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Original Paper

Tectonics of the West and Central African strike-slip rift system

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ABSTRACT

It is essential to intensify research on the strike-slip tectonic system in West and Central Africa to better understand regional tectonic evolution and achieve future breakthroughs in oil and gas exploration. Based on the structural interpretation of extensive seismic data and stratigraphic paleontological analysis of more than 50 wells, this study investigated the tectonic history, sedimentary filling, and evolution of the rift basins in the West and Central Africa, and identified a novel type of intraplate strike-slip tectonic system. It exhibits the following characteristics: (i) the strike-slip tectonic system in the West and Central Africa consists of the Central African Shear Zone (CASZ) and two rift branches, manifesting as an N-shape; (ii) most of basins and rifts are characterized by rapid subsidence at one end and substantial sedimentary thickness; (iii) two types of strike-slip basins are developed, namely the transform-normal extensional basin (TEB) along CASZ and the strike-slip-induced extensional basin (SEB) at each end of CASZ; (iv) two types of basins display their own temporal and spatial evolution history. TEBs underwent two rifting stages during the Early and Late Cretaceous, with a strong inversion at the end of the Late Cretaceous. SEBs experienced three rifting stages, i.e., the Early Cretaceous, Late Cretaceous, and Paleogene, with a weak inversion; and (v) this strike-slip tectonic system was formed under intraplate divergent field, indicating a new type of system. This discovery enhances understanding of the breakup of Gondwana and provides valuable guidance for future oil and gas exploration.

1. Introduction

Strike-slip deformation occurs in various geological environments, and large-scale strike-slip zones are often associated with plate or microplate movements or intraplate deformation (Allen and Allen, 2013). Sylvester (1988) made the distinction between intraplate and interplate strike-slip faults and established a classification system. Mann (2007) described five types of strike-slip fault systems globally: oceanic transforms separating mid-oceanic spreading ridges, continental boundary strike-slip faults, indent-linked strike-slip faults, trench-linked strike-slip faults, and cratonic strike-slip faults. Oceanic transforms separate oceanic crust and offset mid-oceanic spreading ridges. Other types of strike-slip fault systems form under stress field of disequilibrium compression or convergence (Woodcock, 1997; Sylvester, 1988; Mann, 2007). Basins associated with strike-slip deformation are generally small and complex (Allen and Allen, 2013). However, CASZ in Central Africa formed a strike-slip tectonic system during the breakup of Gondwana, including an associated series of large-scale sedimentary basins. On the other hand, although many scholars have currently characterized the features of a single strike-slip-related basin under the intraplate-divergence background based on geophysical data and numerical and physical simulation (Corti et al., 2007; Corti and Dooley, 2015; Dooley and Scheurs, 2012), the research on the planar distribution and the phased evolutionary features of basin groups remains relatively insufficient.

Since 1995, China National Petroleum Corporation (CNPC) has acquired several large-scale risky exploration blocks in Sudan, South Sudan, Chad, and Niger, covering a series of large and medium-sized rift basins. Extensive two- and three-dimensional seismic acquisition has been carried out, hundreds of exploration and appraisal wells have been drilled, and a great deal of stratigraphic and paleontological analysis and correlation has been performed. A number of large and medium-sized oil fields have

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been discovered, establishing an important crude oil production base in the interior of Africa (Tong et al., 2004; Dou et al., 2006; 2021; Dou and Wen, 2021; Wang et al., 2021).

The aim of this paper is to describe and characterize a strike-slip tectonic system created by intraplate divergence based on the tectonic and sedimentary characteristics of the strike-slip rift system and basins in West and Central Africa. This will provide valuable reference for better understanding the breakup of Gondwana and the subduction of the Neo-Tethys since the Early Cretaceous, as well as for guiding oil and gas exploration in this area.

2. Regional geology

The African Plate is an assemblage of multiple ancient cratons, such as the West Africa, Sahara, and Congo Cratons, during the Pan-African orogenic period. Relatively unstable tectonic zones exist between the cratons (Guiraud and Maurin, 1992; Schettino and Scotese, 2005; Moulin et al., 2010), such as the Brasiliano orogenic belt between the West African and the Congo Cratons, the Central African orogenic belt, the linear suture zone, and the active fault zone between the Congo and the Sahara Cratons (Meert, 2003; Fritz et al., 2013; Oriolo et al., 2017; Zhang et al., 2023). Based on their analysis of regional gravity data, Browne and Fairhead (1983) discovered the “nearly NNE-trending, narrow, fault-controlled” Ngaoudee (Foumban) Rift Valley in Central Africa, comprising the current Bongor, Doba, Doseo, and Salamat basins, as well as the Muglad, Melut, and Anza basins that constitute the Central African Rift System. Fairhead (1986) further identified the West and Central African Rift System (WCARS) and the dextral CASZ based on analysis of regional gravity and seismic data (Fig. 1). The dextral shear zone extends from Cameroon in the west eastward to the Khartoum Basin in the western Sudan, spanning over 2000 km (Guiraud and Maurin, 1992). This shear zone and the Pernambuco shear zone in northern Brazil were both parts of a megafracture zone that developed before the Cretaceous (Fairhead, 1986, 2023; Matos et al., 2021). The Anza Basin in Kenya is considered beyond the scope of this study, because it is far away from the CASZ and is underlain by the Triassic-Jurassic deposits of the Karoo rift, and its formation is more likely to be related to the separation of the Indian and Madagascar Plates (Liu et al., 2011).

The large-scale strike-slip tectonic system in West and Central Africa shows obvious segmentation and periodicity involving different evolution stage. The Benue, Bongor, Doba, Doseo, Salamat, Baggara, and other basins are developed along the CASZ, and multiple large rift basins at each end, such as the Muglad Basin on the south side of the East segment and the Melut, White Nile, Blue Nile, and other basins (Southeast Branch), as well as the Termit, Tenere, and Grein Basins on the north side of the West segment (Northwest Branch) (Fig. 1). Although the formation and evolution of this rift system are closely related to CASZ, it is in a relatively unified evolutionary environment and has experienced three stages of rifting. However, significant spatio-temporal discrepancies in structural style and sedimentary strata are evident within the same period in different basins and within the same basin during different periods (Fig. 2).

3. Characteristics of strike-slip rift basins

In terms of dynamics, the rift basins in West and Central Africa are classified as passive rift (Binks and Fairhead, 1992; Genik, 1992; Tong et al., 2004). Based on the position of each basin relative to the CASZ, the Doseo and Salamat Basins are further classified as transtensional basins, with the Termit, Bongor, and Doba Basins also being classified as extensional basins (Genik, 1993). As the CASZ is the main controlling factor for the rift system in West and Central Africa, all the basins in the rift basin group in West and Central Africa are classified as strike slip-pull-apart basins (Dou et al., 2021).

The formation and evolution of the strike-slip fault system in West and Central Africa is characterized by regionality, complexity and periodicity. Mainly based on the dynamic environment during the Early Cretaceous, the rift basins are divided into two types in

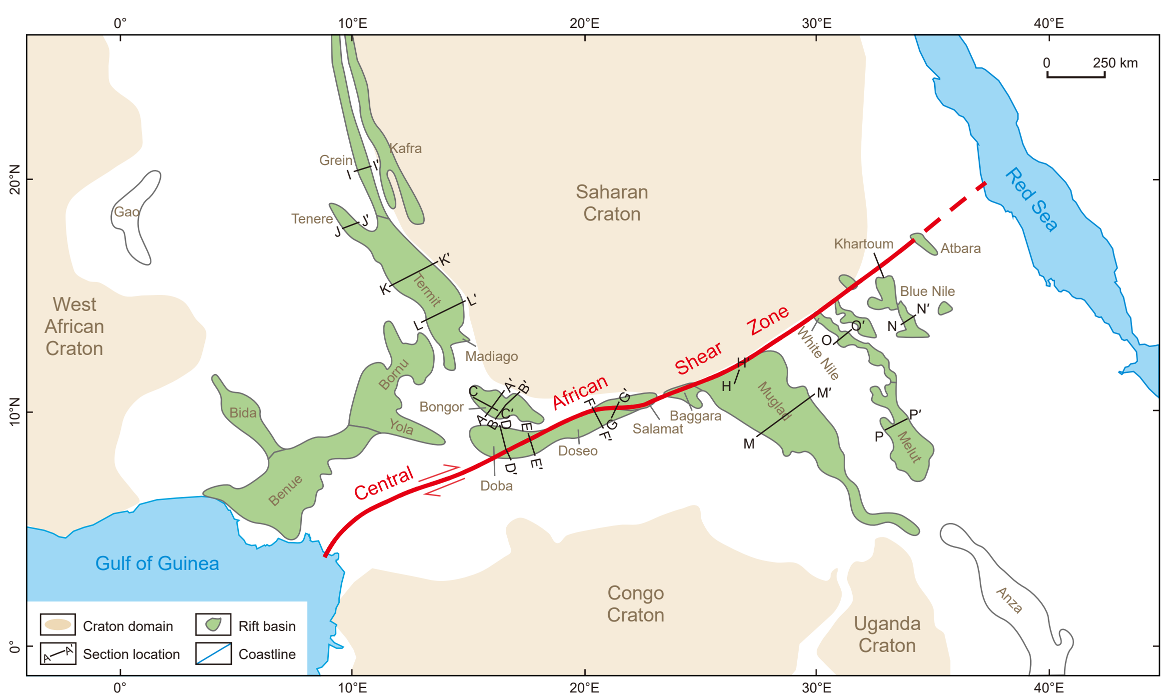


Fig. 1. Sketch of the Western and Central African rift system and crystalline basement (Modified from Genik (1993) and Dou et al. (2024).

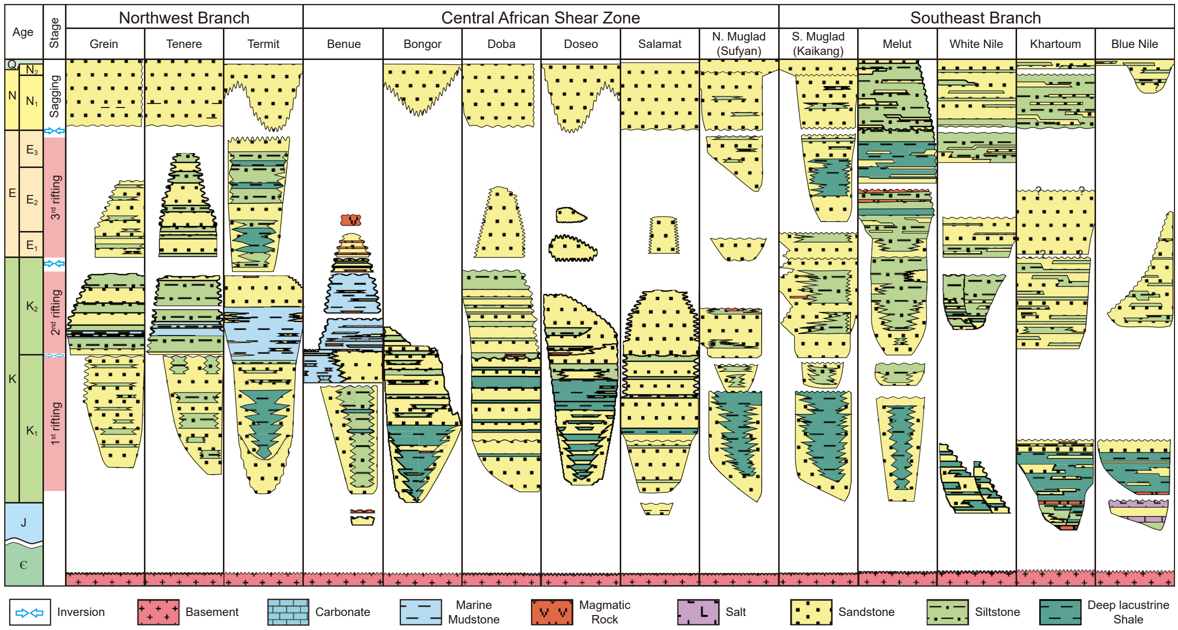


Fig. 2. Generalized stratigraphic columns of the major basins in the West and Central African rift system. Regionally there are three syn-rifting stages (Early Cretaceous, Late Cretaceous and Paleogene) and corresponding sequences in the Northwest and Southeast Branches and two syn-rifting stages (Early and Late Cretaceous) and corresponding sequences in the Central African Shear Zone.

this paper: transform-normal extensional basins (TEB) distributed along the CASZ and the strike-slip-induced extensional basins (SEB) distributed at each end of the CASZ (Fig. 3).

3.1. Transform-normal extensional basins (TEB)

Studies of transform faults have shown the existence of large asymmetric basins that are bounded by transform faults on one side and by predominantly normal faults on the other (Ben-Avraham and Zoback, 1992). The CASZ shows a segmented linear distribution, and the different structural positions within it control the distribution of the several basins. TEBs develop along the CASZ and adjust the strike-slip displacement of the shear zone in two ways. One is manifested as transform faults at basin boundaries, and the other as transverse transfer faults perpendicular to the boundary faults within the basin. TEBs develop in an orderly manner on the plane and can be divided into West and East segments. The West segment includes the Doba, Bongor and Benue

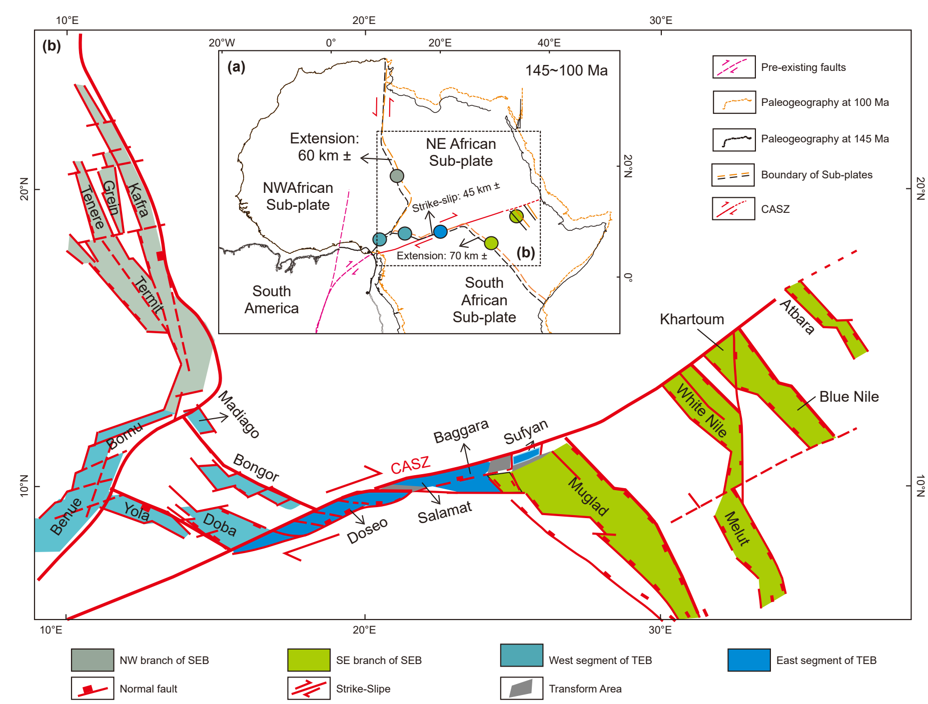


Fig. 3. Sketch of the West and Central African strike-slip rift system and basin types during the Early Cretaceous. TEB: transform-normal extensional basin. SEB: Strike-slip-induced-extensional basins. CASZ: Central African Shear Zone.

Basins, where the NW-trending boundary faults extended, and NE-trending transfer faults within the basins accommodated the strike-slip displacement. The East segment includes the Doseo, Salamat, Baggara Basins and Sufyan sub-basin of Muglad Basin, where the NEE-trending boundary faults extended and accommodated the strike-slip displacement. TEBs have developed only two sets of rifting sequences of the Lower Cretaceous and Upper Cretaceous. The degree of inversion in the basin decreases from west to east at the end of Late Cretaceous.

3.1.1. West segment

The Benue Trough in the West segment has received limited exploration, where 5 exploration wells were drilled and only one sub-commercial gas field was discovered in the Upper Cretaceous (Genik, 1992, 1993; Dou et al., 2022b; Obaje et al., 2004). It is commonly regarded as a failed arm of the triple junction that extended into the interior of the African continent during the Late Jurassic-Early Cretaceous separation of the Brazilian and African plates, thereby forming an aulacogen (Dim, 2021). The structure of the Benue Trough is complex, the N120° E-trending normal faults control the grabens, and but always linked to major sinistral N60° E strike-slip faults (Abubakar, 2014). Three phases of magmatic activity occurred in the basin (147–106, 97–81, and 68–49 Ma), becoming younger from north to south (Maluski et al., 1995). The second phase of magmatic activity is of a similar age to the igneous rocks encountered in the West Doba area in Chad, and the third phase is similar in age to those in the Bongor Basin (Lu et al., 2009a, 2009b; Dou et al., 2024).

The Bongor Basin is oriented NWW-SEE and forms a 30° angle with CASZ. There are two sets of basement faults in the basin: NE-trending strike-slip faults and NWW-trending extensional faults. The tectonic framework of the basin exhibits south-north zonation and east-west block division (Figs. 4 and 5). During the Early Cretaceous, the NWW-trending basin-controlled fault experienced a significant extension of 40 km. This was induced by the dextral strike-slip movement along the CASZ. This led to the deposition of 8000 m of Lower Cretaceous strata. The dip angles between the boundary basin-controlled faults and the depression-controlled faults range from 30° to 50°, with a concentration at 45°. The tectonic patterns of different sub-basins transitioned from “faults in the south and overlap in the north” to “faults in the north and overlap in the south,” with the depocenters also migrating accordingly (Fig. 5(a) and (b)). The dip angles of the NE-trending strike-slip faults (transfer faults) were significantly steeper than those of the basin-controlled faults, with a maximum dip angle of up to 70°, displaying some sedimentation control (Fig. 5(c)), and a maximum horizontal displacement of nearly 20 km. At the end of the Late Cretaceous, an intensive compressional inversion occurred in the basin, with up to 1000–1500 m of the Upper Cretaceous being completely eroded (Dou et al., 2024). A series of compressional anticlinal belts developed on the hanging wall of the boundary fault; the extension of the Paleogene was very weak, and the Cenozoic strata is very thin.

The Doba Basin is in a transitional location, with sedimentation controlled by NW-trending faults (Fig. 6(a)). The Early Cretaceous syn-sedimentary faults were highly active during the principal syn-rift phase, inducing intensive extensional rifting. The Late Cretaceous syn-sedimentary faults were inherited and developed, with a weakening of fault activity and a reduced control of faults on the Upper Cretaceous. At the end of the Cretaceous, the basin underwent strong inversion, with an erosion thickness of up to 800 m (Genik, 1992).

The characteristics of the basins in the West segment of the CASZ are similar to those of the rift basins in NE Brazil, where the boundary faults that control sedimentation are mainly extensional during the Early Cretaceous. The NW-trending faults within the basin have obvious strike-slip, with displacements ranging from 5 to 20 km. In the late Early Cretaceous, the basins were compressed and inverted, with uplift and erosion exceeding 1500 m (Figueiredo et al., 1994; Vasconcelos et al., 2019; Lima et al., 2021; Bezerra et al., 2023; Fairhead, 2023). The obvious difference between the rift basins in NE Brazil and the West segment of the CASZ is that the former experienced only one rifting stage, while the latter went through two rifting stages – one in the Early Cretaceous and another in the Late Cretaceous.

3.1.2. East segment

This segment is composed of the Doseo, Salamat, and Baggara Basins and the Sufyan sub-basin of the Muglad Basin (Figs. 1, 2 and 6(b)–(e)). The long axis direction of the basins is in alignment with CASZ, and in cross-section, they essentially exhibit a half-graben morphology. The Doseo and Salamat Basins are separated by an uplift (Fig. 6(c)). The Doseo Basin consists of several subsiding zones and depocenters. The northern strike-slip boundary fault controls both the basin's extension and deposition. During the Early Cretaceous, the basin's extension ranged from 28 to 35 km, with a

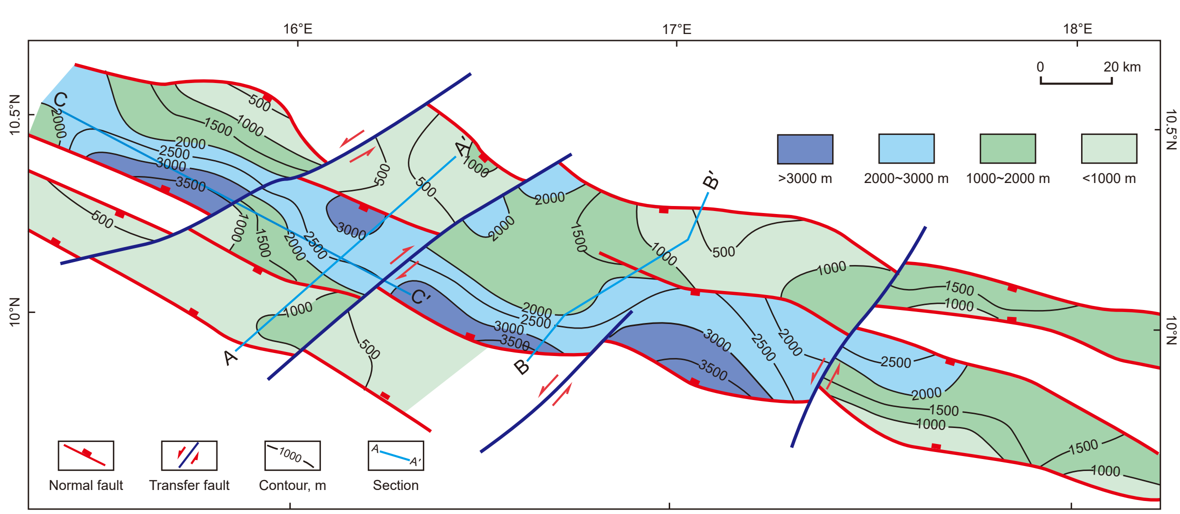


Fig. 4. Isopach map of the Lower Cretaceous P Formation, Bongor Basin in Chad.

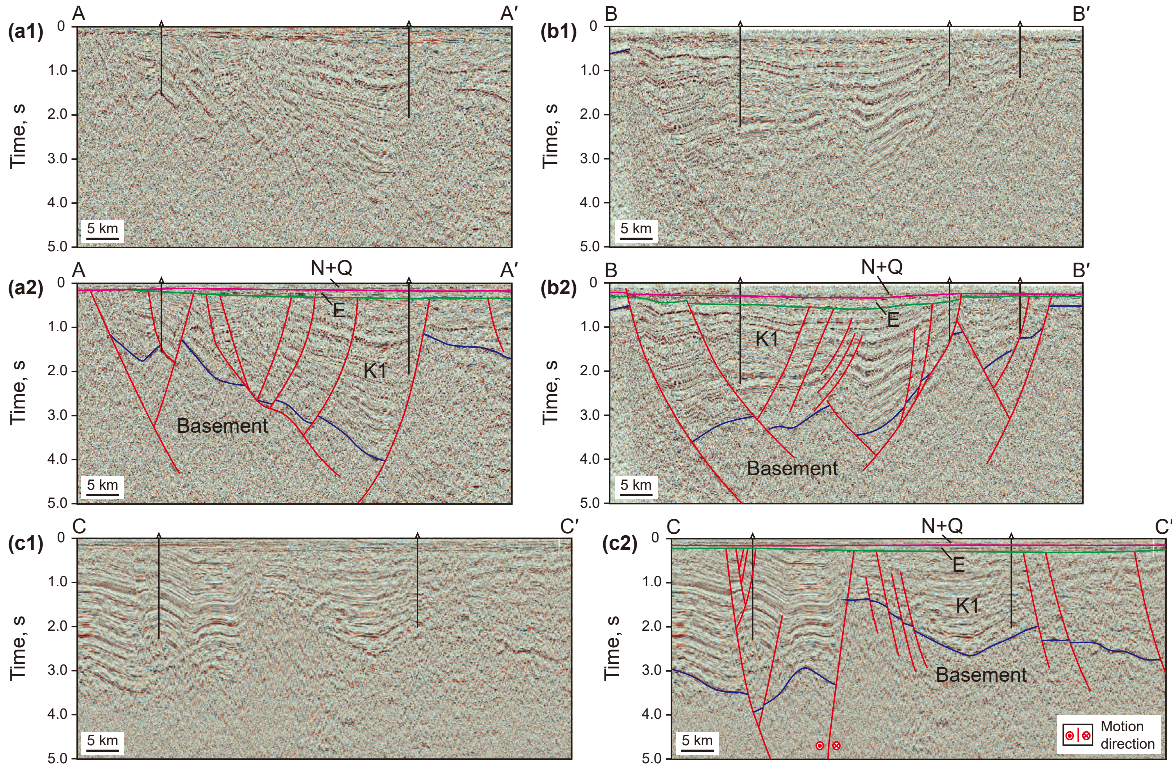


Fig. 5. Seismic profiles of the Bongor Basin. **(a1)**, **(b1)** and **(c1)** are the uninterpreted seismic profiles; **(a2)** and **(b2)** show the major structural elements of the basin; **(c2)** shows the transfer faults which controlled the sediments during the Early Cretaceous (For locations see Figs. 1 and 4). K1: Lower Cretaceous; K2: Upper Cretaceous; E: Paleogene, N: Neogene; Q: Quaternary.

strike-slip displacement of 15–35 km. The maximum sedimentary thickness occurred at the eastern end of the boundary fault (Dou et al., 2022b, 2024). At the end of the Late Cretaceous, compressional inversion led to the erosion of up to 800–1000 m of the Upper Cretaceous strata on the gentle slope. Transpressional inversion anticline zones developed on the hanging wall of the boundary strike-slip fault. A row of antiformal negative-flower structural zones parallel to the boundary faults developed in the central part of the basin, with the geometry being complicated by NWW-SEE-trending en echelon faults (Fig. 6(d)).

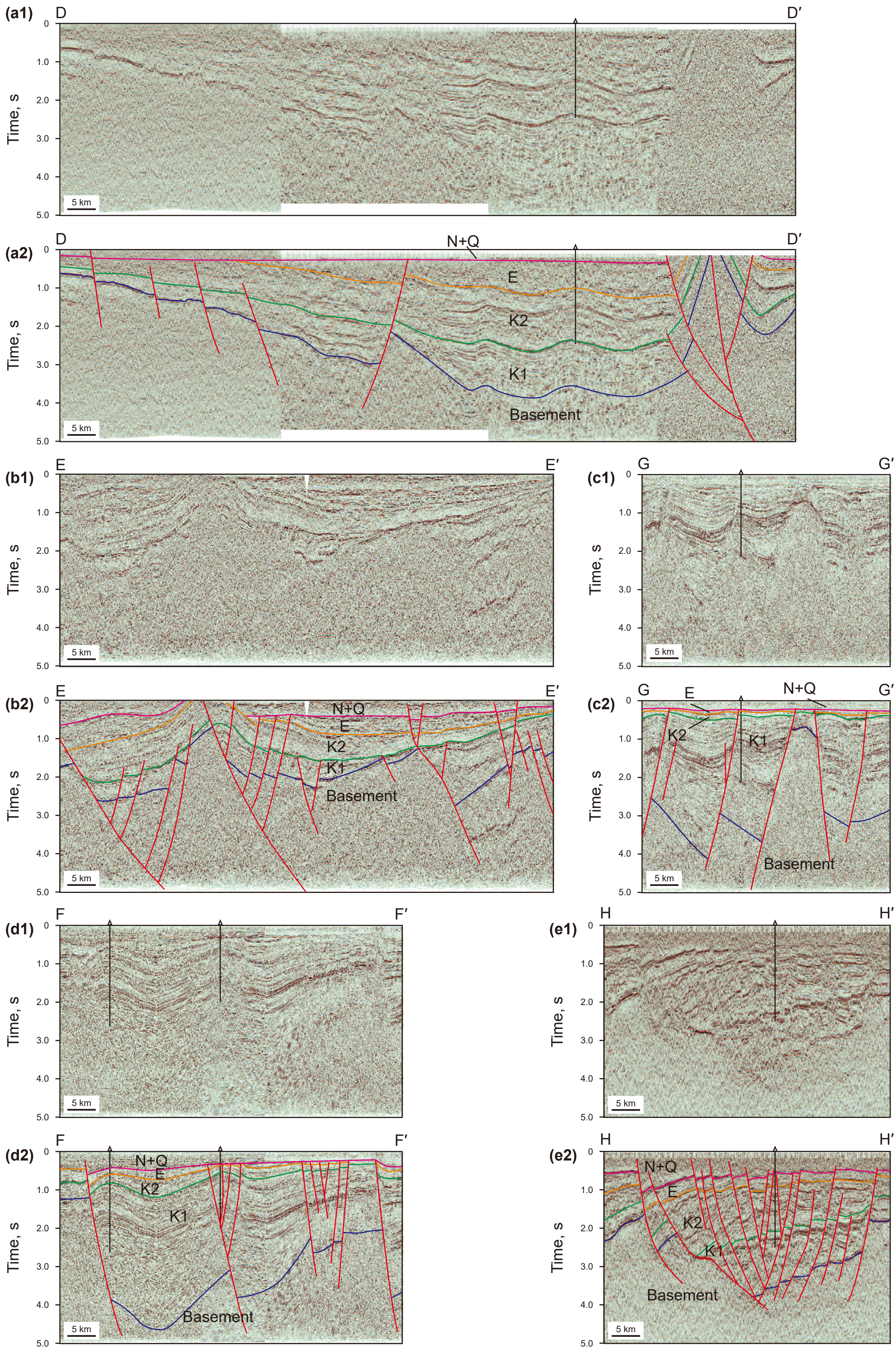
The Salamat Basin, separated from the Doseo Basin by a transform high, extends to the Baggara Basin in Sudan, forming a continuous sedimentary basin. The exploration degree of the Salamat and Baggara Basins is low, accompanying with only one well each and no gas and oil discoveries. Available seismic data indicate that they comprise a graben structure with en echelon faults developed on the plane (Genik, 1992; Hassan and Nadi, 2015). The Sufyan sub-basin of the Muglad Basin is developed eastward along the strike-slip zone. The Tomat Uplift extends from east to west, separating the sub-basin from the main body of the Muglad Basin. There are two sets of faults in the Sufyan sub-basin, trending NNW-SSE and NE-SW. The NNW-SSE-trending faults control deposition, and the NE-SW-trending faults are accommodation (transfer) faults (Dou et al., 2024). The total extension displacement of the sub-basin is 38.3%, with 34% in the early Cretaceous (88.9% of the total extension) and 3.1% in the late Cretaceous (Yassin et al., 2017). The Sufyan sub-basin experienced two rifting sequences during the Early and Late Cretaceous, with the Lower Cretaceous sequence reaching a thickness of up to 5000 m. The Upper Cretaceous rift was inherited and developed and has a stratum thickness of 1000–1500 m. The rift did not develop during the Paleogene, which shows down-warping-type sedimentation, with a thickness of less than 300 m. The inversion is generally not obvious in the sub-basin, and flower structures are only locally developed (Dou et al., 2024).

3.2. Strike-slip-induced extensional basins (SEB)

NW-SE-trending rift basins are developed at each end of the CASZ, and intersect at a large angle with CASZ. These basins share common features: they are controlled by large-scale, steep extensional faults, often developing multiple sags, with depocenters inherited from the Early Cretaceous to the Late Cretaceous. Paleogene was another main extension period, strike-slip faults developed locally, and have a relatively large depositional thickness. Small-scale normal faults developed on the gentle slopes of basins such as the Termit, Muglad, and Melut Basins, controlling local deposition. Compressional inversion in these basins during the later stages was minimal.

3.2.1. Northwest branch

This branch includes the Termit, Tenere, Kafra, and Grein Basins, they are separated by uplifts and generally extending in an NNW-SSE direction (Figs. 1 and 7) (Liu et al., 2011; Yuan et al., 2023a). The basin development in this branch is predominantly controlled by two stages of strike-slip extension (primarily extension) during the Early Cretaceous and Paleogene. In the Early Cretaceous, half-grabens were developed, some with faults in the east and overlapped to the west, or some with faults in the west and overlapped to the east. These half-grabens were filled with a set of coarse-fine-coarse grained continental strata with a thickness ranging from 1000 to 4000 m. The inherited subsidence of the rifts in the Late Cretaceous, coupled with the global sea level rise, resulted in a large-scale transgression, developing a set of marine mudstone deposits which are rich in terrigenous organic matter. This layer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G
G′
(c2)
(d1)
F
F′
(d2)
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H
H′
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became the active source rocks for the basins in this branch (Mao et al., 2016; Dou et al., 2022a; Yuan et al., 2023b).

From south to north of this branch, the basin scale becomes smaller, strike-slip faults become less, and erosion intensity increases. As an example, the Termit basin is about 430 km long from north to south, about 180 km wide, and has a maximum deposition thickness of about 12 km. Its maximum extension amount in the Cretaceous was about 60 km. The NW-SE-striking syn-depositional normal faults are characterized by high angles (50°–70°), long reaches (30–90 km), and large displacements (2–5 km), forming a series of NW-SE-trending grabens and half-grabens. The strike-slip displacement is small, appearing as linear structures at the margins of these basins, and are not intra basin developed. During the Late Cretaceous post-rift period, the basin experienced weak extension and exhibited a "flat on top and convex on the bottom" structure. Termit Basin experienced much stronger extension-strike-slip during Paleogene, which developed a series of NNW-SSE-striking secondary faults. The strike of the secondary fault is at an angle of 15° to the Early Cretaceous fault, indicating that the regional extensional direction was rotated during Paleogene. Nearly S-N striking dextral strike-slip faults were developed in the Trakes Slope in the east of Termit Basin, with right-stepped en echelon faults (Huang et al., 2022b; Wang et al., 2022; Yuan et al., 2022; Zhang et al., 2022; Pang et al., 2023) (Fig. 7(c)).

The Tenere Basin is about 300 km long from north to south and 50–80 km wide, with a maximum deposition thickness of about 8 km. Several half-grabens are developed from west to east, and structural features with obvious zoning in the east-west direction and blocking in the south-north direction. The graben structure developed in the west, half-graben structure complicated by faults in the east, and separated by low uplift (Liu et al., 2011; Yuan et al., 2023b). Compared to Termit Basin, the rift scale is smaller in Tenere Basin, and more post-rift sediments were eroded. Further north in Grein Basin, the maximum amount of stratigraphic erosion in the northwest being up to 1700 m (Pang et al., 2023).

3.2.2. Southeast branch

This branch is composed of several en echelon Mesozoic-Cenozoic rift basins, such as the Muglad, Melut, Rawat, and Blue Nile Basins, which are generally distributed in an NNW-SSE direction. All the basins experienced three stages of strike-slip-extension, and the Early Cretaceous is the main rift stage. The basins are filled with three sets of continental rifting sequences, i.e., Lower Cretaceous, Upper Cretaceous, and Paleogene, with the extension intensity weakening from north to south. The inversion intensity at the end of Miocene followed a similar trend. The basins entered the post-rifting stage since Neogene (Fig. 8).

The Muglad Basin generally has the shape of an inverted triangle, gradually converging from north to south, with a total area of more than 12×10^4 km^2 and a maximum deposition thickness of more than 15 km (Tong et al., 2004; Dou et al., 2006; Awad, 2015). In the Early Cretaceous, dextral strike-slip movement along the CASZ induced strong extension of NW-trending basement faults, with displacements reaching up to 70 km, forming a series of NW-trending syn-sedimentary normal faults. The basement subsided rapidly and was covered by thick Lower Cretaceous deposits (>6 km). In the Late Cretaceous, the basin was inherited and developed, with a maximum deposition thickness of about 4 km. The area with the strongest fault activity shifted to the Nugara and Kaikang sub-basins in the middle of the basin. In the Paleogene, the basin experienced further extension, although it was slightly weaker than the Late Cretaceous extension. The fault activity of the Nugara and Kaikang sub-basins remained the strongest, where the deposition thickness is up to 2 km, but the faults became less active in other parts of the basin and the sedimentary strata were thin. The bullhead-shaped Paleogene rift sedimentary sequence unconformably overlies the Cretaceous (Zhang et al., 2019).

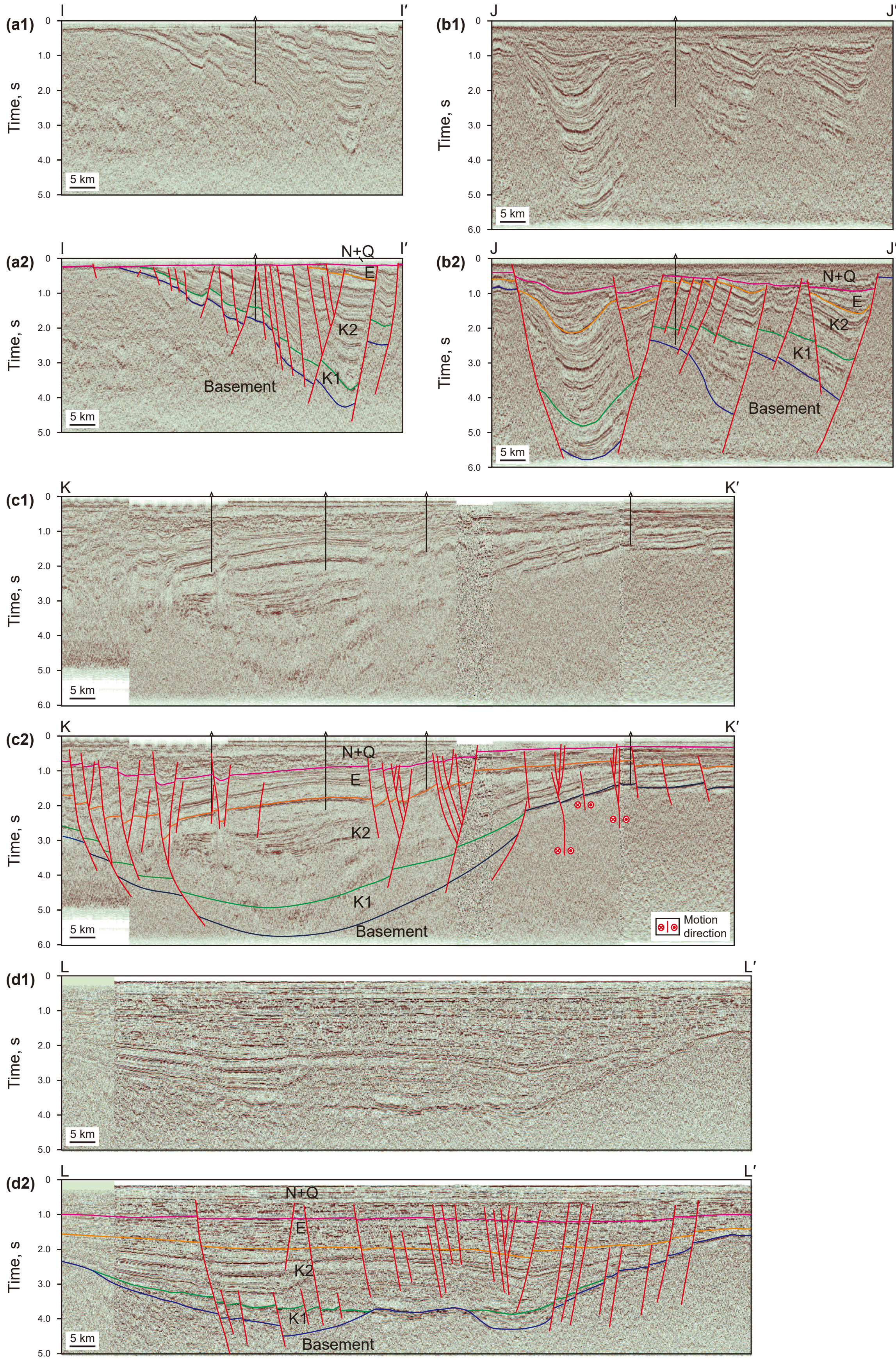
The Melut Basin is composed of five half-grabens and a low uplift. The assemblage of the Early Cretaceous rifts is predominated by series connections, with occasional parallel connections. The trend of these half-grabens changes from NW-SE to NNW-SSE. The Melut Basin also experienced three cycles of rifting evolution. The Early Cretaceous rifting was the most pronounced, filling 1000–3500 m thick interbedded mudstone and sandstone. The Late Cretaceous rifting was inherited, with predominantly sandstone strata, lack of regionally distributed lacustrine mudstones. In the Paleogene, the basin experienced further intensive rifting. The inheritance of the three-stage rifting in the Melut Basin is stronger than that in the Muglad Basin (Dou et al., 2006; Tong et al., 2004).

4. Discussion

Mann (2007) added a fifth type, introduced the "cratonic strike slip fault system", based on the classification of strike-slip fault systems proposed by Woodcock (1997) and Sylvester (1988). He argued that this type of strike-slip fault forms through the reactivation of pre-existing faults or ancient rifts under intraplate stress, driven by far-field stress from continental collisions within low-temperature ancient cratons. He regarded the strike-slip faults in West and Central China as continental boundary strike-slip faults. In recent years, significant progress has been made in understanding strike-slip fault systems in large-scale craton basins such as the Tarim and Sichuan Basins, with the identification of intraplate strike-slip fault systems characterized by small displacements and long distances (Guan et al., 2022; Tang et al., 2023; Jiang et al., 2024). These systems are derived from disequilibrium compression or stress transformation during convergence (Xu et al., 2004; Wang et al., 2021; Huang et al., 2022a; Chen, 2023). In contrast to these convergent systems, the strike-slip fault system in the WCARS is developed within the African Plate under a long-term divergence background. The WCARS was in the interior of Gondwana during the Cambrian-Jurassic and was tectonically stable. The several major orogenies that followed the Pan-African orogenic event had limited impact on it, and it was also unaffected by the sparse Late Triassic-early Jurassic magmatism reported in northeastern Niger and central Sudan (Genik, 1992; Zhao and Dou, 2022b). Since the Cretaceous, the development of the strike-slip rift system in West and Central Africa has been influenced by several factors, including pre-existing structures, basement rock lithology, and regional stress fields. The CASZ is not a single strike-slip fault but the result of gradual evolutionary growth and linkage of several small basement faults. At the end of the Cretaceous, it finally merged as one giant strike-slip zone with a length of more than 1000 km; known as the Borogop Fault. However, the complex evolutionary of this shear zone led to the development of basins with widely varying tectonic characteristics.

During the Late Jurassic-Early Cretaceous, the South Atlantic Ocean gradually opened from south to north. The action of the diverging plates reactivated pre-existing basement faults in Africa, forming a NEE-SWW-trending, giant strike-slip tectonic belt

Fig. 6. Seismic profiles of the East segment of the CASZ (For locations see Fig. 1), showing the structural elements of the transform-normal extensional basin (TEB). **(a1)**, **(b1)**, **(c1)**, **(d1)** and **(e1)** are the uninterpreted seismic profiles. **(a2)** is the interpreted cross sections of the Doba Basin; **(b2)** is the interpreted cross section of the Doseo Basin; **(c2)** is the interpreted cross section of the high between the Doseo and Salamat Basins; **(d2)** is the interpreted cross section of the Sufyan Sub-basin, Muglad Basin; **(e2)** is the interpreted cross section of the Sufyan Sub-basin, Muglad Basin. K1: Lower Cretaceous; K2: Upper Cretaceous; E: Paleogene, N: Neogene; Q: Quaternary.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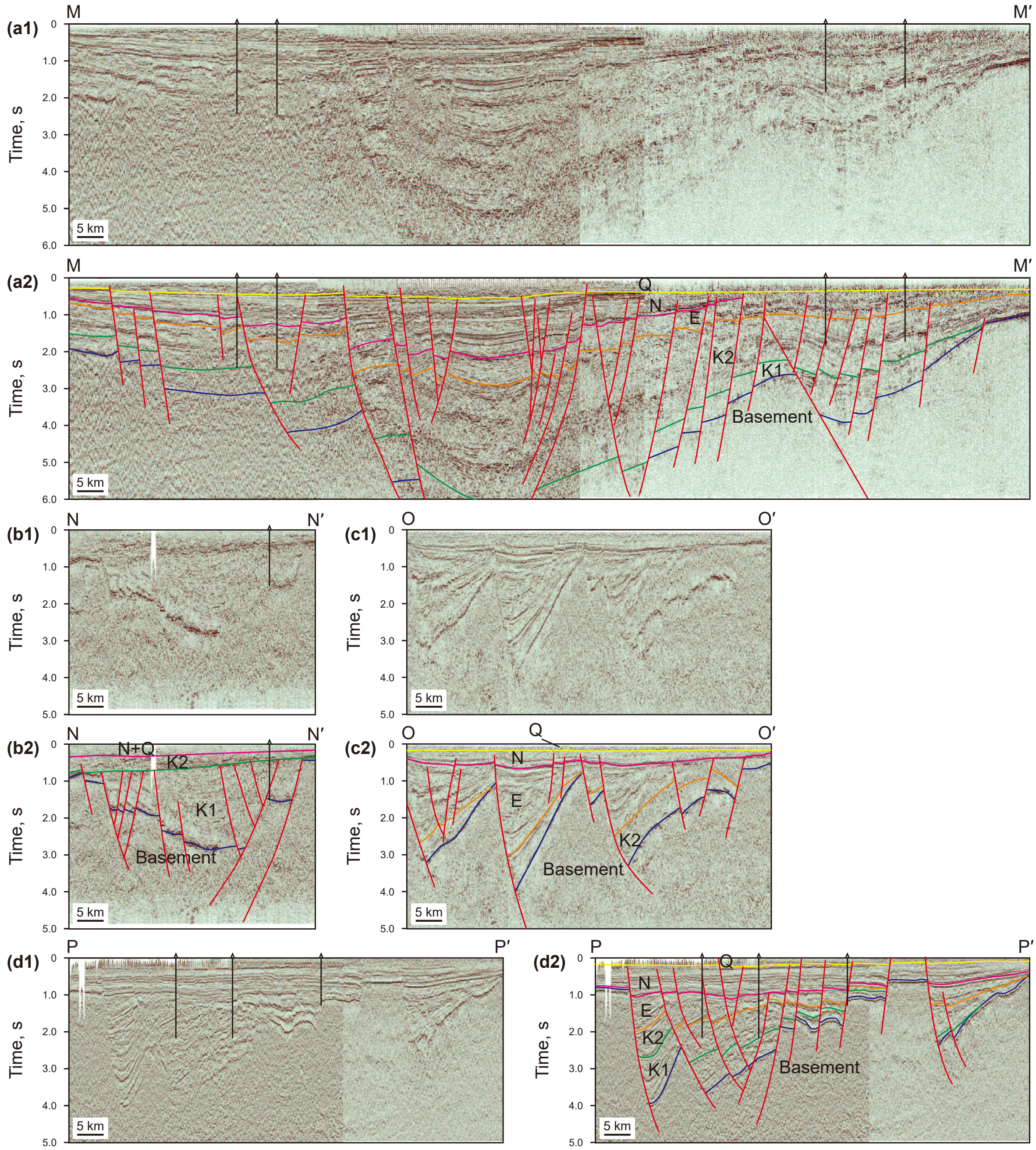

Fig. 8. Seismic profiles of the southeastern branch, showing the structural elements of the strike-slip-induced-extensional basins (SEB) (For locations see Fig. 1). **(a1)**, **(b1)**, **(c1)** and **(d1)** are the uninterpreted seismic profiles. **(a2)** is the interpreted cross-section of the Muglad Basin; **(b2)** is the interpreted cross-section of the Blue Nile Basin; **(c2)** is the interpreted cross-section of the White Nile Basin; **(d2)** is the interpreted cross-section of the Melut Basin. K1: Lower Cretaceous; K2: Upper Cretaceous; E: Paleogene, N: Neogene; Q: Quaternary.

spanning Northeastern Brazil and Central Africa. The eastern part of Brazil was profoundly affected by the Pernambuco dextral shear fault zone, with the Jatoba-Tucano-Reconcavo rift basin group developing to the south. The rift basin group in the West and Central Africa formed in the middle of the African Plate, impacted by the CASZ.

The opening of the South Atlantic Ocean also led to the formation of the Benue Trough during the Early Cretaceous, with a divergent stress field extending from west to east into the interior of the African Plate. A series of strike-slip basins formed in the unstable zone between the three ancient cratons, and TEBs developed along the CASZ, typified by intensive extension and intensive strike-slip. In Niger, Sudan, and the surrounding countries, strike-slip formed many extensional basins characterized by intensive

Fig. 7. Seismic profiles of the northwestern branch, showing the structural elements of the strike-slip-induced-extensional basins (SEB) (For locations see Fig. 1). **(a1)**, **(b1)**, **(c1)** and **(d1)** are the uninterpreted seismic profiles. **(a2)** is in the interpreted cross section of the Grein Basin; **(b2)** is the interpreted cross section of the Tenere Basin; **(c2)** and **(d2)** are the interpreted cross-sections of the Termit Basin. K1: Lower Cretaceous; K2: Upper Cretaceous; E: Paleogene, N: Neogene; Q: Quaternary.

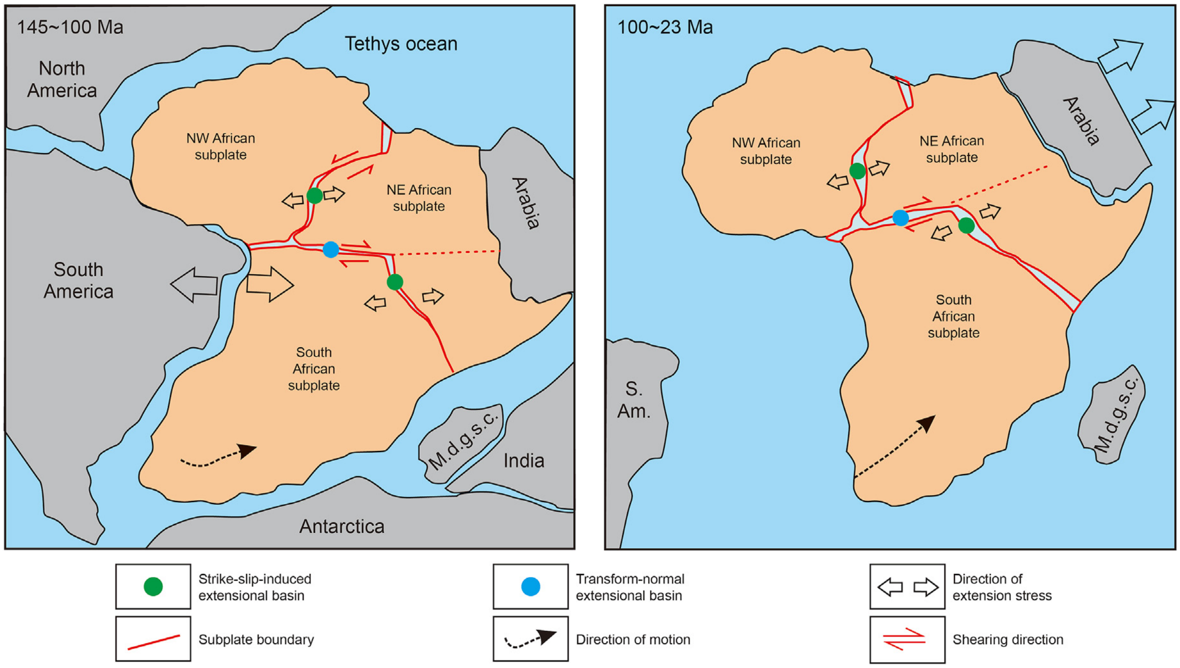

Fig. 9. Strike-slip fault tectonic setting of the West and Central African rift system. Compared with the Early Cretaceous, the direction of the stress field in the Late Cretaceous and Paleogene has a clockwise rotation of 15°. The strike-slip tectonic system in the West and Central Africa consists of the Central African Shear Zone (CASZ) and two rift branches, manifesting as an N-shape.

extension but weak strike-slip.

Since the Late Cretaceous, with the connection of the North and South Atlantic Oceans, intraplate development in South America and Africa has evolved independently. Affected by the subduction of the Neo-Tethys to the north of the African Plate, the eastern Arabian Plate and the African Plate continued to drift in a NE direction, and the interior of the African Plate remained in a divergent environment. The interiors of the strike-slip rift basins in the West and Central Africa were dominated by inherited subsidence and sedimentation.

During the Paleogene, the African Plate drifted northeastward and continued to do so until the Neogene or even later (Zhang et al., 2022). The east-west extension of the CASZ basically ceased, and extension became concentrated in the NW-oriented rift basins. Cretaceous rifting resulted in the thinning of the lithosphere and the uneven uplifting of the underlying mantle. The basin entered its third rifting phase, with sediments becoming more concentrated in the center of the large basin. The early boundary faults were reactivated, and some rotational planar normal faults evolved into listric normal faults, which controlled sedimentation during the Paleogene. Paleogene igneous rocks have been reported in the Termit, Bongor, Muglad, and Melut Basins, indicating that the nature of the basin shifted from early passive rifting to active rifting (Genik, 1992; Dou, 2004, 2018; Lu et al., 2009a, 2009b; Yuan et al., 2023a). The extensional stress direction of Paleogene rift rotated 15° clockwise, contrasted to that of the Cretaceous (Dou et al., 2024).

This analysis shows that the current classification of strike-slip fault systems fails to fully explain the system in West and Central Africa. Woodcock (1997) generally focused on system development under stress conditions caused by convergence between plates, without reference to oceanic transforms separating mid-oceanic spreading ridges. Mann (2007) added a new type of cratonic strike-slip fault system based on Wookcock's original classification, explaining that this new system is a geological body subject to unequilibrium compression that occurs along pre-existing early faults. The specific nature of the strike-slip fault system in West and Central Africa can be summarized as follows (Fig. 9): (i) the system is developed within the African Plate; (ii) divergent stress provides the context for the continuous NE-trending drift of the African Plate in the early Cretaceous, combined with a certain counter-clockwise rotation; and (iii) different types of strike-slip rift basins are developed in an orderly fashion within the system, displaying an "N"-shaped distribution when viewed in plan. We propose adding a sixth type to Mann's classification: the "intraplate divergent strike-slip fault system". The key characteristics of this system are: (i) it develops within the plate, (ii) it forms under a divergent stress field, and (iii) it displays an orderly "N"-shaped distribution of strike-slip rifts around the shear zone.

5. Conclusions

Seismic, structural, and stratigraphic analyses reveal that the strike-slip rift system in West and Central Africa represents a new type: the intraplate divergent strike-slip fault system. This system is related to the pre-existing tectonics of the African basement, the breakup of Gondwana, the incremental opening of the South Atlantic Ocean, the closure of the Neo-Tethys, and the local uplifting of mantle during the Paleogene.

Since the Early Cretaceous, divergent stress on the African Plate has driven the formation and evolution of the strike-slip rift system in Central Africa. Two types of basins are developed within this strike-slip fault system, distributed in an orderly fashion, and displaying an "N"-shaped distribution on the plane. TEBs are developed along the CASZ, while SEBs are developed at each end of the CASZ.

The basin group of the strike-slip fault system in the West and Central Africa is influenced by its tectonic location and basin types. Tectonic evolution and sedimentary processes differed significantly between the Early Cretaceous and the Paleogene, both in time and space. In the Early Cretaceous, TEBs were typified by strong extension and strong strike-slip, while SEBs showed strong extension but weak strike-slip. During the Paleogene, the TEBs featured weak extension, weak strike-slip, and thin Cenozoic sediments (maximum sedimentary thickness $<$300 m), while the SEBs entered the third rifting stage with further strong extension and thick Cenozoic sediments (maximum sedimentary thickness $>$2000 m).

CRediT authorship contribution statement

Li-Rong Dou: Writing – review & editing, Writing – original draft, Supervision, Investigation, Funding acquisition, Conceptualization. **Kun-Ye Xiao:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Ye-Bo Du:** Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Sheng-Qiang Yuan:** Writing – review & editing, Writing – original draft, Conceptualization. **Li Wang:** Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Xin-Shun Zhang:** Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Tong-Fei Huang:** Writing – review & editing, Writing – original draft. **Yi-Fan Song:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

We are confident that there is no conflict of interest in this article. We hereby certify that this article consists of original, unpublished data which are not under consideration for publication elsewhere. This study will not be submitted for publication elsewhere while under consideration for ***Petroleum Science***. All the co-authors were actively involved in data acquisition and interpretation, as well as in writing of the manuscript and discussion.

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