Front. Earth Sci. China 2007, 1(3): 373–379
DOI 10.1007/s11707-007-0046-x

RESEARCH ARTICLE

Interpretation of aeromagnetic anomalies of the Sulu region, eastern China and implications for deep geology

ZHAO Sutao (✉)[1], LIU Qingsheng[2], QIAO Qingqing[2], FU Yuanyuan[3]

1 Graduate School, China University of Geosciences, Wuhan 430074, China
2 Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan 430074, China
3 Department of Geophysics, Peking University, Beijing 100871, China

Abstract By using data on the 1:100 000 aeromagnetic anomalies of the Sulu orogenic belt, we designed three simulated geotraverses, in which deep seismic reflection and other geophysical investigations have been completed. Based on the features of magnetism of the three profiles, and under the constraints of deep seismic reflection data, together with the magnetism of the core petrology at the Chinese Continental Scientific Drilling (CCSD) pilot-hole and areal geology, the three inversions of magnetic anomalies are carried out. The characteristics of terrane structure are presented: the rocks are mostly composed of eclogite, marble, and gneiss at the depth of 5 km. At the depth between 5 and 7 km under the surface, inverse magnetic bodies are mainly the ultra high pressure metamorphic (UHPM) rock slices containing a lot of coesite-bearing eclogite. At the depth between 7 km and the bottom of upper crust are the rocks of the gneiss, granite and granite diorite that underwent ultra high pressure metamorphic process. Middle crust (10–19 km) is mostly composed of UHPM gneiss and granite that intruded later. The rocks of acid and basic granulite dominate the lower crust. Based on the inversed results of the three simulated geotraverses, we know that the UHPM rock slices of the three profiles are dipping north, stacking each other and being uplifted to the earth's surface, which may be the result of the North China craton's subduction and exhumation in the Triassic.

Keywords aeromagnetic anomaly, rock magnetism, deep geology, Sulu orogenic belt

1 Introduction

As is well known, the magnetic texture of the continental crust is closely related to the crustal structure, metamorphic facies, compositions of the crust, exchange of substance of crust-mantle, and so on (Liu et al., 1998b). Generally speaking, the outcrops of terrane with high metamorphic grade and granulite inclosure are considered as the window of studying deep crustal structure and geodynamics (Fountain and Salisbury, 1981; Liu and Gao, 1998; Liu et al., 1998a, 2000a, b; Shive et al., 1992; Jin et al., 2003; McEnroe et al., 2004). The aeromagnetic anomalies of rocks contain a good deal of information about the physical processes and geometry of the magnetic body. Therefore, aeromagnetic anomaly is regarded as one of the most effective geophysical techniques in studying regional tectonics and deep geologic structures.

The Sulu area, located in the eastern part of the Tan–Lu fault zone, and the eastern segment of the Kunlun–Qilian–Qinling–Dabie composite orogen (Wang et al., 1982; Okay et al., 1993; Liu and You, 1997; Suo et al., 2001), was formed by the collision of the Sino–Korean and Yangtze blocks (Fig. 1). It is unique in the abundance and variety of Ultra high pressure (UHP) rocks exposed. Since the discovery of coesite-bearing eclogites and diamond-bearing eclogites (Xu et al., 1992), it has become an outstanding geological location for studying ultrahigh-pressure metamorphism, the continent-continental collision, and interaction between the crust and the mantle (Zhang et al., 2001). As a result, the area has attracted the attention of worldwide geoscientists. And various achievements have been obtained in the fields of geology, petrology and geophysics (Dong et al., 1993, 1998; Liu et al., 1995).

During 1996–2004, the Chinese Continental Scientific Drilling (CCSD) project has chosen the Sulu complex as the preferred site of the first well of the CCSD, within the framework of the International Continental Drilling Program (ICDP). The scope and emphasis of the project is a comprehensive and integrated study on the orogenic belt, involving a lot of geophysical surveys, such as wide angle seismic reflection, refraction, 3D seismic, welling-VSP, magnetic and gravity mapping, and so on (Wang et al., 1997; Yang and Yu,

Translated from *Geological Science and Technology Information*, 2007, 26(2): 107–112 [译自: 地质科技情报]

E-mail: sky_zst@163.com

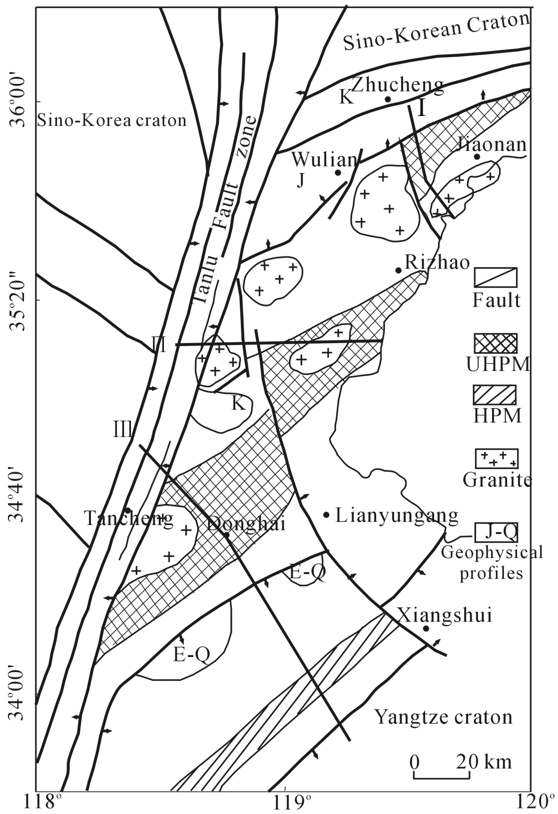

Fig. 1 Sketch showing geology and profile location of the studied area (after Yang et al., 1999a)

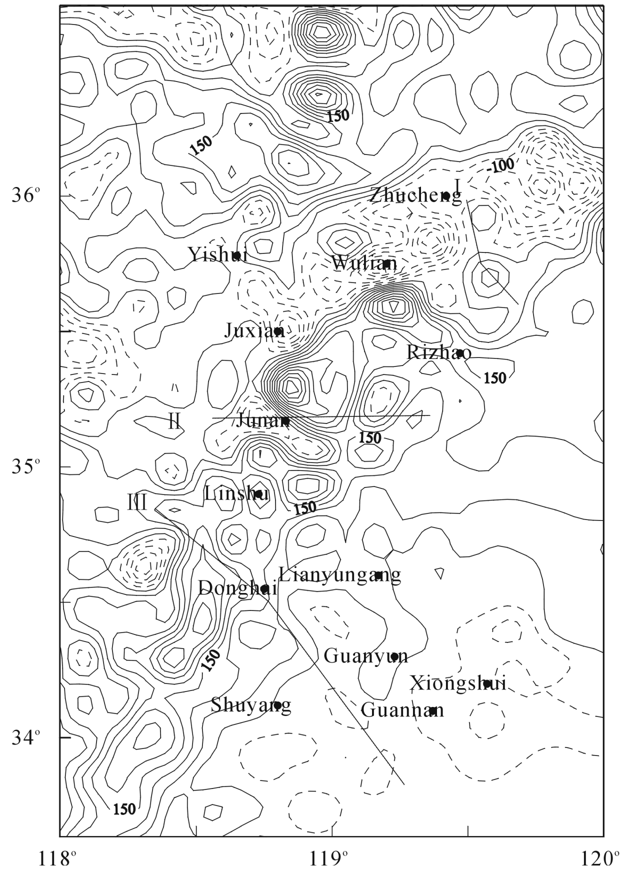

Fig. 2 The observed magnetic anomalies (contour interval: 50 nT)

2001; Yuan et al., 2002; Yang et al., 2003, 2004; Wang et al., 2004; Xu and Zhao, 2004). All of this information is critical for studying the deep crust structure and composition and for understanding the mechanisms of subduction and exhumation of UHP belts. Apart from that, three regional geophysical profiles have been studied (Yang et al., 1999a, b, c): Profile I from Zhucheng to Boli of Jiaonan in Shandong Province, 46 km in length, in which deep seismic reflection, Magneto-telluric (MT), geomagnetism, radioactivity and gamma surveys have been applied; Profile II from Rizhao to Bahu of Linyi, 80 km in length, in which deep seismic reflection, MT, geomagnetism, radioactivity and gamma surveys have been applied; Profile III form Tancheng to Lianshui of Jiangsu Province, 139.5 km in length, in which deep seismic reflection and MT have been applied.

The study of aeromagnetic data is very scarce in this area. Wu et al. (2003) have made some researches on small-scale regional aeromagnetic interpretation; Yang et al. (1999a, b, c) and Yu et al. (2001) only gave the inversed results within several kilometers in depth. In view of the above situation, the aeromagnetic anomaly of three seismic profiles (Figs. 1−3) is processed and analyzed in this paper. Under the constraints of deep seismic reflection data, together with magnetism of the core petrology at the CCSD pilot-hole and areal geology, the terrane structure characteristics of the three profiles are given.

2 Magnetic properties of rocks

High pressure metamorphic belts in the studied area are mostly located in Qingdao, Zhucheng, Rizhao, Juxian, and Donghai. Most rocks are gneiss, monzonite gneiss, granite gneiss, amphibolite plagiogneiss, amphibolite, serpentinite, eclogite, granite, granodiorite, granulite and mylonite in ductile shear zone. Based on the magnetism of the core petrology at the CCSD pilot-hole and previous research findings (Yang et al., 1999a, b, c; Yu et al., 2001, 2002), we summed up the magnetic susceptibility of most rocks in the studied area (shown in Table 1).

Eclogite outcrops mainly exist in gneisses. They mostly have coesite inclusions and alternate beds with surrounding rocks. A part of eclogites are scattered in serpentinites or ultramafic rocks as lens-shaped. The magnetic difference between eclogite and the surrounding rock is not clear. However, altered or rutilized eclogite has high magnetic susceptibility (Liu and Gao, 1998), and relatively large eclogite bodies have distinct aeromagnetic anomalies. Basic or ultrabasic igneous rocks formed in the Mesozoic or Cenozoic era are of high magnetic susceptibility, but none of them corresponds to strong anomalies on the regional magnetic

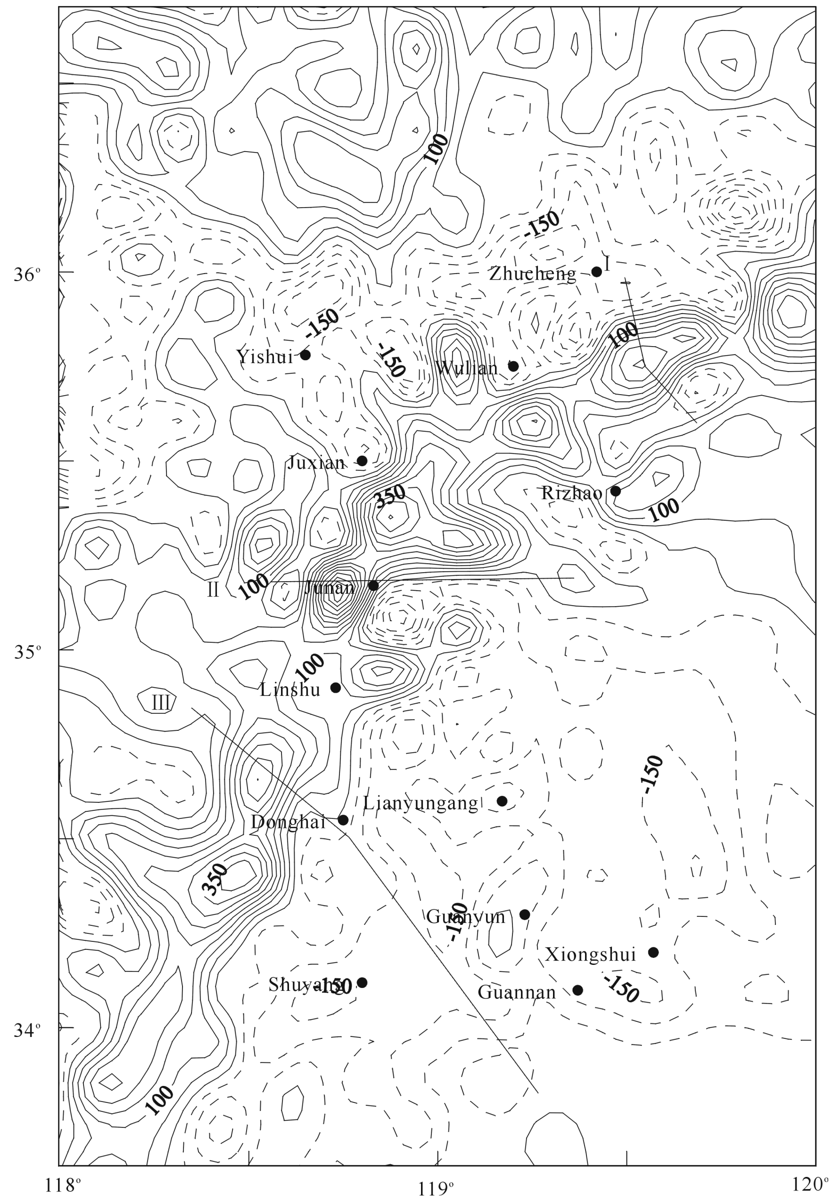

Fig. 3 The results of reduction-to-the-pole of magnetic anomalies (contour interval: 50 nT)

Table 1 Results of rock magnetic susceptibility results in Jiangsu–Shandong area ($\kappa/10^{-3}$ SI)

Rock	Minimum	Maximum	Arithmetic mean	References
Gneiss	0.029	14.60	0.610	Yu et al., 2002
Amphibolite	0.363	0.547	0.447	Yu et al., 2002
Serpentinite	15.07	37.51	24.13	Yu et al., 2002
Granite	0.120	7.490	5.960	Doptmah, 1985
Diorite	0.005	20.96	10.40	Doptmah, 1985
Eclogite	0.267	5.950	1.392	Yu et al., 2002
Granulite	0.050	56.38	1.242	Zhang and Lao, 1999
Mylonite	0.009	0.919	0.055	Xu, 2005

maps because of their small scale and deep depth. The cover rocks in Paleozoic, Mesozoic, and Cenozoic have little magnetic susceptibility (Yu et al., 2002).

3 Data processing and inversion

The studied area is located at east longitude 118°–120°, north latitude 33°40′–36°20′. The area covers about 40 000 km^2. The grid of aeromagnetic data is 500 m × 500 m. The precision is about 5 nT.

3.1 Analysis of aeromagnetic anomalies

As shown on Figs. 2 and 3, magnetic anomalies are usually between 150–200 nT. Anomaly trend is mostly NE and NEE. Positive anomalies are thought to correspond to Archean basement, granite and migmatite, i.e., Archean–Paleo-Proterozoic basement, neutral-basic volcanic rock and high pressure metamorphic belt; negative anomalies with small differences are usually considered to correspond to the Mesozoic–Cenozoic depression. The northeast-eastward positive-negative anomaly belts consist of the southern edge of the Jiaolai basin in the north and Luxi basin in the south; the SE negative anomaly area is mostly located in the Sulu depression. On the aeromagnetic map, linear anomalies belts with the NNE negative belt and the NE large-high positive anomaly belt in the middle show the Tanlu fault and ultra-high pressure metamorphic belt (UHPMB), respectively.

3.2 Reduce magnetic anomaly to pole

With the variety of geomagnetic inclination angle, magnetization direction of geologic body varies with latitude. The geologic body with different magnetization directions will show different magnetic features, which increase the difficulties of explaining the magnetic anomalies. Reducing the magnetic anomalies of tilt magnetism to vertical magnetism, i.e. reducing magnetic anomaly to pole, makes the anomaly simpler and the explanation easier (Xu, 1996; Liu and Gao, 2000; Fausto et al., 2001; Mark and John, 2001; Brown et al., 2003).

In order to avoid the influence on magnetic anomaly of tilt magnetism, we reduced magnetic anomaly to pole. As shown in Fig. 3, the influence of tilt magnetism is decreased. The fact that there are no obvious changes in the shape on the whole and only some small changes in magnitude shows that the ambient field of region magnetic anomalies has small discrepancies.

Filtering factor of reducing magnetic anomaly to pole is

$$H(u,v) = iu\frac{\sqrt{u^2+v^2}}{iu\alpha + iv\beta + \sqrt{u^2+v^2}\gamma}\cdot\frac{\sqrt{u^2+v^2}}{iu\alpha' + iv\beta' + \sqrt{u^2+v^2}\gamma'}$$

where u, v are spatial frequency in the magnetic north direction and magnetic east direction respectively; α, β, γ are the directional cosines of magnetization direction; α', β', γ' are directional cosines of normal geomagnetic field direction.

3.3 Model design and inversion

The detailed positions of three profiles on aeromagnetic map have been given as Table 2.

Table 2 Particular position coordinate of the designed three profiles

Profile		I	II	III
Initial point	Longitude (°)	119.494 4	118.547 1	118.348 9
	Latitude (°)	35.993 5	35.181 2	34.846 9
Turning point	Longitude (°)	119.549 0	–	118.766 4
	Latitude (°)	35.7513 2		34.502 7
Final point	Longitude (°)	119.685 5	119.375 5	119.269 2
	Latitude (°)	35.601 4	35.190 5	119.269 2
Profile length/km		46	80	139

By using the results of the deep seismic reflection (Yang et al., 1999a, b, c; Yuan et al., 2002; Yang et al., 2004; Wang et al., 2004; Xu and Zhao, 2004; Dai, 2004) and the Curie Point Depths calculated by Qiao and Liu (2007) as the initial model, under the constraints of magnetism of the core petrology at the CCSD pilot-hole and areal geology, we designed three simulated geotraverses. According to the basic principles of magnetic distributions of the continental crust, deep magnetic features of the three geotraverses are gained. Based on the magnetic features of rocks, the terrane structure characteristics of the three profiles are explained.

4 Results and discussion

Inverse results of the lithology distribution of the three simulated geotraverses are shown in Fig. 4. Detailed description is presented as follows.

4.1 Profile I

Profile I, from Dazhai of Zhucheng to Boerzhen of Jiaonan, normal to stratum striking direction, is 46 km in length. The inverse results (Fig. 4(a)) show that there are alternatively positive and negative anomalies with an amplitude of (–25)–100 nT in the southeast of the profile. The anomalies show the feature of volcanic rock which coincides with exposed Indosinian diorite; there are relatively strong positive anomalies in the middle of the profile, with 100–275 nT in amplitude. Here the magnetic susceptibility equals that of eclogite-bearing gneiss, so the anomalies reflect gneiss or marble accompanied with lens of eclogite. The length of different lenses of eclogite varies from few meters to scores of meters, involving coesite. Ductile shear zone, located in the south of the UHPM rock belt and composed of granitic mylonite, is dipping south, which reveals the doming and extension of the crust during the Yanshan period. The weak positive anomalies in the north of the profile reflect volcanic rocks, which correspond with the exposed Cretaceous volcanic basin. The middle crust (10–19 km) is mostly composed of UHPM gneiss and granite that intruded later. The lower crust shows the rocks of acid and basic granulite.

4.2 Profile II

Profile II, from Bahu of Linyi to Hushan of Rizhao, 80 km in length, nearly 90° in strike direction, passes through part of the ultra high pressure metamorphic belt. Figure 4(b) shows that the strong positive anomalies, located in the west of the profile, the amplitudes of which are between (–100)–500 nT, correspond with the Qishu fracture zone (part of the Tan–Lu fault northern extending). There are quite a few acid intrusions of the Yanshan Period along the fracture zone according to the ground geology. Therefore, the inversed results show that the acid rocks coincide with strong magnetic anomalies in 18–20 km. In the middle of the profile, there are relatively

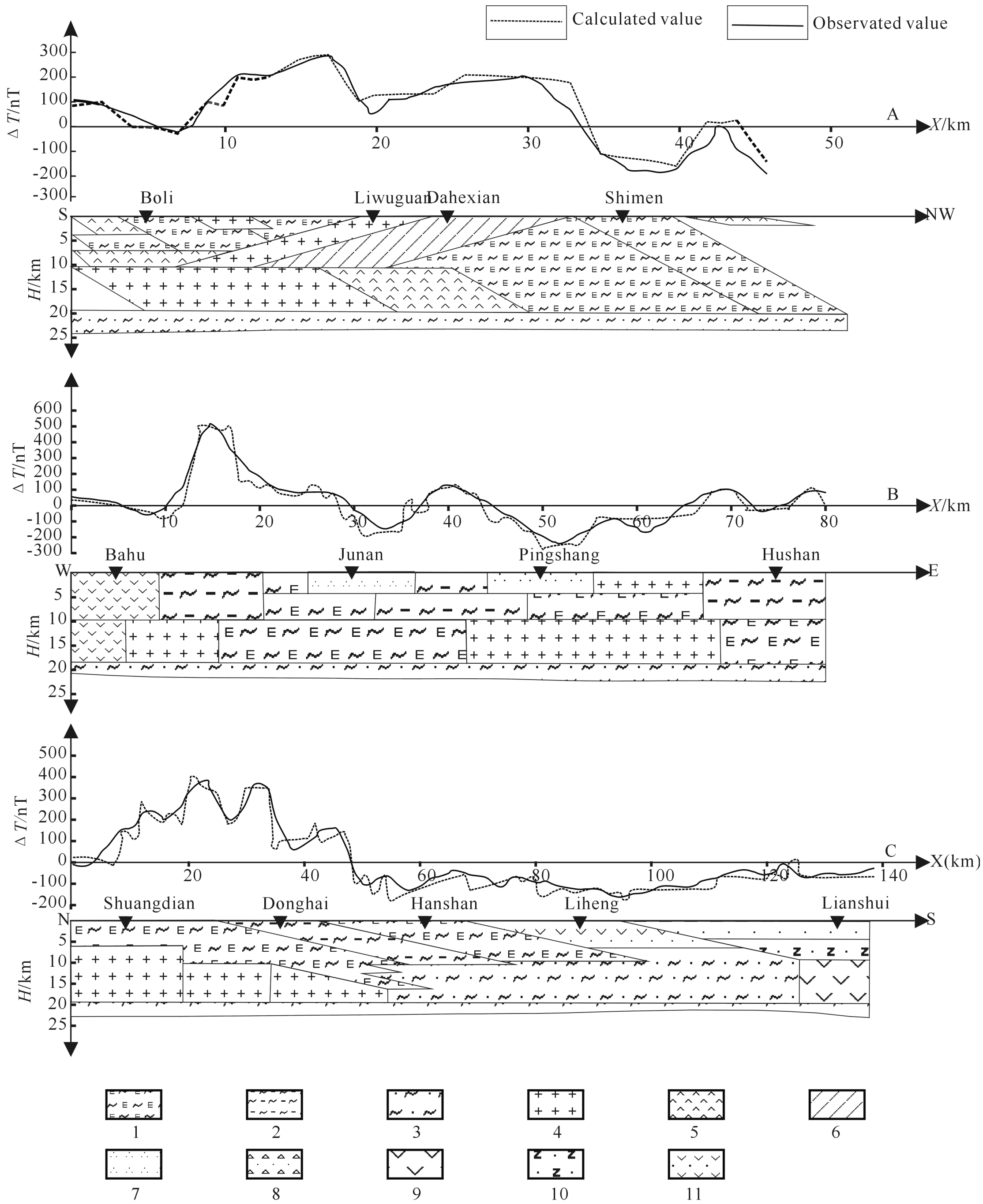

Fig. 4 The results of inversion of (a) Profile I, (b) Profile II and (c) Profile III based on magnetic anomalies
1. Eclogite-bearing high pressure gneiss; 2. High pressure gneiss containing eclogite and marble; 3. Acid and basic granulite; 4. Granite of Yanshan period; 5. Diorite; 6. Mylonite; 7. Quartz monzonite; 8. Cenozoic stratum; 9. Volcanic intrusive rock; 10. Sinian stratum; 11. Proterozoic stratum

strong anomalies with (−100)–100 nT in amplitude, showing the feature of neutral-acid rocks, such as quartz monzonite. This is consistent with the initial seismic model. The alternatively positive and negative anomalies in the east of the profile have an amplitude between (−100)–100 nT. Based on seismic results and geology, it is supposed that in the shallow are high pressure gneisses containing peridotite, marble and eclogite, which coincides with exposed coesite-bearing eclogite. The middle crust (10–19 km) is mostly composed of UHPM gneiss and granite that intruded later. The lower crust (19–23 km) shows the rocks of acid and basic granulite.

4.3 Profile III

Profile III, from Tancheng of Shandong Province to Lianshui of Jiangsu Province, 139 km in length, has a strike direction of 144°. From Fig. 4(c), there are strong positive anomalies in the north of the profile. The amplitude is between 0–400 nT. In the shallow are eclogite-bearing high pressure gneisses and from such depth to 19 km is granite basement, which is consistent with the seismic results. Negative anomalies, mostly located mid-south of the profile, with (–175)–(–50) nT in amplitude, reflect high pressure rocks containing topaz and blue schist. That is consistent with ground geology; the rock-belts are parts of the high pressure metamorphic belt. In the sites of 70–100 km, the aeromagnetic anomalies are relatively low, with (–175)–(–75) nT in amplitude, which reflects Proterozoic stratum. There are relatively low negative anomalies in the south of the profile too. These anomalies reflect Cenozoic sediments and complex rocks of rift. In the depth are acid and basic granulites.

The inverse results of Profiles I, II, III, show that the rocks are mostly composed of eclogite, marble, and gneiss at the depth of 5 km. At the depth between 5 and 7 km under the surface, inversed magnetic bodies are mainly the UHPM rock slices containing a lot of coesite-bearing eclogite. At the depth between 7 km and the bottom of the upper crust are the rocks of the gneiss, granite and granite diorite that underwent ultra high pressure metamorphic process. The middle crust (10–19 km) is mostly composed of UHPM gneiss and granite that intruded later. The rocks of acid and basic granulite dominate the lower crust. The results are consistent with the former study (Yang et al., 1999a, b, c, 2001) and the core petrology at the CCSD pilot-hole.

Various geodynamic models have been provided in the studied area. Major referenced models in this paper include the model of detachment and subduction of the lithosphere from Lu et al. (2005), the revolving model from Yang et al. (1999b), and the subduction model caused by exhumation mechanism of the ultrahigh-pressure metamorphic rocks from Li (2004). From the inverse results of the three simulated geotraverses (Fig. 4), we know that the UHPM rock-slices of the three profiles are dipping north, stacking each other and being uplifted to the earth's surface, which may be the result of the North China craton's subduction and exhumation in the Triassic. The coesite-bearing eclogites are found out according to surface geology. Ductile shear zone, south to the UHPM rock belt, composed of granitic mylonite, is dipping south, which reveals the doming and extension of the crust during the Yanshan period. Therefore, the inversion of aeromagnetic anomaly is one of the most effective geophysical techniques in studying regional tectonics and certain deep geologic structure.

Acknowledgements This paper was supported by the National Basic Research Program of China ("973 Project" No. 2003CB716506).

References

Brown D, Carbonell R, Kukkonen I, et al (2003). Composition of the Uralide crust from seismic velocity (*V*p, *V*s), heat flow, gravity, and magnetic data. Earth Planetary Science Letters, 210: 333–349

Dai M G (2004). Inversion research for gravity and synthetical interpretation of two profiles in the area of East China Sea and its adjacency. Progress in Geophysics, 19(2): 331–340 (in Chinese with English abstract)

Dong S W, Sun X Z, Zhang Y, et al (1993). Basic structure of the Dabieshan orogenic belt. Chinese Science Bulletin, 38(6): 542–545 (in Chinese)

Dong S W, Wu X Z, Gao R, et al (1998). On the crustal velocity levels and dynamics of Dabieshan orogenic belt. Chinese Journal of Geophysics, 41(3): 349–340 (in Chinese with English abstract)

Doptmah H B (1985). Physical Property of Rocks and Minerals (in Chinese, trans. Jiang H Y). Beijing: Science Press

Fausto F, Franco C, Emanuele B, et al (2001). Rifted crust at the East Antarctic craton margin: Gravity and magnetic interpretation along a traverse across the Wilkes subglacial basin region. Earth Planetary Science Letters, 192: 407–421

Fountain D M, Salisbury M H (1981). Exposed cross sections through the continental crust: Implications for crustal structure, petrology and evolution. Earth Planetary Science Letters, 5: 263–277

Jin Z M, Yu R D, Yang W C, et al (2003). Mantle-derived xenoliths of peridotite from Pingmingshan, Donghai County, Jiangsu Province and their implications for deep structures. Acta Geologica Sinica, 77(4): 452–459 (in Chinese with English abstract)

Li S G (2004). Exhumation mechanism of the ultrahigh-pressure metamorphic rocks in the Dabie mountains and continental collision process between the North and South China blocks. Earth Science Frontiers, 11(3): 63–70 (in Chinese with English abstract)

Liu Q S, Gao S (1998). Magnetic petrology of high-grade terrains in the Archean Shield areas—Window into deep crustal structure and geodynamic processes. Journal of China University of Geosciences, 9(1): 81–85

Liu Q S, Gao S (2000). Magnetic structure of the continental crust: Implications for crustal structure and evolution. Journal of China University of Geosciences, 11(3): 356–360

Liu Q S, Gao S, Liu Y S (2000a). Magnetic structure of the continental crustal cross-section in central North China Craton. Journal of Geodynamics, 29(1/2): 1–13

Liu Q S, Gao S, Liu Y S (2000b). Magnetic structure of the continental crustal cross-section in the central North China craton: Implications for deep geological structure and geodynamical processes. Chinese Journal of Geophysics, 43(1): 64–72 (in Chinese with English abstract)

Liu Q S, Gao S, Xu Q D, et al (1998a). Magnetic structure of Archean Kongling Group from Yangtze craton, South China. Journal of China University of Geosciences, 9(2): 144–151

Liu Q S, Gao S, Zheng J P (1998b). Magnetism structure of the continental crustal and research significance. Chinese Science Bulletin, 43(12): 1246–1252 (in Chinese)

Liu J H, Liu F T, Sui R M, et al (1995). Seismic tomography beneath the Qinling–Dabie orogenic belts and both the northern and southern fringes. Chinese Journal of Geophysics, 38(1): 46–54 (in Chinese with English abstract)

Liu J B, You Z D (1997). Isocon analysis of layered migmatite in Qinling Group. Acta Petrologica Sinica, 13(3): 427–438 (in Chinese with English abstract)

Lu F X, Wang C Y, Hu B Q, et al (2005). Structure of the lower crust and detachment and subduction of the lithosphere of the South Qinling. Geology in China, 30(2): 113–119 (in Chinese with English abstract)

Mark P, John A P (2001). Relating crustal magnetization and satellite-altitude magnetic anomalies in the Ungava Peninsula, northern Quebec, Canada. Earth Planetary Science Letters, 194: 127–133

McEnroe S A, Langenhorst F, Robinson P, et al (2004). What is magnetic in the lower crust? Earth Planetary Science Letters, 226: 175–192

Okay A I, Sengoer A M C, Satn M (1993). Tectonics of an ultrahigh-pressure metamorphic terran: The Dabie Shan/Tongbai Shan orogen, China. Tectonics, 12(6): 1320–1334

Qiao Q Q, Liu Q S (2007). Curie point depth investigation of the Dabie–Sulu UPH metamorphic belt (submit to Tectonophysics)

Shive P N, Blakely R J, Frost B R, et al (1992). Magnetic properties of the lower continental crust. In: Fountain D M, ed. Continental Lower Crust. New York: Elsevier, 145–177

Suo S T, Zhong Z Q, You Z D (2001). Extensional tectonic framework of the Dabie–Sulu UHP-HP metamorphic belt, Central China, and its geodynamical significance. Acta Geologica Sinica, 75(1): 14–24 (in Chinese with English abstract)

Wang C Y, Zhang X K, Chen B Y, et al (1997). Crustal structure in Dabieshan orogen. Science in China (Series D), 27(3): 221–226 (in Chinese)

Wang Q C, Sui S, Li J L, et al (1982). The tectonic evolution of the Qinling mountain belt. Chinese Journal of Geology, 2: 129–142 (in Chinese with English abstract)

Wang Y X, Jiang M, Han G H (2004). Crustal velocity structure beneath the site of Chinese Continental Scientific Drilling site. Earth Science—Journal of China University of Geosciences, 29(6): 667–672 (in Chinese with English abstract)

Wu Q F, Lu F X, Liu Q S, et al (2003). An Archean plate existed at lower crust in Sulu area: The evidence from magnetic data. Chinese Science Bulletin, 48(4): 395–399 (in Chinese)

Xu H J (2005). Study on the magnetic susceptibility of rocks from the main hole (100–2000 m) of the Chinese Continental Scientific Drilling Project (CCSD) and its adjacent area. Master Dissertation. Wuhan: China University of Geosciences (in Chinese with English abstract)

Xu J R, Zhao Z X (2004). Regional structure characteristic of crustal root of mountain beneath the Sulu orogenic belt. Acta Petrologica Sinica, 20(1): 149–156 (in Chinese with English abstract)

Xu S T, Okay A, Ji S, et al (1992). Diamond from the Dabie Shan metamorphic rocks and its implication for tectonic setting. Science, 256(5053): 80–82

Xu Y (1996). Aeromagnetic anomaly and deep tectonics in the northern Tianshan seismic belt. Inland Earthquake, 10(4): 304–310 (in Chinese with English abstract)

Yang W C, Cheng Z Y, Chen G J, et al (1999a). Geophysical investigations in the northern Sulu UHPM belt, part I: Deep seismic reflection. Chinese Journal of Geophysics, 42(1): 16–27 (in Chinese with English abstract)

Yang W C, Cheng Z Y, Zhang C H (2003). Geophysical investigations for Site—Selection of Chinese Continental Scientific Drilling and Dabie–Sulu lithosphere. Acta Geoscientia Sinica, 24(5): 391–404 (in Chinese with English abstract)

Yang W C, Fang H, Cheng Z Y, et al (1999c). Geophysical investigations of northern Sulu UHPM belt, part II: Non-seismic methods. Chinese Journal of Geophysics, 42(4): 508–519 (in Chinese with English abstract)

Yu Q F, Guo Y L, Meng X H, et al (2002). Petrophysics parameters at continental scientific drilling site in Subei, China. Chinese Journal of Geophysics, 45(1): 93–100 (in Chinese with English abstract)

Yang W C, Hu Z Y, Cheng Z Y, et al (1999b). Long profile of geophysical investigation from Tancheng to Lianshui, East–Central China. Chinese Journal of Geophysics, 42(2): 206–217 (in Chinese with English abstract)

Yang W C, Yang W Y, Cheng Z Y (2004). Interpretation of 3D seismic reflection data in the Chinese Continental Scientific Drilling site. Acta Petrologica Sinica, 20(1): 127–138 (in Chinese with English abstract)

Yang W C, Yu C Q (2001). Kinetics and dynamics of development of the Dabie–Sulu UHPM terranes based on geophysical evidences. Chinese Journal of Geophysics, 44(3): 61–75 (in Chinese with English abstract)

Yu Q F, Guo Y L, Meng X H, et al (2002). Petrophysics parameters at continental scientific drilling site in Subei, China. Chinese Journal of Geophysics, 45(1): 93–100 (in Chinese with English abstract)

Yuan X C, Ren J S, Xu M C, et al (2002). Reflection seismic profile from Gengxian to Nanzhang, Eastern Qinling and its tectonic implication. Geology in China, 29(1): 14–19 (in Chinese with English abstract)

Zhang G W, Zhang B R, Yuan X C, et al (2001). Qinling Orogenic Belt and Continental Dynamics. Beijing: Science Press (in Chinese)

Zhang J S, Lao Q Y (1999). Tectonic implication of aeromagnetic anomaly and evolution of Huabei–south Tarim–Yangtze super land mass. Earth Science Frontiers, 6(4): 379–390 (in Chinese with English abstract)