Discussion on Guangzhou-Enping Fault Based on Gravity and Deep Seismic Data

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Abstract. In this paper, the gravity and magnetic data and the preliminary results of the interpretation of the artificial seismic depth sounding in the Pearl River Estuary are combined with the geological data for the discussion of the most important northeast fault in the Pearl River Delta region in terms of the characteristics of deep strata of Guangzhou-Enping fault. It is believed that the Guangzhou-Enping fault is an NE-trending deep fault with a cutting depth of more than 30km, a depth of Moho, a steep dip, and the largest extent in the Pearl River Delta, and has a certain cut with the near EW-oriented fault. Therefore, the Guangzhou-Enping fault is active to some extent which provides a channel for deep material upwelling. The deep flow of molten material is the main component of the low-velocity zone of the lower and middle crust, and the surface is characterized by rich mineral resources, hot springs and basalt exposure.

1. Introduction
The Guangzhou-Enping fault is an important NE-trending fault in the Pearl River Delta region. Many studies have been carried out on this fault, and a large amount of geological data has been accumulated[1,4,5,6,8,9,10,11,12,14], but most of the research work only study on the shallow part but on deep features. The hot springs along the fault zone, abundant mineral resources and seismic activities show that it is of great theoretical and practical value to study the deep features of the fault. In order to further enhance the understanding of the crustal structure and active structure in the Pearl River Delta and offshore areas, We used gravity and magnetic data to study the deep fault system in Guangdong Province and its neighboring areas supporting by the projects of the Guangdong Science and Technology Plan in 2006 and 2010, the Guangdong Earthquake Administration, with the support of the China Earthquake Administration and the Guangdong Provincial People's Government, conducted a large-scale active source deep seismic observation experiment with the South China Sea Institute of Oceanology of the Chinese Academy of Sciences and the Geophysical Exploration Center of the China Earthquake Administration. This paper intends to study the deep part features, such as fracture connections, spreads, scale, and especially depth of cut of the Guangzhou-Enping fault, by using the NW-oriented Dinghu-Gaoming-Jinwan L1 line (Figure 1) velocity profile on the west side of the Pearl River Estuary in this observation experiment as well as the above-mentioned results of gravity and magnetic data.
Figure 1. Schematic diagram of the main fault distribution and L1 line location in the Pearl River Estuary

F3: Guangzhou-Zhaoqing fault; F5: Wugui shan-Beilu fault; F7: Wuchuan-Sihui fault;
F8: Guangzhou-Enping fault; F8-1: East branch of Kaiping-Enping fault; F8-2: West branch of Kaiping-Enping fault; F10-1: West branch of Heyuan fault; F10-2: East branch of Heyuan fault; F15: Xijiang fault; F17: Baimu-Shawan fault; F21: Wuguishan Nantun fault; F22: Zhuhai-Macau fault; L1: Dinghu-Gaoming-Jinwan depth sounding profile

2. The brief description of fracture surface geomorphology

The Guangzhou-Enping fault zone is heading toward NE, SW from Hailing island of Yangjiang River to NE by Enping, Kaiping to Foshan area, which is intercepted by the EW-oriented Xijiang fault. The section from Yangjiang to Foshan was divided into east and west parts by passing the Xijiang River fault. Going from Guangzhou, Conghua to Xinfeng area, some literature named the fault as: the west branch of Kaiping-Enping fault (i.e Cangcheng-Hailing fault), the eastern branch of Kaiping-Enping fault (i.e Hecheng- Jinji fault) and Guangzhou-Conghua-Xinfeng fault. In 2006, 2010 [15,16] , We applied the gravity and magnetic data system for analysis and interpretation to show the Kaiping-Enping fault east branch and west branch. The whole NE-trending fault in gravity and aeromagnetics from the shallow part to the upward extension of 30km is still continuous and clearly visible after crossing the Xijiang fault and going to NE via Guangzhou, Conghua to Xinfeng. Therefore, the three separately named faults are collectively referred to as Guangzhou-Enping fault. The overall trend of the whole fault is about NE30°, and the total length is over 400km.

The Kaiping-Enping East and West faults jointly control the development of the Kaiping-Enping Mesozoic and Cenozoic fault basin. The fault zone cuts the Cambrian to Paleogene and controls the development of many water systems and valleys, such as the Nalong River, Jinjiang River and the North Valley. It is also common for fault cliffs and waterfall. The northern part of the Guangzhou-Conghua-Xinfeng fault has obvious contrasts on both sides. The east side is the uplift area.
since the lower Paleozoic, revealing a large area of the Paleozoic metamorphic rock series. The west is the fault depression since the late Paleozoic, and it is also common for cliffs and falls. The Liuxi River often developed along the fault. At the southern end of the fault zone (outside the map), Yangjiang had a magnitude 6.4 earthquake in 1969. The M4.8 earthquake and small earthquake swarms occurred in the history of Guangzhou and Heshan, and this also proved that the fault has certain activity.

3. Interpretation of gravity and magnetic data
The gravity data system was processed in 2006 and 2010 [15,16], with the 1:1 million Bouguer gravity map and the related data which were measured and compiled by the geophysical exploration team of the Guangdong Provincial Bureau of Geology and Mineral Resources according to the national unified regulations. Also, the 1:500,000 aeromagnetic map and the related data of Guangdong Province were used, which were compiled by the Geophysical Exploration Brigade of the Guangdong Provincial Bureau of Geology and Mineral Resources.

The above maps were digitally processed with Mapgis software to form a Bouguer gravity anomaly map of N21°40’-24°, E112-115° with a width of 300km from east to west and a length of 260km from north to south. On this basis, we used the software of the National 863 Project “Deep Ocean Crustal Structure Detection Technology (820-01-03)” in the subproject “Structural and Magnetic Seismic Comprehensive Inversion Technology and Software System”. Different methods were adopted to obtain about 400 pieces of gravity and magnetic maps with different extended depths. Only a few representative pictures are shown in this paper.

It is visible from the 135° NE-trending first-order derivative gravity contour and the grayscale map (Figure 2a, b, c, d) that the NE fracture has a complete reflection to the gradient band and good connectivity. However, there is only a short empty section in the South of Conghua. The gray-scale maps (Figure 2d) show that NE-trending thick black shadows are most prominent in the pearl river delta region. The overall performance is a wide and thick black shadow belt. The scale is magnificent and huge. There is a clear indication of EW-trending F4 cutting off signs at Heshan. To the north, the EW-trending F2 and F3 black shadow is obviously cut off, causing its discontinuity, indicating that it is mutually tangent to the near EW fracture with new tectonic activity [15,16] and should have certain mobility. Thus, the gravity map reflected that the fault zone was the most powerful and largest NE-trending fault zone in the Pearl River Delta, with a cutting depth of more than 30km (the NE-trending fault of 30km depth is not seen in the Pearl River Delta region).

From the maps with different depths of 10km, 20km and 30km (Figure 2a, b, c), it can be seen that the contours of the east branch of the Guangzhou-Enping fault are consistently distributed along the Conghua, Foshan, Heshan, Kaiping. The contours of the west branch are distributed along the west side of Huadu, Sanshui and Enping. The contours of different depths have minor change and the contours are tight. Meanwhile, the grayscale images are reflected as thick black images (Figure 2d). All reflect that the Guangzhou-Enping fault is a fault with a large dip angle and a relatively strong cutting trend (ie, the fault-cut surface is dominant and the structure is intact). At a depth of 30km, the other NE-trending faults in the Pearl River Delta have disappeared, leaving only the strong performance of the fault. It can be seen that it is the largest and deepest NE-trending fault in the Pearl River Delta region. Judging from the width of the contour and the width of the thick black strip, the width of the fault zone should be more than 20km, and some sections may reach more than 30km.
(a) Upward 10km first-order directional derivative contour map (135°)

(b) Upward 20km first-order derivative contour map (135°)

(c) Upward 30km first-order directional derivative contour map (135°)

(d) Upward extension of 30km first-order derivative grayscale image (135°)
The aeromagnetic data is not as good as the gravity data, because the magnetic strength of the regional medium is generally low or even non-magnetic \([15,16]\). Even though the corresponding fault-dislocation effect is also low, but the aeromagnetic data still shows certain basic characteristics of the fault, it is basically consistent with the results of gravity data. As shown in figure 3, the fracture connection, the strike, and the basic structure are generally consistent with the gravity map. The difference is that the contour and gray image structure are not as strong as the gravity map.
Figure 3. Aeromagnetic contour map and grayscale map of the Pearl River Delta
(The name of the break is the same as in figure 2, according to [7,15,16], modified)

Therefore, the results obtained from the interpretation of gravity and magnetic data can fully indicate that the Guangzhou-Enping fault is a large-scale fault composed of two faults in east and west, with a width of more than 20km and some sections up to 30km, and a depth of more than 30km. The Guangzhou-Enping fault should be the largest and deepest NE-trending fault in the Pearl River Delta.

4. Interpretation of deep seismic data

In 2015, the Pearl River estuary land and sea joint survey project laid three wide-angle reflection/refraction profile lines on the land of the Pearl River estuary. The angle between the NW-oriented L1 line (Figure 1) and the west/east branch of the Guangzhou-Enping fault is about 57°. The design goal is to cut through the Wuchuan-Sihui fault zone, the Guangzhou-Enping fault, the Wuguishan fault zone, and other major NE-oriented and near EW-oriented fault zones on the west side of the Pearl River estuary. The active source seismic observations are used to study the deep extension of these faults in the earth's crust.

This paper combines the results of the L1 line velocity model to further interpret the Guangzhou-Enping fault. The northwestern end of the L1 line starts near the Shilong Group of Xinfeng Village, Fenghuang Town, Dinghu District, Zhaoqing City (Figure 1) with the coordinates are N23.4728°, E112.4557°. This line goes to SE in Gaoming District and Nanhui District of Foshan City, Xinhui District and Doumen County of Jiangmen City, and terminates near the coastal area of Jinwan County, Jiangmen City with the coordinates of N22.0583° and E113.2656°. The entire line is basically in the NW-SE direction and has a total length of about 178km [13].

From the 2D section modeling results (Figure 4), there is a low-velocity layer with a minimum speed of 6.05km/s at a depth of 15.0km between the C1 and C2 interfaces located at the 120-130km position of the line between Dinghu and Gaoming. There is a low-speed layer with a minimum speed of 6.37km/s at a depth of about 21.5km between the C2 and the Moho surface, and a ridged Moho surface below the low-velocity layer with a height of about 1km. In the middle crust and the lower crust, the Guangzhou-Enping fault bounds the southeast boundary of the low-velocity layer between C1 and C2, and between C2 and Moho, reflecting the cutting depth of the Guangzhou-Enping fault to at least Moho. The two low-velocity regions have different distributions and the Moho-faced ridges have little change in the vertical direction, which reflects that the Guangzhou-Enping fault is not only cut to the Moho.
surface, but also the inclination angle is relatively erect, and it is compatible with the interpretation results of gravity and magnetic data.

![Figure 4](image-url)

**Figure 4.** Two-dimensional velocity structure of the L1 section on the west side of the Pearl River Estuary (according to [13], modified)

F3: Guangzhou-Zhaoping fault; F5: Wuguishan Beitun fault; F7: Wuchuan-Sihui fault; F8: Guangzhou-Enping fault; F8-1: Kaiping-Enping fault east branch; F8-2: Kaiping-Enping fault west branch; F21: Wuguishan Nantun fault; F22: Zhuhai-Macau fault

5. Conclusions and discussion

1. The results of the interpretation of gravity and magnetic data and the results of the two-dimensional velocity profile of deep seismic exploration show that the Guangzhou-Enping fault is an NE-trending deep fault with a depth of cut of more than 30 km and a depth of Moho and a steep inclination. The gravity and magnetic data show that the overall structure of the fracture is complete and the connectivity is good. It is the largest NE-trending fault in the Pearl River Delta region, and it has a mutual cut with the near EW-oriented fault, which proves that it has a certain activity.

2. The Pearl River Delta land area is mainly the Bouguer gravity positive anomaly area. The area is centered on Foshan, west to Zhaoqing, east to Huizhou, south to Zhongshan, and north to Qingyuan (Figure 5). The Wuchuan-Sihui fault bound the northwestern boundary of the high gravity anomaly zone, and the Guangzhou-Enping fault passed through the middle of the high gravity anomaly zone.

3. From the two-dimensional section of the L1 line, the ridge area with the Moho surface between Dinghu and Gaoming is visible. The upper part of the uplift area is a low-speed anomaly area distributed in different layers. The northwest side of the Guangzhou-Enping fault and the northeast side of Gaoming are the famous Xiqiao Mountain Scenic Area in Guangdong (Figure 5). They are large-scale distributed trachyte. In addition, there are many basic and ultrabasic basalts near the fault zone. The rock is exposed. The Guangzhou-Enping fault is rich in mineral resources (Guangdong Provincial Bureau of Geology and Mineral Resources, 1998) [14,17], and geothermal resources are sufficient, at the same time more than 30 hot springs are exposed on the Fogang-Fengliang fault [18]. Therefore, it is inferred that the low-velocity area of the different layers of the middle and lower crust above the Moho surface uplift between Dinghu and Gaoming, the main component of which should be the molten material in the deep upwelling.
Figure 5. Bouguer gravity anomaly map in the Pearl River Delta
(according to [7,15,16], modified)

Based on comprehensive gravity and deep seismic exploration and geological data, it is judged that the Guangzhou-Enping fault is an NE-trending deep fault with a cutting depth of more than 30km, a depth of Moho, a steep dip, and the largest extent in the Pearl River Delta. The Guangzhou-Enping fault provides a channel for deep material upwelling. The deep flow of molten material is the main component of the low-velocity region of the middle and lower crust. On the surface, it is characterized by abundant mineral resources, hot springs, and basalt and other basic and ultrabasic rocks.

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