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The origin of oceanic crust and metabasic rocks protolith, the Luk Ulo Mélange Complex, Indonesia

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Abstract. The Luk Ulo Mélange Complex (LUMC) is composed of tectonic slices of rocks that surrounded by scaly clay matrix. These rocks consist of serpentinite, gabbro, diabase, and basalt, eclogite, blueschist, amphibolite, schist, gneiss, phylite and slate, granite, chert, red limestone, claystone and sandstone. The LUMC was formed since Paleocene to Eocene, gradually uplifted of HP-UHP metabasic-metapelite (P: 20-27kbar; T: 410-628°C) to near surface mixed with hemipelagic sedimentary rocks. The metamorphic rocks were formed during 101-125 Ma (Early Cretaceous) within 70 to 100 km depth and ~6°C/km thermal gradient. It took about 50-57 Myr for these rocks to reach the near surface during Paleocene-Eocene, with an uplift rate at ~1.4-1.8 km/year to form the mélange complex. The low thermal gradient was due to subduction of old and cold oceanic crust. The subducted oceanic crust (MORB) as protolith of Cretaceous metabasic rocks must be older than Cretaceous. The data show that the basalt of oceanic crust is Cretaceous (130-81 Ma) comparable to the age of the cherts (Early to Late Cretaceous). Therefore, we consider that neither oceanic crust exposed in LUMC nor all of part of the old oceanic crust is the protolith of LUMC metabasic subducted beneath the Eurasian Plate. These oceanic rocks possibly originated or part of the edge of micro-continental that merged as a part of the LUMC during the collision with the Eurasian margin.

1. Introduction

The incomplete ophiolite rocks known as dismembered ophiolite [1-4] intimately related to meta-sedimentary rocks and high pressure-ultra high pressure (HP-UHP) metamorphic rocks are exposed in the Karangsambung area, Kebumen, Central Java, Indonesia (Figure 1). The ophiolite rocks are mixed or tectonically bounded by scaly clay forming the Lok Ulo Mélange Complex/LUMC [5-9]. The dismembered ophiolite was composed by serpentinized peridotite, gabbro, diabase and basalt [8,9]. The metabasic rocks of LUMC present as eclogite, blueschist, and amphibolite, whereas the metapelitic rocks are represented by schist, gneiss and phyllite, and marble [5,10,11]. The deep sea sedimentary rocks such as red limestone and chert and also claystone and sandstone present as blocks in the LUMC [9]. The origin of metabasic rocks are E-MORB and N-MORB tholeiitic, shoshonitic and oceanic basalt, while metapelite or psamit are derived from trench sedimentary rock and greywacke [5,12,13]. The basement rocks or LUMC was unconformably covered by Tertiary sedimentary deposits as a result of basin development and tectonic uplift [7,9].

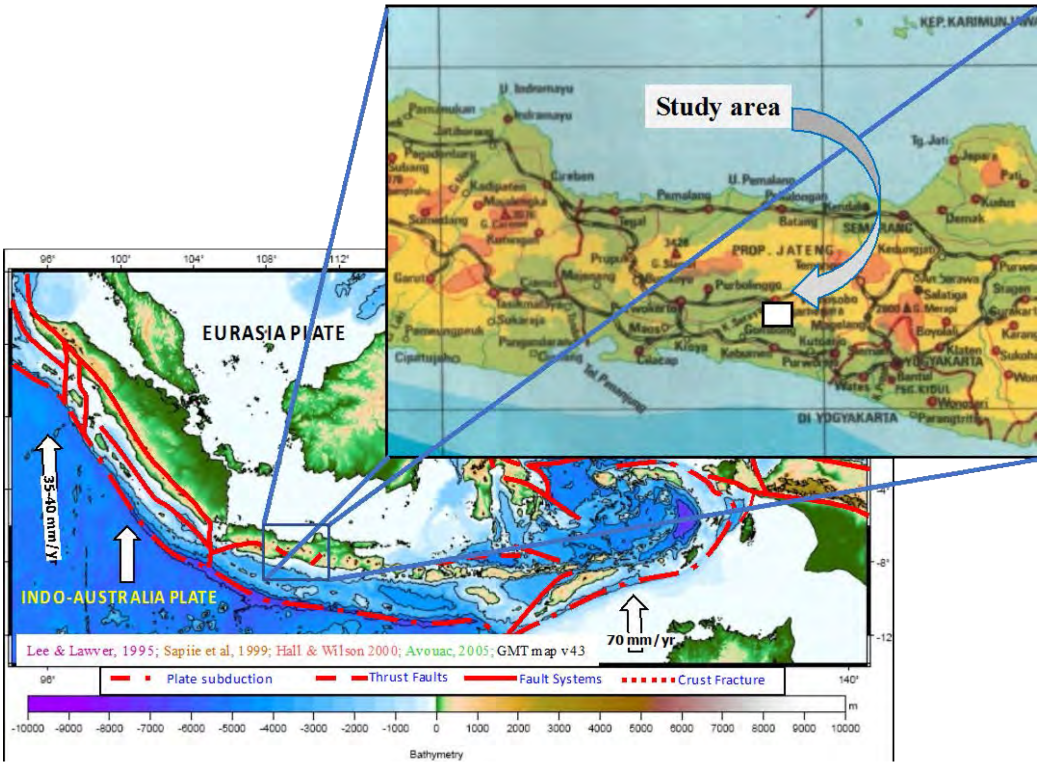

Figure 1. Map of study area (white box) in Karangsambung, Kebumen, Central Java, Indonesia.

2. The P, T and Age of rock Formation

The metabasics rocks are formed at a pressure (P) up to 27.21 kbar and temperatures (T) reached up to 628°C or at about 103.4 km depths with a thermal gradient around 5.6-6.1°C/km [5]. The P and T measurements on the eclogite rock show the formation of the rock at about 20.5 ± 2.5 kbar and 410 ± 50°C or it is formed at the depth of near ~70 km with the thermal gradient about ~6 °C/km [10]. This low thermal gradient can be explained by the subduction of old and cold oceanic crust [14] (Figure 2). On the other hand, metapellite and metapsamite rocks have been metamorphosed at T ranging from 382°-435°C within P around 14.85-21.1 kbar with the geothermal gradient at around 5.3°-6.9°Ckm-1 or at about 56.4-80.2 km depth [5]. The HP-UHP metabasic and metasediment rocks were uplifted to the surface at approximate rate of 0.18 cm/yr and 0.14 cm/yr [5].

Figure 2. A model showing Cretaceous metamorphic rocks formation in low-medium grade to HP-UHP grade of the Pre-Cretaceous oceanic crust. On the right is Cretaceous oceanic ridge development and micro continent separation.

The LUMC component rocks show the age ranges from Early Cretaceous to Late Cretaceous (130-80 Ma). The age of red chert that is widely distributed in LUMC ranges from Early Cretaceous to Late Cretaceous (Late Campanian-Maastrichtian) [15]. Whereas, the metamorphic rocks age such as mica schist (K-Ar method) formed in Cretaceous age (110-124 Ma) [10,16,17] or 101.71 ± 5.9 Ma and 103.71 ± 0.5 Ma [8]. The schist and gneiss based on zircon/U-Pb SHRIMP method resulted in ages about 125.2 ± 2.6 Ma and 102.1 ± 3.8 Ma [5]. Then the basalt and diabase associated with ophiolitic were 81.26 ± 4.06 Ma and 85.03 ± 4.25 Ma measured from K-Ar dating [8]. The pillow lava exposed in Muncar River is of Early Cretaceous (120-130 Ma), whilst the one from Cacaban River is of Late Cretaceous (100-110 Ma) [14]. Based on the terrigenous rocks in the accretion zone, it is estimated that the pillow lava accreted onto the hemipelagic sediments ranging from upper part of Early Cretaceous to Late Cretaceous or Paleocene [14].

3. Facts, questions, and discussion

The results of LUMC research still leave many questions unanswered. The LUMC was composed of rocks originating from different sources varying oceanic crust of N-MORB, E-MORB, tholeiitic to shoshonitic and oceanic basalt in origin, metamorphic rocks, deep sea sediment and trench deposit. All these rocks had undergone slight deformation, brecciated or plastic deformation. How to explain the low degrees deformation of old and cold oceanic crust rocks that have undergone subduction, metamorphism, accretion or obduction and then mixed with trench deposits? What is the mechanism? Or is the LUMC developed gradually in time and processes comprising different rock source?

Various geological models for explaining the mechanism LUMC development have been proposed such as the subduction and accretion model [5,9] and the obduction model [8] especially to explain the presence of rocks derived from oceanic crust. The last model is supported by the results of gravity studies [18]. In the Tertiary, arc-shaped basins arising from collisions between micro-continents with Eurasian continent [7,19] resulted in the LUMC. The continent-microcontinent collision processes have been hypothesized earlier [10]. In general, the mechanism of mélange complex formation can be described [20,21]. The mélange complex could be developed through shale diapirism mechanism [22] or mud diapirism mechanism [23]. Recently, diapiric mélange has been proposed to refine the origin of the mélange complex [24].

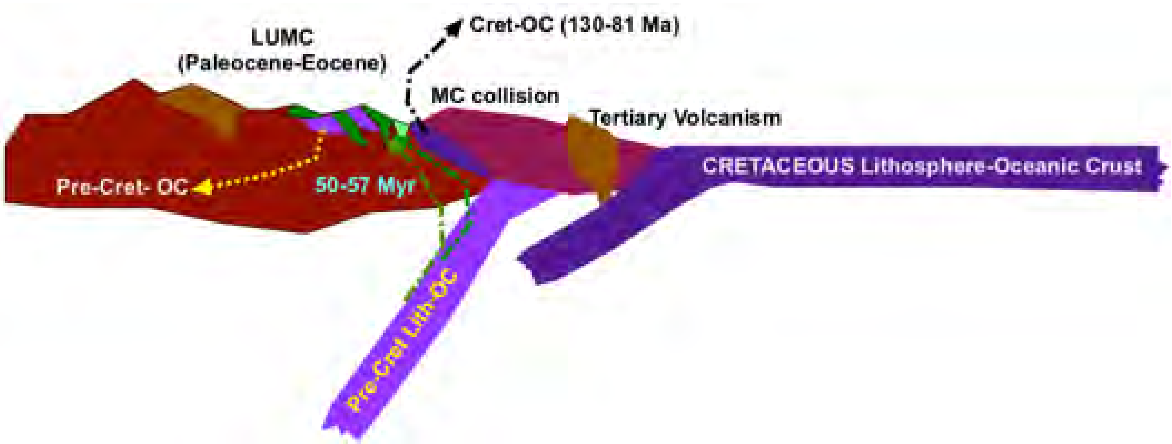

Figure 3. A model showing metamorphic rocks and possibly accreted to the surface with various possibility mechanisms to form Paleocene-Eocene mélange complex. This process is followed by a collision between micro-continent with Eurasia Continent conveying the oceanic crust through the obduction process and now those present with the mélange complex.

The metabasic and metapelite rocks, protolith, had undergone HP-UHP metamorphism at about 70-100 km depth in 101-125 Ma during the Early to Late Cretaceous, while the oceanic crusts (basalt) have relatively similar age about 81-130 Ma (Early to Late Cretaceous). The age of metabasic rocks is relatively similar to those of the oceanic crust that are exposed in the LUMC. So, it is possible that the oceanic crust exposed in LUMC is not the protolith of the Cretaceous metabasic rock. Based on the geodynamic model, the Cretaceous oceanic crust of the LUMC is a part or edge of microcontinent that collided [25-27] (Figure 2) with Sundaland margin (continent-continent collision).

The Cretaceous HP-UHP metamorphic rocks formed at 70-100 km depth slowly accreted (1.4-1.8 km/year) or needed about 50-57 million years to go to shallow depth (retro-morphism) and tectonically mixed with the trench sediment during the Paleocene-Eocene to form mélange complex (Figure 3). These events correspond to the micro-continent and Eurasian continent collision which were followed by the increase of sedimentation in the trench environment [7,16].

4. Preliminary results

The protolith of the metabasic rocks, basalt, diabase or gabbro should be older than Cretaceous, so that they can be incorporated during the subduction. The Cretaceous oceanic crust of the LUMC is the edge of microcontinent that collided with the Sundaland margin. The mixture of the HP-UHP metamorphic rocks with the trench sediments which formed the LUMC most probably occurred during Paleocene-Eocene.

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