Structural Characteristics of Luonan Basin Based on Gravity Data

Jia Hongyang[1,2], Xue Jian[3]

[1]*School of Earth Sciences and Engineering, Xi'an Shiyou University, Xi'an, China*
[2]*Shanxi Key Lab of Petroleum Accumulation Geology, Xi'an Shiyou University, Xi'an, China*
[3]*Xianhe Oil Production Plant, SINOPEC Shengli Oilfield Administration Bureau Co., Ltd, Dongying, China*

Abstract: *The Luonan Basin is a typical intermountain basin in the Qinling orogenic belt. The tectonic characteristics of the basin and its adjacent areas are very complex. Previous studies on Luonan Basin mainly focus on paleontology and sedimentation, and lack of reports on basin studies using geophysical data. In order to study the tectonic characteristics of Luonan Basin, this paper collected 1:500000 gravity data in the study area, and used the sliding average filtering method to separate the remaining gravity anomalies from the Bouguer gravity anomalies, and analyzed the causes of gravity anomalies. In this paper, the normalized total horizontal derivative vertical derivative, total horizontal gradient mode and vertical second derivative are used to infer the faults in the study area by referring to the remaining Bouguer gravity anomalies and geological data. According to the inferred results and geological data, the boundary of the basin is determined. Three gravity profiles across the basin were fitted by a 2.5D human-computer interaction inversion method. The results show that the high gravity is caused by the basement uplift, and the low gravity is the reflection of the Meso-Cenozoic and low-density intrusive rocks. The faults in the study area are mainly in NE, NW and nearly EW directions. The development of the basin is controlled by the basin margin faults. The east-west length of the basin is 85km, the maximum north-south width is 7km, and the basin area is 420km². Cretaceous, Paleogene and Neogene are mainly developed in the basin. The basement depth of the basin is "deeper in the middle than in the west, and deeper in the west than in the east", with the maximum depth of about 1130m.*

Keywords: *gravity anomaly; potential field separation; fault structure; characteristics of substrate*

1. Introduction

The tectonic evolution of the Qinling orogenic belt, which is formed by the collisional splicing of the North China Craton and the Yangzi Craton, has been a hot spot in geological research, but the Luonan basin, located in the East Qinling Mountains, has been less studied. At present, studies on the Luonan Basin are mainly focused on paleontology and sedimentation. For example, Xue Xiangxu et al. (1996) found a large number of paleontological fossils in the basin, which provided a strong basis for the delineation and comparison of stratigraphy in the basin. Yu Shangjiang et al. (2014) analyzed the information on tectonic deformation and denudation in the source area during the formation of the basin through field geological outcrop observation and apatite cryochronological analysis, and concluded that the basin was formed in the Early Cretaceous, and the main and branch faults of the Luonan-Luanchuan Fault controlled the stratigraphy in the southern and northern parts of the basin, respectively. Few previous studies have applied geophysical data to the tectonic aspects of the Luonan Basin. Thus, this paper presents a systematic analysis of the tectonic features of the Luonan Basin using gravity data combined with existing geological research results to provide a reference for further studies of the Luonan Basin.

2. Geological overview

The Luonan Basin is bounded in the north by the backland retrograde fold belt of the Qinling orogenic belt and in the south by the north Qinling stacked tile retrograde thrust tectonic belt. In the Luonan Basin and its neighboring areas, Archaeozoic, Proterozoic, Palaeozoic, Mesozoic and Cenozoic strata are developed (Figure 1). The Archaeozoic is mainly developed by the Taihua Rock Group,

ISSN 2616-5872 Vol.4, Issue 7: 37-41, DOI: 10.25236/AJEE.2022.040707

which is exposed in the area of Zhangjiaping-Qiaonan Town.The Proterozoic strata are widely distributed in the north and south of the Luonan Basin. The Paleozoic strata in the study area are Cambrian, mainly distributed in the north of the Luonan-Luanchuan Fault, and distributed in EW direction along the fault, and also exposed in the north and northeast of the study area, with the orientation mainly in EW direction and NW direction. The Mesozoic strata mainly include the Cretaceous, which is exposed in the southern part of the Luonan Basin and the southeastern part of Shangluo City. The Cenozoic stratigraphy is developed in the Palaeogene and Quaternary . The Palaeogene is developed in the EW direction in the interior of the Luonan Basin, and the trend is NW in the southeast of Shangluo City. Cretaceous monzonitic granite is mainly distributed in the northwestern part of the study area, and Jurassic monzonitic granite is distributed along the Luonan-Luanchuan Fault in an EW direction in the southeast of the Luonan Basin.

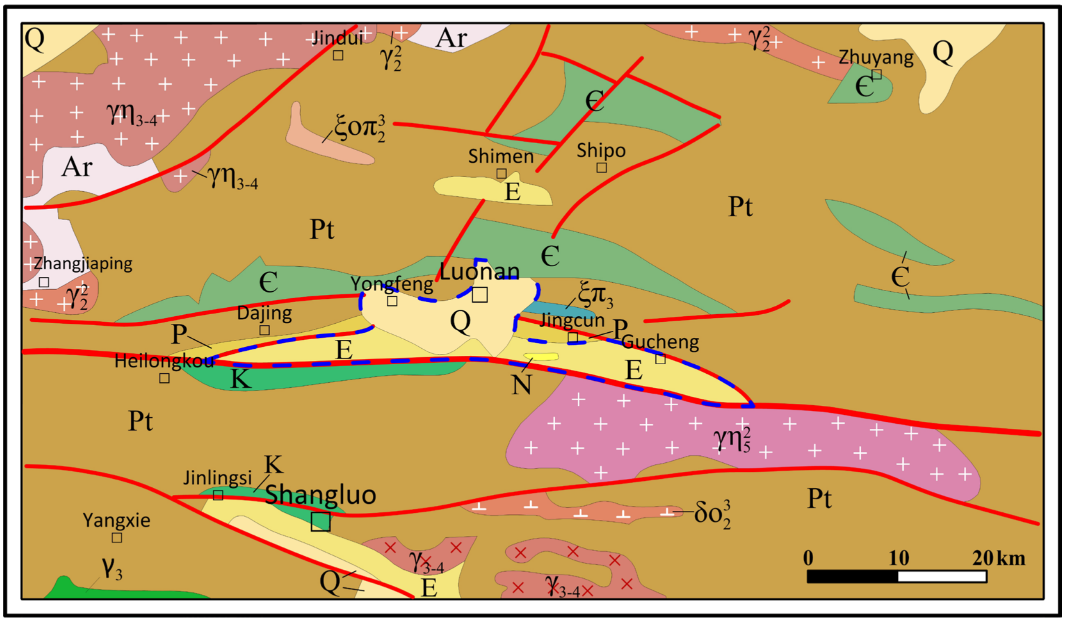


Figure 1: Brief geological map of the study area(The blue discontinuous line is Luonan Basin).

3. Geological overview

Due to the lack of data on the density of rocks in the study area, the density data of strata and rocks developed around the study area were collected in this paper (Table 1~2). From Table 1, it shows that the stratigraphy gradually increases in density from new to old. Table 2 shows the density statistics of magmatic rocks. From Table 2, it can be seen that the density of magmatic rocks gradually increases from acidic to basal, and the density of acidic rocks is less than that of the Archaeozoic, Proterozoic, Cambrian. When the acidic rocks are surrounded by these strata, then the acidic rocks will show low gravity anomalies.

Table 1: Stratigraphic density statistics

Stratigraphic		Symbols	Density ($10^3 kg/m^3$)	
			Range	Average value
Cenozoic	Quaternary	Q	1.52~1.72	1.64
	Neogene	N	2.04~2.58	2.39
	Paleogene	E	2.23~2.66	2.42
Mesozoic	Cretaceous	K	2.29~2.58	2.48
Palaeozoic	Permian	P	2.48~2.64	2.58
	Ordovician	O	2.64~2.88	2.73
	Cambrian	Є	2.59~2.87	2.74
Proterozoic		Pt	2.61~2.94	2.79
Archaeozoic		Ar	2.55~2.74	2.69

ISSN 2616-5872 Vol.4, Issue 7: 37-41, DOI: 10.25236/AJEE.2022.040707

Table 2: Density statistics of magmatic rocks

Rock Category	Density ($10^3 kg/m^3$)	
	Range	Average value
Acid igneous rock	2.53~2.69	2.61
Intermediate-acid igneous rock	2.59~2.82	2.68
Intermediate igneous rocks	2.71~2.90	2.81
Basaltic-ultramafic igneous rocks	2.73~3.04	2.81

4. Gravity anomaly characteristics and explanation

In this paper, 1:500 000 gravity data of the study area were collected and the Bourg gravity anomaly was filtered by sliding average to obtain the remaining gravity anomaly (Figure 2). The variation between high and low values of the remaining gravity anomalies is obvious, reflecting a wealth of shallow geological information. The remaining gravity anomalies in the study area can be divided into four zones from north to south. The high gravity values and low gravity values in Area I are distributed intermittently, and the anomalies are mainly in NE, NEE, NW and near EW directions. Combining with the surface geological data, it can be seen that the basement strata such as Archaeozoic、Proterozoic and Cambrian are exposed at the high values in Zone I. Monzonitic granites are exposed at the NE-oriented low value in Zhangjiaping-Jinduizhen and the NW-oriented low value in southeastern Chen'er. Therefore, it is presumed that the high gravity in I is caused by basement uplift, and the low gravity is caused by basement depression and low density intrusive rocks. II is mainly low gravity, with a near EW trend, and the surface mainly exposes Cretaceous, Paleogene, Neogene, Quaternary and Jurassic monzonitic granite, and it is assumed that the lower density of Middle-Cenozoic strata and acidic intrusive rocks are the cause of low gravity in this area. It is worth mentioning that the low gravity anomaly in II is similar to the morphology of the Luonan Basin, but the large-scale low-density monzonitic granite in the southern neighbor of the Luonan Basin still affects the identification of the boundary of the Luonan Basin. The anomaly in III is oriented to NWW, and the surface distribution of large-scale Proterozoic, which was extruded and uplifted during the period of Garridon tectonic activity, thus forming the gravity high in this area. IV is mainly a NWW-oriented low gravity anomaly with Proterozoic surface outcrop, which is presumed to be caused by the basement stratigraphic depression.

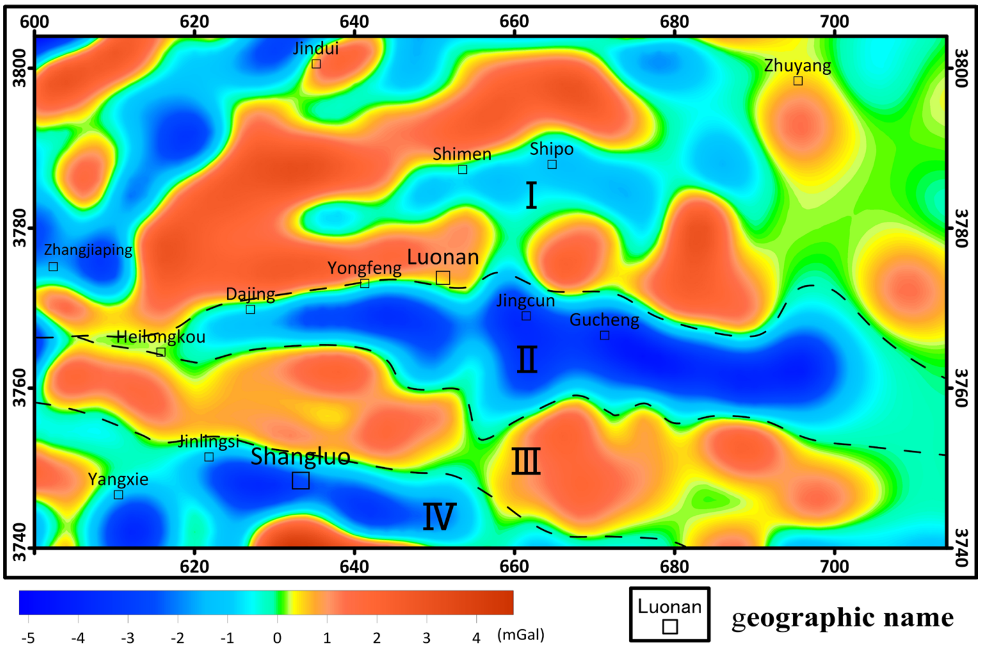
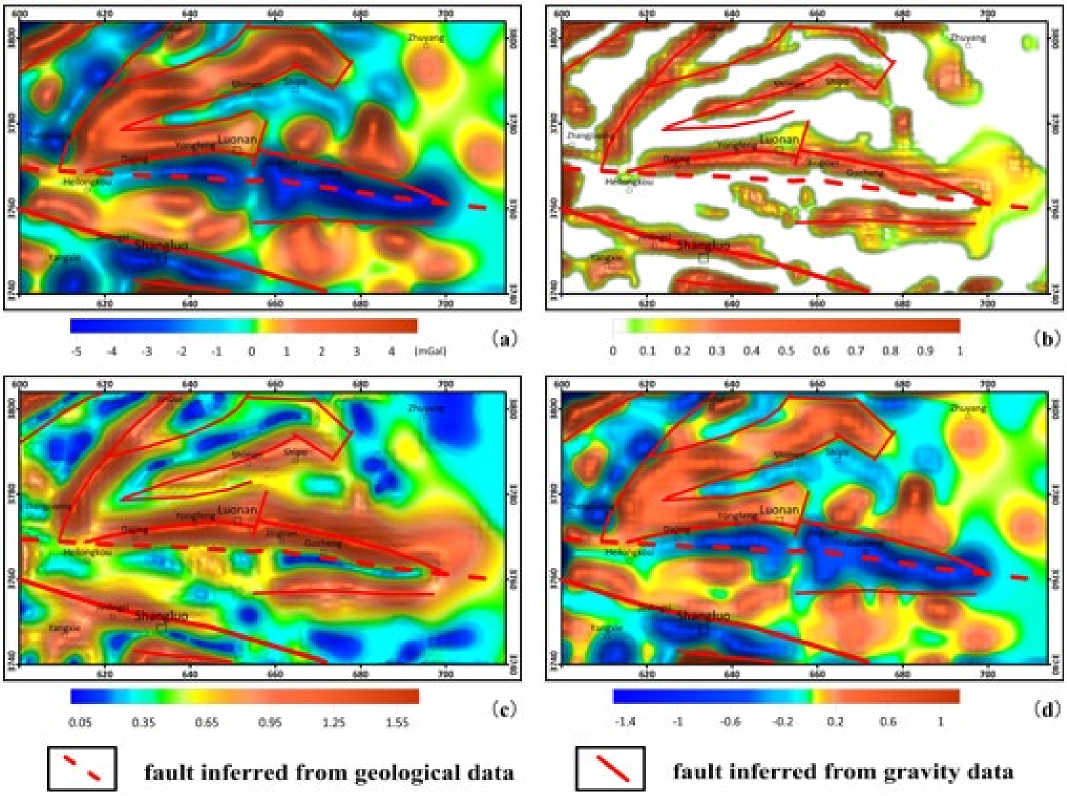


Figure 2: The remaining gravity anomaly map.

5. Structure characteristics

5.1. Fault structure characteristics

To extract the fault tectonic information, the normalized vertical derivative of the total horizontal derivative (NVDR-THDR) [1-3], horizontal total gradient magnitude [4] and vertical second-order derivative [6] of the Bourg gravity anomaly are processed in this paper. Fault structures in the study area are identified based on the characteristic values of the results of the conversion of the above three methods and the variation of the remaining gravity anomalies [6]. Combined with previous geological research results in the area, a total of 15 faults were inferred, whose orientations are mainly NE-oriented, near-EW-oriented and NW (Figure 3). The faults are mainly located in the gravity gradient zone, the ridge of the horizontal total gradient magnitude, the ridge of the NVDR-THDR and the 0 value of the vertical second-order derivative.



(a) the remaining gravity anomaly (b) NVDR-THDR (c) horizontal total gradient magnitude (d) vertical second-order derivative

Figure 3: Gravity anomaly and fault overlay map.

5.2. Identification of the basin boundaries

Since there are large differences in stratigraphic density and no magmatic rock development on both sides of the northern boundary of the basin, the northern boundary of the basin can be inferred accurately using gravity data, while the large-scale Jurassic monzonitic granite developed in the southeast of the basin and the Mesozoic-Cenozoic strata in the basin both show low value anomalies on the gravity anomaly map, which affects the identification of the southern boundary of the basin, so the southern boundary of the basin is mainly determined based on the available geological data (Figure 4). According to the results of this delineation, the basin is bow-shaped, with a length of 85km from east to west, a maximum width of 7km from north to south, and a total area of 420km². The northern boundary of the basin is mainly controlled by the northern branch of the Luonan-Luanchuan Fault, while the southern boundary is mainly controlled by the southern branch of the Luonan-Luanchuan Fault, and to the northeast of Heilongkou Town, the southern boundary bends to the south, showing an unconformity between the Cretaceous and Proterozoic.

ISSN 2616-5872 Vol.4, Issue 7: 37-41, DOI: 10.25236/AJEE.2022.040707

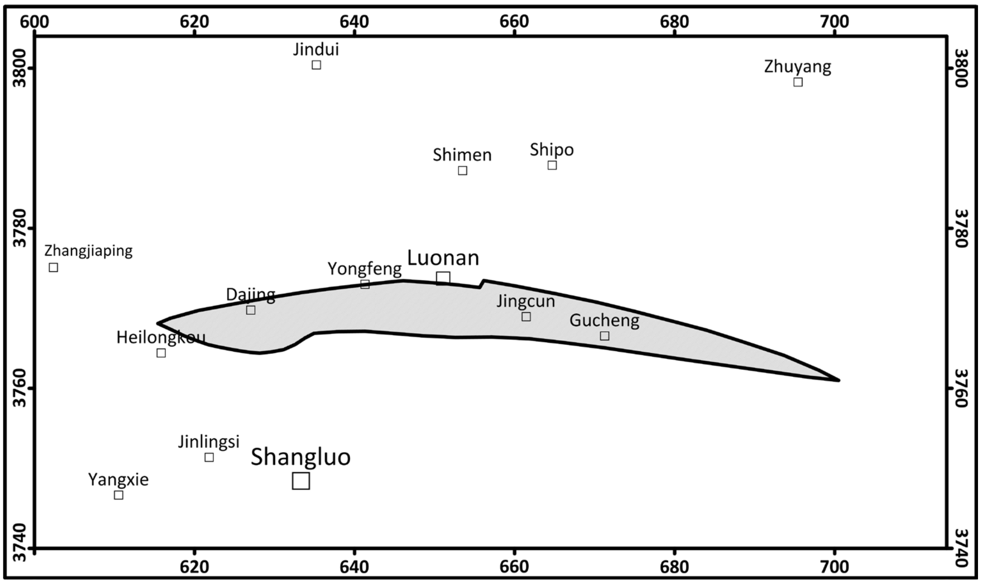


Figure 4: Map of the extent of the Luonan Basin.

6. Conclusions

(1) The high gravity in the study area is caused by the Proterozoic basement uplift, and the low gravity is caused by the basement depression and low density intrusive rocks. The Luonan basin is reflected more obviously on the remaining gravity anomaly map, but the large-scale Jurassic monzonitic granite in its southeast affects the identification of the southern boundary of the basin using gravity data.

(2) There are 15 inferred fractures in the study area, with the main directions of NE, NW and near EW. The boundary of the Luonan Basin was delineated based on the inferred fractures and geological data. The basin is 85km long from east to west, with a maximum width of 7km from north to south and a total area of 420km².

References

[1] Wang Wanyin. (2010) Spatial variation law of the extreme value positions of total horizontal derivative for potential field data. Chinese Journal of Geophysics,9, 2257-2270.

[2] Wang Wanyin, Pan Yu and Qiu Zhiyun. (2009) A new edge recognition technology based on the normalized vertical derivative of the total horizontal derivative for potential field data.Applied Geophysics, 3, 226-233+299.

[3] Xu Wenqiang, Yuan Bingqiang and Yao Changli. (2020) Multiple gravity and magnetic potential field edge detection methods and their application to the boundary of fault structures in northern South Yellow Sea. Geophysical and Geochemical Exploration, 4, 962-974.

[4] Ma Long, Meng Junhai, Shan Zhongxue, Li Xingliang, Li Fengting, Jin Yongming, Wang Jinhai and Li Baolan. (2017) Comparisons and applications of several boundary detection methods for potential field data. Progress in Geophysics, 6, 2514-2519.

[5] Zeng Qinqin, Wang Yonghua, Li Fu, Wu Wenxian and Deng Ke. (2015) Application of the vertical second derivative of gravity anomaly for characteristics analysis of Panxi rift. Progress in Geophysics, 1, 29-33.

[6] Qu Zhicheng, Jia Huichong, Tian Gang, Ma Chao, Chen Jie, Shang Yale, Zhang Yuncui and Yang Minghui. (2022) Gravity anomaly characteristics and tectonic framework in Sanmenxia Basin. Science Technology and Engineering, 24, 10425-10433.