Jour. Fac. Sci., Hokkaido Univ., Ser. IV,
vol. 21, no. 4, Feb., 1986, pp. 583-598.

BOROSILICATES (DATOLITE, SCHORL) AND ALUMOSILICATES (ANDALUSITE, SILLIMANITE) IN THE OKETO RHYOLITE, HOKKAIDO

by

Jun Watanabe and Kiyoshi Hasegawa*

(with 1 text-figure, 4 tables and 6 plates)

Abstract

The second occurrence of datolite in Hokkaido, after the first report from the Furano mine (Sako et al., 1957; Sato et al., 1967), is herein described from the *Oketo Rhyolite* (Watanabe et al., 1981a, 1981b), Kitami Province, Hokkaido.

Datolite from the *Oketo Rhyolite* occurs in the small veinlets cutting the metasomatic facies of the rhyolite of the Miocene intrusion.

Optical data of the datolite are: $\alpha = 1.625$, $\beta = 1.652$, $\gamma = 1.669$. $2V_x = 71.0—72.0°$. Lattice constants are: a = 9.62 Å, b = 7.60 Å, c = 4.83 Å, c/a = 0.50, $\beta = 90°11'$. X-ray data is shown in Table 1. Chemical data are: $Ca_{4.02}B_{4.11}Si_{3.90}O_{15.96}(OH)_{4.04}$ to $Ca_{4.23}B_{3.68}Si_{4.11}O_{15.93}(OH)_{4.07}$ on the basis of 20 (O, OH), namely as the empirical formula is given $Ca_{1.00-1.06}B_{1.03-0.92}Si_{0.97-1.03}O_{3.99-3.98}(OH)_{1.01-1.02}$ for the formula of datolite; $CaBSiO_4(OH)$.

The mineral is associated with dravite-schorl tourmaline including minor content of uvite molecule, andalusite and sillimanite with a very small quantity of fluorite and topaz, showing the mode of occurrence different quitely from any of the known cases in Japan and world. Also, some data of the associated minerals are presented.

Introduction

Datolite ($CaBSiO_4$ (OH)) is a borosilicate mineral, showing diverse occurrences in genesis. The occurrences and localities of datolite in Japan, in spite of rather rare mineral, have been known by several authors (Harada, 1939, 1950, 1954; Imayoshi et al., 1950; Miyahisa et al., 1953, 1964, 1965; Kato et al., 1957; Sako et al., 1957; Yoshimura et al., 1966; Sato et al., 1967). Four types of occurrence have been descriminated:

(1) in skarn-type ore deposits;
  a) associated with axinite in cupriferous pyrrhotite ore (Noborio mine, Nakagoya mine, Iwato mine).
  b) associated with axinite, calcite, grünerite and stilpnomelane in PbS-ZnS skarn ore (Obira mine).
  c) in veinlet cutting garnet-hedenbergite-pyrrhotite skarn ore (Furano mine).
  d) associated with axinite and diopside in limestone included in diorite (Hajikano).

(2) in basic to intermediate volcanites or pyroclastics;
  a) associated with prehnite and laumontite in geodes or veinlets in breccia tuff (Okuzure Cliff).

Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1860.

* Geological Survey of Hokkaido, N18 W12, Sapporo 060, Japan

b) associated with axinite, epidote and hornblende in skarnized limestone xenolith in Sobosan volcanics (Somi).

(3) in veinlets cutting schist or amphibolite;

a) in veinlet cutting green schist (Hoino, Gojo mine).

b) in veinlet cutting quartz schist (Shirataki mine).

c) in veinlet cutting amphibolite (Shinkai).

(4) in manganese ore deposits; associated with barite, calcite and quartz in veinlet cutting manganese-carbonate and -dioxide ore deposits (Ananai).

Compared with the known modes of occurrence, datolite from the *Oketo Rhyolite* suggests the occurrence of a new type, because it is formed as veinlets, which are composed of boro- and/or alumo-silicates with halide (fluorite) and halogeneous silicate (topaz), in the *Oketo Rhyolite* that cordierite and andalusite crystallizing as primary constituent minerals, not as xenocrysts, attain to approximately 35 to 40 volumetric per cent in maximum.

Petrography of the Oketo Rhyolite

The *Oketo Rhyolite* mass (1.5×0.75 km in size) is located in the westernmost of the area of the geological sheet-map "Tsunemoto" (1:50,000) (Hasegawa et al., 1963), and about 25 km southwest of Oketo town, Kitami Province, Hokkaido. The mass intrudes in a junction area between the *"Shirataki structural line"* (developed in pre-Tertiary with a NNW-SSE general trend) and the *"Kamishiyubetsu structural line"* (Tertiary in age with a NE-SW trend), both of which were first termed by one of the authors (Hasegawa et al., 1961). The mass intrudes into the Niitokorogawa Formation composed chiefly of green tuffs in Miocene age. The common facies of the mass, which was formed at the early stage, is a strikingly fluidal rhyolite which excludes cordierite and andalusite. It is, however, worth while stressing that the rhyolite at the later stage contains both of about 35 to 40 volumetric per cent, and borosilicates-bearing veinlets with fluorite and topaz occur.

The *Oketo Rhyolite* is classified into 9 lithofacies from the early to the latest stage:

Early facies;

(1) phenocrysts (quartz and An_{23}plagioclase)-poor, fluidal rhyolite.

Middle (principal) facies;

(2) phenocrysts (quartz and An_{31}plagioclase)-rich, massive rhyolite.

(3) fine-grained cordierite-bearing rhyolite (complex) (Plate 1-B).

(4) coarse-grained cordierite-bearing rhyolite (most of cordierite alter to pinite) (Plate 1-A).

Later facies;

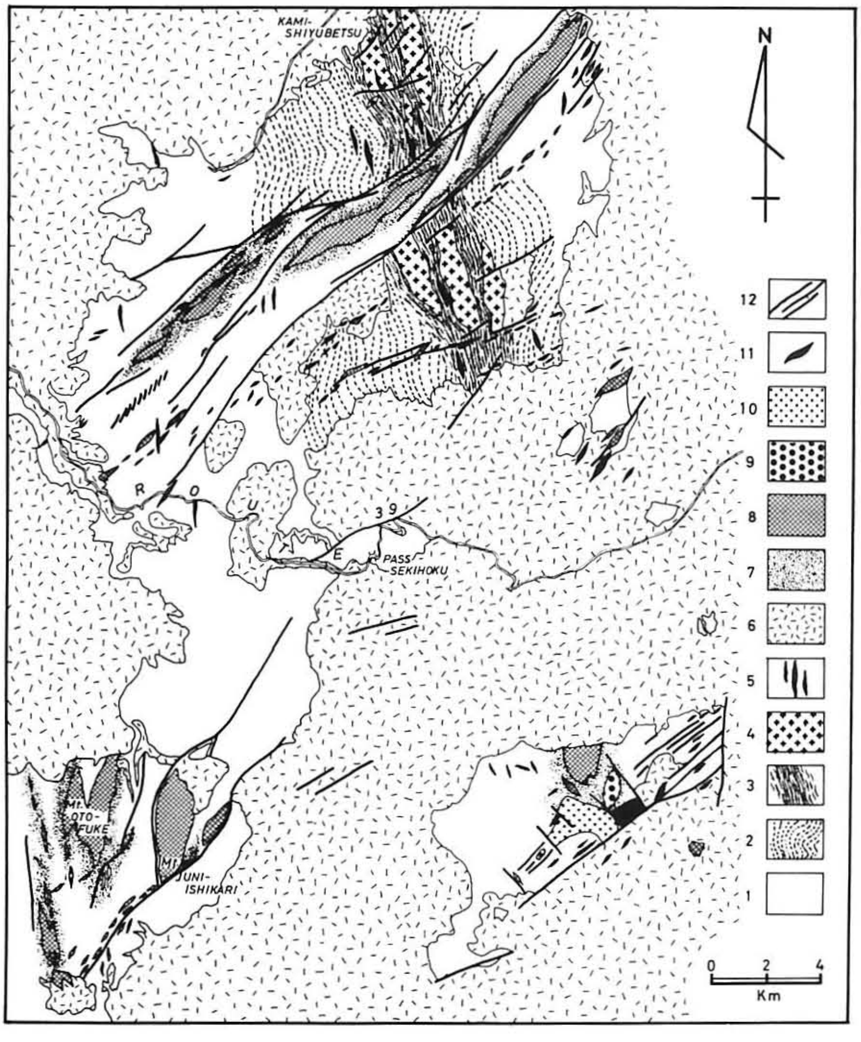
(5) metasomatic (presumably pneumatolytic or deuteric) rhyolite composed of blastic andalusite-sillimanite-(cordierite) with ghost quartz-muscovite-thuringite

(Plate 2-A).

(6) veinlets in the *main* veinlet-forming stage.

  a) $An_{23\text{-}28}$plagioclase-quartz-sillimanite veinlet.

  b) thuringite-muscovite veinlet.



Text-fig. 1 Structural map in the vicinity of the OKETO RHYOLITE mass (showing both of the Shirataki structural line and the Kamishiyubetsu structural one).
NNW-SSE trend: the Shirataki structural line
NE-SW trend: the Kamishiyubetsu structural line
1-5: Pre-Tertiary systems (1-3: Hidaka Supergroup, 1; slate, 2; phyllite, 3; cataclastic rock (sheared zone), 4; Shirataki-type sheared granite, 5; diabase dykes), 6-12: Tertiary systems (6; Kamishiyubetsu Formation: conglomerate and Niitokorogawa Formation: green tuff, 7; hornfels, 8; quartz-diorites, 9; quartz-porphyries, 10; OKETO RHYOLITE, 11; porphyrite, andesite and rhyolite dykes, 12; faults and sheared zones)

c) cordierite-muscovite-biotite-quartz veinlet.

d) cordierite-andalusite-muscovite-biotite-quartz veinlet.

Perhaps these veinlets (a-d) were formed contemporaneously.

(7) veinlets composed of boro- and/or alumo-silicate assemblages with a very small quantity of fluorite and topaz in the *subsequent* veinlet-forming stage (Plate 2-B).

a) dravite-schorl tourmaline-andalusite-muscovite veinlet.

b) datolite-quartz veinlet.

(8) cordierite rhyolite dike occurring at the later stage.

Latest facies;

(9) epithermally altered facies composed of montmorillonite-sericite-quartz-pyrite assemblage.

The minerals, which will be described in this paper, are exclusively limited to the veinlets (7) of the *subsequent* veinlet-forming stage.

Occurrence of datolite, tourmaline, andalusite and sillimanite

Borosilicates are exclusively formed in the above-stated veinlets (7a and 7b) of the *subsequent* veinlet-forming stage. The datolite is locally concentrated as grayish white veinlet (1 to 10 mm in width) and the tourmaline is rather common in dark bluish green veinlets (same in width) filling up the brecciated parts developed locally in a limited marginal area of the rhyolite mass. The brecciation is rather in a small scale, attaining to about 20 m in length and a few to several tens cm in width. Borosilicates-bearing veinlets are grouped on the basis of occurrence of borosilicates; a) dravite-schorl tourmaline-andalusite-muscovite, and b) datolite-quartz veinlet. Despite the veinlets formed simultaneously in the *subsequent* veinlet-forming stage, it may be cited, strictly speaking insofar the occurrence, that the former (a) was formed somewhat earlier than the latter (b). Accordingly, datolite and tourmaline are not neccessarily coexistent, but rather independent.

Mineralogical characters of datolite, tourmaline, andalusite and sillimanite

Datolite

In the above-mentioned veinlet (7b), datolite-bearing veinlet, under the microscope, shows a granoblastic texture owing to the dense aggregating of heterogranular anhedral datolite grains ranging from 0.1 to 0.8 mm (Plate 3-A, -B). In case it often contains the silicified wall-rack breccias, matrices around them are full of fine-grained datolite less than 0.1 mm. Datolite is white with the naked eye and colourless in thin section. It is usually anhedral form without distinct cleavages. Optical data are: $Ch_z(+)$. γ:z$=1$—$3°$. O.A.P. (010). $2V_x=71.0$—$72.0°$. $\alpha=1.625$, $\beta=1.652$, $\gamma=1.669$, $\gamma\text{-}\alpha=0.044$. Lattice constants are: $a=9.62$ Å, $b=7.60$Å, $c=4.83$ Å, $c/a=0.50$, $\beta=90°11'$. X-ray data is shown in Table 1. The data coincide well with

Table 1. X-ray data of datolites

Datolite, Oketo rhyolite			Datolite, Furano mine			Datolite, St. Andreasberg		
d(Å)	I	hkl	d(Å)	I	hkl	d(Å)	I	hkl
4.833	10	001,200	4.83	10	001,200	4.83	16	001,200
3.760	45	111,$\bar{1}$11	3.76	60	111,$\bar{1}$11	3.76	45	111,$\bar{1}$11
3.406	30	201	3.40	50	201	3.40	30	201
3.119	100	211,$\bar{2}$11	3.11	100	211,$\bar{2}$11	3.11	100	211,$\bar{2}$11
2.992	60	220,021	2.995	70	220,021	2.986	35	220,021
2.852	70	121,$\bar{1}$21	2.855	80	121,$\bar{1}$21	2.855	65	121,$\bar{1}$21
2.524	50	311,$\bar{3}$11	2.524	50	311,$\bar{3}$11	2.524	30	311,$\bar{3}$11
2.406	10	400	2.411	5	400	2.409	10	400
2.294	15	410	2.293	5	410	2.297	10	410
2.245	60	$\bar{1}$12,230	2.241	60	$\bar{1}$12,230	2.243	35	$\bar{1}$12,230
2.187	55	321,$\bar{3}$21	2.189	90	321,$\bar{3}$21	2.189	60	321,$\bar{3}$21
2.155	10	401,$\bar{4}$01	2.154	15	401,$\bar{4}$01	2.158	14	401,$\bar{4}$01
2.075	10	411,$\bar{4}$11	2.067	5	411,$\bar{4}$11	2.075	10	411,$\bar{4}$11
1.966	40	$\bar{1}$22	1.966	25	$\bar{1}$22	2.039	8	420,$\bar{2}$31
1.992	25	122	1.992	20	122	1.977	35	$\bar{1}$22
1.900	10	040	1.903	15	040	1.995	35	122
1.870	30	$\bar{4}$21,$\bar{3}$12	1.870	30	$\bar{4}$21,$\bar{3}$12	1.905	4	040
1.770	25	141	1.770	15	141	1.875	40	$\bar{4}$21,$\bar{3}$12
1.740	10		1.747	5	$\bar{5}$11,430	1.770	10	141
1.716	30	$\bar{1}$32,132	1.717	20	$\bar{1}$32,132	1.747	8	$\bar{5}$11,430
1.661	15	412,$\bar{4}$12	1.668	20	412,$\bar{4}$12	1.718	14	$\bar{1}$32,132
1.643	35	232,$\bar{2}$32	1.645	50	232,$\bar{2}$32	1.708	10	$\bar{4}$02
1.525	10	203	1.528	10	203	1.662	18	412,$\bar{4}$12
						1.644	40	232,$\bar{2}$32
a = 9.62Å			a = 9.64Å			a = 9.62Å		
b = 7.60Å			b = 7.61Å			b = 7.62Å		
c = 4.83Å			c = 4.83Å			c = 4.84Å		
c/a = 0.50			c/a = 0.50			c/a = 0.50		
$\beta = 90°11'$			$\beta = 90°14'$			$\beta = 90°09'$		

those of Furano mine (Plate 3-C, -D) and St. Andreasberg, Germany (ASTM 11-70).

Tourmaline

The mineral is not always associated with datolite but andalusite, muscovite and calcite in the veinlets (7a). The tourmaline is usually prismatic and radiating habit is common (Plate 4-A, -B). Grain size ranges from 0.2 to 0.5 mm. Refractive indices are: $\omega = 1.640$, $\epsilon = 1.618$, ω-$\epsilon = 0.22$. Colour is dark bluish green with the naked eye. It shows a marked pleochroism; ω = dark blue to grayish blue, ϵ = pale greenish yellow to pale yellow. Lattice constants are: a = 16.02 Å, c = 7.21 Å, c/a = 0.45. X-ray data is shown in Table 2. Referring to the chemical data, it is a kind of iron-tourmaline, having high content of schorl molecule with low content of uvite molecule.

Andalusite

The mineral, which is abundantly formed as andalusite blasts in the aforementioned facies (5) (Plate 4-C, -D), is also associated with iron-tourmaline, muscovite and sillimanite in the veinlet (7a). Crystal form is usually semi-radiate or anhedral tablet with good 110 cleavages. Grain size ranges from 0.5 to 1.5 mm. Optical data are: Ch_Z (−). $2V_X = 81.0$—$86.0°$. $\alpha = 1.630$, $\beta = 1.634$, $\gamma = 1.639$, $\gamma\text{-}\alpha = 0.009$. The mineral is pinkish to white with the naked eye and colourless in thin section, but occasionally shows a distinct pleochroism as x = rose-wine red, y = z = colourless. Lattice constants are: a = 7.79 Å, b = 7.90 Å, c = 5.55 Å, c/a = 0.71. X-ray data is shown in Table 2.

Table 2. X-ray data of tourmaline and andalusite from the Oketo rhyolite

Tourmaline			Andalusite		
d(Å)	I	hkl	d(Å)	I	hkl
6.38	20	101	5.555	80	110
5.03	25	021	4.539	60	101
4.227	40	211	3.924	40	111
4.000	40	220	3.512	60	120
3.490	50	012	2.770	100	220
3.010	25	410	2.477	30	112
2.971	60	122	2.467	40	310
2.579	100	042	2.376	10	031
2.390	20	003	2.272	35	022
2.374	20	232	2.255	20	311
2.345	20	511	2.170	70	320
2.130	20	303	1.976	10	040
2.056	20	223	1.814	10	
2.047	30	152	1.794	10	
			1.753	5	
			1.671	5	
			1.595	10	
			1.537	40	
a = 16.02 Å			a = 7.79 Å		
c = 7.21 Å			b = 7.90 Å		
c/a = 0.45			c = 5.55 Å		
			c/a = 0.71		

Sillimanite

The mineral, which is very rare in the metasomatic facies (5), is rather abundant as a single crystal or an andalusite-sillimanite intergrowth (Plate 5-A, -B, -C, -D) in the already-described veinlets (6a, 6d and 7a). Terminal faces are absent. In case of intergrowth, fibrolite needles penetrate into andalusite and form along its 110 cleavages. Contortion of matted fibrolite is probably due to growth, not deformation. Needle size ranges from 0.3 to 0.6 mm. Optical data are: Ch_Z(+). $2V_Z = 27.5$—$30.0°$. $\alpha = 1.658$, $\beta = 1.662$, $\gamma = 1.680$, $\gamma\text{-}\alpha = 0.022$. X-ray data and chemical analysis have not been obtained.

In the veinlets, some characteristic minerals such as halide (fluorite) and halogeneous silicate (topaz) are rarely formed.

Fluorite

The mineral, which is very rarely formed in andalusite-tourmaline-muscovite veinlet (7a) cutting metasomatic facies (5), shows an euhedral crystal form and is partly replaced by chlorite- and muscovite-flakes (Plate 6-A, -B). Grain size ranges from 0.5 to 0.7 mm. There is no twinning with interpenetration and no cleavages. It is grayish white with the naked eye and colourless in thin section. Under the microscope, it is isotropic and refractive index is so low that the negative relief is marked. Refractive index has not been determined, but may be roughly estimated to 1.44—1.45. X-ray data and chemical data have not been obtained, because it is impossible to separate the minute grains.

Topaz

The mineral, which is very rarely formed with fluorite in andalusite-tourmaline-muscovite veinlet (7a) cutting metasomatic facies (5), shows an euhedral or subhedral columnar form with imperfect 001 cleavage and is partly altered to biotite- and muscovite-flakes (Plate 6-C, -D). Grain size ranges from 0.2 to 0.8 mm. The colour of topaz is grayish with the naked eye and colourless in thin section. Optical data are: $Ch_z(-)$. $2V_z = 54.0°$. Refractive index has not been determined, but may be roughly estimated to be $\alpha = 1.62$, $\beta = 1.63$, γ-α = ca 0.009. X-ray data and chemical analysis have not been obtained, because it is impossible to separate the minute grains.

Chemical characters of datolite, tourmaline and andalusite

The chemical data for these minerals are tabulated in Tables 3 and 4.

Datolite

Boron was titrated with 0.02N NaOH and mannitol after removal of interfering substances and neutralization. Percision of the method is ± 0.2% B_2O_3. For total water the Penfield method was employed. All the chemical contents except for boron and total water were determined by EPMA.

The numbers of ions on the basis of 20 (O, OH) are given by $Ca_{4.02\text{-}4.23}B_{4.11\text{-}3.68}Si_{3.90\text{-}4.11}O_{15.96\text{-}15.93}(OH)_{4.04\text{-}4.07}$, namely as the empirical formula: $Ca_{1.00\text{-}1.06}B_{1.03\text{-}0.92}Si_{0.97\text{-}1.03}O_{3.99\text{-}3.98}(OH)_{1.01\text{-}1.02}$ for the formula of datolite; $CaBSiO_4(OH)$.

Tourmaline

Partial analysis was carried out by EPMA. Boron and total water were not determined, because it it impossible to separate the minute grains. The obtained data shows that the tourmaline in question has a minor molecule of uvite; $CaMg_3(MgAl_5)\ B_3Si_6O_{27}(OH)_4$ (Dunn et al., 1977) and a major molecule of dravite: $NaMg_3Al_6B_3Si_6O_{27}(OH)_4$ (Bridge et al., 1977)—schorl; $Na\ (FeMn)_3Al_6B_3Si_6O_{27}(OH)_4$ series. Together with help of X-ray data, it may be reasonable to say that the tourmaline is an intermediate variety of dravite-schorl series, rather near the end member of schorl.

Table 3. Chemical data of datolites and tourmaline from the Oketo rhyolite

	Datolite (1)	Datolite (2)	Tourmaline
SiO_2	36.40	38.07	35.25
TiO_2	.02	.00	.08
Al_2O_3	.03	.06	27.88
Cr_2O_3	.03	.00	.02
IRO*	.02	.04	16.20
MnO	.13	.06	.09
NiO	.00	.03	.00
MgO	.00	.02	1.35
CaO	34.98	36.55	1.26
Na_2O	.00	.00	2.24
K_2O	.01	.01	.01
$H_2O(+)$	5.16		n.d
$H_2O(-)$	.50		n.d
B_2O_3**	22.30	19.83	n.d
	99.58	100.33	

Numbers of ions on the basis of 20(O,OH)
(1) $Ca_{4.02}B_{4.11}Si_{3.90}O_{15.96}(OH)_{4.04}$
(2) $Ca_{4.23}B_{3.68}Si_{4.11}O_{15.93}(OH)_{4.07}$

n.d; not determined
*as FeO
**determined by neutralization titration method of 0.02N NaOH solution. Analyst: J. Watanabe

Table 4. Chemical data of andalusites from the Oketo rhyolite

	Andalusite (1)	Andalusite (2)	Andalusite (3)
SiO_2	36.68	35.42	34.83
TiO_2	.11	.13	.21
Al_2O_3	63.16	63.66	64.28
IRO*	.15	.26	.28
MnO	.02	.05	.10
MgO	.01	.01	tr
CaO	.02	.06	.02
Na_2O	.04	.12	.02
K_2O	.01	.09	.02
Cr_2O_3	.03	tr	.06
	100.23	99.80	99.82

(1) $Al_{2.01}Si_{0.99}O_5$
$50.37Al_2O_3 \cdot 49.63SiO_2$
(2) $Al_{2.05}Si_{0.96}O_5$
$51.44Al_2O_3 \cdot 48.56SiO_2$
(3) $Al_{2.06}Si_{0.95}O_5$
$52.09Al_2O^3 \cdot 47.91SiO_2$
*as total FeO
Analyst: M. Akasaka

Andalusite

All the chemical contents were determined by using EPMA. The obtained formula is $Al_{2.01\text{-}2.06}Si_{0.99\text{-}0.95}O_5$ for the formula of andalusite; Al_2SiO_5. The ratio of Al_2O_3 to SiO_2 is 50.37-52.09 *versus* 49.63-47.91.

Concluding remarks on genesis of datolite in the light of formation of mother rock (Oketo Rhyolite)

The new type of occurrence of datolite, which has not yet been known in Japan, was described in this paper. It is characterized by veinlets composed of boro- and/or alumo-silicates with halide and halogeneous silicate. The veinlets are formed in metasomatic facies (chiefly andalusite blastase) of the *Oketo Rhyolite*, which is no doubt considered to have generated through partial melting process from the *Shirataki-type sheared granite* (Watanabe et al., 1981a). This presumption on genesis of the rhyolite will be confirmed by a suitable support from petrochemical point of view as emphasized in the previous paper. To sum up, it may be deduced that the origin of borosilicates and associated minerals is closely implicated in anatectic process due to partial melting of the sheared granite. The veinlets, in fact, were formed under pneumatolytic or deuteric condition inherited intimately, as a so-called *"post-action of igneous activity"*, from the *Oketo Rhyolite* showing a complex geohistory in terms of genetical point of view.

No occurrence showing such characteristic mineral assemblages in the veinlets formed in a very peculiar rhyolite mass may have been found out in Japan as well as in the world.

Acknowledgements

The present authors wish to acknowledge with grateful appreciation to Drs. Mitsuo Hunahashi, Zyumpei Harada, Toshio Ishikawa, Sumitoshi Sako, Mamoru Suzuki, Kenji Togari and Chikara Akiba for valuable advice. The authors are also indebted to Drs. Takeo Watanabe and Akira Kato for their critical readings of this paper in manuscript. Chemical analyses were partly carried out by Drs. Hiroyuki Takahata and Masahide Akasaka. Drs. Takamura Tsuchiya and Koji Uchiyama helped us in various ways. To whom the authors' thanks are due.

References

Bridge, P.J., Daniels, J.L. and Pryce, M.W., 1977. The dravite crystal bonanza of Yinnietharra, western Australia. *Mineral. Record*, 8: 109-110.

Dunn, P.J., Appleman, D., Nelen, J.A. and Norberg, J., 1977. Uvite, a New (Old) Common Member of the Tourmaline Group and Its Implications for Collectors. *Mineral. Record*, 8: 100-108.

Harada, Z., 1939. Zur Kenntnis der Japanischen Bormineralien. *Jour. Fac. Sci., Hokkaido Univ., Ser. IV*, 5: 1-122.

Harada, Z., 1950. Datolite and Associated Minerals from the Iwato Copper Mine, Miyazaki Prefecture. *Jour. Fac. Sci., Hokkaido Univ., Ser. IV*, 7: 217-226.

Harada, Z., 1954. Chemical Analyses of Japanese Mineral (III). *Jour. Fac. Sci., Hokkaido Univ., Ser. IV*, 8: 289-348.

Hasegawa, K., Takahashi, T. and Matsui, K., 1961. *Explanatory text of the geological map of Japan 1/50,000 "Kamishiyubetsu"*. Hokkaido Development Agency, 44pp. (in Japanese with English abstract).

Hasegawa, K. and Watanabe, J., 1963. *Explanatory text of the geological map of Japan 1/50,000 "Tsunemoto"*. Hokkaido Development Agency 28pp. (in Japanese with English abstract).

Imayoshi, R. and Sakurai, K., 1950. Datolite from the Okuzure Cliff, Shizuoka Prefecture — Studies on the Minerals of Japan (9). *Mineral and Geology*, 18: 249-250 (in Japanese).

Kato, A., Kanehira, K. and Horikoshi, A., 1957. On datolite from Hoino, Nakagawa, village, Shūsō district, Ehime Prefecture and Shirataki Mine, Tosa district, Kochi Prefecture. *Jour. Japan. Assoc. Min. Petr. Econ. Geol.*, 41: 198-200 (in Japanese with English abstract).

Miyahisa, M. and Tanaka, N., 1953. Pyrometasomatic ore deposits of the Obira district, Ōita Prefecture, with special reference to occurrence of datolite. *Jour. Geol. Soc. Japan*, 59: 359 (in Japanese).

Miyahisa, M. and Ishibashi, K., 1964. Datolite from the Sobosan valcanics. *Jour. Mineral. Soc. Japan*, 7: 72 (in Japanese).

Miyahisa, M. and Ishibashi, K., 1965. Datolite from Sōmi, Miyazaki Prefecture, Japan. *Jour. Japan. Assoc. Min. Petr. Econ. Geol.*, 53: 169-175 (in Japanese with English abstract).

Sako, S., Suzuki, M. and Matsui, K., 1957. Pyrrhotite ore deposits from the Furano mine, Hokkaido. *Data of Underground Resources in Hokkaido*, 35: 1-17 (in Japanese).

Sato, F. and Yagi, K., 1967. Datolite from the Furano mine, Hokkaido. *Rept. Geol. Surv. Hokkaido*, 37: 97-98 (in Japanese).

Watanabe, J. and Hasegawa, K., 1981a. Cordierite-bearing rhyolite (Oketo rhyolite) and related rocks — 1. Some considerations on the formation and developing processes of the rhyolite. *Rept. Geol. Surv. Hokkaido*, 53: 1-61 (in Japanese with English abstract).

Watanabe, J. and Hasegawa, K., 1981b. Andalusite from the Oketo rhyolie. *Rept. Geol. Surv. Hokkaido*, 3: 102-104 (in Japanese).

Yoshimura, T., Ishibashi, K. and Ozaki, M., 1966. Datolite from Ananai Mine, Kōchi Prefecture, Japan. *Jour. Mineral. Soc. Japan.*, 7: 417-423 (in Japanese).

(Manuscript received on Oct. 28, 1985; and accepted on Nov. 22, 1985).

Explanation of Plate 1

A: Coarse-grained cordierite-bearing rhyolite facies, which is formed in fine-grained cordierite-bearing rhyolite facies, is characterized by coarse-grained euhedral or subhedral cordierites.

B: Fine-grained cordierite-bearing rhyolite facies, in which fine-grained cordierites are formed with a schlieren or a nebulous appearance. Note the pseudo-segregating veinlets composed mainly of coarse-grained euhedral or subhedral cordierites are formed along or across the flow structure of the early facies.

Explanation of Plate 2

A: Metasomatic facies (andalusite rhyolite facies), in which andalusites are formed in amount of 35 — 40 vol.%. Cordierites are associated with a small amount.

B: Andalusite-tourmaline veinlets filling the brecciated part of metasomatic facies, with which datolites are occasionally associated.

Explanation of Plate 3

Photomicrographs of datolite in datolite veins from two localities.

A: Datolite(D) and quartz(Q) showing granoblastic texture in a datolite vein from the Oketo rhyolite. Sp. No. T-Z. 1 nic.

B: As above. + nic.

C: Datolite(D) and garnet(G) showing granoblastic texture in a datolite vein developed in skarnized rock from the Furano mine. Sp. No. FuG. 1 nic.

D: As above. + nic.

Explanation of Plate 4

A: Tourmaline(T)-Muscovite(M) aggregation in an andalusite-tourmaline-biotite veinlet cutting metasomatic facies (cordierite(pinite)-albite(Ab)-quartz(Q)). Sp. No. 3N. 1 nic.

B: As above. + nic.

C: Fan-formed andalusite(A) with quartz(Q) and muscovite(M) in metasomatic facies composed of albite(Ab), quartz(Q) and cordierite(C: pinitized). Sp. No. 1J. + nic.

D: Radial-formed andalusite(A) in metasomatic facies. Sp. No. 1J. + nic.

Explanation of Plate 5

Photomicrographs of andalusite-sillimanite(fibrolite)-biotite intergrowth.

A: Andalusite(A)-fibrolite(F)-biotite(B) intergrowth in an andalusite-tourmaline veinlet cutting metasomatic facies composed of albite(Ab), quartz(Q) and sericite(M). The intergrowth is partly replaced by muscovite(M). Sp. No. Ok-1. 1 nic.

B: As above. + nic.

C: Andalusite(A)-fibrolite(F) intergrowth in an andalusite-tourmaline veinlet cutting metasomatic facies composed of albite(Ab), quartz(Q) and sericite(M). Sp. No. Y. 1 nic.

D: As above. + nic.

Explanation of Plate 6

Photomicrographs of fluorite and topaz.

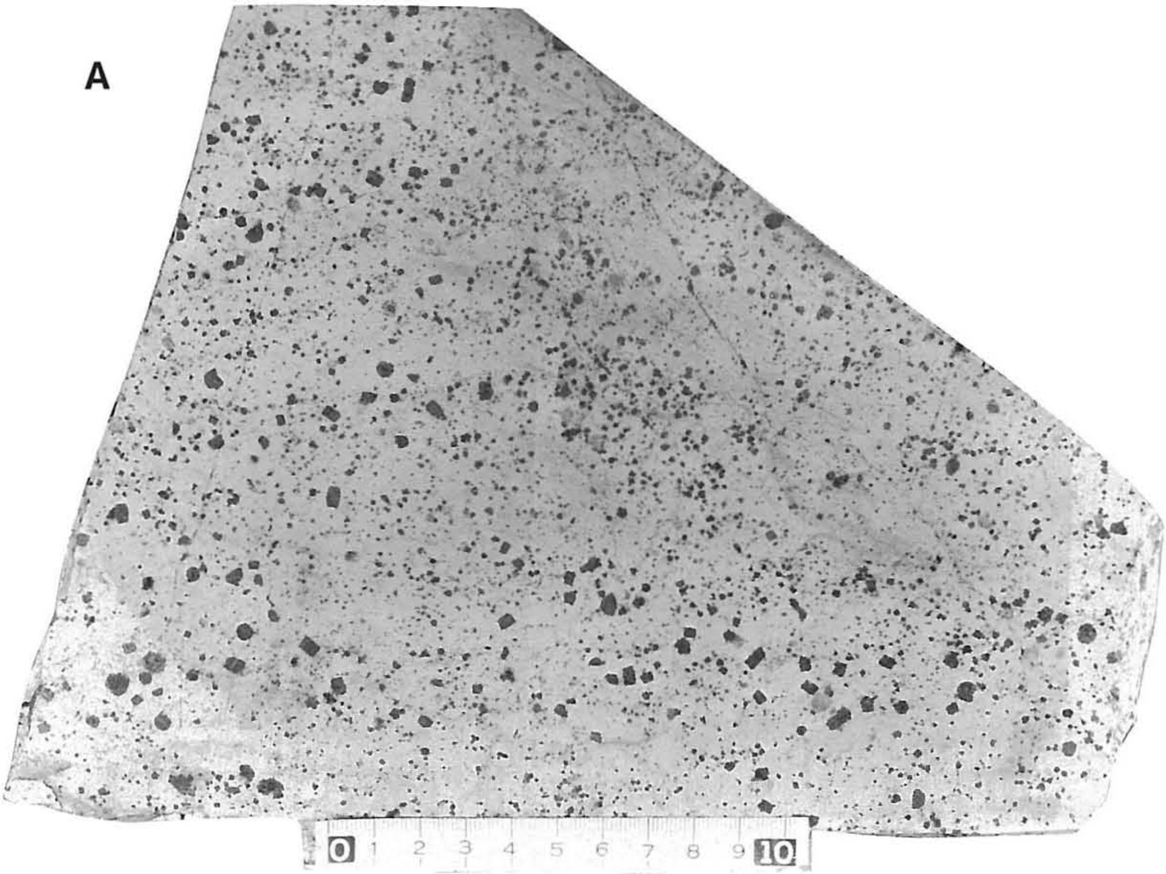
A: Fluorite(Fl) in an andalusite-tourmaline veinlet cutting metasomatic facies composed of albite(Ab), quartz(Q) and sericite(M). Fluorite is partly replaced by chlorite(Ch) and muscovite(M). Sp.No. 4H7A. 1 nic.

B: As above. + nic.

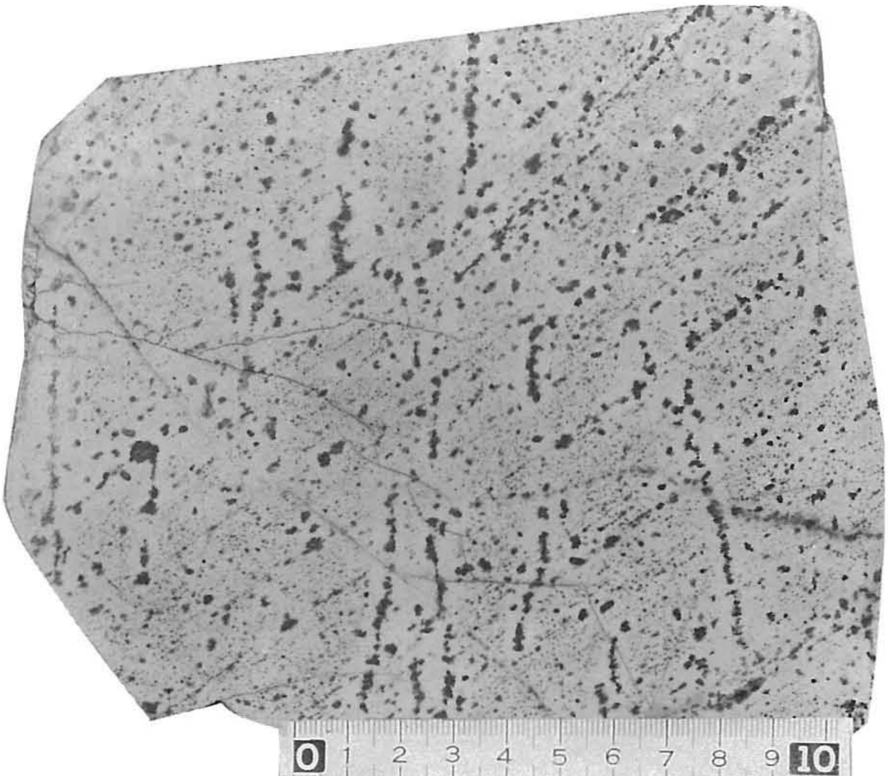
C: Topaz(Tp) grain in an andalusite(A)-tourmaline veinlet cutting metasomatic facies composed of albite(Ab), quartz(Q) and sericite(M). Topaz is partly altered to biotite(B) and muscovite(M). Sp.No. Ok-7. 1 nic.

D: As above. + nic.

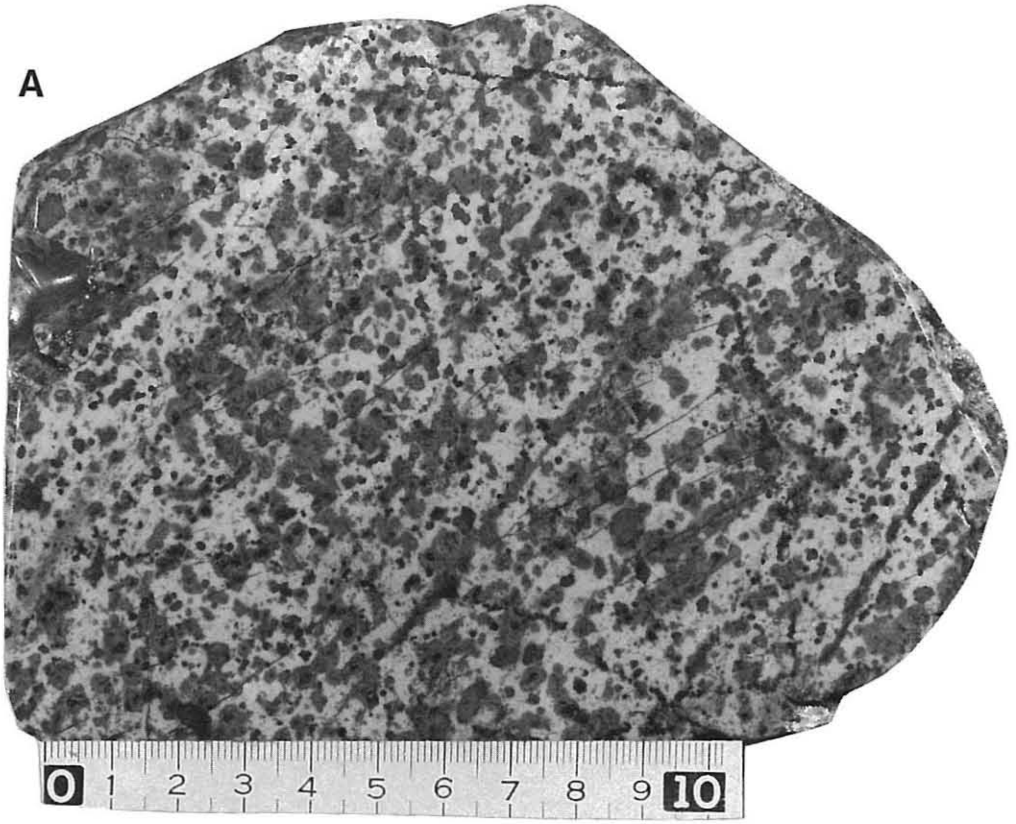
A



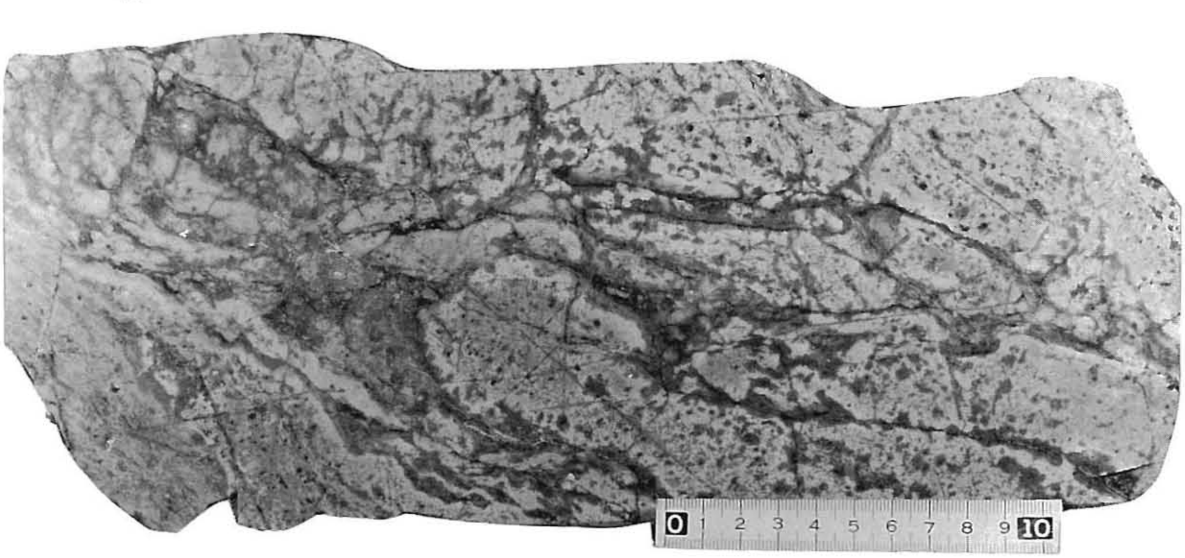
B

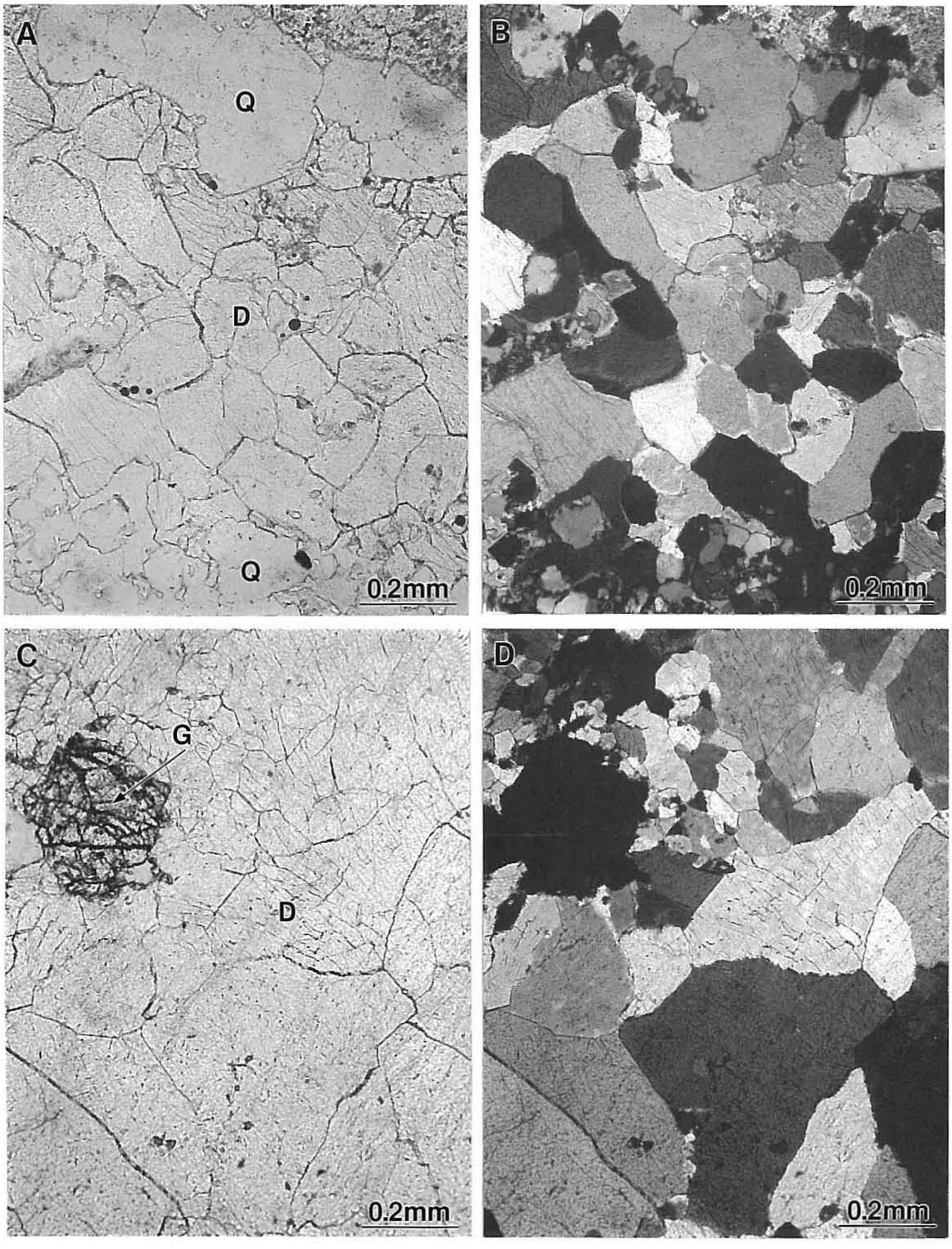


A



B




A
Q
D
Q
0.2mm
B
0.2mm
C
G
D
0.2mm
D
0.2mm

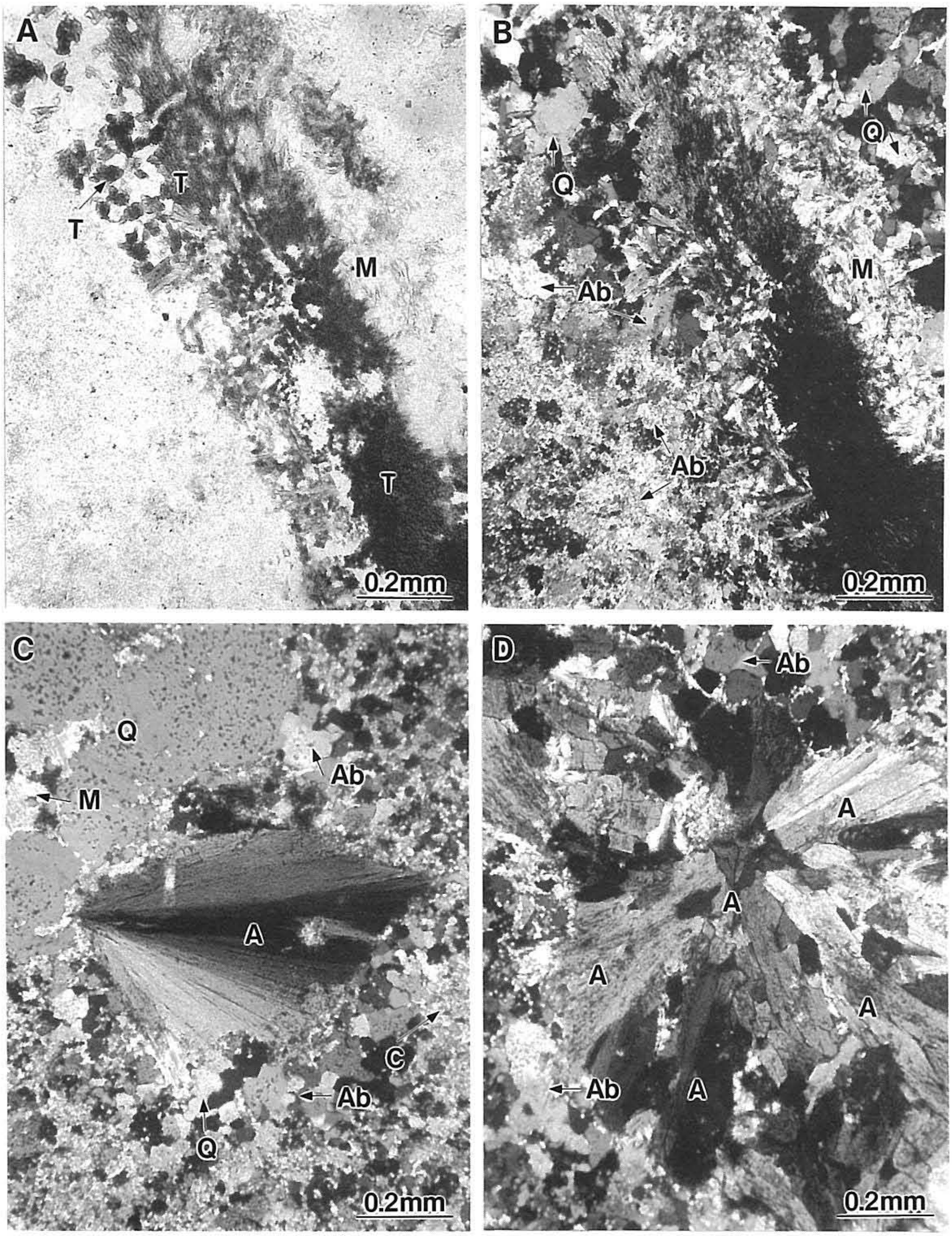
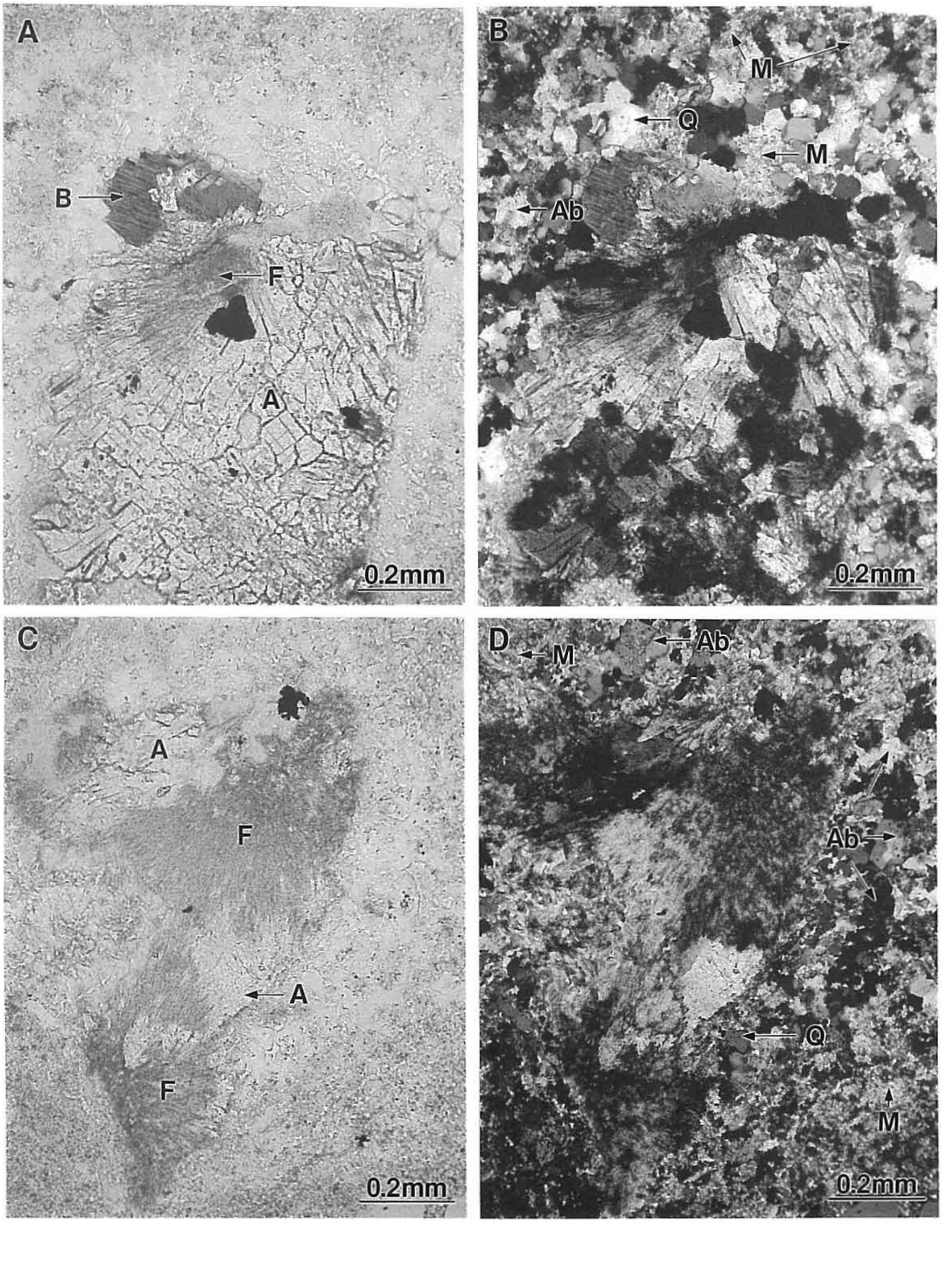
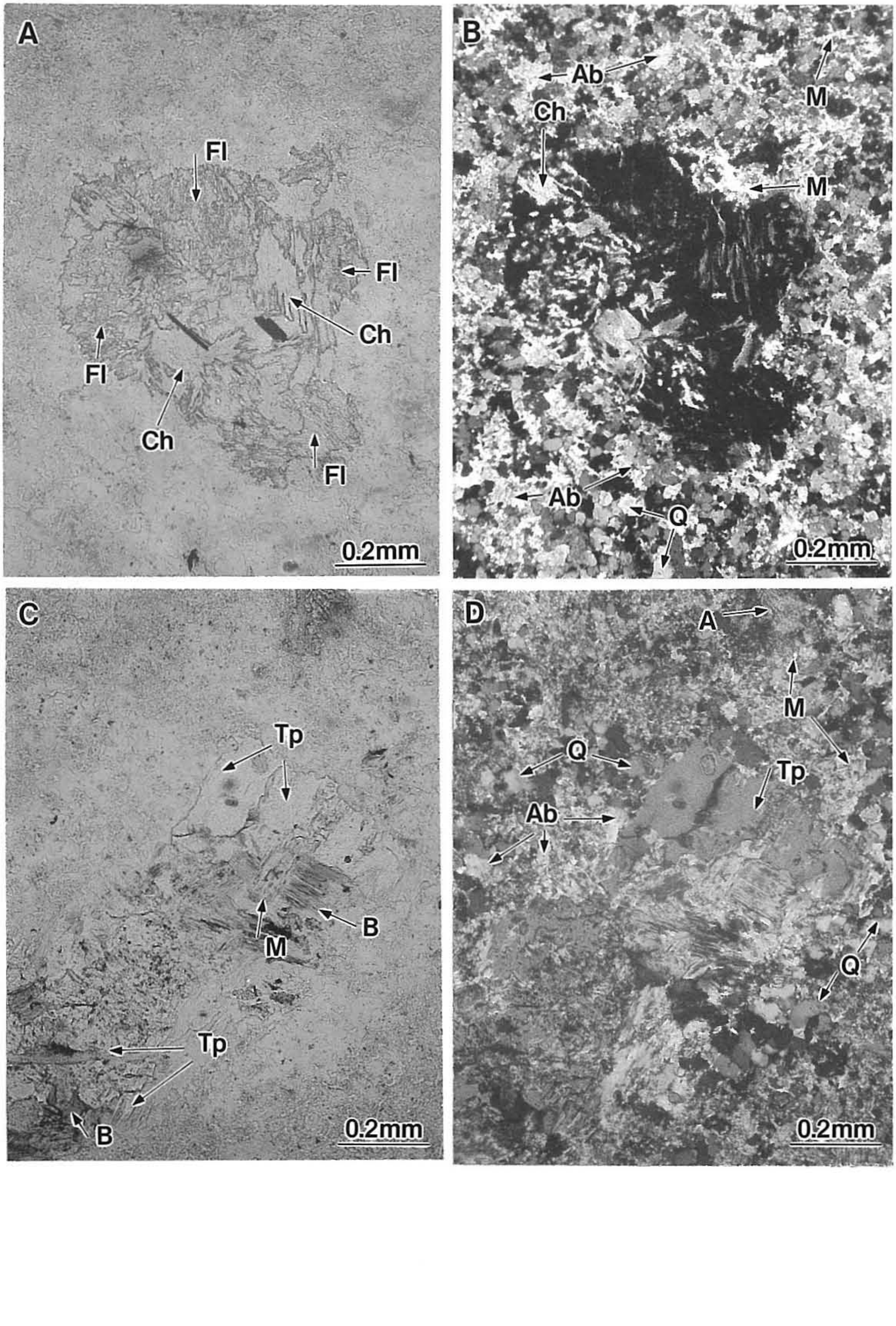

A
T
T
M
T
0.2mm
B
Q
Q
M
Ab
Ab
0.2mm
C
Q
Ab
M
A
C
Ab
Q
0.2mm
D
Ab
A
A
A
A
Ab
A
0.2mm

Plate 5




A
Fl
Fl
Ch
Fl
Ch
Fl
0.2mm
B
Ab
M
Ch
M
Ab
Q
0.2mm
C
Tp
B
M
Tp
B
0.2mm
D
A
M
Q
Tp
Ab
Q
0.2mm