

Origin of mélangé complexes in the Sunda and Banda arcs: Tectonic, sedimentary, or diapiric mélangé

Maruf M Mukti¹, S Aribowo², Ayu Nurhidayati¹

¹ Sedimentary geology & tectonics Group (SaGeT), Research Center for Geotechnology, LIPI, Bandung, Indonesia

² Mining engineering & geological hazards mitigation (UPT Liwa), LIPI, Liwa, Indonesia
E-mail: maruf@geotek.lipi.go.id

Abstract. The origin of mélangé complexes has been the subject of speculation of geologists since their first recognition in the 1900s. Type of mélangé complex plays a role in the tectonic reconstruction of active margin. Several locations in the southern Sundaland margin expose remnant of Mesozoic subduction zone as basement and sedimentary rocks in mélangé complexes. Ciletuh, Luk Ulo, and Meratus formed along the southern margin of Cretaceous Sundaland subduction system have been known as tectonic mélanges based on observation of the exposed rocks and its structural configuration. However, mélangé complexes in the western Sunda arc (Nias) and Banda arc (Timor) have been concluded to form as diapiric mélangé rather than tectonic origin. Recent studies in these two areas showed that mud diapirism was developed in a dynamically active environment. The role of tectonism in these mélangé complexes appears to be indirect. Here, we described results of published results on mélanges along the Sunda and Banda arc to understand the mechanism of their processes.

1. Introduction

Mélanges, chaotic blocks of different ages and origin commonly embedded in the argillitic matrix, represent a significant component of collisional- and accretionary-type orogenic belts [1–3]. The origin of mélangé complexes has been the subject of speculation of geologists since their first recognition in the 1900s. Type of mélangé complex plays a role in the tectonic reconstruction of active margin. The definition of mélangé has evolved to cover tectonic, sedimentary, and diapiric processes [4]. These terms may be ambiguous, as they refer to processes that often overlap and as their original meaning may have changed over time due to the progressive of the geological knowledge [5]. Therefore, caution is needed when a genetic aspect is attributed to a definition, since it may not be easy to define mélangé origin from field observation, especially for those appear intensely deformed [6].

Several locations in the southern Sundaland margin expose remnant of Mesozoic subduction zone as basement and sedimentary rocks in mélangé complexes. Here, we reviewed several exposures of mélangé complexes in the Sunda – Banda active margins to reveal the dominant processes that might have been responsible for the development of mélangé. Furthermore, we tried to describe possible methods that can be used in characterizing genetic formations that took place during the generation of a mélangé complex.

2. Melange development in the Sunda and Banda Arc

2.1. Mélanges in the Sumatran forearc

Pre-Tertiary igneous and metamorphic basement crop out in Nias Island and have been interpreted as mélangé complex of mid-Tertiary subduction system [7]. The Nias mélanges, here referred to as the



Oyo Complex that crops out in linear zones ranging from 100 to more than 2000 m wide, have been suggested to have formed as tectonic *mélange* of an accretionary complex consisting of deformed trench-fill turbidites and slices of oceanic crust and sediments [8]. However, later study observed the Nias *mélanges* and interpreted this unit composed of thin mylonites and olistostromic scaly clay localized at several decollement levels [9]. Later work in Nias Island, reveals a new stratigraphy that is well-controlled by biostratigraphic data [10]. These authors interpreted the basement of Nias referred to as the Bangkaru Ophiolite Complex that is composed of peridotites, plutonic rocks, dolerites, basalts, tuffs, sedimentary and metasedimentary rocks. Furthermore, the *mélanges* have been interpreted to have formed by diapiric mobilization of the thick Oligocene and lower Miocene mudstones that occurred during the Pliocene inversion [11]. However, recent seismic reflection data offshore Nias reveal that the inverted structures are actually set of landward-vergence backthrusts developed in the landward margin of accretionary wedge [12]. *Mélanges* with circular outcrop patterns have also been observed in Siberut Island [13] with a similar description to Nias Island which can be interpreted as diapiric in origin [11]. To the south of Siberut, mud volcano and diapirism appear in the western margin of the Mentawai basin, near the accretionary wedge [14]. A feature of diapirism is also observed in seismic profile crossing the Simeulue Basin, to the north of Nias [15].

2.2. *Mélanges in Java Island*

Ciletuh, Luk Ulo, and Meratus formed along the southern margin of Cretaceous Sundaland subduction system have been considered as tectonic *mélanges* based on the observation of the exposed rocks and their structural configuration. To the south of central Java, Luk Ulo Melange complex has been observed as a remnant of a tectonic mixture formed during Late Cretaceous subduction consisting of tectonic blocks of dismembered ophiolites, volcanic rocks, pelagic sediments, blocks of continental crust origin, and metamorphic rocks embedded in scaly clay matrix [16]. Later work in this area focused on the petrology of the ophiolites and metamorphic rocks [17,18] and radiolarian stratigraphy [19]. Blocks of the Luk Ulo *mélanges* are of Early Cretaceous – Paleocene unconformably overlain by the olistostrome of Karangsambung Formation [16].

Pre-Tertiary rocks are also observed in the southern west Java and crop out as blocks of peridotite, gabbro, basaltic lava, greywacke, limestone, red shale, chert, serpentinite, phyllite and blue schist [20]. Lack of fossil within the *mélange* complex inhibits direct indication for the age of the *mélange*. However, based on the microfossils in the overlying sediments of middle Eocene Ciletuh Formation [21], the Ciletuh *mélange* are of pre-middle Eocene.

To the east of Luk Ulo *mélanges*, basement rocks crop out in Bayat consisting of phyllite, slate, greenschist, limestone, radiolarian chert, serpentinite, quartzite, gneiss, and amphibolite [7,22]. However, recent studies in this area [23,24] did not find these rock assemblages. Glauconite schist and serpentinite have been reported to have occurred in the west Jiwo Hill [25].

2.3. *Mélanges in Banda Arc*

The Bobonaro Scaly clay in Timor Island has been interpreted as olistostrome [26]. However, based on the observation of its fabric, this rock unit is interpreted as tectonic *mélange* [7]. Later on, mud volcano fields and cross-cutting mud diapirs were observed during geological survey mapping [27]. Diapirs and active mud volcanoes appear extensively on all the Banda Outer Arc islands between Seram and Timor [1,2].

3. Characterizing *mélange* emplacement

The Ciletuh, Luk Ulo, and Meratus *mélange* complexes have been regarded as tectonic *mélanges* based on observation of the exposed rocks and their structural configuration. However, *mélange* complexes in the western Sunda arc (Nias) and Banda arc (Timor) have been concluded to have formed as diapiric *mélange* rather than tectonic origin. Recent works on these two areas observed that mud diapirism was developed in a dynamically active environment. The role of tectonism in these *mélange* complexes appears to be indirect [1].

Based on observation of two mélanges in the Hoh accretionary complex that was accreted in Neogene, the diapiric mélange is characterized by: an arcuate foliation pattern in map view, an increase in foliation intensity toward the contacts, opposite fold vergence across mélange, common angular clast, a higher clast-to-matrix ratio in the center of mélange, large clast occurring only in the center of diapir, and an increase in clast long-axis clustering at the contacts [28] (Figure 1). However, if a diapir was sufficiently narrow and viscous, it might be sheared throughout, similar to a shear zone. Circular outcrops pattern is observed in the central and southern part of Sumatran forearc high islands, and have been interpreted to have formed as diapiric mélange [11,13].

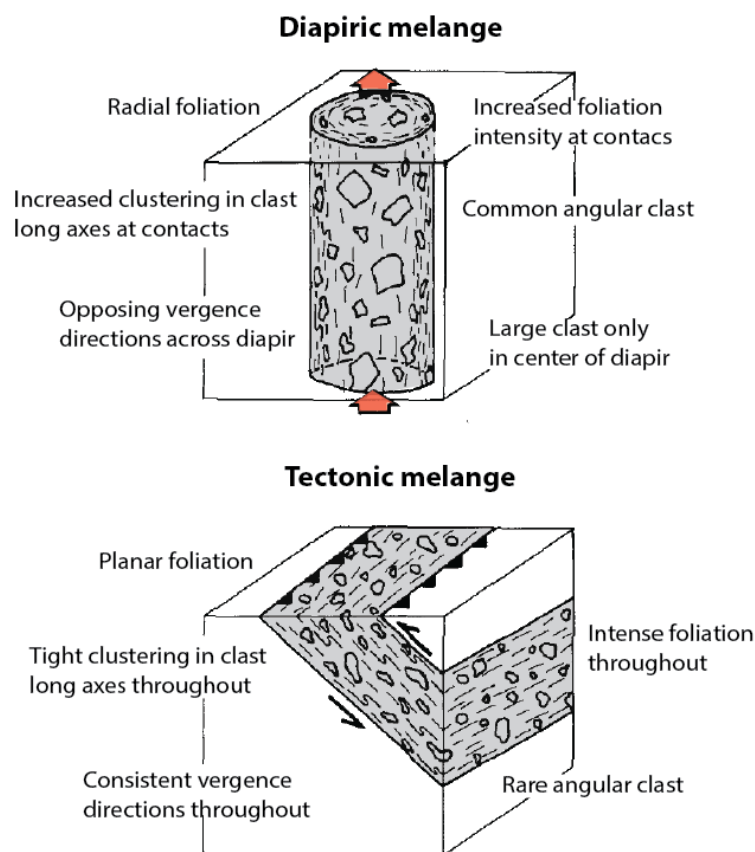


Figure 1. Model showing characteristics of diapiric and tectonic mélanges. Modified after [28].

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