Analytical methods for detecting fraudulent documents

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ANALYTICAL METHODS FOR Detecting Fraudulent Documents

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Fraud is synonymous with deception. For centuries fake objects, including documents, artwork, coins, archaeological artifacts, clothing, and furniture, have passed as authentic items. The U.S. Department of Treasury is involved in fraud detection primarily of questionable documents but also of currency, coins, credit cards, and—in tax cases—valuable works of art. The Bureau of Engraving and Printing, the U.S. Secret Service (USSS), and the Internal Revenue Service (IRS) are among the agencies within the Department of Treasury that have analytical laboratories capable of detecting fraud. Techniques used to detect fraudulent documents and scenarios of actual case work will be presented in this article.

Static and dynamic approaches

Fraud detection involves a static approach, which searches for inconsistencies in the compositional profile of the object, and a dynamic approach, which examines the aging process.

Because counterfeiting often occurs after a genuine item is made, finding a component in suspect currency that did not exist when genuine currency was produced (i.e., an anachronism) is sufficient evidence to prove fraudulence. The compositional profile or chemical fingerprint of an item consists of its major, minor, and trace organic and inorganic components. The specificity or discriminating power of an analytical technique depends on the amount of information included in the compositional profile. Elemental profiles, for example, are highly individualistic. The elemental profile of the ink and paper of suspect currency can be determined with state-of-the-art techniques such as X-ray fluorescence (XRF), neutron activation analysis (NAA), and inductively coupled plasma (ICP) emission spectrometry. This profile is then compared with the profile of genuine currency to uncover inconsistencies. Figure 1 is an XRF profile of a sample of counterfeit paper showing large amounts of Al and Si compared with Ba and Ti. This elemental profile differs from that of genuine currency.

No matter how sophisticated and discriminating the technique, failure to detect fraud does not assure authenticity. Scientists, therefore, must also determine the degree of aging by studying dynamic aging processes. Paper parameters that change with age include fold endurance, tensile and tear strength, and discoloration. Age-dependent ink parameters include discoloration, solubility, and migration of ink components through

paper. Figure 2 shows how the migration (diffusion) of chloride ions from lines written on the same paper with the same fountain pen ink increases with age. The lines were written 8, 13, and 17 days prior to examination. The migration picture was developed by treating cut-out fragments or currency with $AgNO_3$ (forming AgCl) and then reducing this to elemental silver with formalin (*1*).

Counterfeit currency

The USSS was originally created to deter counterfeiting in 1865, shortly after the Civil War. At that time more than one-third of U.S. currency was counterfeit. It was after the assassination of President McKinley in 1901 that the Secret Service acquired its current role of protecting the President. Today, counterfeiting is still a serious problem. In 1990 more than $80 million in counterfeit currency was seized.

In most cases, counterfeit currency is detected visually by factors such as poor printing quality, lack of red and blue security fibers, obvious printing defects, presence of paper watermarks, and lack of magnetic ink. (Magnetic inks contain Fe_3O_4, which can be recognized by using commercially available detectors.) Counterfeit notes can be associated by their similarities, and conclusions can be drawn as to possible common origins.

Often, however, an investigator needs information about the source of the ink or paper. Also, when a counterfeit operation is identified and plates, paper, and inks are recovered as evidence, the investigator needs to determine if the confiscated items can be associated with previously circulated counterfeits.

For source determination, the standard collection of printing inks at the USSS is used to indicate which standard sources can or cannot be eliminated. Normally, the compositional profile of the paper is compared with published results on the origins of individual components (e.g., fibers, fillers, and sizing materials). When possible, the profile is compared with the paper standards of a known source. To determine if the currency is of common origin, the ink or paper samples are examined and compared with each other and then with standard sources (if information about the source is needed).

The primary analytical techniques used for printing ink analysis include TLC (*2*) using a densitometer, HPLC (*3*), and XRF spectroscopy (*4*). For paper analysis, XRF spectroscopy is used to obtain a trace element profile (*5*). Other techniques, such as polarized light microscopy using staining methods for fiber analysis and wet chemical methods for organic and inorganic compositional determination (*6*), are sometimes used to obtain additional information.

In a typical case, TLC was used to provide information about $500,000 in counterfeit bills seized during a major drug raid. All of the bills had the same printing defects (indicating a common origin) and were of the $100 denomination. Because the drugs originated in Colombia, investigators suspected that the bills were manufactured there. When the USSS file of seized counterfeit notes was searched, no notes with similar defects were found, so the currency was assumed to have been recently placed in circulation.

There appeared to be optical similarities between the ink from the notes in question and that from previously seized $50 counterfeit notes of Colombian origin in the USSS file. When the inks were compared using quantitative TLC, no significant differences were found. Thus the notes could have been manufactured in Colombia.

Paper fiber analysis was also performed; however, no matches were made with the fibers from the questionable note (as is often the case, because counterfeiters do not necessarily use the same paper stock every time).

Intelligence sources in Colombia provided other counterfeit documents

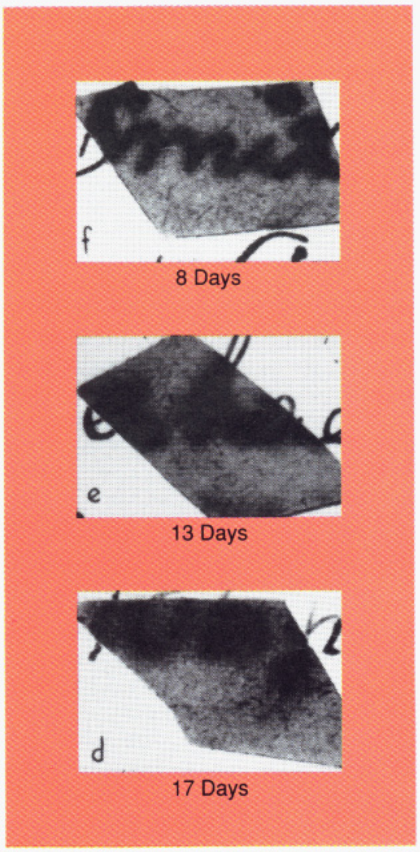

Figure 2. Chloride ion migration (diffusion) pictures of ink 8, 13, and 17 days old (on the same paper) showing that migration increases with age.

Paper fragments were removed for development and then replaced. The development involves treating the fragment with $AgNO_3$ to form AgCl and then reducing the AgCl to elemental silver with formalin. (Adapted with permission from Reference 1.)

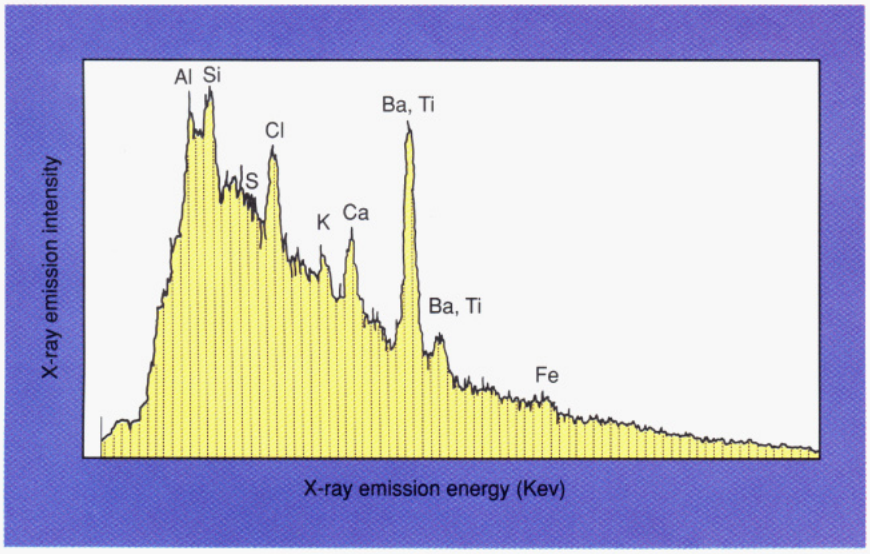

Figure 1. Elemental profile of paper from a counterfeit U.S. note obtained using X-ray fluorescence.

that used similar black and green printing ink, and in one case the inks matched (using quantitative TLC). A brief investigation led to the discovery of the counterfeit operation, and the printing plate for the U.S. $100 note was found and seized. The printing defects matched identically, proving that this operation was the source of the counterfeit notes. At the same time, investigators found that this was also the source of the $50 counterfeit notes on file. The ink associations made using TLC were pivotal in solving this case.

Writing ink analysis

The USSS possesses the largest collection of writing ink standards in the world. The International Ink Library was initiated in 1968 by the IRS laboratory, and when the Bureau of Alcohol, Tobacco, and Firearms (BATF) was created from the IRS in 1972 the library became part of the BATF laboratory. In 1988 the collection was transferred to the USSS, and a portion of it was duplicated for the IRS laboratory.

To match an unknown to a standard ink and provide positive identification, three factors must be considered: the completeness of the ink library, the method of analysis, and the uniqueness of the inks. The USSS ink library consists of more than 6000 different ink formulas from around the world, the oldest of which dates back to the early 1900s. Information is updated annually, and in most cases each ink formula's manufacturer and first date of production are provided.

Formulas can be clearly discriminated by using nondestructive optical (UV–vis, IR) examinations followed by multiple TLC (semi-destructive) examinations. These methods require at least 5–10 mm of writing. Occasionally the TLC separations are quantitatively analyzed using a densitometer. When further discrimination is required, analytical methods such as HPLC (*7*), GC after derivatization (*8*), and FT-IR spectroscopy (*9*) are used.

There are numerous inks that have unique dye features. Others have unique date tags added by manufacturers yearly. One such tagging system involves incorporation of trace levels (5–10 ppm) of rare-earth acetylacetones that can be detected by X-ray optical fluorescence spectroscopy. (*10*). Another involves a combination of fluorescent dyes that can be detected by a TLC method that separates only the tags but not the dyes.

The case of an altered medical record

The Department of Veterans Affairs frequently receives documents from veterans claiming that they wish to obtain federal benefits for medical problems that occurred several years earlier. One typical case involved a 1950 medical record indicating that the patient suffered from an injury sustained during World War II. The only questionable part of the record was the entry supporting his claim. Although all entries were prepared with the same color of ink, analysis of the inks (*11*) showed two different types: one that was used to prepare the questionable entry and another that was used to prepare the remaining entries. Further comparisons with inks from the International Ink Library showed that the suspect ink uniquely matched a standard ink first commercially available in 1972.

To determine if the match meant positive identification of the ink, further information from the manufacturer of the standard ink and further analytical testing were needed. The manufacturer indicated that the standard ink contained certain dyes with unique TLC separations and optical features. All such features were identical for both the questionable and the standard samples. Because of this uniqueness, the chance of discovering another ink that was not in the library but had the same features was extremely remote, if not impossible. As a result of the examination, the veteran was denied benefits.

Nazi war crimes

The Office of Special Investigation (OSI) of the Department of Justice has also enlisted our ink analysis expertise. The OSI is responsible for finding and deporting Nazi war criminals who have entered the U.S. illegally. In almost every case prosecuted by the OSI, documents from the SS file in Berlin or from files in Moscow are used as supporting evidence. The defense often questions the authenticity of these documents and, in most cases, an expert is hired to show that the documents are fake. In an effort to establish authenticity, the prosecution also has the documents analyzed. Experts for both the defense and the prosecution begin by analyzing the ink and paper to determine if an anachronism exists.

The inks are compared with standard inks and sometimes with inks obtained from documents (often borrowed from the National Archives) known to be from the same period and region as those of the questionable documents. Browning's book (*6*) contains a list of components that were *not* used to manufacture paper during World War II, as well as a description of analysis methods. (One of these compounds, an optical paper brightener, was found on fibers from the infamous "Hitler Diaries" that surfaced in 1983. Julius Grant, a British document examiner and paper expert, used a UV lamp to demonstrate that the diaries were fake.)

No backdating fraud of the documents from Berlin and Moscow has been found in any of the OSI cases. But are they authentic? We cannot be certain. However, if the inks matched known inks from the same region that became obsolete shortly after they were used, and if there are signs of aging that were not artificially induced, then an argument could be made more for authenticity than for fraudulence.

The investigation of the death of Dr. Joseph Mengele, the notorious Nazi "Angel of Death," began in São Paulo, Brazil, in the summer of 1985. The skeletal remains of Mengele and the collection of documents allegedly written by him in Brazil between 1968 and 1979 were examined. In the latter case the OSI and the U.S. Marshal Service provided a U.S. team of experts to authenticate the documents. By using reliable handwriting standards, the experts proved that the documents were written by Mengele. The ink analysis showed that more than eight different ink formulas were used throughout the documents, and each of them was available when purportedly used. Some of these inks were discontinued shortly after they were introduced, and all were available in Brazil.

In addition, the paper analysis showed nothing inconsistent with the proposed date and place of their use. Investigators concluded that the documents had been prepared by Mengele in Brazil on the dates indicated.

The case of the missing firearms

This case was the first in which a new concept, relative aging of ink, was used for detecting backdating fraud. This concept is based on the fact that inks of the same formula and on the same paper but written at different times can be discriminated by their extraction efficiency into weak solvents (*12*). In weak solvents fresher inks extract more easily than older inks. (In strong solvents they normally extract to the same extent.) Before relative aging measurements can be made on an ink sample, it must appear on the same paper as inks of the same formula and of a known writing date. Aging measurements are then made on both questionable and known inks, and the results are compared.

In all of the approaches for measuring extraction efficiencies, Beer's law is used to make the measurements independent of the amount of ink sample. They are made by taking aliquots of the extracted ink at different times, spotting a TLC plate, and measuring the spot concentration using a densitometer.

Consider two entries made on the same document with the same ink: one entry (new) was made later than the other (old). Equal amounts of each ink sample (if possible) are extracted into a weak solvent, and the color of the extract, which increases with extraction time, is measured. An extraction curve (Figure 3) shows that the new ink is extracted more quickly than the old ink. Two parameters can be obtained from each curve, removing any dependency on the amount of ink sampled: the R-ratio (a measure of extraction ease and extraction rate) and the extraction difficulty (the time needed to extract 90% of the ink).

In 1978 BATF agents discovered a dealer in Kentucky who appeared to be selling firearms illegally. The agents checked his firearms record book (which every dealer is required by federal law to maintain) and found that every firearm was accounted for except those he indicated as having been stolen. The agents suspected that these entries were prepared after the dealer knew that he was being investigated. The record book was sent to the laboratory, and the ink was analyzed for backdating fraud.

The first 10 pages of the record book contained unquestionable known entries dating from 1975 to 1978. The rest were blank except for page 30, which contained entries allegedly made in 1976 documenting stolen guns. Several different types and colors of inks were used for the known entries. To see if the suspect entries had been made after 1976, researchers first compared them with each other and then with inks from the standard ink library. They found that these entries were all made with one ink that matched a standard ink first available in 1972. Furthermore, the ink was not manufactured by a company that tags its inks. Thus backdating fraud could not be detected by traditional methods.

The suspect ink also appeared among the known entries. Had it appeared only among the latter known 1978 entries, it could have been suggested, although not proven, that backdating fraud had been committed. Because different inks were used on essentially the same paper, it was possible to make relative aging measurements. For this particular formula of ink, a 1:1 mixture of water and methanol was used to differentiate the R-ratios of the known entries made during different years. The R-ratio of the questionable ink matched the R-ratio of inks of the same formula known to have been entered in 1978. When the laboratory report was read to the dealer, he confessed to having sold the firearms illegally.

Other methods used to discriminate similar ink formulas written at different times on the same paper include GC to follow the evaporation of two or more volatile components and FT-IR spectroscopy to monitor a combination of aging parameters (*12, 13*) (see Figure 4). Ink samples of 1-mm diameter were extracted with pyridine and placed on a salt window for analysis. A 1 × 4 mm window was used with a 6× beam condenser.

A case of validity

An owner of a nursing home was suspected of receiving Medicaid kickbacks over a three-year period from the home's management agency. The owner contended that the funds were legitimately received as consultant fees. He provided a two-page agreement between himself and a representative of the management agency. The second page of the agreement contained four signatures: the initial ones made by the owner (party A) and the management company representative (party B), and two addi-

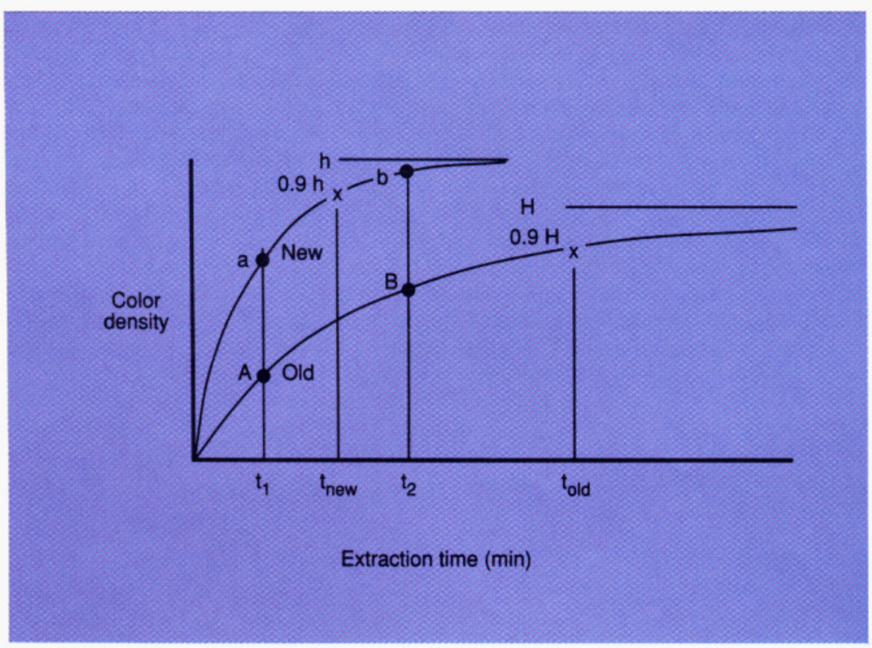

Figure 3. Extraction curves of inks written at different times (old and new).

Two indirect measurements of the rate of extraction are R-ratios (a/b > A/B) and times to extract 90% of ink (90% is arbitrary) ($t_{new} < t_{old}$). Terms: "old" curve—extraction curve of ink from old writing; H—asymptote of extraction curve for old ink; t_{old}—time for extracting 90% of ink from old writing (i.e., 0.9 H); "new" curve—extraction curve of ink from new writing; h—asymptote of extraction curve for new ink; t_{new}—time for extracting 90% of ink from new writing (i.e., 0.9 h); and t_1 and t_2—two arbitrary extraction times at which color density measurements were made. The respective measurements are a < b for the extraction of ink from new writing and A < B for the extraction of ink from old ink writing.

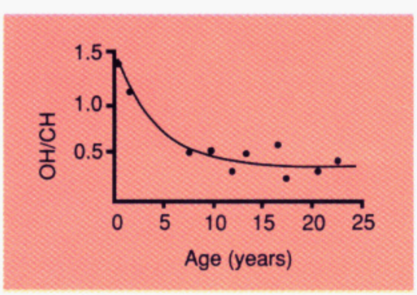

Figure 4. Ink aging curve using changes in IR spectral peaks.

OH/CH intensity ratios versus age. Note that this aging parameter plateaus after 10 years. (Adapted from Reference 9.)

tional ones made by party B—one dated a year later and the second dated two years later. The investigator suspected that all of the signatures were made at the same time after the investigation began.

Ink analysis showed that the three signatures of party B were made with one ink and the signature of party A was made with a different ink. Both inks were available on the alleged date of their use. The fact that the same ink was used over an alleged three-year period by party B implied that the document was backdated.

Of additional interest is the fact that the first page had the indentations from party A's signature and only the first from party B's signatures. These signatures were allegedly made on the same date of the first year. This evidence strongly indicated, if not proved, that at one time the first page was behind the second page when the two signatures were made. Because the other two signatures by party B did not indent, it was believed that perhaps these were indeed made at a later time—possibly over the following two years, as alleged. Thus one argument (similarities of inks) indicated fraud, whereas another argument (indented writing) suggested authenticity.

The case was solved by taking relative aging measurements of the three signatures made by party B. A dilute pyridine solution (1:7 pyridine:water) was used to discern the three inks: the extractabilities (R-ratio) increased as the measurements went from the earliest to the latest entry (two years later). The findings were consistent with the theory that the signatures had been made at different times—perhaps even over a three-year period, as purported. The investigation was closed, and no fraud charges were made.

The tardy theses

A professor from a state university was under investigation for allegedly being involved in unethical academic practices; it was believed that the professor had backdated by one year a signature on a master's thesis because of a personal grudge against the student. It was suspected that the signature was made around the time the investigation began. The department solicited the assistance of the state crime lab, which recommended that the ink be analyzed. The ink analysis was performed three months after the investigation began. As expected, because of the short time frame (one year) between the alleged date of preparation and the time the signature was first seen by the investigator, traditional methods involving formula changes and tags did not detect fraud. Relative aging measurements could not be made because there were no other inks available for comparison.

An experimental procedure that required keeping the evidence for about three months was used to determine the age of the signature. Using traditional analysis, investigators identified the ink and took a sample from the ink library. They then placed the ink on the document close to where the questionable entry appeared and took a relative aging measurement of both the questionable ink and the known "planted" ink. The document was stored under controlled ambient conditions, and investigators took relative aging measurements weekly for about three months. At the end of this time, they found that the "planted" ink had aged to the same extent that the suspect ink had aged when it was first examined. The questionable ink also continued to age and thus was not "aged out." The professor resigned before any charges were made.

The salamander letter

In 1985 several documents of considerable interest to the Church of Jesus Christ of Latter Day Saints (Mormon Church) were circulating among church historians and collectors of antique documents in Salt Lake City, Utah. Some documents allegedly cast doubt on the foundation of the Mormon Church. One, known as the "salamander" letter and purportedly dated October 23, 1830, contended that a white salamander led Joseph Smith, the founder of the Mormon Church, to the golden plates that make up the Book of Mormon. The source of these documents was Mark Hofmann, a collector and dealer of antique documents.

Bothered by the content of the letter, Church officials asked experts to examine it and other documents to ascertain their authenticity. At the same time, Hofmann was suspected by some of his clients, also collectors, of fabricating documents. Hofmann reacted by using bombs to murder them, and in one attempt he ended up hurting himself. As a result of his life-threatening actions, the investigation was hastened.

A detailed and eloquent account of the investigation is presented by Stilltoe and Roberts (*14*). By using the extensive collection of documents archived by the Mormon Church as standards, expert examiners G. Throckmorton and W. Flynn made an exhaustive comparative study of the questionable documents and found evidence suggesting fraud: a series of inconsistencies and telltale signs of artificial aging. These included microscopic ink cracking ("alligatoring"), very high solubility in ammonium hydroxide, and evidence of chemical treatment (such as running of ink) revealed by UV illumination.

However, not until the inks were further analyzed could the investigators be certain that the documents had not been prepared on their purported dates. The inks were mostly iron gallotannate inks and were available when allegedly used. Furthermore, relative aging techniques (extractability or ion migration) could not be used because there were no known inks on the same documents for comparison. The inks on the suspect documents, however, were more easily extracted into an ammonium hydroxide solution than were known old inks on separate documents.

The inks were analyzed with a technique developed by McNeil (*15*) that uses scanning Auger electron microscopy to look at the migration of iron through a paper fibril. McNeil reported that this migration continues for more than 700 years and appears to be independent of ambient conditions (temperature, humidity, and light). The migration thus appears to be an absolute measure of aging. McNeil's technique has an accuracy of at least ± 22 years. Figure 5 shows the analytical curves for the ink aging process on paper, parchment (made from goat or sheep skin), and vellum (made from calf skin).

The salamander letter was shown to have been prepared around 1950 with an error of ± 40 years. Despite the poor accuracy, this clearly indicates fraud. This poor accuracy was explained after Hofmann confessed how he manufactured the documents. He artificially aged them by using ammonium hydroxide or oxidizing agents such as hydrogen peroxides or ozone. These apparently damaged the inks sufficiently to affect the accuracy of the analysis.

Conclusion

One underlying theme of each analytical method presented is the importance of standard reference collections. These collections should contain samples that are stable with time, are sufficiently numerous, and can be reliably discriminated using a series of analytical examinations. A unique match with the collection must be carefully analyzed before it is considered to be a positive identification. Information on the uniqueness of the standards from the manufacturer is a critical factor. Occasionally, repeated measurements are statistically analyzed to test the specificity of the procedure and the validity of the match.

Although inks (writing and printing) and paper are emphasized in

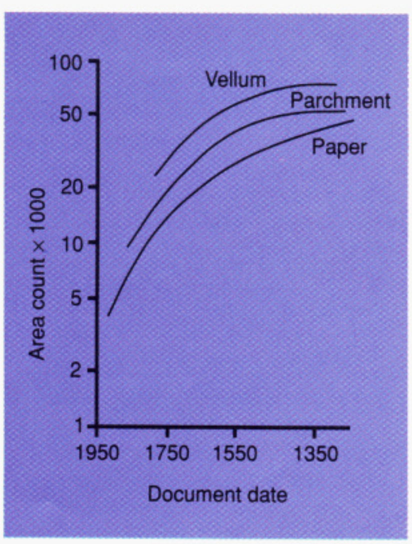

Figure 5. Aging curves of iron-based ink on paper, parchment, and vellum.

Area count measures the amount of iron that has migrated outward from the ink boundary and along a fibril. Each sample was tested in five areas, and the measurements were made in triplicate for each test site. Number of samples for paper, parchment, and vellum were 22, 8, and 7, respectively. (Adapted from Reference 15.)

this article, other items found on documents can be analyzed: stamp pad ink, typewriter ribbon ink, photocopy toners, pencil material, correcting material, erasure residue, and adhesives.

I must comment on the paramount court ruling governing the admissibility of scientific evidence in U.S. courts of law: the Frye Rule (*16*). For more than 65 years it has established the condition for admissibility of scientific methods used to obtain evidence: a scientific principle "must be sufficiently established to have gained general acceptance in the particular field in which it belongs." Therefore, new techniques are always submitted for reliability testing, critical peer review, and whatever else is necessary to gain acceptance among peer groups and qualify for court proceedings.

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Antonio A. Cantu received a B.S. degree in chemistry (1963) and a Ph.D. in chemical physics from the University of Texas, Austin. He began his career in law enforcement in 1972 at the Law Enforcement Assistance Administration. For 10 years he was with the Bureau of Alcohol, Tobacco, and Firearms, where he developed many of the techniques used for document dating. He also worked for 2 1/2 years for the FBI as a research chemist. He has been with the U.S. Secret Service for more than five years and is involved in explosive detection, hazardous materials countermeasures, latent fingerprint development, and document dating.