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Research Article

Fine Scale Geological Modeling Techniques in Kela 2 Gas Field

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ABSTRACT

As the major gas resource of the West-East Gas Transmission Project, Kela 2 gas field plays an important role in the natural gas industry development and social demand in China. After 17 years development, annual gas production of Kela 2 gas field is stable in over 5 billion cubic meters, which has great reference value for the other gas field's development. Kela 2 gas field is in the middle-late development period at present, some gas wells experienced water flooding in advance, which has resulted in a productivity decrease. Main challenges at current development period are development scheme adjustments such as water invasion prevention, water invasion control, production allocation optimization, and the conventional geological modeling cannot meet the scale requirement for the development scheme adjustment. By using the fine scale geological modeling techniques, it could provide a basis for the study of remaining reserves distribution, horizontal well deployment, water control and drainage scheme design.

Keywords: Tarim Basin; Kela 2 gas field; Structural modeling; Facies modeling; Petrophysical modeling; Discrete fracture network modeling

INTRODUCTION

In 1998, the completion testing of Well Kela 2 showed high-yield gas layers, which marked the successful discovery of Kela 2 gas field [1-3]. Kela 2 gas field is located in the Kelasu structural belt of the Kuqa depression, Tarim Basin, and the sedimentary facies are mainly alluvial fans, fan deltas, and braided river deltas (1) [4]. The major reservoirs are the Paleogene dolomite formation, Kumgeliemu group dolomite formation, glutenite formation and cretaceous Bashijiqike thick sandstone Formation, and the total formation thickness is 400-530 m. Kela 2 gas field is a medium-porosity and medium-permeability reservoir, with an average logging porosity of 13.8% and an average logging permeability of 37 × 10^{-3} μm^2 [5-7]. Kela 2 gas field is a normal temperature, abnormally high-pressure block edge-bottom water dry gas reservoir, with the original formation pressure of 74.35 Mpa, the formation pressure coefficient of 2.02, and the original formation temperature of 100°C [8].

Up to June 2021, there are 23 production wells in Kela 2 gas field, which has 19 wells in production currently. Cumulative gas production is 124.5 billion cubic meters with a gas recovery ratio of 43.8%. Formation pressure of single wells decreased simultaneously, which indicates good reservoir connectivity. There are 11 wells producing water, mainly located in the southwestern and eastern area (2). Inhomogeneous water invasion causes the production decreasing, which will affect ultimate recovery of Kela 2 gas field in the future. In order to indicate and control the water invasion, it is necessary to build a fine scale geological modeling to support the development scheme adjustments.

METHODS

Fine scale geological modeling techniques

Combining with static and dynamic data, fine scale geological modeling techniques quantitatively characterize geological structures, sedimentary facies, reservoir characteristics, fluids characteristics and other related parameters [9-12]. According to the development and numerical simulation demand, fine scale structural model, facies model, matrix petrophysical model and fracture model were built in this paper. 3 shows the flow chart of modeling technique based on Petrel.

Fine scale structural modeling

Based on the fine scale 3D seismic interpretation, geological surfaces and faults are imported into Petrel to model the geological

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structure. There are 158 faults in Kela 2 gas field, and 114 faults are in the gas trap. According to the fault occurrence, 158 faults are divided into 7 groups to build the 3D fault models (4). Through analysis of the fault models, it is found that the fault length of Kela 2 gas field is mainly distributed in the range of 200-3000 m, and small-throw and high-angle faults are mainly developed in the gas trap. There are 51 faults run through the whole formations.

From seismic interpretation data, there are 13 structural surfaces from Dolomite formation to Shushanhe Formation River. All the structural surfaces have the good quality and used to build the surface models with well tops (5). In order to meet the scale demand of fine modeling and numerical simulation, the plane grid is set as 100 m × 100 m, while the vertical grid is set as 535 layers. The grid number of structural model is 231 × 55 × 535=6797175 in total.

Facies modeling

Stochastic object is used to build the facies models in the paper. Based on the stratigraphic correlation, 5 facies of dolomite, gypsum mudstone, glutenite, sandstone and mudstone are simulated separately. Through the outcrops survey in Kelasu River Mountain, interlayers characteristics of Kelasu reservoir were described and

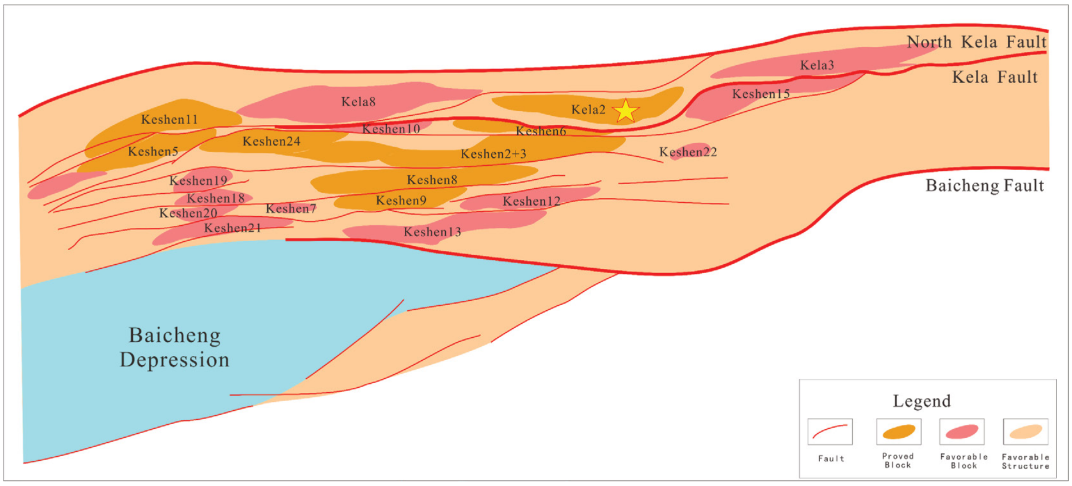

Figure 1: Location of Kela 2 gas field in Kuqa depression, Tarim Basin.

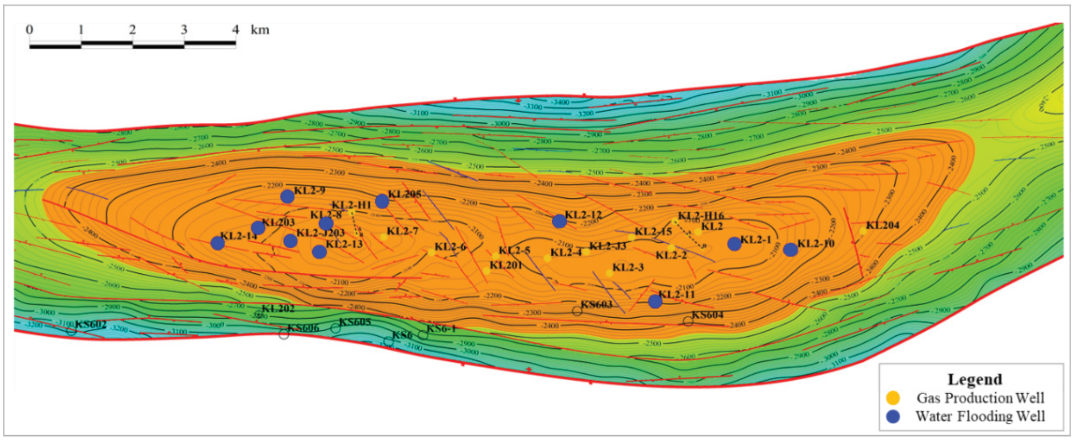

Figure 2: Well production situation of Kela 2 gas field.

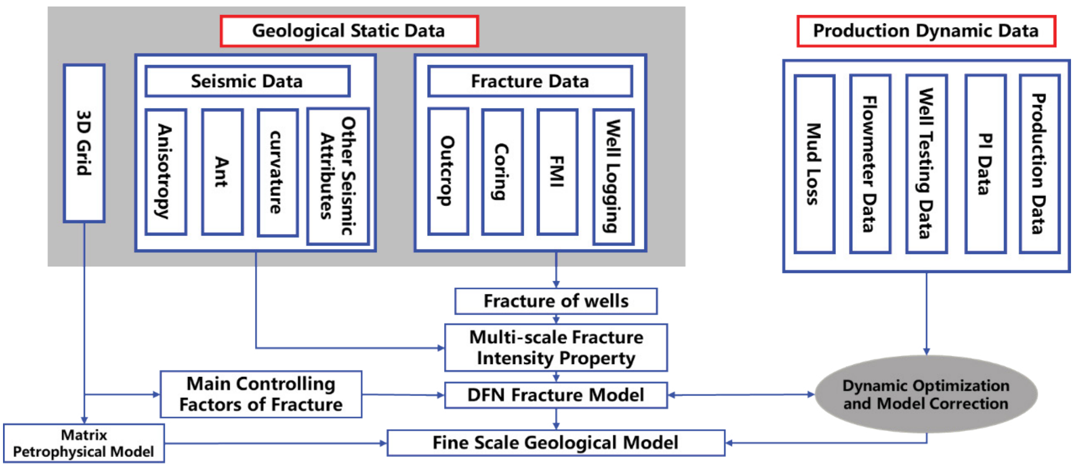

Figure 3: Technique flow chart of fine scale geological modeling.

made statistical analysis. Interlayers thickness of 2-4 m could be extend to about 450 m, and they have a good extension in the plane. These interlayers could form in a small area, which could play as barriers to prevent the liquid migration. Interlayers thickness of 1-2 m could be extend to less than 200 m. Interlayers thickness of smaller than 1 m could only extend 10-30 m, the plane extension is short and they have no barrier effect on the fluid migration.

Through analysis of the well logging, the interlayer thickness is 0.3-1.6 m in Kela 2 gas field, the interlayer density is 0.19 meter per meter, and the interlayer frequency is 0.17 number per meter. From the statistical outcrop data, interlayers of Kela 2 gas field are only developed in partial area and they have no barrier effect on the fluid migration (Table 1). In the facies modeling process, development scale of mudstone interlayers (length, width, thickness, azimuth,

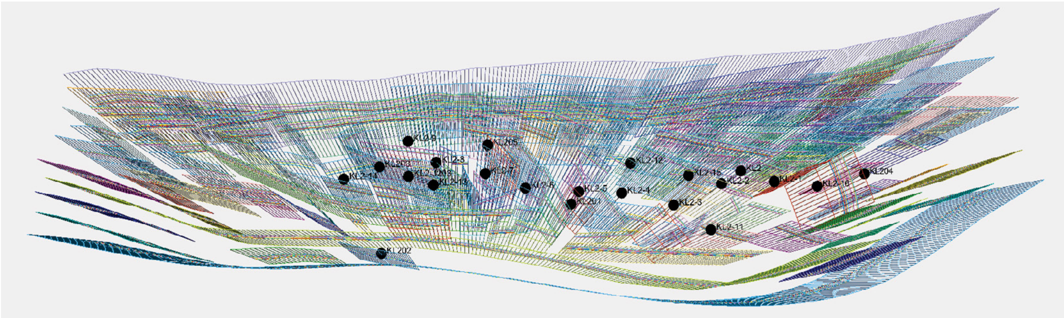

Figure 4: Fault models of Kela 2 gas field.

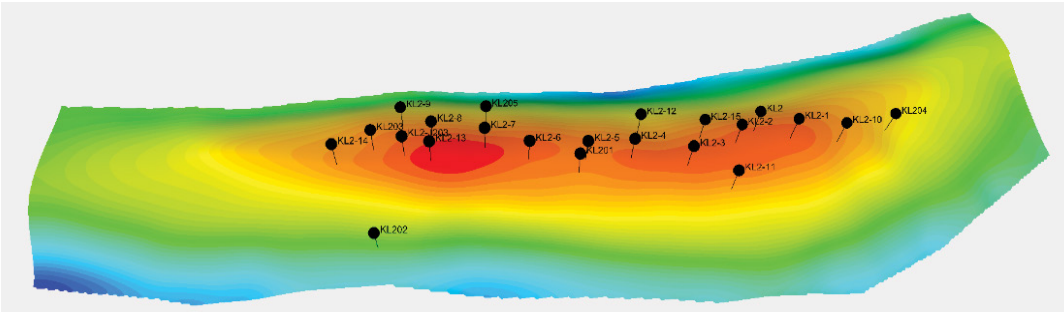

Figure 5: 3D structure model of Kela 2 gas *field.*

Table 1: Statistical interlayer's data of Kela 2 gas field.

Well	Effective Thickness (m)	Interlayer Number	Interlayer Thickness (m)	Interlayer Density (m/m)	Interlayer Frequency (Number/m)	Average Thickness (m)
KL2-14	248.1	56	76.2	0.31	0.23	1.36
KL203	316.5	35	62.8	0.20	0.11	1.79
KL2-9	286.1	46	63.4	0.22	0.16	1.38
KL2-J203	363	30	57.9	0.16	0.08	1.93
KL2-13	393.5	81	113.2	0.29	0.21	1.40
KL2-8	368	51	101	0.27	0.14	1.98
KL2-7	339.9	61	95.2	0.28	0.18	1.56
KL205	240	28	29.9	0.12	0.12	1.07
KL2-6	299.8	60	82.8	0.28	0.20	1.38
KL201	302.2	34	51.2	0.17	0.11	1.51
KL2-5	262.7	25	28	0.11	0.10	1.12
KL2-4	360.4	34	52.7	0.15	0.09	1.55
KL2-12	244.2	58	87.7	0.36	0.24	1.51
KL2-3	380.1	28	49.6	0.13	0.07	1.77
KL2-15	306.5	59	86.5	0.28	0.19	1.47
KL2-11	255.2	45	65.2	0.26	0.18	1.45
KL2-2	350.7	37	61	0.17	0.11	1.65
KL2	351.7	50	75.2	0.21	0.14	1.50
KL2-1	368.9	33	43	0.12	0.09	1.30
KL2-10	287.1	31	39.5	0.14	0.11	1.27
KL204	143.4	12	10	0.07	0.08	0.83

dip) are set based on the statistical outcrop data and interlayer distribution analysis. Facies model shows the sedimentary characteristics of braided river deltas, which is consistent with early geological understandings (6).

Matrix petrophysical modeling

Petrophysical modeling includes porosity modeling, permeability modeling and saturation modeling. Modeling method selects the sequential Gaussian simulation with facies controlled. In the porosity modeling, petrophysical distribution range and trend of input data are analysis by separate layers and facies, and then using variogram analysis to determine the range value in major direction and minor direction separately. Due to a good correlation between porosity and acoustic impedance from seismic interpretation, acoustic impedance of separate layers are used as trend constraints during porosity modeling process (7). In the permeability modeling, porosity model is used as a second variable trend to constraint the simulation (8). Porosity and permeability models are consistent with early geological understandings.

Fracture modeling

Using multi-conditions and multi-scales constraints, Discrete Fracture Network (DFN) simulation is used to build the fracture model in this paper [13,14]. Kela 2 gas field mainly develops high angle structural fractures, which are controlled by faults and geo-stress. Kela 2 gas field is an anticline formed by the compressive stress in north-south direction, which fractures developed most in the structural axis and near faults area. In fracture modeling process, distance from the faults, maximum principal curvature, and the distance from the anticline axis are used as multiple constraints to build the fracture model. Input data are from different scales of outcrop description, seismic data, coring description, FMI interpretation, which are analyzed comprehensively to determine the fracture parameters (9).

Fracture parameters mainly contain distribution, geometry, orientation and aperture. From the analysis above, parameters are inputted into DFN module to build the fracture model (10). Fracture spatial distribution is based on the distance from the faults, maximum principal curvature, and the distance from the anticline axis. Finally, upscale the DFN model and obtain the equivalent fracture porosity and permeability.

RESULTS AND DISCUSSION

After upscaling the geological model of Kela 2 gas field, the model is imported into Eclipse to make the numerical simulation. Fixed production system is used in Kela 2 gas field, and we build the simulation model to predict the future production situation by

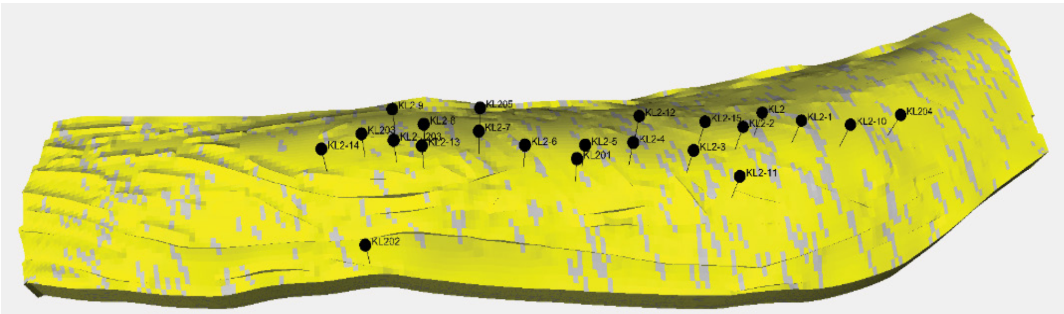

Figure 6: Facies model of Kela 2 gas field.

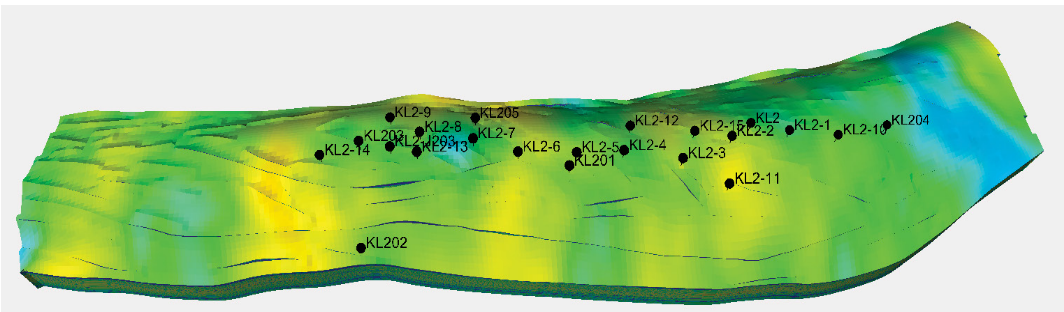

Figure 7: Porosity model of Kela 2 gas field.

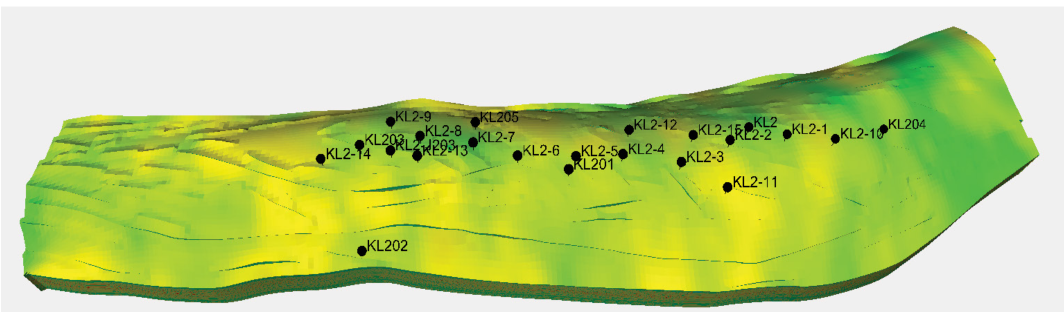

Figure 8: Permeability model of Kela 2 gas field.

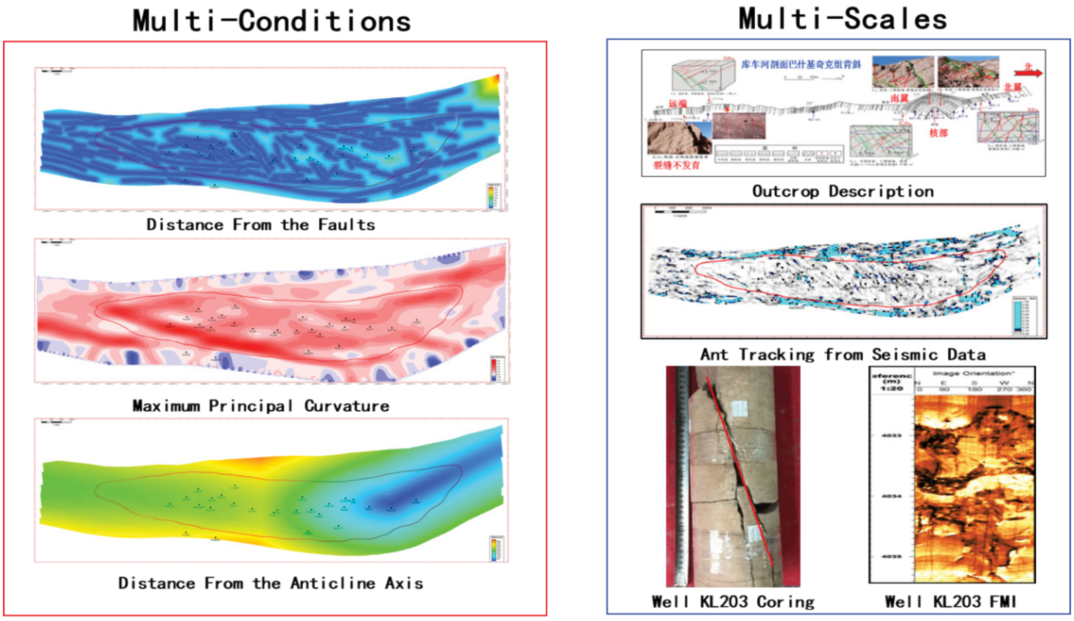

Figure 9: DFN fracture modeling under multi-conditions and multi-scales constraints.

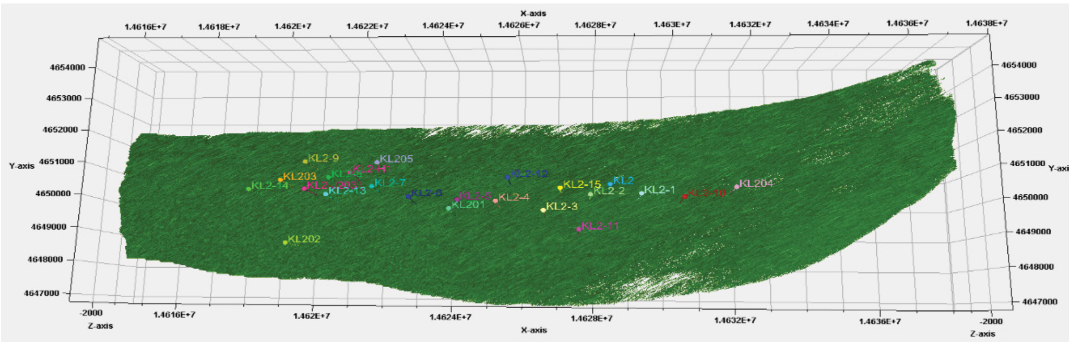

Figure 10: DFN fracture model of Kela 2 gas field.

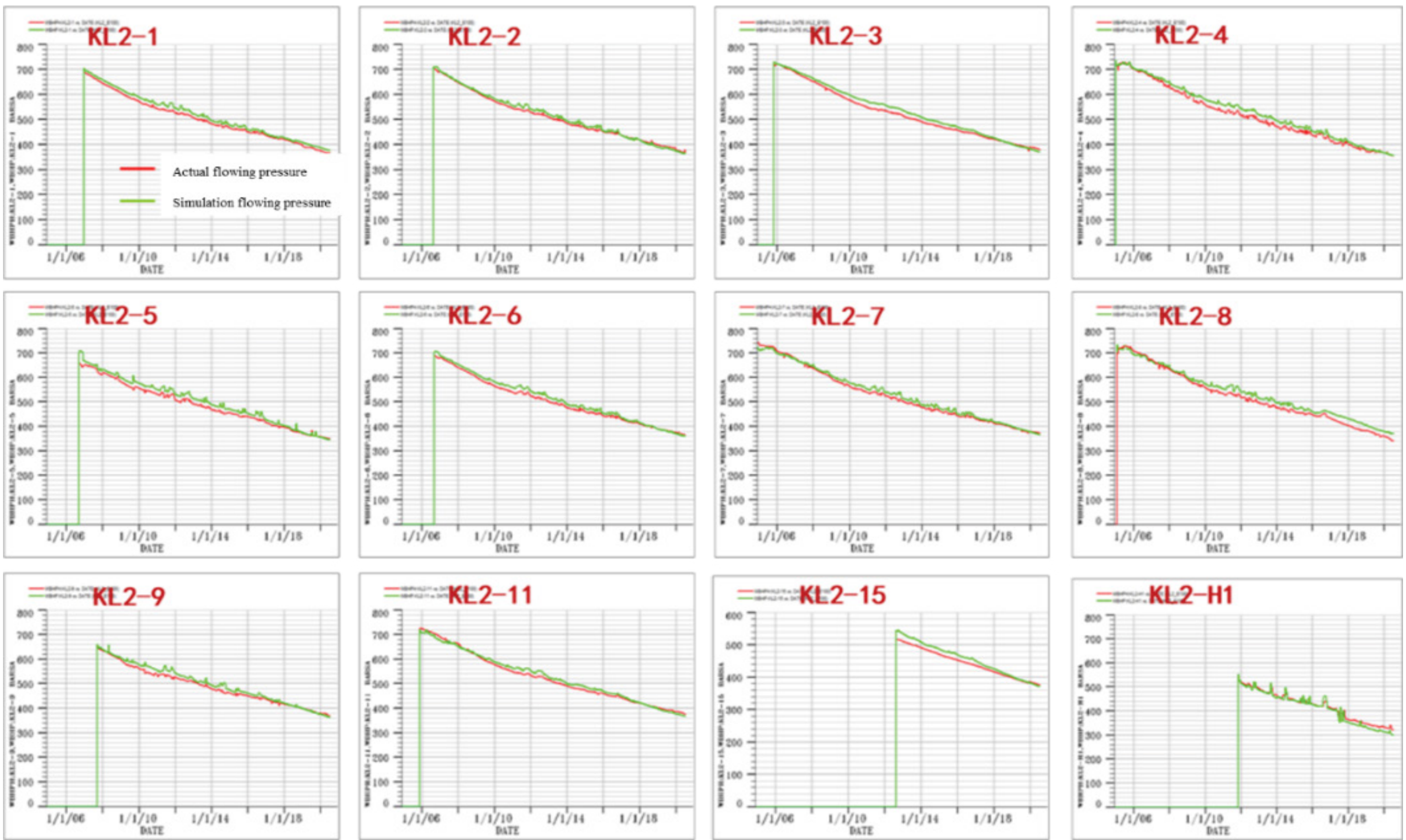

Figure 11: Simulation flowing pressure of Kela 2 gas field.

history matching of flowing pressure and water production. Since development from 2004, Kela 2 gas field has obtained plenty of dynamic production data. From numerical simulation on 22 production wells, first-time fitting rate of single well gas production reaches 100%, first matching ratio of gas production is 100% and the first matching ratio of flowing pressure is 70% (11). While, first matching ratio of water production is also over 50% for the 9 water flooding wells. The entire matching ratio is more than 50%, which indicates the good reliability of this fine scale geological model.

CONCLUSION

Using fine scale geological modelling techniques, geological models could meet the scale demand of middle-late development period for the Kela 2 gas field, and it could provide a basis for the study of remaining reserves distribution, horizontal well deployment, water control and drainage scheme design.

Fine scale geological modelling techniques include structural modelling, facies modelling, matrix petrophysical modelling and fracture modelling. Combining with static and dynamic data, multi-conditions and multi-scales data are constrained to improve the accuracy of the geological models, which are more coincidence with the of geological understandings.

Fine scale geological modelling techniques show good application effects in Kela 2 gas field. The entire initial production matching ratio is more than 50% after the numerical simulation, which indicates that geological model has a good reliability by using fine scale geological modelling techniques.

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