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A Study of the Material and Techniques Used by Some Nineteenth Century American Oil Painters by Means of Neutron Activation Autoradiography

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Introduction

Neutron activation autoradiography of paintings is a useful method for identifying within them characteristics which relate to the artist. In our study this technique is applied to some late nineteenth century American painters. In this context, a special place has been given to Ralph Albert Blakelock (1847-1919) because of the dramatic history of his painting career, which led to a large number of forgeries, and also because of his very personal style and technique. Therefore we have studied a number of his paintings and compared them with some works of his contemporaries, George Inness, Albert P. Ryder, George H. Bogert, and H. M. Kitchell, as well as of his daughter Marian Blakelock. She was taught by her father and hence can be expected to bear a close relationship in her workmanship to him.

Ralph A. Blakelock was a self-taught American artist who was born in New York City in 1847. As a young man (in the late 1860's) he toured the western portion of the United States and pencil and ink drawings exist as records of those journeys. After 1872, Blakelock remained in the New York City area and it is from this time to 1899 that most of his oil paintings were made. As Virgil Barker noted, Blakelock did not generally depict actual scenes in his oil paintings, but he started with a pictorial idea and kept working his pigment until he had produced an imaginatively satisfying parallel or equivalent to nature.[1] He is generally known for his lyric moonlight scenes, and has been linked by this poetic landscape painting with his contemporaries George Inness and Albert P. Ryder.

In 1877 Blakelock married and in the next twenty-two years nine children were born to him. Collectors and dealers did not accept the very personalized landscape style of Blakelock in the nineteenth century and the situation which triggered his final mental collapse in 1899 was one of personal tragedy arising from the avarice of the art marketplace of that time. From

this time until his death in 1919, Blakelock was almost continually confined to mental institutions. Although he did paint little sketches in this period, they are quite different from his earlier work.

Blakelock's paintings commanded very high prices during the period of his confinement but neither he nor his family benefited greatly from this. As the value of his works soared, forgers multiplied the number of "Blakelocks" in existence. It is estimated that there are between 700 and 900 paintings now attributed to Blakelock. However, as Lloyd Goodrich said in the catalogue of the Centennial Exhibition in 1947, "There are several times as many false Blakelocks as genuine ones".[2] Although there is evidence that works of several other artists were passed on to the public as Blakelock paintings, the final tragedy occurred when a dealer bought paintings from Ralph Blakelock's daughter, Marian, scratched out her signature, added her father's and sold them.[3] After such falsifications had been revealed Marian Blakelock also suffered a mental collapse and was confined to a mental institution.

From 1920 until a few years ago there had been little interest in the art world in Ralph Blakelock. The awakening of interest in nineteenth century American art generally has naturally refocused interest in the entire Blakelock problem. He may very well be the most often forged American artist.

In this report we will present the results of our study of nine generally accepted Ralph A. Blakelock paintings and ten of the oil-sketches produced during his confinement, together with six paintings by the other artists, Inness, Ryder, Bogert, Kitchell, and Blakelock's daugher Marian, and two paintings which earlier had been misattributed to Blakelock. We have been able to reveal by neutron activation radiography some specific characteristics of Blakelock paintings, in the meaning that at least some of these characteristics occur in all of his works, while in general they do not show up in paintings of the other artists.

Generally, characteristics relating a painting to the artist include some observations which clearly can be made best by the art historian, such as subject, composition and style of the painting, and others which are a result of technical examination, such as choice of materials and the way in which they are applied. As much information concerning these characteristics lies hidden beneath the surface of the painting invisible to the naked eye, art conservation laboratories regularly employ techniques such as X-ray radiography and microscopic examination of pigment layer cross sections in the study of a painting. X-ray radiographs, by indicating the distribution of the more dense components of a painting, usually lead white, can provide information such as 1) evidence of an overpainted earlier painting, 2) overpainted details, differing from the final design of the painting, which indicate changes in the artist's concept during the work, 3) the presence and location of materials added in later alterations, such as restorations, 4) details of how the artist built up the structure of his painting, e.g., whether he underlaid certain areas with pigments which only subtly show through the surface, 5) details of the application of the pigments, such as thick or thin, uniform or not, by characteristic brush strokes, and other means of application such as by palette knife, and 6) information about the support and ground on which the painting is laid. However, as mentioned above, X-ray radiographs often show the distribution of dense pigments such as lead white, and thus provide only part of the record. The same type of information is gained from neutron activation autoradiography but concerning the distribution of several pigments other than lead white. Hence it provides important additions to that obtained by X-ray radiography. Therefore both of these techniques, rather similar in nature but supplementary in the information provided, may be usefully employed together when studying a painting.

Microscopic examination and X-ray diffraction analysis of small samples taken from the painting are techniques generally employed for the identification of pigments. However, in a painting activated for autoradiography, the chemical elements which constitute many pigments can be identified and their relative abundances within the painting can be determined by measuring the energy spectra of the gamma rays emitted from the painting. Thus the combination of activation analysis with autoradiography can yield, without removal of samples and hence basically nondestructively, much information concerning the pigments used as well as the distribution of a number of them.

The Autoradiographic and the Activation Analytical Techniques

The principles underlying the thermal neutron activation autoradiography technique have been described extensively in earlier publications,[4,5,7] and therefore we will give only a short resumé of them. Exposure of a painting to a beam of thermal neutrons creates within it a number of different radioisotopes, generated from the various elements that are present in the material of that painting. As each of these radioisotopes decays with its own half life, some of them will dominate in turn the radiation emitted from the painting. Therefore a series of autoradiographs, obtained at different time periods after activation, will represent the structural distribution of various radioisotopes, and hence of the different elements in the painting from which they originate. The autoradiographic exposures are produced by placing photographic film in direct contact with the activated painting. In addition to the autoradiography we also make use of gamma ray energy spectroscopy in the study of the activated paintings. A few recordings of these spectra at different times after activation enable us to obtain a quantitative as well as a qualitative analysis of the detected

elements in the material of the painting. The information gained in this way is most useful in interpreting the autoradiographs.

It was determined by Sayre and Lechtman[4] that film darkening was very predominantly caused by electron emission, that the photographic density produced by this emission was proportional to the number of beta particles emitted per unit area of the painting during the exposure period, and that, with the exception of the very low energy cobalt-60 betas, all beta particles, independent of their energies, from all of the elements which are expected to be found in paint pigments that will activate well, were roughly about equal to their effectiveness in producing film darkening. As a result of these simple approximate relationships the contribution to photographic darkening of different activated elements within a painting at a given time can be estimated to be roughly proportional to the rates of electron emission from these elements at that time. This is a value easily calculated from the relative concentrations of these elements as determined by the gamma-ray analyses and from the known activation and decay properties of the elements. In this way graphs can be obtained as the one in Fig. 1 for the R. A. Blakelock painting Moonrise, where the electron emission rates are given as functions of the time elapsed since the activation. One can easily read from such a graph which elements are primarily responsible for the blackening of an autoradiograph taken at any particular time.

For the experiments described here the paintings were activated at the Patient Irradiation Port of the Brookhaven Medical Research Reactor by being exposed to fluxes of thermal neutrons of the order of 10^9 $nsec^{-1}$ cm^{-2}. The exact flux depended upon how close the paintings were placed to the beam port, larger paintings being placed farther away from the 10 inch by 10 inch port to provide a more uniform activation of their entire areas. The uniformity

of activation was checked by activating extended grids of pure iron wire. Upon the basis of such measurements we were able to select activation conditions in which the outer edges of even large paintings received at least the order of half the dose of the painting's center, which was positioned directly in line with the port. Activation periods ranged from 45 minutes to 1.5 hours, depending upon the flux involved.

The films used to record the autoradiographs were Kodak No Screen Medical X-ray film and Kodak Commercial film. The latter is a blue and U.V. sensitive film used in commercial photography which is less sensitive but finer grained than the X-ray film. Occasionally the two films were used together in a double layer placed upon the painting and occasionally more than one layer of the same film was so employed. This was done because some details are best observed in a densely exposed radiograph while others are most clearly revealed in exposures of lower density.

Photographic exposures of only a few minutes duration were taken at the Medical Reactor immediately following activation. At this location, because exposure had to be carried out in a lighted room, the film was enclosed within an opaque black paper envelope. Close contact between the film and painting was first obtained by the use of sandbags pressing them together. Later a large rubber sheet was spread over the film and painting and drawn down onto them by drawing a gentle vacuum (about 5 pounds per square inch) in the volume in which the painting and film were enclosed by the flexible sheet. This technique is, of course, the one normally used when relining paintings on a hot table.

The paintings differed in their support mountings. Some were on wooden panels, some were on canvas which was still attached to a wooden stretcher, and some were on cardboard. When a stretcher was still attached

to a painting on canvas the autoradiographs were taken by first placing the film package upon a flat table, then placing the painting face downward upon it and applying the pressure device to the back of the painting. In all other instances the painting itself was placed face upwards upon a flat table, the film package laid on top of the painting and pressure uniformly applied upon the film.

While the paintings were still at the reactor, spectra of the gamma-ray emission from them were measured using a 2 x 2 inch NaI(Tl)-detector coupled to a 128 channel pulse height analyzer. At this early stage the gamma-ray activities of most of the paintings were dominated by those of manganese (^{56}Mn, half life 2.68 hours) and sodium (^{24}Na, half life 15.0 hours). One exceptional painting, which for some years was accepted as a Blakelock but is now, for many reasons, believed to be a forgery, showed intense aluminum activity (^{28}Al, half life 2.3 min) immediately following activation. In two Blakelock paintings from his earlier period and in one misattributed work the predominant activities were those of zinc (^{69}Zn, half life 57 min and ^{69}Zn^{m}, half life 13.8 hours) and barium (^{139}Ba, half life 82.9 min).

At approximately an hour after activation the paintings were transported to the Chemistry Building where autoradiographs could be taken in a photographic dark room in order that uncovered film could be put in contact with the paintings, and where more sophisticated counting equipment was available. Here, autoradiographs were taken, first a few hours after activation, then throughout the first night, with a slow film, and again the following day. Additional exposures were started after three days, at about a week, and about three weeks after activation. By the end of these series of exposures the activities within the paintings had decreased to the extent that as long as two to three weeks' contact was required to produce an adequate exposure.

Measurements of the gamma ray activities, using a 40 cc Ge(Li) semiconductor detector coupled to a 4096 channel pulse height analyzer, were carried out on a schedule roughly similar to but less frequent than that of the taking of autoradiographs. In order to record an approximately integrated count of the entire painting, the painting ideally was placed at least several feet from the detector. As the activity levels within the painting diminished it was sometimes necessary to count with the detector as close as six inches from the painting as a practical measure. To the extent that the distributions of different activity sources within the paintings were non-uniform, this could produce errors in their relative measurements. No attempt was made to obtain exactly reproducible counting geometries, it being intended to measure only relative rather than absolute concentrations. In order to calibrate the relative activity measurements, a "standard painting" on a plywood panel was prepared which was uniformly coated with a "paint" produced by grinding known weights of stoichiometrically dependable compounds of the elements being measured together with linseed oil. From the measurements made on this "standard painting" it was possible to convert gamma-ray intensities into relative concentrations of elements with reasonable accuracy.

Study of Paintings of R. A. Blakelock and Related Artists

Figure 2 shows six paintings which, according to several experts on American paintings whom we have consulted, are very probably Ralph A. Blakelock paintings of his mature period. Three of these paintings are from the National Collection of Fine Arts, The Smithsonian Institution (Moonrise, Acc. #1909.7.3; Canoe Builders, Acc. #1909.7.4; and At Nature's Mirror, Acc. #1909.7.5G). One is from The Metropolitan Museum of Art (Landscape, Acc. #26.158.2) and the other two are from private collections

(Moonlight and Indian Encampment). The last one has been irreparably damaged by overcleaning. Two paintings accepted to be Ralph A. Blakelock paintings from his earliest period are shown in Fig. 3. They are both from the Krannert Museum of Art of the University of Illinois (Landscape-Evening, Acc. #54-1-2 and Landscape, Acc. #54-1-1, the latter dated 1868). Also shown in Fig. 3 is a painting from the Heckscher Museum, Huntington, N.Y. (In the Forest, Acc. #1959.94). It is judged to have been painted in an intermediate period of Blakelock's artistic development.

To compare with these accepted Blakelock's we have autoradiographed two paintings which have been attributed to R. A. Blakelock but which we have now good reason to question, Woman in Red from a private collection and A Nocturnal Vista (Acc. #2276G) from the Sheldon Memorial Art Gallery of the University of Nebraska. The latter painting was submitted to us as not being a genuine Blakelock. In addition we have studied an unquestioned signed Marian Blakelock, Landscape, from the Sheldon Memorial Art Gallery (Blakelock Inv. No. 303), a George Inness seascape, entitled Coast Scene (Acc. #17.141.2) from The Metropolitan Museum of Art, a second Inness painting Georgia Pines (Acc. #1909.7.33) from the National Collection of Fine Arts, Albert Ryder's Curfew Hour (Acc. #09.58.1) from The Metropolitan Museum of Art, a painting by H. M. Kitchell, Moonlight (Acc. #U-793) and one by George H. Bogert, Sunset (Acc. #U-131), both from the Sheldon Memorial Art Gallery. The paintings by Marian Blakelock, Inness, Ryder, Bogert, and Kitchell were selected for study because these artists were contempoary with Blakelock or painted sometimes in styles somewhat similar to Blakelock's.

In addition to these we studied ten very late oil sketches, executed by Blakelock during his confinement period, which were kindly provided by the Sheldon Memorial Art Gallery.

Study of R. A. Blakelock Paintings

For the work of most artists the pictures obtained by autoradiography of their paintings bear some resemblance to the visual designs of the paintings. This is illustrated by the series of autoradiographs of Inness' Coast Scene in Fig. 4. Although the subsequent autoradiographs, two of which are reproduced, show some evident differences between themselves as well as with the visible design of the painting, these differences appear to be the result of alterations in the design of the painting, as one sees clearly in the varying conformation of the rocks at the viewer's left of the painting. Meanwhile, however, the pictures obtained by autoradiography still largely conform to the painting itself. The same resemblance between autoradiographs and paintings was observed in all paintings studied, except for the Blakelock paintings from his mature period. For these paintings the case is very different. Figure 5 shows the painting Moonrise, the X-ray radiograph and a series of autoradiographs. One sees how the subsequent autoradiographs are very different among themselves, while they only occasionally correlate with the design of the painting in small details. In the Introduction we referred already to the remark of Virgil Barker about Blakelock painting with a pictorial idea and then keeping working his pigments until an imaginatively satisfying parallel was produced. Such a technique is compatible with what can be observed in a comparison of the painting and the series of autoradiographs.

The first autoradiograph of Moonrise shown in Fig. 5 is representative of those taken during the day of activation. As can be seen from the electron emission curves in Fig. 1, the manganese activity is predominant within this painting during the first several hours after activation. This autoradiograph shows only irregular areas of density, some of which have a

rather scraped appearance such as one would expect from material laid down with a palette knife. The X-ray radiograph of Moonrise shows even more extensively scraped areas. Moonrise is painted on a pine board. If the general surface of this panel was relatively uneven and was filled in through a ground paint which was roughly spread over the wood by means of a scraping tool, the resulting distribution of the ground might well correspond to the density distribution observed in the X-ray radiograph. The plausibility of such an interpretation is underlined by the observation of a similar situation in the other Blakelock painting on panel studied, Moonlight, of which the X-ray radiograph is shown in Fig. 6, compared with one of Moonrise. In connection with this it is well worth while noting that it has been stated that "Blakelock frequently prepared his canvas with a wash of something like plaster, then polished it with pumice".[6] Although such a preparation does not seem very probable from the X-ray radiographs of Moonrise and Moonlight, this statement emphasizes Blakelock's use of scraping tools in the preparation of the ground. Occasionally scraped details in the first autoradiograph coincide in position and film density with those in the X-ray radiograph. Possibly in these regions the manganese-bearing pigment was laid down directly upon the rough ground and reflected to some extent its contours. There are also details for which light areas in the X-ray radiograph coincide with dark areas in the autoradiograph, suggesting that a manganese-containing pigment also was sometimes mixed with lead white in application.

For all Blakelock paintings from his mature and intermediate periods the autoradiographs taken during the first few hours after activation represented the manganese distribution. This is not the case, however, with the two of his earliest paintings. Here the early autoradiographs show a horizontally striated pattern, as if a layer, containing the elements whose

activities predominate at this early stage, had been uniformly applied, with broad parallel brush strokes, over the whole area of the painting. The electron-emission curves for these paintings show that in both zinc and barium activities are dominant at this time. One might therefore suppose a ground layer of zinc and barium containing paint, applied in the way described. However, X-ray radiographs show very clearly details of the canvas, thus suggesting a thin lead white ground, very uniformly applied, possibly suggesting a preprimed canvas. Then the zinc and barium containing layer would have been applied on top of the lead white groundlayer. To test this hypothesis, small samples were taken from the edges of the paintings and analyzed by X-ray diffraction. This showed that indeed a lead white layer is closest to the canvas, with on top of it a mixed layer, containing zinc oxide and barium sulphate. It is worthwhile noting here that a similar distribution of a zinc and barium containing groundlayer has been observed in Lady in Red, originally misattributed to Blakelock, but now accepted to have most probably been painted by his daughter Marian. Figure 7 shows autoradiographs taken at an early time after activation of these three paintings.

The second autoradiograph of Moonrise shown in Fig. 5 is typical for those taken on the second day after activation. The appearance of this autoradiograph is almost totally different from that of the first one. Examination of the painting's surface shows that the medium is very unevenly distributed, as if the paint vehicle pulled together forming thick "mounds" surrounded by thinner "valleys". Actually the exposure density distribution of the second autoradiograph shows a close relationship to these variations in thickness. The manganese-56 activity with the rather short half life of 2.6 hours has effectively decayed away at the time of exposure of this

autoradiograph. As can be seen from Fig. 1, the most predominant activity at the time comes from sodium, an element which one does not anticipate encountering in the pigments of nineteenth century paintings. However, in that period, the preparation of linseed oil frequently involved treatment with alkalis or salt brines, both of which could introduce sodium. Moreover the natural resin varnishes contain appreciable amounts of organic salts in which one expects significant concentrations of this element. The solubility of the paint layers of Blakelock's paintings has led to the belief that varnish was often a major part of this medium. Moreover Elliott Daingerfield notes in his Blakelock biography that: "He used most frequently ... dilute varnish (copal) as a medium".[8] It seems therefore quite reasonable to conclude that the second autoradiograph represents the distribution of the varnish or possibly medium, rather than that of particular pigments.

Distribution patterns similar to that in Moonrise have been observed in the autoradiographs taken on the second day after activation of four accepted Blakelock paintings from his mature period, all of which contain appreciable amounts of sodium. They are Landscape, Canoe Builders, Indian Encampment, and Moonrise. They have not been observed in the two earliest paintings, Landscape and Landscape-Evening, nor in the intermediate period painting In the Forest and in the later paintings At Nature's Mirror and Moonlight. Figure 8 shows a comparison of enlarged details from the autoradiographs of the paintings where the discussed phenomenon has been observed.

In some of the paintings studied, there appears to be evidence that the sodium is largely resided in an outer layer. Thus, in Moonrise, in places where the outer layer has been removed by cleaning, as around the signature, the mottled appearance does not show up in the autoradiographs,

and it has not been observed in the two earliest paintings, which have no obvious varnish coats. As stated before, Indian Encampment has been badly overcleaned, and in a large area the paint has been removed to a considerable depth. However, the autoradiographs taken at a time when sodium activity was predominant, show a direct correlation between the presence of sodium and the areas where the outer layer is still intact.

After several days the sodium activity, with a half life of 15 hours, has decayed away. At this time the nature of the autoradiographs of Blakelock paintings changes again. A typical example is the third autoradiograph in the series of Moonrise. In this, one observes rather finely defined details, standing out in sharp contrast. When the third autoradiograph is compared to the second, most of these details can already be found in the second, but now they stand out alone and more sharply. Some of these details are of a rather peculiar appearance and seem to be characteristic of Blakelock paintings. These details have the appearance of small, irregular filaments of high density and could be explained as the results of the application of small quantities of a viscous paint which were then worked into the painting. Actually many of these regions of high density appear to be divided by clear streaks of low density running through them. This could be interpreted as the result of the use of a small hard object, such as the wooden end of a brush, to work the pigment into the painting. Such details, which we have called "squiggles" appear in six of the accepted Blakelock paintings which we have studied. They are Moonrise, At Nature's Mirror, Canoe Builders, Landscape, Indian Encampment, and In the Forest. From the electron emission curves it appears that in all cases arsenic or antimony was responsible for the predominant activity at the time that these characteristics showed up in the autoradiographs. Figure 9 shows a comparison of such details in the six paintings mentioned above. In many instances the "squiggles" can, upon

comparison with the visual design of the painting, be correlated with the highlights within trees, where the artist portrays the light shining through breaks in the foliage. Some of these spots were overpainted, probably because they did not satisfy the artist, others remained visible in the final painting.

In the three other Blakelock paintings studied, Moonlight and the two earliest period paintings, we did not observe squiggles as defined above. However, in these three paintings the artist did also accentuate small details with thick local applications of arsenic or antimony bearing pigments, which however have not been worked into the painting in the way the "squiggles" are. A comparison of enlarged portions from the autoradiographs showing such details for these three paintings is given in Fig. 10.

The last autoradiographs of Moonrise, typified by the fourth one in the series of Fig. 5, were obtained after the arsenic and antimony activities had virtually decayed away. From Fig. 1 it can be seen that at that time mercury activity becomes the most intense. The same holds for five other Blakelock paintings: Landscape, Canoe Builders, In the Forest, and the two earliest period paintings Landscape and Landscape-Evening. The autoradiograph of Moonrise shows how mercury-bearing pigment was applied in a special way, very thinly with broad brush strokes. These strokes in fact are much alike in their appearance to those one observes in water color paintings, which suggests the use here of a very thinly diluted fluid paint. Another argument for this is found in the dribbling runs seen in the upper left part. Moreover one observes blotches, i.e., spots of thin evenly spread pigment surrounded by thicker walls. Such spots would be formed when drops of a thin suspension were allowed to dry on a flat surface, as in such a process a large fraction of the solids is drawn to the evaporating fluid at

the edges of the spots. Figure 11 compares details of late autoradiographs of three Blakelock paintings, Moonrise, Canoe Builders, and Landscape. Not only does one observe the mentioned characteristics in all three autoradiographs, but still one more peculiarity in common shows up, i.e. the granular appearance of the pigment, as if it had been coarsely ground.

Three other Blakelock paintings show the application of very thinly diluted paint with other pigments than mercury bearing ones. In At Nature's Mirror and Indian Encampment such a thin application of a manganese bearing pigment is evident, while in In the Forest an arsenic bearing pigment has been applied in this way. Details of the corresponding autoradiographs of these paintings are shown in Fig. 12. The use of thinly diluted paints has been mentioned in Daingerfield's Blakelock biography. He notes: "... he floated upon it more forms, using thin paints ...".[8]

In the two earliest period paintings we did not observe any thin washes, and the applications of a mercury bearing pigment in these paintings correspond to the visible design on the surface. The same holds for the mercury bearing pigment in In the Forest. although here a change in the artist's conception resulted in overpainting of the design in question. It may be mentioned that the mercury bearing pigment in this work shows again a granular appearance. It is worthwhile mentioning that in all late Blakelock paintings studied the signature seems to have been applied with a mercury bearing pigment, which in the case of Moonlight, was confirmed by X-ray diffraction analysis to be vermillion.

Summing up, the characteristic features one observes in Blakelock paintings by means of neutron activation autoradiography are:

1. The presence in all paintings of a significant amount of manganese, which, in all cases where the distribution of this element could be studied, i.e. in all but the two earliest period paintings, was distributed in irregular patterns, not directly related to structures visible at the surface. The manganese seems often to be present in a pigment which is applied directly onto the ground. These manganese bearing pigments could have been used for tonal underpainting.

2. The presence of a high concentration of sodium in an unevenly distributed varnish or medium, which often leads to characteristically mottled patterns in the autoradiographs taken on the second day after activation. The presence of a high concentration of sodium is in itself not unique for Blakelock, but has also been encountered in a few works by other artists (see Table II).

3. Thick applications of an arsenic or antimony bearing pigment in small localities, in most of his late paintings worked into the surface of the painting, causing the so-called "squiggle", but occasionally applied in a more conventional way.

4. The use of a coarsely ground mercury bearing pigment in a very thin medium, frequently resulting in runs and blotches, or similar thin applications of other pigments. All late paintings studied seem to have been signed with vermillion.

It has already been noted that one does not anticipate finding characteristics for a painter only in the application of his pigments, but also in the choice of them. Table I shows the relative concentrations for a number of elements determined by analysis of the energy spectra of the gamma rays emitted from the activated Blakelock paintings. These concentrations are expressed in weight percents, normalized on the basis that the sum of the

concentrations of all elements determined is one hundred. A few elements which can be present in significant concentrations, such as lead, cannot be measured by the techniques described above because thermal neutron activation does not produce radioisotopes of these elements which can be detected conveniently.

Comparison of the palette used in the Blakelock painting shows a reasonable consistency. One observes an extensive use of iron-bearing pigments, often large concentrations of barium and zinc, while usually mercury, arsenic, antimony, copper, cobalt and manganese appear in sufficient amounts to suggest use of compounds of these elements as pigments. Moreover, appreciable amounts of sodium, potassium and chlorine are always present. It has been discussed how sodium is probably present in the varnish or medium, and the same could be true for the other two elements, although their presence could not be located in the autoradiographs because of their low activity levels. One should note the use of a cadmium bearing pigment in the two earliest period Blakelock paintings, while this element was not detected in any of the later paintings.

Ten of the oil sketches on cardboard produced by Blakelock during his confinement in a mental institution have also been activated and autoradiographed. Although we have not yet studied the results of our measurements very thoroughly, some observations come forward very clearly. Firstly, they appear to be much simpler in structure, with single layers of paint rather than with superimposed and worked pigments. Figures 13 and 14 show two such sketches, together with some autoradiographs. It is obvious that these sketches represent a totally different period in the work of this artist. Such a statement can also be made after observation of the visual design of the sketches. Where the earlier paintings show a rich variation in tone, but

are limited in hue, the reverse holds for these sketches. This of course complies well with the simple structure as found in the autoradiographs. A peculiarity was encountered in the analysis of the elemental abundances in the pigments used for these sketches. In at least two of them we are quite certain that the pigment "emerald green", also called "Paris green", a copper arsenite was applied. This pigment was well known at that time but was rarely used in paintings due to its high toxicity and rather unfavorable properties as an artist's pigment.

Study of Paintings of some Related Artists

If the characteristics observed in Blakelock's paintings are to serve as a means for identification of his works, they must be relatively unique to him. For this reason we have studied the paintings of a number of related artists to determine to what extent these characteristics occur in their work. Of all of the additional paintings studied the one entitled Woman in Red, which is shown, along with its X-ray radiograph and some autoradiographs in Fig. 15, most resembled the Ralph Blakelock paintings in composition and structure. Woman in Red has been attributed to R. A. Blakelock and indeed bears his signature in the lower left corner.

Table II shows that the palette used was not very different from that of the Blakelock paintings. However, the sodium and potassium concentrations found in this painting were relatively low, only about one-fifth of the concentrations encountered on the average in late Blakelock paintings. Chlorine, present in appreciable amounts in late Blakelock paintings, was found to be below our detection limits. Upon examination of the autoradiographs of Woman in Red one does not find many of the characteristics established in the accepted Blakelock paintings. Filamentary structures like the squiggles

so frequently encountered in Blakelock's work at most show up a very few times, and washes, blotches and drips resulting from thin diluted pigment suspensions are completely absent. Interesting conclusions can be drawn from the earlier autoradiograph shown, which was taken at a time when the zinc and barium activities were predominant. In this autoradiograph one sees long vertical striations, sometimes over the entire length of the painting, giving the impression of a paint which was applied with a very broad brush. Moreover, the images of fibers in the supporting canvas are visible. This can be interpreted as an autoradiograph showing the distribution of the ground. This conclusion is confirmed by the fact that some areas at the side of the painting, which are covered with ground paint only, show up clearly in this autoradiograph. A similarly applied ground of comparable composition was found in the two early Blakelock paintings (see Fig. 9).

Although one finds some similarities between the autoradiographs of Woman in Red and those of the Blakelock paintings discussed earlier, the differences are of such an extent that one would hesitate to classify Woman in Red as a Blakelock painting from his mature period. Any suspicions about its authenticity proved to be justified when the rudiments of a partially scraped off and overpainted signature showed up in the lower left corner of late autoradiographs of this painting, as can be seen from the second autoradiograph reproduced in Fig. 15. Examination of the remains of this signature, which do not show up in the X-ray radiograph, suggested that this might well have been the signature of Blakelock's daughter Marian. Subsequently an enlarged detail of this part of the autoradiograph was compared with the one of the signature on Marian Blakelock's Landscape, as shown in Fig. 16. It is obvious that a large similarity exists between these signatures. In addition both show up in late autoradiographs, which indicates that they were

painted with a mercury-bearing pigment. In the Introduction it was mentioned that there have been cases where a dealer scraped Marian Blakelock's signature off her paintings and added her father's to sell them as authentic Blakelocks. It seems quite reasonable to assume that Woman in Red is one of those cases.

For comparison Marian Blakelock's painting Landscape was studied in detail. The painting and two autoradiographs taken at 30 through 45 minutes after activation and 6 through 13 days after activation, respectively, are shown in Fig. 17. In the entire series of autoradiographs, only three basically different types were obtained. The autoradiographs taken on the first day after activation show mainly the distribution of manganese. In those taken between 2 and 14 days after activation, arsenic is the main contributor to the film blackening while at 3-5 weeks after activation the autoradiograph only shows a clear impression of the signature, painted with a mercury-containing pigment. Although an appreciable amount of sodium activity was detected in the gamma-ray energy spectra, no clear indication of this element was found on the autoradiographs. It is believed that most of the sodium activity originates from the supporting structure on which the painting was mounted during activation and gamma-ray measurements. This painting is different from the Ralph Blakelock paintings in many aspects: both manganese- and arsenic-bearing pigments were used to delineate complete structures visible at the surface of the painting, contrary to Ralph Blakelock's use of them in underpainting and providing highlights. There is no evidence of any of the Ralph Blakelock painting characteristics such as squiggles, blotches, and washes. The absence of mercury, except for that in the pigment used for the signature, is also notable. The technique of the application of the paints in Landscape is basically not different from that in Woman in Red,

but these two paintings differ in the use of certain pigments and in the composition of the ground.

Another painting which stylistically is rather related to Blakelock, and indeed has been sold and exhibited as a genuine Blakelock painting, is A Nocturnal Vista, shown together with the X-ray radiograph and some autoradiographs in Fig. 18. More recently, however, its authenticity was seriously questioned for stylistical reasons. Table II shows that the pigments used in this work are significantly different from those in the other Blakelock paintings. Noticeable above all are the little use of arsenic and antimony pigments and the large amounts of aluminum, an element which could not be detected in any of the other paintings. Autoradiographs taken immediately after activation, produced by a dominant aluminum activity, showed a uniform distribution of this element over the painting. This might well be explained as the use of an aluminum mordant as support for organic lake pigments. In the genuine Blakelock paintings we never encountered the use of an aluminum lake pigment. None of the characteristics found in the autoradiographs of the accepted Blakelock paintings show up in the autoradiographs of this painting. Highlights are painted with a pigment other than the arsenic and antimony pigments used for this purpose by Blakelock, while they are applied with brush strokes rather than worked into the painting. Neither does one see washy appearances resulting from the application of very thinly diluted paints. All this evidence, combined with the already existing stylistic doubts, seems to justify discarding A Nocturnal Vista as a genuine Blakelock. Moreover, here again another signature showed up in later autoradiographs. Near the bottom of the right side one sees the initials D. C. appear, which have been painted over and are invisible on the painting as well as in the X-ray radiograph.

Earlier in this paper the painting Coast Scene by George Inness was discussed briefly. In Fig. 19 another painting of Inness, Georgia Pines, is reproduced together with some autoradiographs. Here again one does not find evidence of heavy underpainting and reworking of the pigments, such as in the case of Blakelock, but rather a straightforward approach. From the autoradiographs of these paintings one gets the impression that Inness applied his pigments somewhat thinly with uniform brush strokes. Especially in the first autoradiograph of Georgia Pines one area blends smoothly into the next. The palette used by Inness does not seem very different from those encountered in the Blakelock paintings. However, the structural differences, as they show up in the autoradiographs, are very distinct.

Albert P. Ryder's Curfew Hour is presently in a very bad condition. Heavy contraction, cracking and discoloration obscure the visual design of the painting. Ryder, like Blakelock, is known for his frequent use of inferior materials. Figure 20 presents a photograph of this painting, together with some autoradiographs. The autoradiographs of this painting fall into two types, each of which is represented in Fig. 20. The first type of autoradiograph is obtained during the first day after activation. Electron emission curves constructed for this painting, such as those of Moonrise reproduced in Fig. 1, showed that the predominant activities at that time are due to manganese and sodium. From the second day on all autoradiographs are very much alike, and from the mentioned curves it appeared that antimony was responsible for the predominant activity in these exposures. Comparison of the two autoradiographs reproduced in Fig. 6 shows some very distinct differences, especially in the lower right quarter of the painting, where one observes different details, suggesting that Ryder painted there his antimony-containing pigment on top of the layer with the sodium and manganese compounds.

In this respect Ryder seems to differ from Inness, who appears to fill his forms in rather than paint them on top of each other, while of course the overpainting as encountered in Blakelock's work is again of a totally different nature.

The palette of the Ryder painting, as can be seen in Table II, is especially characterized by the extensive use of antimony. This is the reason why, from the second day on, no changes in the structure of the autoradiographs can be observed, as the antimony activities, of which the two components have half lives of 2.8 and 60 days, respectively, remain predominant for several months. Here one encounters one of the limitations of the neutron activation autoradiographic technique, i.e., the case where an element, which upon activation produces activities with relatively high decay rates and long half lives, is used so abundantly that these activities dominate all autoradiographs. This limitation is rather analogous in nature to that of X-ray radiography where one sees only the heavy element pigments, such as lead white.

In Fig. 21 the painting Moonlight, by H. M. Kitchell, is shown together with its X-ray radiograph and some autoradiographs. Very characteristic for the whole series of autoradiographs of this painting is the structure, most clearly visible in the early autoradiographs, of a layer applied over the whole area of the painting with broad, curving brush strokes. Electron emission curves show that this structured layer contains zinc and barium, which two elements make up ca. 95% of all elements detectable by our techniques in this painting. Upon visual examination of the painting one observes how the surface shows a relief structure which corresponds directly to the zinc and barium distribution as observed in the autoradiographs. Evidently a heavy structured ground layer of paint containing these elements

has been applied. Indeed, closer examination of the painting shows, on several "ridges" where the surface layer of the paint has broken off, how only a thin layer of colored paint is laid down on a high mound of white ground. It is interesting to compare the structure of this layer with the totally different way of application of a ground layer of similar composition in the two earliest period Blakelock paintings and in Woman in Red (see Fig. 7).

The only other elements whose distributions can be studied in the autoradiographs of Kitchell's Moonlight are manganese and chromium. The manganese is visible in early autoradiographs, appearing in the trees and foliage in the foreground. Chromium, showing up in the late autoradiographs, seems to be present in pigments applied thickly in small localities, to highlight the foliage, in a way which reminds one of the similar applications of arsenic and antimony bearing pigments in the two earliest period Blakelock paintings and in his Moonlight (see Fig. 10). Also visible in the late autoradiographs are the trees again, and as according to the electron emission curves this activity is most probably due to iron, they have possibly been painted with an earth pigment. One should note from Tables I and II how Kitchell's pigments in this painting are totally different from Blakelock's. No use is made of mercury, arsenic or antimony bearing pigments. Also the sodium and potassium contents are relatively low.

The results of our study of George H. Bogert's Sunset are represented in Fig. 22, where this painting is shown together with its X-ray radiograph and some autoradiographs. In this painting we were able, by means of neutron activation autoradiography, to study the distribution of the elements manganese, arsenic, and antimony. One sees how the manganese bearing pigment has not, as with typical Blakelock paintings, been applied for tonal underpainting, in a pattern which does not relate directly to the visible image of the painting,

but that here the manganese distribution corresponds to the application of a dark pigment in trees, foliage and part of the foreground. Also the distribution of arsenic, visible in the autoradiographs after the manganese activity has virtually died out, corresponds with visible elements in the image of the painting. The antimony bearing pigments have been used to accentuate the structure in the sky in the upper right part of the painting. This can be consluded from the fact that in very late autoradiographs, where antimony activity is by far the dominant one, one sees only this structure. In comparing Bogert's palette with Blakelock's, one notes especially the absence of detectable quantities of mercury.

Conclusions

It should be noted first of all that the information we have gathered thus far on the characteristics in paintings by Ralph A. Blakelock is only statistically significant as far as it concerns the works from his mature period. One does not necessarily expect to observe every one of the Blakelock characteristics in each of his paintings, but certainly the occurrence of several of them in one painting will lend credence to an attribution of that painting to Ralph A. Blakelock. Although a few of the characteristics established in the Blakelock paintings do sometimes also show up in the works of other artists, one does not observe there such combinations of these characteristics as are encountered in the late period Blakelock paintings. Also the paintings of the other artists do often show their own characteristics which are not observed in Blakelock's work.

Our study through neutron activation autoradiography and activation analysis of paintings by Ralph A. Blakelock and some related artists has thus shown how these techniques can supply valuable information on the pigments

used as well as on the way in which they were applied. It is to be hoped that eventually these methods will find a more widespread use in conservation laboratories for the technical examination of paintings, although the frequency of their application will be restricted, of course, by the limited availability of suitable irradiation and measuring facilities.

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Table I. Relative Weight Percentages of Elements Determined by Gamma Ray Spectroscopy in Activated Paintings of Ralph A. Blakelock.

	Paintings from his Mature Period						from his Intermediate Period	from his Earliest Period	
	Sonrise*	Landscape**	The Canoe Builders**	Moonlight*	At Nature's Mirror**	Indian Encampment*	In the Forest**	Landscape-Evening**	Landscape**
Elements Probably Present in Pigments									
Iron	22	62	48	28	68	6.7	67	39	12
Zinc	16	2.1	3.8	14	3.0	1.8	1.7	28	47
Barium	11	0.29	21	3.2	0.24	2.8	1.2	28	36
Mercury	8.6	11	3.6	2.8	0.08	0.48	7.5	0.65	0.78
Chromium	3.0	0.19	4.2	0.12	0.13	38	0.94	0.25	trace only
Arsenic	0.80	1.5	2.1	2.8	0.32	trace only	6.1	0.14	0.060
Antimony	0.21	trace only	0.21	1.1	0.29	0.44	0.42	trace only	trace only
Manganese	1.2	0.58	0.54	1.5	2.1	0.64	0.76	0.10	0.16
Copper	0.28	0.50	N.D.	0.66	N.D.	1.5	3.1	trace only	trace only
Cobalt	0.58	trace only	0.34	N.D.	trace only	trace only	trace only	trace only	trace only
Cadmium	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	4.1	1.6
Aluminum	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Other Elements Present in Significant Concentrations									
Potassium	18	13	4.9	24	10	23	2.8	1.6	1.1
Sodium	3.8	3.3	7.5	7.6	6.4	5.1	6.7	0.94	0.91
Chlorine	13	4.4	3.5	13	9.3	16	2.0	1.6	1.6
Strontium	2.0	0.45	0.61	1.4	N.D.	1.2	0.18	0.59	0.71
Elements Present in Trace Quantities									
Gold	0.022	0.014	0.0051	0.14	0.0090	0.033	0.0047	0.0009	0.0003
Lanthanum	N.D.	0.0066	0.021	0.096	N.D.	0.017	N.D.	0.0018	0.031
Scandium	N.D.	0.0009	0.0010	0.0027	0.012	0.0062	0.0007	0.0004	0.0003
Antimony	major	0.090	major	major	major	major	major	0.012	0.018
Cobalt	major	0.030	major	major	0.069	0.016	0.014	0.022	0.0074
Bromine	N.D.	0.10	N.D.	N.D.	0.10	1.6	N.D.	0.011	0.012
Indium	N.D.	0.0011	N.D.	0.0078	0.0034	0.0045	0.0027	0.0001	0.0005
Cerium	N.D.	N.D.	0.0022	N.D.	N.D.	0.013	N.D.	N.D.	N.D.
Mercury	major	major	major	major	major	major	major	major	major
Arsenic	major	major	major	major	major	major	major	major	major
Chromium	major	major	major	major	major	major	major	major	0.063
Copper	major	major	N.D.	major	N.D.	major	major	0.052	0.059

N.D. Not Detected

* Oil on wooden panel

** Oil on canvas

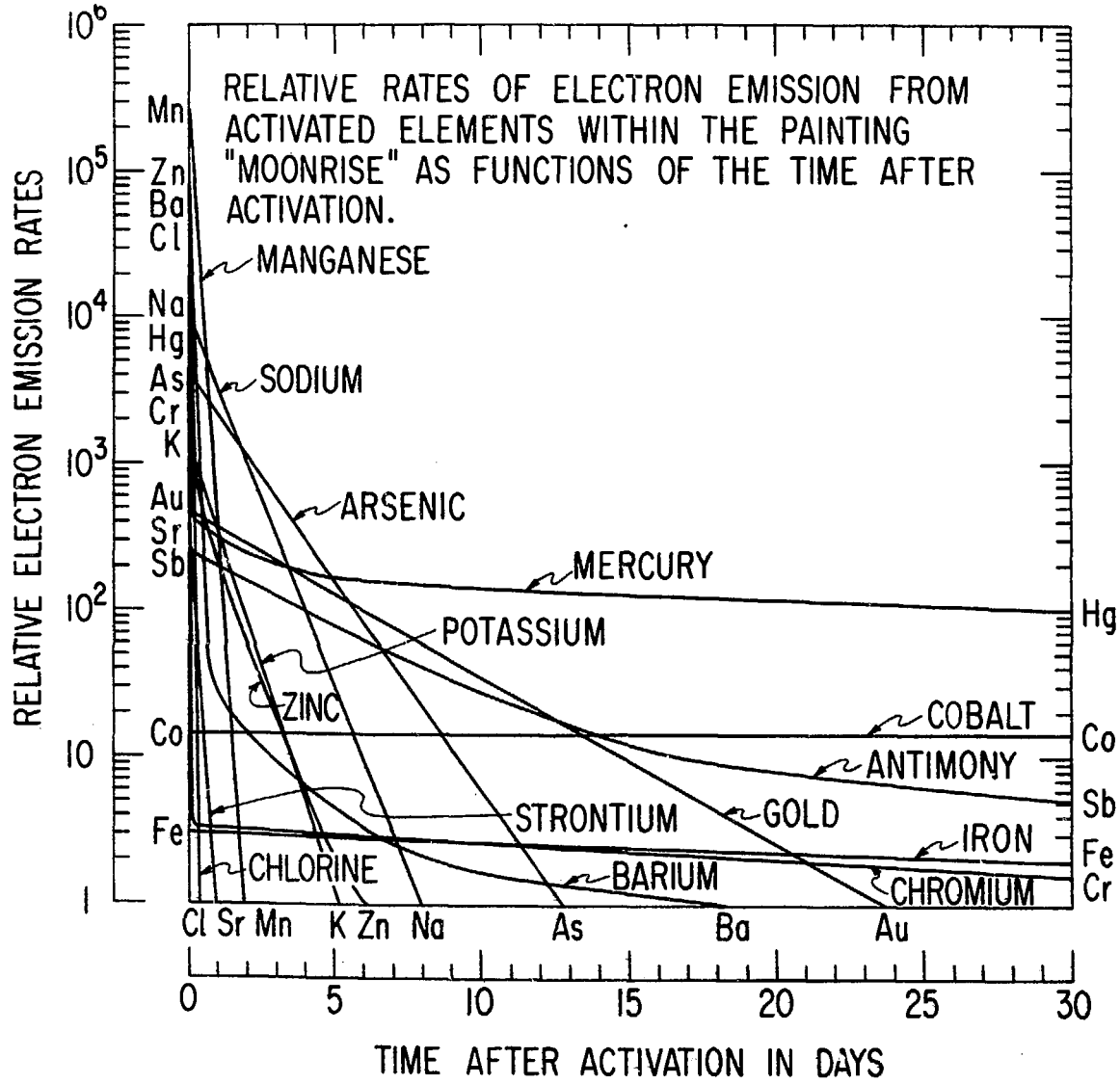
Table II. Relative Weight Percentages of Elements Determined by Gamma Ray Spectroscopy in Activated Paintings of Other Artists

	Marian Blakelock Paintings		Painting by unknown artist	George Innes Paintings		Albert P. Ryder Painting	George H. Bogert Painting	H. M. Kitchell Painting
	Woman in Red**	Landscape**	A Nocturnal Vista**	Coast Scene**	Georgia Pines**	Curfew Hour*	Sunset**	Moonlight**
Elements Probably Present in Pigments								
Iron	25	46	11	32	57	26	70	3.4
Zinc	35	6.4	4.2	1.4	1.5	13	2.6	45
Barium	28	6.0	1.7	32	2.4	<3	10	50
Mercury	7.7	0.091	0.31	18	0.12	1.2	N.D.	N.D.
Chromium	0.51	3.4	0.70	3.3	0.74	2.9	3.0	0.11
Arsenic	0.78	3.2	trace only	0.77	0.37	0.75	0.25	trace only
Antimony	trace only	0.63	trace only	trace only	trace only	9.1	0.14	trace only
Manganese	0.46	0.81	0.21	0.66	0.57	2.3	0.61	0.30
Copper	0.29	N.D.	0.52	0.38	0.54	0.28	N.D.	trace only
Cobalt	trace only	trace only	trace only	3.4	0.23	0.39	trace only	trace only
Cadmium	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Aluminum	N.D.	N.D.	78	N.D.	N.D.	N.D.	N.D.	N.D.
Other Elements Present in Significant Concentrations								
Potassium	1.3	4.6	0.54	2.9	19	6.7	1.6	0.40
Sodium	1.1	11	0.30	4.9	13	6.2	7.9	0.28
Chlorine	<0.3	18	2.4	≤0.67	5.3	7.4	3.9	0.34
Strontium	0.46	0.59	N.D.	2.3	N.D.	N.D.	0.35	0.38
Elements Present in Trace Quantities								
Gold	0.015	0.0016	0.0006	0.0012	0.0053	0.045	0.0005	0.0011
Lanthanum	N.D.	N.D.	0.0008	N.D.	0.052	N.D.	N.D.	0.0013
Scandium	N.D.	0.0019	N.D.	N.D.	0.021	0.022	0.0084	N.D.
Antimony	0.035	major	0.0047	0.095	0.042	major	major	0.0013
Cobalt	0.025	0.010	0.0076	major	major	major	0.040	0.0069
Bromine	N.D.	0.18	0.0014	0.039	0.057	N.D.	N.D.	0.0054
Indium	N.D.	0.0027	N.D.	N.D.	N.D.	0.0048	0.0004	0.00008
Cerium	N.D.	N.D.	0.0035	N.D.	0.0084	N.D.	N.D.	N.D.
Mercury	major	major	major	major	major	major	N.D.	N.D.
Arsenic	major	major	0.013	major	major	major	major	0.0036
Chromium	major	major	major	major	major	major	major	major
Copper	major	N.D.	major	major	major	major	N.D.	0.033

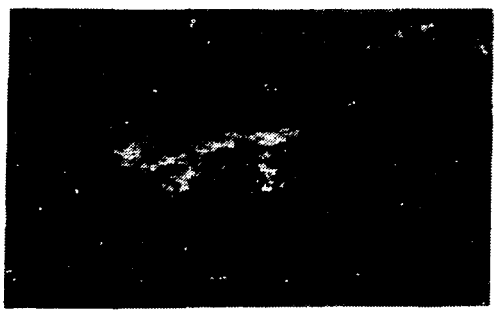
N.D. Not Detected

* Oil on wooden panel

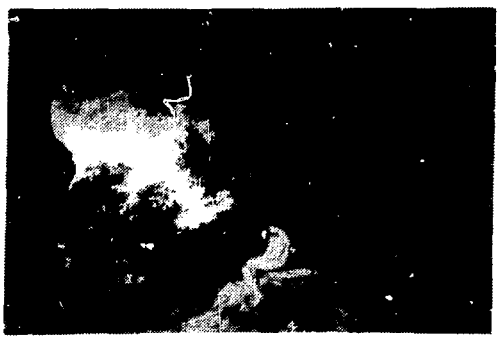
** Oil on canvas


RELATIVE RATES OF ELECTRON EMISSION FROM ACTIVATED ELEMENTS WITHIN THE PAINTING "MOONRISE" AS FUNCTIONS OF THE TIME AFTER ACTIVATION.
RELATIVE ELECTRON EMISSION RATES
TIME AFTER ACTIVATION IN DAYS
MANGANESE
SODIUM
ARSENIC
MERCURY
POTASSIUM
ZINC
COBALT
ANTIMONY
STRONTIUM
GOLD
IRON
CHLORINE
BARIUM
CHROMIUM
Mn Zn Ba Cl Na Hg As Cr K Au Sr Sb Co Fe
Hg Co Sb Fe Cr
Cl Sr Mn K Zn Na As Ba Au
0 5 10 15 20 25 30
1 10 10² 10³ 10⁴ 10⁵ 10⁶

Six Autoradiographically Studied Ralph A. Blakelock Paintings from his Mature Period



"Moonrise"
Oil on Panel, 15½x24 inches
National Collection of Fine Arts,
Smithsonian Institution

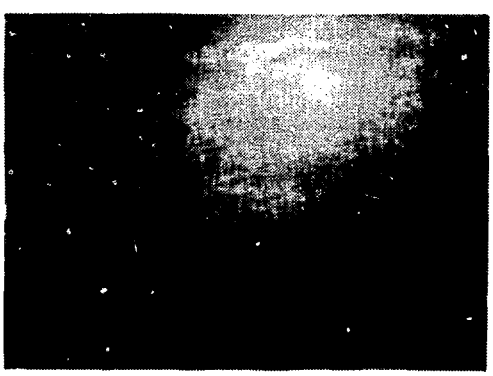


"At Nature's Mirror"
Oil on Canvas, 15x23 inches
National Collection of Fine Arts,
Smithsonian Institution

"Landscape"
Oil on Canvas, 16x24 inches
Metropolitan Museum of Art

"Canoe Builders"
Oil on Canvas, 28x36 inches
National Collection of Fine Arts,
Smithsonian Institution

"Indian Encampment"
Oil on Panel, 10½×17 inches
Private Collection



"Moonlight"
Oil on Panel, 6×8 inches
Private Collection

"Landscape"
Oil on Canvas, 12×23 inches
The Krannert Art Museum

"Landscape-Evening"
Oil on Canvas, 6×12 inches
The Krannert Art Museum

Three Autoradiographically Studied Ralph A. Blakelock Paintings from his Earlier Periods

"In the Forest"
Oil on Canvas, 14×20 inches
Heckscher Museum

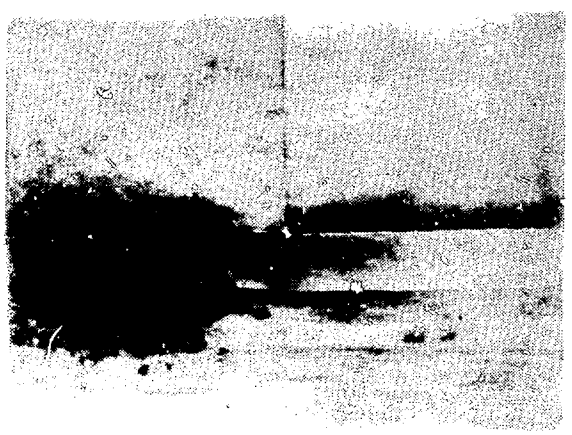
"Coast Scene" — George Inness

Oil on canvas — 22 × 30 inches

X-ray of "Coast Scene"

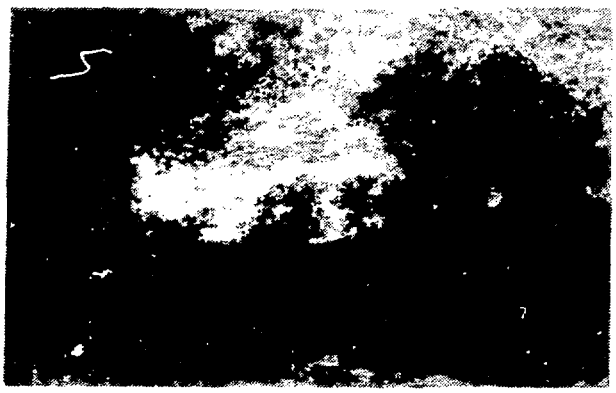
Autoradiographs of "Coast Scene"

Exposure - 5⅓ through 22⅓ hours
after activation



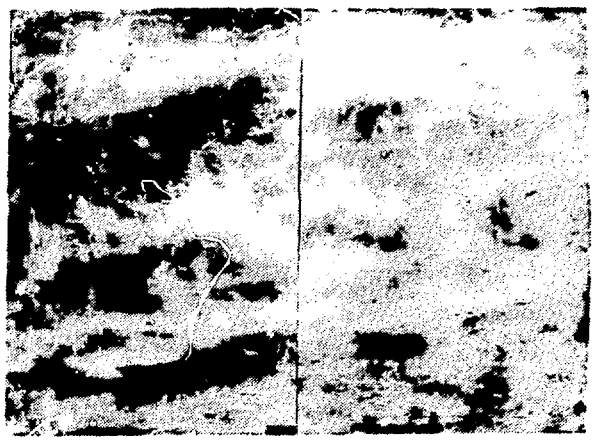
Exposure – 20 through 31 days
after activation

"Moonrise" — R.A. Blakelock

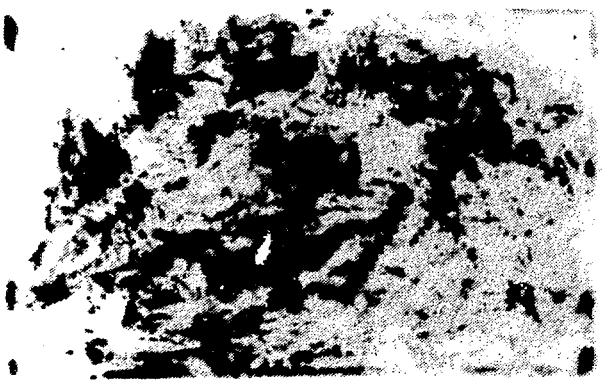


Oil on panel 15½ × 24 inches

X-ray Radiograph of "Moonrise"

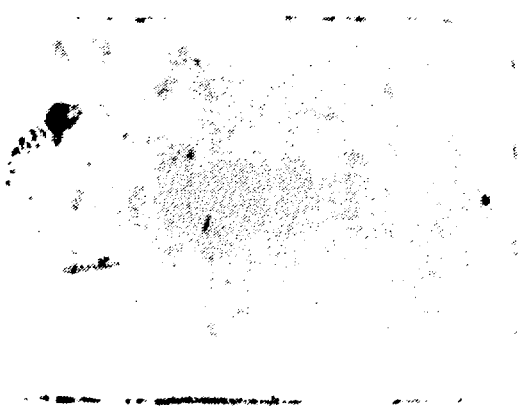


Autoradiographs of "Moonrise"

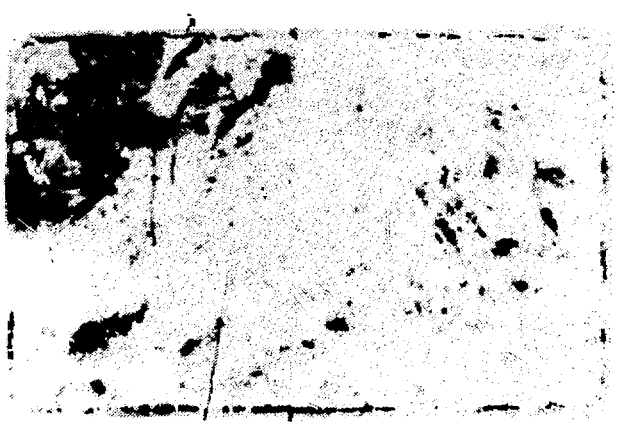


Exposure – 2¾ through 5¼ hours
after activation

Exposure – 25½ through 48 ¼ hours
after activation

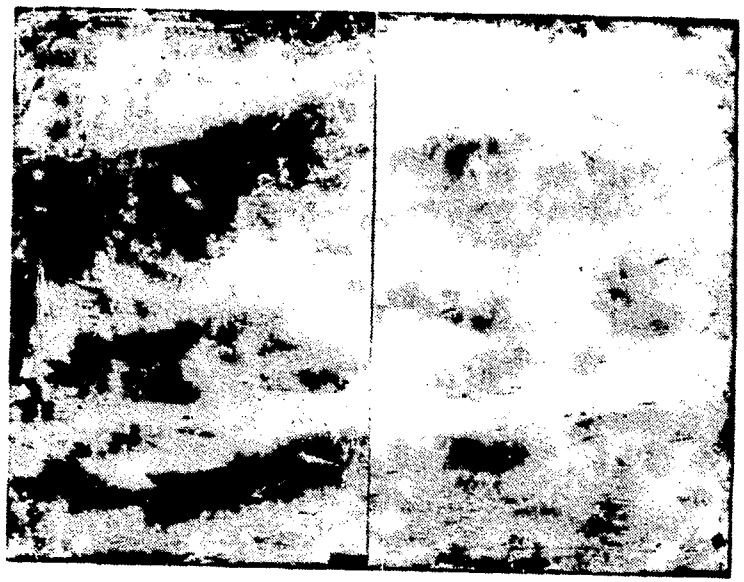


Exposure 3 through 6 days
after activation



Exposure – 14 through 24 days
after activation

Comparison of X-ray Radiographs of "Moonrise" and "Moonlight" – R.A. Blakelock both Oil on Panel



X-ray Radiograph of "Moonrise"

X-ray Radiograph of "Moonlight"

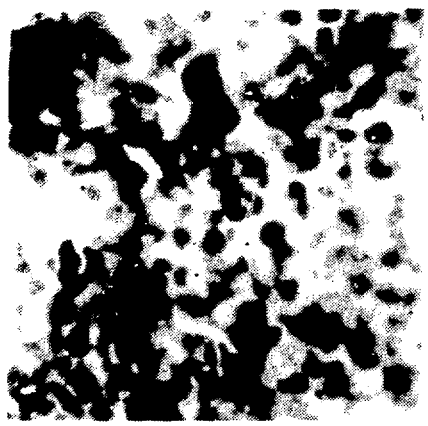
"Landscape"
R.A. Blakelock
Exposure - 2½ through 7½
minutes after activation

"Landscape-Evening"
R.A. Blakelock
Exposure - 1¼ through 2¼
hours after activation

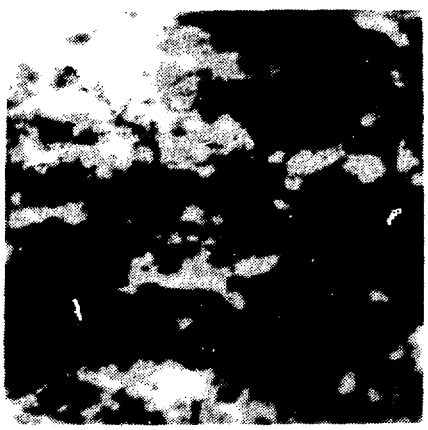
Autoradiographs of Two Paintings by R.A. Blakelock and One by Marian Blakelock showing the Distributions of Zinc and Barium Containing Ground-layers

"Woman in Red"
Marian Blakelock
Exposure - 13 through 33
minutes after activation

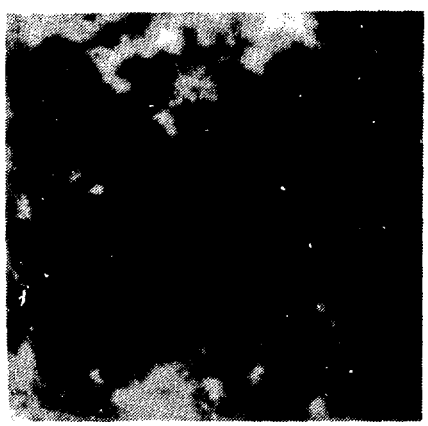
Details, 4 × 4 inches, of Autoradiographs of Blakelock Paintings showing Distributions of Sodium in Varnishes or Paint Media



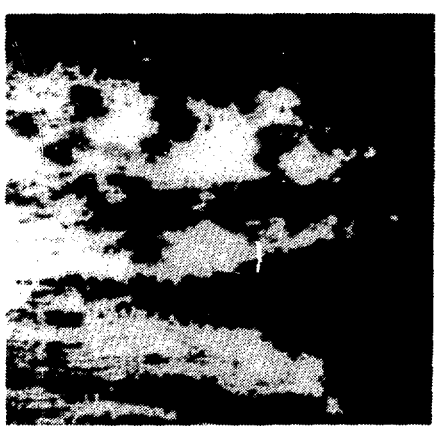
From "Moonrise"



From "Landscape"



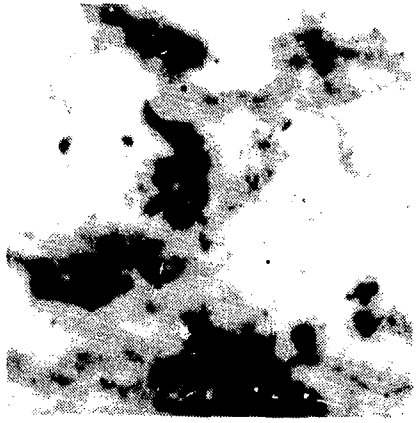
From "Canoe Builders"



From "Indian Encampment"

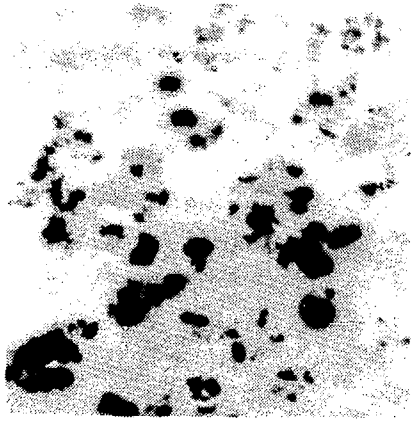
Details, 4 × 4 inches, of Autoradiographs of Blakelock Paintings showing thick small applications (probably worked in) of mainly Arsenic or Antimony bearing Pigments

From "Moonrise"

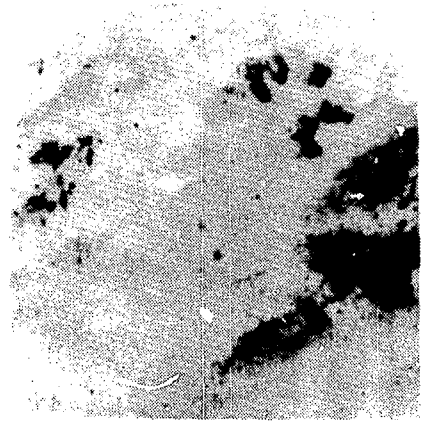


From "Canoe Builders"

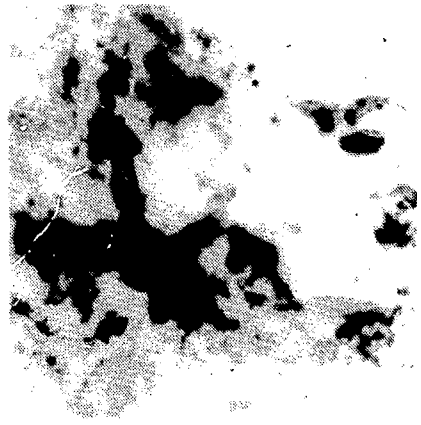
From "Indian Encampment"



From "Landscape"

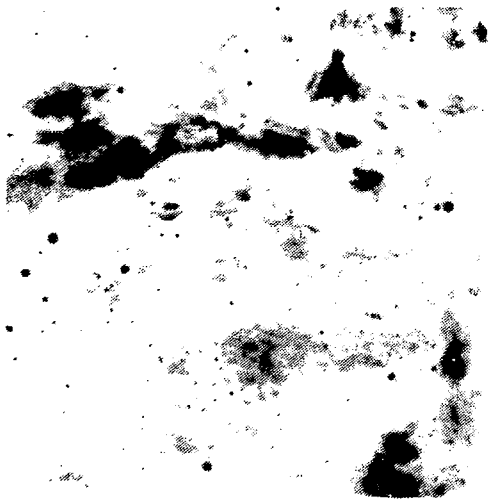


From "At Nature's Mirror"



From "In the Forest"

Details, 4 × 4 inches, of Autoradiographs of Blakelock Paintings showing thick small applications (probably brush- applied) of mainly Arsenic or Antimony bearing Pigments



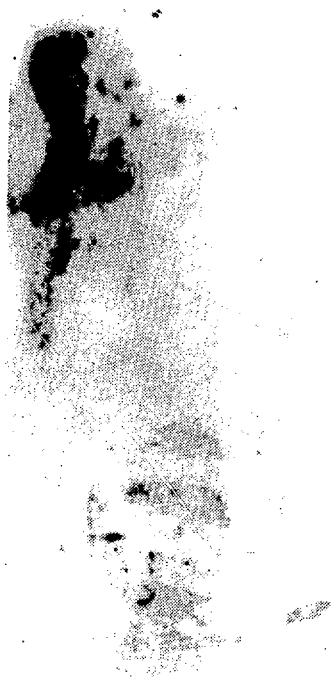
From "Moonlight"

From "Landscape-Evening"

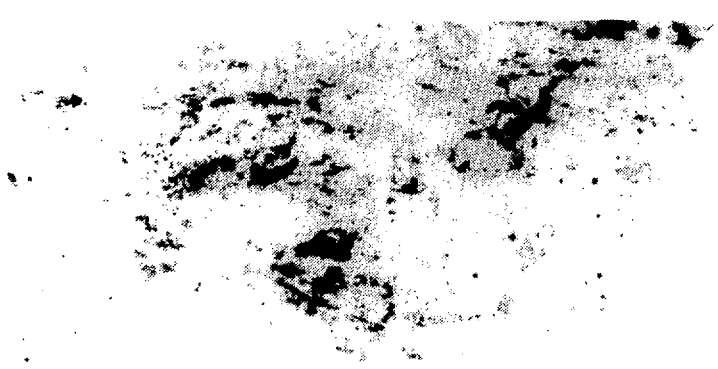
From "Landscape"

Details, 4 × 8 inches, of Autoradiographs of Blakelock Paintings showing application of a Coarse Mercury Pigment in a Thin Vehicle

From "Moonrise"

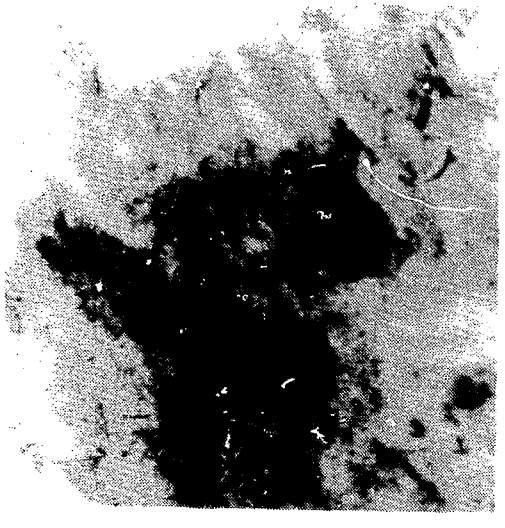


From "Canoe Builders"



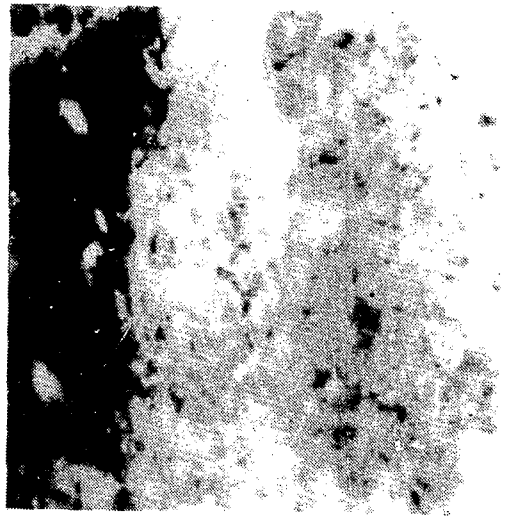
From "Landscape"

Details, 4 × 4 inches, of Autoradiographs of Blakelock Paintings showing applications of Pigments, other than Mercury bearing ones, in a Thin Vehicle



From "At Nature's Mirror"

From "Indian Encampment"



From "In the Forest"

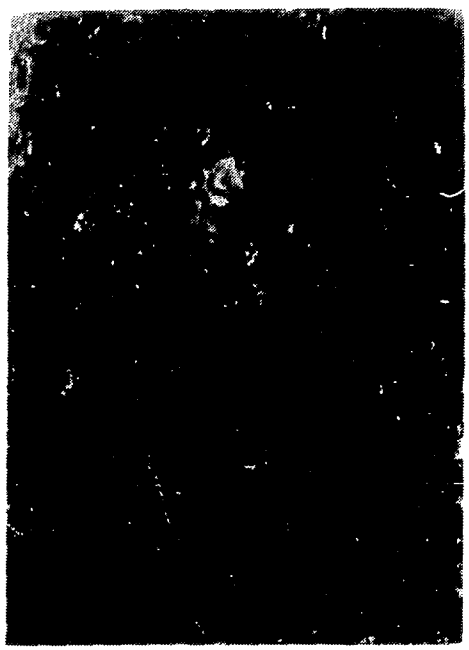
Sketch – R.A. Blakelock
Oil on Cardboard, 3.9x5.9 inches

Autoradiographs of this sketch

Exposure 2½ through 4 hours after activation

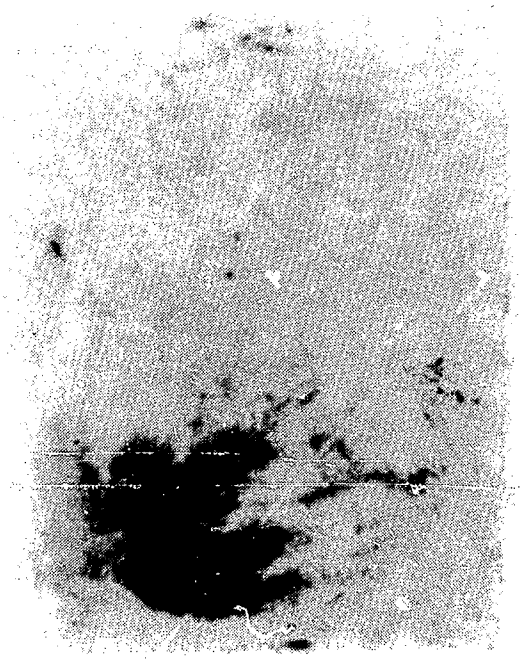
Exposure 1 through 2 weeks after activation

Sketch – R.A. Blakelock
Oil on Cardboard, 6x4.2 inches



Autoradiographs of this sketch

Exposure 5 through 24 hours
after activation

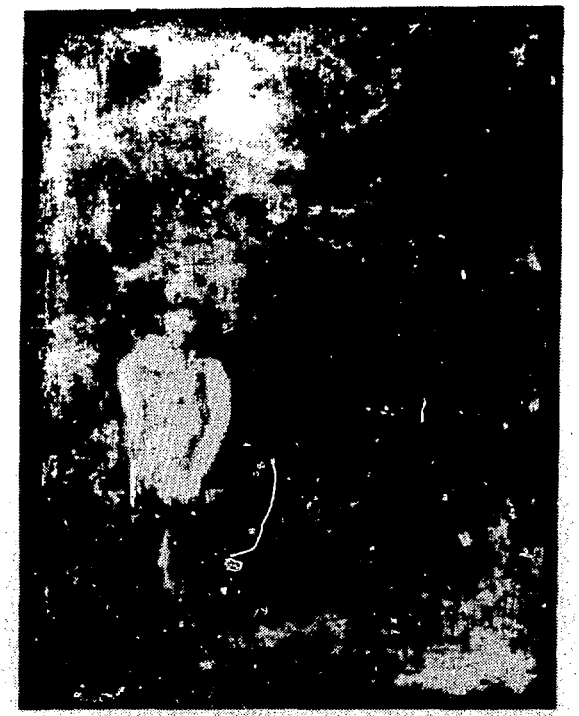


Exposure 5 through 12 days
after activation

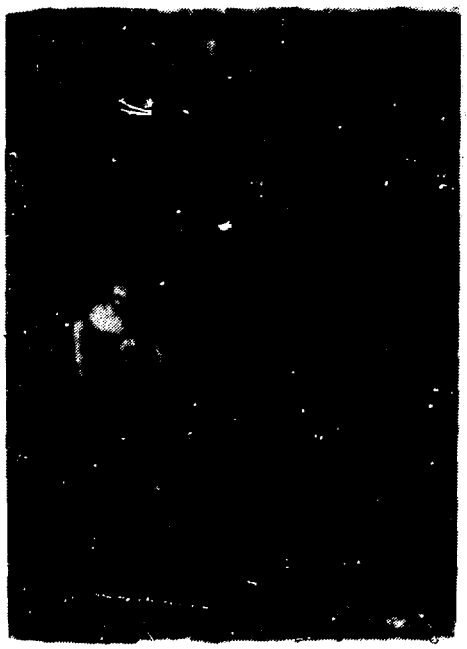
"Woman in Red" Marian Blakelock

Oil on canvas 8½ × 11 inches

X-ray Radiograph of "Woman in Red"



Autoradiographs of "Woman in Red"

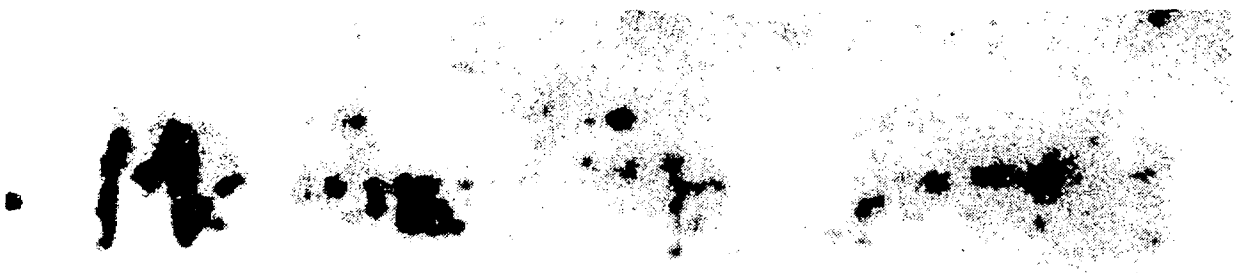


Exposure – 13 through 33 min
after activation

Exposure – 9 through 19 days
after activation

Details of Autoradiographs of Marian Blakelock Paintings

Signature on the Surface
of Sheldon Memorial Art Gallery Landscape



Hidden, partially destroyed
Signature on "Woman in Red"

"Landscape" - Marian Blakelock

Oil on Canvas, 6x9 inches
Sheldon Memorial
Art Gallery

X-ray Radiograph of
"Landscape"

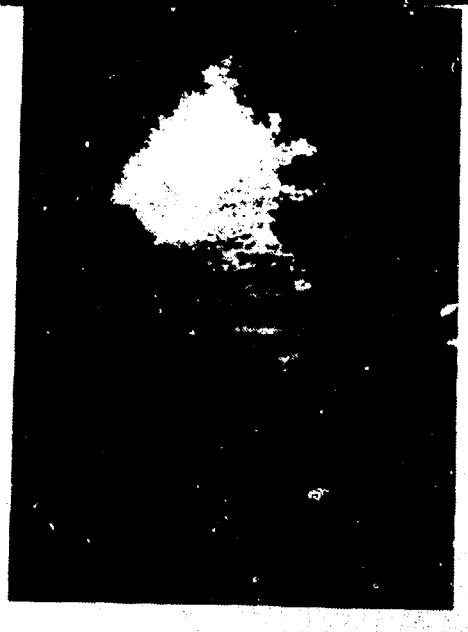
Autoradiographs of "Landscape"

Exposure - 30 through 45 minutes
after activation

Exposure – 6 through 13 days
after activation

"A Nocturnal Vista"
Unknown Artist

Oil on canvas
14½ × 10½ inches



X-ray Radiograph
of "A Nocturnal Vista"

Autoradiographs of "A Nocturnal Vista"

Exposure – 5 through 6 min
after activation

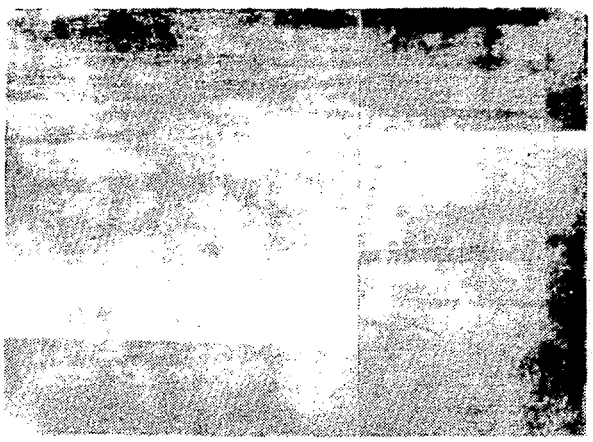
Exposure – 45 through 55 min
after activation

Exposure – 1 through 5 days
after activation

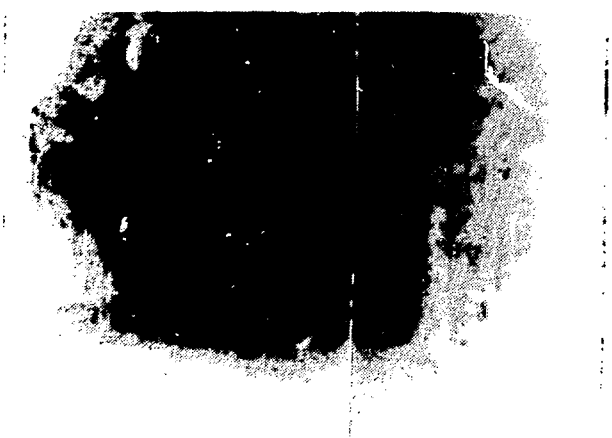
"Georgia Pines" — G. Inness

Oil on Canvas, 17 × 24 inches
National Collection of Fine
Arts, Smithsonian Institution

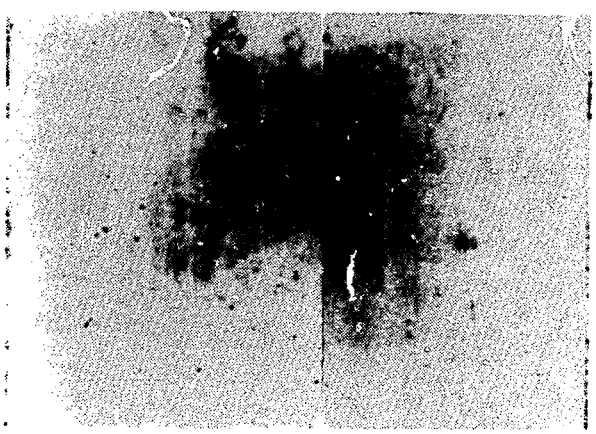
X-ray Radiograph of
"Georgia Pines"



Autoradiographs of "Georgia Pines"



Exposure - 2 through 3
days after activation



Exposure - 13 through 27
days after activation

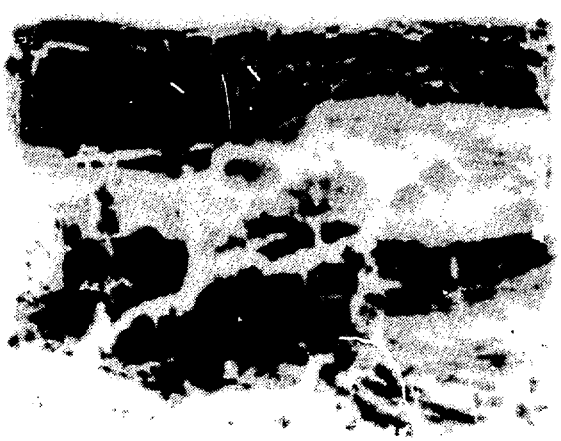
"Curfew Hour" – A.P. Ryder

Oil on Panel, 7⅝x10⅜₁₆ inches

X-ray of "Curfew Hour"

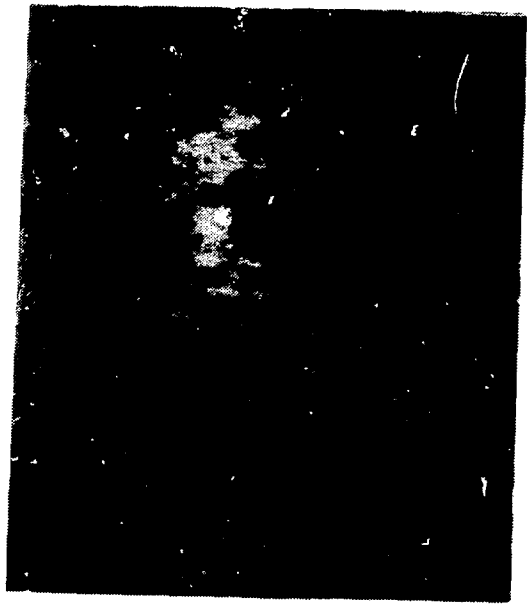
Autoradiographs of "Curfew Hour"

Exposure – 2 through 4 hours
after activation



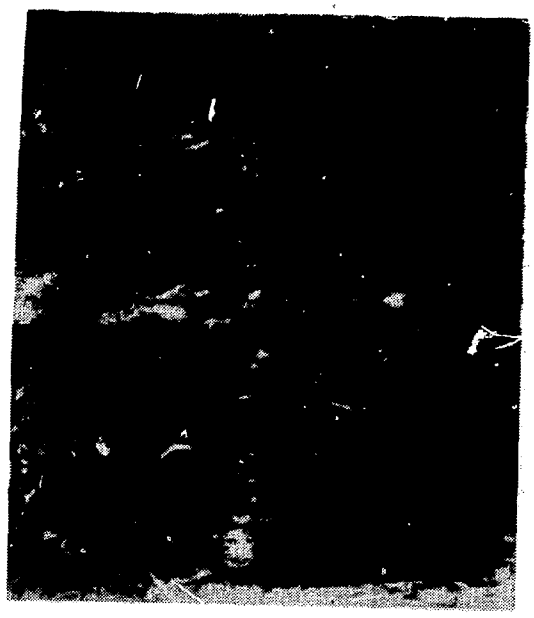
Exposure – 2 through 3 months
after activation

"Moonlight" - H.M. Kitchell

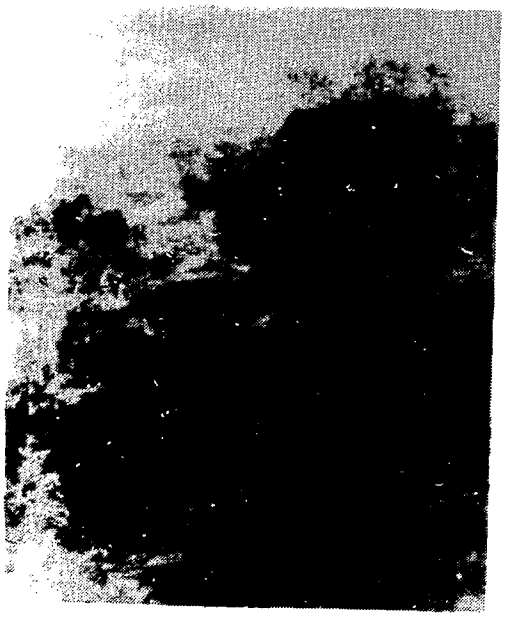


Oil on Canvas, 30×25 inches
Sheldon Memorial
Art Gallery

X-ray Radiograph of
"Moonlight"



Autoradiographs of "Moonlight"



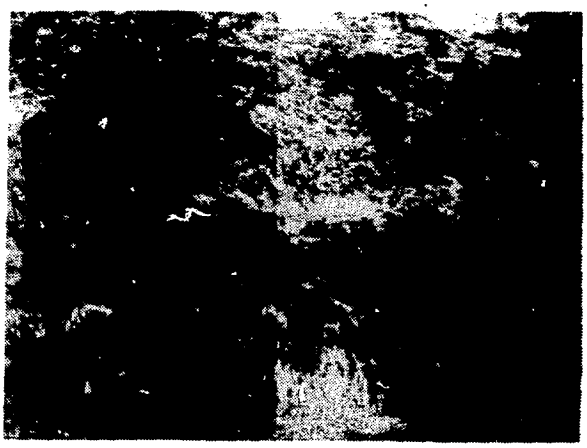
Exposure - 2½ through 4
hours after activation

Exposure - 27 through 83
days after activation

"Sunset" - G.H. Bogert

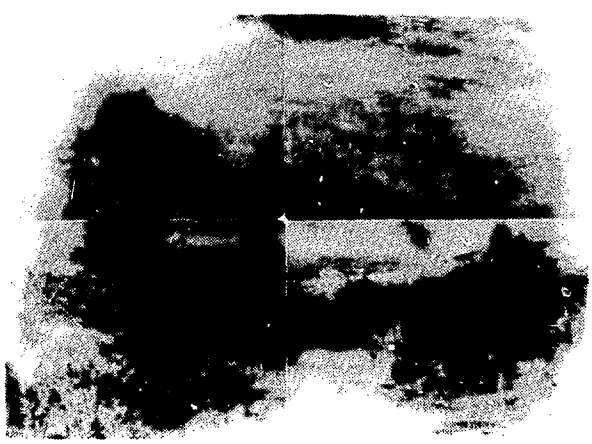
Oil on Canvas, 25 × 30 inches
Sheldon Memorial
Art Gallery

X-ray Radiograph of
"Sunset"



Autoradiographs of "Sunset"

Exposure - 1½ through 2¾
hours after activation



Exposure - 1 through 3 days
after activation