6.1 INTRODUCTION

Each depositional environment can usually be divided into many subenvironments. The Ransi Member sediments were deposited in a lower coastal plain to shallow marine environment. The different lithological distribution from one outcrop to another represents different subenvironments due to the laterally varying depositional conditions that exist in the transition from continental to marine deposits.

The various subenvironments were interpreted from the different logged sections of the Ransi Member. These various subenvironments were combined together to produce a bigger picture of an overall environment of deposition for the Ransi Member.

Facies F1 of graded conglomerate beds

F1 is a fining upward facies sequence with conglomerate of cobble to pebble size at its base, and coarse sandstone at the top.

The conglomerate beds are made up of graded sub-angular conglomerate or pebbly sandstone with erosive bases. The individual paleocurrent pattern for each locality is scattered bidirectionally but the overall downcurrent direction is to the NNE. The conglomerate is composed of mostly metamorphic and some igneous rock fragments. The beds are poorly sorted and the clasts are angular to subangular becoming better rounded higher up.

The coarse grain-size but poor sorting and rounding indicate strong but impersistent current conditions during the deposition of the facies. The coarse facies is interpreted to be channel lag deposits in a fluvial channel fills and ox-bow lake deposits where most of the beds are fining thinning upward sequence.

The igneous clasts are similar to the Piring Hill rhyolite and the metamorphosed quartzite and radiolarian chert clasts are derive from the older Belaga Formation show that it is from at least two different source of rocks.

Facies F2 of cross bedded sandstone

This is a fining upward facies just like the conglomerate facies with coarse sandstone or pebbly sandstone at the bottom, cross-bedded sandstone in the middle and medium to thin parallel laminated sandstone at the top.

This facies is made up of graded pebbly sandstone with erosive bases and abundant trough cross-strata. The paleocurrent patterns for individual localities are variable but the overall direction is generally northwards. The petrology is mainly quartzite composed of quartz grains with undulose extinctions. The coarse grained sandstone is poorly sorted and subangular in the lower part of section but better sorted higher up. The coarse-grain size with poor sorting and its sub-rounded shape of quartz and chert grains suggests rapid but inconsistent current flow and probably reworking of older sediment during the deposition of the facies. The coarse and sub-angular shape facies is interpreted as channel-lag deposits in a fan delta environment. Some of the poorly sorted pebbly sandstone beds with trough cross-bedding were deposits in an upper shoreface environment near the shoreline because it has *Orphiomorpha* burrows and only thin shale beds present (Goldring at al., 2004).

The upper section of facies is a predominantly medium to thin parallel laminated fine sandstone in a fluvial delta environment with active burrowing, dominant normal graded and cross-bedded sandstone and ox-bow lake deposits.

Facies F3 of reddish to greyish shale-silt beds

F3 probably represents deposition of silt and clay from suspended loads in a quiet environment such as an offshore shelf where it is calm and undisturbed. This environment will produce thin graded laminae of clay and silt or fine sand brought in occasionally by gentle currents causing small scale rippling that contrasts with the F1 and F2 argillaceous sandstone and conglomerate.

The greyish color of shale beds changes gradually from the base to light brown at the top due to weathering. Cross bedding is rare and most of the beds appear to be parallel laminated. Sand or silt filled burrows are commonly present in the shale beds.

The gradual increase in thickness and abundance of sandy beds upsection, indicates that it is a coarsening upward facies. Such sequences are normally found in prograding shoreline deposits.

6.2 DEPOSITIONAL ENVIRONMENT

The overall depositional environment of the Ransi Member sediments is probably in a fan delta because it posses the following characteristics:

1. Cobble to pebble conglomerates interbedded with minor silty shale lenses. The clasts are angular to sub-angular and are mainly clast supported with poorly sorted coarse to medium grained sandy matrix. The geometry and composition of the sediment suggests deposition near to the source due to its angularity. This facies is interpreted as deposited within a fan delta with distributary channels.
2. Poorly sorted pebbly sandstone beds with sub-rounded to angular pebbles in medium grained sands. Individual bed are normally graded which suggests that they are river lag deposits.
3. Poorly sorted trough cross-bedded sandstone with rare isolated larger clasts scattered in the lower part of the beds. The individual beds fine upwards and are normally graded bedded. The presence of *Orphiomorpha* in the sandy beds is indicative of a marine environment. This facies probably represents channels within a shallow marine environment.

The delta is fed by channels found in the exposures at Ransi Hill, Tatau Hill and Tutong Hill. The channels may be braided with multiple stacked channel cuts as at Tatau Hill or meandering with ox-bow lakes at Hormat Pasifik Quarry. The current flow is strong enough to transport bedload material of sands and gravels from upstream and deposit them in the river bed. Adjacent to the meandering channels are subaerial overbank deposits which are sites of sedimentation for the suspended sediment load from overflows during floods. These might later be vegetated to form swamps leading to the formation of coal seams such as at Hormat Pasifik Quarry (Fig. 6.1).

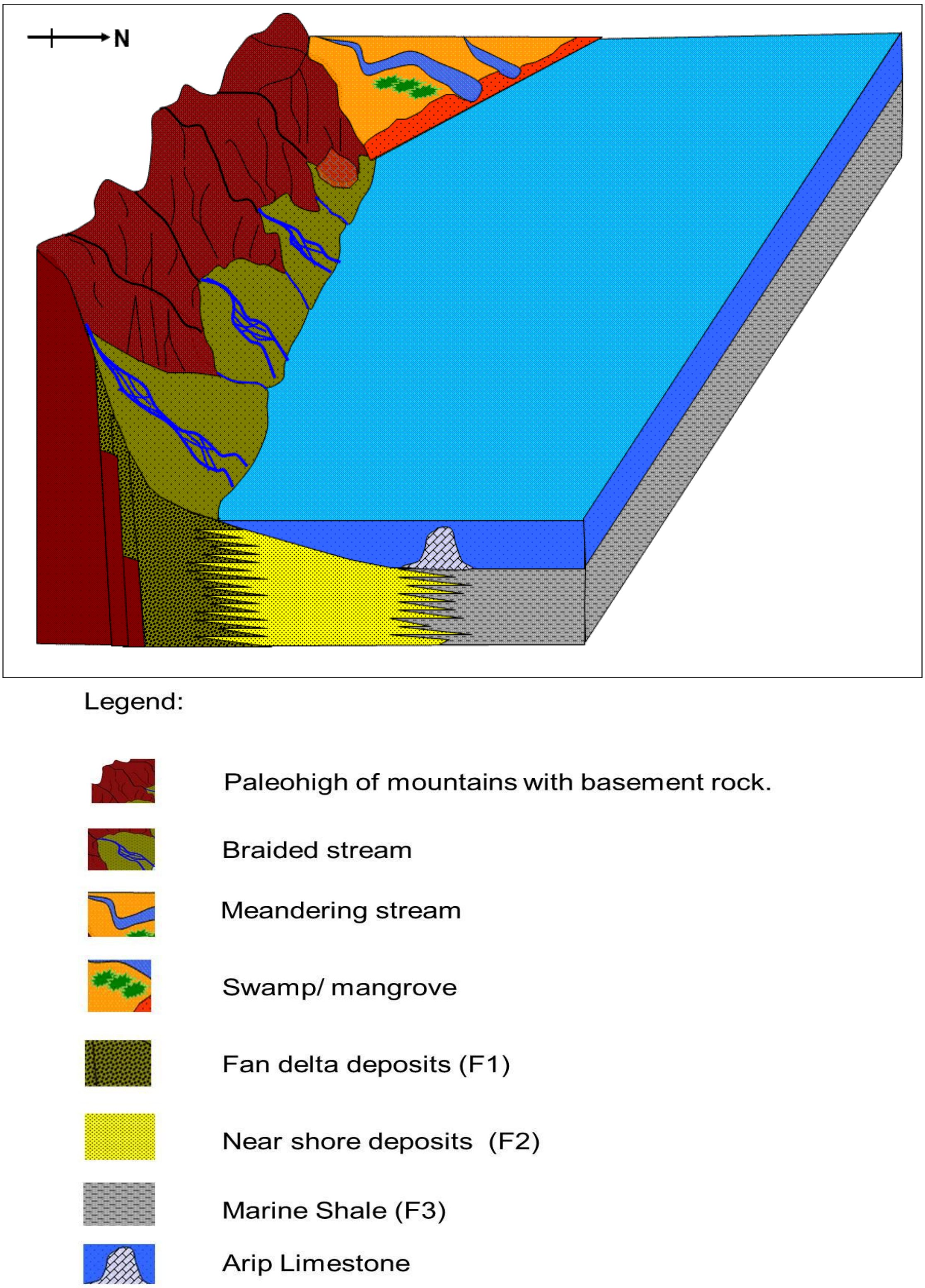

Fig. 6.1 Depositional model for the Ransi Member.

The gravelly to sandy beds suggests that the paleoslope had a high gradient producing strong enough currents to transport gravel and coarse sand into the delta (Orton & Reading, 1993). The deposition of the clastic sediments was probably in alluvial fans to delta plains. The environment might extend up to the delta front if the space between the hinterland and coast is narrow. The sediment size can be directly influenced by the distance of the hill slope to the shoreline.

The presence of *Orphiomorpha* suggests marine influence in some of the sediment deposited near shore to the delta (Fig. 6.2). The coal seams in the swampy areas suggest that they were deposited in some brackish lower delta plains as the shale bed was bioturbated and *Ophiomorpha* was observed in the field. The dips of clasts from the exposure at Tutong Hill suggests bidirectional current flow caused by fluvial and tidal influence, typically near the shoreline.

The angular to subangular grains and clasts geometry and poor to medium sorting of the pebbly sandstone and conglomerate beds suggest that the paleoslope was quite near to the shoreline and the sediment were transported and deposited rapidly within a short distance that was not enough for breaking down the soft clasts and rounding the grains.

Only a small part of the delta plain is flat and wide enough for the meandering channel with ox-bow lake to form at Tutong Hill. Most of the sediments in the Ransi Member were transported by braided streams with low sinuosity towards the delta-front where wave and tidal currents were active to produce bidirectional paleocurrents.

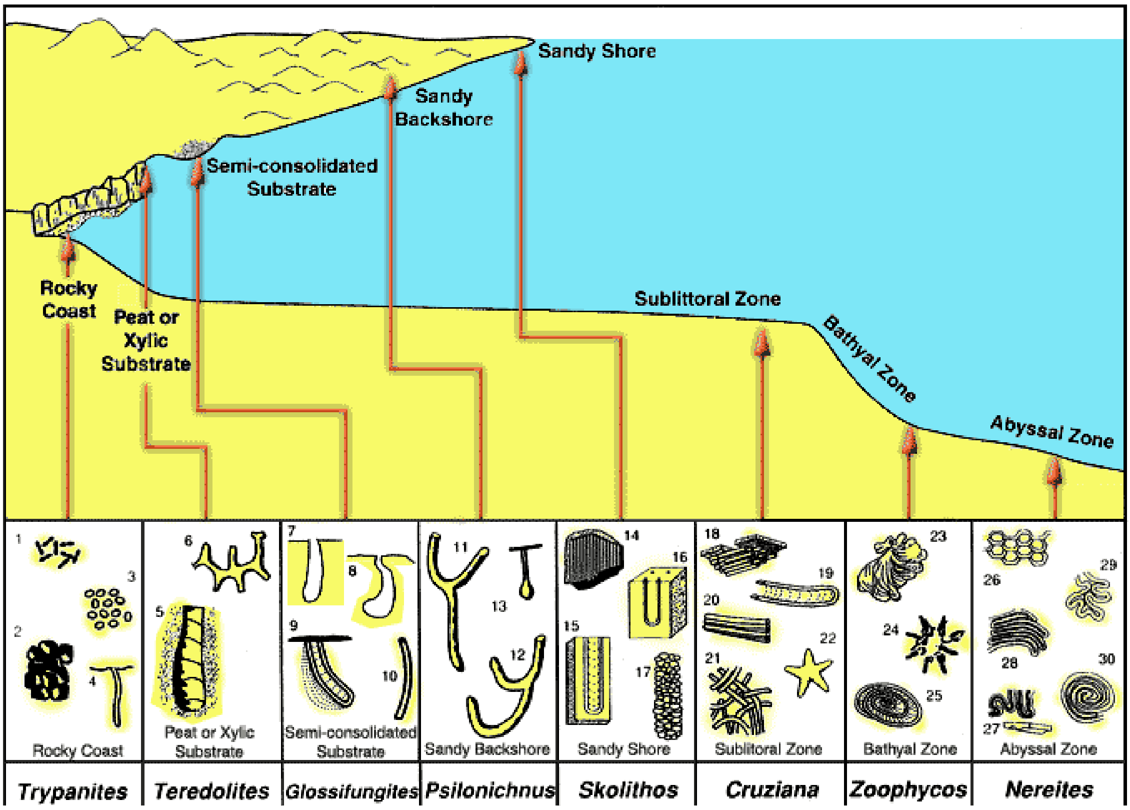

Fig. 6.2 Distribution of common marine Ichnofacies (after Pemberton et al., 1992). Trace fossils include: 1) *Canlostrepsis*; 2) *Entobia*; 3) echinoid borings; 4) *Trypanites*; 5) *Teredolites*; 6) *Thalassinoides*; 7&8) *Grastrochaenolites* or related genera; 9) *Diplocraterion* (*Glossifungites*); 10) *Skolithos*; 11&12) *Psilonuchunus*; 13) *Macanopsis*; 14) *Skolithos*; 15) *Diplocraterion*; 16) *Arenicolites*; 17) *Orphiomorpha*; 18) *Phycodes*; 19) *Rhizocorallium*; 20) *Teichichnus*; 21) *Planolites*; 22) *Asteriacites*; 23) *Zoophycos*; 24) *Lorenzinia*; 25) *Zoophycos;* 26) *Paleodictyon*; 27) *Taphrhelminthopsis*; 28) *Helminthoida*; 29) *Cosmorhaphe*; 30) *Spirorhaphe*.

The presence of limestone and calcareous shale of a similar age to the Ransi Member in the southern part of the Tatau (Fig. 6.1) shows that carbonate deposition was ongoing at the same time. The Arip Limestone suggests a transition from a relatively deep marine environmental dominated by pelagic foraminifera to shallow marine environment dominated by benthonic foraminifera and coralline red algae. This succession was a carbonate reef built up at a distance from the land that lacked clastic input during a period of relative quiescence.

These two different depositional environment were formed at different places at the same time when the Sarawak Orogeny took place during the Late Eocene to Oligocene. The basement was lifted up to form highlands to the centre near the faults to become a source of coarse clastic sediments for the deltaic system. Areas further away to the south from the major faults did not experience much uplift and fine clastic deposition and carbonate deposition dominated.

6.3 GEOLOGIC HISTORY OF THE TATAU AREA

In Early Eocene time, the Belaga Formation was uplifted and folded (Hutchison, 2005) to form highlands such as the Pennian High and Rajang Belt (Wolfenden, 1965). The highlands were gradually eroded and sediments transported by rivers and deposited in various environments such as deltas and near shelf. The succession of this sediment forming the Tatau Formation which is of shallow marine to fluvial origin.

The highland contributes to the forming of lower Tatau Formation with the Ransi Member conglomerate that sits unconformably on the Belaga Formation at the same time as the deposition of the shallow marine Arip Limestone. Sediments that were deposited in the distal area form the thin shale-sandstone heterolitic beds of the Tatau Formation that overlie the Arip Limestone.

The Tatau Formation gradually transits into the Nyalau Formation made up of deltaic Upper Eocene to Miocene deposits (Hutchison, 2005). During Miocene time, both of the Tatau and Nyalau Formations were folded while the Belaga Formation was refolded to a high angle or into tight overturn folds.

A series of faults parallel to the southwest-northeast trending Anak-Nyalau (normal) Fault formed the Tatau Horst with half grabens parallel to the coast (Fig. 6.3). The north graben moved deeper than the southeastern graben. The Tatau Horst was eroded and sediment was transported into both the northern and southeastern grabens and forming the upper section of the deltaic Nyalau Formation at the southeastern of the Tatau area and Quaternary deposits covered the graben in the north. It led to the exposure of older formations such as the Tatau and Belaga Formations in the Tatau Horst.

Folding with syncline and anticline was observed in the upthrown block of the horst. The Nyalau Formation in the southeastern downthrown block was less strongly folded compared to the horst suggesting that the Anak-Nyalau Fault is a synsedimentary fault with the younger Nyalau Formation less affected by regional faulting than the older part of the Nyalau Formation found in the horst (Fig. 6.3).

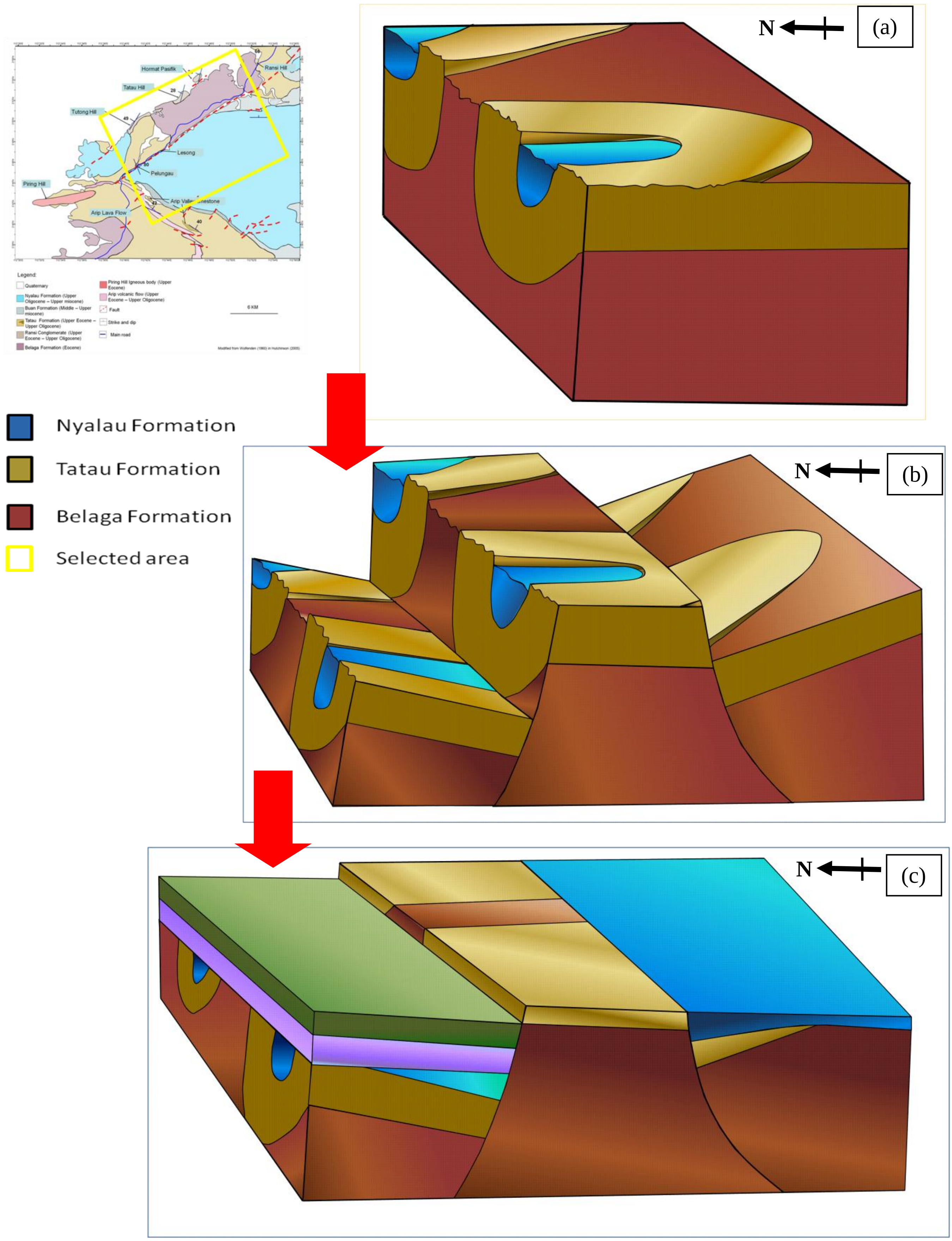

Fig. 6.3 Tectonic model of the Tatau area. (a) Belaga, Tatau and Nyalau Formation being folded in the Miocene time; (b) Anak-Nyalau normal Fault that cut through the Tatau area; (c) footwall eroded and sediment deposited at the hanging wall.