CLAYS.

CLAYS IN THE KOOTENAI FORMATION NEAR BELT, MONT.

By CASSIUS A. FISHER.

INTRODUCTION.

Clays of different varieties are more or less abundant throughout the Kootenai formation in the vicinity of Belt, Mont., and along Otter Creek, where this product has been prospected and mined to some extent. Clay deposits of commercial value are found in this formation at many different places throughout the Great Falls region, but at no other locality, so far as they have yet been observed, are they of as good quality, apparently, as those near Belt. These clays are locally known as "flint" and "plastic" clays. The former term, however, is not here used in a strictly technical sense, being applied to a light-tan-colored, highly siliceous rock, unlike the typical flint clays of Pennsylvania. The latter term is used to designate a fine-grained slate-colored plastic clay of good quality. The so-called flint clay was formerly used to some extent in the manufacture of brick, and the plastic clay is now shipped to Anaconda, Mont., where it is burned into refractory products used in the large smelters at that place. With the completion of the new Billings and Northern Railroad, which passes near some of the best deposits, an excellent opportunity will be afforded for renewed activity and increased development of the clay resources of this district.

LOCATION AND EXTENT.

The area in which the best clays have been observed is situated in the eastern part of Cascade County, which is located near the center of Montana. It comprises about 145 square miles, including in its eastern part the plains region lying between the Little Belt and Highwood mountains and in its western part Belt Creek valley and a small portion of the adjoining plains. (See Pl. V.) Belt, a small coal-mining town, and Armington are located in the extreme north-

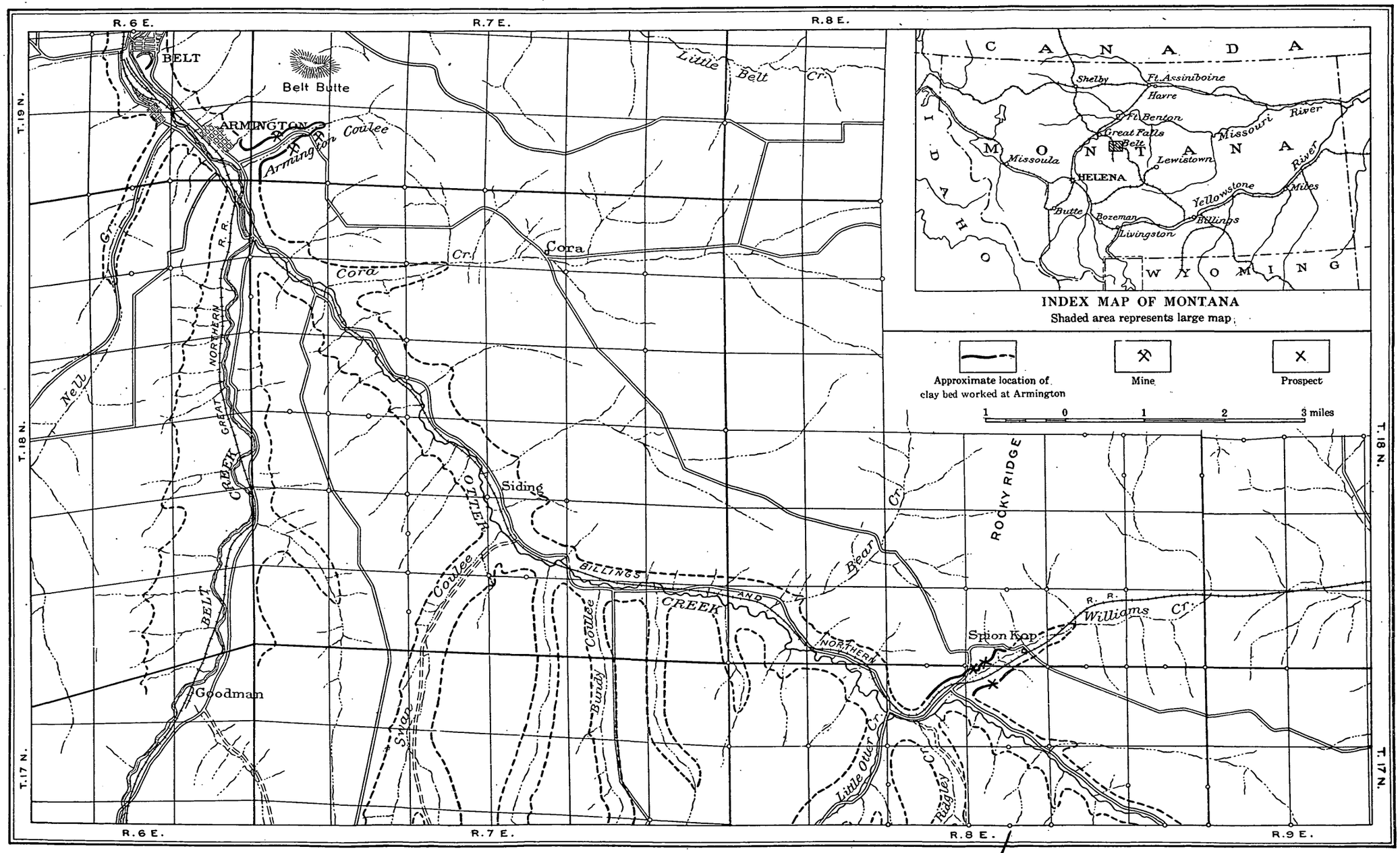
west corner of the area. The Billings and Northern Railroad extends diagonally across it, and the Neihart branch of the Great Northern Railway leaves the above-mentioned road at Armington and extends up Belt Creek to the town of Neihart.

GEOLOGIC OCCURRENCE OF CLAY.

The rocks that outcrop in the district here described range from Carboniferous to Cretaceous in age. They comprise the Quadrant, Ellis, Morrison, and Kootenai formations, and a portion of the Colorado shale. Over a great part of the area, however, the Kootenai formation occupies the surface, and in this formation at several different horizons clay and shale deposits of commercial value are found. The Kootenai formation has a thickness of about 450 feet, and consists mainly of sandstones, sandy shales, and clays occurring in alternate succession. In the lower part sandstones predominate and are massive in character, but higher in the formation the proportion of sandstone decreases and the beds consist largely of red shales and clays, with here and there a thin layer of sandstone or a bed of limestone. The formation rests with apparent conformity upon the variegated sandy shales and sandstones of the Morrison, and is overlain by the somber-colored sandstones and shales of the Colorado. A generalized section of the Kootenai formation of this district is given below:

Generalized section of the Kootenai formation (Lower Cretaceous) in the vicinity of Belt, Mont.

	Feet.
Colorado formation (Upper Cretaceous).	
Shale, red, sandy, and clay, with few thin sandstone layers	195
Shale, red, sandy, capped by sandstone	20
Limestone	5
Shale, red, sandy, capped by sandstone	20
Shale, red, sandy at top	30
Clay and shale, the former light tan color and the latter red, sandy, with an occasional thin sandstone layer (clay formerly mined)	50
Shale, red, containing lenses of impure limestone capped by gray limestone	30
Sandstone and blue clay in alternating layers	6
Sandstone, gray, compact	1
Clay, slate colored, fine grained, homogeneous; mined at present	4½
Sandstone, gray, massive	20
Clay, bluish, sandy	6
Coal	4½
Sandstone and sandy shale	60
Morrison formation (Jurassic).	
	452



MAP OF THE BELT DISTRICT, MONTANA, SHOWING LOCATION OF CLAY DEPOSITS.

The foregoing section is compiled from a number of detailed measurements made in various parts of the field, and as individual beds vary materially from place to place, it can not be regarded as typical of any one locality. It is introduced here mainly to show the succession of the beds in the Kootenai formation and the relative position of the clays here described, also their relation to the Kootenai coal. The red shales in the upper part of the section are in many places associated with clays which are good brickmaking material.

STRUCTURE.

The rocks in this region lie nearly horizontal, dipping at small angles (3° or 4°) to the northeast, away from the Little Belt Mountains and toward the plains. Although they are nearly horizontal, a close examination of the beds along the sides of the canyons shows that they are in reality gently folded into a series of low anticlines and shallow synclines, most of which are not perceptible to the casual observer. No large faults occur within this district, but minor faults are not uncommon, especially in the vicinity of Belt. The throw of these faults is slight, ranging from 5 to 15 feet, and their presence is therefore difficult to detect on the surface. They are usually first encountered by miners working the coal beds, and some of them have presented considerable difficulty to coal-mining operations. In Armington Coulee, about half a mile above the mouth, a short distance east of the Anaconda Copper Mining Company's clay pit now being worked, there is a sharp fold in the rocks which may possibly be more or less fractured along the axis of the fold that here trends northward toward Belt Butte. Exposures at this place were inadequate for determination on this point, but it is a structural condition which should be seriously considered in any extensive development of the clay deposits of Armington Coulee.

DETAILED DESCRIPTIONS OF CLAYS.

ARMINGTON COULEE.

On the north side of Armington Coulee, a small tributary of Belt Creek entering from the east just above the town of Armington, there is a clay mine owned by the Anaconda Copper Mining Company, of Anaconda, Mont. The clay deposit worked at this mine has a thickness of 4 feet 6 inches and occurs about 90 feet above the base of the Kootenai formation and 26 feet above the Kootenai coal horizon. The massive gray sandstone which overlies the coal in this general region has a variable thickness, ranging from about 20 to 80 feet, and in Armington Coulee its thickness is near the minimum.

A section at the Anaconda Copper Mining Company's mine, showing the position of the clay with respect to the coal, is given below:

Section at Anaconda Copper Mining Company's clay mine, Armington, Mont.

	Feet.
Sandstone and slate-colored clay occurring in alternating layers	6
Sandstone, gray, compact	1
Clay, light gray to slate colored, fine grained, homogeneous; deposit worked	4½
Sandstone, gray, massive, weathering tan	20
Clay, slate colored, sandy	6
Coal	4½
	42

The clay at this mine is light gray to slate colored, fine grained, and uniform in texture. It has a greasy feel and a subconchoidal fracture, and in places indistinct laminations can be seen. Although the material contains all the minerals ordinarily found in clay of this character, the only one which could be detected with the naked eye or a hand lens is pyrite, in crystals most of which are cubical in shape, although pyritohedral forms are also present. Throughout the thickness of the deposit the clay is homogeneous in character and notably free from sandy lenses. The workings extend back more than 150 feet from the mouth of the entry and in this distance the clay maintains a uniform thickness. Samples of this clay were shipped to St. Louis, where ultimate analysis was made in the structural-materials laboratory of the United States Geological Survey. The result of this analysis is given below:

Analysis of clay worked by Anaconda Copper Mining Company at Armington, Mont.

Silica	55.38
Alumina	30.86
Ferrous oxide	.86
Lime	.40
Magnesia	1.03
Sulphuric anhydride	.16
Ferric sulphide	2.23
Alkalies Na_2O	.26
Alkalies K_2O	1.04
Water at 100° C	.84
Ignition loss	6.86
	99.92

The analysis shows that this clay has an average percentage of silica, not high enough to cause it to be sandy, and that alumina, the refractory ingredient, is moderately high, so that the clay compares favorably in this respect with plastic clays of Woodbury, N. J., and St. Louis, Mo. Its fluxing constituents, lime, magnesia, and the alkalies, and also the iron are low.

In addition to the above analysis the writer obtained from the reduction works of the company at Anaconda an analysis of an average sample of this clay as utilized, which is here given:

Average analysis of fire clay from Armington, Mont.

Silica	53.70
Alumina	27.20
Ferric oxide	5.00
Lime	Trace.
Magnesia	Trace.
Alkalies	2.90
Sulphuric anhydride	.30
Ignition loss	10.85

The mine has been in operation at this place for about two years. The main entry extends more than 150 feet back from the outcrop, with side entries in either direction. The clay is mined out by hand at the bottom of the bed and then blasted down from above. It is hauled in wagons to the station and shipped to Anaconda, where it is manufactured into refractory products for utilization in the smelters at that place. The output of the mine at present is not large, and only a few men are employed.

About 45 feet above this clay bed stratigraphically there is a light-tan to yellowish sandy clay or impure sandstone which was formerly mined on the south side of the coulee for the manufacture of brick. The material is hard, gritty to the touch, and breaks with an irregular fracture. Although in general it is light yellow in color, there are bands of limonite running through it, and along all joint planes a thin film of limonite occurs. Ruins of the abandoned brick plant can be seen on the south side of Armington Coulee, nearly opposite the Anaconda Copper Mining Company's mine. Clay for this plant was obtained from the bluffs near by, also about one-fourth mile farther up the coulee, on the east side of the Belt-Lewistown stage road.

An analysis made several years ago has been furnished by the Anaconda Copper Mining Company, and is given below:

Analysis of clay formerly mined in Armington Coulee.

Silica	77.6
Ferric oxide	2.3
Alumina	12.2
Lime	.2

The location of this abandoned clay mine in Armington Coulee is shown on the map (Pl. V.)

WILLIAMS CREEK.

On either side of Williams Creek near Spion Kop there is a workable clay bed in the Kootenai formation, a short distance above the coal. The deposits have been prospected at a number of places on Lewis Larson's ranch, which is located near the mouth of the creek. The clay at this place is believed to occur at about the same horizon as that found in Armington Coulee, but an exact correlation with that deposit can not be made, owing to the fact that the clay and shale, also the sandstone members, of the Kootenai formation are very lenticular and individual beds thicken or thin within a very short distance. Sections of the clay on both sides of Williams Creek, measured by A. J. Hazlewood, are given below:

Section of clay deposit on north side of Williams Creek, near Spion Kop, Mont.

	Ft.	in.
Sandstone, gray, impure, soft	3	
Clay, gray, very sandy at base	3	8
Clay, light gray to slate colored, somewhat sandy, hard	5	6
Beds concealed.		

Section of clay deposit on south side of Williams Creek, near Spion Kop, Mont.

	Ft.	in.
Clay, light gray	4	
Sandstone, gray, soft	2	6
Clay, light bluish gray	5	
Beds concealed.		

It was impossible to obtain a continuous section of the beds between the clay and the coal at this place, but it is reasonably certain that the stratigraphic interval between the two deposits does not exceed 40 feet. The massive gray sandstone overlying the coal is present here, but it is not a conspicuous feature and exposures were not sufficiently good for an exact measurement of its thickness. In a railroad cut on the north side of Williams Creek near the wagon road, a bed of gray clay about 6 feet thick was observed. The material appears to be of an inferior quality and occurs in a bed of variable thickness. It is underlain by a sandstone believed to be the one immediately overlying the coal. The correlation of this clay with the workable beds described in the foregoing sections is not certain, but it is probably at about the same geologic horizon.

About half a mile southwest of the locality just described, on the north side of Otter Creek, another railroad cut exposes a deposit of slate-colored clay about 8 feet thick, which contains a 1½-foot layer of red clay near the middle and calcareous concretionary bands near the base and in the upper part. The workable clay in this bed thickens and thins within short distances, so that the deposits can not be regarded as of commercial importance. This lack of persistence in character and thickness in the clay deposits of this region makes correlation of individual beds often uncertain.

OTHER FAVORABLE LOCALITIES.

Although the clay at the horizon of the bed worked at the Anaconda Copper Mining Company's mine has been prospected at only a few places in this general region, clay-bearing sediments of this part of the Kootenai formation are exposed in the bluffs bordering Otter and Belt creeks and their tributaries. The accompanying map (Pl. V) shows the approximate position along these streams of the clay worked at Armington. Clays of equal commercial importance may possibly be found at different horizons a short distance above or below the one described, or in fact throughout a zone 150 feet thick overlying the coal. It is probable that the clay at Armington is not a persistent deposit, but that it dovetails in with deposits above and below of similar character and equal value. The fact that the zone in which the above clays are found occupies a position in the bluffs about 100 to 200 feet above the valley along both Otter and Belt creeks, where lines of transportation have already been constructed, makes the conditions favorable for exploitation.

CLAYS OUTSIDE THE AREA DESCRIBED.

About one-eighth mile west of the Boston and Montana smelters at Great Falls a sandy clay or argillaceous sandstone, mined by Coombs & King, occurs on the north bluffs of Missouri River. The material has a greenish-gray color, is very sandy, and occurs in a bed 30 feet thick near the top of the Kootenai formation. It is used for the manufacture of ordinary brick, also as a lining for converters at the smelters. The clay is satisfactory for these purposes, but it would probably never be mined so extensively were it not for its convenient location to the smelters and the city of Great Falls. It is mined continuously and a considerable proportion of the deposit is utilized.

There is also a sandy clay of some commercial value in the upper half of the Kootenai formation at Fields, a railroad siding 3½ miles east of Great Falls. A large amount of this clay was formerly used in the Boston and Montana smelters, probably before the Coombs & King clay bed was exploited. This material is at about the same horizon as that near the smelters, 4 miles farther north, but exact correlation of these beds can not be made. The clay at Fields is about 42 feet thick, light gray to slate color above, and reddish below. It is very siliceous and in portions resembles a fine-grained impure sandstone. Close examination of a hand specimen shows a large number of minute pyrite crystals and small rounded sand grains embedded in the clay. In addition to its use in the Great Falls smelters this clay was also manufactured into fire brick by the Hosford Fire Brick Company, located at Fields, but this enterprise proved not to be practicable, owing to the high percentage of iron in the clay. The deposit has not been worked for several years.

SURVEY PUBLICATIONS ON CLAYS, FULLER'S EARTH, ETC.

In addition to the papers named below, some of the publications listed under the heading "Cement" contain references to clays. Certain of the geologic folios also contain references to clays, fuller's earth, etc; when these materials are of importance in a particular area, they are printed in italics in the list of folios (pp. 9–11).

ASHLEY, G. H. Notes on clays and shales in central Pennsylvania. In Bulletin No. 285, pp. 442–444. 1906.

BASTIN, E. S. Clays of the Penobscot Bay region, Maine. In Bulletin No. 285, pp. 428–431. 1906.

BRANNER, J. C. Bibliography of clays and the ceramic arts. Bulletin No. 143. 114 pp. 1896.

——— The clays of Arkansas. Bulletin No. 351. In preparation.

BUTTS, C. Clays of the Birmingham district, Alabama. In Bulletin No. 315, pp. 291–295. 1907.

CRIDER, A. F. Clays of western Kentucky and Tennessee. In Bulletin No. 285, pp. 417–427. 1906.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin No. 213, pp. 382–391. 1903.

——— Clays of Garland County, Ark. In Bulletin No. 285, pp. 407–411. 1906.

FENNEMAN, N. M. Clay resources of the St. Louis district, Missouri. In Bulletin No. 315, pp. 315–321. 1907.

FISHER, C. A. The bentonite deposits of Wyoming. In Bulletin No. 260, pp. 559–563. 1905.

FULLER, M. L. Clays of Cape Cod, Massachusetts. In Bulletin No. 285, pp. 432–441. 1906.

GARDNER, J. H. (See Shaler, M. K., and Gardner, J. H.)

HAWORTH, E. (See Schrader, F. C., and Haworth, E.)

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1891, pp. 474–528. 1892.

——— Clay materials of the United States. In Mineral Resources U. S. for 1892, pp. 712–738. 1893.

LANDES, H. The clay deposits of Washington. In Bulletin No. 260, pp. 550–558. 1905.

LINES, E. F. Clays and shales of the Clarion quadrangle, Clarion County, Pa. In Bulletin No. 315, pp. 335–343. 1907.

MARBUT, C. F. (See Shaler, N. S., Woodworth, J. B., and Marbut, C. F.)

MARTIN, LAWRENCE. (See Phalen, W. C., and Martin, Lawrence.)

MIDDLETON, J. Clay-working industries. In Mineral Resources U. S. for 1906, pp. 933–983. 1907.

PHALEN, W. C. Clay resources of northeastern Kentucky. In Bulletin No. 285, pp. 412–416. 1906.

PHALEN, W. C., and MARTIN, LAWRENCE. Clays and shales of southwestern Cambria County, Pa. In Bulletin No. 315, pp. 344–354. 1907.

PORTER, J. T. Properties and tests of fuller's earth. In Bulletin No. 315, pp. 268–290. 1907.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp. 523–575. 1895.

——— The pottery industry of the United States. In Seventeenth Ann. Rept., pt. 3, pp. 842–880. 1896.

——— The clays of the United States east of the Mississippi River. Professional Paper No. 11. 298 pp. 1903.

SCHRADER, F. C., and HAWORTH, E. Clay industries of the Independence quadrangle, Kansas. In Bulletin No. 260, pp. 546–549. 1905.

SHALER, M. K., and GARDNER, J. H. Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico. In Bulletin No. 315, pp. 296–302. 1907.

SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F. The glacial brick clays of Rhode Island and southeastern Massachusetts. In Seventeenth Ann. Rept., pt. 1, pp. 957–1004. 1896.

SIEBENTHAL, C. E. Bentonite of the Laramie basin, Wyoming. In Bulletin No. 285, pp. 445–447. 1906.

STOSE, G. W. White clays of South Mountain, Pennsylvania. In Bulletin No. 315, pp. 322–334. 1907.

VAUGHAN, T. W. Fuller's earth of southwestern Georgia and Florida. In Mineral Resources U. S. for 1901, pp. 922–934. 1902.

——— Fuller's earth deposits of Florida and Georgia. In Bulletin No. 213, pp. 392–399. 1903.

VEATCH, O. Kaolins and fire clays of central Georgia. In Bulletin No. 315, pp. 303–314. 1907.

WILBER, F. A. Clays of the United States. In Mineral Resources U. S. for 1882, pp. 465–475. 1883.

——— Clays of the United States. In Mineral Resources U. S. for 1883–84, pp. 676–711. 1885.

WOODWORTH, J. B. (See Shaler, N. S., Woodworth, J. B., and Marbut, C. F.)

WOOLSEY, L. H. Clays of the Ohio Valley in Pennsylvania. In Bulletin No. 225, pp. 463–480. 1904.

LIME AND MAGNESITE.

SURVEY PUBLICATIONS ON LIME AND MAGNESITE.

In addition to the papers listed below, which deal principally with lime, magnesite, etc., further references on limestones will be found in the lists given under the heads "Cement" and "Building stone."

BASTIN, E. S. The lime industry of Knox County, Me. In Bulletin No. 285, pp. 393–400. 1906.

BUTTS, C. Limestone and dolomite in the Birmingham district, Alabama. In Bulletin No. 315, pp. 247–255. 1907.

HESS, F. L. Some magnesite deposits of California. In Bulletin No. 285, pp. 385–392. 1906.

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3, pp. 795–811. 1896.

STOSE, G. W. Pure limestone in Berkeley County, W. Va. In Bulletin No. 225, pp. 516–517. 1904.

YALE, C. G. Magnesite deposits in California. In Mineral Resources U. S. for 1903, pp. 1131–1135. 1904.

——— Magnesite. In Mineral Resources U. S. for 1906, pp. 1145–1147. 1907.

GYPSUM AND PLASTERS.

SURVEY PUBLICATIONS ON GYPSUM AND PLASTERS.

The more important publications of the United States Geological Survey on gypsum and plasters are included in the following list:

ADAMS, G. I., and others. Gypsum deposits of the United States. Bulletin No. 223. 123 pp. 1904.

BOUTWELL, J. M. Rock gypsum at Nephi, Utah. In Bulletin No. 225, pp. 483–487. 1904.

BURCHARD, E. F. Gypsum and gypsum products. In Mineral Resources U. S. for 1906, pp. 1069–1078. 1907.

ECKEL, E. C. Salt and gypsum deposits of southwestern Virginia. In Bulletin No. 213, pp. 406–416. 1903.

——— Gypsum and gypsum products. In Mineral Resources U. S. for 1905, pp. 1105–1115. 1906.

ORTON, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 506–601. 1888.

RICHARDSON, G. B. Salt, gypsum, and petroleum in trans-Pecos Texas. In Bulletin No. 260, pp. 573–585. 1905.

SHALER, M. K. Gypsum in northwestern New Mexico. In Bulletin No. 315, pp. 260–265. 1907.

SIEBENTHAL, C. E. Gypsum of the Uncompahgre region, Colorado. In Bulletin No. 285, pp. 401–403 1906.

——— Gypsum deposits of the Laramie district, Wyoming. In Bulletin No. 285, pp. 404–405. 1906.

GLASS SAND, ETC.

SURVEY PUBLICATIONS ON GLASS SAND AND GLASS-MAKING MATERIALS.

The list below includes the important publications of the United States Geological Survey on glass sand and glass-making materials:

BURCHARD, E. F. Requirements of sand and limestone for glass making. In Bulletin No. 285, pp. 452–458. 1906.

——— Glass sand of the middle Mississippi basin. In Bulletin No. 285, pp. 459–472. 1906.

——— Glass-sand industry of Indiana, Kentucky, and Ohio. In Bulletin No. 315, pp. 361–376. 1907.

——— Notes on glass sands from various localities, mainly undeveloped. In Bulletin No. 315, pp. 377–382. 1907.

——— Glass sand, sand, and gravel. In Mineral Resources U. S. for 1906, pp. 993–1000. 1907.

CAMPBELL, M. R. Description of the Brownsville-Connellsville quadrangles, Pennsylvania. Geologic Atlas U. S., folio 94, p. 19. 1903.

COONS, A. T. Glass sand. In Mineral Resources U. S. for 1902, pp. 1007–1015. 1904.

STOSE, G. W. Glass-sand industry in eastern West Virginia. In Bulletin No. 285, pp. 473–475. 1906.

WEEKS, J. D. Glass materials. In Mineral Resources U. S. for 1883–1884, pp. 958–973. 1885.

——— Glass materials. In Mineral Resources U. S. for 1885, pp. 544–555. 1886.