Identification of formation plugging risk- A case study of gas reservoir in Deng4 member of Gaoshiti-Moxi block

Jin Yi, Hong Luo *, Chenxuan Gao, Minhao Zhou, Yukun Wang, Yongqiang Wang

Southwest Oil and Gas Field Branch Chuanzhong Oil and Gas Mine, Suining, China

* Corresponding Author Email: luohong123@petrochina.com.cn

Abstract. Gaoshiti-moxi block of Anyue Gas field is a highly heterogeneous carbonate gas reservoir with low porosity and low permeability. According to the production dynamic data, deng4 gas reservoir in Gaoshiti-Moxi block is blocked to some extent. Combined with reservoir parameters, productivity parameters, gas well production curve, RTA analysis and other means, the cause of plugging in special single well was analyzed. Through various experiments, the composition of the plugging material is analyzed, and the formation mechanism of the plugging material is deduced, which provides a reference for the later gas field development and the research of plugging measures.

Keywords: RTA analysis; Blockage analysis; Composition analysis of plugging material

1. Introduction

Gaoshiti-moxi block of Anyue Gas Field in Sichuan Basin is the largest single integrated Marine carbonate gas reservoir discovered in China, which has large reserves, large gas-bearing area, high gas well output and high gas reservoir pressure, and has broad prospects for exploration and development [1]. The reservoir space of Sinian gas reservoir in Gaomo block is complex, and there are many serious clogging caused by different kinds of reasons, such as large amount of drilling fluid leakage, poor formation physical property and wellbore pollution, which ultimately affect the productivity of gas well [2-8].

In view of the plugging phenomenon, scholars have also carried out cause analysis and mechanism research through different ways. Liu JS et al. [9] systematically analyzed the properties of injected water and formation water, and analyzed the causes of blockage in M oilfield by simulating scaling blockage, solid phase particle blockage and crude oil emulsification blockage. Gao YH et al. [10] analyzed the bacterial content, iron ion content and compatibility of formation water and injection water in formation water and summarized the causes of oilfield and injection well clogging.

2. Gas reservoir profile

Gaoshiti-moxi block is located in the middle of gentle tectonic belt in central Sichuan area and the eastern axis of Leshan-Longnusi paleo-uplift in Sichuan Basin. Its main reservoirs include Sinian Dengying Formation and Cambrian Longwangmiao Formation [11]. Gaoshiti-moxi block has gentle structure, large trap area and many high points. Gaoshiti-moxi-longnusi structure forms a cocircle with trap area of 4518.2km2 and closure degree of 429m. The faults are mainly 60°~ 80°normal faults. The reservoir rocks of the fourth Member of The Deng Formation are mainly algal clot dolomite, algal stromatolite dolomite and algal sand dolomite. The reservoir space is dominated by small and medium caverns, followed by intergranular (solution) pores, with poor interpore connectivity and strong heterogeneity of fracture development. The average porosity of the full diameter core is 3.97%, the average horizontal permeability is 2.89mD, and the average vertical permeability is 0.48mD. It belongs to low porosity and low permeability reservoir. Based on the relationship between fracture-cavity and fracture-cavity and its origin, the reservoir can be divided into three types: fracture-cavity type, fracture-cavity type and porosity type, among which the fracture-cavity type and porosity type are high-quality reservoirs.

3. Single well plugging analysis

Well A also had poor reservoir properties and formation blockage, which made it impossible to maintain stable production. As shown in Table 1-3, the porosity and water saturation of well A and its neighboring well Moxi B are similar, but the productivity of well A is much lower than that of well B, and the decline rate increases. The analysis may indicate blockage.

Table 1 Reservoir parameters of well A

Number	Porosity (%)	Water saturation (%)
1	2.1-7.7	3-10
2	2.0-8.6	3-13
3	2.0-6.5	3-21
4	2.0-4.8	5-23
5	2.0-4.7	5-17
6	2.0-5.4	4-25
7	2.0-5.8	3-13
8	2.0-4.7	4-13
9	2.0-4.4	7-16
10	2.0-6.4	4-21

Table 2 Reservoir parameters of well B

Number	Porosity (%)	Water saturation (%)
1	3.78608	10.9883
2	3.6241	10.786
3	3.50253	12.8884
4	5.67121	17.991
5	2.92143	27.0997

Table 3 Productivity parameters of well A and B

Number	Static pressure	Shut-in pressure	Open hole hydraulic	Flowing pressure	△P	Capacity
Well A	46.34	34.51	33.34	44.76	1.58	129.09
Well B	35.45	23.79	16.75	26.44	9.01	17.09

In the early stage of production, well A was shut in for most of the time due to the rapid decline of oil pressure. In the later stage, the well was shut in for several times. At present, the oil pressure is 12.79MPa, the daily gas output is 79,700 m3, the daily liquid output is 2.3 m3, and the water-gas ratio is 0.28m3/104m3.

Well A is located at the edge of Class ii area of Moxi M well area. The reservoir physical properties are relatively poor, and there are small faults on the east and west sides, so the gas supply capacity of the formation is limited. RTA analysis showed that the epidermal coefficient was 7.71>0. On May 10, 2021, dirt was carried out from the wellbore, comprehensively judging the existence of pollution near the well area.

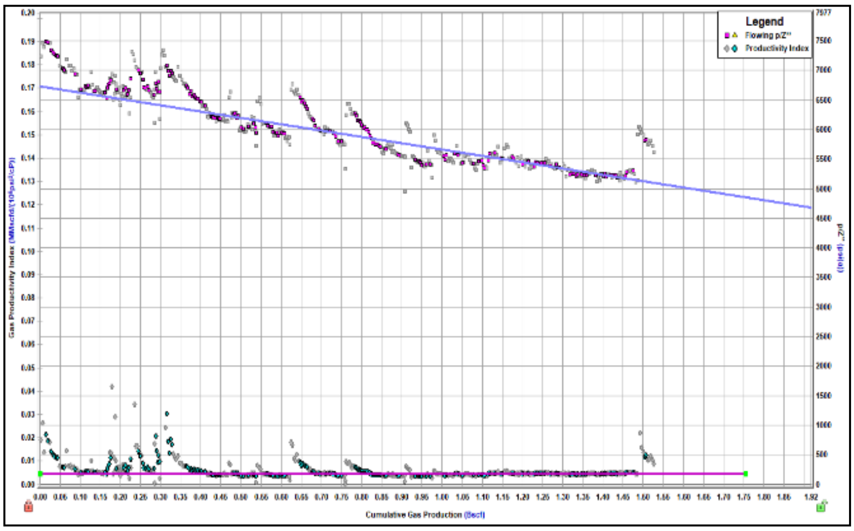

Figure 1. Flow material balance analysis of well A.

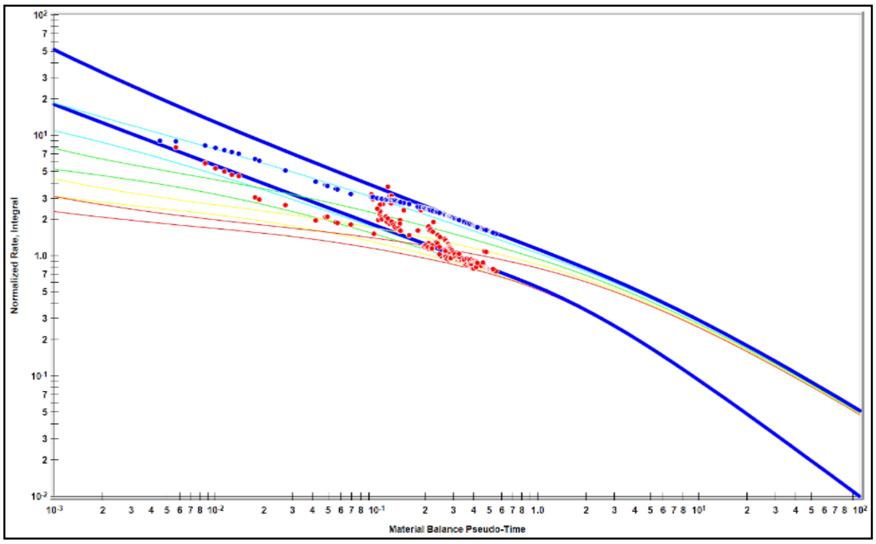

Figure 2. Blasingame analysis of well A.

The productivity of well C is affected by wellbore blockage and has obvious decreasing characteristics. The porosity, permeability and water saturation of well C and its adjacent well D are similar, but the productivity of well C is much lower than that of well D, and the decline rate increases, which may be caused by blockage.

Table 4. Productivity parameters of well C and D.

Number	Static pressure	Shut-in pressure	Open hole hydraulic	Flowing pressure	△P	Capacity
Well C	46.18	34.15	19.20	29.15	17.03	11.78
Well D	51.48	38.65	37.61	49.47	2.01	91.37

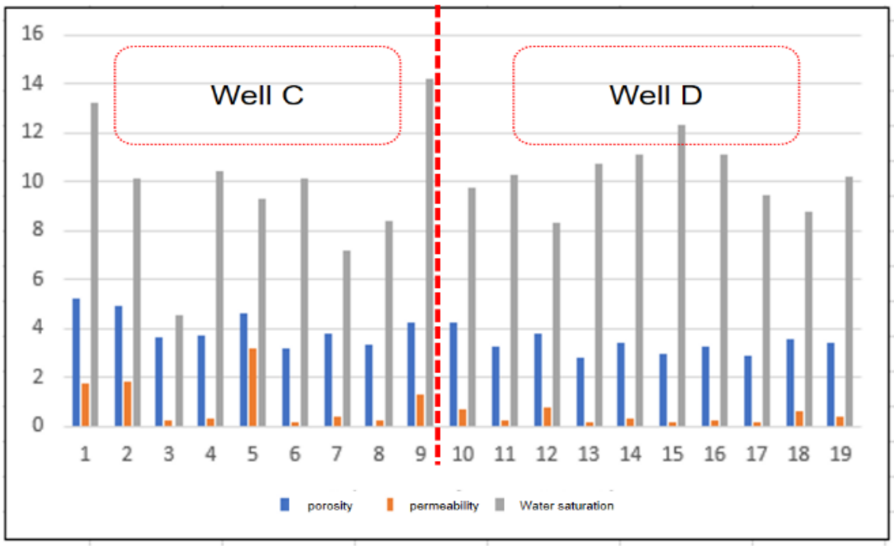

Figure 3. Reservoir parameters of Wells C and D.

In the early stage of oil pressure production, the oil pressure drops rapidly with ↓ 21.96MPa /a, and slows down after stable production. In ↓ 9.4MPa /a, the oil pressure drops 28.39MPa, the daily gas volume is 97,000 m3, the daily liquid is 1.02 m3, and the water-gas ratio is 0.11m3/104m3.

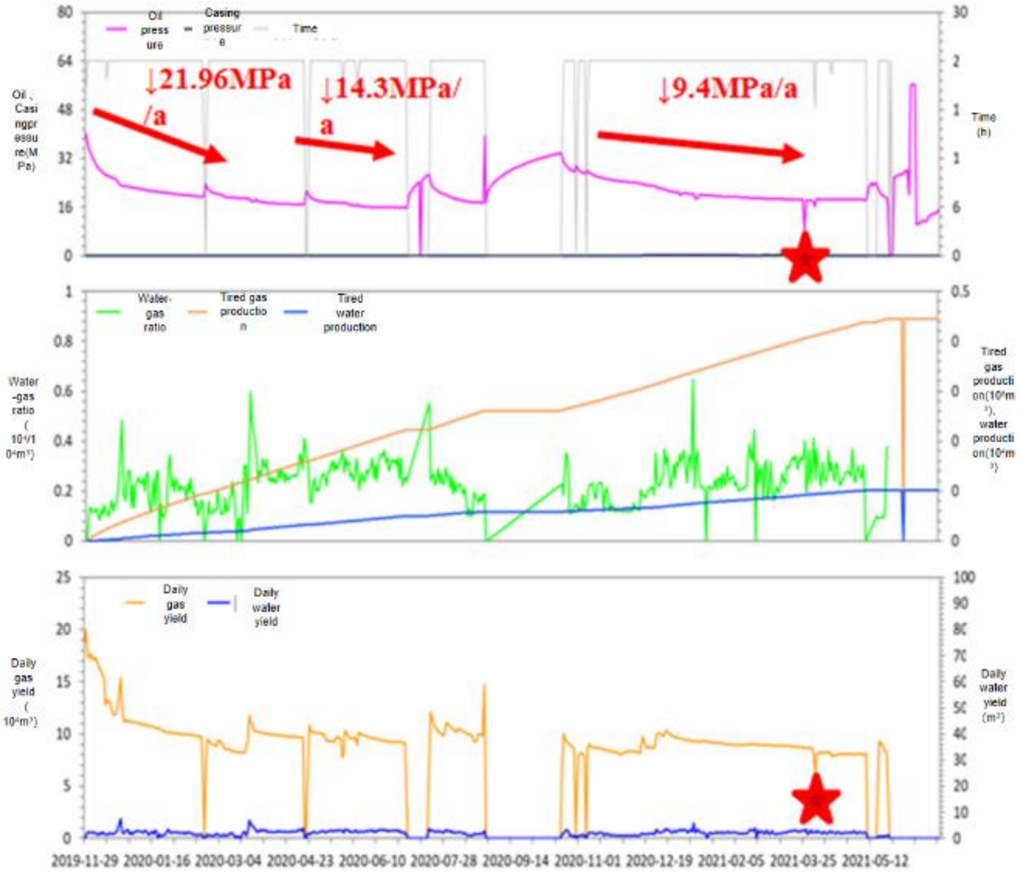

Figure 4. Mining curve of well C.

Well C is close to the favorable area of class ii. Based on the analysis of pressure and production characteristics, the rapid oil pressure decline in the early stage of well opening may be caused by poor reservoir physical properties and insufficient supply capacity in the far well area. On May 20, 2021, the oil pressure drops from 20.23MPa to 6.92MPa, which is basically the same as the pressure delivery, and the gas production drops from 98,800 m3 to 10,000 m3. RTA analysis shows no obvious falling feature, indicating that wellbore blockage may occur.

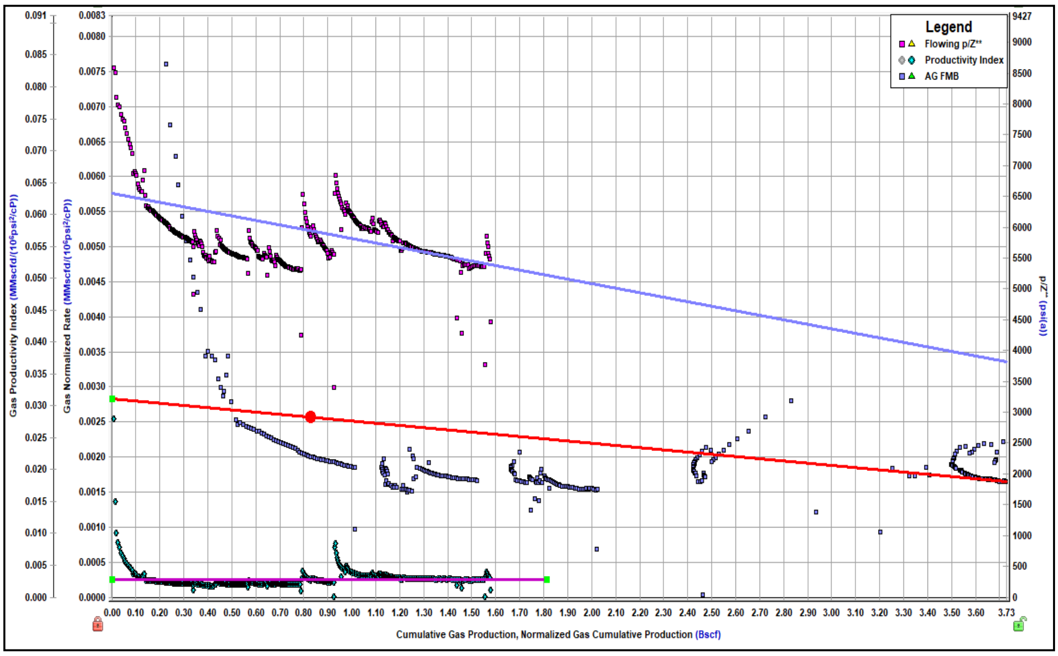

Figure 5. Flow material balance analysis of well C.

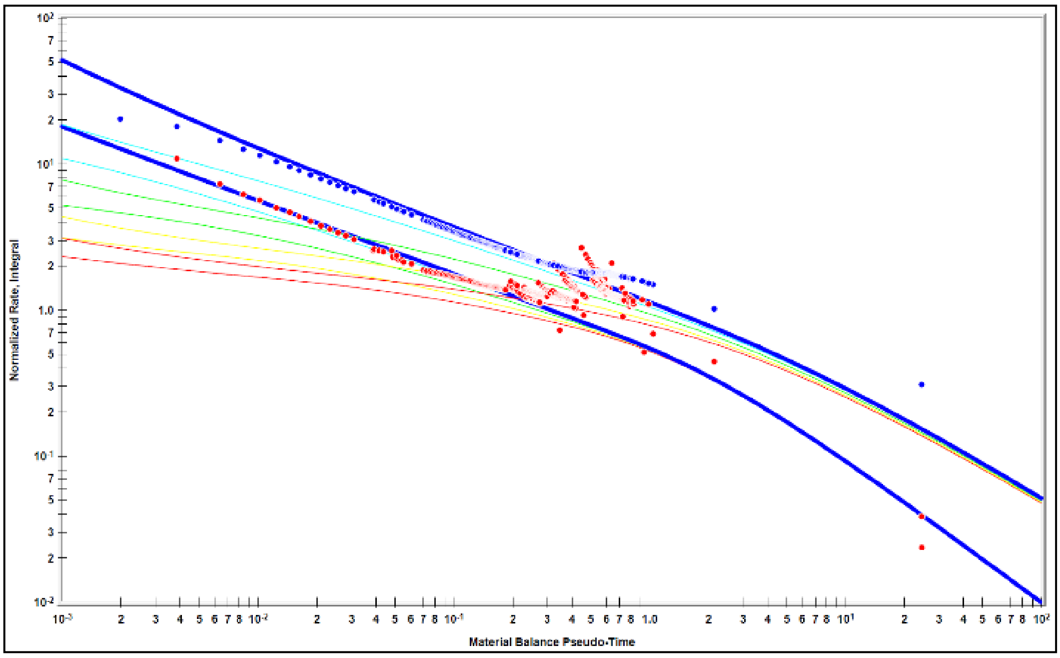

Figure 6. Blasingame analysis of well C.

Well E has poor reservoir properties and may be blocked by wellbore.

In the early stage of production, due to the rapid decline of oil pressure, the well was shut in for most of the time. In the later stage, the well was shut in for several times. At present, the oil pressure is 12.01MPa, the daily gas volume is 37,200 cubic meters, the daily liquid is 0.41 cubic meters, and the water-gas ratio is 0.11m3/104m3.

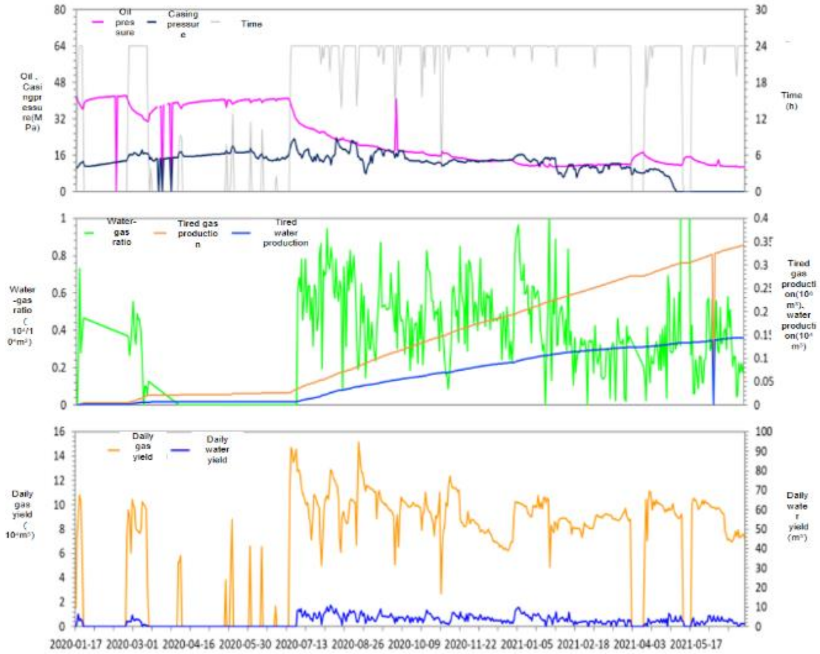

Figure 7. Mining curve of well E.

RTA skin coefficient 2.24>0, RTA did not drop significantly, and the rapid oil pressure decline at the early stage of well opening may be caused by poor reservoir physical properties and insufficient supply capacity in the far well area. In March 2020, foam was found and the well was shut in. Since July, the continuous injection of defoaming agent has been in normal production. After continuous production, oil pressure dropped rapidly, and there was a sudden drop of daily production.

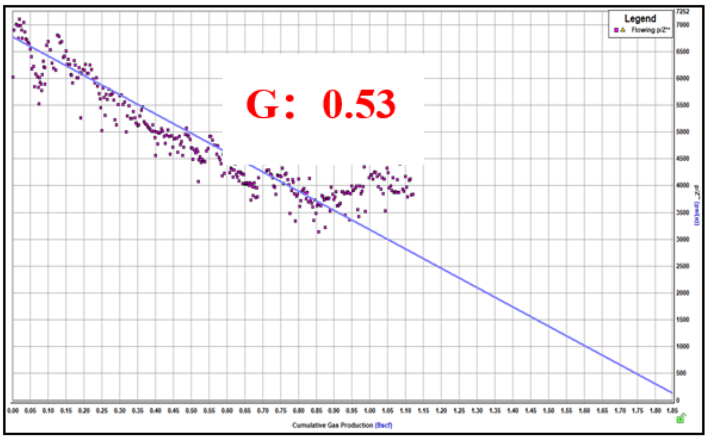

Figure 8. Analysis of flowing material balance method in well E.

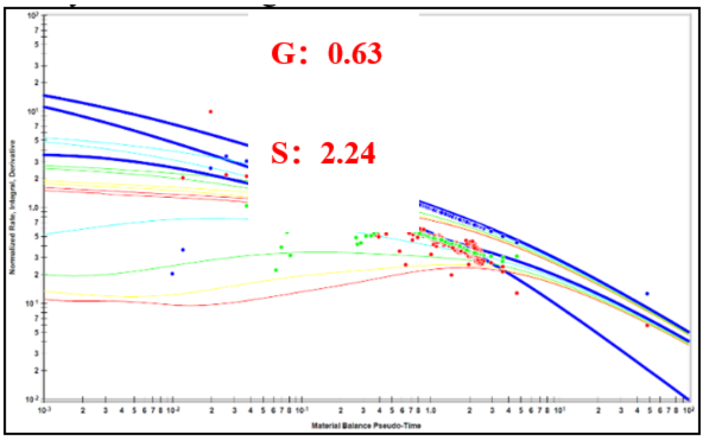

Figure 9. Blasingame analysis of well E.

4. Composition analysis of plugging material

The composition is mainly organic matter and inorganic matter. The inorganic minerals are mainly iron and calcium, mainly composed of $FeCO3$, $Ca2SiO4$, $CaCO3$, $SiO2$, etc. The organic matter is mainly hydrocarbon oil and its derivatives. There are two main components, one is the mixture of wellbore corrosion products and residual acid, pre-construction residues, etc.; Second, the formation debris, asphaltene mixture.

Figure 10. Plugging in well F.

Figure 11. Plugging in well G.

Figure 12. Plugging in well H.

Table 5. Plugging sample analysis results.

Sample name	Sampling time	Appearance	The preliminary analysis
Well F	2019.12.17	Black gelatinous solid, strong smell of oil	It mainly contains Si, S, C, Ca, O, Fe and other elements, among which C is 52.43at.%, O is 32.22at.%, Fe is 10.32at.
Well G	2020.10.13	Gray solid particles, slight odor of oil	It mainly contains Si, S, C, Ca, O, Fe and other elements, among which C accounts for 15.1at.%, O for 65.77at.%, Ca for 16.95at.%, and may contain calcium carbonate, dicalcium silicate, silicon oxide, iron oxide, etc.
Well H	2020.10.13	Black granular material with strong odor of oil	It mainly contains Si, S, C, Ca, O, Fe and other elements, among which C accounts for 29.64at. %, O for 57.8at. %, Ca for 9.41at. %, and may contain calcium carbonate, dicalcium silicate, silicon oxide, iron oxide, etc.

FT-IR analysis was carried out for the plug in F well, and the functional groups of the plug samples were mainly methyl, methylene, alkyne, carbonyl, carbonate, submethyl and silicate.

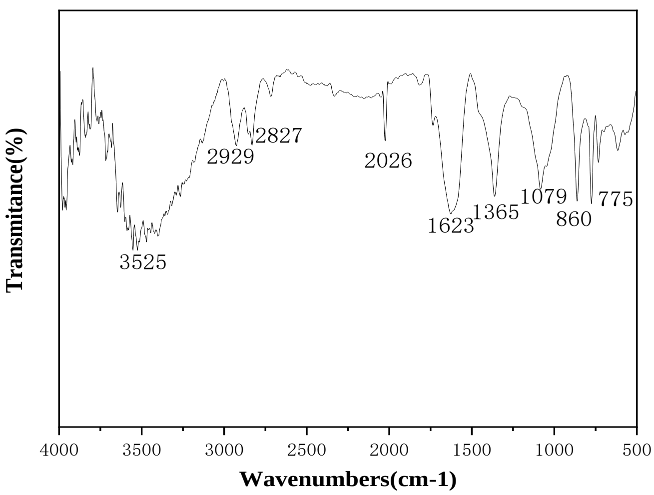

Figure 13. Infrared spectrum of plugging material in well F.

Table 6. Groups corresponding to absorption wavelengths.

Absorption wavelength(cm^{-1})	Corresponding to the group
3400-3600	Water of crystallization
2929	$-CH_3$
2827	$-CH_2$
2026	$C \equiv C$
1623	$C=O$
1454	CO_3^{2-}
1365	C-HBending vibration
1079	SiO_4^{2-}

The plugging element energy spectrum analysis experiment (EDS) was carried out for the plugging material in well F. The EDS experiment shows that the main elements are C, O and Fe, and it is speculated that Fe mainly comes from wellbore corrosion, possibly from formation siderite, while Si, S and Ca mainly come from formation. The ratio of Fe to O atoms is approximately 1:3, and the blockage substance is mainly FeCO3, which is verified by the inorganic composition analysis experiment.

Table 7. Analysis results of plugging element.

The element	Percentage by weightWt％	Atomic percentageAt％
C	33.39	52.43
O	27.33	32.22
Si	0.40	0.27
S	7.20	4.24
Ca	1.12	0.53
Fe	30.56	10.32

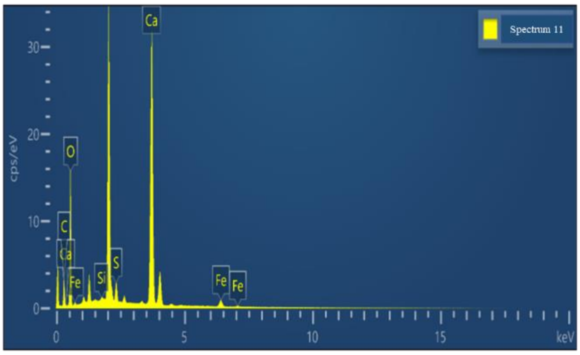

Figure 14. Energy spectrum of plug.

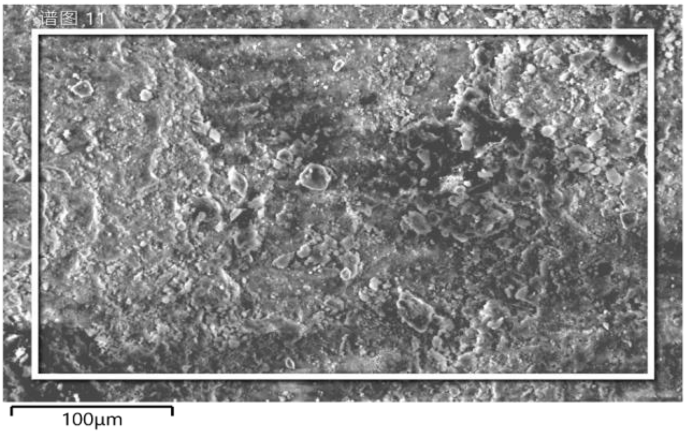

Figure 15. SEM of plugging material.

The inorganic composition analysis experiment (XRD) was carried out for the plug in F well. According to the XRD analysis results of the inorganic composition of the plug in well F, the main component of the inorganic in the colloidal solid of the plug is FeCO3, followed by Ca2SiO4.

On December 14, 2019, the CO2 content in the produced gas of well F was as high as 435.3g/m3 (the well was shut in for nearly a year), and there was serious CO2 corrosion during the shut in period.

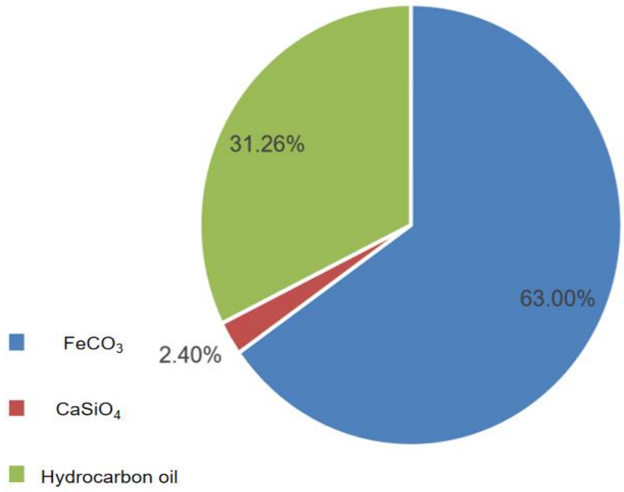

Figure 16. Plugging material composition in well F.

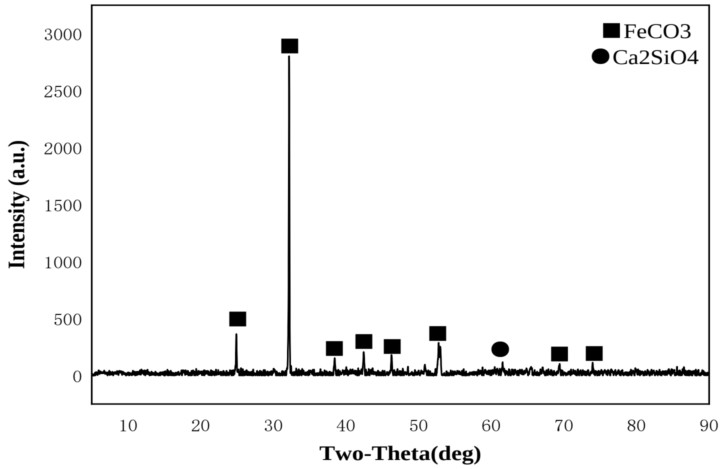

Figure 17. X-ray diffraction of well F.

Source analysis of the plugging in the formation:

(1) FeCO3 (ferrous carbonate) contains CO2 in the gas layer. When carbon dioxide is dissolved in water, it forms carbonate and bicarbonate, and reacts with iron ions on the wellbore surface to produce ferrous carbonate, thus causing wellbore blockage;

(2) Ca2SiO4(calcium silicate), the main component of cementing mud, is presumed to be the residue after cementing due to the existence of well loss and other factors;

(3) SiO2 (silica), stable chemical properties, does not react with general acid, inferred from the early construction or stratum;

(4) CaCO3 (calcium carbonate), commonly found in carbonate rocks, is presumed to have come from pre-construction or formation;

(5) organic mixture, the infrared spectrum results of each sample are close, and it is speculated that the source of organic components of the blockage is consistent, which is the formation asphaltene mixture. As the well depth decreases, the formation temperature decreases, the asphalt deposition sticks to the inner wall of the wellbore, and it is captured in the discharge of inorganic materials, so that the blockage gets bigger and bigger.

5. Conclusions

(1) Some Wells with problematic productivity in this block may have different plugging causes, such as poor reservoir physical property, formation blockage, pollution near well zone and wellbore blockage.

(2) According to the analysis of various components and data research, it can be concluded that the formation mechanism of plug: inorganic plug as the skeleton, organic plug as the filler, solid granular dense mixed plug with a certain viscosity, after a long time of deposition and aggregation, gradually accumulated in the wellbore to cause gas well blockage.

References

[1] Yousheng Song, Jianlong Zou, Baohui Zhao, Aiping Liu. Drilling fluid and completion fluid,2017,34(02):111-116.

[2] Li Song, Ma Huiyun, Ye Jie xiao, Zhou Changlin, Wu Lin. Reconstruction optimization of fractured carbonate reservoir based on prediction of drilling fluid loss invasion depth [J]. Drilling & production technology,2018,41(02):42-45.

[3] Yang Wei, Wei Guoqi, ZHAO Rongrong, et al. Characteristics and distribution of karst reservoirs in Sinian Dengying Formation, Sichuan Basin [J]. Natural gas industry, 2014,34 (3):55-60.

[4] KANG Y L, YOU L J, XU X H, et al. Prevention of natural Damage Induced by Mud Lost in Deep FracturedTight Gas Reservoir in Western Sichuan Basin [J]. Journalof Canadian Petroleum Technology, 2013,51 (1):46-51.

[5] LI S, KANG Y L, LI D Q, et al. Modeling of Bulk Drilling Fluid Flow in radial fracture [J]. Journal of Porous Media, 2014,17 (3):239-254.

[6] zhang ping. Discussion on well test plugging and killing technology in fractured vuggy formation [J]. Drilling & production technology, 2013,38 (3):73-76.

[7] Majidi R, Miska S Z, Yu M, et al. Quantitative analysis ofmud losses in natural fractured reservoirs:The effect ofrheology [C]. Paper SPE 114130, presented at the 2008SPE Western Regional and Pacific Section AAPG JointMeeting held in Bakersfield, California, U.S.A., 31 March- 2 April 2008.

[8] Kang Yili, XU Chengyuan, TANG Long, et al. Building tough barrier around well: theory and method of well loss control [J]. Petroleum exploration and development, 2014,41 (4): 473-479.

[9] Liu Jiansheng, Liu Jiangbo, Liu Xiuhua, PENG Junfa. Drilling & Production Technology, 201,44(01):129-132.

[10] Gao Yonghua, FANG Peilin. Analysis on water quality of injection water and plugging cause of injection well in sz36-1 oilfield [J]. Industrial water treatment,2018,38(07):91-94.

[11] Cui Likai, Sun Jianmeng, Huang Hong, Zhang Zhefu, Wang Yongjun, Chi Peng. Kaolinite ladder - mill creek block carbonate reservoir pore connectivity comprehensive evaluation [J]. Journal of xi 'an university of science and technology, 2019, 33 (4) 6:634-643. The DOI: 10.13800 / j.carol carroll nki xakjdxxb. 2019.0411.