SOME EFFECTS OF HEAT ON THE PROPERTIES OF MINERALS[1]

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On January 27, 1917, fire destroyed the Chemical Laboratory at the University of Virginia, Charlottesville, Virginia. A collection of minerals, belonging to J. W. Mallet, late Professor of Chemistry at the University, stored in the building at the time, was exposed to the direct action of the fire. After the fire the remains of the collection were examined in an attempt to recover some of the more valuable specimens, which included twenty-four diamonds and other rare species. The attempt to recover the diamonds having proved a failure, the salvage was stored until the present time.

The effect of heat upon many of the minerals which constitute the building stones is well known. In regard to the less common minerals, including some of the ore minerals, these data are known only in their application to blowpipe analysis and as applied to very small specimens or to the powder of the mineral. It was thought that the phenomena produced in this collection of minerals might show features not emphasized in the customary blowpipe practice. The collection contained specimens of all sizes from small individual crystals to large masses of material weighing several kilos. Furthermore since the fire lasted for several hours, the heat was applied for a longer period than is customary in producing the reactions obtained in determinative work.

The temperature of the fire is believed to have been approximately 940 degrees Centigrade. Large masses of brass were entirely unaffected by the heat but glass was fused into globular forms. Similarly, silver in wires was fused into globules but copper was unaffected. It is assumed that the temperature was fairly uniform but it must be remembered that there was necessarily some slight variation from place to place, as shown by the examples given. Certain areas of the burning building were more protected than others and the temperature varied accordingly.

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[1] The writer's attention was called to the collection by Dr. Thomas L. Watson, who suggested that a study of the "burned" material might reveal interesting and valuable data on the effect of heat on the properties of minerals. Dr. Watson also gave many valuable suggestions during the course of the investigation.

The procedure of the study was to consider each specimen known to have gone through the fire and to determine its mineral nature, original appearance and the changes produced by the fire. As far as possible the original appearance of the mineral was determined from the mineral itself. In some cases even the interior of the specimen was so changed that its original appearance could not be described. Only cases in which the identification was certain and the original appearance apparent, in the specimen itself, are considered here.

Considerable difficulty was experienced in separating the effect of weathering from that of heat. The collection had been exposed, for a long time, to the action of the weather. Certain minerals, such as those of copper, showed extensive alteration probably caused by weathering and not by the heat. Many specimens were entirely decomposed by the action of the fire and could not be identified. The most durable minerals or those least affected by the fire were the ones determined. Fifty species were positively identified and their changes recorded. The results are tabulated below.

ORIGINAL MATERIAL	BURNED MATERIAL
(1) Antimony. An ore specimen 2″×2″×1″ with scattered grains of metallic antimony. Individual grains less than one-eighth inch in greatest dimension.	Surface of burned material showed accumulation of globular bodies of metallic antimony some larger than ¼″ in diameter. These show that the mineral melted and that the melted part solidified on the surface of the specimen. The interior of the specimen was unaffected.
(2) Silver. Shreds and masses of wire silver in limestone. Single groups of wires up to ½″ long.	Exposed surfaces and points of the silver were fused to globules but some points were unaffected. At this place the temperature must have been very close to 960 degrees Centigrade.
(3) Copper. Zeolitic copper ore showing abundant native copper and cuprite in basalt, 3″×3″×2″.	Neither copper nor cuprite were affected by the fire. Malachite was well developed but probably through weathering.
(4) Tetradymite. A pure specimen of massive tetradymite, 3″×3″×3″, silvery white in color, slightly sectile and very soft.	The surfaces of the burned material were fused with escape of gas bubbles as shown by hollow globular bodies. Surface showed greenish earthy appearance but the interior was unaltered.

ORIGINAL MATERIAL (continued)	BURNED MATERIAL (continued)
	The surface made harder and more brittle than interior. Films of metallic bismuth were developed along cracks in the mineral.
(5) Galena. Cubes of the mineral up to ½″ square.	Luster of surface dulled and rendered non-metallic. This effect extended inward less than one-eighth inch.
(6) Chalcocite. Specimen of pure metallic material 3½″×2½″×2″.	Changed in color to dark grayish to greenish resembling furnace slag. Interior was made porous and vesicular with many bubble holes. Color of fresh surface differed from typical chalcocite in that it had lost gray tint and had become earthy. Pores and openings occupied by metallic copper.
(7) Pyrrhotite. Massive material of typical color, 2½″×2″×2″.	Color was changed, in places from bronze to bluish black. Specimen was rendered slightly more brittle.
(8) Bornite. Pure, massive material 2″×1½″×½″.	Surface of burned material exhibited a dull non-metallic appearance with a dark earthy green color. Interior of specimen was fresh and metallic in appearance.
(9) Chalcopyrite. Impure material 3″×3″×3″.	The burned material showed a powdery green surface with an earthy appearance. The interior was unaltered. There was no evidence of fusion or development of native metal.
(10) Arsenopyrite. Massive material 2″×2″×2″.	The surface was blackened and oxidized with the loss of metallic luster. The interior was unaltered.
(11) Polybasite. Vein quartz with veinlets of silver minerals, cerargyrite and polybasite.	The burned material showed the quartz whitened and made friable. Surfaces carried globules of metallic silver and partly reduced silver minerals. These minerals fused and bubbled up on the surface of the quartz. Interior of specimen showed only slight fusion of the silver minerals.
(12) Cerargyrite. See (11).	See (11).

ORIGINAL MATERIAL (continued)	BURNED MATERIAL (continued)
(13) Fluorite. A mass of transparent crystals of fluorite, aggregating 3″×1½″×1″, with purple color, coated in places with minute grains of sulphide minerals. Crystals cubic, often grown together.	The burned material was whitish nearly opaque at places showing purple tint. Rendered exceedingly brittle being easily broken between the fingers. The sulphides were little affected.
(14) Quartz. A group of transparent crystals 5″×3″×3″ on a base of sandstone. Single crystals up to 1½″ long.	Exposed edges of burned material was rendered opaque or milky. The entire specimen was made brittle and friable being easily crushed by the fingers.
(15) Hematite. A museum specimen of crystallized specular hematite, 3″×2″×1¾″, with well developed individual crystals.	The surface was changed from brilliant metallic appearance of specularite to the dull red color of massive hematite. Minute iridescent flakes of magnetic material, resembling artificial carborundum, were developed on the surface of the specimen. The color change extended inward only a small fraction of an inch toward the center of the specimen.
(16) Ilmenite. Mass of pure material 2″×2″×1″.	Was rendered more brittle than typical material.
(17) Chromite. Pure material 4″×4″×3″.	Burned material was slightly more brittle than typical material and showed the development of a greenish oxide coating along fracture cracks.
(18) Manganite. A radial group of slender striated crystals with a botryoidal structure. Single crystals up to 2″ long, diameter of group 2½″.	In a zone extending ½″ from surface the color of the mineral was changed from black metallic to earthy brown.
(19) Calcite. A mass of vein material with crystallized calcite of yellowish color and transparent.	The mineral was made less coherent and its surface was turned white and nearly opaque. The interior of the specimen was unaffected.
(20) Cerusite. A porous mass of impure cerusite and smithsonite 3″×2½″×1″.	The surface was made black and slaggy in appearance with the development of small globules of metallic lead. The slaggy crust extends inward ¼″ where it is replaced by greenish-gray porous carbonates.

Original Material (continued)	Burned Material (continued)
(21) Garnet. Single crystal ¾″ in diameter in mica schist.	Unaffected though schist was rendered friable and incoherent.
(22) Olivene. A specimen of granular material (dunite) 2½″ in diameter.	Surface was blackened and made earthy.
(23) Andalusite. Fine crystals up to 1″ long in a matrix of milky quartz.	The fire loosened the crystals in the matrix and made the quartz incoherent.
(24) Cyanite. A mass of interlocking bladed crystals with blue color.	The specimen was made friable and the blue color was destroyed nearly to the center of the specimen.
(25) Prehnite. A crust, ½″ thick, of radiate groups of light green crystals covering a 3″×3″ surface of basalt.	Edges showed white color and swelling or intumescence. Interior unaffected.
(26) Muscovite. Crystals, ½″ across base, in matrix of quartz.	Edges and surfaces were darkened slightly.
(27) Lepidolite. A mass of minute flakes with violet color, 6″×5″×4″.	Violet color destroyed leaving specimen uniformly white.
(28) Apatite. A single prismatic crystal, without terminations, 2½″×½″, of reddish brown color.	Reddish color has been changed to gray with a tint of pink. Luster was changed from vitreous to dull. Interior of crystal unaffected.
(29) Pyromorphite. A mass of small greenish crystals in quartz.	The center of the specimen was unaffected. The surface showed development of fused globules with gas holes. The color was changed to brown and grayish-black.
(30) Vanadinite. Massive material 6″×4″×3″.	The surface was blackened and made slag like with small globules of metallic lead. Interior showed a greenish color and a porous structure with many open spaces like channels. These openings were partly filled with metallic lead. The globules often showed gas holes.

Original Material (continued)	Burned Material (continued)
(31) Mimetite. Small crystals and grains in quartz.	Specimen was partly reduced as shown by globules of metallic lead on its surface. Interior was unaffected.
(32) Turquois. Fine. bluish-green material.	Color was changed to white with tint of blue. Center of specimen unaffected.
(32) Celestite. A single crystal 1″×½″×½″.	Specimen was made slightly more brittle.
(34) Gypsum (Alabaster). Pure. white. 3″×2″×2″.	The outer part of the specimen was made powdery with the development of an unctious character showing that the mineral lost water. This effect extended inward ½″.
(35) Anglesite. Magnificent crystals up to 1½″ long with typical orthorhombic development and groups of small crystals forming a felt like mass on a sulphide base.	The color was changed to dull bluish-black with the development of a submetallic luster. The smaller crystals were decomposed with the formation of metallic lead.

In addition to the minerals listed above, the following were entirely unaffected: graphite, molybdenite, niccolite, cuprite, magnetite, rutile, brookite, orthoclase, labradorite, leucite, axinite, tourmaline (black), talc, titanite, and lazulite.

A review of the above table shows that most of the changes produced, by the fire, were the ones to be expected. A few, however, seem to merit special mention. Among the most interesting were the changes in color. The following non-metallic minerals suffered a loss of their characteristic colors: fluorite, cyanite, prehnite, lepidolite, and turquois. Of these, turquois behaved in an unusual fashion. This mineral is supposed to change to a brown color upon heating but it was found, here, to assume a white color.

Other changes related to color are as follows: metallic chalcocite to earthy slag; metallic bornite to earthy material; transparent quartz to milky opaque material; metallic hematite to non-metallic; black metallic manganite to earthy brown material; transparent calcite to cloudy material; and flesh colored apatite to dull grayish material.

Several of the ore minerals suffered decomposition and the formation of the native metal. These were chalcocite, vanadinite, pyromorphite, mimetite and anglesite. In each of these cases there is ample evidence to show that volatile constituents were liberated, for bubble holes can be observed in every case. It is of interest that chalcocite suffered decomposition while bornite and chalcopyrite did not. Gypsum was dehydrated but the temperature was not sufficient to free the carbon dioxide of calcite.

NOTE ON COBALTIFEROUS GAHNITE FROM MARYLAND[1]

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The old copper mines of Carroll County, Maryland, are known to mineralogists as the type localities for two rare cobalt minerals, remingtonite and carrollite. The ores have, however, received little critical mineralogical examination in recent years. While on a visit to several of the mines in company with Drs. Schaller and Foshag the writer found a specimen of a deep blue mineral at the Mineral Hill mine and the same mineral was found at the Patapsco and Springfield mines by Dr. Foshag. This mineral had much the appearance of lazulite but upon optical examination it was found to be isotropic and analysis proves it to be the zinc spinel, gahnite, notable as owing its beautiful blue color to cobalt which is present in definite amount. This analysis is interesting as confirming the work of Wherry who, by microspectroscopic examination, found that distinctly blue spinels gave the absorption spectrum of cobalt.[2] Trial of a thick section of this Mineral Hill occurrence showed only a faint, hazy band, but it occupied the characteristic position in the spectrum, wave length 550.

The mineral is deep indigo blue in color and occurs as octahedral crystals up to 5 millimeters in diameter and as granular masses of smaller crystals several centimeters in diameter. The spinel, in specimens from all three mines, occurs in veins of glassy quartz up to 10 cm. in width enclosed in fine micaceous schist. In the specimen analyzed the spinel forms streaks parallel to the walls of the veins. In the specimens from both the Patapsco and

[1] Published by permission of the Secretary of the Smithsonian Institution. A preliminary paper on the Minerals of Maryland, being compiled under the auspices of the Maryland State Geological Survey.

[2] Edgar T. Wherry. The microspectroscope in mineralogy. *Smithsonian Miscellaneous Collections,* **65,** No. 5, 1915.