Marine-facies gas reservoir identification by numerical seismic modeling

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Abstract At present, few wells penetrate marine-facies reservoirs in Tongnanba area and the reservoirs are characterized of large lateral variability. Fortunately, we can characterize lateral reservoir thickness and variation by applying seismic forward modeling to some different kinds of reservoir models. In this paper, we build corresponding double-phase media models for different types of gas reservoirs, implement forward wave propagation calculation, and indicate characteristic seismic responses of local gas reservoirs. The result of this study is of instructive significance in gas reservoir identification in this area.

Key words forward seismic modeling, bring spot, Jialingjiang Group, characteristic seismic response, gas reservoir

Introduction

The costs of seismic acquisitions and drilling are very expensive in severe areas such as deserts, mountainous areas, and offshore, so it is efficient to design field acquisition appropriately, where numerical modeling plays a key role. In early stage of reservoir characterization, we can not confirm our gas reservoir identification results with drilling data because of very sparse exploration wells. And furthermore, different areas exhibit different geological conditions, so it is hard to recognize characteristic seismic responses of gas reservoir just according to reservoir geophysical theories, or reduce uncertainty in reservoir description.

This difficulty can be well overcome by building double-phase media models, implementing forward wave propagation calculation, and analyzing seismic responses.

In Tongnanba area, we confirm characteristic geophysical responses of gas reservoirs by using seismic forward modeling and the result of this study is of instructive significance in gas reservoir identification.

Basics of seismic modeling

Numerical seismic modeling is an important means to investigate kinematic and dynamic behaviors of propagating seismic waves in the earth, and is fundamental for seismic inversion as well (Carcione, 2002). There are two basic problems involved here, one is what kind of media we choose, and the other is numerical methods. To model wave propagation more realistically, We may use porous, cracked or fractured media in which the wave motions are formulated as some kind of analytic wave equations. Seismic modeling is actually to solve these equations by employing numerical algorithms such as finite difference method. Wave-equation modeling is an ideal way to obtain realistic seismic data from a model. Here we apply wave-equation finite difference modeling to recognize how seismic waves behave in dolomite gas reservoir in our study.

$$(\lambda+2\mu)\nabla^2\vec{u}+\nabla\lambda\nabla\cdot\vec{u}+\nabla\mu\times(\nabla\times\vec{u})-2\frac{\partial\mu}{\partial x_i}\frac{\partial\vec{u}}{\partial x_i}+\vec{f}=\rho\frac{\partial^2\vec{u}}{\partial t^2}$$

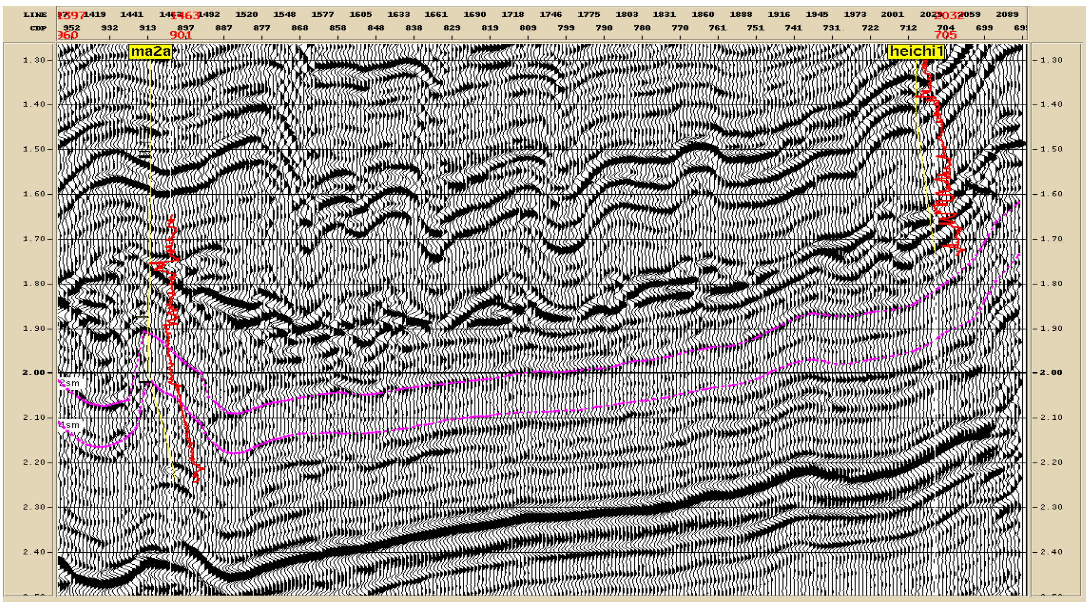
Reservoir properties of Jialingjiang Group in Tongnanba area

The target project belongs to Tongnanba tectonic zone which lies in district of Tongjiang, Nanjiang and Bazhong County in Sichuan Province, and in tectonics of northern slope of Mesozoic depression and southern boundary of Micang Uplift. The target project covers 2920km^2. The trap bounded by the bottom of estheria shale covers 838km^2 with a closure height 1400m, and is the second tectonics in Sichuan province in size (Ma et al, 2005a).Jialingjiang Group in Tongnanba is a transgressive and later gradually regressive sequence, with sedimentary thickness of 500-700m. The main reservoirs are dolomites of Jia2 unit, which are shoal-evaporite sediments and widely spread in Tongnanba. The lithology consists of calcarenite dolomite, vugged dolomite, and gypsum, which are combined in an interbedded way. In lithology, Jia2 unit is well correlatable laterally and ranges considerably vertically (Ma, 2005b).

The main reservoirs are composed of two layers of dolomite at bottom of Jia2 unit. For Jia2 unit of well M2, three corings are implemented, and average core recovery is 96.7% with a accumulated drilling footage of 22.33m and a accumulated core length 21.60m. The Jia2 reservoir porosity ranges from 0.57% to 8.33% (fracture) and averages to 2.4%. The porespace types are listed as followings (Ma, 2006; Wang 2005):Intergranular pore, which is formed among rock matrixes with little mud lime cement, and covers 10% of the total porosity. Intercrystalline pore, which is formed by recrystallized secondary enlargement or in the form of residual intercrystalline space, and covers 5% of the total porosity.Dissolution pore, which is formed by dissolving effects among matrixes or crystalline and covers 10% of the total porosity.Fractures, which are mainly structure-induced with a density of

30/m and in vertical, dip, and horizontal directions. The width of fractures ranges from 1mm to 2mm and they play the role to keep heterogeneous, low porosity and low permeability; b) reservoir space is composed of secondary pores, vugs and fractures; remarkable lateral and vertical variable, difficult seismic identification.**Seismic responses of reservoirs** The Jia2 reservoirs are composed of two dolomite layers in bottom of Jia2 unit. By finely well-seismic correlating of Well H1 and M2, the reservoir bottom corresponds an negative event. Near well spot, are reflections of low dominant frequencies and weak amplitudes. The only two wells in this project can not represent reservoirs of Jia2 unit due to it poor porosity with average value 2.4％. Therefore the seismic responses around the well locations can not be applied to seismic identification of the reservoirs in this area. The reservoirs the reservoir space connected.In general, the dolomite reservoirs in this area have three features: a)

exhibit large lateral variability with the help of regional sedimentary study and physical properties of the reservoirs. Thus there is still the possibility that favorable reservoirs occur between the two wells. After careful investigating seismic data, we find an evident anomaly in seismic reflections of Jia2 unit. At first, an amplitude anomaly is featured as bright spots of mid-low frequency band and mid-high amplitude by inversing polarity because the reservoir is correlated with negative amplitude and it is difficult to find this anomaly (Fig. 2). We infer this seismic anomaly may be reflections from gas reservoirs with better properties. However it is not tested by drilling data for no well available.



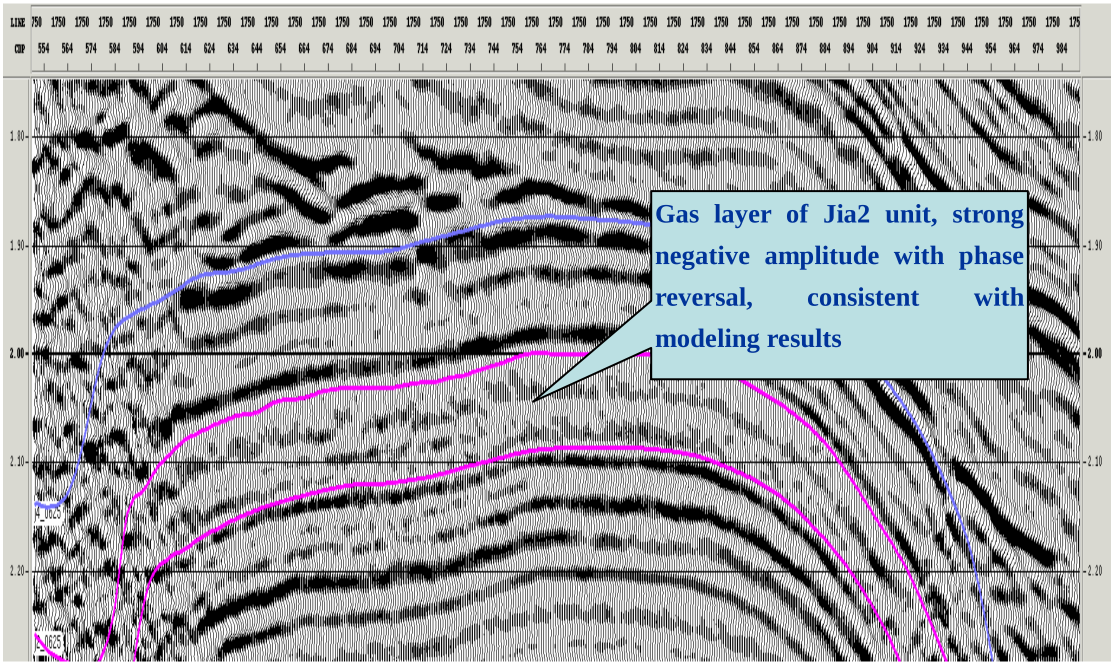
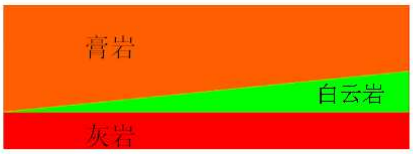


Fig.2 Seismic section displayed in reversed polarity

Anyway forward seismic modeling provides us an alternative and the modeling results demonstrate that the bright spots are associated with the reservoirs with profitable properties.

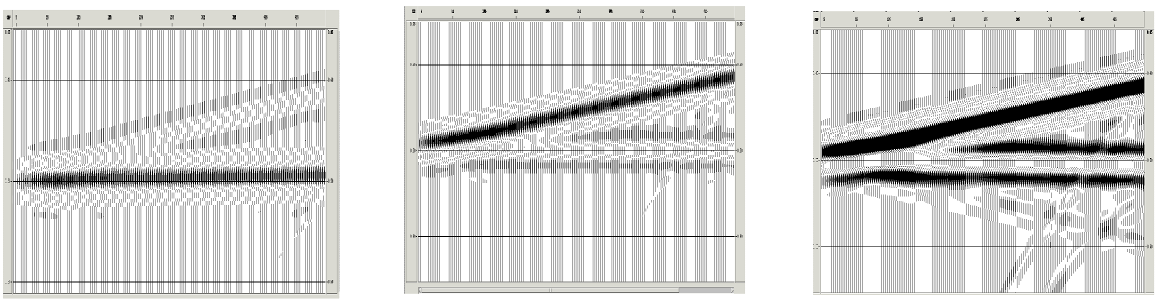
Double-phase media model and seismic modeling of Jia2 reservoirs Jia2 unit is composed of limestone, dolomite and gypsum rock from the lower up. We build three wedged and horizontal-layered models respectively, according to reservoir properties from well and sedimentary distributions. Wedged, gas-bearing and double-phase media, Wedged models are built according to the two wells M2 and H1 (Fig. 3), composed of limestone, dolomite and gypsum rock from the lower up. In these models, gas reservoir is dolomite in the middle in three cases, dry(zero porosity), 5% and 15% porosity. The elastic parameters of rocks and their matrixes are derived from two wells M2 and H1. The 3 models can represent 3 possible types of gas reservoirs for gas reservoir identification. The Modeling results are illustrated in Fig.4. Investigating the modeling results, we can draw such conclusions that in case of dry layer, the reflections from bottom and top exhibit weak energy with a negative top amplitude and a positive bottom one; in case of 5% porosity, the reflections weak energy with a positive top amplitude and a negative bottom one; in case of 15% porosity, the reflections strong energy with a positive to pamplitude and a negative bottom one.

Gas bearing wedged double-phase model
The wedge is a gas-bearing dolomite layer with a limestone base and a gypsum seal, and the dolomite layer is set and modeled in three cases, zero, 5% and 15% porosity respectively.



	孔隙度	骨架速度	介质速度	骨架密度	介质密度
膏岩	0%	6000		2.96	
白云岩	0%	6400		2.85	
	5%	6400	5940	2.85	2.707
	15%	6400	5575	2.85	2.422
灰岩	0%	6200		2.73	

Fig. 3 Gas-bearing wedged double-phase model



a b c

Fig.4 Synthetic sections of three cases (a. 0 porosity, b. 5% porosity, c. 15% porosity)

Model b is similar to situations in wells M2 and H1, the synthetic seismic responses are consistent with field seismic data. Gas reservoir is featured of weak and negative reflection.

Model c is an supposed one with 15% porosity. This case shows that with increasing porosity, gas reservoir exhibits high energy responses in seismic reflections. Thereby we can recognize gas reservoirs with better properties in Jia2 unit. 2.Gas-bearing horizontal-layered model

Our main purpose is to explore the whole characters of gas reservoirs building this model (Fig. 5).

Polarity reversal occurs at the top and bottom contact points of the gas reservoir, at the same time there is a time sag in bottom reflections of gas reservoirs. The later phenomena is more notable after seismic migration (Fig. 6).

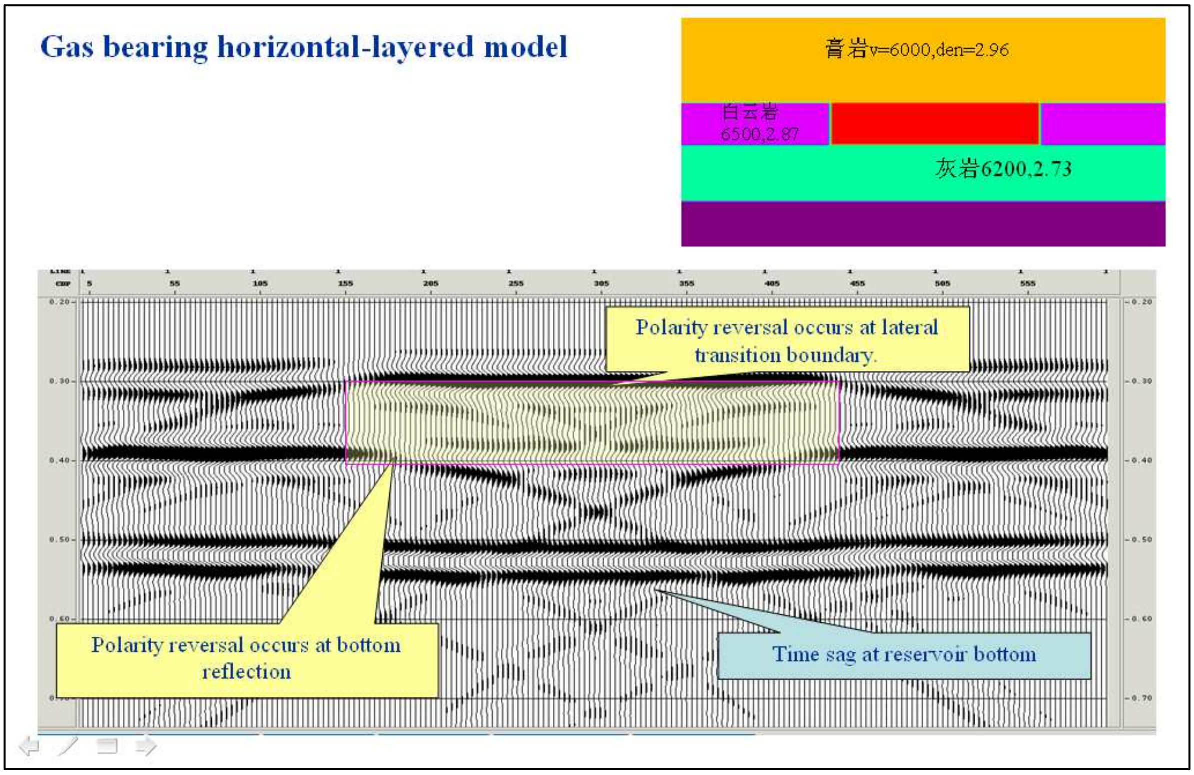


Fig.5 Gas-bearing horizontal-layered model and its synthetic section

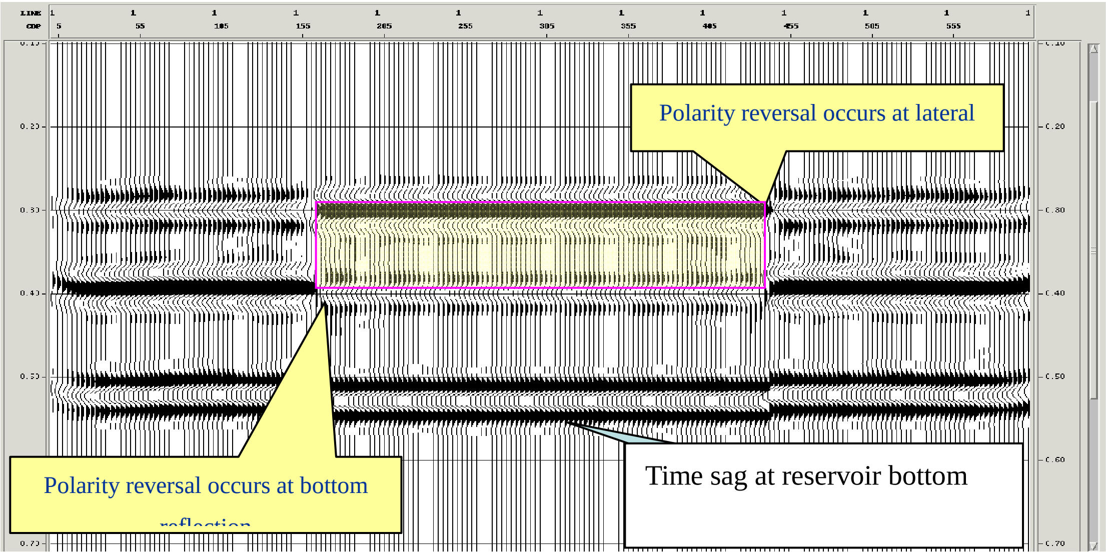


Fig.6 Migration of synthetics of horizontal-layered model

Identification of Jia2 gas reservoirs

Negative polarity amplitude near gas reservoir corresponds reflections from gas reservoir bottom; bright spots may indicate gas reservoirs with better physical properties; and polarity reversal often occurs at bounding points of gas reservoir. The modeling results confirm the characteristic seismic responses we recognize of gas reservoirs in this area. Bright spot mapping (Fig. 7) and polarity mapping (Fig. 8) almost share the same boundary with each other. Together with according results from other techniques, our conclusion of the seismic responses of gas reservoir in this area is validated.

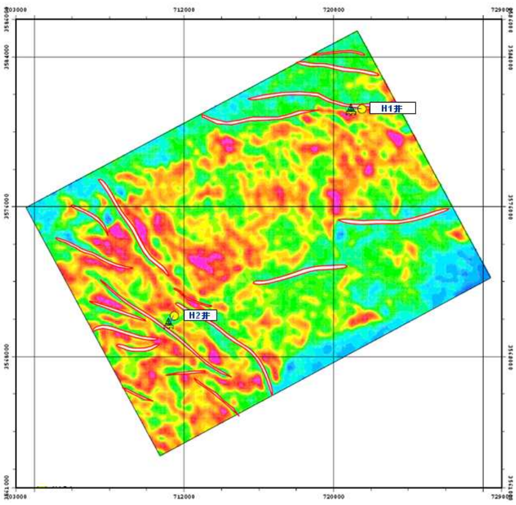


Fig. 7 Bright spot map of top reflection of Jia2

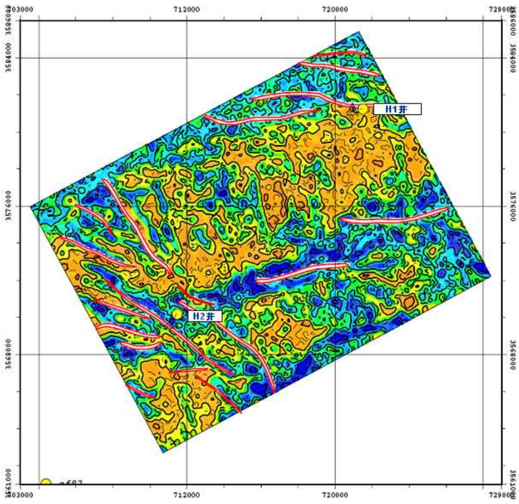


Fig. 8 Polarity map of top reflection of Jia2

Conclusions

Seismic modeling results demonstrate that dolomite gas reservoirs in Jia2 unit are featured of negative polarity and high amplitude. Despite few available well data and no reservoir with better properties from well, forward seismic modeling serves as a good solution to helping identify physical meaning of anomaly reflection, and to supporting further exploration of gas reservoir.

The reservoirs have very low average porosity in the only two wells in this project.

According to the characteristic seismic responses we recognized with the aid of seismic modeling, neither of the two wells is located at a favorable position in the seismic response mapping. However characteristic seismic response covers considerably in the mappings, which reveal the prospective future of gas exploration in this area.

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