CHAPTER 2. GEOTECTONIC FRAMEWORKS

2.1 INTRODUCTION

Undoubtedly the most significant development in the earth sciences over the past 15 years has been the promulgation and widespread acceptance of the doctrine of plate tectonics. It is hence necessary that any discussion of the tectonics in the Northwest Borneo Basin and Sarawak as a whole should be placed in the regional context of the whole Island of Borneo, or preferably South East Asia as a whole.

Recent data on geology of Kalimantan, Indonesia is now available from the works of Indonesian-Australian Geological Mapping Project at the scale 1:250,000 that covers most part of northwest and central Kalimantan (Fig. 2). This work covers 25% the total area of Kalimantan, described in 12 geological map sheets of scale: 1:250,000 report produced by Geological Research and Development Centre, Bandung, Indonesia in 1993. In Sarawak, Malaysia, the geological mapping of 1:250,000 was accomplished by Liechti et al, (1960). The regional geological mapping was continued by the Geological Survey Malaysia Department, Kuching on the scale of 1:50,000 with present coverage of 23% of the 124,000 km^2 total area of Sarawak. These data enable to interpret the geology of Borneo as a whole into the plate tectonic context with some confidence.

In the early days, the geotectonic framework of Borneo was interpreted separately, in a local geology context either Sarawak or Kalimantan separately, without any cross border geologic correlation. The recent data available from both Kalimantan and Sarawak enable to interpret the geotectonic of Borneo as a whole region with more confidence.

2.2 OVERVIEW OF REGIONAL TECTONIC FRAMEWORK:

Figure 9 and 10 illustrate, respectively, the global and regional tectonic framework. South East Asia is one of the most complex areas of Recent plate tectonic activity in the world. The Malay and Philippines archipelagos are located in the area of the triple junction between mega plates; the westward-moving Pacific Plate, the north moving Indo-Australian Plate and the south-southeastward-moving Eurasia Plate. The geotectonic evolution of this region is still far from fully resolved, is thus attracting investigation by numerous workers since early 1970's (Hamilton, 1979; Tan, 1979; Holloway, 1981; Hutchison, 1989, 1995; Rangin et al, 1990's; Hazebroek and Tan, 1993; Metcalfe, 1995, Banda and Ambun, in press).

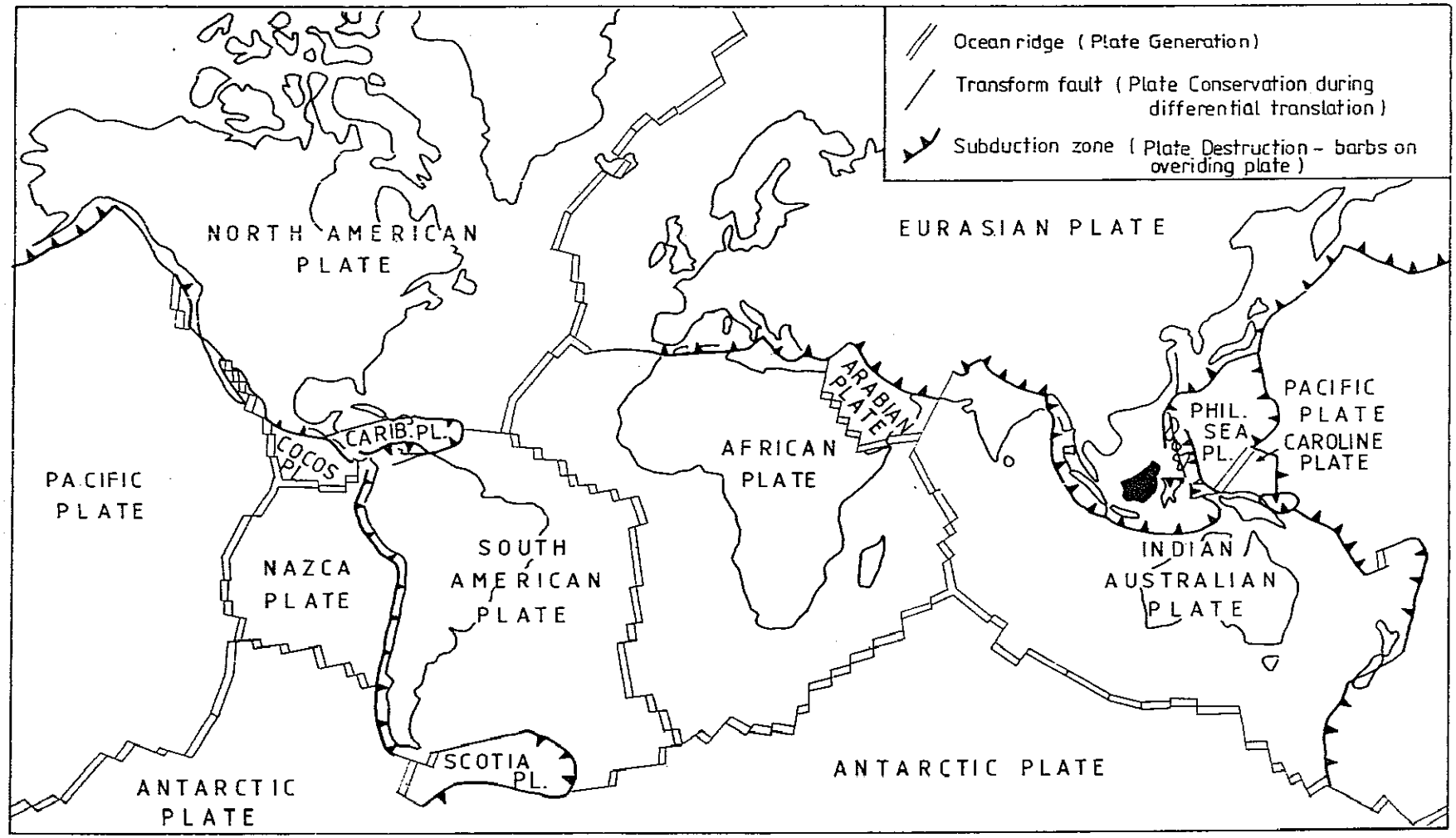

Figure 9. Global tectonic division (after Hamilton, 1979)

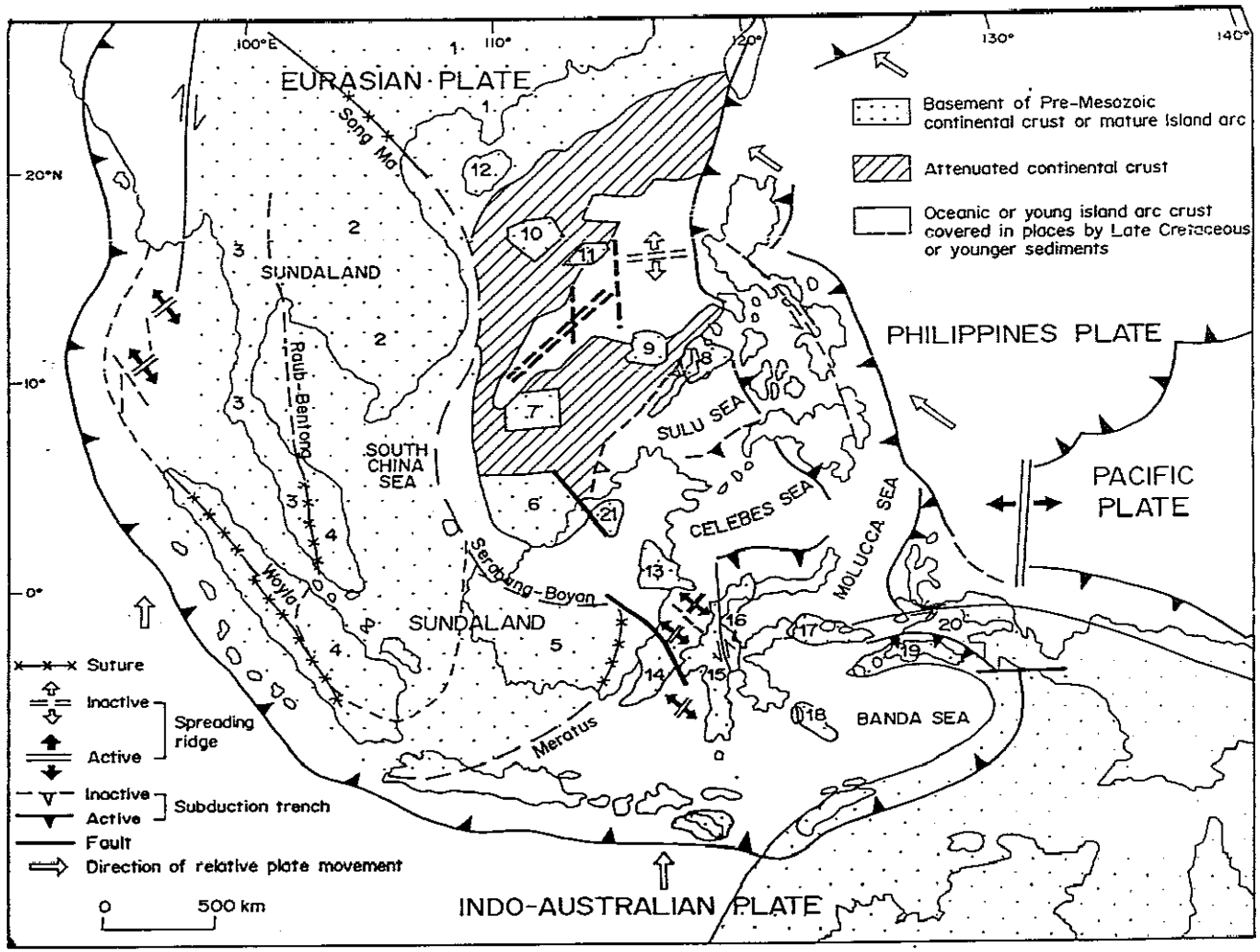

Figure 10. Plate tectonic elements of South East Asia (after Hutchison, 1989; Rangin et al, 1990 and Metcalfe, 1995)

1. South China, 2. Indo China, 3. Sibamasu, 4. East Malaya, 5. SW Borneo, 6. Balingan-Luconia,
7. Spratley Islands-Dangerous Ground, 8. North Palawan, 9. Red Bank, 10. Parcel Islands,
11. Macclesfield Bank, 12. Qiongzhong & Yaxian terranne of Hainan, 13. Mangka Lihat,
14. Paternoster, 15. West Sulawesi, 16. EastSulawesi, 17. Bangai-Sula, 18. Buto, 19. Buru-Seram,
20. West Iran, 21. Kelabit-Longbowan.

2.3 GEOTECTONIC FRAMEWORK OF BORNEO

The tectonic and geological history of Borneo concur with the model of continent-continent collision which dominated the geological evolution of Borneo in the Cretaceous and Cenozoic times. Based on the structural styles and sedimentation histories, the geological framework of Sarawak and its adjoining areas is consisting of 6 main tectonic provinces namely: i) Pre-Cretaceous Borneo Basement, ii) Early Cretaceous Melange, iii) Folded Rajang Group iv) Isolated Basin, (v) Peripheral Neogene Basin and vi) Luconia Block. The term Northwest Borneo Basin which is introduced in this work is to replace the obsolete term Northwest Borneo Geosyncline which was introduced by Liechti et al (1960), to describe Folded Rajang Group and Peripheral Neogene Basin. Figures 11, 12, 13 and 14 show the tectonic provinces, geological map, stratigraphy and the geological history of Sarawak and Northwest Kalimantan, respectively.

2.3a Pre-Cretaceous Borneo Basement

The basement rock is occupying northwest and central Kalimantan. The rock units which form the basement are: pre-Carboniferous Pinoh Metamorphics, the Permian unit of Seminis Formation and Carboniferous-Triassic Balaisebut Group, Triassic Benkayang Formation, Sekudau Volcanics and Semitau, Emboi and Busang Complexes. The Pinoh metamorphics are located in Ketapang and Nangapinoh, central west Kalimantan are comprised of slate, hornfels, phyllite, quartzite, schist, gneiss, migmatite and minor metavolcanics and amphibolite; some areas contains distinctive calcareous psammites and pellites (Amiruddin and Trail, 1993; Keyser and Rustandi, 1993). The Seminis Formation is located in a few places in the southwest of the Siluas area, consists of slate and phyllite, cut by veins of indurated, micaeous meta-sandstone (Rusmana et al., 1993). Intruding and overlying the Seminis Formation are widespread, intermediate to the basic Sekudau Volcanics. The Balaisebut Group is comprised of carbonaceous shale, phyllite, schist and quartzite and minor limestone, marble and chert (Suprianata et al, 1993). This group is located in the northeast and east of the Sanggau area. Permo-carboniferous fusulinid, echinoid spines, bryozoa and plants were observed in this unit. These rocks are ascribed to have been deposited on the shallow marine shelf (Tate, 1991).

There was a period of non-deposition from Permian to Middle Triassic in Kalimantan, which is marked by a major unconformity representing a period of deformation and possibly of an uplift. The igneous-metamorphics Permo-Triassic Emboi and Busang Complexes could have been formed at this time. The Emboi Complex, located in a number of places in Sanggau consists of granite, granodiorite, monzogranite, monzonite, diorite, mafic volcanics, schist and

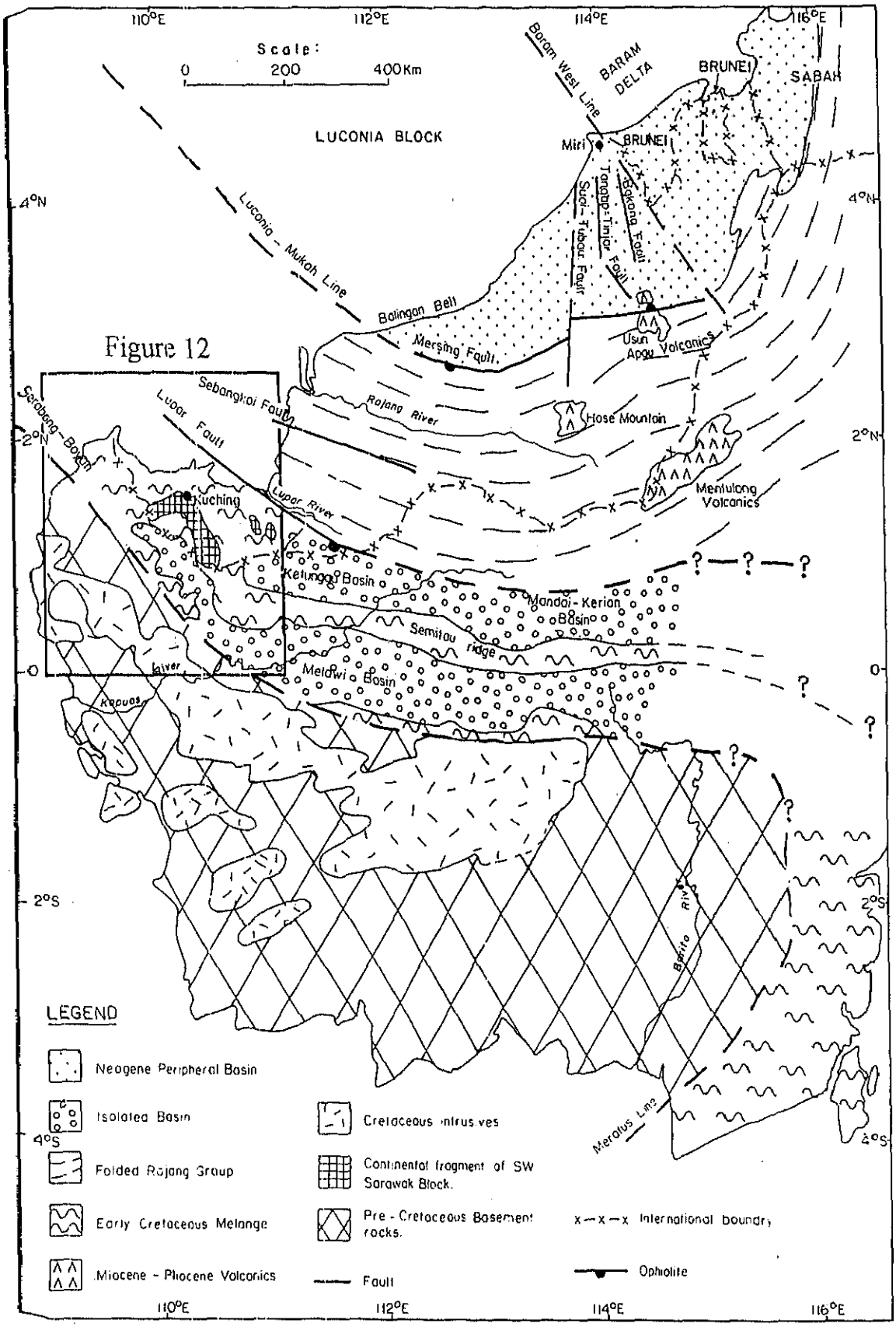

Figure 11. Tectonic provinces of the Sarawak and adjoining areas

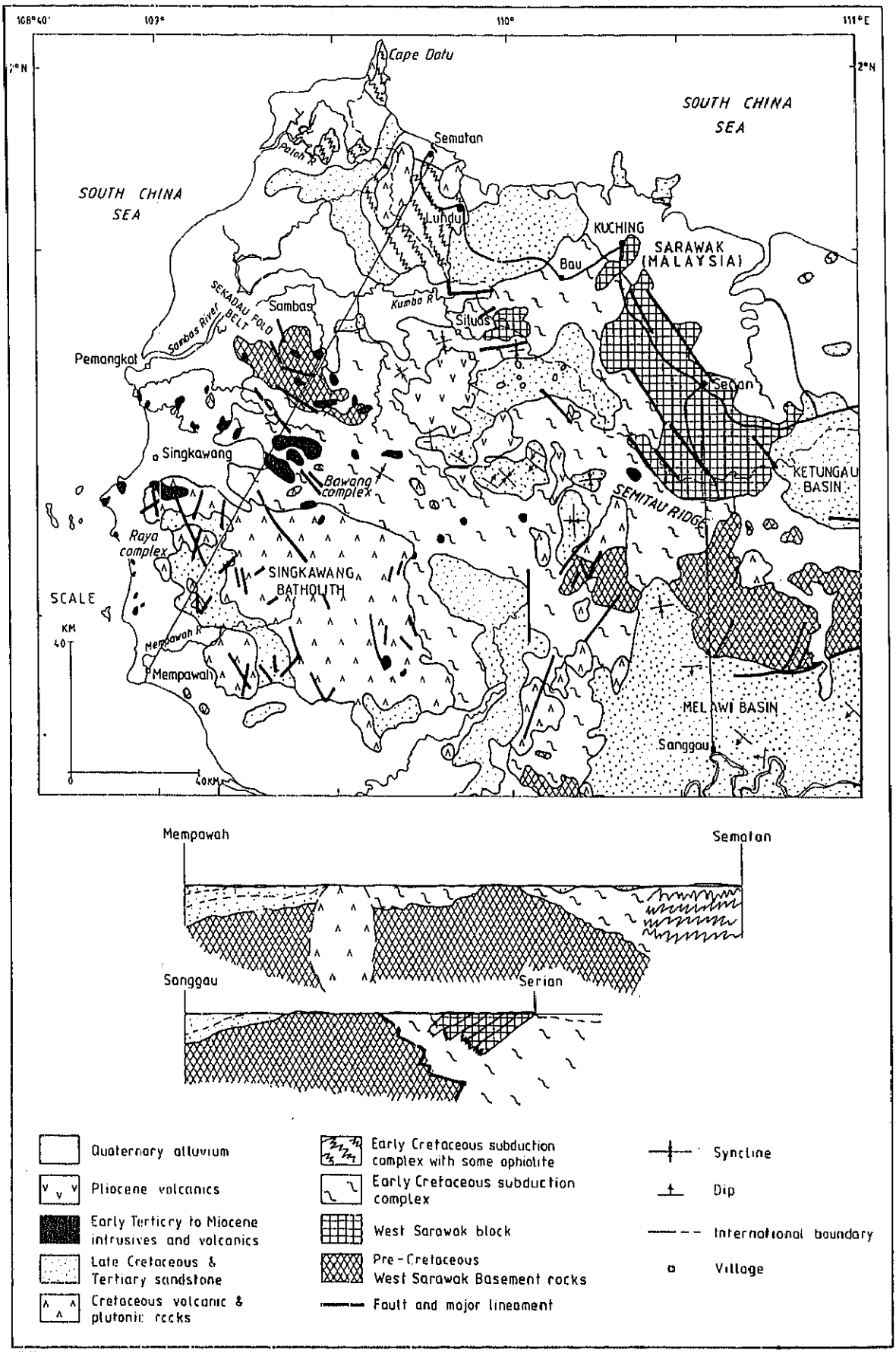

Figure 12. Geological map of West Sarawak and Northwest Kalimantan

amphibolite (Suprianata et al., 1993). This complex was formerly known as crystalline schist of Zeijlmans van Emmichoven (1939). The Busang complex is equivalent with the former in terms of lithology and age, and is located in the Sintang area (Heryanto et al, 1993). The Semitau Complex consists mainly of greenschist, greenstone and minor amphibolite. This unit is also located in the Sintang area (Heryanto et al, 1993).

Another unconformity between Late Triassic and Lower Jurassic have been recorded in SW Kalimantan. The break was marked by the deposition of shallow marine Benkayang Group; consisting of Banan and Sungaibetung Formations. *Ammonites* fossils having the Tethyan affinities were observed in the Banan Formation whereas *Monotis* were observed in the Sungaibetung Formation (Surwarna et al, 1993).

2.3b Early Cretaceous Melange

The Early Cretaceous Melange was formed as result of the narrowing of the Cretaceous sea and the migration of Southwest Sarawak Block towards the Pre-Cretaceous Southwest Borneo Basement. The Southwest Sarawak Block collided with the basement and subsequently transformed into the subduction complex by incorporating with the underlying oceanic crust beneath the continent which is represented by the most part of NW Kalimantan and Sunda Shelf. This subduction was accompanied by the formation of the large continental margin of magmatic arc, and the remnants are preserved as the Cretaceous Schwanner Mountains during the Early Cretaceous.

The melange consists of the broken fragments of the West Sarawak Block materials, shallow to deep marine sedimentary rocks and underlying ophiolitic rocks. The West Sarawak Block consists of numerous slices and faulted pre-Cretaceous blocks, emplaced almost parallel to the paleotrench axis and dipping towards southwest (Figs. 13, 14). These slices or blocks were formerly named as the Kerait and Tuang schists (Fig. 15), Terbat Formation, Sadong Formation, Serian Volcanics and Bau Limestone (Liechti et al, 1960). Recently, the on-going preliminary regional gravity survey of West Sarawak indicated that the West Sarawak Block, especially the Serian Volcanics has no depth extent; which is also implies that the Serian Volcanics are of allochthonous materials (Sirisena, personal communication, 1996). Also incorporated to form the melange is tightly folded Cretaceous sediments and ophiolite, formerly known as the rock formations of Sejingkat, Serabang, Sebangan Pedawan and Kedadom. The Kedadom and Pedawan Formation are tightly folded rock units. Ophiolitic rocks and deep sea sediments such as chert occurred in the Serabang, Sejingkat and Sebangan Formations. These sediments were deposited on the oceanic crust probably during Late Jurassic-Early Cretaceous, however some sediments were deposited in shallow and clear marine environment such as the

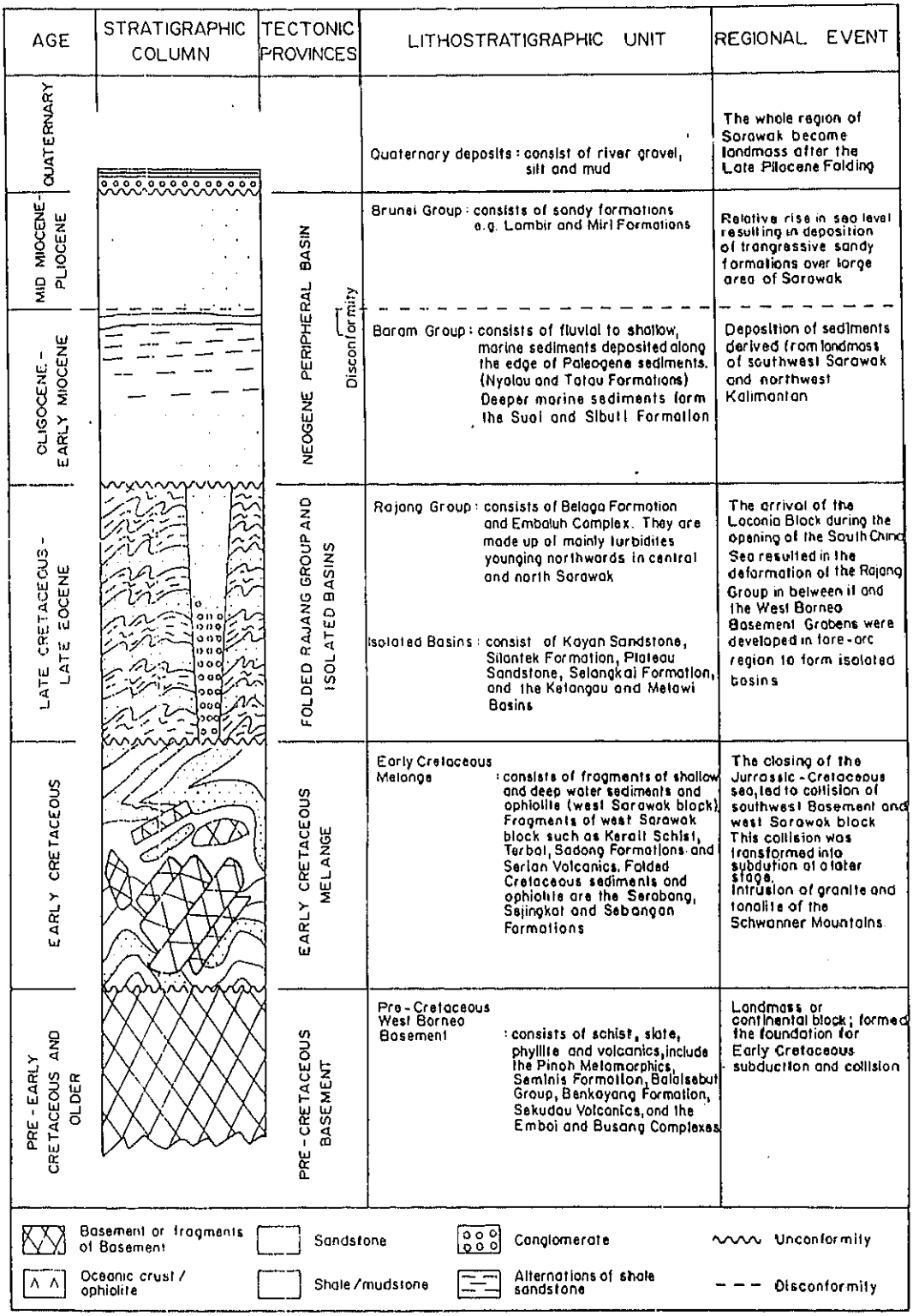

Figure 13. Generalized stratigraphy of Sarawak and Northwest Kalimantan

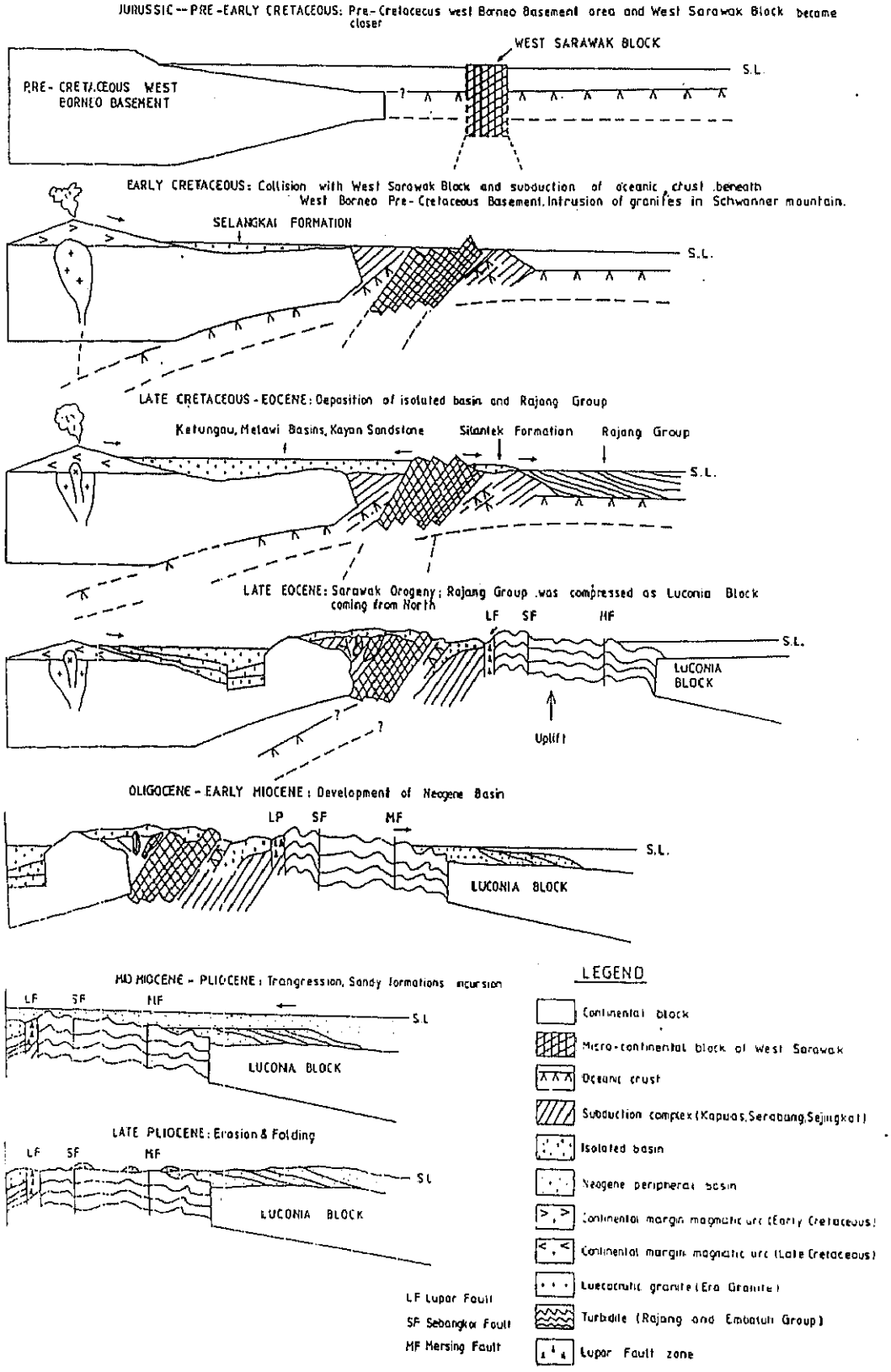

Figure 14. Geological development of Sarawak and Northwest Kalimantan

Bau Limestone. The equivalent unit found in Kalimantan is the Kapuas Complex located in several localities in the Sintang area (Heryanto et al, 1993)

The West Sarawak Block had been interpreted as affinities of Cathaysian Terrain's based on the Kerusin flora of West Sarawak which is the same as the Tonkin flora in North Vietnam (Hutchison, 1989). The plant fossils found in Kerusin are consisting of the south west Pacific *Dictyphyllum* and *Clathopteris* type (Kon'no, 1972). The paleolatitudes of West Sarawak Block and West Borneo Basement were at the Equator during Late Jurassic (Metcalfe, 1995) but the two blocks collided during early Cretaceous.

2.3c Folded Rajang Group

The Rajang Group consists of the Belaga and Lupar Formations of Sarawak and Embaluh Group and Selangkai Formation of Kalimantan. It has a turbiditic sedimentation history from Late Cretaceous to Late Eocene. These rocks are younging towards northwards. The Rajang Group in Sarawak was formerly termed as Rajang Accretionary Prism (James, 1984; Hutchison, 1989). The Rajang Basin, a place where the group developed, was rapidly narrowed by Late Eocene time when the subduction was transformed to collision and the Rajang Group was compressed between Schwanner Mountain Zone and Luconia Block (Hutchison, 1995). As a result the sediments of this group were faulted, thrusted and regionally metamorphosed. This orogeny is termed as Sarawak Orogeny (Hutchison, 1995). Major faults such as Lupar, Sebangkoi and Mersing were developed during the Sarawak orogeny. As a result Late Eocene fault zone, the Lubok Antu Melange (Fig. 16) was developed with the Lupar Fault in it (Tan, 1979).

2.3d Isolated Basin

This basin is Late Cretaceous-Miocene in age; consisting of continental and shallow-water sediments. It was formed after the Early Cretaceous Melange and Rajang Group had been uplifted. The collision, compression and uplift of the landmass between the Schwanner Mountain Zone and Luconia Block during the Late Eocene Orogeny caused the development of a horst and graben. The sediments eroded from the landmass were filling the graben. Since the sedimentation took place in an isolated continental environment, therefore it is appropriate to term it as an isolated basin and thus disqualifies the term fore-arc basin (Pieters, et al, 1993). This type of basin was observed in several places in West Sarawak and adjoining areas in Kalimantan. However, in central North Sarawak the basin is located in Tatau area.

The deposits of this basin are comprised predominantly thick-bedded sandstone, pebbly sandstone, conglomerate lenses, red mudstone, interbedded with thick sequences of regularly interbedded, thin beds of sandstone, shale and

Figure 15. Tuang Formation, Early Cretaceous Melange, West Sarawak. Locality: Km 4, Datuk Stephen Yong Road, Kuching.

Figure 16. Lubok Antu Melange. Locality: Batang Ai Dam Road junction Lubok Antu

mudstone, exhibiting well-developed cross bedding and ripple-marks. The formations developed in this basin are namely; the Kayan and Silantek Formations. They formed high mountains range such as Bungo Range and Mountain Santubong in Sarawak. Figure 17 shows the Kayan Sandstone lies unconformably on the Cretaceous Pedawan Formation. In central part of north Sarawak, the Tatau Formation is consisting mainly of conglomerate, which rests on the steeply and complexly folded Bawang Member of the Belaga Formation of the Rajang Group (Fig. 18).

In Kalimantan, the Ketungau, Mandai and Melawi basins are consisting of continental deposits, which is isolated basins developed during the Eocene-Oligocene. The Ketungau Basin (Late Eocene) consisting mainly of mudstone, siltstone and fine-grained sandstone contains abundant gastropods, pelecypods, echnoids and foraminifers (Heryanto, et al, 1993). Mandai Basin which is equivalent to Ketungau Basin in term of lithology contains coaly beds. This basin is located in the Sintang area.

2.3e Peripheral Neogene Basin

The peripheral basin was developed after the Rajang Group uplifted, forming the landmass together with the basement in the southwest. It was developed during the periods of two major depositional history; the Oligocene-Early Miocene and Middle-Pliocene.The earlier phase (Oligocene-Early Miocene) was the deposition of mainly thick marine sediments. The shallow-water sediments are confined to the upper part of the slope and they are most consisting of coarse clastics. Thus, inland, the Nyalau Formation is consisting mainly of alternations of sandstone and shale; the presence of lignite, cross-beddings, ripple-marks, cut-and fill structures and conglomerate lenses indicates a fluvial, deltaic and littoral environment. Towards the present coastline, the environment became fully marine, inner neritic, the succession being sandstone and shale, with subordinate limestone. The Suai and Sibuti Formations are mainly marine sediments are located near to the present coastline. These units are grouped as the Baram Group (Haile, 1961).

However, the second phase of sedimentation which was occurred during the Late Neogene (Mid Miocene-Pliocene) was a transgressive one which covered the whole area of the central and north Sarawak areas. During this period, a large volume of sand was deposited overlying disconformably the marine sediments. Such transgressive environment was evidenced by the sandy formations such as the Lambir and Miri Formations. These formations are grouped into Brunei Group (Haile, 1961). In central Sarawak, the deposition of thick trangressive sandy sequence ceased in Late Miocene. This is represented by a few outliers of highly transgressive Miocene Nyalau Formation resting unconformably on the Belaga Formation in the Rajang hinterland.

Figure 17. Kayan Sandstone, Isolated Basin unit overlies unconformably the tightly folded Cretaceous Pedawan Formation, West Sarawak. Locality: Km, Bau-Lundu Road

Figure 18. Basal conglomerate of the Tatau Formation, Isolated Basin overlies unconformably the tightly folded Bawang Member, Belaga Formation, North Sarawak. Locality: Km 170, Sibu-Bintulu Road.

2.3f Luconia Block

This block had been interpreted as a continental fragment originally attached to the South China continental margin, that has been transported by the opening of the South China Sea Basin (Holloway, 1981; James 1984). This stable platform is characterized by large number of carbonate reef build-ups, some of which contain major gas accumulations (Scherer, 1980). The Luconia Block is bounded by major NW-SE and WNW-ESE trending faults (SW Locunia-Mukah Line, West Baram Line) which are possibly trans-tensional features related to deep seated NNE-SSW strike-slip faults (Holloway, 1981). Deformation, characterized by wrench-induced folding and thrusting, is present along the southern margin of the Luconia Block: the Balingan Belt. This belt has been interpreted as collisional margin where the Luconia Block has impinged upon the Rajang Group Fold Thrust Belt (James, 1984). However, many features characteristic of sinistral, are also present.