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APPENDICIES

APPENDIX A

SAMPLE LOCATIONS AND PETROGRAPHIC FEATURES OF THE STUDIED OUTCROP SAMPLES

COHERENT FACIES BASALTIC LAVAS

BAN SAP SAWAT, WICHIAN BURI DISTRICT,

PHETCHABUN PROVINCE

Sample no. **WB-1**

Grid Location: **289455, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock sample shows a slightly porphyritic texture, with dark-colored phenocrysts of which sizes are up to about 1 mm across. The groundmass is fine-grained, and has a medium dark gray color.

Microscopic Description: The studied thin section contains phenocrysts/ microphenocrysts of olivine and plagioclase (sizes up to 0.7 mm across) in small amount. These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as cumulocrysts, and sit in the felty groundmass (grain sizes of about 0.1 mm across). The groundmass consists principally of plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide.

Plagioclase phenocrysts/microphenocrysts are largely subhedral, and often show complex zonation. The groundmass plagioclase grains generally show subhedral outlines. All generations of plagioclase have An-content varying from 27 (oligoclase) to 50 (labradorite) on the basis of petrographic technique. The interstitial minerals to felty plagioclase laths include clinopyroxene, olivine and Fe-Ti oxide, characteristic of an intergranular texture. The groundmass plagioclase laths also rarely occur as chadacrysts enclosed in larger clinopyroxene oikocrysts, giving rise to an ophitic/subophitic texture.

Olivine phenocrysts/microphenocrysts are largely anhedral to subhedral; rounded edges have been occasionally observed. They may contain chrome-spinel inclusions and be partly altered to chlorite/serpentine. Groundmass olivine grains commonly have anhedral outlines.

Clinopyroxene occurs as a groundmass constituent and shows a brownish color in ordinary light. They largely have subhedral to anhedral outlines.

Fe-Ti oxide occurs as subhedral to euhedral crystals and irregular, anhedral patches.

Sample no. **WB-2**

Grid Location: **282451, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The slightly porphyritic rock contains phenocrysts of which sizes are up to about 1.0 mm across. These phenocrysts are dark-colored and olive green; a few have been replaced by brownish minerals. The fine-grained groundmass has a dark gray color. A few irregular veinlets of brownish minerals have been observed in the sample.

Microscopic Description: The phenocrysts/microphenocrysts in this rock sample are largely olivine, with subordinate plagioclase. These phenocrysts/ microphenocrysts occur as isolated grains and as glomerocrysts. The groundmass shows a felty texture and has grain sizes largely in a range of 0.03 – 0.08 mm across. The groundmass constituents are made up largely of plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide. The fracture-infilling mineral is Fe-Ti oxide, which is almost totally replaced by hematite/iron hydroxide.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.6 mm across) have anhedral to subhedral outlines and may show complex zonation. The groundmass plagioclase grains are largely subhedral. The interstitial minerals to felty plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide. Ophitic/subophitic intergrowths between clinopyroxene oikocrysts and plagioclase chadacrysts have been occasionally observed. Determination of An-content, on the basis of optical mean, reveals that all the plagioclase phases are compositionally oligoclase to bytownite (An content = 27 – 80).

Olivine phenocrysts and microphenocrysts are commonly anhedral to subhedral, with grain sizes up to 0.8 mm across. They may be slightly replaced by chlorite/serpentine, and show rounded edges and embayed outlines. They may also contain chrome-spinel inclusions. The groundmass olivine grains are largely anhedral.

Clinopyroxene occurs only as a groundmass constituent and shows a brownish color in ordinary light. They largely have subhedral to anhedral outlines.

Fe-Ti oxide occurs as subhedral to euhedral crystals and irregular, anhedral patches.

Sample no. **WB-3**

Grid Location: **279449, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock is slightly porphyritic, with phenocrysts of dark mineral of which sizes are up to 1.5 mm. The groundmass is fine-grained, and has a dark gray color.

Microscopic Description: The phenocrysts/microphenocrysts in this rock sample include olivine and plagioclase.. They occur as isolated grains, glomerocrysts and as cumulocrysts. The groundmass is fine-grained, with grain sizes largely in a range of 0.03 – 0.05 mm across, and is composed largely of felted plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide.

Plagioclase phenocrysts/microphenocrysts largely have subhedral outlines and show complex zonation. The groundmass plagioclase grains are also subhedral. All generations of plagioclase have An-content, on the basis of optical mean, ranging from 25 (oligoclase) to 61 (labradorite). Intergranular to the felty plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide.

Olivine phenocrysts and microphenocrysts are largely anhedral to subhedral; many show rounded edges. They may contain chrome-spinel inclusions and be partly altered to chlorite/serpentine. The groundmass olivine grains largely have anhedral outlines.

Clinopyroxene occurs as a groundmass constituent and shows a brownish color in ordinary light. They largely have subhedral to anhedral outlines.

Fe-Ti oxide occurs as subhedral to euhedral crystals and irregular, anhedral patches.

Sample no. **WB-4**
Grid Location: **279450, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**
Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock is slightly porphyritic, with dark-colored and olive green phenocrysts of which sizes are up to 0.7 mm across. These phenocrysts sit in the fine-grained groundmass that shows a dark gray color.

Microscopic Description: The rock contains phenocrysts/microphenocrysts of olivine and plagioclase in minor amount. These phenocrysts/microphenocrysts occur as isolated crystals and as glomerocrysts, and sit in the felty groundmass of which grain sizes are largely between 0.05 and 0.10 mm across. The groundmass is made up largely of felted plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase phenocrysts/microphenocrysts have sizes up to 0.6 mm across and are largely subhedral. The groundmass plagioclase grains also largely have subhedral outlines. All phases of plagioclase have An-content, based on an optical method, varying from 60 to 75 (labradorite to bytownite). The interstices of plagioclase laths

have been occupied by clinopyroxene, olivine and Fe-Ti oxide grains. In addition to the commonly intergranular relationship, ophitic/subophitic intergrowths between clinopyroxene oikocrysts and plagioclase chadacrysts have been observed in minor amount.

Olivine phenocrysts/microphenocrysts are commonly anhedral to subhedral, and may show rounded edges and embayed outlines. They may contain chrome spinel inclusions and be variably altered to chlorite/serpentine. The groundmass olivine grains commonly have anhedral outlines and are also variably altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass phase. It has a brownish color and largely shows anhedral to subhedral outlines

Two contrasting forms of Fe-Ti oxide have been observed in the sample, i.e. subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-5**

Grid Location: **273454, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock has a slightly porphyritic texture, with olive green and dark-colored phenocrysts of which sizes are up to 1.5 mm across. These phenocrysts are embedded in the fine-grained groundmass that has a dark gray color (brownish on weathering surfaces).

Microscopic Description: The rock contains phenocrysts/microphenocrysts of olivine and plagioclase in minor amount. These phenocrysts/microphenocrysts occur as isolated crystals and as glomerocrysts, and sit in the felty groundmass of which grain sizes are largely between 0.03 and 0.06 mm across. The groundmass is made up

largely of plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase occurs either as a microphenocryst phase or as a groundmass phase. The plagioclase microphenocrysts have anhedral to subhedral outlines, while the groundmass plagioclase grains are largely subhedral. The interstices of plagioclase laths have been occupied by clinopyroxene, olivine and Fe-Ti oxide grains. In addition to the commonly intergranular relationship, ophitic/subophitic intergrowths between clinopyroxene oikocrysts and plagioclase chadacrysts have been observed in minor amount.

Olivine phenocrysts/microphenocrysts are commonly anhedral to subhedral, with rounded edges. They may contain chrome spinel inclusions and be variably altered to chlorite/serpentine. The groundmass olivine grains commonly have anhedral outlines.

Clinopyroxene occurs only as a groundmass constituent and is largely anhedral to subhedral.

Two contrasting forms of Fe-Ti oxide have been observed in the sample, i.e. subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-6**

Grid Location: **268459, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock is slightly porphyritic, with dark-colored and whitish phenocrysts of which sizes are up to 0.8 mm across. These phenocrysts sit in the fine-grained groundmass that shows a dark gray color.

Microscopic Description: The rock occasionally contains phenocrysts/ microphenocrysts of olivine and plagioclase. Of these phenocrysts and microphenocrysts, olivine is more common than plagioclase. These phenocrysts/microphenocrysts occur as isolated crystals and as olivine glomerocrysts, and sit in the felty, seriate-textured groundmass of which grain sizes are largely between 0.1 and 0.2 mm across. The groundmass is made up largely of plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase phenocrysts/microphenocrysts have sizes up to 0.6 mm across and are largely subhedral. The groundmass plagioclase grains also largely have subhedral outlines. All phases of plagioclase grains have An-content varying from 40 to 80 (andesine to bytownite), on the basis of optical mean. The interstitial minerals to plagioclase crystals include clinopyroxene, olivine and Fe-Ti oxide grains. The groundmass plagioclase crystals also rarely occur as chadacrysts enclosed in larger clinopyroxene oikocrysts, resulting in ophitic/subophitic textures.

Olivine phenocrysts/microphenocrysts are commonly anhedral to subhedral, and have sizes up to 0.8 mm across. They may contain chrome spinel inclusions and show rounded edges. The groundmass olivine grains commonly have anhedral to subhedral outlines. All the phases of olivine have been variably altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass phase. It has a brownish color and largely shows anhedral to subhedral outlines.

Fe-Ti oxide minerals have been observed in the sample as subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-7**

Grid Location: **280457, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock is slightly porphyritic, with dark-colored and whitish phenocrysts of which sizes are up to 1.5 mm across. These phenocrysts sit in the fine-grained groundmass that shows a dark gray color.

Microscopic Description: Although the rock shows a slightly porphyritic texture in hand specimen, it is strongly microporphyritic, with abundant plagioclase and subordinate olivine microphenocrysts. These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The groundmass is felty, with grain sizes largely between 0.02 and 0.03 mm across. The groundmass constituents include abundant plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.8 mm across) and groundmass plagioclase grains are largely subhedral. The plagioclase phenocrysts often show complex zonation, whereas the plagioclase microphenocrysts do not show such complex zonation. Both generations of plagioclase crystals have An-content, on the basis of petrographic technique, varying from 50 to 80 (labradorite to bytownite). The interstitial minerals to groundmass plagioclase crystals are common clinopyroxene, and uncommon olivine and Fe-Ti oxide grains.

Olivine phenocrysts/microphenocrysts are commonly anhedral to subhedral, and have sizes up to 0.8 mm across. They may contain chrome spinel inclusions and show rounded edges. The groundmass olivine grains commonly have anhedral outlines. All the phases of olivine have been variably altered to greenish amphibole and/or chlorite/serpentine.

Clinopyroxene occurs only as a groundmass phase. It is brownish in color and largely shows subhedral outlines.

Fe-Ti oxide minerals have been observed in the sample as subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-8**

Grid Location: **275460, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock shows a moderately porphyritic texture, with dark-colored and whitish phenocrysts of which sizes are up to 1.5 mm across. These phenocrysts sit in the fine-grained groundmass that shows a dark gray color.

Microscopic Description: The phenocrysts/microphenocrysts in this sample are olivine and plagioclase, with sizes up to 0.8 mm across. These phenocrysts/microphenocrysts occur as isolated crystals and as glomerocrysts, and sit in the felty, seriate-textured groundmass, with grain sizes largely between 0.03 and 0.15 mm across. The groundmass constituents include abundant plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.8 mm across) and groundmass plagioclase grains are largely subhedral. The plagioclase glomerocrysts may form stellate aggregates. Determination of An-content via a petrographic technique reveals that all the plagioclase crystals have An-content varying from 45 to 80 (andesine to bytownite). The interstitial minerals to groundmass plagioclase crystals are clinopyroxene, olivine and Fe-Ti oxide grains. Some groundmass plagioclase grains are enclosed in larger clinopyroxene grains in an ophitic/subophitic style.

Olivine phenocrysts/microphenocrysts are commonly anhedral to subhedral, and have sizes up to 0.8 mm across. They may contain chrome spinel inclusions and

show rounded edges. The groundmass olivine grains commonly have anhedral outlines. All the phases of olivine have been variably altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass phase. It has a brownish color and largely shows subhedral outlines.

Fe-Ti oxide minerals are present in the sample as subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-9**

Grid Location: **280448, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock shows a slightly porphyritic texture, with dark-colored phenocrysts of which sizes are up to 1.5 mm across. These phenocrysts sit in the fine-grained groundmass that shows a dark gray color.

Microscopic Description: The phenocrysts/microphenocrysts in this sample are olivine and plagioclase, with sizes up to 1.2 mm across. These phenocrysts/microphenocrysts occur as isolated crystals and as olivine glomerocrysts, and are embedded in the felty, seriate-textured groundmass, with grain sizes largely between 0.05 and 0.15 mm across. The groundmass constituents include abundant plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase occurs as microphenocrysts (sizes up to 0.4 mm across), with complex zonation, and as groundmass plagioclase grains. These plagioclase crystals largely show subhedral outlines, and have An-content, measured by a petrographic method, ranging from 25 to 62 (oligoclase to labradorite). The intergranular minerals to groundmass plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide grains.

Occasionally ophitic/subophitic intergrowths between smaller groundmass plagioclase laths and larger groundmass clinopyroxene grains have been detected.

Olivine phenocrysts/microphenocrysts are commonly anhedral to subhedral, and have sizes up to 1.2 mm across. They may contain chrome spinel inclusions and show rounded edges. The groundmass olivine grains commonly form anhedral grains. All the phases of olivine have been variably altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass phase. It has a brownish color and largely shows subhedral outlines.

Fe-Ti oxide minerals are present in the sample as subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-10**
Grid Location: **268419, 1:50,000 Topographic Map, Sheet 5240 III (Amphoe Wichian Buri)**
Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock shows a slightly porphyritic texture, with dark-colored phenocrysts of which sizes are up to 1.0 mm across. These phenocrysts sit in the fine-grained groundmass that shows a dark gray color (brownish on weathering skins).

Microscopic Description: All the larger crystals in the studied thin sections are microphenocrysts of plagioclase and olivine, with sizes up to 0.5 mm across. They form as isolated crystals and as olivine glomerocrysts. The groundmass constituents are felty, seriate-textured, with grain sizes largely between 0.05 and 0.15 mm across. They include abundant plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains. Two contrasting textural types have been observed in the groundmass portions. These include intergranular and ophitic/subophitic textures.

Plagioclase occurs as microphenocrysts (sizes up to 0.5 mm across) and as groundmass plagioclase grains. The plagioclase microphenocrysts may show complex zonation. All phases of plagioclase crystals largely show subhedral outlines, and have An-content, measured by a petrographic method, ranging from 37 to 88 (andesine to bytownite). The intergranular minerals to groundmass plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide grains. Groundmass plagioclase laths as chadacrysts in clinopyroxene oikocrysts have also been observed. The proportion of intergranular groundmass to ophitic/subophitic groundmass is close to unity.

Olivine also occurs as microphenocrysts, with anhedral to subhedral outlines, and has sizes up to 0.5 mm across. They may contain chrome spinel inclusions and show rounded edges. The groundmass olivine grains commonly form anhedral grains. All the phases of olivine have been variably altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass phase. It has a brownish color and largely shows subhedral outlines.

Fe-Ti oxide minerals are present in the sample as subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-11**

Grid Location: **259472, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock sample shows a very slightly porphyritic texture, with dark-colored phenocrysts of which grain sizes are less than 1.0 mm across. These phenocrysts sit in the medium gray, fine-grained groundmass.

Microscopic Description: The rock contains phenocrysts/microphenocrysts of olivine and plagioclase that occur as isolated crystals and as olivine glomerocrysts.

The phenocrysts/microphenocrysts sit in the felty groundmass of which grain sizes are largely between 0.1 – 0.2 mm across. The groundmass consists largely of plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide.

Plagioclase phenocrysts/microphenocrysts have subhedral outlines, with sizes up to 0.5 mm across, and rarely show complex zonation. The groundmass plagioclase laths also have subhedral outlines. Both generations of plagioclase crystals have An-content varying from 38 to 85 (andesine to bytownite) on the basis of optical mean. The interstitial minerals to felty plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide.

Olivine phenocrysts and microphenocrysts are largely anhedral to subhedral, with sizes up to 0.6 mm across. They commonly show rounded edges and may contain chrome-spinel inclusions. The groundmass olivine grains largely have anhedral to subhedral outlines. All phases of olivine grains are rarely altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass constituent and shows a brownish color in ordinary light. They largely have subhedral to anhedral outlines.

Fe-Ti oxide occurs as subhedral to euhedral crystals and irregular, anhedral patches.

Sample no. **WB-12**
Grid Location: **261462, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**
Rock type: **Coherent facies basaltic lava**

Megascopic Description: The rock sample shows a slightly porphyritic texture, with olive green and dark-colored phenocrysts of which grain sizes are less than 1.0 mm across. The groundmass is fine-grained, and has a dark gray color (brownish on weathering surfaces).

Microscopic Description: The rock contains phenocrysts/microphenocrysts of olivine and plagioclase that occur as isolated crystals and as olivine glomerocrysts. The phenocrysts/microphenocrysts sit in the felty groundmass of which grain sizes are largely between 0.05 – 0.10 mm across. The groundmass consists largely of plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.5 mm across) and groundmass plagioclase grains largely have subhedral outlines. The phenocrysts/microphenocrysts of plagioclase may show complex zonation. All phases of plagioclase crystals have An-content in a range of 24 - 74 (oligoclase - bytownite) on the basis of petrographic technique. The interstitial minerals to felty plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide.

Olivine phenocrysts and microphenocrysts are commonly anhedral to subhedral, with sizes up to 0.6 mm across. They may be partly replaced by chlorite/serpentine, show rounded edges, and contain chrome-spinel inclusions. The groundmass olivine grains largely have anhedral to subhedral outlines. They are rarely altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass constituent and shows a brownish color in ordinary light. They largely have subhedral to anhedral outlines.

Fe-Ti oxide occurs as subhedral to euhedral crystals and irregular, anhedral patches.

Sample no.	**WB-13**
Grid Location:	**298505, 1:50,000 Topographic Map, Sheet 5240 IV (Amphoe Nong Phai)**
Rock type:	**Coherent facies basaltic lava**

Megascopic Description: The rock sample shows a seriate texture, with grain sizes up to 1.0 mm across. It has a dark gray color, where weathering has taken place, it turns brown.

Microscopic Description: This seriate-textured rock sample is made up principally of variably sized plagioclase laths and clinopyroxene that almost totally show ophitic/subophitic relationship, producing an ophimottled texture. The subordinate and minor constituents include variably sized olivine and Fe-Ti oxide in respective manner.

Isolated plagioclase crystals and plagioclase chadacrysts largely have subhedral outlines. The former has grain sizes up to 0.4 mm across, while the latter has grain sizes in a range of 0.02 – 0.20 mm across. These plagioclase crystals have An-content varying from 25 (oligoclase) to 80 (bytownite) on the basis of petrographic technique.

Clinopyroxene oikocrysts occur as anhedral crystals, and have a brownish color in ordinary light.

Olivine crystals commonly have anhedral to subhedral outlines, with rounded edges. They have been variably altered to chlorite/serpentine.

Fe-Ti oxide grains are subhedral to euhedral, and irregular, anhedral.

APPENDIX B

SAMPLE LOCATIONS AND PETROGRAPHIC FEATURES OF THE STUDIED CORE SAMPLES,

COHERENT FACIES BASALTIC LAVAS

BAN SAP SAWAT, WICHIAN BURI DISTRICT,

PHETCHABUN PROVINCE

Sample no. **WB-27**

Drill hole: **CD4BII-D002 (Depth 144.7-144.8 m)**

Rock type: **Coherent facies basaltic lava**

Megascopic Description: The core sample represents part of coherent facies of basaltic lava that shows a slightly porphyritic texture, with dark green and black phenocrysts. The groundmass is fine-grained, and has a dark gray color. The rock shows no sign of magnetic property and carbonate minerals.

Microscopic Description: The studied thin section contains phenocrysts/microphenocrysts of plagioclase (sizes up to 0.6 mm across) and olivine (sizes up to 0.7 mm across). They occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts sit in the fine-grained groundmass, with grain sizes largely in a range of 0.04 - 0.10 mm across. The groundmass is composed mainly of abundant felted plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase phenocrysts/microphenocrysts largely have subhedral outlines and rarely show complex zonation. They may contain olivine inclusions and have An-content varying from 43 to 83 (andesine to bytownite), on the basis of petrographic technique. Groundmass plagioclase grains are largely subhedral, and the insterstices among the felted plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide grains. The plagioclase laths may occur as chadacrysts enclosed in clinopyroxene oikocrysts, giving rise to ophitic/subophitic textures.

Olivine phenocrysts/microphenocrysts are largely anhedral to subhedral, while groundmass olivine grains largely have anhedral outlines. These phenocrysts/microphenocrysts may contain minor chrome spinel inclusions, and have rounded edges and/or embayed outlines. Both of the olivine phenocrysts/microphenocrysts and the groundmass olivine grains are slightly to moderately altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass phase. It has a brownish color and largely shows subhedral to anhedral outlines

Fe-Ti oxide minerals occur as subhedral to euhedral grains and irregular, anhedral patches.

Sample no. **WB-30**
Drill hole: **CD4BII-D003 (Depth 59.6-59.9 m)**
Rock type: **Coherent facies basaltic lava**

Megascopic Description: The core sample represents a portion of coherent basaltic lava at a depth interval of 44.1 - 60.4 m. It shows a moderately porphyritic texture that has dark green minerals as phenocrysts. The groundmass is fine-grained, and has a dark gray color. A few veinlets of whitish minerals (0.04 mm thick) have been observed. The rock is non-magnetic and non-calcareous.

Microscopic Description: The studied thin section contains phenocrysts/microphenocrysts of plagioclase (sizes up to 0.5 mm across) and olivine (sizes up to 1.4 mm across) that occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts sit in the groundmass that has grain sizes largely in a range of 0.02 - 0.04 mm across. The groundmass consists mainly of abundant felted plagioclase laths, with subordinate clinopyroxene and olivine, and a small amount of Fe-Ti oxide grains.

Plagioclase phenocrysts/microphenocrysts largely have subhedral outlines and rarely show complex zonation. The An-content of plagioclase crystals varies from 50 to 82 (labradorite to bytownite), on the basis of petrographic technique. Groundmass plagioclase grains have subhedral outlines and the interstitial minerals to felty plagioclase laths are clinopyroxene, olivine and Fe-Ti oxide grains, typical of intergranular texture. In an uncommon case, smaller groundmass plagioclase laths occur as chadacrysts enclosed in clinopyroxene oikocrysts in ophitic/subophitic fashion.

Olivine phenocrysts/microphenocrysts are largely anhedral to subhedral, and commonly show rounded edges and/or embayed outlines. These phenocrysts/ microphenocrysts may have minor chrome spinel inclusions and may have been slightly to moderately replaced by chlorite/serpentine and/or Fe-Ti oxide. Groundmass olivine grains have anhedral outlines and may have been variably altered to chlorite/serpentine.

Clinopyroxene grains are exclusively a groundmass constituent and largely have subhedral to anhedral outlines.

Fe-Ti oxide occurs as subhedral to euhedral crystals and irregular, anhedral patches.

Sample no. **WB-36**
Drill hole: **CD4BII-D003 (Depth 127.83-128.0 m)**
Rock type: **Coherent facies basaltic lava**

Megascopic Description: The core sample represents part of coherent basaltic lava at a depth interval of 125.4 - 132.5 m. It has a moderately porphyritic texture, made up of dark-colored phenocrysts in the dark gray, fine-grained groundmass. A few veinlets of whitish mineral (0.04 mm thick) have been observed in the sample. The rock has no magnetic property and does not react with diluted hydrochloric acid.

Microscopic Description: The phenocrysts/microphenocrysts (sizes up to 1.0 mm across) are plagioclase and olivine that occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts sit in the groundmass that has a hypohyaline texture, with grain sizes largely in a range of 0.01 - 0.04 mm across. The hypohyaline groundmass consists mainly of felted plagioclase laths and tachylite, and a small amount of olivine grains. The veinlets of whitish minerals as observed in hand specimen comprise zeolites.

Plagioclase phenocrysts/microphenocrysts, with sizes up to 0.6 mm across, largely have subhedral outlines and rarely show complex zonation. The An-content

of plagioclase crystals varies from 57 to 83 (labradorite to bytownite), on the basis of petrographic technique. Groundmass plagioclase grains largely have subhedral outlines. All the generations of plagioclase have been slightly replaced by sericite and clay mineral. The interstitial material to felted plagioclase laths is either tachylite or olivine grains.

Olivine phenocrysts/microphenocrysts (sizes up to 1.0 mm across) are largely anhedral to subhedral, and may have minor chrome spinel inclusions. They may show rounded edges and embayed outlines, and rarely enclose smaller plagioclase laths in the form of ophitic/subophitic textures. Groundmass olivine grains have anhedral outlines. All phases of olivine grains have been slightly to moderately altered to chlorite/serpentine.

APPENDIX C

SAMPLE LOCATIONS AND PETROGRAPHIC FEATURES OF THE STUDIED CORE SAMPLES,

COHERENT FACIES BASALTIC CLASTS IN BASALT BRECCIA

BAN SAP SAWAT, WICHIAN BURI DISTRICT,

PHETCHABUN PROVINCE

Sample no. **WB-14**
Drill hole: **CD4BII-D001 (Depth 6.50-6.74 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents a portion of boulder-grade clast with a diameter of about 1.04 m (a depth interval of 5.70-6.74 m). The sample is a non-porphyritic, very fine-grained rock, with a dark gray color, and contains abundant, felty feldspar laths. The core sample slightly has vesicles, fractures, and irregular cavities that are sealed by whitish minerals.

Microscopic Description: The studied thin section shows a seriate texture, with grain sizes up to 1.0 mm across. It is made up of abundant felty plagioclase laths, with subordinate glass and quench crystals (i.e. microlite, acicular clinopyroxene and plagioclase/olivine skeletons), and olivine grains. The whitish fracture- and cavity-infillings as observed in hand specimen are zeolites.

Plagioclase has grain sizes up to 0.6 mm across and generally shows subhedral outlines. These plagioclase grains may have olivine inclusions and are slightly replaced by clay mineral. They have An-content, measured by a petrographic method, ranging from 37 to 88 (andesine to bytownite). The interstitial material to felty plagioclase laths is tachylite and olivine grains. Plagioclase laths may occur as chadacrysts enclosed by glassy patches, giving rise to hyalophitic texture.

Olivine grains largely have anhedral to subhedral outlines, with grain sizes up to 1.0 mm across. These olivine grains may contain minor chrome spinel inclusions, show rounded edges/embayed outlines, and be partly altered to chlorite/serpentine.

Sample no. **WB-17**
Drill hole: **CD4BII-D001 (Depth 50.35-50.70 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample is poorly sorted, made up of gravel-grade, medium dark gray clasts and the finer-grained matrix in roughly equal

proportion. The gravel-grade clasts have highly variable grain sizes, up to boulder sizes (35 cm across). The finer-grained matrix is composed of sand-, silt- and clay-grade clasts that show a dark brown color. Most of the gravel-grade clasts are subangular to rounded, with low to high sphericity. Patches of whitish minerals, as cementing material and as cavity-infillings, are abundantly present in this core sample. The rock is non-magnetic and non-calcareous.

Microscopic Description: The studied thin section has been made on a boulder-sized clasts. The clast shows a moderately porphyritic texture, with phenocrysts/microphenocrysts of olivine and plagioclase (sizes up to 1.0 mm across). These phenocrysts/microphenocrysts occur as isolated crystals and glomerocrysts, and as olivine-plagioclase cumulocrysts, and sit in the felty, seriate-textured groundmass, with grain sizes largely between 0.02 and 0.05 mm across. The groundmass constituents include abundant plagioclase laths, and blackish brown glass (tachylite) with minor olivine grains. The studied thin section slightly contains vesicles sealed by zeolites that may have formed radiate patterns, and/or sealed by clay mineral.

Plagioclase phenocrysts/microphenocrysts (sizes up to 1.0 mm across) and groundmass plagioclase grains are largely subhedral, and may show complex zonation. Determination of An-content via a petrographic technique reveals that these plagioclase crystals have An-content varying from 35 to 75 (andesine to bytownite). The interstitial material to groundmass plagioclase crystals is glass (tachylite) and olivine grains. Some groundmass plagioclase crystals occur as chadacrysts enclosed in larger olivine oikocrysts, giving rise to ophitic/subophitic texture.

Olivine phenocrysts/microphenocrysts are commonly anhedral to subhedral, and have sizes up to 0.8 mm across. They may contain chrome spinel inclusions and show rounded edges. The groundmass olivine grains are commonly anhedral grains.

Sample no. **WB-19**

Drill hole: **CD4BII-D001 (Depth 93.05 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample is a portion of cobble-grade clast (size of about 10 cm across) and has a slightly porphyritic texture, with dark green and black phenocrysts (sizes up to about 1.0 mm across). The groundmass is fine-grained, and has a very dark gray color. The rock shows no sign of magnetic property and does not react with diluted hydrochloric acid.

Microscopic Description: The clast contains phenocrysts/microphenocrysts of olivine and plagioclase, with sizes up to 0.7 mm across. These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. They sit in the felty groundmass (grain sizes largely up to 0.04 mm across), consisting mainly of plagioclase laths and blackish brown tachylite, with minor olivine grains. The clast rarely contains vesicles (sizes up to 0.2 mm across) sealed by zeolites.

Plagioclase phenocrysts/microphenocrysts are largely subhedral (sizes up to 0.6 mm) and often occur as glomerocrysts and cumulocrysts. They also show embayed outlines and/or rounded edges. These phenocrysts/microphenocrysts rarely show complex zonation, may have been slightly replaced by sericite and clay mineral, and have An-content varying from 62 (labradorite) to 83 (bytownite), on the basis of petrographic technique. The groundmass plagioclase grains generally have subhedral outlines. The interstitial material to felty plagioclase laths includes tachylite and minor olivine grains.

Olivine phenocrysts/microphenocrysts are largely subhedral to anhedral (sizes up to 0.7 mm across), while olivine groundmass grains are largely anhedral. The olivine phenocrysts/microphenocrysts may show rounded edges and embayed outlines, and contain chrome spinel inclusions.

Sample no. **WB-21**

Drill hole: **CD4BII-D001 (Depth 173.8-174.0 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample contains gravel-grade, medium dark gray clasts up to cobble (size of about 20 cm across) and dark brown, fine-grained matrix (sand-, silt-, clay-grade clasts). The gravel-grade clasts are angular to subrounded, and have low to high sphericity. Patches of whitish minerals occur as cementing material, cavity-infillings, and as veins. The rock has a non-magnetic property and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of a cobble-grade clast with a moderately porphyritic texture. It has phenocrysts/microphenocrysts of olivine and plagioclase, with sizes up to 0.6 mm across. These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The groundmass is hypohyaline-textured, with grain sizes largely up to 0.05 mm across, and consists largely of felty plagioclase laths and blackish tachylite, with minor olivine grains. The cobble-grade clast contains vesicles (sizes up to 0.25 mm across) largely sealed by zeolites and/or clay minerals.

Plagioclase phenocrysts/microphenocrysts are largely subhedral, and rarely show complex zonation. They have An-content, on the basis of petrographic technique, varying from 30 to 70 (andesine to labradorite). The interstitial minerals to felty plagioclase laths include abundant blackish tachylite, and minor of olivine grains. The groundmass plagioclase laths rarely occur as chadacrysts enclosed in a larger olivine oikocryst, giving rise to ophitic/subophitic textures. Plagioclase crystals are slightly altered to clay minerals and sericite.

Olivine phenocrysts/microphenocrysts largely show subhedral to anhedral outlines, while groundmass olivine grains commonly have anhedral outlines. These phenocrysts/microphenocrysts may show rounded edges, corroded outlines and sieve textures, and contain chrome spinel inclusions.

Sample no. **WB-22**

Drill hole: **CD4BII-D001 (Depth 180.37-1180.47.0 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample is poorly sorted, and consists of gravel-grade, medium dark gray clasts, up to cobble (size of 10 cm across), and dark brown, fine-grained matrix (sand-, silt-, clay-grade clasts). The gravel-grade clasts show subangular to rounded outlines, with low to high sphericity. They are loosely embedded in the finer-grained matrix, leading to matrix-supported fabric. Patches of whitish minerals occur as cementing material and cavity (fracture and vesicle) - infillings. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of a cobble-grade clast with a moderately porphyritic texture. It contains phenocrysts/microphenocrysts of olivine and plagioclase that occur as isolated crystals, glomerocrysts, and as olivine-plagioclase cumulocrysts. Olivine phenocrysts/microphenocrysts have sizes up to 0.6 mm across, while plagioclase occurs only as microphenocrysts with sizes up to 0.4 mm across. The groundmass is fine-grained, hypohyaline textured, and composed largely of felty plagioclase laths, with subordinate blackish brown volcanic glass (tachylite) and minor olivine grains. The groundmass has grain sizes largely up to 0.04 mm across. The rock is slightly replaced by irregular patches of chloritic material/clay minerals.

Plagioclase phenocrysts/microphenocrysts are largely subhedral, and may show complex zonation and embayed outlines. The An-content of these plagioclase crystals are from 58 (labradorite) to 90 (bytownite). Groundmass plagioclase grains largely show subhedral outlines. The interstitial minerals to felty plagioclase laths are abundant blackish brown tachylite and a small amount of olivine grains.

Olivine phenocrysts/microphenocrysts are largely subhedral to anhedral, and may display embayed outlines and rounded edges, and contain minor chrome spinel

inclusions. The groundmass olivine grains have anhedral outlines. All generations of olivine may be slightly altered to chlorite/serpentine and iddingsite.

Sample no. **WB-25**
Drill hole: **CD4BII-D002 (Depth 128.55-128.65 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample is a portion of boulder grade-clast (at a depth interval of 126.5-129.3 m) with a size of 2.8 m in diameter. It shows a slightly porphyritic texture, with dark green phenocrysts (sizes up to 1.0 mm across). The groundmass is fine-grained, and has a dark gray color. The sample is non-magnetic, and does not react with diluted hydrochloric acid.

Microscopic Description: The sample contains occasional phenocrysts but has abundant microphenocrysts. The phenocrysts/microphenocrysts include plagioclase and olivine that occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts sit in the fine-grained groundmass, consisting largely of felty plagioclase laths, with subordinate glass and quench crystals (i.e. skeletal grains, acicular crystals and microlite).

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.5 mm across) generally have subhedral outlines and rarely show complex zonation. They may contain olivine inclusions, and have An-content varying from 45 to 75 (andesine to bytownite), on the basis of petrographic technique. Groundmass plagioclase grains are largely subhedral, and the interstitial material to felty plagioclase laths is tachylite.

Olivine phenocrysts/microphenocrysts (sizes up to 0.7 mm across) are largely anhedral to subhedral, often show rounded edges/embayed outlines, and may contain minor chrome spinel inclusions. The groundmass olivine grains generally have anhedral outlines. All phases of olivine crystals have been variably altered to chlorite/serpentine.

Sample no. **WB-29**

Drill hole: **CD4BII-D003 (Depth 28.6-29.0 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents a boulder-grade clast that has a moderately porphyritic texture, with dark green and black phenocrysts. The groundmass is fine-grained, and has a dark gray color. The studied boulder-grade clast locally contains abundant vesicles and/or fractures sealed by white minerals. In addition, small, black and brown, glassy fragments are present along the fracture-infillings, and the walls of these fractures are glassy, signifying that the glassy fragments formed by *in situ* quench fragmentation.

Microscopic Description: The phenocrysts/microphenocrysts present are plagioclase and olivine (sizes up to 0.6 mm across). They occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts, sitting in the hypohyaline groundmass, with grain sizes largely in a range of 0.01 - 0.04 mm across. The hypohyaline groundmass consists mainly of felted plagioclase laths and tachylite, with a small amount of olivine grains. Rare vesicles in the studied thin section (sizes up to 0.4 mm across) are occupied by zeolites.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.5 mm across) largely have subhedral outlines and rarely show complex zonation. They have been slightly to moderately altered to clay mineral and sericite. The plagioclase crystals have An-content varying from 45 to 84 (andesine to bytownite) on the basis of petrographic technique. Groundmass plagioclase grains generally have subhedral outlines. The interstitial material to felty plagioclase laths is largely tachylite, with a small amount of olivine grains.

Olivine phenocrysts/microphenocrysts (sizes up to 0.6 mm across) largely have anhedral to subhedral outlines and may be slightly to moderately altered to chlorite/serpentine. These phenocrysts/microphenocrysts may have minor chrome spinel inclusions, rounded edges and embayed outlines. Groundmass olivine grains have anhedral outlines and may have been variably altered to chlorite/serpentine.

Sample no. **WB-32**

Drill hole: **CD4BII-D003 (Depth 96.6-96.8 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents a boulder-grade clast at a depth interval of 96.2 - 97.65 m with a size of 1.45 m. It is a slightly porphyritic rock, with dark-colored phenocrysts (sizes up to 1.0 mm across). The groundmass is fine-grained, has a dark gray color and contains abundant felty, whitish feldspar laths. The sample is non-magnetic and non-calcareous.

Microscopic Description: Although the rock is slightly porphyritic in hand specimen, it is moderately microporphyritic under the microscope. The phenocrysts/microphenocrysts (sizes up to 1.0 mm across) are plagioclase and olivine that occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts sit in the groundmass that has a hypohyaline texture, with grain sizes largely in a range of 0.01 - 0.04 mm across. The groundmass consists mainly of felted plagioclase laths and tachylite, with minor olivine and Fe-Ti oxide grains.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.5 mm across) largely have subhedral outlines, and may show embayed outlines. The An-content of plagioclase crystals are from 43 to 75 (andesine to bytownite), on the basis of petrographic technique. Groundmass plagioclase grains are largely subhedral; the interstitial material to plagioclase laths is abundant tachylite and minor olivine grains. All phases of plagioclase crystals have been slightly replaced by sericite and clay mineral.

Olivine phenocrysts/microphenocrysts are largely anhedral to subhedral, may have minor chrome spinel inclusions, and may show rounded edges and embayed outlines. Groundmass olivine grains have anhedral outlines. All phases of olivine grains have been slightly to moderately altered to chlorite/serpentine.

Sample no. **WB-34**

Drill hole: **CD4BII-D003 (Depth 118.6-118.75 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample consists of gravel-grade, medium dark gray clasts, up to cobble grade (size of about 15 cm across), loosely sitting in dark brown, finer-grained matrix (sand-, silt-, clay-grade clasts). The gravel-grade clasts are subangular to rounded, and have low to high sphericity. Patches of whitish minerals occur as cementing material and cavity-infillings. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of a cobble-grade clast with a moderately porphyritic texture. It contains phenocrysts/microphenocrysts of olivine and plagioclase (sizes up to 1.0 mm across). These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts, and as olivine-plagioclase cumulocrysts, and sit in the fine-grained groundmass, with grain sizes largely between 0.02 - 0.04 mm across. The groundmass shows a hypocrystalline texture, consisting largely of felty plagioclase laths and blackish brown volcanic glass (tachylite), with a small amount of olivine grains.

Plagioclase phenocrysts/microphenocrysts are largely subhedral (sizes up to 0.8 mm across), and may contain complex zonation. Groundmass plagioclase grains largely have subhedral outlines. The interstitial material to felty plagioclase laths is largely tachylite, with minor olivine grains. Plagioclase crystals have An-content varying from 37 (andesine) to 70 (labradorite), on the basis of petrographic technique.

Olivine phenocrysts/microphenocrysts are largely subhedral to anhedral (sizes up to 1.0 mm across). They commonly have embayed outlines and/or rounded edges. They may contain minor chrome spinel inclusions. Groundmass olivine grains are commonly anhedral.

Sample no. **WB-35**

Drill hole: **CD4BII-D003 (Depth 124.4-124.60 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample consists of gravel-grade, medium dark gray clasts, up to cobble grade (size of about 15 cm across), and dark brown, finer-grained matrix (sand-, silt- and clay-grade clasts). Patches of whitish minerals occur as cementing material and as cavity-infillings. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of a cobble-grade clast with a moderately porphyritic texture. The cobble-grade clast shows phenocrysts/microphenocrysts of olivine and plagioclase (with sizes up to 0.6 mm across) that occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts are embedded in the fine-grained, hypohyaline groundmass. The groundmass comprises abundant felty plagioclase laths, subordinate blackish brown volcanic glass (tachylite) and yellowish brown volcanic glass (sideromelane), and minor olivine grains. The clast locally contains tiny veins, with thickness up to 0.05 mm, and vesicles that are infilled with zeolites and clay minerals. The portions of yellowish brown sideromelane in contact with fracture- and cavity-infillings often turn to dark brown and bluish green palagonite.

Plagioclase phenocrysts/microphenocrysts are largely subhedral (sizes up to 0.6 mm across). They rarely show complex zonation. These phenocrysts/microphenocrysts may have been slightly replaced by clay minerals and sericite. These plagioclase crystals have An-content varying from 60 (labradorite) to 84 (bytownite) on the basis of petrographic technique. The interstitial material to felty groundmass plagioclase laths includes abundant tachylite, subordinate palagonite and minor olivine grains. The groundmass plagioclase laths may occur as chadacrysts enclosed in olivine oikocrysts, giving rise to ophitic/subophitic textures.

Olivine phenocrysts/microphenocrysts are largely subhedral to anhedral (sizes up to 0.6 mm across), while the groundmass olivine grains are anhedral. They may

show rounded edges and embayed outlines, and may contain chrome spinel inclusions in minor amount.

Sample no. **WB-38**
Drill hole: **CD4BII-D003 (Depth 155.7-156.0 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample is poorly sorted, and consists of gravel-grade, medium dark gray clasts, up to boulder grade (size of 30 cm across), and dark brown, finer-grained matrix (sand-, silt- and clay-grade clasts). Patches of whitish minerals occur as cementing material and as cavity (fracture and vesicle) -infillings. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of a boulder-grade clast with a strongly porphyritic texture. It has phenocrysts/microphenocrysts of olivine and plagioclase (with sizes up to 1.2 mm across) that occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The groundmass is fine-grained, with grain sizes largely in a range of 0.02 - 0.05 mm across, and is composed largely of felty plagioclase laths, with subordinate blackish brown volcanic glass (tachylite) and minor olivine grains. Very few fractures and vesicles have been observed and are sealed by zeolites and clay minerals.

Plagioclase phenocrysts/microphenocrysts and groundmass plagioclase grains are largely subhedral. The plagioclase phenocrysts/microphenocrysts commonly occur as glomerocrysts and as plagioclase-olivine cumulocrysts. They rarely have complex zonation, and may show embayed outlines. The An-content of plagioclase crystals, on the basis of optical mean, varies from 60 (labradorite) to 82 (bytownite). They may have been slightly replaced by clay mineral and sericite. The interstices of felty plagioclase laths have been occupied by blackish brown trachylite that may be replaced by clay mineral, and a small amount of olivine grains.

Olivine phenocrysts/microphenocrysts are largely subhedral to anhedral (sizes up to 0.6 mm across), while groundmass olivine grains are anhedral. They commonly show embayed outlines and/or rounded edges, and contain occasional chrome spinel inclusions.

Sample no. **WB-40**
Drill hole: **CD4BII-D004 (Depth 12.5-12.75 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents an inner part of boulder-grade clast (size of 1.15 m, depth interval of 12.00 - 13.15 m) that shows a moderately porphyritic texture. The phenocrysts have sizes up to 1.0 mm across, with a dark color. They are embedded in the dark gray, fine-grained groundmass that contains abundant small vesicles (sizes up to 1.0 mm across), sealed by pale green and whitish minerals. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section contains phenocrysts/microphenocrysts of plagioclase and olivine (sizes up to 0.8 mm across) that occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts sit in the groundmass that has a hypohyaline texture, with grain sizes largely in a range of 0.02 - 0.05 mm across. The hypohyaline groundmass consists mainly of felted-plagioclase laths, with subordinate tachylite, and small amounts of olivine and clinopyroxene grains. The vesicles as observed in hand specimen have been sealed by zeolites (whitish in hand specimen) and clay minerals (pale green in hand specimen).

Plagioclase occurs as microphenocrysts and as a groundmass phase. The plagioclase microphenocrysts have sizes up to 0.4 mm across, largely have subhedral outlines, and rarely show complex zonation. The An-content of plagioclase crystals ranges from 50 to 77 (labradorite to bytownite), on the basis of petrographic technique. Groundmass plagioclase grains are largely subhedral, and the interstitial material to felted plagioclase laths is mainly tachylite, with minor olivine grains.

Olivine phenocrysts/microphenocrysts (sizes up to 0.8 mm across) largely have anhedral to subhedral outlines and are variably replaced by chlorite/serpentine and iddingsite. These phenocrysts/microphenocrysts may have rounded edges and embayed outlines, and may contain chrome spinel inclusions. Groundmass olivine grains have anhedral outlines and are variably altered to chlorite/serpentine.

Clinopyroxene occurs only as a groundmass constituent and shows anhedral to subhedral outlines.

Sample no. **WB-41**
Drill hole: **CD4BII-D004 (Depth 42.7-43.2 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents a part of boulder clast (size of about 50 cm) in *in situ* hyaloclastite. The sample has a slightly porphyritic texture, with dark-colored phenocrysts. The groundmass is fine-grained, and shows a medium dark gray color. Very few whitish vienlets and drusy fracture-infillings of whitish and colorless minerals have been observed. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of boulder-grade clast with a slightly porphyritic texture. It contains phenocrysts/ microphenocrysts of olivine and plagioclase that have sizes up to 0.6 mm across. The plagioclase phenocrysts/microphenocrysts are more common relative to olivine phenocrysts/microphenocrysts. These phenocrysts/microphenocrysts occur as isolated crystals and as glomerocrysts, sitting in the fine-grained groundmass with a hypohyaline texture. The groundmass is composed largely of felty plagioclase laths, with subordinate blackish brown volcanic glass (tachylite), and minor clinopyroxene and olivine grains. The groundmass has grain sizes largely up to 0.08 mm across. The clast shows many vesicles and cavities that are filled by zeolites and or minor clay minerals. Very few veinlets of zeolites have been observed in the sample.

Plagioclase phenocrysts/microphenocrysts are largely subhedral, and have been slightly altered to clay minerals and sericite; complex zonation has rarely been observed. The An-content of plagioclase crystals ranges from 58 (labradorite) to 82 (bytownite). Groundmass plagioclase grains are largely subhedral, with a felty arrangement, and their interstices are occupied by blackish brown tachylite, clinopyroxene and a small amount of olivine grains.

Olivine phenocrysts/microphenocrysts are largely subhedral. They have been variably altered to chlorite/serpentine and/or iddingsite. They may contain spinel inclusions and show embayed outlines and/or rounded edges. The groundmass olivine grains are anhedral, and also have been variably altered to chlorite/serpentine and/or iddingsite.

Clinopyroxene crystals occur only as a groundmass constituent. They largely show anhedral patches, with minor subhedral outlines; many show quench features.

Sample no. **WB-42**
Drill hole: **CD4BII-D004 (Depth 70.85-71.05 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample is poorly sorted, and consists of gravel-grade, medium dark gray clasts, up to cobble grade (size of 20 cm across), and dark brown, finer-grained matrix (sand-, silt- and clay-grade clasts). The gravel-grade clasts show subangular to rounded outlines, with low to high sphericity. They are loosely embedded in the finer-grained matrix, leading to matrix-supported fabric. Patches of whitish minerals occur as cementing material and as cavity (fracture and vesicle) -infillings. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of a cobble-grade clast with a highly vitrophyric texture. It contains phenocrysts/microphenocrysts of plagioclase and olivine, with sizes up to 0.9 mm across; the former is more abundant than the latter. These phenocrysts/microphenocrysts occur as isolated crystals,

glomerocrysts and as olivine-plagioclase cumulocrysts. They sit in the hyalophitic groundmass, made up largely of tachylite, with subordinate felty plagioclase laths and olivine grains. The glassy groundmass contains many irregular cavities that are partly filled by zeolites. Veinlets of zeolites are rarely present in the sample.

Plagioclase phenocrysts/microphenocrysts are largely subhedral (sizes up to 0.8 mm across) and often show complex zonation. They may have embayed outlines, and/or be replaced by epidote. The An-content of plagioclase crystals varies from 57 (labradorite) to 82 (bytownite) on the basis of petrographic technique. The groundmass plagioclase grains generally have subhedral outlines.

Olivine phenocrysts/microphenocrysts (sizes up to 0.9 mm across) are largely subhedral to anhedral. They may contain spinel inclusions, embayed outlines and rounded edges. They have been variably altered to chlorite/serpentine and/or iddingsite. The groundmass olivine grains are anhedral, and also have been variably altered to chlorite/serpentine.

Sample no. **WB-43**
Drill hole: **CD4BII-D004 (Depth 140.10-140.50 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents a boulder-grade clast (size of 40 cm across) that shows a strongly porphyritic texture, with abundant whitish and subordinate dark-colored phenocrysts. These phenocrysts are embedded in the fine-grained groundmass, which is black in color. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section shows a strongly vitrophyric texture. It contains phenocrysts/microphenocrysts of olivine and plagioclase, with sizes up to 0.6 mm across. These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts, and sit in hyalophitic groundmass. The groundmass consists largely of tachylite and yellowish brown sideromelane (tachylite is more common), with subordinate olivine grains. The

studied boulder-grade clast also has many vesicles and cavities that are filled by common zeolites and/or uncommon clay minerals.

Plagioclase phenocrysts/microphenocrysts are largely subhedral, and rarely show complex zonation. These phenocrysts/microphenocrysts may have embayed outlines and glassy inclusions. Plagioclase crystals have An-content varying from 33 (andesine) to 72 (bytownite) on the basis of petrographic technique. The groundmass plagioclase grains are largely subhedral.

Olivine phenocrysts/microphenocrysts are largely subhedral to anhedral, while groundmass olivine grains have anhedral outlines. Olivine microphenocrysts are more common relative to olivine phenocrysts/microphenocrysts. Olivine phenocrysts/microphenocrysts commonly display embayed outlines and/or rounded edges. They may contain minor chrome spinel inclusions.

Sample no. **WB-44**

Drill hole: **CD4BII-D004 (Depth 144.50-144.8 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents a boulder-grade clast (size of 30 cm across) that shows a slightly porphyritic texture, with dark-colored phenocrysts. The groundmass is fine-grained, and shows a black color. This boulder-grade clast has low sphericity and sits in the matrix that has been largely altered to yellowish brown color.

Microscopic Description: The studied thin section shows a strongly porphyritic texture. The phenocrysts/microphenocrysts are largely plagioclase, with minor olivine. These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The groundmass consists mainly of plagioclase laths, and blackish volcanic glass (tachylite), quench crystals (i.e. microlite and skeletal grains of plagioclase), and small amounts of olivine and Fe-Ti oxide grains. The glassy groundmass may have been altered and replaced by zeolites.

The studied boulder-grade clast contains vesicles that are infilled by abundant zeolites and/or minor clay minerals.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.5 mm across) are largely subhedral, and may have embayed outlines. They are slightly replaced by clay minerals. The An-content of plagioclase crystals are from 45 (andesine) to 70 (labradorite) on the basis of petrographic technique. The groundmass plagioclase grains generally have subhedral outlines. They occur as acicular crystals and skeletal grains that have been formed by quenching. The interstitial material to felted plagioclase laths is volcanic glass, clinopyroxene and olivine. The interstitial clinopyroxene forms as radiate, acicular crystals, typical of variolitic texture.

Olivine phenocrysts/microphenocrysts (sizes up to 0.6 mm across) are largely subhedral to anhedral, while groundmass olivine grains have anhedral outlines. The olivine microphenocrysts are more common relative to the olivine phenocrysts. These phenocrysts/microphenocrysts may have embayed outlines, rounded edges and chrome spinel inclusions, and may be partly altered to chlorite/serpentine.

Sample no. **WB-46**
Drill hole: **CD4BII-D004 (Depth 194.5-194.7 m)**
Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample represents a cobble-grade clast (size of 20 cm across) in *in situ* hyaloclastite. It is a slightly porphyritic rock, with dark-colored phenocrysts. The groundmass is fine-grained, and has a medium dark gray color. Very small vesicles sealed by whitish minerals are abundantly present, however, veinlets of whitish minerals are rare. The sample has no magnetic property and is non-calcareous.

Microscopic Description: Although the sample shows a slightly porphyritic texture in hand specimen, it contains abundant microphenocrysts. The phenocrysts/microphenocrysts include abundant plagioclase and minor olivine, with sizes up to 0.8 mm across. These phenocrysts/microphenocrysts occur as isolated

crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The groundmass is hypocrystalline, with grain sizes of about 0.01 mm across, and consists mainly of felted plagioclase laths, blackish and pale brown volcanic glass, and clinopyroxene, with small amounts of olivine and Fe-Ti oxide grains. This cobble-grade clast also shows vesicles and fractures that are sealed by zeolites.

Plagioclase phenocrysts/microphenocrysts (sizes up to 0.6 mm across) are largely subhedral, and rarely show complex zonation. They may have embayed outlines; their An-content is in a range of 65 (labradorite) - 83 (bytownite), on the basis of petrographic technique. The groundmass plagioclase grains generally have subhedral outlines. The interstitial material to felted plagiolcase laths is clinopyroxene, glassy patches, olivine, and Fe-Ti oxide grains. The plagioclase laths may occur as chadacrysts enclosed in a pale brown glassy patch, giving rise to hyalophitic texture. The plagioclase crystals have slightly experienced alteration, leading to the occurrences of clay minerals and sericite.

Olivine phenocrysts/microphenocrysts (sizes up to 0.8 mm across) are largely subhedral to anhedral, while groundmass olivine grains generally have anhedral outlines. The olivine phenocrysts are much less abundant relative to the olivine microphenocrysts. These phenocrysts/microphenocrysts may have been slightly replaced by chlorite/serpentine, show embayed outlines and rounded edges, and have minor chrome spinel inclusions.

Clinopyroxene occurs only as a groundmass constituent that forms either as quench crystals, i.e. skeletal grains and acicular crystals, or anhedral grains. The acicular crystals of clinopyroxene may occur in the form of variolitic texture.

Sample no. **WB-47**

Drill hole: **CD4BII-D004 (Depth 236.5-236.64 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample comprises gravel-grade, medium dark gray clasts (up to 14 cm across) and dark brown, finer-grained matrix. Patches of

whitish mineral occur as cementing material. A few veinlets of whitish mineral have been observed in the sample. The rock shows no sign of magnetism and does not react with diluted hydrochloric acid.

Microscopic Description: The studied thin section is a portion of a cobble-grade clast (size of 14 cm across) that shows a slightly porphyritic texture in hand specimen, but a highly microporphyritic under the microscope. The phenocrysts/ microphenocrysts include plagioclase (sizes up to 1.2 mm across) and olivine (sizes up to 1.0 mm across). These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The groundmass shows hypohyaline texture and has grains sizes largely in a range of 0.01 - 0.03 mm across. The groundmass consists of plagioclase laths, glassy patches, quench crystals (i.e. plagioclase skeletons, microlite, acicular crystals of clinopyroxene and plagioclase) and a small amount of olivine grains. Vesicles are present in minor amount and are sealed by zeolites and/or clay minerals.

Plagioclase phenocrysts/microphenocrysts are largely subhedral. They may have embayed outlines and olivine inclusions, and rarely show complex zonation. The An-content of plagioclase crystals are from 45 (andesine) to 82 (bytownite) on the basis of petrographic technique. The groundmass plagioclase grains generally have subhedral outlines. The interstitial minerals to plagiolcase laths are largely of glassy patches, with subordinate quench crystals and small amounts of olivine and opaque grains.

Olivine phenocrysts/microphenocrysts are largely subhedral to anhedral. The olivine phenocrysts are much less abundant relative to the olivine microphenocrysts. These phenocrysts/microphenocrysts may have rounded edges, embayed outlines and chrome spinel inclusions. The groundmass olivine grains have anhedral outlines and may show skeletal grains generated by quenching.

Clinopyroxene occurs only as a groundmass constituent that forms either as quench crystals, i.e. skeletal grains and acicular crystals, or as anhedral grains. The acicular crystals of clinopyroxne may occur in the form of variolitic texture.

Sample no. **WB-49**

Drill hole: **CD4BII-D005 (Depth 64.55-64.95 m)**

Rock type: **Coherent facies basaltic clast in basalt breccia**

Megascopic Description: The core sample is a portion of boulder-grade clast at a depth interval of 64.55 to 64.95 m. It has a moderately porphyritic texture and has dark-colored phenocrysts, with sizes up to 1.0 mm across. The groundmass is fine-grained, and has a black color. A number of fractures, occupied by whitish minerals, are locally present in the sample. The rock is non-magnetic and non-calcareous.

Microscopic Description: The studied thin section contains phenocrysts/microphenocrysts of plagioclase and olivine, with sizes up to 0.6 mm across. They occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. These phenocrysts/microphenocrysts sit in the hypohyaline groundmass, with grain sizes largely in a range of 0.01 - 0.04 mm across. The hypohyaline groundmass consists principally of felted-plagioclase laths, with subordinate blackish-colored tachylite, and a small amount of olivine grains. Very few vesicles and fractures, sealed by zeolites, have been observed in the sample.

Plagioclase phenocrysts/microphenocrysts largely have subhedral outlines and rarely show complex zonation. The An-content of plagioclase crystals, measured via a petrographic method, ranges from 60 to 84 (labradorite to bytownite). Groundmass plagioclase grains largely have subhedral outlines and the interstitial material to felted plagioclase laths is tachylite and olivine grains. The plagioclase phenocrysts/microphenocrysts and groundmass plagioclase grains are variably altered to clay minerals and sericite.

Olivine phenocrysts/microphenocrysts are largely anhedral to subhedral; rounded edges and/or embayed outlines have been occasionally observed. They may contain minor chrome spinel inclusions and be variably altered to chlorite/serpentine. Groundmass olivine grains commonly have anhedral outlines and are also variably altered to chlorite/serpentine.

APPENDIX D

SAMPLE LOCATIONS AND PETROGRAPHIC FEATURES OF THE STUDIED CORE SAMPLES,

INCOHERERNT FACIES : MATRIX-SUPPORTED BASALT BRECCIA

BAN SAP SAWAT, WICHIAN BURI DISTRICT,

PHETCHABUN PROVINCE

Sample no. **WB-15**

Drill hole: **CD4BII-D001 (depth 21.7-22.0 m)**

Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample consists of poorly sorted, gravel-grade clasts (sizes up to 5.0 cm across) and finer-grained matrix (sand-, silt- and clay-grade particles). The gravel-grade clasts are much less abundant relative to the finer-grained matrix, resulting in matrix-supported fabric. The gravel-sized clasts are least altered, and have subangular to rounded outlines, with low to high sphericity, and are dominated by pebble sizes. The finer-grained matrix constituents are largely altered, giving rise to a yellowish brown color. Vesicles infilled with white minerals have been observed in some gravel-grade clasts, and tiny patches of white mineral as cementing material are abundantly present.

Microscopic Description: The gravel-grade clasts are strongly vitrophyric basalt, with olivine microphenocrysts and plagioclase phenocrysts/microphenocrysts. They occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The olivine microphenocrysts (sizes up to 0.45 mm across) are largely subhedral to anhedral, and may have chrome spinel inclusions. The plagioclase phenocrysts/microphenocrysts (sizes up to 1 mm across) are largely subhedral, with An-content, on the basis of petrographic technique, varying from 35 (andesine) to 75 (bytownite). The groundmass of vitrophyric clasts is generally pale yellowish brown sideromelane, with dark brownish and greenish palagonite rims (up to 0.05 mm thick), and quench crystals. The dark-colored, tachylite-bearing groundmass is uncommon. Vesicles, variably present in some clasts, are infilled with zeolites and clay minerals, and the glassy walls of vesicles are replaced by greenish and brownish palagonite.

The constituents of finer-grained matrix are clasts of vitrophyric basalt and their derivative constituents, i.e. glass, olivine and plagioclase. The original sideromelane in these fragments of vitrophyric basalt are commonly replaced by dark brown and green palagonite. These clasts are partly cemented by zeolites, giving rise to tiny, white patches.

Sample no. **WB-16**

Drill hole: **CD4BII-D001 (depth 45.7-45.9 m)**

Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The poorly sorted, core sample consists of dark gray, gravel-grade clasts (sizes up to 5.0 cm across) and dark yellowish brown, finer-grained matrix of clay- to sand-grade particles. The gravel-grade clasts are much less abundant relative to the matrix, leading to matrix-supported fabric. The gravel-sized clasts, as framework constituents, have subangular to rounded shapes and low to high sphericity, and are dominated by pebble sizes. The finer-grained matrix constituents are largely altered, and have a yellowish brown color. Patches of whitish minerals have been observed throughout the sample as differently sized cavity infillings and cementing material.

Microscopic Description: The gravel-grade clasts show a strongly vitrophyric texture, with olivine and plagioclase phenocrysts/microphenocrysts. They occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The olivine phenocrysts/ microphenocrysts (sizes up to 0.6 mm across) are largely subhedral to anhedral, and may have chrome spinel inclusions. The plagioclase phenocrysts/microphenocrysts (sizes up to 0.6 mm across) are largely subhedral, with An-content, on the basis of petrographic technique, ranging from 37 (andesine) to 75 (bytownite). The groundmass is glassy textured, consisting of common pale yellowish brown sideromelane, and uncommon dark colored tachylite, with minor quench crystals of olivine and plagioclase. The gravel-grade clasts are commonly rimmed with dark brownish and bluish green palagonite rims.

The constituents of finer-grained matrix are clasts of vitrophyric basalt, compositionally similar to the gravel-grade clasts, and their derivative glassy fragments and crystal fragments. The original sideromelane in these fragments of vitrophyric basalt are commonly replaced by dark brown and green palagonite.

The whitish cavity-infillings and cementing material as observed in hand specimen are zeolites.

Sample no. **WB-18**

Drill hole: **CD4B-D001 (depth 91.25-91.5 m)**

Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample comprises poorly-sorted, gravel-grade clasts (up to 5 cm across) sitting in the finer-grained matrix (sand-, silt- and clay-grade clasts). The gravel-grade clasts are mainly granules and pebbles, and are much less abundant relative to matrix, giving rise to matrix supported fabric. The granule-pebble grade clasts show a dark gray color, and have dark and dark green phenocrysts in minor amount. They have subangular to rounded outlines and low to high sphericity. The whitish mineral has been observed as cementing material and also as occasional veinlets.

Microscopic Description: The gravel-grade clasts show a strongly vitrophyric texture, with abundant olivine and/or plagioclase phenocrysts/microphenocrysts. These phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. Plagioclase phenocrysts/microphenocrysts (sizes up to 1.0 mm across) are commonly subhedral and uncommonly anhedral, and may have zonation. The An-content of plagioclase crystals varies from 35 (andesine) to 75 (bytownite), on the basis of petrographic technique. The olivine phenocrysts/microphenocrysts have sizes up to 1.0 mm across and largely show subhedral to anhedral outlines. These olivine phenocrysts/microphenocrysts may have chrome spinel inclusions. The groundmass of vitrophyric clasts is glassy, consisting largely of yellowish brown sideromelane, with minor quench crystals of plagioclase and olivine. At rims of individual clasts, the groundmass sideromelane has been commonly replaced by brownish and bluish palagonite (black where weathered). The vesicles of vitrophyric clasts are sealed by zeolites and clay minerals. The walls of vesicles are often replaced by brownish and bluish green palagonite.

The matrix is composed of vitrophyric clasts compositionally similar to the gravel-grade vitrophyric clasts and their derivatives, quench crystals of olivine and

plagioclase, and glassy fragments totally replaced by common brownish palagonite and uncommon bluish green palagonite.

The whitish minerals as observed in hand specimen are zeolites and clay minerals.

Sample no. **WB-20**
Drill hole: **CD4BII-D001 (depth 153.6-153.8 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample comprises variably sized, gravel-grade clasts (sizes up to 2.0 cm across) and finer-grained matrix (sand-, silt- and clay-grade particles), leading to poorly sorted fabric. The gravel-grade clasts are much less abundant relative to the finer-grained matrix, resulting in matrix-supported fabric. The gravel-sized clasts are least-altered, and have a black or dark gray color, while the matrix constituents are largely altered, and have a yellowish brown color. The gravel-grade clasts show subangular to rounded outlines, with low to high sphericity. The whitish minerals in this core sample acts as cementing material and cavity infillings.

Microscopic Description: The gravel-grade clasts show a strongly vitrophyric texture, with olivine and plagioclase phenocrysts/microphenocrysts. They occur as isolated crystals, glomerocrysts and as olivine-plagioclase cumulocrysts. The olivine phenocrysts/ microphenocrysts (sizes up to 0.6 mm across) are largely subhedral to anhedral, and may have chrome spinel inclusions. The plagioclase phenocrysts/microphenocrysts (sizes up to 0.6 mm across) are largely subhedral, with An-content, on the basis of petrographic technique, varying from 37 (andesine) to 75 (bytownite). The groundmass of vitrophyric clasts is generally pale yellowish brown sideromelane, with dark brownish and bluish green palagonite rims. Vesicles, variably present in some clasts, are infilled with zeolites and clay minerals, and the glassy walls of vesicles are replaced by bluish green and brownish palagonite.

The matrix is constituted by clay- to silt-grade clasts, compositionally similar to the gravel-grade clasts, and their derivative constituents, i.e. glass, olivine and

plagioclase. The original sideromelane in these fragments of vitrophyric basalt are commonly replaced by dark brown and bluish green palagonite. These clasts are partly cemented by zeolites, giving rise to tiny white patches.

Sample no. **WB-24**
Drill hole: **CD4B-D002 (Depth 74.0-74.3 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample contains poorly sorted, gravel-sized, dark gray clasts (sizes up to 2 cm across) loosely embedded in the yellowish brown, finer-grained matrix of clay- to sand-grade particles, resulting in matrix-supported fabric. The gravel-grade clasts are dominated by granule- and pebble-grade clasts, and have subangular to rounded shapes and low to high sphericity. The cementing material is whitish mineral. Very few fractures sealed by calcite have been observed in the sample.

Microscopic Description: The gravel-grade fragments show a strongly vitrophyric texture, with olivine and plagioclase phenocrysts/microphenocrysts. The matrix consists of finer-grained clasts, including vitrophyric basalt and their derivative constituents, i.e. glass, olivine and plagioclase. The whitish mineral as observed in hand specimen is either clay matrix or zeolite cements. The vitrophyric clasts comprise phenocrysts/microphenocrysts of olivine and plagioclase and glassy groundmass. The phenocrysts/microphenocrysts occur as isolated crystals, glomerocrysts, and as plagioclase-olivine cumulocrysts. Plagioclase occurs only as microphenocrysts (sizes up to 0.4 mm across) and largely has subhedral outlines, and may show zonation. Measurement of An-content in plagioclase via a petrographic technique reveals that they are compositionally oligoclase to bytownite (An-content of 25-75). Olivine phenocrysts/microphenocrysts (sizes up to 0.8 mm across) are largely subhedral to anhedral, and may contain chrome spinel inclusions. They may show sieve and embayment features. The glassy groundmass is made up largely of yellowish brown sideromelane and minor quench crystals of plagioclase and olivine, and tachylite. The rims of clasts are commonly replaced by brown palagonite, with

total thickness up to 0.05 mm. The vitrophyric clasts may have rare vesicles sealed by zeolites and clay minerals. The walls of vesicles are totally replaced by palagonite.

The matrix is constituted by vitrophyric clasts compositionally similar to the gravel-grade clasts and their derivative crystal fragments. The glassy clasts are almost totally replaced by brown palagonite. The cementing material in this sample is zeolite that has a white color in hand specimen. The whitish mineral as observed in this studied thin section is either zeolites or clay minerals.

Sample no. **WB-26**
Drill hole: **CD4B-D002 (depth 133.5-133.8 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample comprises poorly sorted clasts, consisting largely of sand-grade framework constituents and finer-grained (silt- and clay-grade) matrix in roughly equal proportion. Tiny irregular, whitish patches are ubiquitous in the matrix portion. Granule- and pebble-sized clasts (up to 6 cm across) are minor constituents.

Microscopic Description: The studied thin section has been made in the portion dominated by the already described, major constituents, with minor granule-grade fragments. The granule-grade fragments are vitrophyric basalt, with olivine and plagioclase phenocrysts/microphenocrysts. The sand- and silt-grade fragments include those of vitrophyric basalt and their derivative constituents, i.e. glass, olivine and plagioclase. The whitish patches as observed in hand specimen are either clay matrix or zeolite cements.

The fragments of vitrophyric basalt comprise phenocrysts/microphenocrysts of olivine and plagioclase in variable proportions, and glassy groundmass. They may contain variable amounts of vesicles sealed by clay minerals, chlorite and zeolites. Plagioclase phenocrysts/microphenocrysts have subhedral outlines, whereas olivine phenocrysts/microphenocrysts are subhedral to anhedral. These phenocrysts/microphenocrysts occur as isolated grains and as glomerocrysts.

Measurement of An-content in plagioclase via a petrographic technique reveals that they are compositionally andesine to labradorite (An-content of 38-51). Olivine may contain chrome spinel inclusions. The glassy groundmass is made up of quench crystals and yellowish brown sideromelane. Glass in very few fragments is tachylite instead of palagonite. The glassy rims and glassy walls of amygdales of individual rock fragments are often palagonitized, giving rise to dark brown glass.

The larger sand- and granule-grade, vitrophyric clasts have subangular to rounded outlines, with low to high sphericity. The finer vitrophyric clasts and their derivatives are commonly angular.

Sample no. **WB-28**
Drill hole: **CD4B-D003 (depth 1.7-2.0 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample comprises variably sized clasts (up to 2.5 cm across), leading to poorly sorted fabric. The gravel-sized clasts are much less abundant relative to the finer matrix constituents (sand-, silt- and clay-grade clasts), resulting in matrix-supported fabric. The gravel-sized clasts are least-altered/weathered, and have a black color, while the matrix constituents are largely altered/weathered, giving rise to a yellowish brown color. The least-altered/weathered clasts show subangular to rounded outlines and low to high sphericity. Also abundantly present in the core sample is a cement of white mineral.

Microscopic Description: The least-altered/weathered clasts, represented by gravel-grade clasts, show a strongly vitrophyric texture, with abundant olivine and/or plagioclase phenocrysts/microphenocrysts. These phenocrysts/microphenocrysts commonly have subhedral outlines, and occur as isolated crystals or as olivine glomerocrysts. The olivine phenocrysts/microphenocrysts largely contain chrome spinel inclusions. The groundmass is glassy, consisting of yellowish brown sideromelane and minor quench crystals, or tachylite. The sideromelane-bearing clasts are more common than the tachylite-bearing clasts. The clasts may have a

small amount of vesicles that are sealed by zeolites. The walls of amygdules and the rims of clasts are often replaced by chloritic material and palagonite.

The matrix is constituted by clasts compositionally similar to the gravel-grade vitrophyric clasts and their derivative crystal fragments. The glassy clasts are almost totally replaced by chloritic material and palagonite. The white cementing material as observed in hand specimen are zeolites.

Sample no. **WB-31**
Drill hole: **CD4B-D003 (Depth 89.5-90.0 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The poorly sorted, core sample consists of moderate dark gray, gravel-grade clasts (sizes up to 5 cm across) and dark yellowish brown, finer-grained matrix of clay- to sand-grade particles. The gravel-grade clasts are much less abundant relative to the matrix, resulting in matrix-supported fabric, and are dominated by granule-grade clasts. The framework constituents have subangular to rounded shapes and low to high sphericity. Very few fractures sealed by whitish and light olive minerals have been observed in the sample. Also present are rounded amygdales and irregular patches of whitish and light olive minerals.

Microscopic Description: The gravel-grade clasts show a strongly vitrophyric texture, with phenocrysts/microphenocrysts of plagioclase and olivine. These phenocrysts/microphenocrysts occur as isolated crystals and as glomerocrysts. Plagioclase occurs as microphenocrysts (sizes up to 0.4 mm across) with common subhedral outlines, while olivine occurs as phenocrysts/microphenocrysts (sizes up to 0.6 mm across) with subhedral to anhedral outlines. Olivine may be partly altered to chlorite/serpentine and carbonates, and contain chrome spinel inclusions. Plagioclase has An-content, measured by a petrographic technique, varying from 29 to 76 (oligoclase to bytownite). The groundmass is glassy-textured, consisting largely of light yellowish brown sideromelane, with minor quench crystals of plagioclase and olivine. Many clasts of vitrophyric basalt have dark brown or black tachylite groundmass. The sideromelane at rims of individual clasts have commonly been

replaced by dark brownish palagonite. These vitrophyric, basaltic clasts may contain vesicles sealed by zeolites, clay minerals and/or carbonates. The glassy walls of amygdales have also been replaced by chloritic material and palagonite.

The constituents of finer-grained matrix are clasts of vitrophyric basalt and their derivative, glassy fragments and crystal fragments. They are largely angular to subangular, with low to high sphericity. The sideromelane in these vitrophyric and glassy fragments have been replaced by dark brown palagonite and chloritic material. The cementing material in this sample is zeolites and carbonates that have white color in hand specimen, and chloritic material that shows light olive color in hand specimen.

Sample no. **WB-33**
Drill hole: **CD4B-D003 (Depth 111.23-111.43 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample is poorly sorted in nature, and consists of gravel-grade clasts (sizes up to 2.5 mm across) and finer-grained matrix (sand-, silt- and clay-grade particles). The matrix constituents are predominant over the framework constituents, giving rise to matrix-supported fabric. The gravel-grade clasts comprise abundant pebbles and subordinate granules, and show a dark gray color. They have angular to rounded outlines, with low to high sphericity. The matrix is dark yellowish brown in color. Cementing material and cavity-infillings of whitish minerals are commonly present in the sample.

Microscopic Description: The gravel-grade clasts show a strongly vitrophyric texture, with phenocrysts/microphenocrysts of plagioclase and olivine. These phenocrysts/ microphenocrysts occur as isolated crystals, glomerocrysts and as plagioclase-olivine cumulocrysts. Plagioclase occurs only as microphenocrysts, with sizes up to 0.4 mm across, and is largely subhedral. Measurement of An-content, via an optical method, reveals that the plagioclase microphenocrysts compositionally range from oligoclase to bytownite (An-content = 25 – 77). Olivine phenocrysts/microphenocrysts have sizes up to 0.8 mm across and commonly show

anhedral to subhedral outlines. Spinel inclusions may be existent in some olivine phenocrysts/microphenocrysts. The glassy groundmass is composed of either pale yellowish brown sideromelane or dark brown/black tachylite, with quench crystals of plagioclase and olivine. The sideromelane-bearing clasts are more common than the tachylite-bearing clasts. The vitrophyric clasts may contain rounded amygdales in minor amount. Amygdale minerals include zeolites and clay minerals. The sideromelane at the rims of clasts and walls of amygdales have been replaced by dark brown and bluish green palagonite.

The matrix is composed of vitrophyric clasts similar to gravel-grade clasts, glassy clasts and crystal fragments, i.e. olivine and plagioclase. The glassy fragments are almost totally replaced by common dark brown and uncommon bluish green palagonite. The white cementing material as observed in hand specimen is zeolites and clay minerals.

Sample no. **WB-37**
Drill hole: **CD4B-D003 (Depth 151.40-151.70 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample is poorly sorted, consisting of grayish black, gravel-grade clasts (sizes up to 1 cm across), and moderate brown, finer-grained matrix (sand-, silt- and clay-grade clasts). The gravel-grade clasts are much less abundant relative to the finer-grained matrix, leading to matrix-supported fabric. These clasts are dominated by granules and pebbles that are mainly angular to rounded, with low to high sphericity. Tiny specks and patches of white minerals have been observed throughout the sample, in particular the matrix portion.

Microscopic Description: The gravel-grade clasts are strongly vitrophyric basalt, with phenocrysts/microphenocrysts of olivine (sizes up to 0.8 mm across) and plagioclase (sizes up to 0.4 mm across). The mafic phenocrysts/microphenocrysts have anhedral to subhedral outlines and may contain spinel inclusions; many show rounded edges and embayment. The felsic phenocrysts/microphenocrysts are largely subhedral. The mafic and felsic phenocrysts/microphenocrysts occur as isolated

crystals, glomerocrysts and as plagioclase-olivine cumulocrysts. Plagioclase microphenocrysts have An-content varying from 30 to 82 (oligoclase to bytownite) on the basis of petrographic technique. The groundmass is glassy, made up of abundant yellowish brown sideromelane and minor quench crystals of olivine and plagioclase. Brown palagonite and chloritic material are commonly present at rims of the vitrophyric clasts, with thickness up to 0.05 mm. The clasts may have a small amount of vesicles (sizes up to 1.0 mm across) that are sealed by zeolites and have walls of palagonite and chloritic material.

The matrix constituents (sand-, silt- and clay-grade clasts) are composed of vitrophyric clasts similar to gravel-grade clasts and their derivative crystal fragments, but for the fact that the glassy clasts are totally replaced by palagonite. The tiny white specks and patches as observed in hand specimen are zeolites that occur as cementing material and as cavity-infillings.

Sample no. **WB-39**
Drill hole: **CD4BII-D004 (Depth 11.10-11.30 m)**
Rock type: **Matrix-supported basalt breccia**

Megascopic Description: The core sample contains poorly sorted, gravel-grade clasts (sizes up to 0.5 cm across) sitting in finer-grained matrix (sand-, silt- and clay-grade clasts). The gravel-grade clasts are much less abundant relative to the finer-grained matrix, leading to matrix-supported fabric, and have a brownish color. These clasts mainly have subangular to rounded outlines, with low to high sphericity, and are dominated by granule sizes. The matrix is dark yellowish brown in color. Also present in this core sample is abundant cementing material and cavity infillings, which are commonly whitish minerals and uncommonly greenish minerals.

Microscopic Description: The gravel-grade clasts are vitrophyric basalt, with phenocrysts/microphenocrysts of olivine and plagioclase (sizes up to 0.5 mm across), and clinopyroxene microphenocrysts (sizes up to 0.07 mm across). They occur as isolated crystals, glomerocrysts, plagioclase-olivine cumulocrysts and as plagioclase-clinopyroxene cumulocrysts. Plagioclase phenocrysts/microphenocrysts largely have

subhedral outlines, while olivine phenocrysts/microphenocrysts are largely subhedral to anhedral, and are totally replaced by chlorite/serpentine and clay minerals. Plagioclase phenocrysts/microphenocrysts have An-content varying from 31 to 67 (andesine to labrdorite) on the basis of petrographic technique. The groundmass shows a glassy texture and is almost totally replaced by brown palagonite. The clasts are commonly rimmed with brownish palagonite and bluish green chloritic material. The clasts may have a small amount of vesicles that may be sealed by zeolites, clay minerals and chloritic material.

The matrix constituents (sand- to clay-grade clasts) are composed of vitrophyric clasts similar to the gravel-grade clasts and their derivatives. The glassy clasts are totally replaced by palagonite. The whitish minerals as observed in hand specimen are zeolites that occur as cementing material and as cavity infillings.

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