Clay Deposits of the Denver-Golden Area, Colorado[1]

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CLAY DEPOSITS OF THE DENVER-GOLDEN AREA, COLORADO

KARL M. WAAGÉ
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ABSTRACT

Approximately 280,000 tons of clay and shale are mined annually in Jefferson and Douglas Counties, Colorado, for use in the clay-products industries of the Denver-Golden area. About 85 percent of the clay is used in the manufacture of brick, tile, and sewer pipe; the remainder is used in the manufacture of refractory products.

Refractory clay is found in commercial bodies only in the top of the Glencairn shale member of the Purgatoire formation, directly beneath the Dakota sandstone. Owing to local stratigraphic variations, such clay bodies are restricted to three areas: (1) from Golden northward to Coal Creek, (2) from Golden southward to the Alameda Parkway, and (3) from the South Platte River southward for a distance of 6 miles. Absence of clay of refractory grade in the Glencairn shale member north of Coal Creek appears to be coincident with a major change in facies within the member. Most of the refractory clay has been taken from the clay bodies in the Denver-Golden area, and preliminary geologic studies of the clay-bearing beds indicate that chances are against finding new bodies of refractory clay of commercial value in this area.

About 80 percent of the brick, tile, and sewer-pipe clay is mined from the Laramie formation. Some 26 individual clay beds are present in this formation, but only the lower four or five contain clay deposits of commercial value. Some brick clay used in Denver clay-products plants is mined from the Dawson arkose in the vicinity of Castle Rock. Other formations in the Denver-Golden area furnish small amounts of brick and tile clay; these include the Fountain, Lykins, and Morrison formations, the Lytle sandstone member and Glencairn shale member of the Purgatoire formation, and the Benton shale. Surficial deposits of loess in the

city of Denver support a small industry of dry-pressed brick. The supply of raw clay for the production of brick, tile, and sewer pipe appears to be sufficient to support the local industries for some time to come.

INTRODUCTION

Deposits of clay of several kinds in Jefferson and Douglas Counties, Colorado, led to establishment of a clay-products industry as early as 1865 (Berthoud, 1880, p. 374) and have supported a subsequent growth that has made the Denver-Golden area the leading center of clay-products manufacture in the Western Interior region. In 1951, 15 companies in Denver and Golden were utilizing Colorado clay in the manufacture of a variety of products including common brick, building brick, structural tile, sewer pipe, terra cotta, refractory brick and shapes, and earthenware. Clay from other regions in the United States and from abroad is used, both alone and mixed with local clay, in the manufacture of porcelain, other refractory specialties, and some kinds of pottery.

Approximately 300,000 tons of Colorado clay and shale are now being used annually by the clay-products industries in the Denver-Golden area. Of this amount about 280,000 tons is mined in Jefferson and Douglas Counties; the remainder is brought from Pueblo County. Eighty-five percent of the clay is used in the manufacture of brick, tile, and sewer pipe; brick is the principal product, and more than 90,000,000 bricks are produced annually in the Denver area. Most of the remaining 15 percent of the clay is used in the manufacture of refractory products; less than 1 percent is used in the manufacture of terra cotta and earthenware. A new industry that will utilize low-grade bloating clay and shale in the manufacture of light-weight concrete blocks has been started in Denver and, if the plant is run at capacity, will consume an additional 100,000 tons of clay annually.

The clay supply comes from at least nine different geologic formations but a single formation, the Laramie, sup-

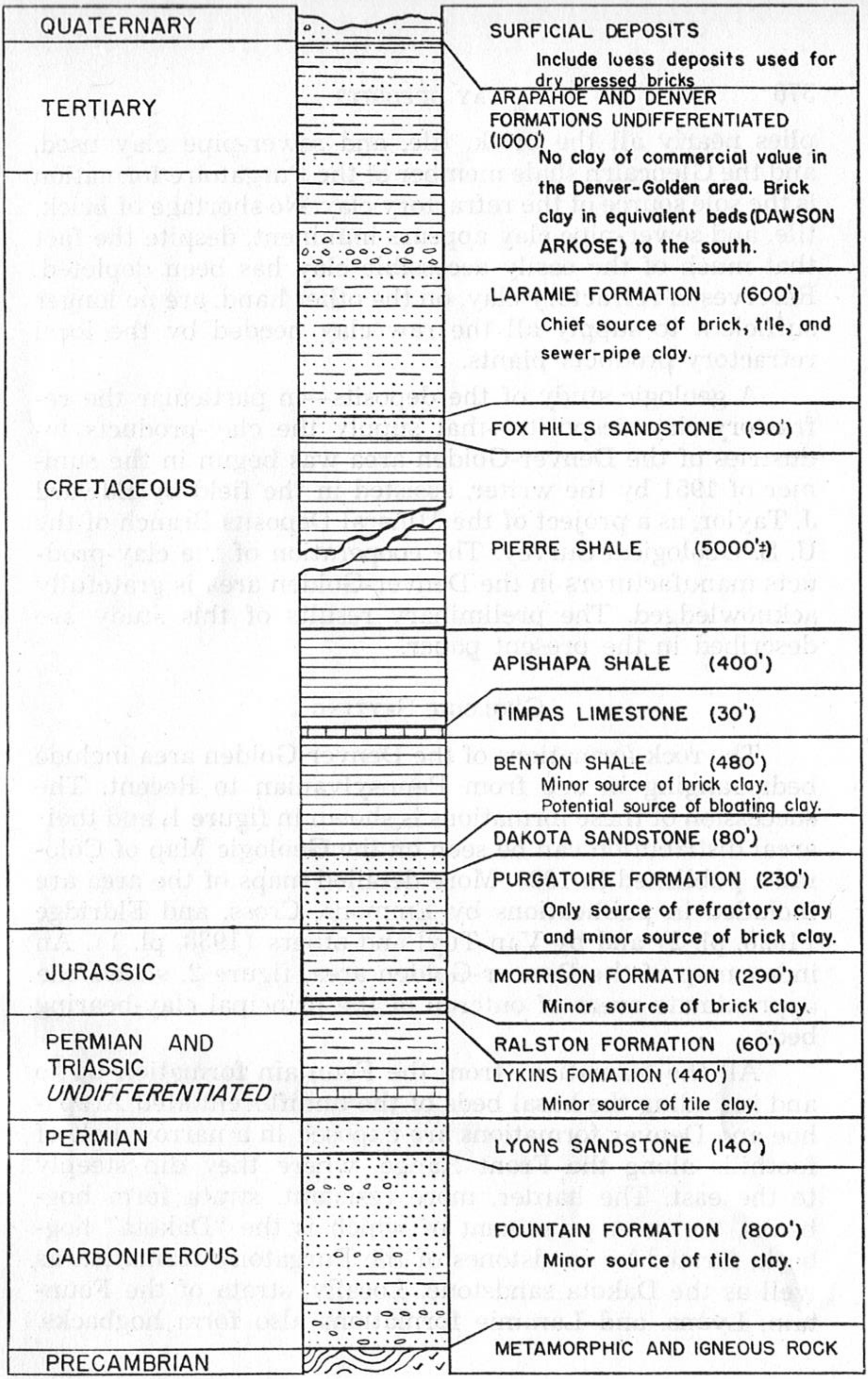

Figure I. Generalized stratigraphic section of rocks exposed in the Denver-Golden area.

plies nearly all the brick, tile, and sewer-pipe clay used, and the Glencairn shale member of the Purgatoire formation is the sole source of the refractory clay. No shortage of brick, tile, and sewer-pipe clay appears imminent, despite the fact that much of the easily accessible clay has been depleted. Reserves of refractory clay, on the other hand, are no longer sufficient to supply all the raw clay needed by the local refractory-products plants.

A geologic study of the deposits—in particular the refractory-clay desposits—that supply the clay-products industries of the Denver-Golden area was begun in the summer of 1951 by the writer, assisted in the field by Edward J. Taylor, as a project of the Mineral Deposits Branch of the U. S. Geological Survey. The cooperation of the clay-products manufacturers in the Denver-Golden area is gratefully acknowledged. The preliminary results of this study are described in the present paper.

Geologic Setting

The rock formations of the Denver-Golden area include beds ranging in age from Pennsylvanian to Recent. The succession of these formations is shown in figure 1, and their areal distribution can be seen on the Geologic Map of Colorado, published in 1935. More detailed maps of the area are included in publications by Emmons, Cross, and Eldridge (1896, pl. 2) and by Van Tuyl and others (1938, pl. 1). An index map of the Denver-Golden area, figure 2, shows the approximate areas of outcrop of the principal clay-bearing beds.

All the formations from the Fountain formation up to and including the basal beds of the undifferentiated Arapahoe and Denver formations are exposed in a narrow belt of foothills along the Front Range, where they dip steeply to the east. The harder, more resistant, strata form hogbacks, the most prominent of which is the "Dakota" hogback, formed by sandstones of the Purgatoire formation as well as the Dakota sandstone. Locally, strata of the Fountain, Lyons, and Laramie formations also form hogbacks.

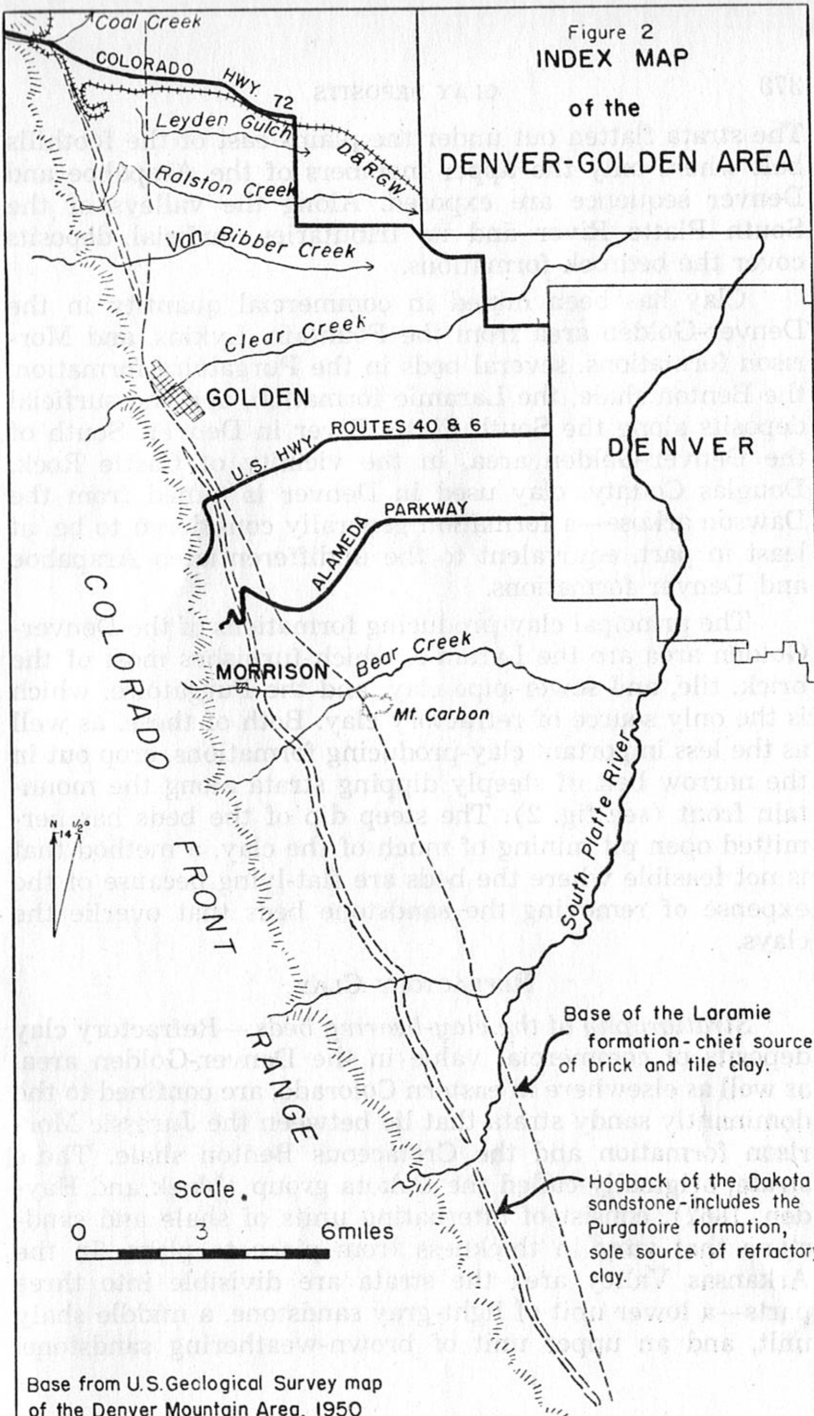

Figure 2
INDEX MAP
of the
DENVER-GOLDEN AREA

The strata flatten out under the plains east of the foothills belt where only the upper members of the Arapahoe and Denver sequence are exposed. Along the valleys of the South Platte River and its tributaries surficial deposits cover the bedrock formations.

Clay has been mined in commercial quantity in the Denver-Golden area from the Fountain, Lykins, and Morrison formations, several beds in the Purgatoire formation, the Benton shale, the Laramie formation, and the surficial deposits along the South Platte River in Denver. South of the Denver-Golden area, in the vicinity of Castle Rock, Douglas County, clay used in Denver is mined from the Dawson arkose—a formation generally considered to be, at least in part, equivalent to the undifferentiated Arapahoe and Denver formations.

The principal clay-producing formations of the Denver-Golden area are the Laramie, which furnishes most of the brick, tile, and sewer-pipe clay, and the Purgatoire, which is the only source of refractory clay. Both of these, as well as the less important clay-producing formations, crop out in the narrow belt of steeply dipping strata along the mountain front (*see* fig. 2). The steep dip of the beds has permitted open pit mining of much of the clay, a method that is not feasible where the beds are flat-lying because of the expense of removing the sandstone beds that overlie the clays.

Refractory Clay

Stratigraphy of the clay-bearing beds.—Refractory clay deposits of commercial value in the Denver-Golden area, as well as elsewhere in eastern Colorado, are confined to the dominantly sandy strata that lie between the Jurassic Morrison formation and the Cretaceous Benton shale. These strata, originally called the Dakota group (Meek and Hayden, 1862), consist of alternating units of shale and sandstone that vary in thickness from place to place. In the Arkansas Valley area the strata are divisible into three parts—a lower unit of light-gray sandstone, a middle shaly unit, and an upper unit of brown-weathering sandstone.

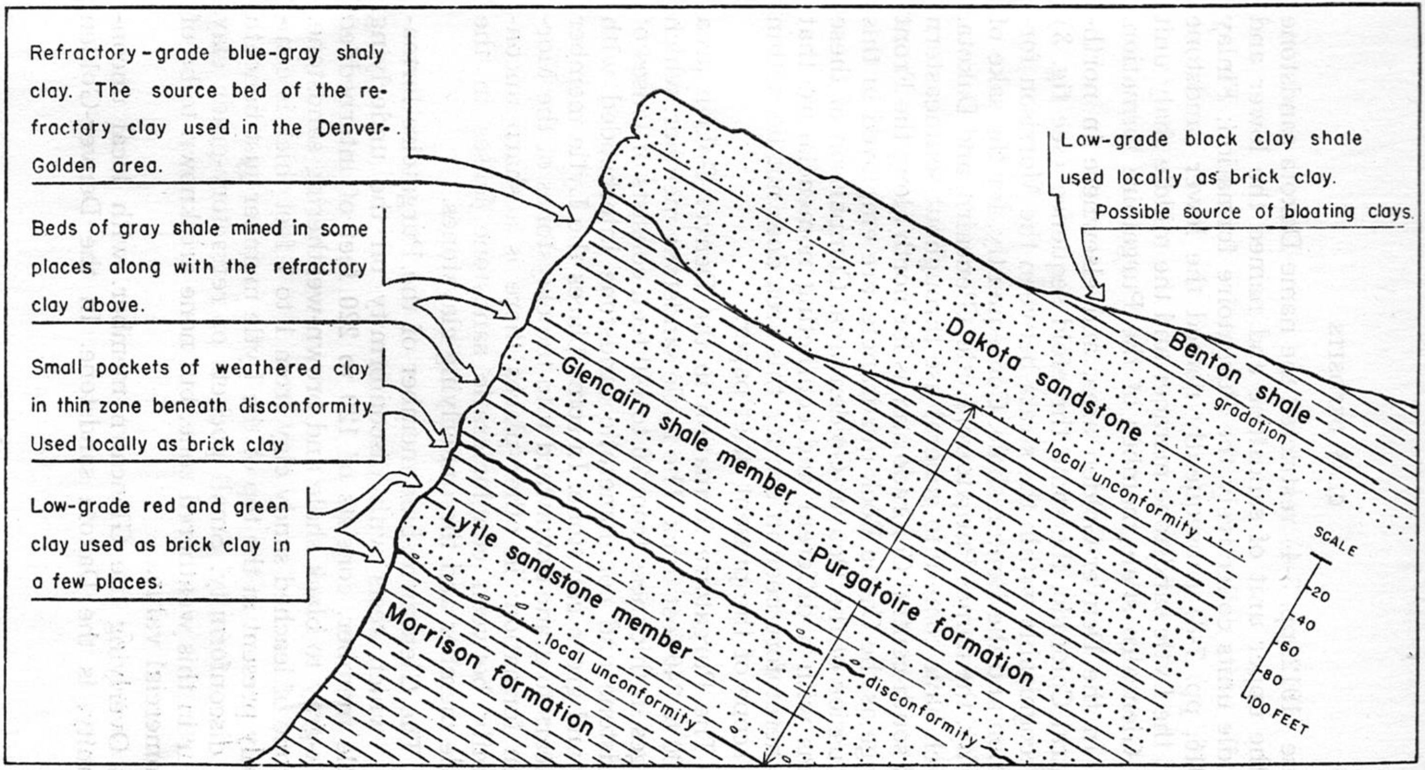

Figure 3. Clay-bearing strata in and adjacent to the Dakota hogback in the Denver-Golden area.

Stose (1912, pp. 3-4) restricted the name Dakota sandstone to the upper unit of sandstone and named the lower and middle units collectively the Purgatoire formation; Finlay (1916, pp. 7-8) subsequently named the lower sandstone unit the Lytle sandstone member and the middle shaly unit the Glencairn shale member of the Purgatoire formation.

In the Denver-Golden area, and elsewhere in north-central Colorado, the same threefold sequence (*see* fig. 3) is recognizable within the strata between the Morrison formation and the Benton shale. Consequently, for the sake of clarity, the names Purgatoire, Lytle, Glencairn, and Dakota, which have come into general use throughout southeastern and south-central Colorado and as far north along the Front Range as the Castle Rock quadrangle, are employed in this discussion of the Denver-Golden area. Comparison of these terms with a different and conflicting nomenclature that has heretofore been in use for this area does not lie within the scope of the present brief paper.

The Purgatoire formation in the Denver-Golden area is 200 to 340 feet thick. The Lytle sandstone member, which ranges in thickness from 70 to 140 feet, consists of lenses of sandstone and conglomeratic sandstone interbedded with red and green claystone. In some places the Lytle member appears to grade downward into the claystones of the Morrison formation; in other places there is a sharp unconformity between conglomeratic sandstone lenses in the Lytle member and the underlying claystones.

The Glencairn shale member of the Purgatoire formation, which rests with disconformity on the underlying Lytle member, consists of 120 to 220 feet of interbedded dark-gray to black shale and brown-weathering sandstone. A zone of leached sandy clay from 1 to 7 feet thick is commonly present in the top of the Lytle member just beneath the disconformity. Small pockets of refractory-grade clay occur in this weathered zone, but none are known to be of commercial value.

Overlying the Glencairn member, with local unconformity, is the Dakota sandstone. In the Denver-Golden area the Dakota consists of 30 to 85 feet of brown-weathering fine-grained sandstone with local zones of shale, the most persistent of which occur in the middle of the unit. Extensive deposits of flint clay, such as those in the middle of the Dakota sandstone in the Pueblo-Canon City area (Waagé, 1947), are not present in the Denver-Golden area.

The Glencairn shale member of the Purgatoire formation is the source of all the refractory clay mined in the Denver-Golden area. Where this member is clay-bearing it commonly consists of three or four units of shale alternating with three units of sandstone. The shale units vary in thickness; some of them are as much as 30 feet thick. The sandstone units are also variable in thickness and locally coalesce, pinching out the shale units. The uppermost shale unit, lying directly beneath the Dakota sandstone, contains refractory and semirefractory clay at several places. The other shale units rarely contain refractory clay and are in general much more silty and sandy than the upper shale unit. All the shale is fairly carbonaceous, and both the sandstone and shale units contain plant remains. Through a fortuitous distribution of very thin beds of a light-colored bentonite-like clay it is possible to distinguish between the different shale units of the Glencairn even where only one or two of them are exposed. The upper shale unit, the principal source bed for refractory clay, has a single bentonite-like layer near the base; the second shale unit, descending, has one near the top; the third unit has two such beds about one-third of the way from the top and from the bottom of the unit; and the fourth shale unit, which is only locally present, contains no bentonite-like layers.

Clay of the Glencairn shale member.—On unweathered surfaces the clay in the upper shale unit of the Glencairn member is dark gray and relatively hard, with a splintery to conchoidal fracture. It can be classified as semiplastic clay, but at a few localities it is almost a semiflint clay. The fusion point of most of the clay is cone 30 or 31, with a maximum of cone 33 recorded for clay from a few localities.

Refractory clay at the top of the Glencairn shale member has been mined in the Denver-Golden area since about 1865. In some localities clay bodies in other shale units of the Glencairn member have been mined along with it. The upper shale unit contains clay bodies in the hogbacks between Golden and Coal Creek, between Golden and the Alameda Parkway, and for a distance of 6 miles south of the point where the South Platte River crosses the hogback of the Purgatoire and Dakota formations. Elsewhere in northeastern Colorado the upper shale unit is either absent or contains only low-grade shale. The distribution of refractory clay in the upper shale unit of the Glencairn appears to be governed by two local and one regional stratigraphic feature. The clay-bearing unit pinches out abruptly about 3 miles south of Golden, where the overlying Dakota sandstone has been deposited in channels cut into and through the upper shale unit of the Glencairn. The cutout extends for a distance of about 6 miles south along the hogback, and even farther south the upper shale unit consists in many places of shaly siltstone. The increase in silt in the upper shale unit and the occurrence of additional channel-type cutouts at the base of the Dakota have effectively eliminated the refractory-clay bed, except for small pockets, as far south as the South Platte River. Between the South Platte and a locality about 6 miles to the south, where the belt of outcrop of the Dakota sandstone and Purgatoire formation is interrupted by faulting, the clay is locally present in bodies of minable size and grade.

From Coal Creek northward, no commercial body of refractory clay is known in the upper shale unit of the Glencairn shale member and a regional lithologic change in the member at this place makes the presence of such clay in economic amounts unlikely. Going northward from Coal Creek, all sandstone beds of the Glencairn member (except the lowest) thin gradually, grading into siltstone and shale; all shale units (except the upper shale) thicken and, from Lyons northward, contain thin beds of calcareous siltstone with marine fossils; the upper shale unit becomes thinner and, near Lyons, increasingly silty, grading into argillaceous siltstone with rare marine fossils in the hogback between Little Thompson Creek and Big Thompson River. This silty phase persists northward to the Wyoming state line, merging with the overlying Dakota sandstone and becoming inseparable from it. The change in the Glencairn member north of Coal Creek is thus a transition from a plant-bearing succession of sandstone and shale beds, probably deposited in coastal swamp and deltaic environments, to a dominantly shaly sequence of strata with shell-bearing calcareous beds, deposited in a shallow marine environment.

The change in the upper clay-bearing unit of the Glencairn member between Coal Creek and Lyons is difficult to trace because of lack of exposures. In this area the overlying Dakota sandstone thins greatly, in some places to as little as a foot, and only locally does it form a protective ridge above the clay. Samples of the clay from exposures between Eldorado Springs and Lyons are silty, shaly and hard; none tested to date are of refractory grade.

The nature of the change from refractory-grade clay to low-grade clay that accompanies this northward change in facies is not completely understood. An increase in the silt content of the clay is one obvious factor. An increase in fluxible impurities and a difference in the clay mineralogy may also contribute to the reduction in grade, but the importance of these possibilities cannot be evaluated until the completion of chemical and mineralogical tests. Kaolinite is the dominant clay mineral in the refractory clay; the clay minerals in the marine facies have yet to be determined.

Reserves of refractory clay.—The principal bodies of clay in the Glencairn shale member between Coal Creek and the pinchout south of Golden have either been removed or been depleted close to the economic limit of mining, and the few holdings that contain reserves of the clay are not available to the local industry. Reconnaissance indicates that farther south, beyond the South Platte River, most of the more easily accessible refractory clay has been mined. North of Coal Creek, no deposits of refractory clay have been found in the Glencairn member, and in the light of the northward change in facies within this member, it is unlikely that any are present. If the more detailed studies now in progress substantiate this appraisal of refractory-clay reserves, the refractory-products plants in the Denver-Golden area will soon have to look elsewhere for the bulk of their raw clay supply.

Brick, Tile, and Sewer-pipe Clay

Approximately 80 percent of the brick, tile, and sewer-pipe clay used in the Denver Golden area is obtained from the Laramie formation. Clay from the Dawson arkose of the Castle Rock area contributes about 8 percent; it is the only brick clay brought in from outside the Denver-Golden area. Surficial deposits contribute about 5 percent of the clay used, the Morrision formation and Lytle sandstone member of the Purgatoire formation about 3 percent, and the Fountain and Lykins formations, and Benton shale about 2 percent. The remaining 2 percent, mined from the Glencairn shale member of the Purgatoire formation, is actually clay of refractory grade that is used, in mixes, for face brick and structural tile.

Clay of the Laramie formation.—Alternating beds of sandstone, sandy clay, clay, and, locally, coal, make up the Laramie formation in the Denver-Golden area. Individual beds appear to be discontinuous, and the thickness of the formation is variable. Detailed sections measured by Leroy (1946, pp. 91-99) indicate that the Laramie is about 600 feet thick in this area. As many as 26 individual clay beds are present in the Laramie, but only the lowermost 4 or 5 beds are extensively mined. The higher clay beds are generally thinner and sandier, and the clay is inferior in grade. Gude (1950, p. 1703) has shown that the Laramie formation in the clay pits south of Golden contains three well-defined zones of clay minerals—a lower zone in which kaolinite is the dominant clay mineral; a middle zone characterized by a mixture of illite-, kaolinite-, and montmorillonite-type clay minerals; and an upper zone containing illite and kaolinite. If this zonation should prove to have lateral continuity, the presence of a persistent kaolinitic zone in the lower part of the Laramie formation would help to explain the restriction of the better-grade clay to the basal clay beds.

The clays in the lower beds of the Laramie formation are variable. They burn from red to light buff in color and generally range from cone 12 to cone 23 in fusion point. The basal clay bed is commonly a buff-burning clay, and at a very few localities where the bed has been shattered by faulting and exposed to weathering, the clay qualifies as a low-grade refractory clay. It has been used as a bond clay in refractory products.

The Laramie formation crops out continuously along the mountain front in the Denver-Golden area except for a distance of about a mile north of Van Bibber Creek, where it is eliminated by faulting (Van Tuyl and others, 1938, p. 34). The lower clay beds of the Laramie have been extensively mined between State Highway 72, near Coal Creek, and the Alameda Parkway west of Denver—an airline distance of about 14 miles. They have also been mined along Bear Creek east of Morrison. Between Bear Creek and State Highway 72 the lower beds of the Laramie are vertical or nearly so and are mined by open pit. The thickness of each of the 4 lower beds averages about 5 feet but varies considerably from place to place. At some localities the sandstone beds between the clay beds are soft and argillaceous and are mined along with the clay. Coal is locally present in thin beds overlying the clay beds.

The most extensive workings in clay of the Laramie formation are in and just south of Golden; second to these are the open pits and mines along the sharp hogback formed by lower sandstone beds of the Laramie between the Denver & Rio Grande Western Railroad tracks (Moffat Tunnel Route) and the head of Leyden Gulch. Other workings lie north and south of U. S. Highway 40, on both sides of the Alameda Parkway, and near Bear Creek east of Morrison, where beds of the Laramie are exposed in a hill called Mount Carbon.

No figures are available showing the amount of clay that has been mined from the Laramie formation in the Denver-Golden area, nor have any surveys been made that would indicate the magnitude of clay reserves in the formation. Although the Golden and Leyden Gulch areas still lead in the volume of clay mined, both have small reserves left. Some clay remains to be mined between Golden and U. S. Highway 40, and it is possible that more can be mined from old workings between U. S. Highway 40 and the Alameda Parkway. Between Golden and Leyden Gulch the only appreciable production from the Laramie has come from the small hogback south of Van Bibber Creek.

Clay of the Dawson arkose.—Clay used by brick and tile plants in the Denver-Golden area has been mined from the Dawson arkose in the vicinity of Castle Rock for many years. The clay bodies occur as irregular lenses interbedded with arkosic sandstone and conglomerate. According to Richardson (1915, p. 7) the conglomeratic beds and their included clays are in the lower part of the formation.

Clay bodies in the Dawson arkose are haphazardly distributed and commonly contain such an heterogeneous mixture of clays that selective mining of the better grades is seldom possible. In the clay mines west of Castle Rock about 9 feet of yellow plastic clay overlies about 6 feet of mottled gray and red plastic clay. The fusion point of run-of-mine clay, which is a mixture of the types, averages about cone 18. Narrow channels filled with arkosic conglomeratic sandstone cut deeply into the clay bodies and penetrate them in some places. Abrupt lateral changes in the grade of the clay are caused by an increase in the silt and sand content and also by the intercalation of beds made up largely of mica flakes.

Clay bodies like those in the Dawson arkose have not been found in equivalent beds of the Arapahoe and Denver formations, and it is unlikely that such clay bodies exist in the Denver-Golden area. Although the Dawson arkose and the Arapahoe-Denver formations were derived contemporaneously from the Front Range to the west, they differ in lithology because the rocks in their respective source areas are different. The Dawson arkose, as Richardson (1915, pp. 7-8) has noted in the Castle Rock quadrangle, is derived chiefly from the mass of Pikes Peak granite that is exposed in the Front Range west and southwest of the Castle Rock area. The known deposits of clay of the type that is mined at Castle Rock are restricted to the Dawson arkose and doubtless were also derived from residual material formed by weathering of the granite. The Pikes Peak granite extends northward in the Front Range only to about the latitude of Louviers (Lovering and Goddard, 1951, pl. 1), 11 miles northeast of Castle Rock, and is not present as a possible source rock in the Front Range west of the Denver-Golden area.

Other sources of clay.—Minor quantities of clay from the Morrison formation, the Lytle and Glencairn members of the Purgatoire formation, and the Benton shale, are used by some companies in mixes with clay from the Laramie formation and Dawson arkose.

Several companies utilize red, sandy clay from the Fountain and Lykins formations in the manufacture of red sill and roof tile. The clay in the Fountain formation occurs as lenses near the base of the unit; one small pit about 2 miles south of Golden is worked intermittently. The clay in the Lykins is also near the base of the formation; clay is taken as needed from two pits, one near Fireclay Siding on the Denver & Rio Grande Western Railroad and the other at Plainview.

Mottled red and green clay of low grade occurs in beds as much as 25 feet thick, interbedded with massive sandstone, in the top of the Morrison formation and in the lower part of the Lytle sandstone member of the Purgatoire formation. The clay of these beds does not qualify as good brick clay, but it has been used successfully in mixes with clay from the Laramie formation.

A yellow to white sandy clay occurs at the top of the Lytle member of the Purgatoire formation, just beneath the disconformity that separates the Lytle and Glencairn members. The bed containing this clay is rarely thicker, and is generally thinner, than 6 feet. Locally the clay has a high fusion point; but, because of mixture with sand and the inclusion of silty zones impregnated with iron oxide, the clay varies so much in grade that the bed is of little or no value as a source of refractory clay. In some places the clay grades downward into sandstone and elsewhere into mottled red and green claystone similar to that in the Morrison formation. In at least one locality, clay has been mined from the top of the Lytle member for use in a mix with clay from the Laramie formation. The clay zone itself occurs locally throughout northeastern Colorado. All the clay samples of refractory grade listed by Butler (1914, pp. 233-254) from Larimer County come from the clay at the top of the Lytle. The clay probably owes its local high grade to leaching of the claystone at the top of the Lytle sandstone member during the period of erosion represented by the disconformity between the Lytle and Glencairn members. Local clay deposits of economic grade and thickness may possibly occur in this zone, but the high sand content generally present and the local concentration of iron oxide make this a remote possibility.

Some of the clay of refractory grade mined from the Glencairn member of the Purgatoire formation is used, in mixes with the Laramie clay, for the manufacture of brick and structural tile. This is not a common practice, and the amount of refractory clay so used is comparatively small.

Minor amounts of the black marine clay shale at the base of the Benton shale are also used in mixes with clay from the Laramie. The black shale is variable in quality and at best is fairly good red-burning brick clay. In many places it bloats readily and cannot be used in brick making. It is a potential source of bloating clay that could be used in the manufacture of light-weight concrete blocks. Great quantities of the shale are available for this purpose; the lower 20 to 40 feet of the Benton shale is a continuous zone of relatively lime-free shale that crops out along the east base of the Dakota hogback in a position suitable for strip mining.

The surficial deposits of loess in and around Denver are extensively used for the manufacture of dry-pressed bricks. Ample supplies of loess are available along the valleys of the South Platte and its tributaries.

Outlook for Clay

The reserves of refractory clay in known bodies within the Denver-Golden area are dwindling rapidly. No new deposits have been found here in recent years, and no deposits appear to be present in beds of the Purgatoire formation cropping out in the hogbacks north of the area. The refractory-products industry in Denver and Golden will eventually be faced with the necessity of obtaining most of its supply of raw clay from other areas. The nearest outside source, and one that has supplied at least one Denver company with some of its clay for many years, is the Pueblo-Canon City area, where considerable reserves of refractory clay are present in a clay-bearing unit in the middle of the Dakota sandstone.

Brick, tile, and sewer-pipe clay appears to be in plentiful supply, although the more obvious and accessible deposits have been largely removed. Most of the clay pits and mines in the Laramie formation are situated (1) in areas where the formation crops out in low hills or hogbacks, (2) in areas where it crops out in stream valleys, and (3) in areas adjacent to towns. Between these places, beds of the Laramie formation underlie flat areas that are locally covered with gravel. The Laramie clay beds under these flats have not been explored, and the depth and accessibility of the clay is unknown. If the basal beds of clay are continuous between productive areas without appreciable change in grade or in depth beneath the surface, the supply of clay should be sufficient to support the industry for many years.

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