[PS]Recognition Technology and Applications of Multi-Genesis Superimposed Karst Reservoir in Tarim Basin - A Case Study on Weathering Crust in Ordovician Yingshan Formation of Tazhong Area*

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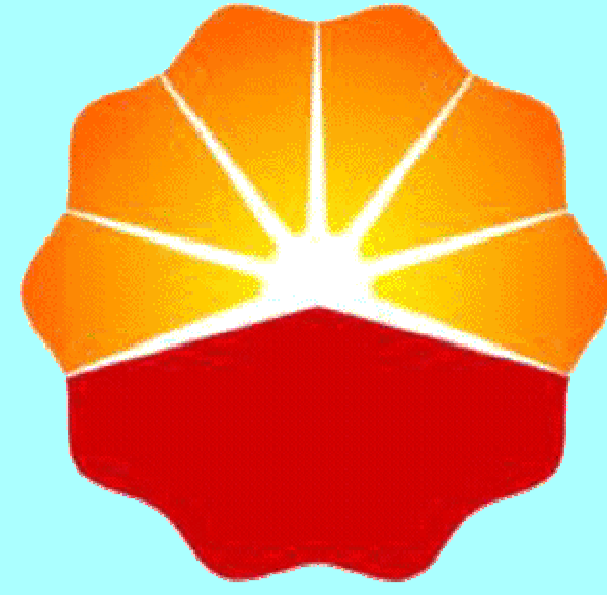
Abstract

Large-scale karst-fractured-cave reservoirs were developed in the weathering curst of Ordovician Yingshan Formation in the northern slope of Tazhong area, which was formed by karstification of two stages: the first stage was karstification of weathering curst that was controlled by karst palaeogeomorphology in mid-Caledonian, and the second stage was burial dissolution that was controlled by fault-fracture network in early Hercynian. This set of reservoir was formed by multi-stages and characterized by multi-types, which result the complexity in the seismic identification for reservoirs. Taking the reservoir evolution as the main line, seismic-response mode of reservoirs and its geological connotation have been confirmed by forward modeling in this paper, based on the genetic types and genetic models of reservoirs. The distribution rules of multi-genesis superimposed karst reservoirs have been described by types and scales according to palaeogeomorphology recovery technology, the well-seismic inversion technology (constrained by multi-attributes) for pore-cave reservoir prediction in weathering crust, the intrinsic correlation calculation for large-scale fracture detection, pre-stack seismic of anisotropy for small-scale fractures detection and etc, where the drilling rate of deployed wells for fractured-cave reservoirs by this method was up to 100%.

Recognition Technology and Applications of Multi-Genesis Superimposed Karst Reservoir in Tarim Basin
---A case study on weathering crust in Ordovician Yingshan Formation of Tazhongarea

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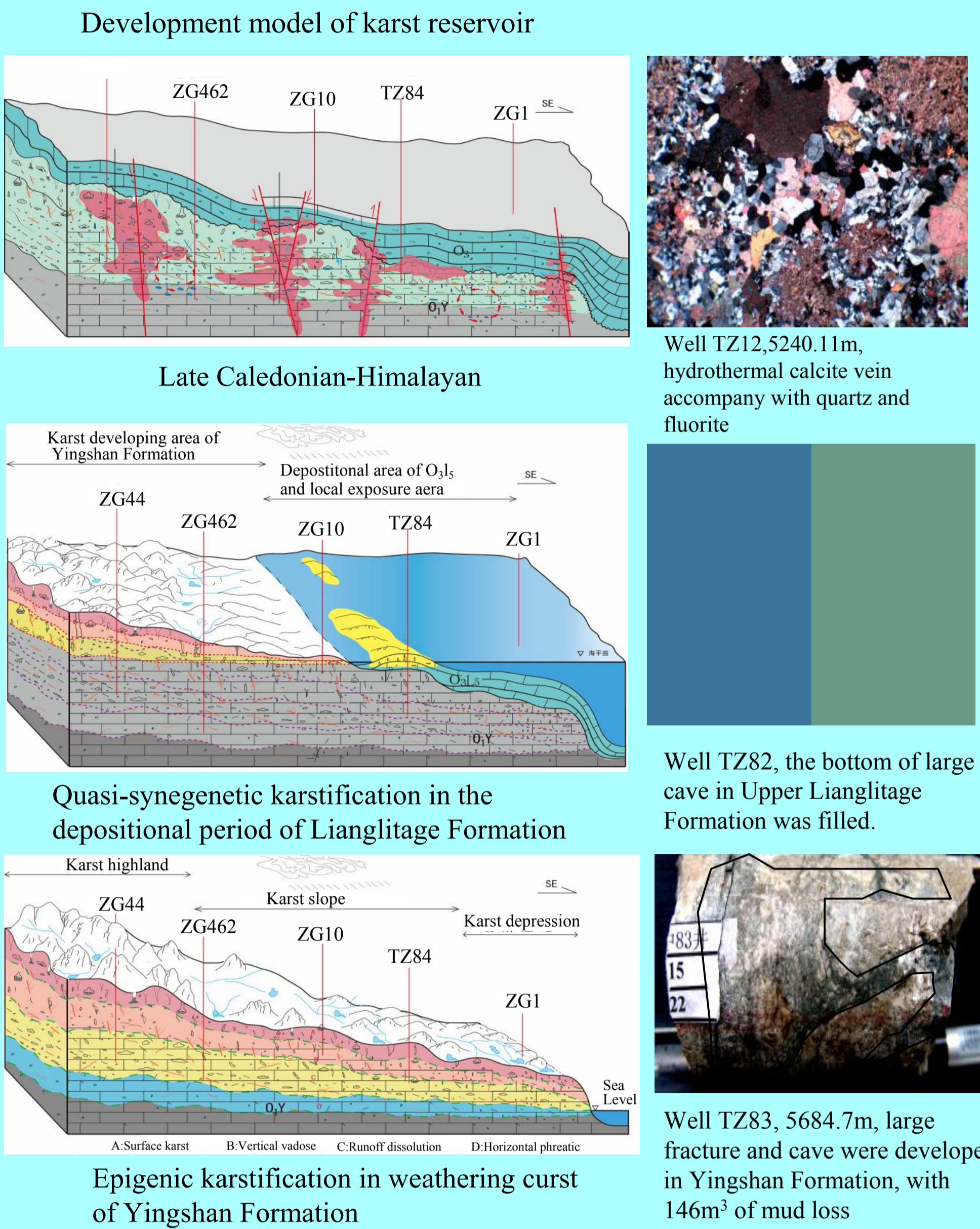
1. Introduction

Large-scale karst-fractured-cave reservoirs were developed in the weathering curst of Ordovician Yingshan Formation in the northern slope of Tazhong area, which was formed by karstification of two stages: the first stage was karstification of weathering curst that was controlled by karst palaeogeomorphology in mid-Caledonian, and the second stage was burial dissolution that was controlled by fault-fracture network in early Hercynian. Formed by multi-stages, the reservoir was characterized by multi-types, which result the complexity in the seismic identification for reservoirs. Taking the reservoir evolution as the main line, seismic-response mode of reservoirs and its geological connotation have been confirmed by forward modeling in this paper, based on the genetic types and genetic models of reservoirs. The distribution rules of multi-genesis superimposed karst reservoirs have been described by types and scales according to palaeogeomorphology recovery technology, the well-seismic inversion technology (constrained by multi-attributes) for porous reservoir prediction in weathering crust, the intrinsic correlation calculation for large-scale fracture detection, pre-stack seismic of anisotropy for small-scale fractures detection and etc, where the drilling rate of deployed wells for fractured-cave reservoirs by this method was up to 100% .

2.Development model of karst reservoir

2.1 Late Caledonian-Himalayan period, karst reservoir that was formed in earlier stage was modified by multi-stages structural fractures, burial dissolution and hydrocarbon accumulation, leading the favorable reservoir distributed along the faults and porous horizon of the earlier stage.

2.2 During the depositional period for the 5th Member of Lianglitage Formation, Yingshan Formation (under the sea level) and the 5th Member of Lianglitage Formation (around the sea level) have been dissolved because of sea level rise, forming the 2nd stage of karst system.

2.3 Before the deposition of Lianglitage Formation in Late Ordovician, Middle Ordovician-Upper part of Yingshan Formation have been eroded by tectonic uplift. The early depositional period of Lianglitage Formation, karstification was developed throughout Tazhong area forming large quasi-layered fractures and caves by stable tectonic subsidence.

Development model of karst reservoir

Late Caledonian-Himalayan

Quasi-synegenetic karstification in the depositional period of Lianglitage Formation

Epigenic karstification in weathering curst of Yingshan Formation

Well TZ12,5240.11m, hydrothermal calcite vein accompany with quartz and fluorite

Well TZ82, the bottom of large cave in Upper Lianglitage Formation was filled.

Well TZ83, 5684.7m, large fracture and cave were developed in Yingshan Formation, with 146m³ of mud loss

3. Prediction of crust karst reservoir by paleogeomorphology

The palaeogeomorphic characteristic of the top of Lower Ordovician in Caledonian presents: From Tazhong No. I slope-break zone to south, it is developed karst slope and high places, in it Tz83-Tz54-Zg8-Zg17 are located in karst slope zone.

The effective reservoir is distributed in vertical vadose zone and lateral underflow zone which the thickness is total account to 160m.In the course of drilling, it has drilled large caves and fractures in Tz721,Tz722,Tz83,Tz45,in which it appears empty and mud loss. In addition, the Late burying and dissolution have improved the Early karst reservoir connectivity forming all kinds all kinds of moniliform dissolution cave. The reservoir is almost distributed karst development zone reflecting control of karst to reservoir. On the whole, Controls of paleogeomorphology on the zone characteristic of crust karst reservoir, It is the most developed in karst slope zone.
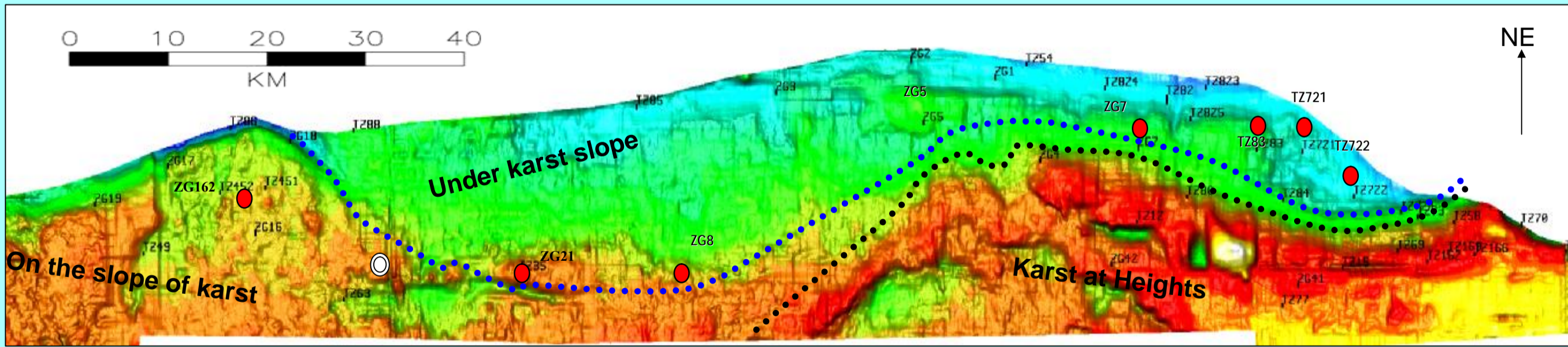

Top of Lower Ordovician paleogeomorphology map in middle Caledonian, Tazhong area

4. Geophysical response of reservoir

4.1 Identification of geophysical response

Based on statistical analysis for 13 parameters of effective reservoir in 39wells (encountered the target horizon) and well-seismic correlation, corresponding geological model has been established, and forward simulation has been carried out by Wave equation. Therefore, reservoir of weathering curst was mainly characterized by string beads-strong amplitude and non-string weak amplitude.

ᴜ String beads-strong amplitude:Characterized by strong amplitude (A>68,) like string beads, mutton chop-shaped, and etc, frequency width was about 12-28-50Hz. Reservoir was dominated by fracture-pores and caves, half-filled to non-filled.
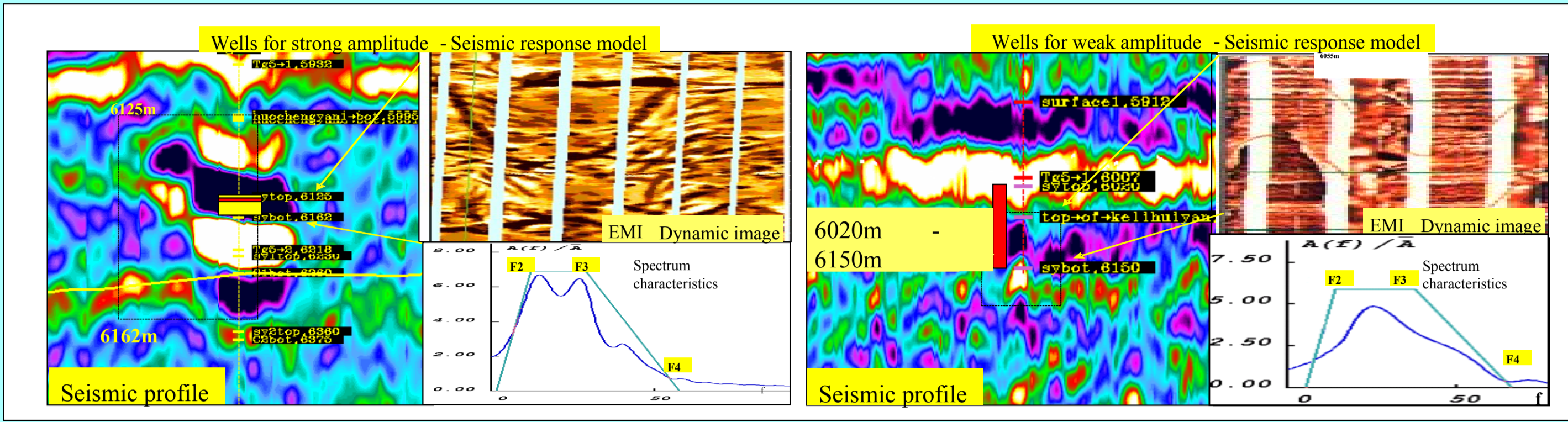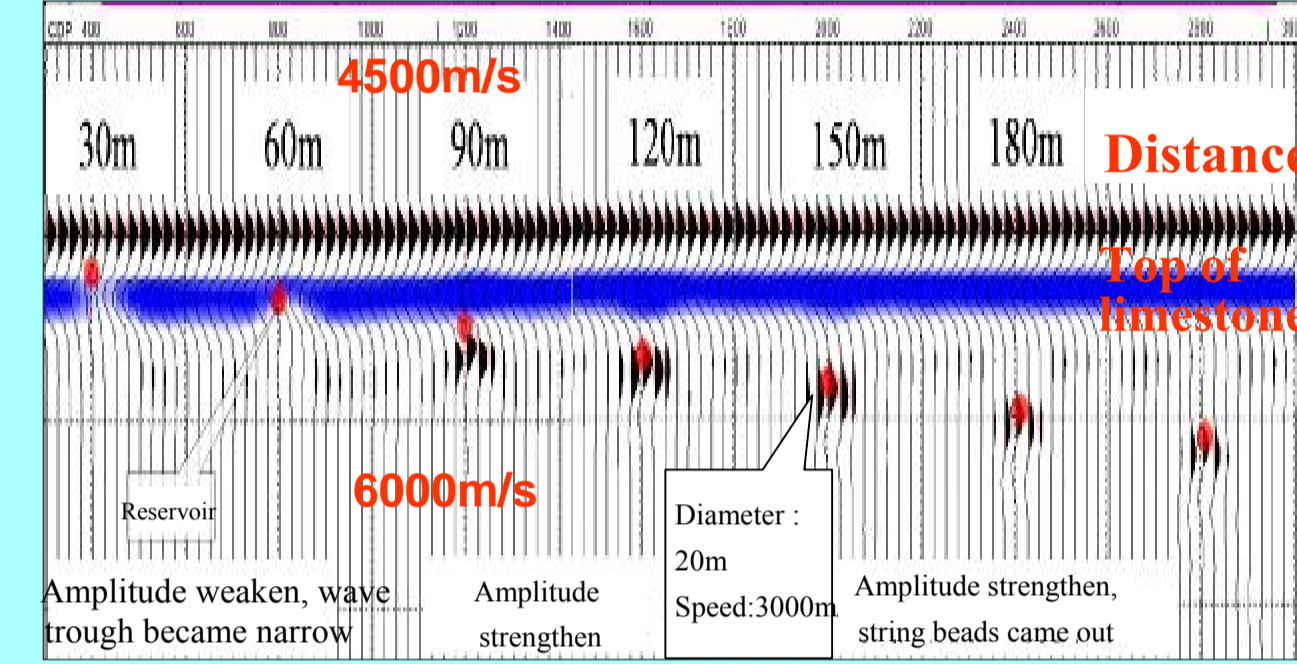

Overflow drilling and mud loss of large quantity can easily observed. Distributed as band-like or tabular-like in spatial, and in the upper part of weathering crust in Yingshan Formation and around the fault in vertical.

ᴜ Non-string weak amplitude: seismic reflection was characterized by non-string weak amplitude or disorder reflection (20<A<35), frequency width was 5-25-50Hz. Reservoir was dominated by fractures and pores-fractures, which mainly proved as low-yield wells, well developed in beach or structural barrier.
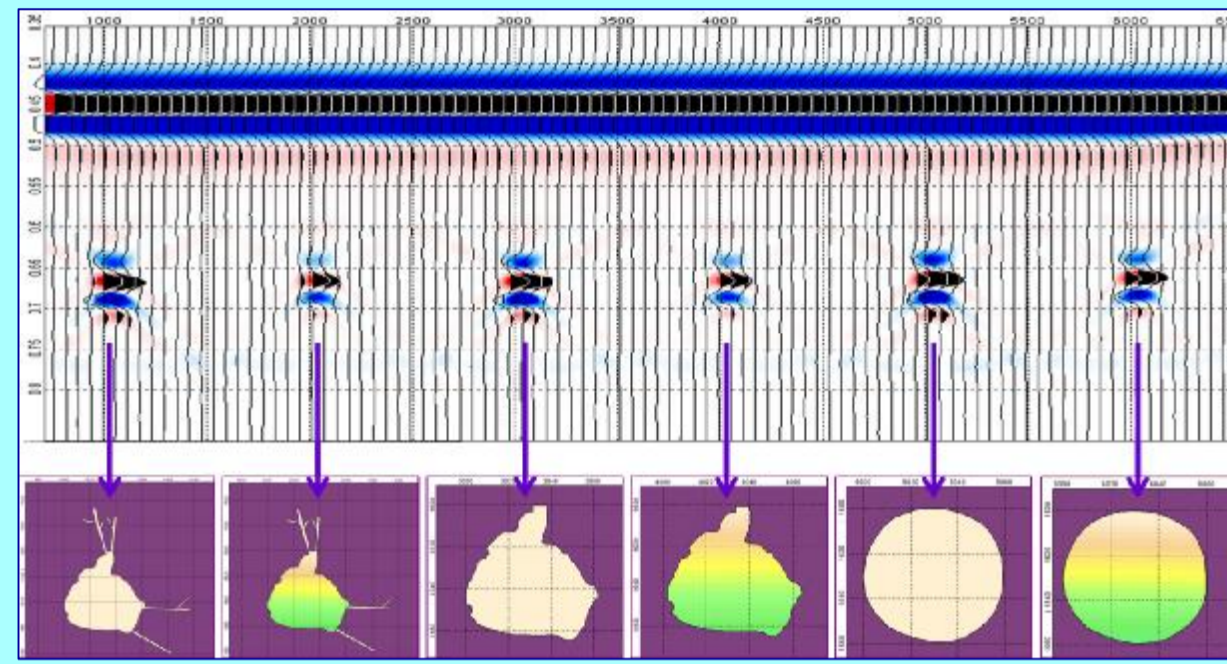
4.2 Forward modeling

ᴜ The seismic response of fracture-pore was string beads while the distance between the reservoir body and the top of limestone was more than 120m, otherwise it was disorder-blank reflection.

ᴜ Seismic reflection response of different shapes remain the same when the volume and spatial position remain the same.

Forward modeling profile indicated different seismic reflections by changes of spatial position

Forward modeling profile indicated seismic reflections of different shapes

5. Attribute abstraction of karst pores and fractured reservoirs

5.1 Distribution of karst pores predicted by well-seismic joint inversion (restrain by multi-parameters)
Using optimism combination of multi seismic attributes, optimize relationship between it and well logging has been established to carry out porosity inversion restrained by multi-attributes. This method can avoid the layer-like model in the model-based inversion, which can fix the requirements of karst reservoirs heterogeneity in carbonate rock.
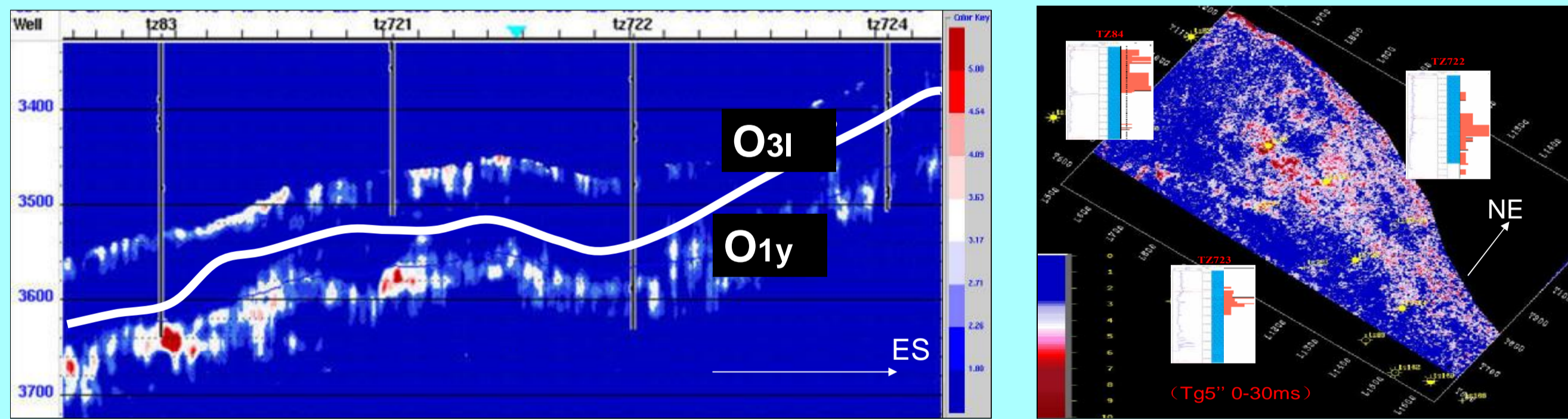

Porosity profile of karst pores cross Well TZ83

Plane distribution of porosity for karst pores in Wellblock TZ83

5.2 Carry out integrated fracture prediction by multi-techniques of prestack and poststack
The fracture direction can be confirmed by the changes of amplitude along with azimuth changes. Density and strength of open fracture can be confirmed by changes of attenuation (frequency) along with azimuth changes.
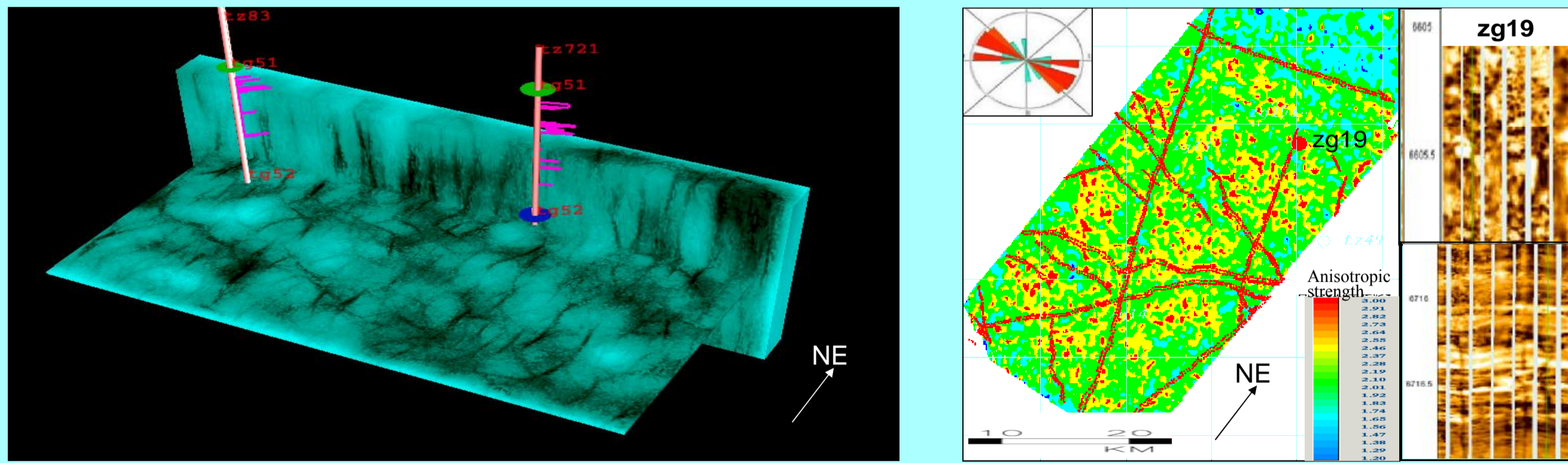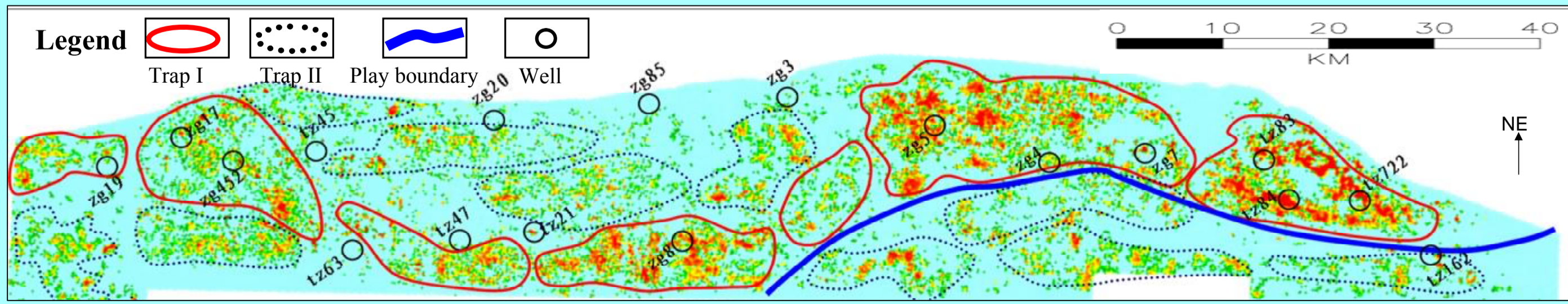

Stereogram of predicted fracture by Poststack in Wellblock TZ83

Prediction map of predicted anisotropic fracture by prestack in Wellblock ZG19

6. Application

The reservoir distribution has been confirmed in Tazhong area, and 22 wells have been employed, where the drilling rate for fractured-cave reservoirs by this method was up to 100%.

Plane distribution of karst weathering curst reservoir in Yingshan Formation of the North slope in Tazhong area

7. Conclusions

ᴜ Different of types and development in reservoirs were shown as strong amplitude and weak reflection, and changes of spatial position can change the seismic response.

ᴜ Identification technique for reservoir response that was guided by palaeogeomorphologic reconstruction by residual thickness and well-seismic joint porosity inversion that was restrained by multi-attributed can described the macro-features of reservoirs in karst weathering crust and heterogeneity inside the reservoir. AFE and anisotropic strength can describe the distribution of fractures qualitatively and semi-quantitatively.

ᴜ Proven by exploration: guided by genetic pattern of fractured-pores reservoir in carbonate rock, this reservoir identification method is suitable for current carbonate rock exploration in Tarim Basin.