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H. R. MacQueen,[1] *B.S., M.S., G. Judd,*[2] *B.S., Ph.D., and S. Ferriss,*[3] *B.A., J.D.*

The Application of Scanning Electron Microscopy to the Forensic Evaluation of Vehicular Paint Samples

At present, characterization of topography of paint fragment samples in criminal cases is being undertaken by use of light microscopy. Wet chemical analysis and a wide range of spectral techniques are being used for elemental identification. Electron optical instruments have been developed that are capable of both topographical and elemental analyses. For example, the scanning electron microscope (SEM) can provide topographical information with greater depth of focus, higher magnification, and higher resolution than optical microscopy. Additionally, the electron beam can be used to excite characteristic X-radiation from the sample, thereby providing a wavelength spectrum for elemental identification and chemical species distribution in the sample.

The imaging capabilities of the SEM allow both topographical and compositional displays that can be readily interpreted. Thus, in the case of a scanning electron photomicrograph, ". . . the SEM image presents information in a form that can be experienced as well as analyzed. . . . In addition to transferring ideas represented by words and numbers, the SEM can be used to extend our senses and to allow intuitive, stylistic, synthetic interpretation of the image" [*1*]. Demonstrative evidence of this type would be valuable as both pre-trial and trial evidence, in civil or criminal actions, provided that the techniques associated with sample preparation and analysis are well understood and documented.

The application of electron optical instrumentation, particularly the electron microprobe and the SEM to forensic science is relatively new and various possible uses of scanning electron microscopy are in the early stages of application. The papers [*2–7*] presented at the Workshop on the Forensic Application of the SEM at the 1971 IITRI Annual Scanning Electron Microscope Symposium discussed many types of possible evidential materials that could be examined. The theory of secondary electron emission, detection, and imaging and also the electron optics considerations involved in scanning electron

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[1] Formerly, Rensselaer Polytechnic Institute; currently, research engineer, IBM Research Laboratory, San Jose, Calif.

[2] Associate professor, Materials Division and director of Electron Microanalysis Laboratory, Rensselaer Polytechnic Institute, Troy, N.Y.

[3] Captain, New York State Police Bureau of Criminal Investigation and director, New York State Police Scientific Laboratory, State Campus, Albany, N.Y.

microscopy are discussed in detail in several recent publications [*9–11*] and therefore, will not be presented in this paper.

At this time no detailed investigation of a particular evidence material has been made. Vehicular paint samples were selected for this investigation both for their direct importance as evidence materials and because they were highly suitable as SEM samples. A detailed investigation was made to determine which surface features might have individuality and therefore be useable for identification. The data obtained from, and the utilization of, scanning electron microscopy and associated energy dispersion analysis techniques are most effectively used as an extension of the application of optical microscopy and solvency techniques outlined by Tippet et al [*8*]. A second program studying firing pin impressions was also started and will be reported on separately.

Experimental Procedure

Seventy paint samples from over fifty different vehicles were received from the New York State Police Scientific Laboratory, eighteen of these being nine duplicate sets. These were numbered and identified as to year, make, and model of vehicle. They included samples from different vehicles of the same year, make, and color (black).

Each sample was divided into three pieces and mounted on a 0.5-in. diameter aluminum stud using conductive silver paint. The three pieces provided an exterior (side A), interface (side B), and cross section (edge) surface. A layer of 200 to 300 Å of 60 percent gold—40 percent palladium was vacuum deposited on the samples to provide a conductive coating. These were then observed with a scanning electron microscope.[4]

Edge samples were, whenever possible, selected so that the edge surface was the result of the original sample collection, and could be mounted with this surface parallel to the plane of the mounting stud. Most of the samples were chips and could be mounted quite easily. Those samples which had been scraped, rather than chipped, from the vehicle were thinner and difficult to mount, particularly on edge.

The sample topography in each of the three possible views was closely examined with the SEM. The entire exterior, interface, and cross section of the paint sample was viewed by moving the sample within the field of view by use of the micrometer translation control on the specimen stage. After an entire view had been examined representative photomicrographs of that view were taken. Thus, while the photomicrograph only displays a small fraction of the total sample surface area it is representative of the specific sample topography.

A series of at least five photomicrographs were taken of each sample. These were: 500× and 2000× of sides A and B, and a magnification (either 500 or 1000) such that a complete cross section of the edge was contained in the photomicrograph. Figure 1 is an example of this series of photomicrographs. All photomicrographs were made using the secondary electron mode.

The magnifications given for all photomicrographs were taken directly from instrument settings. The photomicrographs in Fig. 1 have been reduced by approximately one-half.

Results and Discussion

Current Results

In total, over 400 separate photomicrographs were taken. These were essentially equally divided between exterior, interface (primer side), and cross section observations. All three

[4] Model 700S, Materials Analysis Corp., 1060 East Meadow Circle, Palo Alto, Calif. 94303.

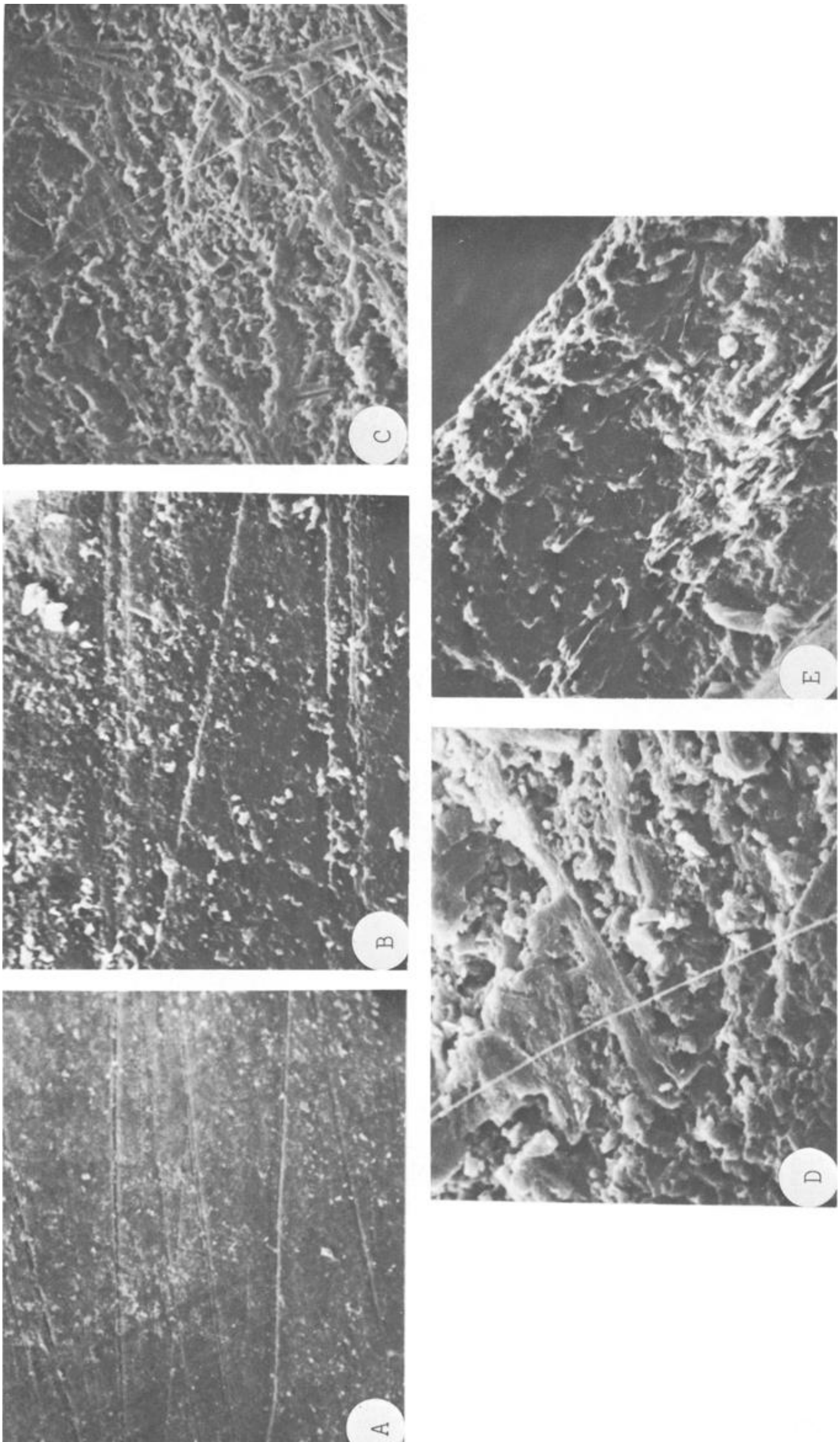

FIG. 1—*Composite of the different SEM photomicrographs taken of a 1959 Chevrolet.* A—*Exterior surface* (300×). B—*Exterior surface* (600×). C—*Interface (primer) surface* (300×). D—*Interface surface* (600×). E—*Cross section (edge)* (300×).

views were used since each view might contain topographical features useful for identification or comparison purposes. The topographies observed were divided into two general categories. Category I includes those topographies which appeared to be unusual with regard to the surface features observed and therefore of particular value for comparison with other samples from the same source. Approximately one out of five samples observed had some distinctly unusual feature. Category II includes those surface topographies which while representative and characteristic of their source were less unusual in appearance and therefore of use only for placement of the sample in a class grouping for further evaluation.

The classification of photomicrographs as "unusual" or as "less unusual" was performed only after the entire surfaces of many specimens had been carefully observed. Based upon demonstrated topographical features such as texture, fracture mode, and contaminant level, criteria of evaluation were chosen. For example, the external sample view shown in Fig. 2, with its rough grooves and impregnated particles was an unusual topography for a relatively new paint sample, while Fig. 3 with its smooth flat topography was typical of new paint samples. Thus the data presented in the photomicrograph in Fig. 2 could be of potential significance in identification or comparison procedures while that contained in

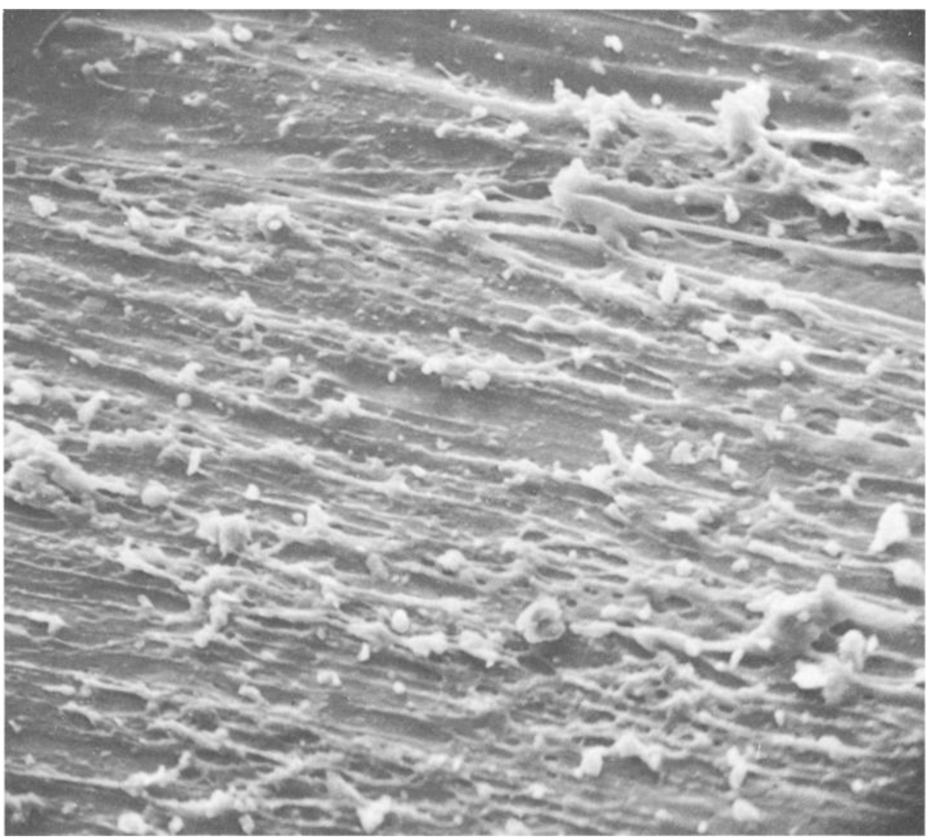

FIG. 2—*SEM photomicrograph of an exterior paint surface having an unusual topography; taken from a 1970 Chevrolet (400×).*

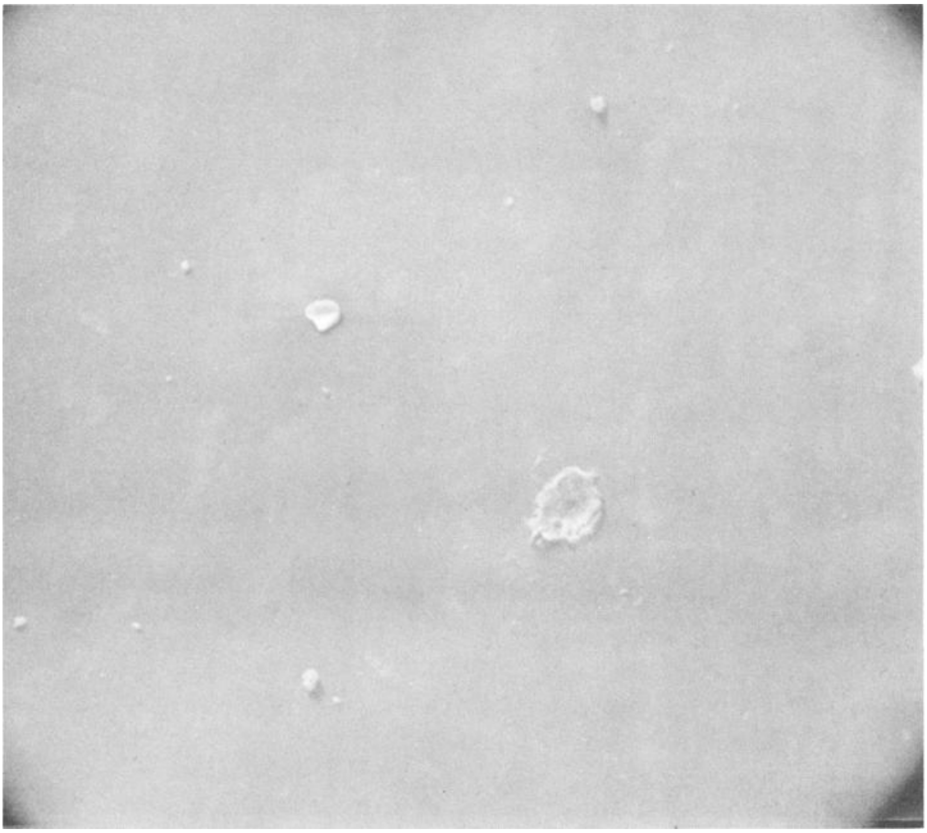

FIG. 3—*SEM photomicrograph of an exterior paint surface of a 1971 Ford Mustang (160×).*

Fig. 3 could be useful merely in terms of assessing the class of sources from which the sample could have originated. Similarly, the cross section observed in Fig. 4 was such that the number of layers together with the individual fracture characteristics of each layer placed this sample in the first category. In contrast, Fig. 5 had too few defining characteristics to render it of particular value for comparisons based upon the data presented in that view. Similar categories were also obtained for interface samples. However, in many instances, it was noted that the "interior" surface topography was more a result of sampling technique rather than being an independent surface characteristic. Thus while topographic features, such as those present in Figs. 2 and 4, when observed over a large area of the sample may be of substantial value; those of the type obtained for Figs. 3 and 5 provide correlative information.

The nine duplicate sets were employed as reference checks for a comparison method. In all these cases the photomicrographs obtained were very similar to each other.

To date this study has relied entirely on surface topography as a sole source of data. This is not to say that the SEM should be used to preempt established color comparison or dissolution techniques. Indeed, in actual evidence examinations it would be essential that the established identification and comparison procedures be performed initially.

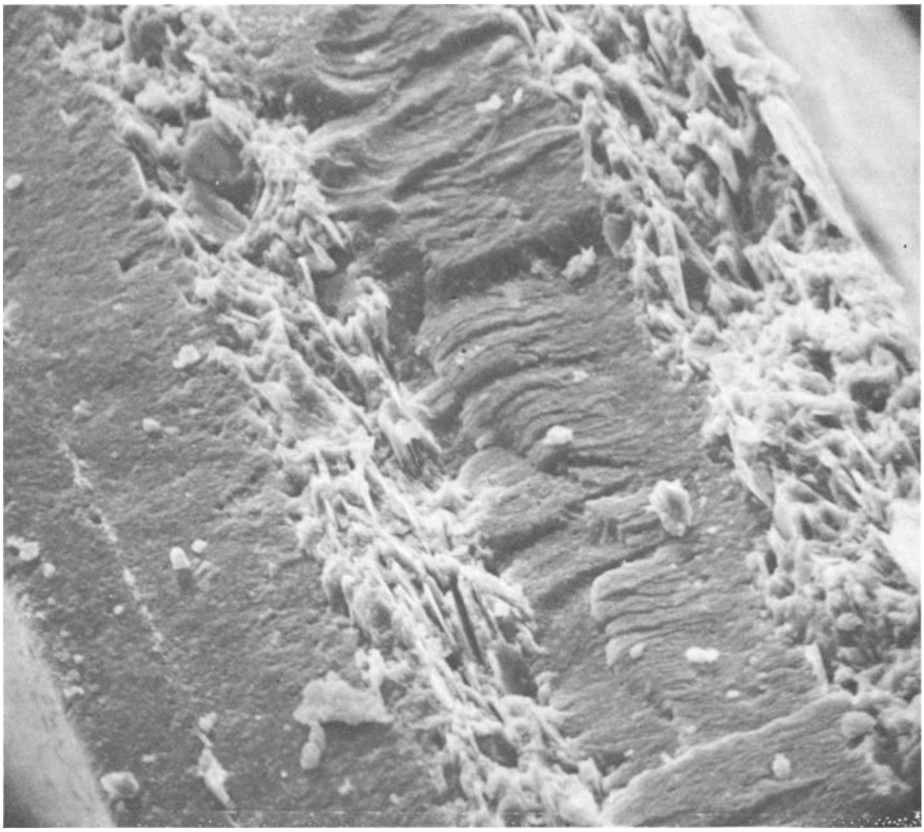

FIG. 4—*SEM photomicrograph of a cross section (edge) of a 1960 Rambler paint sample containing four distinct layers (400×).*

Then if further information or support data appears warranted, the topographical analysis by the SEM would be performed. The techniques employed in paint samples analysis, that is, color comparison, chemical dissolution, and now scanning electron microscopy, are not mutually exclusive tests but rather analyses that respond to different sample characteristics and thus present the forensic scientist with independent rather than redundant or conflicting data. For example, the information obtained by the SEM is not sensitive to the color of the sample. That means that if after visual and optical microscopic examinations, differentiation between samples on the basis of color is not obtained, then the SEM could be employed to determine the microstructural level to which the similarity between the samples persists. The SEM examination would therefore extend the potential of a paint analysis beyond the assignment to a color classification, and present the possibilities of assignment to an additional classification, for example, a new paint surface whose cross sectional fracture characteristic is of a specific type.

Composition analysis such as could be obtained from an energy dispersive analyzer attachment for an SEM has not yet been employed in this study. In addition to the potential of classification by topographical characteristics, the ability to categorize surface contaminants by composition and morphology could greatly increase the number of

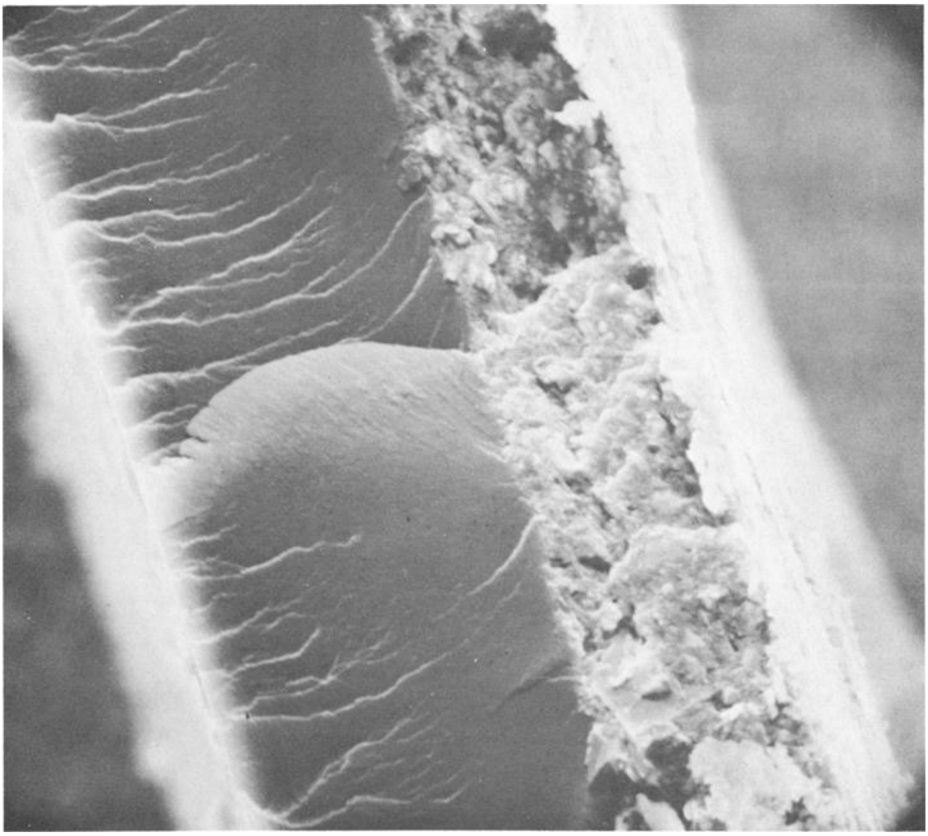

FIG. 5—*SEM photomicrograph of a cross section (edge) of a 1970 Ford paint sample. Note two distinct layers, a thick exterior and a thinner primer layer (800×).*

independent classifications possible and thereby enhance comparison capabilities. An example of surface contamination is shown in Fig. 6.

Future Work

Compositional analysis of contaminant particles and of the paint layers will be performed using an energy dispersive analyzer accessory to the SEM. Emphasis will be on samples from the same make, model, year, and color in order to provide an insight into the critical question of differentiation between samples from such very similar sources.

Summary and Conclusions

The use of scanning electron microscopy (SEM) as a technique for associating a given automobile paint sample to a given source has been investigated. This was based upon the observation that samples of paints have topographical characteristics that are sufficiently unusual within the population of samples so as to be of definite value in a comparison. Approximately one out of five of the samples observed had some different unusual aspect about their topographies. Use of all three views (exterior, cross section, and interface) in

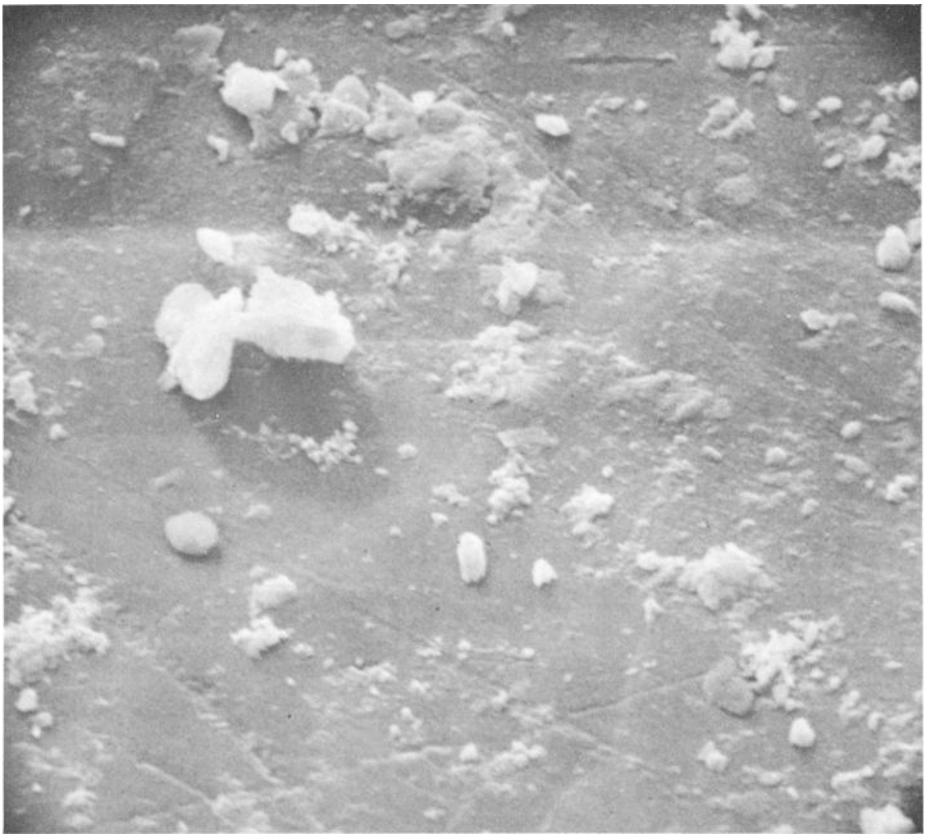

FIG. 6—*SEM photomicrograph of an exterior paint surface of a 1966 Ford Mustang with many contaminant particles present (1600 ×).*

terms of fracture characteristics, contaminant morphologies and distribution, relative wear and scratches, and particulate distribution, were found to be useful in sample characterization. These features are readily apparent in the SEM photomicrographs.

SEM is most effectively used in conjunction with, and in addition to, established paint sample comparison techniques such as color and dissolution tests.

Acknowledgments

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Materials Division
School of Engineering
Rensselaer Polytechnic Institute
Troy, N.Y. 12181