Comparative analysis of the characteristics of the fracture systems of the Yaojia and Quantou Formations in the X Oilfield

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Abstract: With the gradual industrial development of the Fuyu oil formation in the X oilfield and the frequent occurrence of set losses in the stratigraphic parts of the Nengjiang Formation, the importance of the overall characterisation of the fracture system has increased significantly. By establishing an integrated model of the fracture system from the Nengjiang Formation to the Quantui Formation, research work such as batch extraction of fracture elements and comparative analysis of the characteristics of the fracture system in the X Oilfield was carried out. The study shows that the Yaojia Formation to Quantou Formation fault system, vertically, has a multi-phase fault inheritance relationship; when the faults formed at a later stage develop, the faults formed at an earlier stage are revived again and grow together with the later faults, and the development pattern of the present-day faults is the result of multiple phases of tectonic movements and the cumulative development of faults.

Key words: multi-phase faults; fracture elements; Fuyu oil formation.

1. Introduction

The fracture system in X field is complex, and a total of 249 large and small faults were identified after the combined well seismic study of Yaojia Formation, with a density of 1.3 faults/km2, and four strike faults, NW, NWW, NE and SN, co-exist in the area and are distributed in a striped pattern. Each type of fault is the product of the same period of tectonic activity under the same stress environment, and the four types of faults also represent four periods of tectonic activity. The Fuyu oil-bearing zone is mainly located in the western part of the Xingshugang backslope, with 256 faults and a fault density of 0.13 faults/km2, with a predominantly north-westerly strike. There are only 304 oil and water wells in the Fuyu formation. Under the conditions of a sparse well network, it is important to identify the fault evolution pattern and development characteristics, relying on the mature techniques and practices of the Sapulco tectonic study, to provide guidance for the fine delineation of faults in the Fuyu formation, and therefore carry out a comparative analysis of the characteristics of the fracture system of the Yaojia and Quantui formations.

2. Analysis of fault elements of the Yaojia and Quantui Formations

Based on the integrated fault model basis, information on the strike, tendency and dip of the faults in three sections of the Nengjiang Formation, Yaojia Formation to Qingshankou Formation and Quantui Formation in the X Oilfield was extracted in bulk. The following insights were obtained.

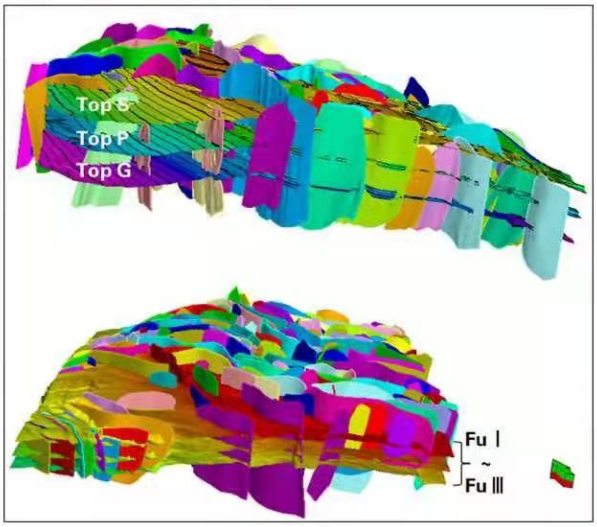

Figure 1 Plan view of the X field fault

① In terms of fault orientation, all of them are mainly north-west oriented, supplemented by north-north-west and north-west, and north-east oriented faults are sporadically developed. The proportion of north-westerly faults increases in the Yaojia Formation, and the distribution of fault orientations becomes more concentrated, with successions of fault orientations at different sections (Fig. 2).

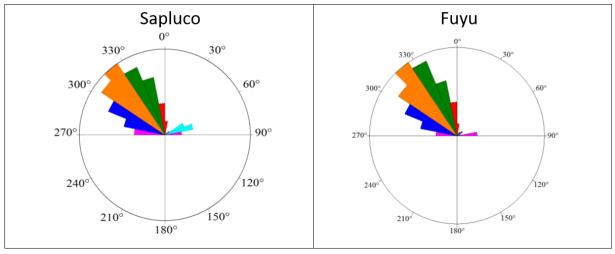

Figure. 2 Comparison of the strike of the Sapulco and Fuyu faults

② In terms of fault orientation, the north-east-south-west trend is dominant, with a decreasing trend from deep to shallow south-west trending faults (Figure 3).

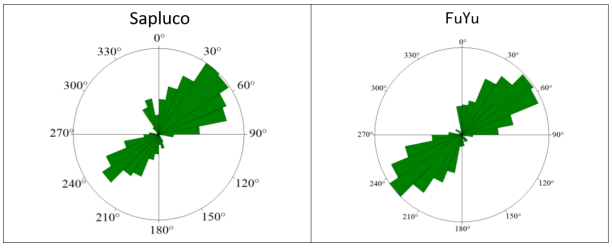

Figure. 3 Comparison of the tendency of the Sapluco and Fuyu faults

③ In terms of fault dip, the fault dip at different sections varies relatively little, mainly between 45 and 60°, with a relatively large dip in the Quantou Formation (Figure 4).

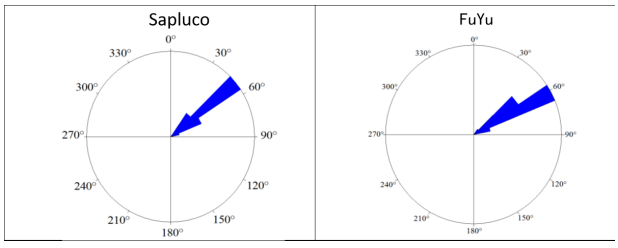

Figure 4 Comparison of the dip angle of the Saputaka and Fuyu faults

④ In terms of fault spacing, the fault spacing of the Quantou Group is mainly above 20m, and there are obviously fewer small faults with a fault spacing below 20m. The fault spacing of the Nengjiang Group and Yaojia Group is more evenly distributed in the range of 10-50m, and there are significantly more small faults compared with the Quantou Group (Figure 5).

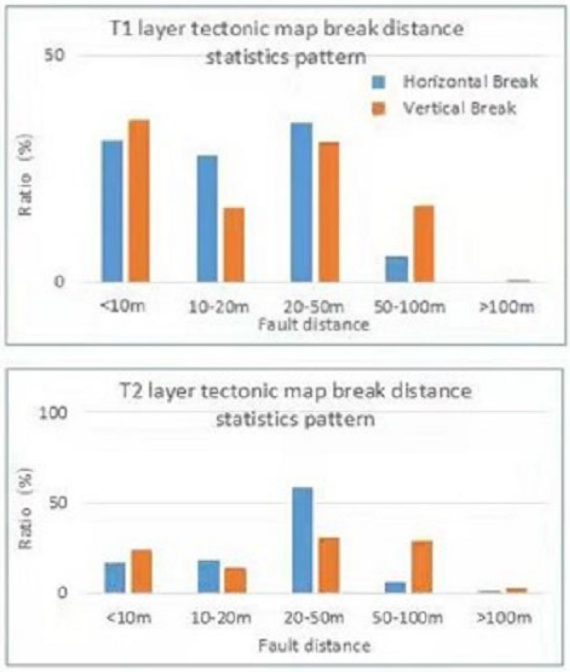

Figure 5 Comparison of T1 and T2 layer break distances

In terms of fault elements and development, the number of Fuyu faults is large and densely distributed, with relatively large fault dips and large faults of 20m or more in distance, with fewer small faults developing, and a clear inheritance relationship with the Sapulco fault in terms of fault orientation.

3. Study of the inheritance of the Yaojia Formation and the Quantou Group fracture system

3.1 Paleostress inheritance studies

The study area underwent three phases of stress field transformation: during the deposition of the Qingshankou Formation-Mingshui Formation, it was mainly extruded in a north-east-south-west direction; during the reversal of deformation from the end of the deposition of the Mingshui Formation to the deposition of the Yi'an Formation, the stress field changed and was mainly extruded in a north-north-west-south-east direction; from the deposition of the Da'an Formation to the present, the stress direction changed to near east-west extrusion and action.

In order to deepen the understanding of the palaeostress conditions in the X oilfield, palaeostress orientation maps (Figure 6, Figure 7) were drawn based on rock gravity, maximum horizontal principal stress, minimum horizontal principal stress and fluid pressure data. The palaeostress before and after the tectonic reversal was compared and analysed, and it was found that the overall palaeostress in the X oilfield did not change much.

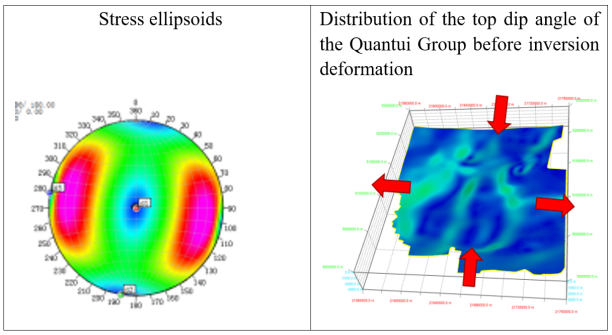

Figure 6 Paleostress map before tectonic inversion

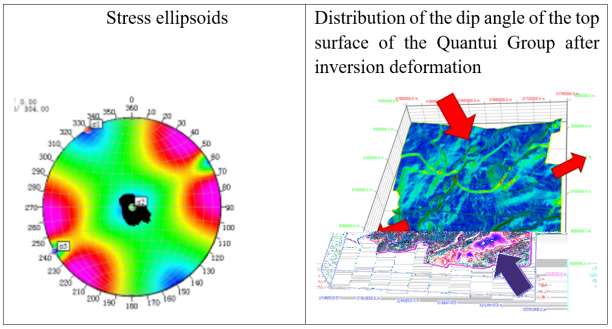

Figure 7 Paleostress map following tectonic inversion

3.2 Study of fault inheritance between the Yaojia Formation and the Quantou Group

In order to study the law of fault vertical evolution, five larger faults in the area of T2-T1 reflection layer were selected to compare the change of vertical fault distance along the fault extension direction, taking fault 1 as an example, the research results show that T2 fault distance is the largest, T1-1 fault distance is the smallest, and T1 fault distance is between the two. In other words, from the Quantui Formation to the end of the deposition of the Qingshankou Formation, the fault activity gradually weakened, and during the period of deposition of the Yaojia Formation strata, the faults were active again; the stability of the faults in the X Oilfield is poor, and when the faults formed in the late stage were developed, the faults formed in the early stage were revived again and grew together with the late faults. The developmental pattern of the present-day faults is the result of multiple phases of tectonic movements and the accumulation of multiple developments of faults (Figure 8).

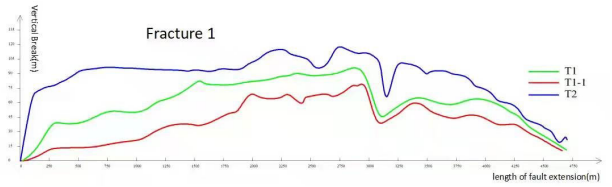

Figure 8 Distribution pattern of vertical break distances

The multiple phases of activity result in the section being vertically segmented, with the late active section being gently segmented and the early active section being steeply segmented; the larger faults today are often segmental growth faults that are connected by multiple, obliquely arranged faults of the same strike developed in the early phase.

Based on the multi-phase activity and inheritance characteristics of the faults, all faults in the X oilfield are interpreted as a whole, and a region-wide integrated fault model is established. Based on this model, the Fuyu oil formation faults are identified and finely delineated under the conditions of a thin well network in the Fuyu oil formation.

4. Conclusion

(1) From the analysis of fault elements, the Yaojia to Quantui Formation fault system has a multi-phase fault succession in the vertical direction.

(2) The stability of the faults in the X oilfield is poor. When the faults formed at a later stage develop, the faults formed at an earlier stage are revived and grow together with the later faults, and the development pattern of the present-day faults is the result of the accumulation of faults developed many times through multiple stages of tectonic movements.

(3) The multi-phase evolution and segmental growth model of the fault can be used as a guide to improve the accuracy of fault identification and mapping of the Fuyu oil formation.

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