Original Research Article

FAUNAL INDICATION OF ASSEMBLING AND ACCRETION OF TERRANES IN MYANMAR

ABSTRACT

Myanmar represents an evolving continent of two crustal formation histories consisting of the Burma plate and the Indochina plate. In western Myanmar, west of the Sagaing Fault (i.e. the Burma plate) consist of three distinct lithotectonic entities of a continental fragment, a subduction-related accreted complex and a coastal area. The eastern Myanmar that is western continuation of the Indochina plate is composed of two tectonostratigraphic terranes. Each terrane is fault-bounded. These terranes have originated in the south than the present location in late Mesozoic, during terrane assembling and accretion to the major continent. These accretionary episodes that ended in early Tertiary, have been followed by post-accretionary deformation of strike- slip faulting of Sagaing Fault in Myanmar since Neogene. To reconstruct the paleogeography of terranes, the paleomagnetic data is the key to determine paleo-latitudes of terranes. A new paleomagnetic study was carried out on the Permian and Middle Triassic limestone from Shan State of eastern Myanmar. The work of reconstructing the paleogeography of terranes was also conducted by using known distribution of Mesozoic representatives of Monotis, Halobia, and Daonella faunas in Myanmar. Distribution of these faunas in Triassic marine strata of Shan Massif and correlation with those of neighboring terranes of Asia gave the evidences that Shan Massif was a part of Gondwana in Carboneferous-Permian time.

Keywords: terrane, assembling, accretion, subduction, paleogeography, correlation,strike-slip faulting

INTRODUCTION

Myanmar region is composed of various lithotectonic belts and it is tectonically active region. Tectonically Myanmar is made up of a mosaic of tectonostratigraphic terranes: four tectonic terranes and three accreted belts. They are as: Rakhine Coastal terrane; Rakhine Western Ranges terrane; Central Myanmar Basin terrane; Shan Massif terrane; Kachin terrane; Shan Baoundary Belt and Than Lwin Belt. Each of the terranes have been bounded with major active faults of the Kalatan fault, the Kabaw fault, the Sagaing fault, the Shan Scarp fault, the Loise-Loilen fault and Shweli-Tingne fault from west to east. These faults are active as indicated by the earthquake occurrences in the past and recent. The accreted belt of Rakhine Western Ranges terrane is the India-Burma subduction-related accreted belt. Halobia-bearing schist of Thanbaya Formation with Upper and Middle Triassic fossils, mostly of Daonella sp. had been recorded in Rakhine Western Ranges. The Shan Boundary belt of Lebyin-Taungnyo-Mengui-Phuket (in Thailand)-Sigma Formation (in Malay Peninsula) represents accretion and collision event between the Burma Plate and Indochina plate in late Cretaceous-Early Eocene. The Than Lwin Belt represents the site of consumption of Paleo-Tethys in Late Triassic-Jurassic. Daonella indica Britten and Halobia salinarum Broon-bearing shales (Upper Triassic) were found in mudstone and shale in Lwekyaw village near Than Lwin River (Fig.1). The Norian age (upper Triassic) Monotis sp. (mostly Halobiidae) is found in clastic and carbonate sediments of Pan-Laung Formation in the Shan Boundary Belt, west of Shan Plateau. Such thin-shelled pectinacid bivalves of the genus Monotis, sensu lato, are widely distributed in Upper Triassic marine strata and different Monotis faunas are geographically restricted and their biogeographic studies will be of great importance for reconstructing pre- to mid-Jurassic intraoceanic plate boundaries and displacement histories of accreted terranes (Siberling, 1984). Studying the different Monotis faunas occurred in Rakhine Western Ranges accreted belt and Shan

Boundary accreted belt between the Burma and Indochina plate, indicate that these deposits are parts of allochthonous accretionary terranes, and hence, suggest that they are displaced by northward plate motion.

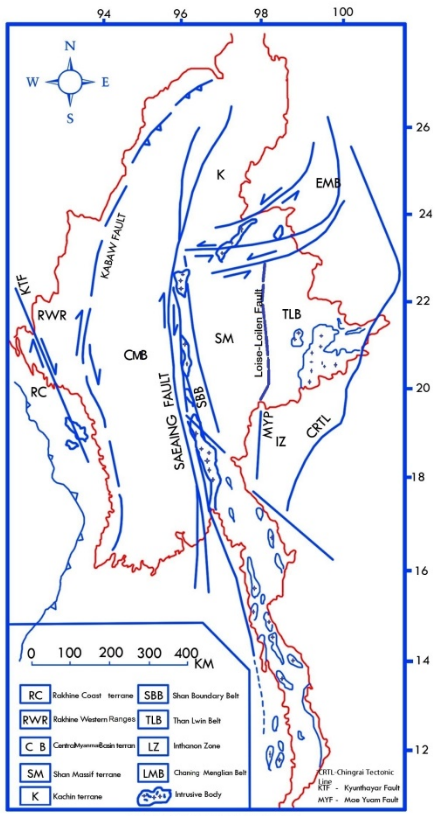


Fig.1.Map of Tectonostratigraphic Terranes of Myanmar
(portrayed by Aung, 1987 and modified in 2009)

PLATE TECTONIC HISTORY OF MYANMAR REGION

The tectonic history of Myanmar region is related to regional geodynamics and plate motions between the India, Burma, Indochina and Eurasia plate. The supercontinent Pangea which originated during the Carboniferous time has been existed till Early Triassic time (248-224 Ma) (Golonka et al.2006). The most significant Triassic convergent event was the Indosinian orogeny, the consolidation of Chinese blocks (South China) with Indochina and Shan Massif (Sibumasu) (Jan Golonka et al.2006). The detailed paleomagnetic analysis revealed that the collision of the Sibumasu terrane and Indochina terrane occurred during or before the Middle-Late Triassic times. A new paleomagnetic study on the Permian and Middle Triassic limestone from Shan State of eastern Myanmar implies that the Sibumasu terrane was located at a paleolatitude of -18.3°N during the Middle Triassic (Zhao J., Huang B.,Yan Y.et al.2019).The site of final closure of Paleo-Tethys Ocean during the Triassic-Jurassic was marked by the collisional event between the Shan Massif and Indochina plate in eastern Myanmar (Aung, 2009). Large complex of granitic rocks at the east of the Than Lwin River that can be correlated with the granites east of Fang (N. Thailand) was assigned to be early Triassic (Bender, 1983). During Indocinian orogeny at Early Triassic (240Ma) Indochina and Shan Massif amalgamated along Loise-Loilen fault forming Paleo-Tethys suture zone in easternmost Myanmar, causing closure of Paleo-tethys Ocean. Uplift of South China, Indochina and Shan Massif followed the conclusion of Indocinian orogeny in Cretaceous (Golonka et al.2006). Indochina and Shan Massif uplifted in Cretaceous (Tran Van Tri, 1956).

The Burma plate rifted and drifted from the neighbors of Gondwana in Middle Jurassic (Lawver et al.2003). Burma plate accreted to the Indochina plate in Late Cretaceous-Early Eocene forming tin-tungsten-bearing igneous belt between the two plates by partial melting of Carboniferous-Permian aged marginal basin metasedimentry rocks of Mergui-Lebyin-Taungnyo Series during a long period of Eocene-Oligocene-Miocene (Aung,2008) (Fig.1).

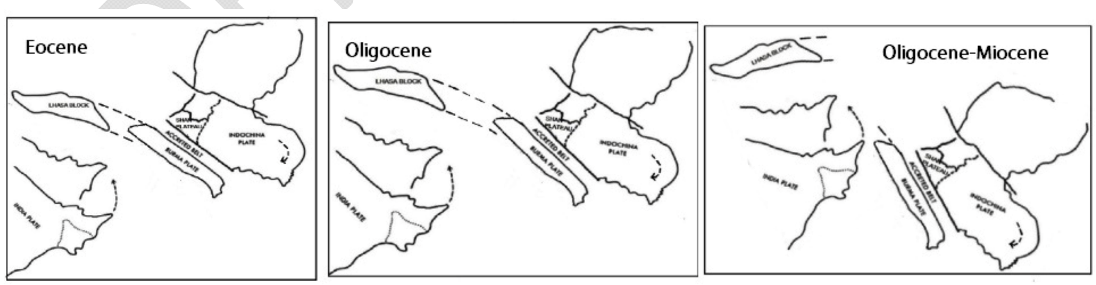


Fig.2. Paleogeography of the India, Burma, Indochina plates in Early Tertiary Period. The orientation of Burma plate is in NW-SE direction during accretion to Indochina plate

The age determination by the Ar/Ar method on biotite, muscovite and phalogopite from igneous belt show that the granitic rocks are gradually young to the north to Kyause area in Manadalay area. (Rangin,1996-1999). Accretion of the Burma plate to Indochina caused the clockwise rotation of the Indochina plate in Eocene (50Ma) (Fig.2). A series of basins formed in Central Myanmar Basin in response to the clockwise rotation of Indochina plate and north-eastward oblique convergence of India plate to the Sunda trench (Michael Christopher Daly et al.1991) due to regional extensional deformation (Fig.3). The formation of these basins commenced in the north at about Early Eocene to Early Miocene and shifted to the south to Central Andaman Basin where spreading occur in Pliocene (4-5 Ma) (Khan and Chakraborty 2005).

RECONSTRUCTION OF PALEOGEOGRAPHY OF TERRANES OF MYANMAR

To reconstruct the paleogeography of terranes, the paleomagnetic data is the key to determine paleo-latitudes of terranes. A new paleomagnetic study on the Permian and Middle Triassic limestone from Shan State of eastern Myanmar implies that the Sibumasu terrane was located at a paleolatitude of -18.3°N during the Middle Triassic (Zhao J., Huang B.,Yan Y.et al.2019). In Myanmar, the work of reconstructing the paleogeography of Myanmar terranes was also carried out by using known distribution of Mesozoic representatives of Monotis, Halobia, and Daonella faunas.Various species of thin-shelled pectinacid bivalves of Triassic faunas are dominant family and occur in open-marine strata of allochthonous accretionary terranes. These strata relate to different parts of single ocean: Tethys, paleoequatorial ocean populated by these faunas containing Tethyan fusulinid. Their occurrences in mudstones, sandstones, shales and limestones are very important for Triassic sedimentary succession as diagnostic fossils. Distribution of these faunas, biogeographic studies and a new paleomagnetic data are important in reconstructing post-Triassic intraoceanic plate boundaries and motion. Distribution of these faunas in Triassic marine strata of Shan Massif (Sibumasu) and correlation with those of neighboring terranes of Asia gave the evidences that Shan Massif was a part of Gondwana in Carboneferous-Permian time facing Paleo-Tethys.

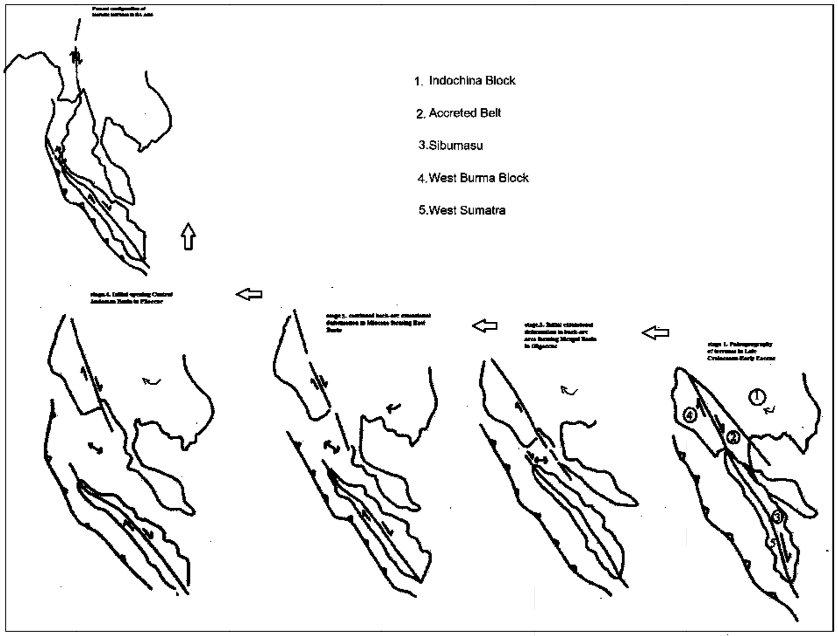


Fig.3. Sequential rotation map show successive motion of the Burma plate during Tertiary period after accretion to the Indochina plate. Change of plate motion due to clock-wise rotation of Indochina plate throughout Tertiary until present time.

The Shan Massif (Sibumasu) probably separated from Gondwana in early Triassic time and moved northward from equatorial position and docked against the Diaxian terrane of Tethys domain of China forming Than Lwin fold belt which lead to consumption of Paleo-Tethys Ocean. Indochina, a super-terrane, was formed after amalgamation and accretion of terranes within terranes. At the end of Mesozoic Era, the whole eastern Myanmar, Shan Massif have risen above 1000m and deformation was mainly in Cenozoic. Separation of India from its former Gondwana neighbors in early Cretaceous (75 Ma) and began to travel very rapidly during another 20 m.y. towards northeast direction during an episode of fast spreading (75 to 55 m.y.B.P) (McKenzi and Scalter,1971). Flysch and turbidites sediments was deposited in the trench throughout Cretaceous and Early Tertiary. Ophiolites thrusted onto the Mesozoic sequences of Halobia schist occurred in pre-Middle Eocene (Rangin,1996-1999). Their position above the metasedimentary rocks is similar to the Halobia schist of Sumatra which also lies on top of metasedimentary rocks of Permo – Carboniferous Sequences (Bender, 1983).

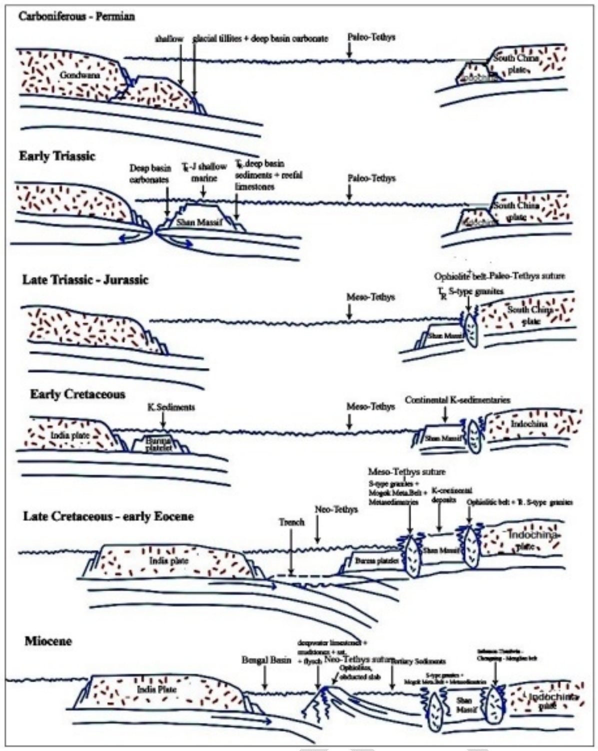
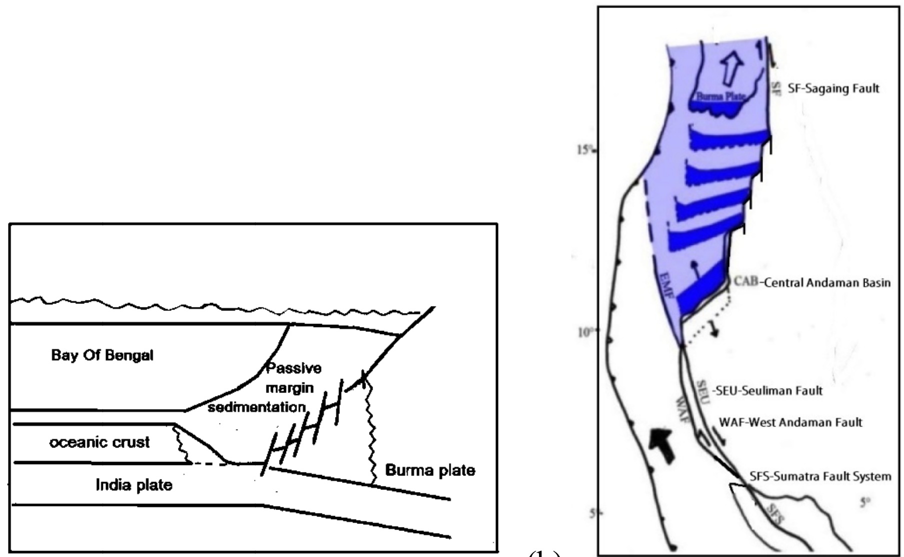


Fig.4. Sequential cross-sections showing evolution of the Sibumasu, Burma plate and India plate in Myanmar region in Late Paleozoic to Tertiary.

Hard collision between India and Burma plate was during Oligocene to Miocene (45 Ma – 35 Ma) and Rakhine Western Ranges became uplifted during Middle Miocene to Upper Miocene (Curray et al, 2005) by thrusting the remnants of NeoTethys sea floor and trench deposits to become Rakhine accretionnary wedge and ophiolites belt at the western part of Burma plate. Subduction zone shifted farther to the west and flyschoid sediments, clastics and carbonates deposited under marine condition in Rakhine Coastal area during Eocene to Oligocene (Bender,1983)(Fig.5a). The Burma plate dispersed from its neighbor by the back-arc spreading mechanism in Central Andaman Basin and moved northward along Sagaing fault since Neogene (Fig.5b).Biostragraphic correlation between terranes in Myanmar and major paleogeographic provinces was made for estimation of paleogeographic position for Myanmar terranes (Aung,2008).



(a) (b)

Fig.5.a.A cross-section showing a passive margin of the western side of the Burma plate.(b) A map showing dispersion model of the Burma plate from the Central Andaman Basin to the north.

AGE (my)	EPOCH		Benthic Foram / Planktonic Foram	Rakhine Coastal Terrane	Rakhine Western Ranges	Central Myanmar Basin Terrane	Neighbouring Countries Major Paleo-Biogeographic Provinces
5	Pliocene						
10 15 20	MIOCENE	Early Middle Late	Planktonic Foram		*Catapsydrax strainforth* *Globorotalia fobsifobi* (Pyawbwe Fm.)		Archipelago Series Andaman-Nicobar Ridge Telisa Formation Sumatra (Indonesia)
25 30 35	OLIGOCENE	Early Middle Late		*Globorotalia kugleria* *Globorotalia opima* *Globigerina cuperoensis* (Kalabon Formation)			Barail Series Bangladesh
25 30 35	OLIGOCENE	Early Middle Late	*Acarinina pentacamerata-* *Planorotalites palmerae* zone 1. *Acarinina Soldadoensis angulosa* *Morozorella aragonensis* zone 2. Lr. Eocene Laungshe Fm.			*Nummulites atacicus* (Tabyin Fm.) (Larger Foram) *Nummulites atacicus* (Laungshe Fm.) (Larger Foram)	Khirar Stage INDIA Laki Stage India Patala Shale N.Parkistan Zhepure Fm. (Tingri Region) Tibet Indonesia

Table.1. Table explain paleogeographic correlation of microfossils between terranes of Myanmar and those of neighboring countries.

Based on paleontologic studies and correlation with major paleogeographic provinces on the micro-fossil assemblages of Tertiary age (Table 1) and pectinatcid bivalve shells of Mesozoic representatives of Triassic fauna from different localities in Myanmar, a scenario of assembling of terranes accretion to the major continent in time and place was emerged to add the constraints given by the tectonic data.

OCCURRENCE OF MONOTIS FAUNA IN ACCRETED BELTS OF MYANMAR

Monotis fauna E, according to the diagnosed groupings in the paper of Siberling, 1984:) is Monotis (Monotis) Salinaria group, small to medium Monotis; subeqivalved; shape oblique; posterior ear smooth, well-differentiated, ribbing fine to medium in strength, regular, commonly wrinkled or wavy posterodorsally, Fauna E was originally distributed in Tethyan region, which represent a wide range in water depths both oceanic and miogeogeonclinal sedimentary environment especially paleoequational seas. Different Monotis fauna are geographical restricted; their biogeographic interpretation bears on the displacement histories. (Siberling 1984).

- Halobia-containing beds of Karnian age at east edge of Rakhine Ranges.
- Halobiidae of Kalemyo and Te-Chaung in Pakokku District, occurred in dark gray shale, has indicated that they were pseudoplanktonic and condition of hostile to life at the sea floor.
- Daonella Lamelli (Myint Lwin. Thein, 1973) in Kalemyo, exhibits genus Halobia, occurred in dark micritic limestones which is equivalent to Thanbaya Formation.
- Halobids, Monotis and agglutinated formainiferas were found in thin beds of dark, grey, calcareous mudstone and micritic limestones of Thanbaya Formation.
- Occurrence of Halobia comata H. lamelli and Monotis suggest a Carnian to Norian stages (M. L. Thein. 1973).
- Daonella sp of Middle Triassic fossils have been found by the staff and the students of Geology Department of the Mandalay Arts /Science University, from several localities of the Eastern foothills of the Western Ranges between Gangaw and Kalamyo. (Win Swe, 1981)

- Halobia Schists of Sumatra, lie on top of epimetamorphic Permo-Carboniferous Sequences (Bender, 1983).
- A specimen containing Halobia and Monotis sp was recorded (Riley, 1964) from Kayah State, but not confirmed by later geologists (Bender, 1983).
- Bender mentioned in his book that Holobiidae-bearing Triassic sequence expected to occur in E. Kachin/Shan unit of Myanmar, as in Yunnan, Thailand and Malay Peninsula.
- Upper Triassic faunal assemblages also were discovered in the Ngapyawdaw Chaung Formation, Thabeikkyin Township, on the eastern side of Sagaing Fault.
- A taxonomic scheme has been adopted for the faunal assemblages of Halobia sp. from Shweminbon Formation in Southern Shan States.

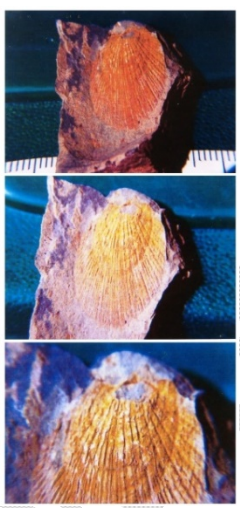


Fig. 6. Photos of Monotis, Dionella

Fig.7. Showing the relation and correlation between various Monotis species of Triassic in Myanmar, Himalaya and the Indochina.

From these studies, terranes in Myanmar are allochthonous terranes, migrated from the Gondwana and accreted to the major continental block in the north. Amalgamation within terranes and accretion to the continent at the end of Mesozoic was followed by the post-accretionary deformation mainly in Cenozoic.

Northward movement of crustal blocks along the Burma plate was evidently indicated by spreading rate in Central Andaman Basin and displacement on the Sagaing fault. The seismicity and the lateral sedimentary facies changes associated with fault scarp in pull-apart basins in Central Myanmar Basin also indicate that northward translation and rotation of crustal blocks are occurring in the past and at present. Deformation is still active reactivating the old tectonic lineaments in the terranes of SE Asia due to the reorganization of intraplate motion between India, Burma, Indochina and Australian plate. Faunal correlation has been made primarily by the author between terranes in Myanmar and terranes of Tethys domain in Asia to get the estimated paleogeographic position for the Myanmar terranes. Acccretionary tectonic provides the additional important constraints for reconstruct-tion of tectonic terranes. More detailed studies of biogeography of accreted terranes in Myanmar are needed for further completion of terranes analysis.

CONCLUSION

The Burma plate rifted and drifted from the neighbors of Gondwana in Middle Jurassic that resulted in the development of a passive margin along the western edge of the plate. A passive margins or rifted margins mark the sites where continents have rifted apart to become separated by an ocean as rift system. The rift is a series of segment offset by transform faults. It is a divergent plate boundary. It forms by sedimentation above an ancient rift and is consist of a seaward tapering wedge of continental crust that is bisected by faults, overlain by sedimentary basins and juxtaposed with oceanic crust. It is also a transition between oceanic and continental lithosphere. The 2000 km long, and approximately 200 km wide elongated tectonic zone, which includes the Central Myanmar Basin and Central Andaman Basin, has been wedged between the northward moving India plate on the west and southeasterly extruding Indochina plate on the east. As a result**,** the Central Myanmar Basin has a classic continental rift structures that are arranged in basin-and-uplift configuration, including seven sub-basins and five uplifts. Extension and rifting occur at around 11 Ma, and extension through seafloor spreading since 4-5

Ma. N-S motion in the Andaman Basin is estimated at 27 mm/yr. The internal rupture has assumed to have broken the Burma plate from that of Sumatra then move northward since the time of creation of rifting ie the time rifting began separating Alcock and Sewell Reses. Seafloor spreading and transform faulting in the Andaman basin was accommodated to the north by slip along the Sagaing fault in Myanmar. The relative rate of movement of these crustal blocks in the Central Myanmar Basin amounts to 8 mm/yr from the result of GPS measurement. The occurrence of earthquakes on each of basin bounding faults indicates the existence of transfer zone in Central Myanmar. The Burma plate moved northward away from the Sumatra, resulting in the development of a passive margin along its southern edge. During the spreading time, hydrocarbon source rocks were developed on the shelf area under extensive warm shallow sea at low latitude where a large quantity of nutrients for hydrocarbon was obtained from the spreading center. The western and southern sides of the Burma plate are bordered by rifted margin Regional paleogeographic reconstruction can suggest potential source rock and favorable timing for petroleum generation.

REFERENCES

1. Aung,H.H.: "Reconstruction of Tectonic Terranes in Myanmar territory" , Abstract Volume, pp-56,International Symposia on Geosciences Resources and Environments of Asia Terranes, GREAT2008, 4th IGCP 516 and 5th APSEG, November, 2008, Bangkok, Thailand. DOI:10.13140/R.G.2.1.4322.

2. Aung,H.H.: "Northward Translation of Crustal blocks indicated by Lateral sedimentary facies changes in Myanmar (Case study: Ayeyarwady Delta Basin)"; Abstract Volume, pp-386, 5th Asia Oceania Geosciences Society International Conference(AOGS2008); June, 2008,Busan, Korea. DOI:10.13140/R.G.2.1.3929.5522

3. Aung,H.H., 2009, *Recognition of Paleo-Tethys suture zone in Eastern Myanmar*, Acta Geoscientific Sinica, vol.30 supplement,pp 1-3, Sept.2009 www.cagsbulletin.com

4. Siberling, N.J. 1984: Biogeographic Significance, Upper Triassic Bivalve Monotis Circum-Pacific Accreted Terranes.

5. Golonka,J., Slaczka,A.,& Picha, F.,2003c. Geodynamic evolution of the orogeny: the West Carpaythians and Ouachitas case studies. Annales Societatis Geologorum Poponiae, 73:145-167.
6. Zhao J., Huang B., Yan Y., et al. A Paleomagnetic Study of the Middle Permian and Middle Triassic limestones from Shan State, Myanmar. Implications of Collision of the Sibumasu terrane and Indochina terrane. Geological Journal, 2019 1-17.https://doi.org/10.1002/gi 3482
7. Bender, F., 1983. In: Borntraeger, G., (Ed.), *Geology of Burma*, Beitra¨ge zur regionalen geologie der erde, Berlin, Stuttgart, p. 1983.
8. Tran Van Tri (Editor in Chief) et al., 1979. (1977 in Vietnamese) *Geology of Vietnam, (the north part)*. Explanatory note to the geological map 1: 1,000,000 scale. Hanoi, Sci. and Techn.Publ.House,354 pp.(in Vietnamese) 77 pp.(in English).
9. Lawver,L.A.et al.(2003), *The Plates 2003 Atlas of Plate Reconstruction (750Ma to Present Day).Plates progress report No.280-0713*. University of Texas Institute for Geophysical Report N.190.University of Texas Press, Houston, Texas
10. Rangin, C.1996-1999. .Deformation of Myanmar, Results of GIAC Projects, GIAC Conf. (Yangon,Myanmar)
11. Michael C.D. et al.,1981: *Cenozoic Plate tectonics and basin evolution in Indonesia*. Marine and Petroleum Geology, vol.8, February 1991.
12. Khan P.K. & Chakraborty P.P.,2005.*Two-phase opening of Andaman Sea:A new seismotectonic insight*. Earth and Planetry Seience letters 229,259-71
13. Mckenzi, D & Sclater, J.G. 1971. The Evolution of the Indian Ocean Since the Late Cretaceous Geophy. J.R.astr. Soc. 24, 437-528.
14. Curray, J.R., et al.2005, *Tectonics and history of the Andaman Sea region*,J.Asia Earth Science XX1-42
15. Myint Lwin Thein: The Lower Paleozoic Stratigraphy of western part of the Southern Shan State, Burma. Geol. Soc. Malaysia, Bull. 6, 1973, pp. 143 - 163.
16. Win Swe,Tectonic Evolution of the Western Ranges of Burma. (Contributions to Burmese Geology, Vol. 1, No. 1, 1981).