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FELDSPARS AND KAOLINS OF SOUTHEASTERN PENNSYLVANIA.*

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FELDSPARS.

Feldspar, or spar, as it is commonly called by the quarryman, is a class or group name that includes several different mineral species, which have certain general resemblances sufficient to distinguish them from other minerals, and differ among themselves sufficiently to have different names. They all have cleavages in two similar directions inclined

*Based on field-work done by the writer during the summer of 1898, under the auspices of the School of Mines of The Pennsylvania State College, and is here given in advance of the College report with the consent of the President of the College.

to each other at an angle of 90 or nearly so. They crystallize in two systems, the crystals resembling each other in angle, habit, and methods of twinning. They vary in hardness from 6 to 6.5, in fusibility from 3 to 5, in specific gravity from 2.5 to 2.9. They vary in color from white to yellow, red, green, or dark.

The feldspars are for convenience divided into two classes :

- (1) Orthoclase, the potash or acid feldspar, and
- (2) Plagioclase, the soda-lime or basic feldspars.

All the feldspars are compound silicates of alumina and an alkali base. The silicate of alumina is common to all the varieties, the alkaline base consisting of potash, soda or lime, rarely baryta, varies in the different species. The first group is called acid because it has a high percentage of silicic acid. It is called orthoclase (meaning straight cleavage) because of the straight cleavage of two faces at right angles to each other.

Chemically, orthoclase is potash alumina silicate, KAlSi_3O_8 (K_2O , Al_2O_3 , 6SiO_2) consisting of silica (SiO_2) 64.7 per cent., alumina (Al_2O_3) 18.4, potash (K_2O) 16.9. Sometimes soda replaces part of the potash forming soda orthoclase, sometimes, in fact, the soda may be in excess when it forms anorthoclase, a triclinic form in which usually the soda is in proportion to the potash as 2 to 1 or 3 to 1.

Orthoclase differs from the other feldspars crystallographically in that it crystallizes in the monoclinic system while the others are triclinic. The crystal habit of orthoclase is generally prismatic or tabular, commonly with two well-developed cleavages. Twinning of the crystals is quite common and follows one of three laws known as the Carlsbad, the Baveno, and the Mannebacher, the distinctions of which are interesting to the mineralogist, but not to the tradesman.

The plagioclase feldspars differ from the orthoclase in being triclinic and in having, besides a twinning according to one of the above laws, another twinning in accordance with the albite or pericline laws. In both of the latter the twinning is usually polysynthetic, that is, repeated many

times, which causes a striation on either the basal pinacoid (the albite law) or the brachypinacoid (the pericline law). These striations may frequently be seen by the naked eye, but are best observed in the microscope. The microcline feldspar, which is chemically a potash feldspar, is crystallographically triclinic, and usually has both the albite and pericline polysynthetic twinning, thus giving a double striation on a basal section, producing the peculiar "window-grated" texture so characteristic of microcline.

The plagioclase group proper, or the soda-lime feldspars, include a series ranging from the soda feldspar, albite $\text{NaAlSi}_3\text{O}_8$, at one end to the lime feldspar, anorthite $\text{CaAl}_2\text{Si}_2\text{O}_8$, at the other. There is a more or less intimate gradation of the one into the other, but four other varieties are introduced between these two by drawing arbitrary lines at regular intervals. This makes the classification more detailed, but more complex and less definite. It would be necessary to draw one arbitrary line to separate albite and anorthite, but by introducing the four intermediate varieties there are four arbitrary lines to be drawn. The intermediate forms are oligoclase, andesine, labradorite and bytownite.

With this chemical change noted in passing through the series, there are corresponding crystallographic and optical changes which are interesting to the professional mineralogist, but have no special interest or value to the tradesman.

The point of difference which interests the manufacturer is the change in fusibility which is governed largely by its chemical composition.

The chemical and physical relations of these forms are best shown by tabulating them :

PHYSICAL AND CHEMICAL PROPERTIES OF THE FELDSPARS.

Name.	Ratio of albite 1 to anorthite <i>n</i> . 1 : <i>n</i> .	Hardness.	Fusibility.	Specific gravity.	Silica.	Alumina.	Lime.	Soda.	Potash.
Orthoclase.	—	6	5	2'57	64.7	18'4	—	—	16'9
Albite.	1 : 0	6-6'5	4	2'624	68'7	19'5	—	11'8	—
Oligoclase.	12 : 1	—	—	—	—	—	—	—	—
	8 : 1	6-7	3'5	2'64	65.7	21'5	2'4	10'4	—
	6 : 1	—	—	—	—	—	—	—	—
Andesine.	3 : 2	—	—	—	—	—	—	—	—
	4 : 3	5.6	—	2'69	57'4	27'1	8'9	6'6	—
	1 : 1	—	—	—	—	—	—	—	—
Labradorite.	3 : 4	—	—	—	—	—	—	—	—
	2 : 3	5-6	3	2'71	53.00	30	12'3	4	—
	1 : 3	—	—	—	—	—	—	—	—
Bytownite.	1 : 4	—	—	—	—	—	—	—	—
	1 : 6	—	—	2'74	46'6	34'4	17'4	1'6	—
	1 : 8	—	—	—	—	—	—	—	—
Anorthite.	0 : 1	6-6'5	5	2'76	43'2	36'7	20.1	—	—

The greater part of the feldspar that goes into the market is orthoclase, and one might expect it would have a uniform composition, but as shown from the following analyses of commercial spars the variation in composition is considerable, which is easily understood when we remember that orthoclase always has a variable percentage of soda and is accompanied by variable quantities of the soda lime or plagioclase feldspars, and contains considerable but varying proportions of quartz and small quantities of other minerals, such as mica, hornblende, etc. The bulk of the foreign minerals is separated in the quarrying process, as far as possible, by careful hand-picking, but it is not practical to remove all. Moreover, as feldspar yields readily to the weathering agencies, there may be a considerable variation in the composition of the commercial product from different localities or from different parts of the same deposit, dependent on the degree to which this disintegration or kaolinization has taken place.

ANALYSES OF FELDSPARS.

NAME.	LOCALITY.	SiO ₂ .	Al ₂ O ₃ .	CaO.	Na ₂ O.	K ₂ O.
Orthoclase (?)	Embreeville, Pa.	67.46	21.76	1.67	5.96	4.28
Orthoclase	Bolton, Mass.	65.23	19.26	.42	2.98	11.80
Orthoclase	Brandywine Summit	65.61	16.92	.16	2.11	12.92
Albite	Unionville, Pa.	66.65	20.79	1.47	8.86	1.36
Albite	Mineral Hill, Pa.	66.24	20.72	1.85	9.44	0.98
Oligoclase	Wilmington, Del.	64.75	23.56	2.84	9.04	1.11
Oligoclase	Sanford, Me.	56.65	25.56	8.25	6.18	1.34
Labradorite	Labrador	56.00	27.50	10.10	5.00	0.40
Anorthite	Mt. Somma	43.98	35.30	18.98	.47	.40

Mode of occurrence.—Feldspar occurs as one of the constituents in a great many different rocks, in fact, in most of the granular igneous rocks and many of the metamorphic ones, in all of which it is associated more or less intimately with a variety of other minerals. While it is one of the most abundant and widely distributed minerals, the localities where it is segregated free from other minerals are comparatively few. The feldspar segregations where it occurs sufficiently pure for commercial purposes in Pennsylvania are in the form of pegmatite veins, or dikes, varying greatly in width and extent. The veins, or dikes,* are frequent in the gneiss and mica schist rocks of Delaware and Chester Counties. They are not limited to the micaceous rocks, however, as some large veins occur in serpentine rocks. The veins may vary in width from an inch or less to 50 feet or more. The actual length is difficult to determine, but, like most veins, they swell out quite large in places, between which enlargements they may be so much restricted as to either partially or wholly cut off the vein. As a result, the commercial spar is obtained from irregular, elongated, lenticular like masses or pockets, sometimes close to each other, sometimes widely separated by an area of barren rock. As there may be a series of parallel veins, these pockets may lie side by side as well as end to end. In some

* To avoid repetition, I shall hereafter use the word veins, and those who think they are dikes may supply the words "or dikes."

cases there are sharply defined walls to the feldspar deposits, in other cases there appears to be a rough gradation from the spar to the country rock, with no sharp line of separation.

These segregations of feldspar are commonly known as pegmatites, "giant granite" or granitic veinstone.

Pegmatite, as first used by Haüy, in 1822, was synonymous with "graphic granite," that unique intergrowth of quartz and feldspar. In 1843 its use was extended by Delesse to include all the very coarse granites, and is so used to-day. It includes not only the coarse segregations of the granitic rocks, but corresponding types of other plutonic rocks as well, thus we have the syenite-pegmatite, gabbro-pegmatite, etc.

Besides feldspar, the other economic products obtained from the pegmatite veins are mica, quartz and a number of minerals containing the rarer earths. They are also the source of many fine crystals of a great variety of minerals that have no particular economic usage, as the conditions favoring the formation of the great feldspar crystals also favor the crystallization of other minerals.

In the feldspar districts these veins are always referred to as the feldspar or spar veins, but the feldspar is only one of the minerals. In most of the Pennsylvania spar quarries the other minerals that occur in large quantities are quartz, muscovite and biotite, the constituents of ordinary granite. The essential difference between the pegmatite and the ordinary granite is in the greater size of the crystals, but there is commonly a segregation of minerals as well, so that some portions of the vein will be nearly pure spar, other portions nearly all quartz, and other portions very rich in mica.

The great size of some of these separate crystals is truly surprising. Professor Crosby mentions * the frequent occurrence of feldspar crystals in the New Hampshire quarries 10 feet or more in length, and one fully 20 feet long; and Brögger † mentions some 33 feet long.

* "American Geologist," Vol. 19, p. 154.

† "Canadian Record of Science," 6, 57.

No such giants as these were observed by the writer in the Pennsylvania quarries, but those a foot or more in length are not infrequent.

*The Origin of Pegmatite.**—Much has been written on the origin of pegmatites, and consequently much that is more or less conflicting. The different theories might be grouped in three classes: (1) Those that suppose a purely aqueous origin; (2) A purely igneous one; (3) That they have an aqueo-igneous origin. All of these theories have had able advocates, and possibly there is an element of truth in each. It is possible, indeed it appears quite probable, that all the pegmatite veins have not originated in the same manner.

The first theory allies pegmatite veins with quartz veins, and explains their formation by water carrying the material in solution and depositing it in fissures or along certain planes. Some writers, particularly some of the earlier writers, assumed that the solutions were heated and came from great depths; others, particularly in recent times, advocate the lateral secretion theory, in which the materials are carried in solution to the veins from the surrounding country rock by waters of comparatively low temperature.

The advocates of the second theory argue that the pegmatites are injected igneous material. Professor Williams offers several strong points in evidence of at least some of the Maryland pegmatites being of igneous origin.

The third theory recognizes the solvent power of water and the active agency of heat and combines the two. It is a well-known fact that, in the presence of water, all the rock materials can be rendered plastic or pasty at a much lower temperature than by simple dry fusion, and, therefore, the rock material saturated with water is reduced to a semi-fluid condition at a moderately low temperature, in which the coarsely crystallized pegmatitic material is segregated.

A very little analysis will show that the last theory is

* This subject is ably discussed by Prof. G. H. Williams in the "Fifteenth An. Report U. S. Geol. Survey," 1893-4, pp. 675-684, and by Prof. W. O. Crosby and M. L. Fuller in the "American Geol.," Vol. 19, page 148, 1897. Both articles are illustrated. The first treats more specifically of the pegmatites of Maryland and the second of those of New Hampshire.

simply a connecting link between the other two. The line between aqueous solution and aqueo-igneous solution is an arbitrary one, as is that between aqueo-igneous fusion and pure igneous fusion. Recent investigation appears to rather emphasize the aqueous end more than the igneous. The speaker favors the aqueo-igneous theory, believing that the water is a more important agent than the heat in the formation of the Pennsylvania pegmatites.

An extended discussion of these theories is not justified here, and those interested in pursuing the subject further are referred to the two papers mentioned above, where numerous references are given to other writers.

Method of Quarrying.—The spar is frequently partially disintegrated by the weathering agencies near the surface, where it can be readily removed with a pick and shovel. In many of the deposits these are the only tools used, as the weathering agencies have penetrated with sufficient power to open the cleavage planes and loosen the whole mass, so that it yields readily to the pick. In some places it is so far disintegrated that much of the feldspar is changed to kaolin and near the surface mixed with constituents of the surrounding rock. In such cases it is necessary to cleanse the solid fragments of feldspar from the dirt in which they occur. Where the material is dry this is sometimes done by screening it on a wire netting, such as is used for screening sand. Where the material is not dry enough to screen, it is washed with a stream of water. From the deeper parts of the quarry, where the surface impurities do not occur, neither washing nor screening is necessary. But in all parts of the deposit there is an admixture of other minerals, such as mica, hornblende, quartz, etc., which are broken out and separated by a careful sorting by hand from the quarried material. Where the spar is too hard to yield readily to the pick, powder is used to blast it loose.

Sometimes the quarry is extended downward with nearly vertical walls and the material lifted in buckets with the aid of a derrick, operated in some places by hand-power, in some places by horse-power, and sometimes by steam-power.

In some of the quarries one end of the quarry is carried down on an incline and the spar hauled out with a horse and cart. In two of the Pennsylvania quarries drifts were run in and the spar mined underground. In the one case the drift runs horizontally from the surface on a steep hill-side. In the other case the drift was from the bottom of a deep pit, and it was necessary to elevate the material to the surface after it was brought from the drift. After the hand-sorting the broken spar is sent to the spar mill.

There are two spar mills in Pennsylvania, one at Toughkenamon, and a much larger one near Brandywine Summit. Some of the spar is shipped in lump to the mills at Trenton and East Liverpool, where it is ground.

The grinding is a two-fold process, the first part consisting in crushing the material to powder under heavy circular stones or rolls, two of which are mounted on a short horizontal axis, which is attached to a rotating vertical axis. The heavy stone rolls, turning on both the horizontal and vertical axes, run in a pan into which the spar is shovelled by a workman. The process is similar to the ordinary dry pan, except that the rolls are stone instead of iron, and the pan is smaller than the average dry pan. After being thoroughly crushed under these rolls, the material is put in a large iron drum or cylinder along with a mass of flint ("Norway") pebbles and revolved at a rapid rate for two or three hours, which reduces it to an impalpable dust, when it is ready for the potters' use.

Uses of Feldspar.—Probably the principal use of feldspar is in china and porcelain ware, where it serves the purpose of a flux. It is used both in the body of the ware and in the glaze. It is used to some extent in making glass. It is also used in making enamelled or porcelain brick and enamelled tiling, where it serves the same purpose as in ordinary china ware. Small quantities are used by the dentists for making artificial teeth.

Distribution of Feldspar.—As the spar veins are limited to the gneissoid, schistose and serpentine rocks, the possible productive areas in this State are not large. All the feldspar quarries in Pennsylvania, so far as known to the

one opening quartz was removed in large boulders; in fact, the dump has more the appearance of a flint quarry than a spar quarry. The spar is all shipped to the mill near Brandywine Summit.

A feldspar quarry, known as the Sharpless quarry, about a mile south of east of Glen Mills, was operated a number of years ago, but is now idle. The spar contains large segregations of quartz and a great many large muscovite crystals, some of which are 8 to 10 inches across.

Near Boothwyn Station is a spar quarry that has been productive for several years. The vein is about 30 feet thick and the quarry opening about 150 feet long and 40 feet deep. The trend of the vein seems to be northwest-southeast, and it dips toward the southwest. Much of the spar is quite white in color.

Near Elam Post-office is the largest feldspar quarry in the State. It has been in operation fifteen years, and it is estimated that not less than 100,000 tons of spar have been removed from it in that time. The open working shows the vein to be 60 to 70 feet wide. It has been worked to a depth of 100 feet, and the opening is probably 200 feet long, but from the north end tunnels have been extended along the vein 100 yards or more further. The rock is partially kaolinized to a depth of many feet, and contains segregations of other minerals in considerable quantities in places; thus near the top of the opening muscovite is quite abundant, and near the bottom are large lumps of coarsely granular quartz. Carts are used to remove the spar to a depth of 20 feet or more. From the lower levels it is elevated to the surface by a derrick and steam hoist. It is hauled by wagon to the spar mill near Brandywine Summit.

Northeast of Unionville are several small feldspar quarries operated by companies outside of the State, one a Trenton company and one at Wilmington, Del. Feldspar was quarried from four openings during the present season, and there are not less than a half dozen other openings from which spar has been removed within the last few years. The openings are comparatively shallow, and appear rather as pockets than veins, although probably enlarge-

ments of veins, but the country rock has so disintegrated that the spar lies in the loose disintegrated material, and the vein walls are not clearly defined. The rock is a mica schist bordering on serpentine, and it appears that some of the quarries are within the serpentine area. Muscovite and biotite are quite abundant in places, and there is considerable diffused quartz, but no large masses were observed. These quarries are near the corundum mine,

where corundum was mined in considerable quantities several years ago.

The spar quarry at Embreeville is on the W. & N. railway, about 100 yards north of the Embreeville station. The vein, which is about 10 feet thick, crosses the railroad, and has been quarried on both sides of the railroad track. The vein appears to correspond in dip and strike to the garnetiferous mica schists in which it occurs, namely,

dipping 40° south, 60° east. The spar is nearly snow-white, slightly stained by dendrite markings in places. The analysis indicates a soda orthoclase with a slight admixture of a lime-bearing feldspar and considerable free quartz.

ANALYSIS OF FELDSPAR FROM EMBREEVILLE QUARRY.

SiO ₂	67.46
Al ₂ O ₃	21.76
CaO	1.67
Na ₂ O	5.96
K ₂ O	4.28

The quarry was first opened in 1885, and in 1886 produced 200 tons of spar ("Min. Res.," 1886, p. 701). The continuation of this vein southwest from the quarry is distinctly shown by the numerous outcrops at different points along the line of strike.

In the vicinity of Avondale there are four active and three idle feldspar quarries. They are all in pegmatite veins in mica schist, some of them in the immediate vicinity of limestone outcrops. The spar has a better defined pegmatite structure than that at any of the other quarries, that is, the quartz occurs intergrown on both cleavages of the orthoclase, giving the regular angular appearance of the ancient hieroglyphics.

Two of the most productive quarries are close to the village of Avondale on the north side of the village. The upper 10 feet of the spar are much decayed. The vein varies in width from a few feet to 31 feet. These quarries produced between 6 and 7 tons per day each during the summer of 1898.

About one and one-quarter miles north of Avondale is a large feldspar quarry with an opening about 120 by 40 by 35 feet in a pegmatite vein which has a general southwest-northeast direction and dips to the southeast. It was operated the first part of 1898, but was idle in the latter part of the summer. It has produced considerable feldspar, and, judging from the dump, there was considerable material handled to produce it.

There is another active quarry on the north side of the

Chatham pike, a mile or more northwest of Avondale, on the Thompson place, and another about half a mile further north, on the Dicky place, both of which contain typical graphic granite, and both of which were operated during the past summer.

The spar in the quarry near Chatham, about three miles west of north from Avondale, is different in appearance from that at Avondale. It has a nearly white color, and the quartz, instead of occurring along the cleavage planes of the feldspar, as in typical pegmatite, is segregated in large masses. The spar contains more plagioclase, and hence runs higher in soda and lime than that at Avondale.

The feldspar quarries near Sylmar, in southern Chester County, have considerable scientific interest in that, to the best of my knowledge, they are the only feldspar quarries in the world that occur in a serpentine rock, except, perchance, some of those near Unionville, Pa. The latter, if in the serpentine at all, are in the border close to the mica schists; but in the Sylmar locality the spar is in the midst of a large area of serpentine, which outcrops on all sides of it. Small feldspar veins occur in serpentine elsewhere in the State, but, so far as known to the speaker, none of the others are of sufficient size to have any commercial value. The spar in these quarries is not a graphic granite, as there is no quartz present, and some of the spar has no well-defined cleavage. It consists of orthoclase, along with some albite and other plagioclase, associated with muscovite, hydro-micas, hornblende and asbestos. The spar is well preserved, showing little evidence of decay, beyond a dull cleavage surface in places, and is frequently marked with a beautiful dendrite coating. The largest one of the quarries lies on a vein running nearly northwest and southeast ($N50^{\circ}W.$). The opening is 30 feet wide, 35 feet deep and 150 feet long. At the south end the vein divides into two (whether permanently or whether only separated by a horse of serpentine is uncertain). Near the north end is a small vein branching off at nearly right angles.

The second quarry is about 200 yards southeast of the first on the line of strike of the vein, and probably on the

same vein, but there are no outcrops between the two to connect them. Chromite mines are operated nearby.

Where did this serpentine feldspar come from? A possible source is from a gneiss or schist underlying the serpentine, or from a former overlying one. Or it may have been a segregation in the rock from which the serpentine was derived; or it might have been produced from the rock from which the serpentine was derived.

As long as the origin of the serpentine itself is a question of dispute, we can hardly hope to satisfactorily explain the origin of the spar.

The feldspar quarries at Chadd's Ford and Fairville were not visited by the speaker, as he did not learn of their existence until he left the field work.

There is an abandoned feldspar quarry in Montgomery County, on the east bank of the Schuylkill River, between Lafayette and Spring Mill.* The quarry was opened in 1886, and 30 tons of spar removed and sold to the potteries in Trenton. The crude spar brought \$5 per ton in Trenton.

The feldspar is orthoclase, with white granular quartz and large masses of biotite. It dips northward beneath the gneiss, and strikes transverse to the gneiss. The feldspar is at least 45 feet thick.

The deposits of feldspar that have been opened in Delaware and Chester Counties are probably but a fraction of the veins that might be worked, and Pennsylvania is likely to be a producer of feldspar as long as there is demand for the same, and the price is high enough to warrant exploitation.

The price of the crude feldspar, as it comes from the quarry, varies from \$3.75 to \$4.25 per ton, f.o.b. The price for the ground spar is about double that of the crude.

The production of feldspar in the State cannot be definitely stated, as some of the producers refuse to give the output of their quarries. A careful estimate by the speaker puts the amount for the year 1898 at 9,000 tons, which is

* Described by Prof. O. C. S. Carter in "Proc. Am. Phil. Soc.," Vol. 29, 1891, p. 49-50.

probably a little less than the actual output, as no estimate was made for two of the companies from which no data were obtained.

KAOLIN.

One of the most common commercial products that result from the decay of feldspar is kaolin. The feldspars are compounds of silica with alumina and one or more alkalies. The alkalies are more soluble than either the alumina or silica, and on exposure to the atmosphere and meteoric waters they are leached out, probably by the action of carbonic and other acids, and at the same time water is added. In the process more or less silica is set free or forms new combinations, as the kaolin molecule has but one-third as much silica as the orthoclase. A hypothetical reaction, in which orthoclase is changed to kaolin, is as follows:
$$\underset{\text{(Orthoclase.)}}{\text{K}_2\text{O}, \text{Al}_2\text{O}_3, 6\text{SiO}_2} + \text{CO}_2 + 2\text{H}_2\text{O} = \underset{\text{(Kaolin.)}}{\text{Al}_2\text{O}_3, 2\text{SiO}_2, 2\text{H}_2\text{O}} + \text{K}_2\text{CO}_3 + 4\text{SiO}_2.$$

The potash is carried off in solution, and the kaolin and at least a considerable portion of the silica remain. Under varying degrees of temperature and pressure feldspars may undergo other transformations and different minerals result.

Pure kaolin, or kaolinite, contains 46.5 per cent. silica, 39.5 per cent. Al_2O_3 and 14 per cent. H_2O , but absolutely pure minerals do not occur in commercial quantities. Kaolin, being a secondary mineral, is liable to have not only the mineral impurities of the original feldspar, but an excess of silica that would result from perfectly pure feldspar, and frequently portions of undecomposed feldspar. There may also be impurities carried in by the meteoric waters.

There are two classes of kaolins, one the residual kaolin, that occurs in the position of the original feldspar as a residuum from the disintegration of the feldspar, the other a transported or sedimentary kaolin caused by streams washing away the residual kaolin and depositing it as sediment at some other locality.

Of the two classes of kaolins, the second or transported ones are liable, under the most favorable conditions, to be

purier than the residual ones, as the wonderful sorting power of water separates all the coarser and heavier particles contained in the residual material. However, the sedimentary deposits are liable to have impurities from other localities of material of the same degree of fineness, or of soluble materials, or materials that have segregated in or on the clay after its deposit. Hence the residual kaolins, while they generally have a smaller percentage of pure kaolin, are more likely to be a source of commercial supply than the sedimentary, because the foreign matter is mostly coarser material that can be separated by a mechanical process. The sedimentary kaolins, while frequently mixed with mechanically inseparable materials, do sometimes occur in commercially pure form, so that they can be used without any refining process, while others can be used like the residual kaolins after refining or washing.

There are several other minerals closely related to kaolin in composition and physical characters, so closely related, in fact, that they might, for the most part at least, be classed as varieties of kaolin rather than as separate materials. Some of these varieties have considerable local interest, some are of commercial importance, but most of them are of interest only to the mineralogist and are unknown to the tradesman. The chemical relations of these minerals to each other and to kaolin are best known by tabulating them:

Kaolin	$\text{Al}_2\text{O}_3, 2\text{SiO}_2, 2\text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 39.5 p. c.,	SiO_2 46.5 p. c.,	H_2O 14.0 p. c.
Halloysite	$\text{Al}_2\text{O}_3, 2\text{SiO}_2, 2\text{H}_2\text{O} + \text{aq}$	$= \text{Al}_2\text{O}_3$ 36.9 "	SiO_2 43.5 "	H_2O 19.6 "
Newtonite	$\text{Al}_2\text{O}_3, 2\text{SiO}_2, 5\text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 32.7 "	SiO_2 38.5 "	H_2O 28.8 "
Rectorite	$\text{Al}_2\text{O}_3, 2\text{SiO}_2, \text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 42.5 "	SiO_2 50.0 "	H_2O 7.5 "
Cimolite	$2\text{Al}_2\text{O}_3, 9\text{SiO}_2, 6\text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 23.9 "	SiO_2 63.4 "	H_2O 12.7 "
Montmorillonite	About $\text{Al}_2\text{O}_3, 2\text{SiO}_2, \text{H}_2\text{O}$, but varies.			
Pyrophyllite	$\text{Al}_2\text{O}_3, 4\text{SiO}_2, \text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 28.3 "	SiO_2 66.7 "	H_2O 5.0 "
Allophane	$\text{Al}_2\text{O}_3, \text{SiO}_2, 5\text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 40.5 "	SiO_2 23.8 "	H_2O 35.7 "
Collyrite	$2\text{Al}_2\text{O}_3, \text{SiO}_2, 9\text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 47.8 "	SiO_2 14.2 "	H_2O 38.0 "
Schroetterite	$8\text{Al}_2\text{O}_3, 3\text{SiO}_2, 30\text{H}_2\text{O}$	$= \text{Al}_2\text{O}_3$ 53.1 "	SiO_2 11.7 "	H_2O 35.2 "
Indianaite (nearly kaolin)		Al_2O_3 38.7 "	SiO_2 44.7 "	H_2O 15.0 "

Any of the above are liable to occur in small quantities associated with kaolin or allied minerals, but the only ones known to occur in commercial quantities are indianait, halloysite and newtonite. Halloysite is mined in Ken-

tucky, South Carolina and Georgia (*Eng. and Min. Jour.*, October 1, 1898).

There are numerous other sub-varieties, such as smectite, bole, pholerite, guembelite, samoite, etc., which are mostly local in their occurrence and importance.

Both the residual and sedimentary kaolins occur in Pennsylvania in two rather widely separated fields—the residual ones in Delaware and Chester Counties and the sedimentary ones in Cumberland, Franklin and York Counties, and possibly elsewhere. There are eight kaolin-washing establishments in operation in the two fields, if we include one that is temporarily idle and one that has but recently started.

The residual kaolins occur in Delaware and Chester Counties. There were formerly two kaolin-washing plants operated in Delaware County, but now there is none. There are three in Chester County.

In the residual kaolins of Pennsylvania the most common impurities are undecomposed feldspar, mica and quartz, which are almost wholly removed in the washing or refining process, except, at times, some of the quartz, which is so finely divided that it is carried over with the kaolin. In some of the mines there is a small percentage of iron oxide in the clay that is not removed in the washing. Ordinarily, the yellow portion containing the iron oxide is thrown aside or put in as a lower grade. But on account of its usually greater plasticity it is advisable to use some of it at times to render the clay tough enough to handle.

Washing the Kaolin.—The method used in the Chester County washing plants is that with the common log washer and troughs. The process is based on the marvellous sorting power of water. One of the essential parts of the process is a horizontal shaft, set at intervals with short iron or wooden arms, which shaft rotates in a rectangular or semi-circular trough, into which the clay and water are thrown. The arms on the rotating shaft break up the lumps of clay and stir it into a slip or mortar, which is carried away by the running water through a long trough, which is frequently about 700 feet long; but for convenience this is cut in sections, which are placed side by side, and the current

follows a zigzag passage. The aim is to so regulate the current of water that all the kaolin will be carried along and the other materials dropped in the bottom of the trough. The greater portion of the coarse sand and heavy particles are dropped in or close to the washer, and one or more sand wheels are inserted to remove it and prevent it from clogging the troughs. At intervals the troughs are opened and the sand scraped out. The water carrying the kaolin in suspension passes from the troughs into settling tanks, where, after the kaolin settles, the clear water is removed and the kaolin slip pumped into a hydraulic filter press, where most of the water is squeezed out.

The kaolin comes from the filter press in large cakes, which are further dried either in racks in the open air or on a dry floor. In many places the dried kaolin is shipped in sacks, but the Chester County producers load the material loose in the car.

Kaolin, Pa.—One of the oldest kaolin-producing localities in the State is that near Kaolin Post-office, in Chester County, where kaolin has been mined and washed since 1839. At present there are two companies operating mines, each turning out about 40 tons of refined kaolin per day. Nearly all the kaolin from this locality is shipped to the large potteries in East Liverpool, Ohio, and Trenton, N. J. Both of the companies make a partial use of the by-products. One company screens the sand, pulverizes it and sells it to the potters for ground flint. The other company uses the sand for making silica brick for furnace use. Yet, despite the usage made of the sand, there is a large accumulation of it at both works.

The kaolin deposit is about 40 to 50 yards wide, with at least one parallel vein, and possibly others. It is all mined from the circular shafts with the temporary timbering. The deepest shaft sunk was 130 feet, but even though the kaolin deposit is deeper than that, most of the shafts are sunk less than 100 feet, as it is claimed that the expense of hoisting the material more than that distance is too great to follow with profit. As all the openings are filled with waste material, except the ones in which work is carried on

there are no exposures except the kaolin in the bottom of the one or two shafts in actual operation. Several large boulders of coarsely crystalline, partially disintegrated giant granite have been left on the surface in one place, and is the only solid rock in sight at the mines. The kaolin is a decomposed pegmatite vein in the mica schists, the structure of the kaolin showing its pegmatite origin. The apparent trend of the vein, as shown by the openings made by the two companies, is northeast-southwest, but neither the width nor the lineal extent can be accurately determined from the openings made, yet they are sufficiently numerous and scattered to show a large deposit of kaolin of good quality. Near the surface the kaolin has a buff or yellow tint due to the admixture of yellow soil from other rocks. The yellow color extends several feet below the surface in most places, although in a few places the white clay is exposed on the surface.

The Hockessin, Delaware, kaolin mines and works are but two or three miles south of east from the kaolin mines described above, and are closely related to them in the character of the kaolin and the mode of its occurrence.

Brandywine Summit.—To the reading public the Brandywine Summit kaolins are better known than any others in the State, because they are the only ones that have been described in the State reports. The Annual Report for 1885 of the Second Pennsylvania Geological Survey gives an illustrated and quite a detailed account of the kaolin deposits and washing plants at that place. They are now idle and have been for many years. As at Kaolin, there were two companies, each of which a few years ago produced kaolin of good grade in large quantities. Both the companies are in existence yet, under the same, or nearly the same, firm names with different personnel, but one is now producing feldspar, as already mentioned under that subject, and the other is manufacturing high-grade building brick from the refuse material from the former kaolin mines.

The reason offered for the abandonment of kaolin washing is that the best material has all been removed from near

the surface and, owing to the abundance of water in the mines and the low price of kaolin, it is no longer profitable to work the deeper parts of the deposit. One company ceased preparing kaolin seven years ago and the other, three years ago. There is thought to be large quantities of good kaolin yet remaining, but not in position to be worked with profit at the present time.

On the Crawford estate, about a mile southeast of Elam Post-office and two miles or more from Brandywine Summit, is a deposit of white clay of considerable extent. It has not been refined for use in china-making, but was formerly used in the crude state for making fire-brick and some of it shipped in the crude state to other points. The material has not been mined for several years, and so far as could be determined from the small exposures now to be seen, it occurs in a sedimentary deposit of recent age. The clay is said to be highly refractory and produced fire-brick of good quality, and was sought after for furnace linings. It is quite probable, from the appearance of the clay, that with proper selection and washing it might produce a fair grade of china clay. Near the clay deposit there is a large sand bank from which considerable sand has been shipped.

Glen Loch.—About a mile and a half north of Glen Loch Station, on the north side of Little Chester Valley, are a kaolin mine and washer that have been in operation for four years, except during the present summer (1898), when they have been temporarily idle. The mine is near the contact of the Chester Valley (Ordovician) limestone and the North Valley Hill sandstone (probably Cambrian). The sandstone outcrops a short distance north of the mine and the limestone a short distance south, but neither rock is exposed at the kaolin opening. There are numerous large masses of coarsely granular white quartz in and near the kaolin, and large masses of granular quartz containing crystallized wavellite. Near the kaolin mine is an old iron mine from which large quantities of limonite were removed years ago. Less than 100 yards north of east is another deep shaft that furnished some iron ore and a rare mineral, *ceruleo-lactite*.

The kaolin is exposed near the surface at the mine, but the owner states that exploration shafts show it to sink rapidly beneath a thick covering of loose material of sand and rock fragments both east and west from the opening. The same authority states that the kaolin vein dips north into the hill and hence runs under the iron ore which lies north of it.

The Glen Loch kaolin bears a remarkable similarity to the white clay deposits of South Mountain in its geological position, but differs quite materially in its chemical composition, as may be seen on comparing the analyses:

ANALYSES OF GLEN LOCH AND SOUTH MOUNTAIN KAOLINS.

	Glen Loch Kaolin. Per Cent.	South Mountain Kaolin. Per Cent.
Silica	51.90	73.80
Alumina	31.29	17.30
Lime	tr	.60
Iron Oxide	tr	.35
Magnesia	1.52	1.18
Potash	4.01	2.49
Soda	2.99	.20
Loss on ignition	8.90	4.69
Total	100.61	100.01

In Chester County, about two miles north of Wagon-town, is an abandoned kaolin mine that was operated twenty years or more ago. A large circular opening about 100 feet in diameter and 60 feet deep shows that considerable work was done here at one time. The country rock is a hornblende gneiss.

SOUTH MOUNTAIN WHITE CLAYS.

Probably the most extensive deposits of white clay in Pennsylvania are to be found in the South Mountain region in Cumberland, Franklin, Adams and York Counties, between Dillsburg on the east and Shippensburg on the west. The most extensive developments have been on the Gettysburg and Harrisburg Railway, south of Mt. Holly, and on the Hunter's Run and Slate Belt branch railway.

Historical.—The occurrence of white clays in this region has been known for many years, but it was only a few years

ago that any attempt was made to put them to commercial use. There are a great many large iron ore mines in which the ore is associated with the white clay. In nearly all these ore mines, which were worked quite extensively years ago, the white clay was found, sometimes underneath the ore and sometimes overlying it. In the latter case it was necessary to remove the clay to get the ore, and it was dumped out as so much waste material, just as the ore is thrown aside at the present time where it interferes in the removal of the clay. In the reports of the Second Geological Survey of Pennsylvania bearing on this region there is mention of the white clays at nearly all the iron mines described, but there is no intimation of any possible

commercial value for them. At that time the ore was the commercial product and the white clay was waste material. The ore users were not clay workers.

The first attempt to make commercial use of the clay was about six years ago, when the Penn Tile Works was established at Aspers, about the same time or shortly after the brick works at Pine Grove began operation. About three years ago two clay-washing plants were established on Mountain Creek, between Pine Grove and Mt. Holly Springs. More than a year ago a clay-washing plant was started at Latimore, and this year, 1898, another large plant started at Mt. Holly Springs. There are other parties exploiting the region for good clays.

Mr. J. W. Ivery has probably done more to develop the clays of this locality than any other individual. It was he that started the works at Pine Grove, at Aspers, and one of the works near Hunter's Run, and he is now Superintendent of the works just started at Mt. Holly Springs.

The factory at Pine Grove manufactures ornamental bricks of different kinds. The white clay, along with some colored clay, is used simply as a bond, the body of the material being a black slate for their reddish-colored bricks, and a greenish talcose schist ("soapstone") for the light-colored ones. The slate is brought to the works by railway from the slate quarry about three miles southwest of the works; the "soapstone" is hauled by wagon from the quarry a quarter of a mile from the works, and the clay is brought by rail from Laurel Station, three miles away. By different mixtures of these materials, this company manufactures quite a variety of ornamental brick, of different colors, shades and sizes. The bricks are moulded by dry press machine, and stacked in the kiln without any preliminary drying. They have two dry press machines, with a capacity of 30,000 per day, but the kiln capacity is only 12,000.

At Henry Clay Station, on the Hunter's Run and Slate Belt Railway, about three miles below Laurel, near the large Henry Clay iron mine, is a clay-washing plant well equipped and capable of turning out 25 to 30 tons of refined clay per day. It has been in operation about three years. The clay is mined in deep shafts 90 to 100 feet deep on the mountain side, a mile or more east of the works, from which point it is hauled by wagon to the works.

At Crane's Siding, on the H. R. & S. B. Railway, one mile above Hunter's Run Station, is a clay-refining plant that has been in operation about three years, and turns out about two carloads, 50 to 60 tons of refined clay per day. The clay is obtained at the long since abandoned Crane iron ore mine, where it underlies the ore, but lies at a high angle on the steep south slope of South Mountain. The mining is done in underground galleries, and the clay run out on tram cars and tipped on a platform from which it is wagoned to the works. The refined clay is shipped to wall-

paper manufacturers and potters. They have also prepared some brown clay from the sludge from the iron ore mine. This branch of the industry has apparently been abandoned.

Near Latimore Post-office, on the south side of South Mountain, six miles south of Dillsburg, the nearest railway point, a clay-washing plant was recently constructed, and has washed 100 tons or so of clay, but the product has not been entirely satisfactory, and the company has not yet put any on the market. Part of the clay is mined near the works, and part is brought from another mine two miles or more north of the works. It is all very short in the grain, apparently high in silica.

The last company to begin operations in the South Mountain district has located its plant at Mt. Holly Springs, and obtains its clay in part from the Upper Mill, a station on the Gettysburg and Harrisburg Railway, and in part from the Henry Clay mine on the Hunter's Run and Slate Belt Railway. From the first point the clay is moved to the works on wagons. From the second it is taken on railway cars. The company has leased clay at other points in the vicinity, but is only working the two deposits at present. This company has one of the largest and best equipped clay-working plants in the State. They have the facilities for washing and refining the clay in large quantities, and they utilize the by-product from the refined clay to make white brick for building purposes. At the time of writing, the company has just begun operations. The machinery was first started in July, 1898, and the first kiln of brick was burnt in September. They expect to refine clay for the wall-paper, the pottery and tile trades, and use the screenings for making high grade brick.

The refining process is different from that in the Chester County washing plants. In place of the log washer, large iron blungers are used to disintegrate and stir the clay to a thin slip. It is run first into large cedar tanks, where the coarse materials are separated and the clay slip pumped into other settling tanks, from which it is pumped into the hydraulic presses. The company now has nine blungers,

twenty-two large cedar tanks and eight filter presses in operation.

The Clays.—The clays of the South Mountain area are sedimentary clays and not formed from the decomposition of feldspar in place like the kaolins of southern Chester County. They are probably of Cambrian age, occurring near the contact of the South Mountain sandstones and shales of supposed Cambrian age, and the Cumberland Valley limestone of Lower Silurian or Ordovician age. The strata are so broken, crumpled and disintegrated that it is not possible in many places to accurately locate the position of the clay beds in the section. In so far as they can be located, they appear to be at or near the top of the supposed Cambrian rocks. They are closely associated with extensive deposits of iron ore. There are a great many large ore mines that were operated extensively a few years ago, and in all these mines that occur in or close to the mountains the white clay occurs in large quantities. In many places the clay is stained in streaks, bands and irregular patches by contact with the yellow, brown and red iron oxides. In some places the ore underlies the mass of the clay, and in other places it overlies the clay, which is the result of the folding of the strata. The iron accumulated on the top of the clay originally, probably derived in part from the overlying limestone, and in part from the associated schists. The meteoric waters percolating through the limestone leached out the iron and deposited it at and near the less permeable clay and slate beds underlying. Further disintegration of the rocks, and later folding and crumpling, aided to mix the ore and clay along the contact, and in the folding of the strata in places the folds were pushed beyond the perpendicular, thus reversing the relative position of the strata on one side of the fold. It may be observed that on the north side of the mountains, or the south side of the valley, the ore underlies the clay, while on the south side of the mountain, or the north side of the small valley, the ore overlies the clay. This may be seen at the Crane Siding mine, which is on the north side of the valley, and where the ore has been worked from the surface openings, and now the

clay is being mined from below and behind the ore bodies. The same condition prevails on the mountain east from the Upper Mill, where Mr. Musser has made several openings in the clay between the ore and the mountain, and while the openings are on the hillside above the ore openings, the strata dip south at a higher angle than the slope of the hill, so that the clay beds are carried underneath the ore.

At the Henry Clay mine and the mine at Laurel the ore dips under the clay at a high angle, and has been worked back until there was a covering of 30 feet or more of clay over the ore. The same condition prevails at the mines of the Reading Iron Company, south of Boiling Springs, where the underdipping ore has been worked back by open cut until the overlying clay was too thick to remove, and then the ore is removed by underground drifts run down the incline underneath the clay.

The structure is rendered more complex and difficult because (1) the rocks in some places are more resistant and the folds have not been overturned, and (2) in several places there have been faults or vertical misplacements of the strata. The difficulties are increased by the scarcity of the exposures of the rocks *in situ*, which is due to the fact that the quartzite rock is quite brittle, and hence much fractured in the folding, thus breaking into loose masses of fragments on exposure, and the slates weather into clays, which, on the steep hillsides, creep down over the surface rocks for long distances. Therefore, while the general structure of the mountains is a series of overturned folds pushed over towards the north, the irregularities due to faults and variations in the strata, further modified by weathering and eroding agencies, render the structure so complex that it is difficult to follow the different strata for any great distance with accuracy. Hence correlation of the different deposits is attended with considerable uncertainty. In the front range, wherever the sandstone or quartzite was observed *in situ* by the speaker, which was in several places, it had a uniform east-of-south dip, but in many of the old ore mines apparent northerly dips are recorded. These apparent variations may be caused by secondary and tertiary folds parallel

with the main one or by the creep of the clay on the hillsides.

The following observations, made by an assistant on the State Geological Survey, fourteen years or more ago, may be of interest in this connection, and as they may not be accessible to all our readers, we take the liberty of giving them.* Owing to the rapid weathering of clays, good exposures made at the time the mines were in operation were quickly obliterated and cannot be observed now, hence the value of observations made years ago as hints and helps now in exploiting the clays which were then "barren clays."

In the Big Pond banks† the southern part of the openings showed 22 feet of white clay (p. 1441).

The George H. Clever bank showed white, yellow and red clays associated with the wash ore (p. 1442).

The Pine Grove bank No. 1 has a large horse of white clay, which still (1886) occupies a place in the east workings, and excavations on both sides of this generally barren dome of clay show excellent ore. The north side of the cut shows a conspicuous amount of black clay (p. 1449).

At the Dunbar mine (R. Boyer) the main tunnel seems to have cut three distinct ore beds, none of them over two or three feet in thickness and separated from each other by an immense amount of barren clay (p. 1460).

At the Crane Iron Company's banks (Phil. Clay Co.) "the stripping, under the most favorable circumstances, amounts to about 20 feet, while toward the mountain, where their best ore is found, it is simply enormous and consists mostly of sandy blue and white clay."

A bore hole for water at the Lehman mine disclosed 340 feet of ore, 40 feet of blue clay, 30 feet of white clay and 25 feet of mountain clay to the Potsdam Sandstone, a total

*These are quotations and abstracts from the report on the iron ore mines and limestone quarries of the Cumberland-Lebanon Valley, by E. V. d'Invilliers, in the "An. Rept. Geol. Surv. of Pennsylvania," 1886, Pt. IV, pp. 1411-1517. The same report is summarized by J. P. Lesley in the "Summary Final Report, 1892, of the Pennsylvania Geol. Surv.," Vol. I, but the summary omits most of the references to the clay.

† See map on page 23 for location of the different banks.

depth of 435 feet. A heavy white clay shows on the western extremity of the cut, similar to that seen at the Crane mine (p. 1462).

At Ege bank (Big Creek) "the gangue material accompanying these ores, and especially that thrown out of the trial pits, is frequently a greenish talcose slate called soapstone by the miners, many of whom state that the base of the ore-bearing clays is a reddish slate, beneath which no ore, but occasionally white barren clay, is found."

At the Heck bank, north of the wash ore deposit, lump ore is said to have been tested by drifts run into the mountain side 25 or 30 feet, beyond which nothing but white clay is found.

At the Muslin bank an "80-foot shaft was sunk in the center of an otherwise promising ore pit, which, however, only developed a stiff white clay through the entire distance" (p. 1483).

The developments at the present time, in fact, the developments twenty years or more ago, are sufficient to show that enormous quantities of beautiful white clays occur in this region, but they are associated with still larger quantities of lower grade clays, that are stained with the associated iron ores. The works erected during the last few years show that the commercial importance of the clays is now established. The developments will be still greater as the quantity and qualities of the clay become better known. Owing to the association of the iron ores with the clays, large quantities of it will be found in all the localities that are stained with the iron oxides, and the company with sufficient capital to use these lower grade clays along with the higher grade will have the advantage.

White clays in the Cambrian rocks are not peculiar to this portion of the South Mountains, but occur in other districts as well. Similar-looking clay has been found, but only slightly developed in rocks of the same age on Never-sink Mountain, at Reading, Pa., where some one* has

* There was no one at the place at the time of my visit, August, 1898, and I could not learn the name of the owner.

opened a deposit of white clay similar in appearance to that at South Mountain.

The Glen Loch kaolin mines may be near the same horizon. A white clay somewhat similar in character, but in smaller quantities, occurs with some of the iron ores in the Nittany Valley. This is probably at a higher horizon, but may have the same source.

Large quantities of white clay are reported at various points along the Great Valley region from Massachusetts to Alabama.* Deposits of the white clay in Lehigh County are said by Professor Prime to be derived from disintegrating damourite slates, and analyses of the clays show close relation chemically to the Cumberland County clays just described.

The Uses of Kaolin.—Kaolin is used in the manufacture of chinaware, hence the name china clay.† It serves to furnish a highly refractory white body for the chinaware. It serves a similar purpose in the manufacture of white tiling, white brick and white clay ware of all kinds. Kaolin, or white clay, is used in large quantities in the manufacture of wall-paper and sized paper, the paper trade taking about the same quantity as the pottery trade. It is used in small quantities for other purposes, but the bulk of the product goes to the potteries and the paper manufacturers.

The output of the Pennsylvania kaolin mines for 1898 is not far from 20,000 tons. As some of the producers will not give their production, this is partly an estimate, but a conservative one, based on observations, reports of railway officials, and a comparison of the working force and facilities of the companies not reporting with those that did give their output.

The prices vary from \$10 per ton for the best grade kaolin to \$6 or \$7 for inferior grades. The prices of one of

* See "Tr. Am. Inst. Min. Eng.," Vol. 3, 1874-5, p. 410. The Brown Hematite Deposits of the Great Valley, by Prof. F. Prime, also "Proc. Amer. Phil. Soc.," May, 1872, and January, 1873, articles by Prof. J. P. Lesley.

† Some writers distinguish between kaolin and china clay by calling the crude product kaolin and the refined product china clay, but the distinction is not scientific nor is it universally adopted.

the companies are, No. 1 kaolin, \$10 per ton, f. o. b.; No. 2, \$8; No. 3, \$7. However, the active competition among the different dealers causes a considerable variation and fluctuation in prices.

ANALYSES OF PENNSYLVANIA KAOLINS.

	SiO ₂	Al ₂ O ₃	H ₂ O	CaO	MgO	K ₂ O	Na ₂ O	Fe ₂ O ₃
1. Glen Loch, Pa.	51'90	31'29	8'90	tr	1'52	4'01	2'99	—
2. Brandywine Summit . .	71'02	19'72	7'04	'32	'03	'27	—	1'58
3. " "	67'71	20'53	7'78	'39	'04	'29	—	3'12
4. Chestnut Hill	67'10	20'10	5'90	'10	'70	2'	tr	3'9
5. E. Nottingham	46'34	36'32	13'75	'04	tr	'77	tr	'64
6. Kaolin, Pa.	—	—	—	—	—	—	—	—
7. Upper Mill, Mt. Holly .	84'05	9'44	2'18	'23	1'35	2'37	'28	'28
8. " "	73'80	17'30	4'69	—	1'18	2'49	'20	'35
9. Mt. Holly Springs . . .	73'30	17'43	4'68	'02	1'28	2'99	'17	'37

No. 1 made by F. A. Genth. 2 and 3 made by J. B. Britton, 1874, 4 and 5 made by F. A. Genth.

Nos. 7, 8 and 9 made in chem. lab. State College; No. 7 the crude kaolin, 8 the refined kaolin, 9 refined kaolin mixture from Upper Mill and Henry Clay mine.

Stated Meeting, March 8, 1899.

SOME FEATURES OF THE STRUCTURAL DESIGN OF BUILDINGS.

BY WM. H. BURR,
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(Concluded from vol. cxlvii, p. 430.)

Experience in modern high building construction during the past three or four years has shown conclusively that although such buildings are from one point of view fire-proof, their interiors are frequently very combustible. Both New York City and Pittsburg, as well as Chicago, can show conflagrations in which steel frames and fire-proof floor construction were but indifferent protection, at least to the interiors of the buildings. It has been conclusively demon-