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Study on Genesis of Wollastonite*

Part II

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(With 10 Tables, 8 Text-figures, and 39 Photographs)

I. Occurrence of wollastonite in Nature

According to the reports so far made public, the main locations of the mineral occurred in Japan are roughly summarized in Fig. 1 and Table 1.

Beside the above-mentioned are there a lot of locations related to the occurrence of wollastonite but some representatives will hereunder be introduced in connection with its genesis.

(A) Gobessho

Geological remarks: The location is situated east of Nyoigadake, Ôtsu-shi, Shiga Prefecture. In the surroundings concerned are found distributed Paleozoic formation, Cretaceous biotite-granite and granite and quartz-porphyry (see Fig. 12). The former exposed at Mts. Hiei and Daimonji are composed mainly of hornfels of slate and sandstone intercalated sporadically with quartzite and crystalline limestone, being probably subjected to contact effects of the latter, and was reasonably correlated to a part of Permian member by Matsushita (1950) on the basis of certain sort of fossils and of interfingered diabase concerning his geological study on the mountainlands disposed on the western, northwestern, and northern sides of Kyoto basin. On the other hand a large mass of batholithic granite, some Km in diameter, intruding into the former, is appeared accompanying, in parts, injetion of lamprophyre, pegmatite, aplite and quartz veins together with basic xenolithes within its own body and more abundantly along the margin. The intrusive under consideration is generally coarse-grained, grayish white or white in color, and composed principally of quartz, orthoclase, plagioclase and biotite associated with accessories such as allanite in considerable amount and so forth and, specifically in the central part appeared east of Yamanaka, porphyritic or coarser-grained in texture and leucocratic in appearance. The injectives, about 7 m in maximum width, represented by lamprophyre, pegmatite, and aplite are found pointing to a general trend on NNW-SSE or NNE-SSW chiefly in granitic mass. Of all, lamprophyre and aplite might have been formed at the later stage of granite intrusion

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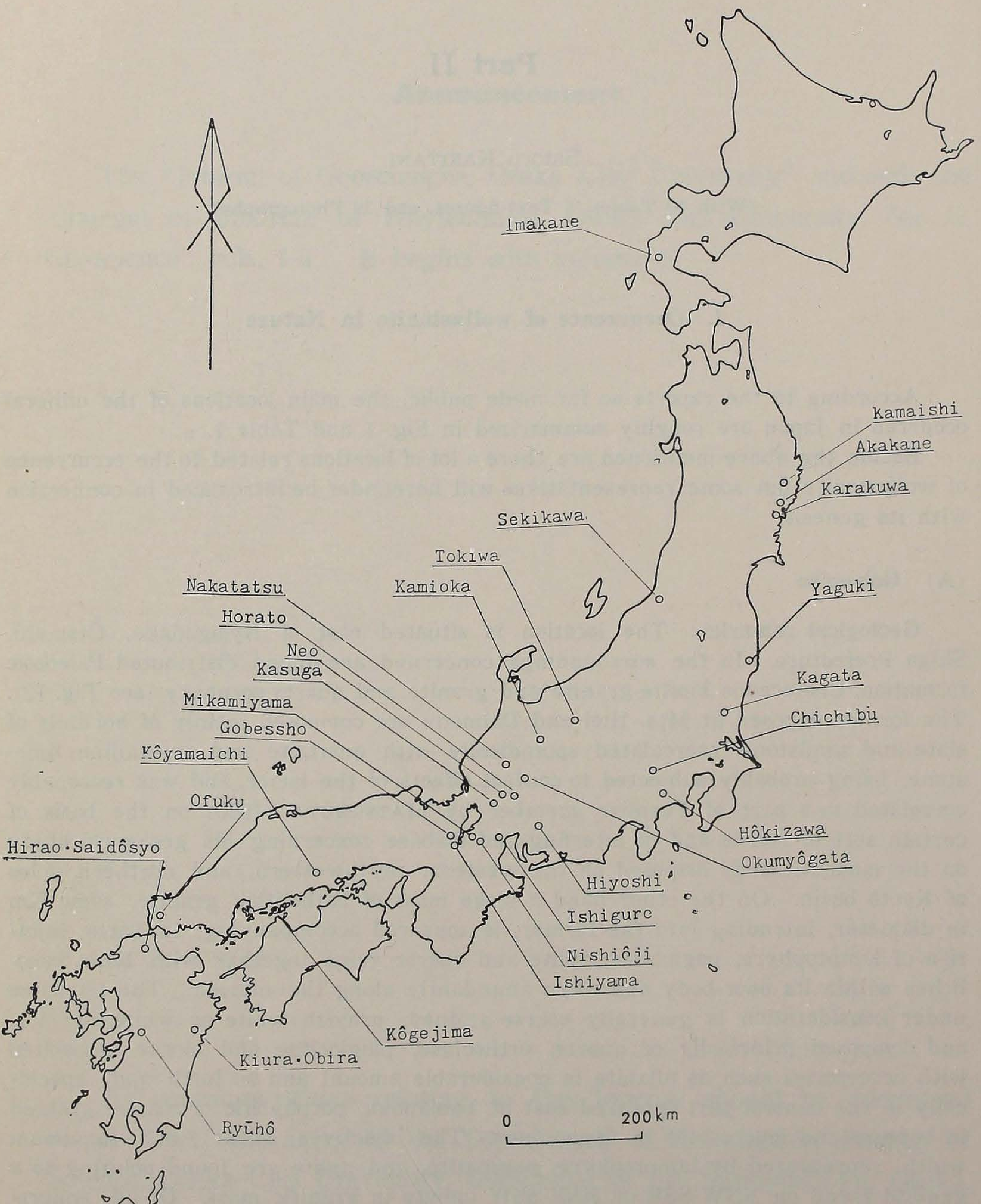


Fig. 11. Distribution map illustrating the main locations of wollastonite in Japan

Table 3. Locations of wollastonite in Japan with geological remarks on the surroundings

Location		Geological remarks
Imakane	Imakane-chô, Sedanagun, Hokkaido	Veins included in andesite and partly in hornblende-granite
Kamaishi mine	Kamaishi-shi, Iwate Pref.	Included in the Permian formation composed of sandstone, green-colored rock, limestone and slate intruded by granodiorite subsequent to monzonite, porphyrite and diorite intruded along the bedding planes of the sedimentaries
Akakane	Esashi, Esashi-gun, Iwate Pref.	Comprised in the contact of Paleozoic formation with granite porphyry and granodiorite
Karakuwa	Karakuwa-mura, Motoyoshi-gun, Miyagi Pref.	Contained in the contact of limestone with granitic intrusive
Sekigawa	Sekigawa-mura, Iwafune-gun, Niigata Pref.	Embraced in the contact of Paleozoic limestone with intrusive
Yaguki mine	Yotsukura-chô, Iwakigun, Fukushima Pref.	Enclosed in the unknown Paleozoic formation intruded by granitic rocks and serpentinite.
Kagata	Kasama-chô, Nishi-Ibaraki-gun, Ibaraki Pref.	Formed in the contact of metamorphics derived from Chichibu formation with biotite-granite
Chichibu mine	Nakatugawa, Otaki-mura, Chichibu-gun Saitama Pref.	Involved in the upper Carboniferous to lower or middle Permian formation composed of slate, sandstone, chert, limestone and diabase intruded by grano-or quartz-diorite intruded at the later stage of Miocene
Hokizawa	Yamakita-chô, Asigara-kami-gun, Kanagawa Pref.	Enclosed in the contact of limestone with granitic intrusive
Tokiwa	Ômachi-shi, Nagano Pref.	ditto
Kamioka mine	Kamioka-chô, Yoshiki-gun, Gifu Pref.	Involved in Hida gneiss intercalated with numerous layers of limestone, intruded by granite
Oku-myôgata	Oku-myôgata-mura, Gunjô-gun, Gifu Pref.	Originated in the contact of limestone with granite intrusive
Nakatatsu mine	Izumi-mura, Ono-gun, Fukui Pref.	In the neighborhood, Jurassic formation composed alternation of sandstone and shale intruded by melanocratic dikes and quartz porphyry and of a small-scaled Paleozoic limestone intercalated with thin layers of slate and sheet of leucocratic kinds are appeared
Neo	Neo-mura, Motosu-gun Gifu Pref.	Occurred in the contact of limestone with acidic intrusive
Hiyoshi	Hiyoshi-chô, Mizunami-shi, Gifu Pref.	Produced through the effects of granite and quartz-porphyry on limestone of upper

Location		Geological remarks
		Paleozoic formation
Kasuga	Kasuga-mura, Ibi-gun, Gifu Pref.	Appeared in the contact of limestone with granitic intrusive
Horato, Itadori, Shimomaki, Inui. (Old gallery of Horato)	Horato-mura, Bugi-gun, Gifu Pref.	Accompanied with the contact deposit of Cu, Pb, and Zu, and included in the contact of limestone with granitic intrusive in association with hedenbergite and garnet
Ishigure	Ishigure-minami-mura, Imben-gun, Mie Pref.	Disposed in the contact of lsmestone with granitic intrusive
Mikami-yama, Saimyôji Hatchôno	Mikami-yama, Nozu-gun, Saimyôji and Hatchôno, Gamô-gun, Shiga Pref.	ditto
Ishiyama	Ishiyama-chô, Ôtsu-shi, Shiga Pref.	ditto
Daimonji-yama (Nyoigadake)	Gobessho, Ôtsu-shi, Shiga Pref.	Disposed in the contact of limestone with granitic intrusive
Kôyamaichi Ohara mine	Kôyamaichi, Kawakami-chô, Kawakami-gun, Okayama Pref.	Deposited in the contact of Paleozoic limestone with granitic intrusive
Kôgejime Okamura mine	Kôgejima, Sekizen-mura Ochi-gun, Ehime Pref.	Found in the contact of limestone with granitic intrusive
Ofuku Yamamoto mine	Ofuku-chô, Mine-shi, Yamaguchi Pref.	Appeared as veins or gangue of contact deposit produced in the contact of limestone with granitic intrusive
Hirao, Yoshiwara, Yoshiwara mine, Yokozuru mine	Yobino-chô, Kokura-shi, Gôya-chô, Tagawa shi, Kôharu-cho, Tagawa-gun, Fukuoka Pref	Gangue of the contact deposit displayed in the contact of limestone with granodioritic mass
Obira	Hasegawa-mura, Ôno-gun, Ôita Pref.	Occurred as veins or in the deposit observed in the contact of Paleozoic formation composed of slate, sandstone, and limestone with lithoidite and liparite
Kiura	Ono-mura, Minamiamabe-gun, Ôita Pref.	Contained in the contact deposit originated in Paleozoic formation composed of slate, sandstone, and limestone
Ryūhô	Ryūhô-mura, Yatsushiro-gun, Kumamoto Pref.	Enclosed in the contact of limestone intercalated in the Ryūhô metamorphics with granitic intrusive

and the latter is considered to have been earlier in stage than the former, whereas Dr. Hiki regarded these injectives from a simple source according to his chemical analyses. Moreover, it seems noteworthy that there are some quartz veins travers-

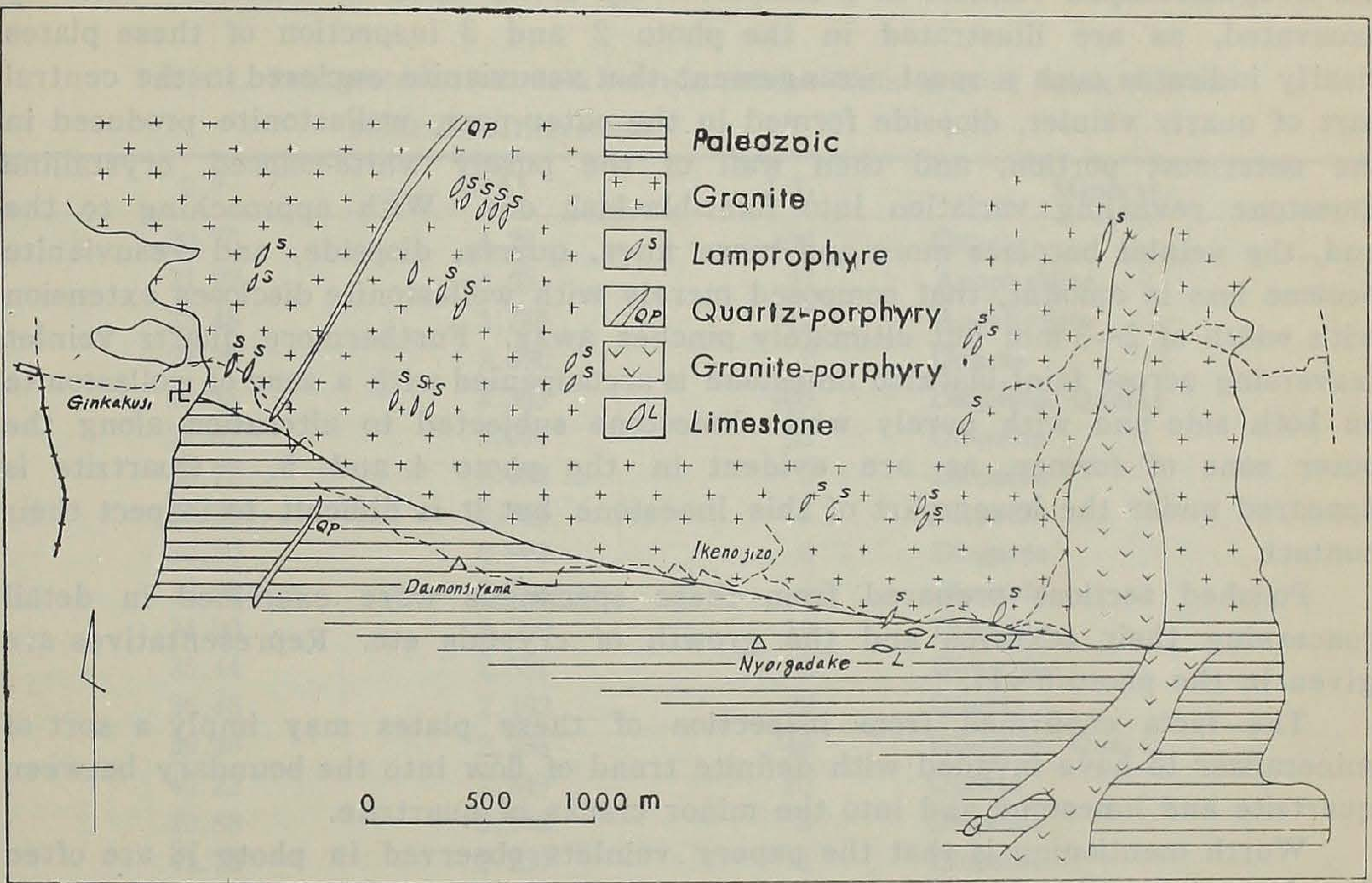


Fig. 12. Geological map in the surroundings of Mt. Daimonji and Nyoigadake. (NAKAJIMA)

ing across the lamprophyre dikes.

In the related area are surely confirmed the networks of faults with the trend of NNW-SSE and NNE-SSW, of which the Hanaore fault running the Hanaore pass located in the southwestern corner of Mt. Hira, the valleys of the Takano River and into Kyoto basin.

Mineralogy: In relation to the occurrence of wollastonite, some species of minerals found commonly in the area are here to be mentioned. Bulk of cordierite are recognized in several parts situated in hornfels of slate and those associating sakura-ishi, a twinned variety of the former, together with a little amount of andalusite are also occurred midway up Mt. Daimonji. Abundance of allanite are observed in fine-grained, compact facies of granite distributed near the contact with slate. It is well-known that various kinds of skarn such as wollastonite, vesuvianite, garnet, and salite etc. are revealed on the outcrop of quartzite and of a part of lenticular limestone, pointing to EW in strike, embraced in slate distributing east of Nyoigadake. In these locations, it is regrettably difficult to inspect the occurrence of wollastonite on account of being stained through weathering and of irregularity in its content and no exposures displaying the paragenetic relation to others are observed in the contact zone between quartzite and limestone. The presence of wollastonite is apt to be ascertainable along quartzite of dike-like appearance but not always symmetrically along its both sides. Its acicular crystals are also scattered within the cracks of quartzite and happen to bear milky-white color. By the road about 200m east of the above-mentioned spot are discernible the irregularshaped veinlets in a comparatively fresh mass of limestone recently excavated, as are illustrated in the photo 2 and 3 inspection of these plates clearly indicates such a zonal arrangement that vesuvianite enclosed in the central part of quartz veinlet, diopside formed in the outer part, wollastonite produced in the outermost portion, and then wall of the purely white-colored, crystalline limestone revealing variation into faint-blackish one. With approaching to the end, the veinlet becomes more and more finer, quartz, diopside, and vesuvianite become less in amount, that composed merely with wollastonite discloses extension with width of 2~3 mm but ultimately pinches away. Furthermore, quartz veinlet traversing across faint-blackish limestone is accompanied with a zone of wollastonite on both side and with purely white limestone subjected to alteration along the outer zone of former, as are evident in the photo 4 and 5. Quartzite is appeared under the lower part of this limestone but it is difficult to inspect their contact.

Polished sections prepared from these specimens were examined in detail concerning their textures and the growth of crystals etc. Representatives are given in the photo 6~11.

The facts confirmed from inspection of these plates may imply a sort of mineralizer to have invaded with definite trend of flow into the boundary between quartzite and limestone and into the minor cracks of quartzite.

Worth mentioning is that the papery veinlets observed in photo 18 are often found traversing across the wall rock, wollastonite-bearing vein, composite vein etc., while röntgenometric examination of those obtained from Hatchôno, Shiga Prefecture evidently indicate the content of riversideite.

These photoplates reveal that in the broader part of veinlets concerned quartz together with a little amount of vesuvianite are found in the center, salite on both sides of the former, and wollastonite along the outermost zone coming into contact with white-colored crystalline limestone but in the narrower part salite associating partly certain amount of vesuvianite is found in the center instead of quartz and other phenomena are similar to that in the former case. Formation of white-colored crystalline limestone appeared along the wollastonite zone might have been ascribed to decomposition of carbonaceous limestone through the mineralizer carrying wollastonite and some others.

On the other hand the minerals in paragenetic relation to wollastonite were also scrutinized by means of X-ray and under microscope.

Materials indissolved in HCl:

(a) Date for the residue obtained from grayish black-colored crystalline limestone similar to the specimen in photo 6 through etching with dil. HCl are indicated in Table 4 in correlation to those of A. S. T. M. card.
In the spacings concerned, presence of quartz and diopside is surely observed but no traces of wollastonite are confirmable. Grayish black-colored residue is not identified with graphite in spite of its megascopic appearance. Microscopically, carbonaceous materials, clastic grains of quartz and crystals of diopside are discernible.
(b) Data for the residue obtained from purely white crystalline limestone are

shown in Table 5.

Table 4. Röntgenometrical data for the residue from grayish black-colored crystalline limestone

2 θ	d(Å)	I/I_1	Mineral
20.76	4.28	100	Quartz
21.92	4.05	22	Apophyllite
23.48	3.786	17	Apophyllite
24.10	3.690	9	Quartz
26.48	3.363	100	Diopside, Quartz
27.82	3.204	33	Diopside
20.78	2.998	9	Diopside
30.26	2.951	5	Diopside
30.80	2.901	6	Diogside
32.98	2.714	4	Diopside
34.90	2.569	10	Diopside
35.44	2.531	6	Diopside
36.46	2.462	28	Quartz
39.40	2.285	40	Diopside, Quartz
40.22	2.240	20	Quartz
40.88	2.206	3	Diopside
41.78	2.160	4	Diopside
42.36	2.132	40	Diopside, Quartz
44.88	2.018	4	Diopside
45.70	1.984	13	Quartz, Diopside
50.02	1.822	44	Diopside, Quartz
54.72	1.676	16	Diopside, Quartz
55.25	1.661	9	Diopside
59.85	1.544	48	Quartz

Table 5. Röntgenometrical data for the residue from white-colored crystalline limestone

2 θ	d(Å)	I/I_1	Mineral
20.78	4.27	34	Quartz
23.02	3.860	11	Wollastonite
24.22	3.672	4	Quartz
25.20	3.531	22	Wollastonite
26.55	3.354	100	Diopside, Wollastonite, Quartz
27.48	3.243	34	Diopside
28.73	3.105	8	Wollastonite
29.84	2.992	26	Diopside, Wollostonite
30.80	2.901	8	Diopside
32.78	2.731	3	Wollastoeite
34.88	2.570	44	Diopside, Wollastonite
35.48	2.528	14	Diopside
36.22	2.478	11	Wollastonite
36.43	2.464	20	Quartz
38.30	2.348	6	Wollastonite
38.97	2.309	7	Diopside, Wollastonite

2 θ	d(Å)	I/I$_1$	Mineral
39.36	2.287	11	Quartz
40.22	2.240	8	Quartz
41.81	2.159	6	Diopside
42.31	2.134	11	Diopside, Quartz
45.68	1.984	12	Wollastonite, Diopside, Quartz
47.16	1.926	4	Wollastonite
50.08	1.820	56	Diopside, Wollastonite, Quartz
52.01	1.757	65	Diopside, Wollastonite
53.07	1.724	4	Wollastonite
54.77	1.675	10	Diopside, Qurtz
55.22	1.662	8	Diopside
45.50	1.627	9	Diopside
58.88	1.567	3	Diopside
59.88	1.543	13	Qurtz

The spacings representing diopside as well as wollastonite are conspicuously appeared and those of quartz are less intense than in the former case. Microscopic inspection also reveals the presence of quartz, acicular wollastonite and diopside.

(c) Data for the remainder of white-colored vein-like materials, 0. 2∼0. 3 mm in with, included in purely white limestone are illustrated in Table 6.

Table 6. Röntgenometrical data for vein-like material included in the remainder

2 θ	d(Å)	I/I$_1$	Mineral
23.56	3.773	100	Rankinite
26.74	3.331	57	〃
28.26	3.155	10	〃
30.14	2.963	14	〃
33.35	2.685	13	〃
39.55	2.456	9	〃
50.13	1.817	8	〃

They reveal good accordance with rankinite illustrated in A. S. T. M. card.

Thin sections of several specimens were microscopically examined under microscope.

Characteristic modes of occurrence of wollastonite and diopside are indicated in photo 12, wherein both minerals are intervened among quartz grains, of which quartzite is composed. In many cases, acicular crystals of wollastonite are observed in vein-like arrangement, while diopside are found scattered.

Photo 13 shows either impregnation of euhedral diopside in grayish black-colored, crystalline limestone or quartz without any traces of reaction in calcite.

Photo 14 illustrates the occurrence of euhedral diopside and wollastonite, the itterstices of which are filled whith later veinlets of calcite.

Photo 15 reveals either the contact of limestone with veinlets of wollastonite or euhedral diopside filling the interstices among calcite and wollastonite, or which the latter is characterized with indices (Nx=1.6205, N_Y=1.622, Nz=1.627) and 2V(−)=39°.

(B) Ishiyama

Geological remarks: The location is situated within the composed of the Ishiyama Temple, Ishiyama-chō Ôtsu-shi, Shiga Prefecture. The area concerned is composed mainly of muscovite-bearing granite and a member of Paleozoic formation. The granite grouped reasonably into a contemporaneous intrusive with that appeared in the district mentioned in the preceding is found cut by aplitic mass at the spot situated east of Mt. Iwama, intruded into the Paleozoic member, and covered with diluvial beds in the depressed area intervening between Mts. Garan and Iwama. The Paleozoic member consisted chiefly of chert and sandstone accompanied with alternation of sandstone and slate or rarely with lenticular limestone generally reveals a trend of EW or F 70° W together with foldings including one anticlinal and two synclinal axes, and is traversed by numerous faults pointing to EW, NE-SW, and NW-SE etc. This member has been correlated to Yamaguchi facies by Kobayashi and to an upper one of the Paleozoic formation by Miyamura on the basis of lithologic features and of occurrence of Triticites, Pseudofusulina, and Neoschwagerina etc. in the vicinity of Kurama.

Most parts of this member might have been altered into hornfels through thermal effects of the granite, and thus faint-purplish colored sandstone as well as somewhat blackish chert probably recrystallized from slate appeared on Mt. Garan and formation of skarns in lenticular limestone cropped out at the Ishiyama Temple are also considered to have been resulted.

It seems accountably conspicuous that the grade of contact metamorphism becomes less intense with remoting far from the intrusive.

Mineralogy: In the compound of the Ishiyama Temple is exposed the limestone associated with some kinds of skarn minerals including wollastonite which is appointed as a sort of memorial for natural resources. Because of being stained through severe weathering, the outcrop concerned is hardly observable. A part of the specimens are however illustrated in the photo 16∼18.

Intense resistance of wollastonite veinlet for weathering is deducible from Alto Relievo appeared in grayish black-colored, crystalline limestone, as is obvious in photo 16.

Photo 17 indicates the occurrence of vesuvianite veinlets remained of account of their higher resistance for weathering than than of surrounding crystalline limestone, in which wollastonite is found scattered.

Photo 18 reveals wollastonite with higher relief to be abundantly impregnated in crystalline limestone, though its occurrence is somewhat obscure because of being soiled.

(C) Hatchono and others

Geological remarks: The localities are distributed on both wings of the Suzuka Mountain-range with NS extension, situating along the prefectural border between Shiga and Mie. Of all, those famous for occurrence of skarns are mentioned as follows:

Ishigure-minami-mura, Imben-gun, Mie Pref.
Tsubaki-ichinomiya, Suzuka-shi, Mie Pref.
Saimyôji, Gamô-gun, Shiga Pref.
Bodaiji, Kôga-gun, Shiga Pref.
Hatchôno, Gamô-gun, Shiga Pref.

Southern half of the mountain-range concerned is composed of biotite granite coming into contact with the Paleozoic formation developed either in the eastern or in the western side, as is shown in Fig. 13. Exposure of the former is roughly parallel to the ridge holding the width of about 8 Km from east to west and the extension of about 39 Km from north to south, while the latter with a general

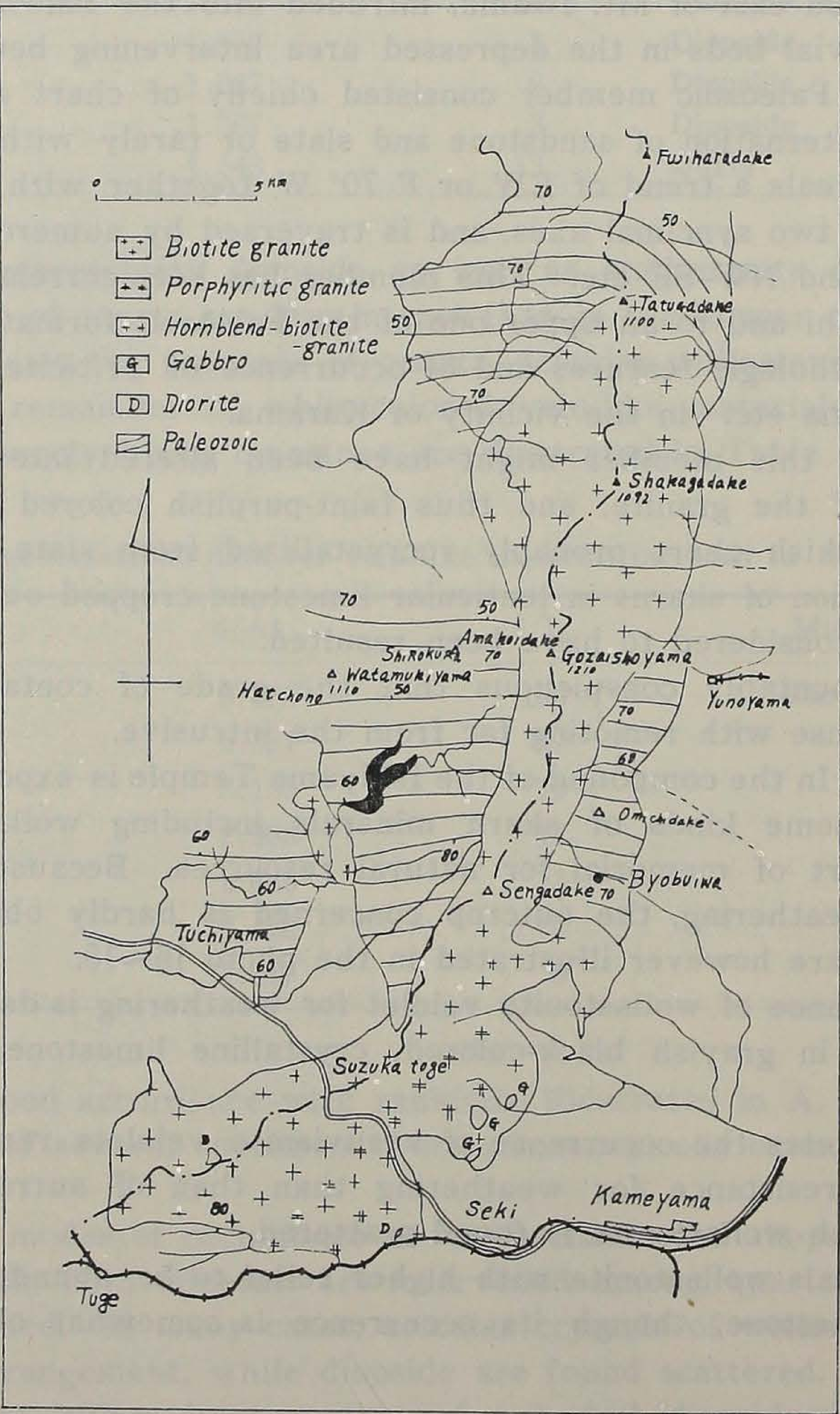


Fig. 13. Geological map of the surrounding of the Suzuka Mountain-range. (OGATA)

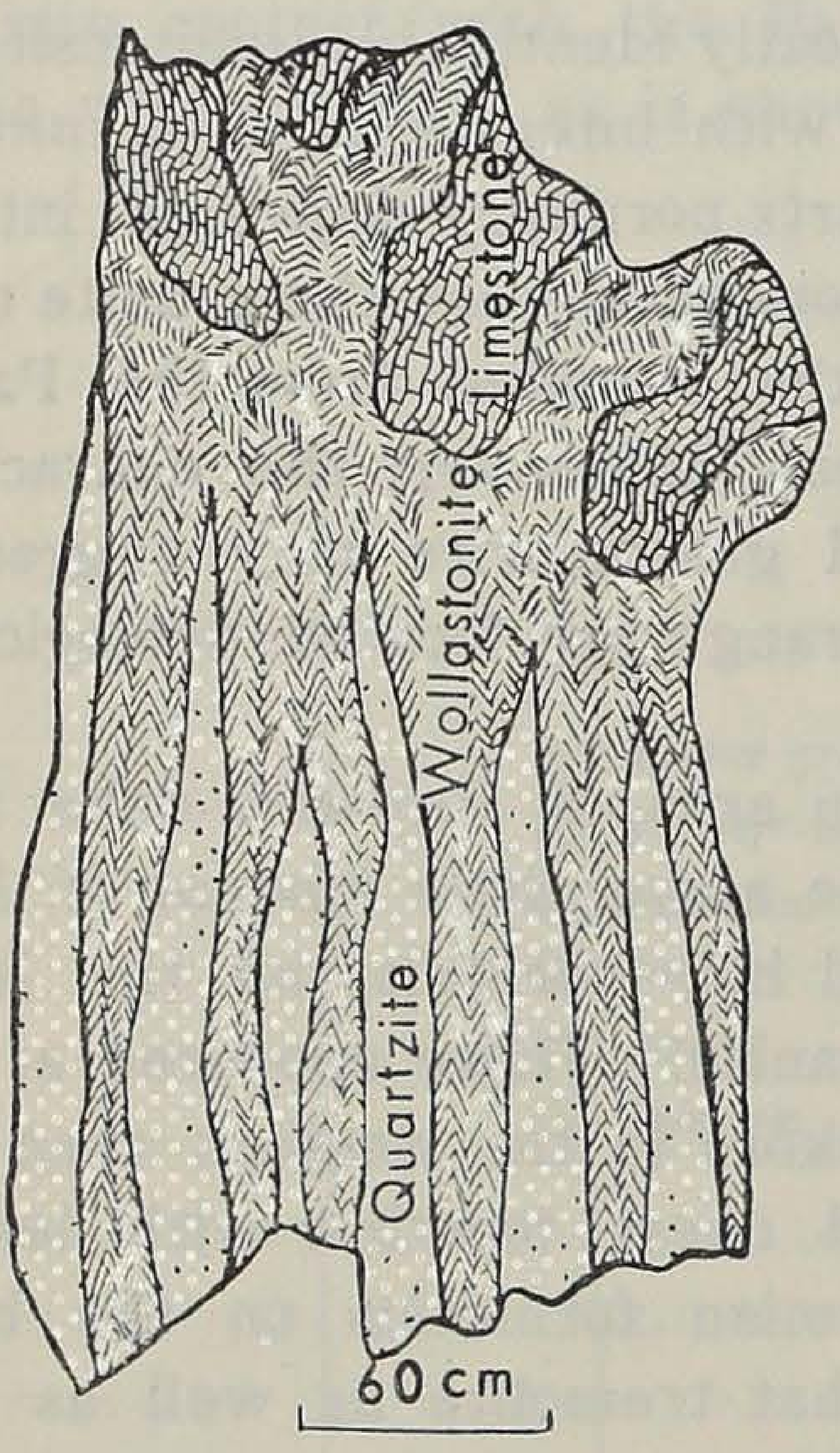
trend of EW is separated into either parts and covered with later formations.

Several kinds of granitic rocks are found in the region. Porphyritic biotite-granite containing large crystals of microcline is exposed in the southern area of Anraku Pass, hornblende-biotite-granite locally in the neighborhood of meta-diorite in the far southern area of the former, large-sized hornblende bearing gabbro surrounded with meta-diorite on Myojô-dake and Amabiki-yama, medium-grained granodiorite resembling the fine-grained one of Ryôke-type in the southern area of Noto-yama, biotite-granite-gneiss bearing megascopically identifiable gneissosity composed of alternation of biotite, and silicious layers with interval of 1~2 mm in the southeastern area of the mountain-range, and quartz-porphyry injecting into slate at the location 1 Km east of Kimigamune. To be noticed is that the granite cropped out in the southern area is abundant in xenoliths supplied from the Paleozoic member than that appeared in the northern area. Moreover, the characteristic presence of granite-gneiss, hornblende-gabbro, and granodiorite may suggest that the southeastern regions of the Suzuka Mountain-range are located geologically in the outer Ryôke zone.

The Paleozoic member exposed in the southern area of Fujiwara-dake is composed of slate, graywacke sandstone, chert, diabase and a little amount of lenticular limestone, of which the former two are altered into hornfels and the last into crystalline facies through thermal effects of the granite. Those appeared at Ochiai in the eastern area of Numata Pass and at Mandokoro in the western area of the same pass are composed of sandstone, slate, and chert together with lenticular limestone correlated to a member of lower Permian formation on the basis of content of Pseudofusulina. It has been reported that tremolite as well as wollastonite were contained in limestone belonging to a Paleozoic member metamorphosed through contact effect of granite in the vicinity of Ishigure-minami-mura. In the northern area of the Oike mine are developed slate including networks of calcite veinlets, sandstone, and diabase. Blackcolored chert distributed between Yunoyama and Takedaira Passes is impregnated with ores. Lenticular limestone associating wollastonite is observable at Shirokuradani, Saimyoji, and Hatchôno. The Paleozoic member developed on the summit of Suzuka Pass is widely silicified and altered into hornfels, revealing higher grade of contact metamorphism. " Byobuiwa ", composed of limestone and located by the Gohei River, is found comprising the skarns such as wollastonite and others. Shaly member accompanying lenticular limestone is developed between Itaya and Tsuge along the Kansai Railway Line and limestone exposed at Tsuge is altered into that of crystalline facies.

Remarkable is that some pairs of reverse faults with high angle in dip are found running through the outer parts of Paleozoic member situated along the granitic mass.

Mineralogy: One of the most noticeable occurrence of wollastonite in the terrain concerned is that appeared at Hatchôno, Hino-chô, Gamô-gun. The specimen as well as other skarns are obtainable from an outcrop of lenticular limestone and quartzite intercalated in the shale of Chichibu formation. This outcrop is located in the contact zone with Suzuka granite, though any exposures of the related intrusive are not recognized in the neighborhood. As are indicated in Figs. 14 and 15, giant mass of wollastonite aggregate is ascertained in certain zone intervening between lower quartzite and upper crystalline limestone splitting into finger-like veinlets. Crystals of wollastonite together with others are found filling up the spaces between quartzite and limestone and between each veinlet. The specimens produced in networks of fine cracks in finger-like quartzite are apparently milky-white in color. Veinlets of wollastonite are observed also in grayish black-colored crystailine limestone appeared slightly far from this outcrop. As is shown in Fig. 16, it happens that wollastonite veinlet, white-colored crystalline limestone and quartzite vein are zonally arranged with one another and zone of wollastonite is not always distributed along both sides of quartzite but assymmetrically disposed.



Fsg. 14. A part of outcrop at Hatchôno

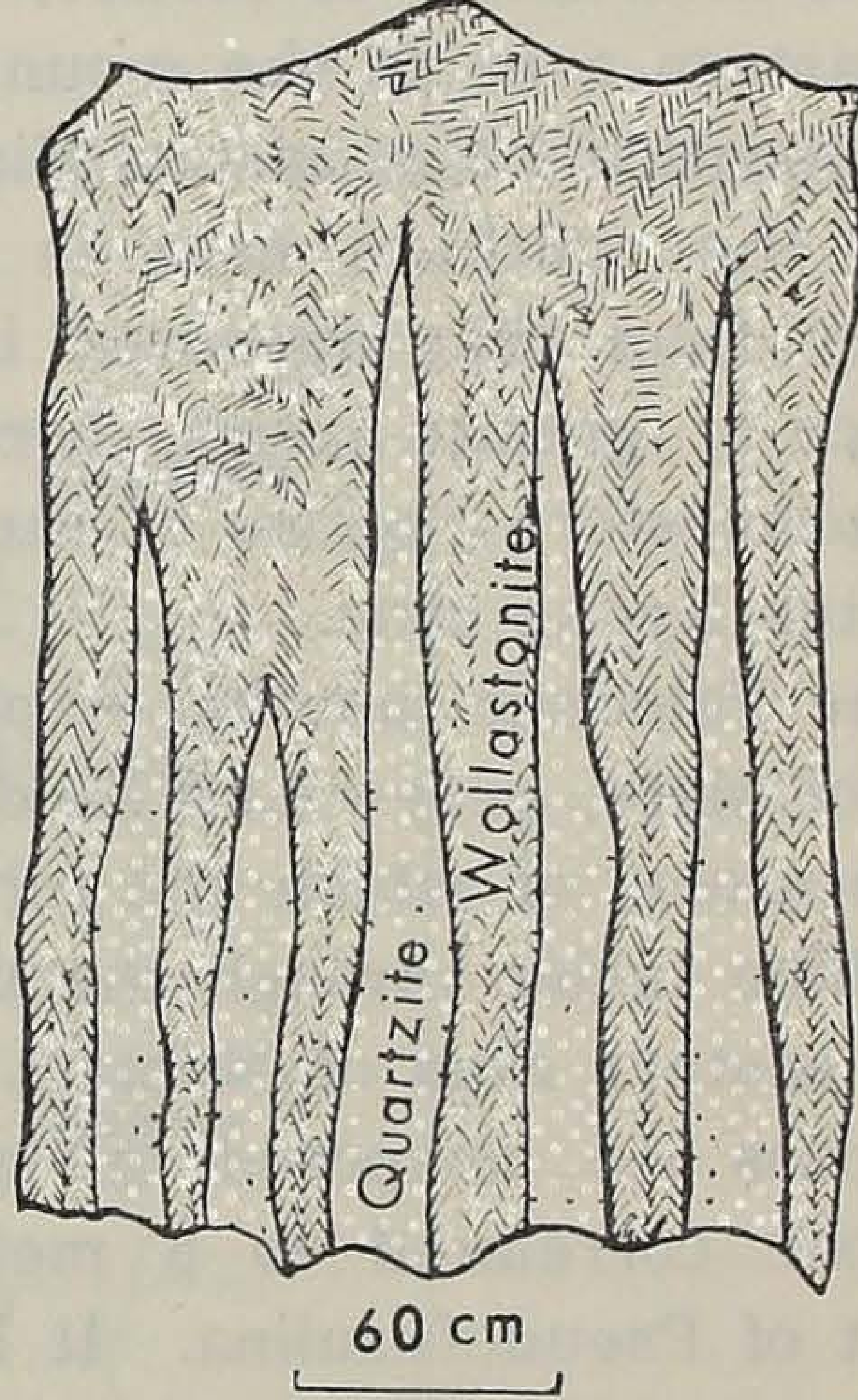


Fig. 15. A part of outcrop at Hatchôno

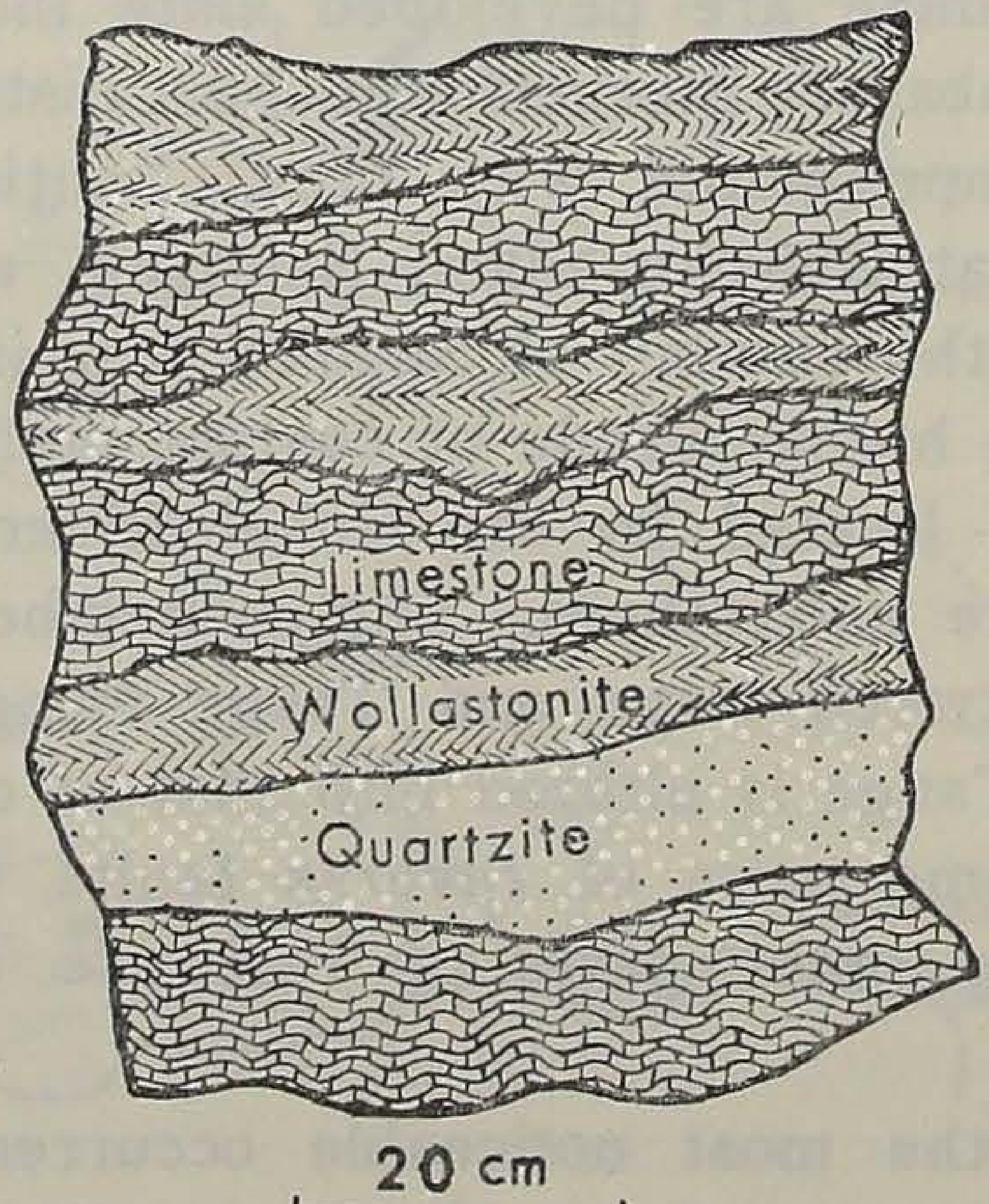


Fig. 16. A block obtained at Hatchôno

Polished sections prepared from the specimens were inspected in detail. A part of the results are shown in the photo 19 and 20 wherein it is clear that veinlets of wollastonite are developed apparrently as white lines along the cracks in quartzite and traversed by composite veinlets comprising faint-grayish green-colored diopside and prehnite.

Photo 21 illustrates that veinlets of vesuvianite running through white-colored crystalline limestone are apt to accompany a sort of wollastonite zone, though in a little amount, along their walls but, as is distinct in photo 22, the former happens seemingly to lack in the latter.

Photo 23 and 24 are the figures obtained through etching of the polished specimens of white-colored crystalline limestone with dil. HCl.

Numerous crystals of wollastonite are observed sticking out on the surface where nothing other than calcite was not recognized in the case of being merely polished, and wollastonite zones with very thin width are also found along composite vein, 2～5 mm in width, composed of vesuvianite and faint-grayish or faint-bluish green-colored diopside identified röntgenometrically.

Paragenetic minerals were inspected by means of X-ray and under microscope.

Table 7. Röntgenometrical data for grayish black-colored crystalline limestone

2θ	d(Å)	I/I_1	Mineral
19.71	4.50	6	Diopside
26.48	3.363	26	〃
27.48	3.243	33	〃
28.37	3.143	2	〃
29.73	3.002	100	〃
30.16	2.961	33	〃
30.75	2.905	33	〃
32.94	2.717	4	〃
34.88	2.570	26	〃
35.48	2.528	41	〃
38.98	2.309	14	〃
40.60	2.220	9	〃
40.85	2.207	8	〃
41.78	2.150	19	〃
42.23	2.138	13	〃
42.74	2.114	9	〃
44.26	2.045	17	〃
44.85	2.019	24	〃
45.97	1.973	7	〃
49.58	1.837	16	〃
50.18	1.816	5	〃
52.01	1.757	18	〃
54.70	1.677	7	〃
55.22	1.662	4	〃
56.50	1.627	24	〃
57.98	1.589	4	〃
58.98	1.565	4	〃
59.50	1.552	5	〃

Materials indissolved in HCl:

(a) Data for the residue obtained some grayish black-colored crystalline limestone through etching are represented in Table 7.

Compared to the specimen collected from Gobessho, Kyoto Prefecture, it is to be noted that nothing other than diopside is found in the spacings. Microscopically the result is also quite same excepting the presence of carbonaceous materials with opaque property.

(b) Data for the residue obtained from purely white-colored crystalline limestone through etching are indicated in Table 8.

Table 8. Röntgenometrical data for white-colored crystalline limestone.

2 θ	d(Å)	I/I_1	Mineral
23.06	3.854	66	Wollastonite
25.20	3.531	38	Wollastonite
26.72	3.333	47	Diopside, Wollastonite
27.40	3.252	28	Diopside
28.80	3.097	42	Wollastonite
29.80	2.996	100	Diopside, Wollastonite
30.74	2.906	17	Diopside
32.72	2.736	10	Wollastonite
34.88	2.570	44	Diopside, Wollastonite
35.42	2.532	30	Diopside
36.10	2.486	36	Wollastonite
38.28	2.349	23	Wollastonite
38.92	2.312	22	Diopside, Wollastonite
40.46	2.228	8	Diopside
41.20	2.189	14	Wollastonite
41.62	2.168	11	Diopside
42.16	2.142	20	Diopside
42.72	2.115	5	Diopside
44.14	2.0.5	10	Diopside, Wollastonite
45.62	1.987	10	Wollastonite
47.22	1.923	10	Wollastonite
49.42	1.843	17	Diopside, Wollastonite
51.84	1.794	22	Diopside, Wollastonite
53.05	1.725	13	Wollastonite
55.20	1.663	9	Dsopside
56.44	1.629	21	Diopside
57.21	1.609	8	Wollastonise
58.77	1.570	4	Diopside

Compared to the specimen collected from Gobessho, remarkable is that the spacings of wollastonite with higher intensity and those of diopside with lower intensity are appeared. Microscopically bulk of acicular wollastonite together with diopside are surely recognized.

(c) Data for somewhat brilliant, translucent, white-colored vein-like parts obtained from white-colored crystalline limestone through etching are illustrated in Table 9 with reference to A. S. T. M. card.

Tble 9. Röntgenometrical data for vein-like part

2 θ	d(Å)	I/I$_1$	Mineral
25.22	3.528	46	Prehnite
28.67	3.467	77	Riversideite
27.06	3.293	54	Prehnite
27.32	3.262	48	Riversideite
29.07	3.069	100	Prehnite, Riversideite
29.89	2.987	29	Riversideite
31.87	2.806	29	Prehnire, Riversideite
34.16	2.623	17	Riversideite
35.07	2.557	91	Prehnite
38.18	2.335	33	Prehnite
38.94	2.311	33	Prehnite
42.33	2.133	11	Prehnete
43.77	2.066	15	Riversideite
46.97	1.933	20	Prehnite, Riversideite
49.37	1.844	20	Prehnite, Riversideite
51.62	1.769	21	Prehnite
55.47	1.655	12	Prehnite, Riversideite
56.32	1.632	8	Riversideite
60.02	1.540	21	Riversideite

The results reveal the veinlet concerned to be composed of prehnite and riversideite.

(d) Data for vesuvianite veinlet remained from dissolution of white-colored limestone with dil. HCl are shown in Table 10.

Table 10. Röntgenometrical data for veinlet of vesuvianite

2 θ	d(Å)	I/I$_1$	Mineral
25.67	3.467	14	Vesuvianite
29.37	3.045	19	″
32.62	2.743	100	″
34.62	2.589	66	″
36.52	2.452	42	″
41.05	2.197	11	″
42.62	2.120	16	″
48.32	1.882	9	″
51.93	1.759	15	″
55.32	1.659	15	″
59.38	1.555	14	″

Thin sections of several specimens were microscopically examined under microscope.

Photo 25 reveals the occurrence of veinlet composed of garnet and prehnite in white-colored crystalline limestone. The garnet was through immersion method identified with grossularite (N=1. 737).

Photo 26 represents the stripes of carbonaceous materials intercalated in grayish black-colored crystalline limestone.

Photo 27 shows the occurrence of diopside included as veinlets and impregnated in quartzite.

Byôbuiwa :

It is essentially an exposure of limestone soaring as a folding screen opposite to the Gohei River, Mie Prefecture. In its vicinity a massive body of skarns is found enclosed in slate of the Chichibu formation (see Photo 25), and it is of significance that any other bodies are not comprised in limestone appeared no the upper and either sides of the former. The skarn body, an aggregate composed irregularly of garnet, augite, diopside, calcite and quartz, is involved in silicified slate, its central part being surrounded with outer weathered zone and furthermore with outermost oxidized zone. Later veinlets of calcite are also observed cutting across all of the skarns.

The polished and thin sections were microscopically pursued for inspection.

Photo 29 shows a part of the outcrop from which the specimen was sampled.

Photo 30 indicates the polished specimen obtained from the outcrop revealed in photo 29. Paragenetic relation between wollastonite and garnet as well as silicification of slate are therein conspicuously confirmed. This garnet was identified with grossularite (N=1. 761) through immersion method.

Photo 28 displays the specimen obtained from the part most close by slate. Finer grains appeared near slate are identified with common augite and coarser ones with diopside (2V=59°).

En passant, some references to the granitic rocks appeared in Kinki Province are considered to be of necessity because of their thermal effects on the Paleozoic formation embrancing wollastonite and other skarns.

On the basis of that the granite concerned is found intruding into that of the Ryôke type and covered unconformably with the Izumi sandstone formed at the later stage in Cretaceous, it is deduced only that its activity might have brought about during certain period later than Triassic.

As regards the absolute age, some data obtained from chemical analyses, and counting of α tracks, of radioactive minerals have so far been made public. TAKEKAWA chemically estimated the age of fergusonite in pegmatite appeared at Ôro, Naka-gun, Kyôto Prefecture as 146×10^6 years and that of allanite obtained from Mie-mura in the same district as 120×10^6 years, suggesting activity of the related granite in Jurassic. The autoradiographical measurements achieved by HAYASE clearly point to that the granite appeared at Mt. Tanokami, Shiga Prefecture is correlative to the middle Cretaceous is age and those developed at Hôfu, Yamaguchi Prefecture, at Kitashirakawa and Hoki, Kyôto Prefecture, and at Katanoyama, Osaka, Prefecture are to the upper Cretaceous in age, while the former is chronologically contemporaneous with, or somewhat earlier in stage than, the Ryôke granite and the granites occurred at Higashi-maizuru and Takeno, Kyôto Prefecture, and at Yumura and Minukiyam, Hyôgo Prefecture are taken as those in Tertiary.

Kobayashi (1941) suggested in his dissertation on Sakawa orogenic cycle and origin of Japan Island that the Ryôke granite was intruded at the earlier stage in Cretaceous, whereas some other authors are of the opinion that plutonism and metamorphism of the Ryôke and Sanbagawa zones are connected with the tectogenesis, which took place in the later Paleozoic or in the earlier Mesozoic. The recent data obtained through K-Ar method etc. show that the age of measured minerals or the Ryôke granites is about middle Cretaceous.

(D) **Kôgejima**

Geological remarks: The islet concerned is isolated in Seto-Inland-Sea 17 Km NNW of Imabari-shi, Ehime Prefecture, as is illustrated in Fig. 17.

Fig. 17. Location map

In Kôgejima and its surroundings are appeared the Paleozoic formation lying roof-pendantly over granite. The former is generally composed of sandstone, slate, quartzite and lenticular limestone revealing the trend pointing nearly to EW and northward dip in low angle with local variation in more or less amount, and altered into hornfels or crystalline facies through thermal effects of the later intrusives. One of the latter is a sort of biotite-granite grouped into the Hiroshima type, accompanying diorite, granite-porphyry, diabase, and later basalt intruding or injecting into the Paleozoic member as batholithes or as dikes.

In Kôgejima, the granite is exposed in small scale on the southwestern coast, diorite is between Kanashiki and Shirohana, granite-porphyry is in the northeastern part, black-colored, doleritic dike with strike of N 30° E and width of 50～60 cm is in limestone located south of Shinmei, and green-colored, severely metamorphosed diabase with width of 80 cm is in limestone occurred at the Okamura mine. The Paleozoic member composed of metamorphosed slate, phyllitic facies and limestone is stratified in succession and developed in arc-like distribution with synclinal axis of EW trend along a line connecting Okamura mine with Kôge mine and those of N 30° W observed at Sekizen mine. Limestone is ordinarily situated on, or interfingered with, phyllite and associated with thin layers of quartzite and slate, splitting into three parts probably through crustal movement. Contact effect of granite on limestone is conspicuous especially at the Okamura mine. Grayish white or black-colored, crystalline, in lower grade, limestones are predominant at the Sekizen mine and purely white-colored, crystalline ones are so at the Okamura and Kôge mines. Phyllitic slates interfingered with the former are developed continuously in the northeastern and central areas and traversed by N S fault in the western area, bearing either black- to blackish brown-colored appearance or appearance or foliation and higher grade of metamorphism with depth. Metamorphosed phyllite situating in the lowermost horizon in this islet is found intercalated with thin layers of slate and chert along the coast, revealing a gradual variation in to the upper strata and EW trend with dip of 30° S on the northern side and with northward dip in low angle on the southern side. Moreover its grade of metamorphism is more distinct on the lower horizon and on the southwestern coast, indicating variation into striped hornfels. Quartzite, translucent, faint blackish in color and about 1m in width, is intercalated in limestone and metamorphosed phyllite but its thin layers with width of some cm happen to be included in limestone, disclosing recrystallization but on stratification.

Mineralogy: Wollastonite is found merely on the excavated spot of the Okamura mine, though limestones occurred in some other mines such as Imura, Kôge and Honmurakami are nor being worked for various purpose ond those appeared at the Kôge mine or particularly near the coast of Tatsu-ga-hana are purely white in color, coarser in grain-size, of higher crystallinity, and considered convenient for occurrence of wollastonite.

At the Okamura mine, either the occurrence of wollastonite, which however is now being excluded as impuritics for the objective, or the contact between limestone and quartzite are observable in detail. As was shown in the photo 31 and 32, wollastonite is, in the main, found included in the veinlet running along, or intersecting obliquely with, the bedding plane of limestone. Its singular arrangement with a definite direction in the veinlet has already been indicated in photo 41.

The mineral is recognized similarly not only in the veinlets developed along the contact plane of stratified quartzite intercalated between limestone, as is distinct from inspection of photo 33, but also in those filling up the cracks of quartzite. An apophyllite vein traversing nearly perpendicular to limestone including quartzite together with veinlets of wollastonite.

Photo 34 illustrate the occurrence of faint grayish greencolored quartzite, around which not trace of wollastonite is discernible, to be enclosed in white- or grayish black-colored crystalline limestone at the Honmurakami mine.

Photo 35 indicates the barren quartz accompanying no trace of wollastonite in limestone though the latter is conspicuously silicified.

Photo 36 also reveals that the veinlets of white-colored crystalline limestone with no content of wollastonite are embraced in grayish black-colored one.

At the Kôge mine, any traces of wollastonite are not found at all in the stripes of stratified slaty limestone included in white-colored crystalline limestone, as are represented in the photo 37 and 38.

Photo 39 discloses a mass of wollastonite, cut across by apophyllite veinlets, obtained from the Okamura mine. Worthy mentioning is at least at this mine that wollastonite vein running nearly along the bedding planes of limestone might have taken a part in decoloration of grayish black-colored limestone or its variation into white-colored crystalline facies. Vesuvianite veinlets are also found cutting across the massive wollastonite composed in white-colored crystalline limestone.

(E) **Ryūhô**

Geological remarks: Mt. Ryūhô, on the foot of which wollastonite as well as some kinds of skarns are found distributed, is located at Ryūhô-mura, Yatsushiro-gun, Kumamoto Prefecture near the coastal plain along the Ariake Sea. The Ryūhô mountain-range is composed of so-called Ryūhô metamorphics. The Miyahara granitic rocks yielding thermal effects of the former are exposed in the northern area, while the Usuki-Yatsushiro structural line is found running through with a trend of NE–SW in the southern area and the Hinaku fault pointing nearly to EW is along the western margin, west of which is covered with alluvial deposits. In the northern area of the Miyahara granite is appeared the Higo gneiss which is surely intruded by the former and composed characteristically composed of the rocks derived from sedimentary origin and of some thick layers of intercalated limestone.

As for the metamorphism of the region including the Ryūhô mountain-range, the works achieved by YAMAMOTO are specifically to be noted. Southern half of the Ryūhô metamorphics is consisted mainly of black-colored slate, calcareous slate and crystalline limestone, and their northern half is of igneous rocks including chiefly the volcanics and injectives of intermediate property as well as some considerably thick layers of limestone. Regional metamorphism on these rocks in lower grade are confirmed in that finer-grained rocks are recrystallized into greenschist facies and medium-grained ones also into that similar to the former in property excepting the blast-poryhyritic texture derived from phenocrysts while foliations are well-developed in either facies.

On the northern end of the Ryūhô metamorphics is appeared the epidote-facies derived through contact effects of the Miyahara granite, on or in which masses of amphibolite are in places found lying roof-pendantly or as xenoliths. Original rocks of the metamorphics displaying a general trend of N45°～60°E with dip of 30°～60° SE have been determined as were formed in the middle Permian on the basis of Verbeekina discovered in the limestone of impure property.

The Miyahara granitic rocks intruding concordantly into the above-mentioned metamorphics are extended from east (less than 100 m in width at Shimoyabe-mura) to west (about 5 Km in width on the western most side) and composed essentially of tonalitic to granodioritic facies. Tonalite occupying the southern half of the mass is coarse- to medium-grained in most parts and characterized with irregular scattering of green- to darkish black-colored hornblende of ca. 0.5 cm in size together with anhedral biotite in less amount. Microscopically, it is composed of plagioclase, hornblende, biotite, quartz, orthoclase including a little amount of microcline, and accessories such as zircon, apatite, magnetite and rarely allanite. Granodiorite appeared in the northern half is medium-grained, massive, homogeneous in property, nearly lacking in schistosity and poor in basic inclusions and characterized with scattered presence of anhedral biotite instead of hornblende. Microscopically, it is composed of plagioclase, hornblende, biotite, quartz, orthoclase with a little amount of microcline and accessories such as zircon, apatite etc.. These end-facies are apt to represent a gradual transition with each other but to come into contact with each other with fault. Porphyritic and aplitic dikes are found injecting into these intrusives. The activity of the Miyahara granite is considered by YAMAMOTO to have taken place in Triassic on the basis of geological happen facts as well as the data obtained through zircon method and previous view suggests it to have a relation to that in Cretaceous but it is still remained questionable whether may be justifiable to more extent.

Mineralogy: Fine-sized crystals of wollastonite are found at the contact of the Miyanohara granite with limestone and state belonging to the Ryūhô metamorphics appeared half-way up a branch of Mt. Ryūhô behind the primary school at Kozenji. On this spot, limestone is observed altered into milky white-colored, silicified crystalline facies and slate into hornfels, in which skarn minerals are not discriminated because of severe weathering. An outcrop of limestone exposed in somewhat lower place is illustrated in Fig. 18 wherein veinlets of wallastonite are

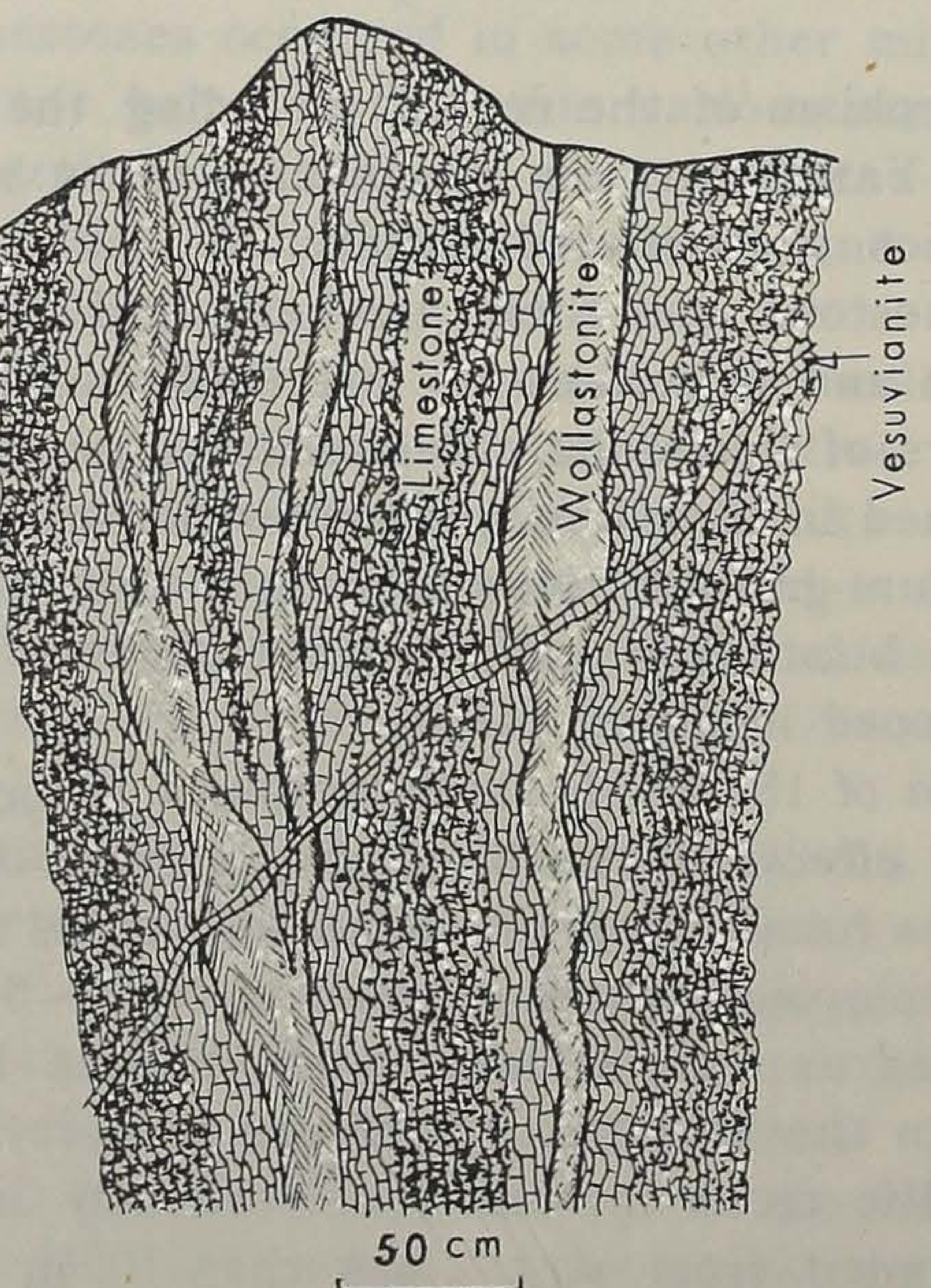


Fig. 18. A part of outcrop at Ryūhô.

ascertainable in white-colored limestone derived from impure facies and traversed by those of vesuvianite.

Minerals in paragenesis with wollastonite are röntgenometrically researched.

White-colored, veinlet-like part remained through dissolution of white-colored, crystalline limestone with dil. HCl yields such spacings as are indicated in Table 11.

Table 11. Röntgenometrical data for the remainder through etching with dil. HCl

2 θ	d(Å)	I/I₁	Mineral
25.17	3.535	100	Tobermorite, Prehnite
25.66	3.469	46	Riversideite
27.19	3.277	39	Prehnite
27.36	3.257	39	Riversideite
28.58	3.121	35	Tobermorite
29.17	3.059	68	Prehnite
31.55	2.833	22	Tobermorite, Prehnite
35.19	2.548	46	Prehnite
35.55	2.523	18	Tobermorite
38.23	2.352	17	Prehnite
38.95	2.310	24	Riversideite
43.82	2.064	21	Riversideite
46.99	1.932	20	Prehnite
49.36	1.845	18	Prehnite

The results obtained surely reveal the presence of prehnite, riverisdeite and tobermorite.

The part composed merely of pale-greenish, papery mineral obtained through exclusion of the veinlet-like part mentioned above gives such spacings as are shown in Table 12.

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The part composed merely of pale-greenish, papery mineral obtained through exclusion of the veinlet-like part mentioned above gives such spacings as are shown in Table 12.

The results obtained clearly suggest the content of tobermorite in most amount together with diopside and riversideite in a little amount.

Composite veinlet including white-colored minerals and transparent ones traversing across the aggregates of wollastonite presents the spacings illustrated in Table 13.

The results obtained evidently the presence of apophyllite and crestmoreite associated with wollastonite mixed on sampling.

(F) Some considerations

As the so-called contact or pyrometasomatic deposits of comparatively large scale in Japan are mentionable those of Kamioka, Yamato, Nakatatsu, Yakuki, Kamaishi, and Chichibu etc., in which the occurrence of skarn minerals or skarni-

Table 12. Röntgenometrical data for pale-greenish papery mineral

2θ	d(Å)	I/I_1	Mineral
25.17	3.535	100	Tobermorite
25.66	3.469	16	Riversideite
26.76	3.329	49	Diopside
27.29	3.265	11	Riversideite
28.62	3.116	41	Tobermorite
29.94	2.982	14	Tobermorite
30.37	2.941	11	Diopside
30.98	2.884	28	Diopside
31.58	2.831	30	Tobermorite
31.97	2.797	11	Riversideite
34.61	2.590	26	Diopside
35.46	2.529	17	Tobermorite, Diopside
36.65	2.450	10	Tobermorite
41.75	2.162	9	Diopside
43.88	2.062	10	Riversideite
44.79	2.022	12	Diopside
45.33	1.999	26	Tobermorite
50.13	1.818	10	Diopside
52.27	1.749	8	Diopside
56.74	1.621	24	Tobermorite, Diopside
60.34	1.533	14	Tobermorite, Riversideite

Table 13. Röntgenometrical data for composite veinlet

2θ	d(Å)	I/I_1	Mineral
19.59	4.528	13	Apophyllite
22.54	3.941	100	Apophyllite
23.21	3.829	19	Wollastonite
23.69	3.753	34	Crestmoreite
24.90	3.573	8	Wollastonite
25.37	3.503	8	Wollastonite
26.67	3.340	8	Wollasthnite
28.67	3.111	59	Crestmoreite
29.96	2.980	64	Crestmoreite, Apophyllite
31.30	2.855	36	Crestmoreite
36.09	2.487	13	Apophyllite, Wollastonite
37.01	2.427	6	Apophyllite
41.24	2.187	25	Apophyllite, Crestmoreite
41.82	2.158	10	Apophyllite
42.89	2.107	5	Apophyllite
45.45	1.994	14	Wollastonite
48.58	1.731	8	Crestmoreite
51.67	1.768	12	Apophyllite
52.37	1.746	5	Crestmoreite
53.26	1.718	11	Apophyllite, Wollastonite
57.25	1.008	11	Wollastonite
58.39	1.579	35	Apophyllite

zation have naturally been recognized in relation mainly to metasomatic process or partly to solid reaction on the whole. " Reaction skarn " derived probably from solid reaction between certain components have also been confirmed in minor content by some authors, e. g. Watanabe, whereas most of the previous works seem to have been dealt in connection with the effects of magmatic solution or with recrystallization of limestone.

On the other hand, the decrepitation data given by NISHIO et al (1953) indicate that the ores of Kamioka deposit might have been formed at 230°-375 °C, those of Chichibu deposit at 227°-405 °C, and those of Obira deposit at 250°-390 °C. The results obtained by MIYAZAWA et al(1957) through heating microscope also show the formation temperature of ores and gangues to have been considerably lower than was so far expected. According to their estimation, lievrite, for example, is believed to have been produced at 405° C, though this may be the highest of all. Regrettable is that there have been no data concerning wollastonite and other skarns.

Some authors have alluded directly to the occurrence of wollastonite. SEKINE (1958) grouped its occurrence at Yamato deposit into six types such as: (1) irregular mass or networks of veinlets in chert, (2) irregular networks of veinlets in limestone, (3) occurrence at the contact between limestone and chert, (4) mass of skarns, (5) paragenesis with ferromagnesian skarns and ore minerals, and (6) paragenesis with ore veinlets. Moreover, he pointed out either the formation of wollastonite at the earlier stage of skarnization prior to ore deposition or difficulty in enlightening the role of thermal effects of the related intrusive and that irregular networks of wollastonite veinlets comprised in limestone are to be connected with the reaction of SiO_2 contained as impurities with limestone as to be ascribed to the reaction of SiO_2 dissolved into high-temperature solution ascending in the process of ore genesis or of thermal metamorphism while wollastonite, less than 5 cm in width, appeared at the contact between limestone and chert might have seemingly been produced through their reaction. According to the view given by INOUE et al (1958), wollastonite occurred at Kôgejima is considered to have been produced merely in the part metamorphosed severely through thermal effects along the bedding planes particularly near quartzite intercalated in limestone. In the report published by HORIUCHI (1960) wollastonite developed at Sawa is reputed to have been formed through complete metasomatism of thin layers of limestone intercalated in alternation of chert, slate, and sandstone or it is found as massive or stratified bodies at the contact of limestone with other rocks or in the cracks of chert; the seemingly colossal mass appeared at Kanamaru is actually nothing other than aggregate of wollastonite filling the cracks of, or coverning the bedding plane of, chert; wollastonite distributed at Tôkakagura is found producing the white- or grayish white-colored veinlets, about 5 cm in maximum width, along the bedding planes of, or in the cracks of, chert accompanied with abundance of garnet and diopside; and that occurred on the spot opposite to Suginosawa is observed as mass derived through metasomatism of a part of limestone.

In spite of the opinions mentioned above, considerably different conclusions concerning genesis of wollasthnite have been reached by the present writer though the researched area was merely confined to the contact zone accomyanying no ore minerals. Indifference of its formrtion to the reaction of quartzite or

SiO_2 included as impurities with limestone is reasonably deduced from that: (1) wollastonite is not always found produced along either walls of quartzite vein; (2) acicular crystals of wollastonite comprised in the well-defined vein are arranged not perpendicular but rather parallel to the wall or obliquely; (3) zones of wollastonite are developed not usually confined to the contact of quartzite with limestone but rather abundantly in limestone even if quartzite is contained in the latter; (4) wollastonite is formed not only along the bedding planes of limestone and quartzite but also, in many cases, intersecting with them and arranged at random in the cracks of quartzite; and (5) wollastonite is used to be embraced not in grayish black-colored, crystalline limestone but in purely white-colored facies, wherein its dendritic arrangement discerned through etching with hydrochloric acid seems to point to a remarkable trend. Furthermore, it seems tolerably rational to take into account that the grayish black-colored crystalline, limestone might have been resulted from earlier effect bringing about its crystallization and then leached into the purely white facies through later invasion of solution along its passage. As for this regards, very significant is SPURR's view (1932) suggesting that the ores, when deposited in limestone, might have been formed in fissures, as is recognized similarly in the case of other kind of country rocks, and marblization of limestone might have been caused not by thermal effects of intrusive but rather by ascending solution.

V. Discussion

A number of works concerning wollastonite have hitherto been carried into effect with respect to various problems taking in synthetic experiments, natural occurrence, morphology or crystallography, physical chemistry or the CaO-SiO_2 system, role in metamorphism and so forth. The present author has also contrived to find out the relation of several experimental data obtained for synthesis of wollastonite to its actual occurrencee in Nature.

LIEBAU (1957) and BELOW (1957) röntgenometrically indicated the mineral concerned to be constructed of repeated three chains of tetrahedral SiO_2 compared to pyroxene constructed of two chains. This difference may take part in their genesis in Nature. In the previous experiments, wollastonite has often been prepared in coexistence of water or water vapour at 400-450 °C under nearly 1 atom. press, while, in the furnace without water or from $CaSiO_3$ glass, it was necessary to be manufactured at 800°-1000° C. C. R. Fonder and H. C. Froelich (1948) obtained the purely synthetic $CaSiO_3$ (β-modification) through firing in presence of steam at 750° for 16 hrs, and stated that (1) $CaSiO_3$ is not synthesized directly with the molecular ratio $CaO : SiO_2 = 1 : 1$, (2) in the reaction, $CaSiO_3$ (metasilicate) is apt to be produced secondarily through combination of SiO_2 with primarily formed Ca_2SiO_4 (orthosilicate); (3) Steam may play a role of nonpermanent gaseous catalyst to activate the reaction and to expect the growth of perfect crystal more likely in the secondary reaction of Ca_2SiO_4 with SiO_2 than in the primary process producing Ca_2SiO_4; and (4) that obtained at 1150 °C lower than transition point represents the higher-temperature modification (α-$CaSiO_2$: pseudowollastonite) and transformation from α to β is not recognizable, while the lower-temperature one (β-$CaSiO_3$) is easily producible through addition of MnO or PbO since solid solution is probably formed between $CaSiO_3$ and $MnSiO_3$ and, in consequence, the transition point from β to α may be raised with content of MnO. HARKER and TUTTLE (1956) also emphasized a sort of catalytic role of water, whatever it may be aqueous or gaseous, in preparation of wollastonite from the reaction of calcite with quartz. It is regrettable that the experiments in the system taking in water are still remained to be scrutinized in detail by the present author, but the presence of water is surely reputed to be extremely of significance in natural formation of the mineral concerned.

As for the genesis of skarns, theories concerning the recrystallization of limestone have long been predominated but that adhering the later seems to have become more active, resulting in prevalence of the term of contact-metasomatic or pyrometasomatic. According to LINDGREN's view on metamorphism of Bingham limestone, it seems that detrital grains of quartz in the Highland Bog formation were almost completely consumed to produce 65% of silicates while on the contrary certain amount, i. e. $24g/100cm^3$, of SiO_2 derived probably from magmatic source were added to the Yampa limestone, and he proposed, in agreement with WINCHELL's theory, an indispensable addition of materials in these metamorphic processes. WILLBOURN (1926, 1927) reached a belief that band of wollastonite in Beatrice mine might have been originated along the contact between pegmatite ascending in liquidus state and marble through chemical action in slight grade. These opinions are considered evidently to place emphasis on the reaction of invading solution with limestone.

Examples of skarns derived intrinsically through so-called contact effects are tolerably scarce, but MAGNUSSON's, reaction skarn' (1936) produced through recrystallization in regional metamorphism, TILLEY's 'primary skarn' (1951) formed at the contact of intrusive with carbonate rock, and KENNEDY's view (1959) concerning the reaction skarn originated through diffusion of Ca as a result of thermal effects of Tertiary dolerite on cornstone enclosed in sandstone and of pseudomorphous replacement of quartz grains, even if probably under accidental or abnormal chemical control, are believed worth mentioning. Nevertheless, these sorts of skarn developed in so-called pyrometasomatic deposits are extremely confined to a few localities and generally of small scale, and surely considered to have not been produced merely through thermal effects. In relation to this, that LORING COES (1955) proved the influence of chemical factor beside temperature and pressure in the synthesis of aluminium silicates is to be remembered, since property of mineralizer or presence of water are believed to have taken an important part not only in genesis of wollastonite but also in that of others in the light of their natural occurrence, some experimental data, and property of water, as to which BERNAL and FOWLER (1933) investigated in detail. Though in no relation to genesis of wollastonite, RAMBERG (1952) pointed out either the agency of water as a sort of catalyst in regional metamorphism or the role of OH radical in formation of metamorphic minerals. As was alluded to already, the present writer has also reached a conclusion pointing to difficulty in synthesis of wollastonite through reaction between SiO_2 and $CaCO_3$ at the state without water, whereas R. I. Harker and TUTTLE (1956) were successful in preparation of minute-grained wollastonite in presence of steam under the pressure of CO_2 and obtained larnite

($2CaO \cdot SiO_2$) at the initial stage under such a condition nearly at 1 atm. press as was similar to in the case of the writer's experiment.

On the hand, it seems indubitable that natural occurrences of wollastonite are to be more emphatically referred to rather than the synthetically obtained data. There seems almost no room to deny its occurrence of magmatic origin. In so-called pyrometasomatic deposits, the veins of hedenbergite and of wollastonite are likely to be appeared more commonly with remoting from the ore bodies. According to the recent works, even these sorts of ores are reasonably reputed to have been formed at a temperature far lower than as were previously believed. As a matter of fact, the occurrences of wollastonite together with certain kinds of skarns observed in some localities and detailed interpretation of the literatures published surely bring out with higher probability that the mineral in question is to be ordinarily produced from hydrothermal solution at not so much high temperature as has hitherto been believed. In consequence, alteration through this kind of ascending solution on wall rocks is ascertainable nowhere at least in the localities of wollastonite and thermal effects of intrusive as well as reactions of volatile or fluidal materials. On the surrounding rocks are not necessarily requisite to genesis of wollastonite and its allied minerals while opening of the passage convenient for ascension of mineralizer, that is to say, structural control on country rocks may be required to a considerable extent. It is to be added to that the occurrence of wollastonite cannot be discussed merely on the basis of its megascopic appearance since those observed at a glance as massive bodies or as impregnation, as if they were derived from thermal effects, are often really composed of assemblages or networks of low-temperature.

References

Allen, E. T., White, W. P. and Wright, F. E. (1960): On wollastonite and pseudo-wollastonite, polymorphic forms of calcium metasilicate. Amer. Jour. Sci., Ser. 4, Vol. 21, No.122, 89-108.

Barnick, M. (1935): Strukturuntersuchung des natürlichen Wollastonits. Naturwiss. Vol. 23, 770~771.

Barth, Tom. F. W., Correns, C.W.U. Eskola, P. (1939): Die Entstehung der Gestein.

Below, N. V. (1957): New silicata structures. Acta Cryst., Vol. 10, Part 12, 757-759.

Bernal, J.D. and Fowler, S.H. (1933): A theory of water and ionic solution. with particular reference to hydrogen and hydroxyl ions. Jour. Chem. Phys., Vol. 1, No. 8, 515-548.

Bowen, N. L. (1933): Vogtite, isomorphous with wollastonite. Jour, wash. Acad. Sci., Vol. 23, 87-94.

——— (1940): Progressive metamorphism of siliceous limestone and dolomite. Jour. Geol., Vol. 48, No. 3, 225-274.

Bowen, N. L., Schairer, J. F. and Posnjak, E. (1933): The system CaO-FeO-SiO_2. Amer. Jour. Sci., Ser. 5, Vol. 26, No. 153, 193-284.

Cobb, J. W. (1910): The synthesis of a glaze glass, or other complex silicate. Part. II. Interaction of lime with silica and with alumina. Jour. Soc. Chem. Ind., Vol. 29, 250-259.

Danielson, A. (1950): Das Calcit-Wollastonitgleichgewicht. Geochim. Cosmochim. Acta, Vol. 1, 55-69.

Day, A. L. and Shepherd, E. S. (1906): The lime-silica series of minerals. Jour. Amer. Chem. Soc., Vol. 28, No. 9, 1089-1114.

Day, A .L., Shepherd, E. S. and Wright, F. E. (1962): The lime-silica series of minerals. Amer. Jour. Sci., Ser. 4, Vol. 22, No. 130, 265-302.

Dornberger, K., Schieff, F., Liebau, F. und Thilo, E. (1952): Zur Struktur des β-Wollastonits, des maddrellschen Salzes und des Natriumpolyarsenates. Acta Cryst., Vol. 8, 752.

Eakle, A. S. (1917): Minerals associated with the crystalline limestone at Crestmore, Riverside County, California, Univ. Calif. Pub. Bull. Dept. Geol., Vol. 10, 327-360.

Eitel, W. (1952): The physical chemtisry of the silicate.

Eskola, P. (1922): On contact phenomena between gneiss and limestone in western Massachusetts. Jour. Geol., Vol. 30, No. 4, 265-294.

Ferguson, J. B. and Merwin, H. E. (1919): Wollastonite ($CaO \cdot SiO_2$) and related solid solutions in the ternary system lime-magnesia-silica. Amer. Jour. Sci., Ser. 4, Vol. 68, No. 285, 165-189.

Fonda, G. R. and Froelich, H. C. (1948): The structure of calcium silicae phosphors. Jour. Electrochem. Soc., Vol. 93, No. 4, 114-122.

Fyfe, W. S., Turner, F. J. an, Verhoogen, J. (1958): Metamorphic reactions and metamorphic facies. Geol. Soc. Amer., Mem.73, 188.

Geig, J. W. (1927): Immiscibility in silicate melts. I-II. Amer. Jour. Sci., Ser. 5, Vol. 13, No. 74, 133-154, Ceram. Abstr., Vol. 6, No. 4, 157.

Geijer, P. (1939): Paragenesis of ludwigite in Swedish iron ores. Geol. För. Förh., Vol. 61, 19-33.

Goldschmidt, V. M. (1922): Die Gesetze der Gesteinmetamorphose, mit Beispielen aus der Geologie des Südlichen Norwegens. Viedenskapsselskapets skrifter. I, Mat-Natuv, Klasse, No. 22.

Harker, R I. and Tuttle, O. F. (1956): Experimental data on the Pco_2-T curve for toe reaction. Calcite + Quartz $\leftrightarrows$ Wollastonite + Carbon Dioxide. Amer. Jour. Sci., Vol. 254, 239-256.

Hayase, I. (1951): Extinct halo "Type A" found in the biotite in the contact zone of Tanakamiyame (in Japanese). Science of the Earth, No. 3, 19-23.

——————(1953): The radioactivity of rocks and minerals studied with Nuclear Emulsion II. Thorium content of granitic allanites. Mem. Coll. Sci. Kyoto Univ. Ser. B. Vol. 20, No. 4, 247-260.

——————(1954): The radioactivity of rocks and minerals studied with Nuclear Emulsion II. Thorim content of granitic allanites. Mem. Coll. Sci. Kyoto Univ. Ser. B, Vol. 20, No. 4, 247-260.

——————(1954): Relative geologic age measurements on granites by pleochroic haloes and the radioactivity of the minerals in their nuclei. Amer. Miner., Vol. 39, 761-772.

Holser, W. T. (1950): Metamorphism and associated mineralization in the Philipsburg region, Montana Bull. Geol. Soc. Mmer., Vol. 61, 1053-1090.

Horiuchi, H. (1958): Wollastonite occurred in Ryuhô district, Kumamoto Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 9, No. 10, 708-710.

——————(1950): Wollastonite deposits in Rekikawa-mura, Niigata Prefecture (in Japanese). Bull. Geol. Rurv. J., Vol. 11, No. 7, 53-56.

——————(1960): Wollastonite deposids at the Hiyoshi area, Gifu Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 11, No. 7, 57-60.

Inoue, H. and Doi, K. (1958): On the wollastonite deposits of Kôge island, Ehime Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 10, 689-697.

Ito, T. (1950): X-ray studies on polymorphism (in Japanese). 93-110.

Jander, W. and Hoffmann, E. (1934): Reaktionen in Festen Zustande bei höhern Temperaturen XI. Mitteilung. Die Reaktion zwischen Calciumoxyd und Siliciumoxyd.. Zeits. f. Anorg. Chem., Vol. 218, 211-223.

——————(1936): Reaktionen im Festen Zustande bei höhern Temperaturen VIII. Mitteilung.

Die Bestimmung von Reaktions-geschwindigkeiten bei Umsetzungen, die mit einer Gasabgabe verbesuden sind. Zeits. f. Anorg. Allg. Chem., Vol. 200, 245-256.

Johns, R. H. (1944): Ribbon rock, an unusual beryllium-bearing tactite. Econ. Geol., Vol. 193-205.

Katayama, N. and Nakamoto, A. (1935): Beitrage zur Mineralogie von Japan Neue Folge, Vol. 1. (in Japanese).

Kato, T. (1916): The ore deposit in the environs of Hanao-yama, near the town of Oda. Prov. Nagato, Japan, Jour. Meiji College of Technology, No. 1, 1-95.

Kennedy, W. Q. (1959): The formrtion of a diffusion reaction skarn by pure thermal metamorphism. Miner. Mag., Vol. 32, No. 245, 26-31.

Kobayashi, T. (1941): The Sakawa-orogenic cycle and its bearing on the origin of the Japanese islands. Jour. Fac. Sci. Imp. Univ.Tokyo, Section II, Vol. 5, part 7, 244.

Kondo, K. and Kawashima, S. (1930): Jour. Ceram. Assoc. Japan, Vol. 38, No. 455, 711-714.

Kroger, C. und Illner, K. W. (1939): Uber das System Alkalioxyd-CaO-Al_2O-$_3SiO_2$-CO_2, 6, Die Gleichgewichte in System CaO-SiO_2-CO_2, Z. anorg. u. allg. Chemie. Bd. 229, 197-224.

Liebau, F. (1956): Umber die Kristallstructun des Natriumpolyarsenates, $(NaAsO_3)_x$. Acta Cryst., Vol. 9, 811.

———(1956): Bemerkungen zur Systematik der Kristallstrukturen von Silikaten mit hochkondensierten Anion. Z. Physik, Chem., Vol. 206, 73-92.

———(1957): The crystal structures of rhodonite, $CaMn_4 [Si_5O_{15}]$, and pyroxmangite, (Ca, Mg) (Mn, Fe)$_6$ $[Si_7O_{21}]$. Acta Cryst., Vol. 10, part 12, 767.

———(1954): On the crystal chemistry of silicates, germanates, phosphates, arsenates, vanadates, and alkali fluoberyllates of the general formula ABX_3 Acta Cryst, Vol. 10, part 12. 790.

Lindgren, W. (1914): The origin of the "garnet zones" and associated ore deposits. Econ. Geol., Vol. 9, 283~292.

———(1924): Contact metamorphism at Bingham, Utah. Bull. Geol. Soc. Amer., Vol. 35, 507-534.

Loring, Coes, J. R. (1955): High-pressure minerals. (discussions and notes). Jour. Amer. Ceram. Soc., Vol. 38, No. 8, 298.

Magnusson, N. H. (1936): The evolution of the lover Archean rocks in central Sweden and their iron, manganese and sulphide ores. Q.J.G.S., Vol. 92, 332-359.

Maskill, W., Whiting, C.H. and Turner, E.S. (1932): The reaction between Calcium carbonate and silica, Jour. Soc. Glass Tech., Vol. 16, 94-110.

Matsushita, S. (1935): Regional geology of Japan, "Geology of Kinki" (in Japannes).

Miyazawa, T. and Nozaki, H. (1957): On the formation temperatures of minerals by the heating microscope stage method (1) (in Japanese). Min. Geol., Vol. 7, No. 26, 265-274.

Morey, G. W. and Ingerson, E. (1937): The pneumatolytic and hydrothermal alteration and synthesis of silicates. Econ. Geol., Vol. 32, Supplment to No. 5, 639-715.

Nagai, S. and Akiyama, K. (1932): Studies on synthesis of calcium silicates. 1. Jour. Soc. Chem. Ind. Japan, Vol. 34, 471_B-473_B.

Niggli, P. (1936): Gleichgewichte zwischen TiO_2 und CO_2, sowie SiO_2 und CO_2 in Alkali-, Kalk-Alkali und Alkali-Aluminatschmelzen.

Nishio, S., Imai, H., Inuzuka, S. and Okada, Y. (1935): Temperatures of mineral formation in some deposits in Japan. As measured by the decrepitation method (in Japanese), Min. Geol., Vol. 3, No. 7, 21-29.

Ogata, S. (1959): On the plutonic rocks in the Suzuka Mountain range. Earth Science (in Japanese), No. 43, 1-10.

Osborne, G. D. (1931): The contact metamorphism and related phenomena in neighbour-hood of Marulan, New South Wales. part 1. The quartz-momzonite-limestone contact.

Geol. Mag., Vol. 68, 289-314.

OSBORN, E. F. and SCHAIRER, J. F. (1921): The ternary system pseudowollastonite-akermanite-gehlenite. Ceram. Abstr., No. 2, 50-51.

——————(1941) : The ternary system pseudowollastonite-akermanite-gehlenite. Amer. Jour. Sci., Vol. 239, No. 10, 715-763.

PEACOCK, M. A. (1935): On wollastonite and parawollastonite. Amer. Jour. Sci., Vol. 30, Ser. 50, No. 180, 495-529.

PICHER, W. S. (1950): Calc-silicate skarn veins in the limestone of Lough Anure, Co. Donegal. Miner. Mag., Vol. 209, 126-141.

RANBERG, H. (1952): The Origin of metamorphic and metasomatic rocks, 269-270.

RANKIN, G. A. and WRIGHT, F. E. (1915): The ternary system CaO-Al_2O_3-SiO_2. Amer. Jour. Sci., Ser. 4, Vol. 39, No. 229, 1-79.

SCHEME, F. (1932): The metamorphosed limestones and associatcd contaminated igneous rock of the Carlingford district, Co. Louth. Geol Mag. Vol. 69, No. 815, 209-233.

SCHMITT, H. (1939): The Pewabic Mine. Bull. Geol. Soc. Amer., Vol. 50, 777-818.

————(1948): The contact pyrometasomatic aureoles, A.I.M.E. Tech. Pub., No. 259.

SEKINE, Y. (1958): Wollastonite ores in the pyrometasomatic copper-tungsten deposits at the Yamato Mine, Yamaguchi Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 9, No. 10, 675-688.

SPURE, J. E. (1923): The Ore magmas, 192.

SUZUKI, J. (1932): The contactmetamorphic ore deposits in the environs of the Ofuku Mine, Province of Nagato, Japan. Jap. Jour. Fac. Sci., Hokkaido Imp. Univ. Ser. 4, Vol. 2, 69-131.

TAKAHASHI, H. (1958): On the wollastonite deposits of Saidosho district, Fukuoka Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 10, No. 9, 699-708.

————(1960): Occurrence of wollastonites in Koyamaichi and Atetsu districts, Okayama Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 11, No. 7, 48-62.

TAKAHASHI, H. and UENO, M, (1960): On the wollastonite of the Kagata Mine, Ibaragi Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 11, No. 7, 45-47.

TILLEY, C. E. (1951): The zoned contact-skarns of the Broadford area, Skye. A study of boron-fluorine metasomatism in dolomite. Min. Mag., Vol. 29, No. 114, 621-666.

TILLEY, C. E. and HARWOOD, H. F. (1931): The dolerite-chalk contact of Scawt Hill, Co. Antrin. The production of basic alkali-rocks by the assimilation of limestone by basaltic magma. Min. Mag., Vol. 22, No. 132, 439-468.

UENO, M. (1958): On the wollastonite deposits in Horado district, Gifu Prefecture (in Japanese). Bull. Geol. Surv. J., Vol. 9, No. 10, 665-673.

UMPLEBY, J. B. (1914): The genesis of the Mackey copper deposits, Idaho. Econ. Geol., Vol. 9, 307-358.

————(1916): The occurrence of ore on the limestone side of contactzone. Univ. Calif. Dept. Geol. Bull., Vol. 10, 25-37.

WARREN, B. E. and BISCOE, J. (1931): The crystal structure of the monoclinic pyroxenes. Z. Kryst., Vol. 80, 391-401.

WATANABE, T. (1943): Geology and mineralization of the Suian district. Tyôsen (Korea), Jour. Fac. Sci., Hokkaido Imp. Univ., Ser. 4, Vol. 6, 205-303.

————(1957): Progress in Economic Geology (in Japanese), 77-78.

WILLBOURN, E. S. (1926): The Beatrice Mine, Selibin, F.M.S. Min. Mag., Vol. 35, No. 6, 329-338.

————(1927): The Beatrice Mine, Selibin, F.M.S. Min. Mag., Vol. 35, No. 1, 9-15.

YAMAMOTO, H. (1935): Metamorphic geology of the Higo gneiss area, Kumamoto, with special reference to Tomita's "Zircon Method". Sci. Rep. Fac. Sci. Kyūshū Univ. Geol., Vol. 6, No. 2, 81-93.

————(1951): Jour. Geol. Soc. J., Vol. 67, No. 670, 312-313.

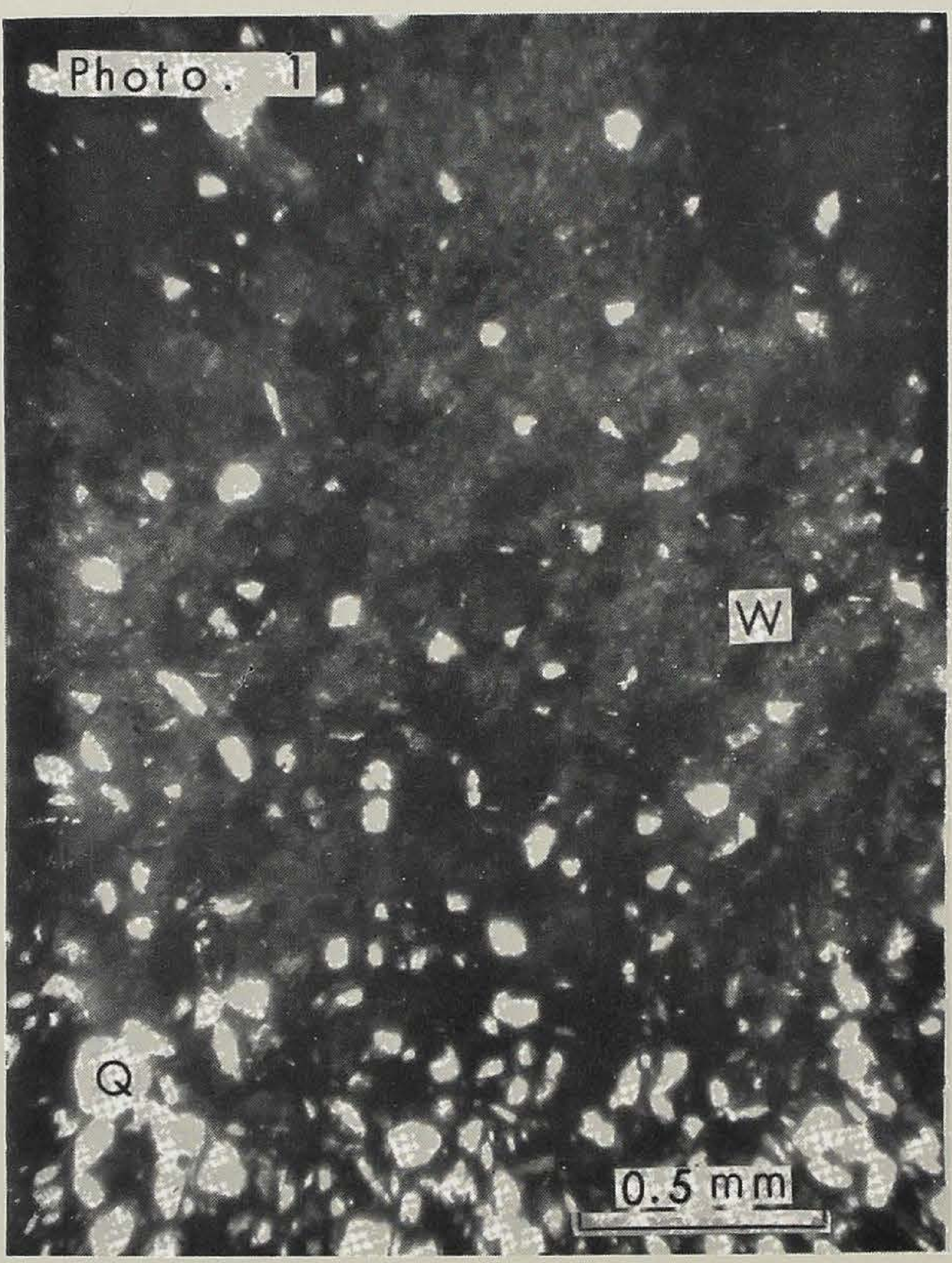

Photo 1. Central part of the reaction layer revealing flow-structure of pseudo-wollastonite (dark-cloudy) together with remained grains of quartz (white-colored). With crossed nicols. (See p. 200 of Part I of this paper.)

Plate I

Explanation of Plate I

Photo 2. Grayish black-colored, crystalline limestone is traversed by quartz vein including vesuvianite. Along the outer zone of the vein is disposed calcite accompanied with the outermost zone of wollastonite comprised in vein-like, white-colored limestone. The later happens to involve only wollastonite.

Photo 3. Quartz vein varying into wollastonite and then pinching out.
Q : quartz-vein, S : salite, V : vesuvianite, W : wollastonite

Photo 4. Vein-like, crystalline limestone bearing no quartz vein.

Photo 5. Silicified limestone (white-colored part) enclosing wollastonite in parts.

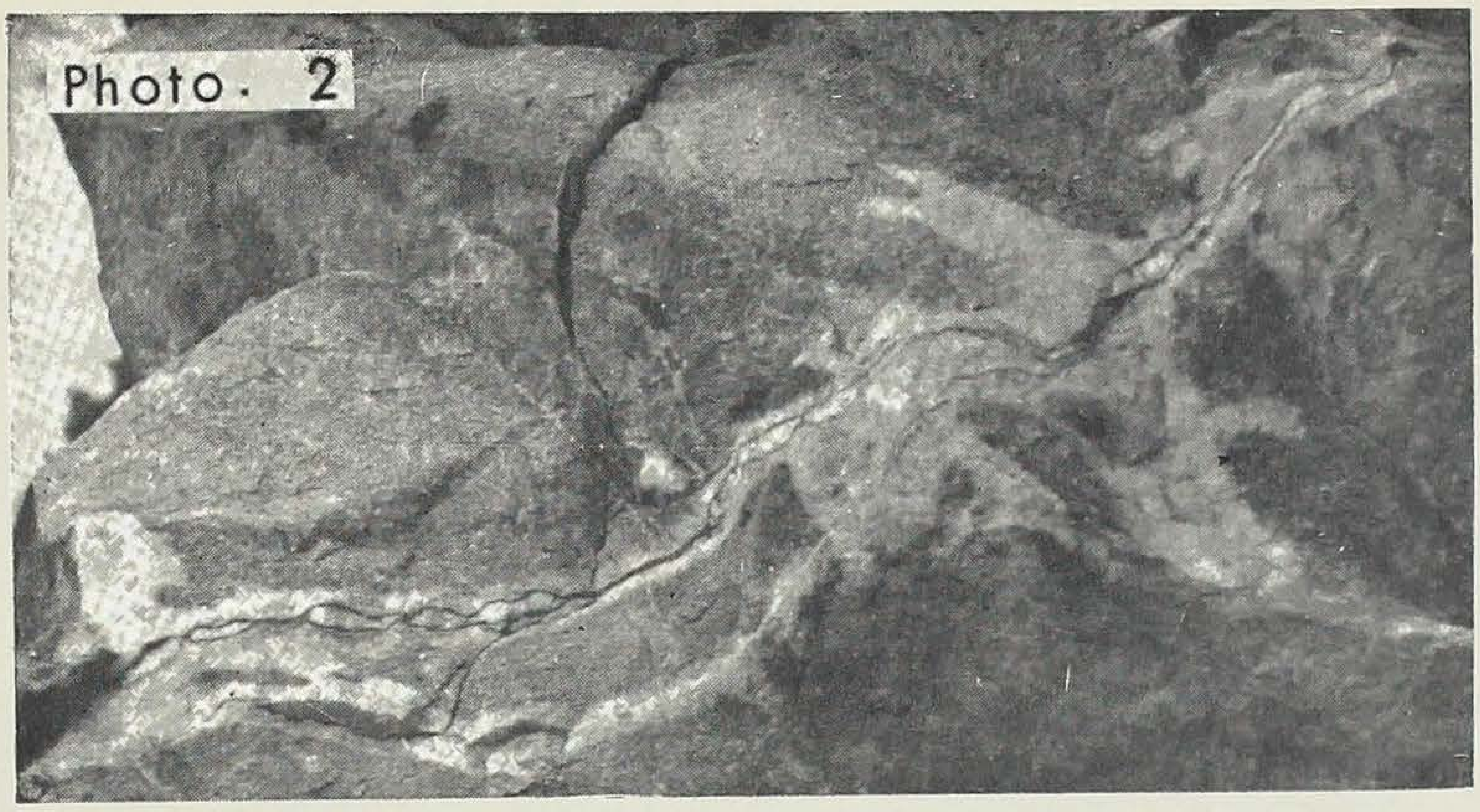
Photo. 2

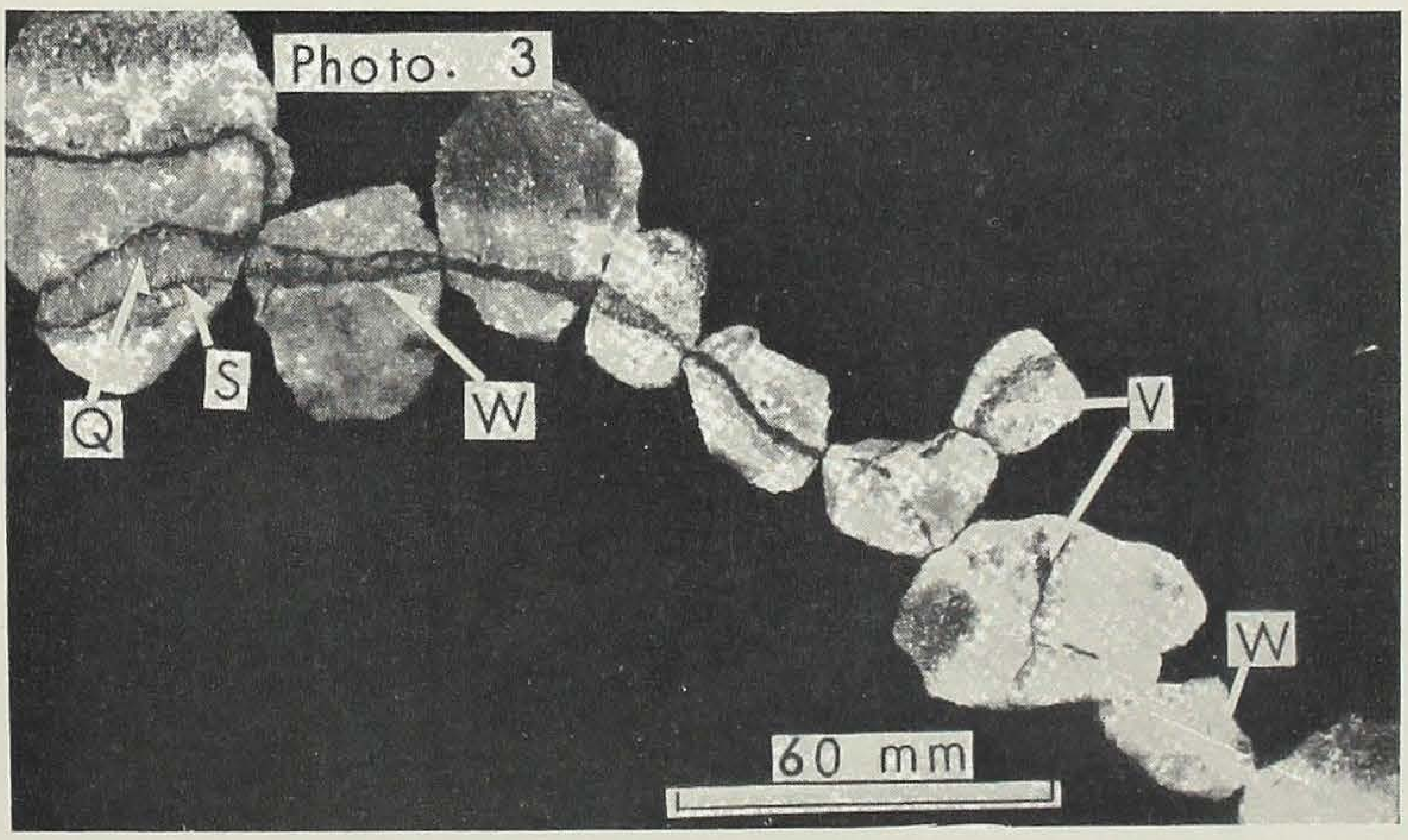
Photo. 3


Photo. 4


Photo. 5

Plate II

Explanation of Plate II

Photo 6. Grayish black-colored crystalline limestone. Blackish stripes represent the aggregates of carbonaceous materials.

Photo 7. Contact of veinlike quartzite with white crystalline limestone. White acicular wollastonite is observed in fluidal arrangement protruding obliquely toward the center of its own veinlet. W : wollastonite, Q : quartz

Photo 8. The specimen obtained through etching with dil. HCl. Composite veinlet including prehnite and diopside is appeared cutting across the white Crystalline limestone and wollastonite is formed between the veinlet and limestone. Silicified parts of limestone, composite veinlet, and some of white-colored papery veinlets cutting almost perpendiculary across the fomer are still remained. D : diopside, P : prehnite, R : reversideite, S. LS : silicified limetshne

Photo 9. The specimen obtained through etching with dil. HCl.
Wollastonite veinlet developed between vein-like quartzite and white crystalline limestone. Wollastonite is comprised also in minor cracks of faint-grayish quartzite, yielding a white-colored appearance.
Dendritic developments wollastonite veinlets, which were not observable on polished planes, are appeared through dissolution of calcite, pointing to their directional invasion. Q : quartz, W : wollastonite

Photo 10. A part of veinlets running through limestone. Q : quartz, S : salite, Wollastonite

Photo 11. A part of veinlets invading into limestone. S : salite, V : vesuvianite, W : wollastonite

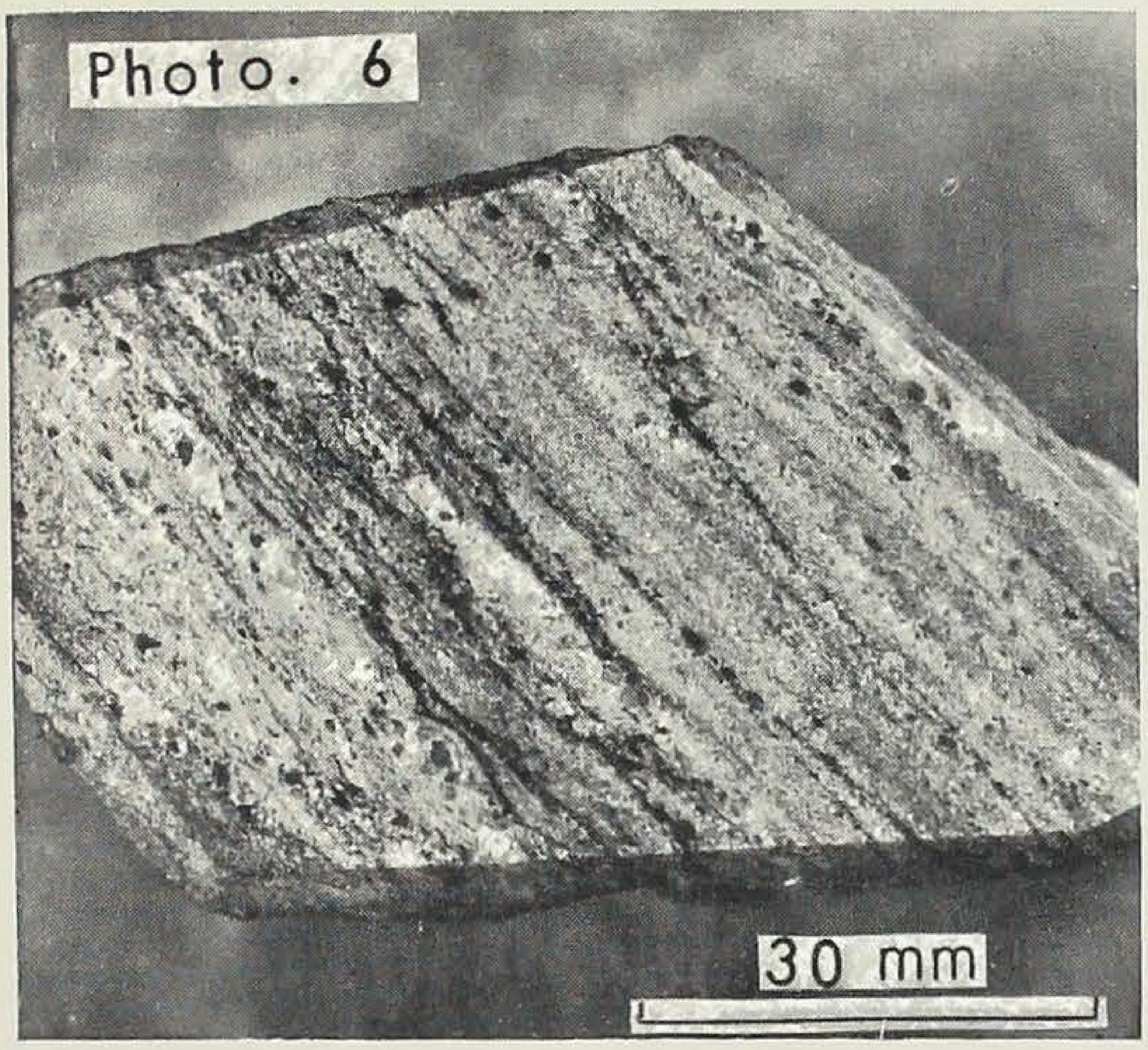
Photo. 6

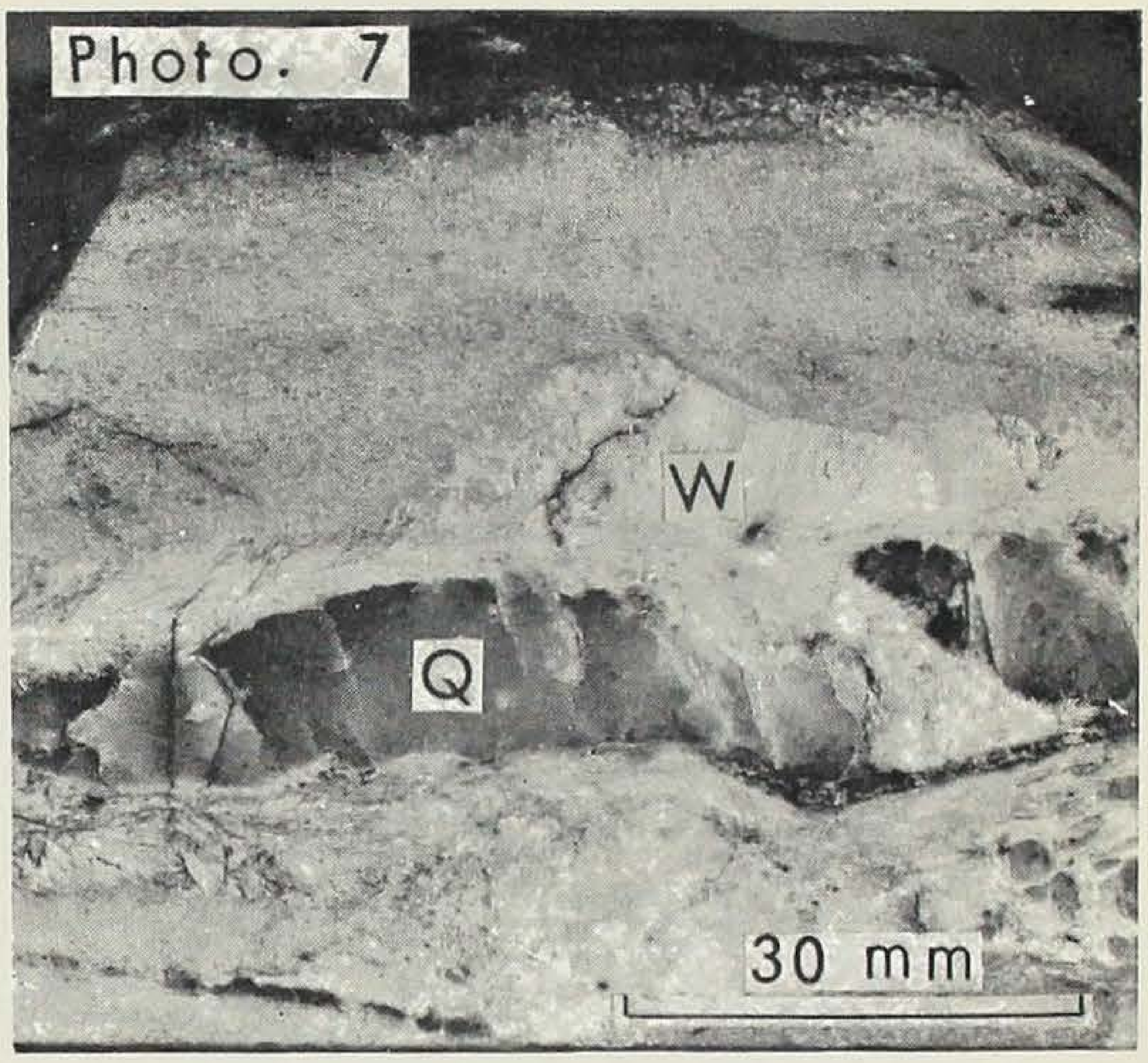
Photo. 7

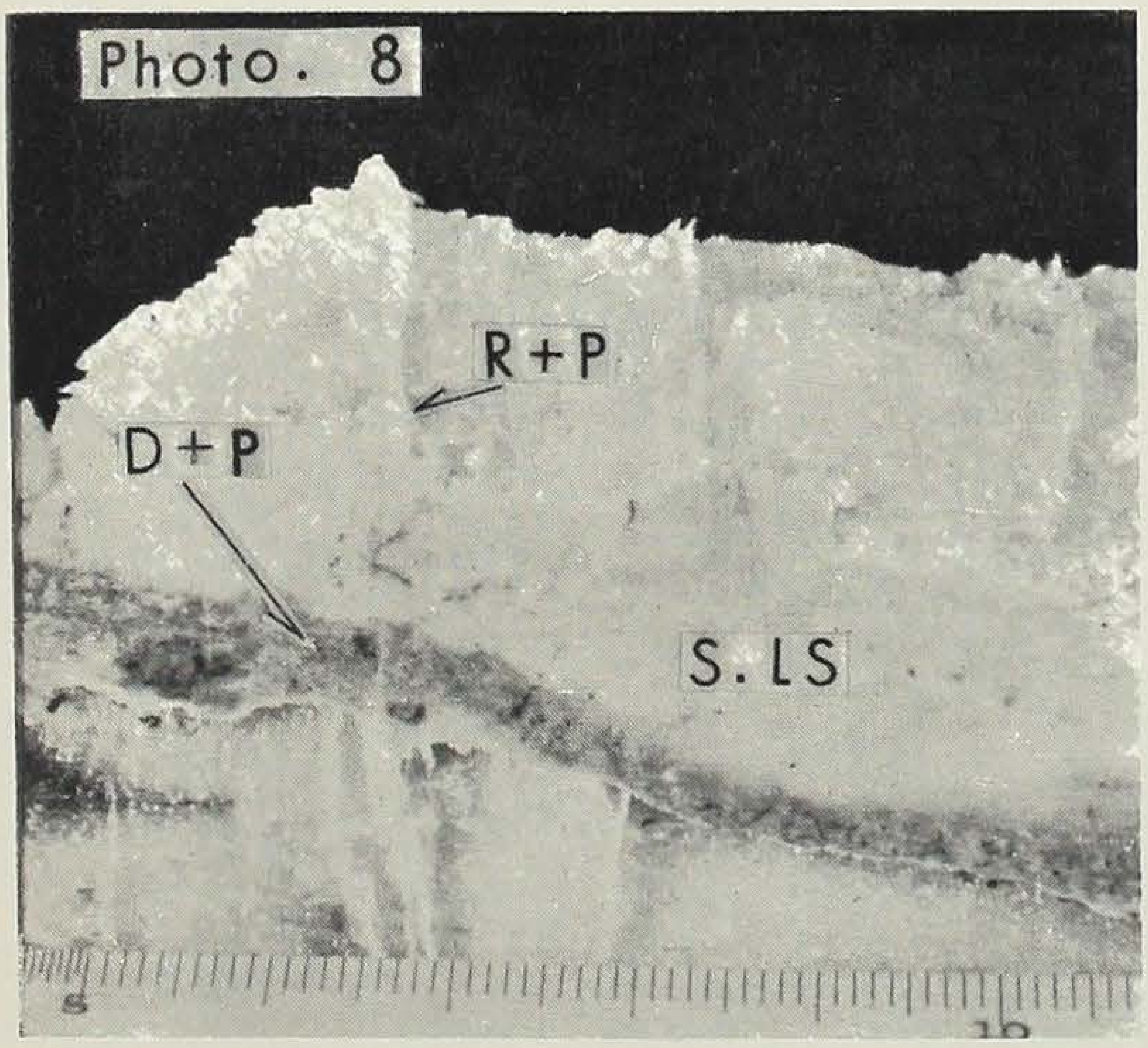
Photo. 8

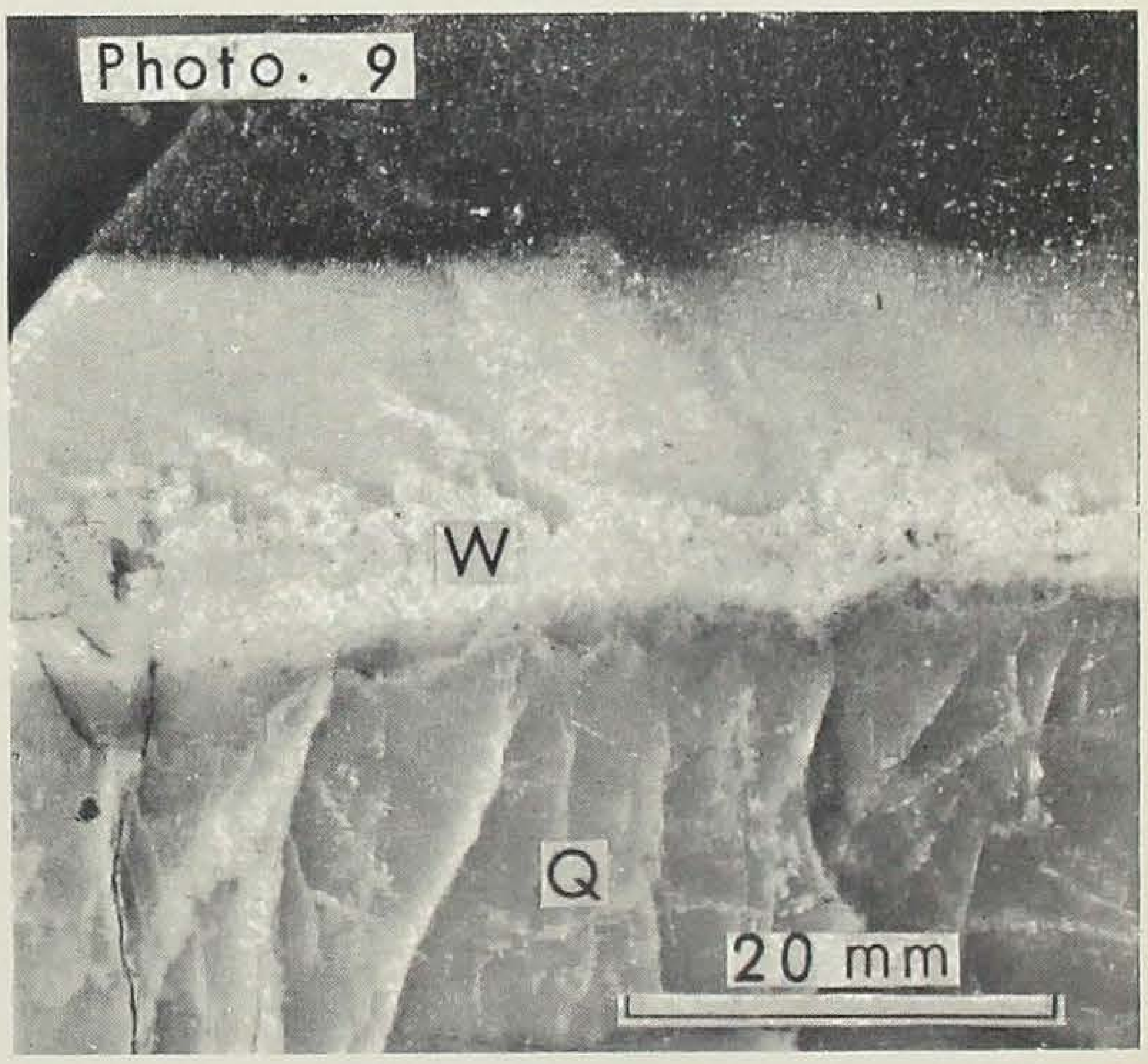
Photo. 9

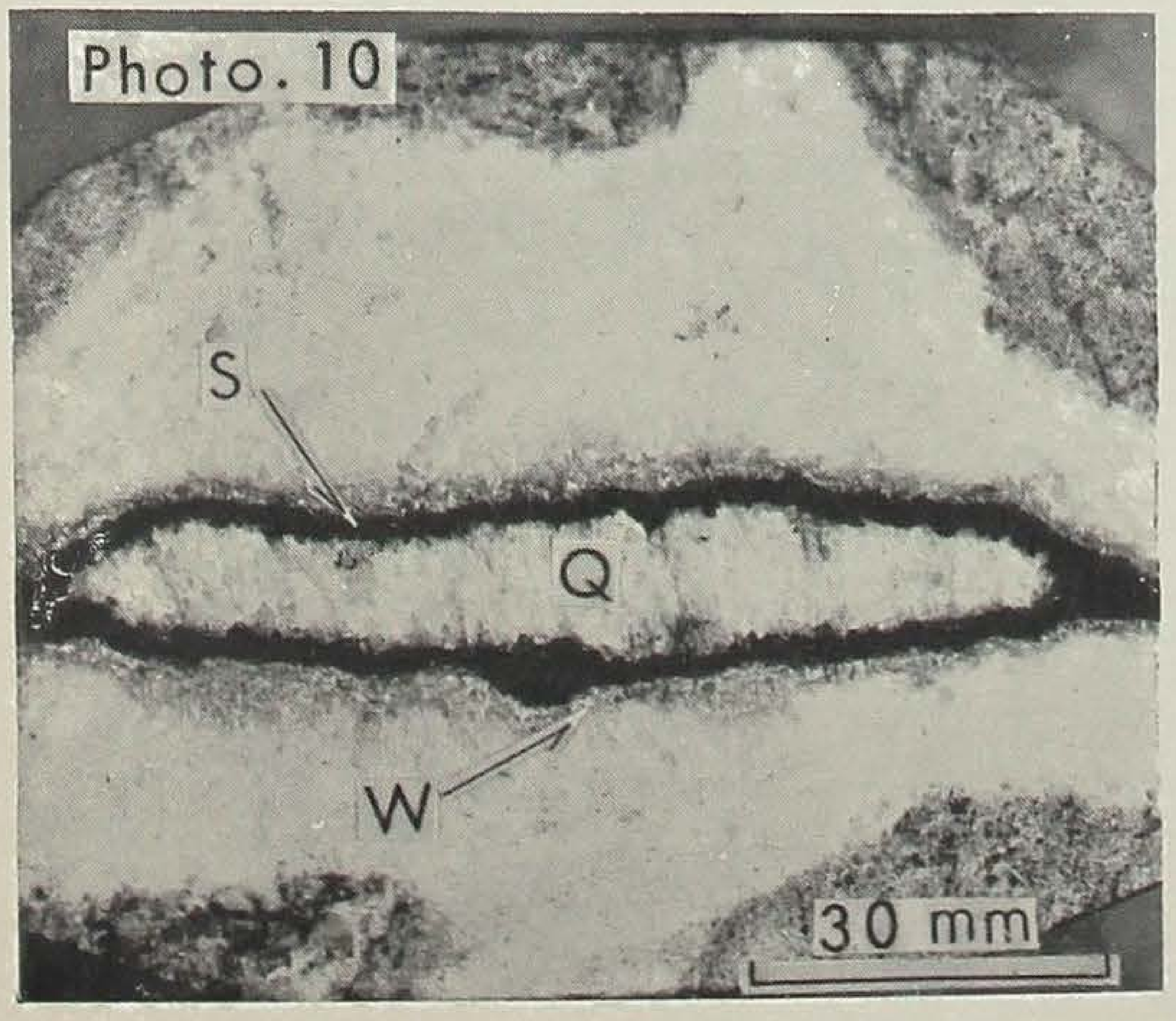
Photo. 10

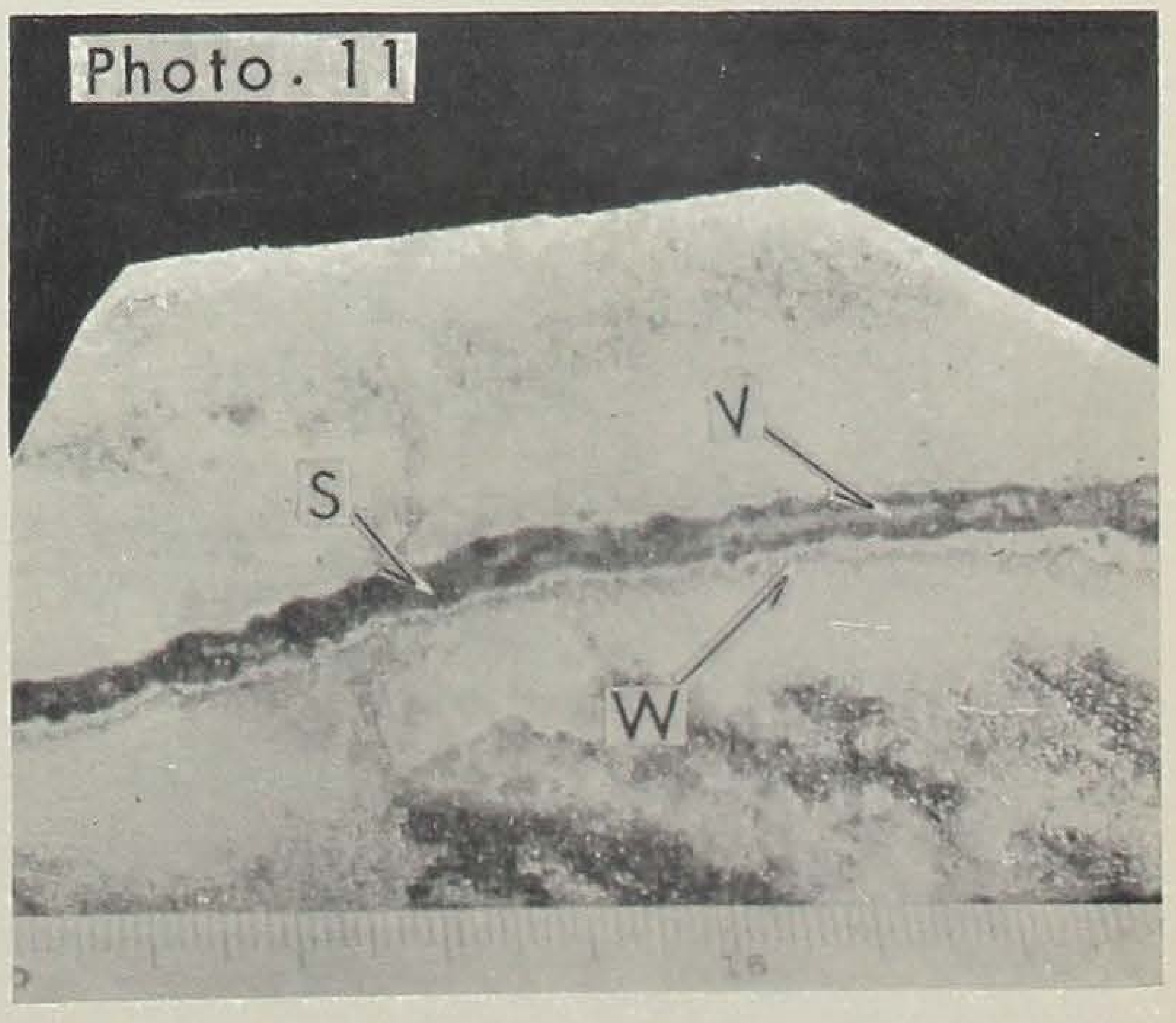
Photo. 11

Plate III

Explanation of Plate III

Photo 12. Wollastonite and diopside. Merely with a lower nicol. Q : quartz, D : diopside, W : wollastonite

Photo 13. Diopside and quartz enclosed in calcite. With crossed nicols. Q : quartz, C : calcite, D. diopside

Photo 14. Diopside and wollastonite. Merely with lower nicol. D : diopside, W : wollastonite C : calcite, Q : quartz

Photo 15. Contact of limestone with wollastonite. With crossed nicols. C : calcite, D : diopside, W : wollastonite

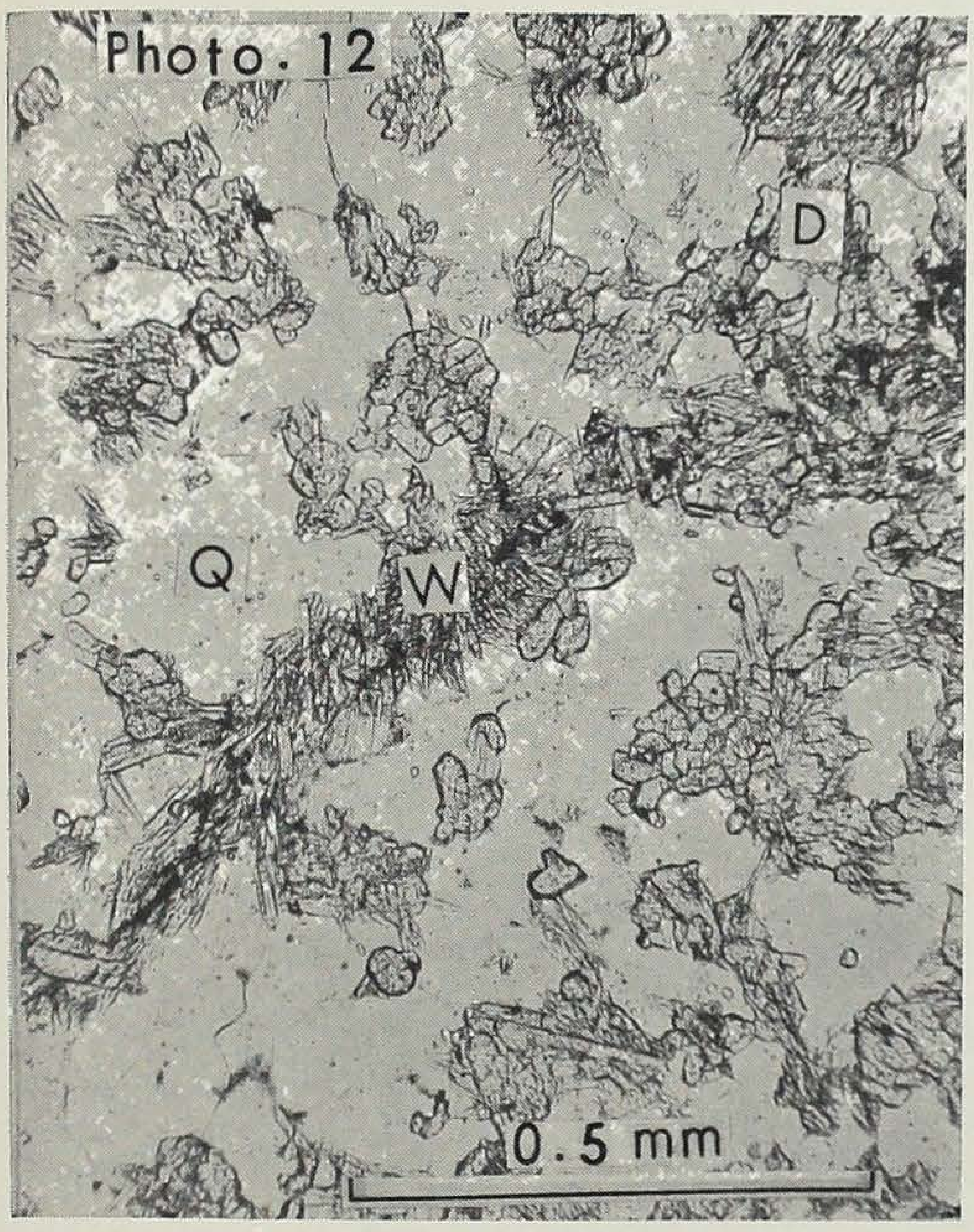
Photo. 12
D
Q
W
0.5 mm

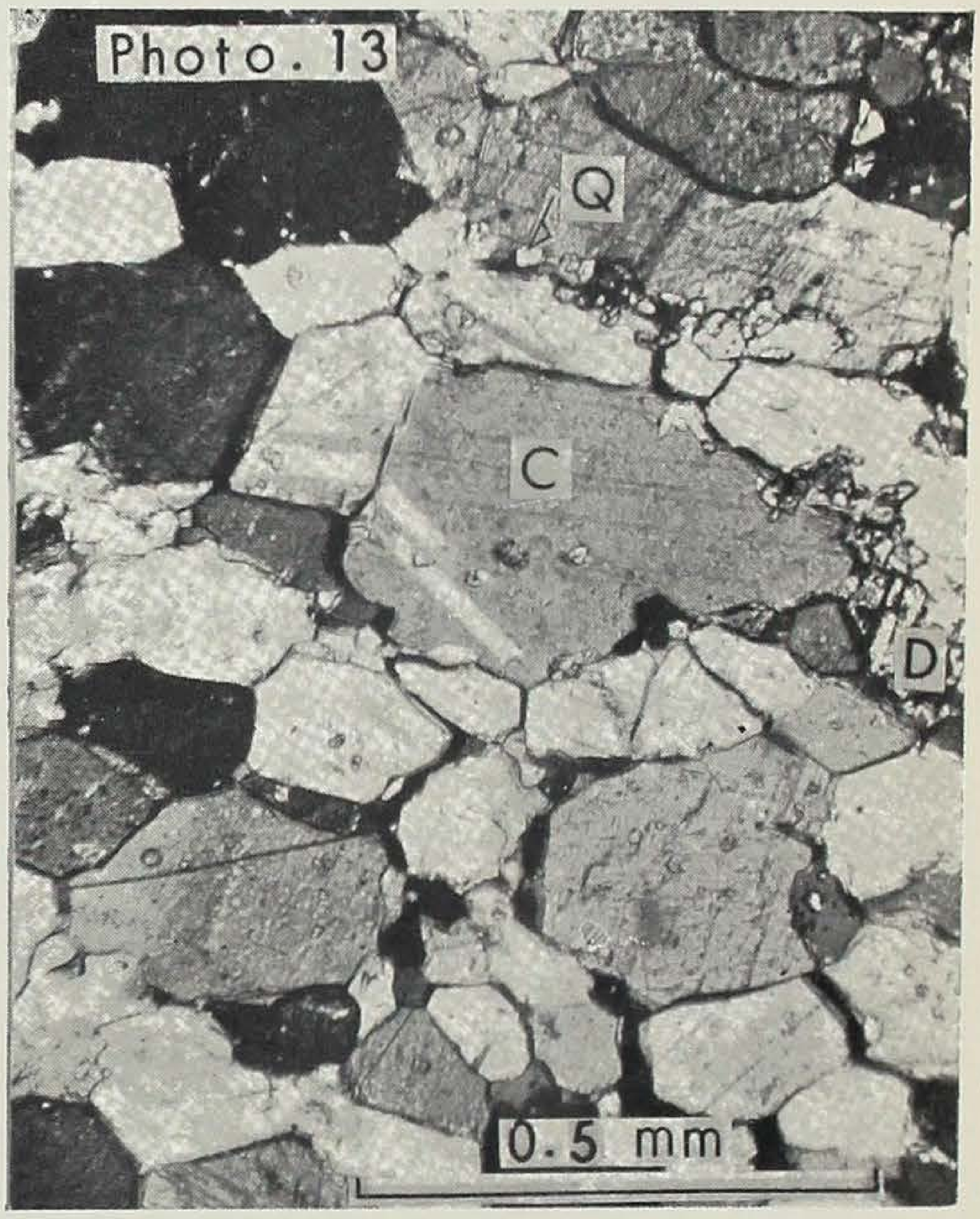
Photo. 13
Q
C
D
0.5 mm

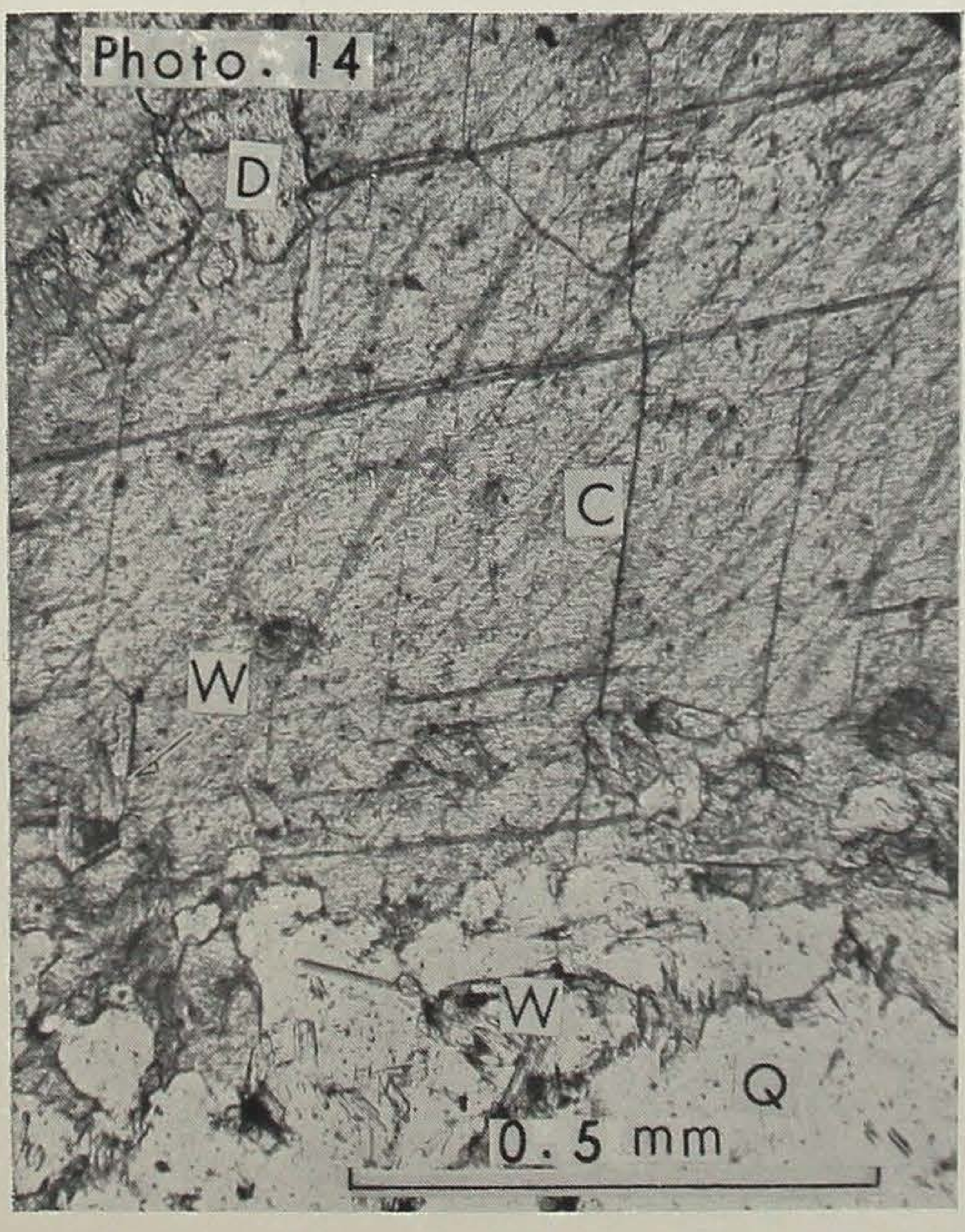
Photo. 14
D
C
W
W
Q
0.5 mm

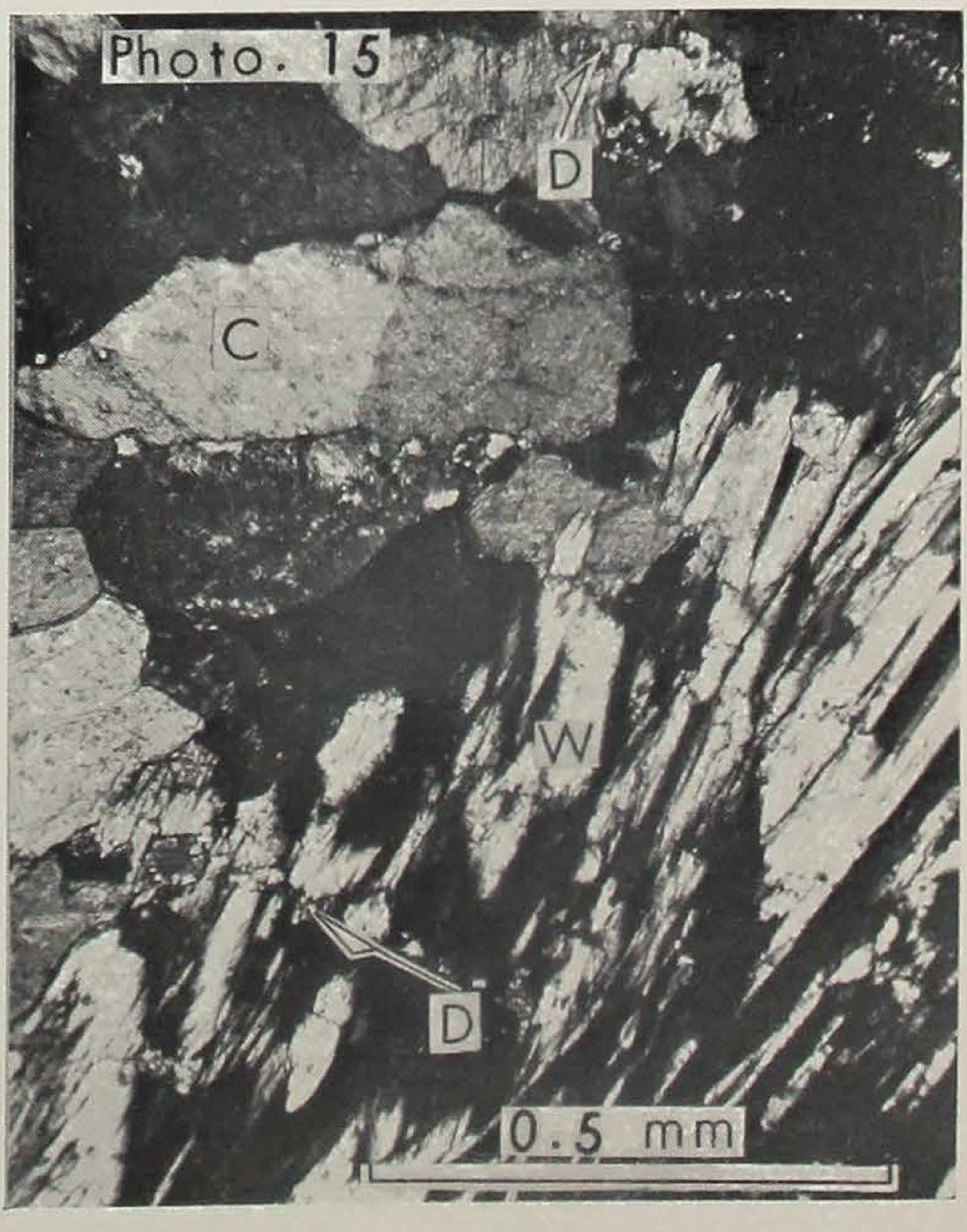
Photo. 15
D
C
W
D
0.5 mm

Plate IV

Explanation of Plate IV

Photo 16. Wollastonite comprised in grayish black-colored limestone.
Photo 17. Veinlets of vesuvianite.
Photo 18. Impregnated wollastonite

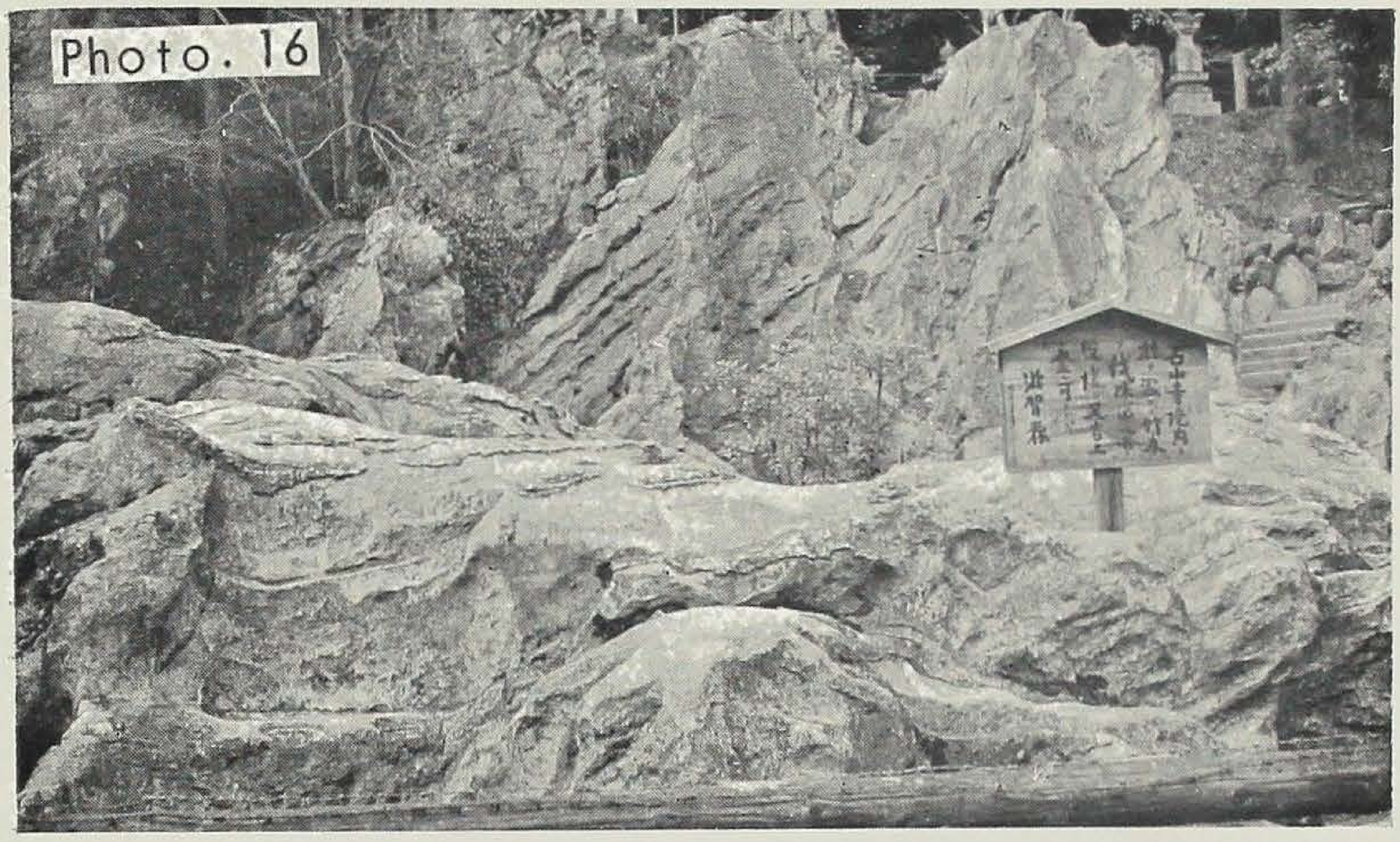
Photo. 16

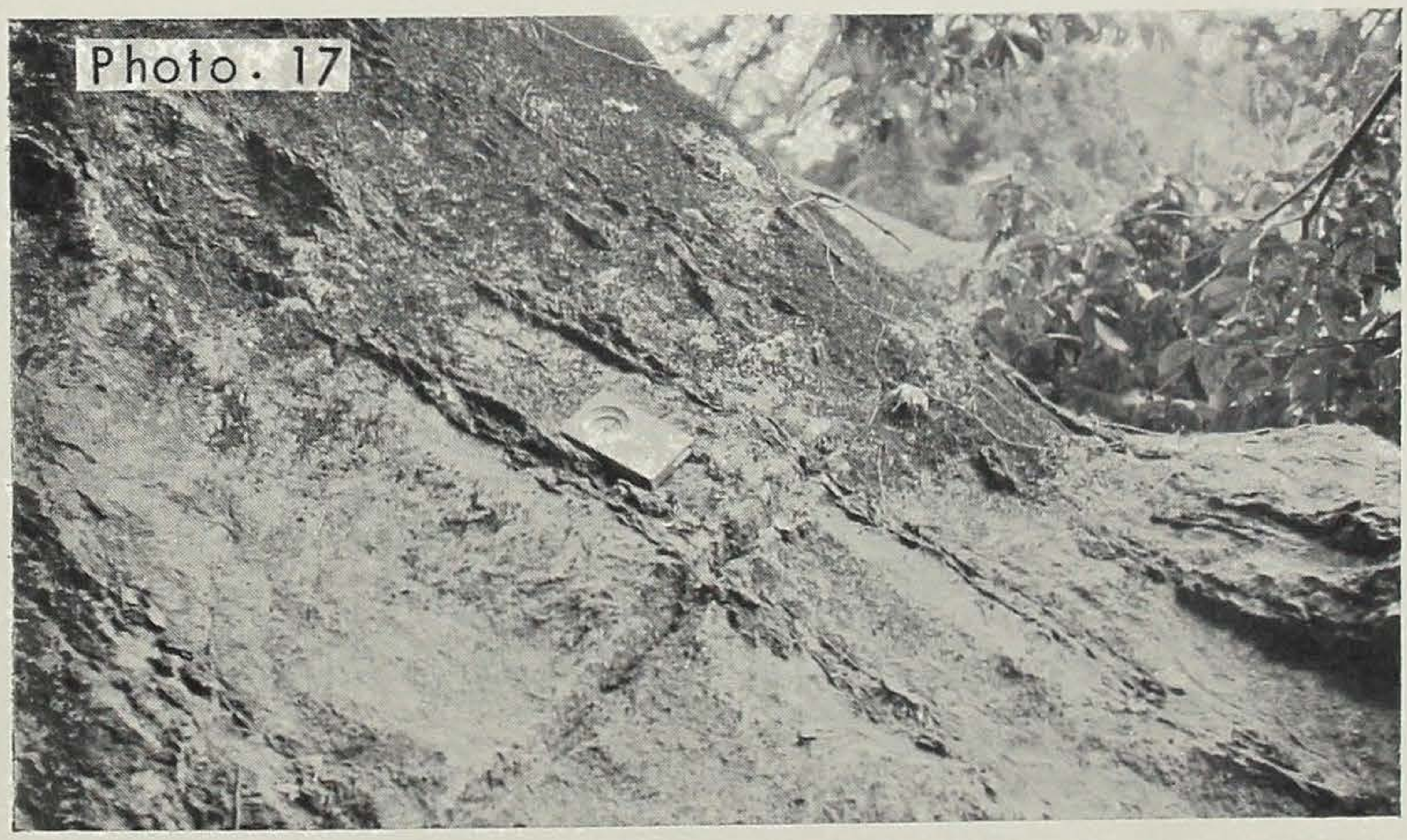
Photo. 17


Photo. 18

Plate V

Explanation of Plate V

Photo 19. Wollastonite included in the cracks of quartzite.
Photo 20. Composite vein of diopside and prehnite cutting across the vein of wollastonite appeared in the cracks of quartzite.
Photo 21. Relation of vesuvianite to wollastonite.
Photo 22. Occurrence of vesuvianite in absence of wollastonite.
Photo 23. Protruding figure of wollastonite on etching of polsihed surface with dil. HCl.
Photo 24. Protruding figure of wollastonite on etching of polished surface with dil. HCl.

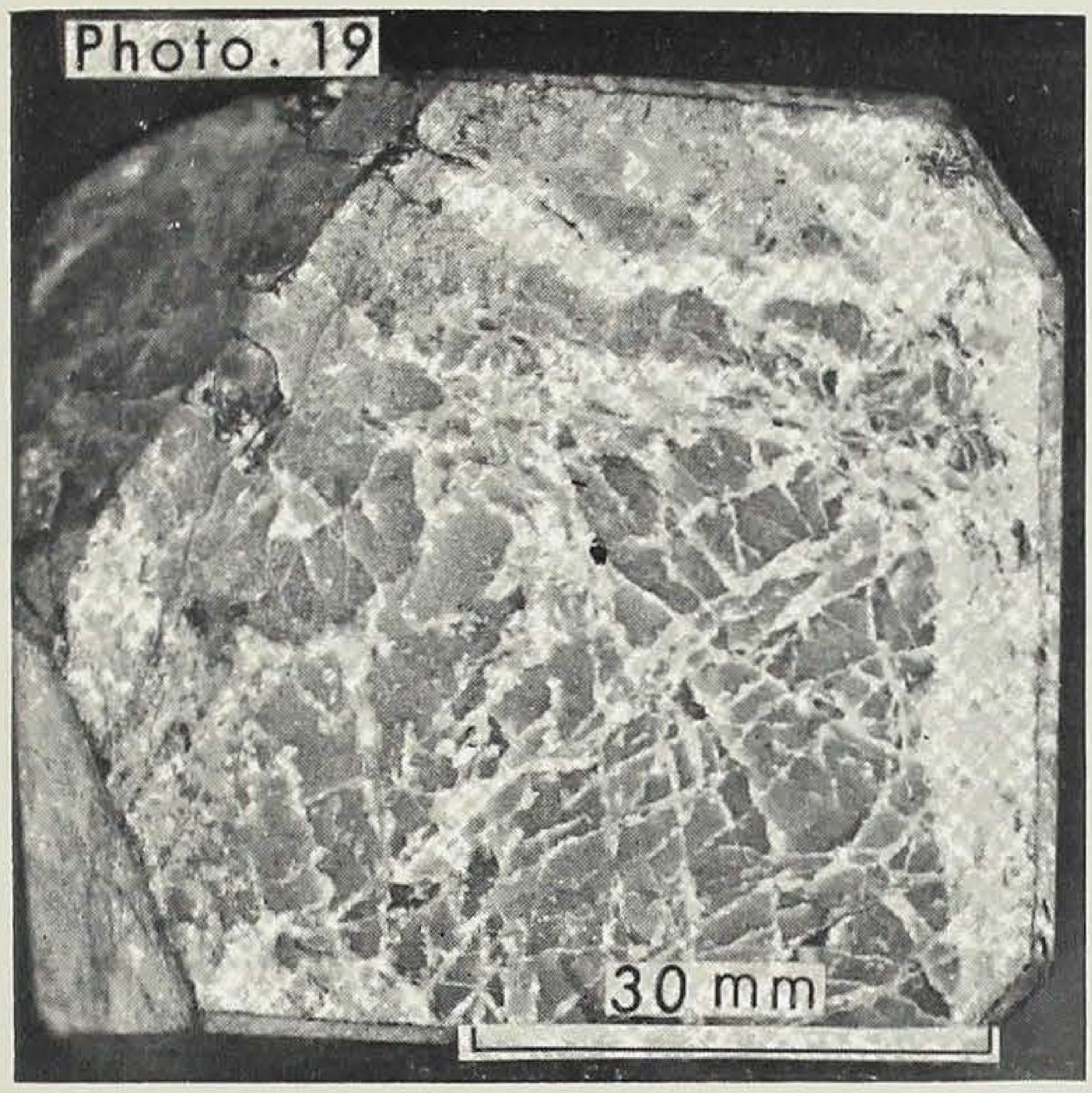
Photo. 19
30 mm

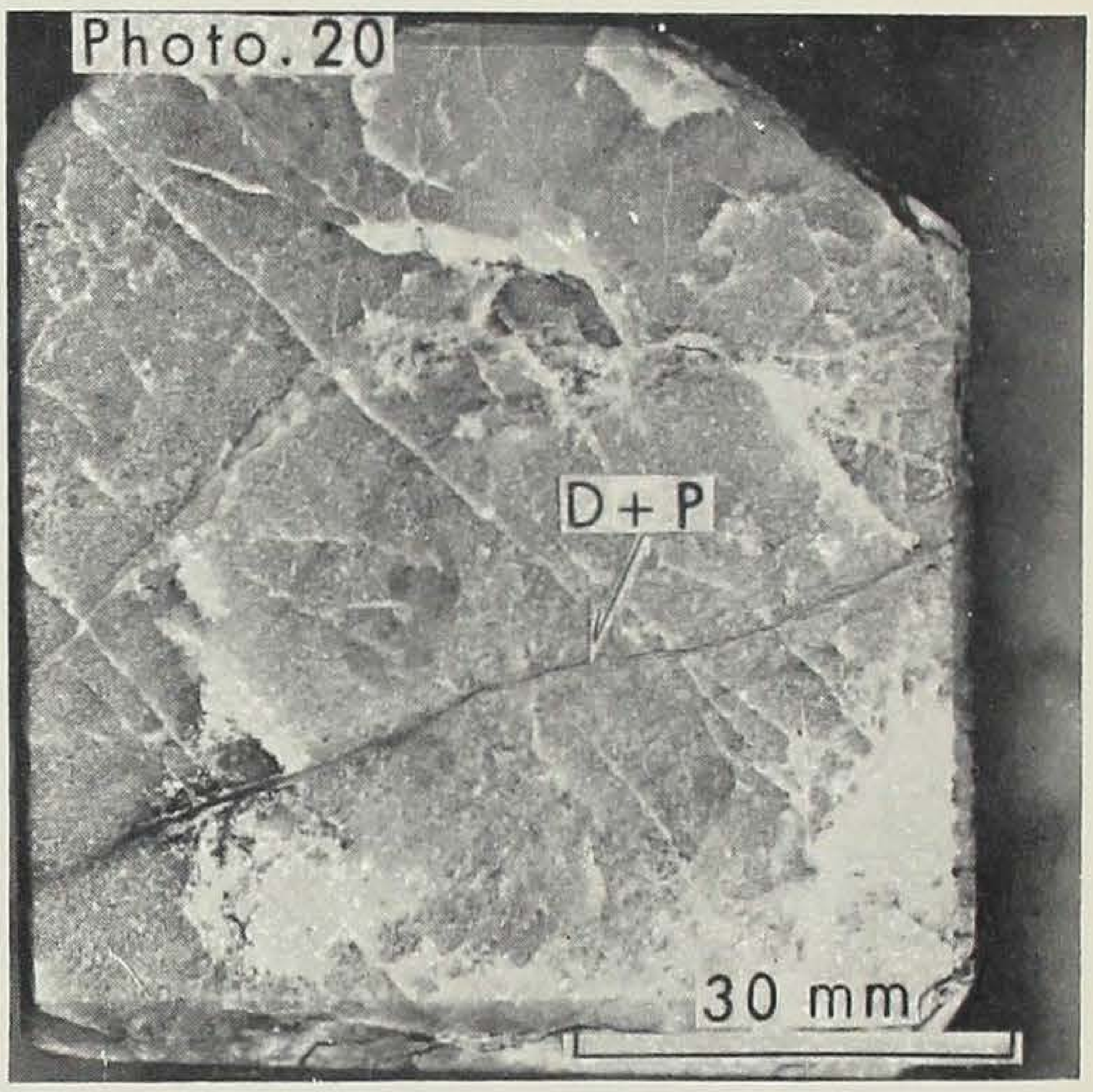
Photo. 20
D+P
30 mm

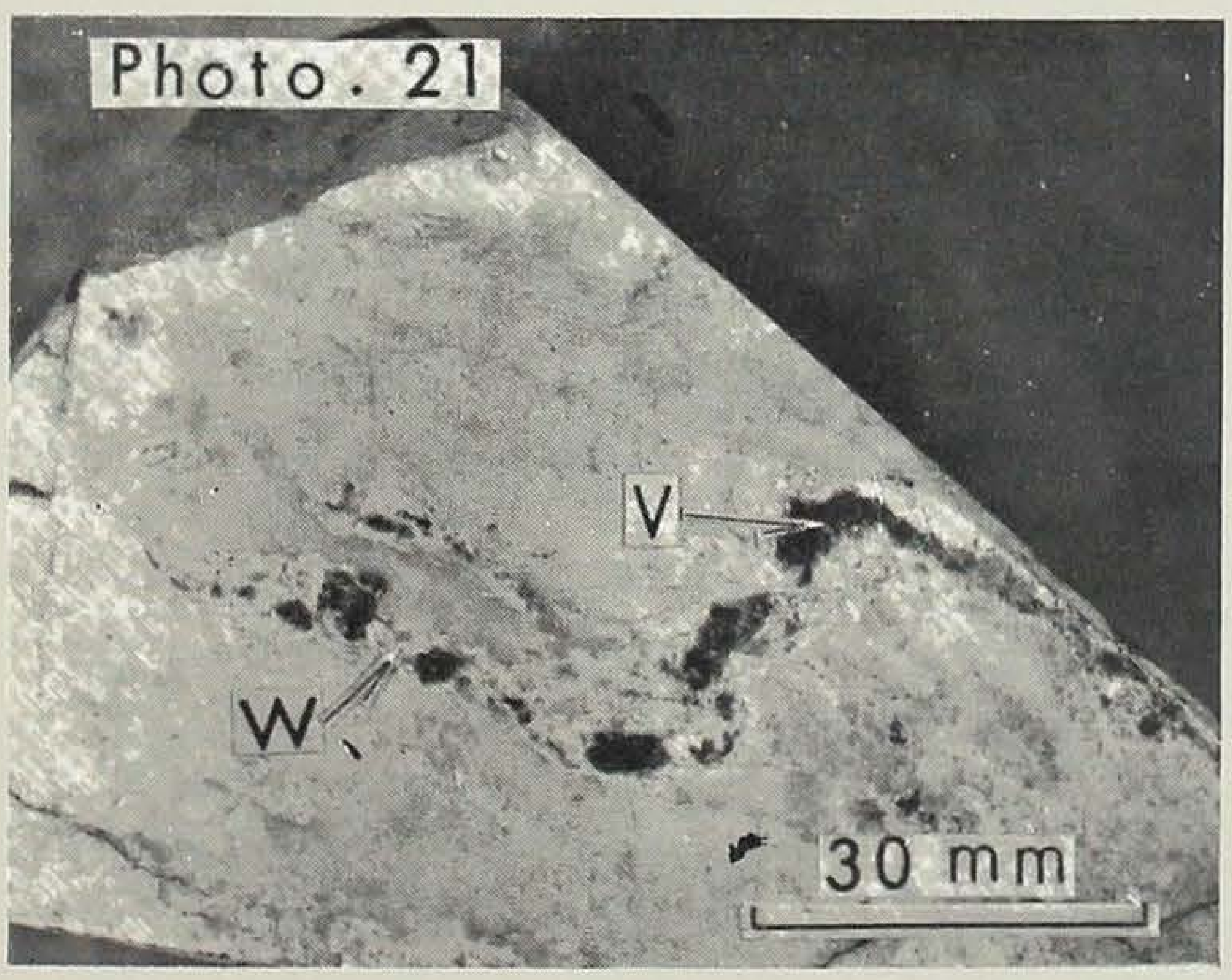
Photo. 21
V
W
30 mm

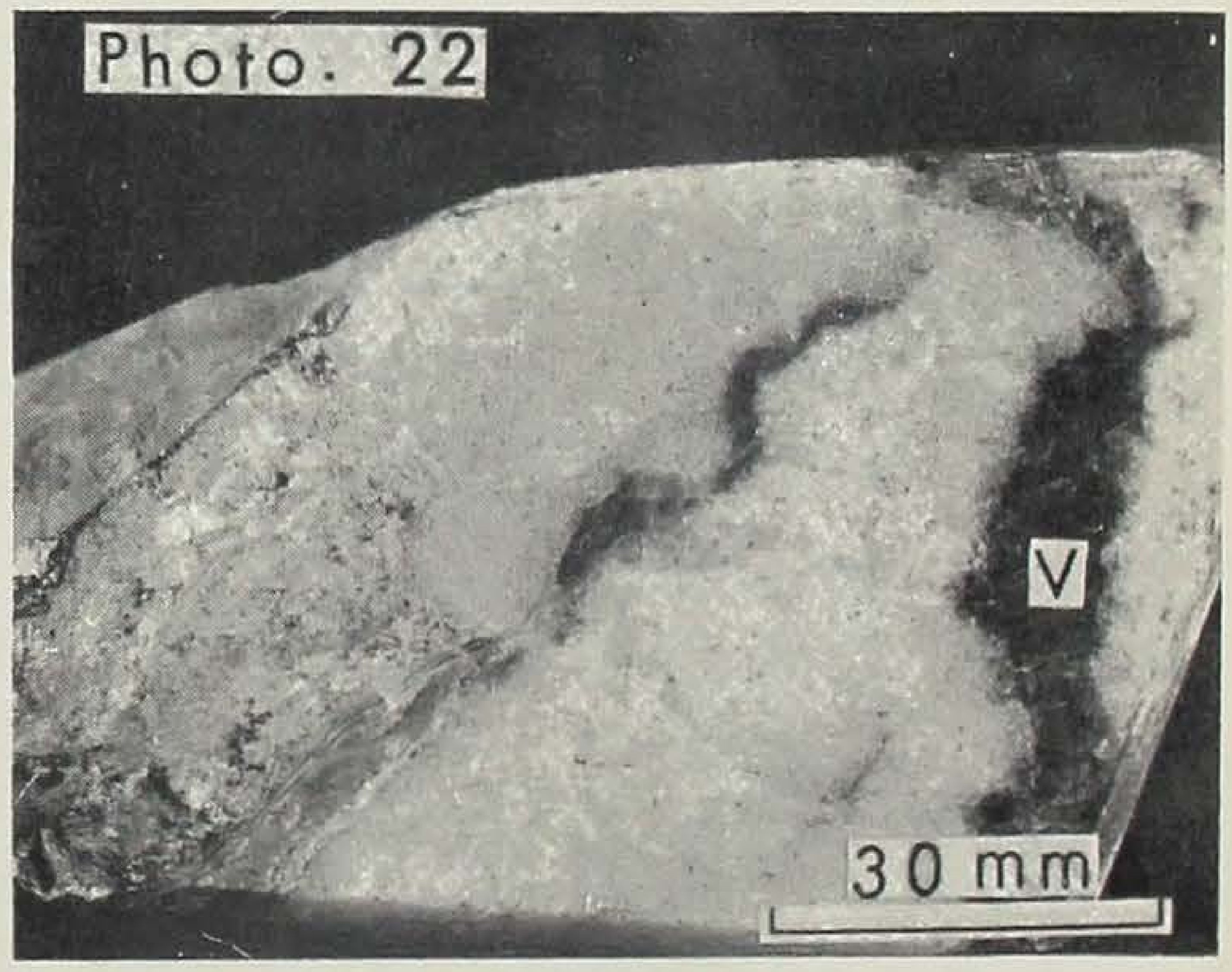
Photo. 22
V
30 mm

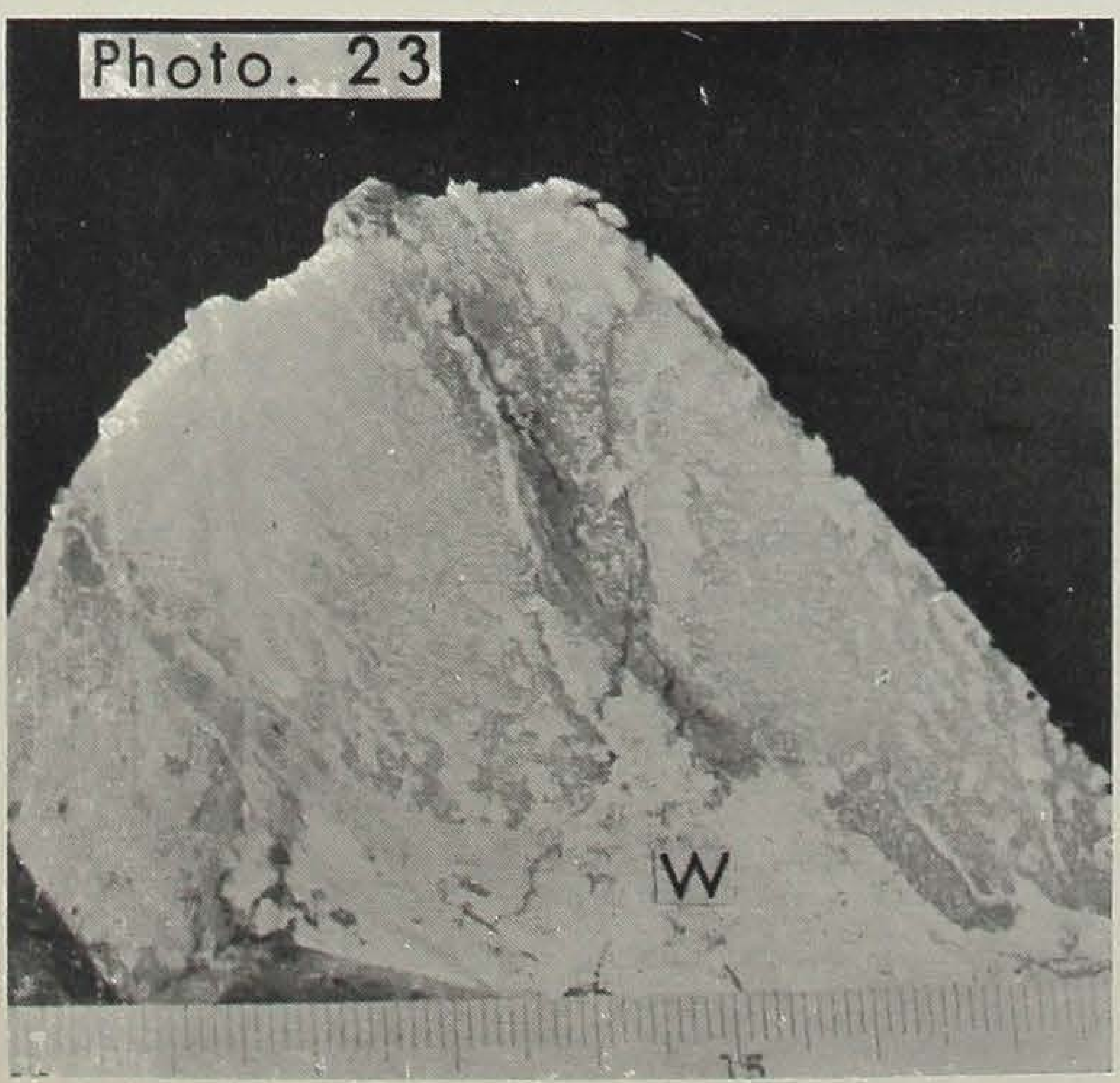
Photo. 23
W
15

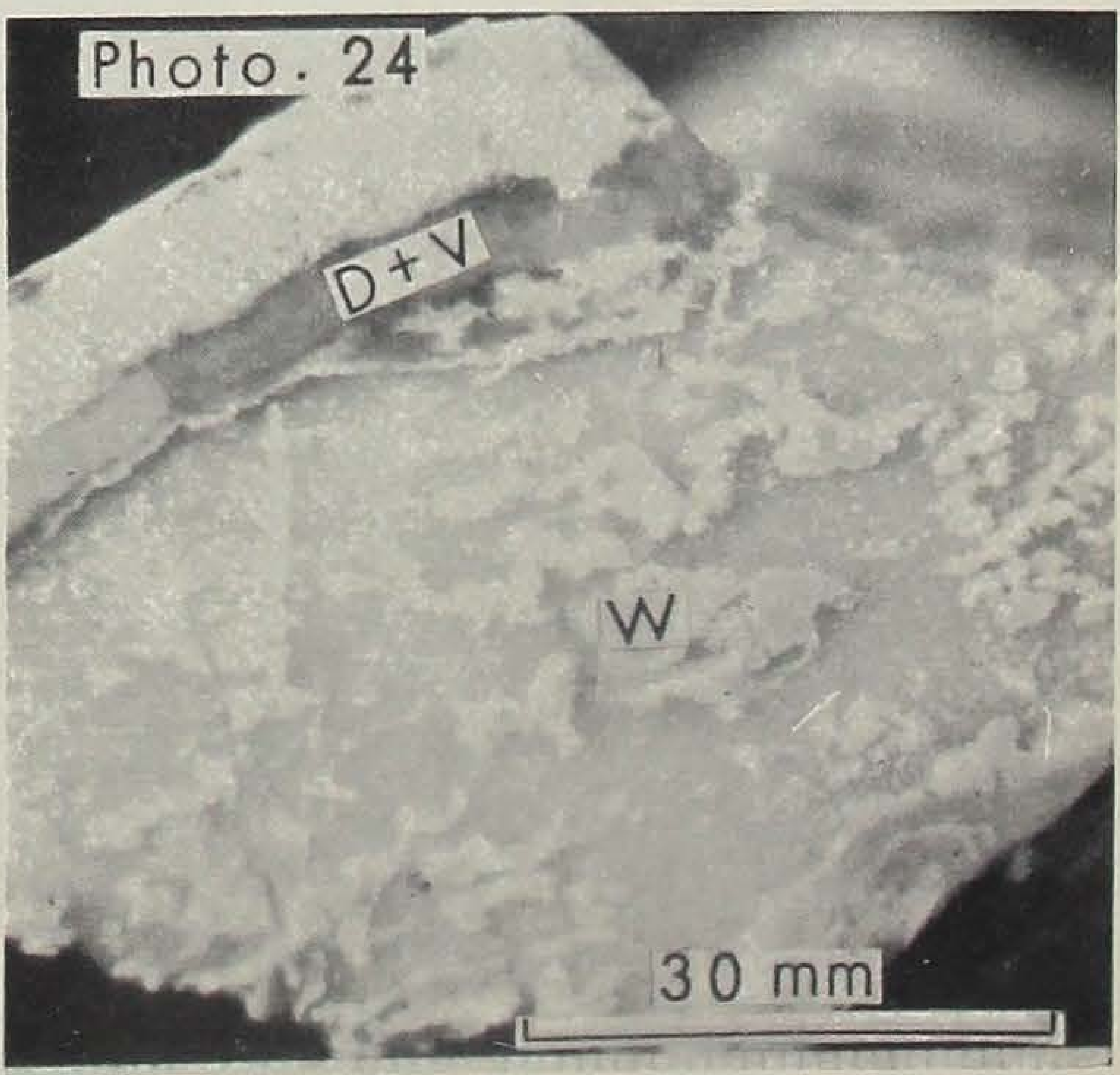
Photo. 24
D+V
W
30 mm

Plate VI

Explanation of Plate VI

Photo 25. Composite veinlet including garnet and prehnite. With crossed nicols.
C : calcite, G : garnet, P : prehnite
Photo 26. Carbonaceous materials. With a single nicol.
C : calcite
Photo 27. Diopside in quartzite. D : diopside, Q : quartz
Photo 28. Specimen obtained near slate.

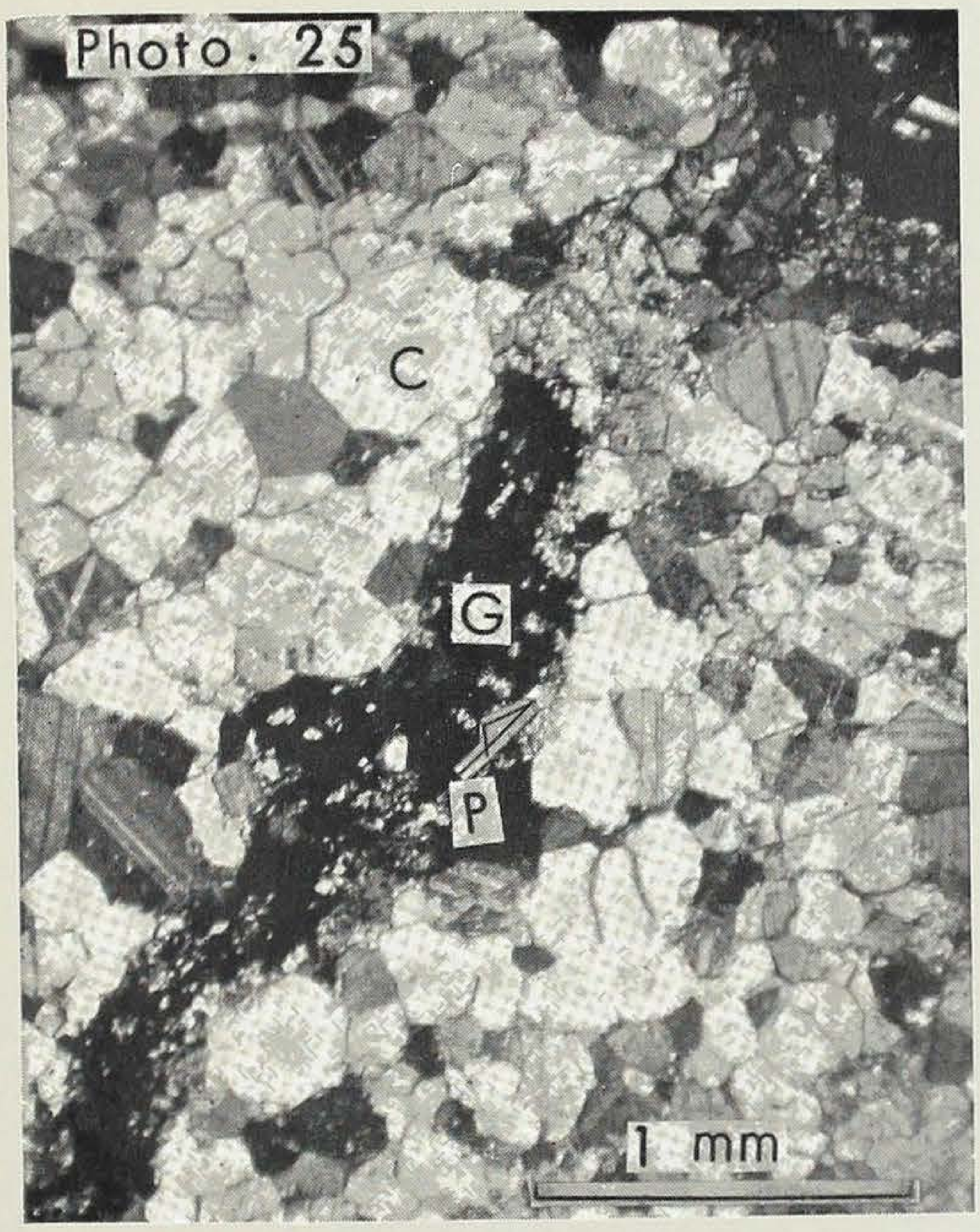
Photo. 25
C
G
P
1 mm

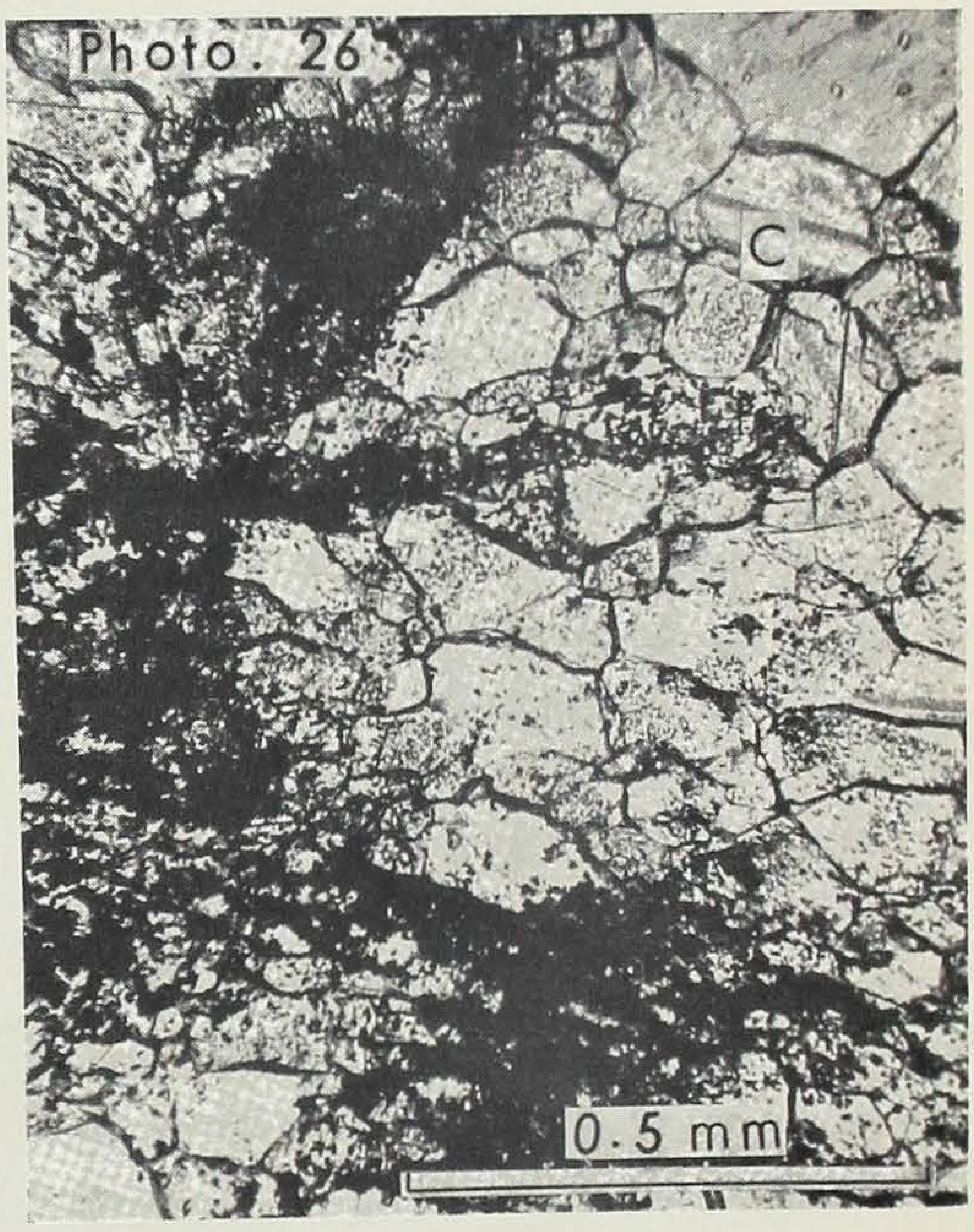
Photo. 26
C
0.5 mm

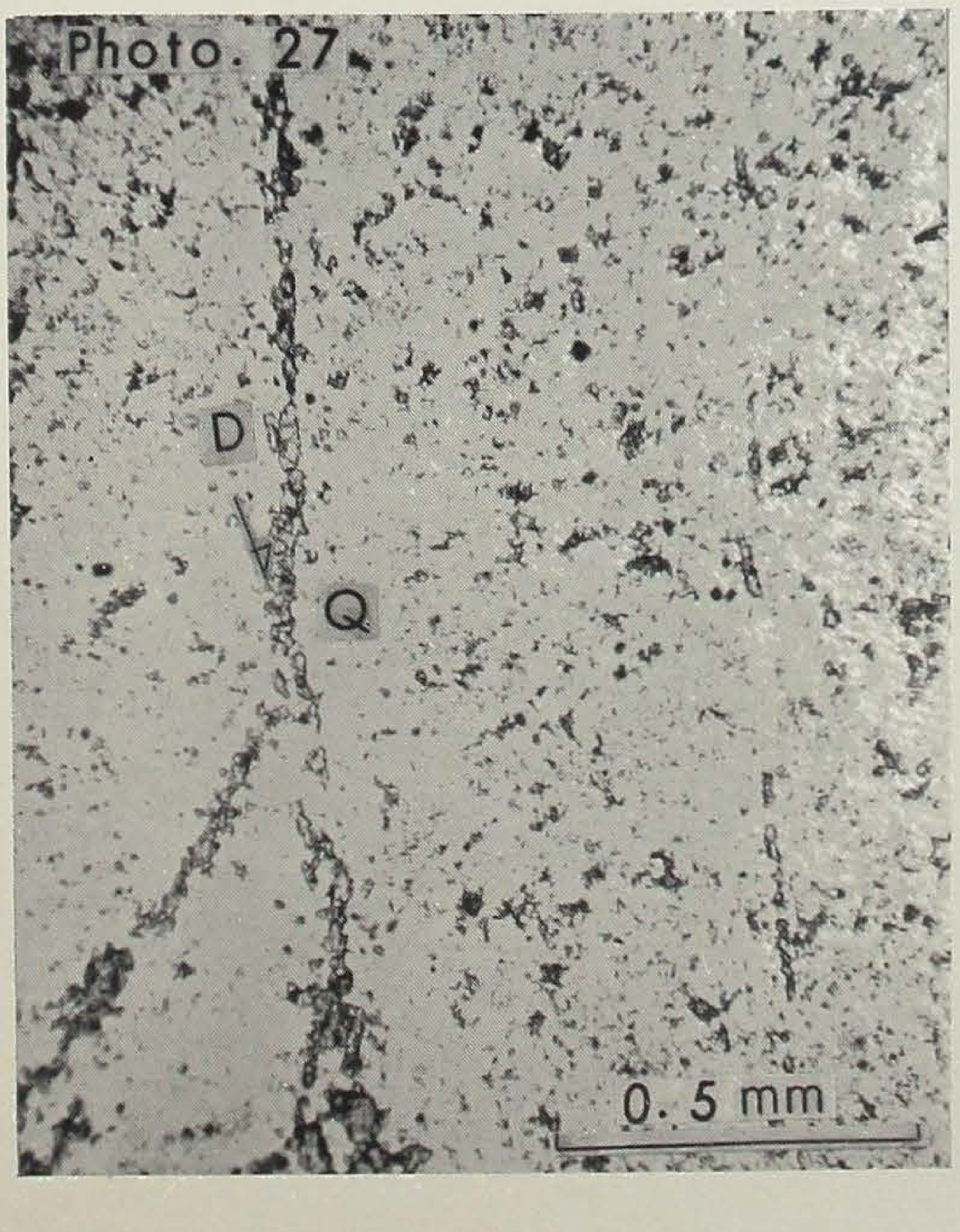
Photo. 27
D
Q
0.5 mm

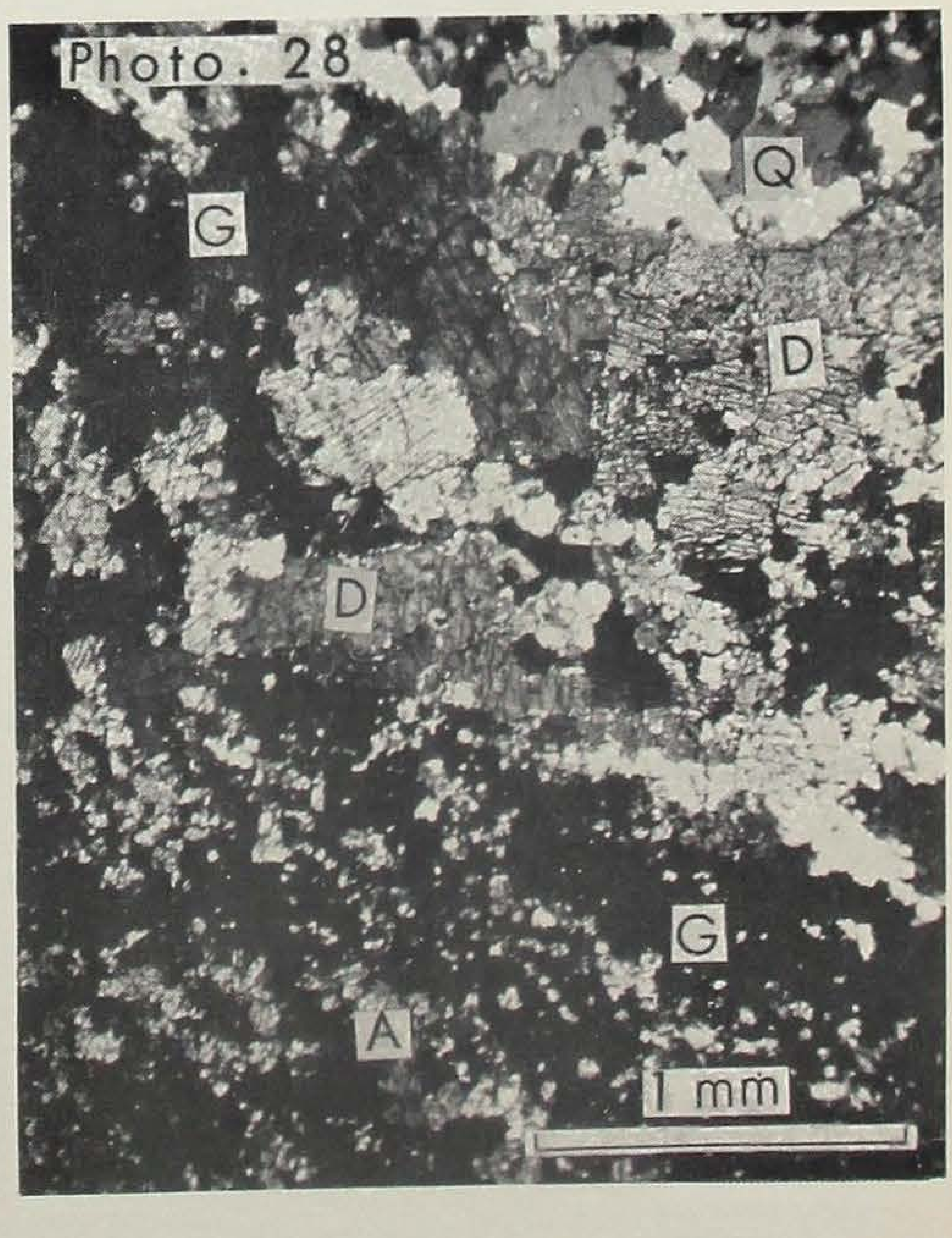
Photo. 28
G
Q
D
D
G
A
1 mm

Plate VII

Explanation of Plate VII

Photo 29. Sight of the outcrop.
Photo 30. Paragenesis of wollastonite and garnet. D : diopside, G : garnet, W : wollastonite
Photo 31. Wollastonite vein distributed along the stratified plane of crystalline limestone. W : wollastonite

Photo. 29

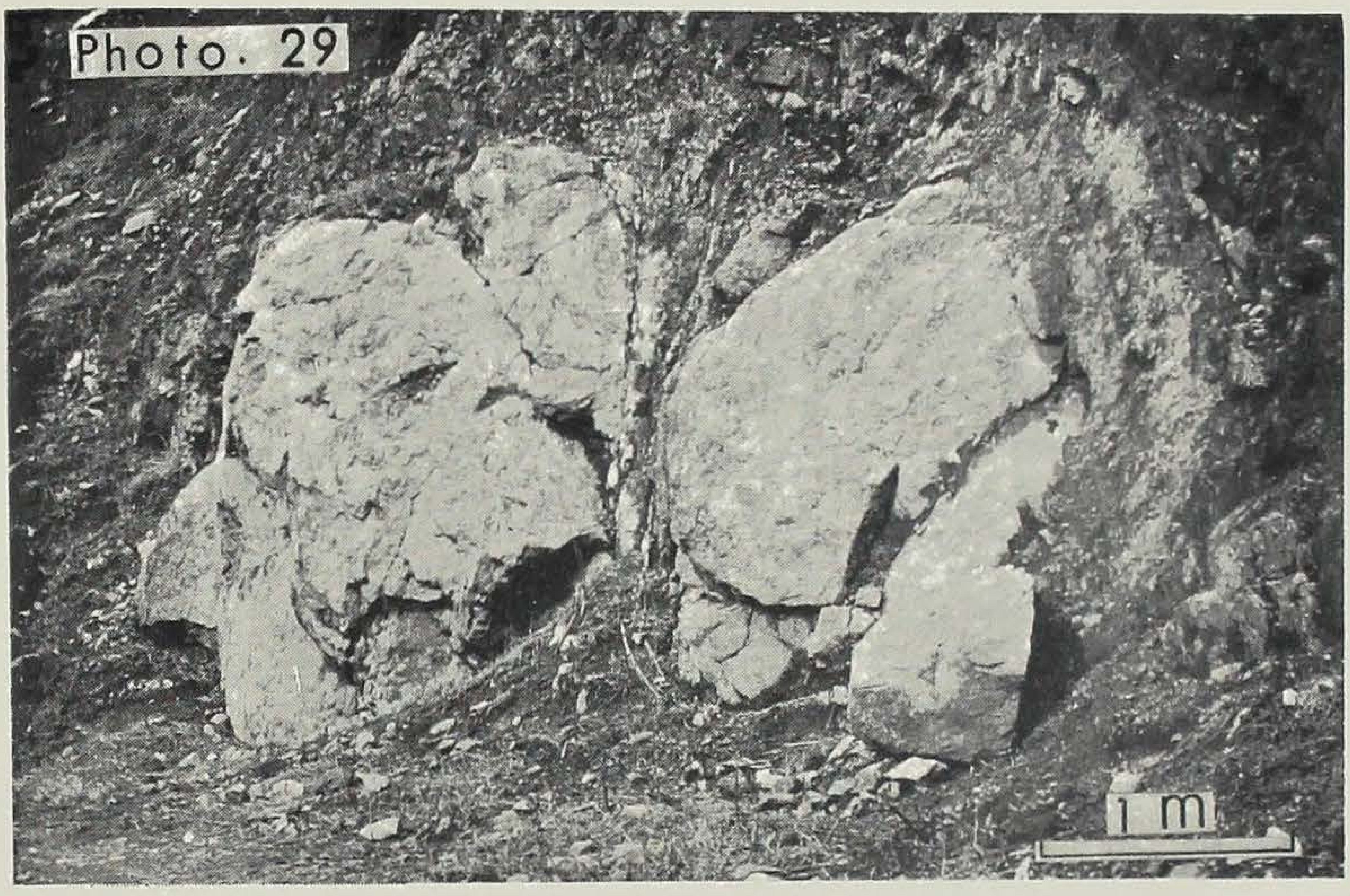

Photo. 30

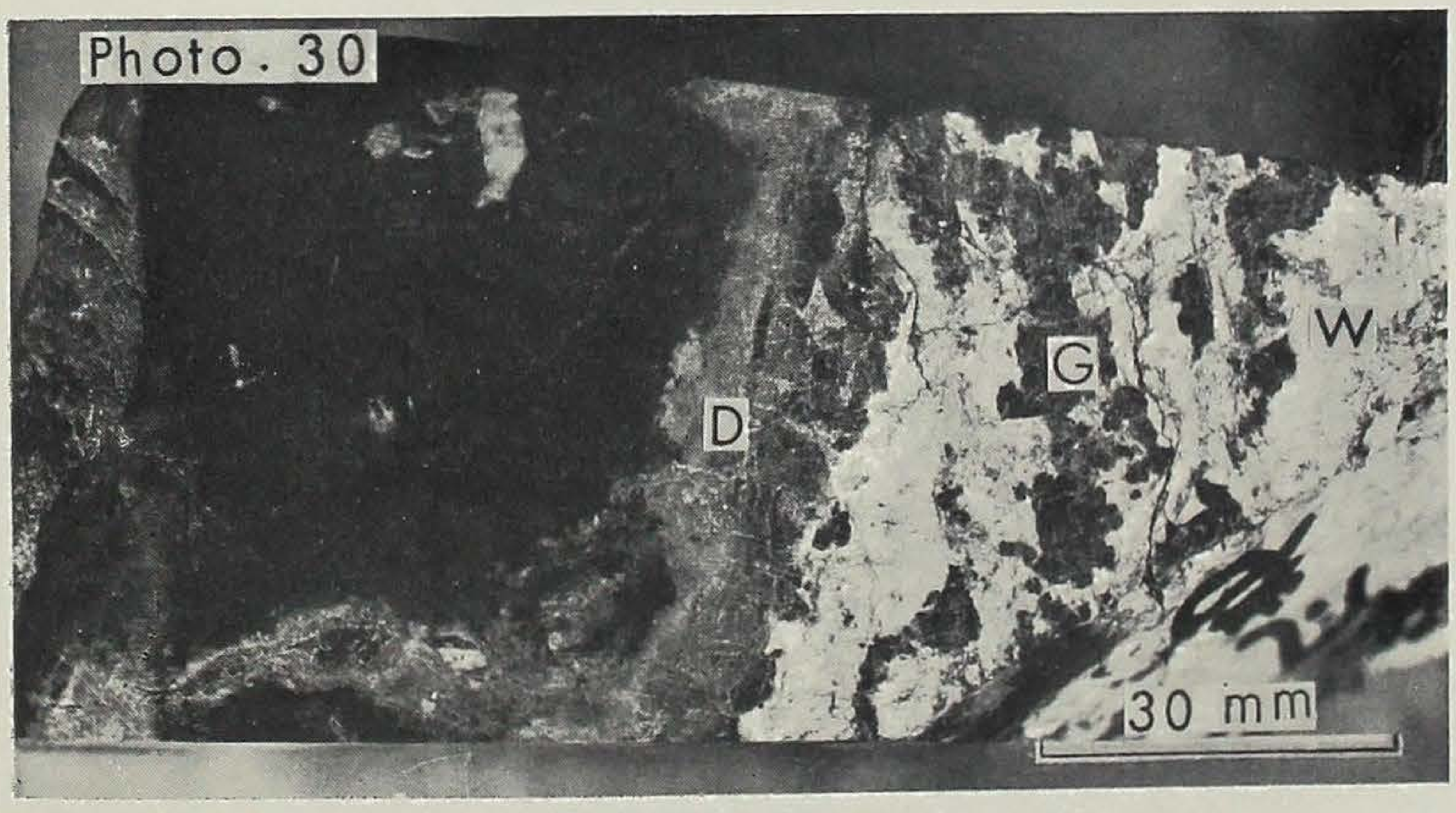

Photo. 31

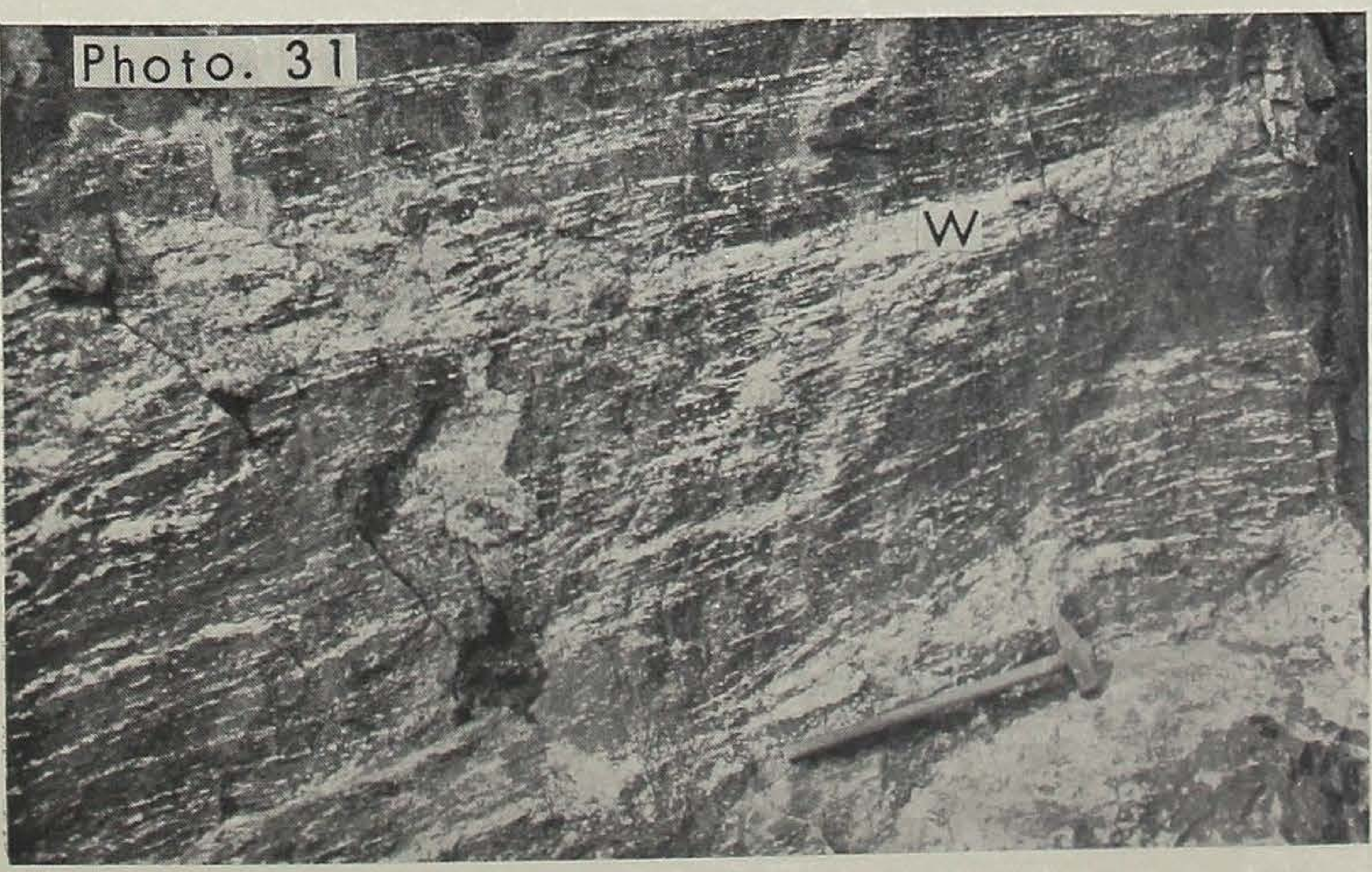

Plate VIII

Explanation of Plate VIII

Photo 32. Wollastonite vein running along the stratified plane of grayish black-colored, crystrlline limestone. Acicular crystals of wollastonite developed nearly along its own vein. W : wollastonite

Photo 33. Veinlet of wollastonite along the contact plane quartzite with limestone.
Q : quartzite, W : wollastonite

Photo 34. Occurrence of quartzite. L : crystalline limestone, Q : quartzite

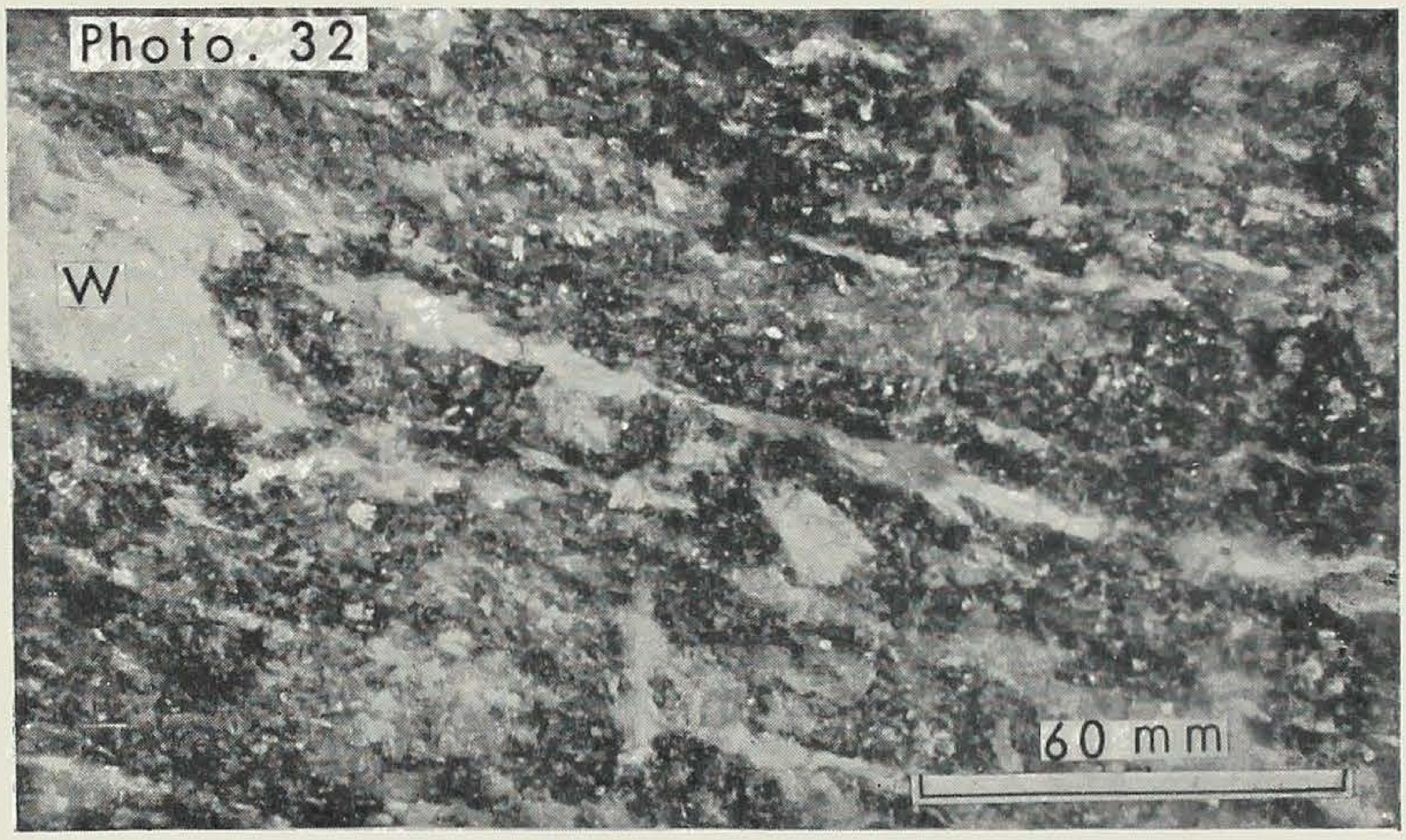
Photo. 32
W
60 mm

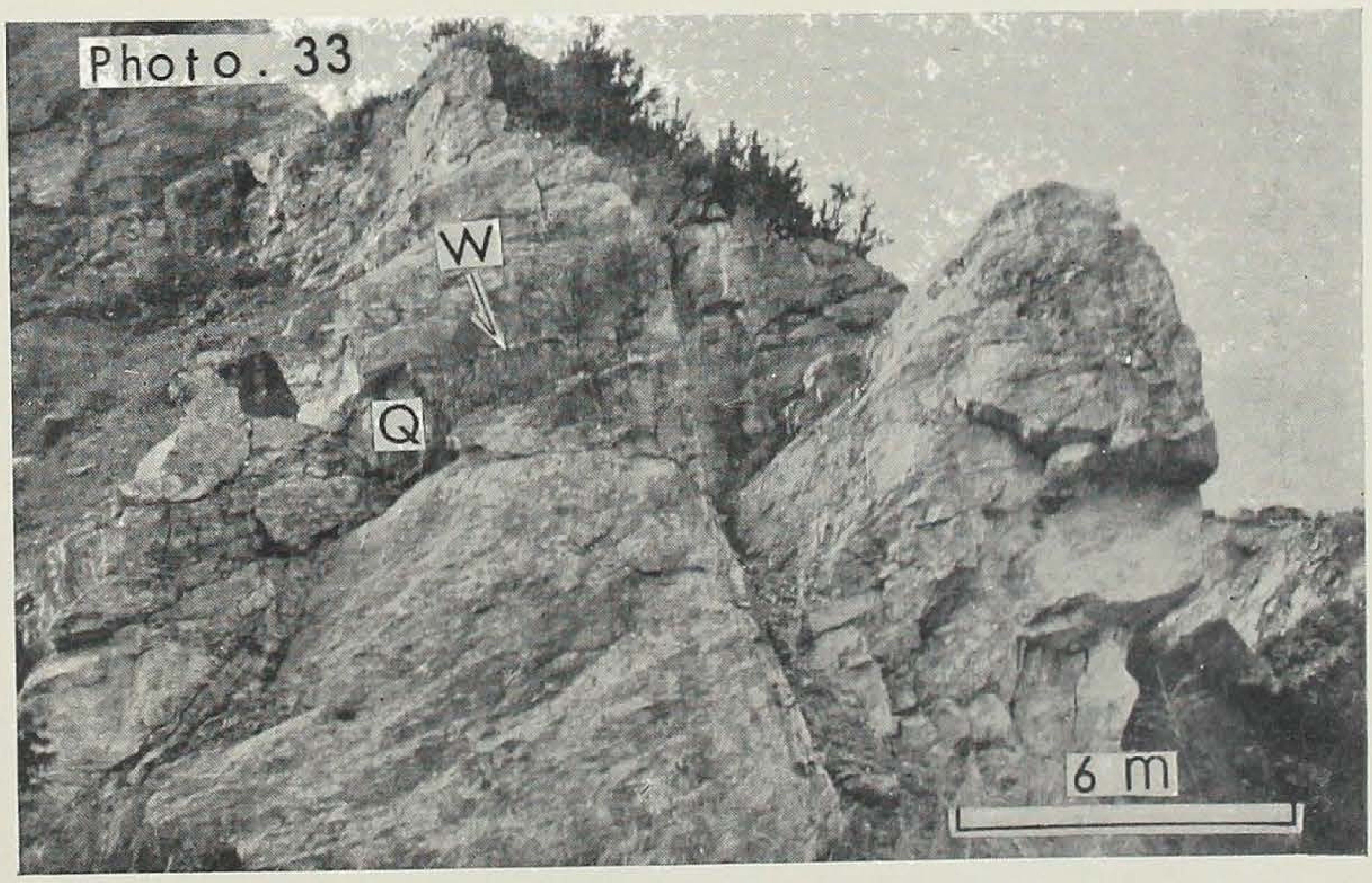
Photo. 33
W
Q
6 m

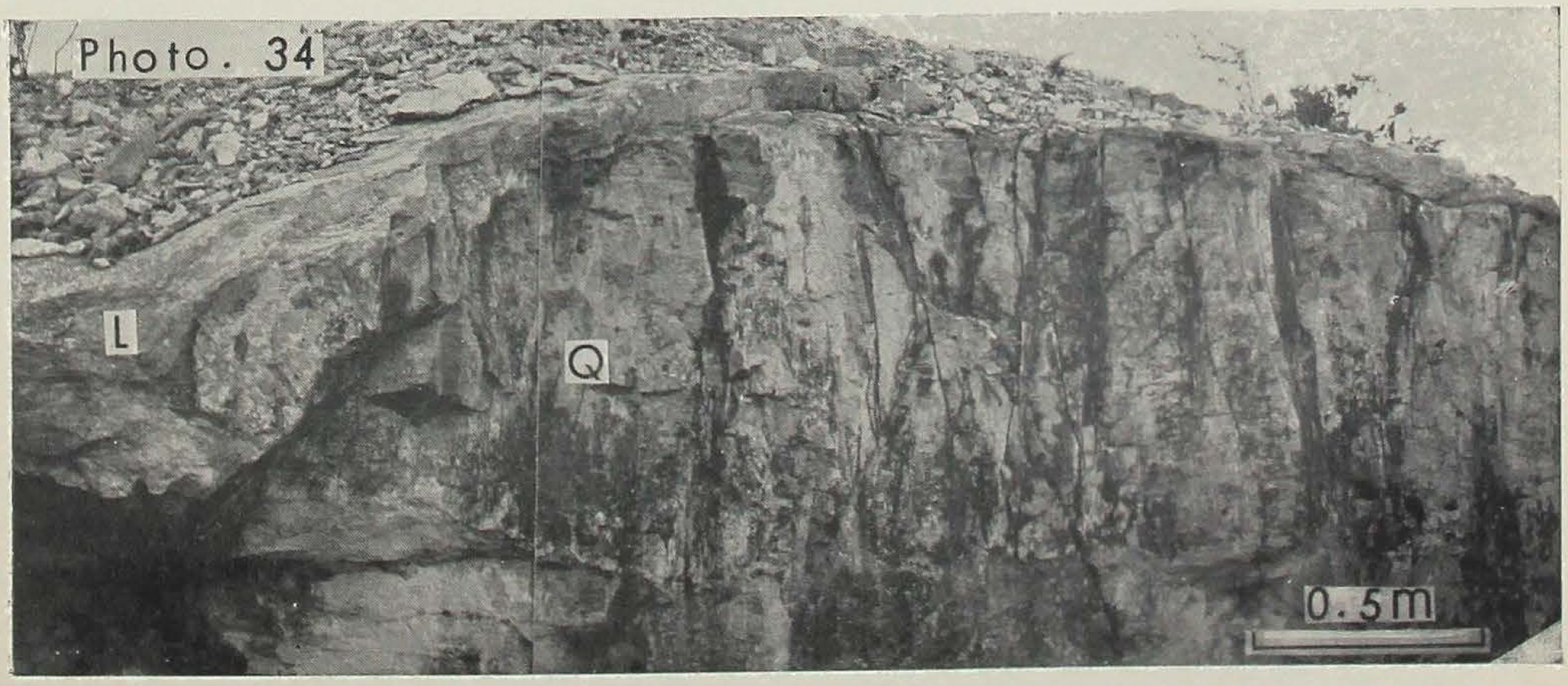
Photo. 34
L
Q
0.5m

Plate IX

Explanation of Plate IX

Photo 35. Quartz vein without wollastonite.
Photo 36. Veinlets of limestone without wollastonite.
Photo 37. Striped limestone. Sl. L : slaty limestone, L : Crystalline limestone
Photo 38. Slaty limestone. Sl. L : slaty limestone, L : Crystalline limestone
Photo 39. Mass of wollastonite traversed by apophyllite veinlets. A : apophyllite

Photo. 35

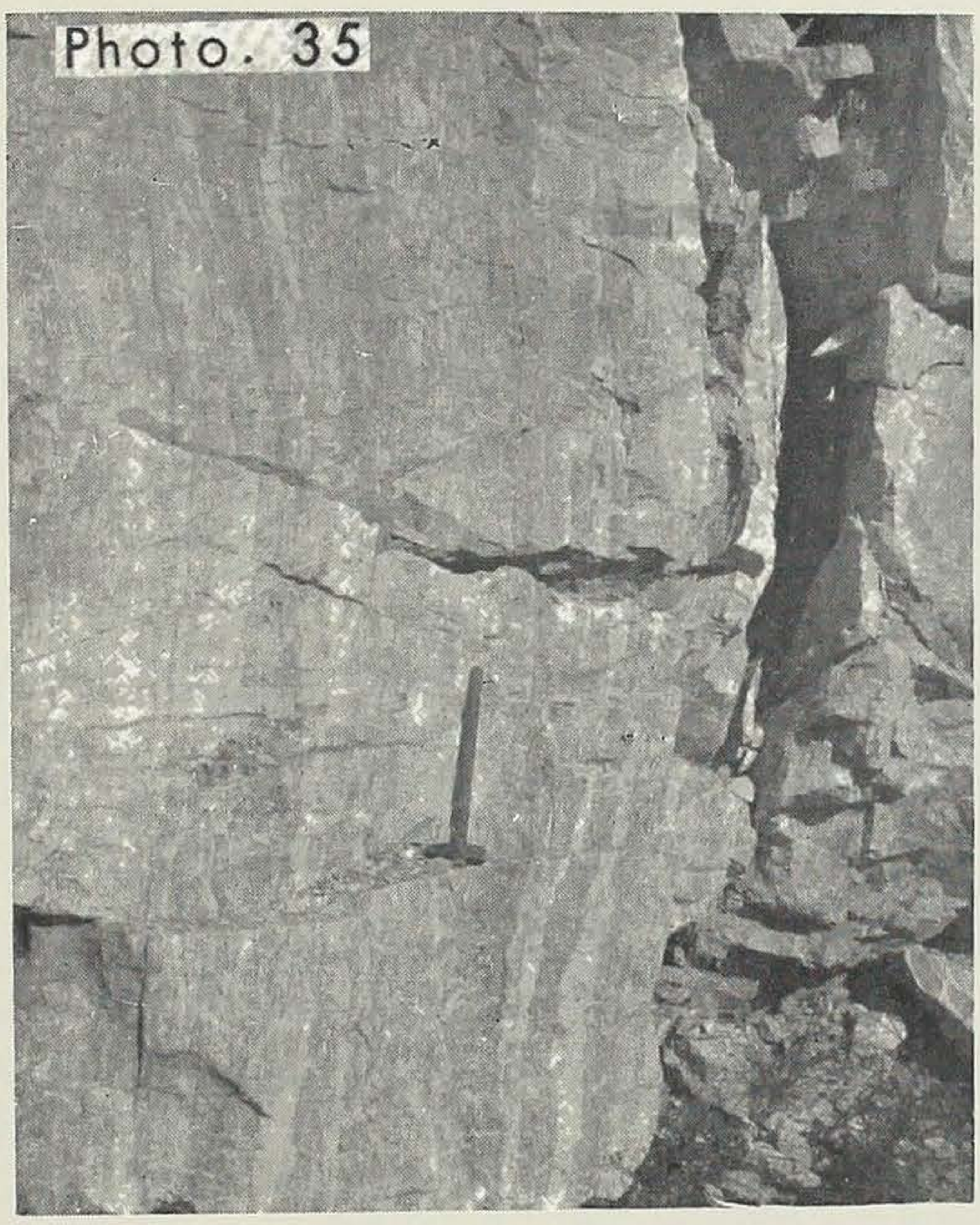

Photo. 36

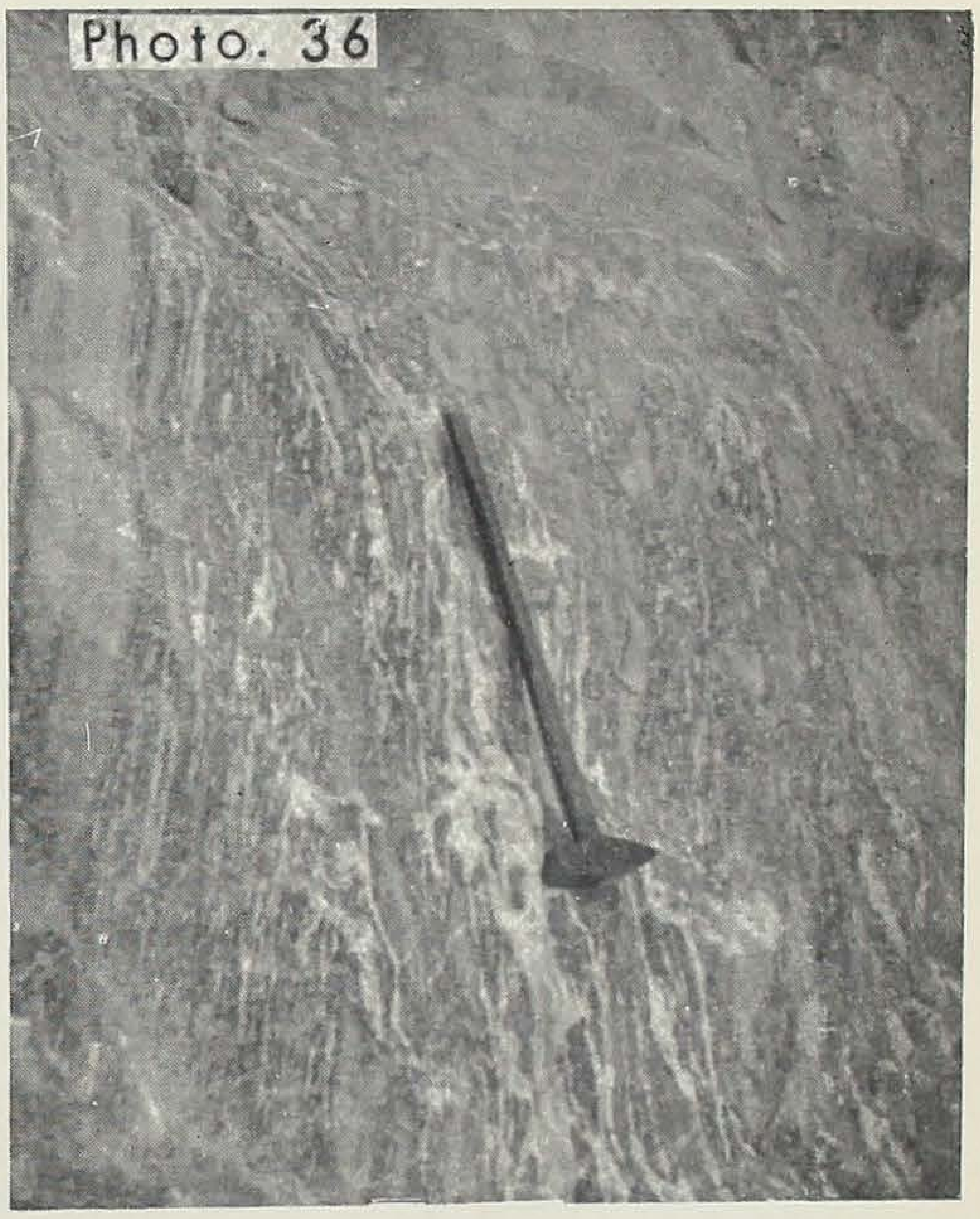

Photo. 37

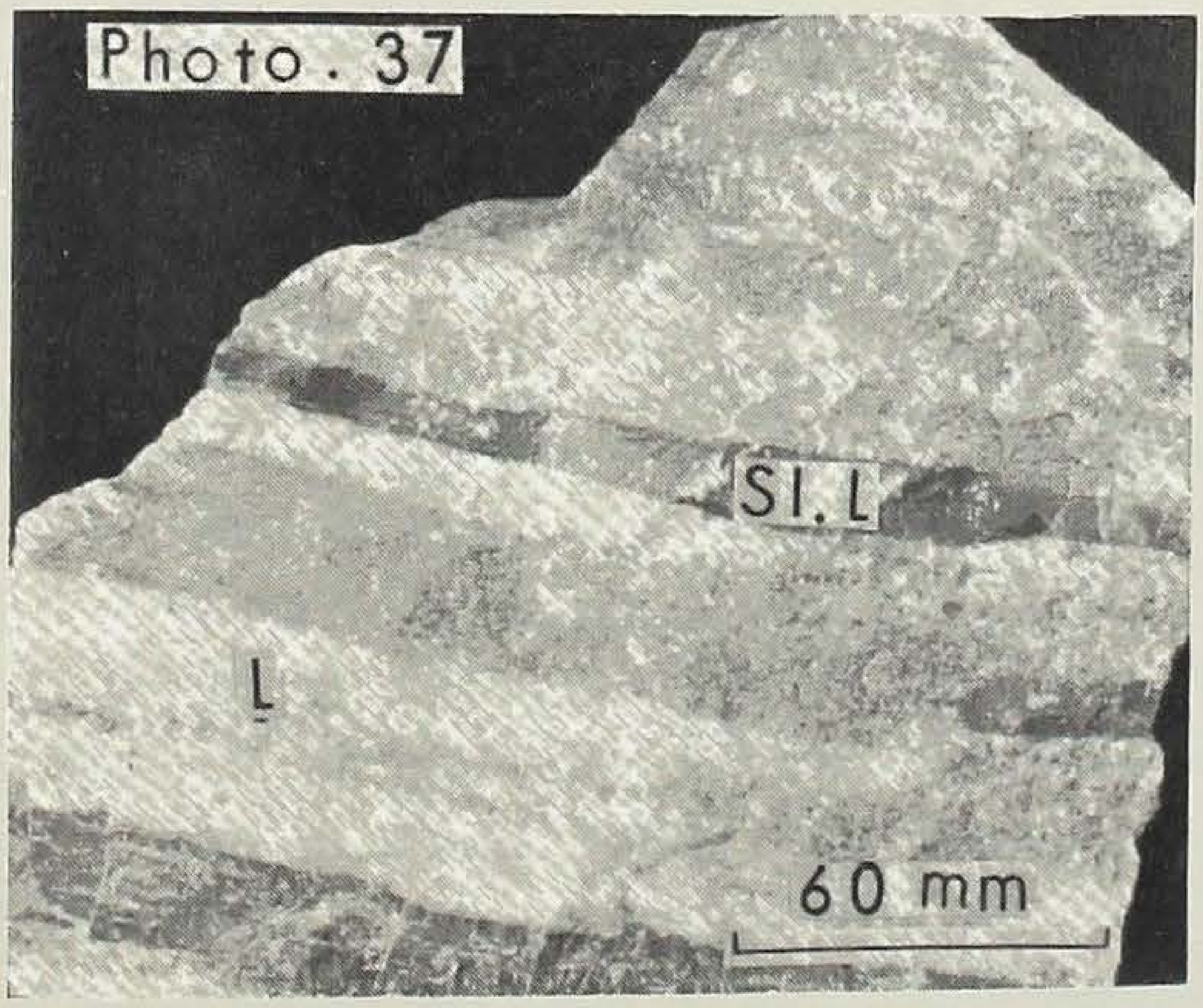

Photo. 38

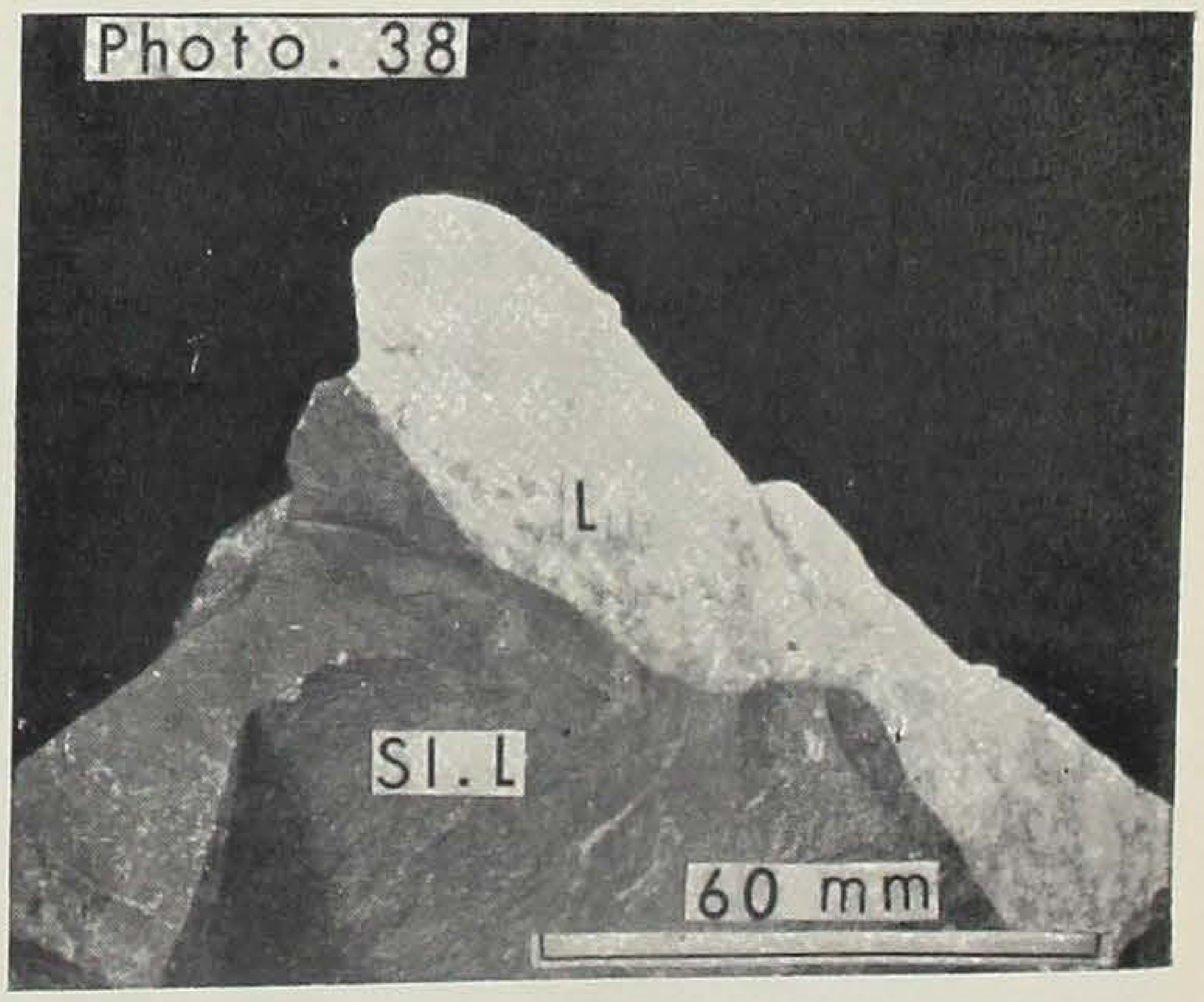

Photo. 39