

CHAPTER 2

GEOLOGIC SETTING

Geologic information of the Ban Sap Sawat area and vicinity has been reported on the 1:250,000 geologic map, sheet ND 47-IV (Amphoe Ban Mi) by Nakhorn Sri (1981), and on the geologic maps at a scale of 1:50,000, sheets 5240 IV (Amphoe Nong Phai) and 5240 III (Amphoe Wichian Buri) by Jungyusuk and Sinsakul (1989). According to these informative data, the project area and vicinity is constituted by a number of rock units from the Permian to the Recent (Figure 2.1). Individual rock units and their structures will be described below.

2.1 Permian Rocks

The Permian rocks in the project area and vicinity can be lithologically divided into three formations from bottom to top as follows: Khao Luak Formation, Tak Fa Formation and Hua Na Kham Formation. They have ages in a range of Lower to Middle Permian (Jungyusuk and Sinsakul 1989).

2.1.1 Khao Luak Formation

Khao Luak Formation (Nakhonsri, 1981) or Nam Duk Formation (Jongrakmanee and Satayarak, 1977) is made up mainly of argillaceous rocks that include abundant, gray to black shale and slaty shale, and minor, yellowish brown, fine- to medium-grained sandstone. These rocks are also interbedded with thinly bedded limestone and may contain gray to dark gray crystalline limestone lenses (Nakhonsri, 1981; Jungyusuk and Sinsakul, 1989).

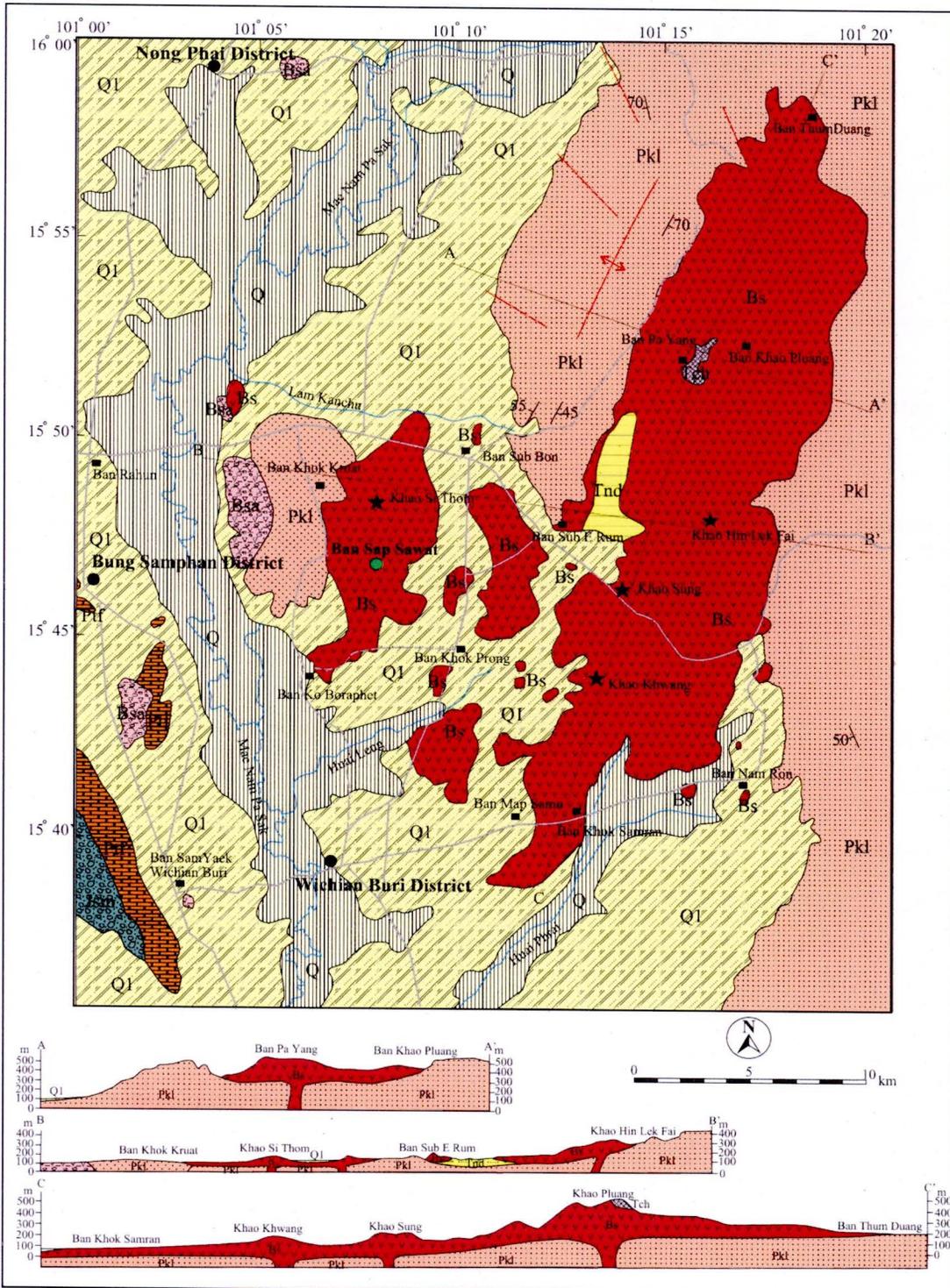


Figure 2.1 Simplified geologic map showing the distribution of Wichian Buri basalt and the location of Ban Sap Sawat study area (green circle) (modified from Vichit *et al.*, 1988 and Jungyusuk and Sinsakul, 1989). See explanation and discussion in the text.



Legend

Age

	Alluvial deposit	}	Quaternary
	Terrace deposit: Gravel, sand and lateritic soil		
	Sandstone, shale and mudstone, with viviparous fossiliferous bed		Tertiary
	Sub Mai Daeng Formation: sandstone, medium-grained, light brown		Jurassic
	Tak Fa Formation: white limestone and brownish shale	}	Permian
	Khao Luak Formation: shale and slaty shale, brown-dark brown intercalated with light brown sandstone and grayish limestone		

Igneous rocks

	Basalt porphyry, andesite porphyry, and agglomerate		Permo-Triassic
	Trachyte porphyry	}	Tertiary
	Basalt		

Symbols

	Attitude of fold		Road
	Strike and dip of bed		River and stream
	Fault		District
	Line of section		Subdistrict
	Study area		Location of Khao

สำนักงานคณะกรรมการวิจัยแห่งชาติ
 ห้องสมุดธรณีวิทยา
 วันที่ 21 พ.ธ. 2555
 เลขทะเบียน..... **E** 47372
 เลขเรียกหนังสือ.....

2.1.2 Tak Fa Formation

Tak Fa Formation is made up mainly of gray limestone that is either thinly bedded or massive. Black nodular or thinly bedded chert and thinly bedded gray shale may be intercalated with the limestone. This formation contains abundant fusulinids, corals, brachiopods and bryozoans of the Lower to Middle Permian (Nakhonsri, 1981).

2.1.3 Hua Na Kham Formation

Hua Na Kham Formation comprises sandstone, siltstone and shale. Limestone may occur as lenses or thin beds in this formation. Andesitic tuff and agglomerate are present as beds associated with bedded sandstone. This rock unit was intruded by andesitic dikes and sills, and small dioritic intrusions (Jongrakmanee and Satayarak, 1977).

2.2 Mesozoic Rocks

The Mesozoic rocks in the project area and vicinity cover a narrow area in the western part of Wichian Buri and Bung Samphan Districts, Phetchabun Province, and are known as Huai Sai Formation or Sub Mai Daeng Formation (Nakhonsri, 1981). They consist of sandstone and conglomerate. The majority of these rocks are reddish brown sandstone that shows cross lamination. Basal conglomerate contains gravel-grade clasts of quartz, chert, sandstone, limestone and volcanic rocks.

2.3 Tertiary Rocks

The Tertiary sediments of the project area and vicinity are known as Nam Duat Formation. They are underlain by Tertiary basalt and made up of semi-consolidated sandstone interbedded with shale. A Viviparous fossiliferous bed and white, calcareous mudstone, with a thin layer of carbonaceous material and lignite, have been reported in this formation.

2.4 Quaternary Sediments

The Quaternary sediments in the study area and vicinity comprises alluvial and terrace deposits. The sediments of alluvial deposits are commonly clay, silt, and fine sand, with decomposed plants, and locally gravel. They were deposited in abandoned channels and flood plains of old river courses. The alluvial terrace covers low and high alluvial terraces; the latter is up to 100 meters above mean sea level. They are made up of unconsolidated sediments, including sand, silt, clay and lateritic soil.

2.5 Igneous rocks

2.5.1 Permo-Triassic Igneous Rocks

The Permo-Triassic igneous rocks are volcanic and shallow intrusive rocks. The volcanic rocks are compositionally basaltic andesite, with a dark gray color, and show a phytic texture. The shallow intrusive rocks are diorite that was intruded the Permian rocks.

2.5.2 Tertiary Trachyte Porphyry

The Tertiary trachyte porphyry in the project area and vicinity overlies the Tertiary basalt and covers an area of about 3 kilometers long and 1 kilometer wide in the areas of Ban Pa Yang and Ban Khao Pluang, with total thickness up to 10 meters. The rock is composed mainly of plagioclase (albite) phenocrysts sitting in the fine-grained groundmass. The geochemical analysis of the trachyte porphyry has been reported by Vichit *et al.* (1988).

2.5.3 Tertiary Basalt

The Tertiary basalt in the project area and vicinity is known as Wichian Buri basalt and has been reported by Jungyusuk and Sirinawin (1983). It is underlain by the Tertiary sediments and covers the area in the eastern part of map sheets 5240 IV (Amphoe Nong Phai) and 5240 III (Amphoe Wichian Buri). The Wichian Buri basalt is alkalic olivine basalt, with a fine-grained texture and a black color. In some certain areas, the Wichian Buri basalt may contain ultramafic nodules and black spinel.

2.6 Field Observation of Basalt and Basalt Breccia

The Ban Sap Sawat area, part of Wichian Buri basalt, is underlain by coherent facies and hyalclastite facies basalt. The coherent facies basalt commonly occurs as *in situ* float rocks in a flood plain (Figure 2.2) and as outcrops on small hills or at the levels higher than 90 meters above mean sea level (Figure 2.3). Columnar and platy joints have been observed in the outcrops of coherent facies basalt (Figure 2.4). The incoherent facies basalt commonly occurs as *in situ* float along with coherent facies basalt in a low-land area (Figure 2.5), however, it is not associated with coherent facies basalt at higher elevations. The basalt occurs as breccia that consists of poorly sorted, angular to subrounded, crystalline and glassy basalt fragments sitting in the finer-grained matrix. The matrix is made up largely of glassy fragments that are highly altered to clay minerals. The proportion of coarser fragments to finer fragments is unity or less than unity, giving rise to matrix-supported fabric (Figure 2.6). Pillow lobes and pillow fragments in the basalt breccia show radial joints (Figure 2.7a) and/or show glassy skins (Figure 2.7b).



Figure 2.2 In situ float of basalt at grid reference of 279449 in the Ban Sap Sawat area



(a)



(b)

Figure 2.3 Outcrops of basalt at grid references of (a) 259472 and (b) 280448 in the Ban Sap Sawat area



(a)



(b)

Figure 2.4 Coherent facies basalt with (a) platy joints at Khoa Si Thom (grid reference of 298505) and (b) columnar joints at Ban Kruat (grid reference of 259472)



Figure 2.5 In situ float basalt breccia and coherent facies basalt in a low land area



Figure 2.6 Basalt breccia with poorly sorted, angular to subrounded mafic volcanic fragments, and fine-grained, glassy matrix



(a)



(b)



(c)

Figure 2.7 A pillow fragment in basalt breccia (a) and pillow fragments with radial joints (b) and a glassy skin (c)

2.7 Core logs of Basalt and Basalt Breccia

The core samples of basalt and basalt breccia penetrated in the five drill holes of the Mineral Resources Exploration and Evaluation Project: 5/2547 (Chon Daen Area), no. 25/2547, Department of Mineral Resources were re-examined in this project (Figure 2.8). Three main lithofacies, including 1) the coherent facies basaltic lava and coherent facies basalt boulder 2) the incoherent facies or basalt breccia which composed of clast-supported basalt breccia and matrix supported basalt breccia and 3) the facies of volcanogenic sedimentary rocks, have been recognized. The coherent facies basaltic lava includes massive basalt and highly vesicular basalt. The clast-supported breccia largely occurs as marginal facies of coherent basaltic lava flow and has widths varying from 25 centimeters to 3.8 meters. A jigsaw-fit texture is a common feature of the clast-supported basalt breccia. The matrix-supported basalt breccia is poorly sorted, and contains variably sized, angular to subrounded, basaltic clasts up to cobble grades. The volcanogenic sedimentary facies has been recognized in drill holes CD4BII-D002, CD4BII-D003 and CD4BII-D005. It shows sedimentary features and is made up of volcanic mudstone, volcanic sandstone and volcanic conglomeratic sandstone, with zeolite and iron oxide cements. The detailed volcanic lithofacies of basalt and basalt breccia penetrated individual drill holes are separately described below.

2.7.1 Drill Hole CD4BII-D001

Drill hole CD4BII-D001 is located at a grid reference of 728400E 1745500N and an elevation of 99 meters above mean sea level, and has a depth of 220 meters. The graphic log of rocks penetrated in this drill hole is shown in Figure 2.9. The incoherent facies/basalt breccia is the only rock type present in the drill hole and consists of variably sized, gravel-grade clasts in the finer-grained matrix that is made up of sand-, silt- and clay-grade clasts, leading to poorly sorted fabric (Figure 2.10). These gravel-grade clasts are generally finer-grained at shallow levels, but coarser-grained in the deeper levels. They, however, have averaged sizes in a range of 5 – 10

centimeters. Abundant coherent facies basalt boulders commonly occupy the lower parts of the drill hole, such as at depths of 110.5, 115.7, 119.1, 152.2, 181.6, 184.4, 189.7, 192.5, 206.42 and 212.20 meters. The cementing material observed throughout the cores sample is zeolites.

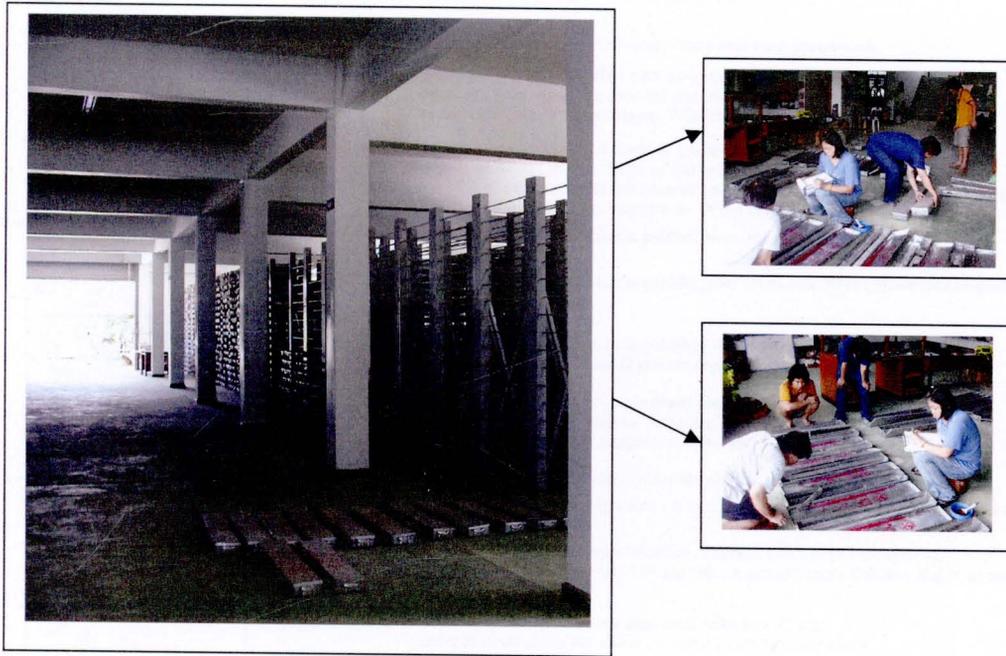


Figure 2.8 Core samples of Ban Sap Sawat basalt and basalt breccia that are housed at the Minerals and Rocks Research Center, Department of Mineral Resources, Rayong Province

The incoherent facies or basalt breccia partly shows jigsaw-fit textured clasts, particularly cobble- and boulder-grade clasts at depths of 5.32 (Figure 2.11), 177.1 (Figure 2.12a) and 219.7 (Figure 2.12b) meters. At a depth interval of 129.0 – 157.8 meters, the core samples are highly altered and highly fractured, with chlorite and smectite infillings, and contain highly amygdaloidal clasts.



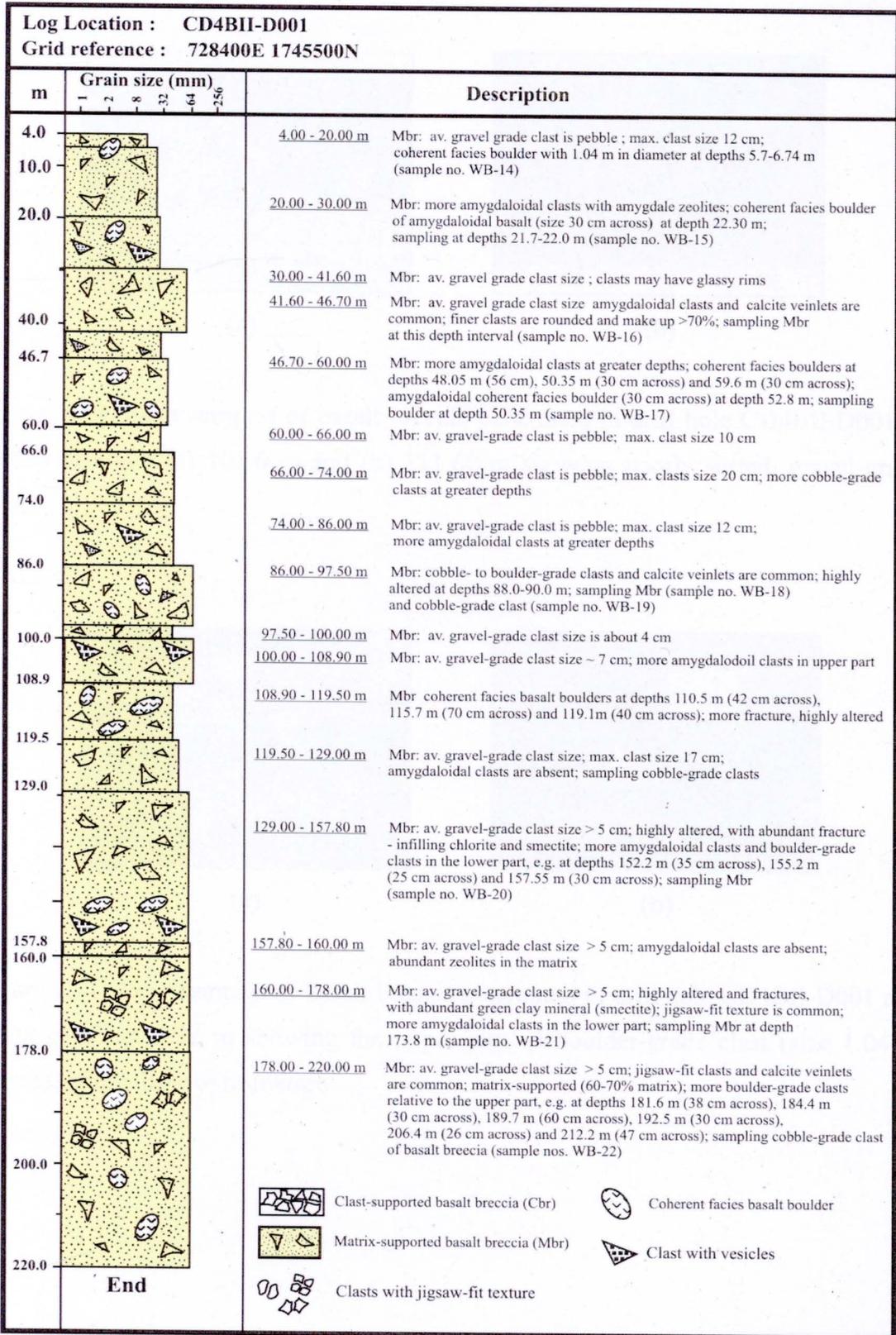


Figure 2.9 Graphic log of core samples penetrated in drill hole CD4BII-D001

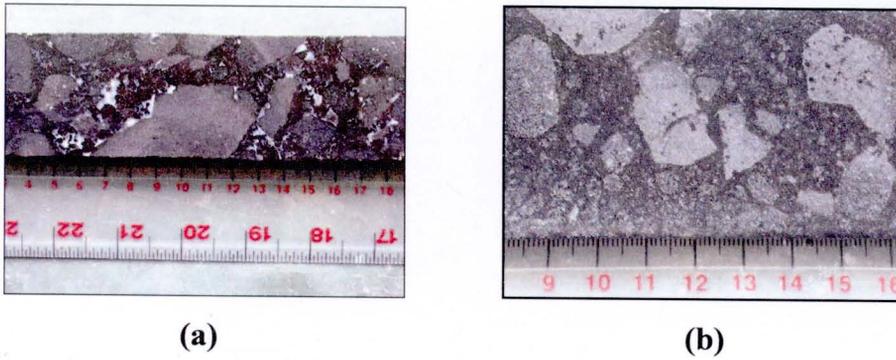


Figure 2.10 Core samples of basalt breccia penetrated in drill hole CD4BII-D001 at depths of about (a) 101.6 m and (b) 111.60 m showing poorly sorted, gravel-grade clasts

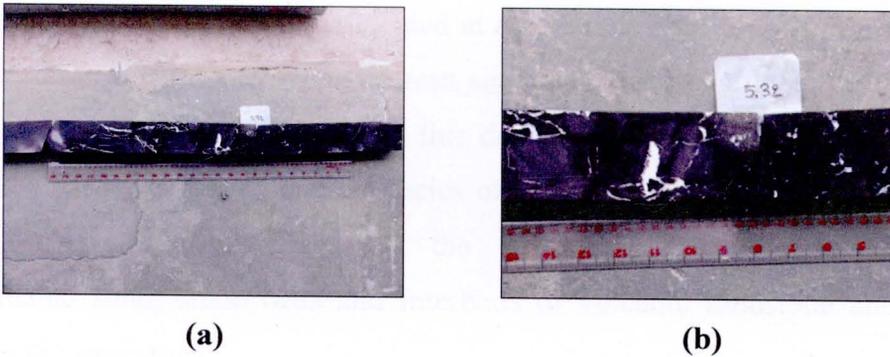


Figure 2.11 Core samples of basalt breccia penetrated in drill hole CD4BII-D001 at a depth of about 5.32 m showing the upper part of boulder-grade clast (size 1.04 m across), with a jigsaw-fit texture

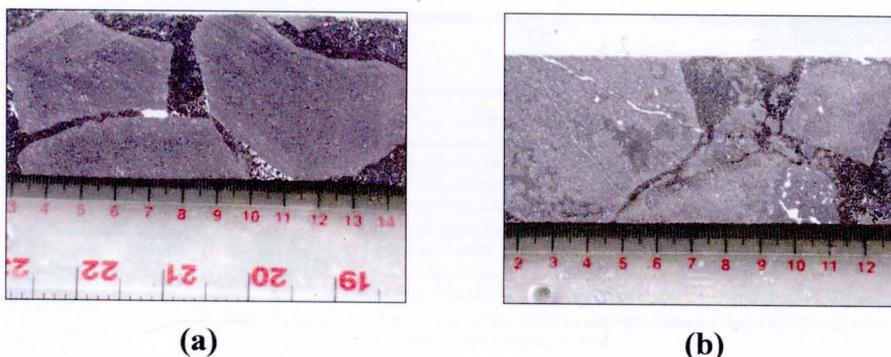


Figure 2.12 Core samples of basalt breccia penetrated in drill hole CD4BII-D001 at depths of about (a) 177.1 m and (b) 219.7 m showing clasts with a jigsaw-fit texture

2.7.2 Drill Hole CD4BII-D002

Drill hole CD4BII-D002 is located at a grid reference of 727600E 1744800N and an elevation of 99 meters above mean sea level, and has a depth of 200 meters. The graphic log of rocks penetrated in this drill hole is shown in Figure 2.13. The rocks are constituted by the coherent facies of basaltic lavas and basalt boulders, the incoherent facies/basalt breccia, and the volcanogenic sedimentary facies with unconsolidated sand, shale beds and interbeds of volcanic sandstone and volcanic conglomeratic sandstone.

Three coherent facies of basaltic lavas have been recognized at depth intervals of 31.35 – 45.00 (Figures 2.14), 98.20 – 117.60 and 144.30 – 149.30 m. All the coherent facies basaltic lavas are largely highly altered, with abundant amygdale zeolites, clay minerals and chlorite (Figures 2.14, 2.15 and 2.16). The coherent facies basaltic lava at a depth interval of 99.80 – 117.60 m contains abundant fracture-infilling calcite. The uppermost coherent basaltic lava is interlayered with matrix-supported basalt breccia, with thickness up to 10 centimeters, at depths of 42.6, 43.85 and 44.5 meters (Figure 2.17). The middle coherent facies basaltic lava show highly altered, abundant fractures and contain clast-supported basalt breccia at a depth interval of 101.50 – 101.80 meters (Figure 2.18).

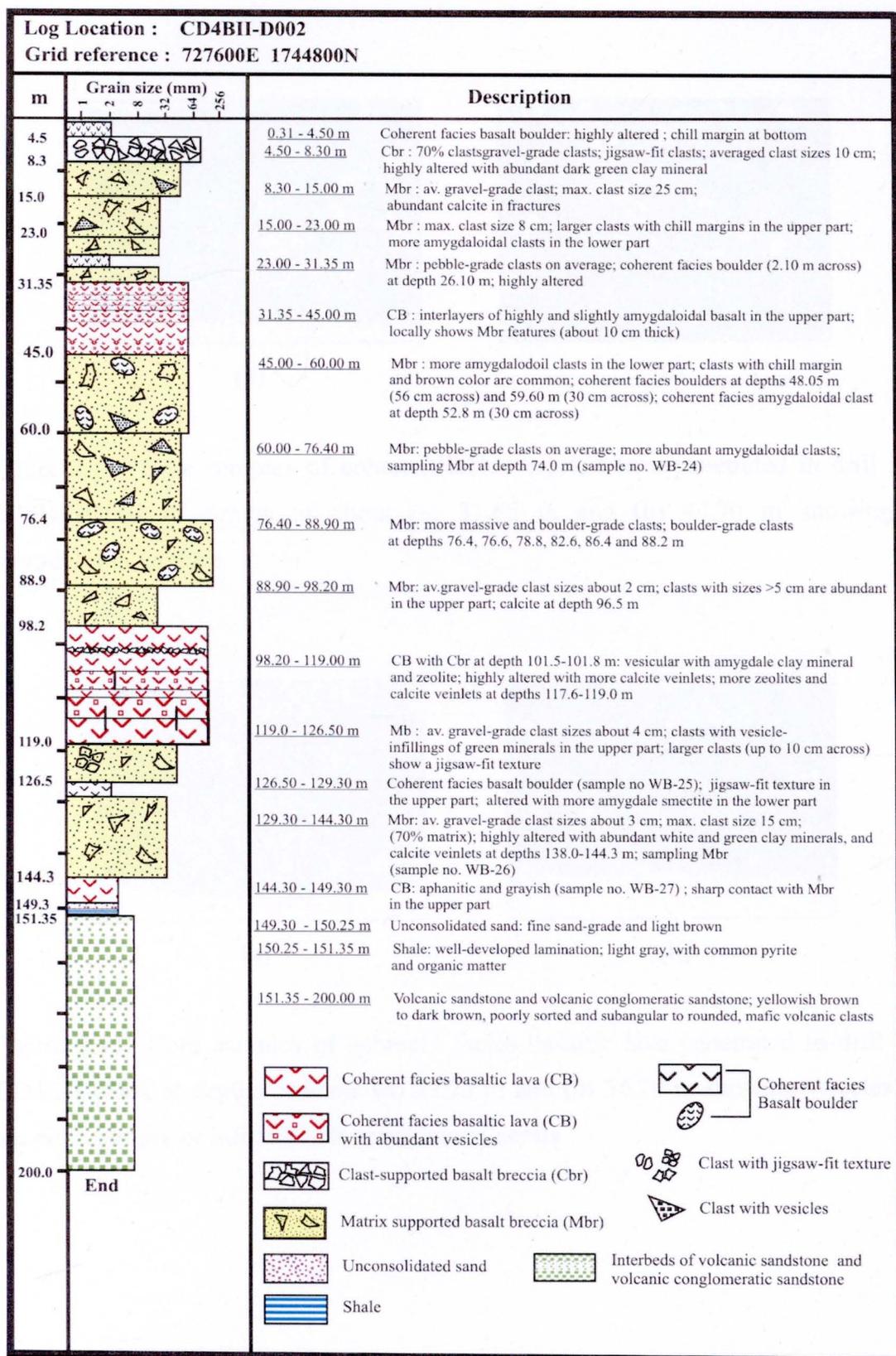


Figure 2.13 Graphic log of core samples penetrated in drill hole CD4BII-D002

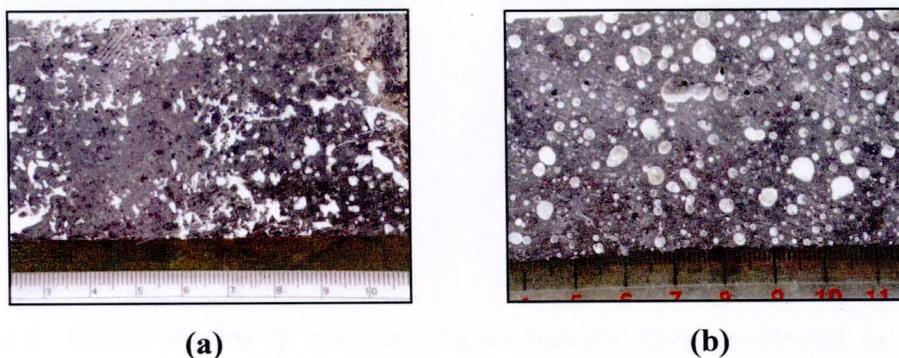


Figure 2.14 Core samples of coherent facies basaltic lava penetrated in drill hole CD4BII-D002 at depths of about (a) 31.65 m and (b) 44.70 m showing an amygdaloidal texture

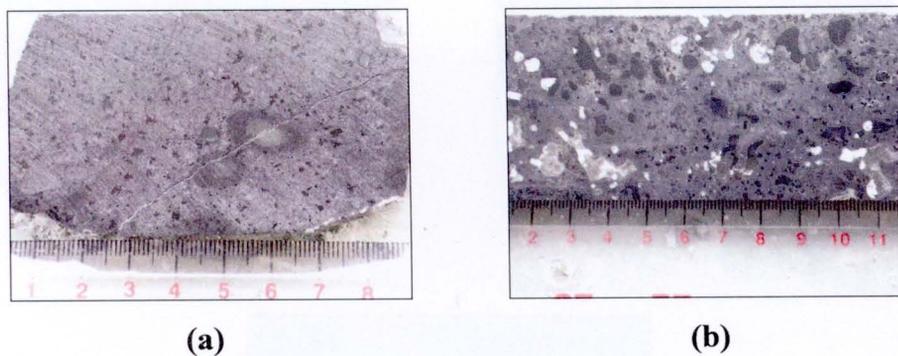
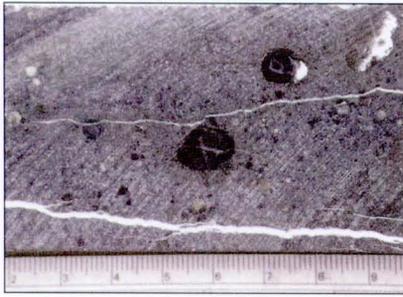
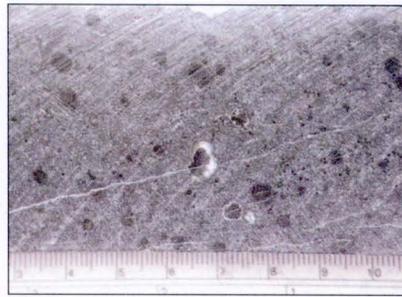


Figure 2.15 Core samples of coherent facies basaltic lava penetrated in drill hole CD4BII-D002 at depths of about (a) 33.75 m and (b) 34.70 m showing vesicles that are either empty or infilled with amygdale minerals

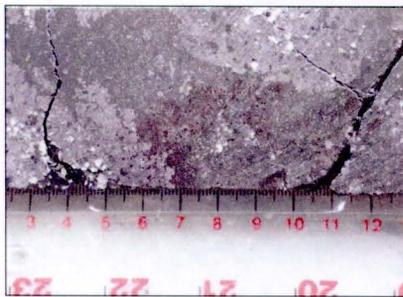


(a)

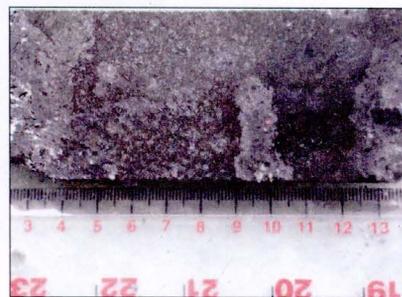


(b)

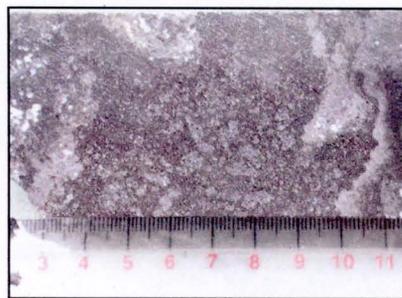
Figure 2.16 Core samples of coherent facies basaltic lava penetrated in drill hole CD4BII-D002 at depths of about (a) 106.40 m and (b) 115.50 m showing amygdale smectite (dark-colored mineral) and zeolite (white), and fracture-infilling calcite



(a)



(b)



(c)

Figure 2.17 Core samples of matrix - supported basalt breccia penetrated in drill hole CD4BII-D002 at depths of about (a) 42.60 m, (b) 43.85 m and (c) 44.50 m

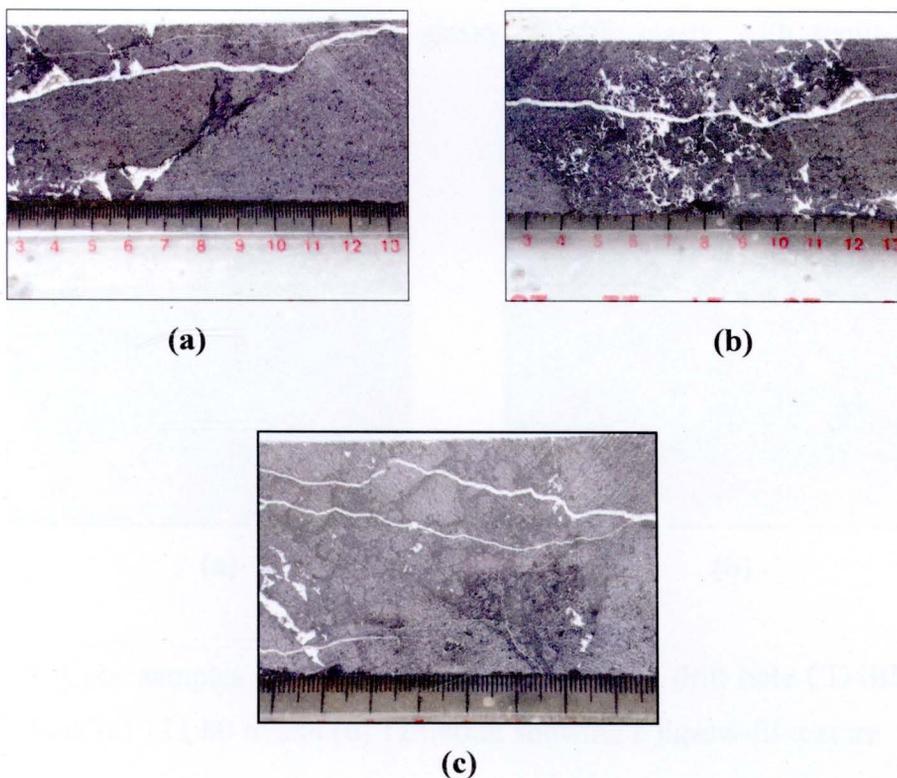
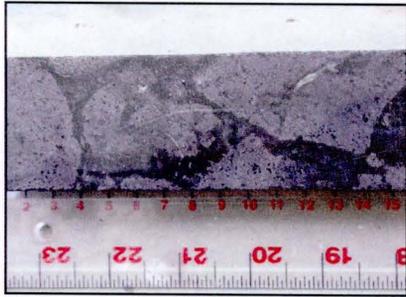


Figure 2.18 Core samples of clast-supported basalt breccia penetrated in drill hole CD4BII-D002 at depths of about (a) 101.50 m, (b) 101.60 m and (c) 101.65 m

The basalt breccia penetrated in the drill hole is commonly matrix-supported and uncommonly clast-supported. The matrix-supported basalt breccia is composed of gravel-grade clasts (pebble sizes on average) and finer-grained, sand-, silt- and clay-matrix that may have been replaced by abundant clay minerals. Part of matrix-supported basalt breccia may contain jigsaw-fit textured clasts (Figure 2.19). Chill margins with a brownish color may have been observed in clasts of the matrix-supported basalt breccia (Figure 2.20).

The volcanogenic sedimentary facies occur at the bottom of the drill hole (a depth interval of 151.35 - 200.00 meters) and is overlain by beds of sand and shale (Figure 2.21) at a depth interval of 149.30 – 151.35 m. The sedimentary unit is in sharp contact with the overlying coherent facies basaltic lava. Pyrite has been observed in the grayish shale (Figure 2.21b). The volcanogenic sedimentary facies are constituted by volcanic sandstone and conglomeratic sandstone interbeds (Figure

2.22) that contain brownish to black, glassy, basaltic clasts, with zeolite and iron oxide cements.

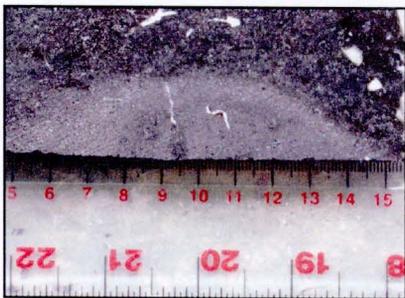


(a)

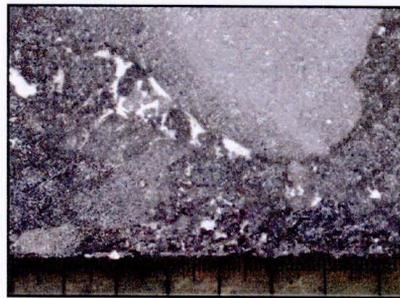


(b)

Figure 2.19 Core samples of basalt breccia penetrated in drill hole CD4BII-D002 at depths of about (a) 121.80 m and (b) 123.40 m showing a jigsaw-fit texture



(a)



(b)

Figure 2.20 Core samples of basalt breccia penetrated in drill hole CD4BII-D002 at depths of about (a) 61.80 m and (b) 62.30 m showing clasts with brownish chill rims

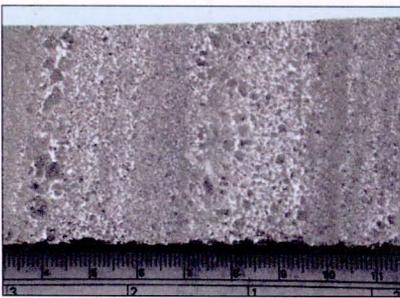


(a)



(b)

Figure 2.21 Core samples of grayish shale and grayish shale, with abundant pyrite crystals, penetrated in drill hole CD4BII-D002 at depths of about (a) 151.00 m and (b) 151.30 m, respectively



(a)



(b)

Figure 2.22 Core samples of volcanic sandstone and conglomeratic sandstone interbeds penetrated in drill hole CD4BII-D002 at depths of about 168.40 m and (b) 175.70 m

2.7.3 Drill Hole CD4BII-D003

Drill hole CD4BII-D003 is located at a grid reference of 728200E 1744800N and an elevation of 97 meters above mean sea level, with a depth of 165 meters. The graphic log of rocks penetrated in this drill hole is shown in Figure 2.23. The rocks are made up of coherent facies of basaltic lava and incoherent faices or basalt breccia. At a depth of 156.50 meters, these igneous samples are underlain by mudstone with many glassy, basaltic clasts, typical of peperite (Figure 2.24).

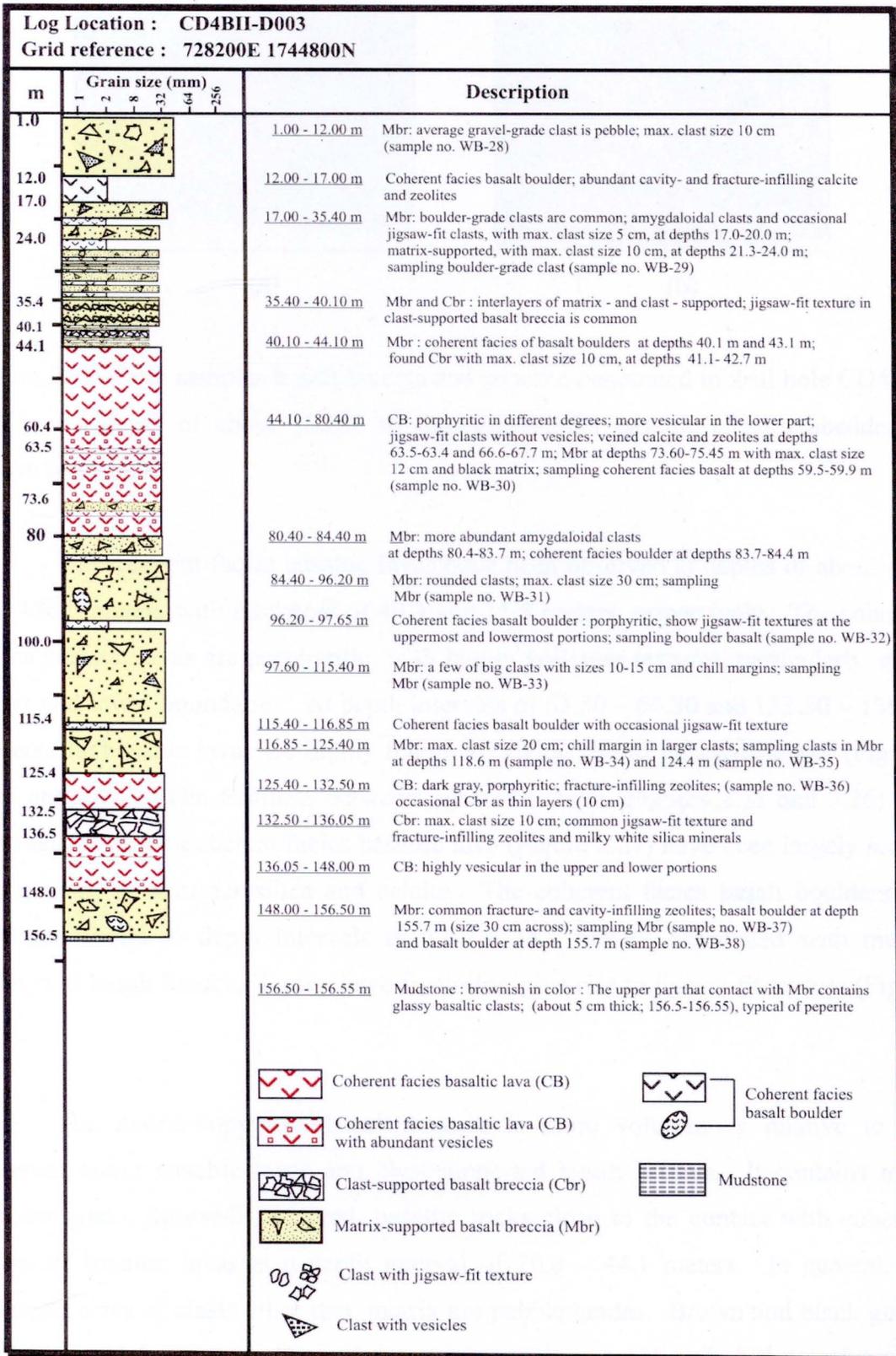


Figure 2.23 Graphic log of core samples penetrated in drill hole CD4BII-D003

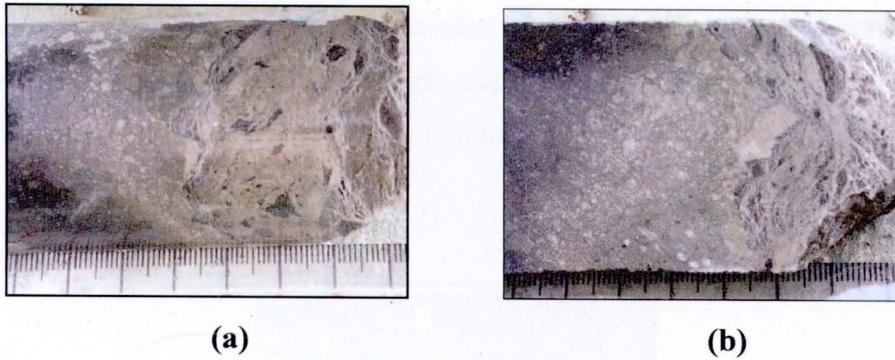


Figure 2.24 Core samples basalt breccia and peperite penetrated in drill hole CD4BII-D003 at a depth of about 156.50 m showing angular basaltic clasts embedded in brown mudstone

The coherent facies basaltic lavas have been observed at depths of about 44.1 and 136.5 meters with thickness of 40.3 and 11.5 meters, respectively. The coherent facies basaltic lavas are porphyritic, with highly vesicular textures, particularly at the upper and lower boundaries. At depth intervals of 63.50 – 64.30 and 132.50 – 136.50 meters, the basaltic lavas are highly fractured, giving rise to jigsaw-fit clasts (Figures 2.25 and 2.26). The fractures between jigsaw-fit clasts (Figures 2.25 and 2.26) and the vesicles in the coherent facies basaltic lava (Figure 2.27) have been largely sealed by zeolites, with minor silica and calcite. The coherent facies basalt boulders are common found at depth intervals of 12.0 - 35.4 meters, associated with matrix supported basalt breccia. It may have fracturing give rise to jigsaw-fit texture (Figure 2.28).

The matrix-supported basalt breccia is more voluminous relative to the coherent facies basaltic lavas and clast-supported basalt breccia. It contains more boulder-grade, jigsaw-fit textured, basaltic rocks close to the contact with coherent facies of basaltic lavas at a depth interval of 20.0 – 44.1 meters. In general, the averaged sizes of clasts other than matrix are pebble grades. Brown and black glassy rinds with thickness up to 2 centimeters across, characteristic of chill margins, may have been observed in larger clasts (Figure 2.29). The clast-supported basalt breccia with jigsaw-fit textures, have been observed at depth intervals of 35.40 – 40.10, 41.10

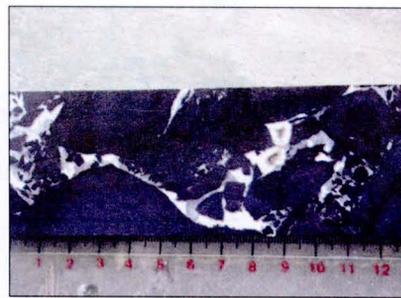
– 42.70 and 132.50 –136.60 meters. The clast-supported basalt breccia at the first two depth intervals are associated with matrix-supported basalt breccia, while that at the last depth interval is associated with a coherent facies of basaltic lava.



Figure 2.25 Core sample of coherent facies basaltic lava penetrated in drill hole CD4BII-D003 at a depth of about 64.30 m showing fractures with a jigsaw-fit texture



(a)



(b)

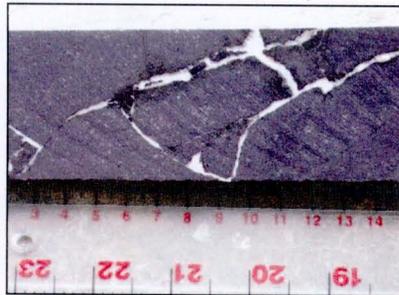
Figure 2.26 Core sample of coherent facies basaltic lava penetrated in drill hole CD4BII-D003 at depths of about (a) 135.40 and (b) 133.55 m showing a jigsaw-fit texture



Figure 2.27 Core sample of coherent facies basaltic lava penetrated in drill hole CD4BII-D003 at a depth of about 137.65 m showing an amygdaloidal texture



(a)

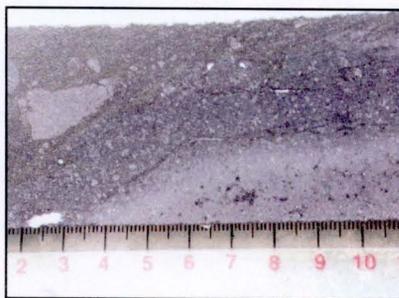


(b)

Figure 2.28 Core sample coherent facies basalt boulder penetrated in drill hole CD4BII-D003 at depths of about (a) 24.40 m and (b) 27.55 m showing fracturing, give rise to clasts with a jigsaw-fit texture



(a)



(b)

Figure 2.29 Core sample of matrix - supported basalt breccia penetrated in drill hole CD4BII-D003 at a depth of about (a) 118.85 m and (b) 155.70 m showing glassy chill margins of large clasts

2.7.4 Drill Hole CD4BII-D004

Drill hole CD4BII-D004 is located at a grid reference of 729000E/1745500N and an elevation of 97 meters above mean sea level, with a depth of 250 meters. The graphic log of rocks penetrated in this drill hole is shown in Figure 2.30. Almost all the core samples are facies of incoherent facies, either clast-supported or matrix-supported basalt breccia. The core sample of highly weathered coherent facies of basaltic lava (Figure 2.31) may exist at a depth interval of 0.5 – 3.0 meters. The coherent facies basalt boulders are common found in this drill hole with size largely up to 1.0 meter. However, there is a large basalt boulder at depth of 59.5-62.0 meters (size 2.5 meter) that also contain the matrix-supported basalt breccia (depth of 60.15-61.0 meter).

The clast-supported basalt breccia occurs at a depth interval of 37.55 – 39.50 meters. It is commonly altered, and shows a jigsaw-fit texture (Figure 2.32). The upper and lower parts of clast-supported basalt breccia have clast sizes in a range of 0.5 – 6.0 centimeters (Figure 2.32). The upper and lower parts of large clasts are commonly highly fractured, giving rise to clast-supported breccia with a jigsaw-fit texture (Figures 2.33 and 2.34).

The matrix-supported basalt breccia consists of gravel-grade basaltic clasts (mainly pebble-grade) and finer-grained matrix (sand-, silt- and clay-grade clasts), with a zeolite cement. The pebble-grade clasts, and the upper and lower parts of boulder- to cobble-grade clasts may show a jigsaw-fit texture and brownish to blackish, glassy chill margins (Figure 2.35). Zeolites (Figure 2.36), clay minerals (Figure 2.36), calcite and/or quartz (Figure 2.37) may occur as fracture- and pore-infillings, and as cementing material.

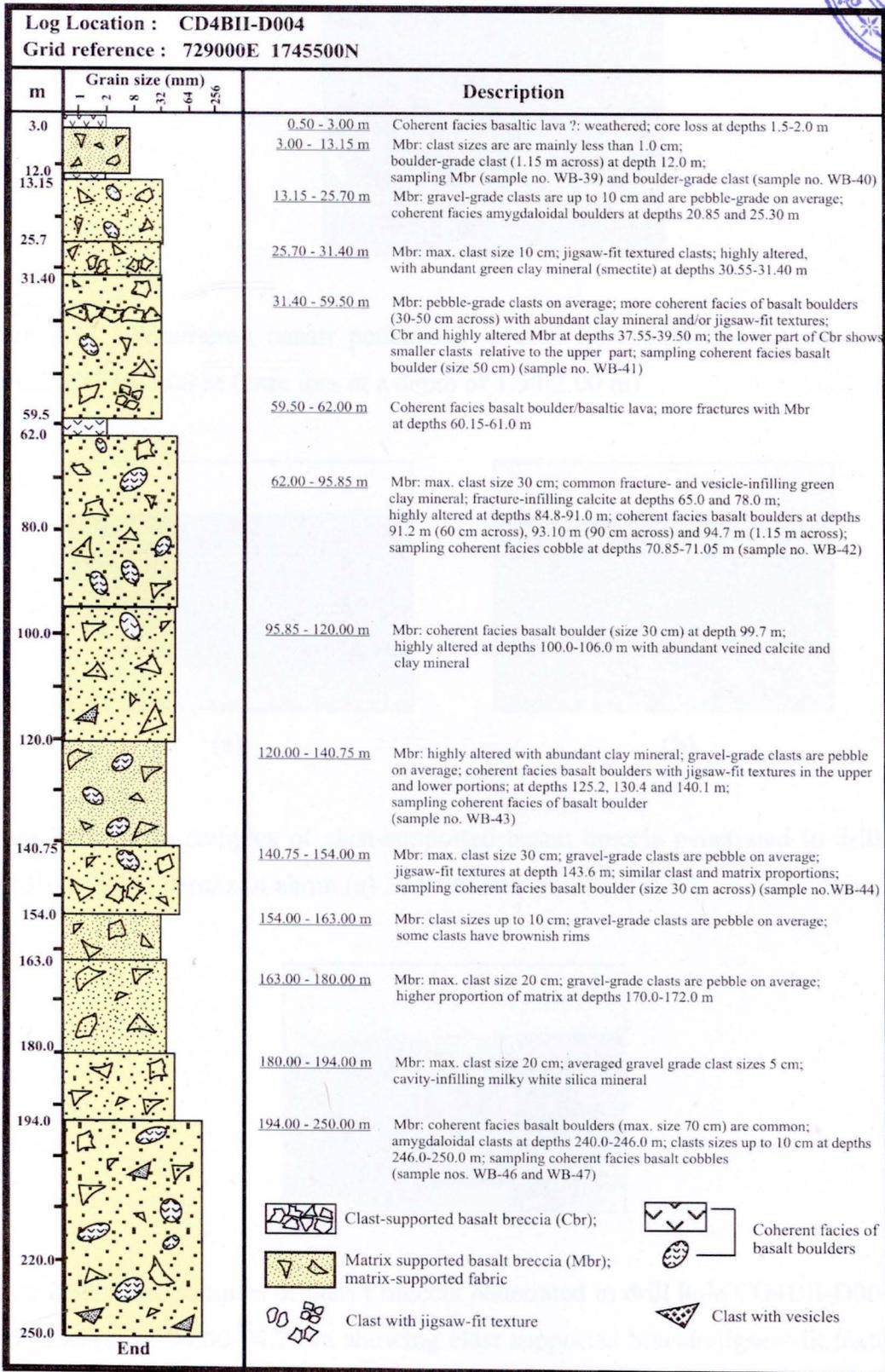


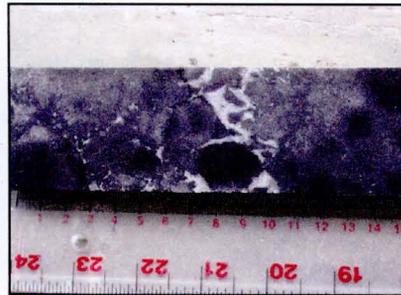
Figure 2.30 Graphic log of core samples penetrated in drill hole CD4BII-D004



Figure 2.31 Weathered basalt penetrated in drill hole CD4BII-D004 at a depth interval of 0.50-3.00 m (core loss at a depth of 1.50-2.00 m)



(a)



(b)

Figure 2.32 Core samples of clast-supported basalt breccia penetrated in drill hole CD4BII-D004 at depths of about (a) 37.95 m and (b) 38.60 m

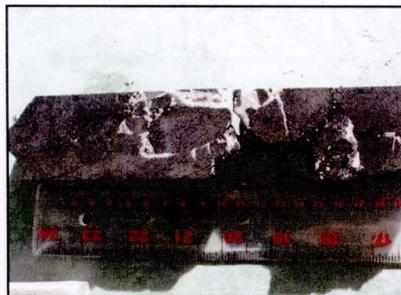


Figure 2.33 Core samples of basalt breccia penetrated in drill hole CD4BII-D004 at a depth interval of 94.00-94.70 m showing clast supported breccia/jigsaw-fit texture in the upper part of basalt boulder

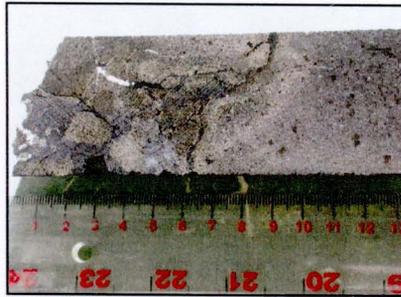


Figure 2.34 Core samples of clast-supported basalt breccia penetrated in drill hole CD4BII-D004 at a depth of about 93.60 m showing a jigsaw-fit texture in the lower part of basalt boulder with size 90 cm

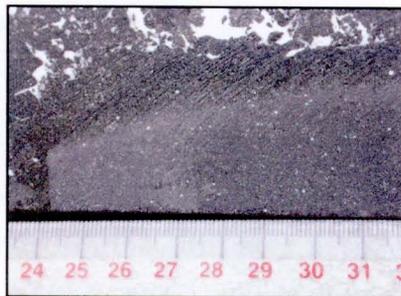


Figure 2.35 Core samples of basalt breccia penetrated in drill hole CD4BII-D004 at a depth of about 198.50 m showing a basaltic clast with brownish and blackish glassy rims

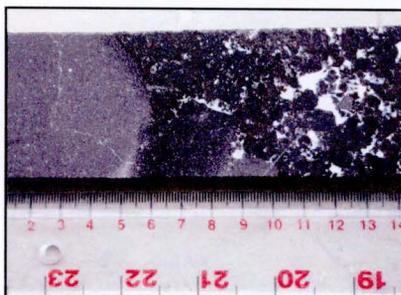


Figure 2.36 Core samples of basalt breccia penetrated in drill hole CD4BII-D004 at a depth of about 194.70 m showing cementing material (whitish color = zeolites; brownish color = clay mineral)

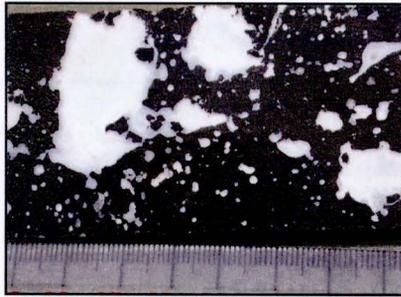


Figure 2.37 Core samples of basalt breccia penetrated in drill hole CD4BII-D004 at a depth of about 222.85 m showing cavity/vesicle-infilling, milky quartz

2.7.5 Drill Hole CD4BII-D005

Drill hole CD4BII-D005 is located at a grid reference of 728550E/1744450N and an elevation of 104 meters above mean sea level, with a depth of 165 meters. The graphic log of rocks penetrated in this drill hole is shown in Figure 2.38. The core samples consist of the coherent facies basaltic lavas and basalt boulders, the incoherent facies (matrix - supported and clast - supported basalt breccia) and the volcanogenic sedimentary facies.

The coherent facies basaltic lavas are present depth intervals of 12.90 – 18.75, 44.90 – 52.40, 90.63 – 97.65 and 115.70 – 142.50 meters. The uppermost coherent facies basaltic lava contains abundant vesicles in the upper part and more fractures sealed by zeolites and calcite in the middle part (Figure 2.39). The coherent facies of basaltic lava at a depth interval of 44.90 – 52.40 meters is porphyritic, and contains abundant vesicles with calcite and clay infillings in the upper part. At a depth interval of 48.30 – 52.40 meters, the core samples are highly altered, with abundant vesicles sealed by dark green minerals and veined calcite. The lower part contains abundant fractures, leading to a jigsaw-fit texture (Figure 2.40), characteristic of clast-supported basalt breccia.

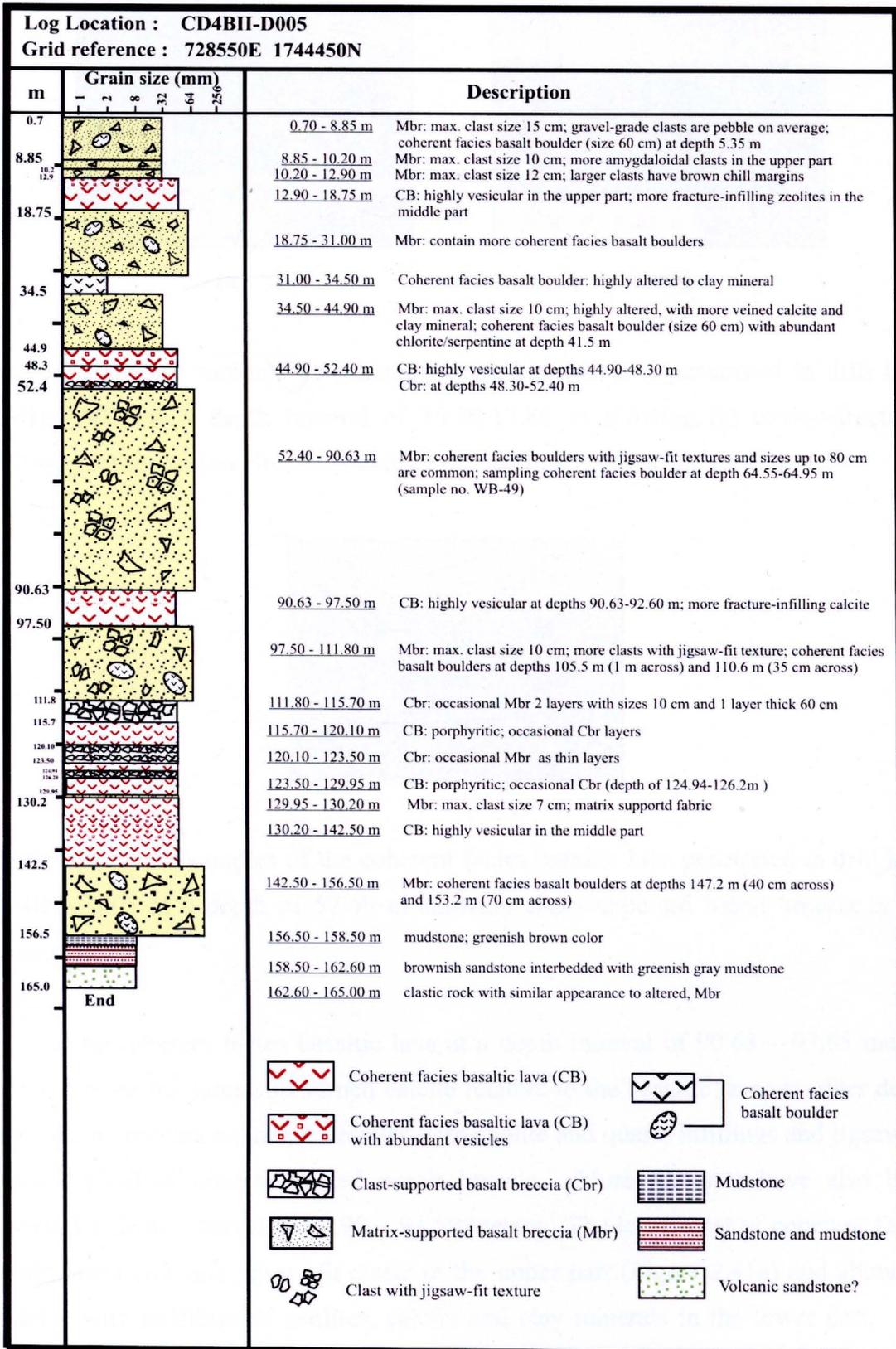


Figure 2.38 Graphic log of core samples penetrated in drill hole CD4BII-D005

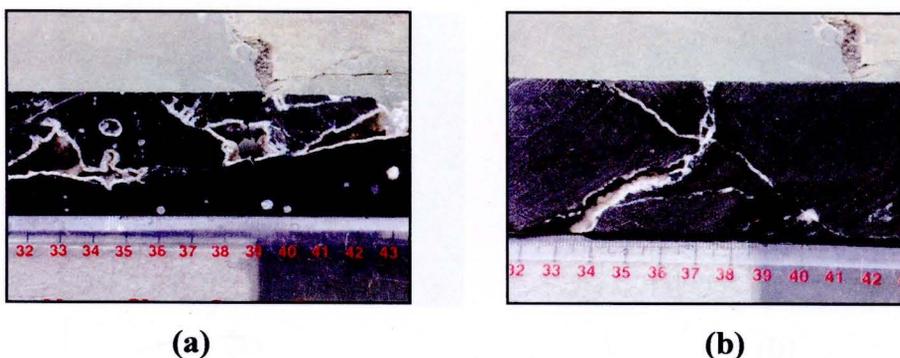


Figure 2.39 Core samples of coherent facies basaltic lava penetrated in drill hole CD4BII-D005 at a depth interval of 15.10-17.80 m showing (a) cavity-/fracture-infilling zeolites and calcite, and (b) fracture-infilling zeolites and calcite



Figure 2.40 Core samples of the coherent facies basaltic lava penetrated in drill hole CD4BII-D005 at a depth of 52.40 m showing clast-supported basalt breccia in the lower part

The coherent facies basaltic lava at a depth interval of 90.63 – 97.65 meters contains more fractures and veined calcite relative to the basaltic lavas at other depth interval. It contains abundant vesicles with zeolite and quartz infillings and jigsaw-fit clasts, typical of clast-supported basalt breccia. More fractures have also been observed a depth interval of 92.90 – 93.50 meters. The lowermost of coherent facies basaltic lava contains jigsaw-fit clasts in the upper part (Figure 2.41a) and abundant vesicles with infillings of zeolites, calcite and clay minerals in the lower part. The matrix-supported basalt breccia has been occasionally observed as a thin layer (10 centimeters thick) as shown in Figure 2.41b. At a depth interval of 135.00 – 136.00 meters, more fracture-infilling calcite and zeolites have been observed.

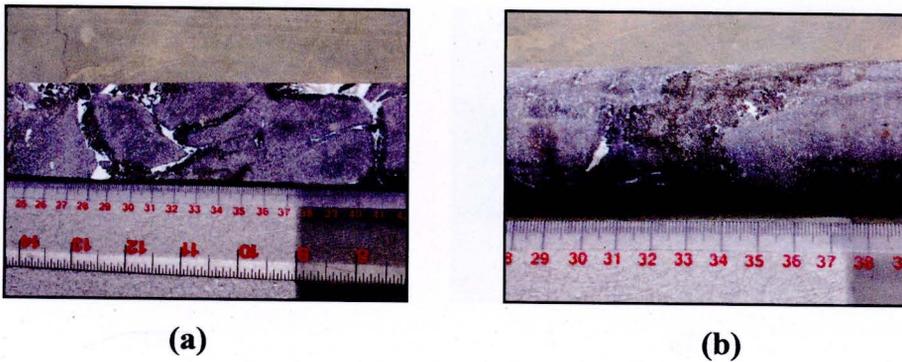


Figure 2.41 Core samples of basalt breccia penetrated in drill hole CD4BII-D005 at depths of about (a) 115.70 m and (b) 119.40 m showing clast-supported breccia in the upper part of coherent facies basaltic lava, and a thin layer of matrix-supported basalt breccia, respectively

The clast-supported basalt breccia shows a jigsaw-fit texture (Figure 2.42) and commonly occupies the upper and lower parts of coherent facies of basaltic lavas. It is also intimately associated with large basaltic clasts, and occasionally contains matrix-supported basalt breccia layers (Figure 2.43).

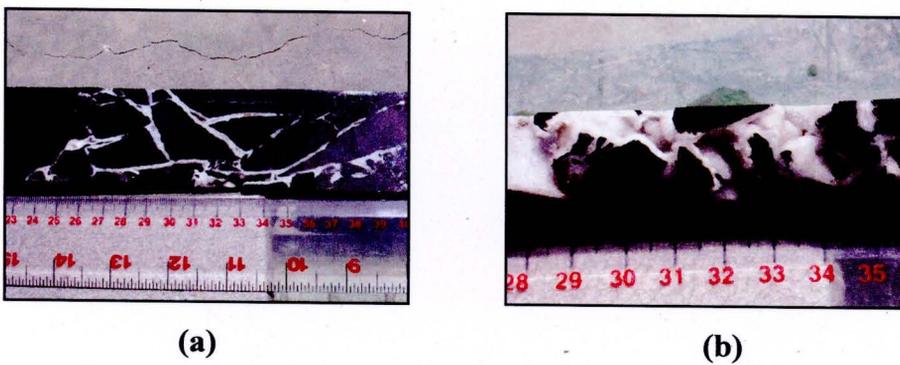


Figure 2.42 Core samples of basalt breccia penetrated in drill hole CD4BII-D005 at a depth of about 124.90 m showing a jigsaw-fit texture (a) and fracture-infilling zeolites (b).

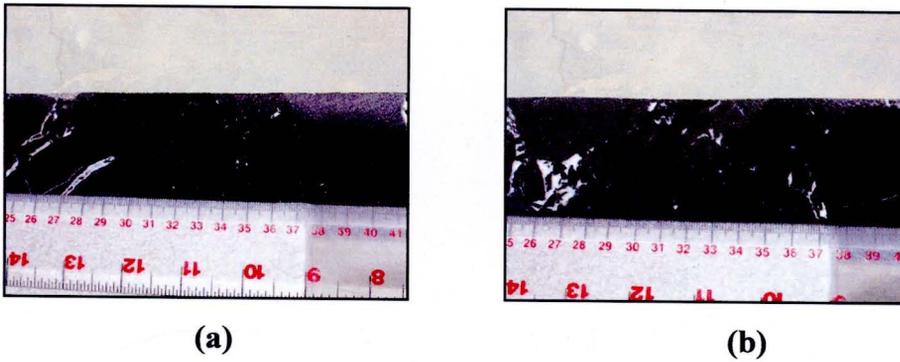


Figure 2.43 Core samples of basalt breccia penetrated in drill hole CD4BII-D005 at depths of about (a) 120.55 m and (b) 121.20 m showing matrix-supported basalt breccia occurs as layers with clast-supported basalt breccia

The matrix-supported basalt breccia has similar appearance to those in the other drill holes. Boulder-grade basaltic clasts are abundantly present at depth intervals of 52.40 – 90.63 meters and commonly show a jigsaw-fit texture (Figures 2.44, 2.45 and 2.46). Fractures in the jigsaw-fit textured clasts are infilled with zeolites and/or smaller glassy fragments (Figures 2.45 and 2.46).

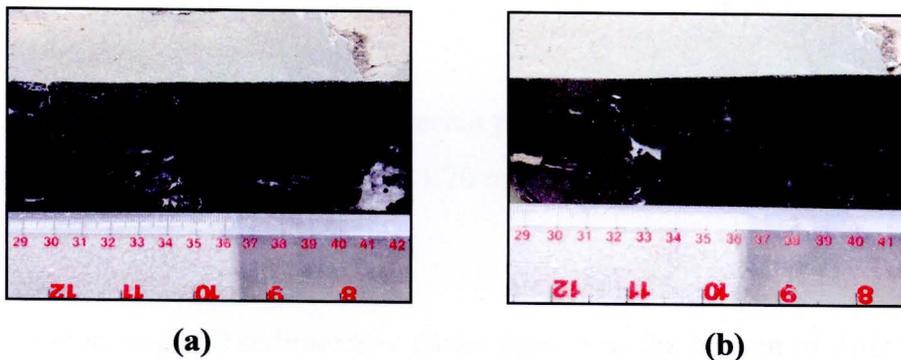
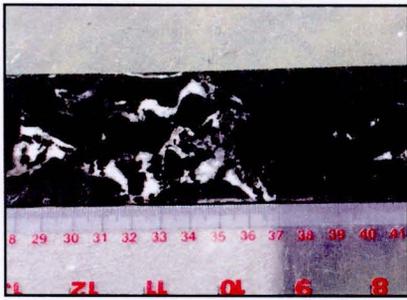
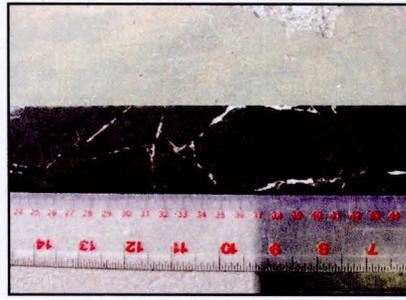


Figure 2.44 Core samples of basalt breccia penetrated in drill hole CD4BII-D005 at depths of about (a) 25.50 m and (b) 30.10 m showing jigsaw-fit texture of basaltic clasts with diameters of 50 and 70 cm in respect manner

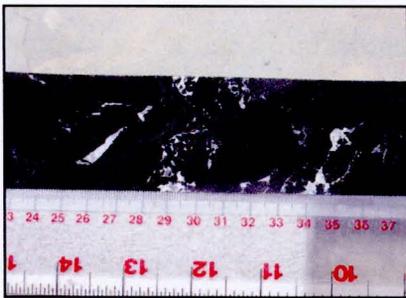


(a)

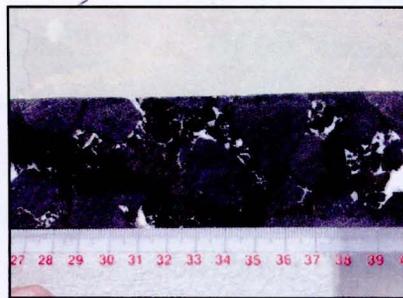


(b)

Figure 2.45 Core samples of basalt breccia penetrated in drill hole CD4BII-D005 at depths of about (a) 67.40 m and (b) 71.30 m showing jigsaw-fit texture and fracture-infilling zeolites



(a)



(b)

Figure 2.46 Core samples of basalt breccia penetrated in drill hole CD4BII-D005 at depths of about (a) 110.60 m and (b) 111.70 m showing jigsaw-fit texture

The volcanogenic sedimentary facies present at the bottom of drill hole, i.e. a depth interval of 156.5 – 165.00 meters. The facies are made up of greenish brown mudstone at a depth interval of 156.50 – 158.50 meters, interbeds of reddish brown sandstone and greenish gray mudstone at a depth interval of 158.50 – 162.60 meters, and a clastic sedimentary rock with volcanic clasts at a depth interval of 162.60 – 165.00 meters.