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Present-day geothermal characterization of the East China Sea Shelf Basin

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INTRODUCTION

Geothermal regime is essential for understanding the tectonic mechanism and geodynamics of marginal basins.

The East China Sea Shelf Basin (ECSSB), located at the junction of the Eurasian Plate and Pacific Plate, has undergone multiple tectonic deformation, making its tectono-thermal evolution complex. Present-day geothermal regime could provide key constrains for deciphering the tectono-thermal process.

However, due to the limited coverage and ambiguous quality of previous heat flow data, the thermal regime of the ECSSB remains poorly understood.

Here we report 52 new heat flow data estimated from the industry boreholes in the ECSSB, and integrate previous data to revisit the thermal regime of the ECSSB.

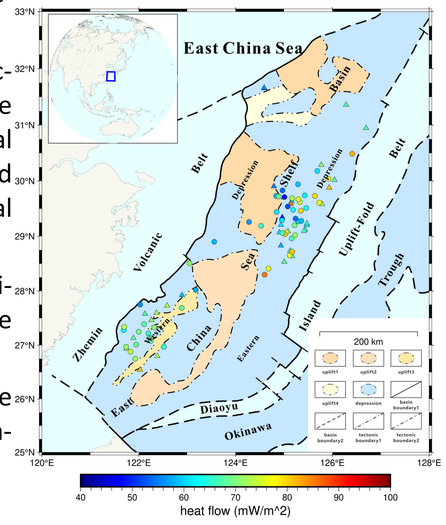


Figure 1: Structural subdivision and heat flow sites in the ECSSB. The circular denotes new data from this study, while the triangular denotes the data from the Global Heat Flow Database of the IHFC

(http://ihfc-iugg.org/)

METHODS AND DATA

The main types of temperature data in this study are drilling test temperature (DST) and corrected bottom hole temperature (BHT).

The temperature measurement data exhibit a linear temperature increase with depth, reflecting typical conductive geothermal characteristics.

Besides the temperature data, we also collected the thermal properties of conductivity and heat production data from this basin.

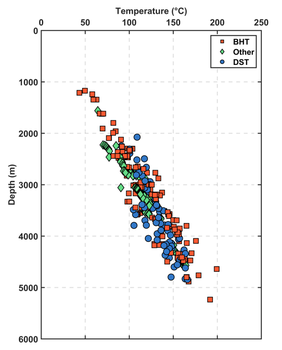


Figure 2: Temperature depth profile of the ECSSB

Thermal properties of sediments in the ECSSB		
Formation Group	Rate of Heat Production (μW/m³)	Thermal Conductivity (W/m·K)
Donghai Group	1.48	1.00-1.20
Santan Group	1.05	
Liulang Group		
Yuquan Group		1.20-2.500
Longjing Group	1.01	
Huagang Group	1.00	
Pinghu Group	0.74	2.6
Oujiang Group		

Table 1: Thermal properties for the ECSSB (Luan et al. 2002, 2003)

Geothermal gradient:

$$G = \frac{T - T_0}{Z - Z_0}$$

Heat flow:

$$Q_s = -K_t \frac{dT}{dZ}$$

Temperature:

$$T_i^b = T_i^t + \frac{q_i^t \times Z_i}{K_i} - \frac{A_i \times Z_i^2}{2 \times K_i}$$

RESULTS

Our results show that the ECSSB has an average geothermal gradient of 32.0 °C/km and a mean heat flow of 67 mW/m², consistent with the average value of continental China.

The Western Depression (WD) shows an average geothermal gradient of 30.7 °C/km and an average heat flow of 65 mW/m², while the Eastern Depression (ED) exhibits an average geothermal gradient of 32.4 °C/km and an average seafloor heat flow of 71 mW/m², indicating an increasing in thermal regime from west to east .

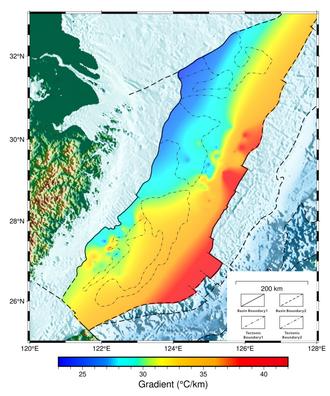


Figure 3. Distribution of geothermal gradient in the ECSSB

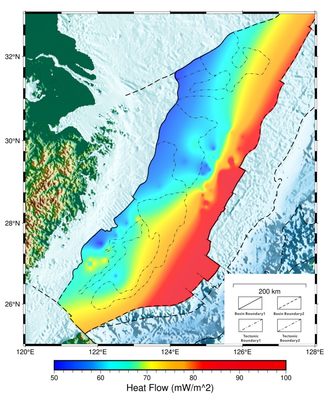


Figure 4. Distribution of heat flow in the ECSSB

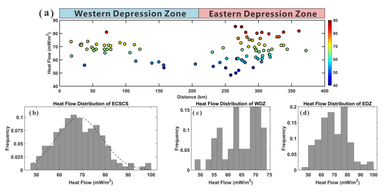


Figure 5. (a) Thermal flow data of the WD and ED in the ECSSB. (b) Frequency distribution of heat flow data in ECSSB. (c) - (d) Frequency distribution of heat flow data in the WD and ED.

We estimated the temperature of sedimentary layers at depths ranging from 1000m to 5000m.

The distribution of formation temperature at different depths still exhibits a zoning feature of higher temperatures in the ED and lower temperatures in the WD, which is similar to the spatial pattern of geothermal gradients and heat flow.

It can be observed that the present-day formation temperature at a depth of 2000m in the basin ranges from 66°C to 119°C, which is within the oil generation window stage.

This depth should currently be a favourable location for petroleum formation or preservation.

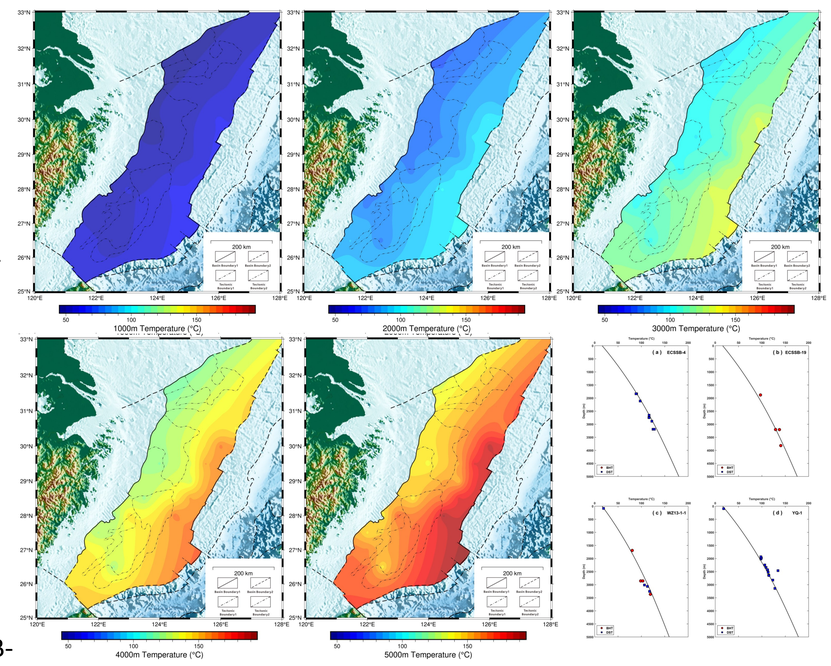


Figure 6. Estimated temperatures at different depths (1000 m-5000 m) in the ECSSB.

Four drilling wells with continuous temperature logging data, namely ECSSB-4, ECSSB-19, WZ13-1-1, and YQ-1, were selected as reference for reliability verification of deep temperature estimation. The results showed a high degree of fitting, indicating that the deep temperature prediction results are reasonable.

Figure 7. Comparison between estimated and measured temperature values in ECSSB.

DISCUSSION

The tectonic pattern of the ECSSB aligns with its east-west differential geothermal regime.

The retreat of the subducting Pacific Plate results in east-west differences in rifting activity within the basin (Cukur et al., 2011; Lee et al., 2006). Therefore, the crustal thickness of the ECSSB is thicker in the WD and thinner in the ED (Ding et al., 2018), which influences the geothermal regime of the basin.

It is evident that the tectonic evolution of the ECSSB controls the geothermal pattern.

Besides, the basement topography and the radiogenic heat contribution by granitic base also account for the localized heat flow anomalies.

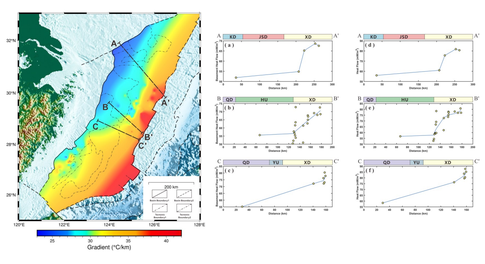


Figure 8. The change in thermal state of the ECSSB from NW to SE direction. KD: Kunshan Depression, JSD: Jinshan Southern Depression, QD: Qiantang Depression, XD: Xihu Depression, HU: Hupijiao Uplift, YU: Yushan Uplift

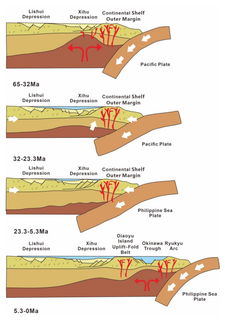


Figure 9. The center of subsidence in the ECSSB has shifted from west to east to the Okinawa Trough, adapted from Zhao et al. (2016).

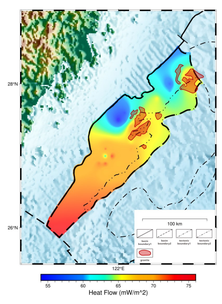


Figure 10. The spatial correlation between the granite basement and the seafloor heat flow in the Lishui-Jiaojiang Depression. Granite distribution modified from Wang et al., (2014).

CONCLUSION

(1) The ECSSB has a moderately high heat flow background. Specifically, the present geothermal gradient of the basin ranges from 23.9 °C/km to 41.1 °C/km, with an average of 32.0 °C/km; the seafloor heat flow ranges from 48 mW/m² to 85 mW/m², with an average of 67 mW/m². The ECSSB shares the same average heat flow with global continental shelf areas and China's land areas.

(2) The spatial distribution of geothermal energy in the ECSSB exhibits a NW-trending zonal pattern, with significant lateral variations. Specifically, the average geothermal gradient in the Western Depression is 30.7 °C/km, and the average heat flow is 65 mW/m²; in the Eastern Depression, the average geothermal gradient is 32.4 °C/km, and the average heat flow is 71 mW/m². From west to east, the thermal state of the basin tends to gradually increase, consistent with the tectonic deformation.

(3) The geothermal pattern of the ECSSB is controlled by the basement pattern and tectonic evolution of the basin. With the subduction and retreat of the Pacific Plate, the rifting and magmatic activity in the ECSSB have gradually become younger from west to east, and the crustal thickness has gradually decreased as well. This tectonic process controls the overall thermal state of the ECSSB. In addition, the radioactive heat contribution from the granite basement also contributes to localized heat flow anomalies.

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