Analysis on the geophysical characters of Qiyueshan fault

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Abstract. Qiyueshan fault is not only a topographic boundary, but also a tectonic boundary. It is of great significance to the structural research, oil and gas exploration and engineering application in this area. It is well displayed in geophysical data. All kinds of geophysical data show that the fault has obvious segmentation, and different sections have different characteristics. Gravity and seismic data have a good response to the whole fault, but the response of magnetic anomaly to the fault is better in the north of Shizhu than in the south of Shizhu. Through the processing and analysis of the gravity and magnetic anomaly data around the fault, and the interpretation of some seismic profiles along the fault, response characteristics of faults on different geophysical data are presented. It shows that the Qiyueshan fault not only has typical zoning characteristics in plane, but also has obvious segmentation in vertical direction. From north to south, the dip angle is steeper and steeper. From the south to the north, the difference between the deep and the shallow parts of the fault is increasing.

1. Introduction
Qiyueshan fault (QYF) is distributed intermittently in the axial part of Qiyueshan anticline with NE strike. It intersects with Fangdoushan fault to the south, which is now and then disappearing, and becomes Jinfoshan fault. Then it continues to extend to Loushan, Guizhou province. Geographically, it spans four provinces and cities, that is Chongqing, Sichuan, Hubei and Guizhou.

Qiyueshan fault is basin- mountain transition zone between Xuefeng orogenic belt and Sichuan Basin [1]. It is the boundary fault between the comb like fold belt in eastern Sichuan and the trough like fold belt in Western Hunan and Hubei [2]. It is not only the eastern boundary of Sichuan Basin [3], but also Traditional boundary fault of upper and middle Yangtze [4]. In the same time, it is one of the main regional faults in Three Gorges reservoir area [5-9]. The surface exposed strata and faults (Figure 1) on both sides of the fault are different. The quality distribution of source rocks around Qiyueshan is stable. The study of fault characteristics is beneficial to the further study of hydrocarbon accumulation and preservation conditions.

2. Geological setting
In terms of regional geological structure, Qiyueshan fault is located in the Yangtze plate area. It is the boundary fault of upper and middle Yangtze [10]. And it is also the boundary of comb like fold belt in the west and trough like fold belt in the east. The tectonic deformation of sedimentary caprock on both sides of the fault is quite different.

Figure 1 shows the distribution of surface faults. On the west side, the surface faults are less exposed. On the contrary, there are more surface faults in the east side. Especially in the southeast area. The
exposed faults are mainly NE trending. The NS and NW trending faults mainly distributed in the south of Wulong, Chongqing municipality [11].

Figure 1. Geological sketch map around Qiyueshan fault.

On the west side, Jurassic is the mainly strata. The Triassic strata occur alternately in NE direction. A few Cretaceous strata are distributed near Chishui, Guizhou province. However, the age of the exposed strata in the East is older than that in the West. There are more stratigraphic ages and obvious regional characteristics. Surrounding Renhuai, Guizhou province, the Cambrian and Triassic strata are mainly exposed. In addition, there are a few Sinian and Permian strata. Between Zheng’an, Guizhou province and Enshi, Hubei province, the main exposed strata are Ordovician and Silurian. In the north of Enshi, Hubei province, the mainly distributed strata is Triassic. The Lower Paleozoic strata are mainly in the east of Enshi. The main strike of the strata is NE, which is obviously controlled by faults. The change trend of stratigraphic age is growing old gradually from west to East.

3. Gravity characters

Figure 2 shows the bouguer gravity contour. All the gravity anomalies are negative. The value is between -160mGal to -50mGal. From west and east sides to the middle, the values become larger. Qiyueshan fault is well reflected in the gravity field. A series of high gravity traps are distributed in beaded shape [12]. There are gradient zones on both sides of the trap. The western gradient zone is the display of Qiyueshan fault. The main trend of anomaly is northeast. But NE anomalies are of discontinuity. Its are cut off by NW trend fault.

Figure 3 is the remnant gravity anomalies after upward 5 km. The positive and negative anomalies are in interphase arrangement. Qiyueshan fault is distributed on the boundary between positive and negative anomalies. The west side are positive anomaly traps. And the east side are negative traps.
Figure 2. Bouger gravity anomalies around Qiyueshan fault (interface 2.5mGal).

Figure 3. The remnant gravity anomalies of upward 5km around Qiyueshan fault.
4. Magnetic characters
Magnetic anomalies around Qiyueshan fault are shown in Figure 4. The values are from -160nT to 260nT. Taking Nanchuan to Enshi as the boundary, the characters on both sides are different. The values are negative in the southeast side. But in the northwest side, the main values are positive. And the negative values located between Zhongxian and Wanzhou.

Anomalies show typical segmented feature along Qiyueshan fault. The anomaly is negative in the southern part of Nanchuan. The gradient of anomaly is not obvious. The anomaly trap is truncated near Xuyong. The anomaly values are positive between Nanchuan and Lichuan. In this section the fault character is not obvious. The obvious distortion and dislocation of contour indicate the existence of fault. The values are on both sides positive or negative at the same time. This shows that the basement fall on both sides of Qiyueshan fault is not big [13]. Generally speaking, the magnetic anomaly in the south of Shizhu is less obvious than that in the north. It shows that the change of basement rock properties in the south of Shizhu is less than that in the north. The basement along the fault is mainly composed of Banxi group of Upper Proterozoic, while the basement from Shizhu to Zhongxian is composed of medium basic volcanic rocks, and the basement from Fengjie to Wuxi is composed of granite.

Figure 4. Magnetic anomalies around Qiyueshan fault (interface 10nT).

5. Seismic interpretation
Seismic data can well explain the vertical structural model of fault. The geometrical and kinematic characteristics and fault evolution history of the Qiyueshan Fault were analyzed systematically using seismic and geological data. Figure 5 shows the interpreted characteristics of differential structural deformation on both sides of fault [14].

Figure 5 (a) presented the combination style of Qiyueshan fault and secondary fault is inverse “y”. It is characterized by thrusting to hidden thrusting decollement fold, strong thrusting and faulting.
Figure 5 (b) shows that Qiyueshan fault is a number of thrust faults with the same dip and nearly parallel. It's zigzag. And the regional structural deformation is characterized by thrusting to fault spreading decollement fold.

Figure 5 (c) shows that Qiyueshan fault is a high and steep thrust structure with shovel shape, and its bottom end disappears above the basement detachment fault.

Figure 5 (d) shows that the Qiyueshan fault is shovel shaped and the fault breaks out of the surface. The regional structural deformation is characterized by basement thrusting, fault spreading fold and detachment fold, with strong thrusting and faulting, mainly thrust structure, fault spreading anticline and thrust up structure.

![Seismic interpretation results of Qiyueshan fault](image)

**Figure 5.** The seismic interpretation results of Qiyueshan fault [3].

Figure 6 presents the interpretation results of another seismic profile near Lichuan, Hubei province. The distribution pattern and depth of strata on both sides of Qiyueshan fault are quite different. Because of the existence of detachment structure layer, the deep and shallow structure model is different.
This fault has different characteristics not only in plane but also in longitudinal direction. From north to south, the dip angle is steeper and steeper. The main fault in the north is deep, which is not consistent with the shallow fault. The shallow part inclines to the northwest, and the deep part inclines to the southeast. When the dip angle of the southward fault becomes steeper, it also penetrates to the surface until it is exposed.

![Figure 6. The seismic interpretation results of Qiyueshan fault.](image)

6. Conclusion
The Qiyueshan Fault is characterized by a sectional structure not only in plane but also in vertical direction. From north to south, the dip angle is steeper and steeper. From the south to the north, the difference between the deep and the shallow parts of the fault is increasing. Both inclination and angle have great changes.

The magnetic anomaly mainly reflects the structural changes in the basement level, while the gravity reflects the changes from the surface to the deep lithosphere. Therefore, the variation of gravity anomaly on both sides of the fault is more obvious than that of magnetic anomaly. In particular, the magnetic anomaly in the south of Shizhu is less obvious than that in the north. The formation velocity is related to the density, so the seismic velocity profile also has a good response to the fault.

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Reference
[1] Song H B, Luo Z L 1995 The study of the basement and deep geological structures of Sichuan basin, *China Earth Science Frontiers (China University of Geo sciences , Beijing)* 2(2-3) 231-237
[2] Bai D Y, Xiong X, Yang J, et al 2015 Characteristics and dynamic mechanisms of the folds in the basin-mountain transition zone, east of the Qiyueshan fault *Geotectonica et Metallogenia* 39(6) 1008-1021
[3] Deng D F 2014 Study on the intracontinental structure of the enrichment of marine paleo-reservoirs in the northern margin of Jiangnan-Xuefeng uplift, Southern China *China University of Geosciences (Wuhan) (PhD dissertation)*
[4] Wang L Z, Tian Y, Tu B, et al 2012 Paleostress analysis of the Qiyue Shan high-angle nnticline in
the Lichuan Area, western Hubei Province, China Geotectonica et Metallogenia 36(4) 490-503

[5] Tang G Z, Tao M 1991 The study of the neo-tectonic movement of Yangze Gorges region and its relation to the damage of the project construction Bull. Yichang Inst. Geol. Mineral Resources, CAGS 19 1-63

[6] Chen M S, Zhang S H 1998 Characteristics and forming mechanism of opposite protruding actsuate structural zones in the Three Gorges area of the Yangtze River, South China Geology and Mineral Resources of South China 1 47-55

[7] He M Y 2019 Investigation and evaluation of neo-tectonic movement and crustal stability in the Three Gorges area Modern Mining 598 1674- 6082

[8] Zhao P 2009 Study on the reservoir induced seismicity in Chongqing under the running of the Three Gorges Reservoir Chongqing Jiaotong University (Master’s dissertation)

[9] Wu S R, Wu G G, Hu D G, et al 1999 Segmentation and fractal dimension of the NE trending active fault population in the upper reaches of the Qingjiang River, Western Hubei Bulletin of the Chinese Academy of Geological Sciences 20(2) 142-149

[10] Fan Y F 2016 Interrelationship between tectonism and hydrocarbon accumulation in marine strata at critical tectonic movement in west Hubei-east Chongqing, South China China University of Geosciences (Wuhan) (PhD dissertation)

[11] Wang Z J, Wang H C, He H L, et al. 2016 Dating of the last active age for Wulong ridge section of Qiyaoshan-Jinfoshan faults EARTHQUAKE RESEARCH IN SICHUAN 1 25-29

[12] Jing X H 2009 Study on Michang mountain and Daba mountain's deep textures and structures Northwest University (Master’s Dissertation)

[13] Wang X D 2008 The Study of magnetic structure over Xuefeng Tectonic Belt and its adjacent areas Northwest University (Master’s dissertation)

[14] Wei F, Chen K Q, Tuo X S 2019 Differential tectonic deformation in the northern Qiyueshan Fault, eastern Sichuan Basin PETROLEUM GEOLOGY & EXPERIMENT 41(3) 348—354