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ORIGINAL ARTICLE

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Triassic Neo-Tethys Ocean opening with development of continental extensional basin in Sibumasu block: Insight from the Kalaw-Pinlaung basin in Shan Plateau, Myanmar

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ABSTRACT

The Kalaw-Pinlaung Basin is a narrow, elongated, NNW-SSE-trending trough, approximately 170 km long and 60 km wide. This Basin is mainly composed of Mesozoic rocks, which overlie the Permo-Triassic limestones. It is situated in the Eastern Highlands (Shan Plateau), bounded to the west by the Sagaing Fault and the Inthanon suture zone to the east. The Shan Plateau (Sibumasu Block) developed as regional-scale en-echelon folding, which is conceptually dragged along by the extensive movement of Gondwana during the Upper Carboniferous, regarding the polar wander path from Ordovician to Permian, particularly the Variscan Orogeny. Leading to the Variscan Orogen in Europe, the Sibumasu Block (Cimmerian Superterrane) was a peri-Gondwana block that was dragged by Gondwana. The Sibumasu Block developed continental extension when the Neo-Tethys Ocean likely began to open around 265 Ma by movement of the Cimmerian Superterrane, while the Paleo-Tethys Oceanic crust has been subducted beneath Eurasia. The Sibumasu block detached from Gondwana in the post-Permian period, so that the Sibumasu Block remained attached to Gondwana until the end of the Permian. A passive continental margin develops through extensional basins towards the ocean, characterized by synthetic half-graben basins that form listric normal faults. These faults are geomorphologically expressed as fault scarps and tilted terrain, indicating the presence of half-grabens. The Kalaw-Pinlaung Basin is characterized as a synthetic half-graben basin by listric normal faults, in which the pre-rift sediments of the Thitsipin Limestone Formation are recognized as fault-bounded blocks, trending parallel with basin alignment. The Kalaw-Pinlaung Basin is divided into five half-grabens from west to east: Half-Graben I, Half-Graben II, Half-Graben III, Half-Graben IV, and Half-Graben V. The Half-graben basins are filled by the Upper Triassic to Cretaceous rocks, turbidite to continental sediments, as well as deep marine to fluviatile environments. The Kalaw-Pinlaung Basin opened an outlet of the extensional basin in the Kyaukse-Lungyaw area south of Mandalay city. During the Mesozoic period, the tectonic development of the present Myanmar Region included the West Myanmar Block (Indo-Myanmar Range and Central Myanmar Basin), the Sibumasu Block (Shan Plateau), and the Sukhothai Block (Inthanon zone).

KEY WORDS

Sibumasu block; Continental extensional basin; Synthetic half-graben basin; Kalaw-Pinlaung basin; Mesozoic rocks

ARTICLE HISTORY

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Introduction

The Kalaw-Pinlaung Basin, named by, is a narrow, elongated, NNW-SSE trending trough, approximately 170 km long and 60 km wide [1]. It is mainly composed of Mesozoic rocks (Triassic, Jurassic, and Cretaceous rocks), which overlie the Permo-Triassic limestones. The Kalaw-Pinlaung Basin is fascinating due to the exposure of Mesozoic sediments between the Myittha-Paunglaung Rivers, or the Paunglaung-Myittha Fault to the west, and the Pindaya Ranges to the east (Figure 1). Several previous studies on the evolution of the Kalaw-Pinlaung Basin during the Mesozoic have been proposed.

Middlemiss named the red beds of Kalaw as the "Purple Sandstone Zone", including the sandstones and coal-bearing shales, which are exposed at Kalaw and Aungban City areas [2]. de Cotter had subdivided into three zones, as lower shaly, middle sandy, and upper coal-bearing zone, based on the floral assemblages from the roof of the coal-seams to name as "Loi-an Coal Measures" and Purple Sandstone Zone as the "Kalaw Red Beds" [3].

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Fox renamed the Loi-an Coal Measures as "Loi-an Series" and proposed the Kalaw Red Beds as upper-middle Cretaceous based on the fossils of ammonites. Brown and Sondhi estimated that the Kalaw Red Beds are younger than the Loi-an Series based on field observations of the latter unit being overlain by the former [4,5].

Clegg believed that the Kalaw Red Beds could be Cretaceous, that is, undoubtedly overlain by the Loi-an Series of Jurassic [6]. Saito and Uozomi indicated that coal-bearing strata and the Klaw Red beds are coeval in age and merely different in facies. Kobayashi noted the differences in structural attitude of the Kalaw Red Beds and the Loi-an Series but accepted the Cretaceous of the Kalaw Red Beds [7,8].

Maung Thein and Ba Than Haq previously mentioned the geology of the Kalaw area in a brief review of their investigation [9]. Maung Thein studied in the Yimabin area, Thazi Township, and divided the Kalaw Red Beds, Yebu siltstone, and Pyinnyaung Alternations (lentils of limestone and conglomerate) in the Pyinnyaung area (Figure 1) [10].

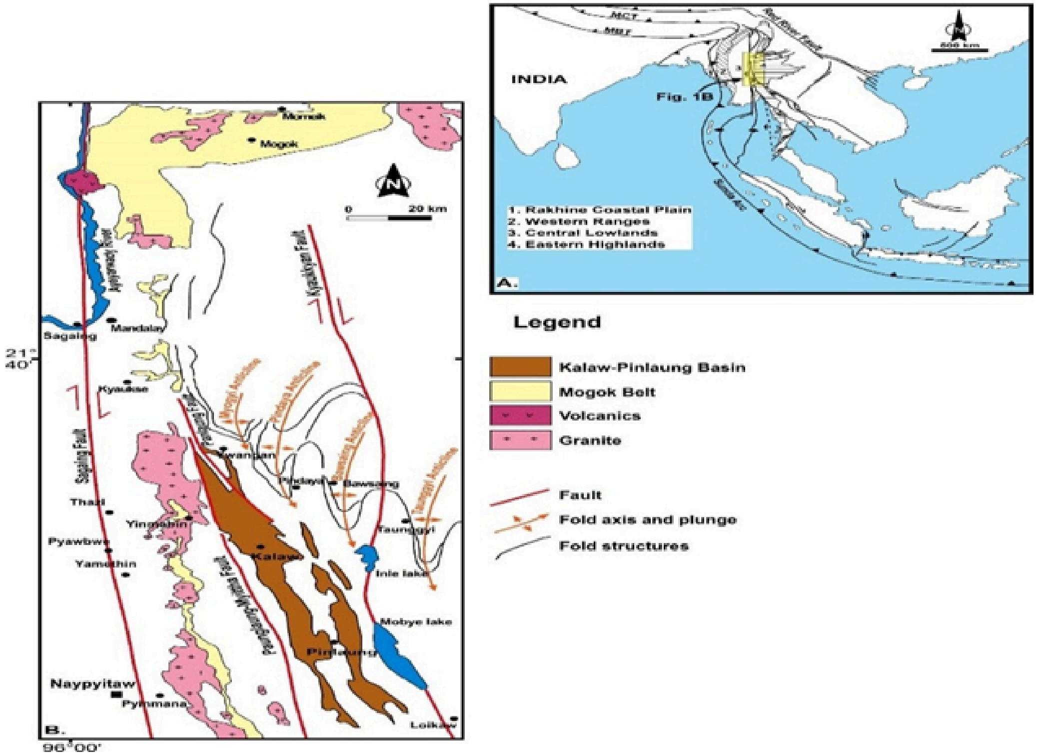

Figure 1. (A) Schematic map of Southeast Asia (modified after) showing major tectonic boundaries (location of Fig. 1B marked). (B) Map showing the relationship of the Kalaw-Pinlaung and its structural development.

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Khin Maung Win investigated the Loi-an Group (Jurassic rocks) using a stratigraphic classification. Loi-an Group included as different lithostratigraphic names, such as Ma-u-bin, Myittha, Nampandet, Gegauk, Ngazu, Nyaungbintaung, Thapanbauk, Kyungeyo, and Minpalaung Formations (Table 1-Table 3) [1,11-15]. Wolfart demonstrated the Mesozoic rock units in the correlation table of Precambrian, Palaeozoic, and Mesozoic formations within the western Shan Massif [16-21].

Table 1. Generalised correlation of the previous researchers for the different areas with their formations to the NW extension in the Kalaw-Pinlaung Basin.

Age		**Myint Thein et al [18] Kyaukse-Belin area**	**Myint Thein & Win Myint [19] Kinda area**	**Mitchell [21] Neyaungga area**		**Maung Thein et al [10] Yinnabin area**	**Khin Maung Win [11] Kalaw-Aungban area**
Cenozoic							
	Cretaceous	U. Pelitic-cal. unit	Yebok Fm	Kalaw conglomerate; Patchaung volcanics; Telu limestone		Kalaw Red Beds	Kalaw Red Beds
Mesozoic		U. Psammitic-pel. unit		Kyaukhsutaung Fm.		Yebu siltstone	Taungni Fm
	Jurassic	Mid. Pelitic-cal. Unit	Pan-laung Fm				
		Lr.Psammitic-pel. Unit		Loi-an Fm	Pan-laung Gp	Pyinnyaung alternation (lentils of Lst. & Conglo.)	Inbyin Fm Thitpalwe Fm Gegauk Fm
		Lr.Pelitic-cal. Unit		Ma-u-bin Fm		Polokkyi greywacke	Nampandet Fm
	Triassic	Calcareous division	Ma-u-bin Fm	Natteik Lst.			
				Nwabangyi dolomite			
			U. Plateau Lst.			U. Plateau Lst.	
Paleozoic			Lebyin Gp	Thitsipin Lst		Yinmabin Metamorphics	

Table 2. Generalised Correlation of the previous researchers for the different areas with their formations to the SE extension in the Kalaw-Pinlaung Basin.

Age	**Garson et al. [20] Ye-nagan area E & W of Pan-laung Fault**	**Burmese National Committee [27] Kalaw area**	**Khin Maung Latt [12] Nampandet area**	**Khin Maung Win et al. [1] Kalaw-Pinlaung area**	**Wolfart et al. [16] Aungban-Kalaw area**
Cenozoic					

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	Cretaceous				Kalaw conglomerate Telu limestone	KRB	Kalaw Red Beds Taungni Fm	KRB	U. Clay U. Conglo L. Clay	KRB
Mesozoic	Jurassic	Yebok Fm Kalaw Red Bed Fm-E Pan-laung Fm-W Pinnacle Lst Fm	Kalaw Red Beds Taungni Fm Thitpalwe Fm Nyaungbin Fm	Loi-an Gp	Taungni Fm Inbyin Fm Thitpalwe Fm Gegauk Fm Nampandet Fm	Loi-an Gp	Nyaungbintaung Fm Minpalaung Fm Inbyin Fm Thitpalwe Fm Gegauk Fm Kungeyo Fm	Loi-an Gp	L. Conglo Loi-an Gp Gegauk Fm Nampandet Fm Myittha Fm	Sh we minbon Gp
	Triassic	Ma-u-bin Fm Mudstone Fm Nateik Lst Fm	Plateau Lst Gp				Plateau Lst Gp		Kondeik Fm Nwabangyi Fm Thitsipin Fm	
Paleozoic		Nwabangyi dolomite Thitsipin Lst Fm	Paukkwa Fm Modi Fm Poklokkyi Fm Kogwe Fm	Lebyin Group					Paukkwa Fm Modi Fm Poklokkyi Fm Kogwe Fm	Lebyin Group)

Table 3.Generalised Correlation of the previous researchers for the different areas with their formations to the Kalaw (Central) area in the Kalaw-Pinlaung Basin.

	Age	Fay Lain [17] North Kalaw area		Khin Maung Latt [12] Nanpandet area		Khin Maung Win et al. [1] Kalaw-Pinlaung area		Kyi Soe [14] West Shan Plateau	Chaw Thuza Win et al. [22] Nanpandet area
Cenozoic									
	Cretaceous	Kalaw Red Beds		Kalaw Conglo Telu Lst	KRB	Kalaw Red Beds Taungni Fm	KRB		
Mesozoic		Thitpalwe Fm Nyaungbin Fm	Loi-an Gp	Taungni Fm Inbyin Fm	Loi-an Group	Nyaungbintaung Fm Minpalaung Fm	Loi-an Group	Nyaungbintaung Fm Minpalaung Fm	Unit D (Nyaungbintaung Minpalaung Fm)
	Jurassic	Gegauk Fm Nampandet Fm Myittha Fm	Shweminpon Gp	Thitpalwe Fm Gegauk Fm Nampandet Fm		Inbyin Fm Thitpalwe Fm Gegauk Fm Kungeyo Fm		Thitpalwe Fm Gegauk Fm	Unit C (Thitpalwe Fm) Unit B (Gegauk Fm)

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Triassic	Plateau Lst Gp	Shweminbon Fm	Unit A (Thapanbauk Fm)
Paleozoic			

Fay Lain subdivided the Jurassic rocks into the Shweminbon Group (older) and the Loi-an Group (younger), and unconformably overlain by the Kalaw Red Beds. The Shweminbon Group, as a turbiditic sequence exposed in the Shweminbon gold prospect area, extends northward along the Thazi-Kalaw car road and Panlaung River valley, juxtaposed with the typical Loi-an Coal Measures and Kalaw Red Beds [17].

Myint Thein mapped the Kyaukse-Belin area, where the Jurassic fossil-bearing sequence (near the east of Sunye Lake) and the underlying fusuline limestone (Plateau Limestone) of Dattaw Taung also reveal that the Jurassic-Cretaceous strata overlie the Plateau Limestone unconformably [18].

Myint Thein and Win Myint reused the formation names to prevent the fluctuation of stratigraphic names, such as Ma-u-bin formation, Panlaung formation, and Yebok formation; however, the Panlaung formation was redefined to separate the Mergui Group and Mesozoic units (including the Jurassic unit) [19,20].

Mitchell presented a generalised stratigraphic column of the Shan Scarp Zone, which included the Mesozoic units, such as the Ma-u-bin formation, Loi-an formation, and Kyauksutaung formation in the Jurassic, and Telu limestone, Patchchaung volcanics, and Kalaw conglomerate in the Cretaceous [21].

Chaw Thuzar Win divided the four-lithostratigraphic units of the Loi-an Group at the Kyatsakan and Nampandet areas as Unit D, Reddish brown soft sandstone, buff coloured siltstone, and grey shale unit with coal seams and carbonised plant remains, Unit C, Light grey to white, hard quartzose sandstone and grit unit, Unit B, Purple and dark brown massive sandstone, siltstone and sand/ shale intercalated unit, and Unit A, a Turbiditic sequence of dark grey sandstone and shale alternated unit [22].

Kyi Pyar Aung established the lateral lithostratigraphic correlation of the diamictite unit (Mergui Group) and its related units (Yinyaw, Thitsipin, Moulmein, and Tenasserim formations) along the western margin of the Sibumasu Block, including Myanmar, Thailand, Malaysia, and Sumatra [23].

Kyi Pyar Aung re-established and clarified diverse and complex stratigraphic names and ages of the Carboniferous-Permian sequences with biostratigraphic data in the Shan Scarp and Shan Plateau zones of Myanmar [24].

The present study clarifies through field investigations, conducting a lithostratigraphic assessment of the Kalaw-Pinlaung area with the Turbiditic Unit, Loi-an Unit, and Kalaw Red Beds Unit, considering the tectono-structural implications of passive continental extensional basin evolution as opening and closing with the palaeogeographical assessment at the western margin of the Sibumasu Block during the Mesozoic period. Concurrently, pre-rift, syn-rift, and post-rift sedimentation are noticeable within the Kalaw-Pinlaung Basin.

Geological setting

The Myanmar Region has been topographically divided into four main domains, which are the Rakhine Coastal and Offshore Islands, the Indo-Myanmar Ranges (IMR), the Central Lowland and the Eastern Highlands from west to east [25-36]. Similarly, Kyi Khin tectonically mentioned the Myanmar Region from west to east as the Chittagong-Tripura-Fold-Belt (CTFB) for Foreland Basins, the IMR for Accretionary Prism, Central Myanmar Basin (CMB), including Forearc and Backarc troughs divided by the Central Volcanic Line, and eastern Shan Plateau Highlands in the Sibumasu Block [37].

The West Myanmar Block, including IMR and CMB, which is juxtaposed with the present west of the Shan Plateau or Sibumasu Block during the Triassic is separated by the Sagaing Fault [38]. The N-S striking Sagaing fault is a 1200 km long right-lateral strike-slip fault that extends across most of the length of Myanmar and cuts through the western margin of the Mogok Metamorphic Belt [39]. The Sagaing Fault links to a series of short transfer faults in the active backarc spreading centre of the Andaman Sea to the south (Figure 5) [40,41].

The Sibumasu Block, which extends from western Yunnan, eastern Myanmar, the western peninsula of Thailand, the western peninsula of Malaysia, and eastern Sumatra, is bounded by the Sagaing Fault to the west and the Inthanon suture zone to the east. To the north, the Baoshan zone in Yunnan is the northern extension [42-44].

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The Sibumasu Block, including the Shan Plateau Highlands, generally consists of Precambrian to Late Mesozoic strata [25]. The Sibumasu Block extends about 1700 km from the Shan Plateau Highlands, Myanmar, to the north to Peninsula Thailand to the south. The part of the Sibumasu Block bordering the Paleo-Tethys suture on its west was designated the Inthanon Zone [45]. Before rifting from Gondwana, the east flank of the Sibumasu Block was a passive margin bounded by Paleo-Tethys from Devonian times to Late Palaeozoic, and its northward drift to its Triassic collision with the Sukhothai, as evidenced by the volcanic arc of the Indochina Block [46]. During the Indosinian Orogeny, a Lower Triassic foredeep basin was formed together with a thrust complex (Thanlwin Suture or Nam Teng Fault) of the Inthanon zone on the eastern flank of the Sibumasu Block.

The Inthanon Zone, introduced is in contact with the Sibumasu Block by the Thanlwin Suture at the west of the Thanlwin River (formerly Salween) in eastern Myanmar at the western boundary of the Inthanon Zone (Figure 5) [45,47]. The Inthanon Zone is characterised as a metamorphic-plutonic basement with a structurally detached sedimentary cover of mainly Palaeozoic age, forming the eastern part of the Sibumasu Block [46]. The Inthanon Zone includes mountain-sized blocks of Carboniferous-Permian limestone interpreted as the capping of former oceanic seamounts [46]. Inthanon Zone is mainly composed of pelagic chert and mudstone, Permian carbonate bodies interpreted as oceanic seamounts, oceanic basalt, and mélange [48]. However, the Sibumasu Block is widespread as the Ratburi Limestone and Phawar Formation in Thailand and Tenasserin, Moulmein, and Thitsipin Formations in Myanmar. Sone, Metcalfe and Hara have interpreted those overthrust Paleo-Tethyan rocks in the Inthanon Zone as an accretionary complex [49-51].

In the CMB, the backarc trough comprises the Bago Yoma-Sittoung sub-basin, the Bhamo sub-basin, the Shwebo sub-basin, and the Hukawng sub-basin, which were filled with molassic sediments and contact with the Sagaing Fault in the east. In the CMB, the forearc trough includes the Chindwin sub-basin, Minbu-Salin sub-basin, Pyay sub-basin, and Irrawaddy Embayment, which are established at the eastern base of IMR, consisting of basin molassic sediments, which are faulted in contact with accretionary flysch sediments.

The IMR is tectonically known as an accretionary prism, extending approximately 1300 km in a north-south direction, broadens to the north, and runs to a maximum width of 230 km from the Kaladan Fault in the west to the Kabaw Valley in the east [52,53,37,38]. Regarding rare faunas, the thick Mesozoic-Cenozoic flysch deposits of the IMR are stratigraphically difficult to differentiate, especially in this accretionary prism. The IMR constitutes the youngest Oligocene sediments in the west [53,37,38] and the oldest Triassic meta-sediments, such as schists and Ladinian-Carnian turbidites in the east [54-56]. In accordance with the latest theory, the Indian Plate was subducted into the Eurasian Plate starting from the Triassic period, and the West Myanmar Block (including IMR and CMB) developed between the subduction zone in the west and the Shan Plateau uplands in the east [37,38]. Neogene siliciclastic sequences in the westernmost part of the Rakhine Coastal Region are recorded by syn-tectonic deep-marine to shallow-marine slope sediments for southward pro-gradational deltaic sedimentation with [57,58].

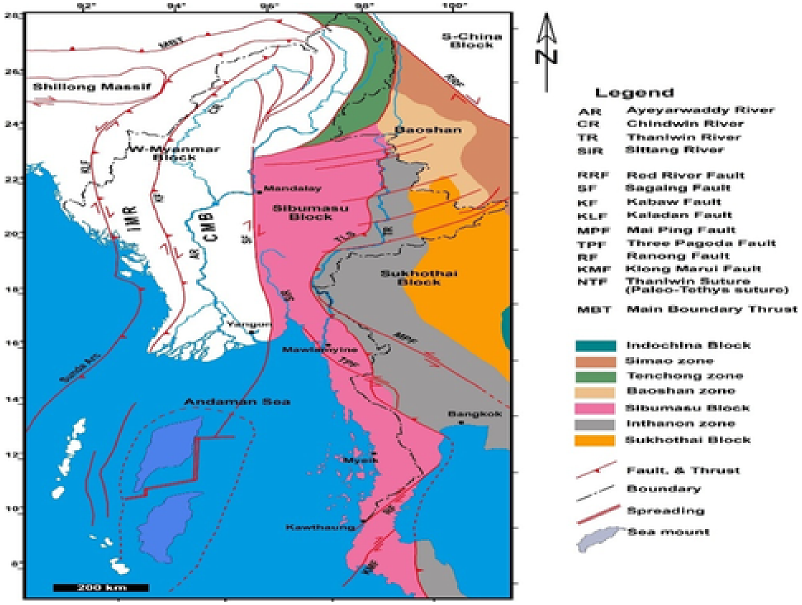

Figure 2. Schematic map of Myanmar, showing major tectonic units of the West Myanmar Block (including Indo-Myanmar Ranges-IMR and Central Myanmar Basin-CMB), Sibumasu Block, and Sukhothai Block (including Inthanon zone) [24].

Methodology

The present regional geological mapping is commonly interrelated with lithostratigraphy, and geological structures related to the tectonic evolution since the breakup of Gondwana. Lithostratigraphic units were also defined differently by various researchers three decades ago;

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however, this study used satellite images and aerial photos for geomorphological interpretation, supplemented by structural lineaments and confirmed by some fieldwork, although most of the areas remain inaccessible. The new geodynamic concept of different lithostratigraphic units related to their basins is based on geological structures and sedimentological interpretation of individual strato-types with lithostratigraphic units to determine the timing of tectonic activities in the Kalaw-Pinlaung Basin.

Geological structures were identified based on fieldwork and aerial photos, and then evaluated using satellite images, such as fault-bounded blocks trending parallel to the basin alignment, to interpret the half-graben basin. Therefore, the synthetic half-graben basin has been proposed based on a hypothesis explaining listric normal fault structures by basin inversion with compressional deformation in our present research.

The stratigraphic study was used to measure the stream sections such as the Thapanbauk, Gegauk, Thitpalwe, Minpalaung streams, and the Kalaw road-cutting, which are favourable for continuous stratigraphic sections of Upper Triassic to Cretaceous. The sections are well exposed for measuring bed by bed at the exposure, with significant lithological changes occurring.

The palaeogeography of the Cimmerian Superterrane, along with Gondwana from Permian to Cretaceous, was illustrated within the global plate tectonic framework by stratigraphic evidence from the Sibumasu Block and the Southeast Asia region. The plate tectonic model used to produce palaeocontinent base maps relies on Plates and Paleomap tectonic reconstruction programmes. Additionally, the maps presented were mainly created as Intergraph Freehand files using computer software and databases. Updated plate motion models are, in turn, marginally connected to the Cimmerian Superterrane and the Neo-Tethys Ocean through extended continental crust. As a result, the West Myanmar Block was considered a separate block from the Sibumasu Block but was positioned as an oceanic plateau with evidence of the I-type magmatic arc in the intra-oceanic subduction.

During the post-Permian (Lower Triassic) separation of the Sibumasu Block from Gondwana breakup during the Cimmerian Superterrane, the stratigraphic evidence indicates this event. The western margin of the Sibumasu Block was a passive margin connected to the Neo-Tethys Ocean by extended continental crust, as depicted in the 3D diagram. To the east, the Sukhothai Block was bordered by the Paleo-Tethys Ocean, with the Raub-Bentong, Sra Kaeo, and Nan-Uttaradit sutures marking its boundary to the Indochina Block. The simplified cross-section of Myanmar (West Myanmar Block, Sibumasu Block) and Thailand (Inthanon zone, Sukhothai Block) wasdrawn based on new evidence from our previous research, such as the double-wedge system of the accretionary prism, Triassic intra-oceanic subduction, and the Cretaceous open-wedge formation of Kanpetlet schist or Mount Victoria. The morphological characteristic of Kanpetlet schist is visible as the highest peak above older rocks, according to the open-wedge model of the Indo-Myanmar Ranges.

Paleotectonic concept of the Shan Plateau

Regarding the polar wander path from Ordovician to Permian, Gondwana was shifted to collide with Laurasia during the Carboniferous (360 to 300 Ma), particularly the Variscan Orogeny. The Cimmerian Superterrane was a peri-Gondwana block that was dragged along by the extensive movement of Gondwana during the Upper Carboniferous (Figure 6) [59,60]. As a result, the Cimmerian Superterrane experienced significant shear forces, likely causing a dextral effect along the terrane, which is notably observed in Myanmar, as seen in the Sibumasu Block.

The absence of Upper Carboniferous (Pennsylvanian) strata on the Shan Plateau resulted from a tectonic gap, which is documented by both structural and sedimentological evidence. The en-echelon folded structure, indicating the Pindaya Anticline, Bawsaing Anticline, Taunggyi Anticline, Mongpawn Anticline, Namsang Anticline, and Mongnai Anticline is prominently displayed in the west-vergent, south-plunging on the Shan Plateau in the Sibumasu Block, which was stratigraphically evident in the Carboniferous period (Figure 3) [23]. In addition, Wang observed that due to the Namurian uplift, no Upper Carboniferous strata were found in the Sibumasu Block. According to the Cimmerian Superterrane, including Sibumasu (Shan Plateau Highland), Tengchong, Baoshan, Lhasa, southern Qiangtang, southern Afghanistan, and southern Iran, is characterised as having no Upper Carboniferous sediments. Sedimentological studies with field evidence suggest that the Lower Carboniferous strata, known as the Loikaw Beds, could be disconformably overlain by the Middle Permian Thitsipin Formation [23,61]. Additionally, the Mergui Group has accumulated particularly oceanward of the present western margin of the Sibumasu Block (Shan Plateau Highlands), relative to the present western flank of the Pindaya Anticlinal folded uplift [23].

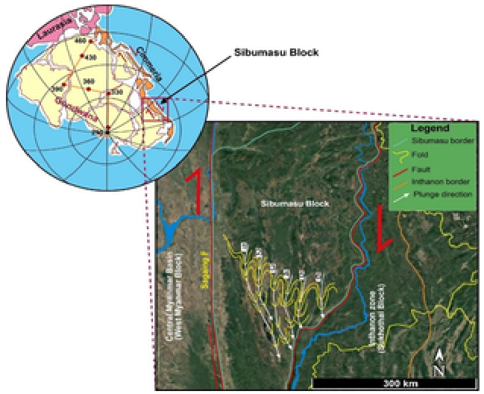

Figure 3. Polar wander path for the Ordovician to Permian relation to Gondwana with Cimmerian Superterrane (Peri-Gondwana), Schmidt projection in the southern hemisphere [59-62]. West-vergent south plunging en-echelon folding development on the Shan Plateau in the Sibumasu Block during the Carboniferous period (Variscan Orogeny) 1. Pindaya anticline 2. Bawsaing anticline, 3. Taunggyi anticline, 4- Mongpawn anticline, 5. Namsang anticline, 6. Mongnai anticline. Cimmerian Superterrane, including the Sibumasu Block, as a peri-Gondwana, was dragged by Gondwana along the long journey to Laurasia during the Variscan Orogeny.

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Neo- Tethys Ocean opening

In the context of palaeogeography during the long journey of Polar migration, the collision between Gondwana and Eurasia led to the formation of the Variscan Orogen in Europe. The Variscan Suture was displaced by an intra-Pangea dextral shear system between Gondwana and Laurasia, spanning 3,000 km (Figure 4). As a result, Gondwana experienced an anticlockwise rotation, aligning the movement of the Cimmerian Superterrane with that of Gondwana [62,63]. This movement likely had significant implications for the geological and tectonic dynamics of the region during that period.

The supercontinent Pangea formed after Gondwana and Laurasia collided in the Early Carboniferous period, opening the east-facing Paleo-Tethys Ocean.During this time, several continental blocks gradually drifted northward from Gondwana, forming the Cimmerian Superterrane [64-66]. The Cimmerian Superterrane, a narrow and elongated block extending from present-day Turkey through Lhasa, South Qiangtang, Baoshan, Tengchong and Sibumasu to Sumatra, is a well-established dynamic rift-drift amalgamation history of the late Palaeozoic and Mesozoic [67,68].

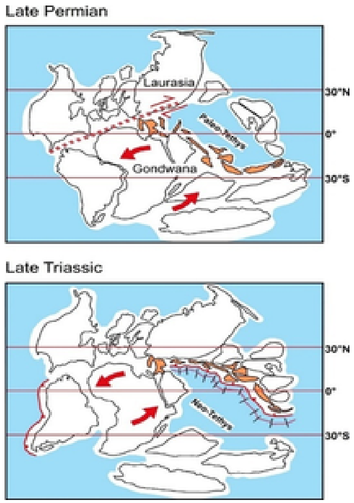

Figure 4. Pangea configuration of Late Permian to Triassic. Late Permian: The intra-Pangea dextral shear system between Gondwana and Laurasia is about 3000 km long, and its related anticlockwise rotation of Gondwana, Late Triassic: Cimmerian Superterrane movement with Neo-Tethys Ocean opening with spreading, as referred to [60,70,71].

The Cimmerian Superterrane was originally located on the northern edge of Gondwana until rifting occurred in the Upper Permian. It's drifting northward across the Tethys Ocean during the Late Palaeozoic and Early Mesozoic periods, eventually collided to amalgamate with the proto-Asian/Cathaysian Terrane in the Late Triassic to Early Jurassic time [68-71].

The Sibumasu Block, the eastern part of the Cimmerian Superterrane, includes western Thailand, western peninsular Malaysia, Sumatra, eastern Myanmar, and western Yunnan [72,73]. It is characterised by Cisuralian Gondwana marine faunas and glaciomarine sediments, which differ from the contemporaneous Guadalupian tropical, fusulinid, and coral-bearing limestones found in the Indochina Terrane with Inthanon zone [74-76].

During the opening of the Neo- Tethys Ocean, the Triassic subduction initiation was proposed [63]. Triassic subduction initiation, along with the development of the West Myanmar Block (including the Indo-Myanmar Ranges and the Central Myanmar Basin) during the Mesozoic, has been proposed by several geodynamic models. The Triassic western margin of the West Myanmar Block was initiated to subduct by the Triassic Halobia fossil occurrences at the western margin of the Central Myanmar Basin and Jurassic Intra-oceanic Island arc, I-type magmatism called the Central Magmatic Popa-Monywa-Wuntho line in the Central Myanmar Basin. The West Myanmar Block, therefore, originated as an oceanic plateau at the present west of the Sibumasu Block, a member of the Cimmerian Superterrane in part of the western Australian-Gondwana margin, and was later rifted and added to Southeast Asia in the Triassic through the suture between Sibumasu and Sukhothai Blocks of the Inthanon zone.

With the opening of the Neo-Tethys Ocean in the Triassic, an ophiolite suite formed in the Mid-oceanic ridge (rifting of sea floor-spreading); however, it obducted as high-pressure metamorphic rocks in the Indo-Myanmar Ranges during the Jurassic [77].

Continental extension on the Sibumasu block

Torsvik estimated that the Neo-Tethys Ocean likely began to open around 265 Ma, while the Paleo-Tethys Oceanic crust has been subducted beneath Eurasia [78]. The spreading of the Neo-Tethys Ocean was associated with the formation of the Upper Permian in the Sanandaj-Sirjan zone in Iran [79]. The Zhongba Terrane disintegrated from the northern margin of Gondwana during the Late Permian due to Late Permian rift-related volcanic rocks from the Zhongba Terrane in Southern Tibet, which facilitated the opening of the Neo-Tethys Ocean [80]. The opening of the Neo-Tethys Ocean at the Yarlung-Zangbo mainly occurred between approximately 250 and 243 Ma in the Early Triassic, not later than the early phase of the Middle Triassic, based on early Middle Triassic seamounts, radiolarian cherts, and normal mid-ocean ridge basalt-like oceanic crust [81].

Likewise, Sevastjanova believed that the Cr spinel is present in most West Myanmar sandstones; it is common in Southeast Asia but rare in Western Australia [82]. Thus, the

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Cr spinel in the Triassic units supports deposition in Southeast Asia rather than Western Australia. If the West Myanmar Block were part of Southeast Asia, the Triassic Cr spinel would have been derived from Triassic or older ophiolite belts, which are common across Southeast Asia, whereas in Western Australia, Cr spinel is rare [83,84]. The Triassic unit of Thanbaya Formation in the Saw and Kalaymyo areas by [85] and the Hainggyi formation on Hainggyi Island [86] are characterised as a passive continental margin and an oceanic island arc based on the chemical data plotting in the discrimination diagrams of (Figure 5) [87,88].

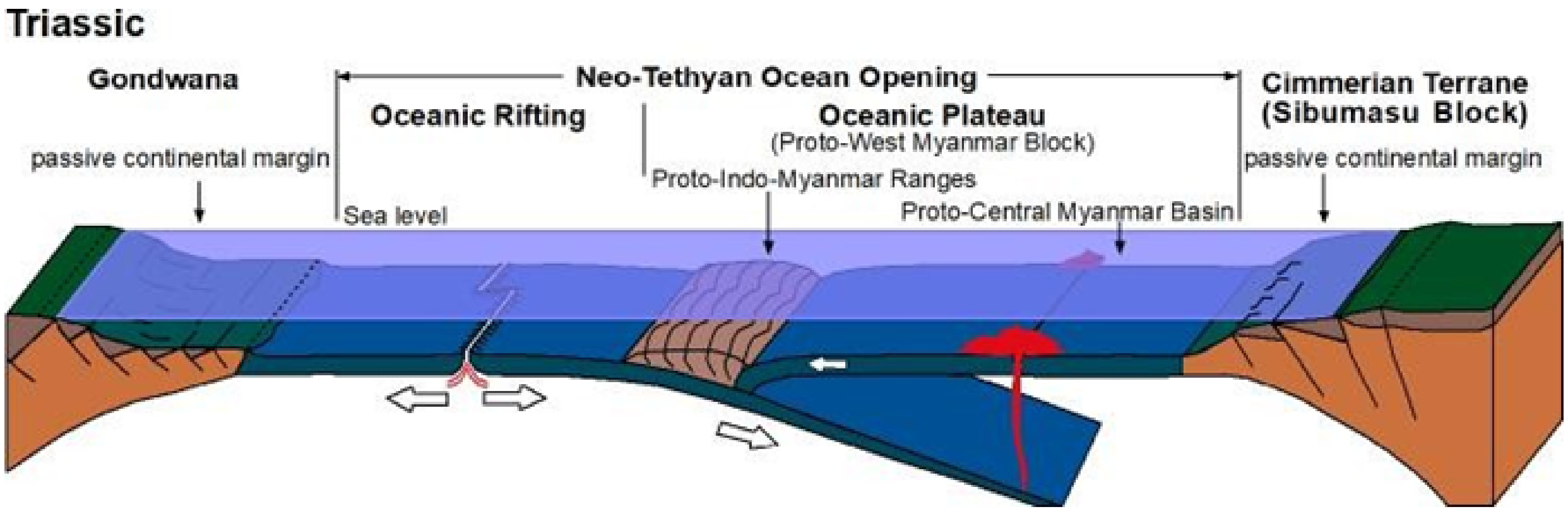

Figure 5. The scenario of the 3D passive margin model between Gondwana and the Sibumasu Block during the Triassic period (249 Ma), showing the Neo-Tethyan Ocean opening with subduction initiation at the Indo-Myanmar Ranges, intra-oceanic subduction (ocean-ocean subduction) development at the oceanic plateau of the West Myanmar Block, and I-type magmatic arc processing in the Central Myanmar Basin [63].

Detachment of the Sibumasu block from Gondwana

Kyi Pyar Aung et al. stated that the Sibumasu Block separated from Gondwana in the post-Permian period; therefore, the Sibumasu Block was connected to Gondwana until the end of the Permian [24]. The Permian limestone of the Thitsipin Formation from the Plateau Limestone Group is distinguished by its bedding nature, which indicates an open, shallow environment [20]. The bedded limestone known as turbiditic limestone formed to initiate carbonate production in the shallow-water environment, under embryonic folding and thrusting [89]. Therefore, a source area may have formed before sedimentation [25]. Most exposures of the Thitsipin Formation occur at high elevation on the south, at the plunging en-echelon anticlinal structures under shallow water conditions [25]. Pelagic sediments contain shallow-water pelagic carbonate sediments, indicating various types of bioherms, particularly coral reefs in the open shallow marine environment [90]. Furthermore, the Thitsipin Formation originated in an open, shallow marine environment with widespread areas of uplifted older rocks (Islands), indicating that reefs and bioherms were locally present in a growth position. Thus, the turbiditic Limestone of the Thitsipin Formation and later its source terrane underwent embryonic folding and faulting by the crustal movement [20,23].

In the Paungdaw-Ngetmi area, the galena mineralisation in the marble and the silty patches or specks, or burrows limestone of the Wunbye Limestone Formation (Ordovician) may occur as relict lithology (protolith) of calc-silicate. The Wunbye Limestone Formation is stratigraphically overlain by the Mergui Group (Early Permian) and Permian-Triassic Limestone [24]. In this case, if

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it is accepted instead that the Sibumasu Block detached from Gondwana during the Permian, then the Wunbye Limestone Formation of the Paungdaw-Ngetmi area was covered by the Mergui Group and Permian-Triassic Limestone (Thitsipin Formation). Therefore, the Wunbye Limestone Formation, a protolith of the Calc-silicate marble unit in the Mogok Metamorphic Belt, is separately well-exposed at the lowlands along the present western edge of the Sibumasu Block [26]. So, the Sibumasu Block detached from Gondwana can be dated to the post-Permian time.

Synthetic half-graben basins development

Geomorphologically, surface features, such as fault scarps and tilted terrain, can indicate the presence of half-grabens. A passive continental margin developed through extensional basins towards the ocean, known as the synthetic half-graben basins with listric normal faults (Figure 6). Continental rifts characterised by listric normal faults can occur at crustal or smaller scales within depositional systems such as deltas; therefore, listric normal faults result from extension. This aligns with constraints where calculations of the depth of detachment assume listric faulting for basement faults, with the hanging wall being extensively broken up by numerous minor faults; however, the footwall remains entirely undeformed.

Inversion tectonics can be caused by the removal of a load (related to isostatic rebound) or by uplifting of rotated fault blocks and rift flank uplift at the margins of large grabens (related to extensional faulting) or due to collisional processes with the rotation of earlier fault blocks (horizontal plate movement). Likewise, former listric normal faults were reactivated as reverse faults during the Cretaceous forced collision in the west (Indo-Myanmar Ranges) [63]. Thin-skinned tectonics is assumed to be the area of the Shan Plateau in the present west bank Sibumasu Block.

The earlier extensional structures are strongly overprinted by collisional structures. Therefore, on top of a limestone basement of Permian age (Thitsipin Limestone) as pre-rift sediments, depositional basins are filled with syn-rift sediments of considerable thickness. This stage reached into the Triassic turbidites, Jurassic turbiditic siliciclastics mark the post-rift sedimentation before inversion by orogenic shortening. The Kalaw-Pinlaung area provides an insight into the extensional depositional basins, which were deformed by later horizontal compression (orogenic compression).

A small-scale 2D model of the inversion tectonics in this long profile can be constructed by the interpretation of the graben type (domino-type), in which synthetic type half-graben basins are distinctly delineated by their type of sediments and stratigraphy systems [91]. They are represented by growth faults in the early through the Mesozoic clastic sediments.

Inversion is involved in the tectonic history, as the main separation of Gondwana began approximately 150 million years ago (Upper Jurassic), essentially as a two-plate system, with spreading between western Gondwana (Africa, South America) and eastern Gondwana (Antarctica, India, Madagascar, Australia, and New Zealand) [92]. During this period, the upper crust of the Sibumasu Block started to shorten, to the inversion of an extensional basin. The lower crust below the extensional Basin of the Sibumasu Block cannot have been deformed. A large amount of horizontal compression above the décollement at the back of the wedge is the main driving force in a fold-and-thrust belt. The necessary condition for the formation of such belts is a weak basal layer, independent of any surface on the topographic slope. Thus, the half-graben basin is typical of coal mining in the Minpalaung, Singu, Inbyin, and Tikyit areas, in the eastern part of each half-graben basin within the Kalaw-Pinlaung Basin.

Continuously, during the Lower Cretaceous (135 million years), Africa separated from South America to form the South Atlantic, and India separated from Antarctica [92]. Therefore, the latest horizontal compression effect on the Sibumasu Block caused the inversion in the Kalaw-Pinlaung Basin, characterised by the deposition of the Kalaw Red Beds, a largely fluviatile formation.

The opening and closing of the Kalaw-Pinlaung Basin are essential to reveal evidence that could be found for a paleosuture, which is distinct along the Sagaing Fault. Accordingly, the Sagaing Fault is in the plain to the immediate west of the Shan Plateau (Sibumasu Block) in the Geological Map view.

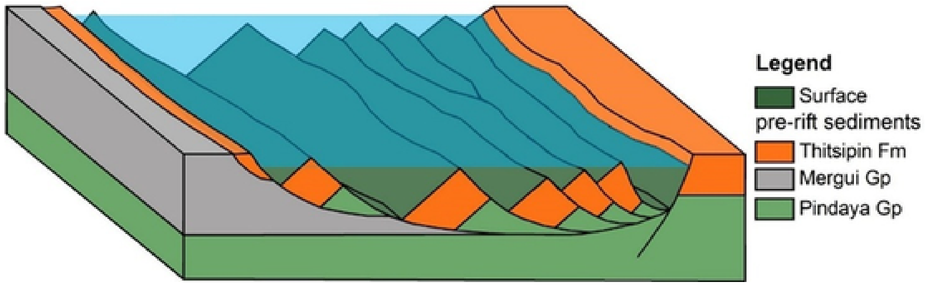

Figure 6. Palinspastic 3D cross-section across the Kalaw-Pinlaung Basin showing rifting with the development of listric normal faults on the pre-rift sediments (Thitsipin Formation) in the passive continental extension during Triassic time.

Kalaw-Pinlaung basin

The Kalaw-Pinlaung Basin is characterised as an extensional basin during continental rifting in the passive margin area in the present-day west of the Sibumasu Block during the Mesozoic. This extensional basin developed as a synthetic half-graben basin by listric normal faults, in which the

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pre-rift sediments of the Thitsipin Limestone Formation are recognised as fault-bounded blocks, trending parallel with basin alignment. Following the Thitsipin Limestone alignment, the Kalaw-Pinlaung Basin is divided into five half-grabens from west to east: Half-Graben I, Half-Graben II, Half-Graben III, Half-Graben IV, and Half-Graben V (Figures 7 and Table 3).

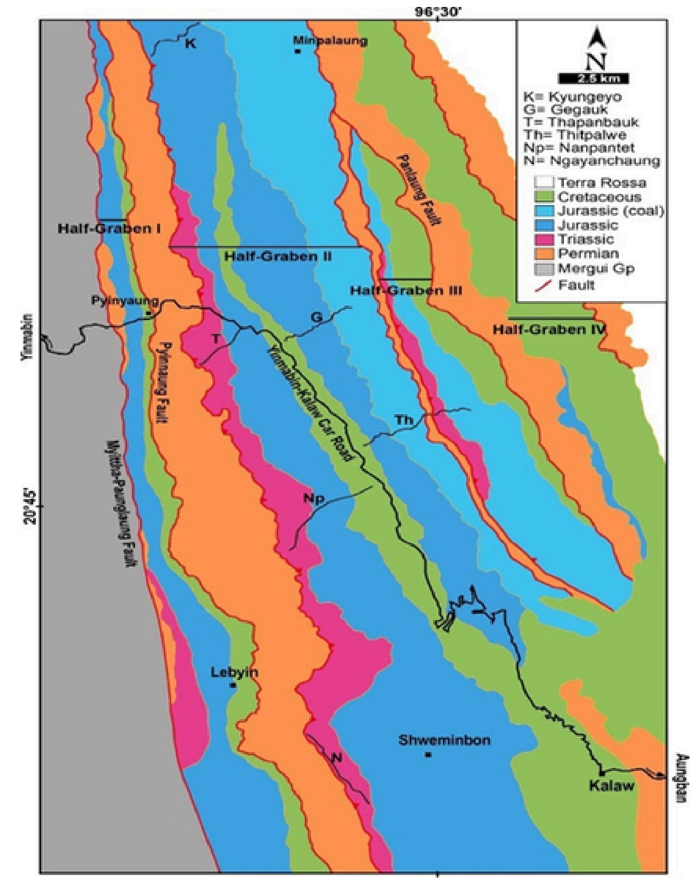

Figure 7. Detailed geological map of the Kalaw area as the north part of the Kalaw-Pinlaung Basin, showing the half-graben basins: Half-Graben I, Half-Graben II, Half-Graben III, and Half-Graben IV with type-sections of Formations.

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Table 4. Lateral correlation of rock-sequence distributions with their different half-graben basins: Half-Graben I, Half-Graben II, Half-Graben III, Half-Graben IV, and Half-Graben V in the Kalaw-Pinlaung Basin from the previous works.

Age			Half-Graben I	Half-Graben II	Half-Graben III	Half-Graben IV	Half-Graben V	General Lithology
Cenozoic								
Mesozoic	Cretaceous	Upper		Myindaik Conglomerate	Kalaw Conglomerate	Sattchan Conglomerate	Conglomerate	Conglomerate
		Lower	Yebok Fm	Taungni Fm	Kalaw Red Beds Fm	Kalaw Red Beds Fm	Kalaw Red Beds Fm	Pink-coloured siltstone, sandstone
	Jurassic	Upper	Pyinnyaug Alternation Fm	Nyaungbintaung Fm Minpalaung Fm	Singu Fm	Nyaungbintaung Fm Inbyin coal Fm	Nyaungbintaung Fm	Sst & sh alternation
							Tikyit Fm	Coal-bearing shale, sandstone & mudstone.
		Middle	Pan-laung Fm / Kyauksutaung Fm	Thitpalwe Fm	Loi-an Fm	Inbyin Fm	Loi-an Fm	Light grey to white hard qtzose sandstone & grit sequence.
		Lower		Gegauk/ Shweminbon Fm				
	Triassic	Upper	Ma-u-bin Fm / Myittha Fm	Kyungeyo / Thapanbauk / Nampandet / Ngayangaung Fm	Kalaw-Inbyin Fm			Purple to dark brown massive sandstone & siltstone alternates. Turbidite unit: dark grey sandstone & shale alternates sequence
		Middle						
		Lower	Plateau Lst.	Plateau Lst.	Plateau Lst.	Plateau Lst.	Plateau Lst.	
Paleozoic			Thitsipin Fm	Thitsipin Fm	Thitsipin Fm	Thitsipin Fm	Thitsipin Fm	

Halfgraben I

Triassic unit

The Jurassic Unit includes the Myittha Formation and Ma-u-bin Formation [17,20].

Jurassic unit

The Jurassic Unit includes the Panlaung Formation, the Kyauksutaung Formation, and the Pyinnyaung Alternations, in which lithostratigraphic correlation indicates the Panlaung Formation as Lower Jurassic, the Kyauksutaung Formation as Middle-Upper Jurassic, and the Pyinnyaung Alternation as Uppermost Jurassic [20,93,10].

Cretaceous unit

The Cretaceous Unit includes the Yebok Formation, which is assigned as Middle Cretaceous age [20].

Halfgraben II

Triassic unit

The Triassic Unit includes the Kyungeyo Formation, Thapanbauk Formation, Nampandet Formation, and Ngayanchaung Formation, which is a laterally correlated turbidite unit consisting

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of dark shales and subordinate indurated sandstones and can be correlated as Upper Triassic units [1,22,17,93].

Jurassic unit

The Jurassic Unit consists of the Gegauk Formation, Thitpalwe Formation, Shweminbon Formation, and Kyauksutaung Formation, which are laterally correlated and consist of brownish grey, medium to thick-bedded, massive indurated sandstones and siltstones with intercalated shales [1, 11, 12, 14, 17, 16,22, 93].

The Lower to Middle Jurassic Unit includes especially the Loi-an group. The name Loi-an Group was revised from the Loi-an Coal Measures, and the Loi-an Series of comprise the clastic sedimentary rocks [3,4]. The Upper Jurassic Unit includes the Loi-an Coal Measures and the Loi-an Series, which are revised as the Loi-an Group. The Loi-an Group comprises greyish-white sandstones at the lower horizon and buff-coloured shales, siltstones, and sandstones with grey shales at the upper horizons. It consists of the Minpalaung Formation [1, 14, 22].

Lithostratigraphical and faunal assemblages clearly indicate the Gegauk Formation and Shweminbon Formation as Lower Jurassic, the Thitpalwe Formation as Middle Jurassic, the Minpalaung Formation with coal measures as Upper Jurassic, and the Nyaungbintaung Formation as Uppermost Jurassic.

Cretaceous unit

The Cretaceous Unit includes, particularly, the Kalaw Red Beds. The name Kalaw Red Beds, which was introduced and consistently used over a long period [3, 5, 20, 29, 94], comprises red and purple-coloured siltstones, conglomerates, and a minor number of sandstones and shales. It consists of the Myinlan Formation, Setkyagon Formation, Thithla Formation and Myindaik Formation [1].

Kalaw Red Beds Formation of Myinlan Formation, Setkyagon Formation, Thithla Formation and Myindaik Formation are indicated as Upper Cretaceous [1].

Halfgraben III

Triassic unit

The Triassic Unit includes Halobia Formation, comprising Genus: *Halobia* (emended), Type species: *Halobia salinarum*, in the Halobia Formation, composed of mudstone, shales and sandstones, east of Kalaw City [94-98]. According to the Halobia fossil, the Halobia Formation indicates Upper Triassic.

Jurassic unit

The Jurassic Unit includes the Loi-an formation and the Singu Formation. Lithostratigraphic correlation indicates the Loi-an Formation as Lower-Middle Jurassic, the Singu Formation with coal measures as Upper Jurassic, and the Nyaungbintaung Formation as the Uppermost Jurassic.

Cretaceous unit

The Cretaceous Unit encompasses the Taungni Formation, consisting of red to purple coloured siltstone interbedded with shales and sandstones [1,11,12].

Concerning the underlying Nyaungbintaung Formation, the Taungni Formation is from the Lower Cretaceous, and the Myindaik conglomerate is believed to be from the Upper Cretaceous, as stated by [1].

Halfgraben IV

Triassic unit

The Triassic Unit includes the Turbidite formation.

Jurassic unit

The Lower to Middle Jurassic Unit includes the Loi-an group. The Upper Jurassic Unit includes the Inbyin Formation, consisting of greyish-white sandstones and buff-coloured shales, siltstones, and sandstones with subordinate grey shale [1,11,12].

Lithostratigraphic correlation indicates the Inbyin Formation as Lower to Middle Jurassic, the Inbyin Formation with coal measures as Upper Jurassic, and the Nyaungbintaung Formation as Uppermost Jurassic.

Cretaceous unit

The Cretaceous Unit includes the Kalaw Red Beds Formation, which comprises the Sattchan Conglomerate. Lithostratigraphic correlation indicates the Kalaw Red Beds as Lower to Middle Cretaceous and the Sattchan Conglomerate as Upper Cretaceous.

Halfgraben V

Triassic unit

The Triassic Unit includes the Turbidite formation.

Jurassic unit

The ammonites, *Tmetoceras*, were found in Tikyit-Hiskhip and near Pinlaung City [98]. The coal-bearing fine sand-shale sequence of Tikyit is very similar to the Loi-an series.

Lithostratigraphic correlation indicates the Loi-an Formation as Lower to Middle Jurassic, the Tikyit Formation with coal measures as Upper Jurassic, and the Nyaungbintaung Formation as the Uppermost Jurassic.

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Cretaceous unit

Halfgraben V included the Kalaw Red Beds Formation and the Conglomerate.

Lithologic Description

Triassic unit

This unit is assigned as the Turbidites, which include the dark or black shales and subordinate indurated sandstones. The upper part consists mainly of grey calcareous shales, black carbonaceous shales, and mudstones. The lower part contains a thick bedded to massive greywacke sandstones (Figures 8 and Figure 9). Sedimentary structures are characterised as groove-, flute- and load casts in most of the thin to medium bedded sandstones.

The Turbidite unit is faulted contact against the Plateau Limestone of the underlying formation; however, the upper boundary is demarcated between grey brittle shales and thick bands of calcareous subgreywacke sandstone of the overlying Formation (Figure 10).

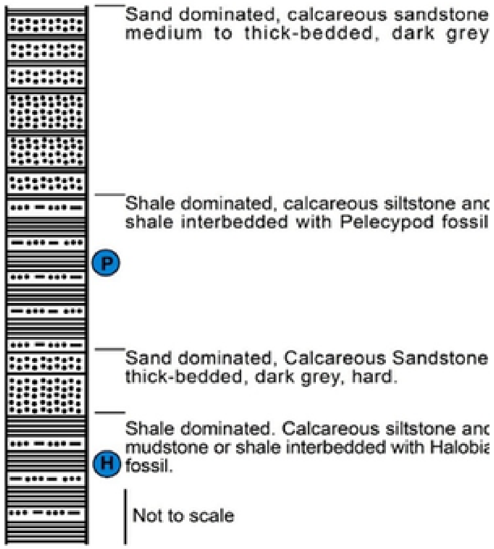

Figure 8. Representative generalised columnar section of the Thapanbauk section from the Turbidite Unit (Triassic) at the Kalaw-Pinlaung Basin, in the Shan Plateau (Sibumasu Block).

Figure 9. Thin to medium-bedded, nearly vertical turbiditic sandstone and shale interbedded in the Thapanbauk section, exposed at the road cut section. Photo looking north-west (20˚ 49' 27.11" N; 96˚ 25' 32.67" E).

Figure 10. A late Triassic Hallobia sp. Observed in the silty mudstone turbidite exposed on a road cut beside the Kalaw-Aungban car road, a mile east of Kalaw (N 20°38′2.24′′, E 96°34′58.72′′) (adopted from [99, 100]).

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Jurassic unit

This unit is assigned as the Loi-an Formation.

Lower part (Lower Jurassic)

The lower part of the Jurassic Unit is composed of medium- to massive, pinkish-brown to grey subgreywacke sandstones and fissile shales. The upper horizon contains a unit of fissile shales. The lower horizon consists of pinkish-brown to grey, medium-bedded to massive, indurated sandstones and siltstones with intercalated shales. The lower part is marked by a sequence of grey subgreywacke sandstone with intercalated shales, while the upper part consists of whitish, thick-bedded to massive, quartzose sandstone (Figure 11).

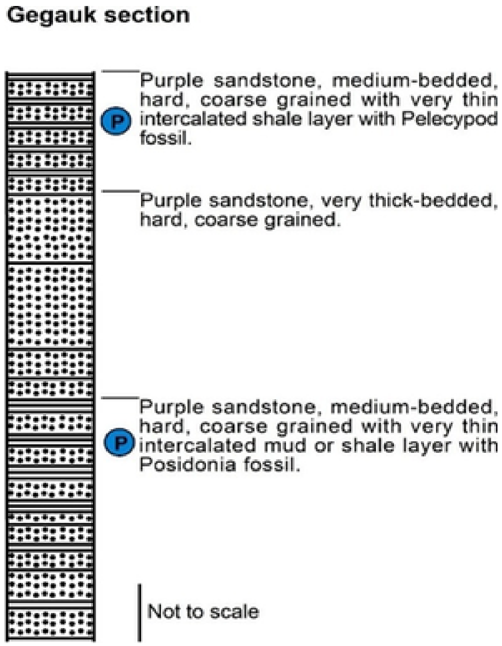

Figure 11. Representative generalised columnar section of the Gegauk Formation from the lower Loi-an Unit at the Kalaw-Pinlaung Basin, in the Shan Plateau (Sibumasu Block).

Fossil content

Pelecypods in the soft siltstones and sandstones, Ammonites in the shales, and Posidonia in black shales and siltstones, Crinoid stems, and sponges in siltstones are predominant.

Pelecypods: *Estheria*, ammonites: *Tmetoceras*, *Erycites*, *Dumertieria*, Posidonia: *Trigonia*, *Corbula Pyriformis*, *Corbula sp.*, *Modiola sp.*, *Arctica sp.*, *Pecten sp.*, *Natica sp. Turritella sp. Erycites cf. fallifax*, *Pseudothurmania*, *Paracrioceras*, *Belemnites* (*Belemnopsis*) [1].

Middle part

The middle part of the Jurassic Unit consists of thick-bedded to massive, white quartzose sandstones with grits and conglomerates (Figures 12 and 13). The white quartzose sandstones are sharply different from the upper part of the overlying coal-measuring formation. It consists of coal-bearing shales, quartzose sandstones and mudstones.

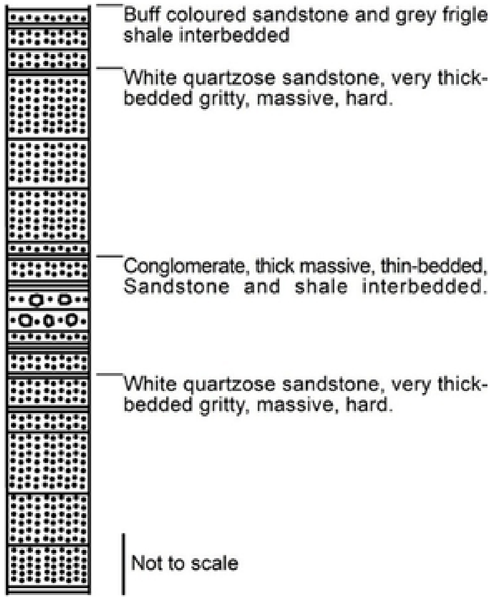

Figure 12. Representative generalised columnar section of the Thitpalwe section from the middle Loi-an Group at the Kalaw-Pinlaung Basin, in the Shan Plateau (Sibumasu Block).

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No Fossil content

Figure 13. Roadside exposure of medium to thick-bedded quartzose sandstone of the Thitpalwe Formation, near Watphyuye Village, Kalaw Township. Photo: looking north-west (20° 42' 14.48" N; 96° 31' 06.32" E).

Upper part (Upper Jurassic)

The upper part of the Jurassic Unit is characterised as a coal-measuring formation, consisting of mudstones or shales with a coal seam, medium to thick-bedded quartzose sandstones and carbonaceous shales. Coal seams occur within the carbonaceous shales (Figure 14).

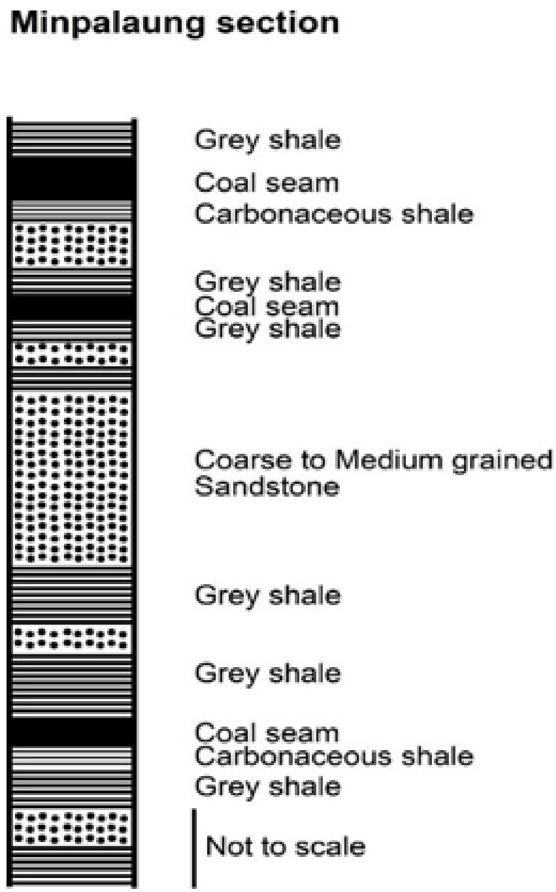

Figure 14. Representative generalised column section of the Minpalaung section from the upper Loi-an Group at the Kalaw-Pinlaung Basin, in the Shan Plateau (Sibumasu Block).

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Fossil content

Abundant Flora: *Ptillophyllum sp., P. brachyphyllum, Todites sp., Alethopteris sp., A. moddieothiana, Glichenites sp., Dicsonia ch. Glecheniana, Zamites cf. gigas, Sphenopteris sp., Pecopteris sp., Echinostrobus rhombicus, Elatides, faleata, Frenelopsis sp., Pagiophyllum sp.*

Uppermost part (Late upper Jurassic)

The uppermost part of the Jurassic Unit is composed mainly of white to buff-coloured siltstone or greenish-grey, purple sandstone and shale alternations (Figure 15).

Figure 15. Exposure of Pyinnyaung Alternation Formation at the Myittha Chaung (20°49'11.87"N, 96°23'56.56"E).

Fossil content

Pelecypod: *Nucula pectinata, Unio sp., Pecten sp., Buchia piochii, Pholadomya sp., Indonearca sp., Radulopecten sp., Lopha gregaria, Unio cf. farri, Gresslya abducta, Ostrea delta, Placunopsis fabrosa, Pinna sp., Patella rugosa* [1].

Cretaceous unit

This unit is assigned as the Kalaw Red Beds Formation. The purple sandstone zone of the Kalaw Red Beds is also revised and proposed to start as the Kalaw Red Beds formation [2,3]. Continental red sediments of the Kalaw Red Beds formation are possibly Cretaceous, as the Cretaceous ammonites reported in the Kalaw Red Beds have been identified as inorganic concretions [4,101].

The Kalaw Red Beds Formation comprised mainly purple or pink-coloured siltstones, sandstones, and conglomerates (Figures 16 and 17). The Kalaw conglomerate includes the upper clay member, which is deep red, calcareous siltstone and shale, soft and friable, with a few thin calcareous sandstones, and the upper conglomerate member: massive, hard, dark purplish; pebbles: 15 cm in diameter, limestone and quartzitic sandstone (Figure 22).

Lower clay member characterised as soft, red clay, siltstone, and shale; a few interbeds of thin calcareous fine sandstone, Ripple, and cross-laminations and the lower conglomerate member: grey to purple, hard, massive; pebbles: 0.5 m in diameter, limestone, greywacke, quartzose sandstone, igneous, metamorphic rocks, Ripple and cross-beds.

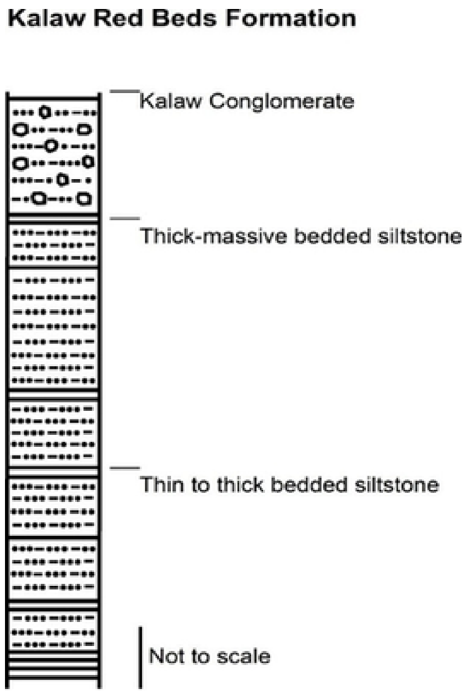

Figure 16. Representative generalised column section of the Kalaw Red Beds Formation at the Kalaw-Pinlaung Basin, in the Shan Plateau (Sibumasu Block).

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Figure 17. Low-angle dipping well-bedded red siltstone of the Kalaw Red Beds Formation is exposed along the road-cut section near Kalaw City (20°37'59.34"N, 96°34'59.67"E).

Figure 18. Sattchan Conglomerate of Kalaw Red Beds formation, including poorly sorted different types of pebbles (21° 1'52.29"N, 96°27'43.28"E).

Lithologic Description

Environmental synthesis

Faunal and floral evidence indicate that the age of the Loi-an Group spanned from the Lower Jurassic (Lias) to the Early Upper Jurassic (Oxfordian). Essentially clastic marine and brackish water sediments of the Loi-an Group (Lower to Upper Jurassic) [1].

A significant change in the depositional environment was caused by tectonic movements, particularly during the main separation of Gondwana into western and eastern Gondwana from the Upper Jurassic onwards [92]. This is evident in the shift from carbonaceous to predominantly clastic sedimentation during the Lower and Middle Jurassic. Turbidites and other clastic rocks were deposited in neritic and paralic environments. In the latter, widespread coal seams originated in the Loi-an Group. Therefore, the facies conditions in the Kalaw-Pinlaung area of the Shan Plateau point to a general regression phase, which was interrupted by minor transgressions (Figure 19).

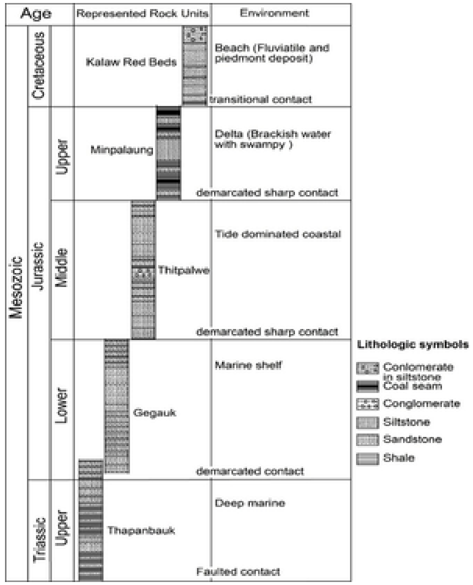

Figure 19. Generalised combined columnar section with its sedimentation environment of the Kalaw-Pinlaung Basin in the period of Mesozoic time.

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The facies and position of the Upper Jurassic sediments in the stratigraphic sequences, as well as their structural deformation, indicate that an uplifting, faulting and folding phase (Late Jurassic- the Kimmeridgean orogenic movements) took place around the Sino-Burman Ranges (Sibumasu Block), before the deposition of the Cretaceous sediments [25].

The Thapanbauk Formation's base (lower boundary) is faulted against the Plateau Limestone (Nwabangyi Formation), and its upper boundary is demarcated by grey to dark grey shale and light grey thick bands of calcareous sandstones of Gegauk Formation. The Gegauk Formation is distinctly marked by its light grey, thick-bedded sandstones, and the overlying Thitpalwe Formation features whitish, massive, too thick-bedded quartzose sandstones. The Thitpalwe Formation clearly differs from its whitish quartzose sandstones from the shales of the overlying Minpalaung Formation. The Minpalaung Formation is demarcated distinctly from buff siltstones and shales. The Nyaungbintaung Formation is transitional, with the upper units consisting of purple or red soft sandstones and siltstones of the Taungni Formation (KRB).

During the Minpalaung Formation, when the coal seams were discovered, the basin became progressively shallower and reached brackish water conditions with swampy environments. Brackish to lagoon-like conditions persisted during the Nyaungbintaung Formation, when a thick sequence of shell-like facies of sandstones, shales, and limestone lenses was deposited (Figure 20).

During the deposition of the red sediments of the Taungni Formation from the Lower Cretaceous onwards, the Kalaw-Pinlaung Basin was characterised by continental conditions, with the areas of the Shan Plateau being subject to strong tectonic movements or inversion tectonics.

Figure 20. Folded and deformed thin-bedded uppermost Jurassic Unit showing different colouring (paleo-weathering) of siltstone and laminated shale alternations (Pyinyaung Alternations or Nyaungbintaung formations) gradationally contact with overlying medium to thick-bedded red siltstone of Kalw Red Beds Formation, near Yeyar Village, northwest of Kalaw City. Photo: looking south-west, (20° 41' 51.54" N; 96° 31' 35.51" E).

Structural synthesis

The Plateau Limestones, especially the Nwabangyi Limestone, were deposited on the Thitsipin Limestone, a pre-rift sedimentary rock that appears as block-faulted high mountain ranges, such as Pyinnyaung, Ngabauk, Sindaung, Panlaung, Myinyoktaung, and Lwelontaung scarps. The block-faulted mountain ranges are generally trending NNW-SSE, and thrust faults, such as Nampandet, Kadan, and Sintaung thrusts, are also nearly the same direction as the block-faulted mountain ranges due to basin inversion during Jurassic and Cretaceous tectonic movements [1].

Near Kalaw, the NNW-trending faults, which detach themselves from the Nwalabo Fault Belt, control the elongated, graben-like structures which contain the tightly folded Jurassic Loi-an Series and the overlying Kalaw Red Beds [5,25]. Garson also described the disharmonic folding of the Loi-an Group, whereas they assumed that the Triassic evaporates may be present around Kalaw as a slip horizon to contribute to the complex fold structure with overthrusts oriented in all directions [20].

Along the Panlaung fault, parallel faulted block structures containing the tight folds are well characterised as the alternation of Permo-Triassic limestones and Jurassic clastic rocks, which indicate the old extensional faults (a normal fault), because developed thrust faults are shown as W- and E-vergence [102,103,21].

Fine clastic turbidite sediments (flysch character) are characterised as a thick sequence of sandstone, with tight folding and faulting, greywackes, graded bedding, and slump structures. The turbiditic sedimentation was followed by a shallower and more stable type of sedimentation when the quartzose sandstone and gritty sandstones were deposited during the Thitpalwe Formation.

Turbidite sedimentation can also originate in fault-controlled extensional basins, as described for the Triassic of northeastern Thailand, for the Middle Devonian of the Lahn-Dill area, Germany, for South Africa, and the Jurassic of the North Sea [104-107].

The pronounced ancient relief of this region, with its long NNW-striking basin (Figure 1B) and faulted-block uplift zones, was caused by syn-sedimentary block movements. This relief yielded the clastic debris of Jurassic to Cretaceous red sediments. Brunnschweiler and Garson et al. stressed that the red beds concordantly overlie the older sediments in the half-graben basins [108,20]. This observation indicated continuous block-tectonic events, which were later followed by the enormous uplift movements resulting from the Cretaceous forced subduction at the Indo-Myanmar Ranges [24].

Brown and Sondhi have stated that Tertiary fault movements also created the intra-montane basins, which received Tertiary and Quaternary freshwater sediments, such as those in the Inle Lake basin, Thamakan basin, and Heho basin [5]. However, those basins are surrounded by the Kalaw Red Beds Formation, which has formed since the Cretaceous period. Likewise, there was

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deposition of shallow-sea and deltaic sediments in a few down-faulted intermontane basins and shallow seas within and along the western part of the still-rising Shan Plateau, including turbidites with coal seams in the Kalaw-Pinlaung Basin; sandstones, shales, and limestones in the Kinda-Kyaukse area [33].

Nwalabo Thrust Belt: Garson et al. include, namely, Natteik thrust and Ganan thrust, which is E-vergence, and probably reactivated the old gravity fault of the Panlaung Basin during the Cretaceous time [20,109]. Similarly, Mitchell reported that the westerly dip and tectonic repetition of Palaeozoic and Mesozoic rocks have been explained by east-vergent thrusting along the Panlaung fault, which was probably initiated in the late Lower Cretaceous [56,110].

Some of these faults control the fault scarp between the Shan Plateau, which is here composed mainly of Permo-Triassic carbonates, and a foreland containing chiefly clastic sediments and locally para-metamorphic rocks (Mergui Group), where the Permian fossils were recently discovered (fossils: reported by [24]).

Garson traced the Panlaung Fault, which separates the Jurassic-Cretaceous Panlaung Formation from the Ordovician to Triassic sedimentary series of the Shan Plateau in the Neyaungga area or the zone of tightly folded clastic sediments of Jurassic-Cretaceous units [20]. Borders on the Panlaung Fault, which separates this unit from the widely folded zone of the Shan Plateau (Figure 20-22).

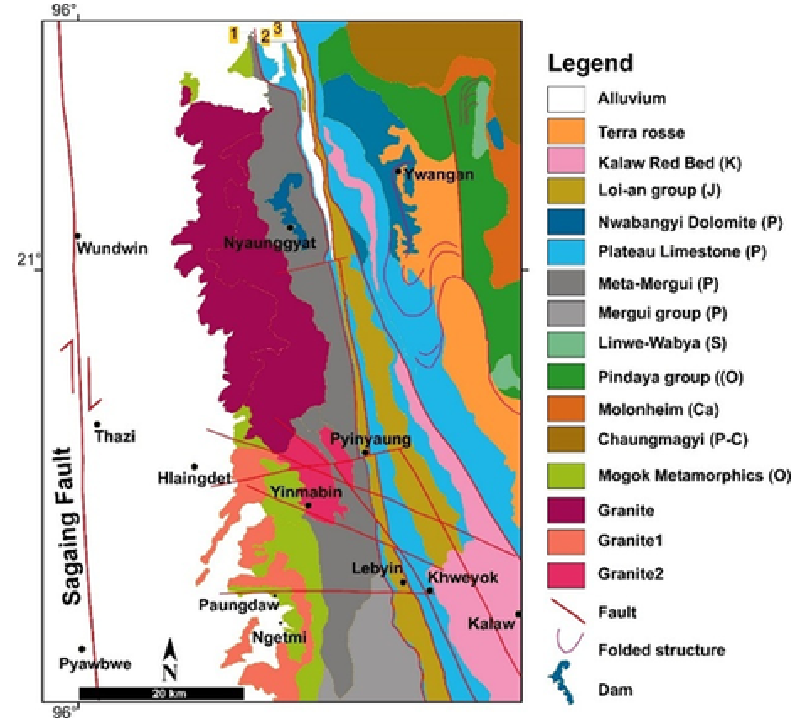

Figure 21. Geological map of the Ywangan-Kalaw area showing the northern part of the Kalaw-Pinlaung Basin. 1= Myitthar-Paunglaung Fault, 2= Pyinnyaung Fault, 3= Panlaung Fault.

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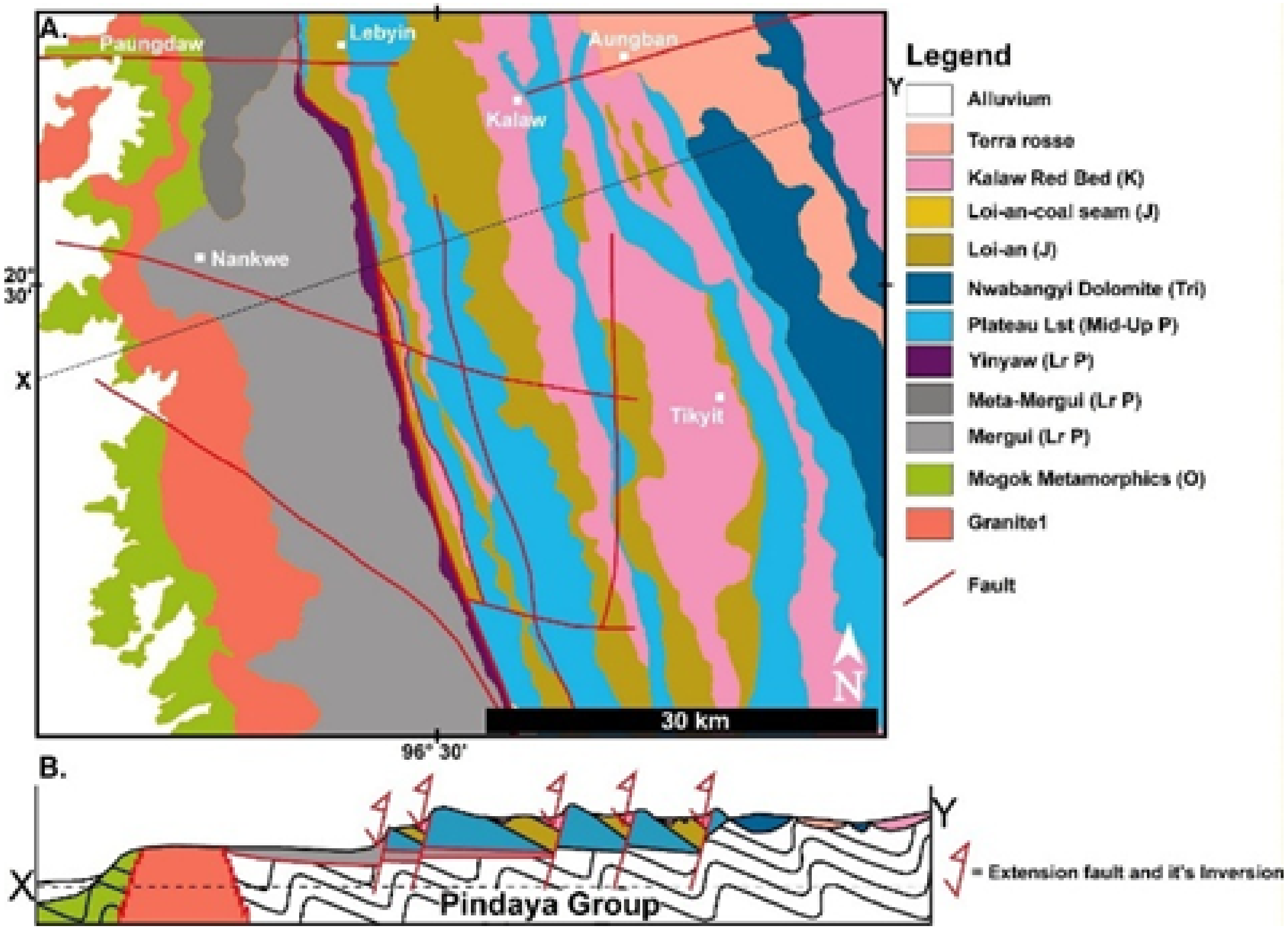

Figure 22. A. Geological map of the Kalaw-Tikyit area showing the middle part of the Kalaw-Pinlaung Basin. B. Interpretative cross-section along X-Y emphasising the stratigraphy of the area of Kalaw-Pinlaung Basin.

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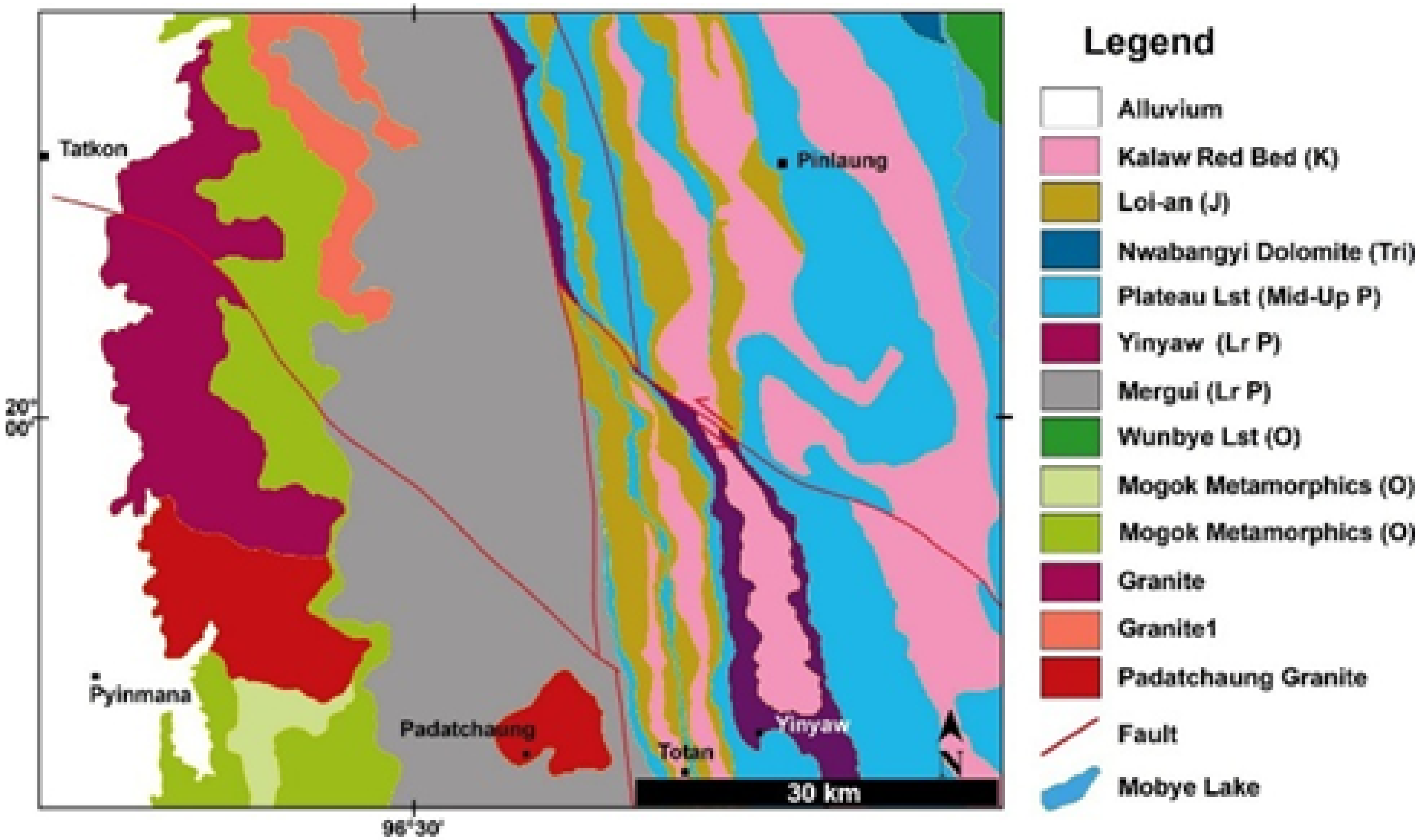

Figure 23. Geological map of the Pinlaung area showing the southern part of the Kalaw-Pinlaung Basin.

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Discussion on Faults development

Sagaing fault

La Touche used a branch of the boundary fault separating the Shan Plateau and the Central Myanmar Basin. Bender adopted the name "Shan Boundary fault" [25,111]. The existence of the boundary or the Shan Scarp fault at the foot of the Shan Scarp was accepted by some workers, including [29,112]. Win Swe revealed that the Sagaing Fault is separate, by the geophysical methods of, from the Shan Scarp Fault or boundary fault of [35,113,114,111]. However, Win Swe presumed that the Shan Scarp Fault, to which the Sagaing Fault is probably related, is nowadays located to the east along the foot of the Shan Scarp [35]. Sagaing Fault is a major dextral strike-slip fault, and vertical component of displacement, further south, up to Sagaing, only piercing through a sedimentary cover and underlying oceanic crust.

Shan-Scarp fault

Although the Shan-Scarp Fault did not exist, previous researchers had presumably divided it with fault throws of approximately 1,300 m from the Shan Plateau. Likewise, Myanmar Geosciences Society and Sloan showed that the Shan Scarp Fault on the western side of the Shan Plateau is a major NNW-SSE-trending fault, as the Panlaung, Paunglaung or Shan Scarp Fault, and it separates the Slate Belt to the west from the Paunglaung-Mawchi zone to the east, linking up with strands of the Mae-Ping Fault Zone [27,115-117]. Morley and Searle and Ridd showed the Shan Scarp Fault in a map view along the Panlaung and Paunglaung Fault [118,119]. Vigny noted that some dextral movement has continued in recent times along the Panlaung Fault (which they call the Shan Scarp Fault), supporting their view that not all the Indian Plate margin shear is taking place on the Sagaing Fault. Ridd indicated that in Central Myanmar, the Karen-Tenasserim Unit's boundary with the Shan Plateau to the east was stated by to be the Panlaung Fault (confusingly called the Shan Scarp Fault by the eastern bounding fault system of the Karen-Tenasserim Unit, which could therefore be viewed as the forerunner of the Miocene and younger Sagaing Fault [25,40,119].

Panlaung fault

The Panlaung Fault (also known as the Panlaung Fault Complex: the Nwalabo Fault Complex: the Panlaung Fault System: the Kanaw Thrust Zone: and the Kanan Thrust Zone: which runs along the Panlaung River as well as a Shan Scarp (west of the Pindaya Anticline), separates the mainly carbonate sequence of the Shan Plateau extending from the Ordovician into the Triassic from the Jurassic-Cretaceous Panlaung formation [20,25,56,120,121]. Garson estimated total fault throws of approximately 1,300 m, representing the amount by which the foreland in the west was lowered relative to the Shan Plateau [20].

Bender stated that the Nwalebo Fault Belt, which accompanies the Panlaung Fault in the E, forms a zone of intensely faulted and shattered limestone, divided up by subsidiary sub-parallel faults into numerous narrow wedges of widely different thickness and extent [25].

To the south, the fault complex disintegrates into a fault bundle trending NNW-SSE, which can be traced alongside the Panlaung Fault to the Paunglaung Fault over several hundred kilometres. It presumably extends into Thai territory, aligning with the Moei-Uthai Thani Fault Zone. The Moei-Uthai Thani Fault Zone, named by was previously referred to as the Papun or Wang Chao Fault Zone; however, it is now known as the Mae-Ping Fault because of the location of Mae-Ping National Park [25,122,123].

Garson was able to show that movement along the Panlaung Fault commenced in the Jurassic but took place for the most part during the Tertiary. However, the region near the Panlaung Fault was already tectonically active during the Palaeozoic, because two areas with different lithofacies (Two: Lebyin Group and Wunbye/Naungkangyi-, Wabya/Panghse-pye Formation) and paleogeographic development adjoin each other along this zone [20].

Paunglaung fault (Paunglaung-Mawchi zone)

The Paunglaung Fault generally runs in an NNW-SSE direction along the Paunglaung River, which separates the Mergui Group (locally known as the Lebyin Group) from the Kalaw-Pinlaung Basin. Earlier researchers considered the Panlaung Fault to the south as a continuation of the Paunglaung Fault over several kilometres. Morley, Searle and Ridd depicted the Paunglaung Fault as the Shan Scarp Fault in map view, starting along the Panlaung Fault [23,118,119]. The Paunglaung-Mawchi Fault separates the Slate Belt to the west from the Paunglaung-Mawchi zone to the east, as noted by and connects with strands of the Mae-Ping Fault Zone [124].

Relocation of the Kalaw-Pinlaung Basin area

The relocation of the Kalaw-Pinlaung Basin, or continental extensional basin, is based on the following evidence.

Regarding the Halobia fossil, the Kalaw-Pinlaung Basin was formed during the Upper Triassic through Turbidite sedimentation in a deep marine environment—the continental extensional basin's opening outlet to the Neo-Tethys ocean.

The Panlaung area is in the northern part of the Kalaw-Pinlaung Basin, where three faults are present: the Panlaung Fault with the Panlaung Scarp alongside the Panlaung River, the Pyinnyaung Fault along with the Pyinnyaung Scarp, and the Myitthar Fault along the Myitthar River. These three faults represent the relict listric normal fault block of pre-rift sedimentary rocks (Thitsipin Formation and Mergui Group) from the Triassic continental extension of the

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Sibumasu Block. Furthermore, the Kalaw-Pinlaung Basin developed as a synthetic half-graben type basin characterised by listric normal faults.

Although these three faults occur together in the Panlaung area to the north, they are separated from each other in the Kalaw and Pinlaung City areas to the south.

The Kalaw-Pinlaung Basin was narrow to the south, as evidenced by the Half-graben basins becoming narrow to terminate based on the exposures of Turbudites, Loi-an Group and Kalaw Red Beds. The Mergui Group, Yinyaw formation, is also exposed near Pinlaung City.

Therefore, the outlet of the extensional basin (Kalaw-Pinlaung Basin) could be located at the Kyaukse-Lungyaw area to the north, south of Mandalay City and narrow to the south, south of Pinlaung City (Figure 24).

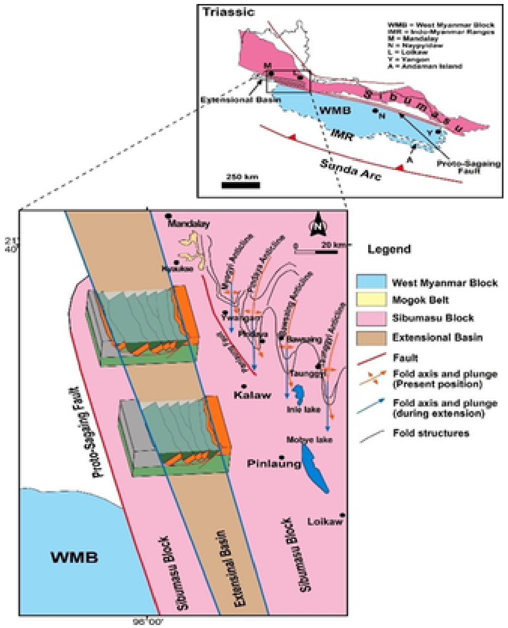

Figure 24. Relocation of the continental extensional basin of the Kalaw-Pinlaung Basin, as a synthetic half-graben basin with listric normal fault development in a 3D diagram during the ongoing Neo-Tethys ocean opening of the Triassic period on the present west margin of the Sibumasu Block. WMB = West Myanmar Block.

Tectonic Interpretation

West Myanmar block

On the Indo-Myanmar Ranges, the Kanpetlet Schist was formed during the Cretaceous period through lithostratigraphic correlation, which was developed as a pop-up structure in the Chin Hills area based on the Mega-Buckle fold concept [38,53]. Morley also indicated that the profile across the Mount Victoria area shows the exhumation of the Kanpetlet Schist at the highest point, positioned as the axis of the IMR between the retro-wedge and pro-wedge [125,126]. Although the formation of a pop-up structure (as an exhumation feature) in an accretionary prism is common, the forced subduction during the Cretaceous suggests the development of an open wedge along the IMR [127]. The Woyla nappe is also interpreted as an intra-oceanic arc thrust over the West Sumatra Block in the mid-Cretaceous [128]. Due to the movement of the Indian Plate relative to the Eurasian Plate during the Gondwana breakup in the Cretaceous, this is characterised by forced subduction along the IMR at the western margin of the proto-West Myanmar Block and the proto-West Sumatra Block [129].

Similarly, the forced collision (Subduction) during the Cretaceous is evidenced by the Kanpetlet Schist (greenschist facies), ophiolite obduction in the IMR, Mawgyi volcanic arc (Izu-Bonin-Mariana proto-arc type), and associated limestone lenses containing Cretaceous fossils that formed an open wedge (double wedge) on the proto-Indo-Myanmar Ranges [63]. During the Cretaceous, limestone units were associated with Flysch as lenses within the Kanpetlet Schist and with Molasse sediments in the Kabaw Formation of the forearc basin.

Sibumasu block

There are three main distinct faults, including Panlaung, Pyinnyaung, and Myitther-Paunglaung faults, characterised by fault scarps over long distances.

The Panlaung Fault, therefore, appears to be a zone where significant structural movements were already active during the Palaeozoic [25]. However, some of these movements occurred after the Jurassic, as suggested [121].

According to the wide folded structures in the Southern Shan Plateau with NNW-trending axes in Cambro-Ordovician sediments were caused by vertical displacements of blocks of the underlying Chaung-magyi Group [20,25]. In post-Permian times, folding was continued about the same axes because of continued upward movements of the Chaung-magyi horst structures. Consequently, the pre-existing folds in the pre-Devonian rocks were accentuated, and the unconformably overlying Permian rocks acquired dips in the same direction but of lesser magnitude.

Bender stated that strong fault movements and thus a resurrection of the division that existed in the Palaeozoic did not take place before the Cretaceous and Tertiary along the

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Panlaung Fault at the boundary between the Palaeozoic sedimentation regions. These movements resulted in an uplift of the Shan Plateau in the east, in which, from then on, only continental sediments were deposited in intermontane basins. The Panlaung fault appears to represent a zone in which considerable structural movements were already active during the Palaeozoic [25].

From the distribution of conglomerates in the Kalaw Red Beds, Gerson was able to deduce a rapidly uplifted block of limestone to the west of the Panlaung Fault. Throughout the Cretaceous and the Tertiary, however, the western blocks were subsiding [20,25].

The Panlaung, Pyinnyaung, and Myitthar-Paunglaung faults originated from listric normal faults, characterised as synthetic half-graben basins with pre-rift sediments of Permian-Triassic units, which were reactivated during inversion, starting with the breakup of Gondwana during the Late Jurassic and Cretaceous periods.

Sukhothai block

Sukhothai Block includes the Sukhothai Block and the Inthanon zone. During the closure of the Paleo-Tethys Ocean, the Sibumasu Block collided with the Sukhothai Block, forming the Inthanon Zone of accretionary prism, which is sutured to the Sibumasu Block, known as the Thanlwin Suture [46,47]. The Paleo-Tethys Ocean was situated between the Cimmerian Superterrane, before it moved north, and the Asian Hunian terranes, including the North and South China microcontinents, which migrated northward during the Triassic. Muttoni noted that plate tectonic scenarios during the Permian-Triassic, involving the opening of the Neo-Tethys Ocean, the subduction of the Paleo-Tethys Ocean, and the movement of the Cimmerian Superterrane, occurred during the Permian-Triassic, a hypothesis supported by several authors [130].

The Cimmerian Superterrane began moving northward, closing the Paleo-Tethys Ocean while the Neo-Tethys Ocean started opening from the south of the Cimmerian Superterrane around 249 Ma (Permian-Triassic boundary) [62]. By the Late Triassic, only a narrow seaway remained of the Paleo-Tethys Ocean.

Instead of a single Cretaceous closure of the Paleo-Tethys, the Cretaceous was a pivotal period where the older Paleo-Tethys was transitioning through its closing process while simultaneously giving rise to the Neo-Tethys Ocean in other areas (Figure 25).

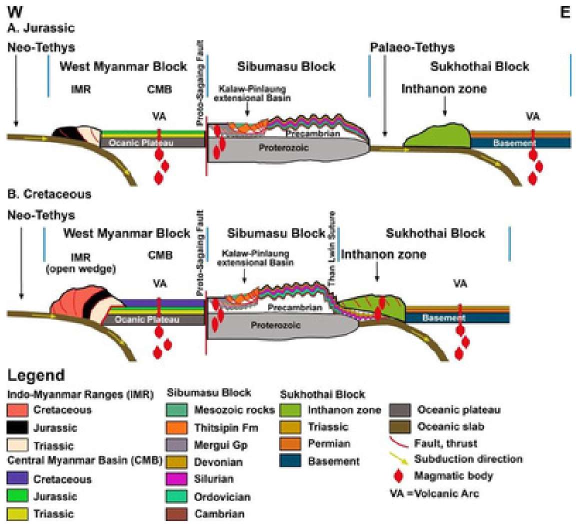

Figure 25. Schematic cross-sections showing the evolution of a double-sided wedge system in the IMR during the Jurassic to Cretaceous. A. Single wedge system until Jurassic. B. The open wedge (double-sided wedge) development in the Cretaceous. The positions of the accretionary prism of IMR, fore-arc basin (part of CMB), and Volcanic Arc (VA). (Note: Flysch-type sediments in an accretionary prism of IMR and Molassic-type sediments in CMB) (for Myanmar and for Thailand) [127].

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Conclusions

The study concludes that the Kalaw-Pinlaung Basin is a synthetic half-graben basin, characterised by its structure, sedimentology, stratigraphy, and paleotology, which reveal the Triassic opening of the Neo-Tethys Ocean and the subsequent development of a Continental Extensional Basin in the Sibumasu Block, as seen in the Kalaw-Pinlaung Basin of the Shan Plateau, Myanmar.

1. Tectono-structural implications of passive continental extensional basin evolution characterised as opening and closing with the palaeogeographical assessment on the western margin of the Sibumasu Block.
2. Lithostratigraphic assessment of the Kalaw-Pinlaung area with the Turbiditic Unit, Loi-an Unit, and Kalaw Red Beds Unit as syn-rift and post-rift sediments.
3. Pre-rift sediments of Permian (Thitsipin Limestone) and Triassic (Plateau Limestone) are recognised as fault-bounded blocks, trending parallel with basin alignment.
4. Stratigraphical arrangement with opening and closing of the extensional basin based on the environment of deep marine to beach (fluviatile) changes.
5. The consequence of tectonic movement on the Myanmar Region is distinguished as a domino-type deformation during the Mesozoic period.

In conclusion, half-grabens are complex geological structures that play a crucial role in understanding various geological processes. Their formation is controlled by extensional tectonics and faulting, and their characteristics and features provide valuable insights into the tectonic evolution of the Myanmar Region. The study of half-grabens is significant for hydrocarbon exploration, geological hazard assessment, and reconstructing Earth's geological history.

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Disclosure Statement

No potential conflict of interest was reported by the author.

References

1. Win KM, Latt KM, Naing T, Minko, Thet Z, Myittar, et al. Stratigraphy of the Kalaw-Panlaung basin (Jurassic- Cretaceous) of the Southern Shan State, Burma. Unpublished report, University of Yangon. 1980;44.
2. Middlemiss CS. Report on a Geological Reconnaissance in parts of the Southern Shan States and Karenni. General report of the geological survey of the India for the year. 1899;1900:122-153.
3. de Cotter G P. Confidential report on the Loi-an coalfield. Rec Geol Surv India 63. 1930.
4. Fox CS. On the occurrence of Cretaceous Cephalopods in the red beds of Kalaw, southern Shan State, Burma Rec Geol Surv. India. 1930;63:182-187.
5. Brown JC, Sondhi VP. The geology of the country between Kalaw and Taunggyi, Southern Shan States. Geol Surv India; 1964.
6. Clegg EL. The Cretaceous and associated rocks of Burma. 1941.
7. Kobayashi T. Notes on the geologic history of Thailand and adjacent territories: Jap Jorn, of geol and geog. 1960;31(2-4):1964.
8. Thein M, Haq BT. The pre-Palaeozoic and Palaeozoic stratigraphy of Burma: a brief review. Union Burma J Sci Technol. 1969;2:275-287.
9. Thein M, Than TK, Ko M. Geology and mineral resources of the Yinmabin and Thetkedeik areas, eastern Meiktila and western Taunggyi District. InBurma Research Congress. 1972;82.
10. Win KM. Geology and Stratigraphy of The Kalaw-Aungban Area, southern Shan State (Doctoral dissertation, MSc Thesis, Geology Department, University of Yangon, Unpublished). 115p.
11. Latt KM. Stratigraphy and structure of the eastern Thazi and western Kalaw Area (Doctoral dissertation, M. Sc Thesis. Geology Department, University of Rangoon, Unpublished.
12. Saw Pe. Regional geology and stratigraphy of Kalaw –Myindaik Area. Unpublished MSc. Thesis, University of Yangon. 1983; 91.
13. Kyi Soe. The Stratigraphic Palaeontology of the Jurassic and Cretaceous Units of the Western part of the Southern Shan state. PhD Thesis. 2006; 170.
14. Thein MM. Sedimentology of the Loi-An Group in the Western margin of the Shan Plateau, Thazi and Kalaw Townships, Doctoral dissertation, MERAL Portal.
15. Wolfart R, Win UM, Boiteau S, Wai UM, Cung UU, Lwin UT. Stratigraphy of the western Shan massif, Burma. Geologisches Jahrbuch. Reihe B, Regionale Geologie Ausland. 1984;57:3-92. Available at: https://books.google.co.in/books/about/Stratigraphy_of_the_Western_Shan_Massif.htmlid=S9l0jwEACAAJ&redir_esc=y
16. Thein M, San B, Thein M. Geological Reinvestigation and Jurassic Cretaceous Sedimentation of the Area East of Kyaukse-Belin, Mandalay Division. Unpublished Report, University of Mandalay. 1984.
17. Fay Lain, et al., 1971. Stratigraphy and sedimentation of the Mesozoic rocks in the northern part of the Kalaw area, southern Shan State. Unpublished report, Myanmar Oil and Gas Enterprise, Myanmar.

https://doi.org/10.61577/jgi.2025.100016

18. Garson MS, BJ A, Ahg M. The Geology of The Country around Neyaungga and YE-Ngan, Southern Shan States, Burma. Available at: https://books.google.co.in/books/about/The_Geology_of_the_Area_Around_Neyaungga.html?id=xG-4ExP8W7UC&redir_esc=y
19. Mitchell AH. The Shan Plateau and western Burma: Mesozoic-Cenozoic plate boundaries and correlations with Tibet. InTectonic evolution of the Tethyan region 1989;567-583. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-009-2253-2_24
20. Win CT, Oo MZ, Aung N, Oo MS, Oo T, Win Z, et al. Lithostratigraphy of the Loi-an Group, Kyatsakan and Nampandet Areas, Tharzi Township, Mandalay Region.
21. Aung KP, Khin K, Zaw T, Moe A. Carboniferous-Permian sequences of the western margin of Sibumasu Block: Implications for new lithostratigraphic correlation in the eastern Highlands of Myanmar. Geosystems and Geoenvironment. 2024;3(1):100240. https://doi.org/10.1016/j.geogeo.2023.100240
22. Aung KP, Khin K, Zaw T, Moe A. Biostratigraphic correlation of Carboniferous-Permian sequences of the western margin of the Sibumasu Block in the Eastern Highlands of Myanmar. Earth Hist Biodiv. 2025:100030. https://doi.org/10.1016/j.hisbio.2025.100030
23. Bender F. Geology of Burma: Gebrüder Borntraeger. Berlin. Stuttgart. 1983.
24. Thein ML, Myint O, Kyi S, Win HN. Geology and stratigraphy of the metamorphosed early Paleozoic rocks of the Mogok-Thabeikkyin-Singu-Madaya Areas. Unpublished staff report. 1990;98.
25. Myanmar Geosciences Society (MGS). Geological Map of Myanmar, 1:2,2014.
26. Stamp LD. An outline of the Tertiary geology of Burma. Geol Mag. 1922;59(11):481-501. https://doi.org/10.1017/S001675680010915X
27. Chhibber HL. The Geology of Burma Macmillan and Co. London, 538p. 1934.
28. Tainsh HR. Tertiary geology and principal oil fields of Burma. AAPG Bulletin. 1950;34(5):823-855. https://doi.org/10.1306/3D933F56-16B1-11D7-8645000102C1865D
29. Thein M. A preliminary synthesis of the geological evolution of Burma with reference to the tectonic development of Southeast Asia.
30. Thein M. The Geologic Evolution of Burma. Department of Geology, University of Mandalay. 1983:26.
31. Thein M. Summarry of the Geologic Evolution of Myanmar. Department of Geology, University of Yangon,(unpublished). 2000:6.
32. T Maung. Geological Map of Myanmar. Explanatory Brochure. Myanmar Geosci Soc. 2014p. 32.
33. Win SW. A major strike-slip fault in Burma. InRegional Conference on the Geology of SE Asia, Kuala Lumpur.1981;1981.
34. Swe W. Outline geology and economic mineral occurrences of the Union of Myanmar. Myanmar Geosciences Society; 2012. Available at: https://books.google.co.in/books/about/Outline_Geology_and_Economic_Mineral_Occ.html?id=QDi3MwEACAAJ&redir_esc=y
35. Khin K, Moe A, Myint M, Aung KP. Dextral transpressional shearing and strike-slip partitioning developments in the Central Myanmar Basin during the collision between the India Plate and West Myanmar Block. J Asian Earth Sci: X. 2021;5:100055. https://doi.org/10.1016/j.jaesx.2021.100055
36. Khin K, Moe A, Aung KP. Tectono-structural framework of the Indo-Myanmar Ranges: implications for the structural development on the geology of the Rakhine Coastal Region, Myanmar. Geosystems and Geoenvironment. 2022;1:100079. https://doi.org/10.1016/j.geogeo.2022.100079
37. Searle MP, Noble SR, Cottle JM, Waters DJ, Mitchell AH, Hlaing T, et al. Tectonic evolution of the Mogok metamorphic belt, Burma (Myanmar) constrained by U-Th-Pb dating of metamorphic and magmatic rocks. Tectonics. 2007;26(3). https://doi.org/10.1029/2006TC002083
38. Vigny C, Socquet A, Rangin C, Chamot-Rooke N, Pubellier M, Bouin MN, et al. Present-day crustal deformation around Sagaing fault, Myanmar. J Geophys Res Solid Earth. 2003;108(B11). https://doi.org/10.1029/2002JB001999
39. Curray JR. Tectonics and history of the Andaman Sea region. J Asian Earth Sci. 2005;25(1):187-232. https://doi.org/10.1016/j.jseaes.2004.09.001
40. Ueno K. The Permian fusulinoidean faunas of the Sibumasu and Baoshan blocks: their implications for the paleogeographic and paleoclimatologic reconstruction of the Cimmerian Continent. Palaeogeogr Palaeoclimatol Palaeoecol. 2003;193(1):1-24. https://doi.org/10.1016/S0031-0182(02)00708-3
41. Ali JR, Cheung HM, Aitchison JC, Sun Y. Palaeomagnetic re-investigation of Early Permian rift basalts from the Baoshan Block, SW China: constraints on the site-of-origin of the Gondwana-derived eastern Cimmerian terranes. Geophys J Int. 2013; 193(2):650-663. https://doi.org/10.1093/gji/ggt012
42. Li G, Wang Q, Huang Y, Chen F, Dong P. Discovery of Hadean–Mesoarchean crustal materials in the northern Sibumasu block and its significance for Gondwana reconstruction. Precambrian Res. 2015;271:118-137. https://doi.org/10.1016/j.precamres.2015.10.003

https://doi.org/10.61577/jgi.2025.100016

43. Barr SM. Toward a late Palaeozoic-early Mesozoic tectonic model for Thailand. J Thai Geosciences. 1991;1:11-22.

44. Ridd MF. East flank of the Sibumasu block in NW Thailand and Myanmar and its possible northward continuation into Yunnan: a review and suggested tectono-stratigraphic interpretation. J Asian Earth Sci. 2015;104:160-174. https://doi.org/10.1016/j.jseaes.2014.01.023

45. Aung HH. University, Bangkok, Thailand, 26-27 October 2015 Delineation of western boundary of Paleo-Tethys suture zone in Myanmar.

46. Ueno K. Gondowana/Tethys divide in east Asia: Solution from Late Paleozoic foraminiferal Paleobiogeography. InShallow Tethys 1999; 5:45-54.

47. Sone M, Metcalfe I. Parallel Tethyan sutures in mainland Southeast Asia: New insights for Palaeo-Tethys closure and implications for the Indosinian orogeny. Comptes Rendus Geoscience. 2008;340(2-3):166-179. https://doi.org/10.1016/j.crte.2007.09.008

48. Hara H, Kunii M, Hisada KI, Ueno K, Kamata Y, Srichan W, et al. Petrography and geochemistry of clastic rocks within the Inthanon zone, northern Thailand: implications for Paleo-Tethys subduction and convergence. J Asian Earth Sci. 2012;61:2-15. https://doi.org/10.1016/j.jseaes.2012.06.012

49. Hara H, Wakita K, Ueno K, Kamata Y, Hisada KI, Charusiri P, et al. Nature of accretion related to Paleo-Tethys subduction recorded in northern Thailand: constraints from mélange kinematics and illite crystallinity. Gondwana Res. 2009;16(2):310-320. https://doi.org/10.1016/j.gr.2009.01.006

50. Hossain MS, Xiao W, Khan MS, Chowdhury KR, Ao S. Geodynamic model and tectono-structural framework of the Bengal Basin and its surroundings. J Maps. 2020;16(2):445-458. https://doi.org/10.1080/17445647.2020.1770136

51. Khin K, Moe A, Myint M. Geology, structure and lithostratigraphic framework of the Rakhine Coastal Ranges in western Myanmar: Implications for the collision of the India Plate and West Myanmar Block. J Asian Earth Sci. 2020;196:104332. https://doi.org/10.1016/j.jseaes.2020.104332

52. Myint LT. On the occurrence of Daonella facies from the Upper Chindwin area, Western Burma. Union Burma J Sci Technol. 1970;3:277-282.

53. Gramann F. Some palaeontological data on the Triassic and Cretaceous of the western part of Burma (Arakan Islands, Arakan Yoma, western outcrops of Central Basin); Some palaeontological data on the Triassic and Cretaceous of the western part of Burma (Arakan Islands, Arakan Yoma, western outcrops of Central Basin). Newsletters on Stratigraphy. 1974;3(4):277-290. https://doi.org/10.1127/nos/3/1974/277

54. Khin K, Sakai T, Zaw K. Neogene syn-tectonic sedimentation in the eastern margin of Arakan–Bengal basins, and its implications on for the Indian–Asian collision in western Myanmar. Gondwana Research. 2014;26(1):89-111. https://doi.org/10.1016/j.gr.2013.04.012

55. Khin K, Zaw K, Aung LT. Geological and tectonic evolution of the Indo-Myanmar Ranges (IMR) in the Myanmar region. https://doi.org/10.1144/M48.4

56. Limarino CO, Césari SN, Spalletti LA, Taboada AC, Isbell JL, Geuna S, et al. A paleoclimatic review of southern South America during the late Paleozoic: a record from icehouse to extreme greenhouse conditions. Gondwana Research. 2014;25(4):1396-1421. https://doi.org/10.1016/j.gr.2012.12.022

57. Şengör AC, Altıner D, Zabcı C, Sunal G, Lom N, Aylan E, et al. On the nature of the Cimmerian Continent. Earth-Sci Rev. 2023;247:104520. https://doi.org/10.1016/j.earscirev.2023.104520

58. Wang XD, Hu KY, Shi YK, Chen JT, Yang SR, Ye XY, et al. The missing upper Carboniferous in the Cimmerian continent: A critical review. Earth-Sci Rev. 2021;217:103627. https://doi.org/10.1016/j.earscirev.2021.103627

59. Dèzes P. Tectonic and metamorphic evolution of the central Himalayan domain in southeast Zanskar (Kashmir, India).

60. Khin K, Moe A, Aung KP, Zaw T. Triassic subduction initiation and Cretaceous forced collision along the West Myanmar Block. Evolving Earth. 2025:100086. https://doi.org/10.1016/j.eve.2025.100086

61. Şengör AC. Mid-Mesozoic closure of Permo–Triassic Tethys and its implications. Nature. 1979;279(5714):590-593. https://doi.org/10.1038/279590a0

62. Ridd MF. Should Sibumasu be renamed Sibuma? The case for a discrete Gondwana-derived block embracing western Myanmar, upper Peninsular Thailand and NE Sumatra. J Geol Soc. 2016;173(2):249-264. https://doi.org/10.1144/jgs2015-065

63. Shen S, Zhang Y, Yuan D, Xu H, Ju Q, Zhang H, et al. Permian integrative stratigraphy, biotas, paleogeographical and paleoclimatic evolution of the Qinghai-Tibetan Plateau and its surrounding areas. Sci China Earth Sci. 2024;67(4):1107-1151. https://doi.org/10.1007/s11430-023-1126-3

64. Şengör AC. The Cimmeride orogenic system and the tectonics of Eurasia. https://doi.org/10.1130/SPE195-p1

65. Metcalfe I. Gondwana dispersion and Asian accretion: an overview. Gondwana dispersion and Asian accretion. 1999:9-28. Available at: https://www.researchgate.net/publication/273694493_Gondwana_dispersion_and_Asian_accretion_an_overview

https://doi.org/10.61577/jgi.2025.100016

66. Muttoni G, Kent DV. Adria as promontory of Africa and its conceptual role in the Tethys Twist and Pangea B to Pangea A Transformation in the Permian. Rivista Italiana di Paleontologia e Stratigrafia. 2019;125(1):249-269. https://hdl.handle.net/2434/652509

67. Golonka J, Embry A, Krobicki M. Late Triassic global plate tectonics. Inthe late Triassic World: Earth in a Time of transition 2017; 27-57. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-68009-5_2

68. Scotese CR, Vérard C, Burgener L, Elling RP, Kocsis AT. The Cretaceous world: plate tectonics, palaeogeography and palaeoclimate. Geological Society, London, Special Publications. 2025;544(1):31-202. https://doi.org/10.1144/SP544-2024-28

69. Metcalfe I. Stratigraphy, palaeontology and palaeogeography of the Carboniferous of Southeast Asia. Memoire de la societe geologique de France. 1984;147:107-118. Available at: https://www.researchgate.net/publication/273380797_Stratigraphy_palaeontology_and_palaeogeography_of_the_Carboniferous_of_Southeast_Asia

70. Metcalfe I. Ordovician to Penian evolution of Southeast Asian terranes: W Australian Gondwana connections.

71. Shi GR, Archbold NW. Permian brachiopod faunal sequence of the Shan-Thai terrane: biostratigraphy, palaeobiogeographical affinities and plate tectonic/palaeoclimatic implications. J Asian Earth Sci. 1995;11(3):177-187. https://doi.org/10.1016/0743-9547(94)E0013-4

72. Ueno K, Charoentitirat T. Carboniferous and permian. https://doi.org/10.1144/GOTH.5

73. Wang XD, Ueno K, Mizuno Y, Sugiyama T. Late Paleozoic faunal, climatic, and geographic changes in the Baoshan block as a Gondwana-derived continental fragment in southwest China. Palaeogeography, Palaeoclimatology, Palaeoecology. 2001;170(3-4):197-218. https://doi.org/10.1016/S0031-0182(01)00228-0

74. Shi GH, Jiang N, Liu Y, Wang X, Zhang ZY, Xu YJ. Zircon Hf isotope signature of the depleted mantle in the Myanmar jadeitite: implications for Mesozoic intra-oceanic subduction between the Eastern Indian Plate and the Burmese Platelet. Lithos. 2009;112(3-4):342-350. https://doi.org/10.1016/j.lithos.2009.03.011

75. Torsvik TH. On the Opening and Closure History of the Palaeo-and Neotethys. InAGU Fall Meeting Abstracts 2008; 2008:T33C-2062. Available at: https://ui.adsabs.harvard.edu/abs/2008AGUFM.T33C2062T/abstract

76. Sheikholeslami MR. Tectono-stratigraphic evidence for the opening and closure of the Neotethys Ocean in the southern Sanandaj-Sirjan zone, Iran. https://doi.org/10.1130/2016.2525(09)

77. Xiao S, Li Y, He J, Wang C, He H, Cheng J, et al. Late Permian rift-related volcanic rocks from the Zhongba terrane, southern Tibet: Implications for the opening of the Neotethys. Int Geol Rev. 2023;65(10):1682-1695. https://doi.org/10.1080/00206814.2022.2103847

78. Liu T, Liu C, Wu F, Ji W, Zhang C, Zhang W, et al. Timing and mechanism of opening the Neo-Tethys Ocean: Constraints from mélanges in the Yarlung Zangbo suture zone. Sci China Earth Sci. 2023;66(12):2807-2826. https://doi.org/10.1007/s11430-023-1175-5

79. Sevastjanova I, Hall R, Rittner M, Paw SM, Naing TT, Alderton DH, et al. Myanmar and Asia united, Australia left behind long ago. Gondwana Research. 2016;32:24-40. https://doi.org/10.1016/j.gr.2015.02.001

80. Hutchison CS. Granite emplacement and tectonic subdivision of Peninsular Malaysia.

81. Metcalfe I. The Bentong–Raub Suture Zone. Journal of Asian Earth Sciences. 2000;18(6):691-712.

82. Nyein S. Petrological Analysis of Sandstone from Hainggyi Island, Ngaputaw Township, Ayeyarwaddy Division. The Second Myanmar National Conference on Earth Sciences (MNCES, 2018), Hinthada University, Hinthada, Myanmar. 2018; 50-60.

83. Bhatia MR. Plate tectonics and geochemical composition of sandstones. J Geol. 1983;91(6):611-627. https://doi.org/10.1086/628815

84. Roser BP, Korsch RJ. Determination of tectonic setting of sandstone-mudstone suites using SiO_2 content and K_2O/Na_2O ratio. J Geol. 1986;94(5):635-650. https://doi.org/10.1086/629071

85. Eder FW, Engel W, Franke W, Sadler PM. Devonian and Carboniferous limestone-turbidites of the Rheinisches Schiefergebirge and their tectonic significance. InIntracontinental Fold Belts: Case Studies in the Variscan Belt of Europe and the Damara Belt in Namibia 1983 (pp. 93-124). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-69124-9_5

86. Arrhenius G. Pelagic sediments. The Sea: ideas and observations on progress in the study of the seas. 1963.

87. Moe A. Structural development of a volcanic sequence of the Lahn area during the Variscan orogeny in the Rhenohercynian Belt (Germany) (Doctoral dissertation). https://doi.org/10.11588/heidok.00001095

88. Lawver LA, Gahagan LM, Coffin MF. The development of paleoseaways around Antarctica. Antarctic research series. 1992;56:7-30.

89. Kirwin DJ. Geological Belts, Plate Boundaries, and Mineral Deposits in Myanmar. https://doi.org/10.5382/econgeo.113.5.br01

https://doi.org/10.61577/jgi.2025.100016

90. Pascoe EH. A manual of the geology of India and Burma. Govt. of India Press, Calcutta. 1959;2:485-1343.
91. Bronn H. Uber die Muschel-Versteinerungen des sud-deutschen Steinsalzgebirges, welche bisher unter den Namen Pectines salinarius zusammenbegriffen wurden. Jahrbuch für Mineralogie, Geognosie, Geologie, und Petrefaktenkunde. 1830;1:279-285.
92. McRoberts CA. Late Triassic Bivalvia (Chiefly Halobiidae and Monotidae) from the Pardonet Formation, Williston Lake Area, Northeastern British Columbia, Canada. J Paleontol. 2011;85(4):613-664. https://doi.org/10.1666/10-051.1
93. Levera M. The Pelagic Bivalve Halobia from the Carnian-Norian Pizzo Mondello Section (Sicanian Basin, Sicily) and Its Bearing of the Definition of the GSSP of the Norian Stage: Dottorato Di Ricerca in Scienze Della Terra, Ciclo 22.: Pdh. D. Thesis. 2010.
94. Von b, Jordan r. The stratigraphy and paleontology of the Mesozoic sequence in the MAE sot area in western Thailand.
95. Aung HH. Faunal Indication of Assembling and Accretion of Terranes in Myanmar. Asian J Geol Res. 2020;3(3). Available at: https://journalajoger.com/index.php/AJOGER/article/view/95
96. Oo T, Thwe TT. Reinvestigation of the Cretaceous marine lithostratigraphic units of Myanmar. Monywa University Research Journal. 2020; 11, 269-281.
97. Sahni MR. On the supposed Cretaceous Cephalopods from the Red Beds of Kalaw and the age of the Red Beds. Rec Geol Surv India. 1936; 71: 166-169.
98. Win Z. Triassic ammonites from the Plateau Limestone, east of Lungyaw and Baukkewzu, Myit-tha and Ywa-ngan Township, Myanmar. Georeports. 1991;1(1):75-87.
99. Win TM. Stream sediment geochemical survey at Monbin area, Yinmabin, Thazi Township. Georeports. 1991; 1:89-99.
100. Cooper MA, Herbert R, Hill GS. The structural evolution of Triassic intermontane basins in northeastern Thailand. InInternational symposium on intermontane basins: geology and resources. 1989:231-242.
101. Behnisch R. Faziesabhängige Ablagerungsprozesse devonischer Vulkaniklastite im Schalstein-Hauptsattel (mittlere Lahnmulde) (Doctoral dissertation, Verlag nicht ermittelbar). Available at: https://rpb.lobid.org/929t930561
102. Eriksson KA. Hydrodynamic and paleogeographic interpretation of turbidite deposits from the Archean Fig Tree Group of the Barberton Mountain Land, South Africa. Geol Soc Am Bull. 1980;91(1):21-26.
103. Ravnås R, Steel RJ. Contrasting styles of Late Jurassic syn-rift turbidite sedimentation: a comparative study of the Magnus and Oseberg areas, northern North Sea. Mar Pet Geol. 1997;14(4):417-449. https://doi.org/10.1016/S0264-8172(97)00010-X
104. Brunnschweiler RO. Contributions to the Post-Silurian geology of Burma (Northern Shan States and Karen State). J Geol Soc Aust. 1970;17(1):59-79. https://doi.org/10.1080/00167617008728724
105. Moe A, Flick H , Requadt H. Messung der Anisotropie der magmatischen Suszeptibilität (AMS) zur strukturellen Analyse der Schuppentektonik im Raum Katzenelnbogen (nördlicher Taunus). Mainzer geowiss Mitt. 2004; 32, 63-82.
106. Mitchell AH, Garson MS. Mineral deposits and global tectonic settings. (No Title). 1981. Available at: https://www.scirp.org/reference/referencespapers?referenceid=1716214
107. La Touche TH. Geology of the northern Shan States. Office of the Geological survey; 1913.
108. Gorshkov GP. Problems of seismotectonics and seismicity zoning of the territory of The Union of Burma. Mineographed Manuscript. 1959.
109. KHEIN A. A study on the gravity indication of the Shan Scarp Fault. Union of Burma. J Sci Technol. 1970;3:91-113.
110. Khin A. Geology and hydrocarbon prospects of the Burma Tertiary Geosyncline. Union Burma J Sci Technol. 1969;2:52-73.
111. Sloan RA, Elliott JR, Searle MP, Morley CK. Active tectonics of Myanmar and the Andaman Sea. https://doi.org/10.1144/M48.2
112. Bertrand G, Rangin C, Maluski H, Bellon H, Party GS. Diachronous cooling along the Mogok Metamorphic Belt (Shan scarp, Myanmar): the trace of the northward migration of the Indian syntaxis. J Asian Earth Sci. 2001;19(5):649-659. https://doi.org/10.1016/S1367-9120(00)00061-4
113. Morley CK. Nested strike-slip duplexes, and other evidence for Late Cretaceous–Palaeogene transpressional tectonics before and during India–Eurasia collision, in Thailand, Myanmar and Malaysia. J Geol Soc. 2004;161(5):799-812. https://doi.org/10.1144/0016-764903-124
114. Morley CK, Searle M. Regional tectonics, structure and evolution of the Andaman–Nicobar Islands from ophiolite formation and obduction to collision and back-arc spreading. https://doi.org/10.1144/M47
115. Ridd MF. Karen–Tenasserim Unit. https://doi.org/10.1144/M48.16
116. Amos BJ. Stratigraphy of some of the upper Palaeozoic and Mesozoic carbonate rocks of the Eastern highlands, Burma. https://doi.org/10.1127/nos/4/1975/49
117. Mitchell AH. Late Permian-Mesozoic events and the Mergui group nappe in Myanmar and Thailand. J Southeast Asian Earth Sci. 1992;7(2-3):165-178. https://doi.org/10.1016/0743-9547(92)90051-C

https://doi.org/10.61577/jgi.2025.100016

118. Campbell KV, Nutalaya P. Structural Elements and Deformational Events. InProceedings of the Conference on the Geology of Thailand. Department of Geological Sciences, Chiang Mai University 1975.

119. Tapponnier P, Peltzer G, Armijo R. On the mechanics of the collision between India and Asia. Geological Society, London, Special Publications. 1986;19(1):113-157. https://doi.org/10.1144/GSL.SP.1986.019.01.07

120. Mitchell AH, Ausa CA, Deiparine L, Hlaing T, Htay N, Khine A. The Modi Taung–Nankwe gold district, Slate belt, central Myanmar: mesothermal veins in a Mesozoic orogen. J Asian Earth Sci. 2004;23(3):321-341. https://doi.org/10.1016/S1367-9120(03)00138-X

121. Morley CK, Naing TT, Searle M, Robinson SA. Structural and tectonic development of the Indo-Burma ranges. Earth-Sci Rev. 2020;200:102992. https://doi.org/10.1016/j.earscirev.2019.102992

122. Najman Y, Sobel ER, Millar I, Stockli DF, Govin G, Lisker F, et al. The exhumation of the Indo-Burman ranges, Myanmar. Earth Planet Sci Lett. 2020;530:115948. https://doi.org/10.1016/j.epsl.2019.115948

123. Khin K, Moe A, Aung KP, Zaw T. Structural and tectonic evolution between Indo-Myanmar ranges and central Myanmar basin: Insights from the Kabaw Fault. Geosystems and Geoenvironment. 2023;2(2):100176. https://doi.org/10.1016/j.geogeo.2022.100176

124. Barber AJ, Crow MJ. Structure of Sumatra and its implications for the tectonic assembly of Southeast Asia and the destruction of Paleotethys. Island Arc. 2009;18(1):3-20. https://doi.org/10.1111/j.1440-1738.2008.00631.x

125. Zahirovic S, Seton M, Müller RD. The cretaceous and cenozoic tectonic evolution of Southeast Asia. Solid earth. 2014;5(1):227-273. https://doi.org/10.5194/se-5-227-2014

126. Muttoni G, Gaetani M, Kent DV, Sciunnach D, Angiolini L, Berra F, et al. Opening of the Neo-Tethys Ocean and the Pangea B to Pangea A transformation during the Permian. GeoArabia. 2009;14(4):17-48. https://doi.org/10.2113/geoarabia140417

127. Van Der Voo R. Paleomagnetism of the Atlantic, Tethys and Iapetus oceans. Cambridge, London. 1993. Available at: https://www.researchgate.net/publication/259307820_Paleomagnetism_of_the_Atlantic_Tethys_and_Iapetus_Oceans_Cambridge_University_Press_Cambridge

128. Scotese CR. Atlas of Earth History.Palaeogeography, Paleomap Project, Arlington, Texas. 2001;1:52.

129. Torsvik TH, Cocks LR. Earth geography from 400 to 250 Ma: a palaeomagnetic, faunal and facies review. J Geol Soc. 2004;161(4):555-572. https://doi.org/10.1144/0016-764903-098

130. Ridd MF, Barber AJ, Crow MJ. Introduction to the geology of Thailand. https://doi.org/10.1144/GOTH.1

https://doi.org/10.61577/jgi.2025.100016