Geologic feature and tectonic evolution in the South Yellow Sea

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Abstract. South Yellow Sea is mainly located on the Yangtze platform, which is a sequence residual basin that has been migrated and superimposed since the late Proterozoic, and has been transformed many times to make the original appearance incomplete. South Yellow Sea Basin has a complex process of formation and evolution. South Yellow Sea has the characteristics of north-south block and east-west zoning. The fault is dominated by the direction of NEE, NE and NW. The fault zone has large extension length and staggered structures in all directions, which is featured by multi-type and multi-order. The main magmatic rocks in the South Yellow Sea are Yanshan period magmatic rock, and the distribution of rock mass is controlled by NE fracture, and has the characteristics of multi-stage activities with large and frequent strength. Since its formation, the South Yellow Sea region has experienced six tectonic movements, among which Yizheng Movement, the First Act of Wubao Movement, and Sanduo Movement are three major tectonic movements. The structural relationship and interaction between the Sino-Korean Block and Yangtze Block as well as Yangtze Block and South China Block, would provide important insights to the formation and evolution process of South Yellow Sea Basin, and the activity of Eurasian plate and the interaction between the surrounding plates.

1. Introduction

The South Yellow Sea faces Shandong and Jiangsu in China, closes to Korean Peninsula to the east, connects to the North Yellow Sea with the line of Chengshan Cape-Changshanchuan as the boundary to the north, and connects to the East China Sea with the line of Qidong-Jeju Island as the boundary to the south [1]. It is a shallow sea on the continental shelf, which is close to a rhombic depression in shape and covers an area of about 300,000 square kilometers.

The South Yellow Sea strides across three major tectonic units. It closes to Shandong Peninsula in the north, belonging to Sino-Korean Block in the south, Fujian and Zhejiang folded-uplift belt in the middle [2, 3]. The fault development in the area is dominated by NW and NE faults. It is the main form
of Mesozoic tectonic movement to control the boundaries of uplifts, depressions, bulges and sag. The characteristics of gravity and magnetic anomalies in the sea area is obvious with Qianliyan uplift from north to south, northern basin and middle uplift, southern basin and Wunansha uplift, as well as eastern uplift. Magmatic activity is developed in the South Yellow Sea and its neighborhoods, especially on the Korean Peninsula and the eastern part of mainland China [2, 3, 4]. The formation and distribution of different types of magmatic rocks are restricted by the tectonic movement, and different tectonic settings have different stages and types of magmatic rocks [5].

The investigation of South Yellow Sea in China began with the national oceanographic survey in the 1960s. The sea area is rich in oil gas and other mineral resources, but so far, oil and gas exploration has not been broken through. The main problem is that the search for oil gas is mainly concentrated in the Cenozoic era, but not enough attention is paid to the Mesozoic and Paleozoic strata. It is not clear about the tectonic evolution of this area, especially the basement structure and Paleozoic evolution, as well as the control effect of block collision on the evolution of the Meso-Cenozoic basin. How to realize oil and gas breakthrough and do a good job of new oil and gas prospect evaluation in this area is an urgent problem to be solved. Further investigation and study on the South Yellow Sea can provide data for the exploration and development of oil, gas and mineral resources, which is of great practical significance for the exploitation of marine energy and the service of national economic construction in China [6].

2. Geologic feature of the South Yellow Sea

2.1. Stratum distribution of the South Yellow Sea

China has drilled 20 exploratory wells in 124°E in the west of sea area, and South Korea has drilled 5 wells in the northern part of South Yellow Sea and the junction of Qunshan depression [7]. The Upper Paleozoic, Mesozoic and Cenozoic strata were found. The Upper Paleozoic carbonitic and Permian were marine facies—ocean and land-carbonate rocks and clastic rocks. Mesozoic Triassic system was dominated by marine carbonate rocks, while the Cretaceous and Tertiary were dominated by continental clastic rocks [8].

2.2. Main fault zones of the South Yellow Sea

Like the characteristics of Eastern China, the South Yellow Sea has the characteristics of north-south block and east-west zoning [9]. The fault is dominated by the direction of NEE, NE and NW. The fault zone has large extension length and staggered structures in all directions, which is featured by multi-type and multi-order. The characteristics of several faults are reflected in the gravity, magnetic anomaly diagram and upward continuation diagram.

The main fault zone in the South Yellow Sea area includes the following seven zones [2]. The overall trend is NNE, and it is Tan-Lu fault zone that is composed of multiple parallel faults; it is located in the east of Tan-Lu fault zone, NEE trend and Wulian-Qingdao-Rongcheng fault zone extending in the EW direction [10]. Located on the south side of Jiaonan Uplift, it runs from Lianyungang-Qianliyan fault zone on the east side of Tan-Lu fault zone in the south [18]. It runs from the east side of Tanlu fault zone in the south, and extends into the South Yellow Sea through Jiashan and Xiangshui, Jiashan-Xiangshui fault zone extending to NE in the south edge of Qianliyan uplift, and Jiangshan-Shaoxing- Kwangju deep fault zone consisting of Jiangshan-Shaoxing fault and Kwangju fault on the Korean peninsula. A pair of "X"-type cross faults are formed in the Yellow Sea central fault zone in the middle and late Triassic period; Yellow Sea is distributed in the near SN direction. It extends from West Korea Bay in the north, and fault zone along the western margin of Korean peninsula of surrounding waters of Daheishan Islands to the south [11, 12, 13].

2.3. Tectonic unit of the South Yellow Sea

On the whole, the South Yellow Sea can be divided into three tertiary tectonic units: Sino-Korean Block, Yangtze Block and South China Block, which are divided into quaternary structural units, such as folded-uplift belt and basin [4]. The South Yellow Sea area is located in the Yangtze Block. From north
to south, it can be divided into five tectonic units: folded-uplift belt of Jiaonan Linjin River, northern basin of South Yellow Sea, middle folded-uplift belt of South Yellow Sea, southern basin of South Yellow Sea and Wunansha folded-uplift belt [3].

2.4. Magmatic activity of the South Yellow Sea
Magmatic activity is developed in the South Yellow Sea and its neighborhoods, especially on the Korean Peninsula and the eastern part of mainland China. The formation and distribution of different types of magmatic rocks are restricted by the tectonic movement, while different tectonic settings have different stages and types of magmatic rocks.

The main magmatic rocks in the South Yellow Sea are Yanshan period magmatic rocks. The magmatic rocks in this period are widely exposed in the North China-Langlin Block, Dabie Mountain-Jiaonan-Linjin River jointing strip, Yangtze-Jingji Block and so on, which are the most developed magmatic rocks in the area [7]. In the early stage, it was mainly intermediate and acidic rocks with batholith and stock output. In the late stage, in addition to the development of acid intrusive rocks, the intermediate and alkaline rocks with the vein output can also be seen. The distribution of these magmatic rocks is mostly controlled by NE faults. The magmatic rock in this period has the characteristics of multi-stage activity with large and frequent intensity. Most of the volcanic activity is medium and acidic, and its formation age is mainly in the early Yanshan period of late Jurassic epoch.

3. Tectonic evolution of the South Yellow Sea Basin

3.1. Main development stage of the South Yellow Sea
The Yellow Sea and its neighbors are located in the eastern part of East Asian Block. Its early geological and historical development process is related to the comprehensive action of Eurasian ancient continent (ancient plate), Gondnaland (Australian plate) and other ancient plates. Especially since the Mesozoic era, the tectonic development history of Yellow Sea and its adjacent areas has been closely related to the relative movement and interaction between Eurasian plate, Indian plate and Pacific plate [14, 15].

The South Yellow Sea Basin is a sequence residual basin which has been migrated and superimposed since the late Proterozoic and has been transformed many times to make the original appearance incomplete, which can be divided into two main stages of development: stable platform and active continental margin. It has experienced the development process from stable deposition, gradual collation, oscillatory migration, extrusion folding fault, and collision orogeny to compression-tension conversion and from strike-slip settlement to tensile block fault. In the Paleozoic Era, it is mainly the stable platform deposition stage. In the Mesozoic Era, it is mainly the foreland and pull basin basins. In the Late Mesozoic-Cenozoic Era, it is the fault depression and depression basin period.

3.2. Six tectonic movements in the South Yellow Sea
Since its formation, the South Yellow Sea region has experienced six tectonic movements: Yizheng Movement, the First Act and Second Act of Wubao Movement, Sanduo Movement, Fanchuan Movement and Yellow Sea Movement, among which Yizheng Movement, the First Act of Wubao Movement, and Sanduo Movement are three major tectonic movements with significant scale and influence [4].

Yizheng Movement was a fault-folded movement that occurred at the end of the Cretaceous, which opened the prelude to the Cenozoic basin. Paleogene was covered by unconformity or disconformity (the northern basin of South Yellow Sea) over the Cretaceous or older strata. This movement is the initial movement after the change of stress field, and the faulted fold is not strong. The faults extend along the steep wing of the Middle Paleozoic anticlinorium, and the fault surface is steep in the upper section, and slow in the lower section, reflecting the characteristics of gravity sliding caused by paleotopography. The direction of the tectonic line has an inheritance, and it is half-graben sag which faulted in the south part and overlapped in the north part [14].
Wubao Movement is a strong tectonic movement in the Himalayan period multi-cycle movement since the Cenozoic era. The movement began at the end of the Eocene epoch and lasted until the early and middle Oligocene, including two movements between Dainan Formation and Funing Group, Sanduo Formation and Dainan Formation. However, the latter movement has little influence on the whole basin, which can only be seen in the northern sag of Gaoyou and the northern basin of South Yellow Sea. Therefore, they are collectively referred to as the Wubao Movement, that is, the first act and second act of Wubao Movement. This movement is dominated by fault lifting action and accompanied by fold movement. The rise and fall of faults separated Eocene lake basins and reduced the depositional range of Dainan Formation. The unconformity between Dainan Formation and Funing Group can be seen in some areas of the sag. For example, Funing Group on the northeast slope of northern sag in the northern part of South Yellow Sea Basin has been stripped and there is an obvious angular contact relationship between the Funing Group and Dainan Formation. Dainan Formation is missing in the slope or protruding part, and the Sanduo Group is directly covered above Taizhou Formation and Funing Group. Wubao Movement is the heyday of development of half-graben sag in the basin. It has an inheritance and a new nature. The movement formed a series of local structures [15, 16].

Sanduo Movement at the end of Oligocene was another important tectonic movement in Himalayan period cycle in the basin. It caused the formation uplift to be denuded, and there was a large scale of basic magmatic intrusion and basalt flow spillage [17, 18]. Two and three reverse faults are also formed in the northern basin of the South Yellow Sea. Sanduo Movement is a faulted fold movement. On the one hand, it showed the inheritance activity of large fault at the boundary of the sag, which made the half-graben sag further perfect from the formation to the development. On the other hand, it showed disconformity and unconformity contact. On the slope, it is also obvious that the uplift of Sanduo Formation on the margin of the basin has been denuded. In addition, a group of NE-SW horizontal compressive stress derived from the interior of half-graben sags is strengthening, forming many small structures of low amplitude. Most of the local structures were formed or finalized at this time, and the distribution of local structures in the NW direction becomes more and more clear. The intensity of Sanduo Movement varies from region to region. On the whole, the northern basin of South Yellow Sea is stronger than the southern basin of Southern Yellow Sea of northern Jiangsu, and the central and eastern part of each basin is stronger than the west [2].

Fanchuan movement in Neogene period caused the southwest of South Yellow Sea Basin in the Northern Jiangsuto to rise, the first member of Yancheng Group to suffer denudation, and the sedimentary center of the second member of Yancheng Group shifted to the east sea area. However, the whole basin is mainly manifested as subsidence and sediment cover. The second member of Yancheng Group has the largest sedimentary range and the basin has obvious depression characteristics. There is also a micro-angle relationship between Wubei Formation and Huanghai Formation, but its scope is small and the influence is not significant [19].

The Yellow Sea movement at the end of Pliocene was developed only in the central part of northern basin of the South Yellow Sea [1]. During the Quaternary period, the sea water was gradually invaded from the east and southeast, and a set of horizontal and gray clay-based strata were widely deposited, which laid the geological structure of the present South Yellow Sea.

4. Conclusion
The South Yellow Sea is mainly located on the Yangtze platform, which is a sequence residual basin that has been migrated and superimposed since the late Proterozoic, and has been transformed many times to make the original appearance incomplete.

The strata of South Yellow Sea are mainly the Upper Paleozoic, Mesozoic and Cenozoic strata. On the whole, South Yellow Sea can be divided into three tertiary tectonic units: Sino-Korean Block, Yangtze Block and South China Block. The main magmatic rocks in the South Yellow Sea are Yanshan period magmatic rock, and the distribution of rock mass is controlled by NE fracture, and has the characteristics of multi-stage activities with large and frequent strength.
The South Yellow Sea has the characteristics of north-south block and east-west zoning. The fault is dominated by the direction of NEE, NE and NW. The fault zone has large extension length and staggered structures in all directions, which is featured by multi-type and multi-order. The main fault zones in the South Yellow Sea include Tan-Lu fault zone, Wulian-Qingdao-Rongcheng fault zone, Lianyungang-Qianliyan fault zone, Jiashan- Xiangshui fault zone, Jiangshan-Shaoxing- Guangzhou deep fault zone, as well as central fault zone of Yellow Sea and the western margin fault of Korean peninsula.

The Yellow Sea and its neighbors are located in the eastern part of East Asian Block. Its early geological and historical development process is related to the comprehensive action of Eurasian ancient continent (ancient plate), Gondnaland (Australian plate) and other ancient plates. Since its formation, the South Yellow Sea region has experienced six tectonic movements: namely Yizheng Movement, the First Act and Second Act of Wubao Movement, Sanduo Movement, Fanchuan Movement and Yellow Sea Movement, among which Yizheng Movement, the First Act of Wubao Movement, and Sanduo Movement are three major tectonic movements with large scale and influence.

Based on the study of the South Yellow Sea, it is of great theoretical significance to study the structural relationship and interaction between the Sino-Korean Block and Yangtze Block as well as Yangtze Block and South China Block, and basement characteristics as well as formation and evolution process of South Yellow Sea Basin to study the formation and evolution of marginal sea basin in Eastern China, and the activity of Eurasian plate and the interaction between the surrounding plate.

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