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

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Abstract. The origin of mélange complexes has been the subject of speculation of geologists since their first recognition in the 1900s. Type of mélange 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 mélange 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, mélange complexes in the western Sunda arc (Nias) and Banda arc (Timor) have been concluded to form as diapiric mélange 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 mélange 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 mélange complexes has been the subject of speculation of geologists since their first recognition in the 1900s. Type of mélange complex plays a role in the tectonic reconstruction of active margin. The definition of mélange 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 mélange 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 mélange complexes. Here, we reviewed several exposures of mélange complexes in the Sunda – Banda active margins to reveal the dominant processes that might have been responsible for the development of mélange. Furthermore, we tried to describe possible methods that can be used in characterizing genetic formations that took place during the generation of a mélange 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 mélange 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. Glaucophane 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 diaper, 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].

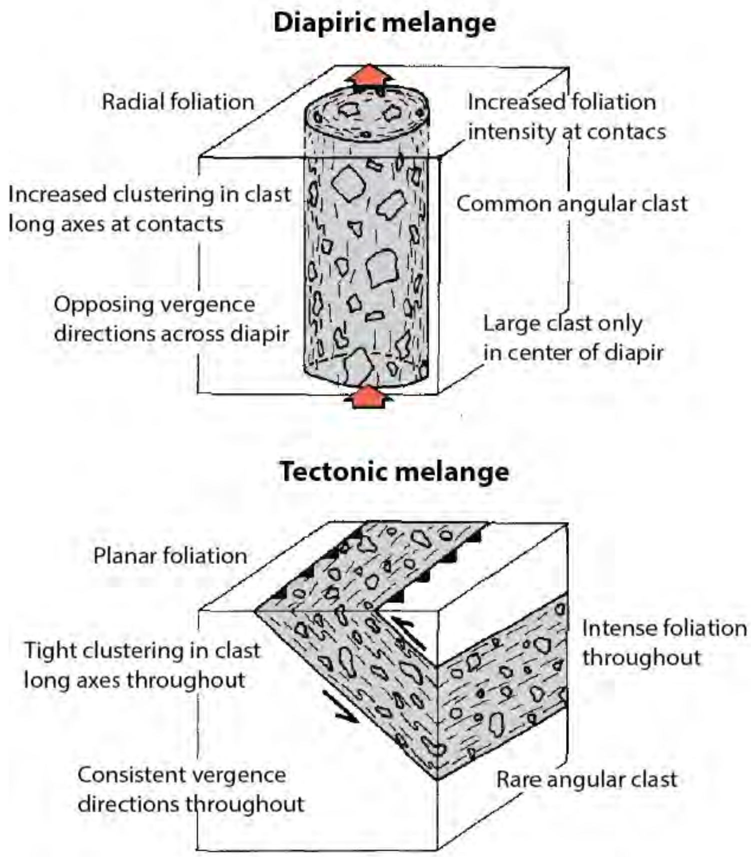

Figure 1. Model showing characteristics of diapiric and tectonic mélanges. Modified after [28].

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