Geology of a Middle Tertiary Clay Deposit in the Patagonia Mountains near Harshaw, Santa Cruz County, Southeastern Arizona

Chapter I of

Contributions to Industrial-Minerals Research

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Abstract

A middle Tertiary rhyolite tuff on the northeast side of the Patagonia Mountains in Santa Cruz County, southeastern Arizona contains lenses of calcareous low-swelling montmorillonite clay, as much as 10 to 15 m thick. The presence of the tuff has been known for years, but the clay has not been described previously. The clay lenses, which are virtually silt- and sand-free, were probably formed by diagenetic alteration of fairly clean ash-fall-tuff beds. In preliminary tests, the clay exhibited only about 9 percent shrinkage on drying and about 1 percent shrinkage on firing. Cracking and distortion were minimal in both drying and firing. Further testing needs to be done on the clay to determine its suitability as a specialty clay or as an additive to other clays.

Introduction

This chapter reports on a previously undescribed montmorillonite clay deposit associated with upper Oligocene rhyolite tuff. The deposit, which is in Coronado National Forest on the northeast flank of the Patagonia Mountains in southeastern Arizona (figs. 1, 2), is informally termed the “Harshaw clay” after the nearby mining ghost town of Harshaw. Although the deposit may consist of common clay and thus may not have a high value, its characteristics have not been tested adequately. Additional testing may show it to have value as a specialty clay or as an additive to other clays.

Sedimentary clay deposits of middle Miocene through Holocene age (younger than the Harshaw clay) are fairly abundant and widespread in the southern Basin and Range Province of Arizona, where they were deposited chiefly in lakes and playas of closed basins (Patterson, 1969). Because of their position in valleys, the younger deposits generally are easily accessible and near population centers. However, most clays from these geologic settings are common clays that contain an unacceptable amount of mixed-layer smectite, an expandable-clay mineral which may cause excessive shrinkage, warping, and cracking during drying. Thus, many clay deposits in Arizona are economically undesirable.

The Harshaw clay of the present study is composed of smectite but in the form of low-swelling Ca montmorillonite. Preliminary tests show that shrinkage of the clay is about 10 percent upon drying, with no cracking and with minimal additional shrinkage upon firing. The relatively low shrinkage, and identification of the dominant clay mineral as Ca mont-

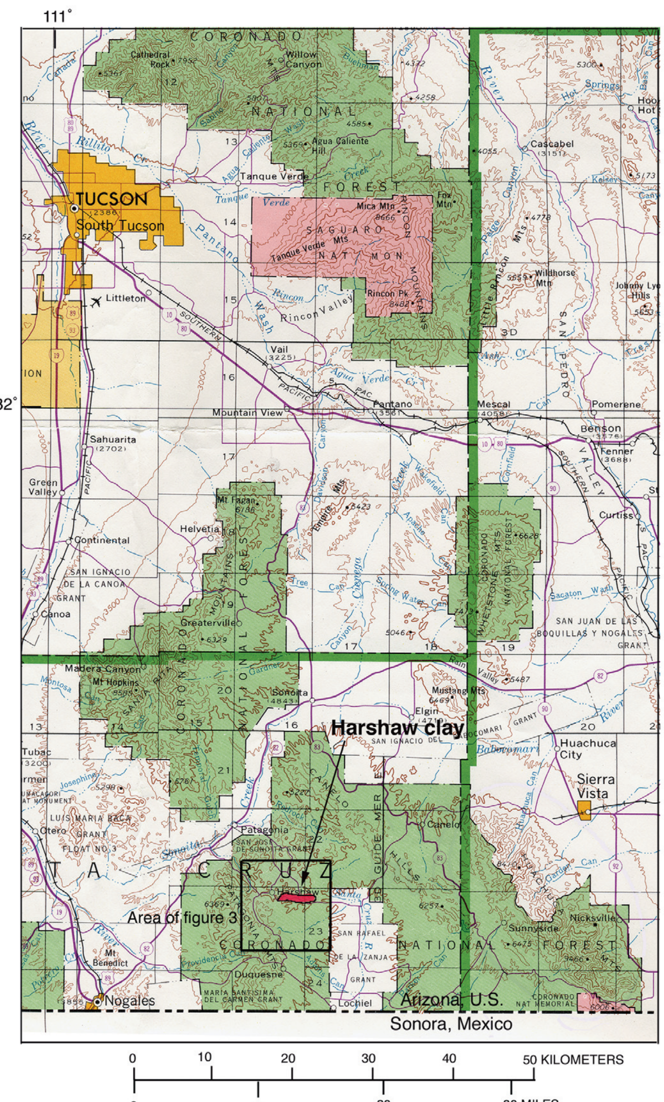


Figure 1. Southeastern Arizona, showing location of the Harshaw clay (in red) relative to Tucson and major highways. Base from U.S. Geological Survey 1:500,000-scale map (1974).

morillonite, are encouraging enough to recommend further testing of material from this deposit.

Geologic Setting

The Harshaw clay crops out on the northeast side of the Patagonia Mountains, where it is associated with Tertiary rhyolite tuff (units Tt, Tl, fig. 3; Simons, 1974). The tuff, which is exposed on both the northeast and northwest sides of the mountains, probably was deposited across the intervening area as well, but it was removed by erosion during Basin and Range faulting and uplift of the Patagonia Mountains in late Tertiary time. The source of the tuff is unknown, although it is coeval with the Oligocene rhyodacitic to rhyolitic Grosvenor Hills Volcanics to the northwest in the adjacent southern Santa Rita Mountains (fig. 1; Drewes, 1968, p. C14–C15; Drewes, 1971; Simons, 1974). Simons reported four K-Ar ages for the tuff that average 25.3 Ma. A new $^{40}Ar/^{39}Ar$ date of 27.65±0.25 Ma was obtained on hornblende in the tuff for this study (M.J. Kunk, written commun., 2004). Because of the greater precision of the $^{40}Ar/^{39}Ar$ method, 27.65±0.25 Ma is the preferred age the tuff.

The tuff is similar on both sides of the range, although its massive clay facies apparently is present only on the northeast side. The section on the northwest side of the Patagonia Mountains consists of as much as 45 m of pumiceous biotite rhyolite ash-fall and ash-flow tuff. Simons (1974) reported that the contact is unconformable between the tuff and underlying Upper Cretaceous volcanic rocks. The top of the tuff is unconformably(?) overlain by middle or upper Tertiary conglomerate.

Northeastern Tuff with Clay Facies and Limestone Cap

The tuff section on the northeast side of the Patagonia Mountains also is as much as 45 m thick, but in places 10 to 15 m of the section consists of massive lenticular clay bodies, in addition to ash-fall and ash-flow tuff (figs. 4, 5). Furthermore, in the easternmost 0.6 km of the outcrop belt (east of U.S. Forest Service Road 58, fig. 4), the upper 2 to 5 m of the section is an ash-fall tuff that has been altered to very hard limestone and opaline chalcedony with wavy laminar bedding (Tl of Simons, 1974). The presence of clay and the limestone cap suggests that the tuff on the northeast side of the Patagonia Mountains had a different diagenetic history from that on the northwest side.

The northeastern tuff crops out in a band, about 4 km long by 0.6 km wide, between Upper Cretaceous volcanic rocks (unit Ka, figs. 3, 4) on the north and middle and upper Cenozoic sedimentary rocks (units Tal, QTal) on the south. Along the north edge of the exposure (west of U.S. Forest Service Road 58, fig. 4), the tuff unconformably overlies Upper Cretaceous trachyandesite flows. The detailed geologic map (fig. 4) shows that east of the road, a basal conglomerate, about 10 m thick, lies between the tuff and trachyandesite. The basal conglomerate is also exposed beneath the tuff in two outcrops farther to the south (fig. 4). These two exposures may have been topographic highs around which the tuff was deposited. The basal conglomerate is dated at probably middle Tertiary (unit Tal), on the basis of its position just below and conformable with the 27.65-Ma tuff.

Along its south edge, the tuff either underlies or is in lateral facies relation with the indurated conglomerate (unit Tal, fig. 4) that probably is coeval with the tuff, as mentioned above (fig. 4). The trachyandesite, tuff, and middle Tertiary conglomerate are all overlain unconformably by poorly indurated gravelly deposits of upper Tertiary basin-fill alluvium and a thin layer of piedmont alluvium commonly dated as Quaternary (unit Qtal, figs. 3, 4). On the detailed geologic map (fig. 4), the middle Tertiary conglomerate (unit Tal) is differentiated from the basin-fill alluvium and piedmont gravel (unit QTal), whereas Simons (1974) mapped all the conglomerate and gravel together as his unit QTal (fig. 3).

The stratigraphy of the tuff and clay is not uniform throughout the deposit, possibly because of high-energy emplacement of the ash-flow tuff. Thus, in some places the clay facies underlies the tuff, in other places at the east end of the exposure the clay facies is absent, and at the west end the clay appears to lie between upper and lower ash-flow-tuff beds. Along the south edge of the western part of the exposure, the clay facies appears to extend to the top of the ridge (fig. 4), indicating that the clay may be more than 20 m thick here, although this indicated thickness is tenuous because of inadequate exposures.

Both the tuff and the middle Tertiary conglomerate are mildly deformed and dip generally about 5°–25° S. A zone

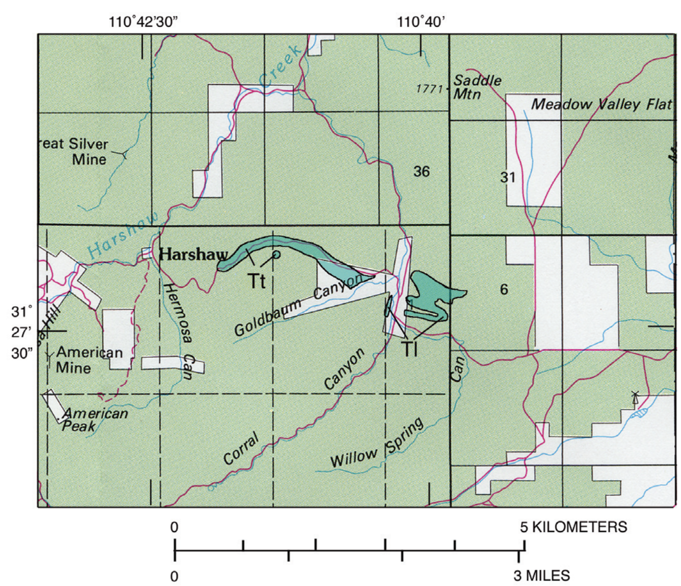
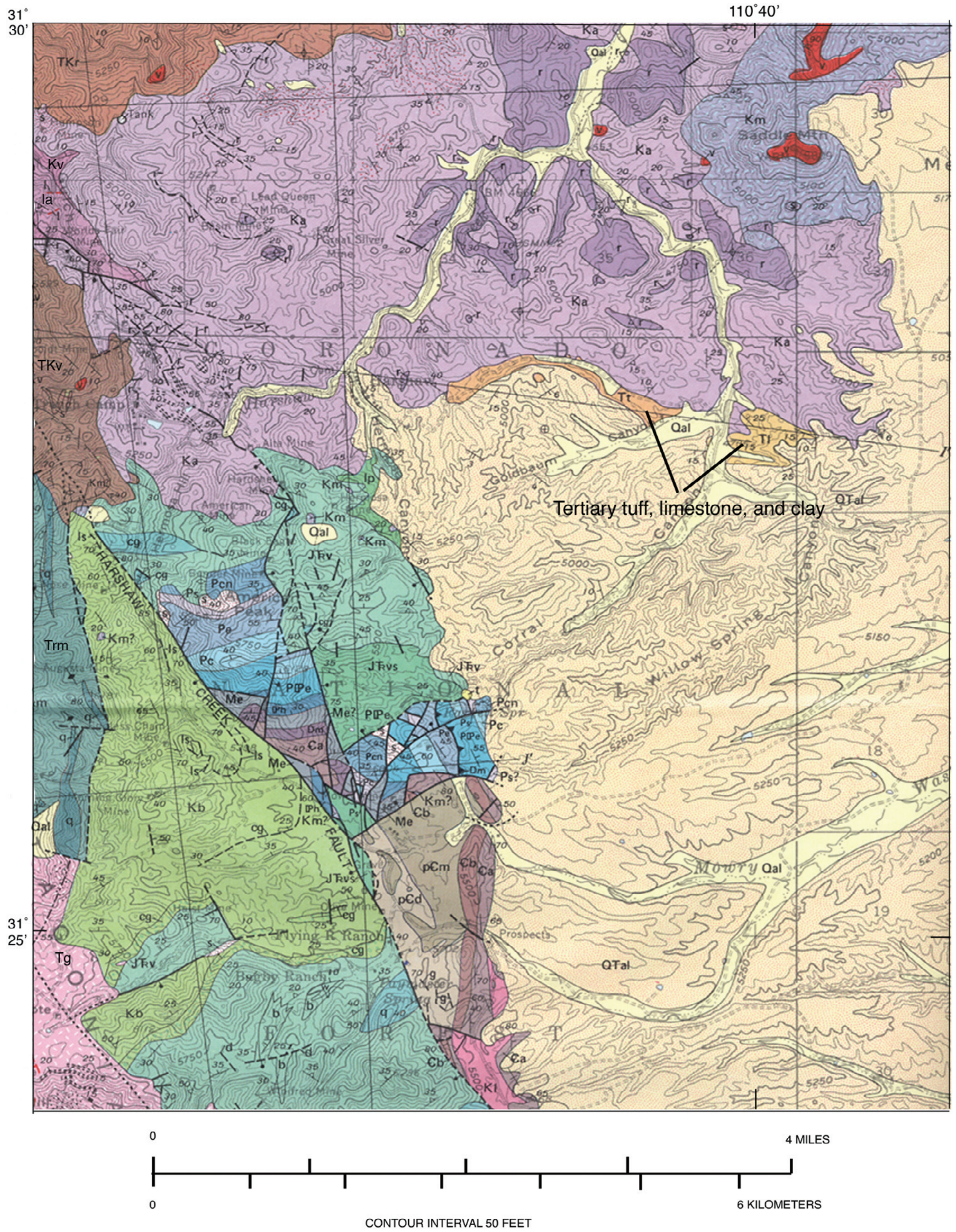


Figure 2. Harshaw, Ariz. area in Coronado National Forest, showing areas of Tertiary tuff (Tt, Tl) with which the Harshaw clay is associated. White areas, privately owned land. Base from U.S. Bureau of Land Management Surface Management Status map of the Nogales 1:100,000-scale quadrangle (1990).



EXPLANATION

Qal, QTal - Quaternary and upper Tertiary alluvium

Tt, Tl - middle Tertiary tuff and limestone

Tg - Paleocene granodiorite

TKv, TKr - Paleocene or Upper Cretaceous volcanic rocks; v, Volcanic neck

Km, Ka, Kv - Upper Cretaceous monzonite, trachyandesite, and silicic volcanic rocks: r, v, la, rhyolite, volcanic neck, or latitic dike or plug

Kb - Lower Cretaceous Bisbee Formation: cg, limestone; ls, limestone

JTrv, JTrvs, Trm - Jurassic and Triassic volcanic and sedimentary rocks: lp, latite porphyry; cg, limestone conglomerate (exotic block?); q, quartzite exotic block

Pcn, Ps, Pe, Pc, PPe, Ph - Permian and Pennsylvanian Naco Formation

Me - Mississippian Escabrosa Limestone

Dm - Devonian Martin Limestone

Ca - Cambrian Abrigo Limestone

Cb - Cambrian Bolsa Quartzite

pCm, pCd - Precambrian monzonite and diorite

Figure 3. Part of geologic map of the Nogales and Lochiel quadrangles, southeastern Arizona (Simons, 1974), showing outcrops of Tertiary tuff, limestone, and clay (units Tt, Tl) with which the Harshaw clay is associated and relation of tuff to Cretaceous andesite (unit Ka) on the north and to Tertiary and Quaternary alluvium (unit Qtal) on the south.

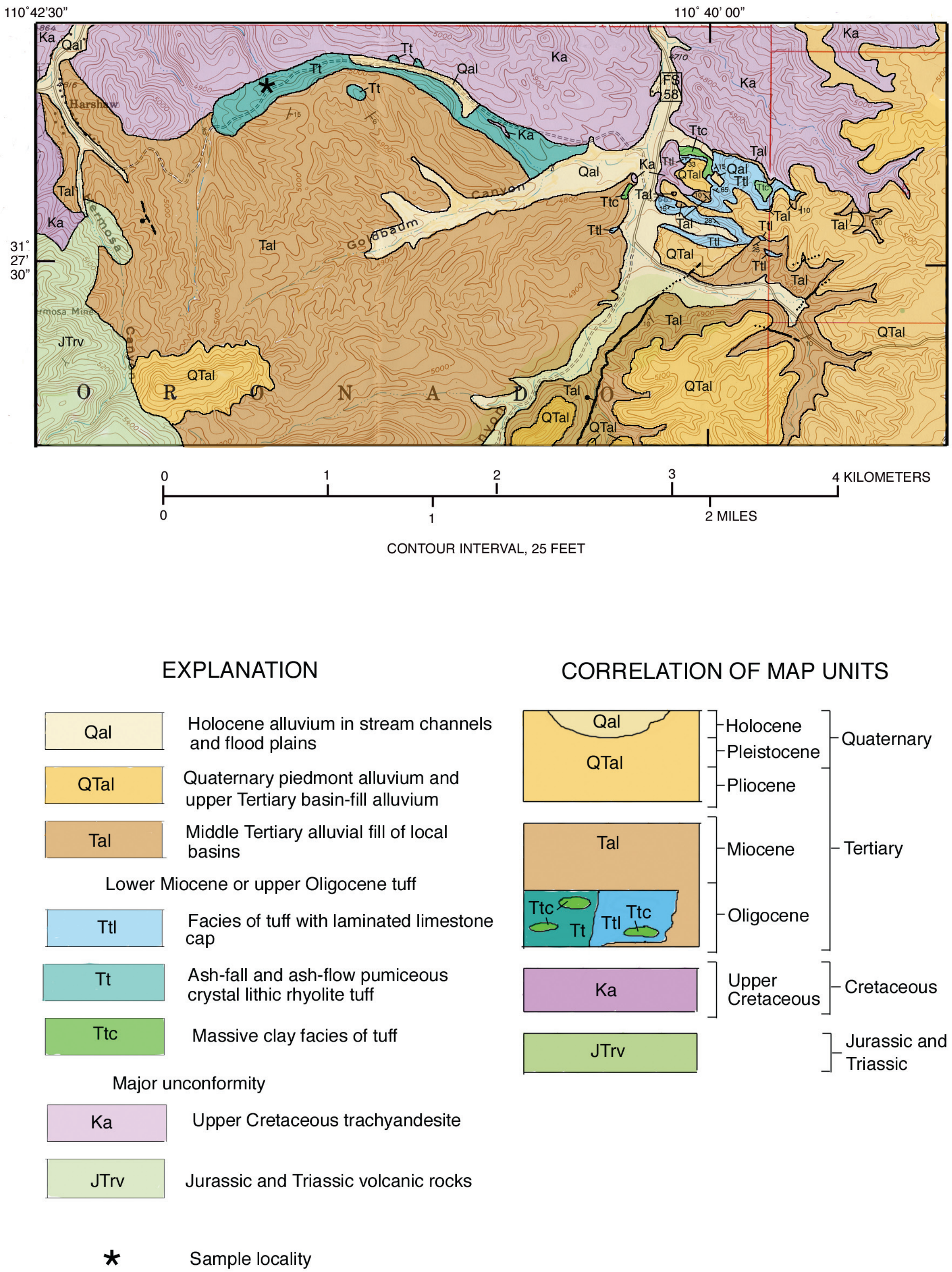


Figure 4. Detailed geologic map of the Tertiary tuff (unit Tt) and limestone (unit Ttl) and the Harshaw clay (unit Ttc) (modified from Simons, 1974). Massive clay facies is present in both western and eastern parts of map area, but because of poor exposure, the Harshaw clay (unit Ttc) was not differentiated west of U.S. Forest Service Road 58 (FS 58). Base from U.S. Geological Survey 1:24,000-scale map of the Harshaw quadrangle (1958).

of steep (25°–65°) northerly dips in the limestone cap of the tuff (fig. 4) may indicate the presence of faulting, although no faults were observed. Northeast-trending faults are common in the middle Tertiary conglomerate and probably also in the tuff, but because of poor outcrop, mapping of the faults or determination of their displacement is difficult. The two outcrops of the basal conglomerate (unit Tal) surrounded by tuff in the eastern part of the exposure may be fault controlled, or, as suggested above, they may have been topographic highs over which the tuff was deposited.

Depositional Environment of the Harshaw Clay

The presence of clay lenses, as much as 15 m thick, within the tuff section and of interlaminated limestone and opaline chalcedony at the top of the tuff (east of U.S. Forest Service Road 58, fig. 4) may indicate that the tuff was partly deposited in a body of standing water. In fact, Simons (1974) described his unit Tl as freshwater limestone. However, detailed inspection in the present study revealed no sedimentary structures, such as crossbedding, mud cracks, trace fossils, or ripple marks on bedding planes, nor such pedogenic features as paleosols and root casts. No ostracode tests were visible in hand specimens of the limestone or in crushed samples of the clay in oil.

Given the absence of sedimentary structures, I interpret the clay lenses and limestone cap of the tuff as products of diagenesis in the presence of Ca-rich alkaline ground water. The massive clay beds most probably represent altered ash-fall tuff that, because of its distance from the likely eruptive source, contained no lithic fragments or pumice and few crystals. The interlaminated microcrystalline limestone and opaline chalcedony facies at the top of the tuff in the easternmost 0.6 km of the outcrop belt (east of U.S. Forst Service Road 58, fig. 4) is traceable downsection into featureless, very fine grained light-gray material that also appears to have originally been a thin-layered ash-fall tuff.

Figure 5. Outcrops of the Harshaw clay near sample locality at the west end of figure 4. *A*, Fresh surface of the Harshaw clay in outcrop, showing blocky fracture pattern and absence of obvious bedding. *B*, Weathered clay slope developed on pale-red and yellowish-gray massive clay. Larger shrubs are about 1 m high.

Description of the Harshaw Clay

The Harshaw clay occurs both as massive, slope-forming beds, 10 to 15 m thick, near the base or middle of the Tertiary rhyolite tuff and as thin laminated beds interbedded with tuff near the top of the section. The massive clay near the base or middle of the tuff is pale red (10R 6/2) (Goddard, 1948) or yellowish gray (5Y 7/2); the laminated clay interbedded with tuff, commonly near the top, is yellowish gray. The massive clay was the subject of further testing, as detailed below.

Except for their color, both the pale-red and yellowish-gray varieties of the massive clay are nearly identical. Clay of both colors contains very little silt and virtually no sand-size detritus. Both varieties are semi-indurated and break into blocky fragments, less than 1 cm across (fig. 5*A*). Although the clay does not slake upon contact with water, wetting and drying causes it to break up into smaller and smaller fragments so that weathered slopes are covered with a layer of loose sand-size clay particles, about 15 cm deep (fig. 5*B*). The induration of the Harshaw clay is probably due to its middle Tertiary age. The presence of calcite cement also may be a factor, although in places where the clay is not calcareous, it still is well indurated.

X-ray-diffraction analysis of samples of both varieties of the massive clay collected at the locality shown in figures 4 and 5 demonstrated the mineral composition to be montmorillonite, muscovite, calcite, quartz, orthoclase, and dolomite (Carol Gent and Steve Sutley, written commun., 2002). The clay was not examined in thin section, and so the distribution of mineral phases is unknown, although montmorillonite is predominant. Calcite, composing about 20 weight percent by solution in HCl, does not occur as visible crystals or nodules in hand specimen; and in outcrop, calcite-filled joints are relatively uncommon. Muscovite occurs as widely separated, very small flakes (sericite). Orthoclase and dolomite were detected in trace amounts. Clear quartz grains and hornblende crystals are rare and are the only minerals in the massive clay that are clearly of original volcanic rather than diagenetic origin. Interestingly, hornblende was observed only in the yellowish-gray colored clay.

Samples of the pale-red and yellowish-gray varieties of the massive clay were ground in a mortar and pestle, mixed with water, and then dried and aged for 2 to 3 days to a working consistency. The clay was rolled out into slabs and cut with a template to form tiles 2.5 by 10.2 cm (fig. 6*A*). Drying-and-firing tests were run on these tiles. Drying shrinkage was about 9 percent (slightly greater for the pale-red than for the yellowish-gray variety), with no cracking or warping. This amount of shrinkage is about the average of the approximately 30 other noncommercial clays tested. After drying, the tiles were fired under mostly oxidizing conditions in a propane kiln to 900°C for about 4 hours (Paul Thornburg, written commun., 2003). An additional shrinkage of 1 percent or less occurred upon firing, with no cracking or warping (fig. 6*B*). After firing, the surface of the yellowish-gray clay was rough with white speckles (fig. 6*B*), and its color was light brown (5YR 6/4), whereas the surface of the pale-red clay was smooth, and its color was pale reddish brown (10R 5/4). The rough texture and speckling of the yellowish-gray clay after firing may be due to less thorough grinding than for the pale-red clay.

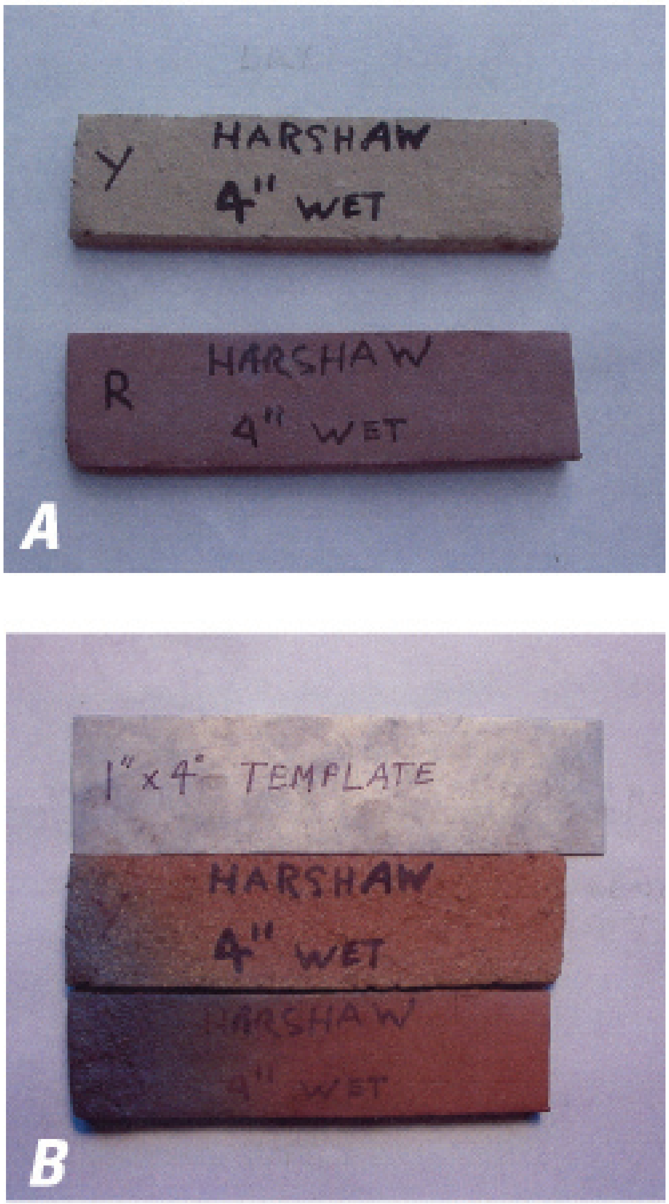


Figure 6. Test tiles of Harshaw clay. Clay samples were collected at locality shown in figures 4 and 5. R, pale-red variety of clay; Y, yellowish-gray variety of clay. "4 in. wet" notation printed on tiles refers to initial length (10.2 cm) when wet. *A*, Test tiles after drying but before firing. Tiles are about 9.2 cm long, demonstrating shrinkage of about 9 percent on drying. *B*, Test tiles after firing. Upper tile is 9.1 cm long, and lower tile is 8.9 cm long, demonstrating additional shrinkage of less than 1 percent on firing.

Summary

The Harshaw clay consists of Ca montmorillonite probably derived from diagenetic alteration of Tertiary (27.65 Ma) rhyolite tuff. The source of the tuff was volcanic eruptions, most likely in the vicinity of the present-day Santa Rita Mountains. The tuff was deposited as ash flows and ash falls.

The tuff is exposed in a narrow belt, about 4 km long by 0.2 to 0.6 km wide. Clay lenses, as much as 15 m or more thick, interbedded with relatively unaltered tuff, occur along the length of the exposure. Thinner laminated clay beds are interbedded with ash-fall tuff near the top of the tuff at the east end of the exposure.

Although exposures are poor, the thick clay lenses appear to be fairly clean and homogeneous. Virtually no sand or silt is present, and the clay seems to be uniformly calcareous, although the easternmost clay body (fig. 4) is noncalcareous in a few places. The clay is semi-indurated, possibly with some calcite cement, and requires grinding before it can be mixed with water and formed. Shrinkage upon drying and firing is about 9 and 1 percent, respectively with no cracking or warping. The clay is pale red or yellowish gray; after firing, it is pale reddish brown and light brown, respectively.

Because the Harshaw clay is composed of montmorillonite and is relatively stable upon forming and firing, additional testing is needed to determine whether it is suitable for use as a specialty clay or as an additive to other clays. If the Harshaw clay does have useful characteristics, then a drilling program should be undertaken to determine whether the deposit is sizable enough to offset its relatively remote location.

Acknowledgments

Norman Hale and his family kindly allowed access across their property to the clay deposits. I thank Paul and Laurel Thornburg, potters in Sonoita, Ariz., for their interest

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