INTERNATIONAL ARCHIVES OF PHOTOGRAMMETRY AND REMOTE SENSING
INTERNATIONALES ARCHIV DER PHOTOGRAMMETRIE UND FERNERKUNDUNG
ARCHIVES INTERNATIONALES DE PHOTOGRAMMETRIE ET DE TELEDETECTION

Volume 28 Part 7-1

ISPRS

PROCEEDINGS OF THE SYMPOSIUM ON GLOBAL AND ENVIRONMENTAL MONITORING

TECHNIQUES AND IMPACTS

SEPTEMBER 17-21, 1990
VICTORIA CONFERENCE CENTRE
VICTORIA, BRITISH COLUMBIA
CANADA

COMMISSION VII

INTERPRETATION OF PHOTOGRAPHIC AND
REMOTE SENSING DATA

A More Discriminating Use of Aerial Photographic Emulsions and Processing Techniques

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1991. pp. 759-778 in Proc. Symposium on Global and Environmental Monitoring - Techniques and Impacts, I.S.P.R.S Commission VII, Victoria, B.C.

A MORE DISCRIMINATING USE OF AERIAL PHOTOGRAPHIC EMULSIONS AND PROCESSING TECHNIQUES

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ABSTRACT

Aerial photographic emulsions have generally been classed into four broad classes: true color, color infrared, black and white panchromatic, and black and white infrared. A number of recent developments have expanded the film use spectrum so that users can now be more exacting and specific in their applications. The introduction of panchromatic-infrared films, a negative process for color infrared film, a greater diversity of color films, plus a greater awareness of average gradient-gamma manipulation have all contributed to a more discriminating user approach in aerial photography. A review of the benefits and applications of these technologies and techniques is undertaken.

INTRODUCTION

The past five to eight years have seen significant advancements made in the field of photographic emulsion technology. The introduction of tabular, core shell, so called "twin crystal" grains, and the application of DIR (developer inhibiting releasing) couplers have produced emulsions with improved granularity, resolution, and color saturation characteristics [1-4].

Aerial photography has also had its share of improvements in emulsion technology, partly as a result of the general improvements in the amateur-professional markets, and partly due to specific requirements in the process of vertical imaging. The effects of these changes has been two fold: one, end users of the imagery have become more aware and demanding of products which suit their needs, two, acquisition firms have had to adapt to the proliferation of these new products and also to the more critical demands of their clients. Although the situation has generally been advantageous to both the production and user sectors, some confusion has inevitably arisen regarding the appropriate application of the various film types.

The four spectral class types of aerial films have traditionally been black and white panchromatic, black and white infrared, true color negative and positive, and false color infrared. These classes are still valid in the general sense, however, the profusion of newer films and more controlled processing techniques have introduced important subtle differences within each ofthe categories. How these differences affect the resultant image information is of key importance to the end user. The major objective of this paper is to delineate the differences in mapping grade films and identify the primary benefits and/or drawbacks in their application.

In 1982, the Canadian Interdepartmental Committee on Aerial Surveys (ICAS) revised their photographic acquisition specification regarding tonal quality. Emphasis was placed on acquiring imagery with a proper contrast (density range) [5]. The aerial photography firms using the techniques to expose for, and modify the density range [6], developed a greater awareness of the possibilities and limitations of emulsions to satisfy the conditions of ICAS quality criteria. This awareness has translated to more efficient photographer-laboratory interfaces and, ultimately, to users obtaining a better quality product. This modification of the acquisition procedure has had an impact to the user as significant as the introduction of newer films; a review of this procedure defines a secondary objective of this paper.

BLACK AND WHITE FILMS

Black and white (BW) aerial films, as noted, have typically been categorized into two basic categories: infrared and panchromatic.

Infrared

The infrared film, Kodak Infrared Aerographic 2424, is regarded as a near infrared sensitive emulsion. Its sensitivity spans from the ultraviolet spectral region to approximately 930 nanometers [7]. A minus blue filter is used during exposure to absorb the wavelenghts shorter than 525 nanometers to compensate for the film's high sensitivity in the blue spectral region. This convention places into question the recording of shadow detail by the film since the spectral quality of the light in these regions tends to be scattered blue light. Evidence shows that image contrast significantly deteriorates and no additional information is gained by removing the minus blue filtration [8].

The exposure latitude of this film is relatively narrow, making it prone to errors in exposure (Figure 1). The problem is further aggravated by the unreliability of conventional exposure meters in sensing infrared radiation. An effect commonly noted is the lack of highlight detail in deciduous tree canopies. The infrared reflection is high therefore producing high densities on the negative film. These high density values are thus recorded on the shoulder region of the characteristic curve where the brightness variations of the deciduous tree cover type may not be adequately portrayed by the emulsion (Figure 1).

Regardless of the film's operational drawbacks it remains the film of choice in many natural resource applications. The two most prominent applications being vegetation data analyses and hydrographical boundary delineation. The different infrared reflection characteristics of deciduous and coniferous forest canopies and the strong infrared absorption of water bodies provide the physical basis for the effects portrayed by the film [9,10].

Panchromatic

Panchromatic emulsions are generally attributed a spectral sensitivity similar to that of the visible light spectrum. The spectral sensitivity of these emulsions range between 400 nm. to approximately 670 nm. [11]. As true panchromatic emulsions only the Ilford aerial films qualify [12,13]. The Kodak aerial films are sensitized to approximately 720 nm. and are described as extended red panchromatic [7]. The Agfa aerial films are sensitized to about 760 nm. and are slightly infrared sensitive [14,15,16]. The 'panchromatic' category displays the widest choice of films, each varying in emulsion speed, granularity, resolution, and as noted, spectral sensitivity. From a user perspective, the subtle differences in spectral qualities and the inherent differences in graininess and resolution will have a significant impact on the image definition and consequent application. For ease of description the panchromatic category is subdivided into low speed, medium speed, fast speed, and very fast speed emulsions. The basis of these categories is obtained from the aerial film speed quoted by the manufacturer. Among these groupings the general tendency is for the granularity - resolution characteristics of the films to improve as the emulsion speed decreases.

Low speed emulsions. Three emulsions are currently available in this class. They are the Kodak Panatomic-X Aerographic II 2412 film, Kodak High Definition Aerial Film 3414 and the Agfa-Gevaert Aviphot Pan 50 film. High resolution and low granularity are key attributes of the three films but the similarities tend to end here.

The Kodak 2412 film is generally regarded as a relatively high contrast film with typical average gradients of about 1.6 to 2.0 [7,17]. Recent tests in Kodak Duraflo and Agfa G74c developers have not indicated otherwise (Table 1). The high contrast of the film has generally prevented the widespread use of the emulsion, even in situations where higher contrast would be thought advantageous such as in small scale applications. In this case, moderate haze can nullify the film's higher contrast attribute.

The Kodak High Definition 3414 film is described as an extremely fine grain, slow speed, thin base film designed for high altitude reconnaissance [7]. Practical use of this very high resolving emulsion is limited due to its low sensitivity; the aerial film speed is in the order of about 8, or about 5 times less sensitive than the Panatomic-X film.

The Agfa 50 film is generally lower in contrast than the Panatomic-X film with typical average gradients of about 1.4 to 1.5, although the range varies greatly depending on the processing conditions (Table 1). This film is gradually replacing its predecessors in small scale aerial applications. Its lower contrast, its ability to penetrate haze due to its slight IR sensitivity, high resolution, and low graininess are all factors working in unison to provide an excellent small scale product.

Some work has been done in using both the Kodak 2412 film and the Agfa 50 film at medium scales in forest inventory applications. The performance of the Agfa 50 film was average in this regard, but definite potential was seen with the Panatomic-X film; it rated second in preference only to the Kodak 2424 IR film [8].

Medium speed emulsions.
Three films are currently available in this class. They are Ilford's FP3, Kodak's Plus-X Aerographic 2402, and Agfa's Aviphot Pan 150. These films are typically used in small scale applications due to their

relatively slow film speed, however, with the advent of forward motion compensation cameras, medium scale applications are now also becoming viable.

The subtle differences in the films' spectral sensitivity is one important factor which establishes their most appropriate application. For example, in small scale applications where haze may be a hindrance in the proper tonal rendition of the terrain, the Agfa 150 film's sensitivity to 760 nm. significantly improves the quality of the imagery (Figure 2). Visual comparisons of graininess and image sharpness also tend to favor the Agfa emulsion (Figure 3), however, due to recent findings* the matter remains open.

The Ilford FP3 film, whose spectral sensitivity falls below both the Kodak and Agfa emulsions, would probably be inferior in cases where atmospheric haze required adequate penetration, but this film does have its merits. The average gradient of both the Plus-X film and the Agfa 150 film tend to be quite high [7,17] (Table 2), but the FP3 film displays an opposite tendency (Table 2). The normal average gradient of this film seems to be about the 1.0 value. In addition, resolution tests performed by Wild (Heerbrugg) place this emulsion above either the Plus-X or the Agfa 150 film**. The FP3 would be advantageous in regions of high brightness range conditions such as mountain forests with alpine meadows and exposed bedrock or in glacial studies, but its utility would have to be judged according to the severity of haze conditions.

Fast speed emulsions. This category comprises of three films: Ilford's HP5, Kodak's Double-X 2405, and Agfa's Aviphot Pan 200.

These films represent many of the general purpose applications in aerial photography, infact, the Double-X film has had widespread use in most aerial survey work. The Kodak film's wide exposure latitude, relatively fine grain, average contrast, and fast emulsion speed has made it the standard survey emulsion.

The Agfa 200 film may be viewed in the same context as the Double-X, however, due to its higher contrast (Table 3) it has been applied in conditions of low brightness ranges such as photography of uniform forest canopies, grassland zones, and arctic vegetation. Its spectral sensitivity, being about 760 nm., has even lead to its use as an infrared film substitute, however, the Agfa 200 suitability as an infrared substitute emulsion may be questionable (Figure 4). Much personal preference and opinion surround this issue and more objective research is required.

For 70 mm. large scale photography it is noted that for forestry applications the interpreter preference decreases as emulsion spectral sensitivity increases [18]. The HP5 emulsion tends to be a lower contrast emulsion than both the Double-X film and the Agfa 200 film (Table 3) thus possibly suited to record high brightness range conditions such as found in mountainous regions.

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* J.Cummings, Kodak, personal communication, Nov. 1989.

** F.Zuberbuehler, Wild, personal communication, May 1989.

Very high speed emulsions.

Only one film currently occupies this class: the Kodak Tri-X 2403 emulsion. It is characterized by relatively low contrast, fair resolution, and very wide exposure latitude. The film has had low use due to its graininess being relatively high, this attribute has discouraged the topographical service sector from using the film because of enlarging factors used in analytical plotters of between six and fourteen times. But in cases where only a 2 times magnification pocket stereoscope is used, and where shadow detail is critical to the application as often is in large scale applications (<1:5000), would the virtues of this emulsion not be an advantage? Unfortunately, not much work has been done in 240mm. format aerial photography but the film is highly regarded in 70mm. applications [18].

Agfa has developed and tested a film in this class, presumably with characteristic extension of the spectral sensitivity into the infrared. This emulsion, however, has not been released to the commercial market except for special applications.

COLOR FILMS

Color films fall into two broad classes: negative type and positive reversal type. The positive reversal films are further subdivided into true color and false color infrared.

Negative Type Emulsions

Two films are currently grouped in this class, they are the Kodak Aerocolor 2445 and the Agfa Avicolor 200 emulsions. The Kodak 2445 film has, until recently, been the only film available in the 240 mm format for obtaining a negative aerial image. The introduction of the Agfa film has provided an interesting alternative in color negative imaging. The end products from the two films are quite similar (Figure 5) but the inherent processes of the two films differ markedly.

The most obvious difference between the films is that Agfa uses an integral mask thus giving the typical orange cast to the negative, while Kodak does not make use of this system (Figure 6). The integral mask aids in minimizing the interference amongst the three color dye layers, thereby producing greater color saturation [19]. The processing conditions are also different; Kodak uses the Aero-Neg color process [7] while Agfa uses the C-41 process [20]. Depending upon the configuration of the processing equipment used (Kodak RT Mdl. 1411C) Kodak film can be processed between 3.2 and 6.4 ft./min. Agfa film processing rate is approximately 2 ft./min. (Kreonite KM3 1010). Production efficiency is, therefore, enhanced with the Kodak product.

The sensitometric characteristics of the two films (Figure 7) are conveyed primarily by a faster film speed with the Agfa product (Agfa= ANSI 242, Kodak= ANSI 137) and higher contrast with the Kodak product (Agfa=.56 A.G., Kodak=.75 A.G.). Higher contrast is attainable with the Avicolor 200 (average gradient=.75) by 'push processing', but at a significant cost in production efficiency as the transport speed is lowered.

Visual inspection of graininess and resolution show the Agfa film with slightly better qualities (Figure 8); RMS granularity values for the two films [19,20] (Aerocolor = 12, Avicolor = 6) confirm this observation.

One final note with regards to the curl of the processed film, the Avicolor film tends to lie flat whereas the 2445 has a significant curl to it. The flat lying film aids in manipulating the film for inspection, annotation, and reproduction.

Positive Type Emulsions

True color films. This class of films encompasses the Kodak Aerochrome MS 2448, and the Agfa Avichrome 200 films. These films have had limited use in aerial survey applications. The low frequency use is mainly attributed to the reluctance of users to use the original positive image in a working environment, instead prints produced from negative original films have been preferred. In some applications reversal positive films have been processed to a negative with the prints used in natural resource studies [21]. In cases where optimum image quality has been required, such as mapping, these films have been used in their positive original state*.

Due to the films' high contrast, they are superior to their negative counterparts in rendering terrain and vegetative textural detail. With proper spectral filtration water related analyses are possible [22,23].

The Kodak and Agfa films are operationally different films. The Kodak emulsion is processed using the EA-5 process [7] while the Agfa film is processed in using E-6 [40]. As with the color negative films, production efficiency is an important factor considering that the production rate of the EA-5 process will enable processing speeds of up to 9 ft./min., whereas with the E-6 process production rate is approximately 2 ft./min.

Color Infrared films. Kodak manufacturers the only color infrared film available: the Aerochrome infrared 2443. It is a "false color" reversal emulsion designed for infrared spectral discrimination in agriculture, forestry, geologic, hydrologic and other environmental studies. Its spectral sensitivity ranges between 450 nm. and 900 nm. A minus blue filter is used to absorb the blue light to which all three emulsion layers are sensitive.

Consistent color rendition with this film requires more technical expertise than with typical color positive or negative emulsions. The color balance of the three dye layers is affected by environmental storage, atmospheric haze, and processing variations, consequently strict sensitometric control and appropriate filtration is required for consistent color balance in the photography [24].

Given that the film has a reversal positive emulsion, contrast control in printing is not possible with electronic dodging contact printers. This situation can be averted by using the 2443 as a negative material [25]. Kodak does not support nor does it condone the processing of 2443 as a negative, mostly because of the lack of supporting data associated with the process*;

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* M.Landreville, I.C.A.S., personal communication, Feb. 1990.

* J.Cummings, Kodak, personal communication, Nov. 1989.

however, the Ontario Centre for Remote Sensing has shown that the process is feasible and advantageous in certain applications [26,27].
The most striking feature of the negative process is the color shift from a cyan-magenta predominance in the positive image to an orange-green cast in the negative printed image (Figure 9). Although the spectral sensitivity of the emulsion is not affected by the negative process there is some evidence to suggest the enhancement of certain features, which would be displayed as cyan in the positive process are rendered better as green in the negative process (Figure 10).

In addition to the soil disturbance depicted by Figure 10, other features which could benefit from the effect would be rock outcrops, stressed vegetation, and terrain as rendered in urban areas.

Possibly the most advantageous feature of the negative type 2443 product is in its use as a conventional negative product in electronic dodging contact printers. Autododge can be controlled, hence more uniform printing can be achieved, consequently products such as mosaics can be produced with better tonal uniformity.

In small scale applications the 2443 emulsion (positive or negative) is definitely the choice film if color is required. Its infrared sensitivity will provide the haze penetration which is often required at higher altitudes.

As a final note on graininess and sharpness of the imagery, it does not seem that it is significantly affected by the negative process (Figure 11), although a more quantitative analysis is needed to substantiate this observation.

IMAGE ACQUISITION TECHNIQUES

Innovation in acquiring aerial photographic imagery has concentrated in two areas: image contrast control and image motion compensation. Contrast control awareness in Canada has evolved primarily as a response to federal requirements on aerial photography, while image motion compensation has been a technological implementation of major aerial camera manufacturers.

Image Contrast Control

Contrast control has been widely used as a tool in photography almost since its inception; the popularization of the Zone System [28] is an attestation to this. In aerial photography the operational concept of controlling contrast is a relatively recent event. Two reasons account for this situation: one, older versions of photographic specifications required constant processing (analogous to no contrast control), two, methods to determine terrain brightness range were either nonexistent or experimental [29]. The revision of the Interdepartmental Committee on Aerial Surveys specifications, specifically item #27, imply that the air photo firm utilize techniques to control the film contrast in order to achieve the aim density range of 1.0 [5]. The modification of exposure through obtaining film speeds associated with varying average gradients and the processing of film to the different average gradients is now generally recognized [30-32]. Users have seen these techniques translated into better overall tonal ranges, more consistent detailed information in shadow areas, and better overall quality in aerial photography product. The problem of determining terrain brightness range, unfortunately, is still generally a subjective evaluation and is likely the reason not all aerial firms follow the ICAS exposure-processing guidelines. Although some effort has been made to alleviate the problem [33,34], only one camera manufacturer, Zeiss Jena, has addressed the issue by implementing a narrow angle light sensor with their exposure system [35].

Image Motion Compensation

The three major manufacturers of aerial cameras, Zeiss Jena, Carl Zeiss, and Wild, all produce camera models with forward image motion compensation [36-38]. This technological advance has improved the overall sharpness of aerial imagery, and in some instances in a dramatic fashion (Figure 12). However, in pushing the limits of the technology with the use of slow high resolution films at large scales, occasional lateral image motion associated with aircraft pitch and roll has been encountered (Figure 13). This situation has required discretionary use of the high resolution films at large scales.

SUMMARY

The new films and processing techniques introduced over the past decade have practically forced both user and production firm to be more conscious in proper film type specifications for aerial photographic needs. Combined with the exposure/processingrequirementsimposed by the ICAS densitometric specifications, the process and use of aerial photography has demanded more knowledge and precision to best depict the information required by the user. As both user and producer agencies become more conversant and comfortable with each emulsion's capabilities the confusion regarding where and how to use what film will diminish.

Future direction. The trend in emulsion engineering to develop finer grain and higher resolving emulsions without lowering emulsion sensitivity identifies the 'state of the art' in photography [39]. The benefits of these developments in aerial photography are particularly critical due to the moving platform used. With improvements forthcoming in aerial cameras, especially in compensating lateral image movement (Carl Zeiss has already addressed this in their most recent model,the RMK TOP), large scale imaging will improve significantly. It will be interesting to see whether Kodak and Ilford will respond to Agfa's panchromatic-I.R. films with an emulsion of their own, infact, with Fuji tentatively entering the aerial market with their HS film, a more competitive environment with regard to product quality and price is inevitable.

ACKNOWLEDGEMENTS

The author appreciates the technical review of the manuscript by Messrs. J.M.Brouwer and A.K.Stade (Alberta Forestry, Lands and Wildlife), and the additional commentary provided by Mr. R.J.Hall (Forestry Canada).

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Table 1

PROCESS* CHARACTERISTICS OF LOW SPEED EMULSIONS

FILM: Kodak Panatomic-X Aerographic II 2412

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Spd.*												
6 ft./min. (1 rack)	2.16	54	.12	Not available			Not available			Not available		
9 ft./min. (1 rack)	2.24	39	.08									
12 ft./min. (1 rack)	1.97	34	.07									
15 ft./min. (1 rack)	1.77	29	.08									
6 ft./min. (2 racks)	1.75	75	.34	1.90	40	.13	2.15	47	.10	2.19	51	.09
9 ft./min. (2 racks)	1.80	65	.19	1.95	30	.12	2.32	35	.08	2.38	37	.07
12 ft./min. (2 racks)	1.90	55	.16	1.90	25	.11	1.66	28	.07	2.43	34	.06
15 ft./min. (2 racks)	1.85	50	.15	1.90	20	.10	1.67	23	.06	2.20	27	.06

FILM: Agfa Aviphot Pan 50

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Spd.*												
6 ft./min. (1 rack)	1.47	44	.05	Not available			Not available			Not available		
9 ft./min. (1 rack)	1.20	32	.05									
12 ft./min. (1 rack)	.99	25	.04									
15 ft./min. (1 rack)	.82	20	.05									
6 ft./min. (2 racks)	1.64	69	.10	1.79	36	.08	2.03	58	.10	2.25	84	.10
9 ft./min. (2 racks)	1.68	52	.08	1.52	28	.07	1.51	39	.08	1.93	64	.08
12 ft./min. (2 racks)	1.50	43	.07	1.36	22	.08	1.10	27	.07	1.81	57	.08
15 ft./min. (2 racks)	1.42	37	.06	1.21	19	.07	.85	18	.08	1.41	48	.08

* Versamat 11C, 30° C

Table 2

PROCESS* CHARACTERISTICS OF MEDIUM SPEED EMULSIONS

FILM: Agfa Aviphot 150

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Speed (2 racks)												
6 ft./min.	1.80	193	.19	1.88	150	.08	1.41	189	.20	2.13	156	.20
9 ft./min.	1.77	151	.12	1.75	123	.08	1.27	90	.15	1.89	95	.12
12 ft./min.	1.76	116	.10	1.76	100	.07	1.10	54	.12	1.77	79	.11
15 ft./min.	1.52	100	.09	1.67	85	.07	.96	37	.11	1.45	70	.11

FILM: Kodak Plus-X Aerographic 2402

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Speed (2 racks)												
6 ft./min.	1.55	260	.06	1.75	105	.07	1.20	227	.12			
9 ft./min.	1.60	200	.06	1.40	70	.07	1.02	133	.10	Not available		
12 ft./min.	1.55	185	.05	1.20	60	.07	.87	74	.09			
15 ft./min.	1.40	210	.06	1.10	55	.06	.78	55	.08			

FILM: Ilford FP3 Aerial Film

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Speed (2 racks)												
6 ft./min.				1.17	180	.22						
9 ft./min.	Not available			1.08	125	.17	Not available			Not available		
12 ft./min.				1.02	100	.16						
15 ft./min.				.99	85	.16						

* Versamat 11C, 30° C

Table 3

PROCESS* CHARACTERISTICS OF HIGH SPEED EMULSIONS

FILM: Kodak Double-X Aerographic 2405

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Speed (2 racks)												
6 ft./min.	1.90	560	.35	1.65	530	.12	1.21	296	.13	1.67	488	.17
9 ft./min.	1.50	490	.25	1.20	400	.11	.92	164	.10	1.15	300	.12
12 ft./min.	1.25	440	.20	1.10	270	.11	.81	116	.07	1.03	214	.11
15 ft./min.	1.10	420	.18	1.00	190	.11	.70	73	.06	.91	136	.09

FILM: Agfa Aviphot Pan 200

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Speed (2 racks)												
6 ft./min.	2.05	501	.24	1.73	248	.12	1.27	283	.20	2.08	368	.18
9 ft./min.	1.81	404	.15	1.57	162	.09	1.10	128	.15	1.56	232	.13
12 ft./min.	1.51	324	.12	1.37	134	.08	.89	75	.12	1.34	182	.12
15 ft./min.	1.28	249	.10	1.20	110	.08	.72	45	.09	1.12	145	.12

FILM: Ilford HP5 Aerial

Developer:	Kodak 885			Kodak Type A			Kodak Duraflo			Agfa G74c		
Densitometry:	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F	G	EAFS	B+F
Machine Speed (2 racks)												
6 ft./min.				1.08	453	.37						
9 ft./min.	Not available			.96	336	.32	Not available			Not available		
12 ft./min.				.91	279	.30						
15 ft./min.				.80	200	.30						

* Versamat 11C, 30° C

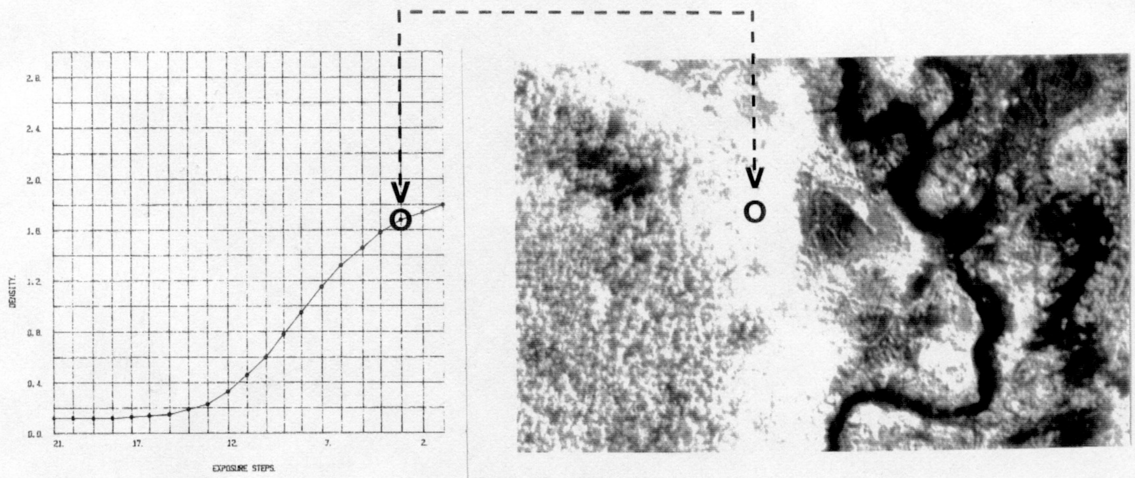

Figure 1. **Characteristic curve of Kodak 2424 I.R. film with associated image. Note the overexposure in the highlights. (Film average gradient = 1.10)**

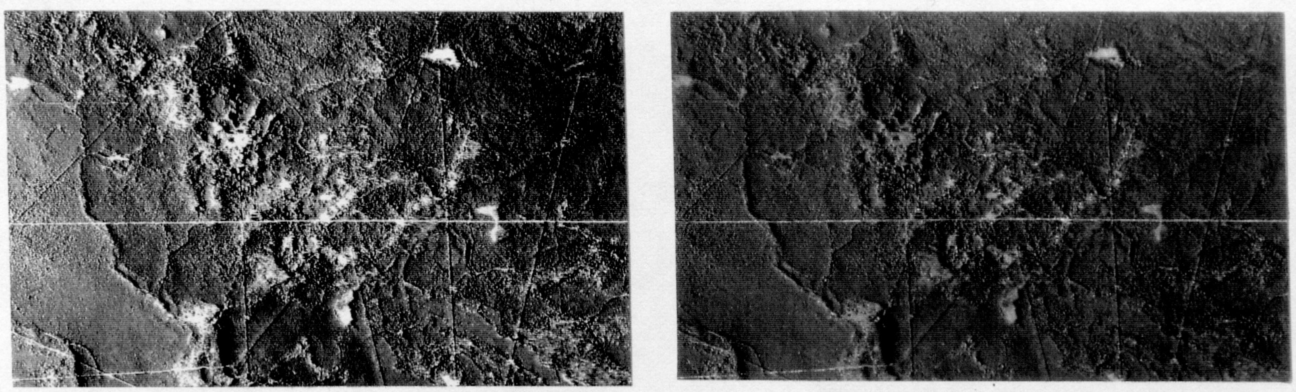

Figure 2. **Agfa (left) and Kodak (right), scale 1:40000, Average Gradients: Agfa=1.77, Kodak=1.91**

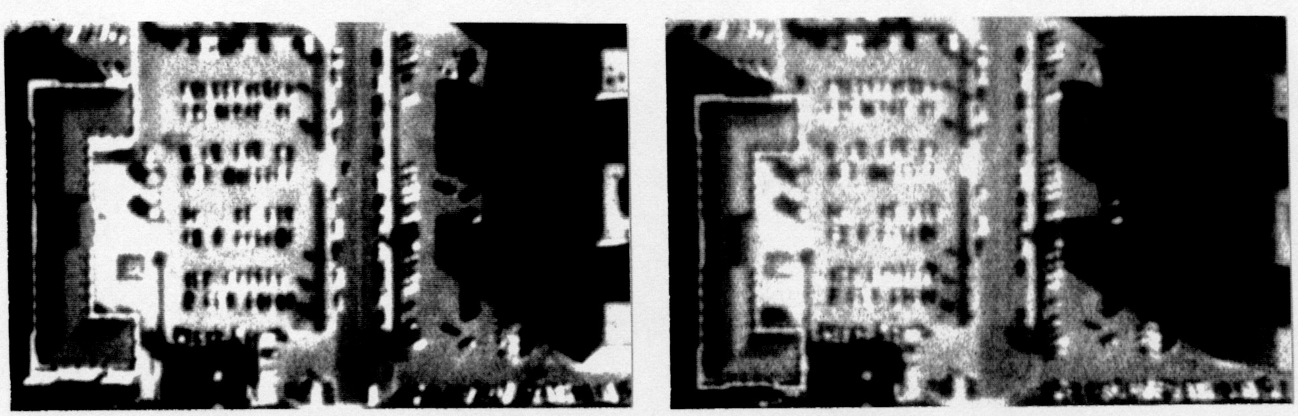

Figure 3. **Agfa 150 (left) and Kodak Plus-X (right), original scale 1:40000 enlarged 18X. Average Gradients: Agfa=1.77, Kodak=1.91.**

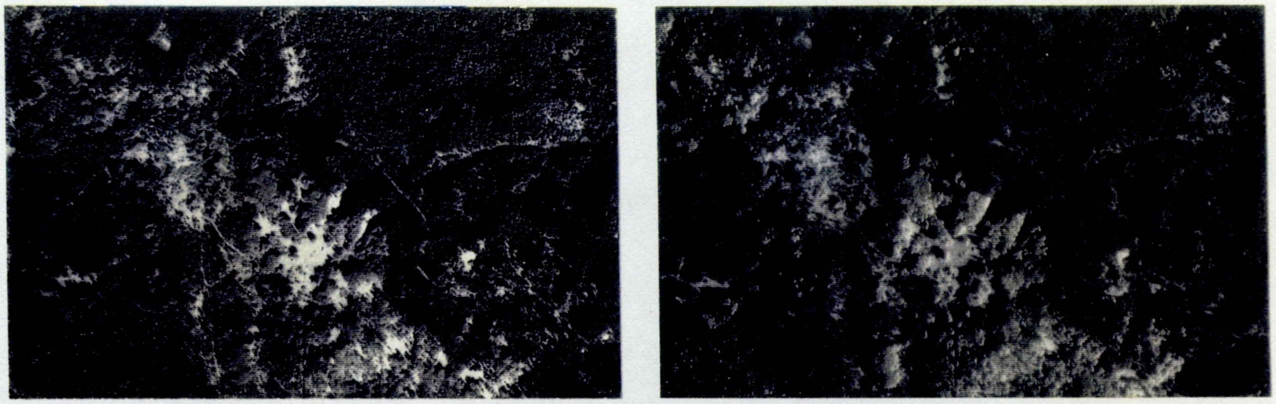

Figure 4. Agfa 200 (left) and Kodak 2424 I.R. (right), scale 1:20000, Average Gradients: Agfa=1.31, Kodak=1.14.

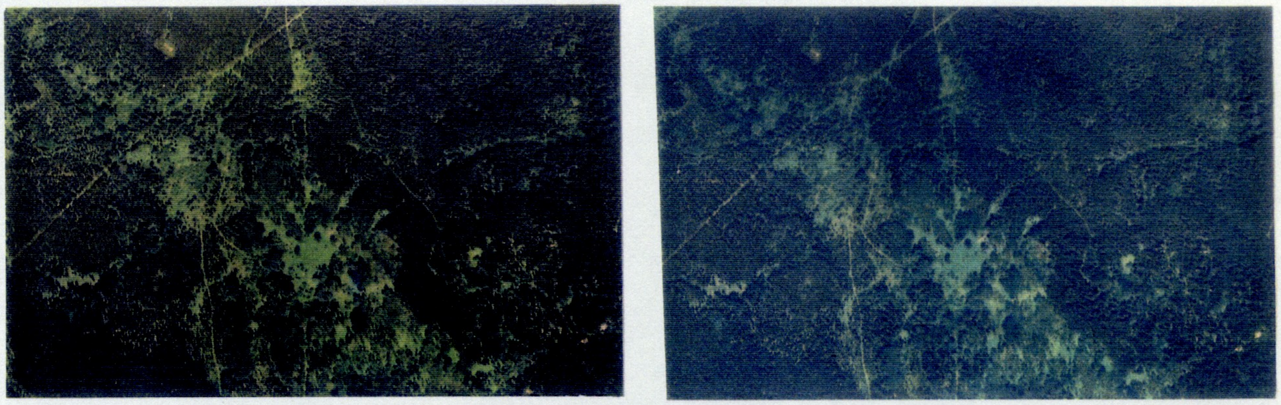

Figure 5. Agfa Avicolor 200 (left) and Kodak Aerocolor 2445 (right), scale 1:20000.

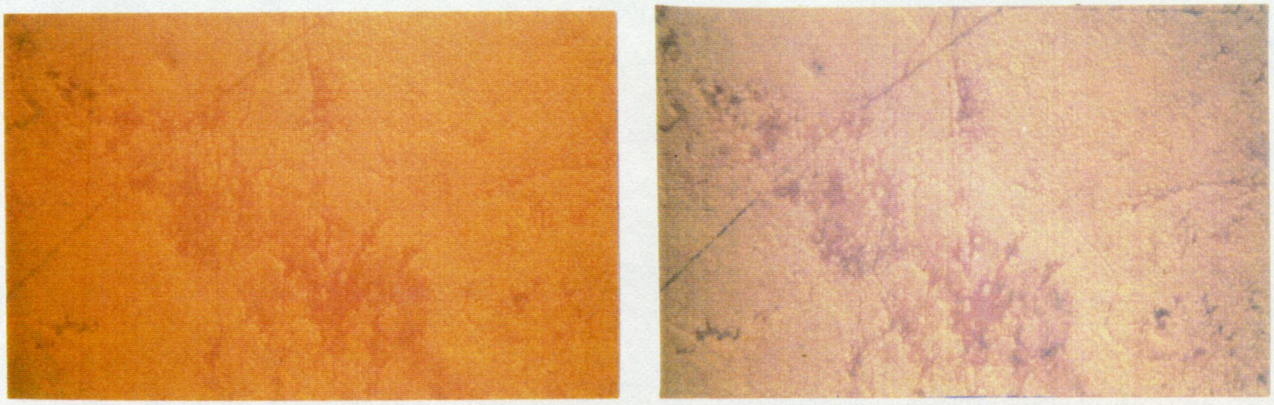

Figure 6. Agfa Avicolor 200 negative (left) and Kodak Aerocolor 2445 negative (right).

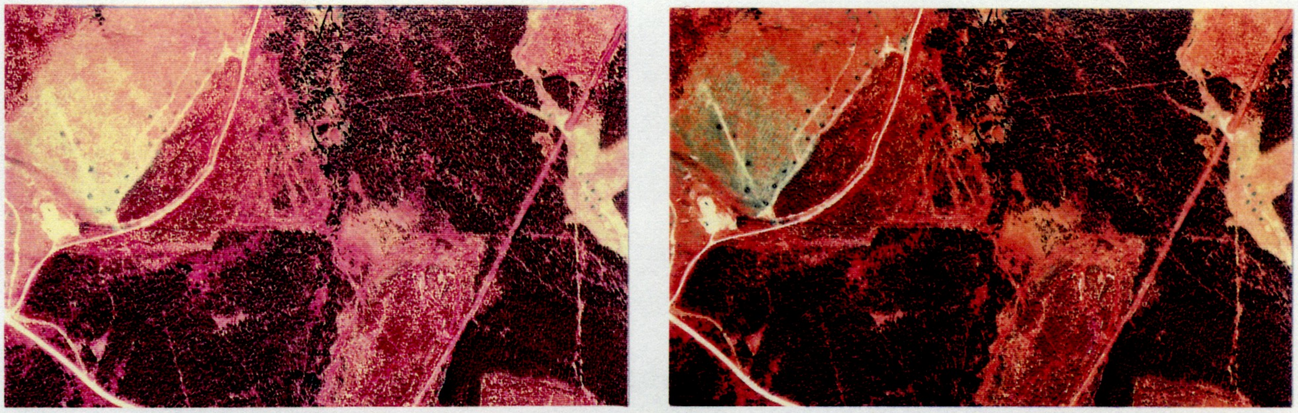

Figure 10. **Kodak Aerochrome Infrared 2443, positive process (left) and negative process (right). Note the differences in soil disturbance areas.**

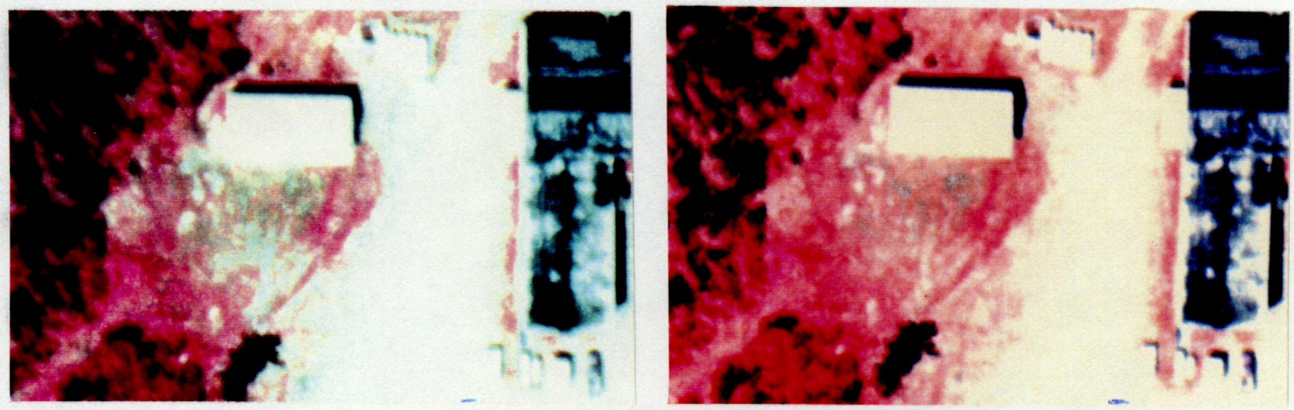

Figure 11. **Kodak Aerochrome Infrared 2443, positive process (left) and negative process (right). Original scale at 1: 20000 enlarged 18X.**

Figure 12. **Photography with forward motion compensation (left) and without forward motion compensation (right). Original scale at 1: 3000 enlarged 6X. Courtesy of Geographic Air Survey.**

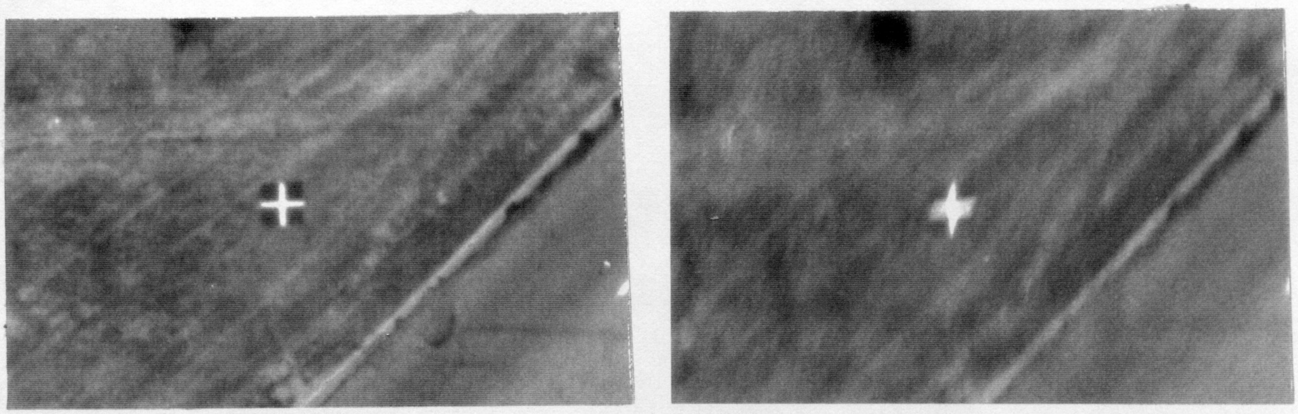

Figure 13. **Photography with forward motion compensation used but exhibiting lateral motion blur in the right side frame. Direction of flight is from left to right, Original scale 1:5000 enlarged 18X. Courtesy of City of Edmonton, Mapping and Graphics Section.**