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A Preliminary Synthesis of the Geological Evolution of Burma with Reference to the Tectonic Development of Southeast Asia

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Far better an approximate answer to the right question, which is often vague, than an exact answer to the wrong question which can always be made precise.

John W. Tukey (1962)*

Abstract: A preliminary synthesis is attempted with a view to trace the geological development of the Burmese region in time and space. It is based partly on regional field experiences and partly on the published and unpublished information that have become available in the last decade. The model approach is found to be quite useful in this synthesis. It is hoped that this paper would stimulate lively discussions, further research and sounder syntheses.

The synthesis is made in term of seven topics: tectonic framework; areas of deposition and non-deposition; regional depositional pattern; tectonic and depositional environments; structural deformation and related metamorphism; igneous activity and associated mineralization; Burmese region in the general framework of continental drift. The tectonic framework is described with the aid of a generalized tectonic map newly compiled by the author; and four geo-tectonic domains are recognized and formally named.

The sequence of major geological events in the Burmese region is encompassed in a summary chart, and fuller and more refined accounts are given in the text by means of time-length diagrams and other kinds of model expressions. Time-stratigraphy of the Precambrian, Paleozoic and Mesozoic rock units is schematically shown by means of a representative time-length cross-section along the Shan-Tenasserim region which has become a stable block since the close of the Mesozoic. The regional depositional pattern of the Tertiary sediments in the Central Cenozoic Belt is shown by means of two time-length cross-sections, one along the general depositional strike and the other across it. The general pattern is interpreted as one of cyclical sedimentation. Contrary to some recent conceptions of the Central Belt as a geosyncline, available evidences seem to support an old idea—that the Central Belt most probably constitutes a graben.

The geological development of Southeast Asia in general and of the Burmese region in particular in the general framework of continental drift is considered in the last section. On the basis of fitting of the pre-Tertiary outlines, presence of the Ninety East Ridge, and similarity of certain rock series, it is speculated that the Bay of Bengal may actually be a *sphenochasm*, thus implying that Southeast Asia and the Indian Peninsula were probably once joined together in the distant geological past.

INTRODUCTION

To some it may seem rather premature to attempt a synthesis of the geological evolution of Burma. It is true that we do not know enough yet, and that there is not much information in the field of regional stratigraphic and tectonic analyses made for the Burmese region. However, there already are available new data and recent findings enough to justify a preliminary synthesis (see "References Cited"). To the author it always seems worthwhile to strive for a unified and integrated picture of the geological events spread over a wide range of time and space, provided, of course, that such an attempt is not mere speculation. This still holds even if one has to stick one's neck out, so to speak. Besides, such an attempt would stimulate discussion, further research and

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* requoted from "Statistical Models in Geology" by W.C. Krumbein and F.W. Graybill (1964).

sounder syntheses which are badly needed for a better understanding of the Burmese geology. There may be the usual pitfall of over-simplification and over-generalization on the author's part. His excuse in this regard is two-fold: (i) that they are desirable at a preliminary stage and may serve as basis for fuller and more refined accounts later; (ii) that they are unavoidable in the face of incomplete information available at present.

This paper may be regarded as a sequel to an earlier paper by the author and a colleague that was first written in 1966 and later published with minor revision in 1970 (Maung Thein and Ba Than Haq, 1970). Many works on the subject, both published and unpublished, that have appeared since then provide valuable information for this synthesis. These are duly acknowledged in appropriate places.

Topics Considered

The model approach is considered indispensable in a work of this nature, and is therefore employed rather extensively. The synthesis will be made in terms of the following topics:

1. tectonic framework of sedimentation.
2. areas of deposition and non-deposition (paleogeography).
3. regional pattern of sedimentation, including sedimentary facies.
4. type of tectonic and depositional environments on the basis of lithologic associations.
5. structural deformation and related metamorphism.
6. igneous activity with or without associated mineralization.
7. Burmese region in the general framework of continental drift.

These topics obviously are inter-related and more or less consequential so that they cannot be considered separately. Most of the topics are encompassed in Fig. (3) which is a general summary chart of the geological events spread out in time and space for the Burmese region. Fuller accounts are given in Figs. (4)–(7).

One of the *right* and pertinent questions to be considered is in connection with the theory of continental drift which has been confirmed lately (e.g., *see* Hurley, 1968; Wilson, 1963; Heirtzler, 1968). The question is: How does the Burmese region fit in the general framework of continental drift? This is dealt with in the last section which, of course, contains some speculations.

TECTONIC FRAMEWORK AND DOMAINS

As is well known, the Burmese region may be subdivided into four linear geomorphic belts, informally named as (from east to west): the Eastern Highlands, the Central Belt, the Arakan-Chin Ranges, the Arakan Coastal Plain. These belts are mere reflections of the underlying stratigraphy and structures in that each contains lithologically and structurally related rock units. Thus they also may be regarded as distinct geotectonic domains. In order to convey the tectonic framework of the region, the author would propose here the following names for these domains: the Shan-Tenasserim Massif, the Central Cenozoic Belt, the Arakan-Chin Folded Belt, the Arakan Coastal Plain (*see* Fig. 1).

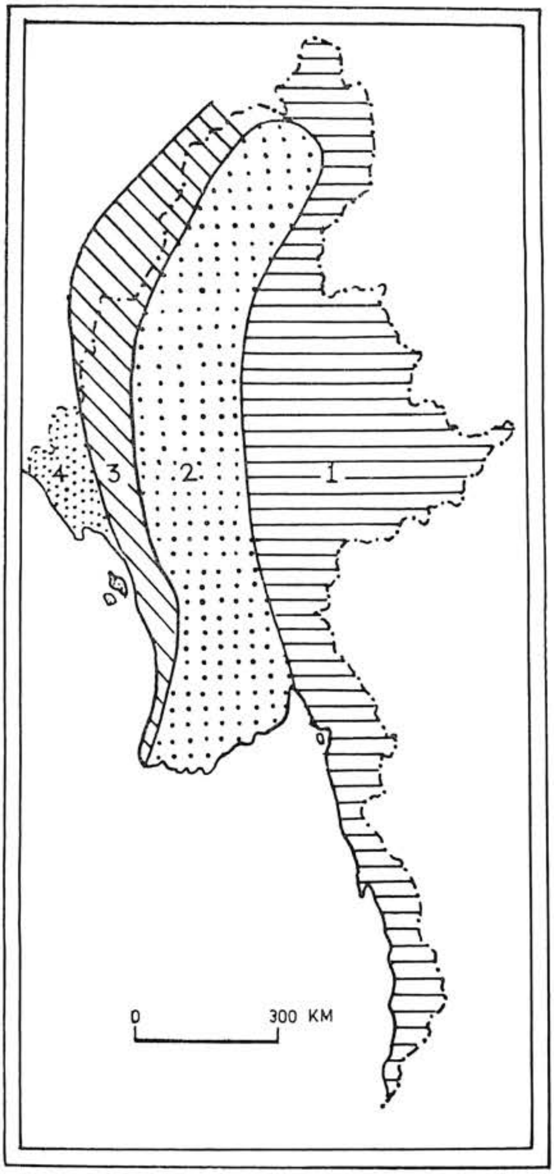

Fig. 1. The Geotectonic domains of Burma (1. Shan-Tenasserim Massif; 2. Central Ceno-zoic Belt; 3. Arakan-Chin Folded Belt; 4. Arakan Coastal Plain).

The Shan-Tenasserim massif is constituted of Precambrian, Paleozoic and Mesozoic rocks, formed partly in mobile belts and partly on shelves, which were later highly deformed and metamorphosed. The Cenozoic sediments are almost completely absent in this part except for small occurrences of oil shales in the Tenasserim area and lacustrine deposits in the Southern Shan States. There probably were at least five periods

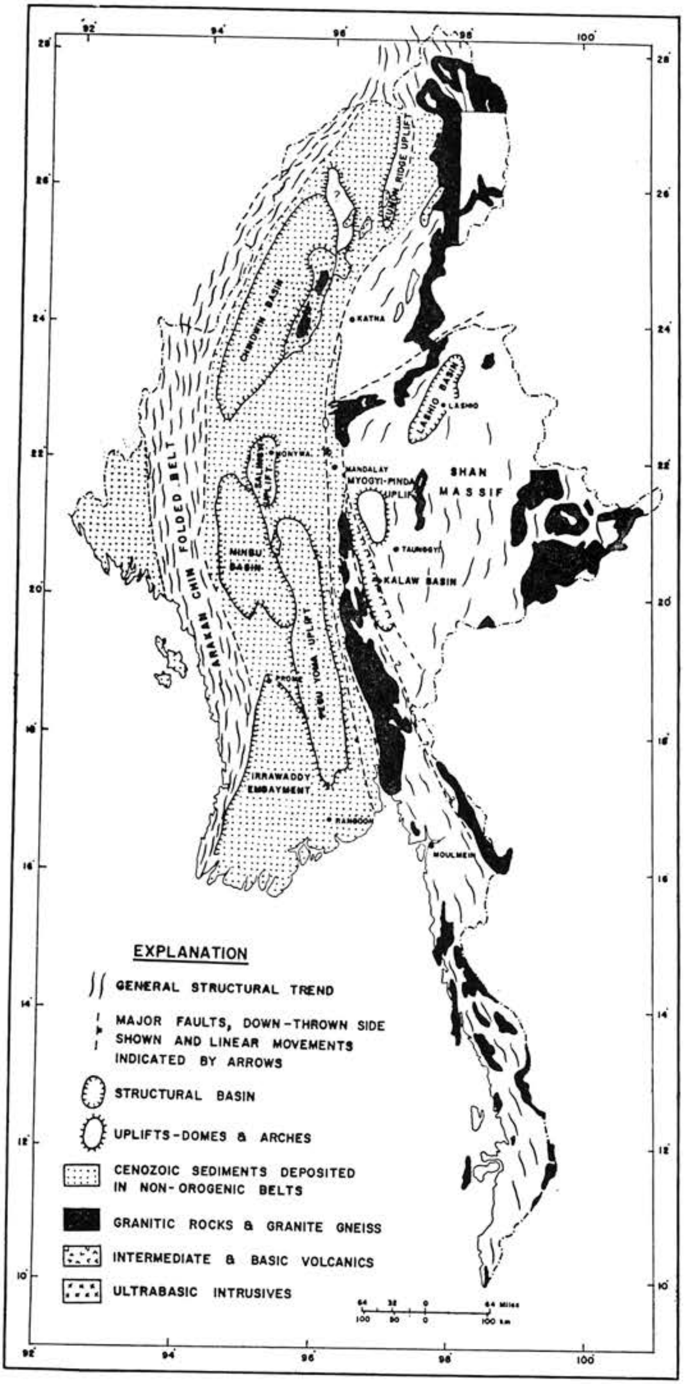

Fig 2. Generalized Tectonic Map of Burma.

of major structural disturbances and upheavals, as manifested by distinct stratigraphic breaks, up till the end of the Mesozoic when the area became a stable landmass (*see also* Fig. 3).

As the name implies, the Central Cenozoic Belt contains almost exclusively Cenozoic sediments. Available evidences seem to indicate that the sediments were laid down in a linear, down-faulted trough, or, a graben (*see* Fig. 2). The rocks were later subjected to gentle and broad folding relating to the Alpine orogeny in the Burmese region. The Arakan Coastal Plain is the narrow southern part of the Assam Trough, and the lithological types deposited there are similar to those of the Central Belt. The two troughs, the Assam and the Central Belt, may have actually formed a twin trough (or, a twingulf as was first envisioned by Stamp, 1922) that was divided by a median positive belt—the Arakan-Chin Folded Belt. The two troughs apparently were non-orogenic in setting, as is evident from the molassic character of their lithology and absence of tight folding and large-scale over-thrusting. The Arakan-Chin belt on the other hand, was a mobile belt which has undergone rather intense orogenic movements manifested by large-scale overthrusting and tight folding in the greywacke-flysch sequences present.

In short, the above-named geotectonic domains constitute the tectonic framework of Burma which is best seen in Fig. 2, a generalized tectonic map compiled primarily from the following sources: Tectonic Map of Burma and Geological Map of Burma (both compiled by M.D.C. in 1963?); Aung Khin and Kyaw Win (1969). It should be pointed out here that the present map is quite different from the M.D.C. map in terms of approach and scope.

Note in Fig. 2 that the four domains may be further differentiated into sub-domains or geotectonic elements. Thus, there are at least three structural basins and at least three structural uplifts in the Central Cenozoic belt which may be regarded as a graben as it most probably is bounded by major faults or fault systems. In the absence of evidences to indicate the existence of intervening tectonic uplifts and arches, these basins should be regarded as structural, rather than depositional, basins.

In the Shan-Tenasserim massif, the differentiation into sub-domains is not clearly seen partly because of the complexity of the structures involved and partly because the region has not been properly mapped yet.

It is interesting to note that igneous bodies form the boundaries of some sub-domains. The alignment of the linear bodies of granites and related rocks with the regional structural trend in the Eastern Highlands is highly suggestive of the syn-tectonic or late-tectonic mode of emplacement for most of these rock bodies.

EVENTS IN THE GEOLOGICAL EVOLUTION

Fig. 3 illustrates, in summary form, the sequence of major geological events that are believed to have taken place through time in the Burmese region. The stratigraphical units are listed in order for three major geotectonic domains under the general heading, "Stratigraphy, Lithology and Thickness". The events, relating to all domains, are grouped under three general headings as follows:

1. tectonic and depositional environment
2. structural deformation and metamorphism
3. igneous activity and/or mineralization.

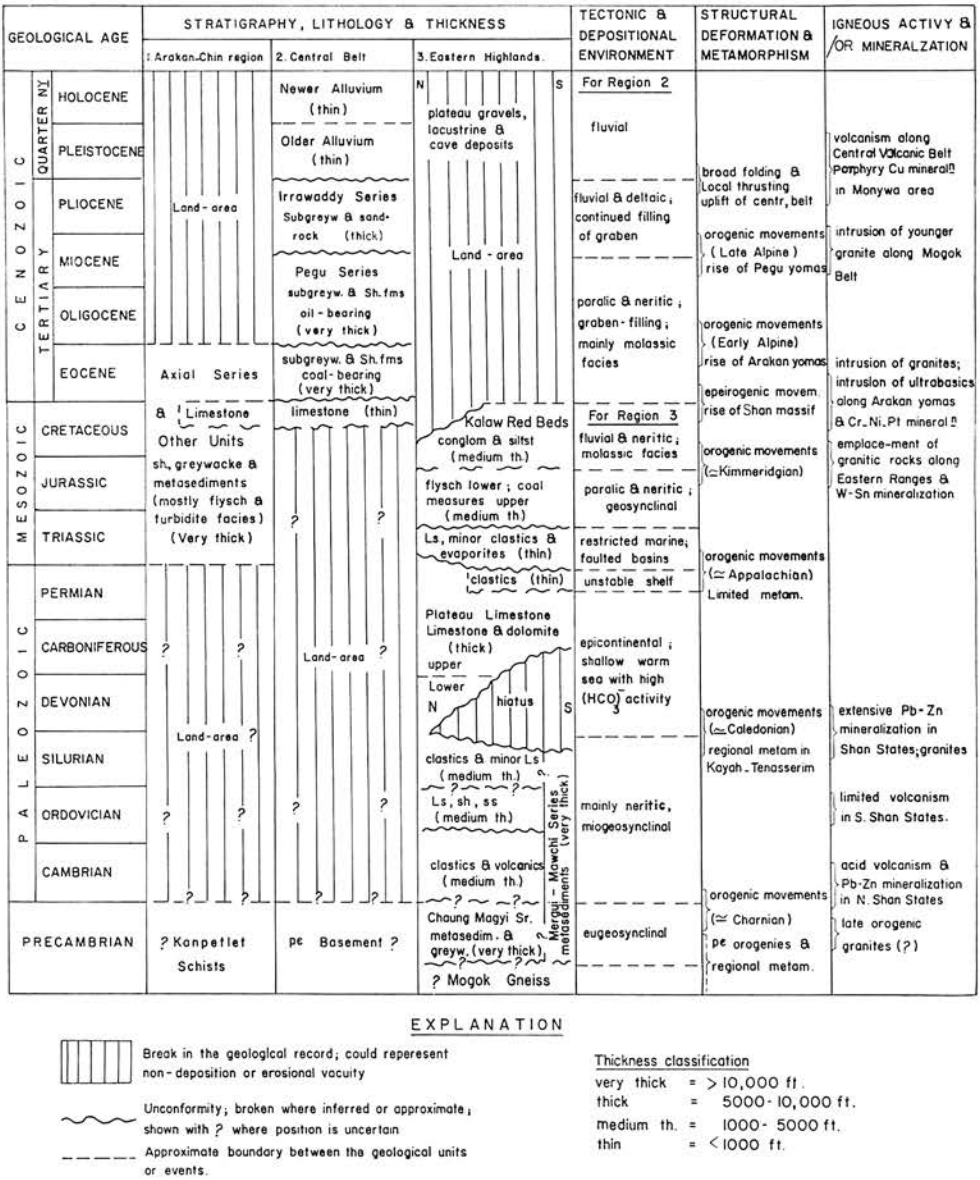

Fig. 3. Chart illustrating the Geological Evolution of Burma.

In addition, Figs. 4–7 are prepared so as to give fuller accounts. Figs. 5, 6(a) and 7(b) are essentially model expressions which are generally referred to as time-length diagrams. Such figures have been used as powerful tools in stratigraphic analysis (*e.g.*, *see* Sloss, 1962).

Figs. 3–7 are the outcome of interpretations and contemplations of the author partly on his own regional field experiences and partly on the information contained

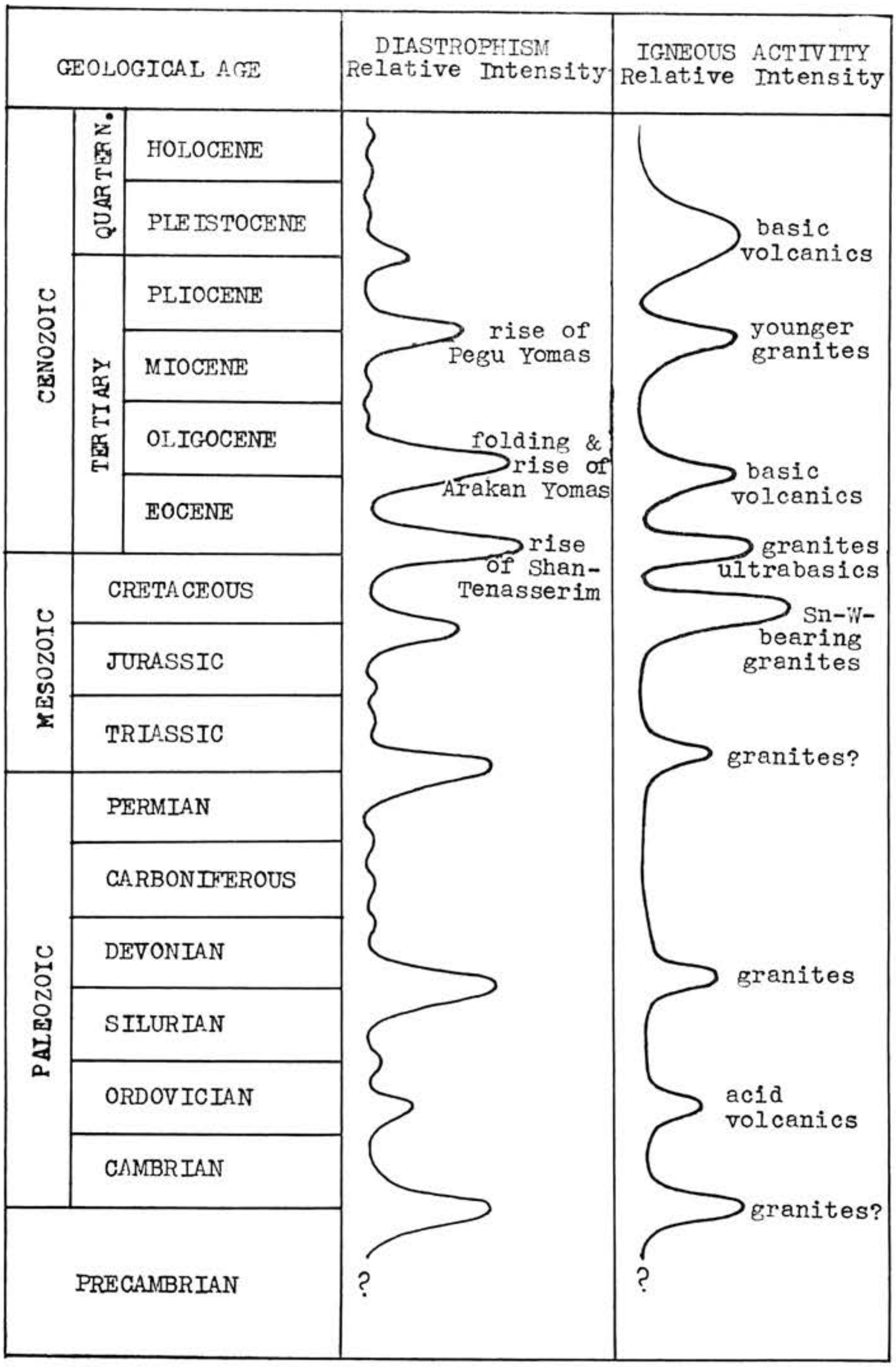

Fig. 4. Relative intensities of diastrophism and igneous activity through time in the Burmese region.

in the following works: La Touché (1913); Chhibber (1934); Nyi Nyi (1964); Brunnsweiler (1966); Hilde and Celeste (1967); Aung Khin and Kyaw Win (1968, 1969); Maung Thein and Ba Than Haq (1970); Ba Than Haq (1970); Myint Lwin Thein *et al* (1971). Certain specific informations would be mentioned in appropriate places.

In order to simplify the author has deliberately omitted the stratigraphic and lithological details. Only some well-known time-stratigraphic-unit names are included.

The sequence of the geological events would now be followed in the chronological order.

Precambrian

Stratigraphy and Age

As in other parts of the world, the Precambrian rock units in Burma are mainly of low-grade metasediments and gneisses (probably orthogneisses). The metasedimentary units, occurring rather widespreadly, were first grouped under the Chaung Magyi Series, and the gneisses, of lesser areal extent, under the Mogok Gneiss by La Touché (1913). It is now known that the Chaung Magyi Series* may be designated a supergroup, being made up of at least two groups, each consisting of a number of formations (Ba Than Haq *et al.*, 1970; Maung Thein *et al.*, 1971).

The series obviously forms a basement of probably Precambrian age in the Shan States, as it is found to be always overlain unconformably by the lower Paleozoic units, which in many places are Ordovician in age (La Touché, 1913; Brown and Sondhi, 1933), but in some places are Cambrian (Myint Lwin Thein *et al.*, 1971). The stratigraphic equivalents of the series in the Kayah State (parts of the Mawchi Series of Hobson (1941)) and in Tenasserim (parts of the Mergui Series of Rau (1930)) also occupy the lowest stratigraphic position in the respective areas. In other words, the Chaung Magyi Series and its stratigraphic equivalents, occurring as large inliers, probably form the basement in the Shan-Tenasserim region. However, as shown in Fig. 5, this basement may occupy a higher stratigraphic position in the Kayah-Tenasserim area. This is because the Mergui-Mawchi Series in the latter area is essentially a composite unit whose age may range from Precambrian up to Silurian (M. Thein and B.T. Haq, 1970).

The presence of a strong negative anomaly along the middle of the Central Belt (Evans and Crompton, 1945) suggests that the Precambrian sialic basement probably is present under the thick Cenozoic cover of the Central Belt. As for the existence or non-existence of the Precambrian rocks in the Arakan-Chin region, the problem has not been solved. The present consensus is that the Kanpetlet Schists, lithologically rather similar to the Chaung Magyi Series, may be Precambrian in age (*see* Kyaw Win, 1969).

La Touché (1913) first correlated the Chaung Magyi Series with Shillong Series of Assam (Dharwarian?) on lithological similarity. This is not as far-fetched as it first seems; as will be seen later it is quite possible.

* The terms Series, Beds used in this paper are merely old names, and as such they generally do not convey any time-stratigraphic connotations as understood in the modern stratigraphic nomenclature. Although they are obviously improper terms, their use cannot be avoided at this stage as most Burmese rock-units have not been reclassified in accordance with the modern stratigraphic practice.

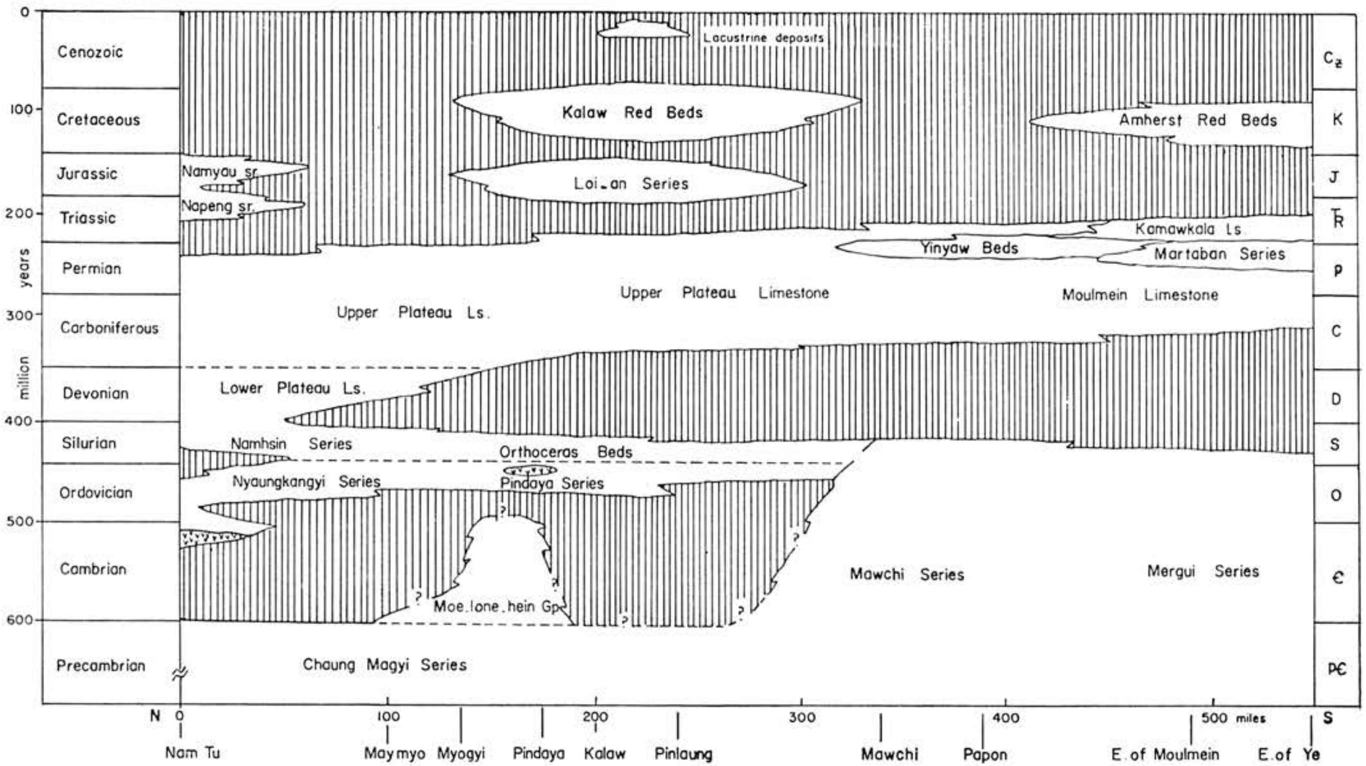

Fig. 5. Generalized north-south time-length cross-section along the eastern highlands (vertically ruled areas denote breaks in the stratigraphic records (lacunas), mostly representing non-deposition (hiatus) in this case)

The stratigraphic position of the Mogok Gneiss is still uncertain, nor is its relationship with the Chaung Magyi Series known. The lithological characters of these gneisses and migmatites—orthogneissic, streaky and banded over fairly wide areas—are somewhat similar to those of the Precambrian gneisses in some parts of the world. In fact, La Touché (1913), Pascoe (1950) and Iyer (1953) held that these gneisses are similar to the Dharwars (Archaean) of Mysore, India. It is probable that these gneisses and migmatites are Precambrian in age and possibly older than the Chaung Magyi Series.

Lithology and Environment

The Precambrian metasedimentary units, particularly the Chaung Magyi Series, contain (in order of abundance) phyllites, slates (some pyritiferous), metagreywackes, psammitic phyllites, mica schists, quartzites and graphite schists. This lithologic association is suggestive of deposition under eugeosynclinal conditions. If correlation of the Chaung Magyi Series/Mergui Series with the Phuket Series in Thailand (Kobayashi, 1960) and with the Kao-liang Series in Yunnan (Loveman, 1919) holds, it means that this Precambrian geosyncline probably extends northwards into Yunnan and southwards into Malaya. This geosyncline probably did not extend westwards into the site of the present Central Belt. One possibility is that the latter was non-existent then (*see* Fig. 8(a)).

Structural Deformation and Metamorphism

It appears that the Yunnan-Shan geosyncline envisioned above was a belt of intense tectonic activity as is suggested by the highly deformed character of the metasediments of the Chaung Magyi Series and its stratigraphic equivalents. The metasediments are tightly folded and isoclinal folding is not uncommon. It is not known how many orogenic episodes occurred during the Precambrian. It is conceivable that the regional metamorphism took place during these episodes. The episodes probably culminated into the Charnian orogeny towards the end of the Precambrian. This orogeny accounts for the pronounced stratigraphic break that exists between the tightly folded and metamorphosed Chaung Magyi Series and the fossiliferous Ordovician units in the Shan States. This break probably is absent in the southern area (*see* Fig. 5).

It was once believed that the so-called Mogok Series was metamorphosed during the Precambrian (La Touché, 1913; Iyer, 1953). However, new information obtained in recent years suggest that the metamorphism of part of this series, particularly the so-called Mogok Crystalline Limestones, occurred much later, probably during Tertiary in relation to the Alpine-Himalayan orogeny (Searle and B.T. Haq, 1964). The original rock units may be Plateau Limestone or even Cretaceous limestones (Clegg, 1941). In fact, Maung Thein and Soe Win (1969) have shown conclusively that the metamorphism in parts of the Mogok Belt is definitely post Plateau Limestone.

Igneous Activity and Mineralization

It is possible that emplacement of large bodies of granite accompanied the Precambrian orogenies. Up to now only small granite stocks have been found to be intrusive into the Chaung Magyi Series' (e.g., Ba Than Haq *et al.*, 1970). It is possible that older granites may have been later metamorphosed into granite gneisses. Even if radiometric dating is done, the problem is likely to remain because dates obtained may merely represent metamorphism of the pre-existing granites. Mineralization relating to the Precambrian igneous activities have not been noted yet.

Paleozoic

Stratigraphy and Age

In Fig. 5 an attempt is made to explain the stratigraphic relationships of the Paleozoic and Mesozoic rocks in the Eastern Highlands by means of a representative time-length cross-section. It will be noted that the Shan States are the only area in the whole Burmese region where a reasonably complete Paleozoic sequence exists. The Cambrian units were not recognized in the Shan States up to 1969. In 1970 a field party from Rangoon Arts & Science University first recognized the existence of rocks bearing Cambrian trilobites in the core of the Pindaya Range in the Southern Shan States, and the lithostratigraphic units thus recognized were formally grouped under the name Moelone-hein Group which is unconformable with the underlying Chaung Magyi Series (Myint Lwin Thein *et al.*, 1971). In many parts of the Shan States it appears that the Cambrian units are missing, and a stratigraphic break is generally recognized. In such areas the Middle and Upper Ordovician units lie unconformably on the Chaung Magyi Series. The Ordovician and Silurian units essentially are either conformable or para-conformable in most parts of the Shan States (*see* La Touché, 1913; Myint Lwin Thein *et al.*, 1971). The correlation of the Ordovician and Silurian units of the Northern Shan States with those of the Southern Shan States has not been properly made. The tentative relationships of the major units are shown in Fig. 5. Recent investigations by the field parties of Rangoon Arts & Science University indicate that the so-called Orthoceras Beds of the Southern Shan States may actually be Silurian, rather than Ordovician, in age (Myint Lwin Thein *et al.*, 1971).

In the Kayah-Tenasserim area the Lower Paleozoic is represented by the composite Mergui-Mawchi Series whose age has been shown to range from probably Precambrian to Silurian (Maung Thein & Ba Than Haq, 1970). Saito's (1959a) attempt to sub-divide the Mergui Series into two groups—the upper of Paleozoic and the lower of Precambrian ages—obviously is premature and misleading as his observation on Pataw and Patit islets near Mergui is areally very limited. The Taungnyo Series of Leicester (1930) in the Kayah State was regarded by Pascoe (1959) to be equivalent to the Mergui Series. The stratigraphic relationship between the Ordovician-Silurian units of the Shan States and the Mergui-Mawchi Series is not known.

Except for some parts of the Northern Shan States where Zebingyi Limestone beds (Upper Silurian) are conformable with the Lower Plateau Limestone of Devonian age (La Touché, 1913), there is generally a major stratigraphic break between the Lower Paleozoic units and the Plateau Limestone (Carboniferous—Permian in most parts) throughout the Shan-Tenasserim region. This break is interpreted to be the widest in the Kayah-Tenasserim area where the presence of Lower Plateau Limestone has not been noted (Fig. 5). Its presence is rather doubtful even in the Southern Shan States.

That this break becomes wider southwards may be due to the southward transgression of the warm, shallow Upper Paleozoic sea. As pointed out by Maung Thein and Ba Than Haq (1970), this is evident in the fact that in the Shan-Yunnan region the thick carbonate section present is Devonian to Permain in age (Plateau Limestone), while in Upper Tenasserim the carbonate section, which is considerably thinner, is Carboniferous to Permian in age (Moulmein Limestone). Further to the south in Thailand there is an extensive occurrence of a thick limestone sequence of Permian age (Ratburi Limestone).

The lithostratigraphy of the thick and widespread Plateau Limestone, first named and described by La Touché (1907, 1913), is still under systematic investigation. It is now known that the Plateau Limestone, in the Southern Shan States at least, is a large group consisting of at least six rock units of formation rank (Maung Thein *et al.*, 1971).

It was recently noted by Fay Lain (personal communication, 1971), on the basis of fossil discoveries, that the Plateau Limestone in some parts of the Southern Shan States probably extends up to lower Triassic in age. Such Triassic components could be the lateral equivalents of the Kamawkala Limestone in the Kawthoolei-upper Tenasserim area. The author considers the Yinyaw Beds (Hobson, 1941) and the Martaban Series as relatively thin clastic wedges in the upper part of the thick carbonate sequence of primarily Upper Paleozoic age (*see* Fig. 5).

The presence of the Paleozoic units has not yet been noted in both the Central Belt and the Arakan-Chin region. This probably means that these areas formed a landmass during the Paleozoic, possibly supplying detritus to the Paleozoic seas in the east. There is also another possibility that the two areas were non-existent as yet then (Fig. 8(a)).

Lithology and Environment

The Lower Paleozoic consists of both clastic and carbonate sediments—limestones, silty, blotchy, also blue and bedded; marls; buff siltstones; graptolite shales; calcareous sandstones; etc. These lithic types together with their faunal contents suggest deposition under primarily a neritic environment; the absence of greywacke-flysch types and the very limited occurrence of dolomitized limestones suggest that the tectonic set-up was very likely a miogeosyncline. On the other hand, the various limestone and dolomite units of Upper Paleozoic (Plateau Limestone), bearing abundant coral remains, were obviously depostied in a warm, shallow sea with high (HCO_3) activity. The Permian clastic units of the Kayah-upper Tenasserim area may be considered as clastic wedges formed in the environment of an unstable shelf.

Structural Deformation and Metamorphism

There occurred at least two major diastrophic episodes in the Shan-Tenasserim region during the Paleozoic (Fig. 4). The first that occurred near the end of Silurian (hence Caledonian) may be regarded as the last phase of the development of the lower Paleozoic miogeosyncline of the Shan-Tenasserim region. It accounts for the structural deformation of the Lower Paleozoic units, and probably is the cause of the big, widespread stratigraphic break that exists between Lower Paleozoic and the Plateau Limestone. It appears that the orogenic activity was felt more strongly in the Kayah-Tenasserim area than in the Shan States as the beds of the Mergui-Mawchi Series are more highly deformed and metamorphosed.

The second that occurred near the end of the Paleozoic (hence Appalachian) accounts for the broad and gentle folding in the thick carbonate sequence. Perhaps the movements were partly epeirogenic in nature, and the initial uplift of the Shan-Tenasserim region must have begun. This episode gave rise to the post-Paleozoic, stratigraphic break which is rather extensive. Regional metamorphic effects relating to this episode are rarely seen. However, these movements could well be responsible for the intense brecciation commonly seen in the incompetent Plateau Limestone beds.

Igneous Activity and Mineralization

There was limited acid volcanism, represented by the Bawdwin Volcanic Series, probably during Cambrian, in the Northern Shan States. Mineralization of the famous lead-zinc deposits of the Bawdwin Mines was probably related to this igneous activity. A rather limited contemporaneous volcanism occurred during Ordovician in the Southern Shan States.

The existence of igneous activity, of considerable intensity, relating to the postulated Caledonian and Appalachian orogenies in the Burmese region seems no longer questionable. Granite bodies having (i) pre-Carboniferous and post-Silurian, and (ii) pre-upper Triassic and post-Permian ages, have been shown (by radiometric dating) to occur in northern Thailand (Baum *et al.*, 1970). The first-mentioned granites, which may be considered as the Caledonian granites, are found to be continuous, across the borders, with the granties in southeastern Shan States (Fig. 2, 20° N/100° E). On the basis of the radiometric dates the presence of Permian and early Triassic granites has also been established in Malaysia (Anonymous, 1966). Thus it is reasonable to say that the Hercynian granites were probably emplaced in the Burmese region too.

Mesozoic

Stratigraphy and Age

Unlike the Paleozoic units the Mesozoic units are not well developed in the Shan-Tenasserim region. In fact, some rock units, such as the Napeng Beds (Rhaetic), are very limited in occurrence. The Mesozoic rocks are found to be mostly restricted to linear outcrop belts which are believed to represent depositional basins. At least two such basins, tentatively named as the Kalaw and Lashio basins, are believed to have existed during the Jurassic (Fig. 2). Regional stratigraphic analysis by Fay Lain (personal communication, 1971) indicates that the Kalaw Basin is a synclinal basin. The Loian Series, deposited in this elongated basin, is a group consisting of a number of formations. Recent field studies (by the author) along the western margin of the Shan Plateau have revealed that another long belt of Jurassic units is also present west of this basin. The Namyau Series (Jurassic) of the Northern Shan States are more limited in occurrence.

There exist some misconceptions on the nature of stratigraphic relationship between the Loian Series and the Kalaw Red Beds. For example, Saito and Uozumi (1959, p. 23–24) stated that the two series are merely two different facies deposited in the same basin during the Cretaceous. This statement is incorrect, because there is an apparent stratigraphic break between the tightly folded Loian units and the overlying Kalaw Red Beds which are broadly folded. As will be discussed later, this break marks the time when fluvial and deltaic conditions first prevailed in the Shan area. The age of the Kalaw Red Beds is still problematical as authentic fossils have not been discovered so far. (Saito and Uozumi (1959) erroneously mentioned that the Kalaw Red Beds contain *Turrites* and *Baculites* sp.). The present consensus is that it probably is Upper Jurassic to Cretaceous in age. Its stratigraphic equivalents could be the Red Beds of Amherst in Tenasserim (Chhibber, 1934), and part of the Khorat Group in Thailand (Sato, 1971).

The Mesozoic rock units are practically absent in the Central Belt. On the other hand, they are now known to be present in the Arakan-Chin region. Myint Lwin Thein (1958) reported the occurrence of *Doanella* sp. in a slate unit occurring in northern Chin Hills. Thus it is evident that at least part of the lithic sequence of this folded belt is as old as the Triassic. Kyaw Win (1969) concluded that a large part of the Arakan-Chin region is Eocene or older in age. Thus it is reasonable to assume that the so-called Axial Series and related rock units are probably Triassic to Eocene.

An interesting point about the Axial Series is the occurrence of large exotic blocks of Cretaceous limestones within the shales (e.g., along the Padaung-Taunggup Pass). The source of their derivation is still problematical.

Lithology and Environment

The Mesozoic sediments as a whole may be considered to have been deposited in synclinal basins and linear troughs, the latter being probably down-faulted, occupying the still submerged parts of the rising Shan Plateau.

The occurrence of evaporites (Panngo Evaporite of Brunnsweiler, 1962) in the Triassic of the Northern Shan States suggests a restricted marine environment. The lithology of lower Jurassic units in the Southern Shan States, consisting mostly of flysch-like sediments (containing shallow-marine ammonites) and some turbidites, indicates that a neritic, geosynclinal environment probably prevailed within the basin. As deposition proceeded the basin became gradually shallower so that a paralic environment ensued. This change probably accounts for the deposition of subgreywackes and coal measures in upper Jurassic. Recent field investigations along the western margin of the Shan Plateau show that a thick unit of greywackes, slate and quartzite may be Jurassic in age. Here too, geosynclinal conditions were prevailing.

The Kalaw Red Beds consist of units of red siltstones and conglomerates which are generally polymictic. Such lithological types are indicative of an oxidising, mainly fluvial to deltaic environment. In terms of tectonic facies, the red beds-conglomerates (in places fanglomerates) association may be said to represent a molassic facies derived from the rising highlands comprising mainly of Loian Series and the Plateau Limestones.

The Axial and related units in the Arakan-Chin region are made up primarily of greywackes, shales, slates and intruded serpentine. The general sedimentary type may be described as flysch. Such a lithological association indicates a deep-water geosynclinal environment of deposition. The sedimentary record shows that this condition continued into Eocene (*see* Kyaw Win, 1969).

Structural Deformation and Metamorphism

There were two major episodes of diastrophism during the Mesozoic. The first which took place near the end of the Jurassic (hence Kimmeridgian) probably accounts for the intricate and tight folding and complex faulting undergone by the incompetent Loian beds. Brunnsweiler (1962), however, contended that these complex structures resulted from gravitational down-sliding. As small-scale over-thrusting has not been observed in association with these structures, this contention cannot be substantiated. It must be pointed out that tight folding may also have resulted from lateral compression due to vertical block movements within the Shan massif. Regional metamorphism of the Jurassic rocks along the western margin of the Shan Plateau might have been related to the Kimmeridgian orogenic movements.

The other episode probably began while the Kalaw Red Beds were still being deposited. The movements involved are considered to be primarily epeirogenic as they caused the final uplift of the Shan-Tenasserim region almost to their present levels. (This uplift, of course, would be coupled by the initial subsidence of the Central Belt that lay immediately west of the faulted junction). In this connection, Sato's (1971, p. 53) statement that the so-called Burmese-Malayan geosyncline became a land before the end of the Triassic seems incorrect. On the other hand, recent informations (e.g., Kyaw Win, 1969) suggest that the Arakan-Chin region became a landmass only at the end of Eocene. This is different from Chhibber's (1934) contention that the Arakan-Chin region was uplifted at the end of Cretaceous.

Saito (1959b) contented that the crustal deformation of the complex Mesozoic structures along the western borders of the Southern Shan States took place during Middle Tertiary. There is no supporting evidence for this statement, however. As mentioned above, the deformation characters and sequence seem to suggest that the Loian beds were complexly deformed during the Kimmeridgian orogeny and the overlying Kalaw Red beds less complexly deformed at the end of the Mesozoic.

The Mesozoic tectonic and magmatic events envisioned in this and succeeding sections (*see also* Fig. 4) are in general agreement with those dated by thermoluminescece in the Indosinian-Thai-Malayan Orogen (Hutchison, 1968a, b). There are not any discernible regional metamorphic effects relating to the movements at the end of the Mesozoic.

Igneous Activity and Mineralization

The Mesozoic was a time of intense igneous activity as the bulk of the granites and granite gneisses in Tenasserim and along the western margin of the Shan Plateau (*see* Fig. 2) were probably emplaced consequent to the postulated Kimmeridgian orogeny. Evidences, though largely indirect, are not lacking for this statement. In view of the fact that the tin-bearing granites of West Malaysia have been shown to be mainly late Jurassic and partly late Cretaceous in age* (Anonymous, 1966; Hilde and Celeste, 1967; Alexander, 1968), it is reasonable to assume similar ages for the tin-tungsten-bearing granites of Tenasserim, which after all are the northern continuation of the West Malaysian granites. Furthermore, recent field investigations in the Yinmabin area have shown that the granite bodies in some places are intrusive into the metasediments of Jurassic age.

These granites could well be the northern continuation of the Tenasserim granites since both lie in the same granite belt. In this regard, Chhibber's conclusion that the Tenasserim granites were intruded during late Cretaceous and early Eocene times is only partly true.

Granite gneisses are quite common along this belt, especially in the middle and northern parts. In many cases they occur closely together with granites, and their mutual contacts are mostly gradational. It is, therefore, clear that they are orthogneisses which were derived from the associated granites by later regional metamorphism. It is not known whether or not some of them were derived from the pre-existing granites emplaced during the earlier orogenies.

The Kimmeridgian igneous activity mentioned above is perhaps the largest recorded for the Burmese region (Fig. 4). In this connection, radiometric dating of the Tenasserim granites would be a most fruitful undertaking.

It is, of course, common knowledge that tin-tungsten mineralization accompanied the hydrothermal phase of the large-scale emplacement of late Mesozoic granites.

* Hutchison (1968b, Fig. 6) mentions some data which disagree with this statement. On the basis of 41 age determinations compiled by him, he purports to show that the larger part of granites in the Indosinian-Thai-Malayan Orogen were emplaced in the late Triassic-early Jurassic times.

Igneous activity relating to the late Cretaceous-early Eocene movements appears to be quite pronounced in the Arakan-Chin region (*see* Chhibber, 1934). In that part, small ultrabasic bodies (mostly serpentine) were intruded into the Axial Series along the eastern side of the folded belt. Nickel-chromium mineralization was associated with these intrusions.

Cenozoic

Stratigraphy and Age

The Cenozoic stratigraphy of Burma is better known because of the following facts: (i) relatively easier accessibility; (ii) less complex stratigraphy and structures; (iii) occurrence of mineral fuels-oil, natural gas, and coal—within the Tertiary formations. Nevertheless, there still remain a number of problems, *e.g.*, the problem of the general pattern of sedimentation and that of regional correlation which is made difficult by lateral facies changes, both in lithological and faunal aspects.

The oldest sedimentary unit in the Central Belt appears to be represented by patches of Cretaceous rocks in the Kachin State which may be the western extension of the Cretaceous limestones exposed at the First and Second Defiles of the Irrawaddy (*see* Clegg, 1941). These patches form small inliers in the Tertiary belt.

The lithostratigraphy and time-stratigraphy of the Tertiary units of the Central Belt and Arakan Coastal Plain have long been a subject of voluminous studies since Theobald (1874) first published his classic memoir on the "*Geology of Pegu*" (Here, only some major works will be mentioned: Cotter (1912); Stuart (1912); Stamp (1922); Lepper (1933); Tainsh (1949); Aung Khin and Kyaw Win (1969); Kyaw Win and Thit Wai (1971). In these works, many rock units have been recognized, but the status and correlation of these are still in a state of flux. A review on the tertiary stratigraphy will not be attempted here. Only some essential points will be mentioned.

The Tertiary rock units may be grouped under three broad units of group rank, namely (in ascending order), the Eocene Series, Pegu Series (Oligo-Miogene), and Irrawaddy Series (Pontian-Pliocene), which are separated from one another by distinct unconformities. These units are very thick sequences, having total accumulated thicknesses of about 40,000 ft., 25,000 ft., and 10,000 ft., respectively, in the Minbu Basin where the Tertiary succession is the most complete and their stratigraphy the best known (data from Aung Khin and Kyaw Win, 1969). This also is the general type area for the Tertiary succession in Burma. In this general area, the Eocene Series consist of at least five rock units of formation rank, and the Pegu Series of at least six such units. An unconformity is locally recognized within the Pegu Series. As for the Irrawaddy Series, differentiation into formation has not been properly done because of the scarcity of index fossils and the rather uniform lithologic character vertically.

In the Arakan-Chin region, recent investigations (Kyaw Win, 1969, p. 1) show that "the main bulk of the Southern Chin Hills is Eocene with inliers of older rocks". Rock units younger than Eocene have not been recognized, and it is, therefore, very probable that the region has been a land-area since the close of Eocene.

There are only minor occurrences of Tertiary sediments in the Shan-Tenasserim region. The best known occurrences are the oil shales of late Tertiary age in the Amherst and Mergui districts, and lacustrine deposits, probably of the same age, in the Southern Shan States (Chhibber, 1934).

It is not known what lies beneath the Eocene beds in the Central Belt. As noted in an earlier section, the Paleozoic and Mesozoic rocks may probably be absent beneath the thick cover of the Cenozoic sediments.

Lithology and Environment

The Eocene and Pegu Series consist of alternating units of subgreywacke sandstones and shales. The sandstones are feldspathic and glauconitic, and mostly calcareous, containing a large proportion of primary calcite cement. Shales in the Eocene series are mostly greenish (hence probably glauconitic), but are black and carbonaceous in some areas (e.g., Yaw Shales). Shales in the Pegu Series are mostly grey-greenish or bluish. All of these units generally contain brackish and shallow marine fauna in the central and southern parts, and fresh-water and brackish fauna in the northern part. Moreover, the Eocene Series is coal-bearing in the Lower Chindwin area. Such lithological and faunal characters suggest that the general environment of deposition is primarily neritic in the central and southern areas, and fluvial and deltaic in the northern area. The general lithological association is more like molasse than anything else. This view is in agreement with that of Brunnsweiler (1966) who put forward a flysch-molasse model for the Arakan Yomas-Central Belt. As will be discussed in the next section, the depositional framework most probably was a graben, and the bordering highlands of the Shan Plateau (since the end of Cretaceous) and the Arakan Yomas (since the end of Eocene) apparently were the source areas.

There was a change in the depositional environment as the sediments of the Irrawaddy Series were laid down. This series consists primarily of buff or reddish sand-rocks* and sandstones with minor shales and shaly sandstones. The sandstones generally are poorly cemented, and contain fossilwood as well as terrestrial vertebrate remains. Large-scale trough-type cross-bedding is commonly seen. All these characters indicate that the Irrawaddy sediments as a whole were deposited under fluvial to deltaic conditions during continued filling of the graben.

Depositional Framework

Contrary to some recent descriptions of the Central Belt as the "Burma Tertiary Geosyncline" (*e.g.*, Aung Khin and Kyaw Win, 1969), the author would rather subscribe, with some modifications, to the old view of Cotter (1918) and Stamp (1922) who considered the Central Belt essentially as a rift valley or graben. To the author this conceptual model is not only simple, but it fits with many observational facts (*see also* Fig. 2).

Available information and evidences in support of this view may be listed as follows:

1. The Central Belt is bounded by major faults or fault systems whose existence is certain in the east, but is less certain in the west (*see* Aung Khin and Kyaw Win, 1969, Geological Map of Burma; Dey, 1968).
2. Enormous thicknesses of the Tertiary sediments (in excess of 75,000 ft.) deposited, under conditions generally not deeper than neritic, within a relatively short interval of geological time, imply a large amount of continual and rapid subsidence of the Central Belt during the Tertiary. This seems possible only if the depositional site is a down-faulted trough.

* The term "sand-rocks" is used for very loosely cemented sandstones, following the usage of Chhibber (1934).

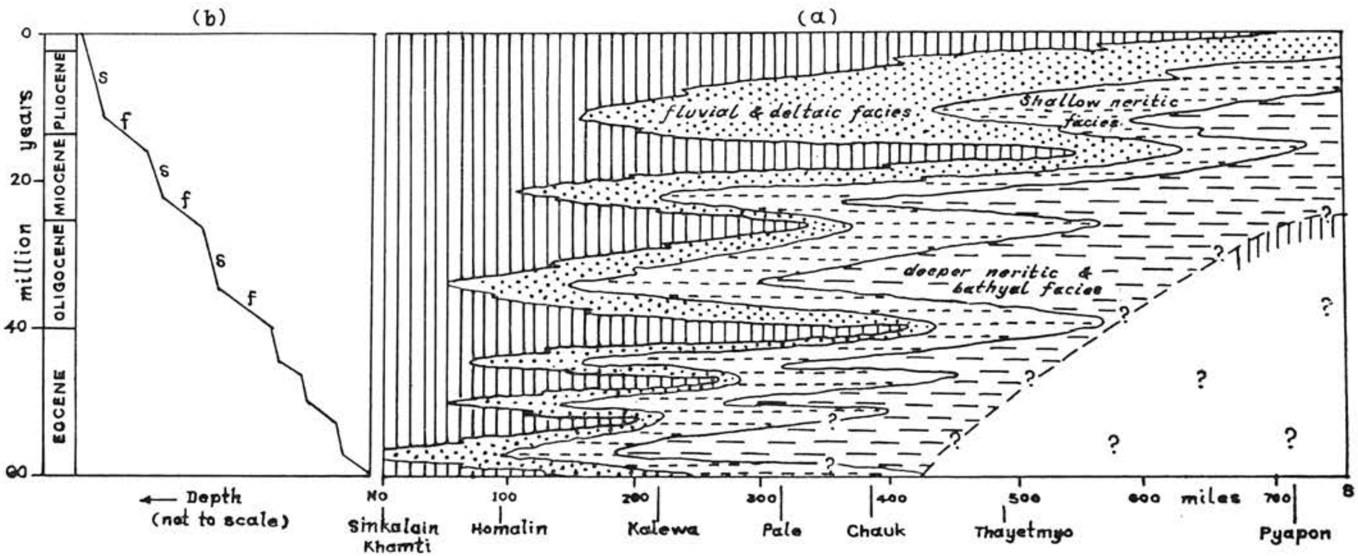

Fig. 6(a). Schematic north-south time-length cross-section along the central belt (vertically ruled areas denote breaks in the stratigraphic records (lacunas), mostly representing non-deposition (hiatus) in this case).

Fig. 6(b). Hypothesized time-depth curve for 6(a) (*f*, faster subsidence resulting in transgression; *s*, slower subsidence and silting-up resulting in regression).

3. The presence of a zone of strong negative gravity anomaly running north-south along the middle of the Central Belt (Evans and Compton, 1946). This finding also implies a large amount of subsidence of the belt with respect to the bordering highlands.

It is not out of place to discuss here the use of the term "geosyncline" to describe the tectonic framework of the Central Belt. The use is inappropriate and misleading in the sense used by most stratigraphers (*e.g.*, Krumbein and Sloss, 1963). For one thing, the Tertiary sediments do not exhibit the lithological, structural and deformational characteristics normally found in geosynclinal areas (*e.g.*, *see* Weller, 1960, p. 250–2). Also, as shown above the Central Belt most probably has been a linear down-faulted trough. In any case, the author would propose a simple and non-committal name for the Central Belt as a depositional unit, namely, the "Burma Cenozoic Trough".

Depositional Patterns

The general depositional pattern of the Tertiary sediments as interpreted and conceived by the author are shown in Figs. 6 and 7. Figs. 6(a) and 7(a) are the author's interpretations based partly on the information given in Stamp (1922) and Aung Khin and Kyaw Win (1968), respectively.

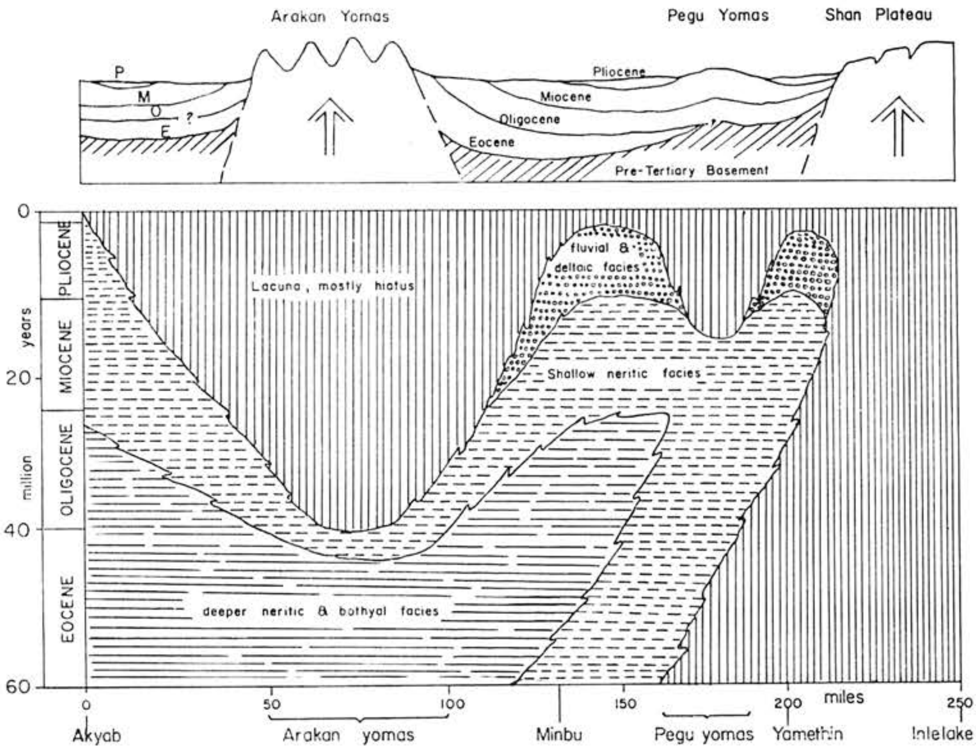

Fig. 7(a). Diagrammatic stratigraphic cross-section along lat. 20°N to show (I) infilling of the raben, (II) off-lapping of the Tertiary formations on both sides of the Arakan Yomas.
Fig. 7(b). Schematic East-West Time-Length cross-section across the Central Cenozoic Belt (along lat. 20°N) (vertically ruled areas denote lacunas, mostly representing hiatus in this case).

It should be noted here that Chhibber's general description (1934, p. 210) of the Tertiary history of the Central Belt as "the infilling of the Burmese gulf by river-borne sediments from the north and by marine sediments in the south" seems still essentially correct. After all, it is easier to visualize deposition at the present Irrawaddy Delta and off-shore as merely the continuation of the Tertiary sedimentation in the Central Belt. What the author attempts to present here, by means of time-length diagrams, is the interpreted cyclical pattern of sedimentation during the Tertiary.

As shown in Figs. 6 and 7, the author considers the various Tertiary formations, present in different structural domains, as genetically related. This consideration is the logical outcome of regarding the Central Cenozoic Belt as a graben subsiding continually, though not necessarily at the same rate throughout the Cenozoic. In other words, areal variations seen in the Tertiary formations of the Central Belt are interpreted as merely lateral facies, shifting north and south across the time lines as a result of marine transgressions and regressions which, in turn, were probably brought about by the alternating phases of slow and rapid subsidences (Fig. 6(b)).

In drawing Fig. 6 (drawn across the depositional strike) the following facts about the Central Belt are taken into account:

1. alternation of sandstone and shale formations in many areas, particularly in the Minbu Basin.
2. predominantly marine sedimentation in the south, and alternation of marine and continental sedimentation in the north for the Eocene and Pegu Series; fluvial and deltaic sedimentation for the Irrawaddy Series.
3. apparent wedging out of some units on a regional scale (*e.g.*, *see* Stamp, 1922).

Explanation for (1) and (3): As shown in Figs. 6(a) and (b) alternation of shale and sandstone formations within the Minbu Basin, for example, are interpreted as due to sudden deepening of the trough (resulting in transgression) followed by slower subsidence, hence the gradual silting up (resulting in regression). In this context, a thick shale unit, such as Pyawbwe Clay, overlaps upon Okhmintaung Sandstone during the transgressive phase and is off-lapped by Kyaukkok Sandstone in the regressive phase. The wedge-shaped units presumably were formed in this way.

Explanation for (2): Although there probably were at least six cycles of major transgression-regression, the general trend of the Cenozoic sedimentation in the Central Belt appears to have been gradual regression towards south (Fig. 6(a). This explains why, as Chhibber (1934, p. 212) put it, "fluvial and deltaic sediments kept continually advancing towards the south". Thus, the Irrawaddy Series constitutes a predominantly continental facies.

Fig. 7 attempts to show the general depositional pattern more or less along the depositional strike of the Central Belt. Infilling of the graben and sideway off-lapping of the Tertiary formations on both sides of the Arakan Yomas are depicted by means of a stratigraphic cross-section and a time-length cross-section. In Fig. 7(b) the following points are worthy of note: (1) regression by gradual filling-up on the two flanks of the Arakan Yomas since the close of Eocene; (2) gradual transgression of the sea eastwards from the site of the present Pegu Yomas towards the Shan Plateau. Minor reversals which must have occurred during major transgressions and regressions are diagramatically shown by means of "kinks".

Structural Deformation and Metamorphism

There probably were at least three major orogenic episodes during the Cenozoic. The first occurred at the end of Eocene, and these early Alpine movements probably caused the folding as well as rise of the Arakan-Chin region. This would be so because, as noted above, sediments younger than Eocene have not yet been found in that region. These movements evidently were also felt in the Central Belt as there is a well-marked unconformity between the Eocene and the younger units in most areas.

There is no evidence to indicate that the Eocene sediments were regionally metamorphosed during the early Alpine movements in the Central Belt proper. However, as believed by Searle and Ba Than Haq (1964), it is quite possible that regional metamorphism along the marginal zone with the Shan Plateau (the Mogok Belt of Searle and B.T. Haq) took place during these movements. This became a zone of intense structural deformation and metamorphism probably because the rocks of the marginal parts were strongly pushed against the stable block of the Shan-Tenasserim region. It is conceivable that parts of the late Mesozoic granites were transformed into granite gneisses during this deformation. Up to now there is no evidence to indicate that the Pegu sediments, present just west of this zone, were ever metamorphosed. This, therefore, seems to rule out the possibility that metamorphism along the Mogok-Belt was post-Miocene.

The second episode probably occurred near the end of Miocene, and this obviously accounts for the unconformity between the Pegu and Irrawaddy Series. The Pegu Yomas must have been uplifted during this time as there are no known occurrences of the Irrawaddy Series on the Pegu Yomas. The movements involved seem only strong enough to cause gentle folding and warping in many parts of the Central Belt.

The third episode must have occurred after the deposition of the Irrawaddy Series, because in many parts of the Central Belt, the Irrawaddy Series and the underlying Pegu units are found to have been structurally defoımed together. Local thrusting obviously accompanied the folding movements, e.g., at Chauk where thrusting is definitely post-Irrawaddian. The Central Belt was probably uplifted at the end of this episode.

Igneous Activity and Mineralization

Igneous activity was pronounced during the Cenozoic. The intrusion of "younger" granites along parts of the narrow Mogok belt were related to the late Alpine movements. A good evidence for this statement is the late Miocene ages obtained (by radiometric dating) for two granites and a pegmatite sample from the Mogok area (*see* Maung Thein & Ba Than Haq, 1970, p. 278). Radioactive minerals are associated with some pegmatites intruded during this activity.

The volcanic activity that is believed to have occurred primarily during the Quaternary is well manifested along the Central Volcanic Line of Chhibber (1934) that passes through the Wuntho mass, Lower Chindwin volcanoes and Mt. Popa. The principal rock types are basalts and andesites, but rhyolites and related types are also present in lesser amounts. As is well-known, porphyry copper mineralization is associated with the acid volcanics in the Lower Chindwin area.

Summary of the Geological Evolution

Although it would be repetitious with respect to Fig. 3, it is thought desirable to give an outline summary of the geological evolution of Burma in a more readable and sequential form as follows:

1. *Precambrian*
   (a) deposition of the Chaung Magyi Series and lower part of the Mergui-Mawchi Series under eugeosynclinal conditions in the Shan-Tenasserim region.
   (b) Charnian orogeny and related regional metamorphism.

2. *Lower Paleozoic*
   (a) deposition of the Moelone-hein clastics in the Southern Shan States, and extrusion of the Bawdwin volcanics in the Northern Shan States, together with associated lead-zinc mineralization.
   (b) deposition of Ordovician and Silurian carbonates and clastics under predominantly neritic, miogeosynclinal conditions in the Shan States, together with limited contemporaneous volcanism in the Southern Shan States.
   (c) Caledonian orogeny and related regional metamorphism in the Kayah-Tenasserim area, probably followed by intrusion of granites, especially in the eastern part; rather extensive lead-zinc mineralization in the Ordovician carbonates.

3. *Upper Paleozoic*
   (a) deposition of a thick carbonate sequence (Plateau Limestone) in a warm, shallow sea (covering most of the Shan-Tenasserim region) which transgressed southwards during the Upper Paleozoic; formation of some clastic wedges during upper Permian in the Kayah-Tenasserim area.
   (b) epeirogenic movements and initial emergence of the Shan-Tenasserim region at the end of the Paleozoic.

4. *Triassic-Jurassic*
   (a) deposition of clastics and evaporites under restricted marine environment in small enclosed basins during the Triassic in the Northern Shan States; deposition of flysch and *Daonella* facies probably began in the Arakan-Chin region.
   (b) deposition of the Loian clastics and coal measures in synclinal basins and down-faulted troughs within the already rising Shan massif under geosynclinal conditions during the earlier part and under paralic conditions during the later part of the Jurassic.
   (c) Kimmeridgian orogeny and tight folding of the Jurassic beds; limited metamorphism along the western marginal zone of the Shan Plateau.
   (d) large-scale emplacement of the bulk of granitic rocks in Tenasserim and along the western margin of the Shan Plateau with associated tin-tungsten mineralization.

5. *Cretaceous*
   (a) deposition of the Kalaw Red Beds essentially as a molassic facies in an oxidising, fluvial to deltaic environment; continued sedimentation in the Arakan-Chin region.
   (b) epeirogenic movements and final uplift of the Shan-Tenasserim region to become a land area. The uplift was probably coupled by the initial subsidence of the Central Belt lying in the west.

(c) intrusion of some more granites along the Shan-Tenasserim region; intrusion of small ultrabasic bodies with associated chromium-nickel mineralization along the Arakan-Chin ranges during late Cretaceous-early Eocene times.

6. *Eocene*

(a) continued sedimentation under eugeosynclinal conditions in the Arakan-Chin region; deposition of molassic facies in the already subsiding Central Belt graben—mainly under continental and deltaic conditions in the south. A cyclical patern of sudden deepening followed by gradual silting-up might have prevailed.

(b) Early Alpine movements resulting in the folding and rise of the Arakan-Chin region; metamorphism along the Mogok Belt.

7. *Oligo-Miocene*

(a) continued filling of the still subsiding graben (Pegu Series) in the same depositional pattern as in 6(a).

(b) Late Alpine movements and uplift of the Pegu Yomas.

(c) intrusion of "younger" granites along the Mogok Belt.

8. *Pliocene-Pleistocene*

(a) deposition of the Irrawaddian sediments under fluvial and deltaic conditions as the Central Belt graben was finally filled up.

(b) uplift of the Central Belt while the Tertiary beds were being broadly folded and locally thrusted.

(c) volcanism along the Central Volcanic Line; porphyry copper mineralization in the acid volcanics of the Lower Chindwin area.

9. *Holocene*

denudation and continental sedimentation going on side by side, and the development of the present configuration of the Burmese region.

SOME SPECULATIONS

As mentioned in the introduction, one of the right and pertinent questions to be considered is: How does the Burmese region fit in the general framework of the continental drift? The solution of this problem is obviously not easy, and speculations are bound to arise in any attempt to solve it. Nevertheless it ought to be attempted in view of the fact that the theory of continental drift has been confirmed lately. Such an attempt, even if a little speculative, would at least serve as food for geological thought.

The results of various attempts to reconstruct Gondwanaland by five different authorities (du Toit, Lester King, S.W. Carey, J.T. Wilson, and Arthur Holmes) are quite different (*see* Holmes, 1964, figs, 874 and 875), but all are very similar in one aspect. This is the omission of the Southeast Asia region in making the respective "reasonable" fits. This may be due to the fact that first it is difficult to fit the region in the general framework. Secondly, to the above authors the region may seem a little insignificant in the world-wide picture. To be sure one cannot simply dismiss that the Southeast Asia mass was non-existent before continental drift first took place probably during late Mesozoic, because there exists a large area of Precambrian and Paleozoic rocks in the region. The author thinks it is about time to consider the development of Southeast Asia in relation to the Continental Dirft.

It is rather well-known that the Southeast Asia mass is a continental area, probably underlain by the sial (*see* "Indian Ocean Floor" prepared by *National Geographic* magazine, 1967). Whether Southeast Asia has drifted from the west is open to question. In any case, the author believes that the geological development of Southeast Asia in general, and of the Burmese region in particular, is closely connected with the development of the Bay of Bengal that separates Southeast Asia from the Indian Peninsula, In this respect, there are three possible explanations for the development of the Bay of Bengal:

1. It has always been an oceanic basin, probably underlain by the sima underneath the Ganges Cone.
2. It represents the "scar" left by the drifting of Australia away from the Indian Peninsula as was postulated by Ahmad (1961).
3. It is a *sphenochasm** formed by the wedging apart of the Indian Peninsula westwards and Southeast Asia eastwards away from the Ninety East Ridge.

As for (1) there are not evidences to indicate either for or against. However, this idea cannot explain the formation of the Ninety East Ridge and the Java Trench. Only by the spreading of the sea-floor can their formation be explained.

As for (2) Ahmad (1961) claimed "a particularly well-established Permian fit" for India and western Australia (*see* Holmes, 1964, Fig. 871), and in Carey's (1958) reconstruction of the Gondwanaland this Indo-Australia link is also shown (*see* Holmes, 1964, Fig. 874). There are, however, at least three objections to this view:

1. As pointed out by Smith (1971, p. 227), perhaps the main general objection against fitting India and Australia together is that the Upper Carboniferous tillite pattern does not match across the join. (*see* also Fig. 15. 14 of Smith's paper).
2. The regional trends of eastern Australia and of Southeast Asia are not fittable.
3. The postulated direction of drift of Australia does not correspond with the direction of sea-floor spreading known at present (e.g., *see* Heirtzler, 1968).

As for (3) it was recently drawn to the author's attention that Burton (1970) already made this kind of proposal formally in print*. It must also be mentioned that the following statement by Burton (1969) came to the author's attention only lately. Referring to wrench faulting in Malaya, Burton states (p. 13): "The present writer considers that this faulting is an expression of the separation of the Yunnan-Malaya orogen from the Indian Shield".

There are at least four points that seem to support the sphenochasm speculation:

1. Presence of the Ninety East Ridge which runs nearly north-south, with its projected northern end apparently passing through the postulated hinge area near the Shillong Plateau. This ridge could well mark the axis of spreading

* in the sense as first used by Carey (1955)
* in Paleogeography/Paleoclimatology/paleoecology, v. 7. I have not seen this paper yet.

sea-floor from which the opposing lands of Indian Peninsula and Southeast Asia have drifted.

2. Rather remarkable fitting of the pre-Tertiary outline of the Shan-Tenasserim-Malaya region with the eastern coastline (of Precambrian and Paleozoic rocks) of Indian Peninsula, except for Ceylon.
3. Similarity between the Shillong Series of Assam and the Chaung Magyi Series of the Shan States (La Touché, 1913) which can be fitted as a continuous belt before the drift (Fig. 8(a)).
4 Spreading of the sea-floor northeastward from the mid-Indian Ocean Ridge, and the floor is finally underthrusted at the continental margin of Southeast Asia to form the Java Trench.

Whether or not the sea-floor is spreading eastwards and westwards away from the Ninety East Ridge is not yet known. It presence, once detected, would provide a more conclusive evidence for the present speculation. In this connection, four points that seem to discard this speculation should also be mentioned.

1. The Mergui Series of Tenasserim are not similar to the Precambrian Khondalites and unclassified crystallines of the Vizagapatam area.
2. As summed up by Chhibber (1934, p. 144, 159) the Lower Paleozoic fauna of the Northern Shan States are more closely related to that of the Northern Europe rather than to that of the Himalayas. This therefore seems to reject the idea that the Shan-Tenasserim region and eastern India were joined together during the Paleozoic as postulated in Fig. 8(a). However, this may not be a serious objection because, as Chhibber (p. 174) also summed up, there is a striking resemblance between the Plateau Limestone fauna and the Permo-Carboniferous fauna of the Salt Range and Central Himalayas.
3. The Permian System of Malaya apparently are dissimilar to the Lower Gondwana System of Peninsular India in terms of both lithology and paleontology. (*see* Gobbett, 1968; Wadia, 1957).
4. The Upper Carboniferous glaciation in India has no counterpart in Malaysia.

To sum up, it is the author's contention that the Indian Peninsula and the Shan-Tenasserim-Malaya region were once joined together in the distant geological past. It should be pointed out that this contention is not in disagreement with the present-day plate tectonics of Northeastern Indian Ocean, because it is merely referring to the pre-Mesozoic tectonic framework of Southeast Asia to which the plate-tectonics model seems not applicable. It should be mentioned in this connection that there are reasons to believe that only the post-Paleozoic geology of Burma can perhaps be fitted in the general framework of the plate tectonics of Northeastern Indian Ocean. (Some of the reasons are: existence of blueschist terranes in the northern part of the Central Belt; alpinotype peridotite intrusions and thick flysch sequences on the trench-side (Arakan Yomas); molasse on the arc-side (Central Belt). All of these are located outside the Shan-Tenasserim massif of Precambrian and Paleozoic rocks.)

This speculation is not necessarily contradicted by the possible south-southeastward movement of the Southeast Asian block suggested by Rodolfo (1969), because this is a more recent event occurring probably during Late Miocene to Recent times according to Rodolfo (p. 1203).

The author's speculations regarding the development of the Burmese region in the general framework of the continental drift are diagrammatically shown in Fig. 8. Fig. 8(c) and (d) correspond to the so-called Kuenen model as cited and named by Rodolfo (1969a).

These speculations are somewhat in disagreement with the interpretation made by Rodolfo (1969a, b), namely, that the Arakan Yomas and the Andaman-Nicobar

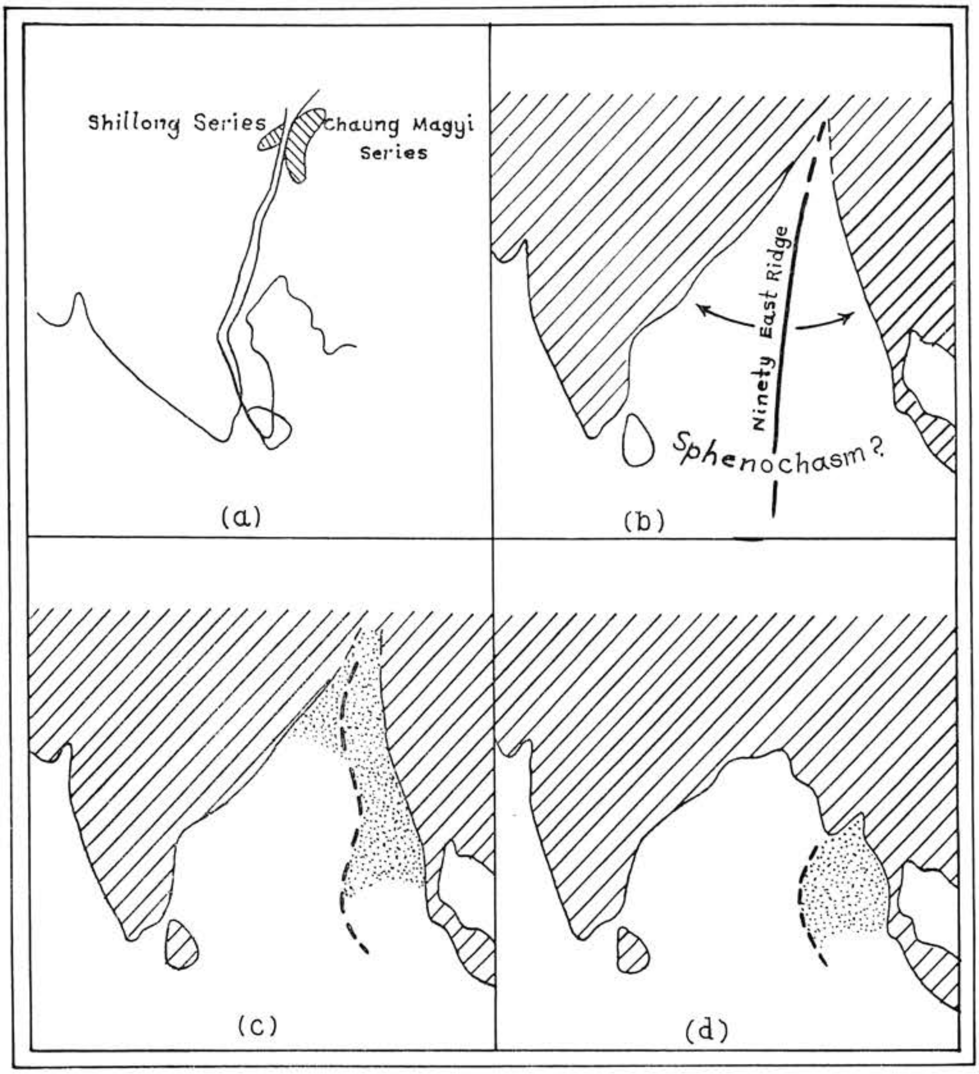

Fig. 8. Speculated stages in the Geological Development of the Indo-Burmese Region based on the possibility of the Bay of Bengal being a Sphenochasm.
a, at the end of the Paleozoic; *b*, at the end of the Mesozoic; *c*, during the Tertiary—development of the Arakan-Andaman island arc, and infilling of the Burmese and Assam troughs which were bordered by landmasses; *d*, during the Quarternary—continued filling of the Andaman Sea and development of the present land configuration.

Ridge have been structurally and lithologically not continuous, and that there existed a landmass as far west as the present Andaman Basin during the Paleogene. The present author considers that the continuity of topographic trends and of serpentine belt, and lithologic similarity of the flysch-type sediments (eugeo-synclinal facies) of primarily Paleogene age are good enough evidences to indicate that the Arakan Yomas and the Andaman-Nicobar Ridge constitute a single geotectonic element, an island arc system, possibly with an adjoining subduction zone in the west, first developed probably during early Tertiary. Admittedly there is the problem of source areas, particularly for the Andaman-Nicobar area; however, island arcs are widely accepted as major sources for geosynclinal fills (e.g., see Krumbein and Sloss, 1963, p. 402), and in this context the eugeosynclinal sediments of the region might have been derived from the ancestral Arakan Yomas-Andaman-Nicobar Ridge, probably a geanticline then.

As for the possible presence of a landmass as far west as the present Andaman Basin, there is no evidence to indicate that the 250 km wide Malay shelf (except in its easternmost part—the Mergui Archipelago) is underlain by the Paleozoic and Mesozoic rocks. Thus Rodolfo's assumption about the beveling of the shelf is rather improbable. Also, in the absence of a proper paleocurrent study, inferences regarding the source areas on the basis of some random observations may be quite misleading.

Further discussion on certain points contained in Rodolfo's two papers may not be out of place as it has bearing on the speculations presented here.

Rodolfo concludes that the Andaman Basin has not existed since Late Cretaceous, because the post-Cretaceous sediment-cover of the basin is too thin (about 1,500 m). It can be argued that the relatively thin cover is apparently due to the basin being at the distal end of the Burmese Cenozoic Trough, thus receiving only a low supply of prodeltaic and hemi-pelagic sediments. Thus, the author's suggestion that the Andaman Basin has existed since early Tertiary is equally likely (*see* Fig. 8(c)).

Rodolfo suggests that the entire Southeast Asian block has moved in a net south-southeast direction. This suggestion is quite possible in view of some recent findings that seem to indicate that the spreading sea-floor from the southwest is finally being underthrusted below the Southeast Asian block along the Java Trench (*see* Heirtzler, 1968, Fig. on p. 64). As mentioned earlier, this movement probably is a more recent event. It must also be mentioned here that there are cases of significant reverse movements within the block, e.g., dextral strike-slip movements noted along the big Sagaing Fault (Hninze Fault of Dey) situated just west of the Shan Scarp. (*see* Win Swe, 1970; Dey, 1968).

An interesting point arising out of the above speculations is the possible reason why the structural trends in the Burmese Cenozoic Belt are primarily NNW-SSE. This is to be expected if there has been continually east-northeastward movements (due to the drift) of the crustal rocks in the region.

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