Clay and Shale Resources of Spencer County, Indiana[1]

GEORGE S. AUSTIN
Indiana Geological Survey, Bloomington, Indiana 47401

Abstract

Clay mineral analyses of the less-than-2-micron fraction and particle-size analyses were run on 128 of the 152 samples collected in the summer and fall of 1972 from rocks of Pennsylvanian age in Spencer County. Shales, siltstones, mudstones, underclays, and a few sandstones were sampled. The clay mineral suite of these rocks consists dominantly of illite, kaolinite, and mixed-layer (mixed-lattice) clay minerals. Chlorite is present in minor amounts, principally in shales and mudstones. A minor amount of smectite is found in a few samples taken from weathered exposures.

Thick shales suitable both in clay mineralogy and particle-size for use as raw material for manufacturing structural clay products and expanded shale lightweight aggregate are found above and below the Buffaloville Coal Member and its underclay, and below the Mariah Hill and St. Meinrad Coal Beds and their underclays. An underclay and subjacent shale below a thin unnamed coal found about 30 feet below the Buffaloville Coal Member offer another possible source of raw material. The thick underclays contain kaolinite as the dominant clay mineral and can be used for pottery manufacture or for raw material additives in structural clay products and cement. In all, four thick units of rock should be examined further as possible sources of clay raw material.

Introduction

A program to study the clay and shale of Spencer County, Indiana (Fig. 1), was initiated by the Indiana Geological Survey in the

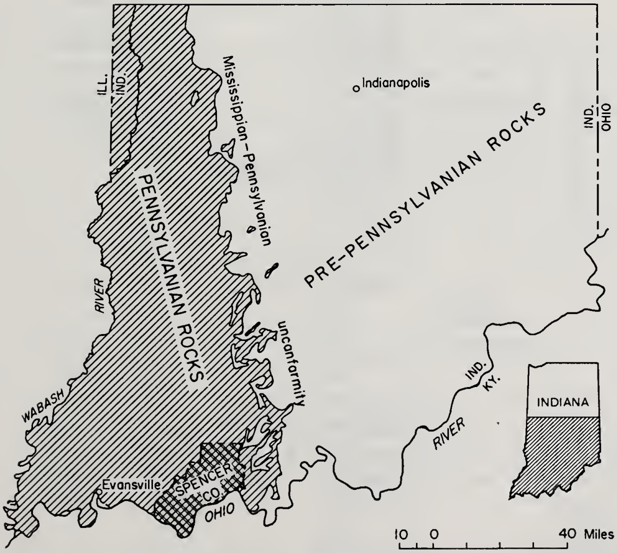

FIGURE 1. *Map showing the location of Spencer County, Pennsylvanian and pre-Pensylvanian rocks, and the Mississippian-Pennsylvanian unconformity in southern Indiana.*

---

[1] Published with permission of the State Geologist, Indiana Geological Survey.

summer of 1972. Exposures of argillaceous rock in the county were described and sampled and the samples were tested to determine their possible use as a source of raw material for industry.

Pennsylvanian clayey formations, more than 600 feet thick, overlie the irregular Mississippian-Pennsylvanian unconformity in Spencer County and dip to the west-southwest at about 20 to 30 feet per mile. Mississippian rocks are found only in the deeply incised valleys in the northeastern part of the county and here they are mantled with alluvium.

From the bottom upward the Pennsylvanian formations (Fig. 2) cropping out in Spencer County are the Mansfield, Brazil, Staunton, Linton, Petersburg, and Dugger. Nearly all of the 152 samples collected to date for this study come from the Mansfield, Brazil, and Staunton Formations. Because the Lower Block Coal Member, the lowermost unit in the Brazil Formation, is poorly developed in this area, rock units are related to the major coals in this part of the section rather than to the Mansfield-Brazil contact.

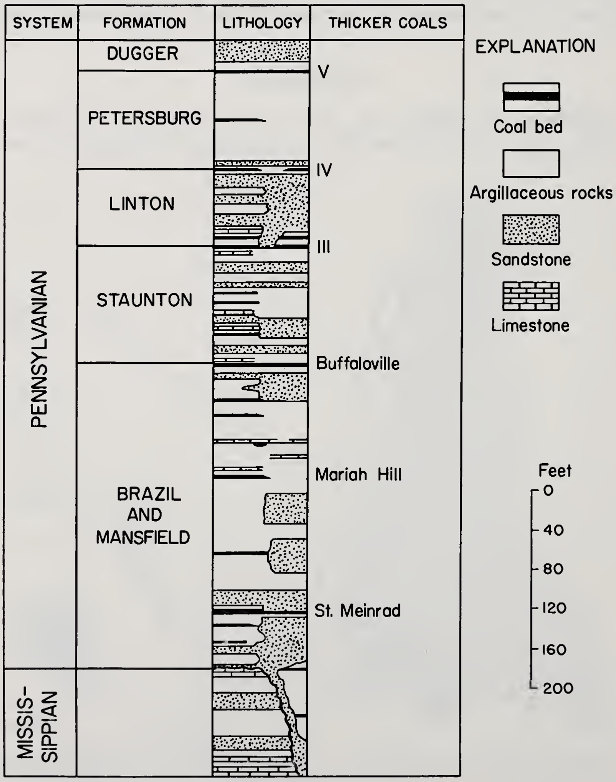

FIGURE 2. *Generalized columnar section of outcropping rocks in Spencer County. The Lower Block Coal Member is poorly developed and thus the Mansfield and Brazil Formations are not differentiated. Modified from Hutchison (3, 4).*

The most numerous and extensive exposures of Pennsylvanian formations are in eastern and central Spencer County, where considerable relief and sizeable stripping operations have exposed the argillaceous rocks above the St. Meinrad, Mariah Hill, and Buffaloville coals (Fig. 3). Only a few small exposures are found in the western and southern parts of the county and in rocks above Coal III.

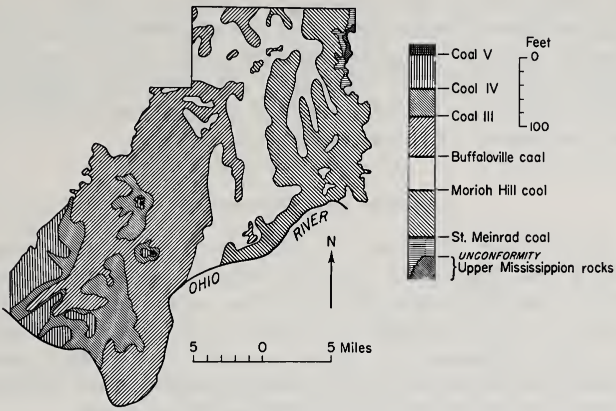

FIGURE 3. *Map showing the location of the major coals in Spencer County. Modified from Hutchison (3).*

Analytical Procedure

For the most part, limestones and sulfides, the two most objectionable constituents of a ceramic clay, are rare or absent from the argillaceous rock samples in Spencer County. Consequently, many of the properties, and therefore the value of these rocks, can be determined in general terms by two simple tests, particle-size analysis and clay mineral analysis. In this study the samples were dried in an oven at 105°C for about 24 hours and then crushed and mixed. The percentage of clay-, silt-, and sand plus-size (larger than 1/16 mm) particles was determined on an approximately 20-gram split by sieving to remove the grains greater than 1/16 mm and then pipetting to separate the clay and silt particles. Non-clay minerals in argillaceous rocks are dominated by quartz and are unaffected by the heat in most ceramic processing. Non-clay particles in amounts as much as 25 and 60%, respectively, of sand and silt may be acceptable for some ceramic products. The actual upper limit for non-clay particles depends on the use and necessary properties of the finished product. In this study the clay-size particles in these samples of clay material range from 20 to 95% by weight.

For the clay mineral analysis a small amount of each sample (about 20 g) was placed in distilled water and allowed to disperse. For a few samples several drops of NH_4OH were used as a dispersing agent and for a very few stubborn samples Calgon was used. Oriented aggregates of the less-than-2-micron fraction obtained by sedimentation were prepared on glass slides and dried at room temperature. For each sample, three X-ray diffractograms were obtained: on the air-dried clay slide, on the slide after soaking in an ethylene glycol atmosphere for approximately 24 hours, and on the slide after heating at 300°C for approximately 1 hour. Nickel-filtered copper radiation was used throughout the study.

The proportion of the major clay mineral groups in the clay material is in part directly related to the relative peak heights on the diffractogram, and the percentage of each group can be calculated from these curves. This method is considered to be fast and simple but semiquantitative, and thus the clay mineral groups are assigned parts in 10 rather than parts in 100 (per cent).

Applied Clay Mineralogy

The rocks sampled consist of shales, siltstones, mudstones, underclays, and a few sandstones. The clay mineral suite, regardless of the rock type, consists dominantly of illite, kaolinite, and mixed-layer (mixed-lattice) clays. Chlorite is present in small amounts, principally in shales and mudstones. A minor amount of smectite (montmorillonite group) is found in a few samples taken from weathered exposures and probably is related to modern soil development.

Clay materials containing a high proportion of kaolinite have high refractoriness and water absorption, intermediate drying shrinkage, and low firing shrinkage and fired strength (Table 1). Clay materials containing a high proportion of illite have high firing shrinkage and fired strength, intermediate refractoriness, and low drying shrinkage and water absorption. Clay materials with a high proportion of mixed-layer clays have high drying shrinkage; intermediate firing shrinkage, fired strength, and water absorption; and low refractoriness. Mixed-layer clays also show severe bloating characteristics upon heating. High-chlorite sedimentary clays are rare and therefore seldom used for ceramic purposes; however, their plasticity is known to be poor and their refractoriness is intermediate. Many of the cations in chlorites, chiefly iron, impart a brown, red, or black color to the fired products.

TABLE 1. *The influence of clay mineralogy on some ceramic properties. Modified from Elberty (1) and Grimshaw (2).*

	Kaolinite	Illite	Mixed Layer	Chlorite
Refractoriness (resistance to heat)	High	Intermed.	Low	Intermed.
Water Absorption (after firing)	High	Low	Intermed.	—
Drying Shrinkage (before firing)	Intermed.	Low	High	—
Firing Shrinkage	Low	High	Intermed.	—
Fired Strength	Low	High	Intermed.	—

Raw clay materials suitable for refractory ceramic products, whiteware, paper clays, and similar products (Table 2) contain extremely small amounts of alkalis, iron, and other fluxes. They must consist essentially of alumina and silica and be highly refractory. Clay materials of this type commonly are composed almost entirely of kaolinite and quartz.

TABLE 2. *Uses of clay containing high proportions of kaolinite, illite, and mixed-layer clays.*

High Kaolinite	High Illite	High Mixed Layer
Refractories	Structural Clay Products	Lightweight Aggregate
Pottery	Lightweight Aggregate	Structural Clay Products
Chinaware	Pottery	
Chemical Stoneware		
Sanitary Ware		
High-grade Tile		
Porcelain		
Paper clay		
Cement		
Fillers and Extenders		
Structural Clay Products		

Structural clay products, which include bricks, sewer pipe, wall coping, and drain tile, generally do not require a high-purity or high-kaolinite raw material. For example, it is possible to make a fairly acceptable brick from almost any type of argillaceous material. However, structural clay products that come in contact with liquids (such as water or sewage) must be nearly impermeable. Glazes, which lower permeability, are now considered too expensive for many of these bulk products. Consequently, clay material with large proportions of illite and mixed-layer clays is particularly desirable because of its low permeability after firing. Another restriction is the amount of allowable shrinkage. This is not usually an important factor with brick or drain tile, but it is of considerable importance with sewer pipe. For this reason clay materials with large amounts of mixed-layer clays are not desirable as a raw material used in manufacturing sewer pipe.

Clays suitable for pottery commonly contain a large proportion of kaolinite because of its high plasticity, low drying and firing shrinkage, and white or light fired color.

Expanded shale lightweight aggregate is made by heating the clay material until it begins to fuse and bloat, then cooling it to trap gas bubbles. High illite, chlorite, and mixed-layer clay materials are most suitable for this purpose because of their low to intermediate refractoriness.

Clay materials low in alkalis are used to supply alumina in the manufacturing cement at some plants. A high-kaolinite clay or shale is best for this purpose.

Results

The particle-size and clay mineral analyses of the underclays and shales below the St. Meinrad and Mariah Hill coals indicate that there is a considerable thickness of high-kaolinite argillaceous rock containing a wide range in particle sizes (Fig. 4). The argillaceous material below the St. Meinrad contains a considerable amount of sand plus-size material. A large part of this sand plus-size material, however, is siderite concretions which possibly can be dispersed by grinding or eliminated by screening. Illite and kaolinite are the dominant clay minerals; mixed-layer clays and chlorite are present in smaller amounts. This underclay and shale is perhaps most suitable for structural clay products.

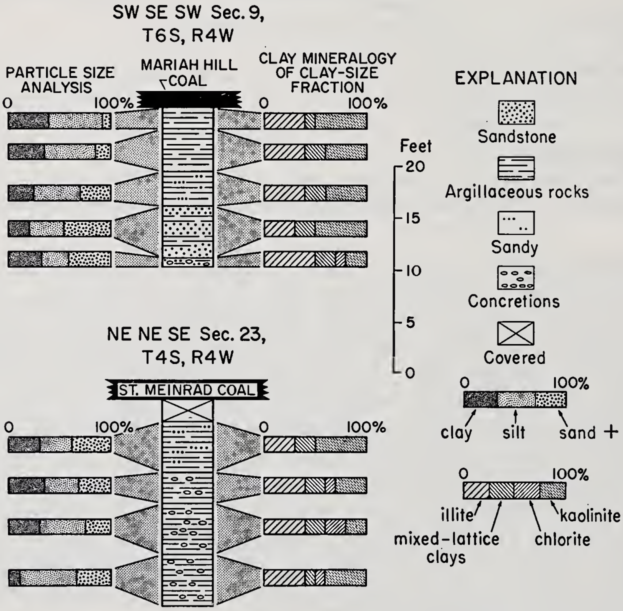

FIGURE 4. *Particle-size and clay mineral analyses of samples from below the St. Meinrad and Mariah Hill coals.*

The underclay and shale material below the Mariah Hill coal is also variable in particle size. The largest proportion of clay-size material is in the underclay just below the coal. Clay mineral analyses of the rocks below the Mariah Hill coal show them to be high in illite and kaolinite. Of special interest is the large proportion of kaolinite in the clay-size fraction of the sandier rocks from 9 to 14 feet below the coal. Kaolinite, in addition to being a detrital mineral, can also be of authigenic origin and commonly is developed in porous rocks, particularly sandstones. The clayey rocks below the Mariah Hill coal would be suitable raw materials for structural clay products but probably are less suitable than the rocks below the St. Meinrad coal. The variable but high proportion of sand and the low percentage of illite, and the corresponding high percentage of kaolinite, also make these rocks less appealing than the clayey rocks underlying the St. Meinrad coal as a source of raw materials for a structural clay products industry. However, they are promising as a source of alumina for cement raw materials.

Below the Buffaloville coal the best possibilities for a raw clay material in terms of grain size appear to be the 19 feet directly below the coal and the 10 feet farther down in the section below the thin coal stringers, 35 to 45 feet below the Buffaloville (Fig. 5). On the other hand, the best unit of rocks in terms of clay mineralogy appears to be the lower 10-foot clayey zone. There may be too much kaolinite in the 19-foot clayey zone immediately below the Buffaloville for sewer pipe manufacture, but it could be considered as a source of alumina for cement.

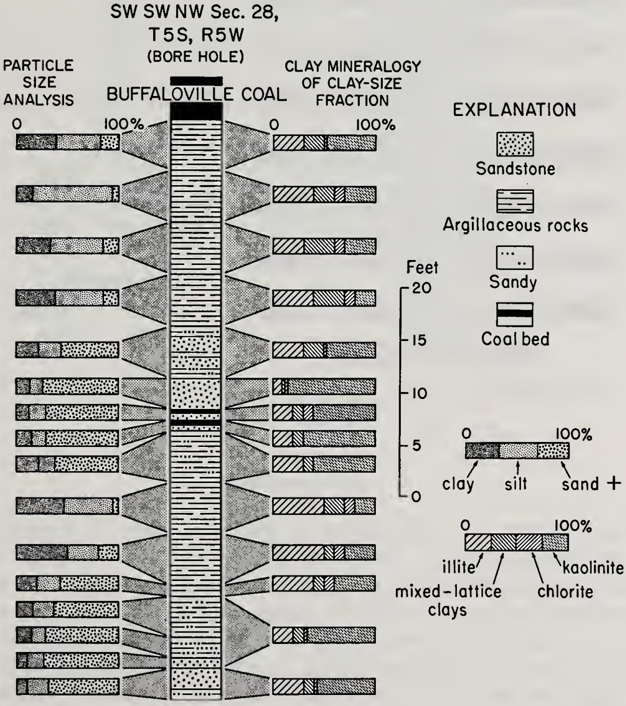

FIGURE 5. *Particle-size and clay mineral analyses of samples from a bore hole into rocks below the Buffaloville coal.*

Figure 6 illustrates the results of the analysis for a series of samples taken from above the Buffaloville coal. In this case, the almost 40 feet of clay material above the thin limestone immediately above the coal is fine grained and extremely uniform in size. The less-than-2-micron fraction of this unit is more than 5 parts in 10 illite and quite uniform in composition. This sequence of rocks offers the greatest promise of any of the units examined as a source of raw material for a structural clay industry. It may also be suitable for an expanded shale lightweight aggregate industry. This material must be stripped to get to the Buffaloville coal in any case and therefore offers the coal companies a potential additional source of income.

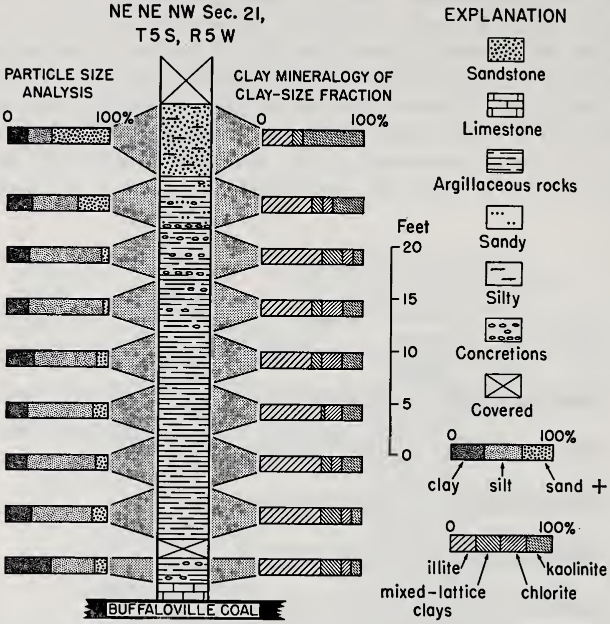

FIGURE 6. *Particle-size and clay mineral analyses of samples from above the Buffaloville coal.*

Conclusions

Because of the lack of high-purity kaolinite clays, it is unlikely that any of the clayey rocks in Spencer County could be used as a source of refractories, whiteware, paper clays, or similar products. On the basis of mineralogy, thickness of clayey units, and grain size, the manufacture of structural clay products appears to be the best ceramic use for these rocks. Some of the clays could be used by a pottery industry, although their use would be restricted because of their relatively low kaolinite proportion. The shales and other non-underclay shaly rocks are considered possible sources of raw material for an expanded shale lightweight aggregate industry. The underclays and related high-kaolinite rocks are distinct possibilities for sources of alumina in the manufacturing of cement.

It would be misleading to give the impression that all units of rock discussed in this report are laterally continuous throughout Spencer County or of suitable grain size and clay mineralogy to be commercially important. This is certainly not the case. The shale units examined in this report in particular are quite variable laterally. The most significant point advanced by this study is that preliminary tests have shown that at least four thick units of argillaceous rock in the county should be examined further as possible sources of raw material for industry.

Acknowledgments

These investigations were aided by a grant to the Geological Survey by Can-Tex Industries, Cannelton, Indiana, and by the field assistance of Michael Carpenter, a graduate student at Indiana University, Bloomington.

Literature Cited

1. ELBERTY, W. T. 1960. Effect of clay minerals on ceramic properties. Unpublished Ph.D. Dissertation. Indiana University, Bloomington, Indiana. 120 p.

2. GRIMSHAW, R. W. 1971. The chemistry and physics of clays and allied ceramic materials, 4th ed. Ernest Benn Ltd., London, Great Britain. 1024 p.

3. HUTCHINSON, H. C. 1959. Distribution, structure, and mined areas of coals in Spencer County, Indiana. Prelim. Coal Map No. 8, Indiana Geol. Surv., Bloomington.

4. ————. 1971. Distribution, structure, and mined areas of coals in Perry County, Indiana. Prelim. Coal Map No. 14, Indiana Geol. Surv., Bloomington.