ART. XXV.—Phosphorescence and Luminescence in Calcites; by Wm. P. Headden.

In 1906,¹ I described some yellow calcites, principally from Joplin, Mo., that phosphoresced on insolation. This phosphorescence differed from that of ordinary calcites in its duration; the maximum observed being between 13 and 14 hours.

I recorded three failures to obtain phosphorescence. Later Professor Nichols, of Ithaca, N. Y., recorded a complete failure to obtain phosphorescence,² and in 1922 Dr. W. S. Andrews, Schenectady, N. Y. (private communication) also failed to obtain phosphorescence on insolation. These failures were not due to the samples for they all responded on insolation at Fort Collins under favorable conditions. The cause of these failures probably lay in the character of the atmosphere through which the sunlight had to pass. The present object is to show that it did.

If two samples, equally sensitive to sunlight, but one covered with a plate of ordinary window glass and the other not, be exposed to a strong clear sunlight for a few minutes (3-5), the naked one will phosphoresce, the covered one will not. Colored glasses are more efficient in preventing this phosphorescence; red glass will prevent it when the exposure is extended to 40 minutes. The light of the visible spectrum passes through ordinary glass; the rays that excite this phosphorescence do not pass through it readily.

Dr. Andrews finds that the light of the iron spark does not excite phosphorescence in this calcite, and Prof. Nichols finds that neither the iron spark nor the aluminum spark under water excites it to phosphorescence. The light from these sparks is very rich in ultra-violet radiations, but it does not excite the phosphorescence. It might be thought that the water under which the aluminum spark was produced had absorbed the exciting rays. This is probably not the case for the calcite when insolated under a 3/4-inch layer of water phosphoresces brightly.

¹ This Journal, April, 1906.
The phosphorescence is, then, not excited by the light of the visible spectrum, nor by the ultra-violet radiations emitted by the iron and aluminum sparks, but the sunlight does excite it to phosphorescence.

The ordinary carbon arc fails to excite it but if we use 30 amperes it excites it feebly at a distance of 12 inches and with an exposure of 5 minutes. If the carbons be saturated with molybdate acid the light excites a brilliant and lasting phosphorescence on very short exposure at a distance of 12 inches.

Prof. Nichols informs me that this arc is very rich in light, having a wave-length of $3790 \text{ A.U.}$. When samples of calcite are exposed to this light with and without a cover, they deport themselves in the same manner as when exposed to sunlight. This indicates that this wave-length is the principal one in exciting this phosphorescence and is readily absorbed by glass. The absorptive power of glass for this molybdenum arc-light is limited, and so it is for the sunlight and approximately to the same extent.

It has been emphasized that a clear sunshine is necessary to excite this phosphorescence. I have no means of measuring and designating conditions of the sky. The best that I have been able to do has been to ascertain the time required to excite phosphorescence. With covers of different glasses I have found the time required to produce phosphorescence to vary from $2\frac{1}{2}$ minutes with a colorless optical glass to a practical prohibition for a plate of red glass $\frac{1}{4}$ inch thick. This is the thickness of the glass plate, but the colored portion was very thin. The slightest haze in the sky had the same effect and varied with its intensity from a slight retardation to prohibition. Sometimes the effect seemed to be greater than one would expect from the degree of haziness. Actual cloudiness produced a varying effect but always in the same direction. These results indicate the exciting agent and the cause of our recorded failures.\footnote{We used Petri dishes as containers for the samples exposed to the arc light, also in insulating them; in some cases the glass phosphoresced very brightly for 3 or 4 minutes and the calcite had to be removed from the dish for observation.}

In making these experiments it became advisable to compare samples that had been kept in a cabinet for about 20 years with others that had been wrapped and
kept in the dark. The 20-year exposure had evidently weakened the phosphorescence, though a diminution in the intensity of the color could not be predicated; on the other hand, samples that had been heated when the laboratory was burned out had lost nearly all of their color and responded only faintly on insolation. These samples were not decomposed; they preserved their form, cleavage and luster prefectly and the yellow color was not wholly discharged. The amount of carbon dioxide present was unchanged; before the fire I found 43.950 per cent, after the fire Mr. Vail, an assistant, found 43.955 per cent. Different portions of this calcite have different colors; yellow, purple or colorless is the range. The purple portions were decolorized as well as the yellow. The purple and colorless portions have not heretofore been mentioned because they do not phosphoresce on insolation.

These yellow calcites can be heated to 200°C. for a short time without perceptible change in color and they retain the property of phosphorescing on insolation. This point will be taken up later.

There is something in these yellow calcites, be it a question of composition or of structure, which is temporarily changed by the exciting agent which is evidenced by the emission of light when removed from these sources of excitation. But few, if any, other calcites possess this property. I have found but one other, a brown one, and this may not be an identical case. On the other hand, the exciting cause seems to be confined to a definite section of the ultra-violet spectrum not very far removed from the visible spectrum.

The X-ray excites a phosphorescence in the yellow calcite which may possibly be identical with that excited by the sunlight and that of the molybdenum arc. Its color and duration suggest that it is, but the X-ray excites a luminescence in other calcites, also in the yellow that has been heated until colorless and no longer responds to the sunlight, or molybdenum arc, and even in burnt lime.

I have maintained that whatever causes the yellow color in these calcites is the necessary condition for the exciting of phosphorescence by the sunlight, by the molybdenum arc and also of the phosphorescence, not the luminescence excited by the X-ray.
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I am aware that certain colors in minerals have been attributed to certain radiations. Dr. A. Debierne in explaining the theory of phosphorescence says, "When a phosphorescent body has been exposed to certain radiations for a long time, for example to the radium rays, one frequently observes a visible modification of the phosphorescent substance which takes on a peculiar coloration. Glass and the alkaline chlorides are colored brown, violet or green; the natural fluorides violet or green; colorless quartz becomes identical with smoky quartz, etc. The colored bodies thus obtained present a new phenomenon known under the name of thermoluminescence. When one heats these colored substances to a sufficiently high temperature, they emit light and at the same time return to their original condition. Some minerals are met with in nature (especially the fluorides) which exhibit this phenomenon with decoloration, and one is generally able to color them anew and render them capable of giving this luminescence by exposing them to the radium rays."

Luminescence with decoloration is shown by these yellow calcites, also by the purple calcite. The property of thermoluminescence in calcites is by no means confined to colored ones, and the theory does not always apply and we must make distinctions in different cases of this thermoluminescence. The fact is that most calcites possess the property of thermoluminescence, some of them in a very high degree.

Dr. Debierne explains phosphorescence as a slow change from one body into another with the emission of light. In heating a violet fluor spar we change, according to his views, a violet compound into a colorless one, which is shown by luminescence during the change. In the case of a phosphorescent body this change goes on slowly at ordinary temperatures with the emission of light.

Our yellow calcite, insolated at a temperature of \(-3^\circ C\), phosphoresced brightly for more than two hours and there was no perceptible change of color. This fact is mentioned as suggestive of the necessity of making some distinctions in cases like this between luminescence and phosphorescence, and perhaps between different cases of phosphorescence.

What the body is that suffers these changes is not explained beyond the suggestive statement that phosphorescent bodies are generally mixtures, and that the impurities constitute, in the majority of cases, the material sensitive to the exciting rays, whereas the principal substance is simply a diluent. There is no doubt about our calcite containing a variety of substances as impurities. Whether these are really the cause of the different colors is evidently open to question. There is, however, no doubt but that the yellow becomes phosphorescent and the purple and colorless do not. They all contain impurities and the same impurities; to the best of my knowledge, however, in different proportions. I am aware that the amount of impurity necessary to determine some properties of phosphorescent substances lies beyond the range of our chemical manipulations to detect.

The yellow color is so regularly defined by lines of growth that it is difficult to resist the idea that it is due to the composition of the depositing solution, and yet this may not be so. The purple, on the other hand, is generally more diffuse but is sometimes limited by a cleavage plane and there is no suggestion of a definite relation to the growth of the crystal. I at one time thought that yellow color was due to some member of the yttrium group and the purple to didymium, because it shows the absorption lines of this element which would seem to be a good reason for the conclusion. This, of course, considers the impurities as the cause of both of the colors, and in the case of the yellow, as the cause of the phosphorescence. I am, however, fully convinced that this at best is only part of the explanation.

I have nowhere found any distinctions made between the phenomena of phosphorescence produced in different subjects or in the same subject by different agents. It seems to be accepted that the various instances of phosphorescence are essentially of the same character. Different subjects give different phosphorescent spectra, but no further investigations seems to have been made to show whether a substance excited by a single agent may give a phosphorescence divisible into simpler ones. There are many statements giving the effects of different parts of the spectrum in exciting phosphorescence, but no
mention of differences in the phenomenon, due possibly to different compounds or to different physical conditions in the phosphorescing subject.

To make plain the questions in mind in writing the preceding paragraph, I will formulate some of them. This yellow calcite phosphoresces when heated to temperatures between 60° and 180°C. and also when isolated at a temperature of −3°C. These phosphorescences differ in color and duration. The length of the heat waves at 60° to 180°C. must be well down in the infra red, and yet they excite a fairly bright phosphorescence with a distinctly reddish-yellow light. Insolation at −3°C. excites a phosphorescence having a mild yellow light and of longer duration than the preceding. They can scarcely be identical or owe their existence to the same compounds or perhaps better, to the same structure in the mineral.

The phosphorescence produced by heating to temperatures between 60° and 180°C. appears even more remarkable when we consider that the light from a carbon arc using a 7-ampere current and at a distance of 3 inches (Dr. Andrews) has no power to excite it, and a 30-ampere one at a distance of 12 inches with an exposure of 5 minutes excites it only very feebly. We know that in the latter case the spectrum extends into the ultra-violet, but it excites a very feeble phosphorescence. Here the less feeble excitant produces the greater result. Again, a sample may show a thermoluminescence at a low temperature which can be destroyed, but the same sample, even without a rest, may show a brilliant luminescence at a higher temperature. These phenomena are certainly not the same.

Phosphorescence for the purposes of these notes means a luminescence that persists after the exciting cause ceases to act, while luminescence includes all emissions of light that cease as soon as the exciting cause ceases.

Very brief phosphorescences, such as are measured by the use of a phosphoroscope, are not considered. I use luminescence to designate the emission of light by fluor spar when it is heated. I have no means of exact measurements of time, but our results extend over such long periods that this defect is not very serious.

In many instances various salts are heated with the
addition of manganese or some other oxide preparatory to tests for phosphorescent phenomena. In the case here presented such a procedure would be wholly inapplicable, for the properties which we wish to study are destroyed by a temperature of or below 400° C. These phenomena are due to different conditions.

I found, in previous experiments, that this yellow calcite, in small cleavage pieces, begins to emit light when heated to 60° C., or in larger pieces at 75° C. Further, that the property of phosphorescing on insolation was not destroyed by heating it to 200° C. for one hour. In order to be more certain of these facts I have repeated and extended these observations. I have previously stated that exposure in a cabinet for 20 years weakened the phosphorescence, also that heating to a temperature lower than that necessary to effect the decomposition of calcite will discharge the yellow color and destroy the property of phosphorescing on insolation. It is probable that exposure to the sunlight for a sufficient length of time would eventually destroy this property too. We shall determine the time and temperature necessary to effect this. I have already stated that this property will survive a temperature of 200° C. for one hour, but I did not note the changes effected in the samples, only the survival of the phosphorescence on insolation.

The temperatures chosen were 200°, 250°, 300°, and 400° C., maintained for periods of 20, 30, 40 and 60 minutes. All samples used were insolated and only good, sensitive ones chosen; of course they were tested in the same manner after heating.

Sample number 1 was strongly yellow crystal recently obtained. Small cleavage pieces heated to 200° C. for 20 minutes, color still good, phosphorescence fainter than original; 30 minutes, fainter than preceding; 40 minutes, feeble phosphorescence, color perceptibly diminished; 60 minutes, feeble phosphorescence, color diminished. Two portions were heated for 40 minutes as checks on each other; the results were the same.

Sample number 1, heated to 250° C., no portion phosphoresced after heating and the color was almost wholly discharged.

Sample number 2 was a portion of a crystal used in many of my former experiments. It was heated to
300° C. All portions failed to phosphoresce and were decolorized.

The preceding hearings were carried out in a hot-air oven and we could not observe the deportment of the samples while being heated, but some decrepitation had taken place at 300° C.

Sample number 3 represents different crystals that had been used in other experiments. The periods of heating were the same as before and the temperature 400° C. None of the portions phosphoresced on insolation after heating and the color was discharged.

Shortly after these portions were brought into the muffle, they decrepitated sharply and the interior of the muffle was quite brilliantly lighted; the pieces of calcite luminesced strongly with a reddish yellow light. This experiment was repeated; the luminescence was very bright and lasted 12 minutes. Observation was made in a room only partially darkened.

Sample number 4, periods of heating same as before, temperature 400° C.; no portion phosphoresced after heating. Cleavage pieces of this sample put into muffle at 490° C. began to luminesce in 20 seconds with orange-colored light, duration 18 minutes 5 seconds. There was some variation in the different pieces, partly due to difference in size, but there seemed to be some variation aside from this. The sample contained 21 larger and many small pieces so that this variation probably showed its maximum.

The property of this yellow calcite to phosphoresce on insolation is destroyed by a temperature of 250° C. maintained for 20 minutes. This is wholly different from the phosphorescent properties produced in mixtures by heating them with sensitizing agents, manganese or some other oxide, or by igniting a sulphate. The samples vary somewhat in their sensitiveness to heat and in the luminescence excited by heating them.

The yellow calcites when heated from 60° to 180° phosphoresce; they fade rapidly for the first 35 minutes but from this point on quite slowly. This is not the phenomenon that we have just described as making its appearance at 300° C. usually accompanied by decrepitation.

There are two temperatures at which this calcite shows luminescence, from 60° to 180° C. and again at 300° C.
The former temperature can be maintained for some time, several hours, without destroying its responsive-ness to sunlight; whereas the temperature that excites the latter destroys it in twenty minutes or less. The latter luminescence dies immediately on removal from the muffle; the former continues for more than one hour. These phenomena may appear independently of any sensitiveness to sunlight and they are evidently different phenomena.

Some cases of luminescence at about 300° C. may be given. Observations on duration should be made in a darkened room, as the rate of decay is sometimes quite slow.

Samples from the same locality may differ greatly in the character and duration of their response to the same exciting cause. Crystals of calcite from Joplin, Mo., may have yellow, purple and colorless portions. The colorless and purple portions do not phosphoresce on insolation; the yellow ones do. Some failures are explained in the earlier paragraphs of this paper. Their deportment toward heat is quite different; the colorless luminesces feebly when heated to 400° C., the yellow rather brightly for about eighteen minutes as an average, while the purple luminesces very brightly and longer than any other material that I have tested, 2½ hours. The samples here described were parts of the same large cleavage piece. The yellow phosphoresced strongly on insolation, the colorless and purple did not phosphoresce at all. The X-ray produced a phosphorescence in the yellow but a luminescence in the purple.

I have met but few samples of calcites that do not luminesce in some measure when heated. It is common knowledge that Iceland spar shows brief (1⁄8 sec. or less) phosphorescence when examined in a phosphorescope. Iceland spar gives no phosphorescence, in the sense of this term as here used, on insolation and only a transient luminescence with the X-ray, but when heated to 300° to 400° C. it luminesces brilliantly for 18½ minutes with an orange light.5

5 The yellow calcites from Missouri are not the only ones that phosphoresce on insolation. There are yellow or yellowish calcites that occur near Ft. Collins that possess the same property. The duration of this phosphorescence varies greatly. I have a sample that insolated with a Missouri sample for comparison showed a stronger initial phosphorescence than the Missouri sample, but its duration was not more than 3 minutes. I believe it quite possible to obtain samples showing phosphorescence varying in duration from the briefest to the longest yet observed.
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In nearly every instance I have used small cleavage pieces but occasionally larger ones. The size of the pieces used makes a marked difference in the results. A sample of purple calcite brought into the muffle at 400° C. continued to luminesce for 2½ hours; a portion of the same piece pulverized in an agate mortar and heated in the same manner luminesced for 5 minutes and 38 seconds. All experiments were made with cleavage pieces unless otherwise stated.

Other calcites tested for thermoluminescence gave very varying results; a crystal of colorless transparent dog-tooth spar luminesced 1 minute 45 seconds; a second similar crystal luminesced 4 minutes 30 seconds; two others luminesced very briefly and two did not luminesce. None of these were responsive to sunlight.

Of five samples of nail-head spar that did not respond to sunlight, three luminesced very briefly, one for 5 minutes and 5 seconds and one for more than an hour. A colorless calcite from the Benton shale near Ft. Collins, no phosphorescence, no luminescence. A yellow calcite from the same locality phosphoresces on insolation with a duration of 2½ hours and luminesces feebly on heating. Calcite, Trona, Calif., color, liver brown, organic matter present, responsive to sunlight, luminescence doubtful.

Brown calcite, Ft. Collins, Colo. This is neither a true calcite nor a limestone. It is very coarsely crystalline. The color is due to included ferruginous clay. There are some segregations of a pellucid, yellowish white calcite. On insolation the pellucid calcite and a great number of points, otherwise indistinguishable from the brown mass, phosphoresce; the brown does not. On heating, the brown decrpetitates violently but does not luminesce. The white does not decrpetitate but luminesces for 9 minutes.

A few fluor spars were tested for purpose of making comparisons:

1. A purple one luminesced 21 minutes 38 seconds.
2. A green one luminesced 7 minutes 55 seconds.
3. A light green one luminesced 1 hour 30 minutes.
4. A colorless one did not luminesce. Test repeated with the same result.
These fluor spars vary as greatly in their deportment on being heated as the calcites, if not more so.

So far we have assumed that the deportment of these calcites on being heated to 60° to 180° C. is the same that it was eighteen years ago. Four samples, three that had been used at that time and one other, were heated to 110° C. for 20 minutes when they were about equally phosphorescent. They were observed for 10 minutes, but the duration of this phosphorescence was not determined. The general deportment of these samples in becoming phosphorescent under these conditions has not changed.

There is no question but that the properties peculiar to these calcites perish under certain conditions. A temperature of 250° C. maintained for 20 minutes destroys the property of phosphorescence at a lower temperature, and on insolation. We have also noted an abatement in the brilliancy of their response to sunlight after an exposure of 18 years in a mineral cabinet. The suggestion presents itself that these properties may perish in a certain order and that this may enable us to reorganize individual characteristics and ascertain whether they are independent of one another or not.

The temperatures given, 250° to 400° C. are not high ones, but they are high enough to destroy two distinct properties of these calcites: 1st, their property of becoming phosphorescent at temperatures between 60° and 180° C.; 2nd, their phosphorescence on insolation.

There are strong indications that the luminosity shown when heated from 60° C. to 180° C. includes two phases; a phosphorescence which may last upwards of an hour, and a luminescence which dies quickly while the sample is still hot and which is completely masked by the phosphorescence when both are present.

I tried to ascertain whether continued heating to a temperature below 200° C. would accomplish the destruction of these properties including the sensitiveness to sunlight, one after another, and in this way demonstrate the independence of these three phenomena, namely, thermophosphorescence and thermoluminescence, each below 180° C., and photophosphorescence on insolation. We would then have seven phenomena in our study, the three just given and the following four: phosphor-
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escence, also a luminescence produced by the X-ray, a theromoluminescence at about $300^\circ$ C. and the phosphorescence produced by the cathode ray.

We already have reason for distinguishing between the phosphorescence excited by a temperature below $180^\circ$ C. and that excited by sunlight, for some samples of calcite show the former and not the latter. But the yellow calcites show both forms and if we can destroy the one and not the other it will be stronger proof of their independence and contribute to showing that they are due to different conditions, probably of structure, in the calcites. Further, we wish to destroy the phosphorescence excited at $180^\circ$ and not the property of luminescence, if possible, to show that these two properties may exist in the same sample and that a crystal may possess one, two or all three of these properties.

In the brown calcite from Trona, California, we have an instance of sensitiveness to sunlight but it shows no luminosity at $120^\circ$ C. or at $400^\circ$ C. or at most a very doubtful one at the latter temperature. The presence of organic matter in this brown sample constitutes an objection to its use, and further, the phosphorescence may be due to the organic matter and therefore different from that of the yellow calcites.

In order to test the points mentioned in a preceding paragraph, four sets of samples were taken. Two of them showed phosphorescence at $60^\circ$ to $180^\circ$ C., also on insolation; two showed phosphorescence at $60^\circ$ to $180^\circ$ and were not responsive to sunlight. These were heated to $145^\circ$-$155^\circ$ C. for four hours when one set of each was taken out; the other set of each was heated for another period of four hours and cooled. On being heated to $110^\circ$ they showed no thermophosphorescence but they did show thermoluminescence. The set that originally showed photophosphorescence was still responsive to sunlight. The thermophosphorescence can be destroyed at a temperature of about $150^\circ$ C. maintained for 4 to 8 hours, but the thermoluminescence survives. Other samples were then heated for various periods at temperatures ranging from $145^\circ$ to $155^\circ$ C. At the end of 36 hours the thermoluminescence had been destroyed and the photophosphorescence very greatly reduced, and in 46 hours it too was destroyed. The samples had become
practically colorless; in other words, the yellow color and
the photophosphorescence were destroyed simulta-
neously, whereby we have established the facts that it is
not an accident that the photophosphorescence is con-
fined to the yellow portions of the crystals, also that
thermophosphorescence and thermoluminescence in these
calcites are different phenomena dependent upon some
differences in the calcite, also that the photophosphores-
cence is independent of the other forms of luminescence.
These samples were not changed in regard to their
luminescence at 300° to 400° C. This property is inde-
pendent of the others.
All samples that had been heated to 400° C. lumines-
ced when exposed to the X-ray; none phosphoresced.
Each sample was divided in two parts, one of which was
heated to 600° C. and the other to 800° C. for one hour,
after which they still luminesced under the action of the
X-ray. The samples were then pulverized to pass a
50-mesh sieve; some of them were heated to 600° C. for
one hour, others to 800° C. for one and a quarter hour,
and two were heated over a blast lamp for 30 minutes.
All of these samples luminesced under the action of the
X-ray.
The phosphorescence produced in the yellow calcite
by the X-ray was probably identical with that produced
by sunlight; at least it was evidently a quality inherent
in the yellow calcite. The luminescence produced in the
other calcite, especially that produced in these very
strongly heated and ignited samples, is possibly a
property inherent in calcic oxide in which minute quanti-
ties of impurities may play a part.
There are impurities in the Missouri calcites amount-
ing, in all, to approximately 0.20 per cent; manganese,
zinc and the rare earths are included in these. They are
present in the colorless as well as in the yellow and
purple, but the colorless has different properties from
these. They are present in the yellow as well as in the
purple, but the purple never phosphoresces on insola-
tion while the yellow does. The yellow luminesces for
about 18 minutes with a maximum of 32 minutes when
heated to 300°-400° C., the purple luminesces much more
strongly for 2½ hours. I thought that the colors and
properties were both due to composition. The fact that
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the absorption spectrum of the purple portion of these calcites coincides with the α and β lines of a solution of didymic chloride would ordinarily be considered as pretty good evidence that the purple color was due to some didymic compound. No portion of this calcite other than the purple will give this spectrum. I think, however, that these things remain to be proven.

Recapitulation.

The failures to phosphoresce on insolation were due to atmospheric conditions.

The phosphorescence is excited by the light of the molybdenum arc whose characteristic wave-length is 3790 Å. U.

Phosphorescence may be delayed or entirely prevented by glass covers; red glass is the most effective.

Sunlight and that of the molybdenum arc act similarly in this respect.

Haziness, as well as the cloudiness of the sky, delays or prevents phosphorescence.

Exposure in a mineral cabinet for about 20 years caused an abatement in its intensity.

The yellow color can be discharged by heating to a temperature below that necessary to cause any decomposition of the calcium carbonate.

The purple calcite does not phosphoresce but its color, too, can be discharged and its deportment toward heat changed without chemical decomposition.

The yellow calcite shows a thermophosphorescence at temperatures between 60° and 180° C., which is destroyed by heating to about 155° C. for a short time,—less than eight hours.

The yellow calcite shows a thermoluminescence at 60°-180° C. which can be destroyed by heating to 155° C. for 36 hours.

The yellow calcite phosphoresces on insolation. This property is destroyed by a temperature of 155° C. in 46 hours; it withstood a temperature of 200° C. for one hour but was greatly weakened and the color was partially discharged. A temperature of 250° C. maintained for 20 minutes destroyed this property and discharged the color. There is some variation in samples
but no sample withstood a temperature of 400° C. for 20 minutes.

Samples that have been heated to 155° C., until the preceding properties, thermophorescence, thermodisphorescence and photophorescence, have been destroyed, show a strong luminescence at 300° to 400° C.

The purple samples also show a two-phased luminescence.

The duration of the luminescence at 300° to 400° C. is for the yellow from 12 to 32 minutes, usually about 18 minutes, and for the purple 2½ hours.

The color of all samples is discharged at these temperatures. The calcites are then clear, transparent, and lustrous, particularly the purple.

Cleavage pieces were used in these experiments; powdering the samples lessens the period of luminescence.

The yellow calcites, in their natural condition, phosphoresce on exposure to the X-ray. Duration of this phosphorescence varies up to an hour.

All samples heated to 400° C. luminesce in the X-ray. The composition of the calcites is not changed up to this point, but the deportment toward the X-ray was not changed when it was powdered and heated over the blast lamp for 30 minutes.

The property of luminescing under the influence of the X-ray is common to all calcites that I have tested, but the yellow one, in its natural condition, is the only one that shows a persistent phosphorescence.

Luminescence at 300° to 400° C. is shown by most, but not by all calcites.