Stratigraphy and Tectonics of the Sengkang Basin, South Sulawesi

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ABSTRACT

Sulawesi was formed during the Oligocene - Miocene collision between the Eurasian Plate and micro-continental fragments detached from the Indian-Australian Plate. The Sengkang Basin situated on the South Sulawesi Province, was formed by a major north northwest - south southeast trending fault system of the Walanae Fault Zone, which was followed by the formation of Late Neogene foreland basin and syn-orogenic deposition. The fault system separated the eastern and western parts of South Sulawesi and influenced the deposition during the Late Miocene to Quaternary. The lower part of the deposition unit consists of small carbonate reefs of the Tacipi Member occupying the East Sengkang Basin, where this shallow marine facies is intercalated within or overlies marine claystones representing the base of the Walanae Formation. The middle sequence is interpreted as a delta foreset consisting of the Samaoling and Beru Members. During the deposition of these two members, the northern part of the Sengkang Basin gradually changed from a tidal and deltaic to fluvial environments. Furthermore, the upper sequence of this sedimentary unit is dominated by fluvial deposits.

Keywords: Sengkang Basin, Late Neogene, Walanae Formation, Sulawesi

SARI

Sulawesi terbentuk akibat tumbukan antara Lempeng Eurasia dan kepingan kontinen mikro yang lepas dari Lempeng India-Australia. Cekungan Sengkang yang terletak di Provinsi Sulawesi Selatan terbentuk oleh suatu sistem sesar berarah utara barat laut - selatan tenggara di Zona Sesar Walanae, yang diikuti oleh pembentukan cekungan busur muka dan pengendapan sin-orogenik pada Neogen Akhir. Sesar utama ini memisahkan bagian barat dan timur Sulawesi Selatan, dan berpengaruh terhadap pengendapan selama Miosen Akhir sampai Kuarter. Runtunan bagian bawah endapan sedimen di Cekungan Sengkang terdiri atas terumbu kecil karbonat bagian Anggota Tacipi, dan fasies laut dangkal ini berselingan atau menindih batulempung marin yang mewakili bagian bawah Formasi Walanae. Bagian tengah runtunan diperkirakan sebagai delta bagian muka yang terdiri atas Anggota Samaoling dan Anggota Beru. Bersamaan dengan pengendapan kedua anggota ini, bagian utara Cekungan Sengkang berubah secara berangsur dari lingkungan pasang-surut dan delta menjadi lingkungan fluviatil. Selanjutnya runtunan batuan sedimen paling atas di cekungan ini dikuasai oleh endapan sungai.

Kata kunci: *Cekungan Sengkang, Neogen Akhir, Formasi Walanae, Sulawesi*

INTRODUCTION

Indonesia lies on a junction of three converging major plates, *i.e.* the Eurasian, Indo-Australian, and Pacific Plates. Charlton (2000) proposed that at 30 Ma, the Australian continental margin collided with southern region of Indonesia between Sulawesi in the west and Papua in the east.

The subsequent rotational history of Kalimantan and Sulawesi, and therefore their relative position, in the Paleogene to Neogene is still a matter of debate-interpretations offered include "no rotation" (Lee and Lawyer, 1993, 1995), "clockwise rotation" (Rangin *et al*., 1990), "counter clockwise rotation" (Haile *et al*., 1978; Hamilton, 1979; Hall, 1996; Charlton, 2000), and "mixed rotations (Bri-

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ais *et al*., 1993). Sulawesi was formed along the Oligosen-Miocene collision between the Eurasian Plate and micro-continental fragments derived from the Indian-Australian Plate. It can be divided into four arms, each is characterized by different tectonic provinces with a particular reference to divergence of Kalimantan and Sulawesi through the Cainozoic (Hamilton, 1979; Rangin *et al*., 1990; Parkinson, 1991; Bergman *et al*., 1996; Simanjuntak and Barber, 1996; Hall, 1996).

This paper describes the geology, stratigraphy, and tectonic setting of the Sengkang Basin, South Sulawesi region (Figure 1), on the basis of detailed sedimentological and biostratigraphical data. All

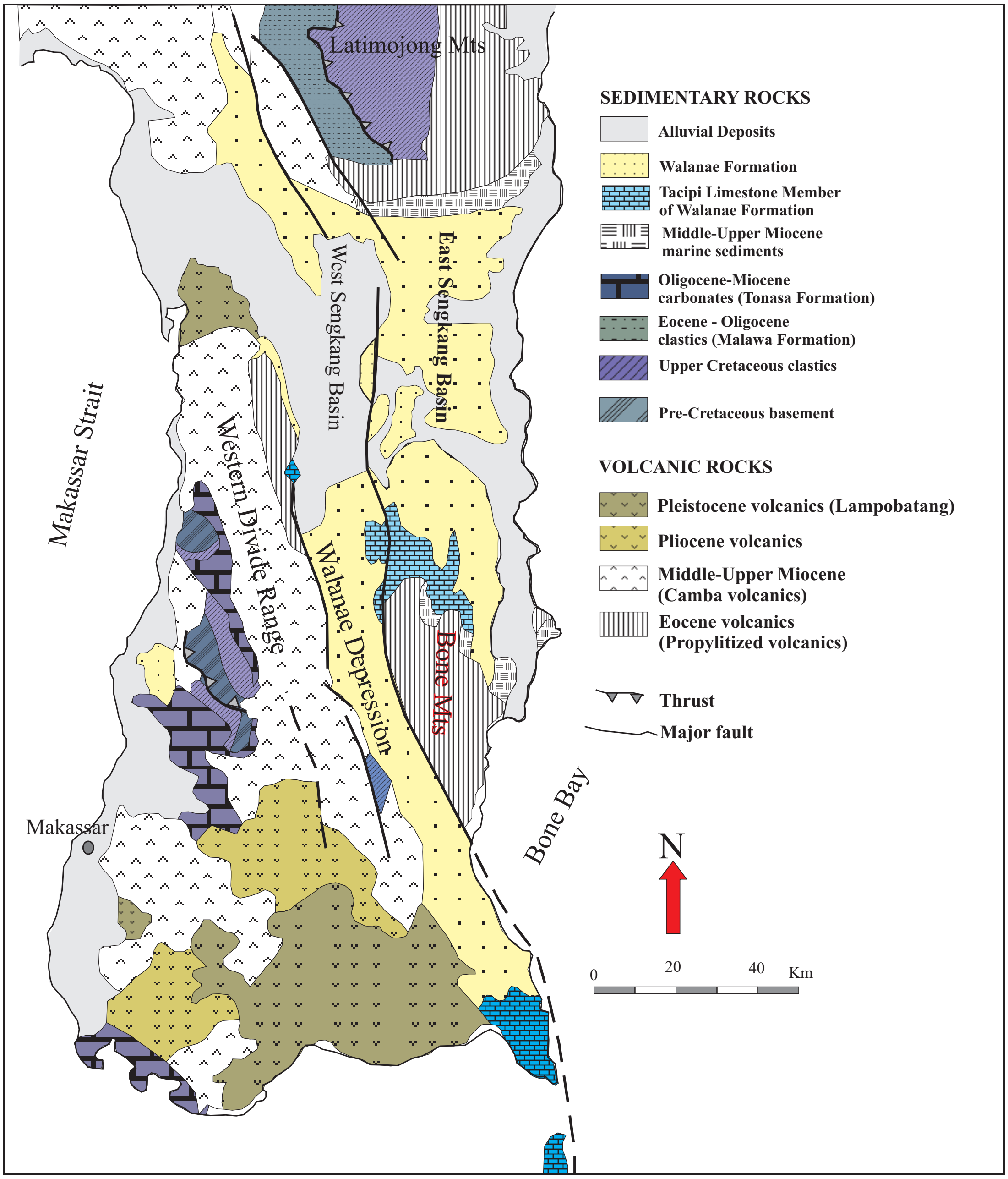

Figure 1. Geological map south Sulawesi (modified from Sukamto, 1975; van Leuwen, 1981; Bergman *et al*., 1996; van den Bergh, 1999).

samples belong to the Sengkang Basin that were collected during the fieldwork at 2008, a research project between the University of Wollongong (UOW) and Centre of Geological Survey (PSG). Evidences from the eastern Kalimantan, the southwestern part of Sulawesi, and Makassar Strait are particularly relevant and they are used to reconstruct the tectonic and palaeogeographical history of the region.

Methodology

Accomplishing the purpose of the study, specific geological investigations and laboratories were carried out. Then, the study focused on the stratigraphic analysis of each member of the Walanae Formation, with measured section methods using a geological compass and GPS. Basically, each member of the Walanae Formation was selected for a representative section, which was supported by collecting rock samples for laboratory analysis aims, such as pollen and mollusk analyses in order to get ages and depositional environments in this basin. The analysis was conducted at GSI paleontology laboratories, following standard procedures. The detailed sedimentological and biostratigraphical studies of the sedimentary succession led to the construction of an updated stratigraphy of the Sengkang Basin.

Geological Outline

The Sengkang Basin (or Wallanae Depression) was formed by a major north northwest – south southeast trending fault system of the Walanae Zone, which was developed as a foreland basin in Late Neogene. The Late Neogene basin is filled by clastic sediments containing fossils of Late Miocene age.

Sarasin and Sarasin (1901) named the clastic deposits that filled the Late Neogene sedimentary basins in South, West, and Southeast Sulawesi, as the "Celebes Mollase" (van Bemmelen, 1949). Later, Hoen and Zyegler (1917) used a term "Walanae Formation" for syn-orogenic molasse deposits in South Sulawesi. The term is used here for the Late Miocene to Holocene clastic sequences which developed in the Walanae Depression and northern extension of the Sengkang Basin.

In the centre of West Sengkang Basin, the Walanae Formation comprises a continuous sequence up to the modern floodplain and lake deposits around Lake Tempe. In addition, reef talus of the Tacipi Limestone interfingers with the lower mudstones of the Walanae Formation (Sukamto, 1982; Grainge and Davies, 1985).

Stratigraphy and Tectonics

Stratigraphy

The Walanae Formation is formally divided into the Tacipi Limestone, Burecing Marine Mud, Samaoling Sandy Marine, and Beru Fluvial Clastic Members (van den Berg, 1999).

In the Soppeng area, the West Sengkang Basin sediments are dominated by calcareous grey claystone in the lower part of the Walanae Formation, known as the Burecing Member, after Burecing Village along the Cabenge –Pampanua road. Its exposure can also be found along the Lakibong and Walanae Rivers and in the Parenring Creek. The mollusk (02 YN LKB and BC 03) and pollen contents (Table 1) tend to show open marine and transition depositional environments. The Burecing Member interfingers with the shallow marine Tacipi Coral Limestone Member, locally. The claystone is approximately 900 m thick.

The Samaoling Member is the middle part of Walanae Formation, characterized by an alternation of shallow marine silty mudstones and fine-to medium-grained well-sorted sandstone. The type locality of the sandy interval between the lower marine and fluvio-deltaic strata is situated near the Samaoling Village. This member is approximately 31 m thick at its type locality (Figure 2).

Massive well bedded sandstones, with scoured structure, dominate the lower part of the sequence. In the same sequence, an intercalation of thinly bedded fine-grained sandstones and siltstones is clearly exposed with wave ripple and cross lamination structures. The middle part of the sequence is characterized by parallel laminations of siltstone and claystone. Unfortunately, the interval of Samaoling Member is poorly exposed. A concretionary, calcareous layer, which contains mollusk fossils, lies at the boundary between the lower and middle part of this member. A thick, massive sandstone bed with alternating silty and clayey layers dominates the upper part.

The deposition of the upper part, consisting of shallow marine sandstones probably was deposited

Table 1. Pollen and Mollusk Analysis Result

No	Sample Code	Pollen	Mollusks	Remarks
1	LK 2, Lakibong	*Rhizophora* type (*Zonocostites ramonae*), *Sonneratia alba (Florschuetzia meridionalis)* *Avicennia* type, *Sonneratia caseolaris (F. levipoli)* Fossil index: *F. levipoli & F. meridionalis*.	-	• Depositional environment: back mangrove. • Age: not older than Late Miocene.
2	BRC 28 YN	*Rhizophora* type (*Zonocostites ramonae*), *Sonneratia alba (Florschuetzia meridionalis), Avicennia* type, *Corylus* type, *Laevigatosporites spp., Acrostichum , Verrucatosporites, Pteris type, Cyathea* type Fossil index: *F. levipoli & F. meridionalis*	-	• Depositional environment: possible close to back mangrove. • Age: not older than Late Miocene.
3	BRC 27 YN	*Rhizophora* type (*Zonocostites ramonae*), *Sonneratia alba (Florschuetzia meridionalis), Avicennia* type, *Gramineae (Monoporites annulatus), Casuarina* type (*Haloragacidites sp*.), *Retitricolporites, Acrostichum, Laevigatosporites spp., Verrucatosporites, Pteris* type, *Cyathea* type Fossil index: *F. meridionalis*	-	• Depositional environment: possible close to mangrove. • Age: not older than Late Miocene.
4	02 YN LKB	-	**Class Bivalvia** *Anadara sp., Arca sp., Cardita sp., Corbula sp., Chione sp., Ostrea sp., Nuculana sp., Veneridae indet.* **Class Gastropod** *Turitella sp., Natica sp., Babylonia sp.* **Class Scaphoda** *Dentalium sp.,* Fragment koral, Fragment *Carapace, Crustacea*	• Depositional environment: open marine environment, *soft substrate*, with low to medium energy.
5	BC 03	-	**Class Bivalvia** *Geloina sp.*	• Depositional environment: transition zone with strong energy. • Fossil content dominantly fragmented with a few well preserved.

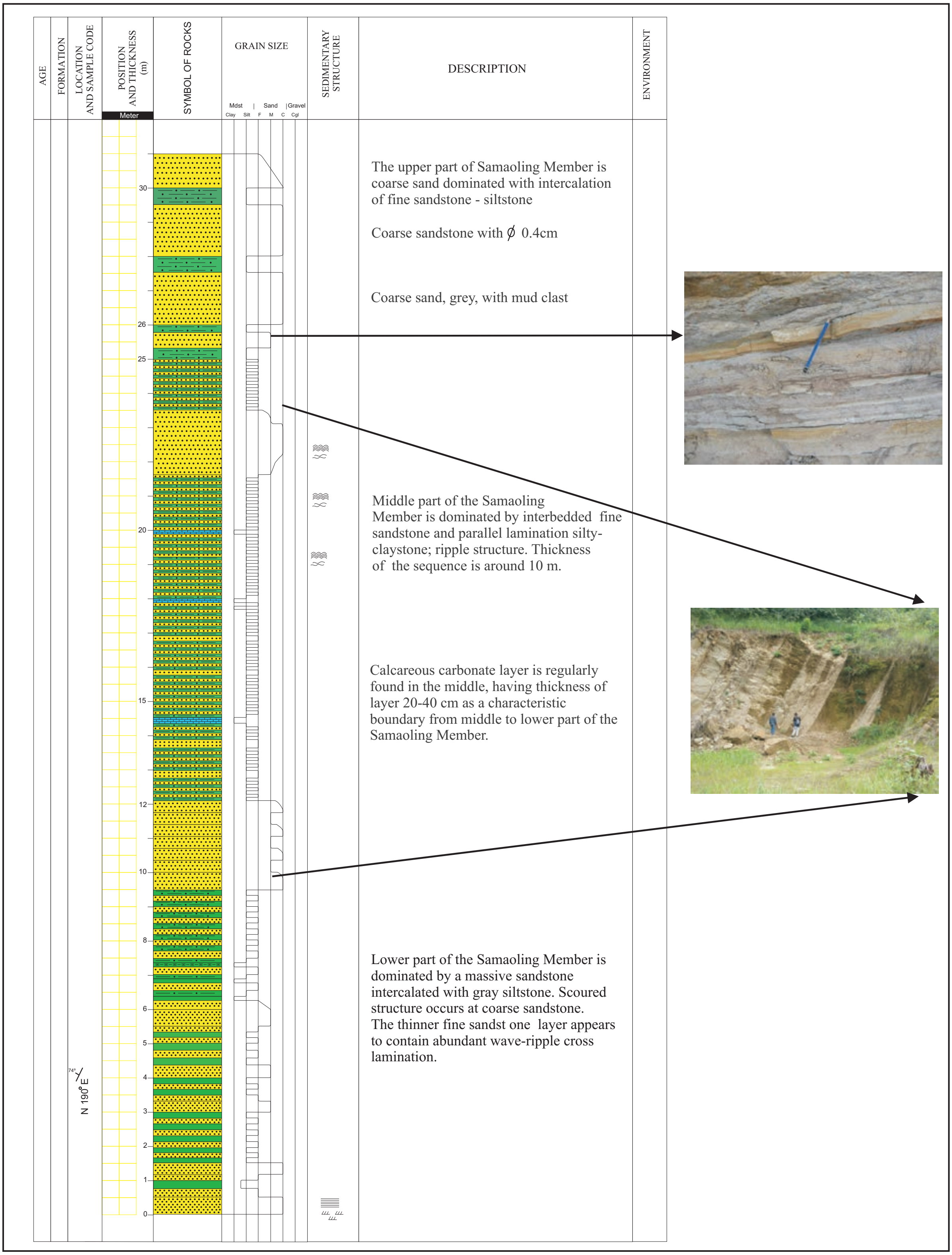

Figure 2. Detailed stratigraphic section and photographs of the Samaoling Member along Cabenge to Pampanua road in the location of 04 19’53.4” S and 120 01’49.5” E. The bedding dip varies from 50° and 75° to the northwest.

in a shallow marine shelf, in a lagoonal, tidal setting, but open to wave-action and storm currents.

The Beru Member which unconformably overlies the Samaoling Member, forms the upper part of the Walanae Formation. Sartono (1979) argued that this member, dominated by sandstones, was formed as the Late Pleistocene fluvial deposits that were subsequently deposited into terraces. On the other hand, the Beru Member representing the upper part of the Walanae Formation, was developed along the western flank of the Sengkang Anticline and adjacent areas.

The Beru Member is well exposed at the Lepangeng Village (04º23’19.2” S and 120º02’19.4” E) where it is characterized by medium-grained sandstones with pebbles, showing massive and scoured sedimentary structures. It is around 50 m thick and was deformed by a tectonic activity, as indicated by the presence of tilting of the sandstones with bedding dip between 54º and 60º to the southwest. About 30 m distant to the west, a tide bundle sequence of mud drape structures is exposed on a fine-grained sandstone bed. The stratigraphic section on the western flank of the Sengkang Anticline shows an alternation between fluvial layers and lagoonal or estuarine deposits, indicating that the area was a transition zone between lagoonal/estuarine and fluvio-lacustrine environments.

The lower Beru Member is well exposed near the Paroto Village, where it consists of fine-grained sandstones with mud drape structures (Figure 3). The member is unconformably overlain by old terraces, which can be divided into unconsolidated parts, dominated by small fragments and cemented terraces in the upper part. The cemented terraces comprise big rock fragments, as well as stone artifacts. The middle sequence of the Beru Member appears to have been eroded, and changed from a tidal to point bar or bench setting by a continued uplift of the basin.

Mega-ripple cross bedding at the transition zone between the Beru and Samaoling Members shows fluctuations in the paleo-current direction, with an east-west trend. These probably reflect an ebb tide and flood currents.

A northwest-southeast seismic profile in the northern part of Sengkang Basin shows large-scale, westward-dipping strata, interpreted as a delta foresets (Grainge and Davies, 1985). This deltaic sequence reaches the surface in the Sengkang Anticline and it can be correlated with the Samaoling and Beru Members of the Walanae Formation. During the deposition of this member, the northern part of the Sengkang Basin was gradually changed from a tidal and deltaic to fluvial environments.

The sequence is predominantly composed of coarse-grained sandstone and lag deposits, intercalated with indurated compact conglomerates. The scoured base structure is dominant in this sequence; often ripple cross stratifications on medium- to fine-grained sand can be observed.

A detailed stratigraphic section in the Lenrang Village was taken at a hill cut behind local houses. On the basis of composition, sedimentary structures, lateral accretion, and thin layers of fine-grained deposit, the depositional area was interpreted as a point bar with an occasional high energy transport, in the meandering system of Paleo-Walanae River system.

Tectonic Evolution

The northern and southern arms of Sulawesi are here referred to as “Western Sulawesi” for simplicity. The east and southeast arms have an oceanic origin comprises Mesozoic and younger allochthonous metamorphic and ophiolitic rocks, which were obducted onto western Sulawesi during the Oligocene to Early Miocene. In addition, there are several small continental fragments which have collided with eastern Sulawesi, including the Banggai-Sula, Tukang Besi, and Buton Islands.

Geologically, southwest Sulawesi was formed during the Early Cretaceous time as a basement complex, and apparently includes an old continental crust of Australian origin. This is supported by the presence of recycled ancient zircons from Miocene igneous rocks, which on the basis of their chemical composition, they were originated from northern Australia. Possibly, these igneous rocks accreted onto the Sundaland during the Oligocene to Miocene collision event (Bergman *et al*., 1996; Priadi *et al*., 1993).

During the Middle to Late Eocene, the west basement of the Walanae depression was overlain unconformably by volcanic and marginal marine coal-bearing deposits of the Malawa or Toraja Formations (Sukamto, 1982). Later, the deposition of Oligocene Tonasa Formation (Figures 1 and 4) indicates the development of extensive areas of shallow water carbonate platforms in southern Sulawesi,

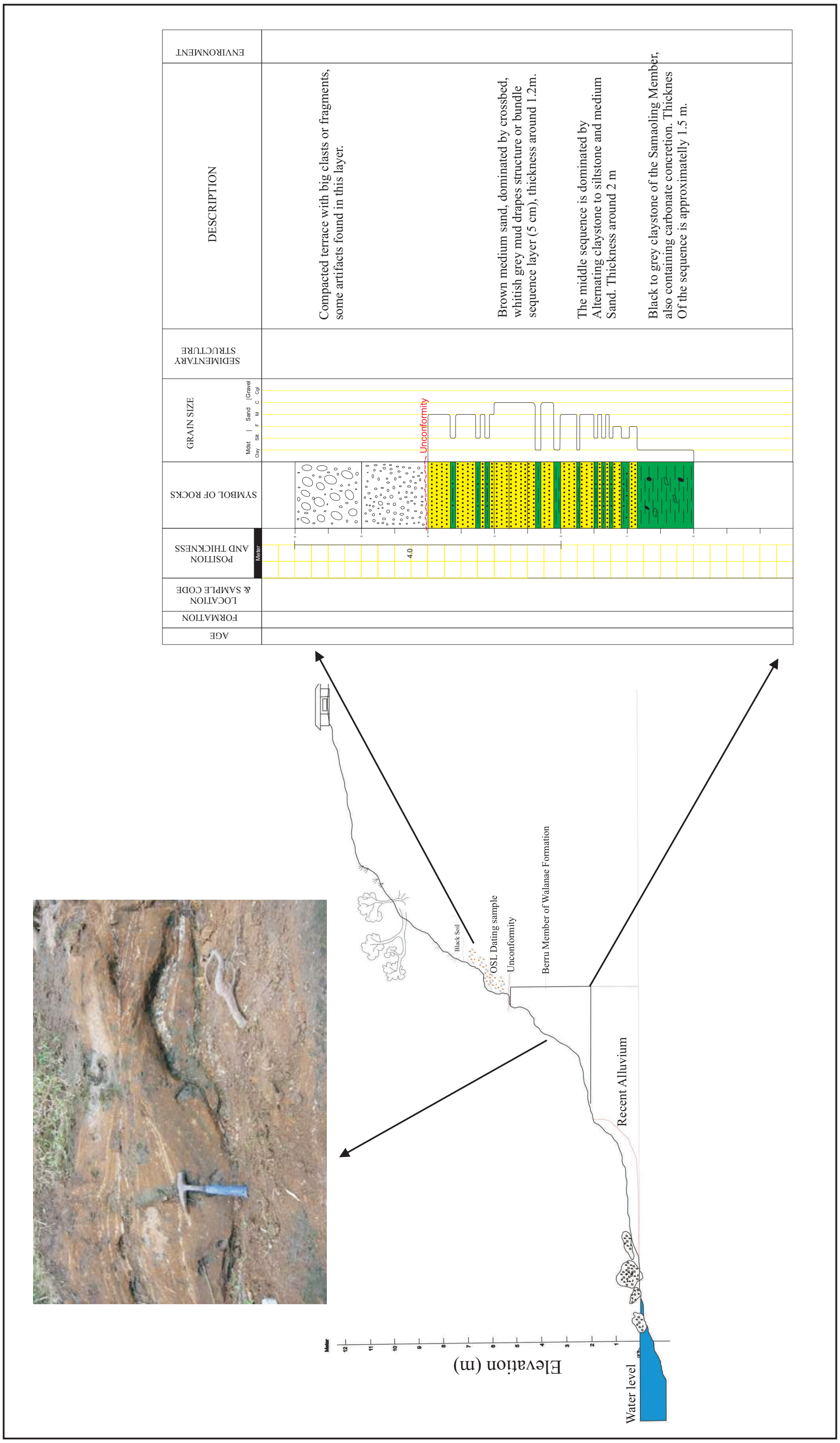

Figure 3. Detailed stratigraphic section and plan of the Beru Member exposed at the Paroto Village. The mud drape structures also occur in the middle part of the sequence.

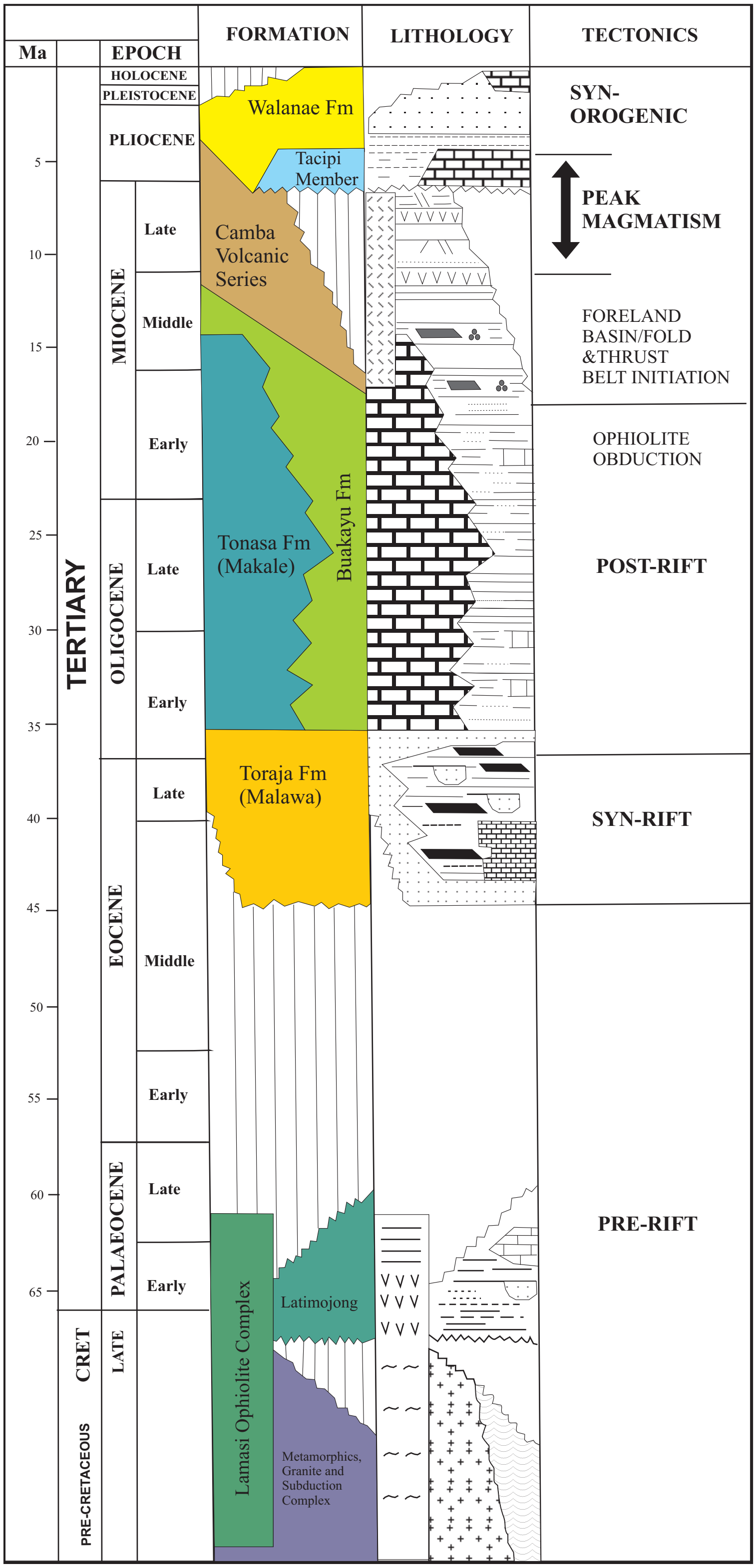

Figure 4. Stratigraphic column of southwest Sulawesi (modified from Sukamto, 1982; Wilson and Moss, 1999; and Guntoro, 1999).

whilst deep water marls were deposited in adjacent areas (Supriatna *et al.*, 1993; Wilson and Moss, 1999). A contemporaneous carbonate platform is also found in the East Java Basin and southern Kalimantan Basin, where a tectonic activity is recorded by the presence of lateral deposition of reworked carbonate facies in the down faulted blocks. This deposition continued until Middle Miocene (Wilson and Bosence, 1996).

The igneous rocks of Camba-Enrekang-Mamasa Volcanic Complex and derivative volcaniclastics were deposited occupying more than 75 % of the surface of western Sulawesi in Middle to Late Miocene time. This volcanism was related to a north-south trending volcanic system. Analyses of trace elements indicate that the Miocene igneous rocks are subduction-related, associated with compressional boundaries, in which oceanic crust is subducted beneath the continental crust.

Locally, small carbonate reefs of the Tacipi Member were formed in the East Sengkang Basin, where this shallow marine facies interfingered with or conformably overlaid marine claystones representing the base of Late Miocene Walanae Formation. The claystone accumulated in the down faulted Walanae depression and north of the Bone Mountains (Grainge and Davies, 1985; van den Bergh, 1999). During the Pliocene, the structural evolution of South Sulawesi was probably characterized by a compressive deformation. It was started by the Miocene collision with East Sulawesi, which produced the post collisional uplift and nappe obduction by a low and high angle normal faulting (Harris, 1989; Bergman *et al*., 1996).

The Lamasi Ophiolite Complex in western Sulawesi and the analogous ophiolite in the eastern arm are separated by the deep intervening Bone Bay, suggesting that an orogenic collapse may have occurred here. Thus, local compressive forces are still active until Late Miocene to recent times.

A major north northwest-south southeast trending fault system, the Walanae Fault Zone, separated the eastern and western parts of South Sulawesi and influenced a deposition during the Late Miocene to Quaternary (Figure 1). Grainge and Davies (1985) suggested that this fault consists of two major components, a western part, designated as the West Walanae Fault (WWF) and an eastern part as the East Walanae fault (EWF). Furthermore, these faults divided the Late Cainozoic basin on both sides of the EWF into the West and East Sengkang Basins (WSB and ESB). The WSB corresponds with the Walanae and Lake Tempe depression.

Discussion

The stratigraphy and tectonic history of Sulawesi, Makassar Strait, and eastern margin of Sundaland (eastern Kalimantan) from the Middle Eocene to the present provide a context for development of the Sengkang Basin. This section is concerned with the stratigraphy and tectonic evolution in the Sengkang Basin during the Late Neogene based on the present data.

During Middle to Late Miocene, the Camba volcanics accumulated in the western part of the Walanae Depression and a time when the eastern part was predominantly occupied by the deposition of Walanae Formation with shallow marine of Tacipi and claystone of Burecing Members.

The Walanae Formation consists of four members and each member has a (typical) characteristic depositional environment from marine to fluvial (Figure 5). They are:

a) The Tacipi Member is typically coralline limestones deposited within a shallow marine environment.
b) The Burecing Member is dominated by calcareous grey claystone in the lower part of the Walanae Formation. The rock sequence which is rich in foraminifera, pollen, and marine mollusks, indicates an open marine to transition depositional environment.
c) The Samaoling Member being the middle part of Walanae Formation is characteristically an alternation of shallow marine silty mudstones and sandstones. This member was deposited within a lower marine and fluvio-deltaic environment.
d) The Beru Member is the upper part of the Walanae Formation. It is dominated by sandstones of the Late Pleistocene fluvial deposits which later on were shaped into terraces. In the western flank of the Sengkang Anticline, alternating fluvial layers and lagoonal or estuarine deposits occurs, indicating that the area was a transition zone between lagoonal/estuarine and fluvio - lacustrine environments.

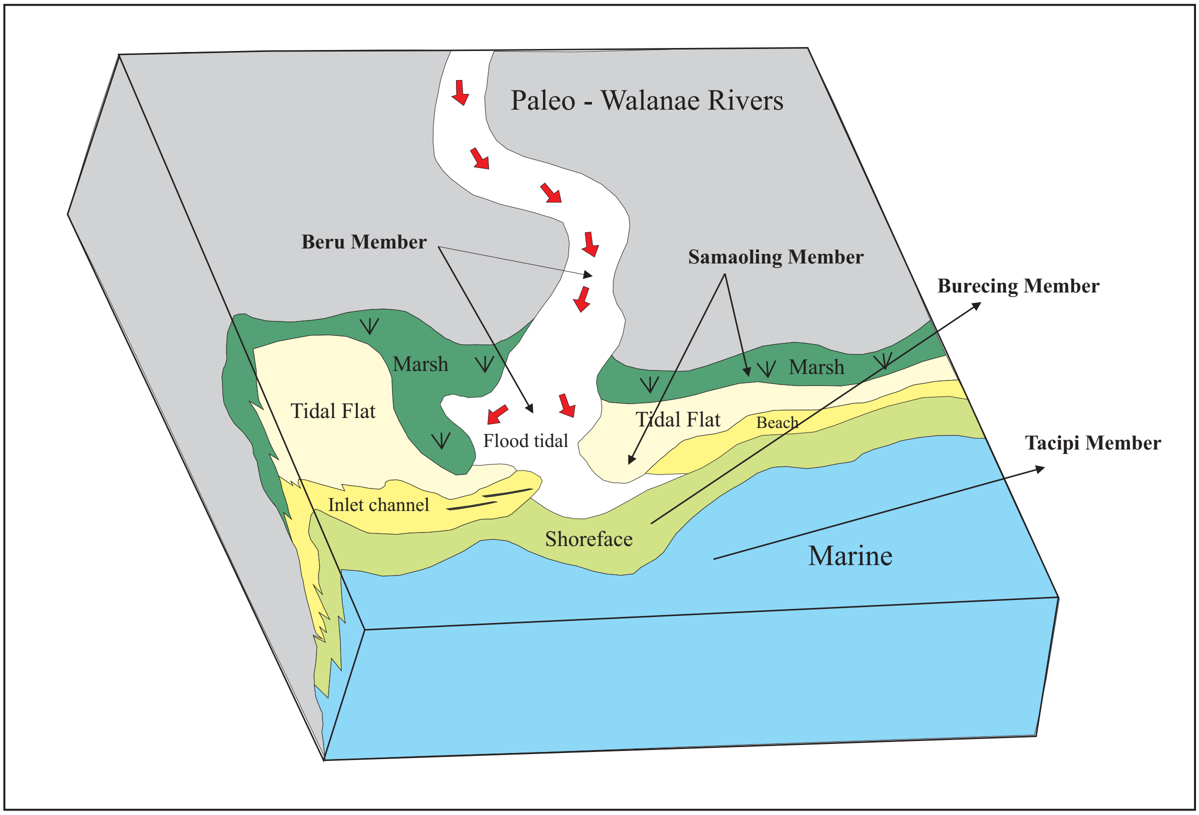

Figure 5. Facies modelling of the Sengkang Basin during Late Neogene.

Conclusions

The Sengkang Basin (or Walanae Depression) was formed by a major north northwest-south southeast trending fault system in the Walanae Fault Zone, which was then developed as a Late Neogene foreland basin or syn-orogenic deposition.

In the Late Miocene, locally, small carbonate reefs of the Tacipi Member were formed in the East Sengkang Basin, where this shallow marine facies intercalated or conformably overlaid the marine claystone representing the base of Late Miocene Walanae Formation. The claystone accumulated in the down faulted Walanae depression and north of Bone Mountains.

The middle parts of the sedimentary unit were interpreted as a delta sequence showing large-scale, westward-dipping foreset strata. This sequence consists of the Samaoling and Beru Members of the Walanae Formation in the northern part of the Sengkang Basin. During the deposition of these members, the northern part of the Sengkang Basin was gradually changed from a tidal and deltaic to fluvial environments.

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