Heat Flow Distribution and Thermal Mechanism Analysis of the Gonghe Basin based on Gravity and Magnetic Methods

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Abstract: Geothermal resource is indispensable as a clean, renewable, stable and cheap resource. Nowadays in China, the Gonghe Basin, located in northeastern Qinghai Province, has been thought to be a promising geothermal area. To explore geothermal energy potential in and around the Gonghe Basin, geophysical means including magnetic and gravity methods were used to plot distribution. Firstly, we inversed Moho depth and Curie point depth in and around the basin using gravity and magnetic data, respectively, through an improved Parker–Oldenburg algorithm. Secondly, seven different thermal models were established, considering radiogenic heat, basement depth, anomalous heat source and simulated corresponding temperature field and heat flow. These were analyzed numerically and we found the high heat flow in the Gonghe Basin co-acted with radiogenic heat, an anomalous heat source and conductive heat. The distribution of seismic activities indicates that the Langshan–Wuwei–Gonghe Fault might have provided channels for transporting heat effectively.

Key words: geothermal energy, heat flow, thermal mechanism, Curie point depth, Moho Depth, Gonghe, Qinghai–Tibet Plateau

1 Introduction

Conventional fossil fuels are being disputed for their capacity for pollution and CO₂ emission contributing to global warming. Sustainable, environmentally friendly and renewable resources are thereby being introduced, such as wind, solar and geothermal energy (Zou et al., 2016; Wang B et al., 2018). Of these, the popular geothermal energy is the most ecofriendly with its production unaffected by weather (Li et al., 2015). To explore for geothermal resources, there is a need to achieve geological and tectonic structure of an area, and geophysical methods have been the active tools to realize this target (Domra et al., 2015). For instance, 2D or 3D magnetotelluric (MT) data inversion has generally been used for geoelectrical investigation of geothermal fields in Ethiopia (Cherkose and Saibi, 2021), the United Arab Emirates (Saibi et al., 2021) and Rwanda (Uwidiuhaye et al., 2021). And Seismic profiles are used for 3D model in heat flow study in Songliao Basin (Shi et al., 2019) and the Gonghe Basin (Gao et al., 2018).

In terms of density and susceptibility contrast, gravity and magnetic methods can be applied for modelling subsurface structures, as in Egypt, Ethiopia, and Rwanda (Abdel et al., 2018; Uwidiuhaye et al., 2019; Dejene et al., 2021), and detecting alteration zones and geothermal-related faults regionally (Saibi et al., 2006; Pandarinath et al., 2014). For deeper zones, the Curie point depth (CPD) and Moho depth (MD) can be inversed by magnetic and gravity anomaly. For example, Oruc et al. (2017) used the Parker–Oldenburg method to gain MD depth along a steady-state geothermal profile in Eastern Anatolia, Turkey, to provide the possible geodynamic mechanism in this area. CPD can be used to analyze heat distribution; Bilim et al. (2016) and Erbek and Dolmaz (2019) got heat flow values through CPDs in Turkey. Herein, we use the Parker–Oldenburg method, which is a common inversion method (Parker, 1973; Oldenburg, 1974). Additionally, Wang and Pan (1993) suggested that geological bodies should have upper interface and lower interface to improve the algorithm based on a dual interface model. Feng (1986) extended the model from even layers to uneven ones, with density or magnetization varying by exponential or linear functions. Xu (2006) and Zhang et al. (2015) raised an iteration method using upward continuation in a form equivalent to inversion iteration in the Fourier domain instead of the divergent, downward continuation term, to solve a divergence problem in traditional method.

The Gonghe Basin in China has been shown to be a prospective geothermal field. Geophysical surveys including MT, seismic, gravity and magnetic methods have been conducted, but a possible thermal mechanism was still being discussed within these datasets. The MT data shows that there was a partial melting body at depths of 15–35 km in the western Gonghe Basin, with a length...
of ~41 km and a width of ~34 km (Zhang et al., 2020b). A three-dimensional MT imaging indicated a conductive layer in the middle-upper crust in southeastern Gonghe Basin and a possible magma chamber near Gonghe town (Gao et al., 2018). The seismic results also show partial melting with low-velocity at depths of 1–10 km, 25–40 km and about 60 km in the basin (Zhang S et al., 2019). With the multiple geophysical datasets, Zhao et al. (2020b) proposed a conceptual geothermal model for the Gonghe Basin with MT, seismic, MD and CPD evidence. From this, there is a stable structure in the low crust and mantle with induced magma chambers at mid-crust. However, heat distribution and the thermal mechanism at basin scale still need to be discussed.

In this paper, we focus on heat flow distribution in the Gonghe Basin and its adjacent area through gravity and magnetic data. We integrate improvements of the Parker–Oldenburg algorithm to gain the MD and CPD estimations. Then, we register 3D temperature field and heat flow distribution in the study area, and analyze the thermal mechanism numerically.

2 Geologic and Tectonic Setting

Geothermal distribution has close relationship with geological and tectonic setting (Feng et al., 2019; Tang et al., 2020). The Gonghe basin is located on the northeastern margin of the Qinghai–Tibet Plateau, with an area of 21,186 km² (Zhao et al., 2009). The basin is in the subsidence zone of a compounding zone between the Kunlun–Qinling zonal tectonic belt and the Hexi system tectonic belt, and surrounded by fault-folded uplift mountains, including Qinghai South Mountain and Laji Mountain in the north, Guinan South Mountain in the south, Waligong Mountain in the east, and Ela Mountain in the west (Li and Li, 2017) (Fig. 1).

Several faults (Fig. 1) control the margins of this basin to make it stretch along a NWW direction. To the west of the Gonghe Basin, the Wahong Mountain–Hot Spring Fault (WHF) is in a 20°NW direction and has intensive extrusion. To the north of the basin, the south slope fault zone of Qinghai South Mountain (QSF) is a NW dextral strike-and-compression slip. The transtensional Waligong Mountain teconomagmatic belt (WMB) is in NNW direction to the east of the basin. The faults cut deeply and have strong Quaternary tectonic movement, acting as channels of heat fluid and heat conduction, where many hot springs exist (Sun et al., 2011). Additionally, according to geophysical work (Li, 2002), there might be a NNE-large strike-slip hidden fault, the Langshan–Wuwei–Gonghe fault zone (LWGF) crossing the Gonghe Basin, which is important for uplift of heat conduction and seismic activities (Lu et al., 2017).

Triassic beds occur in the uplift zone around the basin and in the basement. Intrusive rock is mainly Indosinian granite, granodiorite and porphyritic granite, which are widely distributed at the basin margins and intrude into the Triassic as part of basement of basin (Wang et al., 2015). Jurassic sandstone, conglomerate and mudstone are exposed only at the southern margin of the basin. Quaternary and Neogene strata are the main sediments in the Gonghe Basin, with an upper composition of interbedded mudstone and sandy mudstone, and a lower sandy mudstone with an insert of sandy conglomerate and a total thickness of 1300–1500 m near Qiabuqia Town (Zhao et al., 2020a). A thick, low-thermal conductivity cap rock of Quaternary and Indosinian granite with good radioactivity contribute to the important ability of heat storing in the basin.

3 Thermal Information

The geological conditions in the Gonghe Basin meet requirements of two hot dry rock (HDR) source types, including the sedimentary basin and the active tectonic zone, as suggested by Lu et al. (2017). In fact, this basin

![Fig. 1. (a) Map of geothermal distribution in research area of the Gonghe Basin (shown with brown outline) and adjacent area (after Xue et al., 2013; Zhang C et al., 2019; Zhang S et al., 2019); (b) location of research area in central China (China basemap after the China National Bureau of Surveying and Mapping Geographical Information).](image)
has been revealed as a potential geothermal field in different temperature ranges, including high (≥ 150°C), medium (90–150°C), and low (< 90°C) (Wang et al., 2017; Wang K et al., 2018). For regional heat flow, the Gonghe Basin lies in the northeastern corner of Qinghai province and adjacent to Gansu province, so we used the newest heat flow values in Gansu and Qinghai among the 4th heat flow data compilation in continental area of China (Jiang et al., 2016) to get the heat flow distribution in these two provinces (Fig. 2a) and the research area (Fig. 2b) through Kriging interpolation (Pauselli et al., 2019 ). From this we found that the study area has an increasing heat flow trend from northwest to southeast, and has a higher heat flow background (60–136 mW/m²) than other places in Gansu and Qinghai provinces (25–95 mW/m²); the eastern part of the study area has the highest heat flow value (95–136 mW/m²) (Jiang et al., 2016) (Fig. 2a). The only two heat flow values known in the study area in the 4th heat flow data compilation are 136.6 mW/m² in Gonghe and 123.1 mW/m² at Guide (Fig. 1b).

There are two kinds of geothermal hot waters in and around the Gonghe Basin. One is the fracture convection type, with many hot springs distributed along a tectonomagmatic belt, including WHF and WMB, and convective hot springs having high temperatures, up to 93.5°C. The other kind is normal hot water in the basin, such as Nos. 4 and 5 hot springs (shown in Fig. 1), which generally have temperatures less than 40°C (Wang et al., 2010).

Boreholes can provide the most accurate and direct thermal information. Three reservoirs have been found through boreholes in Qibuqia Town, Gonghe County. Two reservoirs are in the sedimentary cap layer, one is a reservoir in Lower Pleistocene, mainly fine sandstone and coarse sandstone, with depths at 100–200 m, thickness greater than 100 m and a temperature of 38–46°C. The other one is a Neogene reservoir, which is mainly sandstone and gravel, with depths of 669–718 m, thickness of 80–200 m and temperatures of 82–84.2°C. HDRs, the reservoir we pay most attention to, have been drilled into Indosinian granite with a thermal conductivity of 2.52 to 2.81 W/(m·K) (Zhang et al., 2018) in boreholes GR1, GR2, DR3, DR4, all located in the transition zone of the Tanggemu depression and Yellow River uplift, where there is a high average temperature gradient (Zhang C et al., 2019) (Fig. 1). HDR with the highest temperature in China of 236°C was drilled at a depth of 3705 m in GR1 (Fu et al., 2018). Although there are hot springs near Guide, no HDRs have been found in Guide, the average thermal conductivity in Guide is 2.61 W/(m·K) (Zhang et al., 2018).

4 Materials and Methods

4.1 Geophysical data

A combination of magnetic and gravity methods is crucial towards assuming superior cognition of geothermal structure. Herein, we use the Bouguer gravity and magnetic data at a scale of 1:500,000 covering the whole Gonghe basin and adjacent area, ranges from 3919787 to 4087500 in the X direction and 17479866 to 17727586 in the Y direction. Gravity data have been corrected using standard corrections to get the complete Bouguer anomaly (Uwiduhaye et al., 2018). Additional, free air and Bouguer corrections were computed using the International Association of Geodesy 1967 formula (Tóth et al., 2005). Terrain correction was also adopted with the 90 m-SRTM data (Jarvis et al., 2008). The magnetic data have been corrected by normal correction and diurnal correction (Nabighian et al., 2005), and reduced to the magnetic pole using a magnetic inclination of 55.37° and magnetic declination of 0° (Baranov, 1957). These processed data are from the Qinghai Provincial Bureau of Geological Survey. What’s more, we gained seismic activities during 1980–2020 from the Advanced National Seismic System (ANSS) to help with analyzing the geothermal distribution.

4.2 Calculation of Moho depth and CPD

Parker–Oldenburg is a traditional inversion algorithm for gravity and magnetic data. With the ordinary Parker–Oldenburg algorithm, it considers the gravitational attraction from a layer of material, with lower boundary \( z = 0 \), and upper boundary \( z = h(\mathbf{r}) \). Suppose the Cartesian axis system has the positive \( z \) direction of vertically upward, then positions in space are represented by vectors.
like $r = (x, y, z)$, the projected $r$ onto x-y plane is $\tilde{r}$. Parker (1973) stated an iterative formula in wave-number domain

$$F[\Delta g] = -2\pi G \rho \exp(-|\tilde{k}| z_0) \sum_{n=1}^{\infty} \frac{|\tilde{k}|^{n-1}}{n!} F \left[ h^n (\tilde{r}) \right],$$  \hspace{1cm} (1)

where $F[ ]$ denotes Fourier transformation, $\Delta g$ is the gravity anomaly, $G$ is the Newton’s gravitational constant, $\rho$ is the density contrast across the interface, $k$ is the wavenumber ($\tilde{k}$ can be expressed as $1/\tilde{\lambda}$, $\tilde{\lambda}$ is the wavelength in kilometres), $z_0$ is the reference observation interface; Oldenburg (1974) suggested a relevant iterative interface inversion formula (2)

$$F \left[ h^n (\tilde{r}) \right] = \frac{F[\Delta g]}{2\pi G \rho} \delta_{\tilde{r}} - \sum_{n=2}^{\infty} \frac{|\tilde{k}|^{n-1}}{n!} F \left[ h^n (\tilde{r}) \right],$$  \hspace{1cm} (2)

The Parker–Oldenburg inversion formula has a non-convergent term $e^{-2\pi k z_0}$, Oldenburg (1974) added a low-pass filter to make the formula convergent but the filter should make high-frequency signal go away. Correspondingly, we have improved the Parker–Oldenburg inversion method by considering double-interfaces, the index changed parameter, and used an integral iterative calculation proved by Xu (2006), to get the inversion algorithm of MD $H_{\text{MD}}$ (3) and CPD $H_{\text{CPD}}$ (4), respectively.

$$H_{\text{MD}} = h_{\text{bg}} + \Delta H_{\text{1g}} + \frac{s}{2\pi G \rho} e^{\Delta\mu} (\Delta g - F^{-1}[e^{\hat{P}} \cdot (F[2\pi G \rho e^{\Delta\mu}] - \Delta H_{\text{1g}}))] \sum_{n=1} \frac{(a - |\tilde{k}|)^{n-1}}{n!},$$  \hspace{1cm} (3)

Where $\rho_0$ is the density contrast at ground surface, $a$ is the variability index of $\rho_0$, $h_{\text{bg}}$ is the reference plane, $s$ is the iteration step, $\Delta H_{\text{1g}}$ and $\Delta H_{\text{2g}}$ are differences between the lower boundary, upper boundary and the reference plane, respectively.

$$H_{\text{CPD}} = h_{\text{bg}} + \Delta H_{\text{1g}} + \frac{2s}{\mu_0 M_0 e^{\Delta\mu} c^2} (\Delta T - F^{-1}[e^{\hat{P}} \cdot (F[2\pi M_0 e^{\Delta\mu}] - \Delta H_{\text{1g}}))] \sum_{n=1} \frac{(b - |\tilde{k}|)^{n-1}}{n!},$$  \hspace{1cm} (4)

where $\mu_0$ is the magnetic permeability in a vacuum, $\mu_0 = 4\pi \times 10^{-7}$ H/m, $M_0$ is the magnetization contrast at ground surface, $b$ is the variability index of $M_0$, $\Delta T$ is the magnetic anomaly, $h_{\text{bg}}$ is the reference plane, $\Delta H_{\text{1g}}$ and $\Delta H_{\text{2g}}$ are differences between the lower boundary, upper boundary and the reference plane, respectively. The complete deduction process is shown in Supp. file.

To get a more reliable CPD inversion result, we added an extra step to reduce the influence of the sediments before inverting the CPD. Firstly, we calculate the magnetic anomaly upon the basement; this is a forward process, wherein, ground surface and basement interface were upper interface and lower interface, respectively. Then we subtract the anomaly produced upon the basement from the total anomaly in the study area to get the residual anomaly, which is used to inverse CPD; in this inversion process, the upper surface and lower surface should be the basement interface and Curie interface. Finally, heat flow values can be gained from the CPD.

### 4.3 Heat flow estimation

The Moho interface is the geological boundary between the earth’s crust and the mantle, and the Curie interface can be considered as an isothermal surface, with a temperature of 580°C (Tanaka et al., 1999; Elbarbary et al., 2018), which is used as a limiting condition when getting the thermal field underground. The temperature field can be solved by the equation (Howell et al., 2021):

$$\frac{\rho c}{\lambda} \frac{\partial T}{\partial t} = \nabla (\lambda \nabla T) + Q,$$  \hspace{1cm} (5)

where $c$ is heat capacity, $\lambda$ is thermal conductivity, $\nabla T$ is temperature gradient, $Q$ is radiogenic heat production. The relation between heat flow $q$ and $\nabla T$ can be given as:

$$q = -\lambda \nabla T.$$  \hspace{1cm} (6)

### 5 Results and Discussion

#### 5.1 Gravity and magnetic anomaly distribution

Gravity data in and around the Gonghe Basin varies from $-475$ mGal to $-350$ mGal (Fig. 3a). The gravity map displays a gradient E–W-trending gravity low, and a variation of the structural trend from NNW to NNE occurring from west to east near Gonghe County, which indicate that there might exist a fault, corresponding with the hidden LWGF.

Magnetic data in and around the Gonghe Basin varies from $-120$ nT to $180$ nT (Fig. 3b). The magnetic map shows a numerical change from positive to negative. The contour line valued 0 nT splits the study area into two parts that differ in magnetic properties; the orientation of this line also agrees with NNE-trending LWGF.

We gained basement depth of the Gonghe Basin from the petroleum industry, and it ranges from 0.6 km to 4.8 km (Fig. 4a) (Wang and Lv, 2004). Part of the Guide Basin, involved in the study area, has a basement depth set at 1.5 km according to drilling information (Wang et al., 2015). The basement depth excludes basement outside of the basin, but this does not matter because, according to the geological setting and stratigraphic map in and around the Gonghe Basin, granite outcrops surround the Gonghe Basin and the sediment affects the magnetic data much more in the basin (Zhang et al., 2020), where we pay also more attention. The residual magnetic anomaly is shown on Fig. 4b, which is used to calculate the CPD to reduce the influence of sediments inside the Gonghe Basin.

#### 5.2 Moho depth and CPD maps

MD and CPD in the study area were calculated using gravity and magnetic data through the improved Parker–Oldenburg algorithm.

To get MDs, we used 0.0188 as the density variability index $a$, and 0.92 g/cm$^3$ as the known point $\rho_0$ (Ke et al., 2006). The map of MD for the study area shows a maximum depth of 59 km below the southwestern corner and a minimum of 51.5 km below Qinghai Lake and the eastern part of study area (Fig. 5a). The MD deepens roughly from east to west with a gradient variation.

During CPD estimation, the known magnetic susceptibility point is set to $1 \times 10^{-3}$ SI (Zhang et al., 2020a; Zhao et al., 2020a). The CPD map shows that there
is a maximum depth of 25 km below the northwestern corner of study area and a minimum of 16 km below Guide County and Guinan County (Fig. 5b). The CPD map displays a more irregular variation and reflects a deepening trend roughly from east to west.

Herein, we take the Moho interface the geological interface between earth crust and mantle, and the Curie interface as a geothermal interface without direct geological significance. The trends of MD and CPD indicate that mantle structure is more stable and thermal activities in the crust might contribute more to high heat flow in study area.

5.3 Heat flow distribution

Under a steady-state thermal condition, equation 1 can be transformed as follows (Howell et al., 2021):

$$\nabla (k \nabla T) = -Q. \quad (7)$$

It is clear that temperature and heat flow value are decided by radiogenic heat $Q$ and thermal conductivity $\lambda$. Radiogenic heat originates from uranium, thorium and potassium elements in rocks. The radiogenic heat from the Indosinian granite has been thought of as an important heat source in the study area. Here we give different thermal conductivities and radio heat productions, shown in Table 1, according to the geological interfaces, to make a more accurate thermal model. The basement depth at Gonghe of 2.7 km (Fig. 4a) is different from that gotten from logging data (1.5 km), so we consider both depths when building models. Six models are set out to study the thermal contribution of radiogenic heat and sedimentary

layers (Table 2) with corresponding heat flow maps (Fig. 6). Heat flow values in Gonghe and Guide are shown in models a–f (Table 3). Through comparison between a and b, c and d, e and f, it can be found that the contribution of radiogenic heat in Gonghe is ~23 mW/m², and in Guide is ~27 mW/m². Comparing a, c and e, b, d and f, we find that the basement depth difference in Gonghe contributes little to the heat flow value, about 2 mW/m², so it is feasible to use basement depth at basin scale (Fig. 4a) as a geological interface when giving a thermal conductivity matrix. For model f, the heat value in Guide is 124.48 mW/m², agreeing with 123.1 mW/m² in previous research. However, in this model, the heat flow value in Gonghe (114.15 mW/m²) is smaller than that in Guide, and is smaller than known heat flow value here (136.6 mW/m²). Moreover, in the temperature field of model f (Fig. 8a), we can find the undulations of the field under the limitation of the Curie isotherm, and the temperature is higher beneath Guide compared to that beneath Gonghe. Thus, there appear to exist thermal anomalies in Gonghe.

Referring previous geophysical results, we assume a model g, in which a heat source is buried at 15–30 km beneath Gonghe. The initial temperature of the heat source is 500°C. The total simulation time is 0.16 Ma, which corresponds to the Gonghe Movement (Zhang et al., 2018). The simulated result illustrates that the heat flow value in Gonghe is high (140.12 mW/m²), corresponding with previous study. In the temperature field of model g (Fig. 8b), the temperature beneath Gonghe is higher than that of Guide. The heat flow value has a range of 63.29–141.14 mW/m². The heat flow map has highest values around Gonghe, relatively high values near Guide and Guinan, lower values in the northwestern basin, and low values outside of the basin (Fig. 7).

On the basis of the simulated temperature field and heat flow maps of the different models considering radiogenic heat, basement depth and heat source, we consider that the high heat flow in Gonghe (140.12 mW/m²) is contributed by radiogenic heat (~23 mW/m²), heat source (~27 mW/m²), and transferred heat (~91 mW/m²), while the relatively high heat flow in Guide is co-acted by radiogenic heat (~27 mW/m²) and transferred heat (~98 mW/m²).

5.4 Correlation of seismic activity with thermal structure

Heat and seismic activities have proven indicative of each other in many geothermal fields (Elbarbary et al., 2018; Erbek and Dolmaz, 2019). In order to find correlation of seismic activities with thermal structure in the study area, earthquakes were added onto the heat flow map (Fig. 7). We find that earthquakes have a striped horizontal distribution, corresponding with a known phenomenon that earthquakes often occur in a thermal gradient zone (Tang et al., 2020), on the margin of a gradient field (Dolmaz et al., 2005), in a concave-convex alternation region (Yang, 2015), or on the margin of an uplift of the Curie interface (Rajaram et al., 2009). This distribution also indicates seismic activities are controlled by the NNE-trending hidden LWGF, and intensive earthquakes here might provide positive channels for heat energy to improve the probability of a geothermal anomaly beneath this zone. In fact, until now, all HDRs in the Gonghe Basin were found in this hidden fault zone. By comparison, the WMB has proven to be a positive target area for a hydrothermal geothermal reservoir with intense

Table 2 Six thermal models for the Gonghe and Guide basins

<table>
<thead>
<tr>
<th>Depth of sedimentary layer</th>
<th>With no radiogenic heat</th>
<th>With radiogenic heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500 m in the study area</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>1500 m in the Gonghe Basin and the Guide Basin</td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>Fluctuate basement shown in Fig. 4a.</td>
<td>e</td>
<td>f</td>
</tr>
</tbody>
</table>

Table 3 Heat flow values in Gonghe and Guide in each model described by Table 2

<table>
<thead>
<tr>
<th>Heat flow values (mW/m²)</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonghe</td>
<td>88.68</td>
<td>113.34</td>
<td>88.39</td>
<td>111.36</td>
<td>90.82</td>
<td>114.15</td>
<td>140.12</td>
</tr>
<tr>
<td>Guide</td>
<td>98.21</td>
<td>126.75</td>
<td>96.27</td>
<td>123.20</td>
<td>96.74</td>
<td>124.48</td>
<td>124.48</td>
</tr>
</tbody>
</table>

Fig. 5. Maps of (a) Moho depths; (b) Curie Point depths in the Gonghe Basin and adjacent area.
tectonic activities in the late Quaternary and high heat flow, also providing channels for convection and conduction of thermal fluid. However, lack of seismic activities in the WMB indicates a more stable geological structure and lower probabilities of geothermal anomalies, which also means lower probability of HDR.

Based on the above discussion, seismic activities have a positive relationship with thermal distribution in the study area. Thus, depth of seismic activity might indicate depth of thermal activity. Seismic energy in the basin is concentrated at depths of 0–40 km, and stronger earthquakes generally occur above the Curie interface, which means that there might exist intense thermal activity shallower than 40 km. This discovery also supports the
conjecture that a heat source anomaly may exist in the crust.

6 Conclusions

Both geological structure and tectonic setting suggest that the Gonghe Basin is a fracture-convection basin as well as a heat conduction basin, and might contain an immense distribution of geothermal resources. In order to investigate geothermal distribution, we used geophysical processes, including gravity and magmatic methods, to gain the heat flow and temperature distribution in the study area.

Firstly, we integrated improvements of the Parker–Oldenburg algorithm, including dual interfaces, changing parameters and upward continuation to estimate the MD and CPD estimation. We put forward an improved Parker–Oldenburg method, introducing double-interfaces, index changed parameter and an integral iterative method based on the traditional Parker–Oldenburg algorithm to inverse MD and CPD in the Gonghe Basin. MDs range from 51.5 to 59 km, CPDs range from 16 to 25.5 km, and they were used to establish different thermal models, which considered radiogenic heat, basement depth and heat source to analyze heat flow and temperature field distribution. The results indicate that the high heat flow value in Gonghe (140.12 mW/m²) is contributed by radiogenic heat (~23 mW/m²), heat source (~27 mW/m²), and transferred heat (~91 mW/m²). Moreover, the distribution of seismic activities shows that the LWGF may provide an important thermal channel.

On the whole, this study simulates heat flow and temperature field in and around the Gonghe Basin, and analyzes the thermal mechanism numerically.

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