Petrology of Stone Artifacts from Mongolia

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Article VI.—PETROLOGY OF STONE ARTIFACTS FROM MONGOLIA[1]

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Plates XXV–XXXII

INTRODUCTION

During the several seasons of exploration carried on in Mongolia by the Central Asiatic Expeditions of The American Museum of Natural History, large numbers of artifacts were collected from various parts of the Gobi Desert. In 1925 and 1928 the archaeologists made especially large collections, not only of the finished and partly finished implements, but also of flakes and "raw material." In classifying and cataloging this material at the American Museum of Natural History, it soon became apparent that many of the rock types used by the Stone Age inhabitants of the Gobi could not be easily identified. Accordingly it seemed advisable to make a petrographic study of a representative series of the artifacts. This study has shown that there is a wide variation in the physical and chemical make-up of the artifacts, and an even wider variation in their geologic histories. In many specimens, furthermore, the structure and history of the rock, as observed and interpreted under the microscope, differ greatly from what would be expected from the megascopic appearance. It seems desirable, therefore, to call attention to the internal character of the rock materials used in the making of artifacts, not for devising a classification, but rather to exhibit the range of differences in the nature of the rocks. Nearly all the materials described below were collected either in 1925 by Mr. N. C. Nelson, or in 1928 by Mr. Alonzo Pond, archaeologists of the expeditions.

From the viewpoint of the petrologist nearly all stone implements fall into two general groups: first, those used for cutting, scraping, or piercing, and hence requiring a sharp point or edge, and secondly, the stones used for hammering, pounding, or grinding. The first group requires a dense, fine-grained stone, hard and compact enough to retain an edge or point, and of sufficient homogeneity in its internal structure so that the fracture can be controlled during the flaking process. Hammer-stones and grinding implements also call for certain requirements, but the specifications are less exacting. The present study is concerned only with the rocks used for edged or pointed tools.

[1]Publications of the Asiatic Expeditions of The American Museum of Natural History. Contribution No. 126.

[2]New York University; Geologist Central Asiatic Expeditions, 1928.

The requirements of hardness, homogeneity, fine grain, and conchoidal fracture are fulfilled by three relatively common and abundant rocks: flint, chert, and certain varieties of obsidian. Each one of these rocks can usually be identified without serious difficulty, and each one normally represents a fairly definite geologic history. These rocks are found in many, if not most collections of artifacts and would be the materials selected wherever the stone age worker was confronted by a choice of materials; however, neither flint nor chert is sufficiently abundant in Mongolia to serve as an important source of supply, and obsidian, though present, is not suitable for artifacts. Unfortunately, such terms as "flint," "chert," and "jasper" have been expanded and misused by archaeologists to include many dissimilar rock types, with the result that it is frequently impossible to determine the nature of rock materials from the written descriptions of artifacts. The present study was commenced with the purpose of providing the archaeologists of the Central Asiatic Expeditions with as simple a description of the artifact materials as the complexity of the rocks might allow.

It may be reasoned that the more or less precise identification of the rock used to make an arrow point is scarcely even of academic interest to the student of arrow points, and in many cases this is perfectly true. On the other hand, it is not necessary to preface a study of artifact materials with an apology, where such a study can be of value to the archaeologist. From the place where the rock occurs to the site where the artifacts were made, the distance may be several scores of miles, and if the road between the quarry and the workshop can be traced it is a matter of some importance. Furthermore, whenever a single cultural stage within a more or less limited area is represented by similar implements of various degrees of size, symmetry, or perfection of finish, the explanation for these variations may sometimes be found in the nature of the rocks. It is in these, and in similar questions, that petrology may be of service to archaeology.

ARTIFACT ROCKS OF MONGOLIA

Among the many kinds of rocks selected for flaking by the early peoples of Mongolia there are comparatively few simple types. Many of the rocks used are the products of several geologic processes, and the final material may be, and usually is, complex in its geologic history and in its physical and chemical make-up. The general, underlying cause for their complexity is that many of the harder and better consolidated rocks belong to the pre-Cretaceous floor of the Gobi and may have been subjected to various cycles of deformation, volcanism and exposure to the atmosphere. In this way some of the rocks have passed through a variety of physical and chemical environments, any one of which may tend to superimpose changes of composition or structure on the original material. For this reason it is seldom possible to refer to the artifact material by a simple name in current usage, and the rocks must be labeled, or rather described, by terms that indicate something of their histories.[1]

Since the artifacts were fashioned from so many rock types of diverse origins and modifications, in some cases totally unrelated to each other, it is more appropriate to arrange them in convenient groupings than to attempt a systematic but necessarily incomplete classification scheme. The following list includes the rock types found most abundantly among the Gobi artifacts.

A. Pyroclastic rocks, tuffs.
   a. Simple lithified tuffs.
   b. Devitrified tuffs.
   c. Silicified tuffs.
B. Clastic rocks other than pyroclastics.
   a. Quartzite.
   b. Argillite or hornfels.
C. Dense silicious aggregates with disseminated iron oxides, formed either as replacement products or as metacolloids, "Jaspers" etc.
D. Chalcedony, in several colors and degrees of transparency, mostly of doubtful origin.
E. Fossil (silicified) wood.

The most abundant materials found in the artifact collection are the fragmental rocks, of both the pyroclastic and water-laid types, and the complex silicious products listed in group C above.

The tuffs, quartzites, and other rocks that are composed of cemented particles or rock fragments are of relatively simple history. They owe their flaking properties, that is to say their usefulness as artifacts, to the character of the matrix that binds the particles together: they have been rendered firm and compact either by the recrystallization of the groundmass, or else by the introduction of silica minerals.

THE JASPERS

By far the most abundant artifacts are those consisting of silicious aggregates of the Shabarakh Usu type. (See descriptions of specimens

[1]Berkey, C. P. 1922. 'The New Petrology,' New York State Mus. Bull. 251, pp. 105–118.

Ncs. 1471, 1486, 1542–F, 1542–H, 1542–A, 12288–A, and 12288–D.) These have been found in large numbers in the general region of Shabarakh Usu and Orok Nor, and they are also distributed widely in other parts of the Gobi. This "jasper" admirably fulfils the requirements necessary for flaked implements: it is dense, homogeneous and usually free from flaws. The rocks of this group vary in color from a yellowish buff to a deep red, depending upon the amount of iron present and its degree of oxidation.

Although the composition of these rocks is essentially similar, there is considerable variation in their textures and structures. They consist of silica minerals, predominantly of a chalcedonic character, with finely divided iron oxides. A few specimens only have been found to contain minor amounts of sericite and carbonate. They are all fine-textured, and the greater part consist of aggregates too dense to be resolved into distinct minerals under the microscope.

While the origin of many of the "jaspers" is doubtful, most of them seem to have been derived from the hardening and crystallization of colloidal, probably gelatinous, silica. Evidence for this type of origin is displayed in the presence of globular-shaped masses of silica minerals, in which the individual crystals are fibrous and radiate outward from a center, after the fashion of spherulites in devitrified volcanic glasses. Some of the rocks can be identified only by comparison with a series of similar specimens of less obscure origin in which definite structures permit observation and interpretation.

Frequently two or more generations of silica are present; usually the earlier and finer-textured part has been fractured and the resulting cavities filled by a later introduction of silica.

In some specimens the earlier silica seems to have been replaced during the introduction of later material. Other specimens are banded and have the appearance of having been built up by consecutive layers. There is little or no evidence for pre-existing rocks of a different character; nevertheless it is possible that some of the jaspers represent intense silicification and replacement rather than simple deposition in open spaces.

Although the source and mode of occurrence of the jaspers are not known with certainty, it seems probable that they were formed by processes that took place during the later stages of volcanic activity.[1] One possible source is in the Oshih Basin where a group of stacks of red

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[1]This origin was suggested by Doctor Berkey, who reports that the stacks mentioned below consist of similar-looking material.

silicious rocks of volcanic origin were discovered in 1922 by the geologists of the Central Asiatic Expeditions.[1]

Silicified Rocks

Rocks that have suffered all degrees of silicification can be found among the artifacts. The simplest type is exhibited by those rocks that were fractured and the fissures subsequently healed by quartz or chalcedony. The veins so formed did not affect the usefulness of the material, as the conchoidal fracture passes impartially across vein-filling and the rock. In contrast to these, there are rocks in which the silicification is complete and the entire rock is replaced by silica minerals. In many cases the original structure of the rock may be seen and its origin determined, but in some the history of the rock has been obliterated. Where the form of the original material still remains, it is usually displayed by variations in the textures of the silica minerals.

In most of the specimens it is not possible to determine either the physical nature or the source of origin of the solutions that carried on the replacement, but there is good evidence to show that there is considerable variation in the solutions. For instance, one specimen was examined that had not only been silicified, but also impregnated with tourmaline, a process normally associated with mineralization carried on under conditions of high temperature and strong pressure. In contrast there are some rocks in which opaline silica was deposited, and which is interpreted as deposition by relatively cool or cold waters.

The least desirable rocks are the unmodified tuffs, but these constitute only a small proportion of the artifacts. It is interesting to note that at most of the stations where artifacts were collected (1928) the flakes and implements were restricted to a few rock types, even though the station was more often than not at a considerable distance from any known source of supply. Only the largest stations displayed a wide variety of rocks.

In contrast to many other desert regions of the world where artifacts have been collected, the implements from the Gobi are seldom coated with a patina or crusted with weathering products. The only subsequent modification by which they have been affected is a slight rounding, dulling, or smoothing that must, no doubt, be attributed to the work of the wind. There is almost no chemical weathering. The lack of

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[1]Berkey, C. P., and Morris, F. K. 'Geology of Mongolia.' Natural History of Central Asia, II, p. 272 and Plate XXXVII.

decomposition and of patina is the result of the chemical stability of the minerals under atmospheric conditions and of their low porosity.

Of the many thousand specimens available, only a few of each type have been selected for petrographic examination. The specimens described on the following pages have been chosen as illustrations because they are typical representatives of materials in general use by the Stone Age workers. A few of the rarer types are also included because they serve to demonstrate the range of the rocks employed. No descriptions are included of rocks or minerals of an "obvious" character.

In many of the descriptions that follow it has been impossible to give an adequate account of the petrography and mineralogy of the specimen under discussion, because of the extremely fine texture of the constituents occurring in the form of aggregates. This is especially true in the case of the "jaspers."

While an attempt has been made to avoid using terms that are more or less restricted to the vocabulary of geologists, and to substitute phrases in more general use, it has not been practicable to follow this method in all the descriptions, as there are processes and rocks which can be expressed by a single technical term, but which would otherwise require over-long explanations in more popular language.

ACKNOWLEDGMENTS

The writer is under obligation to Mr. N. C. Nelson of The American Museum of Natural History, not only for making the Mongolia artifact collection accessible, but also for aid in selecting the specimens. He is particularly indebted to Professor C. P. Berkey, of Columbia University, without whose aid and suggestions the origin of the siliceous colloidal products would not be understood, and to Professor R. J. Colony, of the same institution, for similar aid.

SYSTEMATIC DISCUSSION OF SPECIMENS STUDIED

1. **Jasper**

Catalogue Number 1486[1] (A.M.N.H.) Plate XXV, Figure 1.

Locality.—Shabarakh Usu. 1925.

Hand Specimen.—Dense, dark red material with a good conchoidal fracture. This type is especially abundant in the artifact stations in the Shabarakh Usu region, and is the most common material among the artifacts in the A.M.N.H. collection from Mongolia.

[1]The catalogue numbers are those of the Department of Anthropology of The American Museum of Natural History.

MICROSCOPIC STUDY.—The texture of this rock is too fine to permit the precise identification of its minerals, with the exception of hematite. The remaining material resembles chalcedony. Its structure (see photomicrograph) is patchy and irregular, and the differences in the appearance of the various areas are due to the relative abundance of the finely divided hematite that is disseminated throughout the rock. It is judged to be the product of the hardening of a silica gel, carrying iron. The rock is rather intimately cut by minute fractures of irregular shape and distribution, which give it a "crackly" appearance. These fractures are filled with later silica minerals, giving rise to small veins which merge into the denser parts of the rock and lose their identity.

IDENTIFICATION.—Jasper.

2. **Banded Jasper**

CATALOGUE NUMBER 1542-C (A.M.N.H.). Plate XXV, Figure 2.

LOCALITY.—Shabarakh Usu. 1925.

HAND SPECIMEN.—Dense red material with excellent conchoidal fracture and sharp edges. It closely resembles specimen 1486, except that it has a banded appearance.

MICROSCOPIC STUDY.—This is an extremely fine-grained aggregate of iron oxide and silica minerals. The only structure visible is a faint parallelism, which is seen more readily in the hand specimen than under the microscope. It results from the varying abundance of iron oxide in the different streaks. Except for the banding and the absence of fractures, this rock is essentially the same as specimen 1486. The layered arrangement is interpreted as resulting from the addition of successive layers of silica.

IDENTIFICATION.—Banded jasper.

3. **Volcanic Ash**

CATALOGUE NUMBER 12401. (A.M.N.H. Geol. Coll.). Plate XXVI, Figure 1.

LOCALITY.—Chilian Hotogha. 1928.

HAND SPECIMEN.—This rock is of a light gray color; it is porous and has an irregular fracture. In spite of its poor quality, it was used extensively in the manufacture of the artifacts found at Chilian Hotogha.

MICROSCOPIC STUDY.—The rock consists of mineral grains embedded in a dense matrix. With rare exceptions the fragments are sharply angular and they are unassorted. Quartz is by far the most abundant mineral. The matrix is a dense brownish clay substance, too fine in texture to be determined.

IDENTIFICATION.—Volcanic ash. (Tuff.)

4. Volcanic Ash

CATALOGUE NUMBER 668. Plate XXVI, Figure 2.

LOCALITY.—Shabarakh Usu. 1925.

HAND SPECIMEN.—Dense dark green material with a somewhat rough fracture.

MICROSCOPIC STUDY.—Rock is composed of sharply angular fragments of minerals and rock fragments. The sorting is poor. The rock shows evidence of some recrystallization. A fracture has been filled with chalcedony. The fragments include:

Alkali feldspar.
Quartz.
Chlorite.
Pyroxene.
Hornblende.
Glass shards (devitrified).
Apatite.
Rock fragments.

There is also some carbonate present.

IDENTIFICATION.—This rock is a fairly fine-grained volcanic ash or tuff that has undergone a slight recrystallization and silicification. It is similar to some of the Keewatin volcanics of Quebec and Ontario.

5. Modified Tuff

CATALOGUE NUMBER 1301. (A.M.N.H.).

LOCALITY.—Shabarakh Usu. 1925.

HAND SPECIMEN.—Dense, hard, fine-grained material of the "greenstone" type. The fracture is straight and smooth rather than conchoidal.

MICROSCOPIC STUDY.—This rock possesses a clastic structure, subsequently modified by reorganization. It owes its green color to the presence of a large amount of a dark chlorite scattered throughout the rock. The fragments are angular. Many different substances are present, but the most abundant are fragments of altered feldspar. There are also a few lithic fragments that resemble altered and devitrified volcanic products. Further evidence of the pyroclastic origin of the material is presented by what appear to be curved splinters of volcanic glass (shards), now devitrified.

The matrix is extremely fine, and much of it has an aggregate structure in which the individual minerals cannot be identified. Its texture and composition are variable from place to place. The most conspicuous constituents are quartz, chalcedony, sericite, chlorite, and carbonate.

The chlorite, however, is not confined to the matrix but appears as a secondary product in some of the fragments. It seems to have been formed during the moderate recrystallization that affected the rock. In some instances it forms a border surrounding the altered rock fragments.

The rock has suffered some silicification; silica minerals occur in irregular patches, and a fracture in the rock is healed with introduced quartz.

The minerals in the rock are as follows:

Quartz.
Chalcedony.
Sodic plagioclase.
Chlorite.
Magnetite. (Rounded grains.)
Pyrite. (In cubes.)
Carbonate.
Apatite.
Carbonaceous material.
Sericite.
Lithic fragments.

IDENTIFICATION.—Modified tuff.

6. **Quartzite**

CATALOGUE NUMBER 1759–A (A.M.N.H.). Plate XXVII, Figure 1.

LOCALITY.—Orok. Nor. 1925.

HAND SPECIMEN.—Gray-green quartzite. Rough fracture.

MICROSCOPIC STUDY.—This specimen is a quartzite, or graywacke, of medium texture. The grains comprising it consist of minerals and particles of rock (lithic fragments), sharply angular in shape and poorly assorted. Quartz is the most abundant mineral constituent, but there is some altered feldspar, magnetite and hornblende. Some of the rock fragments occur as dense formless aggregates in which sericite is conspicuous. These probably represent argillaceous materials. The other rock fragments are mostly altered to chlorite. The matrix of the rock is an aggregate containing sericite and chlorite.

IDENTIFICATION.—Quartzite, or highly indurated sandstone, bordering on graywacke.

7. **Indurated Silt**

CATALOGUE NUMBER 1759–B.

LOCALITY.—Orok Nor. 1925.

HAND SPECIMEN.—A black rock with an exceedingly fine texture resembling hornfels. The fracture is fairly regular, but the edges are scarcely sharp enough for good artifact material. The rock is harder than its appearance would suggest.

MICROSCOPIC STUDY.—Fine grains of sharply angular quartz constitute most of this rock. The grains do not vary much in size, although the sorting is by no means perfect. A few other minerals are present in minor amounts. The matrix is fine-textured, so that not all its constituents can be determined; however, there is a good deal of chlorite, sericite, and finely divided carbonaceous matter, together with some carbonate. A small amount of carbonate has also been introduced along fractures. There is no other structure present.

IDENTIFICATION.—Highly indurated silt, possibly a quartzite.

8. **Silicified Wood**

CATALOGUE NUMBER 12288–E (A.M.N.H. Geol. Coll.). Plate XXVII, Figure 2.

LOCALITY.—Inner Mongolia, location uncertain. 1928.

HAND SPECIMEN.—This is a dense gray, silicious rock, fashioned into a double-ended scraper about 2½ inches long.

MICROSCOPIC STUDY.—The specimen consists of fossil wood, in which the original material has been completely replaced by chalcedony. Although the cell structure has been obliterated, the fibrous arrangement of the wood structure can be plainly seen under ordinary light. Fragments of fossil wood are quite common among the pebbles on the desert floor, and there are several artifacts made from this material in the collections of The American Museum of Natural History. In much of the silicified wood from the Gobi, the cell structure has been preserved.

IDENTIFICATION.—Fossil (silicified) wood.

9. **Feldspar Vitrophyre**

CATALOGUE NUMBER 1973 (A.M.N.H.). Plate XXVIII, Figure 1.

LOCALITY.—Orok Nor. 1925.

HAND SPECIMEN.—This rock was collected in 1925 by Mr. Nelson, from an outcrop near Orok Nor. It is pink in color and has a porphyritic structure, although most of the phenocrysts have weathered out of the exposed surfaces, leaving holes. Large and irregular areas of the rock are occupied by a reddish-colored opaline material that bears a resemblance to many of the red-colored artifacts collected in the vicinity of Orok Nor and also at Shabarakh Usu. The specimen was collected and selected for microscopic study, in the hope that it might throw light on the origin of the dense, fine-grained red material that is so common among the artifacts of this part of the Gobi. Associated with the opaline mineral, and near its margins, there is an appreciable amount of quartz.

MICROSCOPIC STUDY.—The rock is a feldspar vitrophyre, characterized by abundant phenocrysts, and a particularly well developed flowage structure. The feldspars display the rounded edges and re-entrants of resorption but are free from weathering effects, except on the outer surface of the rock. The principal interest attached to the rock is the red amorphous material, and the process by which it was introduced. In several places this silicious material occupies very irregular-shaped areas. These patches do not have the appearance of replacing the rock, but seem to represent the filling of irregular fractures. The invasion of the silica-bearing solutions gave rise, first to a lining of quartz that surrounds the cavities, and then brought in the amorphous silica which forms the red patches of the hand specimen. There has also been some infiltration of carbonate, which occurs as thin veins, following the margins and cracks in the feldspar phenocrysts. It is also sparingly present in the ground-mass. The matrix of the rock has been partly devitrified.

IDENTIFICATION.—Feldspar vitrophyre (glassy porphyry with feldspar crystals) with introduced opal.

10. Yellow Jasper

CATALOGUE NUMBER 1471 (A.M.N.H.). Plate XXVIII, Figure 2.

LOCALITY.—Shabarakh Usu. 1925.

HAND SPECIMEN.—Dense, opaque yellow rock. Conchoidal fracture.

MICROSCOPIC STUDY.—Only two substances occur in this rock: limonitic iron oxide and silica, mostly chalcedony. The bulk of the rock consists of small globular masses, closely packed together. Each globule consists of fibrous crystals of chalcedony, radiating outward from the center, after the fashion of spherulites in glassy rocks. The limonite is concentrated at the margins of the spherulites, and also occurs as a filling between them. This structure is interpreted as the hardening and crystallization of colloidal gelatinous silica. There is no evidence in the rock of an earlier structure, nor any other evidence of replacement. There are present a great many fractures that have been subsequently filled with fibrous chalcedony. That these fractures and their subsequent silica filling were not contemporaneous is indicated by the later ones cutting and offsetting the earlier. No other vein materials are present to give a further clue as to the source and nature of the silica-bearing fluids. This rock is of some importance as being the simplest of a series of rocks of similar origin, described in this paper as "jasper."

Identification.—Yellow jasper (metacolloidal silica with disseminated limonite).

11. Banded Jasper

Catalogue Number 1542–F (A.M.N.H.). Plate XXIX, Figures 1 and 2.

Locality.—Shabarakh Usu. 1925.

Hand Specimen.—Dense red rock, distinctly banded.

Microscopic Study.—This specimen is similar to 1542–C, but is included to show a variation in the banded structure. The photomicrograph shows a fragment of the rock, with its parallel structure twisted out of alignment with the rest of the specimen. No doubt this represents the result of movement before the material was completely "set" and hardened.

Identification.—Banded jasper.

12. Jasper?

Catalogue Number 1542–D (A.M.N.H.). Plate XXX, Figure 1.

Locality.—Shabarakh Usu. 1925.

Hand Specimen.—Red-colored (deeper shade than 1542–C and 1486, which it resembles closely). Surface slightly mottled. Good conchoidal fracture.

Microscopic Study.—The texture of this specimen is too fine to permit the identification of its constituents, which occur as a dense aggregate of silicious material stained with small specks of iron oxide. There is also a small amount of sericite and carbonate (?) present. Only a few of the sericite flakes are large enough for identification. There are a few rounded areas of lighter color and greater transparency than the rest of the rock. These are the only structures visible, and their significance is not understood by the writer.

Identification.—It is impossible to give a precise name to this rock, or to trace its origin with any degree of confidence. When taken into consideration with similar but less obscure rocks, it would appear to be another fine-textured member of the jasper series, which it closely resembles in the hand specimen. When considered alone, there are no diagnostic textures or structures which furnish a definite clue or even give a reasonably suggestive criterion as to its origin. Jasper.

13. **Brecciated Jasper**

CATALOGUE NUMBER 1542–H (A.M.N.H.). Plate XXX, Figure 2.

LOCALITY.—Shabarakh Usu. 1925.

HAND SPECIMEN.—The rock consists of a dense matrix of deep red color that is crowded with angular fragments of various sizes. Most of the fragments are banded and lighter colored than the matrix. The fracture is conchoidal but somewhat irregular.

MICROSCOPIC STUDY.—The history and the physical make-up of this rock are somewhat more complicated than in the jaspers described on the preceding pages. Its structure is distinctly fragmental, and the broken pieces which constitute most of the rock are exceedingly fine-textured aggregates of silica minerals and iron oxide. These fragments are interpreted as an earlier generation of a silica gel, which hardened and was then spread apart by the intrusion and infiltration of later material. The mineralogy of the matrix is similar, though richer in iron, and its texture is considerably coarser. Many of the fragments are cut by blind fractures, into which the later material has penetrated. Some of them present the appearance of having been partially replaced by the later invasion of silica.

IDENTIFICATION.—Jasper fragments, cemented by a later introduction of similar composition.

14. **Jasper**

CATALOGUE NUMBER 1542–A. Plate XXXI, Figures 1 and 2.

LOCALITY.—Shabarakh Usu. 1925.

HAND SPECIMEN.—Dense ocher-colored jasper. It is streaked with small, irregular veins. Good conchoidal fracture.

MICROSCOPIC STUDY.—The rock consists of angular fragments of diverse shapes and sizes. They appear to be fragments of earlier silicious material, embedded in a matrix which represents a later introduction. This rock is similar to 1542–H, except that this one is cut by many veins of silica minerals. The veins do not impair the rock for use in artifacts, since the crystals in the veins are extremely fine and of the same material as the bulk of the rock.

15. **Banded Jasper**

CATALOGUE NUMBER 12288–A (A.M.N.H. Geol. Coll.). Plate XXXII, Figure 1.

LOCALITY.—Sinkiang Trail. 1928.

HAND SPECIMEN.—The hand specimen has a marked banded structure, produced by alternate wavy red and black layers. This rock is not suitable for artifacts but is included in this study because of its close relationship with the jaspers described on previous pages, with which it shares a similar origin.

MICROSCOPIC STUDY.—The primary structure of this rock is a strongly developed banding, which stands out conspicuously as a series of dark wavy streaks, rich in oxides of iron. It consists essentially of aggregates of silica minerals and iron oxides. The texture is fine, but varies somewhat from band to band. A large part of the rock consists of fibrous crystals of chalcedony, radiating outward in the fashion of spherulites and displaying the characteristic uniaxial cross form under crossed nicols. The structure is interpreted as the result of crystallization from an amorphous condition. Somewhat similar results might be obtained from the devitrification of glassy flow rock, but there is no suggestion of minerals other than the limonitic and silica products.

IDENTIFICATION.—Banded jasper.

16. **Banded Jasper**

CATALOGUE NUMBER 12288–D. (A.M.N.H. Geol. Coll.). Plate XXXII, Figure 2.

LOCALITY.—Iren Dabasu region. 1928.

HAND SPECIMEN.—Flat fragments arranged in a sub-parallel linear pattern, embedded in a dense red matrix. This type of material is very common in the eastern central part of the Gobi Desert.

MICROSCOPIC STUDY.—This rock is similar to the preceding and is another example of hardened and crystallized silica. The wavy arrangement of the banding is probably the result of movement while the material was still in a viscous condition. The rock is traversed by veins of chalcedony with a radial arrangement. Pseudo-spherulites make up the bulk of the rock.

IDENTIFICATION.—Banded jasper.

PLATES XXV TO XXXII

Plate XXV

Figure 1

Catalogue Number 1486. Jasper from Shabarakh Usu.

The different intensity of color displayed by patches results from the varying amounts of hematite present. White streaks are cavities filled with silica minerals.

Magnification × 38. Plain light.

Figure 2

Catalogue Number 1542–C. Banded jasper from Shabarakh Usu.

The parallel structure probably originated from the building up by successive layers of silica.

Magnification × 28. Plain light.

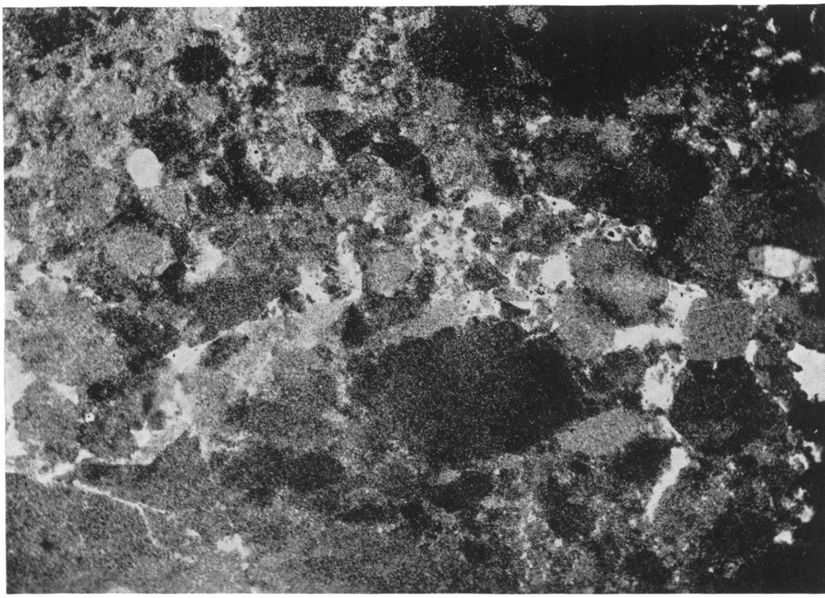

Fig. 1

Fig. 2

PLATE XXVI

Figure 1

Catalogue Number 12401. Tuff from Chilian Hotogha.

The light-colored angular areas are grains of quartz. The dark patches are denser portions of the matrix.

Magnification × 30. Ordinary light.

Figure 2

Catalogue Number 668. Tuff from Shabarakh Usu.

The lighter-colored areas are mostly quartz and feldspar. Attention is called to the angular shapes of the fragments and to the variation in size.

Magnification × 30. Crossed nicols.

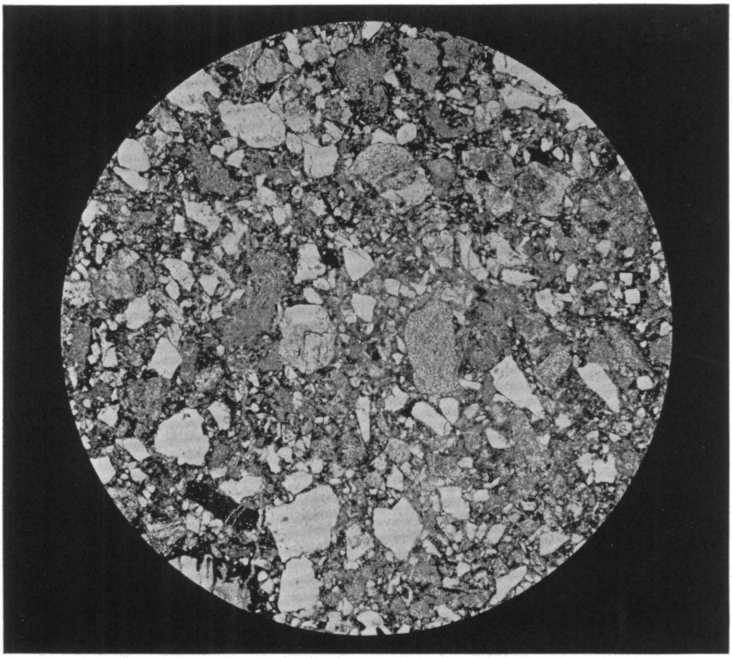

Fig. 1

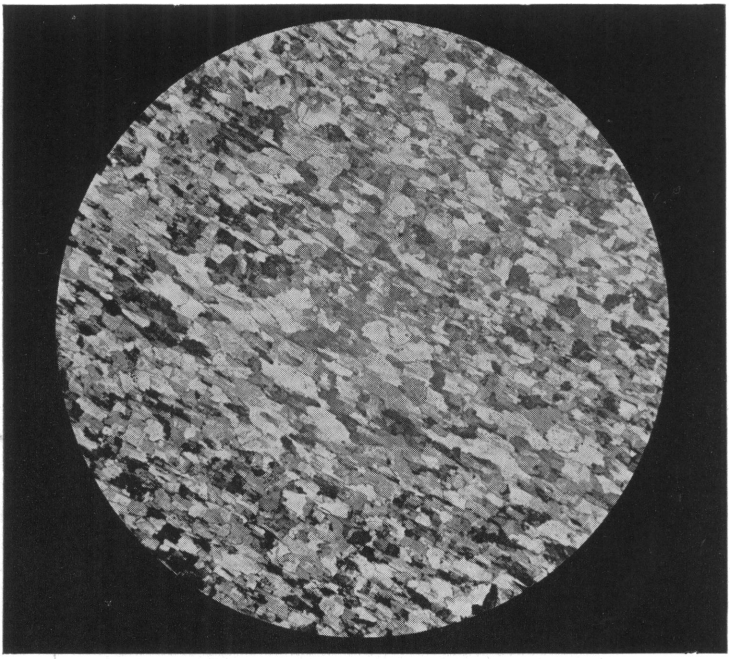

Fig. 2

Plate XXVII

Figure 1

Catalogue Number 1759–A. Quartzite from Orok Nor.

The photograph brings out the angularity and diverse sizes of the grains. The white areas are the quartz grains.

Magnification × 30. Plain light.

Figure 2

Catalogue Number 12288–E. Fossil wood from Inner Mongolia.

Photographed under crossed nicols in order to emphasize the linear arrangement of the chalcedony as it follows the wood fibers.

Magnification × 22. Crossed nicols.

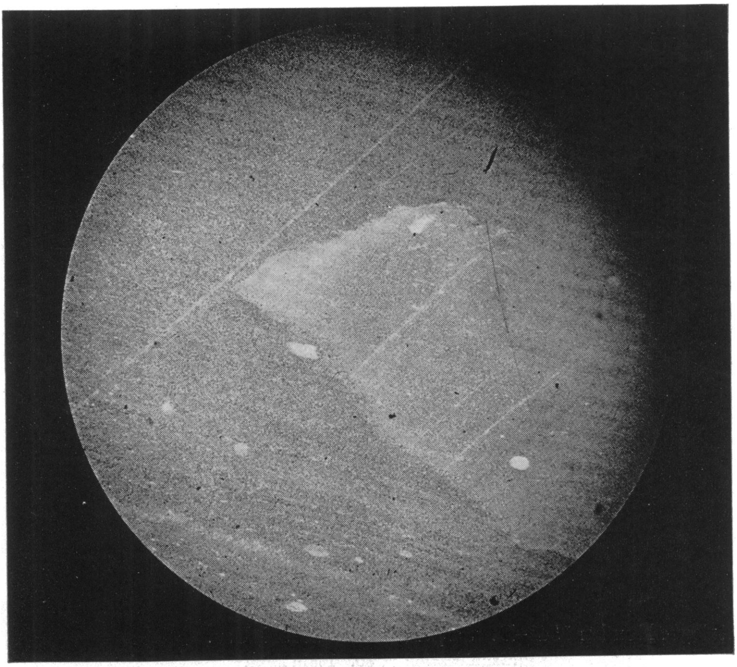

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Plate XXVIII

Figure 1

Catalogue Number 1973. Porphyry from Orok Nor.

The irregular light gray area is the introduced opal. It is surrounded by lighter-colored material, the quartz lining of the cavity, and the position which both occupy cuts across the flowage structure.

Magnification × 28. Plain light.

Figure 2

Catalogue Number 1471. Jasper from Shabarakh Usu.

The rounded areas consist of fibrous chalcedony and limonite. The white streaks are fractures that have been healed by chalcedony.

Magnification × 50. Plain light.

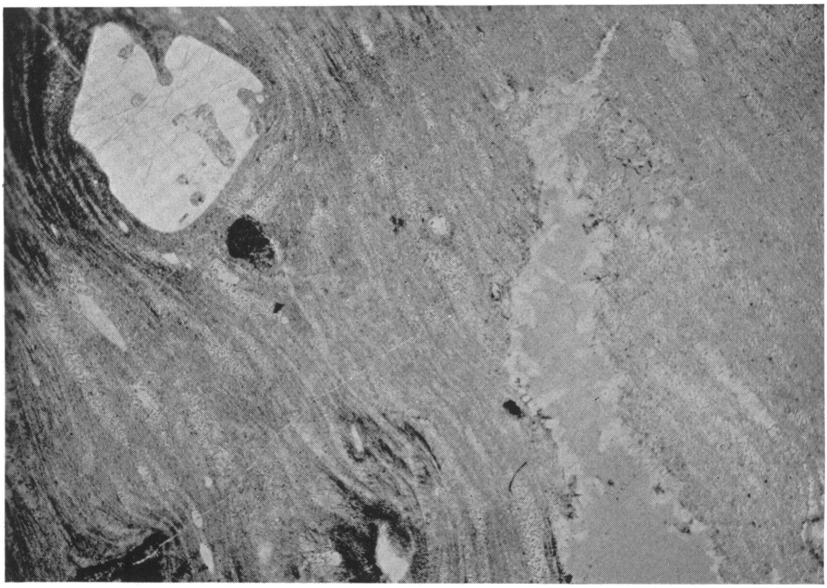

Fig. 1

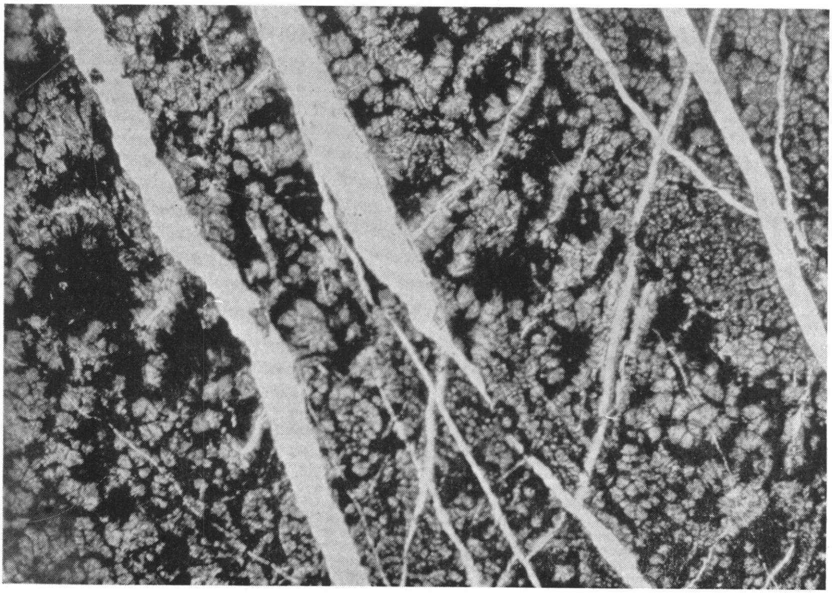

Fig. 2

Plate XXIX

Figures 1 and 2

Catalogue Number 1542–F. Jasper from Shabarakh Usu.

The angular banded fragment has been twisted out of alignment with the rest of the rock.

Magnification × 15 and × 25. Plain light.

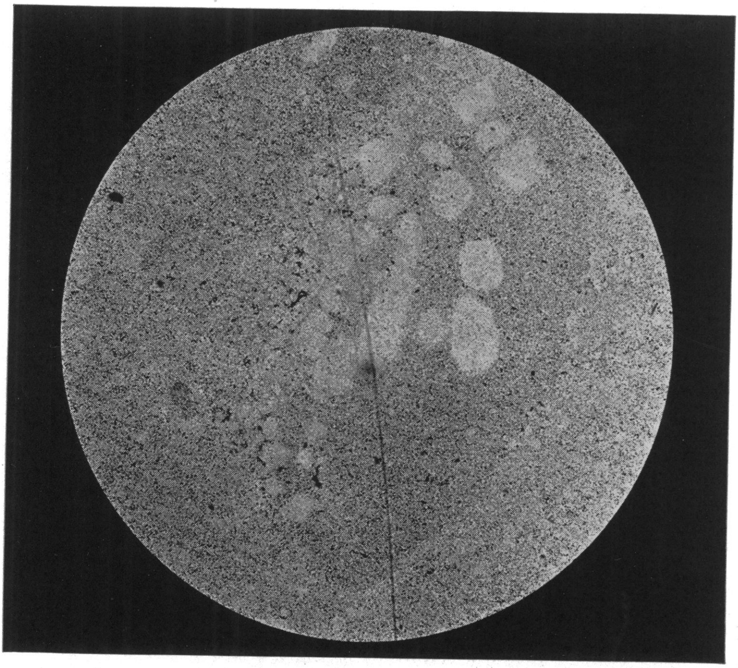

Fig. 1

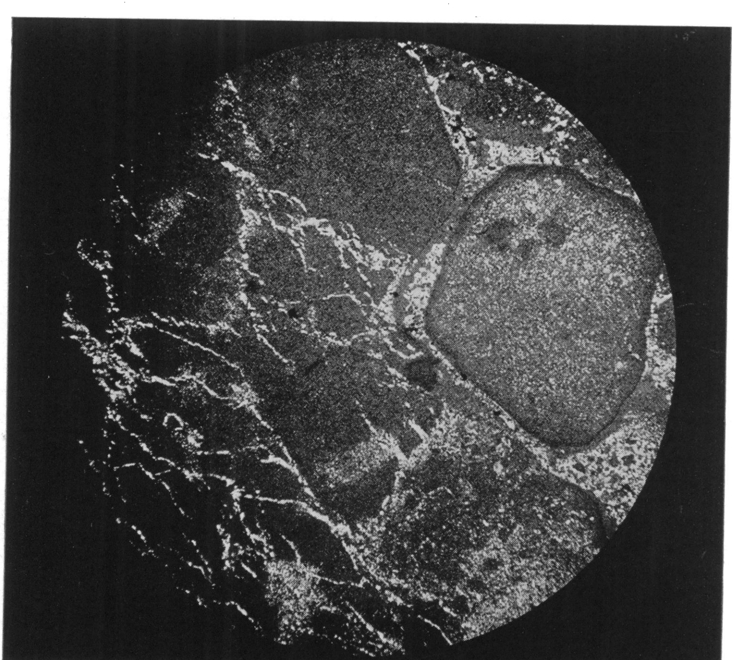

Fig. 2

PLATE XXX

Figure 1

Catalogue Number 1542–D. Jasper from Shabarakh Usu.

Magnification × 30. Plain light.

Figure 2

Catalogue Number 1542–H. Jasper from Shabarakh Usu.

The earlier jasper, as shown by the fine-grained fragments, has been broken, and the spaces are filled by a later generation of introduced silica minerals.

Magnification × 28. Crossed nicols.

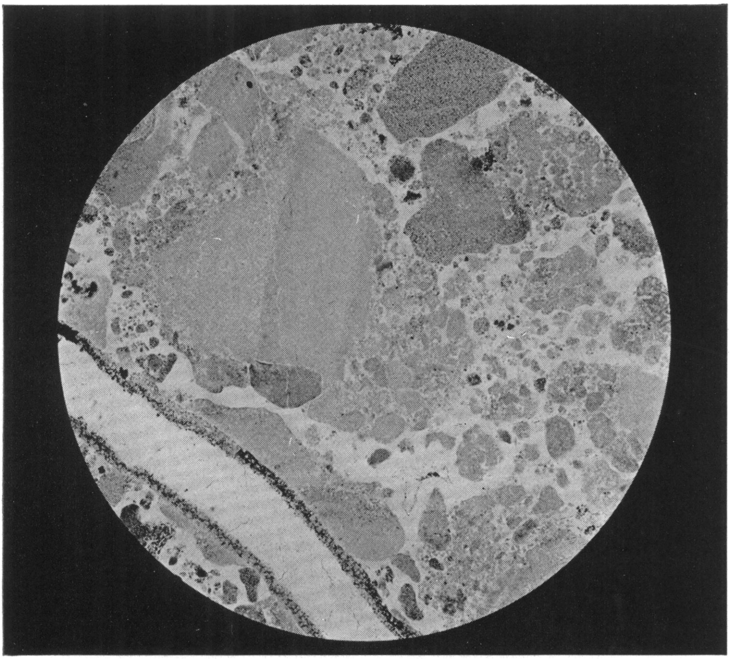

Fig. 1

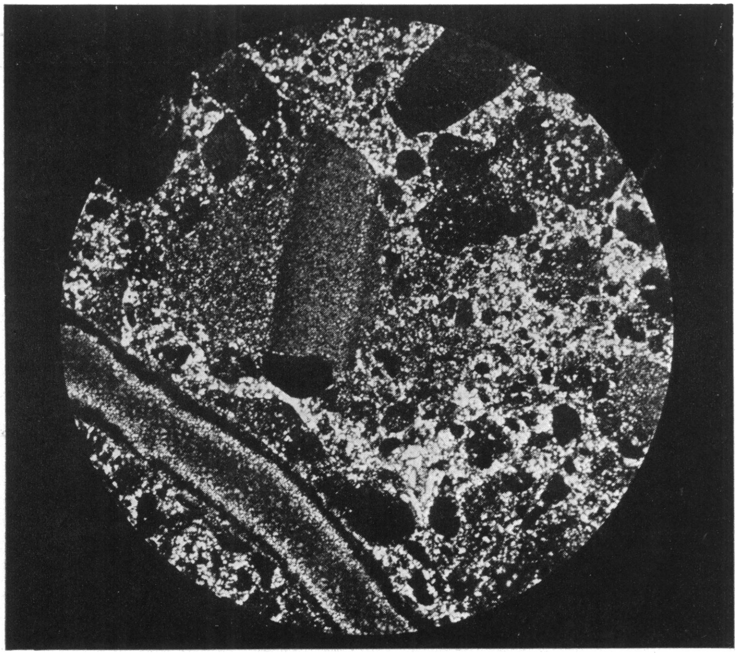

Fig. 2

PLATE XXXI

Figures 1 and 2

Catalogue Number 1542–A. Jasper from Shabarakh Usu.

The photomicrograph shows three generations of silica, (1) the earliest material represented by the fragments, (2) the matrix, and (3) the vein.

Magnification × 30. Figure 1 is photographed in plain light, and figure 2, the same field, under crossed nicols.

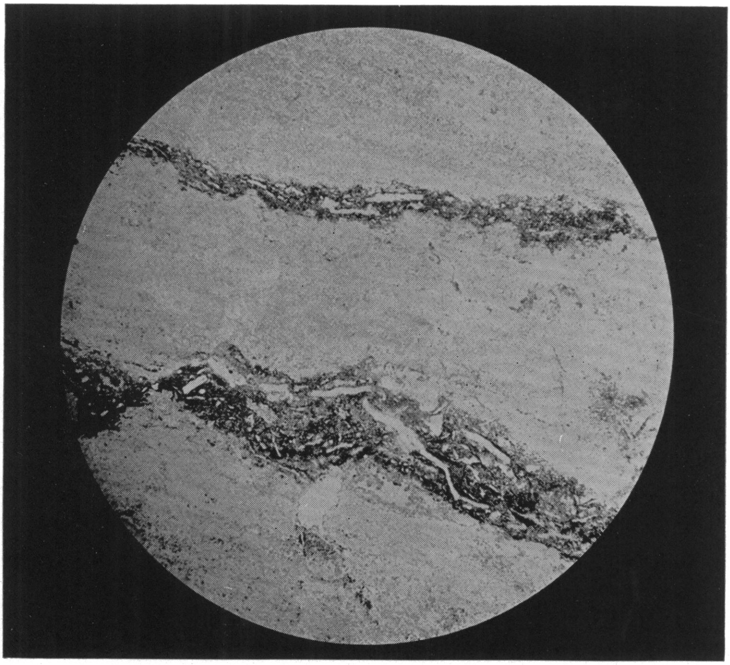

Fig. 1

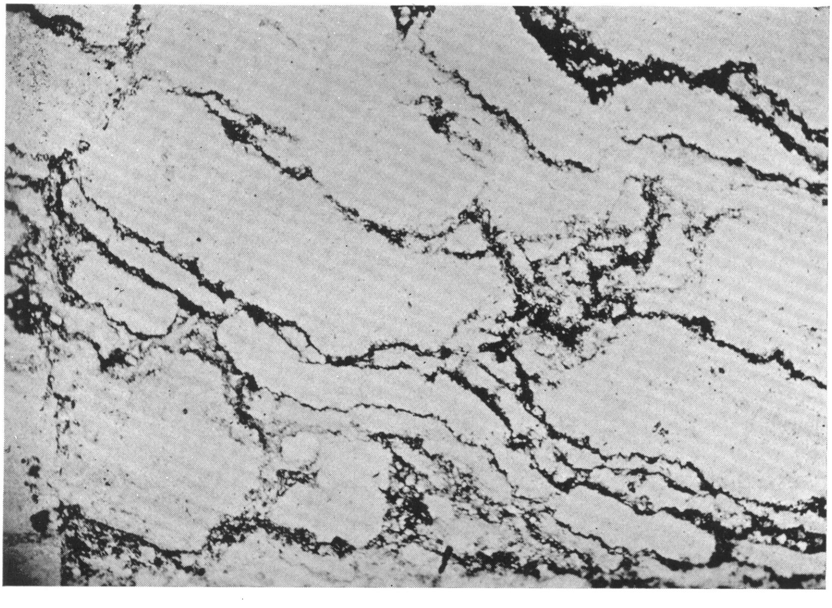

Fig. 2

PLATE XXXII

Figure 1

Catalogue Number 12288–A. Banded jasper from the Sinkiang Trail. The dark streaks are rich in limonitic material.

Magnification × 15. Plain light.

Figure 2

Catalogue Number 12288–D. Banded jasper from the Iren Dabasu region. The wavy banding is attributed to movement before consolidation was complete.

Magnification × 28. Plain light.

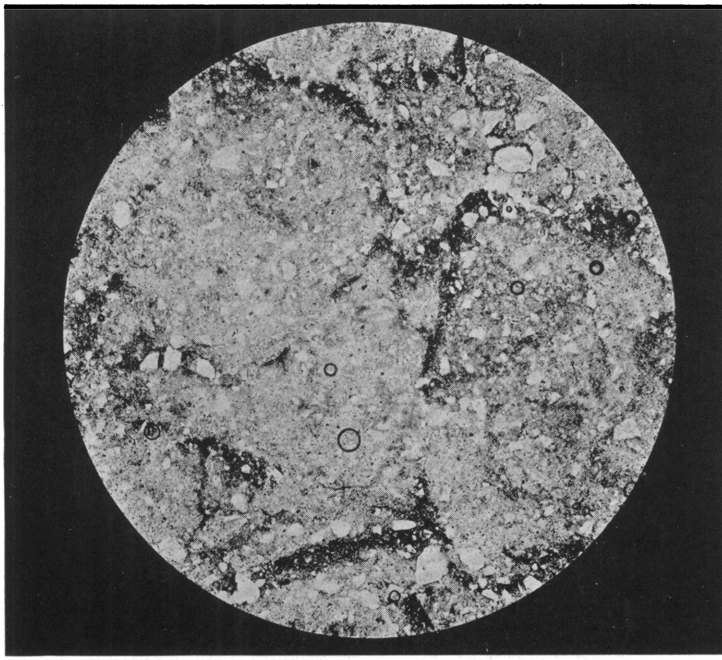

Fig. 1

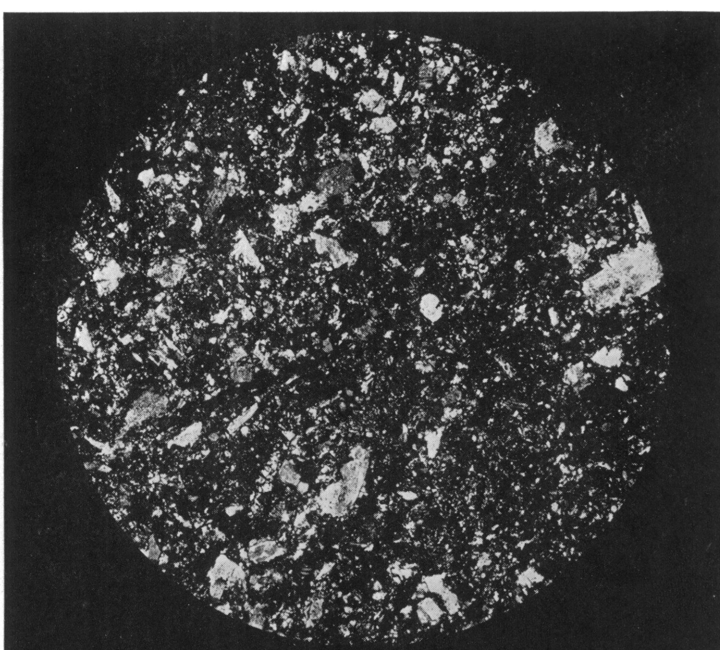

Fig. 2