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Volcanic Facies of the Doi Phra Baht Volcanic Deposits, Mueang District, Lampang Province, Thailand

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Abstract

In Thailand, the Pre-Jurassic Chiang Khong – Tak volcanic belt has been renowned for the most voluminous igneous rocks and various magmatic suites, where rhyolite – rhyodacite and their pyroclastic equivalents are predominant. A sequence of volcanic rocks exposed at Km marks 8-10 on Highway number 11 (Lampang-Denchai), Mueang District, Lampang Province offers a remarkable section for facies analysis and thus leads to the understanding of clast – forming, transportation, and deposition processes. From field observation and petrographic study, the rocks can be classified as pyroclastic facies and volcaniclastic/volcanogenic sedimentary facies. The pyroclastic facies is a mass flow deposit that includes welded and non-welded ignimbrite in part. It was interpreted to be products of subaerial eruption of silicic magma and deposited onshore or a shallow water environment. The volcaniclastic/volcanogenic sedimentary facies is characterized by well-bedded volcanic mudstone and volcanic sandstone, with laminae to thin-beds of black mudstone/claystone that contain sedimentary structures, such as load casts and flame structures. Subaqueous depositional environment with influence of turbidity current is proposed for transportation and deposition of this facies.

Key words: Volcanic facies, Ignimbrite, Volcaniclastic rocks, Doi Phra Bath, Lampang, Chiang Khong – Tak Volcanic Belt

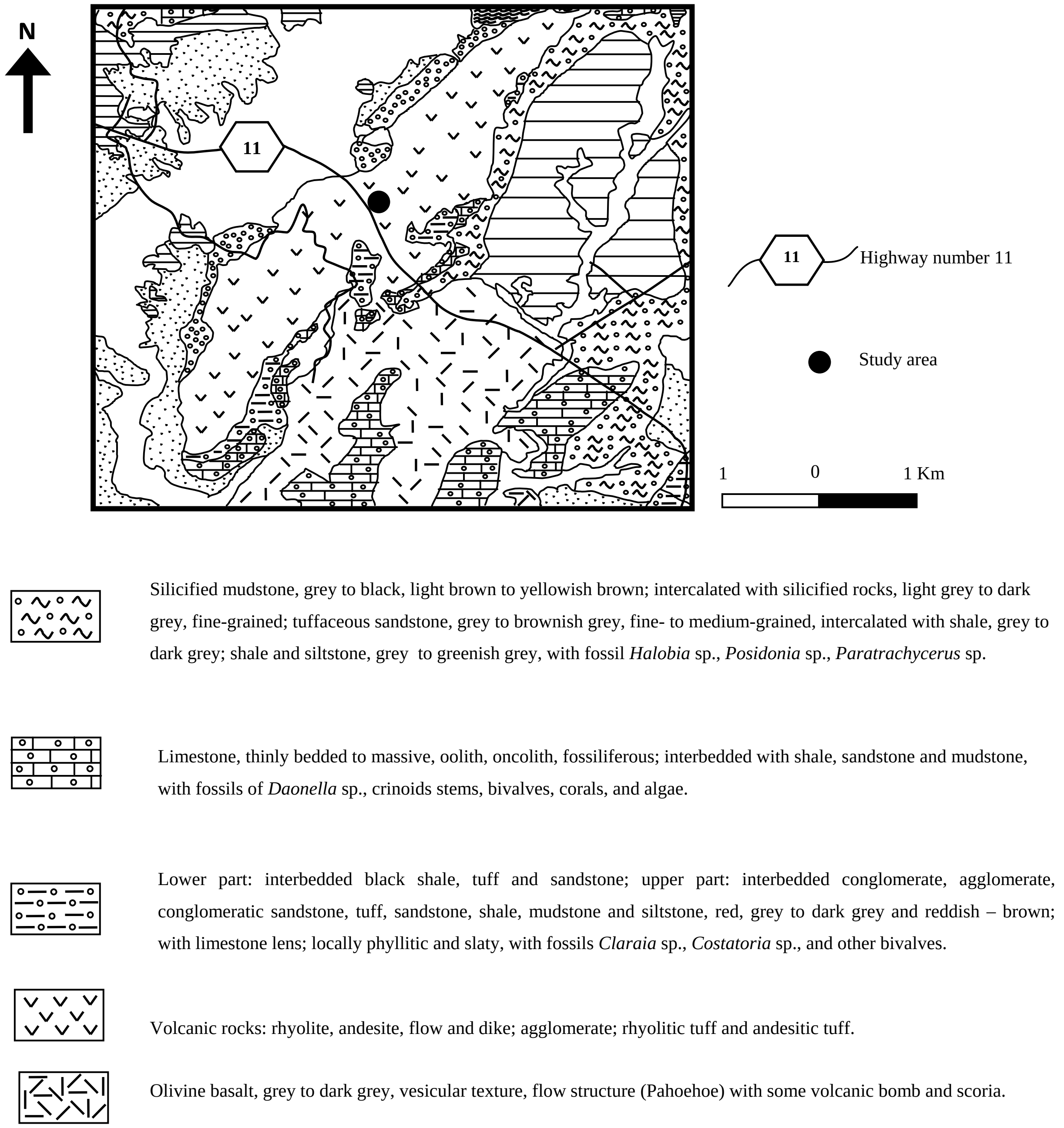
1. Introduction

Volcanic activity is a geologic process that generates diversity of geologic materials from the Earth's interior to the surface. It was estimated that 27% of post-Archean sediments had been derived from primary eruptive products through the processes of erosion and reworking, and subsequently formed volcaniclastic rocks (Fisher and Schmincke, 1984; Manville et al., 2009). A large volume of Permo-Triassic volcaniclastic deposits in Lampang Province, which is part of the voluminous Chiang Khong-Tak volcanic belt, emphasizes the significance of volcanic activity during the Permo-Triassic terrain evolution. The eruption products, including pyroclasts - volcaniclasts as well as coherent lavas and syn-eruptive domes, are the main sources of sediments for the formation of the lower part of the Lampang Group. The marine sedimentary sequence, one of the thickest and the most renowned Triassic rocks on the Thailand's Shan-Thai plate, is up to 5,000 meters thick (Chaodumrong, 1992).

This work presents lithostratigraphy and petrography of the volcaniclastic and volcanogenic sedimentary deposits along the road-cut exposures from Kilometer stones 8 to 10, Highway number 11 (Lampang-Denchai) that is part of Doi Phra Baht (Fig. 1). The characters of the deposits and modes of transport and emplacement are discussed, and consequently a possible scenario of volcanic eruption is depicted.

2. Geologic setting

The volcaniclastic rocks in the study area have been reported as part of Permo-Triassic volcanic-volcaniclastic rocks (Piyasin, 1972; Tiyapirat and Mahabhumi, 1991a, 1991b; Charoenprawat et al., 1994) that cover a vast area of Lampang Province (Fig. 1). The rocks form a northeast-southwest trending mountain range, with well-known summits like Doi Farang, Doi Jao Nai, Doi Ton and Doi Phra That Muang Kham. The majority of volcanic rocks are abundant rhyolite and subordinate andesite, and their pyroclastic



Silicified mudstone, grey to black, light brown to yellowish brown; intercalated with silicified rocks, light grey to dark grey, fine-grained; tuffaceous sandstone, grey to brownish grey, fine- to medium-grained, intercalated with shale, grey to dark grey; shale and siltstone, grey to greenish grey, with fossil *Halobia* sp., *Posidonia* sp., *Paratrachycerus* sp.

Limestone, thinly bedded to massive, oolith, oncolith, fossiliferous; interbedded with shale, sandstone and mudstone, with fossils of *Daonella* sp., crinoids stems, bivalves, corals, and algae.

Lower part: interbedded black shale, tuff and sandstone; upper part: interbedded conglomerate, agglomerate, conglomeratic sandstone, tuff, sandstone, shale, mudstone and siltstone, red, grey to dark grey and reddish – brown; with limestone lens; locally phyllitic and slaty, with fossils *Claraia* sp., *Costatoria* sp., and other bivalves.

Volcanic rocks: rhyolite, andesite, flow and dike; agglomerate; rhyolitic tuff and andesitic tuff.

Olivine basalt, grey to dark grey, vesicular texture, flow structure (Pahoehoe) with some volcanic bomb and scoria.

Figure 1. Geologic map of the study area (modified from Charoenprawat et al., 1994).

equivalents. These volcanic rocks are nonconformity overlain by conglomerate and agglomerate of the Triassic Lampang Group and conformably underlain by shale and sandstone of the Late Permian Huai Tak Formation (Piyasin, 1971). In addition, porphyritic dacite with quartz, plagioclase (andesine-labradorite composition) and orthoclase phenocrysts in the matrix of finer quartz, feldspars and chloritised hornblende grains has been reported by Tiyapirat and Mahabhumi (1991a, 1991b). The later version of geologic map sheet NE 47-7 (Lampang Province) at a scale of 1:250,000 shows that the Permo-Triassic volcanic rocks are composed of rhyolite flow and dyke, agglomerate, lapilli tuff, rhyolitic tuff, andesitic tuff (Charoenprawat et al., 1994). The Geologic map of Lampang Province, compiled by Department of Mineral Resources (2004), likewise, the Permo-Triassic volcanic rocks in this area are constituted by tuff, agglomerate, rhyolite and andesite. The age of 240 ± 1 Ma, dated from zircon using U-

Pb technique, has been given to the volcanic rocks by Barr et al., (2000).

3. Lithostratigraphy and volcanic facies

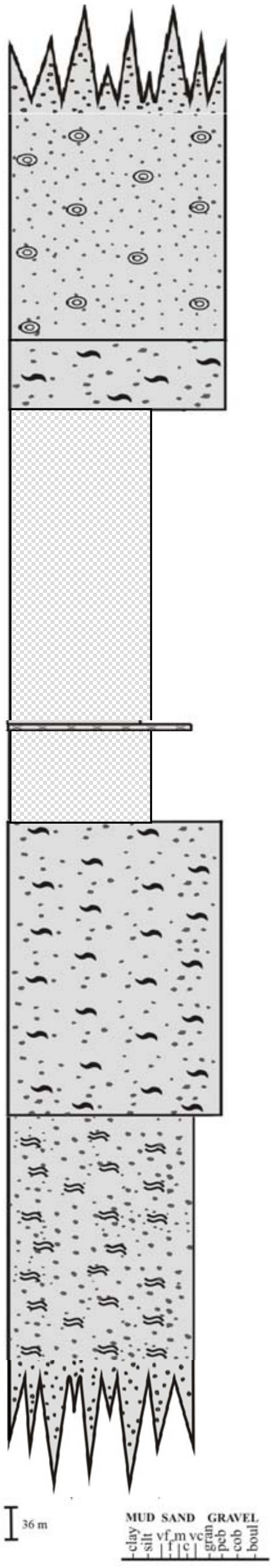
The characteristic features of rocks, including composition and texture/structure that reflect a genetic implication like eruption and deposition, allow lithofacies to be constructed (Cas and Wright, 1987; Song and Lo, 2009). In volcanic terrain, the term volcanic facies is employed to emphasize the genetic significance of the deposit. The volcanic rocks in the study area can be divided into pyroclastic and volcaniclastic/volcanogenic sedimentary lithofacies. In discussing lithofacies, lithostratigraphy is necessary to be established. A number of faults observed in the studied road-cut exposures and soil covers, however, make a complete lithostratigraphy impossible. For the sake of convenience in discussion, the road-cut exposures are separated into eastern and western sections. The boundary between these sections is marked by the place where a rock exposure is covered by top soil. The simplified lithostratigraphy of eastern and western road-cut exposures is depicted in Figures 2 and 3. It is worth noting here that descriptive terms are applied to the volcaniclastic/volcanogenic sedimentary rocks (McPhie et al., 1993). In case of identifiable epiclasts/pyroclasts, genetic terms are used.

3.1 Eastern road-cut exposure

The eastern road-cut exposure is assigned to be pyroclastic facies. It is made up of 3 rock units, including non-welded ignimbrite in the lower part, silicified rocks in the middle part and welded ignimbrite in the upper part (Fig. 2).

The lower non-welded ignimbrite can be further separated into volcanic sandstone and volcanic breccia. The volcanic sandstone underlies the volcanic breccia. The boundary between these sub-rock units is however unclear due to the superimposed of latter processes like silicification and chloritisation, but very likely to be gradational. The volcanic sandstone forms a small hill, with 280 meters thick. It exhibits an apparent porphyry texture, consisting of flattened milky white pumice and feldspar crystals/fragments (1-2 mm in diameter) in the finer vitriclastic matrix, which can be easily observed on the light greyish brown weathered surfaces. The rock has been subsequently silicified, leading to very similar features to rhyolite porphyry. The volcanic breccia is 310 meters thick and locally interbedded with lamellae to thin beds of volcanic mudstone and volcanic sandstone. Graded bedding can be seen through the whole deposit. The greyish green volcanic breccia is poorly sorted, and composed of lapilli and ash grains in similar proportion. The lapilli-grade fragments are common pumice, tuff and sedimentary rocks (mudstone and claystone), and uncommon crystals. The coarse ash grains are plagioclase, K-feldspar, quartz and rock fragments (tuff and silicified rocks). The lapilli-grade pumice fragments are partly flattened, forming remarkable fiamme, and eutaxitic texture (McPhie et al., 1993; Bull & McPhie, 2007). These are probably the results of compaction or mildly deformation rather than welding process (Marti, 1966). However, black mudstone/claystone fragments with diffused grain boundaries in part are indicative of partly welding nature of this rock unit. Most of the pumice clasts have been transformed to microcrystalline quartz, however, the original morphology is still preserved. The preferential altered of the pumice/fiamme to chlorite and sericite creates a "Swiss cheese" feature (Marti, 1996) as shown in Figure 4.

Figure 4. Preferential alteration of pumice/fiamme to chlorite-sericite gives a "Swiss cheese" feature.



Welded ignimbrite

Upper part: evenly distributed spherulites/lithophysae with sizes up to 1.5 cm.

Lower part: light purplish grey, flow banded (up to 0.5 mm thick), apparent porphyritic texture.

Silicified rocks with light greyish green color, dense, and evenly fractured. Diorite dykes are locally present.

Volcanic breccia (non-welded ignimbrite)

Dark greyish green, rich in fiamme (flattened pumice fragments) that altered to chlorite/sericite giving rise to a mottled deep green look, moderately exhibits eutaxitic texture, clast-supported, poor sorting with thickness ~ 310 meters. Locally interbedded with medium greyish green lamellae-thin beds of fine tuff, and commonly has lithic (accidental) clasts of black mudstone of various sizes (3-20 cm) and shapes.

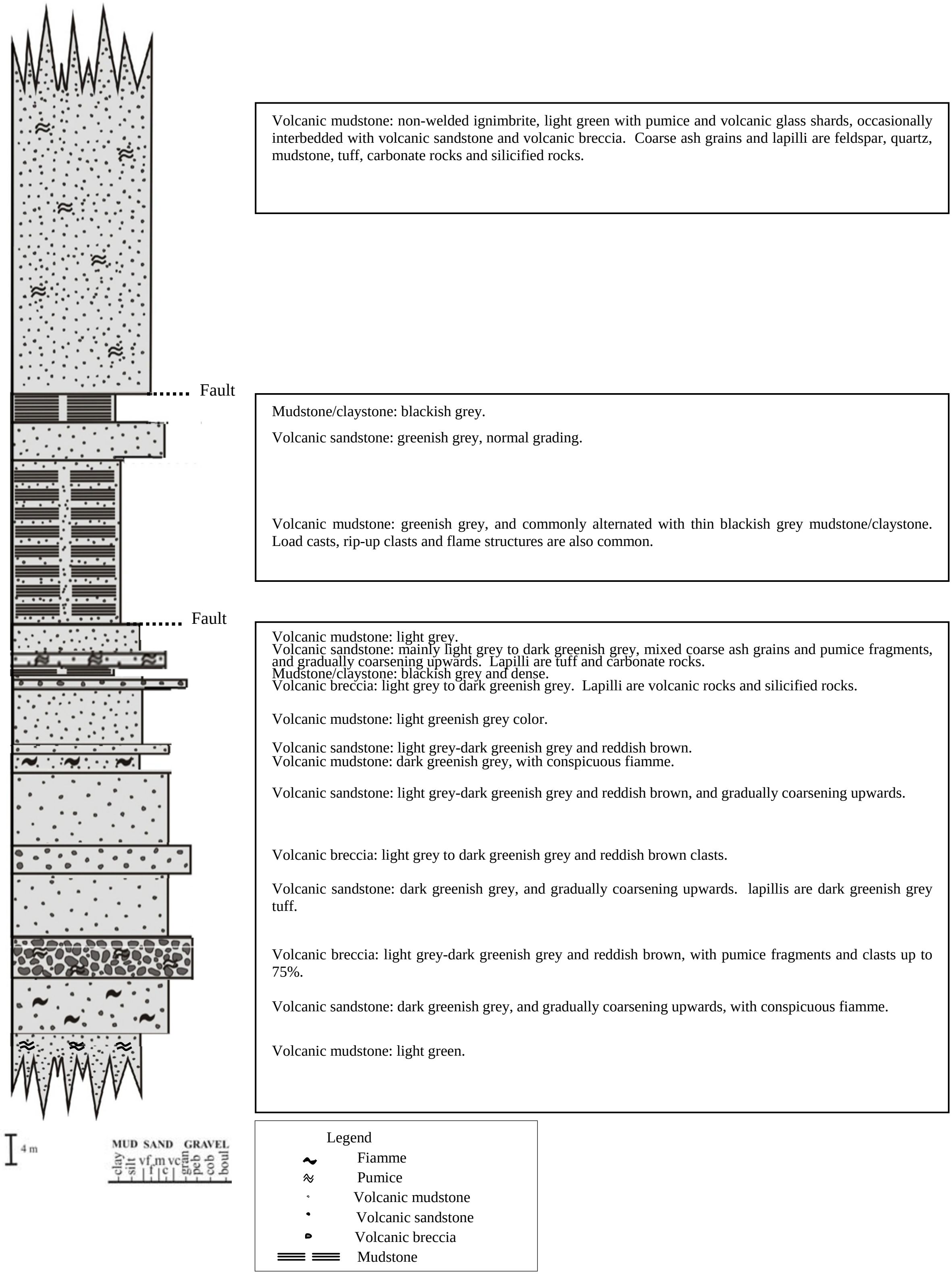
Volcanic sandstone (non-welded ignimbrite)

Light greyish green with whitish patches of feldspar and pumice crystals/fragments, moderately exhibit eutaxitic texture, matrix-supported, poor sorting with thickness ~ 280 meters, and mostly silicified.

Legend

◎	Spherulite/Lithophysae
~	Fiamme
≈	Pumice
▨	Silicified rocks
× × ×	Diorite dykes
•	Volcanic sandstone
●	Volcanic breccia
═ ═	Mudstone

Figure 2. Simplified lithostratigraphic log of eastern road-cut exposure.



Volcanic mudstone: non-welded ignimbrite, light green with pumice and volcanic glass shards, occasionally interbedded with volcanic sandstone and volcanic breccia. Coarse ash grains and lapilli are feldspar, quartz, mudstone, tuff, carbonate rocks and silicified rocks.

Mudstone/claystone: blackish grey.

Volcanic sandstone: greenish grey, normal grading.

Volcanic mudstone: greenish grey, and commonly alternated with thin blackish grey mudstone/claystone. Load casts, rip-up clasts and flame structures are also common.

Volcanic mudstone: light grey.

Volcanic sandstone: mainly light grey to dark greenish grey, mixed coarse ash grains and pumice fragments, and gradually coarsening upwards. Lapilli are tuff and carbonate rocks.

Mudstone/claystone: blackish grey and dense.

Volcanic breccia: light grey to dark greenish grey. Lapilli are volcanic rocks and silicified rocks.

Volcanic mudstone: light greenish grey color.

Volcanic sandstone: light grey-dark greenish grey and reddish brown.

Volcanic mudstone: dark greenish grey, with conspicuous fiamme.

Volcanic sandstone: light grey-dark greenish grey and reddish brown, and gradually coarsening upwards.

Volcanic breccia: light grey to dark greenish grey and reddish brown clasts.

Volcanic sandstone: dark greenish grey, and gradually coarsening upwards. lapillis are dark greenish grey tuff.

Volcanic breccia: light grey-dark greenish grey and reddish brown, with pumice fragments and clasts up to 75%.

Volcanic sandstone: dark greenish grey, and gradually coarsening upwards, with conspicuous fiamme.

Volcanic mudstone: light green.

Figure 3. Simplified lithostratigraphic log of western road-cut exposure.

The silicified rocks are 400 meters thick and separate the upper welded ignimbrite from the lower non-welded ignimbrite. They are light greyish green to dark greyish green, dense and evenly fractured. It is uncertain whether their protoliths prior to silicification are non-welded and/or welded ignimbrite since their original features have been totally obliterated by silicification. A 1-meter thick diorite dyke has been observed in the silicified zone.

The upper welded ignimbrite is 250 meters thick and can be further subdivided into non-devitrified welded ignimbrite in the lower part and devitrified welded ignimbrite in the upper part. The non-devitrified ignimbrite has very similar appearance to rhyolite porphyry. It shows a purplish grey color, with remarkable alternate darker and lighter flow bands (up to 0.5 mm thick), and an apparent porphyritic texture, with evenly distributed subhedral to euhedral feldspar crystals/fragments. The devitrified welded ignimbrite is characterized by the occurrences of abundant spherulites and lithophysae (Fig. 5).

Figure 5. Devitrification zone with abundant spherulite/lithophysae in welded ignimbrite.

3.2 Western road-cut exposure

The western road-cut exposure has a total thickness of 132 meters and can be separated into lower, middle and upper rock units (Fig. 3). The lower and middle units are well bedded pyroclastic and volcaniclastic/volcanogenic sedimentary rocks, with general orientation of N5ºW 65ºSW, whereas the upper unit is massive non-welded ignimbrite. The units are juxtaposed against each other by faults.

The lower unit is 60 meters thick and made up of light grey to dark greenish grey volcanic sandstone interbedded with subordinate light grey to light green mudstone and light grey to dark greenish grey volcanic breccia, and minor blackish grey mudstone. The volcanic sandstone is gradually coarsening upwards and may grade to volcanic breccia. The coarse ash grains and lapilli in these rocks are plagioclase, K-feldspar, quartz, rock fragments (volcanic mudstone, andesite/basalt and silicified rocks) and pumice/fiamme fragments.

The middle unit is 32 meters thick and consists of greenish grey mudstone interbedded with thin blackish grey mudstone/claystone in the lowest part. They commonly contain load casts, rip-up clasts and flame structures (Fig. 6). The uppermost part of this unit is greyish black mudstone/claystone that is underlain by 4-meter-thick greenish grey volcanic sandstone. Normal graded bedding is common in the volcanic sandstone.

Figure 6. Load casts developed at the interface of volcanic mudstone and mudstone/claystone.

The upper unit is 40 meters thick and consists almost totally of light green volcanic mudstone with occasional volcanic sandstone and volcanic breccia interbeds. Coarse ash grains and lapilli are crystal fragments of feldspar and quartz, and rock fragments of mudstone, volcanic mudstone, carbonate rocks and silicified rocks. Volcanic glass shards are also generally present. They may have been completely altered to sericite but their morphologies are still well-preserved.

4. Discussion

4.1 Facies interpretation

Pyroclastic deposit

The presented pyroclastic rocks, dominated by welded and non-welded ignimbrite, contain abundant glass shards, highly vesicular fragments and pumice, typical of explosive eruption (Breitkreuz, et al., 2001), particularly, those eruption of felsic magmas like dacite, rhyodacite and rhyolite. The abundant pumice glass and reverse graded bedding are evidences for mass flow deposits or resedimented mass flow deposits. The rare scarcity of dense lithic pyroclasts suggests that the deposit is not close to the source. The presence of mudstone/claystone laminae or thin beds in non-welded ignimbrite implies a water settling process in some part of the eruption/deposition episodes. The coexistence of welded and non-welded ignimbrite in the eastern road-cut exposure signifies a shallow-water deposition environment.

The heat conservation of juvenile pyroclasts in a central part of thick pyroclastic mass flow gives rise to the welding and devitrification features. The features include dense compaction and welding of pyroclasts, apparent flow bands and eutaxitic textures. These features have been partly obliterated by high-temperature devitrification, giving rise to abundant spherulites/lithophysae. The eastern pyroclastic flow deposit may have occurred in the lower part of flow as shown by the ideal zoning in an ignimbrite mass of McPhie et al. (1993) in Figure 7.

Volcaniclastic/volcanogenic sedimentary deposit

The 32-meter thick of volcanic mudstone interbedded with mudstone/claystone in the middle part of the western road-cut exposure commonly exhibits diversity of clasts, well-developed stratification with fining upward sequence, load casts, rip-up clasts and flame structures. These are evidences for subaqueous deposition from suspension. The well-developed stratification with fining upward sequence is characteristic of the upper parts of many turbidite sequences. These features and the absence of cross strata and ripple marks signifies a below wave base setting for deposition.

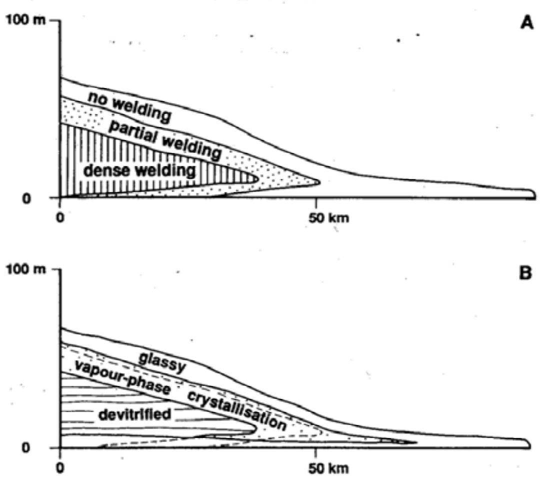


Figure 7. Welding zone (A) and devitrification zone (B) in ignimbrite (after McPhie et al., 1993).

5. Conclusions

The volcanic facies can be divided into 2 main lithofacies as pyroclastic facies and volcaniclastic/volcanogenic sedimentary facies. The pyroclastic facies is composed of pyroclastic mass flow deposits/resedimented pyroclastic mass flow deposits that partly include welded and non-welded ignimbrite, while the volcaniclastic/volcanogenic sedimentary facies is composed of stratified volcanic mudstone and volcanic sandstone, locally interbedded with mudstone/claystone. The pyroclastic facies is interpreted to be the result of subaerial eruption of silicic magma and deposited onshore or a shallow-water environment. The presence of volcaniclastic/volcanogenic sedimentary rocks, with sedimentary structures like load casts, rip-up clasts and flame structures, are attributed to the influence of turbidity current.

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