CHAPTER 3

OCCURRENCE AND PETROGRAPHY

3.1 Occurrence

The Mae Tha basalt occurs as scattered masses of highly variable sizes, covering an area of approximately 140 km^2 between Amphoe Mae Moh and Amphoe Mae Tha, Changwat Lampang (Fig. 5). This basaltic pile commonly forms a low-lying land inbetween high mountains, which are made up of Permian limestone, Permo-Triassic volcanic rock, Triassic volcaniclastic - sedimentary strata (Lampang Group), Tertiary sedimentary rock and Quaternary gravel beds, except for the vicinities of small cinder cones. The basalt also rests unconformably on the older rocks, and consists mainly of subaerial lava flows; subaqueous lava flows and pyroclastic debris are locally present. These lava flows and pyroclastic debris have largely experienced extensive weathering and decomposition, giving rise to brown and brownish yellow soil with *in situ* float basalts (Figs. 6 and 7). The eruptive products are well exposed along cliffs and slopes of hills, road cuts and railway cuts.

The subaerial basalt flows generally show typical internal structures of worldwide subaerial flows, i.e. vesicular top, massive with platy joints and columnar joints (Figs. 8 and 9) at center, and vesicular base. Their platy and columnar joints show different attitudes, possibly due to paleogeography; the axes of columnar joints, and dip angles of platy joints are, however, almost vertical and horizontal, respectively (Table 2). Although a number of flows have been known at some locations, e.g. at grid references 661044, 703210 and 705178, the total number of flows cannot be clearly determined because of the scarcity of good exposures. Fortunately, on the basis of their internal structures, the core samples of these basalts, that are penetrated in 50 m deep groundwater well at grid reference 705178 (Ban Huai Rak Mai), can be separated into six flows with individual thicknesses varying from more or less 1 m to greater than 12 m. Accordingly, the Mae Tha basalt is inferred to

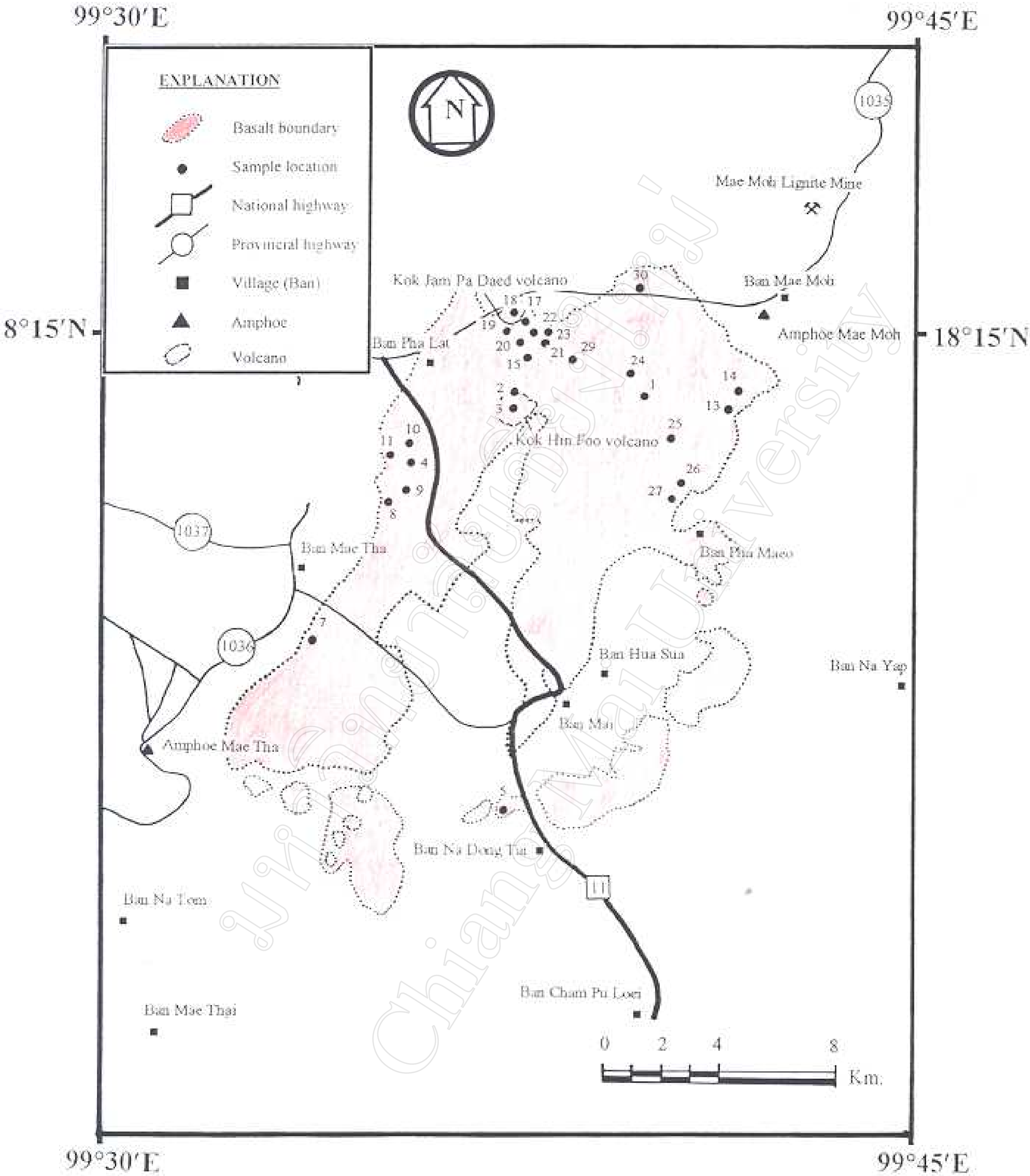


Figure 5 Map showing boundaries and sample locations of the Mae Tha basalt presented in this study.

Figure 6 *In situ* float of the Mae Tha basalt at grid reference 622159. Note that brownish soil has been decomposed from basalts.

Figure 7 Thinly baked contact (dashed line) between the upper and lower basaltic flows at grid reference 661044. Note that brownish yellow soil has been decomposed from basalts.

Figure 8 Exposure of the Mae Tha basalt on the cliff at grid reference 736179 showing columnar joints.

Figure 9 Exposure of a basalt flow at grid reference 719145 showing columnar and platy joints (Assoc. Prof. Dr. Yuenyong Panjasawatwong as a scale).

Table 2 Locations of the Mae Tha basalt with attitudes of platy joints and thicknesses of individual flows.

Grid reference	Attitude of platy joint	Thickness of flow	Remarks
661044	N14°W 12°NE	Upper flow : >4 m Lower flow : >3 m	Consists of two subaerial flows. The upper flow is coarser-grained than the lower flow. Baked contact occurs in the upper part of the lower flow.
705178	-	Flow A : >2 m Flow B : ca. 7 m Flow C : ca. 1 m Flow D : ca. 8 m Flow E : ca. 4 m Flow F : >12 m	Core samples in groundwater well at Ban Huai Rak Mai. Made up of six subaerial flows: A, B, C, D, E and F (from top to bottom).
736180	N20°W 26°SW	>2 m	Railwaycut exposure near the railway bridge, close to Mae Moh railway station. Subaerial lava flow overlies a pile of basalt pillows.
627145	-	>3 m	An exposure of subaerial lava flow at Mae Tha reservoir spillway.
624158	-	>3 m	A subaerial lava flow underlain by Permo-Triassic volcanic rocks.
719145	-	>2 m	A subaerial lava flow with vesicular top and bottom, and massive in the middle portion.
703210	N58°E 18°SE N80°W 20°NE N72°W 26°NE N70°W 24°NE	Upper flow : >3 m Middle flow : more or less 2 m Lower flow : >4 m	Subaerial flows at a roadcut, Lampang-Mae Moh road. Platy joints are conspicuous in the upper flow.

be constituted by at least six flows. Characteristics of some Mae Tha subaerial basalt flows are summarized in Table 2.

The minor subaqueous lava flow, characterized by basalt pillows, hyaloclastites and associated pahoehoe toes, is restricted to the northeastern margin of the Mae Tha basalt. Basalt pillows have circular to oval cross-sections (Fig. 10) with wrinkle to ropy surfaces (Fig. 11). Interpillows are commonly hyaloclastites, whereas intrapillow lava tubes with magmatic stalactites and stalacmites are uncommon (Y. Panjasawatwong, pers. comm., 1997). The internal structures of individual pillows are made up of concentric and radial cracks that yield blocky appearance as illustrated in Figure 10. These pillows have thin glassy rinds (1-2 cm) and holocrystalline (fine-grained) interior; vesicles are commonly present along the margin of individual pillows.

Two small cinder cones with openings in the northern flanks and craters on top have been recognized due north of Ban Pha Lat, i.e. Pha Kok Jam Pa Daed and Pha Kok Hin Foo (Fig. 5). These craters have diameters of about 150 and 250 m, respectively, and their original rounded shapes are well-preserved. The minor volcanic debris is closely associated with these cinder cones.

3.2 Petrographic Study

A number of the Mae Tha basalt samples were collected from many localities. These samples were carefully selected to avoid rocks showing:

(1) extensive development of mesoscopic domains of secondary minerals, e.g. quartz resulted from silicification, epidote minerals and chlorite,

(2) xenoliths, other than basalt itself,

(3) abundant vesicles and amygdale minerals, and

(4) quartz, epidote or calcite veining or patches totaling more than approximately 5 modal percent.

Figure 10 Outcrop of the pillow lava at grid reference 736180. Note that pillows are vesicular at their surfaces and massive in their middle parts.

Figure 11 Basalt pillows with ropy and wrinkled surfaces at grid reference 739180.

Occasional samples had very few xenoliths but were included in this study in the absence of rocks from that particular area. Consequently, thirty-five basalt samples from twenty-six localities are regarded as least-altered samples that may represent magma prior to eruption. Sample locations of these least-altered samples are shown in Figure 5 and listed in Appendix A.

Lithologic and petrographic studies have been carried out on the least-altered basalt samples. Megascopically, these samples have colors varying from medium dark gray to dark gray, and are dense, fine-grained (Fig. 12), but for the sample from the chill margin of basalt pillow that is grayish black with glassy texture. Close examination reveals that they may contain phenocrysts/microphenocrysts of olive-green olivine and dark greenish to black minerals with sizes up to 5 mm across. White xenoliths (sizes up to 4 cm across) have been sporadically observed in many samples. Vesicles, slightly infilled with calcite and zeolitic minerals, are rarely present. Fractures have been occasionally observed in a few samples, and are partly infilled with carbonate and/or iron oxide/hydroxide.

Under the petrographic microscope, the studied basalts range texturally from phyric (Figs. 13, 14 and 15) to microphyric (Figs. 16, 17, 18, 19, 20, 21, 22, 23, 24 and 25) with variable amounts of phenocrysts and microphenocrysts (mainly moderately microphyric), except for the sample from chill margin of basalt pillow (sample no. 14/2) that is vitrophyric (Fig. 26). The phenocryst/microphenocryst assemblages in these basalts include olivine + plagioclase ± Fe-Ti oxide, olivine + clinopyroxene ± Fe-Ti oxide, and olivine + plagioclase + clinopyroxene ± Fe-Ti oxide. Chromian spinels (Boontrarika Srithai, pers. comm., 1997), which occur as common inclusions in olivine (Figs. 19 and 23) in most basalt samples, are an additional microphenocryst phase to the already mentioned phenocryst/microphenocryst assemblages. The most common phenocryst/ microphenocryst assemblages are olivine + plagioclase + chromian spinel ± Fe-Ti oxide, and olivine + plagioclase + clinopyroxene + chromian spinel ± Fe-Ti oxide. These phenocrysts/microphenocrysts, but for chromian spinel, mainly form as discrete

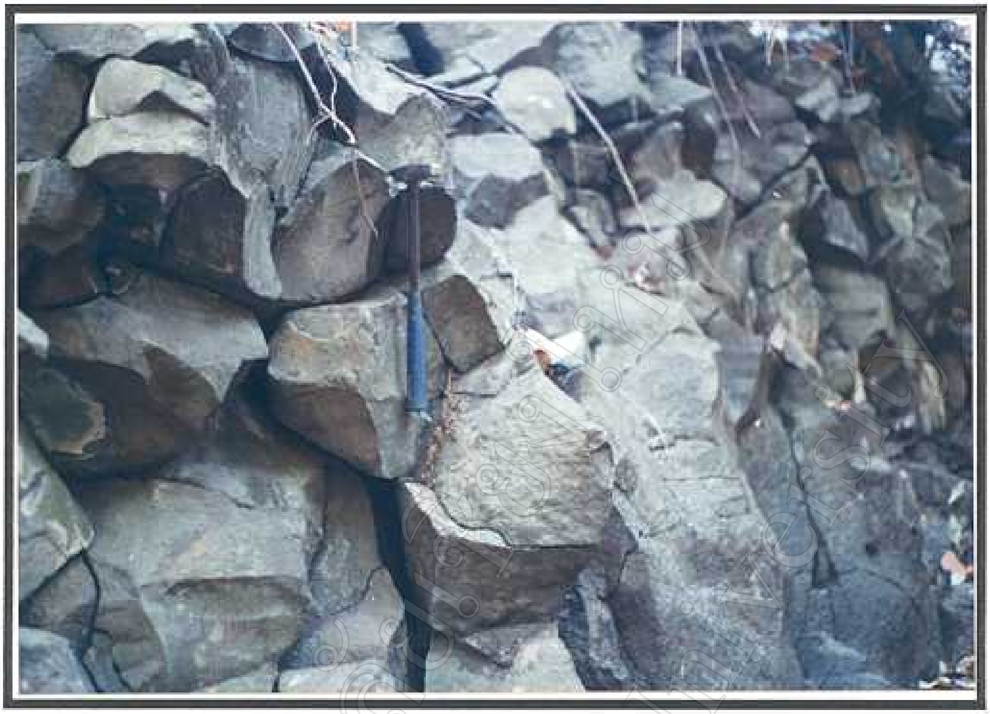


Figure 12 Outcrop of basalt with columnar joints and poorly developed platy joints at grid reference 719145.

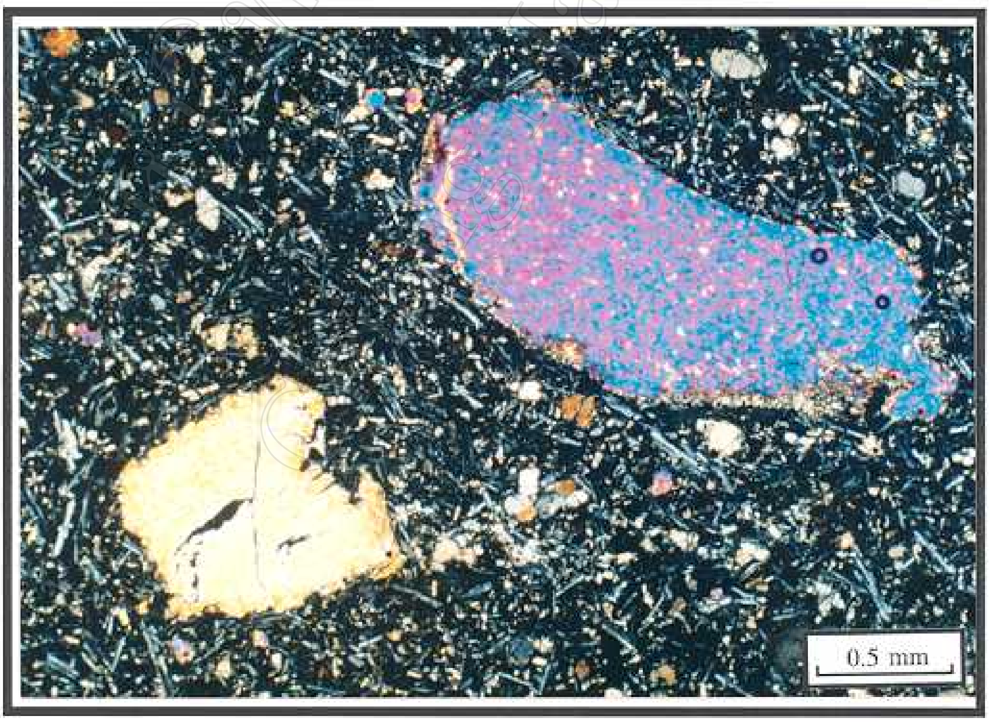


Figure 13 Photomicrograph of sample no. MT 10/2 showing olivine phenocrysts with rounded edges, sitting in hypocrystalline groundmass. Crossed polars.

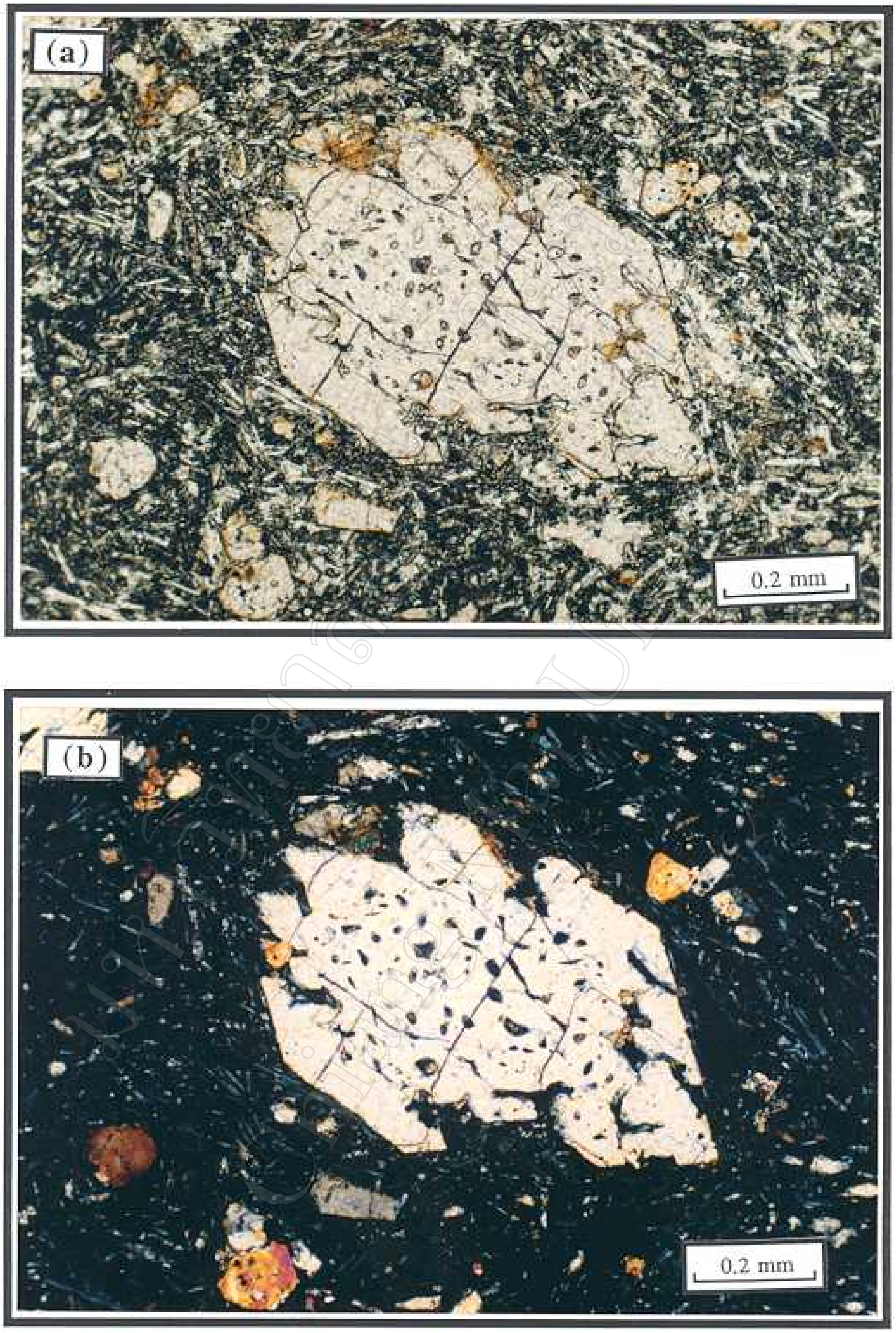
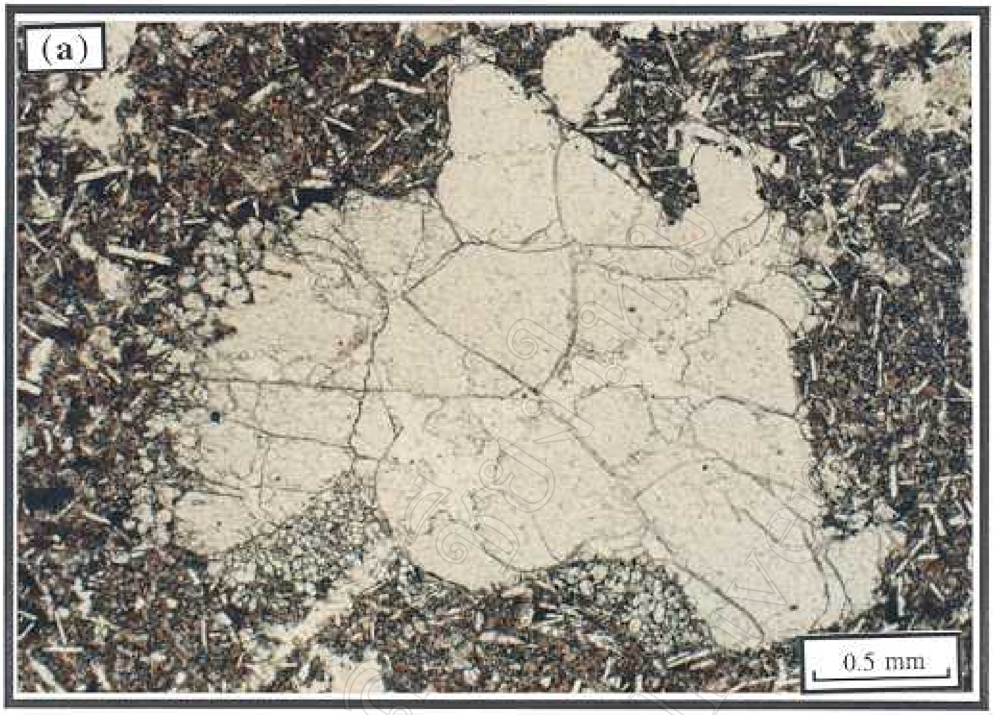


Figure 14 Photomicrographs of sample no. MT 21 displaying a sieve-textured olivine phenocryst with embayment features, and felty groundmass. (a) ordinary light, (b) crossed polars.



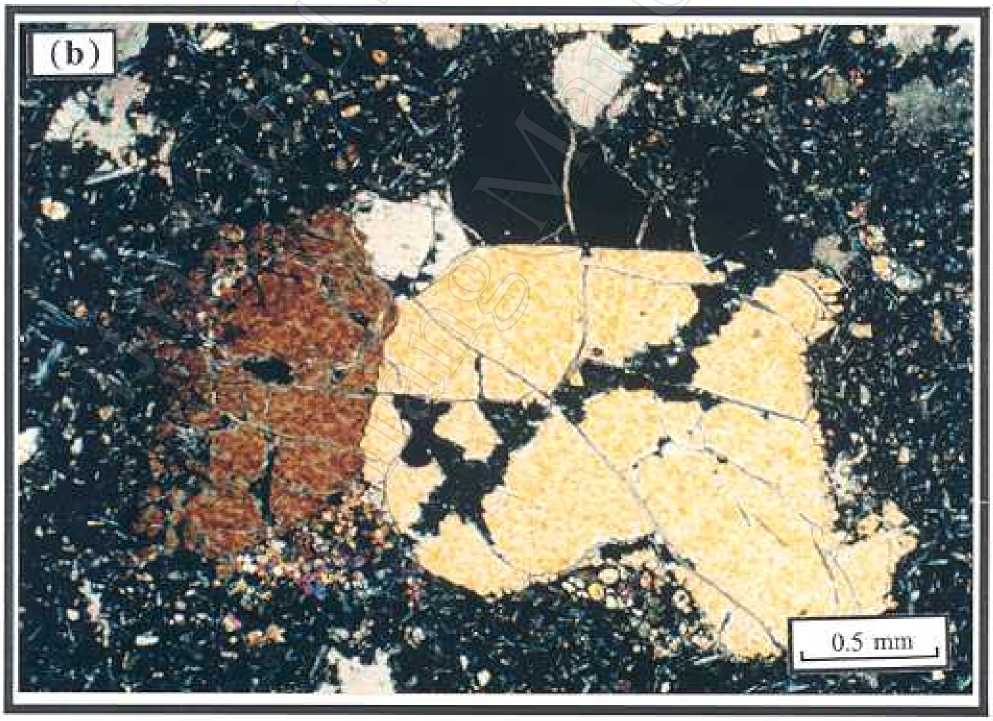


Figure 15 Photomicrographs of sample no. MT 11 illustrating an olivine glomerocryst and felty hypocrystalline groundmass. (a) ordinary light, (b) crossed polars.

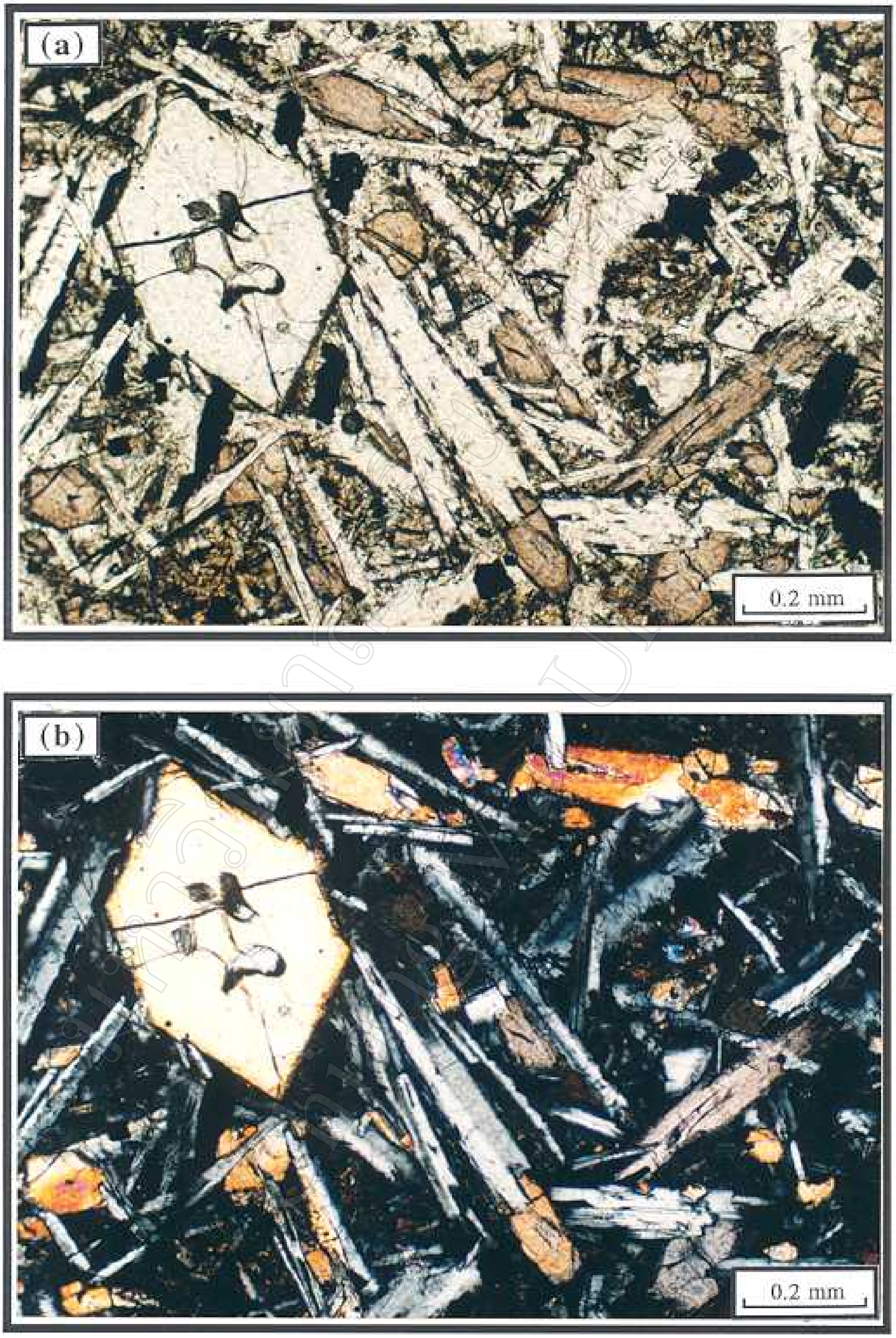


Figure 16 Photomicrographs of a microphyric basaltic rock (sample no. MT 24) showing microphenocrysts of sieve-textured euhedral olivine, and opaque minerals that are embedded in felted hypocrystalline matrix. Note that groundmass clinopyroxenes largely show subophitic intergrowths. (a) crossed polars, (b) ordinary light.

Figure 17 Photomicrograph of a microphyric basalt (sample no. MT 17) displaying microphenocrysts of olivine (Ol) and opaque minerals (Op) that are embedded in felted groundmass. Note that the brownish rims of olivine crystals are iddingsites. Ordinary light.

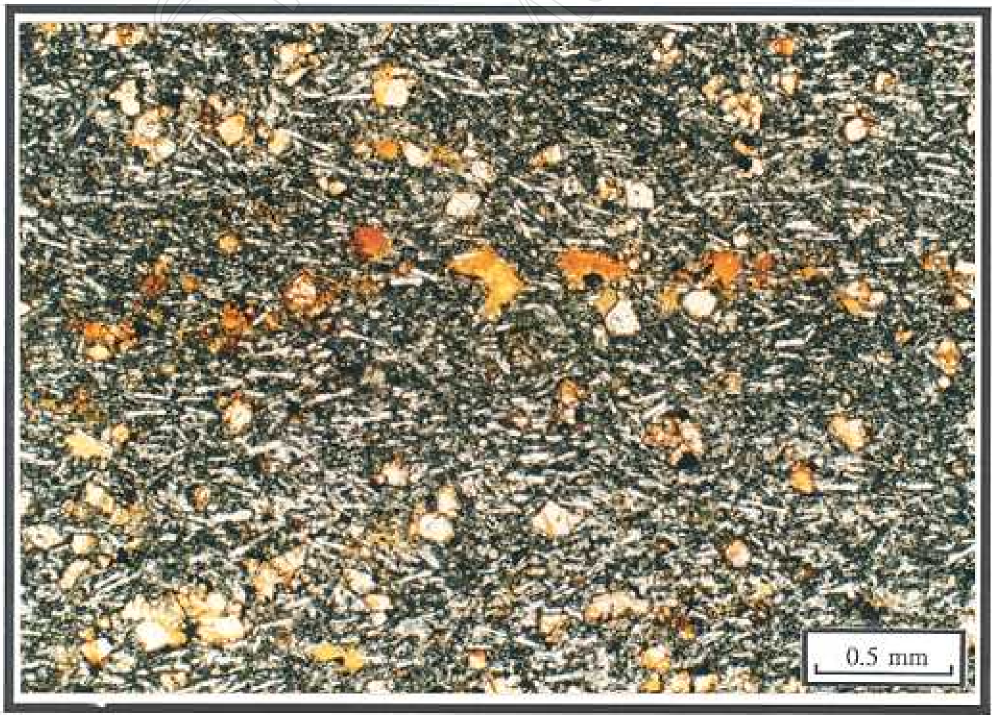


Figure 18 Photomicrograph of a microphyric basalt (sample no. MT 19) showing olivine microphenocrysts and trachytic groundmass. Note that the brownish and yellowish minerals are iddingsites, partly or totally pseudomorph after olivines. Ordinary light.

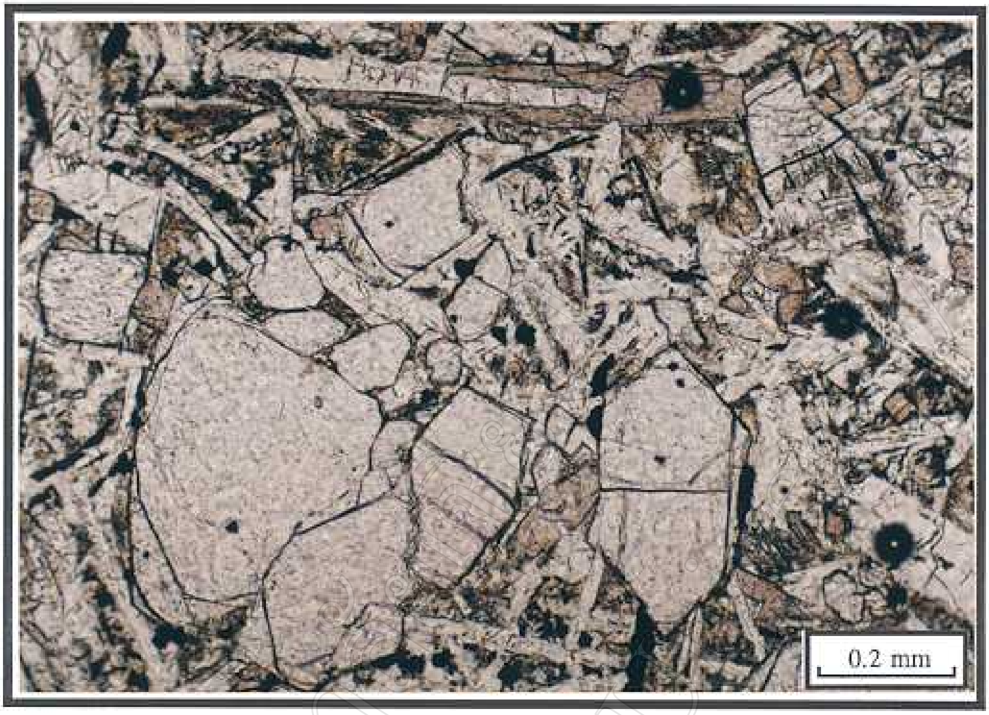


Figure 19 Photomicrograph of sample no. MT 24 illustrating isolated anhedral and euhedral olivine microphenocrysts and an olivine glomerocryst. Also shown are chromian spinel (?) inclusions in olivines. Ordinary light.

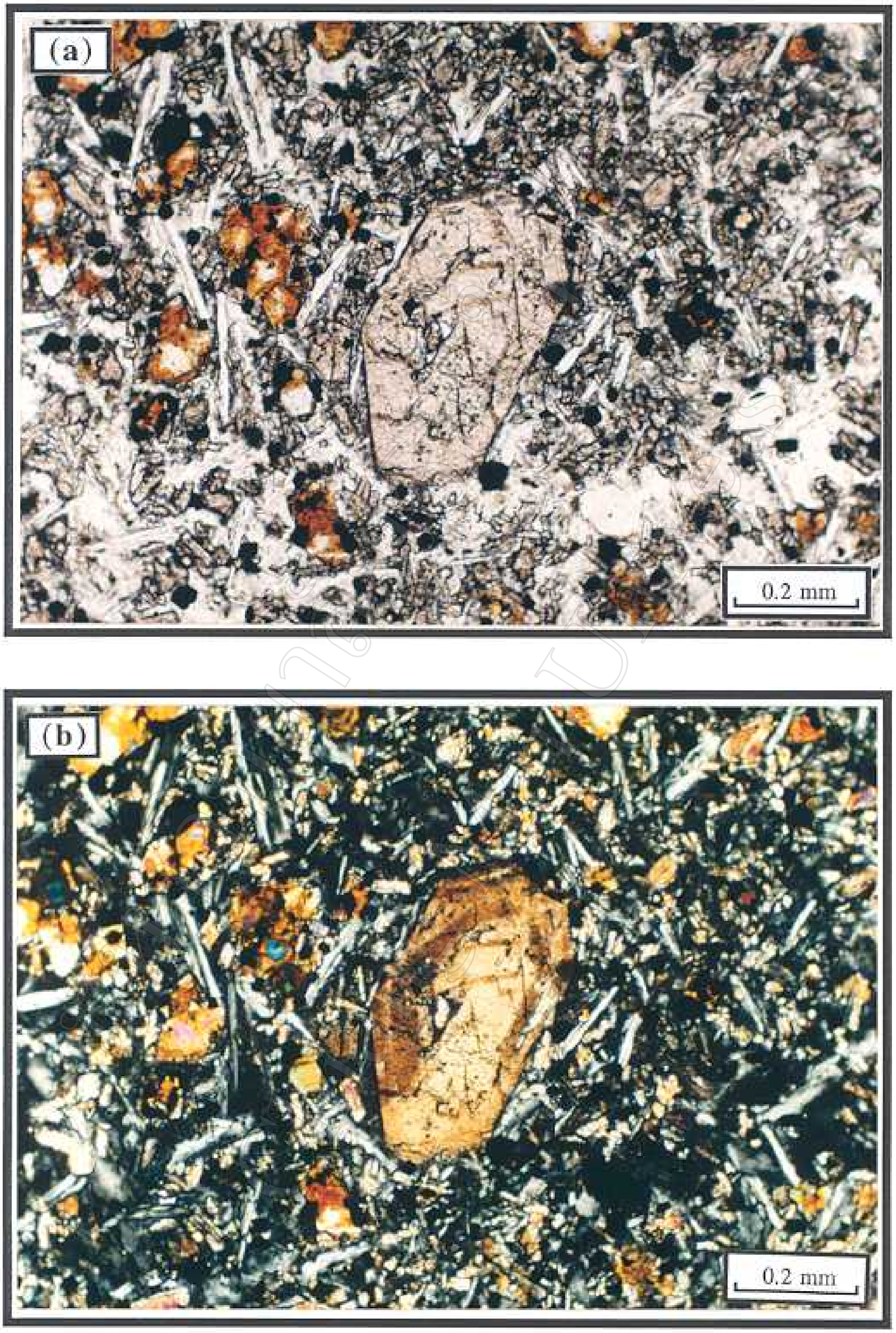


Figure 20 Photomicrographs of sample no. MT 1/F displaying an euhedral clinopyroxene microphenocryst with opaque inclusions. (a) ordinary light, (b) crossed polars.

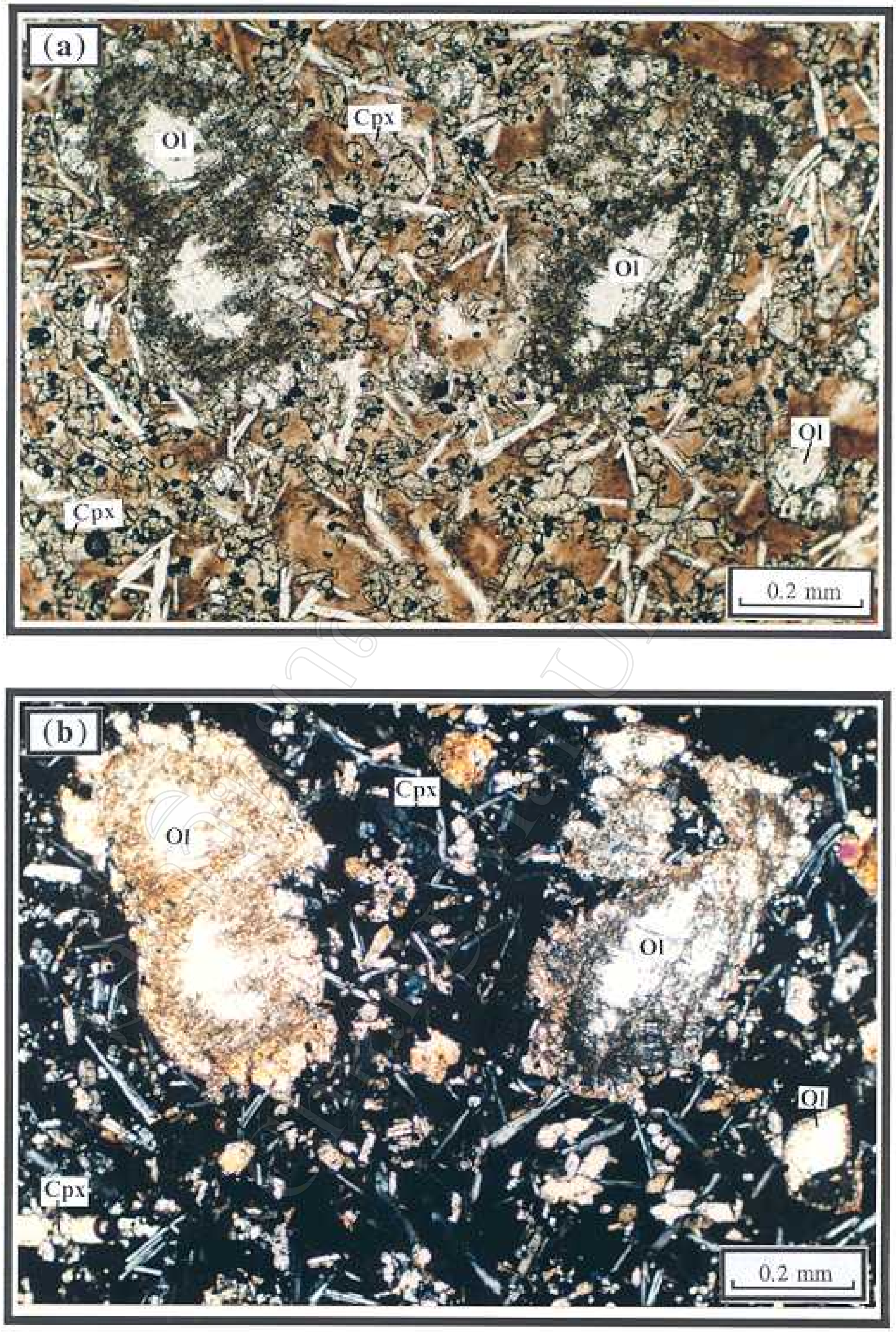


Figure 21 Photomicrographs of a microphyric basalt (sample no. MT 8) showing microphenocrysts of olivine (Ol) and clinopyroxene (Cpx) that are embedded in hypocrystalline groundmass. (a) ordinary light, (b) crossed polars.

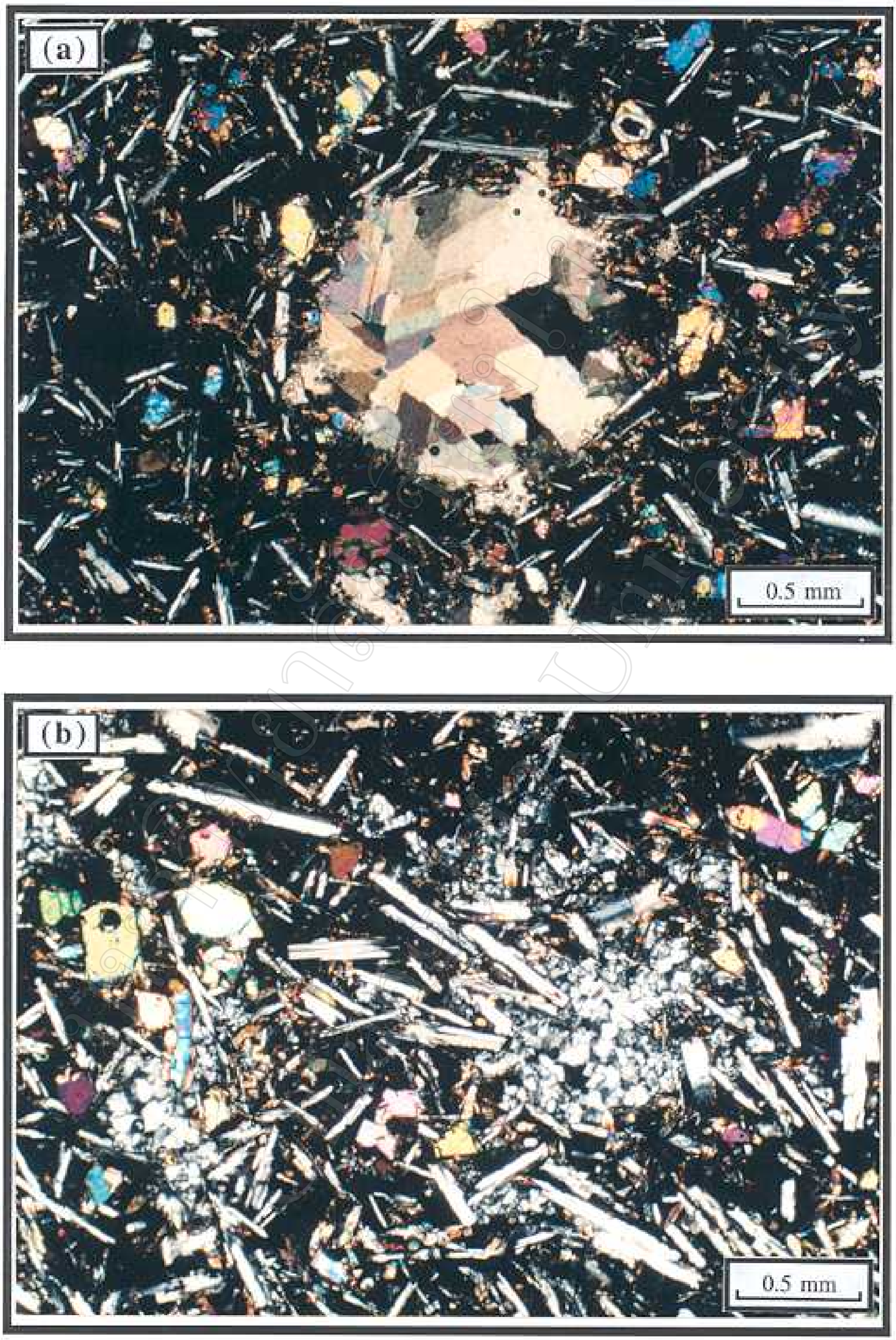


Figure 22 Photomicrographs of sample no. MT 13 illustrating (a) amygdale calcites and (b) amygdale and fracture-infilling zeolites. Crossed polars.

Figure 23 Photomicrographs of sample no. MT 25 showing olivine microphenocrysts and glomerocrysts with chromian spinel (?) inclusions. Note that some olivine crystals are largely replaced by iddingsite. (a) ordinary light, (b) crossed polars.

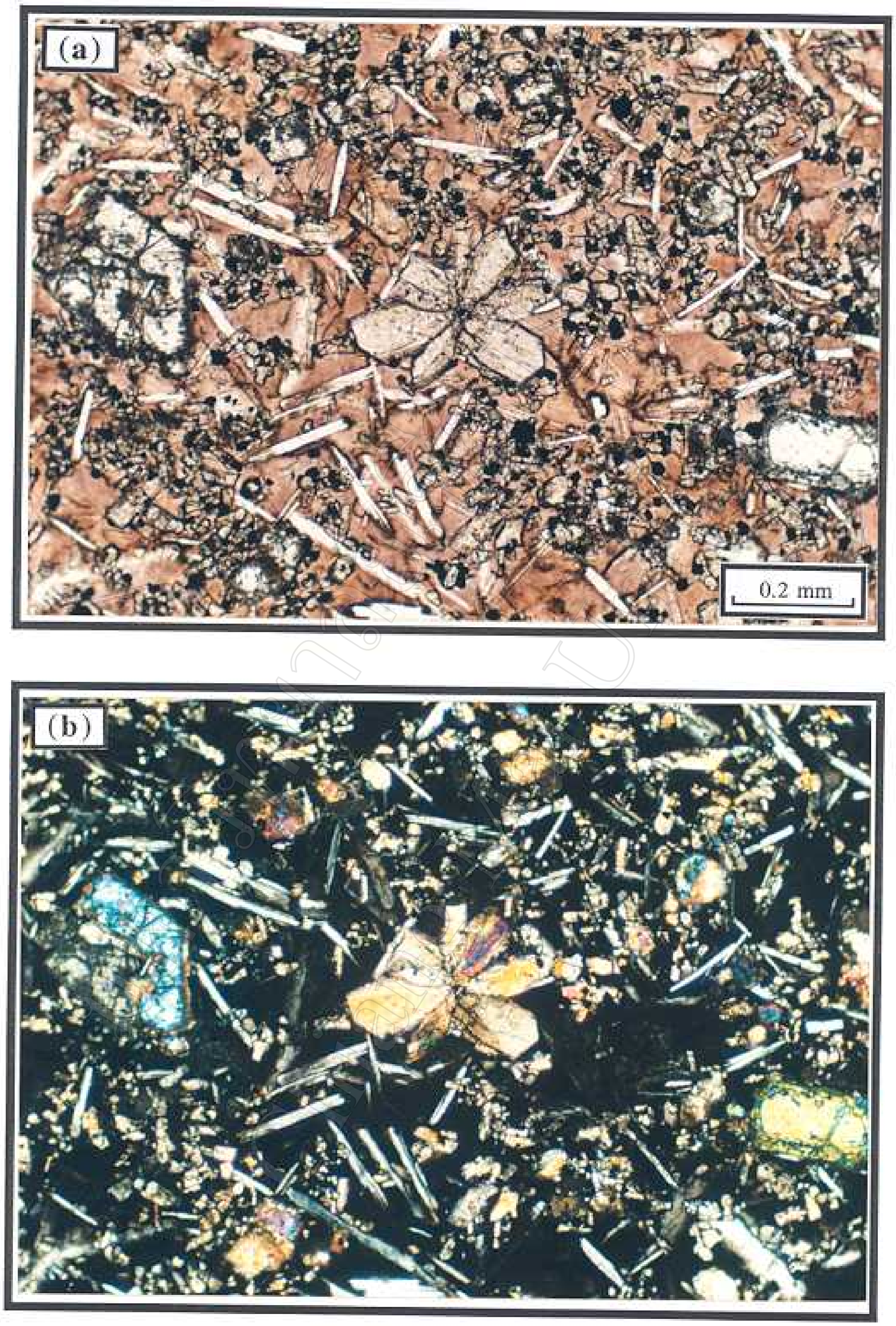


Figure 24 Photomicrographs of sample no. MT 9 displaying a clinopyroxene microphenocryst with stellate fashion in felted hypocrystalline groundmass. (a) ordinary light, (b) crossed polars.

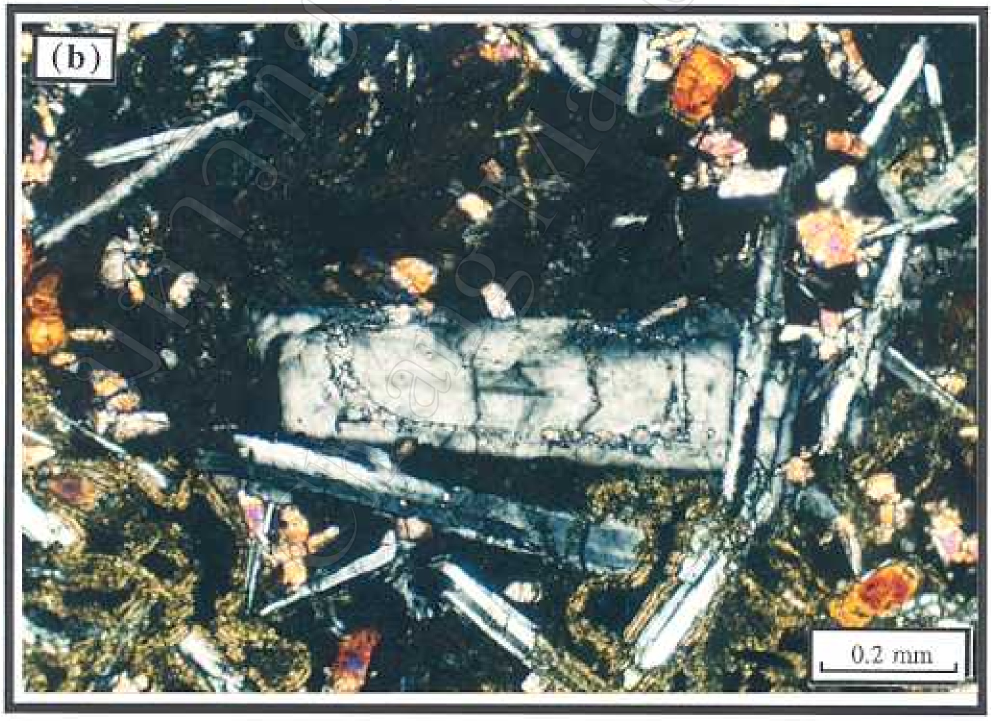


Figure 25 Photomicrographs of sample no. MT 1/D showing a plagioclase microphenocryst with clinopyroxene inclusions (middle of the photo). (a) ordinary light, (b) crossed polars.

Figure 26 Photomicrographs of sample from chill margin of basalt pillow (sample no. MT 14/2) displaying olivine and plagioclase microphenocrysts in glassy matrix. (a) ordinary light, (b) crossed polars.

isolated crystals. Olivine, plagioclase and clinopyroxene phenocrysts/ microphenocrysts may occasionally be in the forms of glomerocrysts (Figs. 15, 19, 23 and 24), and olivine-plagioclase, olivine-clinopyroxene and plagioclase-clinopyroxene cumulocrysts. The most abundant phenocrysts/microphenocrysts in individual samples are olivines. In addition, megacrysts of quartz (Fig. 27) and Permo-Triassic (?) volcanic xenoliths (Fig. 28) have been sporadically detected in some samples. The phenocrysts/microphenocrysts, megacrysts and xenoliths present in the studied basalts are embedded in holocrystalline to hypocrystalline (largely hypocrystalline) groundmass with common felty texture (Figs. 13, 14, 15, 17, 20, 21, 22, 23 and 24) and uncommon trachytic texture (Fig. 18), except for the sample from chill margin of basalt pillow that has glassy groundmass and is made up of brown glass and quenched crystals (Fig. 26). In general, the groundmass constituents of the holocrystalline samples are constituted largely by plagioclase laths with subordinate intergranular pink clinopyroxenes, and olivines, and minor Fe-Ti oxides, whereas those of the hypocrystalline groundmass is compositionally similar to the holocrystalline groundmass. However, it contains light brown to dark brown glass (slightly to totally devitrified) and quenched crystals (Figs. 21, 24 and 29) as subordinate and minor constituents. In addition, clinopyroxenes in a few samples of the basalts with hypocrystalline groundmass are subophitic to plagioclase laths (Fig. 16). Clinopyroxene and olivine may become the most abundant groundmass constituents along with plagioclase laths in some samples and very few samples, respectively. In similar manner, Fe-Ti oxide may be an additional subordinate constituent in many samples. The majority of the studied basalt samples contains fractures and vesicles in small amounts. These fractures and vesicles may be infilled with carbonates (Fig. 22), chlorite, zeolites (Fig. 22) and iron oxide/hydroxide. Petrographic features of individual samples are briefly presented in Appendix B.

Olivine phenocrysts and microphenocrysts (largely microphenocrysts) have anhedral to euhedral (mainly anhedral to subhedral) outlines with sizes up to 3 mm across. They commonly display disequilibrium features, i.e. common embayment and rounded edges (Figs. 13, 14, 15, 19, 21 and 23), and rare sieve texture (Figs. 14 and

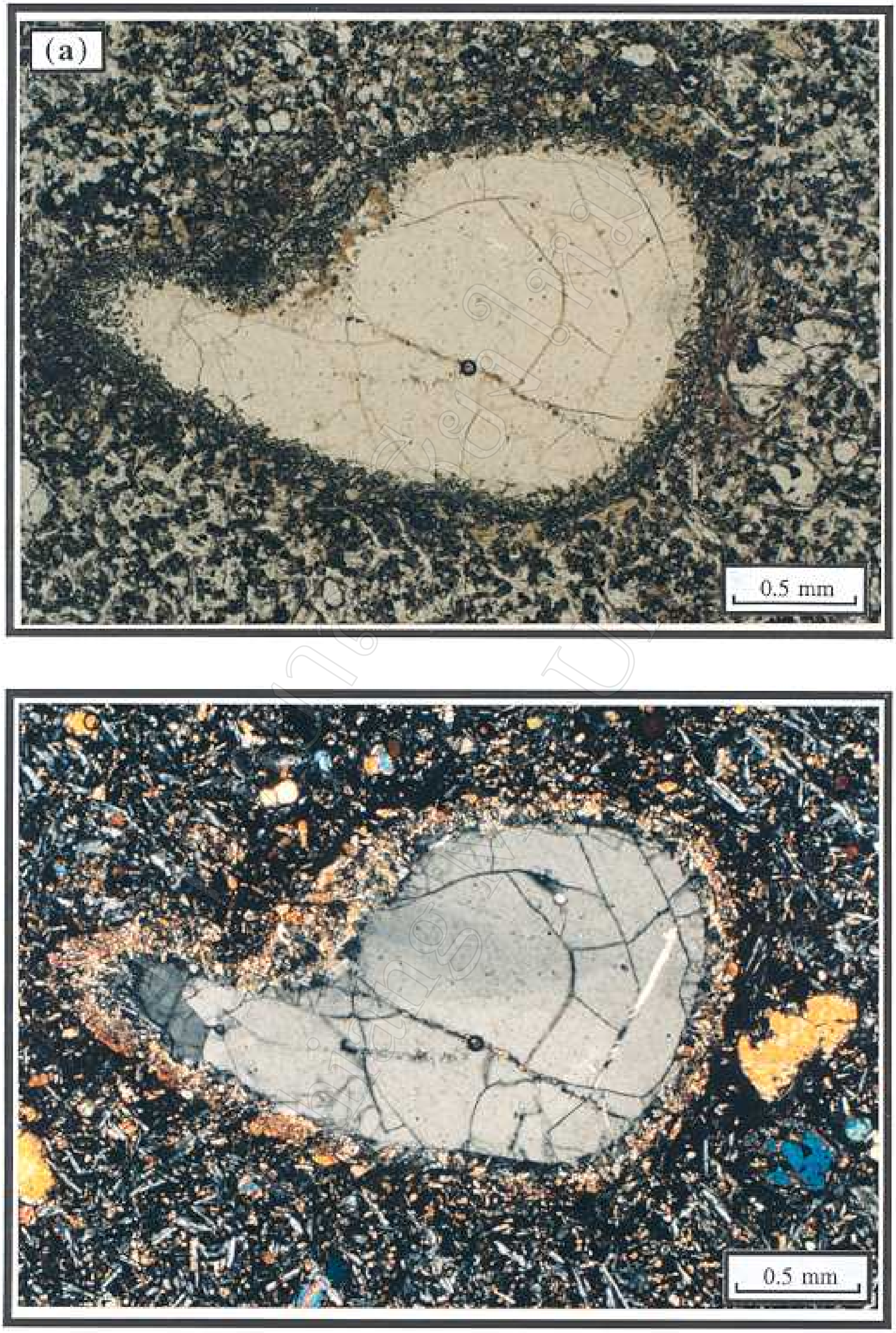


Figure 27 Photomicrographs of sample no. MT 10/2 illustrating a quartz xenocryst with reaction corona made up of diopside crystals. (a) ordinary light, (b) crossed polars.

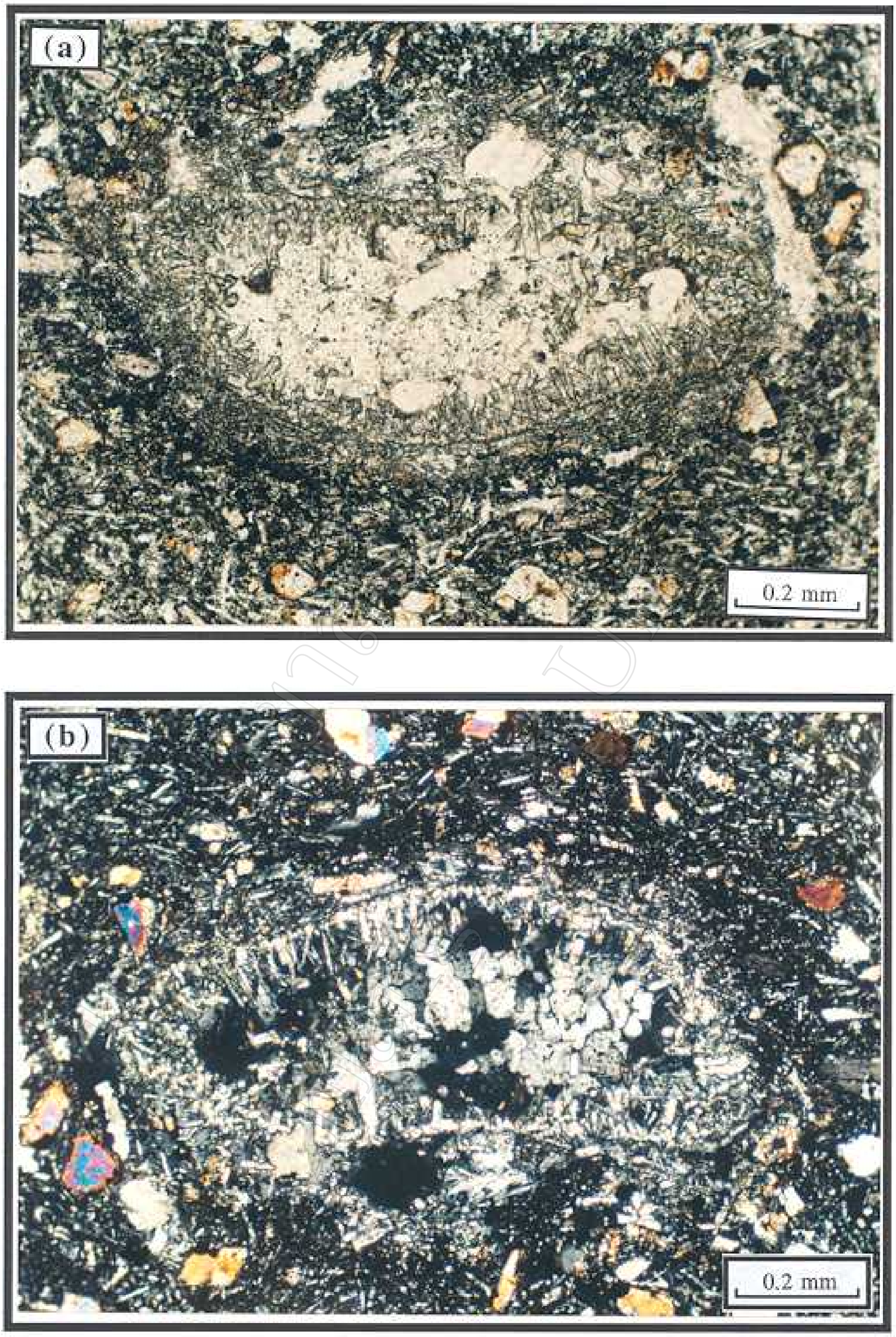


Figure 28 Photomicrographs of a Permo-Triassic (?) volcanic xenolith with reaction rim of diopside aggregate in sample no. MT 17. (a) ordinary light, (b) crossed polars.

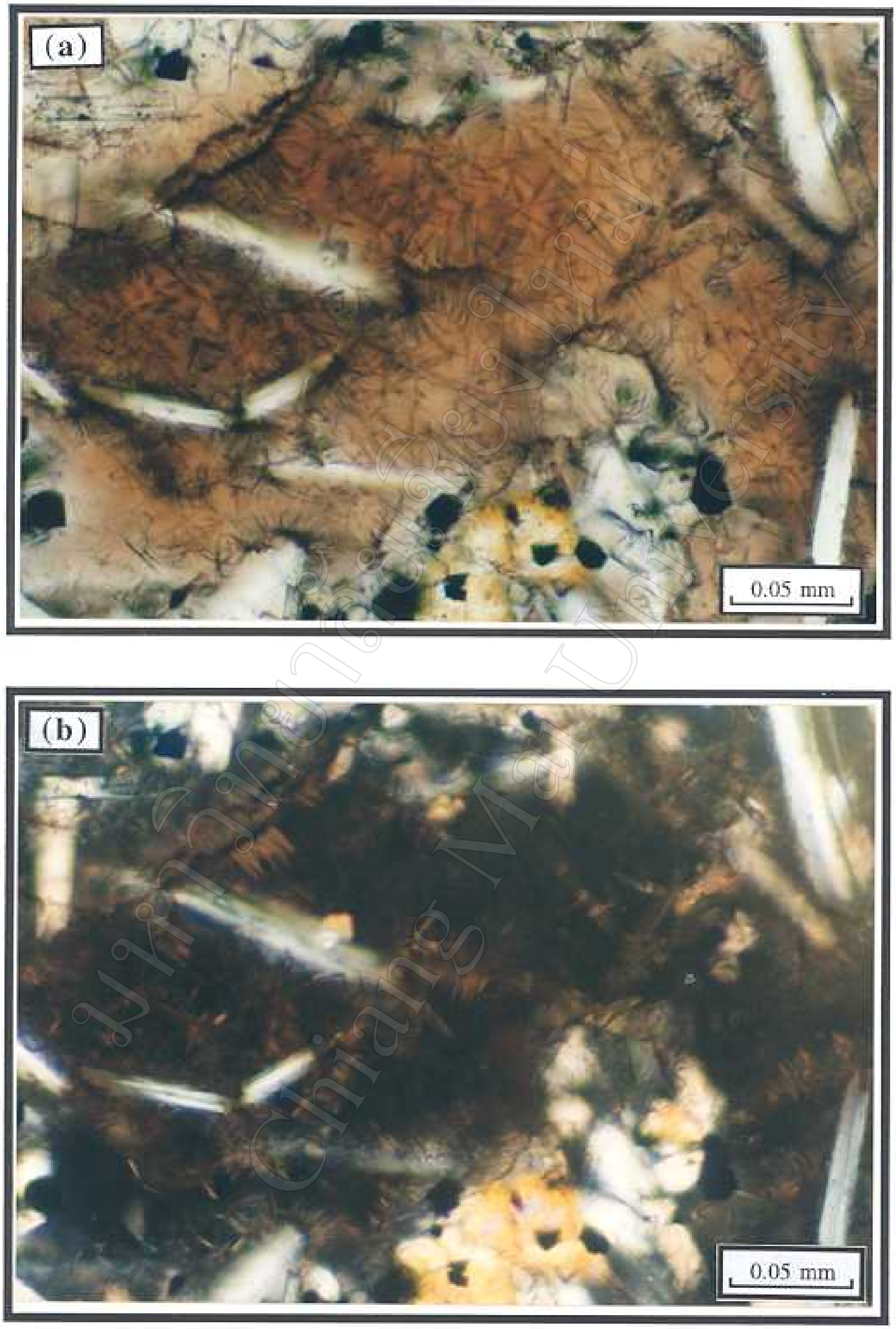


Figure 29 Photomicrographs of sample no. MT 1/E displaying glass and quenched crystals. (a) ordinary light, (b) crossed polars.

16); many have chromian spinel (?) inclusions. Electron-probe analyses of these olivine phenocrysts/microphenocrysts in a few representative samples reveal that they have Mg / (Mg + Fe^{2+}) number (herein Mg#) in a range of 0.77 - 0.85 (Appendix C). Groundmass olivines are mainly anhedral and are intergranular to groundmass plagioclase laths. All phases of olivine are slightly to highly altered. Their alteration products may include chlorite/serpentine, iddingsite and iron oxides/hydroxides (Figs. 17, 18, 20, 21 and 23).

Plagioclase laths are almost totally present as microphenocrysts and as a groundmass phase. Plagioclase phenocrysts and microphenocrysts commonly show anhedral to euhedral outlines; some show corroded features and have inclusions of clinopyroxene and opaque minerals. Zonal patterns and polysynthetic twins are very common in these phenocrysts/microphenocrysts. Groundmass plagioclases are subhedral to euhedral, and at times form stellate patterns (Fig. 30). The alteration products of both the phenocryst/microphenocryst and groundmass phases may be sericite, clay minerals, and iron oxides/hydroxides.

Clinopyroxenes are pink, and occur as phenocrysts/microphenocrysts and as groundmass phases. Clinopyroxene phenocrysts/microphenocrysts (almost all as microphenocrysts) are subhedral to euhedral (generally subhedral), with sizes up to 0.80 mm across. A few phenocryst/microphenocryst crystals show corroded features; some are zoned (Fig. 20) and may contain opaque inclusions. Rare clinopyroxene glomerocrysts with stellate patterns have been detected (Fig. 24). Groundmass clinopyroxenes mainly have anhedral to subhedral outlines and are commonly intergranular to plagioclases laths. Clinopyroxene, both as microphenocryst/ phenocryst and groundmass phases, are very slightly to slightly replaced by chlorite and iron oxides/hydroxides.

Chromian spinels are present as microphenocrysts, whereas Fe-Ti oxides are present both as microphenocrysts and as a groundmass phase. These Fe-Ti oxide microphenocrysts show anhedral to euhedral outlines and have sizes up to 0.5 mm

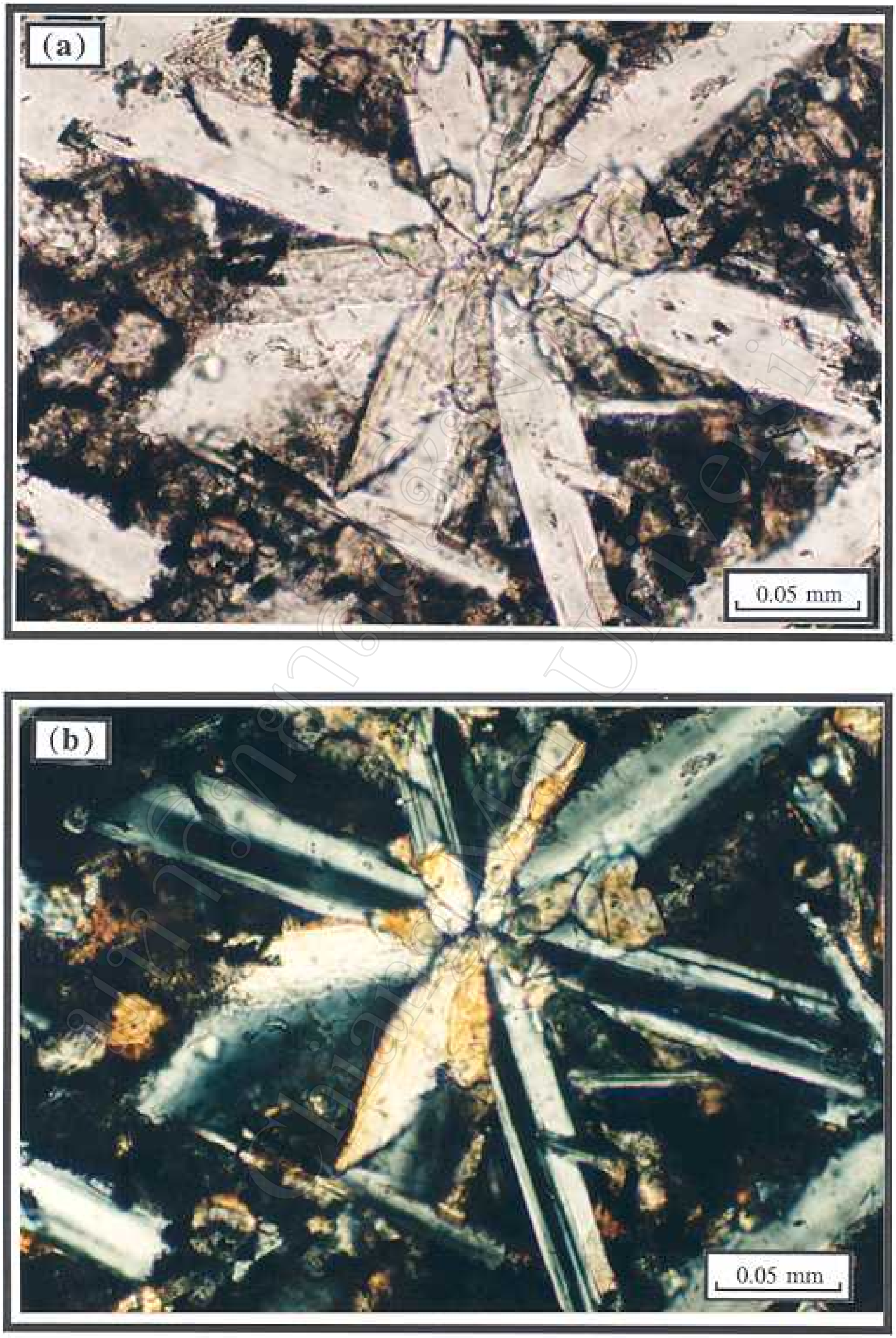


Figure 30 Photomicrographs of sample no. MT 5/1 showing groundmass plagioclase and clinopyroxene with stellate fashion. (a) ordinary light, (b) crossed polars.

across. Groundmass Fe-Ti oxides are anhedral to subhedral, and commonly associated with other interstitial minerals in all samples.

Quartz megacrysts (sizes up to 3 cm across) are commonly mantled by acicular clinopyroxene, in terms of reaction coronas (Fig. 27) with glassy crusts, possibly resulted from quenching when cold quartz reacted with hot magma. These megacrysts are crustal xenocrysts incorporated into basalts during the upward movement of basaltic magma.

Xenoliths (sizes up to 5 cm across) in the Mae Tha basalts have flattened, rounded, and oval shapes. They are very fine-grained, and made up of quartz, feldspar, prismatic clinopyroxene and Fe-Ti oxide in variable proportions, i.e. highly possible Permo-Triassic volcanic rocks. These xenoliths are commonly mantled by acicular clinopyroxene, in terms of reaction corona (Fig. 28) with glassy crusts.