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ELECTRON OPTICAL OBSERVATIONS OF FINE-GRAINED SILICA MINERALS

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ABSTRACT

Chert, flint, and jasper has a predominately granular texture, whereas chalcedony has chiefly a spongy-porous texture. Some samples of chert and chalcedony show both the granular and porous types transitional to one another. The granular texture agrees with petrographic observations, whereas the porous type corresponds in general to the fibrous petrographic texture. Electron optical studies fail to reveal the petrographic fibrosity of chalcedonic silica. Opal has a spongy-porous electron microstructure similar in all respects to that of chalcedony. A purely descriptive textural nomenclature is suggested in place of the existing ambiguous terms.

INTRODUCTION

The purpose of this investigation was to examine the texture of a variety of the fine-grain silicas including opal and to compare the *x*-ray diffraction, petrographic and electron microscopic observations. Special attention was given to chalcedonic silica where a discrepancy exists between the petrographic and electron optical textures.

Fresh fracture surfaces of chert, flint, jasper, chalcedony, agate and opal were studied by electron microscopy using the two-step replication technique of faxfilm-carbon with platinum-carbon shadowing. The shadows appear as regions of a lighter hue in the micrographs. Powders of these samples were also examined by *x*-ray diffraction and by light microscopy with magnifications up to 800×.

Electron optical studies of the fine-grained silicas which are reported in the literature are very limited. The most definitive work is by Weaver and Folk (1952) who reported two general types of electron optical texture, one being granular which is characteristic of chert and the other being a spongy porous texture which is found in chalcedonic silicas. These two textures correspond to the two distinct petrographic textural types, one of which is granular, typical of chert, and the other fibrous, representative of chalcedony. An electron microscopic study of opal was not found in the literature.

X-RAY DIFFRACTION RESULTS

According to *x*-ray diffraction all the flint, chert, chalcedony, and agate specimens were composed of well-crystallized, fine-grained quartz. No noticeable line-broadening was observed which indicates that the average grain-size was greater than about 0.1μ diameter. The specimen of red jasper contained an appreciable amount of hematite in addition to quartz.

The two opal specimens yielded a poor, diffused low-cristobalite x-ray pattern and, in addition, there was some evidence for the presence of low-tridymite.

Microscopic Observations

Flint and Chert. Three different specimens of flint and chert were studied. The polarizing microscope showed an uniform texture of interlocking grains less than about 0.1 mm in diameter. The grains of specimen 1, Dover flint, were fairly clear and free of opaque inclusions or voids whereas the other two specimens showed numerous poorly resolved opaque inclusions or voids in the grains. The electron optical texture was predominately granular.

Specimen 1, black flint nodule from Dover Cliffs, England. The electron micrograph, Fig. 1a, illustrates the granular texture. A wide variation in grain size was present. Some grains that were plucked from the sample's surface onto the replica are pictured in Fig. 1b. Some of these grains display euhedral habits.

Specimen 2, gray flint (chert), collection locality is unknown. The electron microscopic examination revealed a granular texture, very similar to specimen 1.

Specimen 3, grayish-white chert, collection locality is unknown. Figure 1c shows the typical granular texture grading into less commonly occurring spongy-appearing areas. The spongy region is further magnified in Fig. 1d. This spongy region consists of spherical pores about 0.1μ or less in diameter in an otherwise fairly smooth surface. The pores are both randomly distributed and aligned to form short arcs. The shadows cast by the pores attest that they were depressions in the specimen's surface. This porous texture is characteristic of chalcedonic and opalline silica. The opaque inclusions and/or voids which were poorly resolved under the light microscope at 800× may correspond to these pores.

Jasper. With an increasing amount of impurities, especially iron oxide, chert or flint grades into jasper. Three specimens of jasper were studied. Under the polarizing microscope the two brown jasper specimens had a texture of interlocking grains which contained many poorly resolved opaque inclusions and/or voids. The texture of the red jasper could not be ascertained with the polarizing microscope because of the opacity. All these specimens displayed a granular electron optical texture.

Specimen 4, yellow-brown jasper, collection locality is unknown. The granular electron optical structure is presented in Fig. 2a.

Specimen 5, red jasper from Shimersville, Pa. The granular texture of

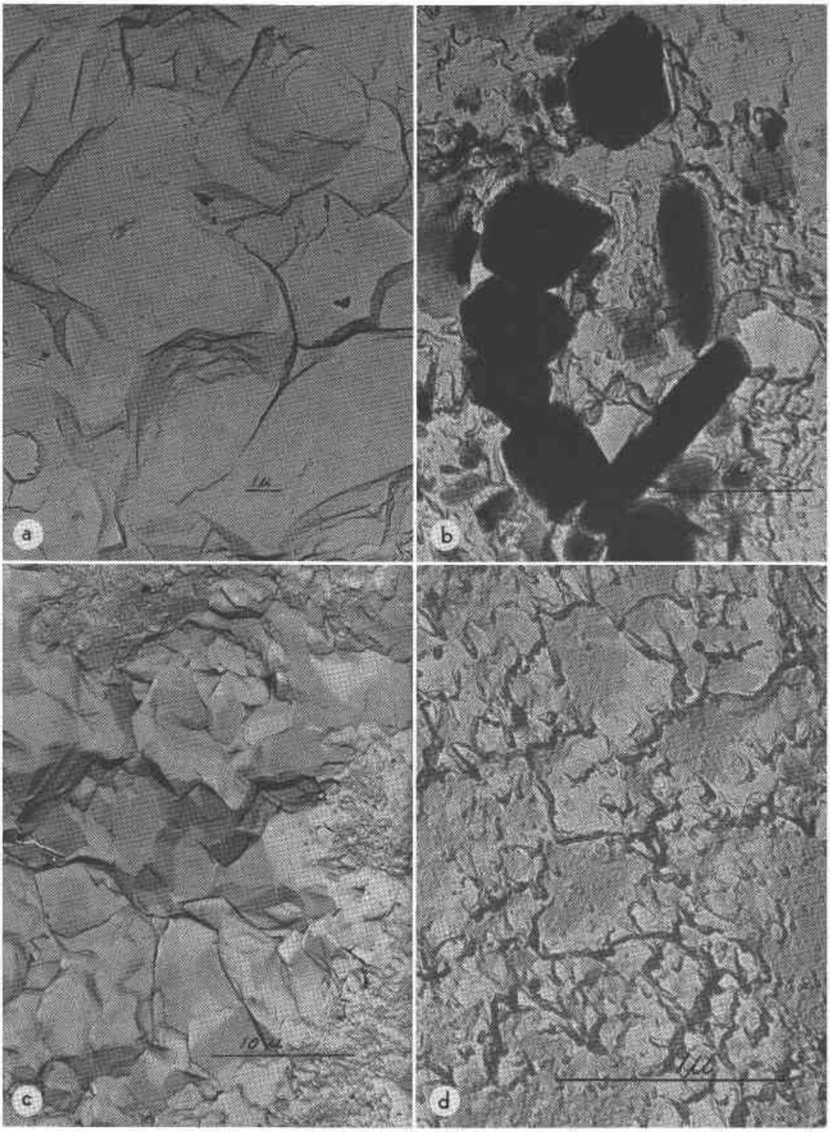

FIG. 1. Electron micrographs of flint and chert.

a. Granular texture of flint specimen 1 (×7200).
b. Plucked grains of flint specimen 1 viewed directly in the microscope (×32,000).
c. Granular texture gradational to porous, spongy-appearing regions. Chert specimen 3 (×3000).
d. Spongy, porous microstructure of chert specimen 3 (×48,000).

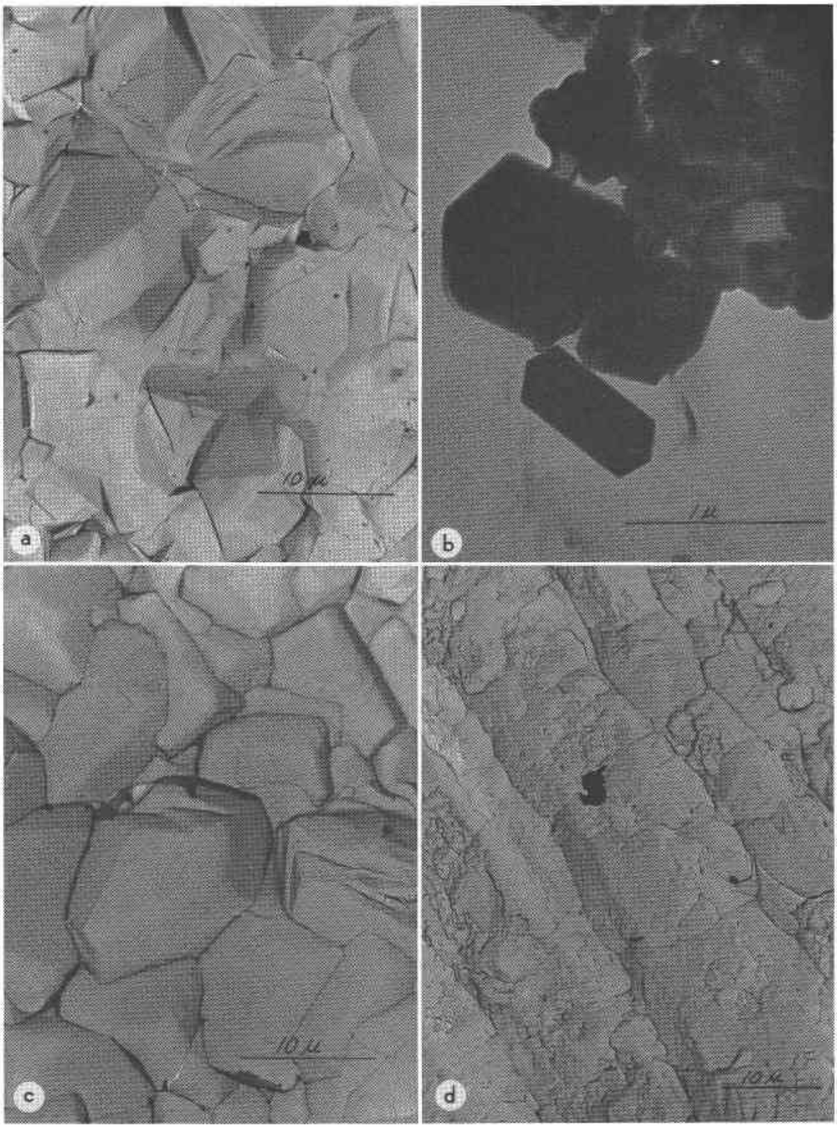

Fig. 2. Electron micrographs of jasper.

a. Granular texture of specimen 4, Yellow-brown jasper (×2800).
b. Plucked grains of specimen 5, red jasper, viewed directly in the microscope (×41,000).
c. Granular texture of the jasper specimen 6, petrified wood (×2800).
d. Jasper specimen 6, petrified wood, showing a lineation (×2100).

this specimen was similar to Specimen 4. Some grains that were plucked from the surface appear in Fig. 2b.

Specimen 6, brown petrified wood from Yuma, Ariz. The electron micrographs, Fig. 2c and 2d, illustrate the granular texture of this specimen. In Fig. 2c the pores can be seen on the grains which may correspond to the speckling seen under the light microscope. In Fig. 2d the lineation of the grains presumably delineates the original wood structure.

Chalcedony and Agate. Specimen 7, petrified wood of white translucent chalcedony, collection locality unknown. The polarizing microscope showed a granular texture with the clear, transparent grains having undulatory extinction. The electron microscopic texture was porous with less commonly occurring granular areas. Figure 3a illustrates this microstructure.

Specimen 8, grayish-white translucent chalcedony, collection locality is unknown. The light microscope showed both granular areas and poorly defined fibrous areas. Some poorly resolved speckling in the grains was seen at about 800×. The electron optical texture was both granular and spongy, similar to Specimen 7. The pores in the spongy areas are often arranged to form arcs which give a scallopy appearing pattern. The spongy region is shown under high magnification in Fig. 3b.

Specimen 9, yellowish-white translucent chalcedony from Monterey, Mass. The polarizing microscope showed the typical chalcedonic microstructure of radiating bundles of fibers and blades. Bundles of elongate grains showed abrupt termination with adjacent bundles. The grains are transparent except for poorly resolved dark speckling. In Fig. 3c the typical porous, sponge-like electron optical texture is shown. The pore distribution is both random and aligned.

Specimen 10, grayish-blue, translucent agate from Minas Gerais, Brazil. The light microscope showed a texture of interwoven short glades or fibers. The grains had a poorly resolved opaque speckling. The electron microscopic texture as seen in Fig. 3d was spongy with lineation of the pores. Here also the pores are often arranged in arcs to give the scallopy pattern.

Specimen 11, gray translucent agate from Uruguay. Both the petrographic and electron microscopic textures were very similar to the previously described agate Specimen 10.

Opal. Two specimens of opal were studied. Under the light microscope both opals were isotropic and fragments of the specimens were transparent with a poorly resolved opaque speckling.

Specimen 12, milky white opal from Las Vegas, Nev., and *Specimen*

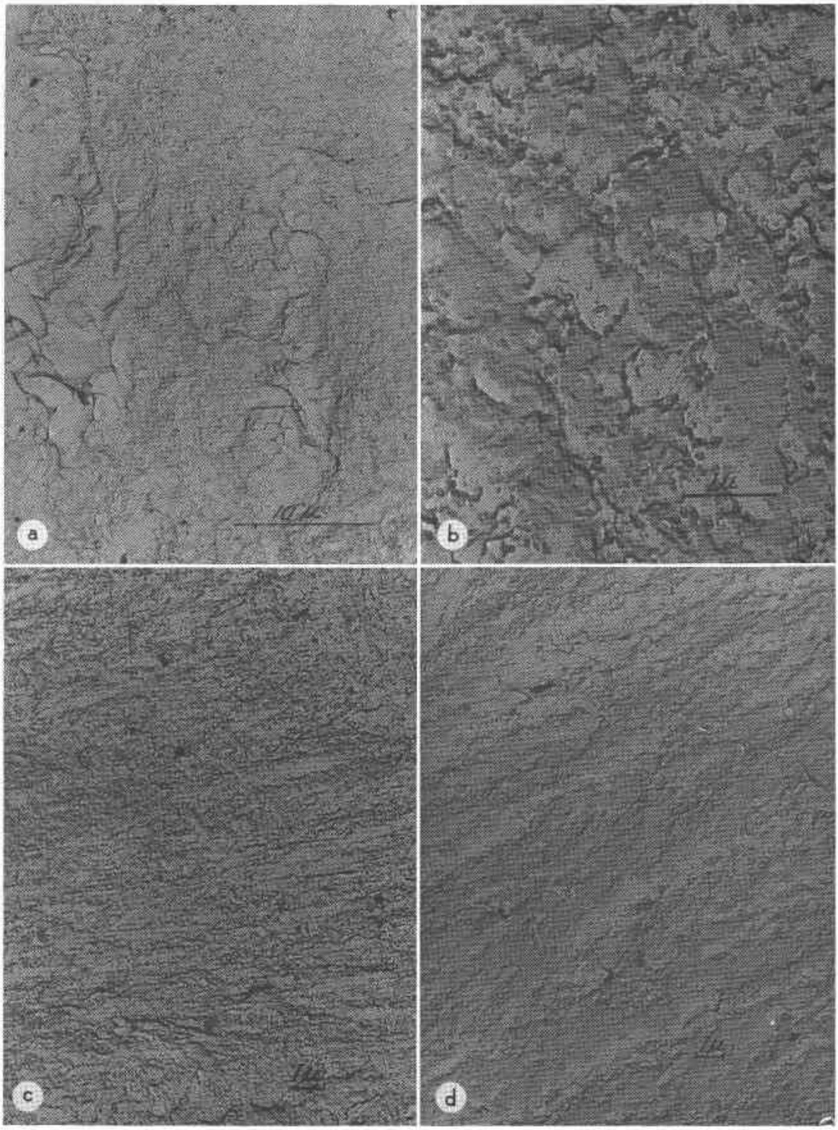

FIG. 3. Electron micrographs of chalcedony and agate.

a. Porous and granular microstructure of chalcedony specimen 7 (×2800).
b. Enlargement of the spongy microstructure of chalcedony specimen 8 (×19,600).
c. Porous texture of chalcedony specimen 9 (×7400).
d. Porous texture of agate specimen 10 (×5800).

13, yellowish-white opal from Virgin Valley, Nev., both had a spongy texture when observed with the electron microscope. This porous, spongy texture shown in Fig. 4a and 4b was similar to that described for the chalcedony and agate specimens. Here also the pores were both randomly arranged and aligned into arcs which give a scallopy-appearing pattern.

Summary and Discussion

The electron optical microstructure of these specimens of silica were either granular or porous. Both textures were observed in some speci-

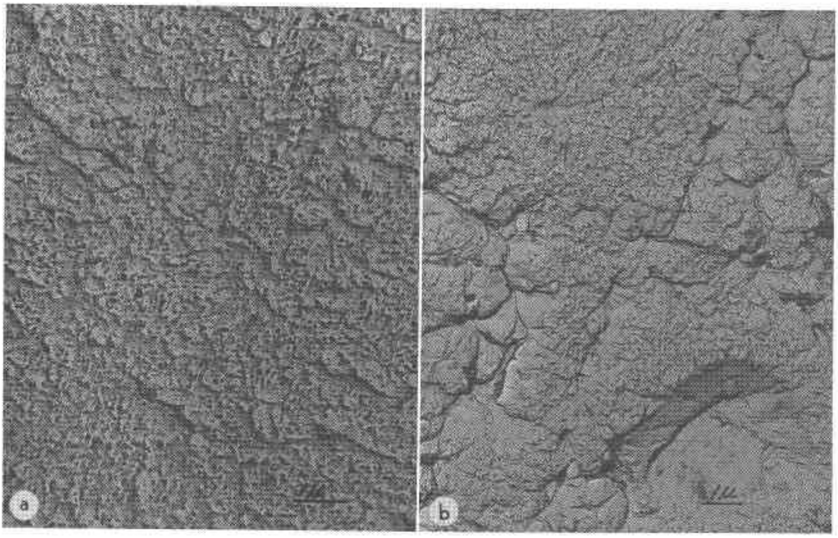

Fig. 4. Electron micrographs of opals.

a. Porous texture of opal specimen 12 (×12,000).
b. Porous texture of opal specimen 13 (×8400).

mens. The three chert and flint samples and the three jasper samples were dominately granular with one sample also having porous regions. The four chalcedony and agate samples showed dominately porous textures with two of the specimens also having granular regions. The two samples of opal both had porous textures. This porous-spongy texture of chalcedonic silica and opal appeared identical and it would be impossible to differentiate between them by replication electron microscopy.

The granular texture typical of the chert, flint, and jasper varieties of silica usually showed a mosaic pattern of well-defined polyhedral grains. The individual grains varied widely in size, but were most often in the range of about 1μ to 10μ diameter. The observation of both the electron microscope and the polarizing microscope revealed a similar granular texture. In some cases the polarizing microscope observed a poorly resolved speckling of the grains which may correspond to pores seen in the grains by electron microscopy, *e. g.*, specimen 6, Fig. 2c. Some non-granular silica, either of the chalcedonic or opal variety, may occur intimately mixed with the granular silica as seen by spongy-porous regions, *e. g.*, chert, specimen 3, Fig. 1c. Other electron optical studies of chert by Weaver and Folk (1952), Iwao (1953), Bates (1958), and Pittman (1959) have reported similar findings.

In the porous-spongy texture typical of the chalcedony-agate and opal varieties of silica, the more or less spherical pores ranged in size from about 0.1μ to 0.01μ diameter with the average size nearer to 0.01μ. The pores sometimes had a random distribution, but very often displayed a scallopy or chain-like arrangement with the pores closely spaced and at times appearing to coalesce. The number of pores per unit area ranged from about 50 to 150 per μ^2. These pores are probably the sites for the water contained in both opal and chalcedonic silica.

Comparing the observations of the electron and polarizing microscope, the porous electron optical texture probably corresponds to the poorly resolved opaque speckling typically seen under the polarizing microscope. In the case of opal, no other textural features were seen and both sets of observations are in apparent agreement. However, in the chalcedony and agate samples the polarizing microscope revealed the typical texture of radiating bundles of fibers in three of the five samples in addition to the speckling. These fibers were usually a few microns in diameter and several hundred microns long and had undulatory extinction. The electron microscope showed only the spongy-porous texture and failed to detect this fibrous character. Also, treating the chalcedony-agate with an HF etch solution did not reveal any new textural features. In the other two chalcedony-agate samples the polarizing microscope showed granular or poorly defined fibrous regions, while the electron optical texture was both porous and granular. It is interesting to note that the granular texture was detected by both microscopic techniques, but that the petrographic fibrosity was never detected. This fibrous texture seen with the polarizing microscope has been reported by many investigators and, also, preferred orientation x-ray diffraction studies have demonstrated the existence of this texture, Frondel (1962). On the other hand, the porous electron optical character has been found by a number of previous studies, Weaver and Folk (1952), Iwao (1953), Pittman (1959) without detecting the fibrous petrographic structure. The grain size of the chalcedonic silica should be easily detectable by the electron microscope as evidenced by the petrographic study and the x-ray diffraction pattern.

A possible correspondence that may exist between these two textures is that the lineation of the pores which is commonly found may correspond to the fibrous character. Additional electron optical studies of chalcedony and its subvarieties using various etching techniques may reveal the fibrous texture.

The textural nomenclature should be as descriptive as possible and clarification made as to whether petrographic or electron optical observations are concerned. The terms used in this study, granular and porous-spongy for the electron optical textures and granular and fibrous for the petrographic textures, seem to fulfill this purpose. However, the nomenclature commonly used is the term microcrystalline signifying the granular texture for both petrographic and electron microscopic observations and the term chalcedonic signifying the fibrous petrographic texture or the porous-spongy electron optical texture. These terms, microcrystalline and chalcedonic, are ambiguous and should be replaced by more descriptive nomenclature.

References

Bates, T. F. (1958) Selected electron micrographs of clays and other fine-grained minerals. *Penn. State Univ., Coll. Mineral Ind., Circ.* **5.**

Frondel, Clifford (1962) *Silica Minerals, V. III, Dana's System of Mineralogy,* John Wiley & Sons, New York.

Iwao, S., H. Akakori, M. Koizumi and H. Minato (1953) Electron micrographs of some silica rocks, with special reference to the micropores with fluid inclusions. *Jour. Jap. Assoc. Min., Petrol., Econ. Geol.* **37,** 166–179.

Pittman, J. S. (1959) Silica in Edwards limestone, Travis county, Texas, in, Silica in Sediments, *Soc. Econ. Paleont. Mineral. Spec. Publ.* **7,** 121–134.

Sella, Cl. and G. Deicha (1962) Vacancies of crystallization between grains of quartz. *Electron Microscopy,* 5th Inter. Congress Electron Microscopy, S. S. Breese, Jr., Ed., Academic Press, New York.

Weaver, C. E. and R. Folk (1952) A study of the texture and composition of chert. *Am. Jour. Sci.* **250,** 498–510.

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