

## MISCELLANEOUS NONMETALS.

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### VOLCANIC ASH NEAR DURANGO, COLO.

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By LESTER H. WOOLSEY.

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*Introduction.*—Deposits of volcanic ash suitable for abrasive material have been reported to occur in Colorado north of La Veta Pass in Huerfano County, near Wray Station in Yuma County, and near Durango in La Plata County. In this paper the occurrence near Durango will be considered. During the field season of 1905 the writer visited the deposits in La Plata County and procured the data for the following sketch. The distribution, occurrence, and character of the known deposits were studied, but the results of the investigation were such that no careful search was made for others.

*Distribution.*—These deposits form three isolated beds which lie within a radius of 4 miles of Durango. One is located at the east end of the dry valley north of Animas City Mountain, on the shoulder of the southward-facing spur. Opposite the west end of the same valley, on the crest of the ridge between Dry Gulch and Junction Creek, occurs another bed. Both of these deposits have the same elevation—about 400 feet above Junction Creek at this point. The third bed lies nearly east of Durango on the east slope of Florida Mesa, 250 feet above Florida River. All these beds lie at nearly the same elevation and have a somewhat similar mode of occurrence.

*Occurrence.*—The broad geologic features of this region are as follows: The rocks consist mainly of the conspicuously colored Jurassic, Triassic, and Cretaceous sediments which overlie the Carboniferous beds exposed farther north. The whole series is gently upturned to the north and northwest and wraps about the south and west margin of an old Archean surface. Upon the beveled edges of these sediments the deposits of volcanic ash occur. The deposit north of Animas City Mountain lies across the edges of the main upper sandstone of the La Plata formation and the overlying thin beds (Jurassic-Triassic). The actual contact is concealed, but the bottom of the ash is very near bed rock and 20 feet may be considered a maximum interval. Above the ash no rocks occur in place, and the covering consists of rounded pebbles, possibly of glacial origin, dislodged blocks of conglomerate, and fragments of shale belonging to the Cretaceous. The form of the deposit is probably that of a horizontal lens, possibly occupying an irregularity in the bed-rock surface. The extent of the lens is no doubt small, for ash is more or less evident about 100 feet horizontally along the outcrop, and its thickness ranges from 25 to 50 feet. The weathered exposure shows thin horizontal laminations, as if the material were deposited in quiet water. The bed on the ridge southwest of Junction Creek presents a conspicuous outcrop of white ash, lying upon the dark-gray shale of the Cretaceous. It is covered chiefly by rounded gravel, probably of stream origin, mixed with shale and sandstone fragments. In size and form the bed at this point resembles that last described. The lens has been partially eroded and the exposed surface is not over 150 feet long and 15 feet wide. No stratification was apparent and the bed exhibits a homogeneous mass.

The occurrence on Florida Mesa was at the time of visit not well exposed, but over an area approximating 2 acres fragments of ash were thrown out by ground animals. It was reported to have been uncovered in several places years ago and excavated to a depth of 3 feet. The covering consists of a few feet of soil and mesa gravel, and the underlying bed rock belongs to the coal-bearing series of the Cretaceous. From the above facts concerning these ash beds it may be concluded that they occur with no regard to horizon in the sedimentary series, that they are all overlain by surficial deposits, and that they are small in extent, probably occupying basins in an old topography. This old land surface, if we may judge from the elevation of the ash deposits, was not so deeply dissected by streams as it is to-day, and the present dissection may be considered as deepest in the lower courses of the present streams. New deposits of volcanic ash, therefore, are not likely to be found along the lower courses of streams, but may be discovered on the crests of ridges or high up on the valley sides.

*Character.*—All three occurrences are very similar in appearance and exhibit a very fine dust-like powder of white opaque flakes which glisten in the sunlight. The powder has a gritty feel and was not seen consolidated in a hard mass. Under the microscope the powder is seen to consist chiefly of thin minute flakes with angular edges and fair uniformity in size for all the beds. Nearly all the flakes exhibit the transparent amorphous and isotropic character of glass, but some particles show interference colors, extinction, and other characteristics of quartz grains. Few of the glass flakes show air bubbles, and the material on the whole resembles powdered volcanic pumice and may be considered volcanic dust or ash. It is entirely similar to the volcanic ashes from Montana and Idaho collected by Peale of the Hayden Survey and later described by Merrill. The chemical content is no doubt largely silica, and the composition is probably close to that of similar ashes already analyzed, as follows:

*Analyses of volcanic ash.*

	1.	2.
SiO <sub>2</sub> .....	68.92	68.91
Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub> .....	16.22	6.12
MgO.....	Trace.....	
CaO.....	1.62	3.44
Na <sub>2</sub> O.....	1.56	3.09
K <sub>2</sub> O.....	4.00	.36
SO <sub>3</sub> .....		8.88
Ignition.....	a 6.00	8.75
Water.....	1.60	
	99.92-	99.55

a Organic.

1. Marsh Creek Valley, Idaho. G. P. Merrill, *Am. Jour. Sci.*, vol. 32, 1886, p. 202; J. E. Whitfield, analyst.

2. Average sample from Nebraska. E. H. Barbour, *Proc. Nebr. Acad. Sci.*, No. 5, 1895, p. 13; H. H. Nicholson, analyst.

*Relations.*—Deposits of this sort, to judge from published reports, are very common through Nebraska, reaching into South Dakota and Wyoming on the north and west and into Kansas and Oklahoma on the south. In many localities the beds are apparently very extensive and in some places very thick, but usually they are thinner than the Durango beds. The bulk of the deposits on the Great Plains, as stated by Barbour, are fine and uniform, but variations are known, and the ash may be coarse, of a dark-gray color, or mixed with sand, silt, etc. He notes the eastern limit to be Iowa, where the deposits are very fine, while in

Nebraska the beds grow coarse and heavy toward the southwest, and he suggests that the source is in that direction. Scattered deposits, besides those in Colorado, Montana, and Idaho, above mentioned, have also been found in Arizona and Nevada. The age of the deposits in the various States, according to published accounts, is not the same, for ash beds occur at several horizons and in many localities contain distinctive fossils. The beds have been found to range from the Oligocene up into the loess of the Great Plains. In the Durango deposits, however, no fossils were observed, and the indications of age are limited to the relations of occurrence. These restrict the age to post-Cretaceous and probably pre-Pleistocene. The nearest known deposit bearing fossils is in Huerfano County, 140 miles east of Durango. Vertebrate remains discovered there by R. C. Hills have been referred to the Pliocene. While this deposit closely resembles the Durango beds in character and is but a short distance away, its geologic relations are not similar, and the correlation of the two occurrences can not yet be made.

*Development and uses.*—The bed north of Animas City Mountain has been prospected by Mr. Charles Naegelin, the owner, by means of a shaft to a depth of 12 feet and by auger borings several feet deeper. He has made no attempt to prepare the material for market. He was formerly owner of the deposits west of Junction Creek, which he sold several years ago to the Lavaline Company, of Durango. This company has opened the bed by a surface excavation 10 feet deep and 20 feet in diameter. The ash was chuted into carts and hauled to Durango, where it was put up in packages for market as a cleaner. For some reason the company failed and ceased operations, and now the property is abandoned. The bed on Florida Mesa, owned by Mr. Spencer, was opened eight or ten years ago, but for what purpose is unknown.

Ash of this sort in other parts of the West was used by early settlers, it is said; as a plaster for building purposes, but it crumbled and was not durable. It is now locally used in many of the States named as a scouring powder and is put up, especially in Nebraska, under the names "Nebraska Silicate," "Geyserite," "Gibson Grit," "Diamond Polish," etc., and sold as a polishing powder. It has also been used to some extent in the manufacture of sand soaps at Denver and Omaha, but it is said to be not so good for this and other cleaning purposes as the imported article, because the latter is made of particles very angular and pointed, whereas the domestic material consists of flat glassy scales.

That the Durango deposits may likewise be used as an abrasive for many purposes is undoubted, but in view of the reports that in Nebraska, where it can be loaded on cars at \$2.50 to \$3 a ton and where freightage is low, the yearly output of the whole State does not exceed \$5,000, it seems that the Durango deposits are chiefly valuable for local consumption. Of the many uses which have been suggested for this kind of ash may be mentioned semi-fused filling brick, fireproofing, and mineral wool for packing as a nonconductor of heat and sound. It might also be used in its natural state as a nonconductor of heat in refrigerating, and there seems no reason why it should not be used as one of the elements in the manufacture of puzzolan cements, and perhaps of some varieties of glassware.

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## GRAPHITE IN MAINE.

By GEORGE OTIS SMITH.

Two occurrences of graphite in western Maine were visited by the writer in 1905. At one locality, near Madrid, Franklin County, development work had been prosecuted throughout the summer by the Maine Graphite Company, so that the relationships of the deposit were well exhibited. The other locality is in Yarmouth, Cumberland County, and although no recent work has been done here the exposures are sufficient to indicate the character of the deposit. These two occurrences are of interest from both the industrial and the scientific standpoint. The evidence presented in the following descriptions has a scientific value as indicating two modes of origin of graphite, but these genetic relationships have in turn a direct and important bearing on the question of economic value.

### MADRID OCCURRENCE.

The Madrid graphite deposit is located in the town of Phillips, although only a short distance from the little village of Madrid. The nearest railroad point is Madrid station, on the Phillips and Rangeley Railroad. The schist, which together with intrusive granite constitutes the country rock in this region, outcrops here along the northern slope of a hill immediately south of the village. Beds of varying composition can be distinguished in this schist and indicate a northeast-southwest strike. The general dip is nearly vertical, although the schist is much contorted. The development work is in the form of an open cut which extends into the hill approximately parallel with the strike of the schist, the face at the southwest end measuring about 30 feet in length by 25 feet in height.

In the upper part of the face on the western side there is a triangular area of fine-grained white rock with a sandy texture. This rock contains varying amounts of quartz and, where it cuts directly across the schist, shows a selvage of muscovite and a general banding conformable with the contact with the schist. Another mass of similar rock, somewhat coarser grained, occurs in the eastern part of the same face, the two being separated at one point by not over 2 feet of schist. Near the entrance to the cut and on the east side is another mass of white rock which probably connects with the second. This third mass is plainly pegmatitic in texture and composition, containing quartz and muscovite, with subordinate amounts of feldspar. Close examination of the other masses of white rock, especially where exposed on the hill slope above the open cut, makes it evident that these are also of pegmatite. The three somewhat irregular-shaped masses may be regarded as possibly portions of one intrusive body of pegmatite, which in part cuts across the schist and in part follows the bedding planes.

The graphite occurs locally in the schist, always close to the contact with the white rock, with the exception of the sporadic occurrence of a few slickensided lenses of graphitic rock, about 18 inches in their longer diameters. At no place seen in this rock cut did the graphitic portion of the schist extend more than a few inches from the contact. At the point in the face of the cut where the two bodies of pegmatite are nearest together the schist is crumpled and crushed into blocks which appear to be largely graphite. However, all of the schist is not strongly graphitic at the pegmatite contact. Where the bedding planes can be traced with certainty, it is seen that one stratum may be graphitic and the beds on either

side relatively barren, even at the point of contact with the pegmatite. This pegmatite-schist contact is well defined, and while the muscovite selvage contains a small content of graphite, the muscovite does not apparently extend into the schist.

Microscopic examination of thin sections of these rocks simply confirms the field evidence. The schist contains varying amounts of graphite, adjoining beds also differing considerably in their other constituents. A specimen collected at a distance of several feet from the pegmatite contact is a quartz-biotite schist in which graphite is present as very fine dust, which gives the gray color to the rock. A thin section cut from another rock, apparently relatively barren of graphite although close to the contact, shows a similar small content of graphite dust, the mass of the schist being composed of muscovite, quartz, tourmaline, and pyrite. The adjoining bed, which was mentioned above as graphitic, is a schist darker in color, but when the rock is studied in thin section the amount of graphite present is found to be small. The abundance of needles of brown tourmaline doubtless contributes to the dark color, and pyrite is again present, in close association with the tourmaline.

A thin section of the best grade of graphitic rock collected at the Madrid cut shows this schist to contain small grains of graphite evenly distributed throughout the rock. This is in most intimate association with muscovite, the small folia of muscovite being thoroughly interwoven with the graphite flakes and grains. In other bands fine grains of quartz form the matrix for the graphite particles. The schist is beautifully foliated and a glance at either the hand specimen or the thin section leads the observer to overestimate the amount of graphite present. This is due to the fineness of grain and the thorough dissemination of the graphite throughout the rock. Although it is evenly distributed in the rock, the foliated character of the graphite causes the surface of this graphitic schist to seem very rich in graphite. The graphite particles are in reality minute and range from 0.20 to 0.01 mm. in diameter, the average size being less than 0.04 mm.

A sample was collected of the best of the graphite schist as exposed in October on the face of the cut at Madrid. The amount of graphite in this sample was determined in the Survey laboratory by E. C. Sullivan as 8.5 per cent.

#### YARMOUTH OCCURRENCE.

In the town of Yarmouth the graphite locality is about one-half mile northwest of the village. The country rock in the southern part of Cumberland County is a fissile schist, fine grained, but apparently not at all carbonaceous. This schist in the town of Yarmouth is cut by large intrusions of granite, and in one of the large masses of granite graphite-bearing pegmatite occurs. This pegmatite has been prospected at several points within 200 yards and occurs in the form of a dike with an average width of 1 foot. The exposures were not sufficient to determine whether there is not a possibility of two parallel dikes being present rather than a single dike. At one point a basaltic dike is in contact with the pegmatite, and, though the contact relations are not at all plain, the pegmatite is presumably the older.

The pegmatite is for the most part of medium grain, and quartz and feldspar are the principal constituents. Small amounts of mica occur, but only sporadically, while graphite is an important constituent. A few nests of graphite about an inch in diameter occur in the pegmatite, but the most of the graphite is in the form of disseminated flakes evenly distributed throughout the rock. No definite difference between the content of graphite near the walls of the dike and that at the center could be noted, nor was any variation noticed in the amount near the contact with the basaltic rock.

Examined microscopically, this pegmatite is found to resemble other pegmatites except in the presence of the graphite. Quartz, orthoclase, and plagioclase form a mosaic similar to that typical for granite. The only other constituent present is biotite, which occurs in small amounts and is largely altered to chlorite. The graphite, as already mentioned, occurs in the larger masses and in flakes. These lustrous flakes are disseminated in the

larger masses of quartz and throughout the finer-grained matrix. No graphite was noted in the larger crystals of feldspar. As seen in the thin section of the pegmatite, the graphite forms irregularly shaped masses, interlocking with the quartz grains. These flakes and smaller masses range from 1 to one-half millimeter in their longer diameters.

A chemical determination of the graphite in a representative sample of this graphitic pegmatite from Yarmouth was made by Mr. Sullivan and shows 9 per cent to be present.

### ORIGIN OF THE GRAPHITE.

The field observations and microscopic study indicate clearly a difference in the character of the graphite in the two occurrences described. The Madrid graphite is exceedingly fine grained and of the variety that is often called amorphous graphite, although the minute particles are in reality crystalline, possessing all the luster of the larger flakes of the Yarmouth graphite. This lack of similarity in size of particles and the differences in form of occurrence are suggestive if not indicative of wholly different modes of origin.

The presence of graphite in the Madrid locality, at the contact between an intrusive mass of pegmatite and somewhat carbonaceous schist, at once suggests a contact origin for the graphite. The relative concentration of the graphite at the contact indicates that the processes active in the formation of that mineral were connected with the intrusion of the granitic magma rather than with the dynamic forces which have affected to some extent the rocks of the region. The source of the carbon thus crystallized into graphite was presumably in the original sediments from which the beds of schist were formed. This inference is based on the variation in content of graphite in adjoining beds even at the pegmatite contact, a variation believed to express the original difference in percentage of carbon in the successive layers of muddy sediments. The possibility is recognized, however, that certain parts of the schist may have exercised a selective influence in the concentration of the graphite, just as it is noted that these adjoining beds contain varying amounts of tourmaline, which doubtless originated from the pegmatite magma. The graphite at Madrid is believed to be the product of the conversion and concentration of carbonaceous particles of sedimentary origin through the agency of the heated vapors issuing from the intrusive rock magma now consolidated as pegmatite.

In the Yarmouth occurrence there is no evidence of any source of the carbon of the graphite other than in the molten rock itself, which intruded the granite. The graphite is as much an essential and original constituent of the pegmatite dike as is the quartz or the feldspar. The graphite crystallized possibly later than the feldspar, but plainly earlier than the quartz, and like these minerals was of magmatic origin.

### ECONOMIC CONSIDERATIONS.

The practical questions concerning these deposits refer to the quality of the graphite and the quantity present. Certain deductions may be made from the observations given above and may serve to answer the question of economic worth.

The graphite at Madrid is of the type often called amorphous, a relatively low-priced material except when fairly pure and free from other minerals. As has been noted above, the size of grain in this graphite is minute and its association with muscovite and quartz very intimate. These two characters would render even partial separation of the graphite and mica especially difficult. The size of the larger grains being only 0.2 mm., and the average being less than 0.04 mm., the graphitic rock would need to be crushed so as to pass at least a 200-mesh screen before the complete separation of graphite from the mica could be effected. Such a procedure would be impracticable, and it is very doubtful if crushing to 60-mesh size would facilitate separation of the graphite from the other minerals. In short, the intermixture of graphite and mica is on so minute a scale as to prevent recovery of anything but a very impure graphite by any known method of separation.

The quantity of graphite present is also disappointing. The results of close observation of the occurrence at Madrid clearly point to the localization of the graphite at the contact

of the schist with the pegmatite bodies. Exploration of the schist away from these contacts in the hope of discovery of other and larger deposits would be unwarranted. The amount of graphite exposed along these contacts would vary much from place to place, but judging from the exposures seen in October, 1905, as well as the nature of this deposit, the tonnage of even 8 per cent product would be too small to form the basis of profitable mining. Any doubt as to the truth of this statement regarding quantity is at once set aside, if the difficulties of milling the rock are considered. It is difficult to conceive of a practicable process by which this graphite percentage of 8.5 would be increased to 20. Even if a product of that grade could be secured, it would hardly be marketable in competition with higher grade graphite. The content of graphite would be too small to give the material much value even for the manufacture of paint or stove polish, while the impurities present would unfit it for other purposes.

The graphite at Yarmouth differs greatly from that already described. The size of the flakes is larger and the proportion of graphite present more constant. The smaller individual flakes vary from one-half to 1 mm. in diameter, with larger flakes often 2 mm. or more in diameter. If this rock were crushed and sized on a 60-mesh screen it seems probable that the material would be in good condition for a mechanical separation of the associated minerals. The small amounts of mica noted might make it difficult to secure a perfectly pure product. The fineness of this clean graphite would affect its value, but a coarser and more valuable product might be secured by improved methods.

The percentage of graphite in the Yarmouth pegmatite is given above as 9. The sample analyzed was collected as representative of the whole dike so far as seen in the few exposures. If this truly represents the proportion of graphite present, it indicates roughly the amount of rock that must be quarried to secure a ton of commercial product. This becomes an important factor in the question of practicability of utilizing this deposit, especially since the dike is so narrow that the amount of dead work would be proportionably large. On the other hand, the proximity to the seaboard is one feature favoring the working of the Yarmouth deposit. All these details need to be carefully considered in estimating the cost of mining and milling the graphitic product. Thus, while flake graphite is present in good amount in the Yarmouth dike, the practical value of the deposit is somewhat in doubt in view of the size of the dike in which this mineral occurs. It is probable that this dike is persistent for a considerable distance horizontally and to whatever depth it could be profitably followed, and there seems no reason to expect the content of graphite to change essentially.

Other occurrences of graphite are reported in Maine, and are believed to belong to one or the other of the types described above. Their economic utilization is desirable, yet it involves questions, similar to those suggested in this article, which deserve careful consideration. Thorough investigation will be necessary in each case to determine the actual value of the deposit.



## SURVEY PUBLICATIONS ON MICA, GRAPHITE, ABRASIVE MATERIALS, ETC.

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ROTHWELL, R. P. Pyrites. In Mineral Resources U. S. for 1886, pp. 650-675. 1887.

SPURR, J. E. Alum deposit near Silver Peak, Esmeralda County, Nev. In Bulletin No. 225, pp. 501-502. 1904.

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The following papers relative to phosphates, gypsum (land plaster), and other mineral materials used as fertilizers have been published by the United States Geological Survey or by members of its staff. Further references will be found under the head of "Gypsum" in the list on page — of this volume:

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## SURVEY WORK ON WATER.

In addition to the investigations of the metallic and nonmetallic resources of the country, which are carried on by the geologic branch, the Survey, through the division of hydrology, has also made extensive studies of the occurrence, character, and economic value of underground waters, including mineral water and water used for public, industrial, and irrigation purposes.

The value of mineral waters sold for medicinal and table purposes alone is over \$10,000,000 annually, which places them among the most valuable mineral products of the country, while it is probably safe to say that the value of the water used for public supplies and irrigation is more than that of all other mineral products combined.

The results of the investigations of mineral waters are published in a series of reports on "Mineral Resources," which appear each year, while those dealing with all other classes of water are issued mainly as Water-Supply and Irrigation Papers. Occasionally, however, important papers relating to waters have appeared in the Geologic Folios, Bulletins, Annual Reports, and Professional Papers. The various papers on underground waters may be classed as follows:

1. Detailed reports, consisting of descriptions of the occurrence, quantity, and quality of the underground waters of limited areas. Nearly every State is represented, but few are completely covered.
2. Preliminary reports, containing summaries of the occurrence of underground waters. All States east of Mississippi River and a number of those west of the river have been covered.
3. Reports on mineral and potable waters.
4. Reports on springs and spring deposits.
5. Papers on artesian requisites, movements of ground water, etc.
6. Report on laws relating to underground waters.
7. Reports on measurements of flow and head.
8. Lists of wells and borings.

In addition to the special reports on underground waters a large number of Survey papers on other subjects contain more or less important references.

For a complete classified list of special publications on underground waters, Water-Supply and Irrigation Paper No. 160, entitled "Underground-Water Papers, 1906," should be consulted. A full subject index of Survey publications on ground waters up to the beginning of 1905 will be found in the "Bibliographic Review and Index of Papers Relating to Underground Waters published by the United States Geological Survey, 1879-1904," issued as Water-Supply and Irrigation Paper No. 120.



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