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A Study of the Micro-Texture of Cherts

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Abstract

Electron microscope study of polished and etched surfaces of chert and silica is presented. Three types of surface morphology of chert are recognized in the chert specimens from the Tamba district. Field evidences of the cherts in the district are discussed in relation to the results of electron microscopic observation. Presence of clay minerals in the chert specimen is suggested.

Introduction

Chert and other siliceous sediments are common in geological columns. Some of these sediments have been clarified on their origins. However the origins of most chert and other siliceous sediments have not yet been interpreted sufficiently. Many theories or hypotheses have been proposed by various authors, and some of them are valid to explain the origins of a few examples, but most of them have remained unexplained.

Why are the origins of these siliceous sediments not known, while other ordinary clastic or argillaceous sediments are almost thoroughly clarified on the elementary mechanisms of their formation? There are some considerable difficulties in the problems of these origins: in the case of the other sediments, present sea-floor offers analogous sediments to these clastic or argillaceous sedimentary rocks, but the siliceous sediments are not abundant on the present sea-floor, and although they are found in a small part, the recent siliceous sediments are not analogous to the siliceous sedimentary rocks on their environments or composing materials and other properties. Moreover the chemical data of silica, especially of its solubility, are not sufficiently obtained because of difficulty in detections of the quantity of soluble silica, and of the slowness of the reactions of silicic acid under the ordinary condition.

Accordingly the investigation of the siliceous rocks and their field evidences, as well as the theoretical or the experimental investigations from the physico-chemical point of view, are important in order to study the origin of cherts.

In the Paleozoic formations distributed in the Tamba district, a large ammount of chert are contained. The chert of this region have been studied by only a few investigators. And the classification of these cherts as well as their origin have not yet been stated.

The writer is going to present, in this paper, general characteristics of the chert of this district and results of electron microscopic observation of its micro-texture as a part of his investigation series of the chert in the Tamba district.

More advanced field investigation and microscopic and electron microscopic observation of chert will be presented in another paper.

Cherts in the Tamba District

In the Tamba district situated mainly to the northwest of Kyoto, there distributes the upper Paleozoic formation which is estimated to be more than 10000 meters in thickness. It is correlated to the Chichibu Paleozoic System together with the other Upper Paleozoic formations which are distributed in many extensive areas in the Inner Zone of Southwest Japan.

This formation consists of shale, sandstone, chert and schalstein, and contains very little ammount of calcareous member. The strict stratigraphical sequence or succesion of the formation has never been established, however a few reliable stratigraphical sequences have been proposed. The latest one of them is made by S. Sakaguchi on the areas around Sasayama Town.

According to S.SAKAGUCHI (1960), the upper Paleozoic formation of this region is divided into three subgroups: the Upper, the Middle and Lower sugbroups in descending order. An extraordinary thick bed of chert is contained in the Lower subgroup. The lower and upper boundaries of this chert bed contact possibly conformably with the shale. The lowest part of the Middle subgroup consists of remarkably thick and continuous bed of schalstein and an intermitent but partially thick bed of chert is traceable immediately above this schalstein bed.

The Upper subgroup contains almost none of chert, even the smalllest lenses of it. But in the Middle and Lower subgroups, numerous small lenticular cherts are contained. Especially in the Lower subgroup, a great number of chert lenses which are a few to less than a hundred meters thick and some hundred meters in elongation are found as intercalations in massive shale.

It is a well known fact that numerous manganese ore deposits are scattered in the Tamba district, and they are intimately connected with the chert beds.

The writer with his collaborator should like to propose some presumed horizons in which most manganese deposits are distributed and consequently the chert beds of peculiar type with which manganese deposits are associated, are distributed in the same horizons. These horizons, however, are not so distinct as to be available for keys of the stratigraphy.

This characteristic distribution of manganese ore deposits in the district must be taken into the interpretation of the origin of chert.

The cherts in this region can be preliminarily classified by the features observed with the unaided eyes as follows:-

A) Bedded chert

(1) Mn-type chert: thickness of a single layer is 2-10 cm. Veining feature is regular. Colors are bluish, dark greenish gray, red or purplish red. The chert of this type composes a small lens, exclusively associated with manganese ore deposit.

(2) Intermediate type: thickness of the layer is more than 10 cm. Colors are translucent gray or dark. This type is intermediate between bedded chert and massive chert.

B) Massive chert

(1) Large rock body type: the distinct bedding plane is absent or partially barely visible, but when it is recognized, the shape of bedding plane is disturbed and transformed. Colors are light gray, bluish gray, cholcolate brown, greenish gray or white.

(2) Massive type proper: only a few veins develop in this type, but brecciated features are observed in some specimens. Color varies from brownish to greenish gray.

C) Transitional type

(1) Transitional type to schalstein: beddings are observed in some outcrops. Colors usually vary from dark red to reddish brown. Veins are scarcely recognized. However a specimen obtained from a silex producing area is cut with many networks of veins. This type of chert, tentatively named silex-type is considered to have a different origin from that of the other types of chert, namely it is a chert-like rock, but not chert.

(2) Transitional type to shale: this is a well-bedded variety, and resembles closely the Mn-type in field appearances. And its occurrence is also closely associated with the Mn-type chert. Some of this type contains regularly shaped systems of veins, but most of this type are cut with few veins. This type may have a continuous transition to and from the Mn-type within the same horizon even within a single bed, but the evidence of the fact is lacking.

Electron Microscope Study

A) Preparation of rock specimens

Rock specimens of various cherts were cut with the diamond saw into pieces of a few centimeters square. The selected surface of the piece was polished on an even glass plate, using the polishing powder of about 3000 mesh grain size.

After the surface was sufficiently smoothed, the specimen was fully cleaned in water and finally in distilled water especially on the polished side. The specimen was left to be dried, and then it is ready to make replica. Some freshly fractured unpolished specimens are prepared to confirm the fidelity of reappearance of the polished surface.

Etched surface of some specimens are also prepared for the replica. The polished surface was soaked for about 5 seconds in fluoric acid diluted with water of two times volume as the acid. After the etching treatment, the specimen was washed thoroughly with distilled water and treated just as the non-etched one.

B) Replica method

Because of the low penetrating power of the electron beam, it is impossible to study chert specimens directly, and a very thin replica or mold of the actual surface must be made with a plastic film, which was, in this study, made of the methylmethacrylate polymer. One or two drops of the polymer dissolved in suitable volume of acetone, is placed on the polished surface of vertically held specimen, and allowed to spread over it. And the specimen is immediately placed in a desiccator in order to dry the plastic film in water-free air. For the purpose of removing any dust or adherent material on the surface, some blanc-replicas are taken. In the case of the present study, the filmy replica method was employed for the purpose and was effective in saving time for the treatment of rock specimens.

After the film was dried, the specimen is immersed in distilled water to make it easy to tear off the film from the surface of the specimen. The film is carefully peeled from the surface of the specimen and the inner side of the plastic film is then a negative replica of the surface of the chert.

Molding replica method was also applied to some specimens. A sheet of plastic film which was previously made of methyl-methaerylate polymer and cut into a suitable size, is pressed tightly against the surface and heated up at about 130°C for a few minutes. After the cooling in the air, the film is taken off and the pressed film, which is a negative replica too, is ready to the next treatment, the shadowing.

The replica is shadowed with vaporized chromium under high vacuum and then coated with vaporized carbon under vacuum (two-step replica method). The coated plastic film is cut with a sharp-edged tool such as razor blade into 3 mm square size. And the square cut film is immersed in the soluvent prepared with benzene and chloroform mixed half and half. After the plastic film was thoroughly dissolved, the chromium-shadowed carbon replica is scooped with a seat mesh screen and then it is ready to the electron microscopic observation.

1000 to 10000 magnifications were used.

C) Descriptions of electron micrographs of some cherts and silica

R.L. FOLK and C.E. WEAVER (1952) proposed three types of surface morphology of chert through the electron microscopic observation.

They are two distinct end-points and a transitional type between them. One of the end-points is called the "novaculite" type surface. It is characterized by sharply defined, equant polyhedral blocks with slightly curved surface, all blocks being of about the same size. The novaculite type surface occurs with varying degrees of distinctness. and shows a complete transition to the "intermediate" type. A few blocks contain small swarms of beautifully defined spherical cavities, which are almost uniformly 0.1 micron in diameter.

The other end-point, "spongy" type surface, is found exclusively in specimens that are classed petrographically as chalcedonic quartz. The appearance is somewhat like a piece of "Swiss cheese" or a sponge. The surface of the chert contains no descrete grains, but permeated with tremendous numbers of small hemispherical holes, many of which coalesce to form vague tubules, which tend to be parallel to each other and perpendicular to the orientation of the fibers as seen under the light microscope.

The "intermediate" type of surface apparently represent a transitional stage between the novaculite and spongy types. It consists of highly irregular, somewhat indistinct areas of low relief without many cavities. It sometimes contains patches showing the novaculite type surface.

The writer describes his electron microscopic observation of some chert specimen, based on the thesis of surface morphology presented by R.L. FOLK and C.E. WEAVER, which is shortly summarized above.

The descriptions are made with special reference to the following properties: which type of the surface morphology each specimen belongs to, where the judgement is given collectively from various points, and whether the spherical cavities are present or not.

The following descriptions are of some examples extracted from more than three hundred micrographs of about forty samples of chert and silica.

(The abbreviations: (p) stands for polished surface, (e) for etched surface.)

1. (p). 610730-3. Bedded chert occuring in the lenticular masses intercalating a thick schalstein bed. Reddish in color, especially shaly partings are deeply red.

Characteristic novaculite type surface with well-defined block outlines. Grain size of the blocks ranges from 0.5 to 1 micron in the finer grained part and from 3 to 6 microns in the coaser. Few or no bubbles are observed on the surface, no spongy type surface is contained. (See Pl. 6, Fig. 1)

2. (p). 601103-2. Hornfelsic chert of probable intermediate type. Brownish gray in color, and it is cut by many veins.

Novaculite type surface with well developed crystal grains. The grain size is remarkably large, in the finer grained part it is 4 to 8 microns, and the crystal outlines are sharply defined and the along the margins of blocks, a few pillar shaped crystals, which may be clay minerals, are observed. The unusually large size of the crystals may have been originated by the heat of contact with the granite which occurs near the point of the sampling locality of this specimen. Some etched figure-like spots which are convex on the actual surface of the specimen, are found. Since the specimen did not undergo etching treatment, the spots seem to have developed from the cavities in some stage of treatment, possibly by immersion in water. (Pl. 6. Fig. 2)

3. (p.) 610618-5. Chert of Mn-type, red colored and slightly leached. Veins are distributed in the middle part of the bed.

Surface of novaculite type proper. Crystal outlines are very sharp and have the grain size of 3 to 5 microns in the coarser part, and in the finer part it is 1 to 3 microns. Spongy type surface is hardly observed, but spherical bubbles are in places noticeable, etched figure-like spots are also noticed. (Pl. 7, Fig. 1)

4. (p). 610731-7. Chert of transitional type to shale or siliceous shale, which is well-bedded just like the Mn-type chert. Dark gray to black in color. An appreciable ammount of pyrite grain is observed to be enclosed.

Rather poorly developed novaculite type surface, which is named, in this study, "semi-novaculite" type surface. But outlines of the blocks are not so distinct as to enable the estimation of the grain size. Conchoidal frauctures are clearly seen on the surface with some bubbles. Spongy type surface is observable in places. The whole surface has poorly developed relief, the fact can be partly ascribed to the comparatively low hardness of the rock specimen, which was more thoroughly smoothed by polishing than the other chert specimens. (Pl. 7, Fig. 2)

5. (unpolished). 620326-No.5. This sample was not collected from usual outcrop but in the Tamaiwa manganese Mine, near the ore bed. Bedded chert or cherty rock of gray color. Many veins filled partially with manganese compounds are observed.

Novaculite type surface with well-defined crystal outlines. Grain size of the blocks is medium, bubbles are abundantly scattered on the crystal surfaces. Spherical cavities of larger scale and etched pits of the same dimension are observed. A small amount of spongy surface is present among the blocks of larger relief, which is naturally developed much better than that of the polished surface. (Pl. 8, Fig. 1)

6. (p). 610618. Chert of intermediate type, and cut by veins. Chocolate brown. in color.

Typical spongy surface with no distinct crystal outlines. Bubbles are extraordinarily abundant, and the surface has low relief. (Pl. 8, Fig. 2)

7. (p). Agate. White in color.

Spongy type surface with numerous cavities or bubbles. Crystal outlines are never appreciable. (Pl. 9, Fig. 1)

8. (e). 620326-No. 5. The same sample as the 5. the surface is etched.

Novaculite type surface with clear crystal outlines, which are more sharply defined than that of non-etched one. Grain size of the blocks is of course equal to that of non-etched, but the shapes of each grains have become more sharply edged. Etched pits are developed all over the surface of the crystals, and the shape of the etched pit shows property of the crystallographic face of quartz, on which the etched pits of peculiar shape develop. Accordingly the approximate orientation of the quartz grain, which may be equivalent to each block on the surface, can be determined by etching treatment.

Spongy type surface which is recognized partially on the non-etched surface, survives through the etching process. Clay minerals or pillar shaped minerals of that kind, which are assumed to be developing along the margins of quartz crystal grains or blocks are more easily attacked by fluoric acid than quartz grain around, consequently the etched surface has higher relief than the non-etched and along the margins of the grain, fissures of the replica film are ready to develop, where carbon coating thinly covered the plastic film because of high relief. The fact that pseudo-replicas are more abundantly found on the replica of the etched surface, can also interpreted as an evidence for the presence of the clay or such-like minerals along the margins of quartz crystals. (Pl. 9, Fig. 2 and Pl. 10, Fig. 1)

9. (e). 610802-5. Etched surface of the sample 3.

Novaculite type surface. The crystal outlines are more definite than those of non-etched one. Spongy surfaced-part still survive though the surface feature is slightly altered. Etching has given different modification on the surface of the specimen from the sample 8, which has been etched in the same way. Few etched pits and some what blunt edges of the blocks are observed, and these fact seem to be caused by the different degree of etching reaction. There is also such a tendency that fissures of the replica film develop along the margins of the blocks.

10. (e). 601103-2. Etched surface of the sample 2.

Novaculite type surface with clearly defined crystal outlines. No spongy surface is found. A number of regularly arranged etched figures are observed. The fissures along the margins of the blocks and comparatively abundant pseudo-replicas are observed.

11. (p). Opal. Spongy type surface with plenty of cavities. No crystal outlines or blocks are recognized. (Pl. 10, Fig. 2).

12. (unpolished). Agate. Spongy type surface, but in a part, probably it is vein, rather definite crystal grains are observed. The grain size in the "vein" is rather fine (about 0.5 micron) along the contact line with the spongy part, and it increases towards the inner part of the vein up to the size as large as approximately 5 microns, therefore the contact line can be regarded as the wall of the vein. Bubbles or cavities are observed both on the spongy part and the vein. One of the micrographs of this sample shows streaks which were made by the scratching of the diamond saw. (Pl. 11, Fig. 1)

13. (unploished). Quartz. Tabular section, approximately normal to c-axis.

The surface is almost wholly covered with conchoidal fractures. But in a limited part of the surface, spongy type-like feature is noticed, which is apparently somewhat porous by the presence of bubble-like cavities. (Pl. 12, Fig. 1)

14. (e). Agate. Etched surface shows a peculiar pattern which resembles a sort

of mesh or network. Accordingly this hydrous variety of silica is more easily attacked by fluoric acid than anhydrous member of silica, that is, quartz. Spongy part and bubbles are still observed. (Pl. 12, Fig. 2)

15. (e). Opal. Etched surface of beautiful network, the pattern is more regular and finer than that of agate. The size of the unit mesh is estimated to be in the neighborhood of 0.2 to 0.3 micron. Some bubbles or cavities are observed. Numerous pseudoreplicas are found. Opal is possibly the variety of silica that is most easily attacked by fluoric acid among these three varieties of silica such as quartz, chalcedony and opal itself. (Pl. 12, Fig. 3)

D) Discussions

Microcrystalline quartz

A majority of the observed specimen contain sharply defined, polyhedral blocks. The blocks range, in diameter, from 0.5 to more than 5 microns. Through their demensions of diameter and shapes of outlines, these blocks may correspond to that novaculite type surface termed by Folk and Weaver. The individual block shows partially sexangle-like outlines, which can be said possible crystal outlines, however the decisive evidence is lacking but for the etched figure on the surface of the block. Unless each grain of the block correspond with a crystal grain of quartz, the block must be a part of quartz grain, because under the light microscope thin section of chert always consists of numerous microcrystalline quartz, and other components such as chalcedonic quartz, chloritic minerals and carbonates are very small in quantity. Moreover the grain size of quartz crystal measured under the microscope roughly coincides with that of electron micrograph.

Chalcedonic quartz

According to Folk and Weaver, chalcedonic quartz appears to be composed of radiating or sheaf-like bundles of fibers under the light microscope, and each fiber not more than a few microns in diameter and attaining 200 microns or more in length. But under the electron microscope, no fibrous structure is dtectable. And abundance of spherical cavities causes the surface of chalcedonic quartz to have spongy look with no descrete grains. Some specimens of chert show spongy type surface, and the samples of chalcedony and opal show their surface almost entirely covered with spongy type surface.

Bubbles or cavities

In transmitted light chalcedonic quartz often appears to contain brownish zones. Under 1000 times magnification, the brownish area are found to be made up of a swarm of very minute dots (Folk and Weaver). The features of these dots are similar to the water-filled cavities in the quartz of igneous rocks. On the basis of this similarity, the brownish dots are also interpreted as water-filled cavities by Folk and Weaver. They believed that the cavities are filled with water and not gas because of its moderate relief, and chemical analyses of chalcedony show a content of water, which must be present as free water.

Some replicas of the specimen show a plenty of bubble-like spheres on the surface. By the shadowing treatment of the plastic film, the spheres are prooved to be concave cavities on the actual surface of the rock specimen. These cavities can be interpreted as identical with water-filled cavities.

Etched figure

Through the replica method, many patterns of peculiar shape are observed on the surface of the etched specimen, which turned out through the shadowing to be concave on the surface of the specimen. From their peculiar shape and mode of arrangement, they are considered as etched pit which have been caused by the treatment of fluoric acid. And the fact that the shapes of the pits resembles closely to that of etched figure on the surface of ordinary quartz crystal and the arrangement of the pits are also just like that of etched figure, can be regarded as the evidence for the pits to be minute etched figures on the surface of microcrystalline quartz. The shape of these pits are found to be uniform within a single plane of a block such as triangular or sexangular. So, by the shape of the etched pit crystallographical property of the plane can possibly be determined. Provided that the etched pit can be produced on the surface of most crystal grains, the orientation of each crystal can be detectable.

Clay minerals

Along the margins of blocks, a few pillar-shaped crystals of unknown mineral are occasionally observed in some chert specimen. The fibrous or linear structure of the surface may be a proof of crystalline states. This columnar mineral is also observable under the light microscope and it has strong dispersion, but it is too small to be identified. The length of this unknown mineral measured under the light microscope roughly corresponds to the demension of that measured under the electron microscope. Presence of the clay minerals in the chert is expected from the result of X-ray defraction independently of this fact. Therefore this analogical inference may have some validity in spite of the poor evidence. According to the writer's preliminary study, the clay minerals in the chert may be chlorite or sericite and in hornfelsic chert presence of muscovite is assumed.

Surface morphology of chert

In various samples selected from many rock specimens of chert, all of the surface types of chert which were presented by Folk and Weaver have been observed in this study. However one of the purpose of this study, that is to clarify the mutual relations between the surface morphology and the megascopic property, has not been accomplished successfully. Only a general tendency of the mutual relation is induced from the results of the electron microscopic observation.

Novaculite type surface is commonly found in the samples of Mn-type chert. Spongy type surface is found in a few samples: some cherts and agates, but in a small part of replica this type of surface is rather frequently observed. Intermediate surface between the two end-points, is appreciable in some cherts.

Moreover an additional type of the surface is found to be proposed. But this type may not be essential to the surface of chert. It is "semi-novaculite" type. This type may be essentially equal to intermediate type. The difference of replica technique might have caused the divergency of appearance. In the transitional type of chert, a peculiar type of surface is observed. This type of surface is proposed to be named preliminarily as "transitional" or "non-cherty" type, which is characterized by rather poor ammount of quartz grain. The type is consequently not an essential type as is shown by the name.

The interpretation that chert originates from the amorphous silica on the sea floor which has primarily precipitated as colloidal or hydrated state, and then the amorphous silica is gradually crystallized and dehydrated in the process of diagenesis, seems valid to explain the texture of the chert which is presented here.

The degree of crystallization and dehydration of microcrystaline quartz or chalcedonic quartz is higher in the surface of novaculite type and naturally lower in the spongy type surface. And in relation to the types of chert determined by the field observation, the higher degree of crystallization corresponds to the chert of Mn-type and of large rock body type, and the lower degree to that of massive type or intermediate type as well as agates and opals.

Summary

The foregoing descriptions and discussions are summarized as follows:-

Through the study of field evidences of cherts of the Tamba district, the characteristics of these cherts can be summed up as follows:

1) The ammount of the chert is extremely large compared with that of Paleozoic formations distributed in the other regions. The quantity ammounts up to more than 15 per cents of the whole thickness of this formation.

2) Association of igneous rocks or carbonate rocks with the chert can hardly be found in this district. Association of sandstone are also scarcely found.

3) Numerous small lenses of chert which develop in the Lower subgroup, are frequently associated with manganese ore deposits and seem to form an indistinct manganiferous horizon.

4) A preliminary classification of the cherts of this region is offered based on the megascopic observations. They are of Mn-type, intermediate type, massive type and large rock body type.

An electron microscope study of cherts has been made next to R. Shoji. Ecthing treatment of the surface of chert specimen may have been the first attempt.

Through the electron microscopic observation, three types of surface morphology have been confirmed to exist in the surface of the chert specimens collected in the studied region. And two additional but not essential types of surface are proposed.

Clay minerals are observed along the margins of microcrystalline quartz. But identity of the minerals have not been confirmed under the electron microscope.

Through the discussions of the results of electron microscope investigation, the following factors concerning the origin of chert are pointed out:-

Chert seems to have been precipitated originally as the silica of amorphous and hydrated state on the sea floor and the amorphous silica then has been dehydrated and crystallized as the lithification has proceeded. The crystallization of microcrystalline quartz shows the best development in the cherts of Mn-type and large rock body-type. Degree of this crystallization of quartz in the chert of this district may be generally well developed far more than that of foreign hitherto-reported cherts.

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Explanation of Plate 6

Electron micrographs of chert. Figure 1. Novaculite type surface. 610730-3 (p). ×20000. Figure 2. Novaculite type surface with extremely large diameter of microcrystalline quartz. Some columnar mineral (clay mineral?) is seen. 601103-2 (p). ×6000.

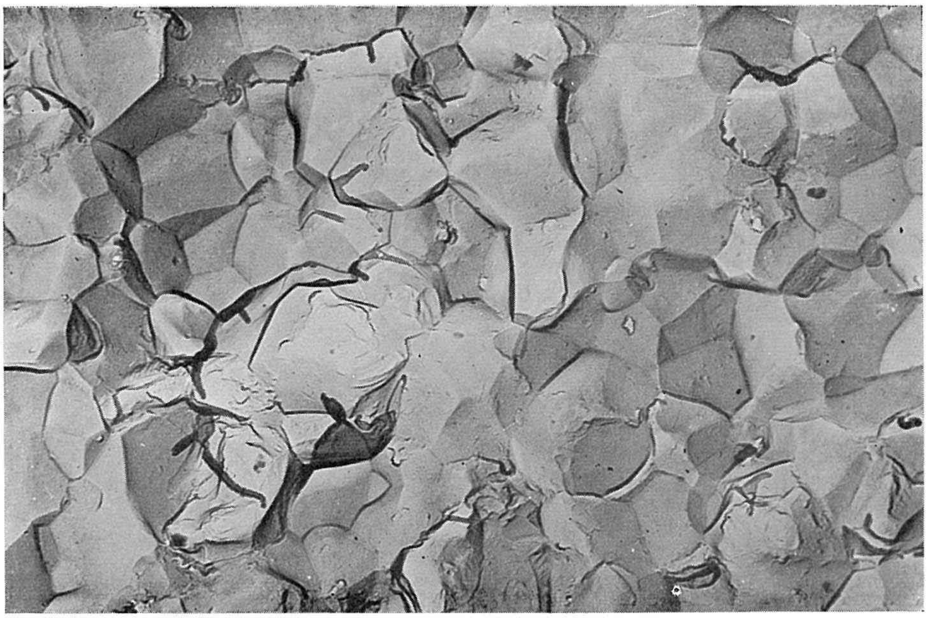

Figure 1

Figure 2

Explanation of Plate 7

Figure 1. Novaculite type surface with etched figure-like pits on some planes of the blocks. 610618-5 (p). ×10000. Figure 2. A part of semi-novaculite type surface. 610731-7 (p). ×20000.

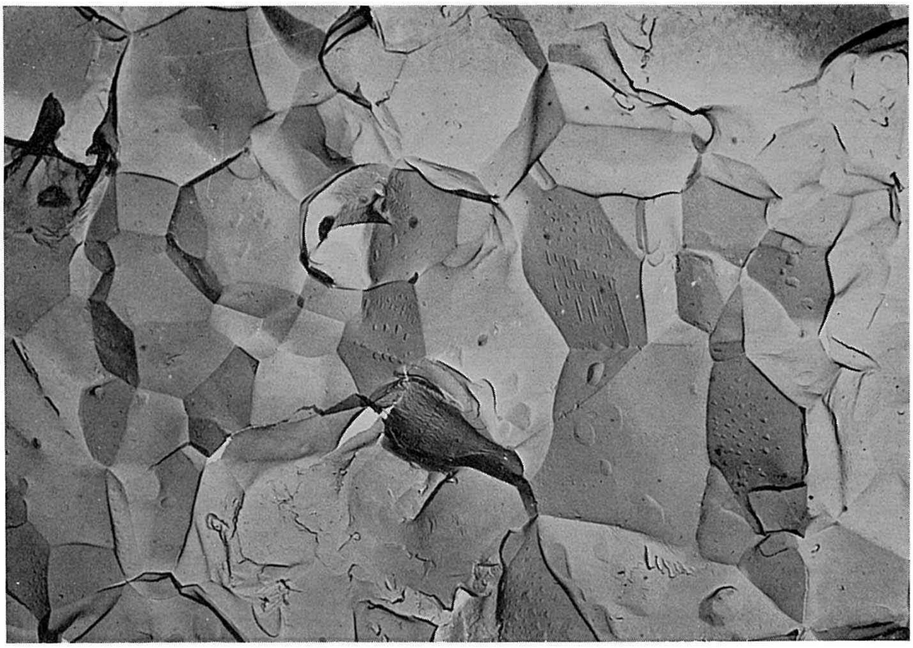

Figure 1

Figure 2

Explanation of Plate 8

Figure 1. Novaculite type surface with some fissures of carbon coating. The relief of the surface may be larger than polished surface. 610326-No. 5. (unpolished) × 20000. Figure 2. Spongy type surface with no distinct crystal outlines. 610618. (p). × 10000.

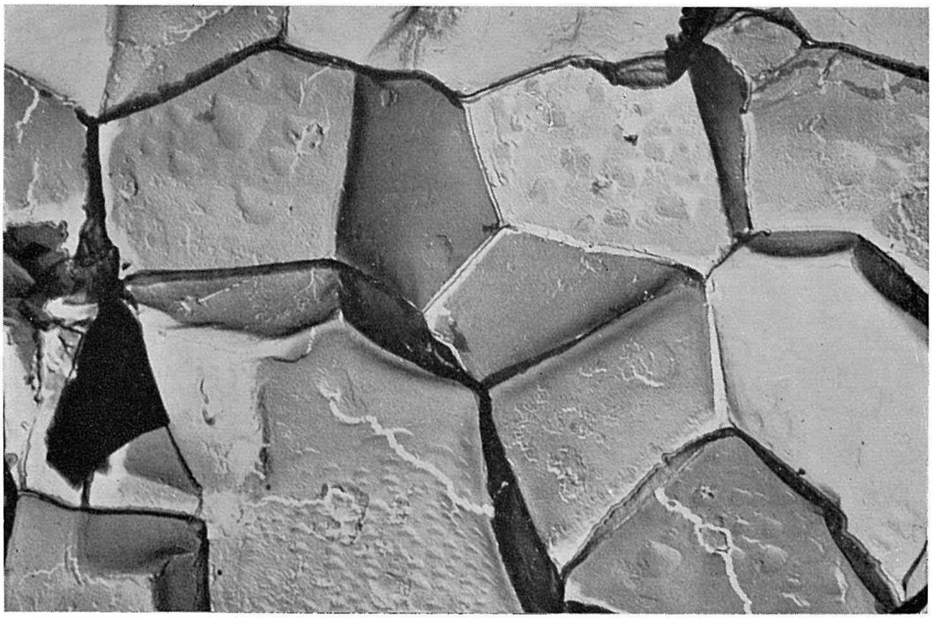

Figure 1

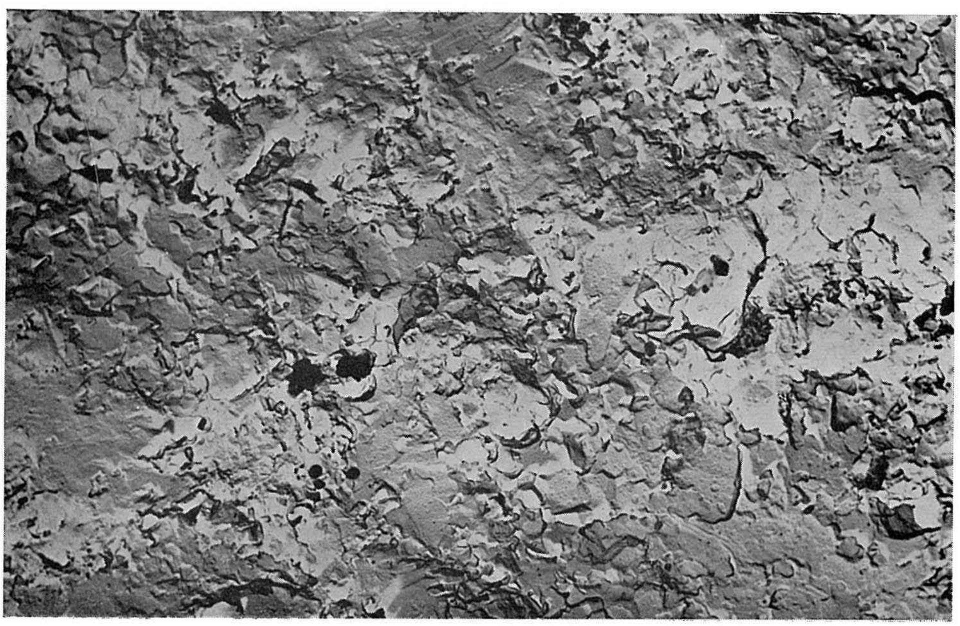

Figure 2

Explanation of Plate 9

Figure 1. Spongy type surface. Agate (p). × 10000. Figure 2. Novaculite type surface with numerous etched pits. 620326-No. 5 (e). × 20000.

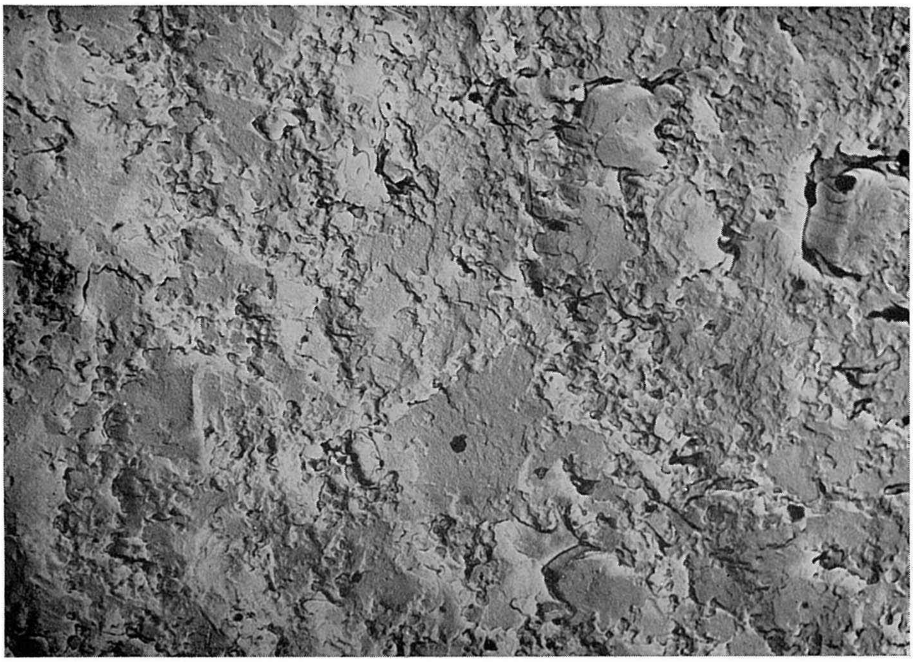

Figure 1

Figure 2

Explanation of Plate 10

Figure 1. Sexangular etched pits. same specimen as Pl. 9 Fig. 2. × 10000. Figure 2. Spongy type surface. Opal (p). × 10000.

Figure 1

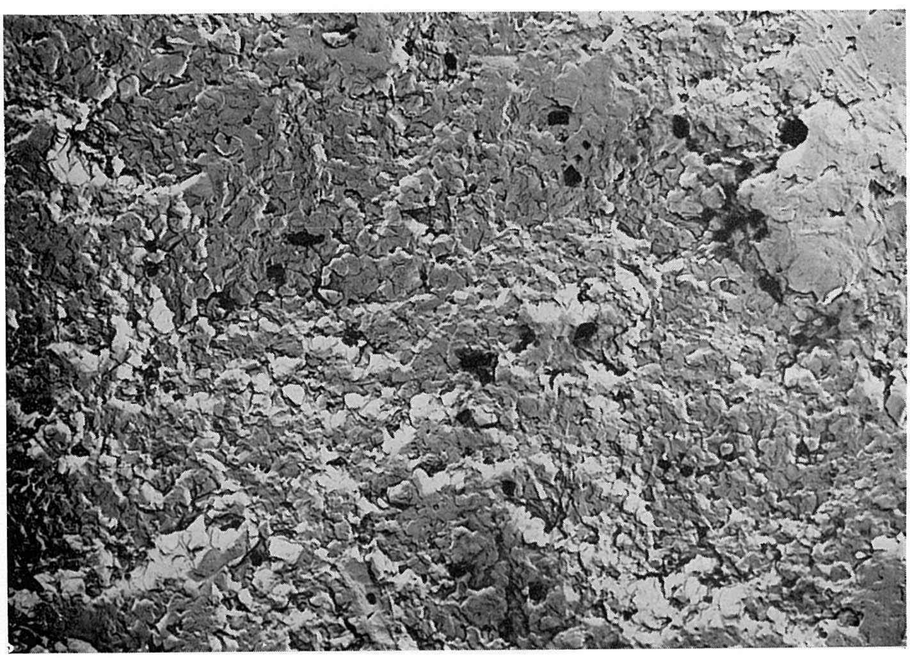

Figure 2

Explanation of Plate 11

Figure 1. Spongy type surface. Agate (unpolished). × 20000. Figure 2. Veiny part, the same as above Fig. 1. × 10000.

Figure 1

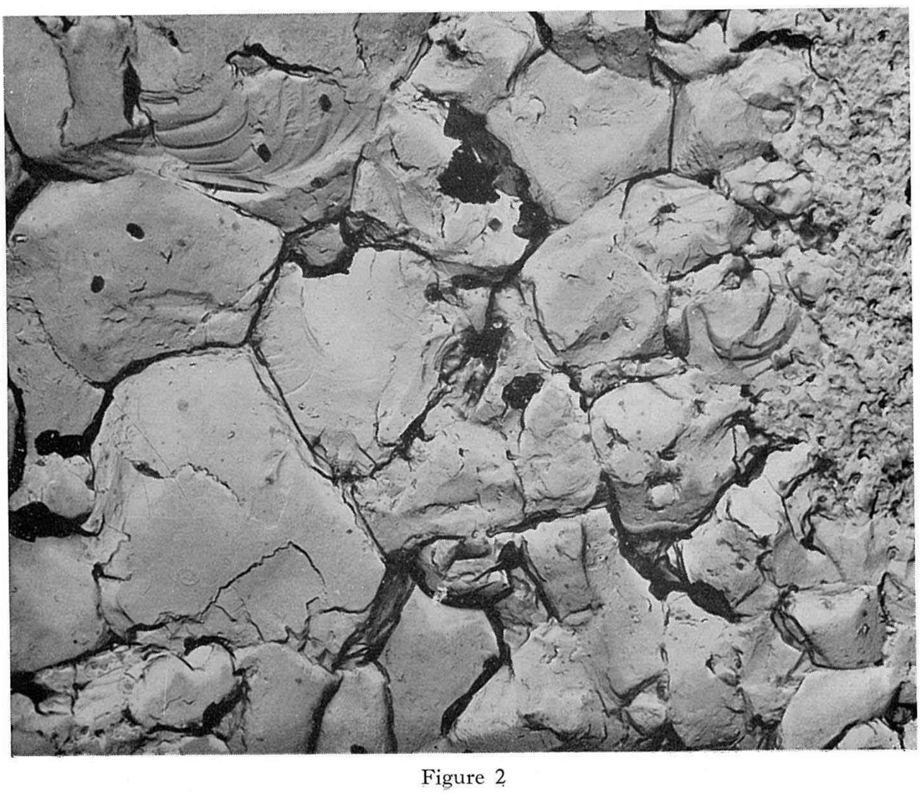

Figure 2

Explanation of Plate 12

Figure 1. Columnar section of quartz. Many conchoidal fratures. Quartz (unpolished). × 10000. Figure 2. Peculiar etched pattern like network. Agate (e). × 10000. Figure 3. Beautiful mesh or network-like pattern finer than the left, Fig. 2. Opal (e). × 10000.

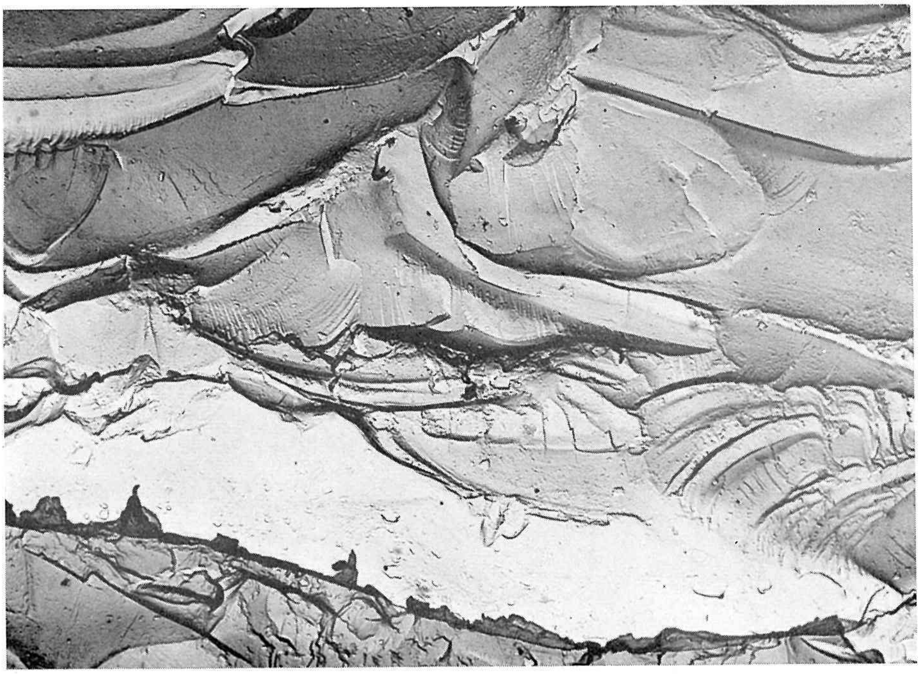

Figure 1

Figure 2

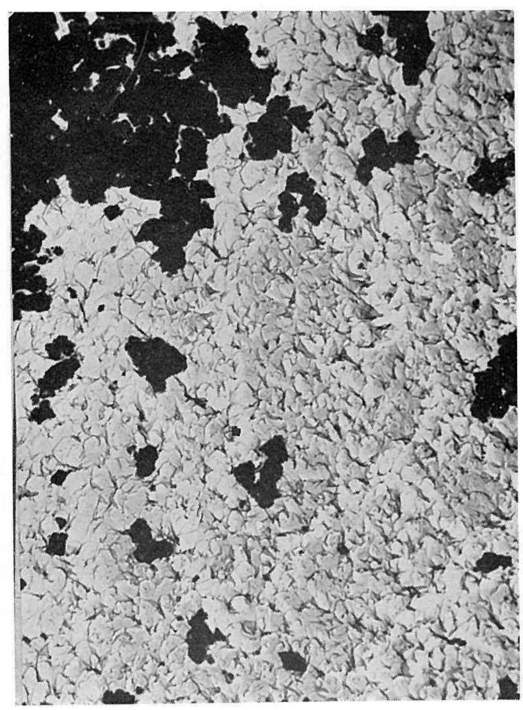

Figure 3