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Examination of Line Crossings by Low KV Scanning Electron Microscopy (SEM) Using Photographic Stereoscopic Pairs

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ABSTRACT: An update on the examination of the sequence of crossed lines, specifically, between ball point pen strokes (waterfast glycol and aqueous based inks) and faint typewritten impressions (produced by old, poor quality fabric ribbon), utilizing a contemporary Hitachi S-2500 SEM and photographic stereoscopic pairs.

KEYWORDS: forensic science, questioned documents, scanning electron microscopy

The sequence of events in the preparation of documents has always been a question posed to Document Examiners from pre Albert S. Osborn time to the present. One of the questions frequently asked is: Which was placed on the document first—the printed/typewritten text or the signature/handwritten text? In the early 1980s the authors conducted this type of examination, involving carbon ribbon typewritten impressions and ball point pen writing, with good success using the methodology outlined in P. A. Waeschle's[3] paper, "Examination of Line Crossings by Scanning Electron Microscopy."

More recently, in 1993, we were requested to conduct similar examinations but the conditions were somewhat different than on previous occasions and were as follows: green background printed cheques bearing light, poor quality typewritten impressions from an old, dry fabric ribbon—probably produced on an old portable typewriter; the handwritten signature(s) (crossing) utilized very light pressure and a light green ball point pen ink. Examination by conventional, non-destructive, light optical methods gave no conclusive results.

Utilizing the aforementioned scanning electron microscopy (SEM) Waeschle methodology, specific results were not obtained. Therefore, considerably more SEM instrument time was required for experimentation and eventually, in one of several examinations, a conclusive determination could be made.

The foregoing was therefore instrumental in conducting this further research utilizing a contemporary S-2500 Hitachi SEM.

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[3]Examination of line crossings by scanning electron microscopy—Journal of Forensic Science. Received for publication 11 Jan. 1979.

Specimen preparation was by a third party, using assorted widths and colors (blue, green, black and red) of ball point pen inks and a portable Smith Corona Sterling typewriter with a fabric ribbon which had not been changed for some years. The pressure both within the writing and typewritten impressions was varied but as a whole was kept on the light side. See Figs. 1 and 2.

Instrumentation

A modern SEM offers far greater capabilities than the early Cambridge Stereoscan SEMs used in 1979 by P. A. Waeschle in his work titled "Examination of Line Crossings by Scanning Electron Microscopy."

Although the instruments are basically similar, evolutionary improvements in electronics, electron gun design and specimen manipulation, have led to much improved imaging at low accelerating voltages (in some cases less than 1 KV) and greater capabilities in examining large sample areas. The Cambridge stereoscan typically used 12 mm (.5 in.) diameter sample mounts that could only be translated 25 mm (1 in.) in the x and y directions.

A typical modern SEM can handle samples up to 150 mm in diameter and stage movements can be up to 100 mm in the x and y directions.

Easily adjustable instrument conditions give the SEM operator the flexibility needed to produce images with the right contrast range and sharpness that are necessary to show features of interest. When examining organic materials, such as paper, that contain fibers and other fine features, it is often necessary to experiment with the accelerating voltage and electron detector conditions in order to minimize charging effects and maximize resolution of fine surface features.

A Hitachi S-2500 SEM was used in this work. This instrument can be operated at accelerating voltages ranging from 0.5 to 30 KV. It is equipped with two secondary electron detectors designated "upper" and "lower." The lower detector is used in most routine SEM work and yields good, normal electron micrographs. The upper detector is often used when very minute details, such as surface deposits or sharp edges, are to be imaged.

In this work it was found that an accelerating voltage of 5 KV together with the use of the upper electron detector produced the most useful and informative electron micrographs.

Sample Preparation and Examination

The sample (specimen) pages were photo-copied before any segments were cut out. Areas on the original specimen pages with a variety of line crossings were examined under a stereo microscope and typical examples were cut from the sample pages using a sharp surgical scalpel. All segments were cut in distinctly different

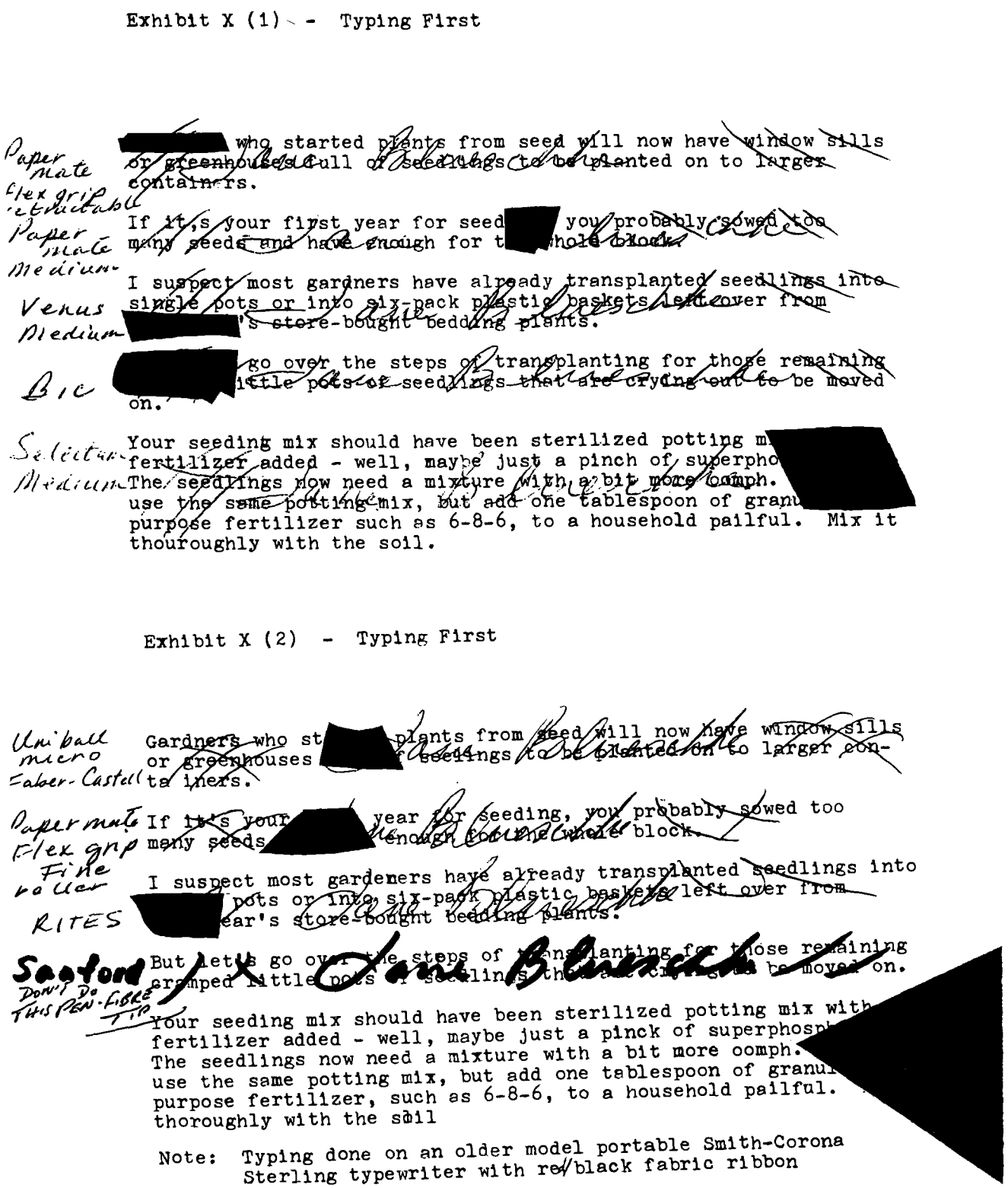

FIG. 1—*Specimen samples: typing first, ball point pen handwriting on top, showing various cutouts for specimen mounting.*

shapes in order to provide positive identification with their original locations. See Figs. 1 and 2.

The sample pages were again photocopied, this time showing the various shapes of the cut out segments with a black background. See Figs. 1 and 2.

The cut out segments were mounted on 40 × 80 mm sample holders using double sided adhesive tabs. See Fig. 3. Care was taken to mount the samples in such a way that all the segments could be reached using the available stage movement in the SEM (in this case 40 × 80 mm).

In actual case examinations only minute samples would be cut out in critical crossing areas and only after written permission has been received from the court or counsel because the cutouts are of a destructive nature.

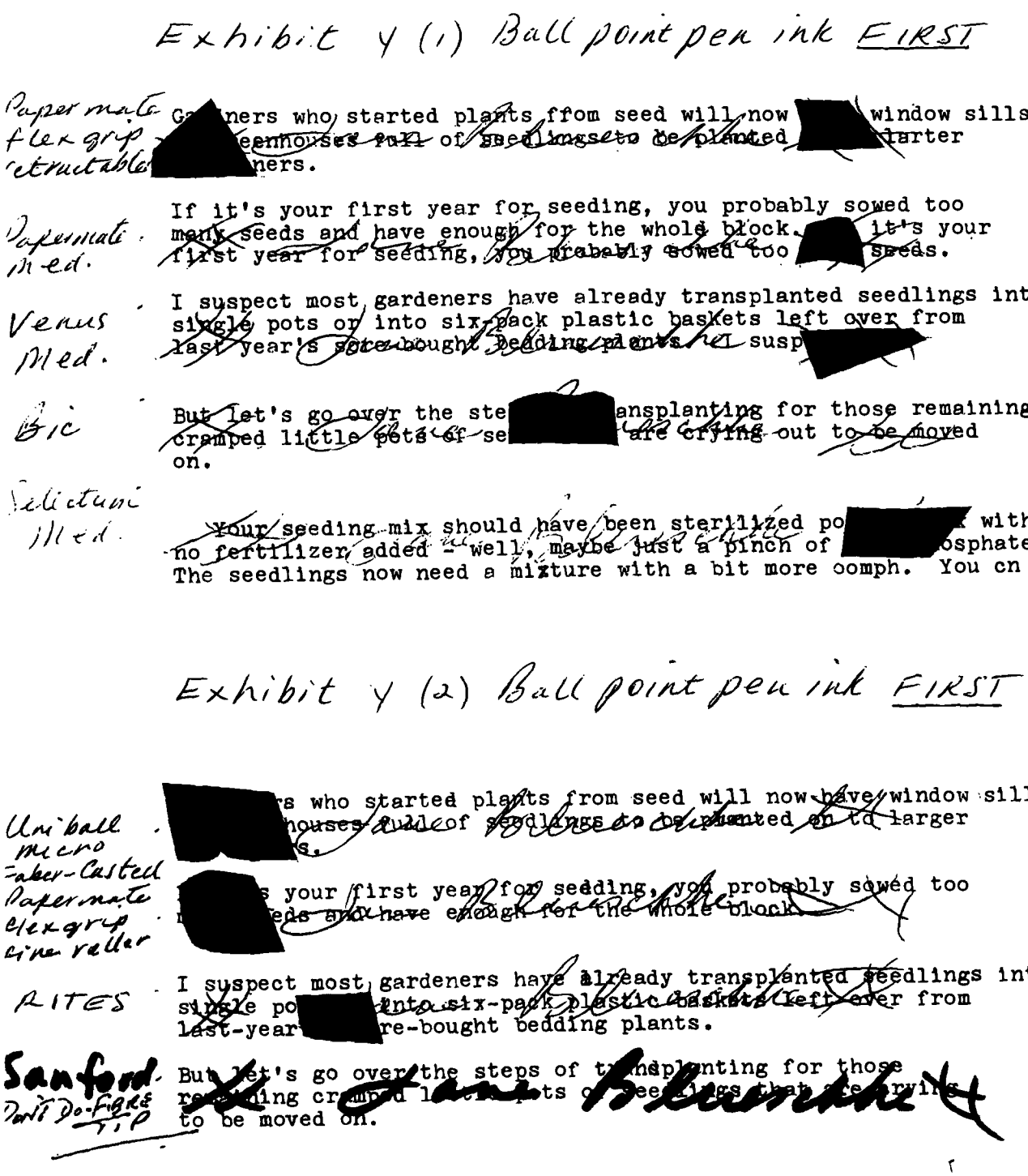

FIG. 2—*Specimen samples: ball point pen ink handwriting first, typing on top, showing various cutouts for specimen mounting.*

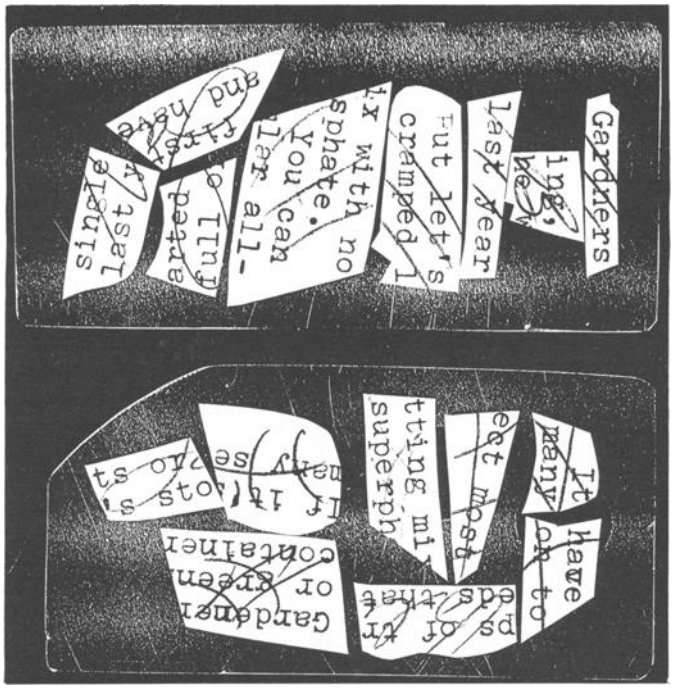

FIG. 3—*Two specimen mounts 40 × 80 mm (large) with cutouts from Figs. 1 and 2 for placement into SEM after gold-coating.*

FIG. 4—*@ 20X magnification. Typing first, letter "t," then blue "BIC" ball point pen ink. Arrow indicates crossing area examined.*

A thin layer of gold was then vacuum sputtered on to the samples. This layer should be only as thick as necessary to eliminate surface charging and need not be so thick as to obliterate the lines and letters on the paper.

Procedure

The samples were examined in the SEM while adjusting various instrument conditions (KV, beam current, working distance, contrast, brightness) in such a way as to provide the most useful images.

Photos were taken at 20X, 50X, 200X and 1000X. See Figs. 4–7. This range of magnifications allowed for continuity in location and identification features from whole typed letters to areas of interest on individual fibers.

The photos at 1000X were produced as a stereo pair. The sample was tilted approximately 7 to 9 degrees from the first to the second photo.

The final examination is conducted on the 1000X stereo pairs (photographs) set in juxtaposition, with the photographs correctly placed as to left and right and using, in this case, a Geoscope stereo viewer. This gives one about 1000 times the depth of field over conventional optics. On correct setting up and initial viewing one looks for obvious high and low points such as fiber crossings, whether on top or below, determined by their continuity.

When examining crossings in stereo of waterfast glycol based ball point pen ink deposits and fabric ribbon pigment (particles) deposits, it is their respective appearance and height which ultimately determines which is on top and which is below. Glycol

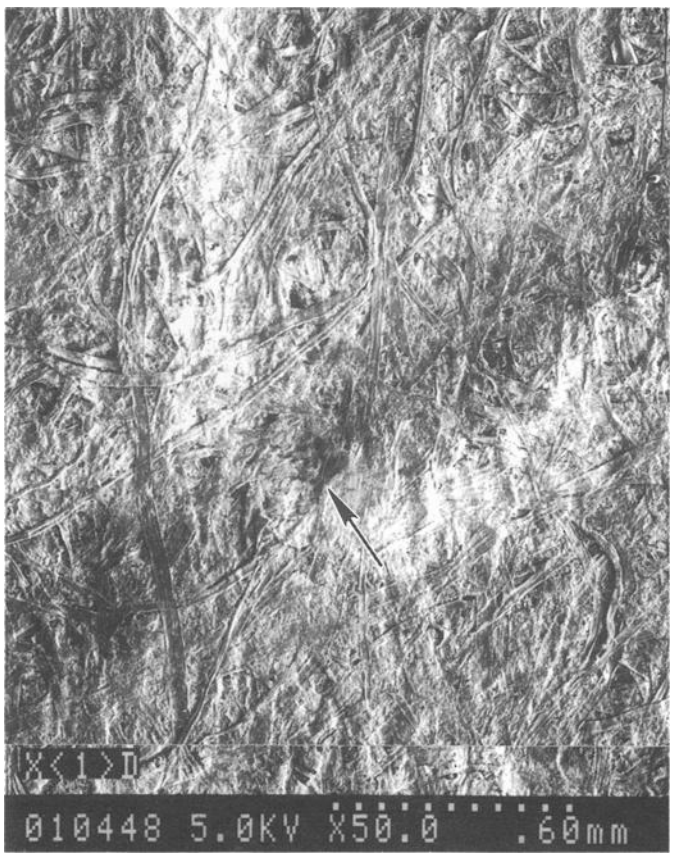

FIG. 5—*@ 50X magnification. Typing first, letter "t," then blue "BIC" ball point pen ink. Arrow indicates crossing area examined and relates back to Fig. 4.*

FIG. 6—*@ 200X magnification. Typing first, letter "t," then blue "BIC" ball point pen ink. Arrow indicates crossing area examined and relates back to Fig. 5.*

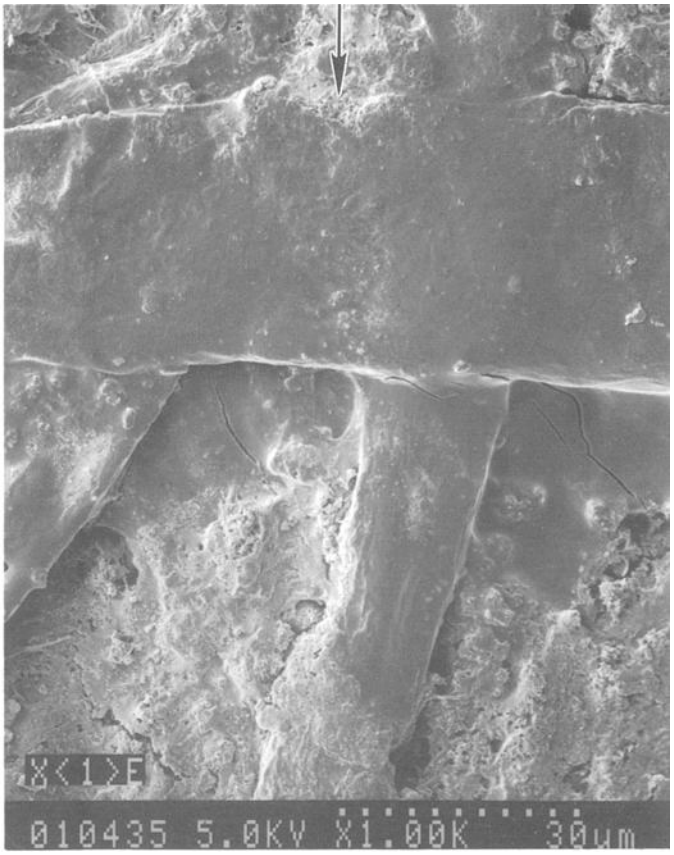

FIG. 8—*@ 1000X magnification. Typing first, letter "u," then green "Selectum Medium" ball point pen ink. Arrow indicates crossing area examined. Note: light pen ink deposit.*

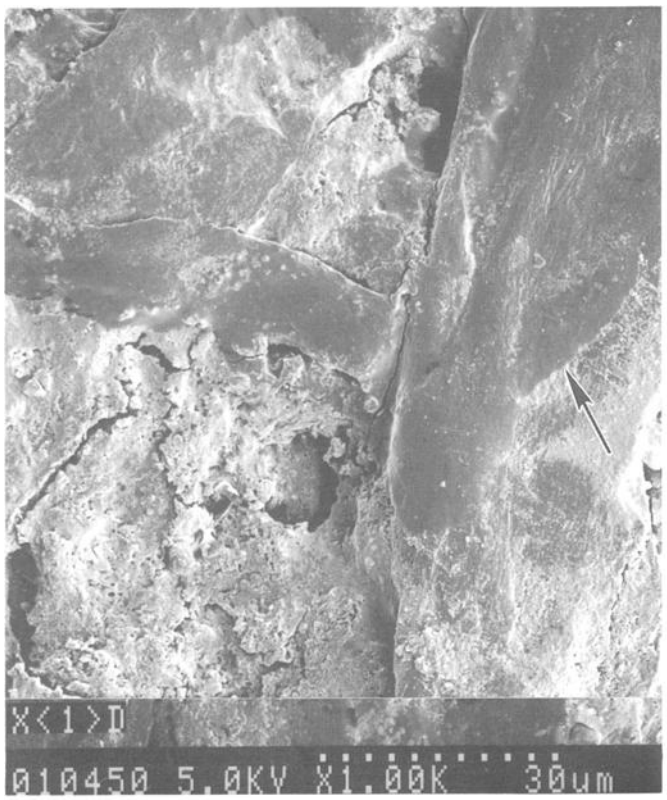

FIG. 7—*@ 1000X magnification. Typing first, letter "t," then blue "BIC" ball point pen ink. Arrow indicates crossing area examined and relates back to Fig. 6.*

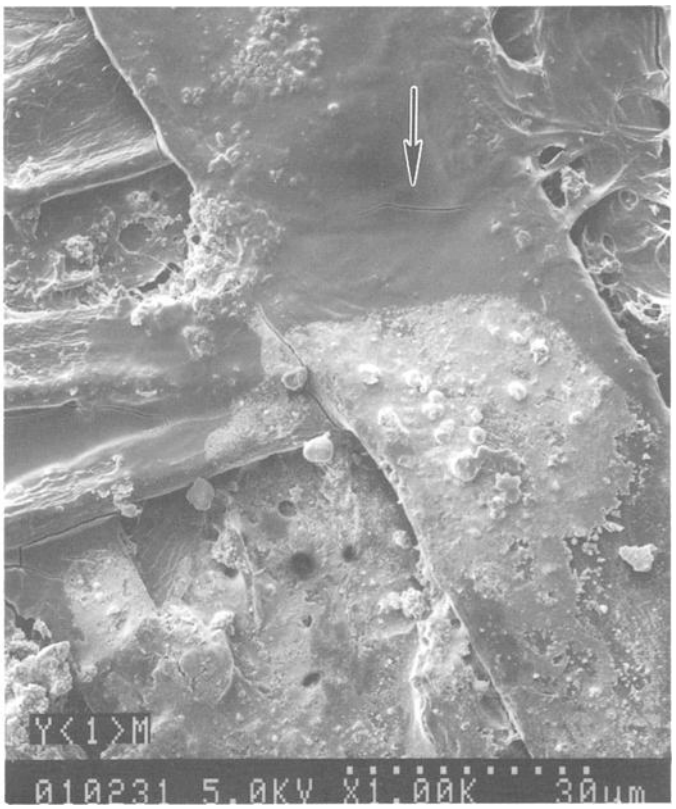

FIG. 9—*@ 1000X magnification. Ball point pen "Selectum Medium" green ink first, letter "r," then typing. Arrow indicates crossing area examined. Note: light pen ink deposit.*

FIG. 10—*@ 1000X magnification. Ball point pen "RITES" reddish/pink ink first, letter "r," then typing. Arrow indicates crossing area examined. Note: heavy ink deposit.*

based ball point pen ink appears as a fluid, smooth, dark layer covering. Waterfast glycol-based ballpoint pen inks do not normally contain any solid particles or precipitates. Fabric ribbon pigment consists of particle deposits which appear essentially as a textured white. Textured areas in a secondary electron image appear brighter or whiter than smooth surfaces due to the nature of electron interaction with sample surfaces, more secondary electrons are emitted from surfaces containing small particles or protruberences. This is somewhat analogous to dust particles on a smooth glass surface becoming visible when struck by a beam of light.

In Fig. 7 the arrow points to sharp ridging of a fluid dark layer covering on top of, or higher than, the white textured ribbon pigment (particles) deposits. Where the glycol-based ball point pen ink is light, ribbon pigment (particles) deposits at times partially protrude. In addition very low areas in the paper fiber structure may contain ribbon pigment (particles) deposits, but are not covered by ball point pen ink even though the stroke crosses over the area as the ball speed and size has not permitted penetration. One should also examine the paper fillers in unmarked areas and compare them to the fabric ribbon pigment (particles) deposits so as to be able to differentiate between the two, thus avoiding the potential possibility of error.

In Fig. 8 characteristics are similar to those described in Fig. 7. The ball point pen ink deposit is heavier and shows some fracture lines. Note: Direction of stroke can be determined by edge and none edge deposits on certain fibers.

In Fig. 9 the ball point pen ink is on a high surface fiber and in depressions in the immediate arrow area. The arrow points in the direction of the white ribbon pigment (particles) deposits which cover or obliterate the ball point pen ink mass, showing a sharp distinct white raised edge. Note small fracture in heavy layer of ball point pen ink in front of arrow.

The long diagonal fiber in Fig. 10 is higher than the surrounding paper surface, which is covered by ball point pen ink; the diagonal fiber and portions of the adjacent fiber at about 30 degrees are covered with white ribbon pigment (particles) deposits. Note white edging on the adjacent fiber.

Conclusions

1. The sequence of events in all cases tested as to crossings between waterfast glycol based ball point pen ink, even when light, and poor quality fabric ribbon pigment (particles) deposits can be conclusively determined utilizing Low KV Scanning Electron Microscopy (SEM) methodology.

2. The sequence of events as to crossings using either water/aqueous based ball point pen inks or fiber tip pen inks and poor quality fabric ribbon pigment (particles) deposits can not necessarily be determined using Low KV SEM methodology, especially when the pen inks are translucent. The aqueous nature of the inks generally permits the dye stuffs to be absorbed into the cellulose fibers, hence not permitting layering as in glycol based ball point pen inks. The absorption of aqueous based ink can readily be determined by examination with a conventional optical microscope.

3. Pigment water soluble inks as in some markers such as "Staedler Lumocolor 311 Non-permanent" deposit sufficient black pigment to permit determination of sequence of crossings with poor fabric ribbon pigment (particles) deposits using Low KV SEM methodology.

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