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SAMPLING AND ANALYSIS OF KGa-1B WELL-CRYSTALLIZED KAOLIN SOURCE CLAY

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Abstract—Additional well-crystallized kaolin from Washington County, Georgia, has been supplied to the Clay Minerals Society Source Clay Repository to replace the exhausted supply of KGa-1. This kaolin is called KGa-1B and is from a geographic location and stratigraphic position close to where KGa-1 was collected. Slight mineralogical and chemical differences are observed between KGa-1 and KGa-1B. KGa-1B crude appears slightly better crystalline than KGa-1, and it has a slightly higher titania content than KGa-1. The Al_2O_3, SiO_2, Fe_2O_3, alkali, and alkaline earth contents appear similar for both samples. KGa-1 has a slightly coarser particle size than KGa-1B crude. More intensive post-depositional alteration may have cleansed and crystallized the KGa-1B material to a slightly greater degree than the KGa-1 material.

Key Words—Georgia, Kaolin, Kaolinite, Source clay, Well crystallized.

INTRODUCTION

The Clay Minerals Society Source Clay Repository has obtained additional well-crystallized kaolin to replace the exhausted supply of KGa-1. This replacement material is called KGa-1B because it was collected from a geographical location and stratigraphic position very close to KGa-1. The location, description of sampling conditions and analytical data on unprocessed KGa-1B is provided here to benefit scientists utilizing this material for research. The analytical data provided is only intended to indicate approximate KGa-1B composition. These analytical results should not be used as reference numbers for the source clay material distributed by the Source Clay Repository because this work was performed on a portion of sample split at the mine. Processing of KGa-1B was conducted at AP Green Industries under the direction of Charles Stack prior to its arrival at the Source Clay Repository.

The well-crystallized Georgia kaolin used as a source clay is from non-marine Upper Cretaceous age sedimentary kaolins that are overlain by Tertiary age sandstones of the Huber Formation. The KGa-1 and KGa-1B materials were collected at the same stratigraphic position located near the top of the Buffalo Creek Kaolin Member (Figure 1), which represents the top of the Gaillard Formation (Huddlestun and Hetrick, 1991; Pickering and Hurst, 1989). The provenance for the sediments appears to be granites and coarse-grained metamorphic rocks located on the Piedmont north of the Middle Georgia Kaolin District. Post-depositional alteration commonly observed in the Georgia kaolins includes removal of organics, oxidation of Fe minerals and continued kaolinitic alteration of any labile minerals remaining in the sediments.

MATERIAL

Selection

KGa-1 was collected from the Coss Hodges Mine (van Olphen and Fripiat, 1979), which is not actively being mined and, therefore, is not accessible at the present time. Effort was made to find a well-crystallized Middle Georgia kaolin that best matched the mineralogical and chemical properties of KGa-1. Grab samples were collected from six ECCI mines located in Washington County, Georgia (Figure 2), and each sample was analyzed for Hinckley crystallinity and for chemical composition by ICP-AES. All mines examined contain well-crystallized "soft" kaolin, a term describing how easily the clay is broken apart by hand. Kaolin from the Buffalo China Mine (Figure 2) was selected as the KGa-1 replacement because of 1) its geographical proximity to the Coss Hodges Mine; 2) its relatively high Hinckley crystallinity; 3) Fe_2O_3 and TiO_2 content similar to KGa-1; and 4) grab sample SiO_2 and Al_2O_3 content higher than KGa-1 and more consistent with ideal kaolinite chemistry.

Sampling

Well-crystallized kaolin KGa-1B material was collected on the afternoon of January 22, 1993. Weather conditions were clear with temperature near 17°C. The collection site was the Buffalo China Mine, Yates property block D, operated by ECC International, located in Washington County, Georgia, south of Ga. 24 about 19 km west of Sandersville in the Tabernacle 7.5′ quadrangle, at Lat. 32°57′12″N and Long. 83°59′37″W. The sample was taken at the 69 m (226′) elevation above sea-level near the top of a thick kaolin strata actively

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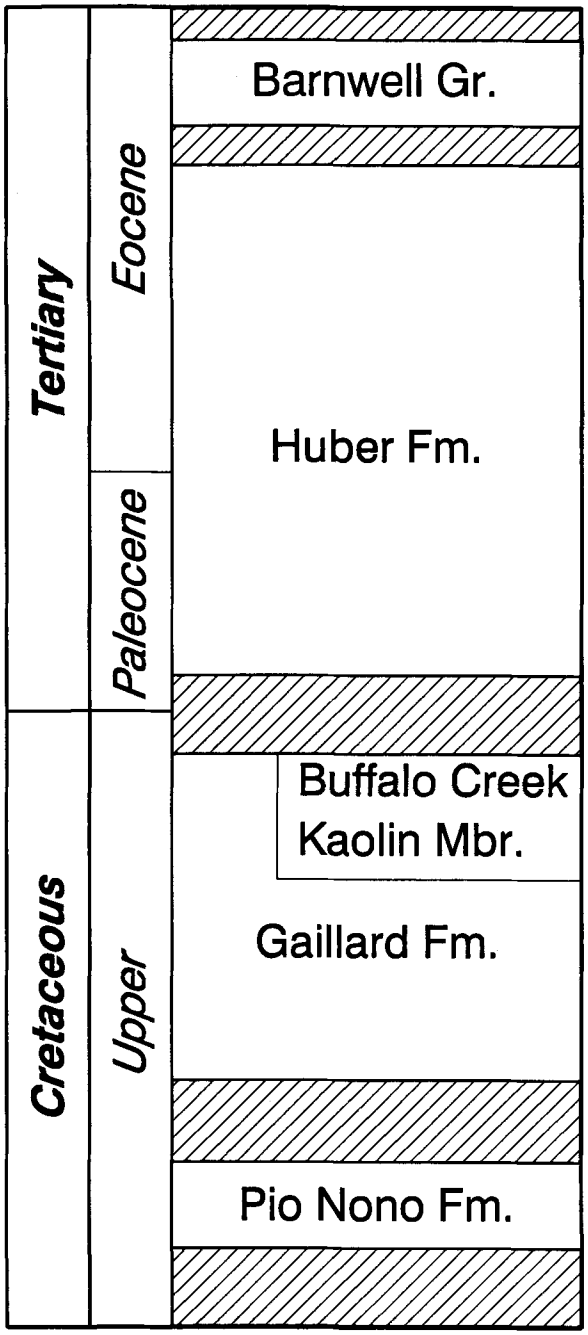


Figure 1. Stratigraphic column for the Middle Georgia Kaolin District based on Huddlestun and Hetrick, 1991. Crystalline basement underlies the Pio Nono Formation.

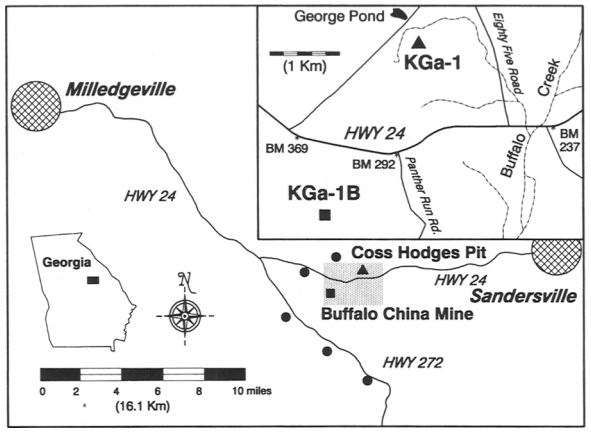


Figure 2. Map showing location of Middle Georgia Kaolin District and locations for six Washington County mines (solid circles and square) containing kaolin evaluated as a replacement for KGa-1. THe Buffalo China Mine (solid square) is where KGa-1B was collected in 1993. The Coss Hodges Pit (solid triangle) is where KGa-1 was collected in 1972.

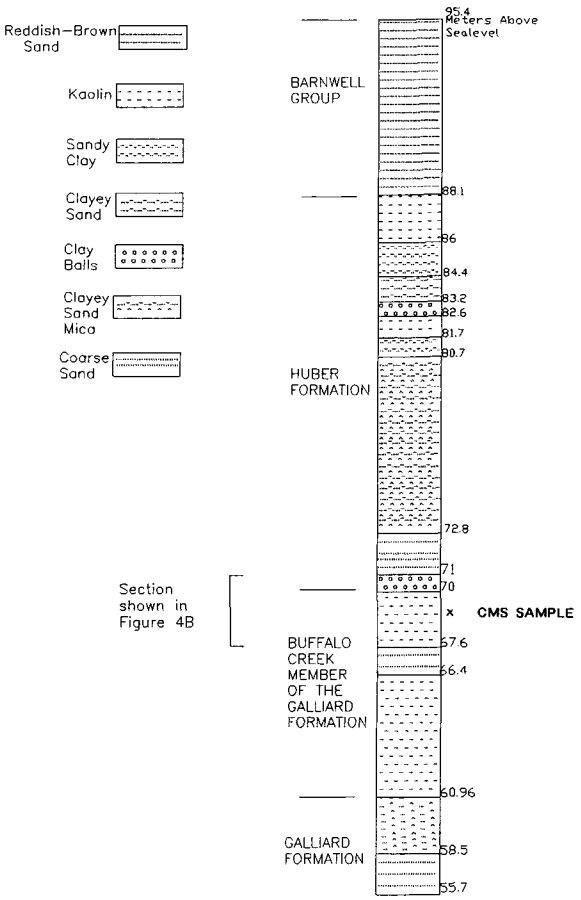


Figure 3. Lithologic section for the Buffalo China Mine showing stratigraphic location of KGa-1B denoted by CMS SAMPLE. This section is based on drill core records and the mine highwall shown in Figure 4A. The sample was collected near the top of the Buffalo Creek Kaolin Member, which is approximately 9 m thick in this mine (see Figure 4B).

mined for paper industry applications (Figures 3, 4A and 4B). The top of the sample site was scraped clean with a bulldozer prior to sampling with a backhoe (Figure 4C). Approximately 3 to 4 m^3 of kaolin were churned with the backhoe to break the kaolin into small chunks prior to placing the clay into four 208-liter fiber drums

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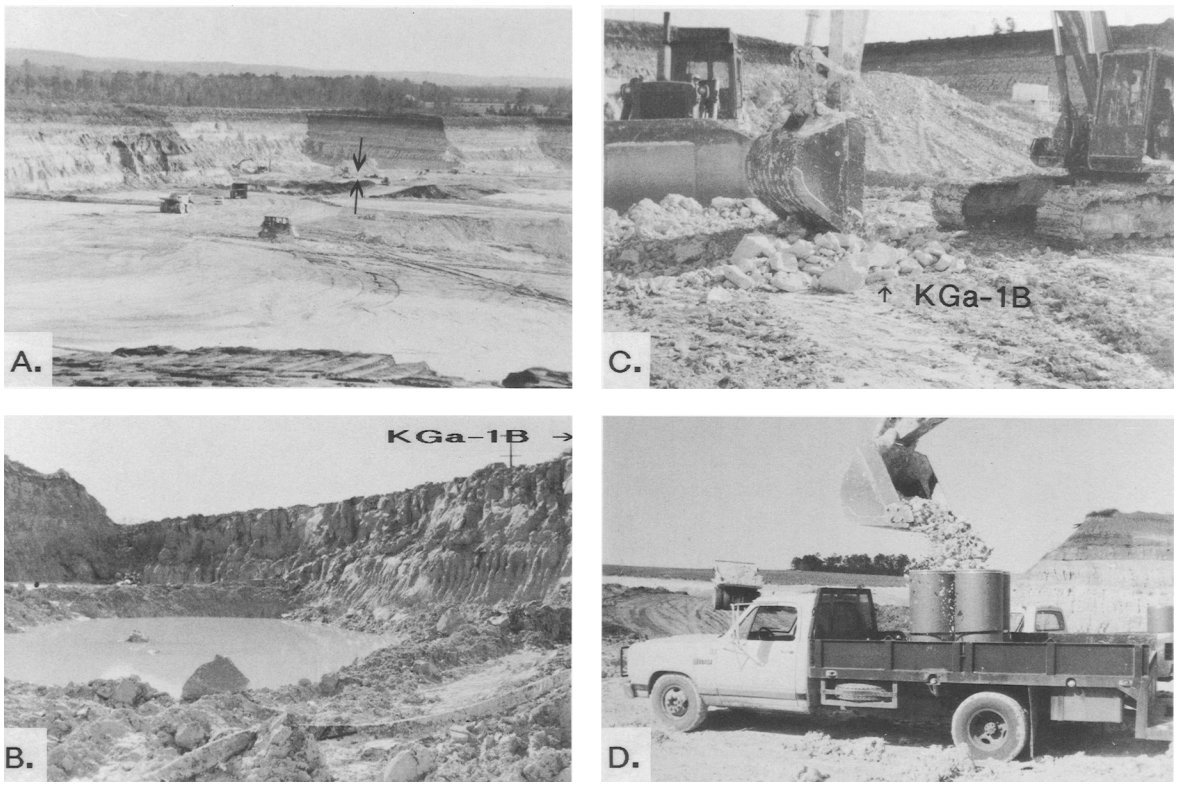


Figure 4. Photographs showing KGa-1B sample collection process: A) An overview of ECCI Buffalo China Mine on January 22, 1993. Arrows bracket location of sample site on mine floor. B) View showing exposed top 3 m of Buffalo Creek Kaolin Member. KGa-1B was collected from the top 1 m of the thick kaolin unit at a location to the right, approximately 5 m west and 30 m north of the mine face illustrated. C) Photo showing backhoe churning KGa-1B in the sample pit indicated by the arrow. The conchoidal fracture visible on the kaolin blocks is typical for "soft" Georgia kaolin. D) Photo showing KGa-1B being loaded into fiber drums used to transport clay to AP Green Industries.

having an interior coating that retains moisture (Figure 4D). The sample weighed 1071 kg with a natural moisture content of 22.5 wt. %. The KGa-1B material was shipped to A.P. Green Industries in Mexico, Missouri, where the clay was dried at 120°C and hammer-milled to pass 200 mesh before shipment in seven drums to the CMS Source Clay Repository.

METHODS

Mineralogical and chemical data on the crude unprocessed kaolin was collected by ECCI's Technology Center in Sandersville, Georgia, and ECCI's Central Labs near St. Austell, Cornwall. X-ray powder diffraction (XRD) analysis was performed on KGa-1; on KGa-1B dried in a 60°C oven, then ground with a SpectroMill® ball pestle impact grinder for 2 min; and on KGa-1B wet-screened through 325 mesh to remove the +44-μm fraction, then dried in a 60° oven, and pulverized 2 min in a Varco grinder. Powders were side-packed into sample holders and analyzed using a Scintag PAD V XRD (CuKα radiation, 45 Kv, 40 ma, HPGe solid state detector) controlled by DMS 2000 software. The <2 μm fraction of KGa-1B was dried onto a glass slide to orient clay particles. XRD analysis of the clay slide after air-drying, exposure to a glycol atmosphere for 48 hr, and heating to 500°C for 2 hr indicated no other clay minerals are present.

Electron microscopy was performed on surfaces of fractured kaolin and on 325 mesh screen residues using a Hitachi S-2500 scanning electron microscope (SEM) interfaced with a Link AN-10,000 energy dispersive X-ray analysis system (EDS). Samples for electron microscopy were mounted on aluminum stubs using silver paint and sputter coated with a mixture of gold and palladium.

A Phillips PW1480 X-ray fluorescence spectrometer (XRF) equipped with a Sc/Mo dual anode X-ray tube was used to quantify the Si, Al, Fe, Ti, Ca, Mg, K, and Na in samples fused and cast into glass discs. The six initial grab samples were analyzed using a Perkin-Elmer Plasma 40 inductively coupled plasma-atomic emission spectrometer (ICP-AES). Total organic carbon (TOC) was determined by the Walkley-Black method (Nelson and Sommers, 1982) with Fe^{++} interference alleviated by drying samples 2 days in a 60°C oven.

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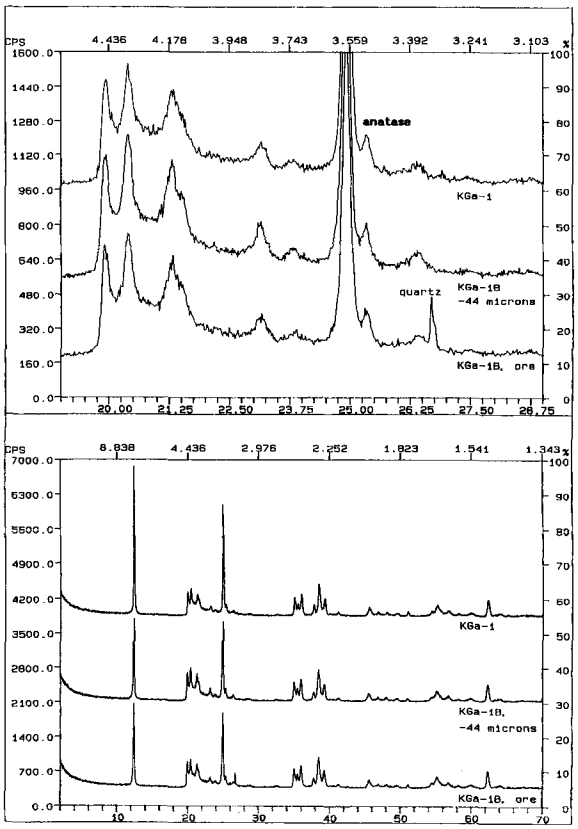


Figure 5. X-ray powder diffraction collected on KGa-1, KGa-1B <44 μm fraction, and KGa-1B crude after 2 min dry-grinding with a Varco model 228 electric grinder. Well-ordered kaolinite and anatase are common to all samples. Quartz is observed in the KGa-1B crude but appears to be removed after wet-screening through 325 mesh.

ANALYTICAL RESULTS

XRD indicates KGa-1 and the <44 μm fraction of KGa-1B are almost identical. Both samples contain well-ordered kaolinite with a trace abundance of anatase (Figure 5). Kaolinite crystallinity values were calculated using two different methods (Table 1) and both methods show KGa-1B having slightly higher crystallinity than KGa-1. The unprocessed KGa-1B ore contains 0.009 wt. % particles >44 μm that include quartz grains, kaolinite stacks, mica plates and anatase agglomerates. Electron microscopy reveals the presence of kaolinite stacks and plates in KGa-1B. The kaolinite stacks can be vertically grooved (Figure 6A) and display edge to face orientation on fractured surfaces (Figure 6B). Pseudohexagonal kaolinite plates dominate the matrix between the kaolinite stacks, and kaolinite plates appear in places to be inter-grown (Figure 6C). Horizontal striations on the edges of some kaolinite plates can be observed (Figure 6D).

Chemical results are reported in Table 2. The unprocessed KGa-1B material corresponds very well to KGa-1. The TOC for unprocessed KGa-1B is 231 ppm, which is within a range typical for cream Georgia kaolins. Nitrogen BET surface area measurements show KGa-1B has a higher, 11.7 m^2/g, surface area than the 8.4 m^2/g measured for KGa-1. The higher surface area of KGa-1B is apparently caused by its finer particle size. SediGraph 5100 particle size measurements indicate KGa-1B is 57.8% <2 μm and 32.0% <0.5 μm, whereas KGa-1 is 47.3% <2 μm and 21.4% <0.5 μm.

Table 1. Kaolinite crystallinity determined for KGa-1 source clay and screened KGa-1B material.

	Method of Hinckley, 1963	Method of Johns and Murray, 1959
KGa-1	1.03	0.23
KGa-1B, <44 μm	1.09	0.34

DISCUSSION

The KGa-1B material is a suitable replacement for KGa-1 because of strong chemical and mineralogical similarities. KGa-1B appears to have more defect-free crystallites than KGa-1. Electron micrographs showing inter-grown kaolinite plates suggests the presence of some diagenetic alteration within the KGa-1B material. No other clay impurities were detected in KGa-1B, although anatase, Fe oxides, quartz, and micas are observed in trace abundances. The high purity and the well formed crystallites of KGa-1B can be related to its occurrence below a regional unconformity overlain by coarse sandstones. The potentially high-meteoric water flux through these very permeable sandstones probably helped to purify the underlying kaolin strata. Oxidizing and low pH conditions probably favored the alteration observed in many Georgia sedimentary kaolin deposits, including organic removal, Fe mineral oxidation, and labile mineral and poorly crystallized material replacement or dissolution. The Al_2O_3 and SiO_2 placed into solution during labile grain dissolution

Table 2. Chemical results* for KGa-1 and crude and screened KGa-1B sample.

	KGa-1B Crude	KGa-1B <44 μm	KGa-1
SiO_2	45.2%	45.1%	45.4%
Al_2O_3	39.1	39.2	39.2
TiO_2	1.64	1.66	1.54
Fe_2O_3	0.21	0.21	0.22
MgO	0.05	0.06	0.02
CaO	0.02	0.03	0.01
Na_2O	0.04	0.03	0.02
K_2O	0.02	0.02	0.04
Loss on Ignition @ 1025°C	13.7	13.8	13.7

* Determined by Peter Salt, ECCI Central Labs.

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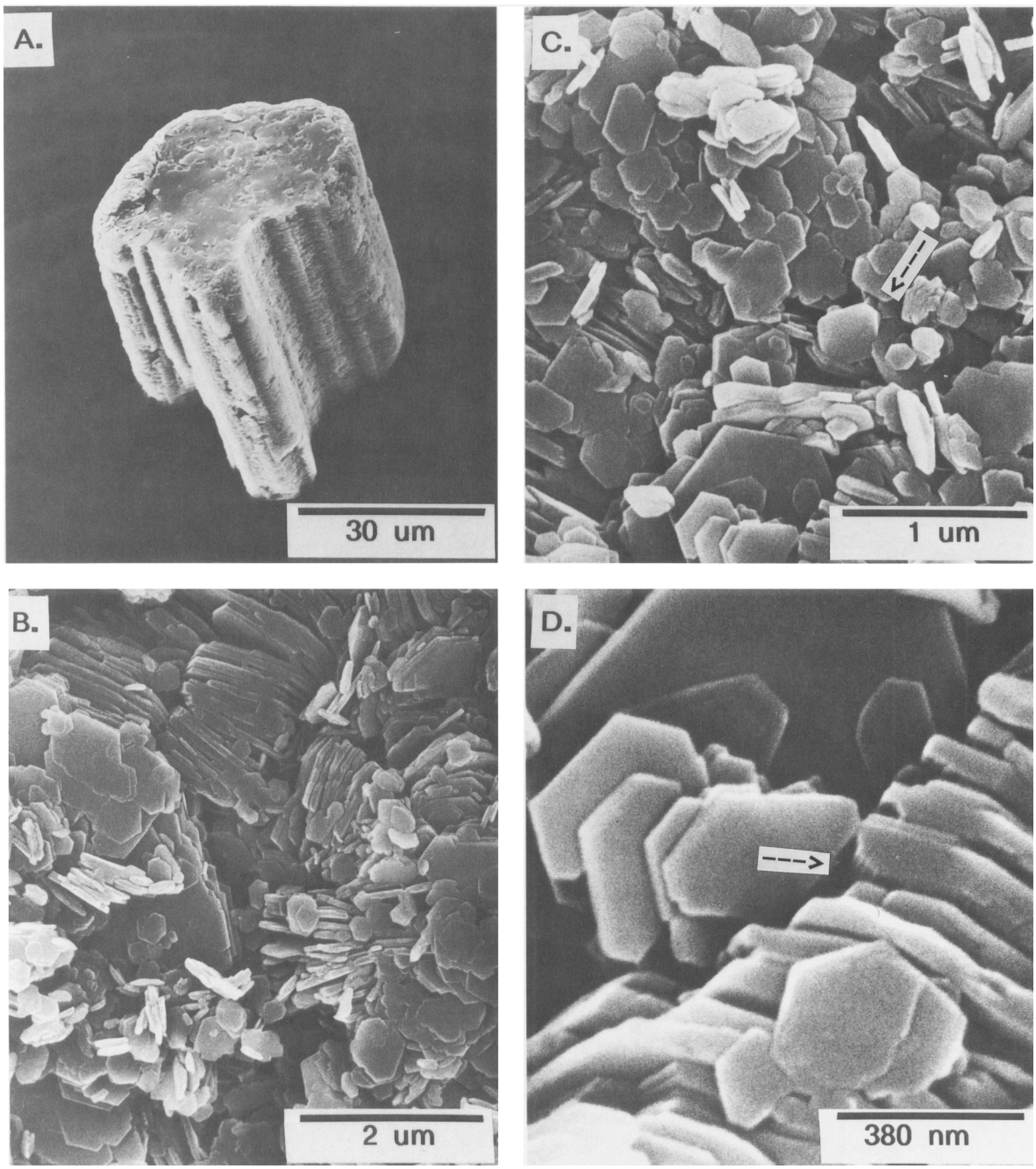


Figure 6. Electron photomicrographs of kaolinite in KGa-1B: A) Large kaolinite stack with vertical grooves that is typical for kaolinite grains retained on the 325 mesh screen. B) Vermiform kaolinite stacks showing edge-to-face orientation on fracture surface. C) Pseudohexagonal kaolinite plates that typify matrix between kaolinite stacks (note inter-locking plates in region indicated by arrow that can be indicative of post-depositional kaolinite precipitation). D) Pseudohexagonal kaolinite plates with interlocking texture (upper right) and kaolinite stack (note horizontal striations on edge face of platelet indicated by arrow). Micrograph D is a closeup of the bottom-center in micrograph C.

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are the probable sources for well-ordered kaolinite precipitation in pore spaces within the kaolin.

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