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SCAN ELECTRON MICROGRAPHS OF KAOLINS COLLECTED FROM DIVERSE ORIGINS—III. INFLUENCE OF PARENT MATERIAL ON FLINT CLAYS AND FLINT-LIKE CLAYS

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Abstract—The nature of the parent material from which flint clay or flint-like clay is derived may modify the texture of the clay as observed by SEM. Flint clays occurring in Pennsylvanian-age swamp basins into which were transported residues weathered from sedimentary country rock exhibit a texture of interlocked kaolin pockets and sheaves. On the other hand, flint clay or flint-like clay derived by weathering of volcanic ash exhibits a texture resembling, on a micro-scale, the scalloped, "oak-leaf" pattern of montmorillonite. The interpretation is that an expanding clay having a transitional role between the ash and the kaolinite is the donor source of the micro-scalloped pattern inherited by kaolinite. X-ray powder diffractograms of the clays support the interpretation.

INTRODUCTION

In Parts I and II of this series, scan electron micrographs (SEM) have shown that certain textures of kaolin clays generally characterize particular environments of kaolin genesis. In this report the effect of different parent material on the texture, as observed in scan electron micrographs, of flint clays and flint-like clays will be demonstrated. Specifically, the texture of flint clay and/or flint-like clay derived from volcanic ash will be shown to be distinctly different from otherwise lithologically similar clay whose parent material was clay residue from older sedimentary rocks.

TYPICAL FLINT CLAY

Flint clay is a kaolin clay characterized lithologically by a conchoidal fracture, a very fine-grained smooth or "slick" surface tecture, and by pronounced resistance to slaking. Flint-*like* clays, on the other hand, while they exhibit megascopically similar lithologic features of flint clay, typically possess lower bulk-densities than those characteristic of first-quality refractory flint clay (e.g. 2.3 or higher, Baumann and Keller, 1975), or have less desirable ceramic properties. This report will not emphasize the role of ceramic properties.

Typical flint clays occur in Maryland, where they were first named by Cook (1886), in Missouri, Ohio, Kentucky and Pennsylvania. The origin of these clays has been interpreted as deposition in Pennsylvanian-age swamps and marshes (Keller, 1968; Patterson and Hostermann, 1962)). The parent material for the Missouri clay was interpreted to be weathered clay residues (Robbins and Keller, 1952) from carbonate and other sedimentary rocks comprising the country rock of the region in which the depositional basins for the clay were located.

Scan electron micrographs of typical Missouri and Kentucky flint clay are shown in Figs. 1 and 2, respectively. These micrographs show flint clays to be comprised of small sheaves and packets of subhedral to anhedral kaolinite flakes, tightly intergrown, interlocked, and closely compacted to form a relatively dense clay rock. A few of the packets may show tiny plates of kaolinite as leaves in books but they are in the minority. The sheaves and packets appear to be mutually crystallized and interlocked, thereby developing so-called mutual boundaries.

CLAYS DERIVED FROM VOLCANIC ASH

In contrast to the preceding swamp-deposited flint clays, a sequence will be shown of flint and flint-like clays known from geologic field evidence to have formed by the weathering of volcanic ash (or tephra). The first examples were collected from the Cowlitz–Castle Rock region in southwestern WA (Popoff, 1955) and the adjacent Salem–Sublimity region in northwestern Oregon (Wilson and Treasher, 1938). The essentially monomineralic character of the Castle Rock clay is shown by its X-ray powder diffractogram (Fig. 3). Lithologically similar clay derived from geologically similar Tertiary ash-tephra as the Castle Rock clay occurs about 150 km south in OR. At King's locality No. 11 (Wilson and Treasher, 1938), 16 km south and east of Salem, and 4 km north of Sublimity, OR, the white, fine-grained, conchoidally fracturing clay can be traced laterally and downward through coarser-grained, mealy transition clay into partly decomposed volcanic ash.

Powder diffractograms of these clays solvated in ethylene glycol, (shown in Fig. 3), illustrate the mineralogical changes. The first product of weathering the ash is an expanding clay, "X" in the diffractogram,

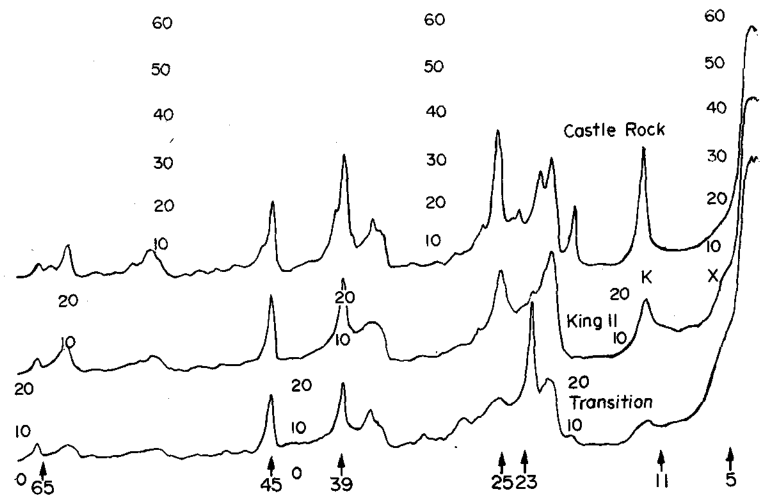

Fig. 3. X-ray powder diffractograms of Castle Rock–Cowlitz clay, clay from King's locality No. 11, and transition clay from weathering volcanic ash, all glycolated. CuKα radiation, degrees 2-θ along base. K refers to kaolinite, X to expanding clay.

while additional weathering close to the surface of the ground transforms the expanding clay to kaolinite, "K" in the diffractogram.

Scan electron micrographs of the Castle Rock Clay, the King ("slick") clay, and "transition" clay, are shown in Figs. 4–6 respectively. All three SEM's are at 5000×. Noteworthy are 2 textural features. The crystals, grains, or flakes or the ash-derived clays are smaller and less regularly developed morphologically than in the swamp-deposited clays. Perhaps more significant, the textural pattern of the flakes of ash-derived clays, especially that in the King "slick" clay (Fig. 5) is a smaller-scale representative of the "cornflakes" or "oak-leaf", scalloped texture common to smectite, or to montmorillonite specifically, as from Chambers, AZ (Fig. 7). Just as this "oak-leaf" textural pattern is typical of freshly fractured surfaces of smectites (Borst and Keller, 1969), so is its "micro" pattern developed in ash-derived flint or flint-like clays. Apparently the physical morphology of the kaolinite in ash-derived clay is inherited from its parent expanding-clay. Additional examples support such an interpretation.

A different flint clay from Kentucky, not from the refractory-producing Olive Hill stratum described by (Patterson and Hostermann, 1962), was collected by Charles L. Rice, U.S. Geological Survey, from about 3.5 km northwest of the southeast corner of the Prestonburg Quadrangle. Rice wrote (personal letter, March, 1965), "It has been suggested by Huddle and others that the flint clay bed might represent a volcanic ash fall, and Victor Seiders (U.S.G.S.) reportedly has identified sanidine in thin sections of the clay." Its SEM (Fig. 8) shows a smectite-inherited type of textural pattern that accords with those of other flint and flint-like clays derived from volcanic ash. It obviously differs from the orthodox Olive Hill type of flint clay (Fig. 2).

Flint clays and tonsteins from the Sydney Basin in Australia, sent me by Fred Loughnan, include two whose SEM's are shown in Figs. 9 and 10. Pertinent to their origin is a recent note published by Loughnan and Corkery (1975) on clays and tonsteins from the Sydney basin, "fragments ..... contain undistorted pseudomorphs of volcanic textures ....." Possibly these clays have a heritage of volcanic ash in accord with their textural pattern.

In the "Alameda road cut," U.S. 6, west, Denver, CO, the Cretaceous Dakota Sandstone contains several sharply defined, 1-cm thick layers of fine-grained flint-like kaolin clay. Because of their sedimentary characteristics in the sandstone formation, these have been regarded as derived from thin beds of volcanic ash. Their mineral composition as kaolinite has been considered anomalous because volcanic ash in the Cretaceous of the western U.S.A. commonly alters to montmorillonite. In Fig. 11 it is seen that the textural pattern of this clay is similar to that of ash-derived flint clay.

A clear-cut example of the influence of parent rock on the texture of kaolin (not restricted to flint clay) is taken from two clays occurring within a few meters of each other at a huge, open-pit, brown-coal mine near Berzdorff, East Germany (GDR). The basement rock of the mine is granodiorite which has weathered to kaolin. Unconformably overlying the granodiorite are tuff and basalt lava of Oligocene/Miocene age and their weathering products, also kaolin. Mucke *et al.* (1975) state that kaolinization of the granodiorite was terminated by overlapping deposition of the volcanic rock in the Upper Oligocene/Lower Miocene, and the weathering of the volcanic rocks which occurred between Upper Oligocene and Mid-Miocene. The kaolinite formed from both rocks has a low degree of order. As seen in Fig. 12, the kaolinite from the granodiorite shows coarse, loosely packed books, whereas that from the tuff (Fig. 13) is strikingly different. It is much finer grained and resembles, on a microscale, the texture of expanding clay. Presumably the dominant variable between the two kaolins is a difference in parent rock.

SUMMARY

Photographic evidence is strong that volcanic ash typically weathers directly to an expanding clay mineral whose texture resembles that of identified montmorillonite. In turn, this expanding clay may be weathered further or leached to kaolinite which, to a considerable extent, may retain the textural pattern of the expanding clay. Flint clay derived from weathered sedimentary rocks deposited in Pennsylvanian-age swamp basins presumably was crystallized, or re-crystallized ("diagenized") to kaolin which possesses the typical external morphology of kaolinite. Feldspathic rocks, as in the Berzdorff granodiorite, may weather directly to books of kaolinite.

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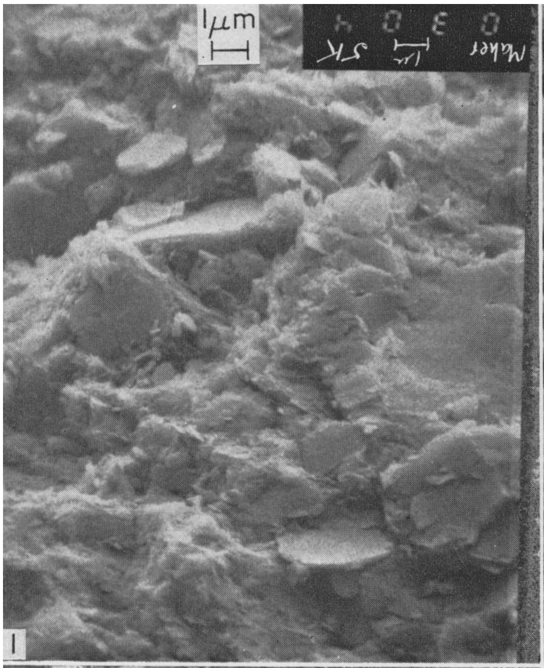
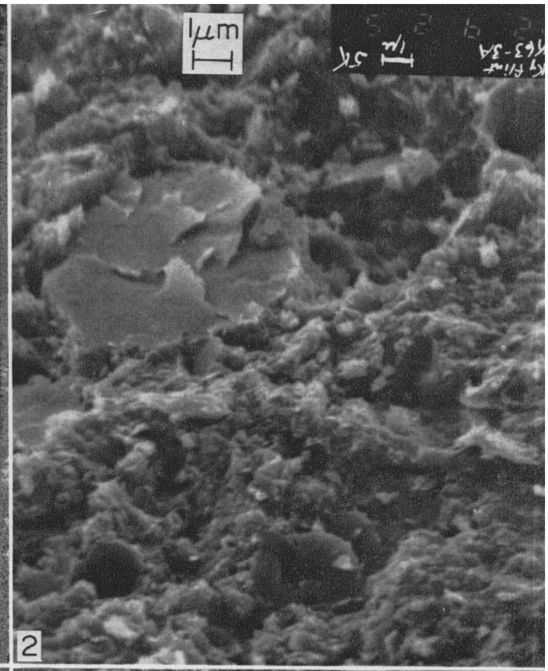
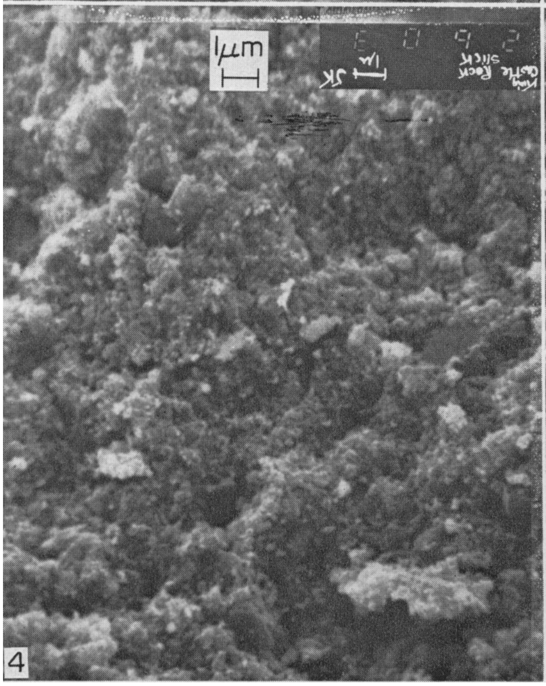






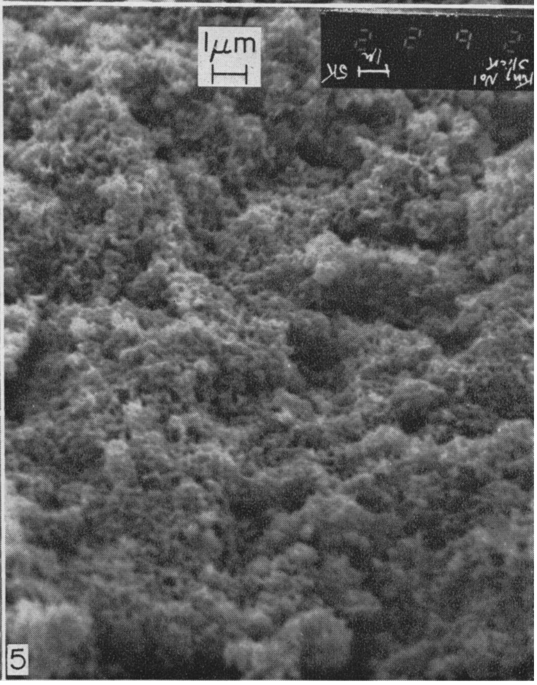
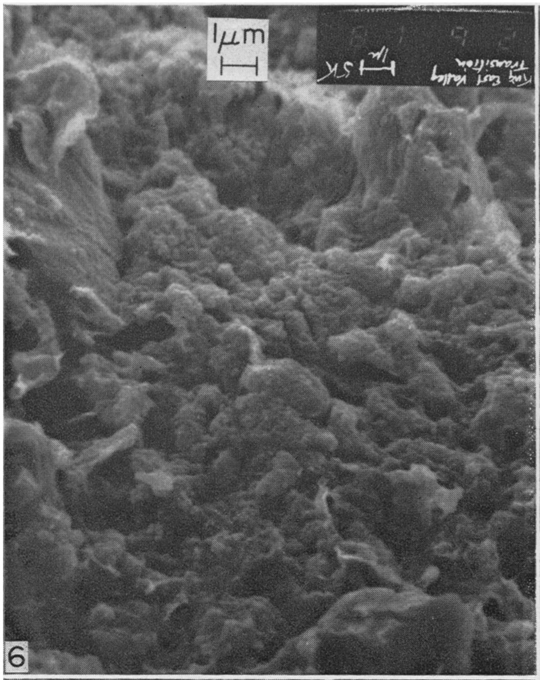


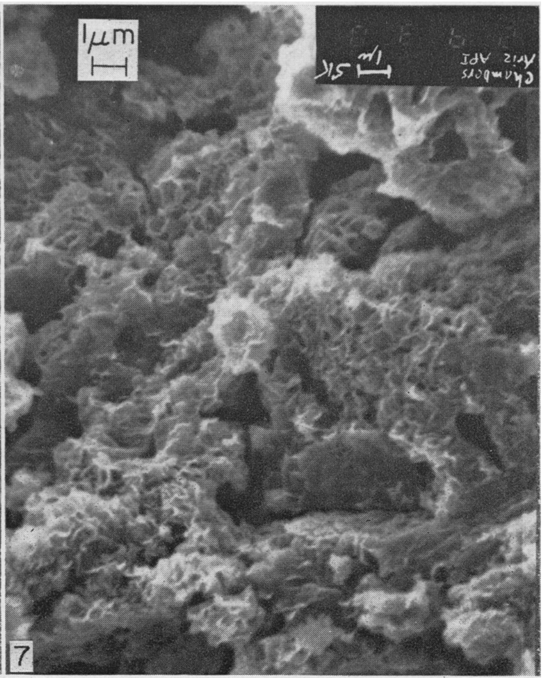
Fig. 1. Scan electron micrograph of Missouri flint clay. Maher pit, Whitesides, MO, 5000×. White bars indicate 1 μm, except in Fig. 12.

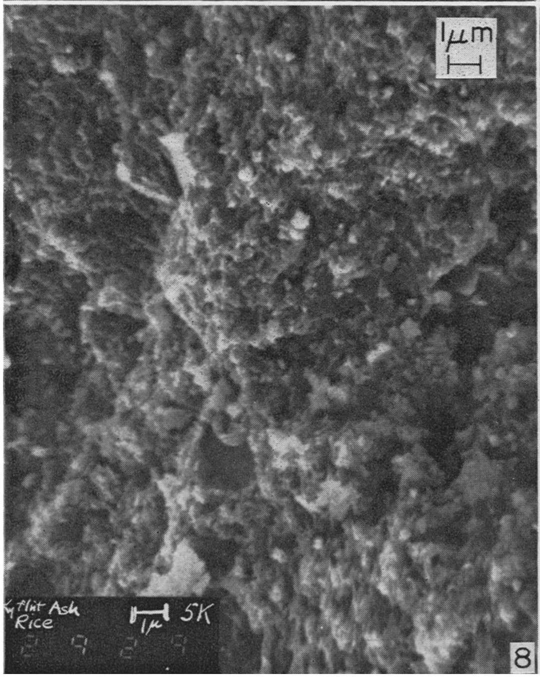
Fig. 2. Scan electron micrograph of typical Kentucky flint clay. Moorehead–Clearfield district, 5000×.

Fig. 4. Scan electron micrograph, Castle Rock clay, Cowlitz County, WA, 5000×.

Fig. 5. Scan electron micrograph, clay from King's locality No. 11, Sublimity, OR, 5000×.







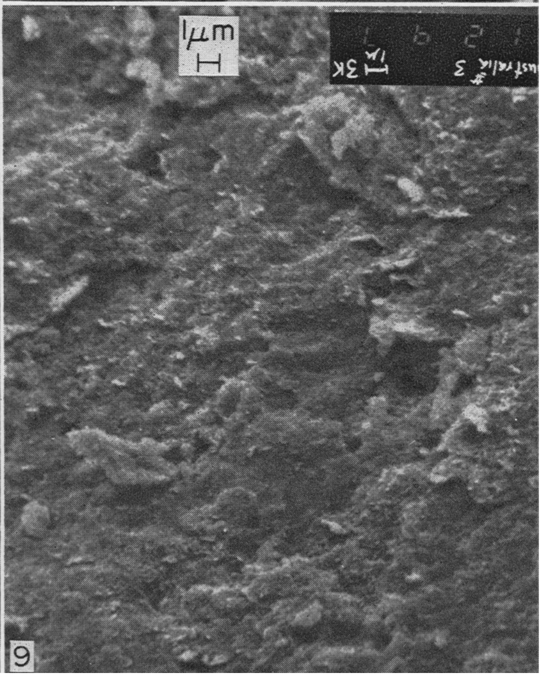


Fig. 6. Scan electron micrograph, "transition" clay between weathered volcanic ash and flint-like clay, King's locality, Sublimity, OR, 5000×.

Fig. 7. Scan electron micrograph, montmorillonite, Chambers, AZ, 5000×.

Fig. 8. Scan electron micrograph, flint clay derived from volcanic ash (?), Prestonburg Quadrangle, KY, 5000×.

Fig. 9. Scan electron micrograph, flint clay, Australia No. 3, Sydney Basin, 5000×.

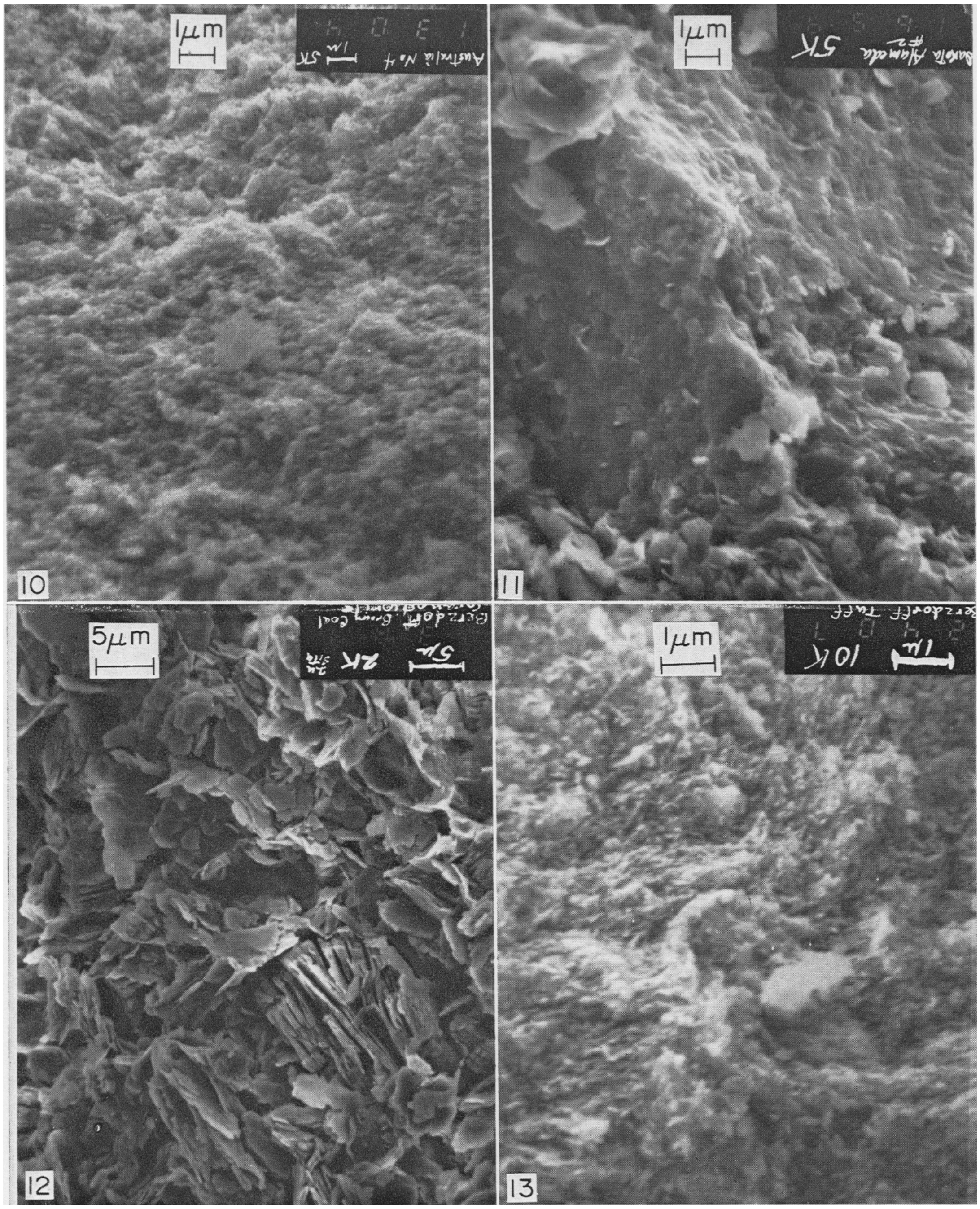


Fig. 10. Scan electron micrograph, No. 4, Sydney Basin, Australia, 5000×.
Fig. 11. Scan electron micrograph, thin-layered, flint-like clay, Cretaceous Dakota sandstone, "Alameda road cut" on U.S. Highway 6, West, Denver, CO, 5000×.
Fig. 12. Scan electron micrograph, kaolinite from granodiorite, brown-coal mine, Berzdorff, East Germany, (GDR) 2000×. Note that the scale bar indicates 5 μm in this coarse-grained clay.
Fig. 13. Scan electron micrograph, kaolinite from tuff, same mine as Fig. 13, 10,000×, much finer-grained than the kaolinite in Fig. 12.

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