Fracture propagation simulation and construction parameter optimization of eruptive phase volcanic rock

Changlin Zhou¹, Lang Zhou², *, Huali Zhang¹, Li Li¹, Rui Wang³, Ming Jing⁴, Rong Zeng¹

¹Engineering Technology Research Institute, Southwest Oil and Gas Field Company of CNPC, Chengdu, China
²Southwest Oil and Gas Field Branch, Chengdu, China
³Exploration Division of Southwest Oil and Gas Field Company, Chengdu, China
⁴Chengdu University of Technology, Chengdu, China

*Corresponding author e-mail: zhoulang@petrochina.com.cn

Abstract. A large number of volcanic gas reservoirs are developed in the Sichuan Basin. Up to now, 92 wells have been drilled into Permian volcanic rock, which have good prospects for exploration. Among them, large areas of volcanic facies are distributed in the Sichuan Basin. The uneven distribution of pores in volcanic rocks of eruptive facies and the large difference in rock mechanics combination between different lithofacies make it difficult to develop volcanic gas reservoirs of eruptive facies effectively. Therefore, studying the characteristics of eruptive facies volcanic rocks and reservoir reconstruction schemes is very important for the later development of volcanic rocks. Significantly, this paper builds a finite element model of a volcanic rock reservoir of the effusion facies based on the geological characteristics of the volcanic rock of the effusion facies, and optimizes the construction parameters in terms of construction displacement, fracturing fluid volume, and proppant. The research results show that, the injection pressure of the spouting phase under different stress difference conditions exhibits oscillating characteristics. The stress difference between the barrier and the reservoir is positively related to the injection point pressure and fracture fracturing. The recommended construction displacement is 4.5-5.5 m³/min and the fracturing fluid dosage is 400-500 m³, and the amount of proppant is between 30-40 m³. The research content of this article is of great significance for the effective development of volcanic gas reservoirs in eruptive facies.

1. Preface
In today's world, the demand for energy is increasing day by day, and the exploration and development fields of oil and gas are constantly expanding. Among them, volcanic reservoirs, as a new field of oil and gas exploration, have attracted the attention of experts and scholars from all over the world [1]. Volcanic rocks are widely distributed in petrolierous basins all over the world. Since the 1970s in China, volcanic oil and gas reservoirs have been successively discovered in Bohai Bay, Junggar, Tarim, Songliao and Subei basins [2]. In 2018, the discovery of Yongtan 1 well, the first industrial volcanic gas...
well in the Sichuan Basin, confirmed that the Permian igneous rocks in the Sichuan Basin have good reservoir conditions and good exploration prospects.

Volcanic eruption phase as an important part of volcanic gas reservoirs in Sichuan Basin, reasonable and effective development of eruption facies volcanic rock has become one of the highlights of the Sichuan Basin volcanic gas reservoir development, but due to the eruption facies volcanic rock pore distribution and the Sichuan Basin large difference of different rock and rock mechanics combination way, cannot be effective to develop of volcanic eruption phase, so the urgent eruption facies volcanic rock fracture simulation and parameter optimization of construction, in order to get a set of reservoir reconstruction scheme to realize reasonable development of the volcanic eruption phase, in this paper, based on the study area reservoir geological characteristics, establish finite element model of eruption facies volcanic rock reservoir. The reasonable range of construction displacement, fracturing fluid volume and support dose is determined. The results of this study show that under different stress differences, the injection pressure before the spout phase presents a characteristic of shock, and the post-injection pressure tends to be stable. The greater the stress difference between the interlayer and the reservoir, the greater the pressure at the injection point and the greater the fracture fracturing. It is suggested that the optimal construction displacement is 4.55.5 m³/min, the fracturing fluid dosage is 400-500 m³, and the proppant dosage is 30-40 m³.

2. Characteristics of volcanic reservoir

Eruption-facies lithology is dominated by breccia lava, tuffaceous breccia lava, tuffaceous breccia lava and other pyroclastic lava [3]. Chengdu Jianyang area for alkaline volcanic rocks of basic, super basite, lava, low viscosity, good liquidity, not form is given priority to with volcanic clastic rock burst facies, but strongly the volcano eruption phase development near the empty fall in the center of the eruption of volcanic breccia volcanic clastic lava, lithology is mainly the lava and lava flow formed in the process of the broken breccia, and typical eruption facies pyroclastic rock and overflow facies basalt have difference, is the transition of the overflow and eruption facies types. This kind of lithofacies is the main facies belt of volcanic rock reservoir in Sichuan Basin.

Permanent agent 1 well reservoir rock is given priority to with volcanic clastic lava, basalt, contain volcanic clastic lava, low limestone, tuff and volcanic breccia and volcanic agglomerate, volcanic tuff, breccia and agglomerate [4], the tuff to light gray or gray fine-grained ash, surface after the air handling land surface by magma package; The breccia and aggregates are mostly basaltic and partly limestone, which are wrapped by molten slurry and cemented by molten slurry into diagenesis [5].

The measured porosity of samples from Well Yongtan 1 is 6.68-13.22%, and the weighted average porosity is 10.17%. The vertical permeability is 0.0137-0.425 mD, with an average of 0.1883 mD. Horizontal permeability ranges from 0.518 to 4.43 mD, with an average of 2.3537 mD. In general, this area has low porosity and low permeability, and the reservoir has certain elastoplasticity. The reservoir space types of pyroclastic rocks are mainly pores with a few fractures developed, and the reservoir space types include intergranular pores, intergravel pores, dissolution pores, dissolution micropores, intercrystalline pores and fractures [6].
Fig. 1 Comprehensive histogram of single well in volcanic rock section of Yongtan Well 1

Fig. 2 5 lithologic sections of volcanic rocks in Yongtan Well 1

According to PetroChina Southwest Oil and Gas Company, 2019

Fig. 3 Physical properties of effluent facies reservoir

3. Finite element model establishment of volcanic rock reservoir of efflux facies

Eruption facies rock types are mainly volcanic clastic lava, low limestone, tuff and volcanic breccia and volcanic agglomerate [4], volcanic eruption phase finite element node, a total of 36057 hydraulic fracturing model, stress and seepage coupling C3D8P unit 28000, crack COH3D8P unit: 28000, model size: 50 m, 100 m long, 60 m wide, of which 10 m, reservoir thickness or insulation layer thickness of 20 m each. The rock mechanical parameters of reservoir and interlayer are shown in Table 1 and Table 2.

| The input parameters          | The numerical          |
|------------------------------|------------------------|
| Reservoir tensile strength   | 4 MPa                  |
| Reservoir fracture energy    | 900 Pa·m               |
| Modulus of elasticity        | 18 GPa                 |
| Poisson's ratio              | 0.18                   |
| Permeability                 | 0.085 mD               |
| Porosity                     | 14%                    |
| Effective stress σH/σh/σv    | 13/20/28 MPa           |
Table 2. Mechanical parameters of interlayer rock

| The input parameters          | The numerical                     |
|------------------------------|-----------------------------------|
| Reservoir tensile strength   | 6 MPa                             |
| Reservoir fracture energy    | 1400 Pa·m                         |
| Modulus of elasticity        | 25 GPa                            |
| Poisson's ratio              | 0.20                              |
| Permeability                 | 0.067 mD                          |
| Porosity                     | 9.5%                              |
| Effective stress σH/σh/σv    | 15/20/28 MPa                      |

When the reservoir stress is 5MPa higher than the interlayer, the stress cloud diagram of fracture height profile at different times is shown in Fig.4. It can be seen from the figure that the artificial fracture height expands vertically in the reservoir at the beginning and enters the interlayer after 30.47s injection. Due to the high stress and elastic modulus of the interlayer, it enters a short distance in the interlayer when it reaches 400s.

As shown in Fig.5, the 3D cloud diagram of the spout and overflow phase fracturing shows: ① Fracture height 15.47m, width 7.13mm, and length 33m; ② When the reservoir stress is 5MPa higher than the interlayer, the fracture height is about 1.99m from the reservoir to the interlayer when the injection is 400s.

![Fig. 4 Crack propagation stress nephogram at different times of spout phase](image_url)
Fig. 5 3D cloud image of spout-discharge phase fracturing

The injection pressure curve of the spout phase under different stress differences is shown in Fig. 6. It can be seen from the figure that: ① The pressure presents the characteristics of shock, which is caused by the interaction between layers in the direction of fracture height, and the back pressure tends to be stable and expands and extends stably in the layers. ② The larger the stress difference between the interlayer and the reservoir, the greater the pressure at the injection point, and the greater the fracture fracturing.

Fig. 6 Variation curve of injection pressure of injection phase under different stress difference conditions

4. Optimization of outpouring volcanic rock reservoir reconstruction scheme

4.1. Construction displacement

The influence of different construction displacement on fracture conductivity is proposed, and the relationship between different construction displacement and hydraulic fracture length is drawn.

With the increase of construction capacity, also increase fracture diverting capacity, through the relationship between displacement change chart can be found that construction of seam long effect
obviously, with the increase of displacement of construction, hydraulic fractures growing, the displacement and the crack length is also obvious positive correlation, including construction of displacement in 4.5-5.5 m³/min, hydraulic seam long slow growth rate. It is recommended to use low damage fracturing fluid, and the recommended construction displacement is 4.5-5.5 m³/min.

**Fig. 7** Influence of displacement on hydraulic fracture length

4.2. Fracturing fluid dosage
Based on the influence of different dosage of fracturing fluid on fracture conductivity, the relationship chart between the dosage of fracturing fluid and hydraulic fracture length is drawn.

By fracture simulation software can be observed that with the increase of dosage of fracturing fluid, fracture diverting capacity increase, also possesses the dosage of fracturing fluid can be found through the relationship between change of length effect obviously, and with the increase of dosage of fracturing fluid, hydraulic fractures increase, and the dosage of fracturing fluid and the length of the crack has obvious positive correlation, the dosage of fracturing fluid after 500 m³, hydraulic seam long slow growth rate.

It is recommended that the fracturing fluid dosage should be 400-500 m³, the low damage fracturing fluid system should be adopted, and the well inflow fluid quantity (400-500 m³) should be properly controlled to prevent the secondary damage of the reservoir.

**Fig. 8** Influence of fracturing fluid dosage on hydraulic fracture length

4.3. Proppant optimization
The influence of different proppant dosage and sand ratio on fracture conductivity was simulated, and the relationship between proppant dosage and effective fracture length, sand ratio and fracture conductivity was drawn.

By the influence of different dosage of proppant fracture diverting capacity of crack propagation simulation software results can be observed that with the increase of dosage of proppant, also increase
fracture diverting capacity, through the relation chart can be found the influence of different dosage of proppant fracture diverting capacity, with the increase of dosage of proppant, effective length increase, and when the dosage of proppant after 30 ~ 40 m³, hydraulic seam long slow growth rate.

![Influence of prop pant dosage on hydraulic fracture length](image1)

**Fig. 9** Influence of prop pant dosage on hydraulic fracture length

By the influence of different sand ratio on fracture flow conductivity of fracture simulation software results shows that the higher the sand ratio, fracture diverting capacity, the greater the relationship chart can be found that the change of different particle sizes, ceramsite influence on fracture diverting capacity significantly, with the increase of sand ratio, fracture diverting capacity increase, and in the sand, than when a certain 20/40 to flow conductivity of propping agent, the best effect, but in order to reduce the risk of sand plug, under the condition of small fracture diverting capacity gap, choose size smaller ceramsite type.

It is recommended to use 40/70 mesh and 30/50 mesh combination proppants to improve the conductivity of the main fracture. The average sand ratio is recommended to be 16-20%, and the proppant dosage is recommended to be 30-40m³.

40/70 mesh ceramsite was used in the early stage, and 30/50 mesh ceramsite was tailed near the wellbore to ensure the conductivity of the main fracture. Recommended proppant dosage of 30-40m³, properly control the construction sand ratio (average sand ratio 16-20%), to reduce the risk of construction.

![Influence of sand ratio on conductivity](image2)

**Fig. 10** Influence of sand ratio on conductivity
5. Conclusion
Pretreatment with acid pretreatment in the spout phase, construction displacement 4.55.5m³/min, well inflow fluid volume (400-500m³), 40/70 mesh ceramsite used in the early stage, 30/50 mesh ceramsite tailings near the wellbore, proppant dosage 30-40m³, and proper control of construction sand ratio (average sand ratio 16-20%).

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