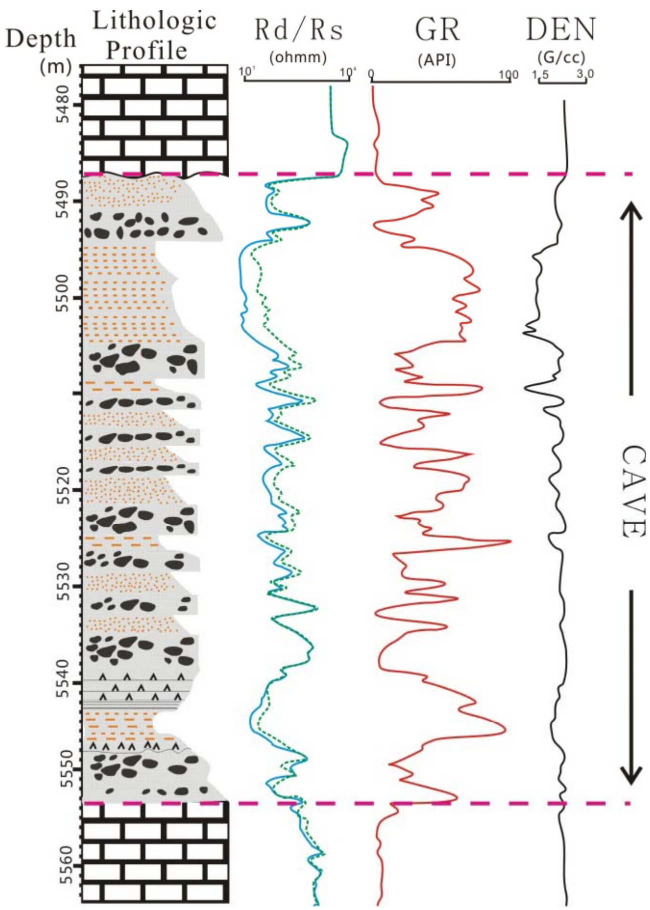
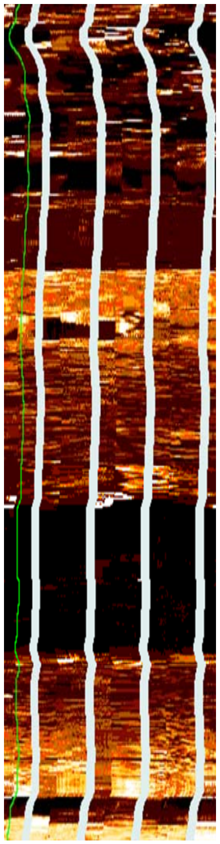
3.1 Cave identification in well



Log

Cores



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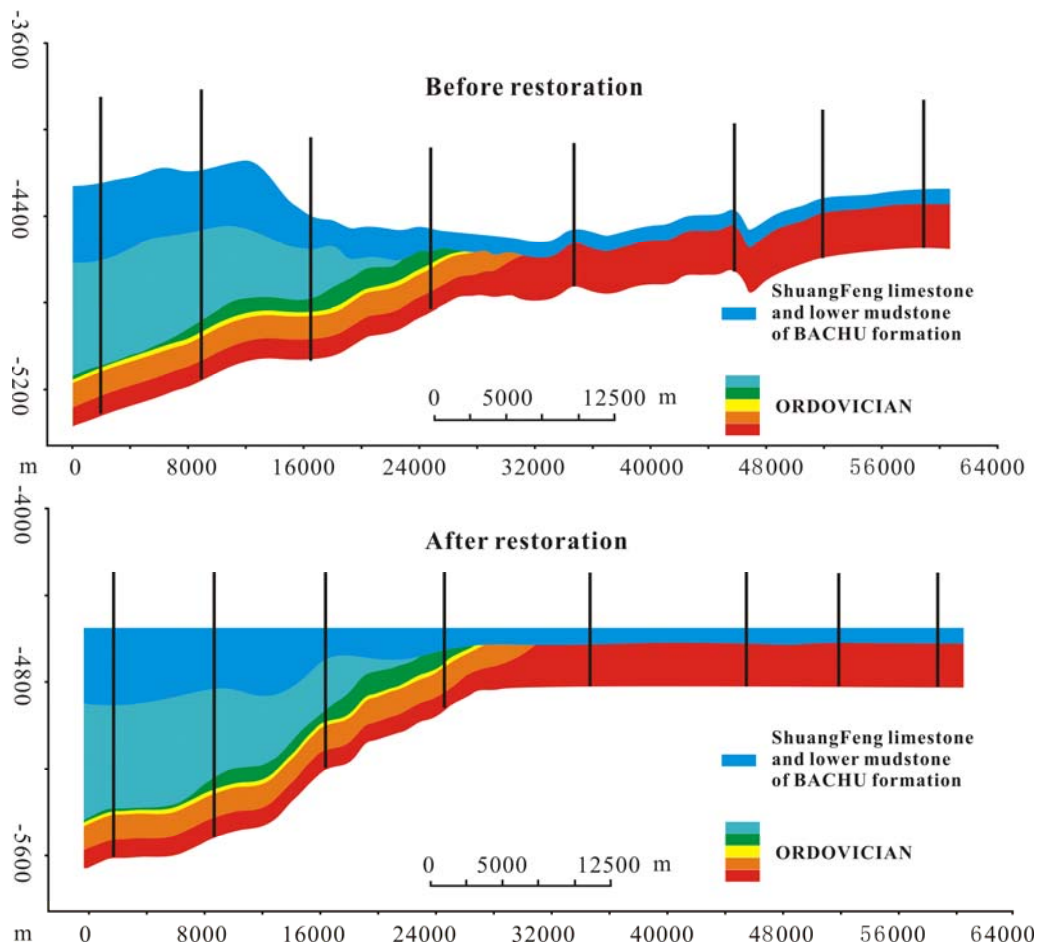
3、Modeling

3.2 Interwell uncertainty handling



Restoration of paleogeomorphology

Paleogeomorphology

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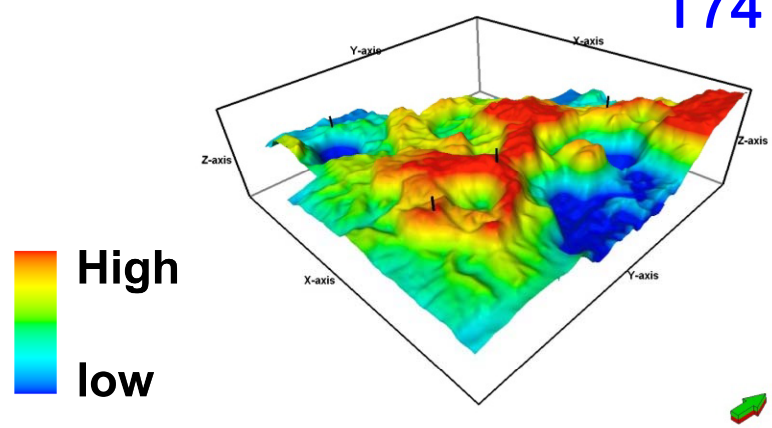
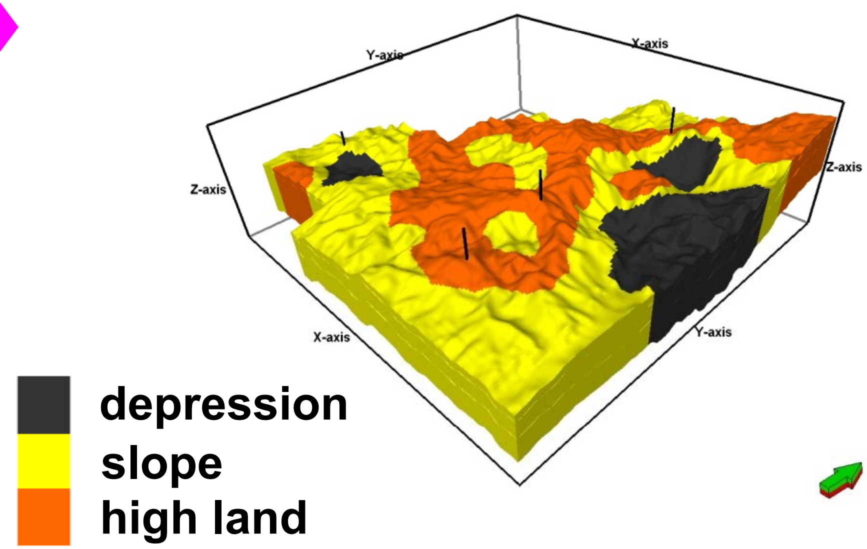


model



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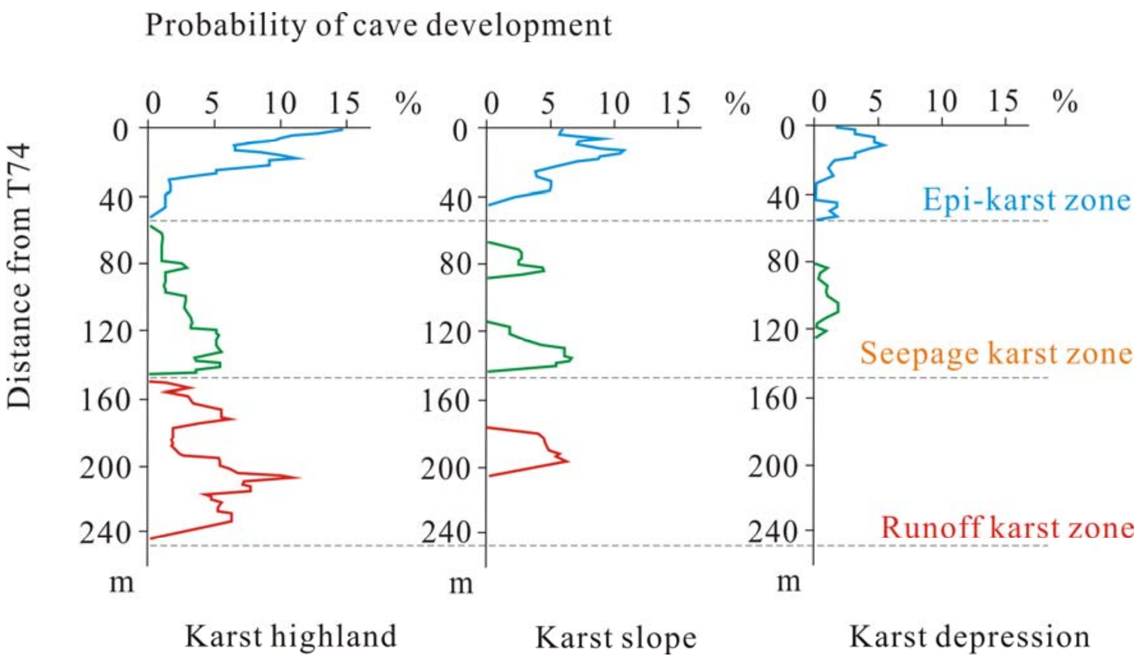
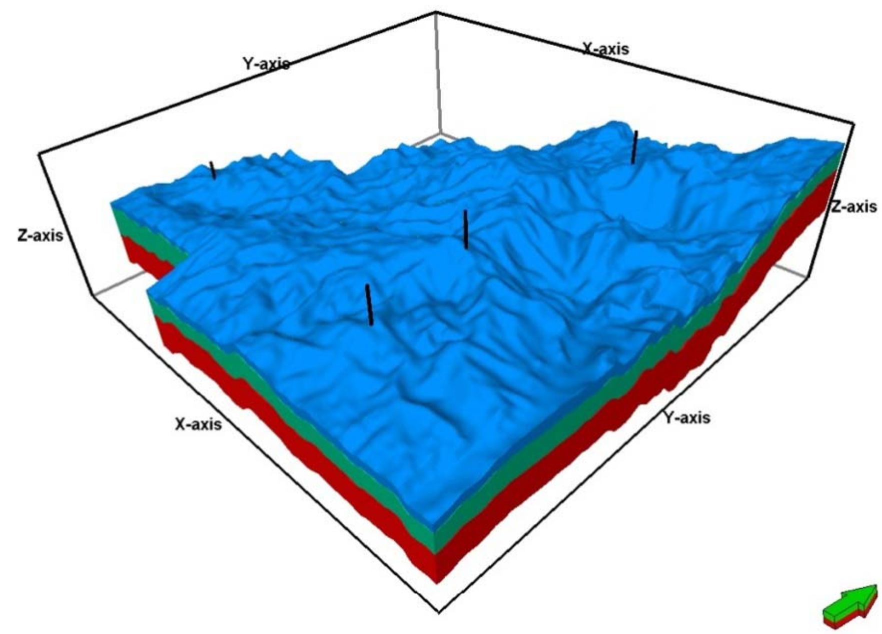
3、Modeling

Karst zone

3.2 Interwell uncertainty handling





- Epi-karst zone（0-60m）
- Seepage karst zone（60-150m）
- Runoff karst zone（150-245m）

epi-karst zone
seepage karst zone
runoff karst zone

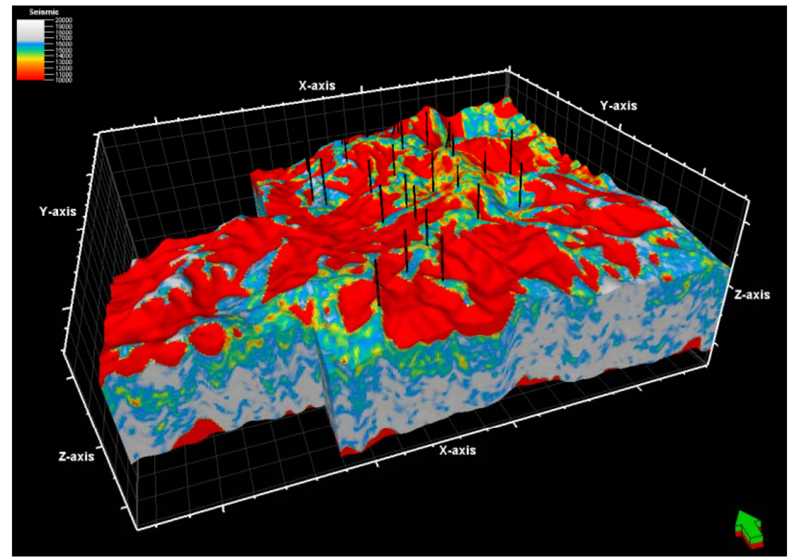
3、Modeling

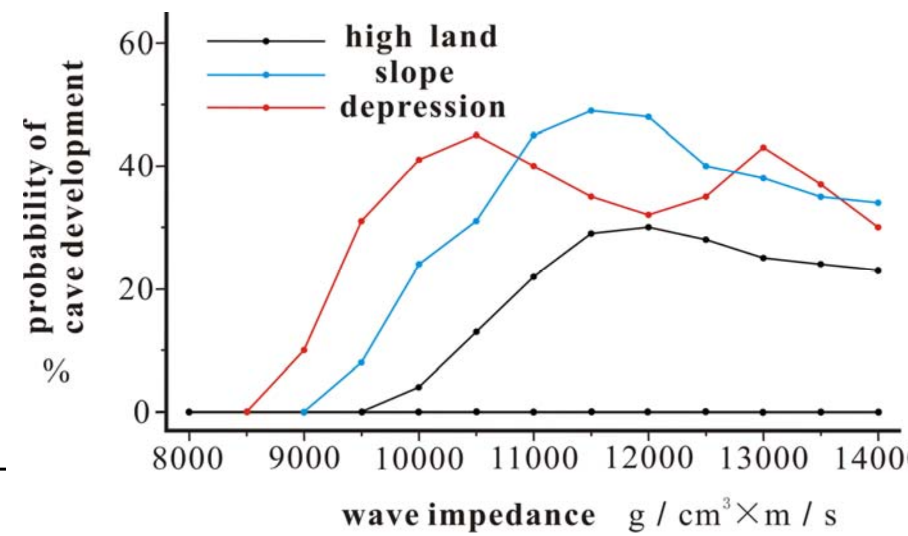
3.2 Interwell uncertainty handling

Wave Impedance data → probability

Karst zone	Paleogeomorphology	P-impedance (g/cm³·m/s)	Probability of cave development
Epi-karst zone	High land	10250~16000	0.1~0.3
	Slope	9600~16000	0.1~0.5
	Depression	9000~15500	0.1~0.5
Seepage karst zone	Highland	10500~16000	0.1~0.5
	Slope	13000~15000	0.1~0.2
	Depression	15200~16500	0.1~0.55
Runoff karst zone	High land	15400~16100	0.1~0.3
	Slope	15000~16200	0.1~0.2
	Depression	14500~16000	0.1~0.3

Wave Impedance

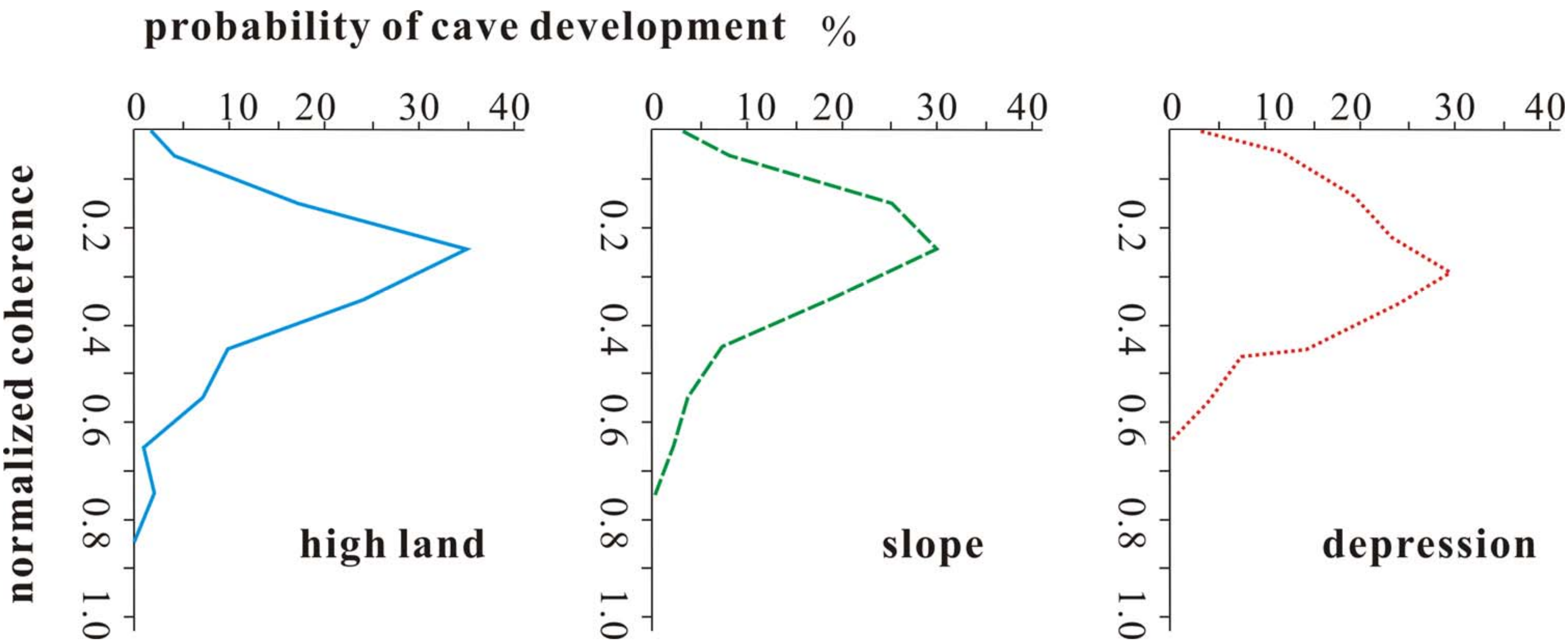




3、Modeling

Coherence

3.2 Interwell uncertainty handling



3、Modeling

3.3 Algorithm application

SICoSimTR

Sequential indicator co-simulation with a trend

- consider the second variable
- integrate probability information from well and seismic
- Reflect prior geological concept

3、Modeling

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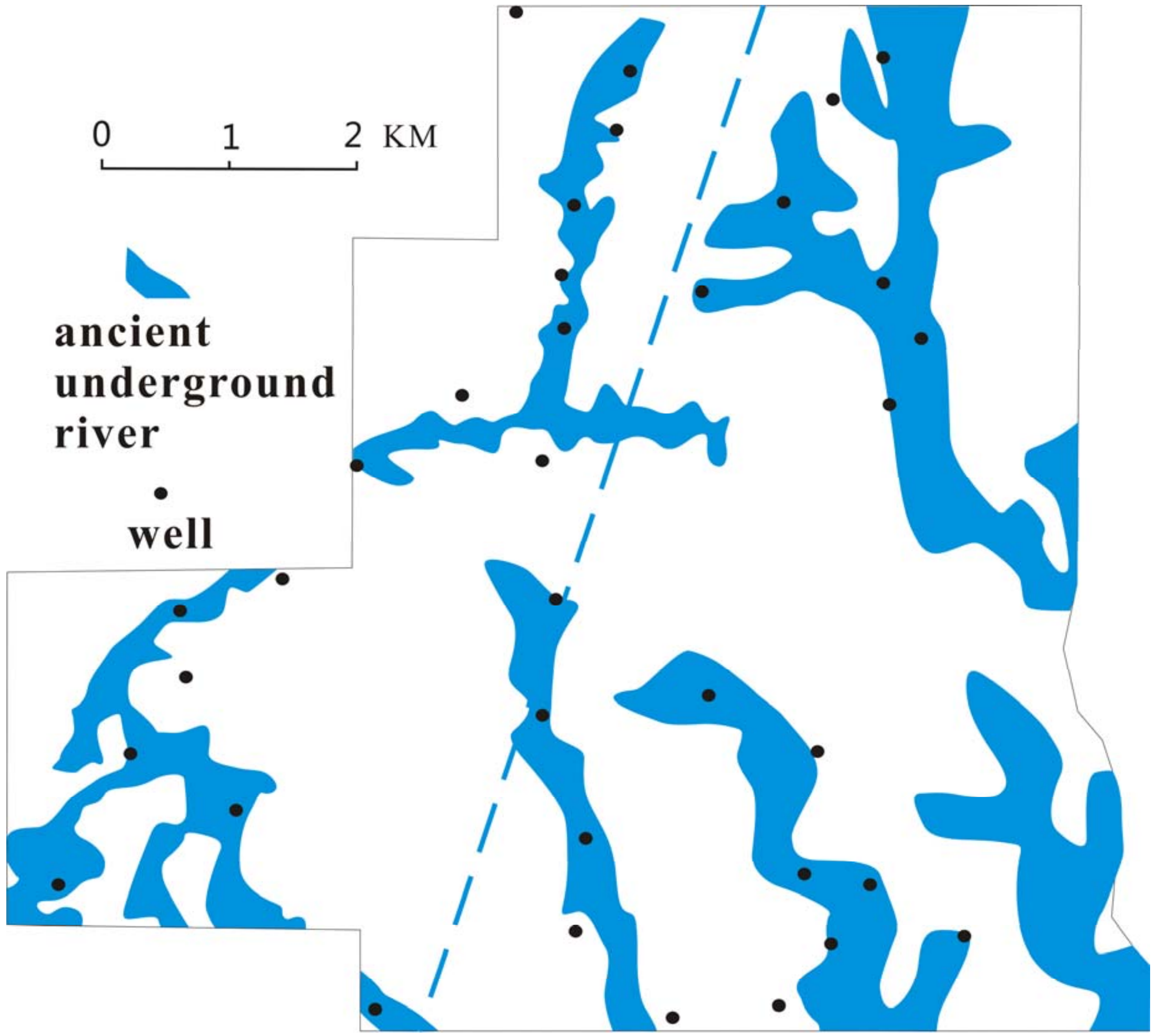
3.4 Variogram settings

- **Regional Variogram**
  2 directions
- **Range**
  Shape and scale



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3.4 Variogram settings

	Karst zone	Paleogeomorphology	Parameters			
			Direction of long-axis range (°)	Long-axis range (m)	Short-axis range (m)	Vertical range (m)
Eastern block	Epi-karst zone	High land	NW 315	775.2	458.0	15.1
		Slope	NW 313	487.6	309.8	8.2
		Depression	NW 316	171.5	94.7	4.9
	Seepage karst zone	High land	NW 316	1076.6	646.8	25
		Slope	NW 309	915.5	752.1	14
		Depression	NW 312	274	192.4	7.2
	Runoff karst zone	High land	NW 316	1004.9	584.0	10.6
		Slope	NW 309	873.2	483.5	7.5
		Depression	NW 312	221.3	192.4	2.8

3、Modeling

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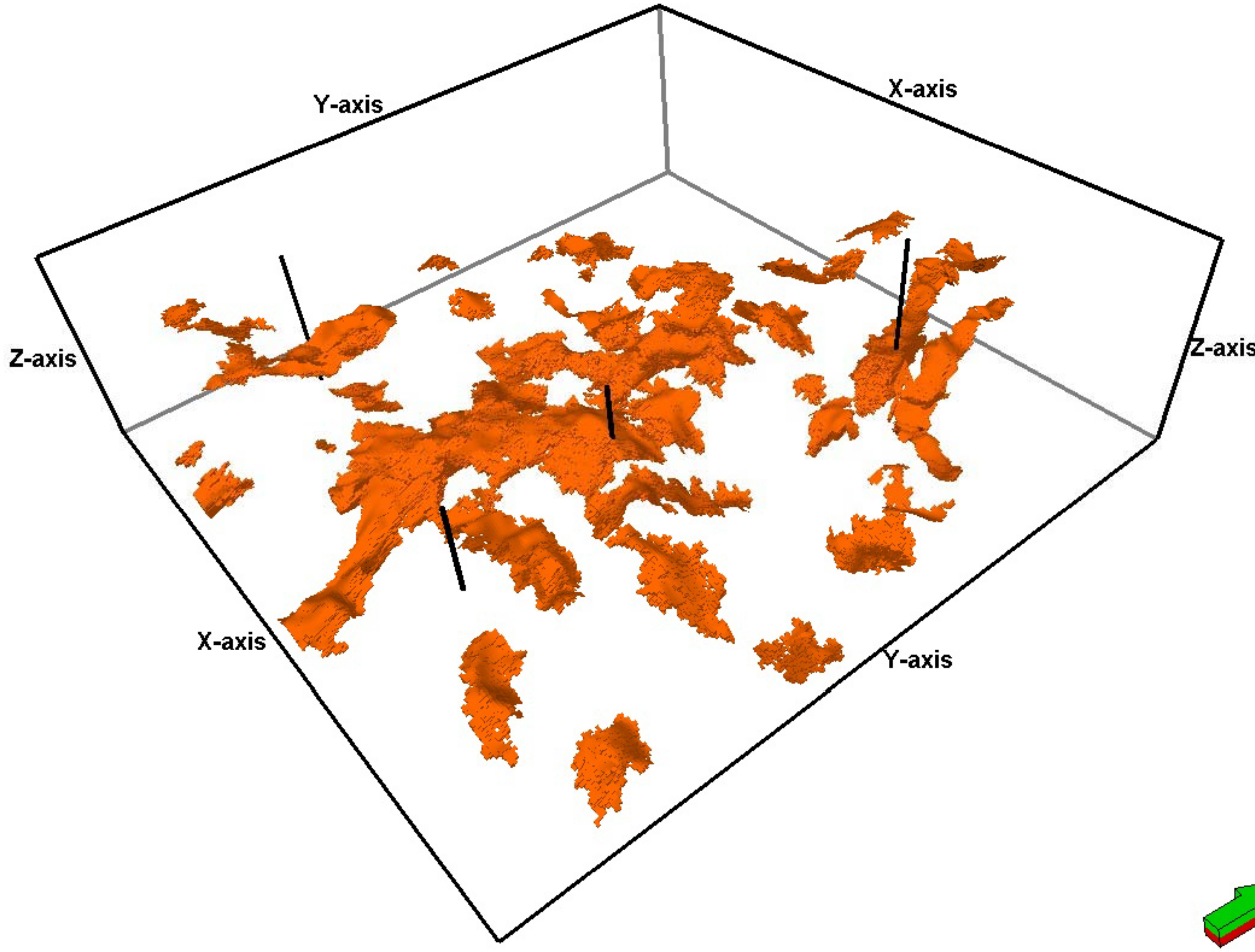
3.5 Results



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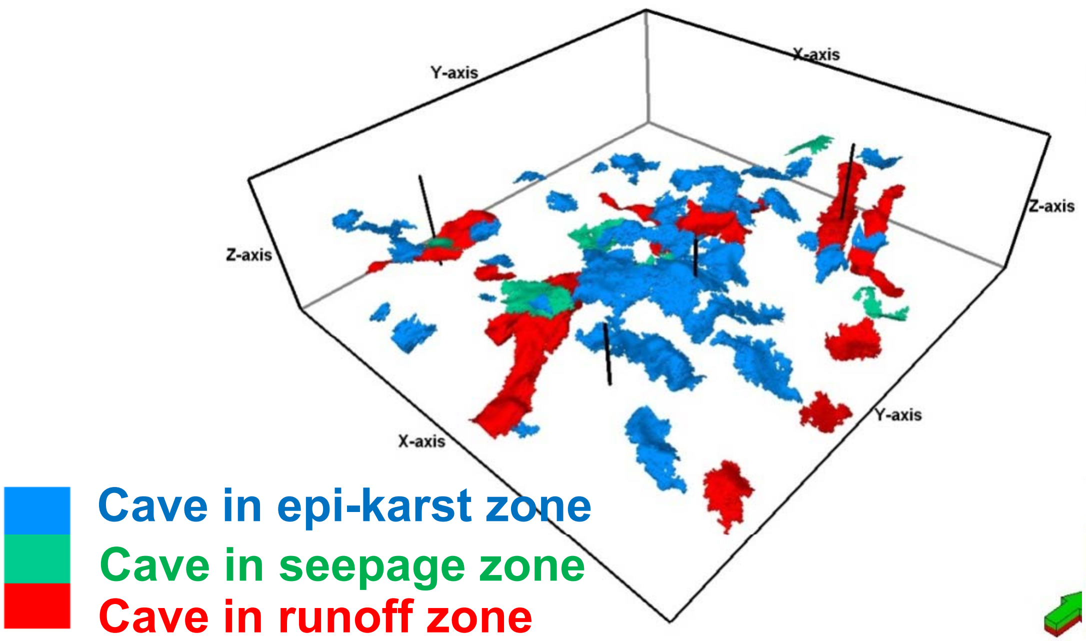
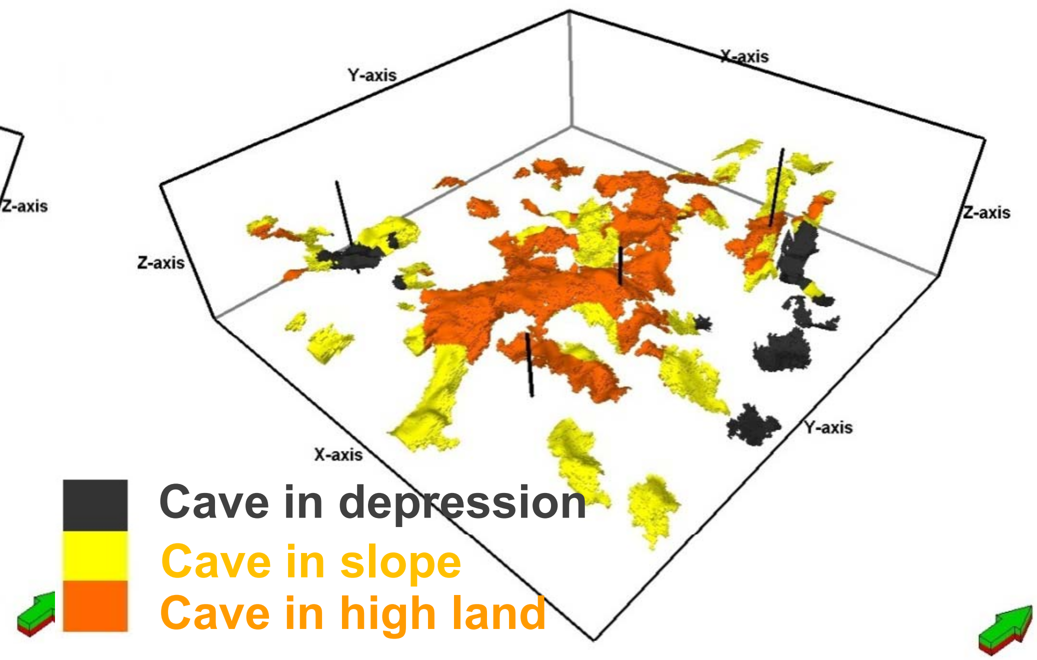
3.5 Results





- According to law of karst development
- Integrating the seismic information
- Regional variogram

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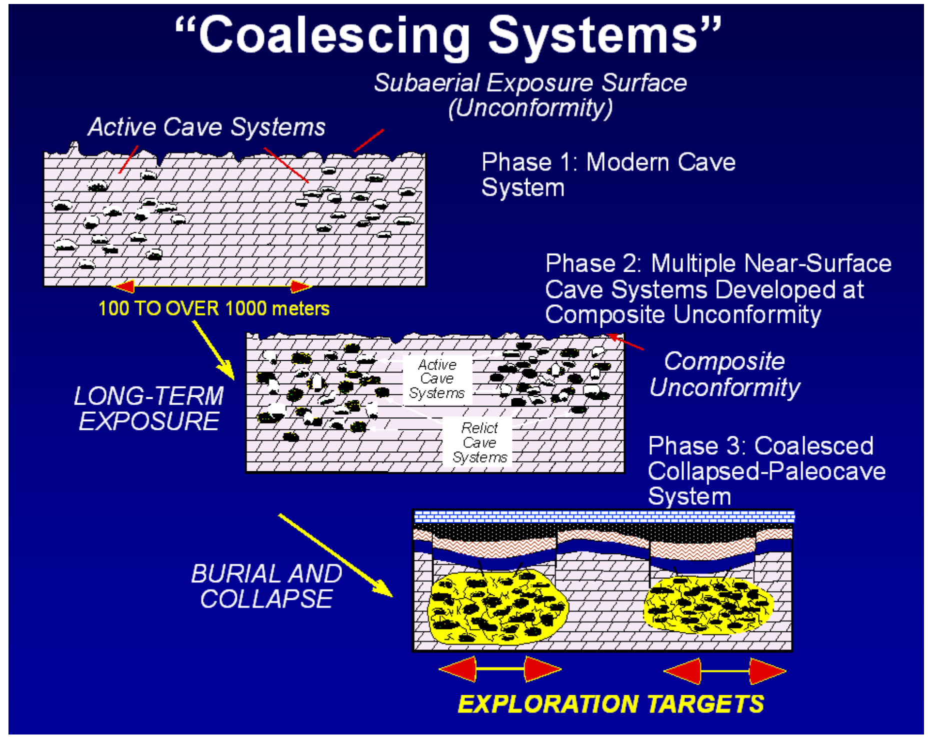
1、Architecture



Loucks, 1999

2、Multiple-point geostatistics