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GEOPHYSICAL MANIFESTATIONS OF OPENING AND CLOSING STRUCTURES AT DIFFERENT SPATIAL AND TEMPORAL SCALES

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Abstract: Opening and closing tectonics is a new hypothesis that studies the opening and closing movement of the earth and its tectonic characteristics, analyzes the formation mechanism of the opening and closing tectonic system, and explores the origin and evolution of the earth. Opening and closing structures at different spatial and temporal scales have different geological manifestations and require research from different angles. Taking the giant open-closed tectonic area in Asia, Europe and Africa, the large-scale open-closed tectonic area in the Mediterranean, and the medium-sized open-closed tectonic area in East Dabie as examples, the application of the open-closed tectonic theory in geotectonic zoning, seismic activity, and interpretation of modern geodetic survey results was studied. applications. Research shows that: (1) Based on the perspective of open-closed tectonics, the giant open-closed structures in the Asia-Europe-Africa neighborhood can be divided into the Russian tectonic cluster, the African tectonic cluster, the North Asian tectonic cluster, the Central Asian tectonic cluster, the South Asian tectonic cluster and the East Asian tectonic cluster; (2) Strong seismic activity in Asia, Europe and Africa is closely related to the Cenozoic opening and closing tectonic transition zones between tectonic clusters; (3) Seismic profiles and focal mechanisms in the large opening and closing tectonic areas of the Mediterranean reveal the Mediterranean-Turkey-Iran — The current tectonic movement in the Afghan tectonic transition zone is mainly coalescence; (4) The ground tilt and ground strain, peripheral GNSS and flowing gravity observations of Shizishan, Huangmei, Macheng and other stations around the East Dabie medium-sized opening and closing structure reveal that It is found that there is a trend transition from "closing" to "opening" with short time scale and weak magnitude around this area. The opening and closing movement is a common mechanism for the quasi-synchronous changes in the trends of many recent observation data.
Keywords: Geotectonic division; Opening and closing structures; Earthquakes; Crustal deformation observation; Dabie orogenic belt

1 INTRODUCTION

Since its establishment in the mid-19th century, geotectonics has experienced two major discussions: "activity" or "fixation", and "catastrophe" or "uniformitarianism". Many views during this period had a significant impact on the subsequent development of earth sciences. However, limited by the level of understanding at that time, tectonic research during this period rarely involved the effects of the Earth's interior. Since the 20th century, the discovery and confirmation of mid-ocean ridge zones, transform faults, and Benioff zones have given geotectonics a truly global perspective and developed into global geotectonics [1-4]. However, the continental drift theory and plate theory that were founded during this period and are still popular today are still not the true overall dynamics of the earth, but the dynamics of lithospheric plates based on the mantle convection hypothesis. Their ideas can be summarized as oceanic rocks. Circle subduction leads to continental accretion and ocean basin disappearance, followed by continent-continent collision [5-6]. These ideas have one thing in common, that is, they all believe that oceanic lithosphere is active in tectonic evolution, while continental lithosphere is passive. Later, scholars from various countries discovered many continental fragments in the ocean, which falsified this argument. That is, there is no huge difference between active and passive between continents and oceans. The two can be transformed into each other. The mutual transformation between the multiple layers of the earth. The role is the dominant factor in tectonic evolution [7].
The tectonic pattern of the Earth can be summarized as two characteristics: vertical stratification and lateral blockage. The layers of different depths are connected together by the mantle plume as a link. The deep "layers, blocks, and columns" are large in scale but simple in structure, while the shallow "layers, blocks, and columns" are small in scale but complex in structure [8]. Large structures control surrounding small structures and determine the direction and process of structural evolution. Therefore, geohistory divides the global tectonic evolution into several large stages of different levels, and then divides into multiple small stages nested in the large stages. The essence of modern geology, such as the trough theory, plate theory and geomechanics, all utilize or reveal this law from different angles. The concept of "opening and closing tectonics" is a geotectonic idea originally created by my country's geoscience pioneers such as Academician Ma Xingyuan. It can be widely used in areas such as regional geotectonic research, petroleum and mineral exploration, and geological disaster prevention. The view of "opening and closing structures" summarized by my country's fourth generation geologists represented by Yang Weiran is based on these theories, getting rid of the

shackles of the debate between fixed theory and activity theory, and distinguishes different periods, levels and levels. Tectonic movements that develop independently and are dynamically balanced are summarized as "opening and closing movements" [8-10]. The subjects of the opening and closing movement are hierarchical in scale, the activity process is circular in time, the activity areas are complementary in space, and the evolution direction is directional in process [11-12]. In 2012, under the guidance of this idea, the author analyzed and summarized the basic characteristics and evolution rules of Asian geotectonic structures, and divided Asia into four structural clusters, 11 geotectonic cycles, 23 subduction zones or collision zones, and three types of structures. Movement programs have gained many new insights [12]. After the implementation of the national “One Belt, One Road” initiative, geological environment and disaster research in neighboring regions of Asia, Europe and Africa have gradually attracted attention. Therefore, this paper further expanded the research area to the neighboring regions of Asia, Europe and Africa to study the opening and closing structures at different times. and spatial scale performance, and explore the application methods of structural geology, seismology and modern seismic geodesy in the study of open and closed structures.

2 GEOTECTONIC DIVISIONS IN THE ASIA-EUROPE-AFRICA NEIGHBORHOOD

The geotectonic evolution of Asia, Europe, and Africa is characterized by multiple levels and cycles in time, and can be divided into three first-level cycles or three major stages (i.e., continental basement formation stage, Pangea-supercontinent formation and development stages, modern plate formation and intracontinental evolution stages), each large cycle stage can be divided into secondary or smaller cycle stages. Among them, the formation of the continental basement is crucial. Orogenic belts in different formation periods are finally formed on the continental basement after complex cracking and aggregation.

The geotectonic zoning suggestions put forward by Professor Yang Weiran during the study of geotectonic zoning in the Asia-Europe-Africa neighborhood. This view emphasizes that there are essential differences between oceans and continents, which are not only reflected in the differences in material composition and structural structure, but are also reflected in the depths. Through discussions with Professor Yang Weiran, the author adopted this suggestion in this study and divided the research area into two categories: oceanic area and continental area. At the same time, according to the theory of opening and closing tectonic structures, the author believes that the oceanic area is mainly open, and the continental area is mainly closed, and opening and closing can be converted into each other. The opening and closing tectonic transition zone is of great significance in both theory and practice.

Referring to the zoning standards of the geotectonic map of central Asia [12], this study still divides the tectonic division units of the Eurasian and African continental regions into three levels: structural clusters, continental blocks, tectonic union areas, massifs, subduction zones and orogenic belts. Six major categories. Among them, structural clusters are first-level structural units, which refer to a collection of continental blocks that are connected in the generation background, blocks of different sizes, and orogenic belts with different formation periods. Geological bodies within the same structural cluster are basically similar in terms of continental basement and geological structural evolution; their geological structures, stratigraphic paleontology, magma and metamorphism and other characteristics are basically the same; their motion directions and motion programs are also basically consistent; the geological bodies are unified. dynamics background. In addition, the differences between some structural clusters are vague or controversial, and it is difficult to separate them with a structural boundary. This article divides them into structural combination zones based on subduction zones or collision zones to avoid the fate of the geological bodies within them. Structural basement obviously plays a controlling role in the evolution of orogenic belts, causing adjacent orogenic belts to often transform accordingly. Among them, the part with a larger area, the development of caprock or overlapping basins, and the supply of terrigenous debris to the outside is called a continental block, and the basement that is transferred to the orogenic belt is called a block. Within continental blocks, they are divided into three categories: continental rise, continental flat and continental depression according to their adjacency to orogenic belts.

After the study area was expanded to the adjacent areas of Asia, Europe and Africa, we added two first-level tectonic units, the Russian tectonic cluster and the African tectonic cluster, based on the geotectonic map of central Asia, and classified the original East Asian tectonic cluster into the oceanic region, and finally in The continental area forms an Asia-Europe non-main structural pattern composed of five structural clusters. The five tectonic clusters are the North Asian tectonic cluster that opens and closes around the Siberian continental block, the Central Asian tectonic cluster that opens and closes around the ancient Chinese continental block, the South Asian tectonic cluster that opens and closes around the Indian continental block, and the Baltic continental block that opens and closes. The Russian tectonic cluster and the African tectonic cluster that opens and closes around the African landmass.

The Russian structural cluster has Archean and Paleoproterozoic metamorphic basement. There are basement exposures on the surface in some continental rise areas around the Baltic Sea, but the basement in most areas is covered by caprock. Deep seismic detection and gravity data show that the land masses within the Russian tectonic cluster are typical continental crust, including three major shell layers: sedimentary rock, granitic metamorphic rock and basaltic rock (granulite-basic rock). The original sedimentary rocks, volcanic rocks and intrusive rocks that make up the basement are everywhere subject to regional metamorphism of granulite, amphibolite and greenschist levels, making it difficult to restore their original rock composition and structure. The caprock is composed of nearly horizontal or gently dipping Neoproterozoic, Paleozoic, Mesozoic and Cenozoic strata. The thickness generally ranges from a few hundred meters to 10km, and even exceeds 20km in some places [13]. Before the formation of the caprock, the continental rise area was mainly uplifted and subject to erosion and cutting. During the formation of the caprock (up to 1500 Ma), the lithosphere mainly moved vertically [14]. The uplifts and depressions within the Russian structural cluster show meridional zoning, manifesting as a longitudinal uplift system, connecting the eastern Baltic continental block - the Latvian anticline - the Belarusian anticline to the western Ukrainian platform.

The oldest basement continental blocks of the African tectonic cluster existed in the early Paleoproterozoic. During the Proterozoic Pan-African Orogeny, foreign lithospheric fragments gradually spliced with these basement continental blocks, covering a very wide range [15-16]. West Africa, the Congo, and the Kalahari Craton were "welded" under thermodynamic metamorphism and granitization, forming the prototype of the relatively stable Gondwana ancient continent. The Ordovician-Triassic African tectonic cluster was dominated by horizontal movements, and each continental block drifted one after another. Gondwana experienced a movement of converging in the south and dispersing in the north. The landmass in southern Africa, as the core of Gondwana, experienced an overall drift movement, while the northern region was in the craton marginal environment on the periphery of Gondwana. From the Devonian to the Early Carboniferous, each land mass was in the convergence stage, and the cluster as a whole continued to move horizontally. Carboniferous Period - The northern Permian collided with Laurasia to form Pangea. The Carboniferous Period began in the southeast. It was in an extensional environment under the continuous influence of the Karoo mantle plume, forming the Karoo period intracontinental rift deposits. Other areas are located within the continent. craton environment. From the Late Triassic to the Paleogene, the cluster entered the breakup period. From the Late Triassic to the Early Jurassic, Gondwana and Laurasia split apart, northwest Africa split from North America, the North Atlantic formed, and the passive continent began to form in Morocco, Africa. margin basin. The evolution process of the North Asian tectonic cluster, Central Asian tectonic cluster, and South Asian tectonic cluster has been introduced in detail in the literature [12].

3 CHARACTERISTICS OF OPENING AND CLOSING MOVEMENTS AND SEISMIC ACTIVITY IN THE MEDITERRANEAN-HIMALAYAN REGION

The Cenozoic opening and closing tectonic transition zone is the area with the most intense opening and closing movements today. Its most eye-catching, direct and important symbol is the distribution of earthquakes and volcanoes. The United States Geological Survey provides 5 data from the Mediterranean Sea to the Himalayas since 1970. Distribution of earthquakes above magnitude, most earthquakes in the range occur in the Mediterranean-Turkey-Iran-Afghanistan orogenic belt between Africa and Russian tectonic clusters, while there are very few earthquakes in the African and Russian continents on both sides.

This earthquake-prone zone is often called the Mediterranean-Himalayan seismic zone or the Eurasian seismic zone, which extends eastward to the Himalayan arc and the Sunda arc. Structurally, it consists of the Himalayan, Yanshanian and Indosinian orogenic belts. It is a relatively broad tectonic transition zone between the African tectonic cluster and the Russian tectonic cluster, with numerous micro-plates and small ocean basins interspersed in it. Each microplate has complex and changeable movement directions. For example, the Panno microplate mainly moves eastward, the Adriatic microplate mainly moves northwest, the Tyrrhenian microplate mainly moves southeast, and the Iberian microplate mainly moves northward. Lord. This causes the directions of the main structural lines around each micro-plate to become chaotic, making it difficult to distinguish the two major plates with a simple boundary [17]. Generally speaking, the orogenic belts located on the north and south sides mainly move backwards (opening) in the direction of movement, while the orogenic belts located in the middle mainly move from both sides to the middle (closing), that is, they show typical opening and closing movements. Circulation in time and complementary characteristics in space.

Geometrically speaking, the movement of geological bodies can be decomposed into horizontal and vertical components. The idea of opening and closing tectonics believes that the vertical motion component is related to the rise and fall of the deep mantle, while the horizontal motion is related to the convergence and separation of rigid lithospheric plates and the non-uniform rheology of the mantle. In terms of seismic activity, generally speaking, vertical motion mainly breeds thrust or extensional earthquakes, while horizontal motion mainly breeds strike-slip earthquakes [18]. But this understanding must not be applied mechanically, because the two movements are just two forms of opening and closing movements, not essential characteristics, and the two can be transformed into each other. The opening and closing structure unifies the vertical movement and horizontal movement of the earth, the deep structure and the shallow structure of the earth into an organic whole, that is, the "opening" (expansion) of vertical movement, which also appears as "opening" (geological body) horizontally. Backward movement); the "close" (shrinkage) of vertical movement is also "close" horizontally (geological bodies move toward each other); at the same time, the strong vertical movement "open" (centrifugal movement) is also a strong "close" horizontally. "Open" (separate); vice versa [10]. Therefore, when studying the opening and closing rhythm of present-day tectonic movements through focal mechanism solutions, attention should be paid to taking the regional geotectonic style into consideration.

According to the focal mechanism solution of the Mediterranean region given by Harvard University's CMT, there were 299 earthquakes of magnitude 5 or above in the area, including 81 thrust earthquakes (accounting for 27.1%), which were mainly concentrated at the edge of the tectonic transition zone between tectonic clusters, reflecting It reflects the convergence of the African tectonic cluster to the Russian tectonic cluster; there were 138 strike-slip earthquakes

(46.2%), mainly concentrated in the tectonic transition zone, such as the Aegean Sea and around Turkey, reflecting the uncoordinated convergence speed of the east and west sides of the African tectonic cluster. ; There were 80 normal fault -type earthquakes (accounting for 26.7%), distributed between thrust-type and strike-slip earthquakes, reflecting the local extension formed in the back arc during the deep subduction of the African continental block. Dynamically, this area is restricted by the activities of the African continental block and the Eastern European platform to the north and south, and the Indian continental block and the Central Asian continental block to the east. It is the result of the joint action of multiple plates. The above characteristics reflect that the modern tectonic activity in the area is in an evolutionary stage dominated by coalescence, during which material exchange, tectonic movement, and magmatic activity are very intense. There are many peaks in the area, rich mineral resources, and geological disasters such as earthquakes, volcanoes, mudslides, and landslides. Frequent. Zhao Xiaoyan et al. [19] used Harvard University's CMT data to count the types of focal mechanism solutions of magnitude 5 and above in the Eurasian seismic belt since 1970. The results showed that the earthquake types conform to the basic characteristics of plate edge earthquakes between tectonic clusters, and are generally characterized by thrust faults. Types of earthquakes and strike-slip types are dominant, among which reverse fault earthquakes account for 42.7%, followed by strike-slip earthquakes (37.6%), and normal fault earthquakes are relatively rare (19.7%); in the Iran-Afghanistan region, earthquakes The proportion of thrust focal mechanism solutions on both sides of the Gross Fault Zone is as high as 55.8%. There are a certain number of strike-slip earthquakes distributed in the Iranian Plateau, but there are very few normal fault earthquakes. The birth of earthquakes among tectonic clusters is related to the large-scale uplift of the mantle. The earthquake source is inserted obliquely from the middle and upper crust into the upper mantle in a belt shape. The earthquake source profile can clearly depict this feature. Figure 1 is a NE-trending section through the orogenic belt obtained using focal depth data provided by the United States Geological Survey. This figure clearly shows the contact relationship between the African tectonic cluster and the Russian tectonic cluster: the crust is interpolated northward from the trench at a high angle., the earthquake spreads downward along the subducting slab, reaching a maximum depth of 120km. The dynamic mechanism that causes the large-scale and continuous collision and subduction of the two tectonic clusters is generally believed to be related to the mantle plume activity deep in the African plate [15]. These densely populated moderately strong earthquakes have become a macroscopic portrayal of the regional tectonic background in which the African tectonic cluster and the Russian tectonic cluster are now dominated by "fusion". In fact, the collision between the two tectonic clusters is far from simple. There are a large number of continental blocks, blocks and micro-blocks involved in the orogenic system in the tectonic transition zone, resulting in many small differences in seismic activity characteristics in local areas.

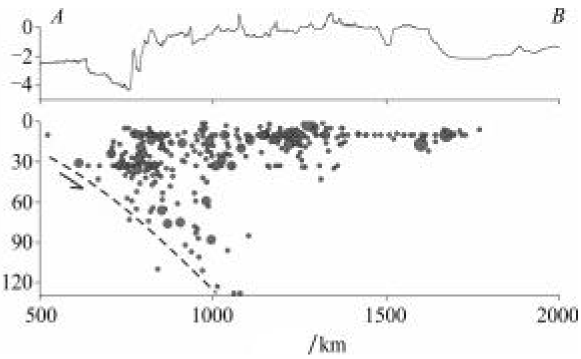

Figure 1 Focal depth profile across the Eurasian seismic zone

Chiarabba et al.[20] studied the seismic profile characteristics of the Apennine and Ionian subduction zones by relocating earthquakes in the central Mediterranean region from 2005 to 2012. The results showed that there was an obvious vertical downward intrusion of seismic activity in the northern Apennine Peninsula to the south. The arc-shaped structure extends from the northern part of the Ferrara Arc to at least the central Apennine Peninsula; while the Ionian subduction zone in the south has an obvious vertical arc-shaped structure that intrudes northward, with a maximum intrusion depth of 300km, which is shallow. Source earthquakes are basically completely restricted to the back-arc Calabria region, while medium-deep source earthquakes all occur within the Ionian plate on the south-east side. Modern geodetic survey results also show that the current movement of the African plate is significant. Taking the Eurasian plate as a reference, the average rate of convergence in the northwest direction is 5mm/a, with differences between the north and the south. This uneven feature reflects the complexity of the movement of each microblock within this tectonic transition zone.

4 MODERN OPENING AND CLOSING MOVEMENTS AND GEODETIC RESEARCH ON THE EASTERN DABIE OROGENIC BELT

Because the opening and closing movement is circular in time, complementary in space, and hierarchical in scale. Therefore, for a certain area, one period is dominated by opening, and in another period, it may switch to being dominated by closing; the main area is dominated by opening, while the surrounding area is dominated by closing. Openings of different sizes and closings of different sizes alternate with each other, ultimately forming a series of progressive opening and closing motion cycles. The Qinling-Dabie orogenic belt, as the collision orogenic belt between the Sino-Korean continental block and the Yangtze continental block and the transition zone between the Paleo-Asian Ocean tectonic domain and the Tethys tectonic domain, occupies a very important position in the tectonic evolution of the Chinese continent.

Although there are still many disputes in the academic community about the uplift mechanism and deformation process of the Dabie orogenic belt, the understanding of the major tectonic stages it has gone through is basically consistent [21-22]. It is generally believed that the Dabie orogenic belt has experienced four tectonic stages from the Sinian to the Cretaceous. Among them, the Sinian is a stage of large "opening" and large "closing", characterized by the interaction between continents and oceans; the Paleozoic is a stage of small "opening" and small "closing", characterized by lateral compression and strong deformation, which may be Related to deep mantle convection; the Late Triassic to Early Cretaceous was the bedding "opening" and "closing" stages, characterized by lateral extension, thermal uplift, slipping, low-angle overthrust, and thrust faulting; Late Cretaceous Since ancient times, it has been the "opening" and "closing" stages of shear layers, characterized by the development of high-angle normal faults and local compression tectonic thermal events, which may be related to mantle diapirism and delamination [11]. It was after the above multiple opening and closing cycles that the Qinling-Dabie ancient ocean located between the Sino-Korean continental block and the Yangtze continental block gradually closed, and the oceanic crust gradually transformed into continental crust, eventually forming the towering Dabie Mountains. It has left its imprint in geology, petrology and geochemistry. Seismic, electromagnetic and other geophysical detections have given the geometric shape of the present-day Dabie orogen, and geological studies have also initially given its kinematic characteristics, that is, the Dabie orogen is generally in a "V" shape and is divided into the Yangtze Massif and North China. The block is lifted in the middle, and a large number of shovel-type faults are developed on the north and south sides that are inclined toward the center of the orogenic belt, and the dip angle gradually decreases toward the depth [23].

Earthquakes of similar magnitude have roughly the same recurrence period. For example, earthquakes with magnitude 6 to 7 generally last for hundreds of years, earthquakes with magnitude 5 last as short as decades, and earthquakes with magnitude 8 or above are only on the order of thousands of years at their longest [24-27]. Therefore, for earthquake research, the tectonic evolution before the Cenozoic and even before the Quaternary can only be treated as a tectonic background. Scholars in the field of earthquake monitoring and prediction pay more attention to the rules of tectonic activity on a smaller time scale. However, traditional geology is currently unable to provide practical basis and conclusions. Modern geodesy or crustal deformation observation makes up for this regret and is widely used in the field of earthquake monitoring and prediction in my country.

Currently, commonly used crustal deformation observation methods include water pipe inclination measurement, vertical pendulum inclination measurement, cave strain measurement, borehole inclination measurement, borehole strain measurement, etc. The instruments are generally deployed in caves or boreholes and have good anti-interference capabilities. Crustal tilt measurement is mainly used to continuously measure the relative motion or dynamic deformation angle of the ground. Crustal strain measurement is mainly used to continuously measure parameters such as the deformation state and solid tide of the shallow crust. There are currently 4 continuous fixed-point deformation observation stations around the East Dabie Orogen, with a sampling period of 1 min. In addition, a GNSS measurement network and a mobile gravity measurement network are also deployed in the surrounding area, and field observations are conducted twice a year. Among them, Huangshi Observatory was not used in this article due to distortion of observation data due to interference from nearby engineering construction.

After the phenomenon occurred, the China Earthquake Administration's Seismological Research Institute sent experts many times to investigate and verify factors such as instruments, surrounding environment, and human factors. No significant non-tectonic interference was found. At the same time, the author analyzed the solid tidal characteristics of the observation data from each of the above stations and found no interference, and the tidal characteristics of each instrument remained basically unchanged. Through a comprehensive inspection of the instruments, it is believed that since 2012, all deformation observation instruments have been operating normally, the calibration and zeroing operations are timely, and they meet the crustal deformation observation standards of the China Earthquake Administration, and the data trend changes are true and reliable. In addition, the simultaneous occurrence of the above changes in instruments that are far apart in space (nearly 100km) also mutually confirms that there is no fault in the instruments, there is no interference from the surrounding observation environment, the data is authentic and reliable, and the quasi-synchronous changes in data trends are a true reflection of crustal deformation.

According to the principle of the crustal deformation observation instrument, it can be known that the decrease in the north-south component data in the crustal tilt observation means that the crust is tilting south, and vice versa, it is tilting north; the decrease in the north-south component data in the crustal strain observation means that the crust is changing. Compressive changes, and vice versa. The monitoring results show that from March to June 2016, the north-south component of the vertical pendulum of the Wuhan Shizishan Platform, the north-south component of the water pipe of the Wuhan Shizishan Platform, the north-south component of the Huangmei vertical pendulum, and the north-south component of the Macheng Cave body strain appeared to be approximately synchronous. The trend turns; the crust on the southern side of the Dabie orogenic belt where the Shizishan Platform and Huangmei Platform are located tilts southward, while the crust within the Dabie orogenic belt where the Macheng Platform is located experiences pressure changes. The rate of change and cumulative amplitude of each station after 2016 are very significant. The southward tilt of the vertical pendulum inclinometer of Shizishan Station even exceeds the overall trend of the previous four years. Before 2016, the crustal deformation trends at each station either remained stable or showed the opposite trend to today. Compared with fixed-point deformation observation, GNSS observation can obtain crustal deformation information in a wider range and longer baseline, and is widely used in the field of current crustal movement and dynamics research. Based on the observation data of GNSS continuous stations, regional stations and CORS stations of the Chinese mainland tectonic environment monitoring network around the Dabie orogenic belt, the author used GAMIT10.6 to calculate the crustal motion velocity field, and used the GPS velocity field to calculate the crustal strain rate tensor. Method [28] obtained the regional principal strain rate distribution. The length of the arrow of the strain vector represents the magnitude of the strain rate, and the direction of the arrow indicates the two orthogonal directions of the maximum and minimum principal strains. Opposite arrows indicate that the crust is compressive, and opposite arrows indicate that the crust is tensile. The results show that before 2015, the pressure characteristics of the East Dabie area east of the Macheng-Tuanfeng fault were significant, and the area from Huangmei to Wuhan on the southern edge of the Dabie orogenic belt was generally NWW-directed compression, especially The magnitude of compression in the Huangmei area is much higher than that in other surrounding areas, and the NNE direction is generally tensile with low values. After 2015, the NWW compressive characteristics of the East Dabie area decreased sharply, and the NNE tensile direction remained at a low level. This short-term compression-tension transition is a manifestation of the temporal cyclicity of the opening and closing structure. Interestingly, in addition to the significant changes in the East Dabie area, there is a huge change from tension to compression in the Hong'an-Macheng area in the western section of the Dabie orogenic belt, which is far greater in magnitude than the changes in the East Dabie area., consistent with the change time of the strain trend of the Machengtai Cave mentioned above. The changing boundary between compressive and tensile properties happens to be the Macheng-Tuanfeng fault that separates the East-West Dabie region. This reflects the spatial complementarity of opening and closing structures and reflects the deep structural and evolutionary differences in the East-West Dabie region. Changes in the gravity field can reflect the material migration situation in the region. Positive gravity changes reflect material accumulation, and negative gravity changes reflect the diffusion of matter. The junction of the two is the area where material exchange is most intense [29-31]. In order to continuously observe regional gravity changes, the Hubei Provincial Seismological Bureau has deployed 24-hour uninterrupted gravity observation instruments at Huangmei, Macheng, Jiufeng and other seismic observation stations, which is referred to as continuous gravity observation. Continuous gravity observation data has high precision and rich historical data, which has played a huge role in previous research. However, continuous gravity stations are relatively sparse and cannot provide data with a high spatial distribution rate. After more than 40 years of continuous adjustment and optimization, the China Earthquake Administration has established a field gravity monitoring network with mobile instruments and regular remeasurements (twice a year) across the country, called mobile gravity observation. After a series of steps such as absolute gravity calculation, relative gravity calculation and data adjustment [32], the difference in observation results of each period is used to reveal the gravity change characteristics of the same area in a specific time period. Since 2016, there has been a transformation from positive anomalies to negative anomalies in the East Dabie area, that is, there has been a process of gradual diffusion of material in the area after 2016, reflecting the expansion characteristics of the East Dabie orogenic belt, that is, the opening movement.

Based on the above various types of crustal deformation observation results and the geotectonic characteristics of the area, it is not difficult to infer that around March 2016, there were opening and closing movements with smaller time scales and weaker magnitudes around the Dabie orogen. Before 2016, "Close" is the main one, and after March 2016, "open" is the main one. Tectonic activities dominated by the Xiaohe before 2016 caused the Yangtze continental block on the southern side of the Dabie orogenic belt to steadily subduct and push northward. Therefore, the Shizishan and Huangmei platform tiltmeters on the edge of the Yangtze continental block and the southern Dabie orogenic belt N-tilt occurs. At the same time, due to the "V"-shaped backthrust structural characteristics of East Dabie, the movement direction of the massif within the orogenic belt has changed from horizontal compression to vertical expansion, and the principal stress field has also changed from deep compression-based characteristics. Transformed into tension-based changes on the surface. Under this tectonic environment, the strain of the Machengtai cave located inside the orogenic belt was dominated by tension before 2016. After March 2016, after the tectonic environment of the East Dabie area was transformed into a small "open", the compressive stress in the contact zone between the Yangtze continental block and the Dabie block was relieved, and the deformed crust also rebounded, causing The tilt direction of stations such as Huangmei and Shizishan changed in reverse direction (i.e. southward tilt), and the ground strain in the shallow layers inside the orogenic belt also changed from tensile to compressive.

Small earthquake activity in the surrounding area also proves this speculation. Before 2016, multiple earthquakes of magnitude 4 or above occurred continuously around the Dabie orogenic belt. For example, there were the 2005 Jiujiang magnitude 5.7 earthquake, the 2011 Ruichang magnitude 4.6 earthquake, and the 2014 Huoshan magnitude 4.3 earthquake. After 2016, the surrounding small earthquake activity gradually subsided, and no earthquake above magnitude 4 has occurred yet. Research on the focal mechanisms of the above three earthquakes also shows that the Jiujiang and Ruichang earthquakes on the south side of the Dabie orogenic belt were compression-torsion [33], while the Huoshan earthquake in the interior of the Dabie orogen was tension-torsion [34]. All are the result of stress field adjustment in the surrounding area. Xu Jiren et al. [35] believed that under the background of weak seismic activity level, the occurrence of multiple moderate-intensity earthquakes indicates that the Sulu-Dabie belt and its surrounding areas may enter the active period of modern tectonic movement. The author believes that the regional geotectonic movement changed from "close" to "open" after 2016, which undoubtedly played a role in stress unloading on the surrounding crust, easing the accumulation of seismic strain energy, and leading to a temporary lull in surrounding small earthquake activity.

However, the opening and closing movement is cyclical in time, and the current "small opening" can only suspend the seismic activity around Dabie, but cannot reverse the geotectonic background of strong collision and docking in the area [36]. Moreover, due to the short cumulative observation time of modern geodetic methods, it is not possible to speculate how long this "small opening" stage can last. Therefore, we should continue to adhere to the continuous observation of crustal deformation and continuously expand observation methods to discover the opening and closing rhythm of regional structures and lay the foundation for the long-term development of earthquake monitoring and prediction.

5 CONCLUSION

This paper takes the Asia-Europe-Africa neighborhood, the Mediterranean region and the Eastern Dabie region as examples to study the geological manifestations of opening and closing structures at different spatial and temporal scales. First, the geotectonic divisions of Asia, Europe, and Africa were divided using the perspective of opening and closing tectonic structures. Second, the overall relationship between seismic activity and tectonic divisions in the Mediterranean region was studied. Then, the Dabie orogenic belt was used as an example to explore the application of modern crustal deformation observations in medium-sized development. Application in composite structural research. The article mainly gained the following insights:

(1) The main structural pattern of the Asia-Europe-Africa neighborhood is divided into two categories: continental and oceanic. The continental area is divided into five structural clusters, namely the North Asian structural cluster that opens and closes around the Siberian continental block, and the North Asian structural cluster that opens and closes around the ancient Chinese continental block. The Central Asian tectonic cluster, the South Asian tectonic cluster that opens and closes around the Indian landmass, the Russian tectonic cluster that opens and closes around the Baltic landmass, and the African tectonic cluster that opens and closes around the African landmass.

(2) The transition zone between structural clusters is the most tectonically active zone and is also an earthquake-prone zone. The vast majority of earthquakes above magnitude 6 in the Asia-Europe-Africa region occur in the Mediterranean -Turkey-Iran-Afghanistan orogenic belt between the African and Russian tectonic clusters. The seismic activity profiles and focal mechanism solutions in the Mediterranean region intuitively reflect the overall "joint" movement characteristics of the tectonic transition zone since the Cenozoic.

(3) Modern crustal deformation measurement results can reflect regional opening and closing movements with short time scales and small magnitudes. After March 2016, crustal deformation observations such as the tilt of Wuhan Shizishan Platform and Huangmei Platform, Macheng Cave body strain, GNSS, flowing gravity, and surrounding seismic activities share a common geotectonic mechanism, that is, around March 2016, East Dabie The tectonic movement in the region has changed from "coupling" to "opening".

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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