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Ordway Hilton

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PENCIL ERASURES—DETECTION AND DECIPHERMENT

ORDWAY HILTON

The author is an Examiner of Questioned Documents, New York City, and Police Science Editor of this Journal. He is a member of the American Society of Questioned Document Examiners and a Fellow of the American Academy of Forensic Sciences and has served as president of both organizations. As vice-president and one of the convenors he was active in the First International Meeting in Questioned Documents which was held in London in April 1963. This paper was presented at the 1962 meeting of the American Society of Questioned Document Examiners.

Document examiners are frequently called upon to examine suspected erasures of pencil writing. Working records and informal documents are commonly kept in pencil. From time to time they are changed or altered, some in the course of preparation, some to commit fraud. If the papers form the basis of some phase of litigation or claims against another individual or corporation, the changes must be disclosed and evaluated. It is the document examiner's task to reveal these facts.

HOW IS PENCIL ERASED?

Pencil writing is rather easily erased, but fortunately, complete erasures are not nearly as easy and as frequent as the layman believes. Pencil is usually erased by means of a rubber eraser. Many pencils are manufactured with such an eraser as part of the writing instrument. Occasionally, a problem will be encountered in which the pencil writing was scraped from the paper using a knife or razor blade. Some people prefer to use an abrasive type of eraser, such as the kind used for erasing typewriting. Emery paper and fiberglass erasers are sometimes employed. Chemicals as a rule are not helpful, especially when we are dealing with black pencil, since chemicals do not bleach the carbon of the graphite. However, the use of hydrogen peroxide solution has been reported (1). It has some effect on loosening the bonding between the pencil graphite and the paper, making subsequent erasing easier.

A soft rubber removes most of the pencil rather effectively. It disturbs the paper fibers far less than the more abrasive erasers. The latter may take the carbon off a little more quickly, but even with the best grade papers, there is danger of rubbing a hole or seriously roughing the surface. Skillful pencil erasures can be made so that it is almost impossible to detect the presence of an erasure or subsequently to decipher what was erased. This class of erasure however is not too common.

WHAT IS LEFT?

Depending upon the original writing, the kind of pencil used, and the skill and perseverance of the person erasing, no original writing may remain, or very little may have been removed from the paper. With very light original writing and careful and thorough erasing, all trace of writing can be removed. When a heavy pencil stroke was originally written, very prominent smudges of carbon may be left or after diligent rubbing microscopic study will disclose only small fragments wedged in the paper fibers. The course of the original pencil stroke may be suggested by the greatest concentration of carbon fragments. With erased pencil writing, a definite indentation or track of the original writing often remains. More commonly there are combinations of these conditions which establish a weak fragmentary outline of the original writing. These remnants of the original writing form the basis upon which the document examiner works.

HOW ARE ERASURES DETECTED?

In order to detect a pencil erasure, one must examine the document carefully and critically. Several techniques are available. The first step is a visual examination under good lighting conditions. Diffused daylight is an ideal light, especially when its direction can be controlled. Erasures often can be detected more readily on a dull day. Bright sunlight or high intensity lighting may interfere with the detection of erasures rather than assist. While only crude erasures wear holes in the paper, other erasures tend to create thin spots. Consequently, every document suspected of having been erased should be examined with transmitted light. In the course of visual examination, one should hold the paper almost at eye level sighting across it with the light coming toward the examiner. For this study it is often helpful to step back into a closet or a hallway so that the light strikes the pa-

per from only one direction. A spotlight or incandescent light may be substituted for daylight or used as a supplementary step.

Examinations described should be directed toward discovering any evidence of a pencil erasure. This evidence includes partially erased writing in the area under scrutiny, smudges of carbon or stains from the rubber eraser, indentations of erased strokes, disturbed paper fibers or thin spots in the paper, differences in the reflective quality of the paper surface, or with colored or tinted paper dulling or weakening of color. If any of these conditions is present, it must then be carefully evaluated to be sure that it is true evidence of an erasure.

Examination with hand magnifiers and the binocular microscope of all suspected areas should follow as a second step. Here again illumination under side lighting, either by daylight or with a microscope spotlight, is helpful in disclosing roughened paper surfaces or slight indentations from the original writing.

Dr. Wilson Harrison has developed a technique of detecting erasures by placing a piece of highly polished, well cleaned, silver in tight contact with a paper at the suspected point (2). If a rubber eraser was used, the fact is disclosed by the tarnishing of the silver due to the rubber residue on the paper. He reports that this technique reveals erasures which cannot be established by any other method of examination.

HOW ARE ERASURES DECIPHERED?

In almost every case, the document examiner is ultimately asked to determine what has been erased. Pencil writing cannot be restored in the sense that by some type of treatment the original writing can be brought back again on the surface of the paper. Rather, it is a question of deciphering from the fragments and residues in the paper what was originally written. Methods of attack include visual techniques, photography, and in some rare instances, chemical treatment and physical examinations.

Visual Methods. Visual techniques are the same as those used to determine whether or not there has been an erasure. The emphasis now is placed on determining what was originally written. The order of steps is repeated. One starts with unaided vision and then supplements the study with hand magnifiers or possibly with a low power microscope all coupled with carefully controlled lighting. Success depends upon a detailed study of the fragments of writing or of the writing strokes impressed in the paper. Many erasures can be deciphered by these

means. The most useful lighting is subdued daylight which strikes the document principally from one side or oblique side lighting from a spotlight which allows slight adjustments in direction and intensity. Oblique light is of help when there are indentations of the original erased writing left in the paper.

In making visual examinations, attention must be given to the amount of magnification used. To some extent this is a personal choice, but in general erasures are more easily deciphered under low magnification, if not by actual one to one examinations. Too much magnification, even as low as $2\frac{1}{2}$ to 3 diameters, may restrict the decipherment. Some workers prefer to use a reducing lens to concentrate the writing fragments and thus intensify them by virtually connecting them.

The quality of light for visual examinations is extremely important. Diffused daylight, especially from a north window, has extremely good quality. It has been this writer's experience that dull rather than bright days supply the best quality of light for deciphering erased pencil writing. Artificial light, unless it can be directed from one side of the document at relatively low intensity, is not too satisfactory. Many times overhead fluorescent lighting creates light in which it is very difficult to examine erased pencil writing successfully. With all types of light, better results are obtained if the light is not balanced but more concentrated on one side of the paper. The paper should be examined with the light coming from the right and then from the left, from the top and then from the bottom. Sometimes intermediate directions are helpful to decipher completely and to prevent false determinations.

Among the available types of artificial light sources, the spot illuminator with a variable intensity rheostat is particularly useful since it permits adjustment both in the direction and intensity of light. Writing indentations can often be effectively intensified and deciphered by the skillful adjustment of the direction of the spot, its angle relative to the paper surface, and its intensity.

A helpful technique in examining erasures is to let them "age." Problems may prove to be more readily deciphered after they have been around the laboratory a few days than when first presented. A possible explanation is that a slight accumulation of dust collects in the writing indentations, thus intensifying them.

Photographic Methods. Photographic methods are in fact an extension of the visual techniques. In this way a permanent record is made of what can

be seen, but the most important role of photography is its ability to intensify slightly the weak fragments that are present so that they can be better interpreted. A series of different types of photographs can be prepared, combining different lighting and emulsion characteristics to achieve the most complete decipherment.

No single photographic method is completely superior to the others in the detection of erased pencil writing. Several techniques give consistently good results, but unless complete decipherment is achieved by the initial attempt, it is desirable to try two or three different methods. The methods that are commonly employed include a carefully made photograph in which the contrast is increased slightly, a photograph with a high contrast emulsion sometimes incorporating special development techniques, a photograph with low angle (oblique) side lighting, a long exposure photograph with a low intensity light source, an infrared photograph, and a color photograph. While each method is to be evaluated, we must recognize that a successful photograph incorporates the maximum detail with some increase in contrast. Contrast at the expense of sharp detail or detail at the expense of good contrast usually restricts decipherment. In all photographs of erased pencil writing a snappy print with full detail effectively records all of the partially erased fragments.

There are certain erasure problems in which a good photographic copy of the questioned document will disclose what has been erased. The use of standard emulsions, such as Eastman Panatomic-X, coupled with developers and developing techniques to give above average contrast, are to be recommended. Certain filters, such as a Wratten K-2 or K-3, may improve the photographs. Excessive contrast is not necessarily the ultimate goal.

Improved results can generally be obtained by special photographic methods. One of the most effective in this writer's experience is the use of low intensity lighting directed from one side of the document (3). If daylight is the source, these photographs are more easily made on dull days. If it is necessary to proceed on a brighter day virtually close the blinds so that exposure time at 1 to 1 size and f. 16 stop requires at least 10 to 20 seconds. The slight outline of unerased pencil writing or the indentations from the original writing appear to be more easily recorded by such techniques. Panatomic-X film with a developer which produces moderately sharp contrast is recommended.

With erased pencil problems, the control of

lighting is highly important. Side light photographs, especially with light directed across the paper at a very low angle, is particularly helpful when there are writing indentations in the paper. If there are no indentations, then this type of photography as a rule is not of value. With a badly roughed paper surface this kind of light may emphasize the erasure but confuse decipherment. Oblique lighting in photography, as in visual examinations, creates shadows along the indentations, thus intensifying them. With this technique it is often helpful to prepare several different photographs in which the direction at which the light strikes the paper relative to the line of writing should be changed in at least units of 90°. Thus, the light comes from the top, the bottom, the left, and the right. At times, it is also desirable to change the angle between the light beam and the paper surface. Extremely acute lighting, less than 15°, may intensify even slightly disturbed paper fibers so much that they and the indentations are badly confused, whereas light from a less acute angle may still intensify the indentations without emphasizing the paper fibers.

A useful tool in preparing side light photographs is the unit developed by the Royal Canadian Mounted Police Laboratory (4). It is a box which provides a flat bed and a suction unit to hold the paper absolutely flat. The scheme of moving the exposure slot and enclosed light across the sheet several times provides oblique lighting but a balanced negative. Books and very large sheets of paper may not be accommodated, but standard size papers can.

Contrast emulsions, such as Eastman Contrast Process Panchromatic or Kodalith film may assist slightly in photographing erased writing. These emulsions can be combined with any suitable type of lighting techniques, and some workers prefer them to lower contrast emulsions. Over the course of years with comparable exposures, a contrast emulsion showed better results than Panatomic-X in some problems, but on other occasions, the results were decidedly inferior.

Eastman Kodak recommends a special technique with Kodalith film and weak writing traces. The film is exposed normally and then developed in a tray without agitation. Slightly better than usual details of the weak writing are reported, but this writer has not had particularly gratifying results with the technique. Tuttle has also suggested using Kodalith film to make a contact print with the document as the negative (5). Results of the method have not been observed by this writer.

The almost classical method of photographing erased pencil writing is with infrared sensitive films and plates. To read many writers, this is *the* method. If it were only true, solution of these problems would be far simpler. There are instances in which infrared photography gives excellent results; in others it gives about the same results as other techniques as far as completeness of decipherment. In theory, it is supposed to intensify the weak pencil traces. It does if there are slight fragments of pencil writing left, but these fragments can also be intensified by other photographic methods. There are no hidden bits of carbon buried in the paper since all of the pencil writing is deposited on the paper surface and the erasing process is directed toward removing these surface deposits. It is probably more effective than other techniques when the original writing was done with a soft pencil in which the erasing has left some smears of original writing without significant indentations. When a hard pencil has been used, which created pronounced writing indentations and the erasing has successfully removed the carbon, other methods are more effective. If ink is used to write over the erasure and the ink is not recorded by infrared, an infrared photograph eliminates the interfering overwriting and makes decipherment easier. The writer has also experimented with a combination of infrared and side light photography and at times found it helpful.

Selection of infrared emulsions are important. The ordinary Eastman infrared film works satisfactorily, but does not give the highest quality results. Better results are obtained with infrared plates which have somewhat higher contrast and improved resolving power, such as Eastman Infrared Spectroscopic plates with a type N emulsion. However, as is true with all document photography, the particular emulsion used depends upon personal preferences. With experience, slight modification in handling may mean that two workers using different materials will obtain comparable results. The writer has never attempted to develop infrared plates or films to their highest contrasts.

Discussion to this point has dealt primarily with the erased writing which had been prepared with a black pencil. If colored pencil writing was erased, infrared film is ineffective, although all other photographic and visual methods are applicable. Addition of a photographic filter which contrasts with the color of the erased writing, for example red with green writing, may improve results. With erased red pencil, orthochromatic or color blind (blue sensitive) film is recommended.

Only limited experiments have been made with color photographs of erased pencil writing. If color balance is to be maintained, then photographs must be made and processed without manipulation of exposure times or processing techniques which are commonly employed in black and white photography. Color photographs of erased pencil writing reveal that the emulsions record partially erased writing as well as black and white emulsions, and under some conditions the color reproduction could be preferred. Possibly further work with these emulsions may develop techniques which in a particular case will give results superior to black and white photographs.

Processing of negatives in erased pencil writing problems is somewhat of a personal preference. Almost all examiners have photographic solutions which they like, and for the most part these are to be recommended in preference to some specific solution. Familiarity with a developing formula and how negatives can be manipulated in it to control contrast and density generally leads to better results than using a special developer only occasionally. Still we must not stop looking for an improved processing method. The writer in recent experiments found that in addition to a standard developing solution, which he uses for processing of all negatives, Eastman's recommendation of developing Panatomic-X film for greatest sharpness by using Microdol-X developer, diluted 1 to 3 as indicated on their data sheet, gives a very high quality result. Some workers may prefer to use a special high contrast developer. Microdol-X is not this type and tends to substantiate the theory that detail is as important as contrast in erased writing problems.

In printing from negatives, several grades of glossy paper should be used and slightly different densities of prints should be made with each. In this way, the best print can be chosen, since there seems to be differences from problem to problem as to which grade of paper is going to give the most complete decipherment. It must be recognized that seldom can a pencil erasure be effectively deciphered by making one negative and one print.

Improvement in the final photographs may result from special treatment of the negative—reduction and intensification. The best negative is bleached with Farmer's reducer and then intensified with appropriate solution to increase contrast slightly. Similar results may be achieved by rephotographing the print which represents the best decipherment. Both techniques require experience and skill,

and a more complete decipherment cannot always be guaranteed.

In all erased pencil problems, the back of the sheet should not be neglected. When there is writing on only one side of the page and the original writing caused some embossing, it may be possible to get a better photograph of the original writing from the back side than from the front. The positive, of course, is made by printing with the emulsion side of the negative down so that the decipherment reads normally.

Overwriting in the erased area often seriously restricts decipherment. When possible, a photograph which eliminates or weakens the second writing should be made. For example, with infrared transparent overwriting an infrared photograph achieves this result while with colored overwriting proper selection of a filter weakens it. But usually writing over erased pencil is black pencil. Gayet has proposed preparing a photograph which records primarily the overwriting. A positive transparency is made from this negative. The negative which best deciphers the erasure and this positive transparency are superimposed, and a print is obtained in which the overwriting is virtually eliminated and the deciphered erasure is better revealed (6).

One of the greatest advantages in photographic methods of deciphering erased writing is that photographic prints can be marked in the course of examination and decipherment. A technique that is extremely useful is to mark every fragment, letter, or word which can be deciphered from the print with colored ink or pencil. Thus, if several prints and the original document are being studied simultaneously, it may be that some parts of the writing can be better deciphered from one than from another. When all of this information is recorded on a single print, it can be collated and more extensive decipherments can in this way be achieved.

Chemical Methods. Chemical methods of deciphering erased pencil writing are limited, and for the most part are not highly recommended. An iodine staining solution, such as the one patented some years ago by Ehrlich (7), depends upon a differential absorption of the paper where there has been pressure due to writing and where there has been none. When the back of the sheet is treated, the entire sheet is stained, but the outline of writing, both erased and overwriting, is developed in a deeper color than the surrounding area. However, the solution is not too reliable. It tends to react differently on different papers sometimes destroying all evidence without producing any results. It

also develops latent fingerprints and smudges from those who handled the paper. The difficulty in removing the stain with hypo without leaving some evidence of treatment means that the technique should only be used when all other methods fail and when there seems to be some chance that it might add something to the decipherment.

Indented writing is sometimes developed by fuming the sheet with iodine, especially in a fuming chamber where the action is slow. When similar indentations are present in an erasure problem they may be developed by this technique. Handling the sheet during erasing and subsequently oftentimes causes latent finger smudges and fingerprints to be deposited, and the iodine develops these. Besides, the disturbed paper surface and fibers tend to interfere. While iodine fuming may assist in an occasional case, it cannot be highly recommended.

Alcohol spray may help to decipher an erasure of copy pencil writing according to Longhetti and Kirk (8). When all the dye stuff, which is added to the graphite of these pencils, is not removed by erasing, the alcohol reacts with it to develop its full blue or purple color. Application by means of a nebulizer gives a fine spray which does not seriously harm the paper. In addition these erasures can be deciphered by the same procedures as any other erased pencil problem.

Other Methods. The use of infrared viewing equipment in connection with erased pencil writing may be of slight assistance. However, infrared photography is more effective. Nevertheless, in the course of visual examination the viewer has value. Again careful manipulation of the light source and the paper aids in decipherments of difficult areas, and supplementing other techniques the infrared viewer may lead to more complete results.

Several years ago, Longhetti and Kirk suggested the use of plastic replicas as a means of deciphering writing impressions (8). The technique consists of subjecting a thermo sensitive plastic to heat from an infrared light source, while the plastic and paper are held in tight contact by weights. When the plastic flows slightly, the heat is removed, and the plastic is allowed to reset. After separation from the paper, the plastic sheet with the indentations impressed on it can be manipulated readily, and the indentations are said to be easier to read. This writer has experimented with the technique on several problems, but has not found it to be sufficiently effective with either erased or impressed writing problems to warrant its use in place of visual and photographic techniques. One must develop proficiency in handling the plastic to get the

best results, and there is some slight danger of damaging the evidence due to its occasional sticking to the plastic surface.

Several years ago, Godown suggested the use of Ronchi rulings as an aid in reading impressed writing strokes and erased pencil writing (9). In a measure these rulings are of value in deciphering erased writing. With some material they have a tendency to intensify letters and words which can be dimly seen, especially when these are principally indentations in the paper. The plate is laid in tight contact with the paper, and the light source adjusted for the best reading. However, experiments show that there is a certain cut off point at which the rulings seem to eliminate any weak fragments. Thus, very weak writing is entirely lost, while somewhat stronger fragments are slightly intensified. When using the plates, examinations must be made without any magnification since the magnifier separates and enlarges the rulings and thus destroys the effect of their fine ruling and spacing. Ronchi rulings do have limitations but may assist in an occasional case.

Polarized light has been considered as a possibly superior type of illumination for visual and photographic examinations. After extensive experimentation with it, however, this writer finds that it has no particular merit as an aid in deciphering erased writing.

Filtered ultraviolet radiation does not help very much in deciphering erased pencil writing. With black pencil there is no special fluorescence noted as with some ink erasures. Some red pencils do fluoresce brightly and with such material ultraviolet may help. Occasionally, it is of some assistance in examining an erasure of black pencil. If there is some doubt about the decipherment, ultraviolet examination may confirm an interpretation that fragments are actually graphite deposits and not merely "fantom strokes." Certain papers appear very different under ultraviolet than under ordinary light, and the change in contrast brought about by ultraviolet between the paper and the fragments of erased writing is occasionally of value.

CONCLUSIONS

The techniques described in this paper are the more common and most effective ones. Having tried the various methods described, the writer prefers photography. In the majority of cases photographs produce the most complete and satisfactory results.

After all of the techniques have been applied to a pencil erasure problem, there is generally need for careful evaluation and interpretation. A number of the decipherments is clear, but some problems are more difficult. In the decipherment of certain erasures one must interpret the meaning of fragments to form a judgment or opinion as to what appears to have been erased. It may even be necessary to establish first that a fragment is actually erased pencil and not a crease or smudge. When an erasure is studied at length, it is always advisable, if possible, to put the problem aside for a period of time and to come back to it later. If this is not possible and the decipherment is marginal, it is advisable to have some impartial observer or another expert critically inspect the findings. An occasional shadow in a photograph, a small crease in the paper, or an indentation from some source other than the erased writing can fall in the area in question and be misinterpreted unless the greatest care and critical review are applied. Fortunately, with many problems, these trouble spots are reduced to an absolute minimum by patience and the techniques described.

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