2. Aerial photographs can be used to determine what the parent material is. Various features visible in the photographic image can be used to interpret the nature of the material lying on the earth's surface.
3. Aerial photographs can be used to locate natural deposits or road-building materials, many of which are hidden from observation on the ground.
4. Aerial photographs can be used to locate sand dunes which move and so provide difficulties in highway construction and maintenance.
5. Color tone in aerial photography can be used to distinguish between moist and dry soils. This provides an indirect way of distinguishing course-grained soils from fine-grained soils.
6. Aerial photographic interpretation does not eliminate ground work, however; it supplements the ground work.

*Kodak Panchromatic Negative Films for Aerial Photography**

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ABSTRACT: *A review of the progress leading to the manufacture of the presently available aerial negative films is given.*

The results of investigations into the factors influencing aerial photography and a technological improvement in photographic emulsions have led to the introduction of improved aerial panchromatic negative films. The characteristics of these new films are indicated.

WORK on sensitized materials and equipment for aerial photography was started at the Eastman Kodak Company before World War I. During that war, improvements in the sensitivity of photographic materials were made so that, at the time of the Armistice, orthochromatic and panchromatic films, 9½ inches by 75 feet, were being manufactured (1). The most sensitive of these films, Eastman Panchromatic Aero Film, Hypersensitized, could be exposed at about 1/100 second, *f*/5.6, through a Kodak Wratten Filter No. 25. The K-1 camera was also designed at that time to use this film and is the granddaddy of the large-format automatic aerial cameras of today (2).

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Between the two World Wars, much progress was made in photographic science and technology so that, when the United States entered World War II, what is now called Kodak Super-XX Aerographic Film was available for both reconnaissance and mapping purposes. Also, Kodak Tri-X Aerographic Film, having twice the sensitivity of Super-XX, was made available for use in night photography or at other times of reduced illumination. Just prior to the war, advances made in cellulose chemistry provided a material of improved dimensional stability so that a safety

* Presented at the Society's 25th Annual Meeting, Hotel Shoreham, Washington, D. C., March 8 to 11, 1959.

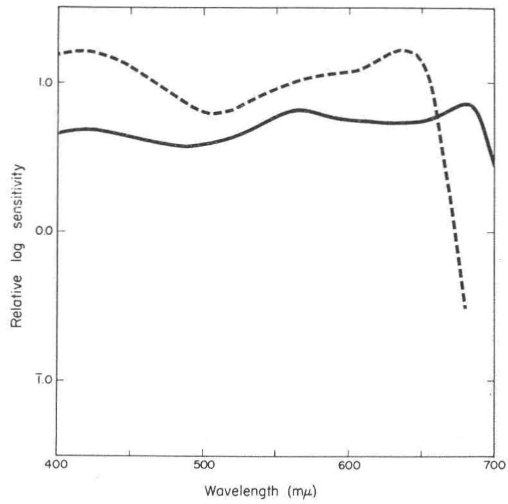

Fig. 1. Spectral sensitivity curves of Kodak Super-XX Aerographic (dashed curve) and Plus-X Aerecon films. Plus-X Aerecon has "extended-red" sensitivity.

support for use in mapping operations replaced the inflammable cellulose nitrate used previously (3).

The use of aerial photography as an intelligence weapon during World War II was expanded so rapidly that facilities for the production of Super-XX Aerographic Film became overloaded, and therefore a non-topographic support aerial film, Kodak Super-XX Reconnaissance Film, was provided to the armed forces for reconnaissance purposes.

Following World War II, Super-XX Reconnaissance Film was modified by hardening its emulsion in manufacture to withstand elevated temperatures during processing, and was introduced as Super-XX Aerial Recon R. P. Film. This material was available for use in the Korean conflict in 1950.

In recent years special research of significance to aerial photography has been re-emphasized in the Kodak Research Laboratories so that fundamental knowledge in this field could be kept abreast of the advances made in related areas. Along with this, from the general research program, a significant advance was made in photographic emulsion making in 1953 which provided an improved speed–graininess ratio. These fundamental investigations and technological advances have made it possible to improve the characteristics of negative films being offered for aerial photographic applications.

In December, 1954, an experimental aerial film with improved characteristics, identified as SO-1121, was supplied to the United States Armed Forces. A material on aerographic support, identified as SO-1129, was provided for tests by commercial and military aerial photographic organizations for mapping use. Subsequently, a new type of sensitizing, known as "extended-red" sensitizing (Figure 1), was applied to these films and the identifying numbers were changed to SO-1166 for the reconnaissance support and SO-1159 for the aerographic support materials. The United States Department of Defense accepted the SO-1166 material as an improved film, and it was announced as Kodak Plus-X Aerecon Film, Type 8401, in 1957. The topographic support material is now being made available as Kodak Plus-X Aerographic Film, Type 5401. These films have an exposure index of 80, the "extended-red" sensitizing characteristic, and are hardened in manufacture for processing at temperatures of 85°F. in suitable equipment. Figure 2 shows the sensitometric curve of these materials when developed in Kodak Developer D-19 for 8 minutes at 68°F. Figure 3 shows the sensitometric curve in Kodak Developer D-76 which provides a lower gradient without undue speed loss. Graininess and resolving power are also somewhat improved with this developer.

Also in 1957, a new, high-speed aerial film, Kodak Tri-X Aerecon Film, Type 8403, was announced. It is hardened for elevated-temperature processing and has "extended-red" sensitivity. Figure 2 shows the sensitometric characteristics of this material when developed in Kodak Developer D-19 at 68°F. Recommended manual development is 12 minutes while 20 minutes produces about the maximum speed that can be obtained with forced development.

Film materials with a thinner support than that used for aerial films have been available for many years, particularly as amateur roll-film products. In many military applications, a thinner material of this type for aerial photography would be very useful, but, until recently, adverse effects have been encountered when a thin film having a pelloid backing[1] is wound in contact with the emulsion surface. Recent advances in film manufacturing have overcome these adverse effects to a large extent, and Kodak Plus-X Aerecon Film (Thin Base), Type 8402, is now available. It was first made available in 1957 on special order as SO-1188. Photographically similar to the

[1] A pelloid backing is a gelatin layer on the support opposite the emulsion used to provide curl control.

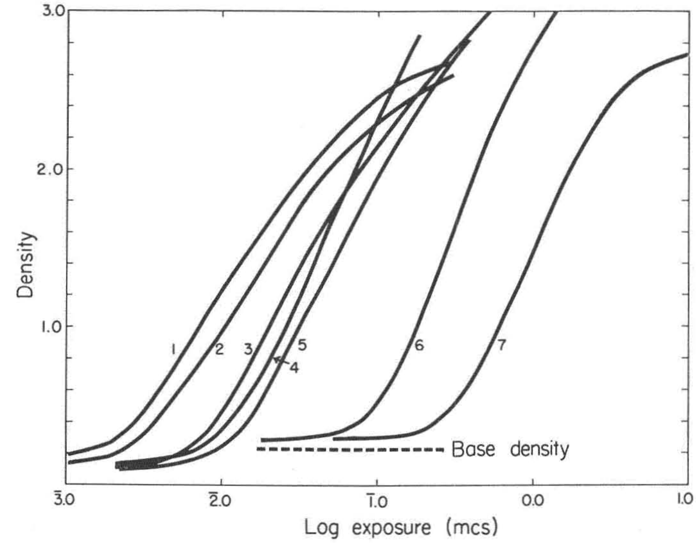

FIG. 2. Characteristic curves of Kodak panchromatic aerial negative films developed in Kodak Developer D-19, at 68°F. Exposed to sunlight through Kodak Wratten Filter No. 12.

(1) Tri-X Aerecon developed for 20 minutes, $\gamma=1.80$.
(2) Tri-X Aerecon developed for 12 minutes, $\gamma=1.60$.
(3) Super-XX Aerographic developed for 8 minutes, $\gamma=1.90$.
(4) Plus-X Aerecon developed for 8 minutes, $\gamma=2.21$.
(5) Plux-X Aerecon (Thin Base) developed for 8 minutes, $\gamma=1.98$.
(6) SO-213 developed for 8 minutes, $\gamma=2.71$.
(7) SO-243 developed for 8 minutes, $\gamma=2.21$.

Plus-X Type 8401 product, the antihalation dye in the pelloid effectively reduces the speed by half a stop so that its exposure index is 64. Figure 2 shows the sensitometric curve when the film is developed in Kodak Developer D-19 for 8 minutes at 68°F. and Figure 3, the curve when it is developed in D-76 for 10 minutes at 68°F.

It has been evident in recent years that energetic efforts are being made to improve the optical and mechanical components of aerial photographic systems. Realizing that these efforts would probably be successful, and that films with better definition than the new materials discussed so far would be needed, the Eastman Kodak Company decided to enlarge the Kodak family of aerial negative films. Consequently, a material with an index of about 6, with three different supports, has been made available in limited quantities. The clear-support material is identified as SO-220.[2] For antihalation purposes, the material is available as SO-213[2] having a gray support. The thin-base version with an antihalation pelloid is identified as SO-221.[2] The materials have "extended-red" sensitivity, and they are hardened for elevated-temperature processing. Figure 2 shows the sensitometric curve for the materials when developed in Kodak Developer D-19 at 68°F. and

FIG. 3. Characteristic curves of Kodak panchromatic aerial negative films developed in Kodak Developer D-76 at 68°F. Exposed to sunlight through Kodak Wratten Filter No. 12.

(1) Plux-X Aerecon developed for 10 minutes, $\gamma=1.15$.
(2) Plux-X Aerecon (Thin Base) developed for 10 minutes, $\gamma=1.27$.
(3) SO-213 developed for 4 minutes, $\gamma=1.34$.
(4) SO-243 developed for 5 minutes, $\gamma=1.29$.

[2] These were formerly identified by the numbers SO-1220, SO-1213, SO-1221, and SO-1243, respectively. Inquiries about these materials should use the 3-digit numbers for identification.

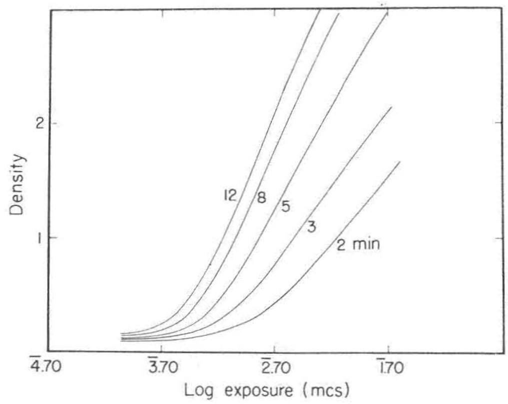

FIG. 4. Characteristic curves of Kodak Plux-X Aerecon Film developed in D-19 at 68°F. Exposed to sunlight through Kodak Wratten Filter No. 12.

Time of Development (min.)	*Gamma*
2	1.18
3	1.35
5	1.67
8	2.21
12	2.38

Figure 3 shows the curve for development in D-76 at 68°F.

For applications where the highest definition obtainable consistent with reasonable exposure conditions is required, a material with an index of about 1.6, identified as SO-243,[2] has been made available. It has a gray support, "extended-red" sensitizing, and is hardened for elevated-temperature processing. Figure 2 shows the sensitometric curve for this material when it is developed in D-19

TABLE I

R.M.S. GRANULARITY VALUES
SCANNING-APERTURE DIAMETER—24μ

Kodak Material	*Developer*		*R.M.S. Granularity (at net density=0.80)*
	Kodak Formula	*Time (min.)*	
Tri-X Aerecon	D-19	12	0.114
	D-19	20	0.114
Plus-X Aerecon	D-19	8	0.065
Plus-X Aerecon (Thin Base)	D-19	8	0.076
Super-XX Aerographic	D-19	8	0.081
SO-123	D-19	8	0.030
SO-243	D-19	8	0.0135

at 68°F. Figure 3 shows the curve for development in D-76 at 68°F.

In the early experimental work with SO-1121, the prototype for Plus-X Aerecon Film, an important new characteristic was obtained for application in aerial photography in that the speed varied markedly with development time in D-19 while gamma varied only slowly. This characteristic was retained for Plus-X Aerecon Films (Figure 4) and all the other films discussed in this paper except Tri-X Aerecon, which, of course, should generally be used only when the illumination conditions require an extremely fast emulsion. This characteristic provides the facility of exposing the film under conditions of marked changes in illumination level without neces-

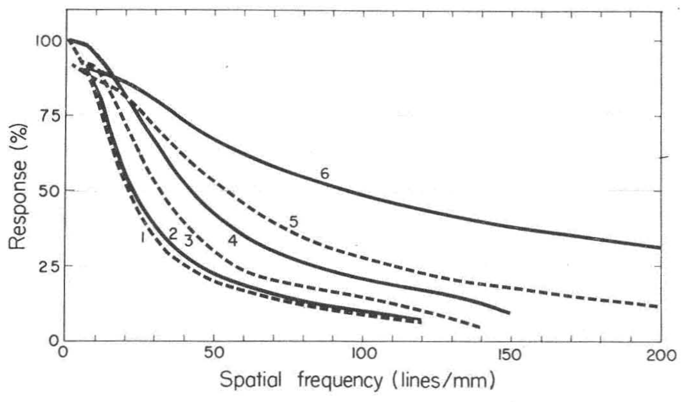

FIG. 5. Sine-wave response of Kodak panchromatic aerial negative films developed in D-19:
(1) Super-XX Aerographic
(2) Tri-X Aerecon
(3) Plux-X Aerecon
(4) Plus-X Aerecon (Thin Base)
(5) SO-213
(6) SO-243

TABLE 2

MAXIMUM RESOLVING POWER

Kodak Material	*Developer*		*Maximum Resolving Power (lines/millimeter)*	
	Kodak Formula	*Time (min.)*	*1,000:1*	*1.26:1*
Tri-X Aerecon	D-19	12	72	15
	D-19	20	65	15
Plus-X Aerecon	D-19	8	94	27
Plus-X Aerecon (Thin Base)	D-19	8	115	35
Super-XX Aerographic	D-19	8	80	15
SO-213	D-19	8	180	55
SO-243	D-19	8	225	95

sitating adjustments in camera exposure. During processing, the film can be examined and, based on a suitable criterion, development can be halted or resumed, depending on whether or not sufficient density has already been produced. Thus, exposure control is provided in aerial photography without using complex and heavy equipment for this purpose in the photographic aircraft.

General investigations on image-quality evaluation in recent years have led to the use of "sine-wave response" as a measure of the image quality in a photographic system that is not limited with respect to graininess. Sine-wave response is a measure of the ability of a film to reproduce a test pattern in which the luminance varies sinusoidally with distance in one direction. As the frequency of variation is increased, the amplitude of the variation in the photographic image generally decreases. For a high-definition material, the amplitude in the photograph remains higher as frequency increases than it does for low-definition materials. A curve showing amplitude response as a function of frequency therefore provides much information about the image-quality characteristics of a film (4).

Figure 5 shows the sine-wave frequency response of these materials when developed in D-19. Table 1 provides R.M.S. granularity data for these materials when developed in D-19 (5). Table 2 shows the resolving-power figures for the materials at 1,000:1 and 1.26:1 contrast ratios (6). The filter factors for these materials are: Tri-X Aerecon and Plus-X Aerecon—2 for the Wratten No. 12 and 4 for the No. 25; for the SO-213 and SO-243 types—1.5 for the No. 12 and 3.0 for the No. 25.

The data given in this paper represent average characteristics of the materials as measured by standard procedures in the Kodak Research Laboratories. Particular samples may exhibit slight variations. Also, because of improvements which are made from time to time in all sensitized products, sometimes without announcement, these data may not describe the characteristics of similarly identified material manufactured in the future. When precise quantitative data are needed, therefore, measurements should be made under the actual conditions under which the material will be used.

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