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AUTHENTICATION OF PAINTINGS BY RALPH A. BLAKELOCK THROUGH NEUTRON ACTIVATION AUTORADIOGRAPHY+

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Following his mental collapse at the end of the nineteenth century the paintings of Ralph A. Blakelock suddenly began to bring exceptionally high prices. Not surprisingly, therefore, many forgeries attributed to him were produced in the early twentieth century. In fact, some experts consider him to have been the most widely forged American painter. At Brookhaven National Laboratory a group of paintings attributed to him have been studied by thermal neutron activation autoradiography combined with solid state high resolution gamma-ray spectroscopy. Most of the paintings studied were of unquestioned authenticity coming from the collection of the Metropolitan Museum of Art, the National Collection of Fine Art of the Smithsonian Institution, the Sheldon Memorial Art Gallery of the University of Nebraska, and two private collectors with well established histories of acquisition. These included paintings produced by Blakelock both before and after his breakdown. In general a number of characteristic consistencies in the types of pigments and media used and how they were employed in these paintings were revealed by the activation study. Of course, major differences exist between his early and later work. However, a lack of these characteristics and hidden overpainted details which are not revealed in conventional X-ray radiographs have provided evidence that two of the paintings attributed to Ralph Blakelock are the work of other artists.

Some paintings of Blakelock's contemporaries George Inness and Albert Ryder have also been investigated.

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Introduction

In a period in which the market values of some individual oil paintings have increased to millions of dollars, questions as to the authenticity of paintings have increasingly become matters of forensic concern. Probably the most unquestioned pedigree a painting might have is an unambiguous historical record of its ownership leading directly back to the artist. Few paintings other than contemporary ones, however, have such well recorded histories. Lacking such direct evidence one seeks to observe within a painting characteristics that relate it to the artist to which it is attributed. Such characteristics include the subject and composition of the painting, the style of painting, the materials used by the artist, and how the artist employed these materials. It has long been recognized that much information useful in establishing these characteristics lies buried beneath the surface of the painting. For this reason art conservation laboratories have for many years studied paintings by such techniques as X-ray radiography and microscopic examination of pigment layer cross sections. Of course, X-ray radiography by separately indicating the distribution of particular components, usually lead white, can provide otherwise undetected information concerning what is visibly present on the painting surface.

In an X-ray radiograph of an oil painting one might be able to observe (1) an overpainted earlier painting, (2) overpainted details which differ from the final design of the painting, indicating changes in the artist's concept as he worked, (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 subtilely show through to the surface, (5) details of how the artist applied his pigments, e.g., whether the pigments were applied thickly or thinly, uniformly or not and with characteristic brush strokes or by other means of application such as a palette knife, and (6) information about the support and ground upon which the painting was laid. Because an X-ray radiograph reveals only the distribution of dense pigments, such as lead white, it more often than not provides only a portion of this information. Because neutron activation autoradiography records the distributions of a number of pigments other than lead white it provides additional oppurtunities of obtaining this full range of information. Although X-ray radiographs and thermal neutron activation autoradiographs are very similar in nature, the information they provide tends to be supplementary rather than redundant. Hence both techniques should be employed together.

Identification of pigments is generally achieved by microscopic examination or X-ray diffraction analysis of small samples taken from a painting. However, by measuring the gamma-ray energy spectra of the activated paintings, the chemical elements of many pigments also can be identified and their relative abundances within the paintings determined. Thus the combination of activation analysis with autoradiography can yield, non-destructively, much information concerning the pigments used as well as the distributions of a number of them.

Experimental

The autoradiographic technique

The thermal neutron autoradiographic technique as developed by Sayre and Lechtman[1] and described in the proceedings of the First International Conference on Forensic Activation Analysis[2] is a relatively simple process to carry out providing one has available an irradiation facility adequate for carrying out the initial activation. One simply exposes the painting to a flux of neutrons for a period adequate to generate the desired level of internal radioactivity, then at various times after activation repeatedly places photographic film in close contact with the painting for periods adequate to produce the required exposures. One also periodically counts the gamma rays emitted from the painting with a Ge(Li) detector or other appropriate equipment. In the specific measurements of this study the paintings were exposed at the patient port of the Brookhaven Medical Research Reactor to fluxes of thermal neutrons of the order of 10^9 neutrons per square centimeter per second. The exact flux depended upon how close the painting was placed to the beam port, larger paintings being placed farther away from the 10" by 10" 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 bases 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 forty-five minutes to one hour and a half, 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 was 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 sand bags 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 method of pressing sheet materials against a painting produces a uniform and gentle pressure which allows for surface irregularities. It is a technique widely used in art conservation laboratories.

The paintings differed in their support mountings. Some were on wooden panels, some were on canvas which was still attached to a wooden stretcher, some were on canvas which had been removed from its 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 with a NaI(Tl) scintillation detector coupled to a portable 400 channel analyzer. At this early stage the gamma-ray activity of all of the paintings but one were dominated by those of manganese (^{56}Mn, T = 2.68 hrs) and sodium (^{24}Na, T = 15.0 hrs). The exceptional painting, which for some years was accepted as a Blakelock but is now, for many reasons, believed to be a forgery, showed intense aluminium activity (^{28}Al, T = 2.3 min) immediately following activation. This activity presumably arises because of the extensive use in this painting of an organic lake pigment carried on an alumina mordant. We have not encountered the use of an alumina lake pigment in any of the paintings judged to be genuine Blakelocks.

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, a large Ge(Li) detector coupled to a 3200 channel analyzer, 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.

Countings of the activities 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 paintings 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 distribution of different activity sources within the paintings were nonuniform, 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 relative photopeak intensity measurements into relative concentrations of elements with reasonable accuracy.

Study of paintings of R.A.Blakelock and related artists

Although Ralph Blakelock is not today one of the most famous and esteemed of the nineteenth century American artists, he is considered by some to have been the one whose works have been most widely forged. The principal reason for this is that there was a period early in the twentieth century during which his works became very popular and commanded exceptionally high prices. When it 1916 one of his paintings was bought at auction for 20000 dollars it was front page news. Ralph Blakelock himself benefited little from this late popularity and indeed led a tragic life. He was essentially a self-taught artist who used unorthodox materials and painting techniques and was not widely recognized nor supported during his productive years. The strain of supporting a large family on his meager earnings as an artist finally resulted in his suffering a severe mental breakdown in 1899, after which he essentially remained under institutional care for the remainder of his life. Of course, it was only after this breakdown that his paintings were truly valued. However, in these later years he produced only a series of relatively simple oil sketches, of which we have autoradiographed ten. We shall not discuss these late works in this paper except to remark that they are very different in construction and general painting technique from his earlier paintings, although some of the characteristics observed in the earlier paintings carry over into some of these. It was primarily the paintings of his mature period preceding his breakdown which have been simulated by forgers and it is these with which we shall be primarily concerned.

After Ralph Blakelock's mental breakdown his daughter Marian Blakelock continued to support the family through her painting. Having been taught by her father she not surprisingly painted in a style and method resembling his. When it was discovered that unscrupulous art dealers were buying her paintings, removing her name from them and substituting that of her father in order to resell them at high prices as Ralph Blakelocks, she too experienced a mental collapse.

Of the paintings we have studied, five have been accepted by each of several experts on American paintings we have consulted as very probably being genuine Ralph Blakelock paintings of his mature years. Three of these paintings are from the National Collection of Fine Arts, The Smithsonian Institution ("Moonrise," "Canoe Builders," and "At Nature's Mirror"). One is from the Metropolitan Museum of Art. It is entitled simply "Landscape". The fifth is from the collection of M.J.Cotter and is entitled "Moonlight". To compare with these accepted Blakelocks we have autoradiographed two paintings attributed to R.A.Blakelock but which we now have good reason to question, "Woman in Red" from a private collection and "A Nocturnal

Vista" from the Sheldon Memorial Art Gallery of the University of Nebraska. In addition we have studied an unquestioned signed Marian Blakelock landscape from the Sheldon Memorial Art Gallery, a George Inness seascape entitled "Coast Scene" from the Metropolitan Museum of Art, a second Inness painting, "Georgia Pines", from the National Collection of Fine Arts and Albert Ryder's "Curfew Hour" from the Metropolitan Museum of Art. The paintings by Inness and Ryder were selected for study because these painters were contemporaries of Blakelock, both of whom at times painted in styles somewhat like Blakelock's. In addition to these, ten very late Blakelock oil sketches we have studied were kindly provided by the Sheldon Memorial Art Gallery.

It is hour hope to extend this study to include examples of Ralph Blakelock's early paintings which are painted in a style distinct from that he used in his more mature works and also to study the paintings of some of Blakelock's contemporaries who were more closely related to him in their work and lives than Inness and Ryder.

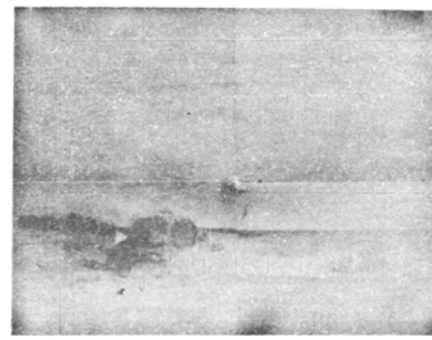
As a rule the autoradiographs of a painting bear some resemblance to the design of the painting as one observes it visually. An example of this is provided in the autoradiographs of the Inness "Coast Scene" shown in Fig. 1. Here one can see that although each of the subsequent autoradiographs, of which only two are shown, show some differences between themselves and from the visible design of the painting they still largely conform in details to the painting. One notes in the first autoradiograph that the rocks at the viewers left have a different conformation than in the finished picture. However, they appear to conform to the design of the painting in its original composition, which was later altered. This same general correlation between autoradiographs and the finished painting characterized the radiographs taken of the second Inness and of the Ryder painting.

More often than not the autoradiographs of the Blakelock paintings have shown little if any correlation with the painting designs. This is most dramatically shown in the series of autoradiographs of the painting "Moonrise" presented in Fig. 2. The first radiograph of the series typifies those obtained during the day of activation. It shows only irregular areas of density, some of which have a scraped appearance rather like they represented material laid down with a palette knife. The X-ray radiograph of "Moonrise" shows even more details of a scraped like appearance. Some of the details in the X-ray and first autoradiograph essentially coincide in such a way as to lead us to believe that in part the X-ray shows the distribution of an underlying lead white ground roughly scraped on, while portions of the first autoradiograph show regions in which a paint layer, placed upon this ground, filled in its rough contours forming an inverse relief of the ground. "Moonrise" is a painting upon a wooden panel. The painting "Moonlight" is similarly a panel painting and its X-ray radiograph similarly has a scraped appearance which probably relates to the painting's ground.

The gamma-ray spectra of "Moonrise" taken during the day of activation show activity arising from manganese to be strongly predominant. It is easy to relate the relative intensities of gamma-ray emissions from different components and the relative

a)

b)



c)

Fig. 1. a - "Coast Scene" by Georges Innes, oil canvas, 22" x 30". b - Autoradiograph, exposure 5 1/3 through 22 1/3 hrs after activation, c - autoradiograph, exposure 20 through 31 days after activation

contributions of these components to film darkening. It was determined by Sayre and Lechtman[1] that film darkening was very predominately 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 ^{60}Co betas, all beta-particles independent of their energies from all of the elements which are expected to be found in paint pigments that will active well were roughly about equal in 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 pro-

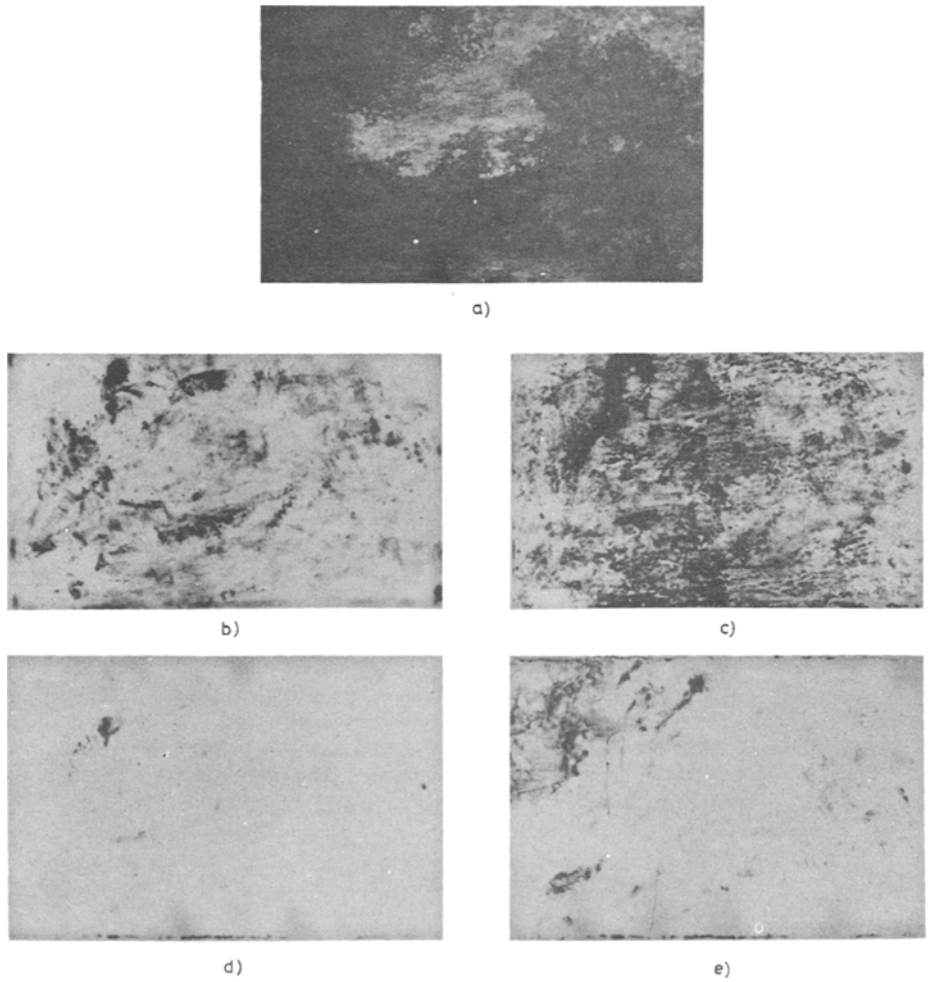


Fig. 2. a - "Moonrise by R.A. Blakelock, oil on panel, 15 1/2" x 24", b - Autoradiograph, exposure 2 3/4 through 5 1/4 hrs after activation, c - autoradiograph, exposure 25 1/2 through 48 1/4 hrs after activation, d - autoradiograph, exposure 3 through 6 days after activation, e - autoradiograph, exposure 14 through 24 days after activation

portional 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 the graph in Fig. 3 was generated which pre-

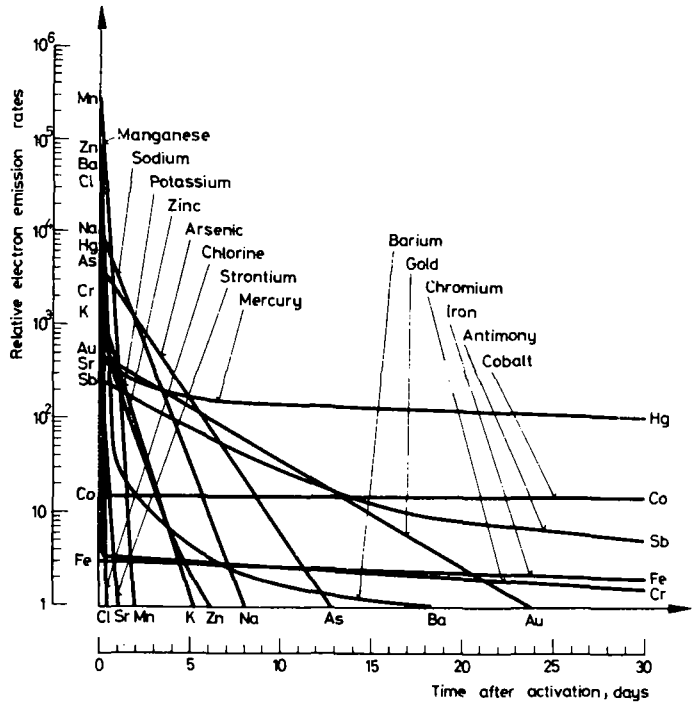


Fig. 3. Relative rates of electron emission from activated elements within the paint ing "Moonrise" as functions of the time after activation

sents for the painting "Moonrise" the relative electron emission rates as a function of time of each of the elements which have been determined in this painting. Such graphs have proved very useful as aids interpreting the autoradiographs. It can be seen from Fig. 3 that during the first several hours after activation of the painting "Moonrise" the manganese activity within it indeed dominated in the exposure of the autoradiographs.

The autoradiographs of "Moonrise" obtained during the day following the day of activation, of which the second radiograph in Fig. 2 is an example, are almost total different from those obtained the first day. Of course by then the manganese activity would have effectively decayed away. The radiographs now have a mottled appeara Examination of the surface of the painting shows that the paint layer is very non-uni form in thickness as if the paint vehicle did not dry to or remain as a smooth uniforr layer but rather pulled together to form thicker "mounds" surrounded by thinner "valeys". In general the distribution of exposure density in the autoradiographs taken at this time conform to these variations in thickness.

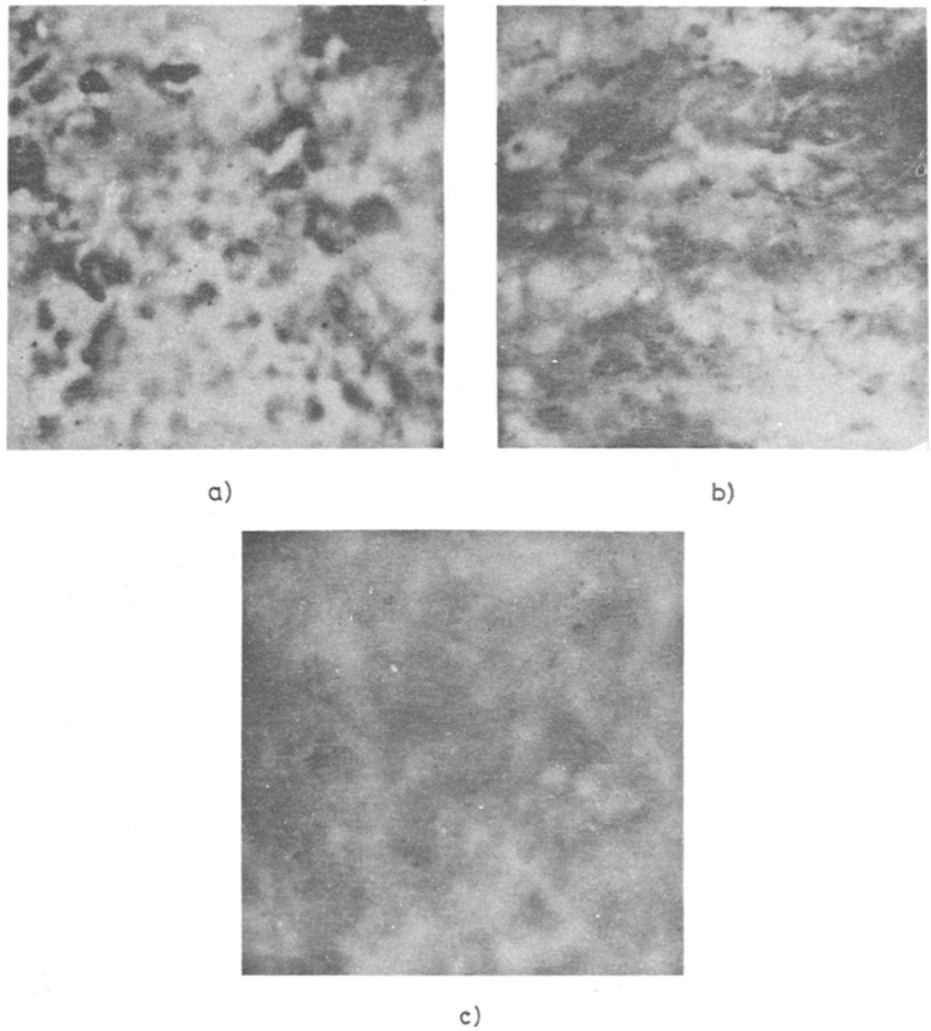


Fig. 4. Details, 4" x 4" of autoradiographs of Blakelock paintings showing distributions of sodium bearing paint media. a - From "Moonrise", b - from "Landscape", c - from "Canoe Builders"

Somewhat surprisingly the predominant activities existing within the painting a day after activation are not ones arising from elements one anticipates encountering in nineteenth century paint pigments. It is instead the activity arising from sodium, see Fig. 3. This element, however, might likely have been present in the paint vehicle. In the nineteenth century, linseed oil was frequently treated with

alkalis or with salt brines, both of which could have introduced sodium. Also the natural resin varnishes often have a significant inorganic salt content in which one would expect to find sodium as an appreciable component. It is to be expected that paint vehicles used in the nineteenth century would contain either or both of these or similar materials. Upon the basis of these considerations it is reasonable to conclude that in these autoradiographs one is more likely observing the distribution of the paint vehicle itself than that of particular pigments.

All five paintings of accepted Ralph Blakelock attribution have contained significant amounts of sodium. In three of the five we have seen structure in the radiographs taken a day after activation which appears to relate to uneven vehicle distribution. Comparison of such details in these three paintings appears in Fig. 4.

The next alteration in nature of the radiographs is best observed in those taken several days after activation when the sodium activity, which has roughly a half day half-life, has decayed away. At this time, in autoradiographs of the Blakelock paintings, one tends to pick up rather fine details that stand out in relatively sharp contrast. Most of these detailed structures can be observed in the earlier sodium dominated autoradiographs but now they remain pretty much by themselves. Among these details are some relatively peculiar ones that are particularly characteristic of this group of paintings. They tend to be small irregular filaments of high density. They may be seen in the third autoradiograph in Fig. 2, or in enlarged detail and compared to similar images in radiographs of each of the other four Blakelock paintings, in Fig. 5. The filament-like clumps that are recorded could have resulted from the separate application of small quantities of a viscous paint which were then worked into the painting. In many instances the regions of high paint density appear to be divided with clear streaks running through them. These could be the result of a small hard object, such as the wooden end of a paint brush, being used to work in the paint. For want of a better name we have called these details squiggles. In each of the five Blakelock paintings they have been most apparent at a time during which activity from arsenic and to a lesser extent antimony was predominant. In many instances they can be correlated with golden highlights within trees, that is, regions in which the artist was portraying breaks in the continuity of foliage. It is to be inferred that the artist applied small quantities of an arsenic-containing pigment, possibly orpiment, to achieve the effect desired.

Fig. 3 shows that after the arsenic and antimony activities have decayed sufficiently in "Moonrise" mercury activity becomes most intense. This was also true in two other paintings of this group, "Landscape" and "Canoe Builders". The autoradiographs of these three paintings show that the mercury pigment, presumably vermillion, was applied in a very unusual way. If one considers the last of the autoradiographs of "Moonrise" (Fig. 2), one observes a region in the upper left corner in wich the pigment appears to have been applied very thinly with broad brush strokes. Two dribbling runs have obviously run down the painting from this region. It would seem that the mercury containing paint applied in this area must have been very

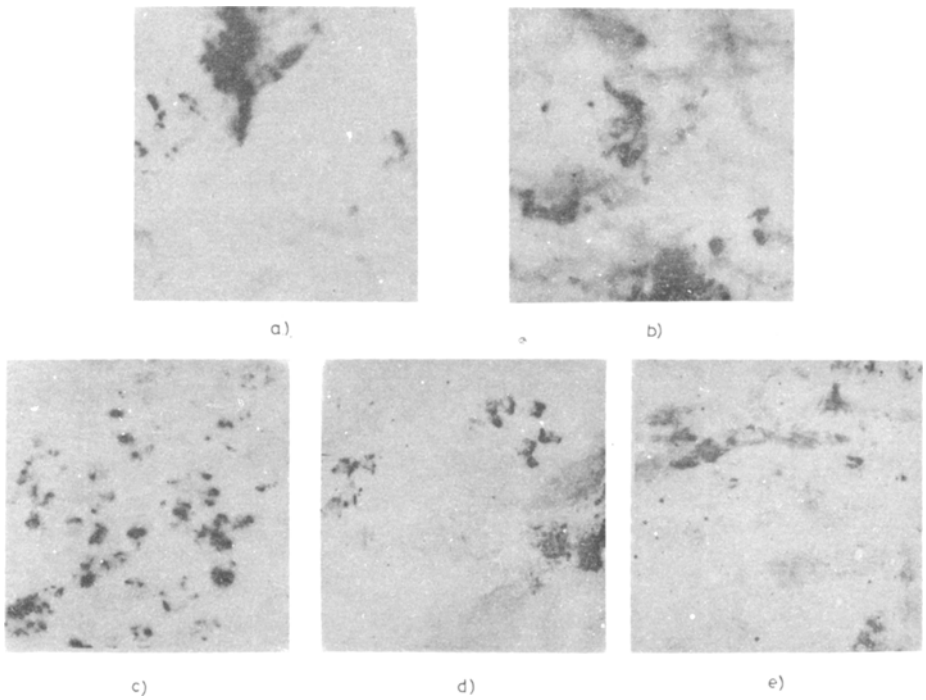


Fig. 5. Details, 4" x 4" of autoradiographs of Blakelock paintings showing working of highlighting pigments, mainly arsenic bearing, a - From "Moonrise", b from "Canoe Builders", c - from "Landscape", d - from "At Nature's Mirr e - from "Moonlight"

dilute and fluid. The broad brush strokes have very much the appearance of strokes often observed in water color paintings and, of course, only a thin paint would have run down in dribbles. Also there are present blotches, that is, spots of thin, relative evenly spread pigment surrounded by more dense rings. These are the type of spots which can be formed when drops of a thin, fluid liquid containing suspended solid is allowed to dry on a flat surface. In this process an appreciable fraction of the solids is usually drawn to the outer edge. Fig. 6 present a comparison of areas in which a very fluid mercury containing paint appears to have been used in three Blakelock paintings in which mercury appears extensively. A close examination of these three autoradiographs reveals yet another characteristic in common, a decidedly granular appearance. It seems likely that the mercury pigment in each case had been coarsely ground. It should also be noted that other pigments sometimes appe to have been spread with a thin, fluid vehicle. In "At Nature's Mirror" the first au

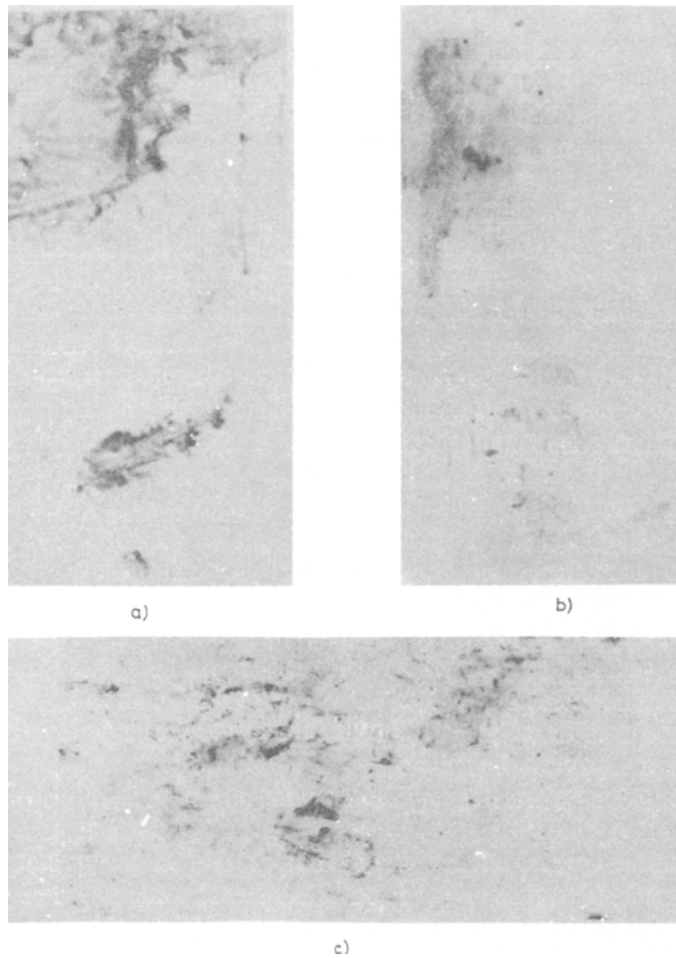


Fig. 6. Details, 4" x 8" of autoradiographs of Blakelock paintings showing of a coarse mercury pigment in a thin vehicle. a - From "Moonrise", b - from "Canoe Builders", c - from "Landscape"

radiographs taken when manganese activity is predominant have a water color like appearance in some regions.

Thus one observes a number of very similar characteristics in the five paintings attributed with reasonable confidence to Ralph Blakelock, i.e., (1) scraped on grounds in the case of panel paintings, (2) the presence of sodium in the paint medium, (3) the placing of accent pigments in a thick localized way that produces characteristic squiggles, and (4) the placing of a coarsely ground mercury pigment

in a thin, fluid wash that results in runs and blotches. With very few exceptions these characteristics have not appeared in the autoradiographs of the comparative paintings we have studied. Of course, one would not observe all of these characteristics in all Blakelock paintings but the observation of some of them on the autoradiographs of a painting attributed to Blakelock would add much credence to that attribution.

The relative concentrations of pigment elements in a number of the paintings studied also are presented in Table 1. Data for the Blakelock painting "At Nature's Mirror" are at this time incomplete and have not been included. In Table 1 the relative elemental concentrations have been expressed as weight percents arbitrarily normalized to the basis that the sum of all measured concentration percentages is equal to one hundred. It can be seen that the pigment palette used in the four paintings attributed to Ralph Blakelock was relatively consistent. There was a very extensive use of iron containing pigments which were most probably earth pigments, although by the late nineteenth century some synthetic iron containing pigments such as Prussian Blue were used. Large concentrations of zinc and barium often are present, which could indicate the use of the white zinc - barium pigment lithopone or the use of zinc white and the occurrence of barium sulfate as an extender in this or other paints. Mercury, chromium, arsenic, antimony, manganese, copper and cobalt were usually present in sufficient amounts to indicate the use of compounds of these elements as pigments. Among those pigment elements which are probably present but do not activate well and hence are overlooked in our measurement, the most significant one is lead.

A rather similar group of pigment elements are observed in the paintings of Innes and Ryder that we have studied. It probably would not be possible to differentiate clearly between these paintings and those of Blakelock on these data alone. Fortunately, however, the autoradiographic images of these paintings are significantly different from what we have observed in the Blakelock paintings. One would expect to encounter many other paintings in which significantly different arrays of pigments were employed. An example of this is the painting "A Nocturnal Vista" which we have listed in Table 1 as being by an unknown artist. Here the extensive use of an aluminum bearing pigment and the little if any use of arsenic and antimony pigments stand out in contrast to the pattern that has characterized the Blakelock paintings.

The painting "A Nocturnal Vista" does relate to Blakelock paintings in an interesting manner, however. It is painted in a style very similar to some Blakelock paintings and for many years was sold and exhibited as a Blakelock. In recent years its authenticity as a Blakelock has been seriously questioned on stylistic grounds. It was sent to us by the Sheldon Memorial Art Gallery as a painting which in their opinion had been misrepresented as a Blakelock. The activation autoradiographic results provided considerable evidence to confirm this opinion. First there was the observation, which has already been discussed, that different pigments were used in this painting from what we have encountered in accepted Blakelocks. Moreover,

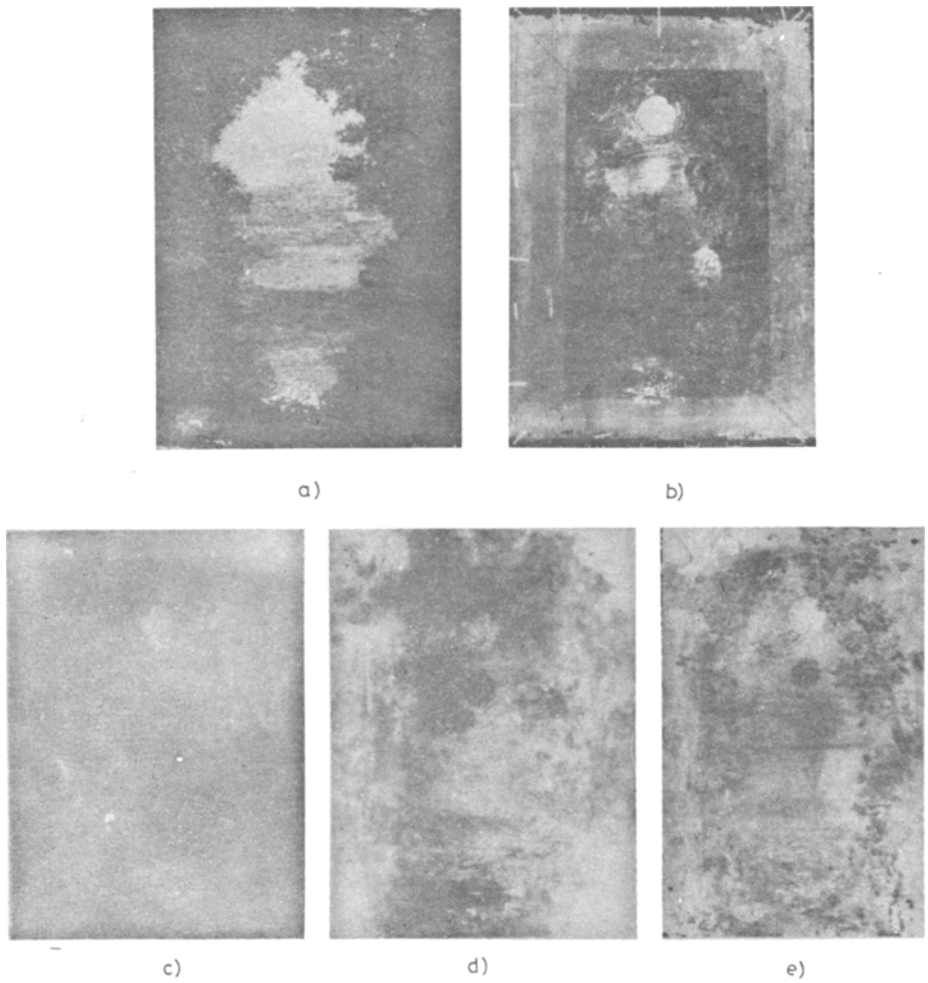


Fig. 7. a - "A Nocturnal Vista": unknown artist, oil on canvas 14 1/2" x 10 1/2". b - X-ray radiograph, c - autoradiograph, exposure 5 through 6 min after activation, d - autoradiograph, exposure 45 through 55 min after activation, e - autoradiograph, exposure 1 through 5 days after activation

none of the characteristics we have observed in autoradiographs of Blakelock paintings showed up in the autoradiographs of "A Nocturnal Vista", two of which are shown in Fig. 7. For example, the highlights in the painting were added with small brush strokes rather than worked in in "squiggles". Finally, in later autoradiographs the initials D. G. appeared toward the bottom of the right side. These initials had been

Table 1

Relative weight percentages of elements determined

Element	Ralph A. Blakelock paintings			
	Moonrise*	Landscape**	The Canoe Builders**	Moonlight*
Probably present in pigments				
Iron	22	63	48	28
Zinc	16	2.1	3.8	14
Barium	11	0.29	21	3.2
Mercury	8.6	11	3.6	2.8
Chromium	3.0	0.19	4.2	0.12
Arsenic	0.80	1.5	2.1	2.8
Antimony	0.21	trace only	0.21	1.1
Manganese	1.2	0.58	0.54	1.5
Copper	0.28	0.50	N.D.	0.66
Cobalt	0.58	trace only	0.43	N.D.
Aluminium	N.D.	N.D.	N.D.	N.D.
Present in significant concentrations				
Potassium	18	13	4.9	24
Sodium	3.8	3.3	7.5	7.6
Chlorine	13	4.4	3.5	13
Strontium	2.0	0.45	0.61	1.4
Present in trace quantities				
Gold	0.022	0.014	0.0051	0.14
Lanthanum	N.D.	0.0066	0.021	0.096
Scandium	N.D.	0.0009	0.0010	0.0027
Antimony	major	0.090	major	major
Cobalt	major	0.030	major	major
Bromine	N.D.	0.10	N.D.	N.D.
Indium	N.D.	0.0011	N.D.	0.0078
Cerium	N.D.	N.D.	0.0022	N.D.
Mercury	major	major	major	major
Arsenic	major	major	major	major

N.D. Not detected.

*Oil on wooden panel.

**Oil on canvas.

activated paintings by gamma-ray spectroscopy

Marian Blakelock paintings		Painting by unknown artist	George Inness paintings		Albert P. Ryder painting
Woman in Red**	Landscape**	A Nocturnal Vista**	Coast Scene**	Georgia Pines**	Curfew Hour*
25	46	11	32	57	26
35	6.4	4.2	1.4	1.5	13
28	6.0	1.7	32	2.4	<3
7.7	trace only	0.31	18	0.12	1.2
0.51	3.4	0.70	3.3	0.74	2.9
0.78	3.2	trace only	0.77	0.37	0.75
trace only	0.63	trace only	trace only	trace only	9.1
0.46	0.81	0.21	0.66	0.57	2.3
0.29	N.D.	0.52	0.38	0.54	0.28
trace only	trace only	trace only	3.4	0.23	0.39
N.D.	N.D.	78	N.D.	N.D.	N.D.
1.3	4.6	0.54	2.9	19	6.7
1.1	11	0.30	4.9	13	6.2
<0.3	18	2.4	≤0.67	5.3	7.4
0.46	0.59	N.D.	2.3	N.D.	N.D.
0.0015	0.0016	0.0006	0.0012	0.0053	0.045
N.D.	N.D.	0.0008	N.D.	0.052	N.D.
N.D.	0.0019	N.D.	N.D.	0.021	0.022
0.035	major	0.0047	0.095	0.042	major
0.025	0.010	0.0076	major	major	major
N.D.	0.18	0.0014	0.039	0.057	N.D.
N.D.	0.0027	N.D.	N.D.	N.D.	0.0048
N.D.	N.D.	0.0035	N.D.	0.0084	N.D.
major	0.091	major	major	major	major
major	major	0.013	major	major	major

painted over and are not visible on the surface nor in the X-ray radiograph of this painting. We do not know who the artist D.G. was but he does not appear to have been Ralph Blakelock.

Another painting has contained similar buried evidence of its true origin which autoradiography alone has revealed. It is the painting "Woman in Red" which is in a style similar to Blakelock's and has in its lower right corner the signature R.A. Blakelock surrounded by an arrowhead, which is the manner in which Blakelock customarily signed his paintings. The autoradiograph results of this painting, shown in Fig. 8, are in a few ways similar to those observed on Ralph Blakelock paintings but differ from them in some significant points. In Table 1 one can see that the relative concentrations of pigment elements are somewhat similar to those in the Blakelock paintings, but that this painting contained relatively little of the sodium and potassium which had been so characteristic of the other paintings. In the autoradiographs of "Woman in Red" there are at most a very few filamentary structures which can be related to the Blakelock squiggles and no evidence of pigments being used in a thin fluid state such as might produce washed, run or blotched areas. One point in common with "Moonrise " is that "Woman in Red" appears to have a manganese containing ground. The early, manganese dominated, radiographs are remarkably uniform with long striations apparent which sometimes run down the entire length of the painting as if the ground had been scraped on or applied with a broad brush. These striations are in addition to the images of fibres of the supporting canvas which also can be made out in these radiographs. At the sides of the painting there are areas in which ground alone appears and these areas show up distinctly in the autoradiographs. All of these are indications than one is seeing as part of the early autoradiograps an image of the ground as one did in "Moonrise".

Despite the few similarities noted one is sufficiently impressed with the differences that exist between the autoradiographic data for this painting and the others bearing R.A. Blakelock signatures to have reservations about accepting this as a genuine Ralph Blakelock painting. These suspicions were confirmed when in the late autoradiographs of "Woman in Red" an image of a residue of a partially scraped off signature became apparent in the lower left corner, opposite the R.A. Blakelock signature. This signature shows up clearly in the second autoradiograph presented in Fig. 8. It is not visible in the X-ray radiograph nor on the surface of the painting. The signature is composed of two relatively long words, the first of which clearly starts with an M and ends with an n. The second portion of the name has been so nearly scraped off to be illegible. The overpainted, partially destroyed, signature certainly could have been that of Marian Blakelock, R.A. Blakelock's daughter. To confirm whether this signature did correspond to that of Marian Blakelock we sought out a signed Marian Blakelock painting for comparison. The Sheldon Memorial Art Gallery generously provided us with such a painting for study. In Fig. 9 there is compared the autoradiographic image of the hidden signature in "Women in Red" and the Marian Blakelock signature on the Sheldon Memorial Gallery painting.

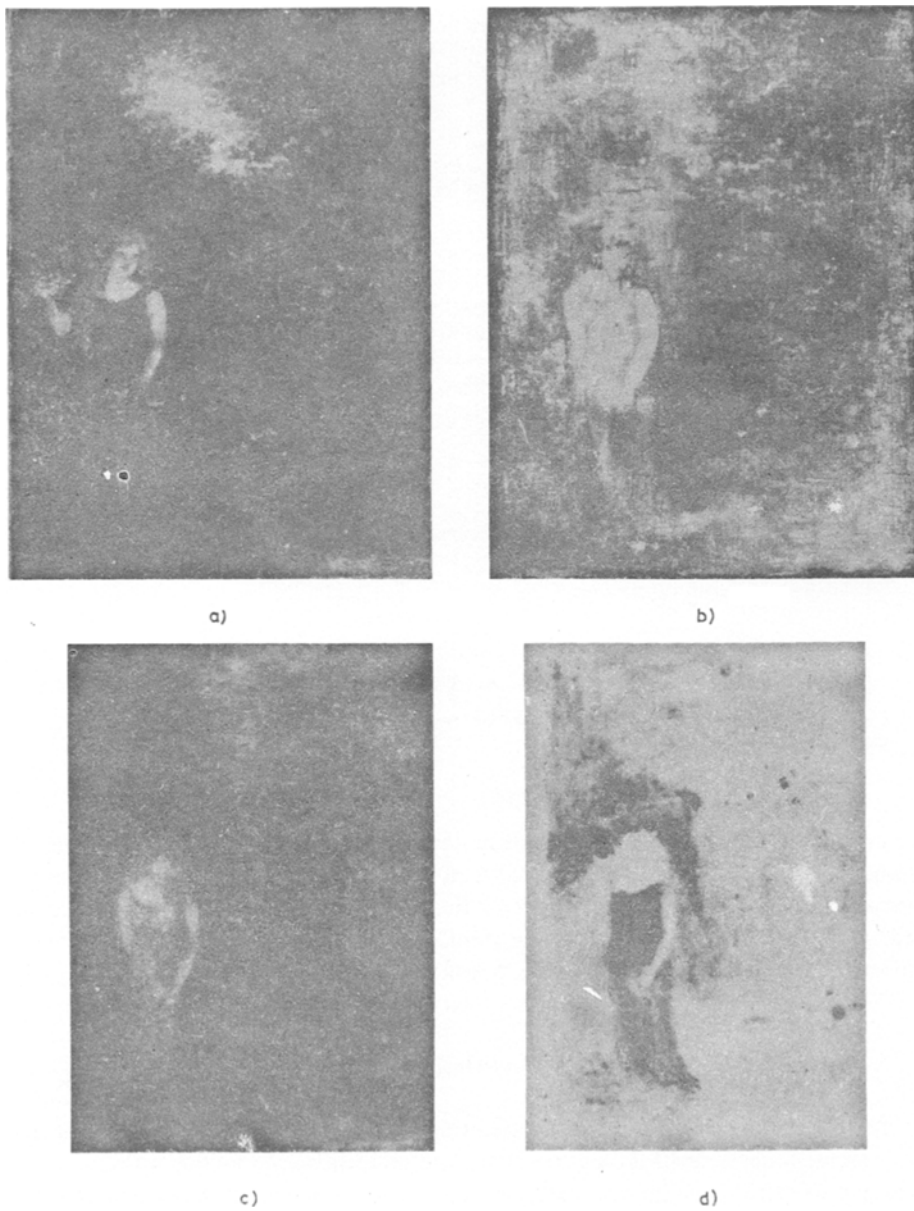
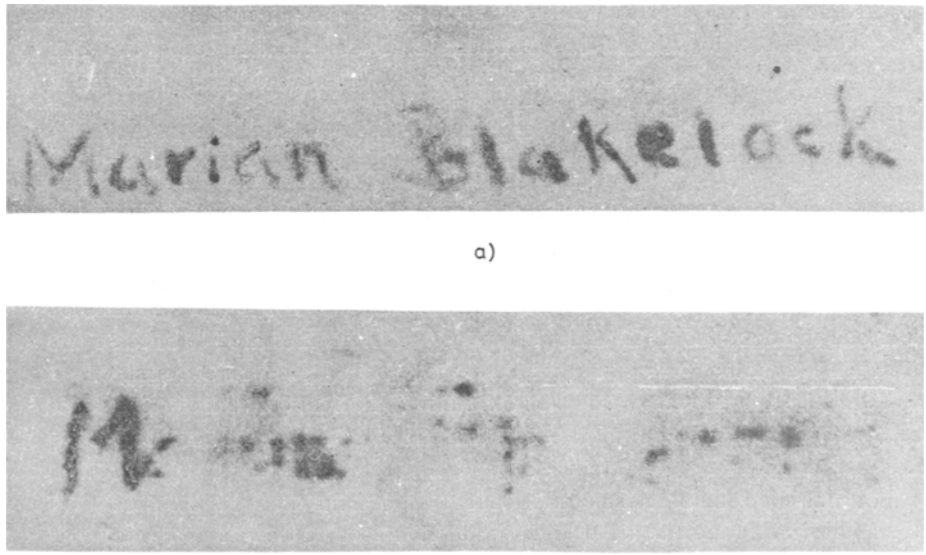


Fig. 8. a - "Woman in Red" by Marian Blakelock, oil on canvas 8 1/2" x 11", b - X-ray radiograph, c - autoradiograph, exposure 13 through 33 min after activation, d - autoradiograph, exposure 9 through 19 days after activation



a)

b)

Fig. 9. Details of autoradiographs of Marian Blakelock paintings. a - Signature on the surface of Sheldon Memorial Art Gallery Landscape, b - hidden, partially destroyed signature on "Woman in Red"

Both signatures appeared to be painted in vermillion. It is obvious in comparing them that the starting Ma and the final n in the first names of both signatures are formed in similar manners. There seems little reason for doubting that "Woman in Red" was a Marian Blakelock painting from which her signature was partially removed and painted over and to which her father's signature was added.

Conclusions

The study of Ralph A. Blakelock paintings by neutron activation autoradiography has provided much new information about the materials used by this artist in his late mature period and how he applied them. It was discovered that his paint vehicle was loaded with sodium and probably also contained large amounts of potassium and chlorine. He often applied arsenic containing pigments to form highlights by adding thick paint in such a way that if formed into characteristic irregular filaments and he often painted on the pigment vermillion in a thin wash that sometimes

ran down over his painting and also formed blotches. Also, upon occasion he appears to ha laid on paint with a palette knife or related tool. His choice of pigments in the paint ings we studied was fairly consistent with paints containing such element as iron, zin barium, arsenic, mercury and manganese used extensively. Individual characteristic of this type very much represent the type of technical evidence that is required to identify the works of an individual artist. The obtaining of information of this type about a painting attributed to Ralph Blakelock should significantly supplement stylistic examination and other forms of technical examination in testing the validity of the attribution.

These measurements have also demonstrated that alterations of paintings with the attempt to conceal their true origins so as to pass them off falsely as works of more prestigious artists can sometimes be observed in autoradiographs when they remain invisible in conventional X-ray radiographs. Neutron activation autoradiography indeed can help in many ways in detecting deliberate art forgeries and accidental misattributions.

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