

Tectonostratigraphy and Structures of Eastern Seram

Tektonostratigrafi dan Struktur Seram Bagian Timur

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Abstract

The eastern Seram is part of the Outer Banda Arc consisting of para-autochthonous and allochthonous units which are unconformably overlain by the autochthonous units. The para-autochthonous units are derived from the outer margin of the Australian NW Shelf. This sequence comprises Permian metamorphic rocks of the Kobipoto Complex and its cover of Triassic - Jurassic to Cretaceous - Tertiary age. The allochthonous unit, or the pre-collisional Banda fore-arc sequence was overthrust onto the NW Shelf sequence. The sediments overlying unconformably the allochthonous and para-autochthonous units are referred to as autochthonous units. These autochthonous units comprise sediments deposited post-Neogen collisional event between the Australian Continent and the Banda subduction zone. Structures develop in the eastern Seram are thrust, normal faults, folds, and cleavages. The thrusts are verging to the northeast suggesting that the deformation occurred before Seram was rotated in an E-W direction.

Keywords: para-autochthonous, allochthonous, autochthonous, Outer Banda Arc, Australian NW Shelf

Sari

Seram bagian timur adalah bagian Busur Banda Luar yang tersusun oleh satuan-satuan paraotokton dan alokton yang ditindih tidak selaras oleh satuan otokton. Satuan-satuan paraotokton berasal dari tepian luar paparan barat laut Benua Australia. Runtunan ini terdiri atas batuan malihan Kompleks Kobipoto yang berumur Perem beserta batuan penutupnya yang berumur Trias - Jura hingga Kapur - Tersier. Satuan alokton, atau runtunan Busur Banda Luar pra-tumbukan Neogen, terdiri atas batuan ultrabasa yang tersesar-sungkupkan di atas runtunan Paparan Australia Barat Laut. Batuan sedimen yang menindih tidak selaras di atas satuan paraotokton dan alokton disebut sebagai satuan otokton. Satuan otokton ini terdiri atas sedimen yang terbentuk setelah tumbukan Neogen antara Benua Australia dan zona tunjaman Banda. Struktur yang terbentuk di Seram bagian timur adalah sesar naik, sesar normal, lipatan, dan belahan bidang sumbu. Sesar naik memiliki kecondongan struktur ke timur laut yang mengindikasikan deformasi terjadi sebelum Seram terputar ke arah barat-timur.

Kata kunci: paraotokton, alokton, otokton, Busur Banda Luar, paparan barat laut Australia

Introduction

Geological Setting

The Seram Island is part of the Outer Banda Arc forming a nonvolcanic arc, metamorphic belt, and accretionary terranes (Figure 1). This area, the continuation of Timor, is previously located in the collision zone between the Australian Continent and the Banda Subduction Zone, where the NW margin of Australia moved towards the Banda Subduction

Zone. The NW shelf of Australia itself was generated due to the break-up of the Gondwana Land during Jurassic (Powel, 1976; Veevers, 1982). The Banda Subduction Zone was resulted from the oceanic crust subduction beneath the Banda Volcanic Arc that was located to the north of Australia, during the Eocene time (Hartono, 1990).

The time of collision between the Australian Continent and the Banda Arc is still controversial. Carter and Audley-Charles (1976) and Hartono

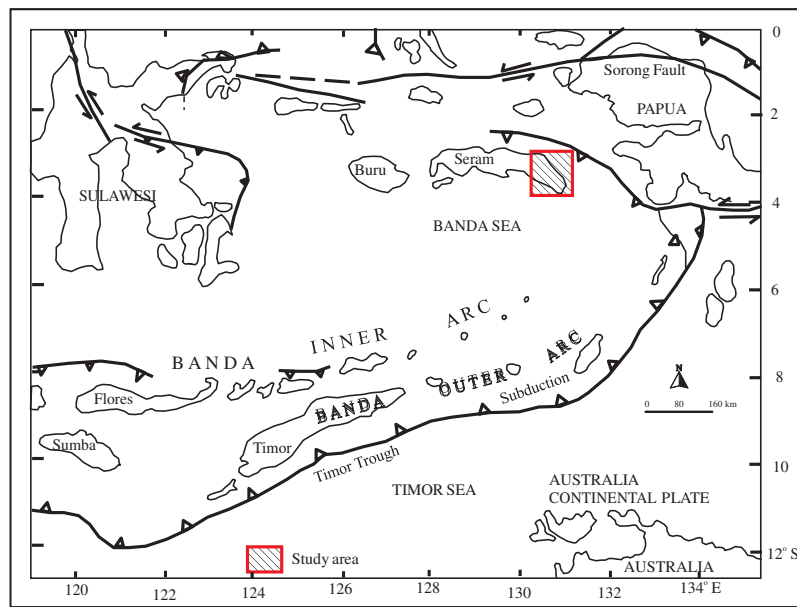


Figure 1. Regional tectonic setting of the Seram Island and its surrounding area, modified after Silver (1979).

(1990) interpreted the collision occurred during Pliocene; Charlton *et al.* (1991) presumed to be Late Miocene - Pliocene; whilst Berry and Grady (1981) supposed it to be Miocene. All these opinions point to Neogene time collisional event between arc and continent.

The continent - volcanic arc collision has overthrust as part of the pre-collisional Banda fore-arc onto the rocks derived from the Australian shelf. The first can be considered as allochthonous sequence, and the latter may be regarded as a para-autochthonous sequence. The sediments that were deposited during and after the collision can be categorized as the autochthonous sequence.

The Neogene tectonic setting of the Banda Arc is a result of an interaction between three major plates, *i.e.* the Eurasian Plate moving eastward, the Pacific Plate moving westward, and the Australian Plate moving northward. Seram is believed to be a fragment of the Australian continental fragment (Hamilton, 1979; Pigram and Panggabean, 1984). Previously, during Miocene, the Banda Arc was located to the northeast of Tanimbar Islands (Linthout *et al.*, 1996) and later on moved northwestward approaching the SW Pacific Plate along a NNW transform forming the eastern boundary of the Banda Sea Plate (Linthout and Helmers, 1994). In the Early Pliocene, Seram was block-faulted and rotated into an E-W

orientation, and afterwards Seram migrated westward to the present position (Linthout *et al.*, 1996).

Methodology

The present paper is prepared on the basis of fieldwork along several gravity lines of Kufpec (Indonesia) Ltd running NNE-SSW, radar-landsat image interpretation, and literature studies.

Tectonostratigraphy

The similarities of the Seram Island and Timor Island in the tectono-genesis imply that the stratigraphic grouping or tectonostratigraphy shall be similar, *i.e.* subdivision of the rock units into allochthonous, para-autochthonous and autochthonous sequences. Unfortunately, interpretation on the origin of each rock unit in this collision zone is still controversial up to now, particularly in distinguishing the Asiatic facies (allochthonous) from the Australian facies (para-autochthonous). Basically, the allochthonous sequence shall have a volcanic - island arc affinity, whilst the para-autochthonous sequences are representing a continental crust or sediments having a continental affinity.

The NW Shelf sequence is called para-autochthonous unit since this sequence is interpreted still lying

on its original (initial) basement rather than tectonically separated and/or transported from the basement.

Based on the time of arc-continent collision, all the rock units of older than Neogene age should be regarded nonautochthonous, either allochthonous or para-autochthonous. The occurrence of overthrusts is a conclusive evidence for the allochthonous facies. The existing geological map of the eastern Seram (Gafoer *et al.*, 1984a) does not subdivide the rock units on the basis of their origin, and therefore it is necessary to identify the rock units on the basis of the age and to compare then to the stratigraphy of the Eastern Timor (Bachri, 1995). Figure 2 shows the distribution of the allochthonous, para-autochthonous, and autochthonous units.

Para-autochthonous Sequence

The oldest unit in the para-autochthonous sequence is the Permian Kobipoto Complex which is composed of mica schist, tremolite-actinolite schist, chlorite schist, marble, epidote schist, amphibole schist, and gneiss (Gafoer *et al.*, 1984a). This metamorphic rock is unconformably overlain by the Triassic-Jurassic Kanikeh Formation. The Triassic - Jurassic sediments consist of flysch-type sediments of the Kanikeh Formation and limestone

of the Manusela Formation. The two formations interfinger each others. The Kanikeh Formation is composed of alternating sandstone, siltstone, and claystone. The sandstone is poorly sorted, micaceous and carbonaceous, with parallel lamination, wavy lamination, cross-lamination, graded bedding, and erosional surface structures (Gafoer *et al.*, 1984b). Wanner (*in van der Sluis*, 1950) mentioned the presence of *Lovcenipora vinassai* (Giatt), *Halonella*, *Monotis salinaria* Br, and Amonites of Triassic age. This formation is supposed to be not less than 100 m thick. Fragments of this formation are found in the Salas Complex as exotic blocks or olistolith (Gafoer *et al.*, 1984b).

The Manusela Formation is well bedded to massive limestones, contains algae and foraminifers of Triassic to Jurassic age (Shell, 1977, *in* Gafoer *et al.*, 1984b), and deposited in a shallow marine environment. The thickness is up to 700 m. The Manusela Limestone and the Kanikeh Formation are unconformably overlain by the Cretaceous - Late Miocene Nief Formation and the Cretaceous Sawai Formation.

The Nief Complex (Gafoer *et al.*, 1984b) or Nief Bed (Audley-Charles *et al.*, 1976) is strongly deformed and sheared, consisting of calcilutite, shale, and marl of Late Cretaceous - Late Miocene age.

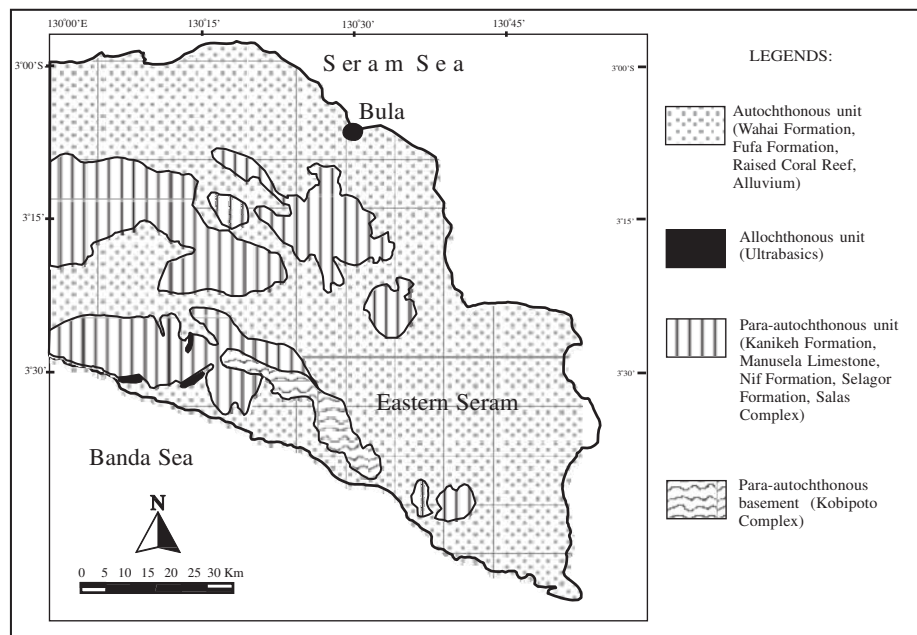


Figure 2. Simplified geological map of the eastern Seram showing distribution of the para-autochthonous, allochthonous, and autochthonous sequences.

The presence of chert and manganese nodules suggests a deep marine environment, probably bathyal. Probably this unit was deposited in the continental rise of the Australian continental margin.

The Sawai Formation consists of calcilutite with thin intercalations of chert containing radiolaria. The foraminifers and radiolaria indicate a deep marine environment and Late Cretaceous age (Sudijono, 1976, *in* Gafoer *et al.*, 1984b). The thickness is up to 500 m. The Sawai Formation is conformably overlain by the Hatuolo Formation.

The Hatuolo Formation consists of reddish brown sandy shale, well bedded, with intercalations of red and light grey marl and chert lenses containing radiolaria. The foraminifers content indicates Paleocene age (Sudijono, 1976, *in* Gafoer *et al.*, 1984b), but Van der Sluis (1950) mentioned the presence of Eocene foraminifers. The thickness is probably more than 500 m. This formation is unconformably overlain by the Selagor Formation.

The Selagor Formation consists of limestone, marl and intercalation beds of shale. The foraminifer assemblage indicates Late Oligocene to Middle Miocene (Karmini, 1976, *in* Gafoer *et al.*, 1984b) whereas the depositional environment is probably shallow marine as indicated by the presence of algae and larger foraminifers. Boulders of this formation are also found in the chaotic rocks of the Salas Complex, suggesting that the formation was deposited pre-tectonically with respect to the Neogene arc - continent collision. This formation is overlain unconformably by the Salas Complex of the autochthonous sequence.

Allochthonous Sequence

The base of the allochthonous sequence in the Eastern Seram is the Permian ultrabasic rocks. The rocks have tectonic contacts with the other units in many places (Gafoer *et al.*, 1984b). The ultrabasic rocks seem to be comparable to the ophiolite rocks in the eastern Timor that was also interpreted to be the Banda allochthon derived from the Banda oceanic crust (Bachri and Partoyo, 1995). The ophiolitic rocks in the eastern Timor and in the eastern Seram may be comparable to the ophiolite of the Mutis Complex in the western Timor. The Mutis Complex in western Timor consists of schist gneiss, and dismembered ophiolite which are interpreted to be allochthonous (Brown and Earl, 1983).

Autochthonous Sequence

The Salas Complex is a chaotic rock unit consisting of scaly clay matrix and boulders (up to 10 m) of older formations. The foraminifer content indicates Middle Pliocene age (PT Shell, *in* Gafoer *et al.*, 1984b), whereas Audley-Charles *et al.* (1976) mentioned an Early Miocene age. The depositional environment is presumed to be deep marine.

The nature of the Salas Formation is similar to the Bobonaro Complex in Timor that was also deposited in a deep marine environment as olistostromal deposits during Middle Pliocene (Bachri and Partoyo, 1995). The Bobonaro Complex has a multiple genesis, *i.e.* (1) mainly as olistostrome, (2) tectonic melange, and (3) due to shale diapirism and mud volcanoes activity (Bachri *et al.*, 1995). The similarities in the nature between the Salas Complex and the Bobonaro Complex suggest that probably the Salas Complex is mainly composed of olistostrome deposits resulting from submarine landslide during the Neogene arc-continent collision. The possibilities of the tectonic melange occurrence and shale diapirs in the Salas Complex are also plausible.

Since the Salas Complex is regarded as syn-collisional deposits occurring in the Seram area, consequently this unit can be categorized as the autochthonous deposits. This unit is overlain, probably conformably, by the Wahai Formation.

The Wahai Formation consists of marl, yellowish white to light grey, thinly to very thickly bedded, with intercalation beds of sandy limestone and fine sandstone at the upper part (Gafoer *et al.*, 1984b). The foraminifer content indicates Pliocene age, whereas the depositional environment is supposed to be relatively deep marine to neritic in the upper part.

The Wahai Formation is overlain conformably by Fufa Formation that was deposited during Pleistocene, consisting of sandstone, siltstone, claystone, lenses of conglomerate, and peat. Limestone Member can be found in several places. The lithological association suggests a deltaic environment, probably a delta plain, to shelf environment as represented by the occurrence of the Limestone Member.

The youngest units in the autochthonous sequence are the uplifted Quaternary coral reef and alluvium that were deposited unconformably over the older units.

The tectonostratigraphic subdivision of the eastern Seram is summarized in Figure 3.

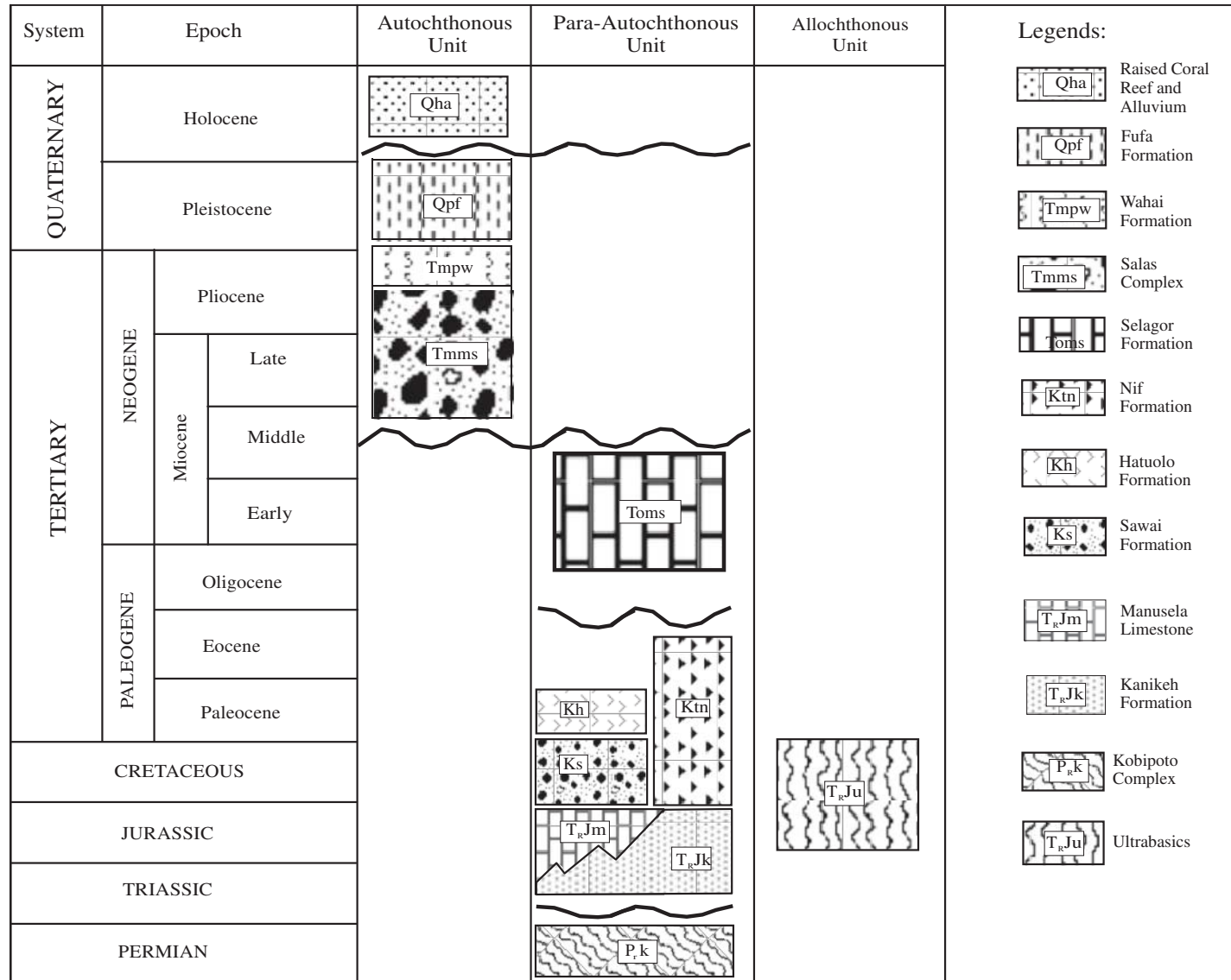


Figure 3. Tectonostratigraphic unit of the eastern Seram.

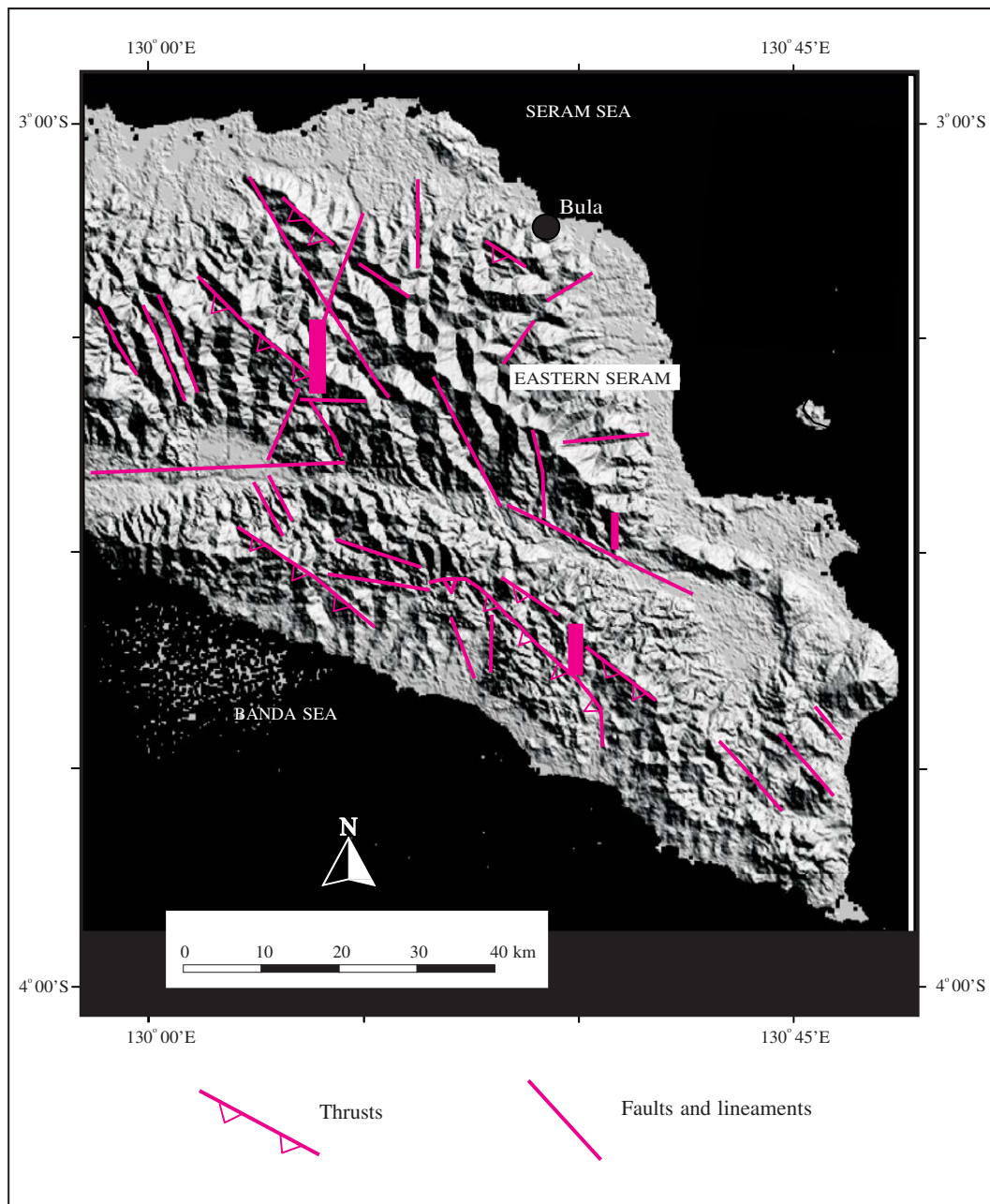


Figure 4. Radar image combined with landsat image showing some structural features.

Structures

A structural interpretation on radar - landsat image of the eastern Seram has been conducted, with some information derived from the field observation (Figure 4). The radar - landsat image suggests the presence of thrusts verging to the

northeast. The vergence of the thrust is the opposite of that of the Timor area, and this may indicate that the deformation occurred before Seram was rotated to an E-W direction and move westwards. The thrusts are normally associated with Paleozoic - Mesozoic rocks as indicated in the Kanikeh Formation (Figure 5).

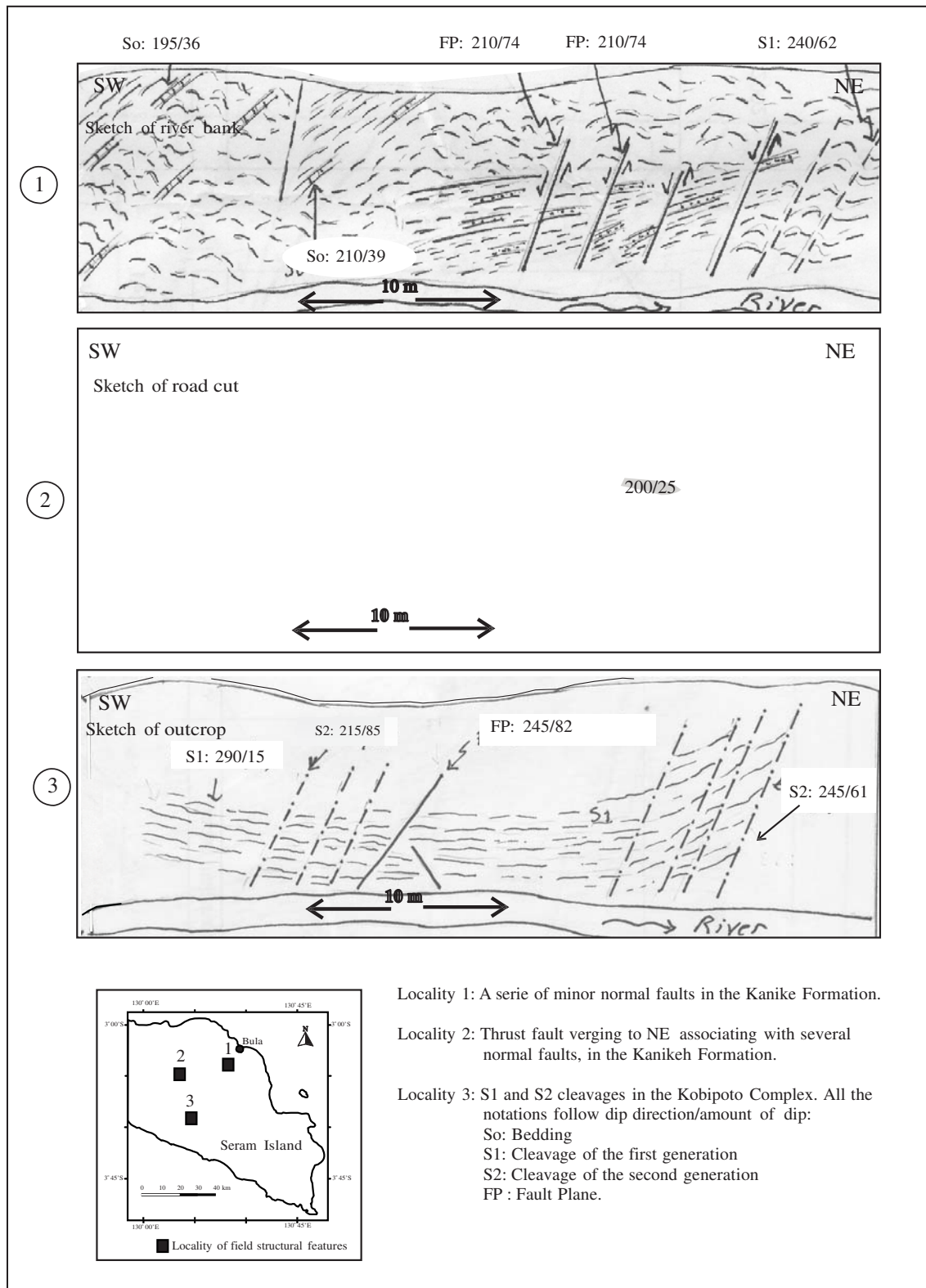


Figure 5. Some field structural features.

Meanwhile, fold axes are not recognizable from the image, however from the existing geological map (Gafoer *et al.*, 1984a) they can be identified relatively parallel to the long axis of the island trending from nearly east - west to nearly northwest - southeast, which are normally involving either the Quaternary rocks or the older units.

The presence of folds in the Quaternary autochthonous rocks indicates that tectonically Seram is still active. The structural orientation suggests a north-south or northeast-southwest maximum compressive stress that may be related to a subduction in the Seram Trough.

Several lateral faults and normal faults are also found to cut across the autochthonous sequence indicating that the structures were generated post - Neogene arc-continent collision.

Conclusions

The tectonostratigraphy of Eastern Seram is representing an interaction between three major plates, *i.e.* the Indo-Australian Plate, the Eurasian Plate, and the Pacific Plate, resulting in the presence of several rock units of different tectonic affinities.

The para-autochthonous sequence was derived from outer margin of the Australian NW Shelf which migrated to Banda Outer Arc. The allochthonous sequence comprises ultrabasic rocks which represent oceanic crust of the Pre-collisional Banda Arc. Meanwhile, the post-orogenic sequence is composed of sediments deposited during and after the arc - continent collision, and unconformably overlies the para-autochthonous and allochthonous sequences.

The Neogene collisional event has played an important role in stratigraphic setting of the eastern Seram, or in the Banda Outer Arc in general.

The Neogene compressional tectonics is interpreted to be an orogenic event in eastern Seram resulting in the uplift of eastern Seram and development of major structures, particularly the thrust fault. The post-Neogene tectonics has been responsible for the formation of structures in the autochthonous units.

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