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Rift Volcanism and Rift Basin in Central Myanmar Basin

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Abstract

The Central Myanmar Basin is made up of Tertiary sedimentary rocks between the Rakhine Western Ranges in the west and Shan Plateau to the east. The basin consists of six sub-basins: Putao, Hukawng, Chindwin, Salin, Pyay and Ayeyawady Delta basin. This 1000 km× 200km tectonic strip in NNW-direction in Central Myanmar Basin is characterized by the presence of numerous ENE to northeast and east-west trending normal faults and north-south to NW-SE and NNW-SSE trending folds and thrusts. This arrangement of structures is indicative of an extensional stress in NNW-SSE direction and a compressional stress in ENE-WSW direction. Tensor solution of earthquakes which occurred in Central Myanmar Basin also indicates a dominant extensional stress direction oriented NNW-SSE. This NNW-SSE extensional direction appears to have favored the formation of rifts in ENE-WSW, NE-SW and E-W direction which were later emplaced with volcanic rocks. These volcanic rocks were derived from mantle material which risen into the several segments of rifts from underneath of the crust during rifting. Majority of these volcanic rocks are different types of basalt, andesite, dolerite, volcanic tuff, volcanic ash, lava flow and rhyolites. The studies of associated sedimentary rocks with the volcanic rocks indicate that extension and volcanic activity began in the north in Early Tertiary and migrated to the south from the Miocene to Quaternary. The Central Myanmar Basin and Central Andaman Basin record an active extensional process that varies laterally from continental rifting in the north in Central Myanmar Basin and sea-floor spreading in the south in Central Andaman Basin. The objective of this paper is to define regional volcanic differentiation pattern and their linear emplacement which are in accordance with regional tectonic stress field and to interpret them in term of tectonic deformation. Bimodal basalt-rhyolite suite with the presence of intermediate composition and compositional variations of volcanic rocks indicate that the volcanic rocks are formed by assimilation, fractional crystallization and the crustal components and magma mixing. Geochemical analyses of these volcanic rocks reveal that they are also enriched in the alkalis, high level of barium and strontium and light rare earth elements.

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Associated host rocks of the volcanic material are sedimentary rocks of the Peguan Group (Oligocene-Miocene) and Irrawaddian Group (Pliocene-Pleistocene).

Keyword: volcanic; fault, extension; basalt; sedimentary; differentiation; emplacement; assimilation.

1. A Brief Account of 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. 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 [24:1-15]. 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 [2:1-3]. During Indocinian orogeny at Early Triassic (240Ma) Indochina and Sibumasu (Shan Massif) amalgamated along Loi-se-Loi-len 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[8:145-167]. Indochina and Shan Massif uplifted in Cretaceous [23].

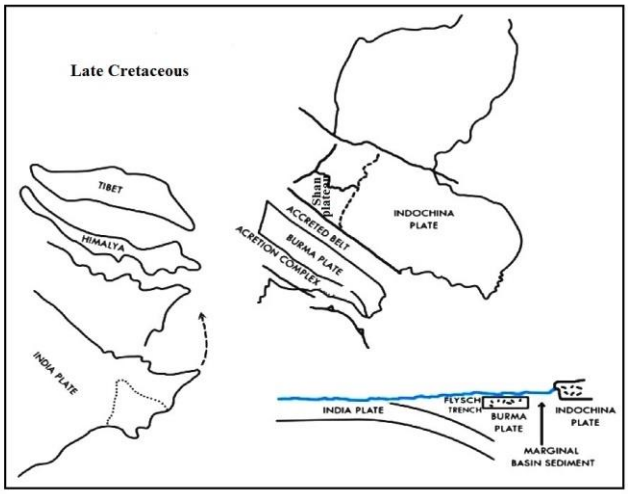

Figure 1: Paleogeography of the India, Burma, Indochina plates in Late-Cretaceous Period. The orientation of Burma plate is NW-SE direction during accretion to Indochina plate.

The Burma plate rifted and drifted from the neighbors of Gondwana in Middle Jurassic [11]. Burma plate accreted to the Indochina plate in Late Cretaceous-Early Eocene [4]. The tin-tungsten-bearing igneous belt was formed between the two plates resulted from partial melting of Carboniferous-Permian aged marginal basin metasedimentry rocks of Mergui-Lebyin-Taungnyo Series during a long period of Eocene-Oligocene-Miocene. Accretion of the Burma plate to Indochina caused the clockwise rotation of the Indochina plate in Eocene (50Ma) (Fig.1).

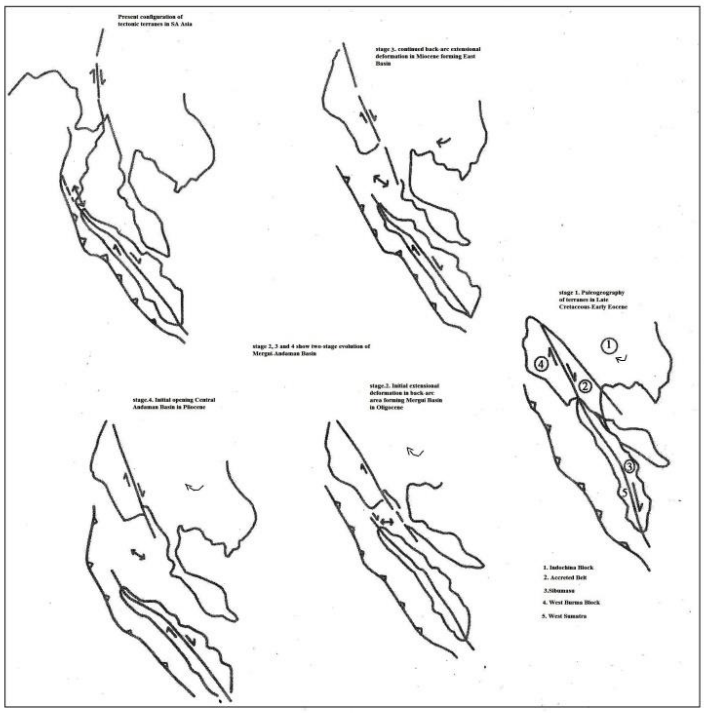

Figure 2: A mosaic of maps show successive motion of the Burma plate during Tertiary period after accretion to the Indochina plate. Change of plate motion due to clock-wise rotation of Indochina plate throughout Tertiary.

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 [13] due to regional extensional deformation. Formation and evolution of basins is related to the interaction of lithospheric plates and deep-seated geodynamic processes. The closure and accretion of the Burma to the Indochina plate in Late Cretaceous-Early Eocene, crustal rotation of Indochina plate, southeastward extrusion of Indochina plate, the closure of Neo-Tethys sea and collision of the India plate with the Burma plate in Miocene, northeastward motion of the India plate and oblique subduction of India beneath Burma plate dominated asthenospheric upwelling and lithospheric stretching, rifting, volcanism and magmatism during different rifting stages in Central Myanmar Basin (Fig.2).

2. Tectonic Setting

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.

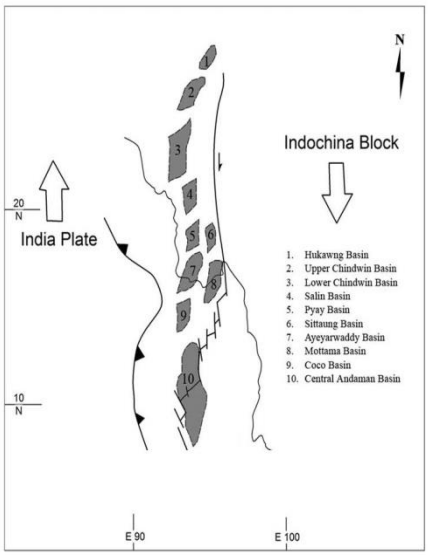

Figure 3: Distribution of rhomb-shaped basins in Central Myanmar Basin and central Andaman Basin for 2000 km length of rift zone between northward moving India plate and southeasterly moving Indochina plate.

The tectonic setting between these moving rigid plates and the highly oblique subduction has caused extension to occur on the ductile crust. In turn, this has caused the brittle continental crust to be pulled apart laterally, forming a rift zone. According to the existing data found in the Geology of Burma by F.Bender, 1983, there are pairs of en echelon basin-uplift from the northernmost part of Myanmar to the Andaman Sea (fig.3). 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 (Putao Basin, 28°N Uplift, Hukawng Basin, 26°N Uplift, Upper Chindwin Basin, 24°N Uplift, Lower Chindwin Basin, 22°N Uplift, Salin Basin, 20°N Uplift, Pyay Basin, Ayeyawady Delta Basin) (Fig.4a). To the southeast of it, transverse structural elements of uplift area trending NE-SW or ENE-WSW occur between Latitudes 14° N and 15° N. To the south of this uplift, there is Mottama Basin. Initial rifting commenced in Early Eocene (40 Ma) in the north due to magma upwelling beneath the crust. Extension and rifting occur at around 11 Ma, and extension through seafloor spreading since 4-5 Ma [18:259-271]. In these basins, 10,000 m thick Tertiary and Quaternary sediments are found associated with volcanic rocks.

3. Volcanic rocks with variation in age and associated structures

Extensional tectonics dominates Tertiary onshore/offshore basins in Central Myanmar Basin and Central Andaman Basin and rifting was responsible for contemporaneous occurrence of basin subsidence, volcanism and magmatism. Key aspects of volcanic occurrences in Central Myanmar Basin was summarized based on Geology of Burma by Chhibber,1934, Geology of Burma by F. Bender, 1983 and existing data is reviewed and new idea is added for operative geotectonic of continental crustal stretching and rifting in the basin.

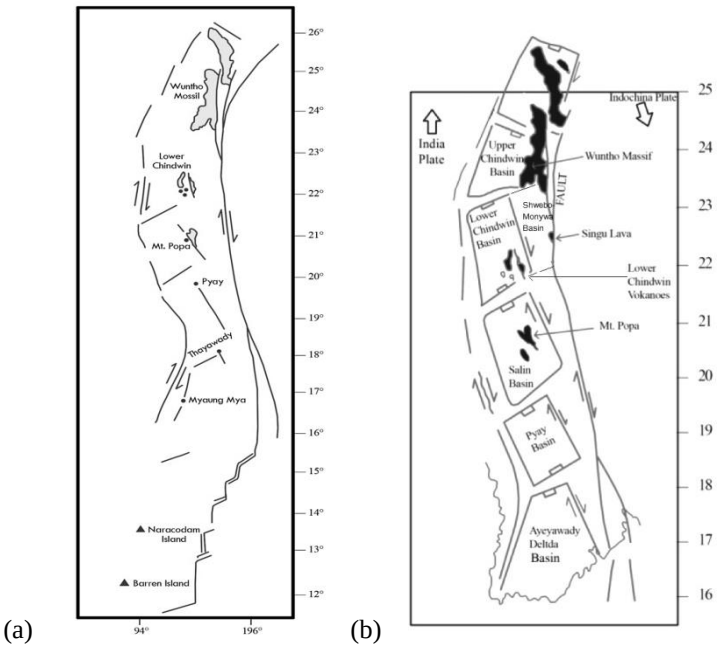

Figure 4: (a) Sketch map shows distribution of basins in Central Myanmar Basin and Andaman basin for 2000 km length from north to south and volcanic occurrences with their associated structures. (b) Sketch map shows basin-uplift province including 12 crustal blocks along Central Myanmar Basin for 1000 km length with volcanic Rocks associated with linear structures.

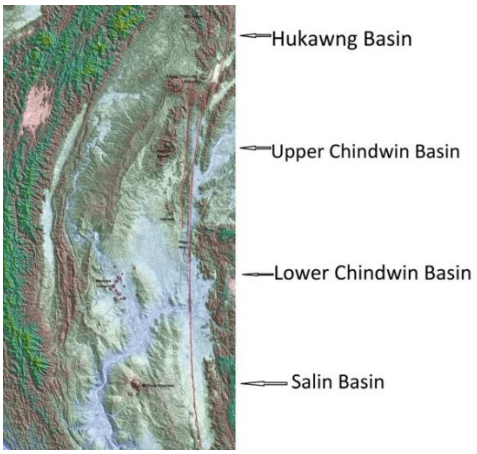

Figure 5: Shaded relief map show volcanic occurrences with linear emplacement in sub-basins of Hukawng, Chindwin and Salin in Central Myanmar Basin.

The presence of structure-controlled volcanic occurrences strongly suggests a major role of extensional deformation regime in Central Myanmar Basin. The linear emplacement of these volcanic occurrences was recognized in previous studies. A low hill extending in NW-SE direction is composed of olivine basalt. In some area on Yinmabin road, in the west of Monywa are composed of bedded rhyolites and andesites and they are bedded with rocks of Pegu Series of the Miocene age. In the environs of Salingyi area, dacites, dolerites, diorites and lava intruded into the Pegu Series. At Shinmadaung, andesite, basalt and rhyolite occur at the base of Irrawaddian rocks along the fault striking NNW-SSE direction. Small intrusions of doleritic rocks associated

with rocks of Pondaung Age (Eocene) occur along the fault. A sheet of basaltic lava called Silaung sheet occur along the fault. Kyaukadaung hill in the east of Monywa is composed of olivine basalt, surrounded with Peguan rocks occurring along the fault. Hill 779, northeast of Kyaukadaung Hill is composed of olivine basalt for 7 miles along NNW-SSE direction. At Thazi Hill , picrite basalt occur along the fault on the edge of the Pegu Series. At Inde Hill, northernmost of the group of olivine basalt occur with volcanic ash along the fault resting on Irrawaddian rocks. At Nayintaung , olivine basalt mass is found along N-S direction resting on Irrawaddian sands. Mojority of volcanic occurrences in Monywa area are occurring along the fault in Lower Chindwin basin. Mugearite basalts are found as horizontal sheet resting on folded Irrawaddian bed, located 40 kilometers north of Mandalay at latitude 22° 44' and further south to Singu for 24 square miles. These volcanic occurrences associated with faults are observed on the right bank of the Chindwin River (Fig.4b). Recent study using satellite image interpretation also reveals the relationship between geological structures and distribution of volcanic occurrence in shaded relief map (Fig.5)

Table 1: This table explains various occurrence of volcanic rocks in Central Myanmar Basin/Central Andaman Basin with different types of volcanic and their associated linear emplacement. Transition in age of volcanic rocks and associated sedimentary rocks from north to the south. (Derived from F.Bender,1983 and H.L.Chhibber,1934).

Serial#	Name of volcanic area	Volcanic Rocks	Structure and associated sedimentary rocks
1	Mt.Kawtabum, Hukawng Basin	Andesitic Breccia	Interbedded with Nummulitic Limestone(Early Eocene)
2	Mt.Loimye, 70 km NNE of Indawgyi,Hukawng Basin	Basaltic tuff, basalt, andesites, volcanic ash	Intercalated in lacustrine sediments along the fault in N-S direction
3	Jade Mines area, Upper Chindwin Basin	Hornblende andesite, picrite basalt, agglomerate, olivine basalt	Volcanoes of this area along the fault between serpentine & agglomerates
4	NNE-trending Wuntho Massif Upper Chindwin Basin	Andesite dykes, Basalt dykes	?Lower Oligocene, ?Oligocene -Miocene (Bender,1983)
5	Kabwet area	Pillow lava, basic volcanics	Interbedded with the folded Irrawaddian rocks, occurrence of pillow structures
6	Lower Chindwin region Lower Chindwin Basin	Picrite basalt, acid andesite, rhyolites, volcanic ash	At Monywa, craters of rhyolite and sheet of lava in NE-SW, overlying Irrawaddian rocks.Bedded with Pegu Series, intruded into Pegu Series, at base of Irrawaddian rocks of NNW-SSE direction. Miocene-Pleistocene (Bender,1983) K/Ar dating of Hb.-Bio.Porphyry gives Middle Pliocene (Bender,1983).
7	Mr. Popa region Salin Basin	Pyroxene andesite, Augite andesite, rhyolites, Olivine basalt	Interbedded with the Irrawaddian rocks, coincide with fractures or faults, along the fault in NW-SE direction.Pliocene-Pleistocece (Bender,1983)
8	Pyay area, Pyay Basin	Olivine dolerite	Intruded into Pegu Series along the direction of dyke in NNW-SSE direction
9	Thayawaddy area, Pyay Basin	Olivine dolerite	Dolerite sill along the bedding plane of a big anticline
10	Myaungmya area Ayeyawady Delta Basin	Tuffs with Nummulites	Hills of volcanic ashes in a line in NW-SE direction
11	Narcodam island, Andaman Basin	Hornblend andesite, agglomerate	Interbedded with fragmentary ejectamenta
12	Barren island Andaman Basin	Olivine basalt, agglomerate, volcanic ash	Barren and Narcodam island developed upon the ocean floor along the N-S striking transform faults. Recent

Bimodal volcanism is the eruption of both mafic and felsic lavas from a single volcanic center with little or no lavas of intermediate composition. This type of volcanism is normally associated with areas of extensional tectonics, particularly rifts. It represents volcanic associations, and sometimes intrusive equivalents, where rocks with two distinct compositional characteristics and lineage erupt contemporaneously with no rocks of intermediate composition. Majority of these volcanic rocks are different types of basalt, andesite, dolerite, volcanic tuff, volcanic ash, lava flow and rhyolites (Table 1). Typical basalt-rhyolite bimodal suites are most

commonly observed in rift tectonic environments. In seismic reflections of the Gulf of Mottama and Ayeyawady Delta Basin, the associated basic tuffs, volcanic rocks and agglomerates are visible together with Tertiary sediments [3].

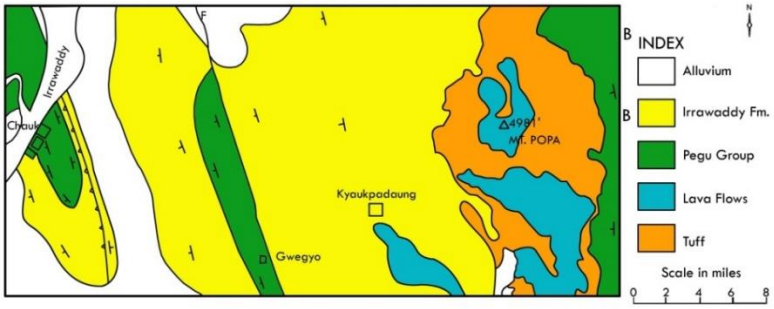

Figure 6: Geological map of the Mt.Popa region showing the relationship between volcanic rocks and sedimentary host rocks. Volcanic tuff and lava are found at the junction between Pegu Group and Irrawaddian Group.

4. Variation in space

Table 2: This table shows volcanic rocks with variation in space at different basin. volcanism starts with basic lava in the east and decreases basicity towards west. (Derived from H.L.Chhibber,1934).

Jade Mines area
Start with Picrite basalt in the east to olivine basalt to hornblende andesite, augite andesite, trachyandesite to rhyolite and rhyolite breccia siliceous agglomerate in the west.
Variation in space from late Pliocene in the east to Recent in the west.
Lower Chindwin area
Picrite basalt of basic lava along a fault in the east to olivine basalt and trachylytes, ashes to mainly rhyolites in the west
Decrease in basicity from east to west
Mt.Popa region
NW-SE trending Popa Hill with older andesite in the east to biotite andesites to rhyolites and rhyolitic tuffs in the west
Differentiation in space from east to west
Transition in age from Early Tertiary in the north (Hukawng Basin) to Late Tertiary in the south (Andaman Basin)

Earlier petrographic and geochemical studies were done on volcanic rocks of Central Myanmar Basin by members of Geological Survey of India (GSI) [4]. It is interesting to note that the volcanic occurrences of Central Myanmar Basin show a well-marked and unmistakable evidence of variation in space (Table 2). The evidence indicated by the volcanic occurrences is still more interesting, and the variation in space, especially during late Tertiary times, occurs progressively from east to west and a variation in age from north to south, the direction in which the land was gradually formed and the sea was receded to the south until the present offshore at Mottama Gulf.

5. Variation in composition

The variation diagram obtained from plots of SiO_2 vs K_2O, Na_2O, CaO, TiO_2 reveals significant results of the major element distinctions of volcanic rocks and the evidence of genetic linkages [4]. Variation curve in alkalies is higher conforming to the high K-field. The volcanic rocks from the continental areas are rich in K_2O and CaO but in respect of soda, no distinctive between the two series of continent and oceanic. Generally it can be concluded that the different types of volcanic rocks found in Central Myanmar Basin of continental areas are rift volcanic. The basalt isotope composition of Mt.Popa [19] and the basalt andesite of Twin Taung [3] show Ba level (Ba 1517ppm, Ba1069ppm) and Sr level (Sr 1567ppm, Sr 1050ppm) are within the known range of intraplate basalt, indicating higher contents of Large Ion Lithospheric Element (LILE) and Light Rare Earth Element (LREE). It suggests that the parent magma is modified by fractional crystallization. Composition variability also reflects the assimilation of crustal components and magma mixing (Fig.6). The bimodal basalt-rhyolite occurrences are thought to reflect combination of mantle and silica rich crustal melt. It appears that with a few exceptions, the igneous occurrences of the Central Myanmar Basin show differentiation in space from east to west. It reflects assimilation, fractional crystallization and crustal material and magma mixing before emplacement at the surface. During early stage of volcanic activity, basic magma may have risen through the fault tract or fissures fairly slowly allowing time for assimilation, fractional crystallization and crustal contamination (AFC) to modify the magma to produce basalt-andesite-rhyolite composition or the volcanic rocks of Central Myanmar Basin may have originated with two primary magma: sublithospheric mantle and subcontinental lithosphere which on differentiation, many volcanic rocks with high alkalies are formed by assimilation of limestone from Pegu Series with basaltic magma at depth and crustal contamination with sands of Pegu or Irrawaddian Group. The presence of the intermediate lava may be derivatives of parental mafic magma via fractional processes [1:1-10]. In rift setting, mafic magma is possibly derived from at least two magma sources: sublithospheric origin or Oceanic Island Basalt (OIB) and rift basalt within subcontinental lithosphere with distinctive REE. Basaltic magma generated in continental rift are similar to those of Oceanic Island Basalt, derived from a mantle source enriched in trace elements LILE, high Sr. The geochemistry of mafic volcanic rocks extruded at continental rifts provides information on the sources and mechanism of magma generation during rifting. Rift basalt typically are enriched in alkalies (Na_2O_3, K_2O, Cao), LILE as K, Ba, Rb, Sr; LREE, volatiles as halogens. Tholiietic basalts are also common and may be associated with silica lavas including rhyolites. There are three ways of mechanism to produce basaltic magma beneath rift. Melting may be accomplished by transfer of heat from deep mantle plumes or reducing in ambient pressure by the rise of mantle plume or the effect of lowering of solidus temperature by addition of volatiles. All three of the mechanisms probably contribute to generation of basaltic melts beneath continental rift. Once mafic magma was formed, the magmatic differentiation can occur by partial melting or by fractionation or by assimilation and crustal melting to produce the bimodal basalt-rhyolite eruption at continental rift [9].

6. Conclusion

The 2000 x 200 km span of crust which includes the Central Myanmar Basin and Central Andaman Basin has been undergoing two tectonic deformations. The first deformation is a NNW-SSE oriented extensional scheme,

which commenced in Early Eocene and occurred primarily during the Miocene epoch. The second deformation is a compression regime during the Pliocene-Pleistocene time. Along this N-S strip of the tectonic zone, volcanic activity show variation in age started in the north in Early Tertiary and migrated to the south during the Miocene and Pliocene-Pleistocene to the Recent in the Andaman basin. In this case the most important point to be noticed is that the land along the Central Myanmar Basin was gradually rifted from the north to the south. Their style of emplacements are also controlled by lines of major faulting and folding of N-S or NW-SE or NE-SW or NNW-SSE direction along which most of the volcanic occurrences are found. These structures are developed in the rift system of Central Myanmar Basin by the extensional deformation from Eocene to mainly the Miocene to Recent. In most cases, volcanic rocks are associated with sedimentary rocks from Pegu Series of the Oligocene-Miocene and the Irrawaddian rocks of the Pliocene-Pleistocene. The linear emplacement of volcanic occurrences in Central Myanmar Basin can be interpreted as basin-and-uplift type, extensional setting and rift volcanism, where extension leads to generation of magma from the subcontinental lithospheric mantle which is enriched in the alkalies. In these volcanic occurrences, fragmental erupted products are scare and it support that these volcanic rocks are rift-related volcanic rocks.

7. Discussion and Recommendations

The structural signature of basin-uplift zone in the Central Myanmar Basin between the Rakhine Western Ranges to the west and the Shan Plateau to the east is dominated by NE-to ENE-WSW trending faults. This 1000-km-long, 200-km-wide elongated tectonic zone is bounded to the west by the Kabaw Fault and to the east by the Sagaing Fault. The detailed studies of sedimentary rocks associated with the volcanic rocks and linear emplacement of volcanic occurrences indicated strong conformity with the regional structural direction. The existence of volcanic rocks within the tectonic strip implies an intimate relationship between extensional deformation and volcanic occurrence. Results of this study have the important implication for tectonic regime and their associations with the distribution of volcanic rocks. Some large copper deposits are found within the Upper Tertiary volcanic rocks in Lower Chindwin Basin.

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