[PS]Construction of Stochastic Model for Ordovician Karsted Carbonates Reservoirs of Tahe Oilfield, China: Dimensional and Geometric Implications and Structural Considerations*

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Abstract

The paleokarst reservoirs of the Ordovician Yingshan Formation represent relevant reservoirs for oil and gas production in Tahe oilfield, western China. Since the 2000s, the oil exploitation of these very deep reservoirs located north of the prolific Tarim Basin, have been very significant. The complexity for karsted patterns modeling, essentially, caves or sinkholes, drives the need for applying different techniques to obtain a suitable geological model. Hence, this investigation aims at the construction of a 3D model using the relative acoustic impedance seismic attribute and seismic facies analysis as inputs data in a stratigraphic grid, to propagate karst facies and physical properties. Highlighting the tectonic features that occurred during the Caledonian and Hercynian orogeny, that produced the exhumation of carbonate platform, configured its current position, and oriented the karstification processes. With regards to the paleokarst fillings, those are compositionally heterogeneous, mixed siliciclastic and carbonates. For this case study, 61 faults (thrust, reverse, and sinistral strike-slip faults) and 3 stratigraphic horizons in depth sited on an area of 245 km² were interpreted and validated. The displacements of strike-slip and reverse faults formed during the Hercynian orogeny were slighted. The rock-properties and discrete facies data of paleokarst and host rock were obtained from petrophysical evaluation of 163 wells and previous sedimentological analysis. The average effective porosity and permeability values calculated were around 8% and 3 mD, respectively. From seismic data a relative acoustic impedance seismic attribute was computed. Takin into account the values under -40.500 km/s*g/cm³ of this seismic attribute, for building the probabilistic cube in trend analysis of the model. In order to distinguish patterns with similar characteristic to paleokarst, it means, patterns with tubular and sub-redounded forms randomly distributed in carbonate host rock associated to the vadose zone.

To improve the upscaling and connectivity of karst facies in the model, created a very thin stratigraphic grid which covers karst patterns size < 2 m. The upscaling of karst facies in the model is around 90% effectiveness. In addition, a seismic traces map classified in 8 classes was generated between the unconformities dating to 474 - 476 Ma (karsted interval). It determined that seismic facies 6 and 7 are associated with geomorphology of paleokarst patterns. These seismic facies were extracted and used as second input data in the model. As results, the seismic

attributes and stratigraphic well sections permitted identifying paleokarst patterns with similar dimension and geometries of surface rivers and streams channels. The paleocave chamber sizes in the model fluctuate between 40-50 m wide and 20-30 m high, being thinner in branches and sinkholes, 4x2 m. The facies seismic model recognized two main karst systems orientated northwestern and southeastern. On this model applied kriging with external drift statistical to propagate porosity and permeability values, demonstrating an effective algorithm for the propagation of rock-properties based on karst facies. The geological model also confirmed that the paleocaves have the same orientation as the main faults. Finally, the model shows good continuity of paleocave chambers according to depth. Besides, this supports the geological scheme described (distribution, dimension, and geometry) in outcrops for the Yingshan Formation. In addition, the model exhibits various non-perforated segments paleocaves which could mean business prospects for the oil and gas industry.

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Construction of stochastic model for Ordovician karsted carbonate reservoirs of Tahe oilfield, China: dimensional and geometric implications and structural considerations

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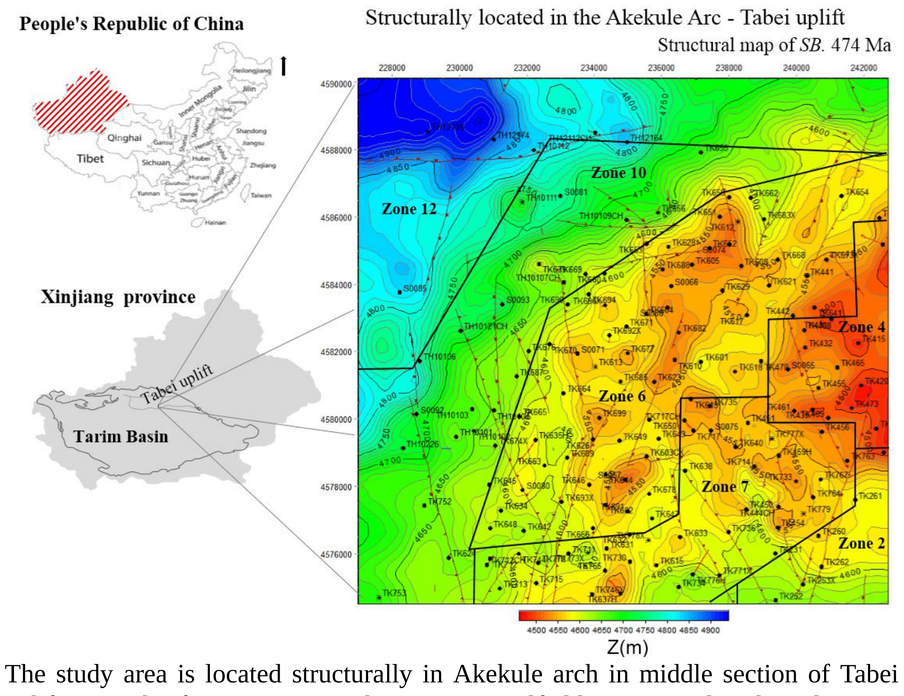
Abstract

The karsted carbonates from Ordovician Yingshan Formation represent relevant cavities storages for oil and gas production in Tahe oilfield, western China. The complexity on karst elements modeling, drives the need to apply different techniques to honor the geological features. Hence, this research aims the construction of a geocellular model using the acoustic impedance cube and traces seismic as input data in stratigraphic grid for karst facies and physical properties propagation. Highlighting, the tectonic features occurred during the Caledonian and Hercynian orogeny that produced the exhumation of carbonate platform and configured its current position. The compositional scheme of fillings that cover these paleokarst is very heterogeneous, composed fundamentally by siliciclastic and carbonates mixed. The effective porosity values most frequent oscillates between 1-5% in karst zone. Moreover, to obtained a relative acoustic impedance cube from seismic data processing, which subsequently was classified hierarchically in 8 seismic facies according to its impedance values between the unconformities 474 - 476 Ma. From this classification, determined that below values -40.500 km/s*g/cm³ make match with the similar morphology to karst cave, with tubular and sub-rounded forms distributed randomly into carbonate host rock, related with vadose and phreatic zone. It used as secondary data a seismic traces classification map of target interval generated through discretization of seismic facies 6 and 7, improving the connectivity between paleokarst in model. Through seismic attributes and stratigraphic well sections identified various cave chambers and branches with similar dimension and geometries to descripted in Kepintage mountains outcrops. Using facies seismic model highlight two main karst patterns orientated to northwestern and southeastern. As well, applying kriging with external drift statistical on porosity estimated values allowed obtaining a more logic spread of this property in karst zones. As result, the stochastic model exhibits partially a better connectivity between paleokarst according to kind of filling, supporting the geological data about the paleokarst distribution and geometry descripted in outcrops. Finally, this model unfolds caves patterns not drilled yet in middle zone of research area, which would involve reexploratory prospects for oil and gas industry.

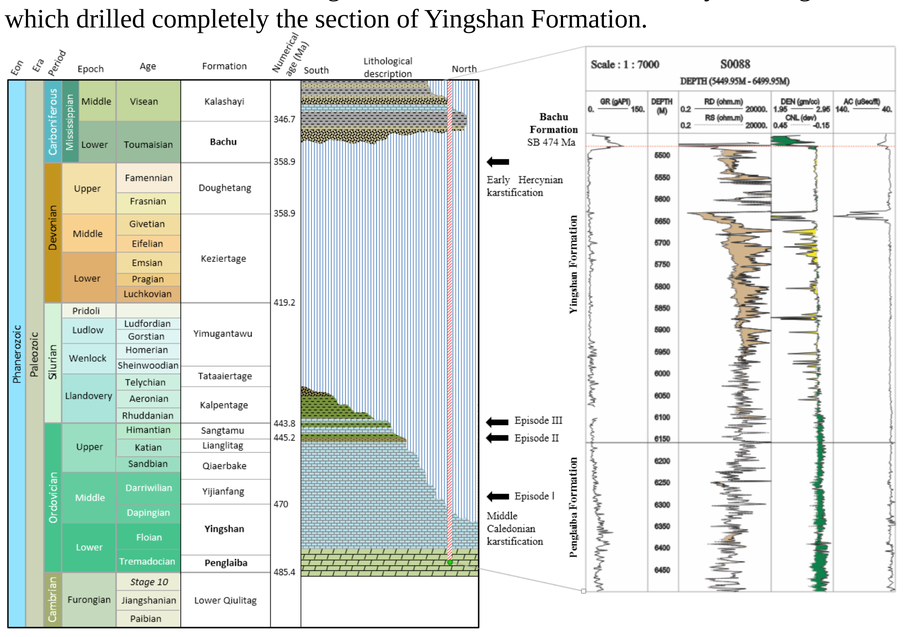
1. Geographic location



The study area is located structurally in Akekule arch in middle section of Tabei uplift at north of Tarim Basin, where various oilfields associated with Ordovician carbonates reservoirs have been discovered. This area covers an extension of 245 km² and has been drilled by 167 wells in operational zones: 2, 4, 6, 7, 10 and 12, into Tahe oilfield

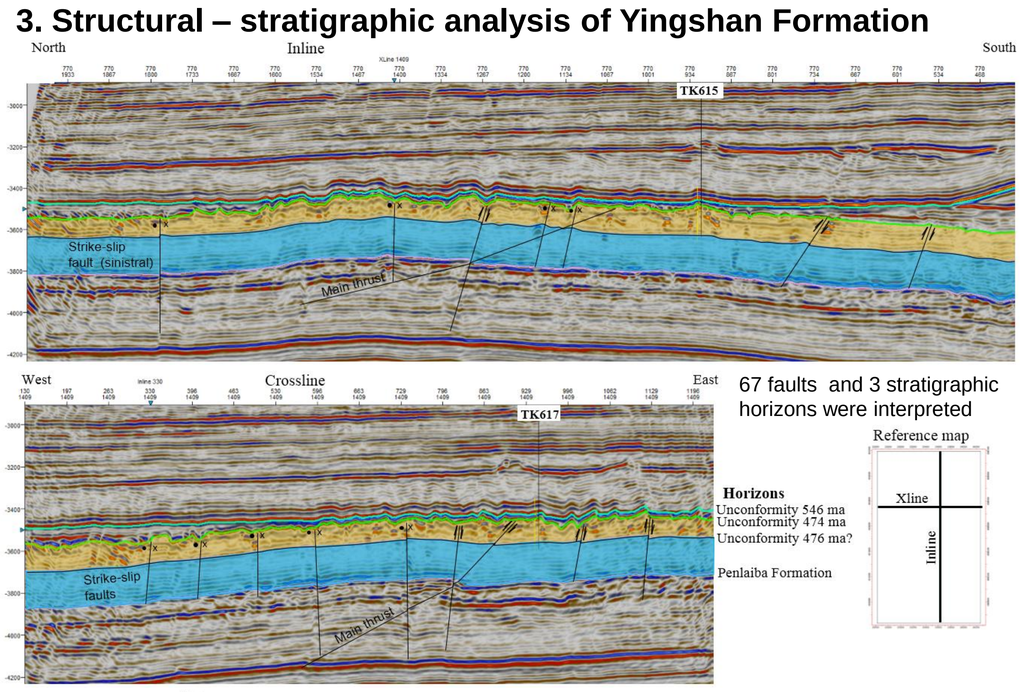
2. Geological settings

Details of proposed stratigraphic column for Tahe oilfield where indicate the main tectonic events occurred during Paleozoic Era. In addition, the key well log of area, which drilled completely the section of Yingshan Formation.



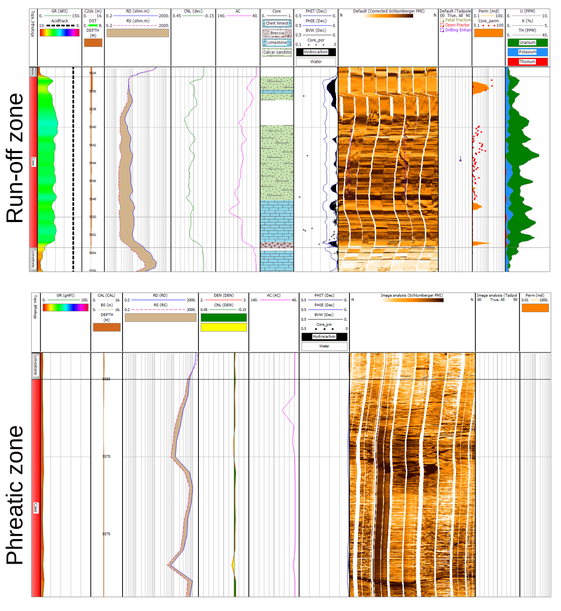
The analogue model of paleokarst and fillings in Yingshan Formation, (a) Distorted cave filled with graded bedding and interbedded depositional deposits, (b)&(c) Detail unfilled caves, (d) Chert deposits, (e) Chaotic breccia deposits with various lithic fragments of subangular shape (f) Polymictic conglomerate deposits composed by subredound fragments, and clay, (g) Impregnated calcareous sandstone, and (h) Impregnated limestone sample with high wear.

3. Structural – stratigraphic analysis of Yingshan Formation



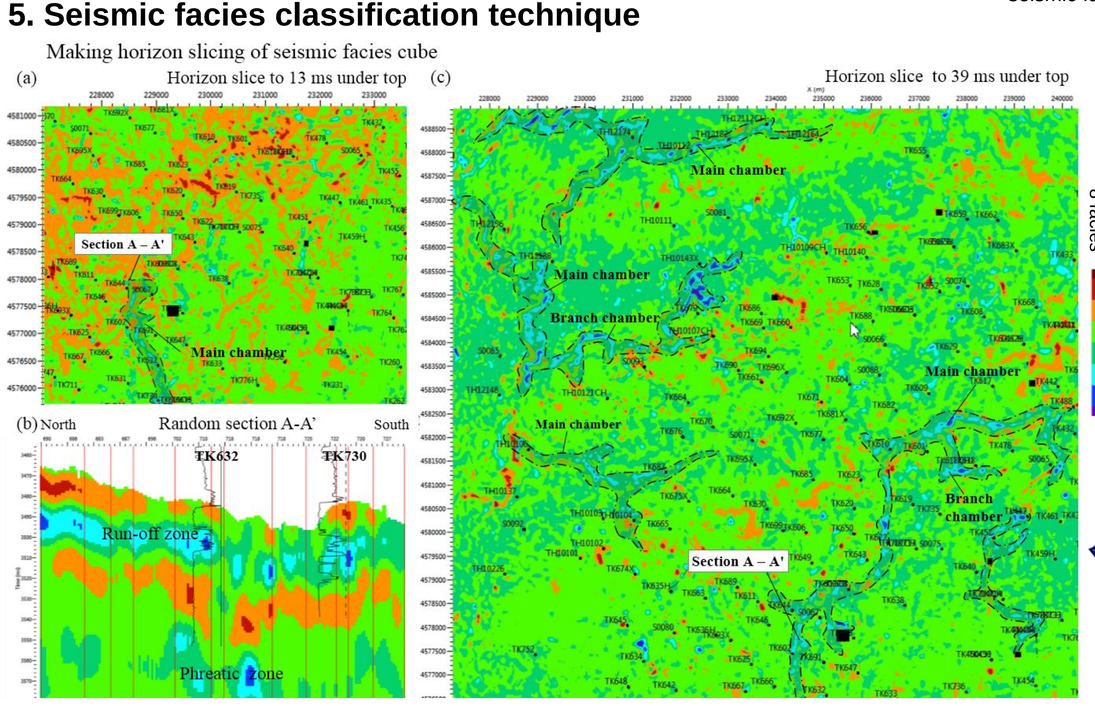
4. Petrophysical evaluation of karst

The evaluation made of conventional form focused in karst zone. The example in run-off zone filled by calcareous sandstone exhibits an average of effective porosity and permeability around of 3% and 0.6 mD (adjusting to core), respectively. On other hand, the long phreatic zones exhibit very low averages of effective porosity and permeability around of 2% and 0.2 mD. In where the carbonate rocks exhibit holes and vugs with oil traces.

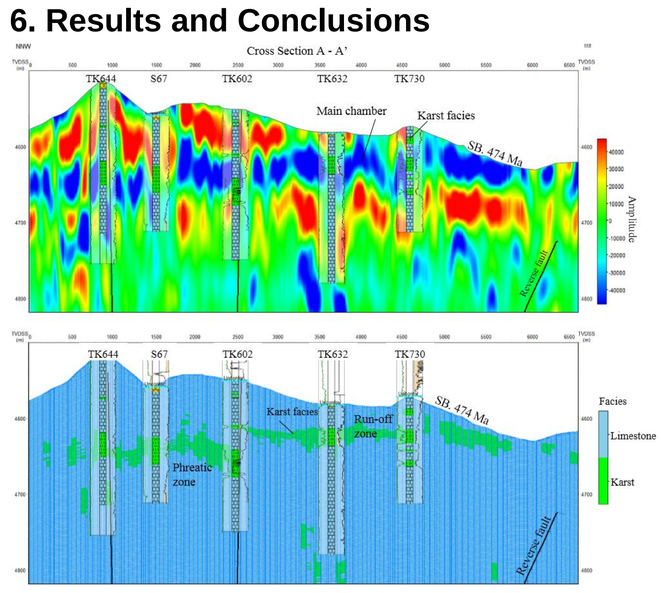


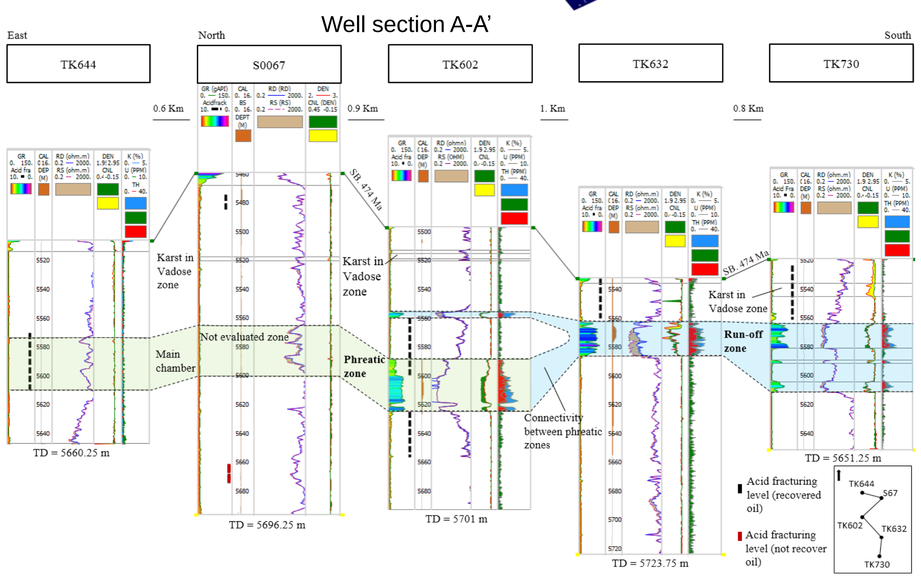
Karst zone	Gross	Net/Gross	Av Phi (%)	Max Phi (%)	Av Sw (%)	Av Vcl (%)
Run-off	1.75	0.092	3.66	12.93	38.2	26
Phreatic	35	0.029	0.43	2.35	28.7	45.7

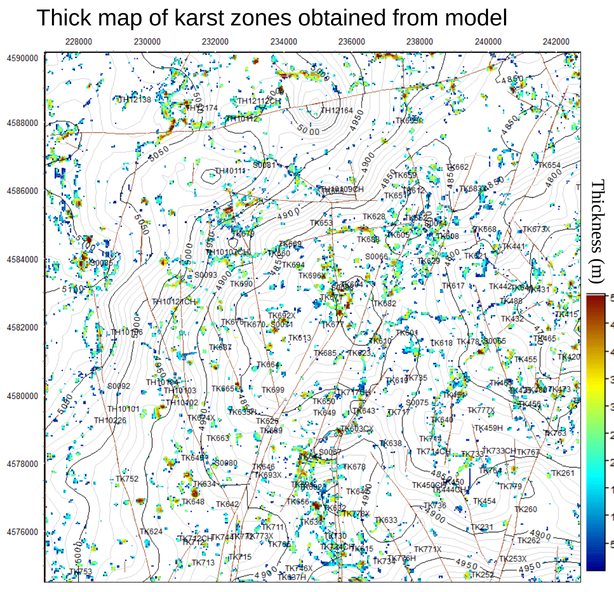
5. Seismic facies classification technique

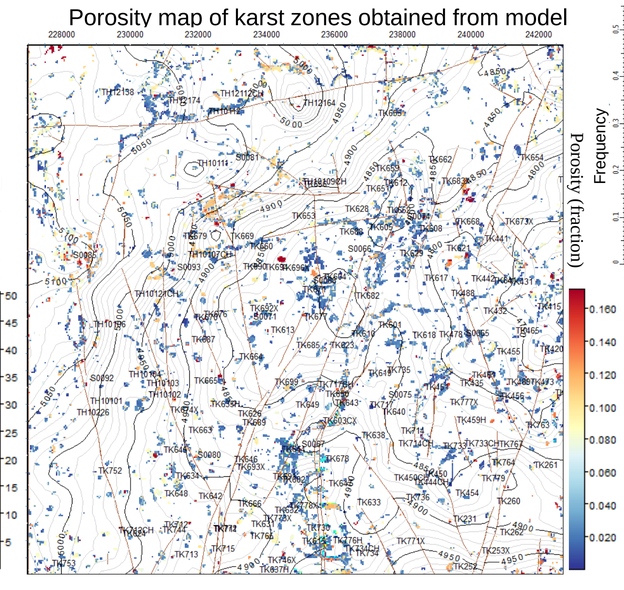


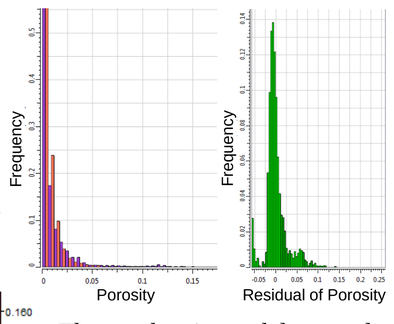
6. Results and Conclusions











The stochastic model not only honor the geological features, also determined allowed identify new business opportunities not drilled yet in phreatic zone. The maximum thickness of determined karst is relatively 50 m.

Acknowledgements

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