Tectonic Characteristics of the East Sichuan Basin and Regional Tectonic Evolution Characteristics of Regional Tectonic Belt

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Abstract. Most sedimentary basins in China have undergone multi-stage tectonic evolution. This paper takes the eastern Sichuan region as the research object and relies on modern geological research methods to systematically study the basin's dynamic characteristics and tectonic evolution process in the eastern Sichuan region. The results show that the tectonic squeezing of SW and NW from the Daba Mountain orogenic belt and the Jiangnan-Xuefeng Mountain orogenic belt, respectively, make eastern Sichuan a complex structural interference zone that is both combined and compounded. The eastern Sichuan NE and NW structural combinations The type clearly records the structural transformation effect of the two. The history of tectonic evolution since the Middle Paleozoic in the eastern Sichuan Basin is divided into five phases: the deposition of source rocks of the Wufeng Formation-Longmaxi Formation in the Caledonian Period and the parallel unconformity contact with the overlying strata caused by the end of Silurian tectonic compression; Haixi The tectonic transformation of the Early-Indochina period is mainly manifested by the inheritance of the Caledonian period, and the parallel unconformity contact with the overlying strata caused by the end of Silurian tectonic compression; Haixi The tectonic transformation of the Early-Indochina period is mainly manifested by the inheritance of the Caledonian period, and the parallel unconformity contact with the overlying strata caused by the end of Silurian tectonic compression; Haixi The tectonic transformation of the Early-Indochina period is mainly manifested by the inheritance of the Caledonian period, and the interaction between the Devonian-Early Carboniferous strata and the early Indosinian marine facies and terrestrial sediments is lacking, and the fold deformation in the region is weak. In the early period, a series of NE-directional faults formed mainly in the eastern Sichuan region during the NNW-SSE compression. In the late Yanshan-Early Himalayan period, the NNW-SSE ~ NWW-SEE compression became stronger than in the early Yanshan period, and the eastern NE NE-boundary faults formed. In the late Himalayan period, NE-SW was squeezed. The Wujiang fault system at the border of the southeast of Sichuan was mainly formed during this period, and the southern strata were obviously transformed by this period.

Keywords: East Sichuan; Tectonic Control; Equilibrium Profile; Orogenic Belt; Tectonic Evolution.
1. Geological background
The tectonic part of the eastern Sichuan region is located in the Yangtze block, sandwiched between the two high-angle basement deep faults of Qiyue Mountain and Huaying Mountain, with the Qinling-Daba mountain fold belt in the north and the Xuefeng-Sichuan-Exiang structural belt in the southeast. The fragmentation and merging of plates in geological history, collisions between different plates in different periods, splicing, and intraplate thrusting and overthrowing of orogenic movements all strongly influenced the area and superimposed and compounded here to form the very complicated “barrier folds” in eastern Sichuan (Figure 1). In this paper, the eastern Sichuan Basin is taken as the research object, relying on modern geological analysis methods, through field geological survey, regional structural control research is carried out, the main structural control characteristics of the eastern Sichuan area and the basin dynamics characteristics are studied, and based on the balanced section restoration method in the Fuling area of eastern Sichuan, a structural evolution characteristic study was carried out, and the research results have a certain theoretical significance for the structural evolution of the Sichuan Basin and the central and upper Yangtze area.

2. The process of tectonic evolution in eastern Sichuan
2.1. Joint stage and tectonic stress characteristics
The study of tectonic period and tectonic stress field is not only the key to understanding the structural development of a region, but also an important link to study the hydrocarbon accumulation and preservation. Analyze the stress state of regional geological structure according to the occurrence of joints measured in the field. This part mainly uses the conjugate joint principal stress orientation function in the structural analysis software for simulation analysis. By entering the relevant parameters of the supporting conjugate joint occurrence and other related parameters, the regional geological structure principal stress orientation state reflected by the observation point can be simulated (δ1, δ2, δ3) (Table 1). Structural analysis results show that the main principal stress directions in the study area are: 23°~39°, 199°~240°, 295°~353°, indicating that the joint structure records in the eastern Sichuan area are NE-SW and NW-SE. The tectonic stress is localized as the NNE-SSW and NW-SE stress directions.
Table 1. List of tectonic principal stress orientations at various observation points in eastern Sichuan

| Location | Number of principal stress | Occurrence | δ₁ | δ₂ | δ₃ | Joint |
|----------|----------------------------|------------|-----|-----|-----|-------|
| Wayao    | 2                          | 235° ∠ 7⁰  | 353° ∠ 31° | 180° ∠ 59° | 85° ∠ 3° | 110° ∠ 75° | 240° ∠ 80° |
| Jiao1 well | 1                          | 345° ∠ 10⁰ | 34° ∠ 52°  | 232° ∠ 37° | 136° ∠ 9° | 153° ∠ 73° | 297° ∠ 81° |
| Danzitai | 2                          | 145° ∠ 35° | 23° ∠ 45°  | 175° ∠ 42° | 278° ∠ 14° | 135° ∠ 72° | 245° ∠ 70° |
| Luoyun   | 1                          | 295° ∠ 14⁰ | 163° ∠ 4⁰  | 258° ∠ 53° | 71° ∠ 36° | 210° ∠ 67° | 300° ∠ 75° |
| Damu     | 1                          | 275° ∠ 43° | 32° ∠ 14°  | 294° ∠ 31° | 142° ∠ 56° | 260° ∠ 80° | 345° ∠ 70° |

2.2. The evolution of tectonic evolution in eastern Sichuan

In order to further study the structural stage and deformation mechanism of the eastern Sichuan Basin, combining the characteristics of the Jiangnan-Xuefeng uplift and the Daba Mountain tectonic activity and the structural evidence at different scales in the eastern Sichuan Basin, the structural evolution stage of the study area was demonstrated, and the strata in the eastern Sichuan Basin Since the deposition, the formation process is divided into five stages, namely the Caledonian movement period, the Hercynian-Indo-Sinian movement, the late Indosinian movement-early Yanshan movement, the late Yanshan movement-early Himalayan movement, and the late Himalayan movement.

(1) Caledonian period

The Caledonian movement had a profound impact on the tectonic evolution in the south. By the end of the Silurian period, the stratum was uplifted and eroded due to the Caledonian structural compression. However, the effect of this period of tectonic movement on the entire eastern Sichuan showed uplift. Folding occurs.

(2) The Hercynian period-early Indochina period

The Hercynian movement inherited the Caledonian tectonic form, resulting in the absence of Devonian-Early Carboniferous strata in the area, only depositing thinner Middle Carboniferous strata, and causing the Middle Carboniferous strata and the overlying Permian. The false integration contact of the underlying Silurian strata. Entering the early Indosinian movement, the eastern Sichuan area was affected by the long-range effects of the Qinling orogenic belt uplift and the eastern Jiangnan-Xuefeng mountain uplift, and the eastern Sichuan area evolved to form a northwestern slope. Folding structures are formed in the eastern area, which are mainly manifested as overall uplift and subsidence.

(3) Late Indosinian Movement-Early Yanshan Movement

The tectonic styles in central Sichuan are mainly northeast-directed arcs or parallel goose-columns, and different structural styles are formed under the stress field in the same area, indicating that different base structures have been formed in central Sichuan before strong deformation occurred. The squeezing power during this tectonic period mainly comes from the continuous uplift of Jiangnan-Xuefeng Mountain in the east, and produces a gradual squeezing effect from north to west, but the main transformation range of squeezing stress in this direction is in the west of Hunan and Hubei. By the time it was passed to East Sichuan, it was already relatively weak. Therefore, the NW-SE squeezing stress in this phase is weak to the caprock reform in the eastern Sichuan Basin, and a fault prototype may have formed in the basement rock series(Fig.2).
(4) Late Yanshan Movement-Early Himalayan Movement

During this period, the Jiangnan-Xuefeng Mountain continued to uplift, while the north Daba Mountain’s overthrowing effect weakened. The east Sichuan area was further strengthened by the northwest-southeast squeezing stress. Combined with the microstructure of the directional sandstone samples collected in the field, the rock fabric experiment, and the results of the phased matching analysis of the field joints (Figure 3), it reflects that the main principal stress during this period is the NW-SE squeezing stress, which is subject to local Due to stress, the direction of the maximum principal stress is deflected towards NNW-SSE or NWW-SEE, but the whole is consistent with the regional stress field. Therefore, the tectonic stress field in eastern Sichuan during this period should be NNW-SSE~NWW-SEE.
Late Himalayan Movement

The late Himalayan period was the final period of transformation and shaping of the arc structure in eastern Sichuan. During this period of tectonic activity, the Jiangnan-Xuefeng Mountain uplift belt activity weakened, and the northeast Daba Mountain nappe belt now exhibited a strong thrust nappe movement, forming an area in the eastern Sichuan area that was very different from the late Yanshanian to the early Himalayas. Stress field characteristics, the regional stress direction changes from NW-SE to NE-SW compression stress. Coming from the south-west compression of the Qinling Mountains, Daba Mountain continued to subduct south-west to the basin and superimposed on the NE-directed arc-shaped fold belt formed by the Indosinian and Yanshanian periods, which caused a certain degree of twisting or strengthening.

3. Study on Regional Structure Control of Eastern Sichuan

3.1. The Daba Mountain orogenic belt controls the structure of the eastern Sichuan area

The Daba Mountain orogenic belt is located on the northern margin of the Middle-Upper Yangtze Plate and on the southern margin of the Qinling tectonic belt. The tectonic combination is a series of tightly arranged NNW-NW-EW striking arc-shaped fold-thrust belts that protrude from southwest to west [7-9]. It is significantly different from the linear structure of the Qinling-Dabie orogenic belt, but its formation and evolution history are obviously controlled by the Qinling orogenic belt.

The western belt of the East Sichuan Fold (including Huaying Mountain, Tieshan, Tongluo Gorge, and Qilixia and other high and steep anticline belts) was produced by the continuous migration and expansion of the structure to the west. At this time, the compression from the Daba Mountain side The tectonic migration is delayed or weakened, so that the Huaying Mountain and other anticlinal belts are not affected by it, and they maintain a linear extension from north to north. Since then, activities from the Daba Mountains have intensified and tectonic movements have continued, resulting in northwest-oriented structures superimposed on northeast or north-north-eastward structures in the foreland basin. Therefore, the Daba Mountain orogenic belt occupies an important position in the evolution of the tectonic pattern in the eastern Sichuan region. Due to the uneven spreading of the Daba mountain folds and the eastern Sichuan folds, the northeastern Sichuan has become a complex structural interference area that is both combined and complex (Figure 4).

Fig. 3 Regional tectonic stress circle in the late Yanshan-early Himalayan region of eastern Sichuan

(5) Late Himalayan Movement

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3.2. Jiangnan-Xuefeng uplift zone controls the structure of eastern Sichuan

The Jiangnan-Xuefeng uplift is located on the west side of the broad junction of the Yangtze block and the Cathaysia block, separating the two tectonic blocks, the Cathaysia and Yangtze blocks, extending from northern Guangxi and southeast Guizhou, passing through western Hunan and northern Jiangxi to southern Anhui. The Cambrian shallow metamorphic rock series dominated the uplift zone, with a complex evolutionary history [11-13]. As one of the main dynamic sources of deformation in the Yangtze plate, it caused the transformation of the strong and weak progressive (attenuation) deformation in the Paleozoic basin of the Yangtze plate combined with basement detachment and multi-layer cap sliding. It affected the degree of erosion of Mesozoic in different deformation zones and the preservation conditions of caprocks, and controlled the trap types and the state of oil and gas accumulation in different zones [14].

4. Conclusion

Through the research in this article, the following conclusions are obtained:

1. The tectonic part of the eastern Sichuan area is located in the Yangtze block, sandwiched between two high-angle basement deep faults, Qiyue Mountain and Huaying Mountain. The main structural development models include barrier-type fold belts and associated fault structures. The tectonic function is complex, and there are many tectonic periods. The Daba Mountain Orogenic Belt and the Jiangnan-Xuefeng Mountain Orogenic Belt played an important role in the evolution of the tectonic pattern in the eastern Sichuan region. The structural compression of the Daba Mountain Orogenic Belt and the Jiangnan-Xuefeng Mountain Orogenic Belt toward SW and NW respectively, Sichuan The combination of East NE and NW clearly records the role of tectonic transformation of the two.

2. The history of tectonic evolution since the Middle Paleozoic in the eastern Sichuan Basin is divided into five stages: Caledonian Wufeng Formation-Longmaxi Formation source rock deposition and tectonic compression at the end of the Silurian parallel unconformity contact with the overlying strata. The tectonic transformation of the Hercynian-Indosinian period is mainly manifested in the inheritance of the Caledonian period, and the fold deformation in the area is weak, mainly due to overall uplift and subsidence; The structural deformation in the eastern area is not obvious, and a series of NE-shaped fault prototypes are mainly formed; the late Yanshan-early Himalayan NNW-SSE-NWW-SEE directional compression is further enhanced than the early Yanshan, and the main period of the formation of NE-boundary faults in eastern Sichuan; Himalaya In the late period, the NE-SW squeezed, and the
Wujiang fault system in the southeastern Sichuan border was mainly formed during this period, and the southern strata were significantly modified by this period.

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