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THE USE OF AERIAL PHOTOGRAPHS AND REMOTE SENSING TECHNIQUES IN RESEARCH ON FOSSIL PERIGLACIAL FEATURES

INTRODUCTION

At the Symposium on Periglacial Research in Aberystwyth, 1—10 July 1975, held by the Co-ordinating Committee for Periglacial Research (I.G.U.), it was felt that although many researchers study present-day periglacial phenomena on air photos, much more use might be made of them in the study of fossil periglacial phenomena. It was proposed that an inventory of features which may be indentified on air photos should be made, together with an enquiry to determine the best conditions for photography and other remote sensing techniques to be employed.

For the collecting of this information a questionnaire containing 12 questions was composed. Even if a broad spectrum of information was desirable and best obtainable by putting many detailed questions, a moderate number of questions was considered advisable in order — hopefully — to give a large number of answers.

The questionnaire was distributed to 124 institutes and scientists in 22 countries. 37 were replied, some of which giving very interesting aspects of the use of air photos, other telling that for one or antoher reason air photos were not used in periglacial research. Only few comments on the use of other remote sensing techniques than conventional aerial photograhy were given.

Together the replies cover a number of phenomena within the periglacial form group. Some features, however, are not represented in the replies. It could mean that the features are not studied by means of aerial photographs or in some cases that it is on the whole hard to decide whether a form is in fact inactive (fossil) or not.

As it was my intention also to include a bibliography on the use of air photos in the research of fossil periglacial phenomena, information about publications were asked for. Some reprints and literature references were received, but unfortunately the bibliography must be considered incomplete.

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TYPE OF AIR PHOTOS USED IN THE RESEARCH

By far, vertical air photos are the most frequently used material. This type of photographs makes possible a measuring of object dimensions and an adequate mapping of the distribution of ground features. In using the stereovision of overlapping photographs, the exaggeration of the vertical dimension could get also low ground features to stand out in otherwise plain surfaces. By photogrammetric methods profiles could be constructed and maps drawn for areas of interest.

It is clear that most of the vertical photographs used are taken for other reasons than for the identification of periglacial features, mostly for geographical survey, for construction and prospecting purposes. This means that often neither the season, nor the scale is suitable for imaging the periglacial phenomenon of special interest.

Also oblique air photos are used in some periglacial works, mostly for getting an overall view of the field studied. If they are not taken with an aerial camera or with another camera of well defined optical qualities the photographs cannot, however, be used for measuring the dimensions of the features or for mapping the terrain.

Oblique hand held photography is undertaken with a shutter speed of 1/125—1/250 sec. A flight altitude of 150—250 m is reported for recording vegetation patterns in plain areas.

TYPE OF FILM USED

Black and white is the ordinary negative material employed which is a consequence of the fact mentioned above that already existing photo coverage must be used. In consequence hereof it is in many answers not considered what type of black and white film the vertical photographs represent. In some cases it is, however, specified that the photos were on panchromatic film. Probably this holds true in most of the cases, as it is the normal negative material for aerial photography in combination with a yellow haze filter (minus-blue filter).

In two replies black and white infrared film is mentioned, but without annotating the result or comparing it with pictures of the panchromatic negative material.

As to the aerial colour material the amount of pre-existing vertical air coverage is much lower than that of black and white. In many replies it is stressed that it would be preferable to use conventional color film or color infrared film (false color), but for economic reasons it is usually not achievable to cover large research areas. However, for oblique hand held photography it could be done.

The black and white and the color infrared photography extends the possibility of imaging in a small band of the near-infrared (0.7—0.9μm) just outside the visible spectrum. It ought to be stressed that it is still reflectivity qualities of objects that are recorded and not the emissivity. For recording temperature patterns, (thermal infrared) other sensor systems than camera-film must be used.

FOSSIL PERIGLACIAL FEATURES IDENTIFIED IN AIR PHOTOS

A broad spectrum of periglacial phenomena (even present-day forms) is advanced in the replies. The most frequent feature listed was the polygonal pattern of ice wedges, fossil ice-wedge polygons [1].

From the point of view of photointerpretation it may be adequate to make a differentiation in macrotopographical, microtopographical, and „nontopographical" features. The first category is clearly identifiable by its relief. In large-scale photographs the second could be stereoscopically observed by its low relief, but is more a surface pattern phenomenon. The third type has no observable relief and stands out only due to vegetational or material contrast sometimes composing a surficial ground pattern.

There will of course exist transitions between the three categories. Some macrotopographical features may develop from a micro stage and microtopographical features may have been smoothed out to a nontopographical pattern. However, from the systematical point of view it seems appropriate to maintain the division.

Especially the first category could be further differentiated in (a) rock forms and (b) loose material forms.

MACROTOPOGRAPHICAL FEATURES

(a) Rock forms

This type is very sparsely represented in the replies and concerns altiplanation terraces and nivation forms (more generally). It is only lately that the discussion on the origin of altiplanation (or cryoplanation) terraces has been more intense. For the further discussion an important task is to identify the phenomenon in distant or not easily accessible areas and to find its geographical distribution. An inventory and mapping of these cryogenetic rock forms could be highly simplified by using air photos. In former periglacial areas, now covered by dense vegetation, there could however, be the problem of observing smaller terrace features.

(b) Loose material forms

Distinct relief features as sand dunes, collapsed pingos, thaw lake basins could be distinguished by normal geomorphological photointerpretation. As these forms usually occur in groups, sometimes also distinctly oriented, even small-scale photographs could be used for the pattern recognition. Dunes are for instance reported to be observed on a scale as low as 1:250 000.

Periglacial asymmetrical valleys also belong to clear relief features, but because of the vertical exaggeration of stereovision it could be hard to make

[1] Against the term *fossil* in connection e. g. with ice-wedge polygons objections can be raised, but it is used by many colleagues for surficial pattern and makes possible to clearly detach it from present-day *active* and *inactive* ice-wedge polygons. Alternatives could be relict and extinct. For the vertical form *ice-wedge cast* or *ice-wedge pseudomorph* is an adequate term.

immediate conclusions as to significant differences of slope in opposite valley sides. By stereo-measurement cross sections could, however, easily be constructed for determination of slope values and possible asymmetrical qualities of the section.

Often active rock glaciers are clearly manifested in air photos on a scale as small as 1:30 000, both because of their surface pattern and their typical topographical situation. In one reply it is stated that there are chances also to identify collapsed or deflated rock glaciers in air photos of a scale of 1:20 000. Wind-drifted snow is reported to be able (by accumulation) to depict and enhance a surface pattern of fossil rock glaciers. If ice-cored moraines are to be included among the periglacial features, it can be mentioned that this morphological type is reported to have been identified on a scale of 1:50 000.

MICROTOPOGRAPHICAL FEATURES

In spite of their low relief, the trenches of fossil ice-wedge nets or frost--fissure polygons stand out stereoscopically in scales of 1:10 000 — 1:15 000. This holds true for areas of very sparse vegetation in northern areas, as raised deltas or beach ridges and fluvial terraces.

In areas of hard winds the microtopographical net pattern is often accentuated by the low vegetation, offered shelter and moisture in shallow polygon troughs. The pattern could also be enhanced by snow accumulation or by shadow efects in photographs taken at low sun elevation.

Shadow effects also make visible rough trenches of large-scale polygonal nets in block fields (photographic scale 1:10 000), where no fine-grained material is present to offer conditions for a vegetational outlining of the pattern.

In air photos of peat bogs in subarctic areas, groups of circular to oval contours can be observed at scales of 1:20 000. The low-relief feature represents remnants of palsas. As, however, the palsa formation is a cyclic process, the low, ring-shaped contour is more a late stage of the degeneration than a true fossil form. The features are most easily observed, when the depressions are still water-filled.

Of much the same shape, but formed in minerogenic material are the shallow depressions closed by a low flat wall and partly filled with organic material, which are interpreted as smoothed forms of collapsed pingos. They are reported to have been identified in air photos of the scale of 1:10 000 — 1:25 000. When varieties of this form occur in former glaciated areas that during the deglaciation were controlled by a periglacial climate, precautions must be taken against confusing the relief with forms of dead-ice depressions.

In their active form lobated steps represented a microtopography in slopes. Being inactive and subjected to later processes (erosion and accumulation) their original relief is now fragmentary. Considered a feature of photointerpretation, it belongs thus more to the section that follows.

„NONTOPOGRAPHICAL" FEATURES

For distinguishing objects within this category the stereoscopic view cannot be used. Instead the analysis must be concentrated on surficial contrasts and their probable spatial arrangements.

In a bare ground surface, tonal contrasts could indicate soil and/or moisture differences. In that way the existence of former sand dunes, now strongly flattened out (started by cultivation) are depicted in black and white photographs on scales of 1:20000 — 1:30000.

Observations are made that in air photos from early spring a pattern of fossil ice-wedge polygons is delineated in light gray tones in a bare, darker ground surface. The recording of the net is probably due to a higher moisture content (pore ice) in the lines than in the surrounding surfaces. The same effect could be thought to appear because of a more intense development of needle ice or hoar frost, if the infilled material of the ice wedge has a higher moisture content than the material outside. In this respect there is also a microclimatic effect to be considered.

In a quite newly ploughed field the higher moisture of the infilled material could give a delineation of the pattern because of a higher reflectivity in the polygonal lines. This has, however, only been observed in low altitude (200 m) oblique colour pictures.

Vegetation gives by far the most distinct signals of physically or chemically induced soil qualities. Thus large cryoturbation patterns and collapse structures could be traced in the ground surface (silt and clay) as a mottled pattern in arable land. The black and white photographs used were on the scale 1:10000.

In sloping ground vegetational differences are observed to compose a more or less fragmentary system of linear patterns of stripes, oriented in the direction of slope.

More often vegetation lines occur in plain surfaces (plant or crop marks of arable land), randomly spaced, branching and intersecting, giving the impression of a network of present-day ice-wedge polygons. Test diggings have shown ice-wedge cast underlaying such lines. Experiences are reported that air photos make observable ice-wedge polygons also of a surface that was covered with younger deposits. The network could strike through thin beds of fluvioglacial or wind blown sand and stands out as a fragmentary vegetation pattern.

Polygonal patterns could either be outlined by lower, sparse vegetation in the lines or by higher dense vegetation. That depends on the quality of the infilled material in relation to the matrix. The polygonal patterns usually are most distinct during dry periods.

In fields where the pattern is delineated by lower vegetation, it will easily vanish, when the crop grows higher and the vegetation surface is levelled. In fields with higher growing cereals delineating the pattern, the difference usualyl remains for the season and also induces and earlier ripening of the plants of the lines.

Long-rooted cereal crops are observed to give the most distinct delineation of fossil ice-wedge polygons, but under extremely dry conditions the pattern can stand out also in grass-covered surfaces. In areas with natural vegetation it is reported that just the grasses constitute the net, while plants with deeper root systems cover intervening surfaces underlain with coarser material.

OTHER POSSIBLE REMOTE SENSING TECHNIQUES THAN CONVENTIONAL AERIAL PHOTOGRAPHY

In some replies great expectations are advanced as to the use of high altitude photography or to satellite borne imaging systems, firstly to get an overall view, but also to depict geomorphological features. Naturally this type of pictures must be expected to be a better tool for identifying the distinct active forms than for tracing the fossil ones. The dimension of the fossil features in the ground are also to be considered in relation to the resolving power of the image. The resolution of Landsat-(ERTS)-1 and -2 MMS-images is for instance 75 m.

For detecting large forms or extensive surface patterns, e.g. fossil dunes or thermokarst morphology, however, satellite imagery (multispectral scanning) of the Landsat type seems to be adequate. Parenthetically it can be noted that Landsat pictures of thermokarst features in arctic regions are now used for comparison with Martian pictures (Mariner and Viking) to discuss the possible existence of subsurface ice in some landscape types on Mars.

Thermal mapping (infrared scanning 8—14μm) has been tried to locate fossil polygon patterns in arable land. From experiences in coastal areas of Sweden it is, however, evident that the geometric resolution in thermal imaging airborne platforms is too low to achieve a good mapping of polygonal patterns.

Ground-based equipment for thermal imaging (Thermovision) is tried to record moisture controlled thermal anomalies in vertical sections through periglacial features, e.g. ice-wedge casts.

In Russian research „electric prospecting" has been proposed to detect a complex of polygonal and thermokarst forms.

Among other airborne or ground-based non-photographic imaging systems the microwave radiometry (active and passive) could be a tool in distinguishing significant surface roughness and soil structures. For the equipment at present available for civilian use, the resolution power seems, however, to be insufficient.

COMMENTS AND RECOMMENDATIONS

Many replies informed that air photos are very useful in the study of *active* periglacial phenomena. This fact only confirms the experiences advanced at the Aberystwyth Symposium that also were the initiating reason to set up a questionnaire to survey the applicability of remote sensing even in the research of *fossil* features.

From the questionnaires it was quite clear that in the research of active forms by means of aerial photographs, quite fossil features were recognized in present periglacial areas.

If judging the received questionnaires answered as significant for the inventory, it is surprising to see the low usage of aerial photographs in the research of fossil periglacial morphology. For an objective criticism of this fact three things must be kept in mind.

Firstly: air photos are not available for all areas of interest in periglacial research.

Secondly: some periglacial phenomena are of too small dimensions to be identified or studied in air photos, even in large-scale ones.

Thirdly and very important: for the direct and detailed study of certain periglacial forms air photos cannot replace the field work. As branches of periglacial research is concentrated on the study of material and structural qualities of the phenomena, air photos are considered an inadequate tool for the research and may be of interest only to give an environmental survey of the field.

Based on the material received and experiences gained in periglacial research, the following recommendations may be advanced:

1. Air photos ought to be more frequently used in the research activity, especially for detecting fossil forms and for mapping their distribution.

2. It must be accepted that periglacial ground patterns are made fainter by fossilisation and by later surficial processes and may therefore be hard to observe immediately and to identify intuitively in air photos. A thorough examination of the air photos is necessary.

3. Air photos make possible the comparison of possible traces of fossil features with present-day true periglacial forms in order to gather indices for a conclusion on the suspect features.

4. If no traces of a ground pattern searched for are observed in the first air photo that offers, it is no proof that the pattern does not exist in the area. It is advisable to analyze more sets of photographs (different years, seasons and scales) if available.

5. If no air photos exist for an area of interest (or only exist for a ,,wrong" season) it could be recommended for reconnaissance purpose to take the photographs yourself by a hand held camera from a small aircraft.

6. By taking the air photos yourself, an optimal period could be chosen from the point of view of vegetation, soil moisture, shadow, etc. A high wing aircraft is to prefer to give the best outlook for photographing the ground.

7. For ,,home flown" oblique photographs black and white panchromatic film is generally sufficient to image clear relief forms and large-scale surface patterns.

8. If the traces of periglacial features are delineated by vegetation conventional colour film is more adequate for hand held photographing.

9. For recording patterns outlined by vegetational differences colour infrared film will give more complete information of pattern characteristics and distribution than black and white and conventional colour photography. By using colour infrared film in a hand held camera it is important to take the photographs through open windows.

10. There is no doubt that studies in periglacial geomorphology have benefited from the use of air photographs. The field of remote sensing is rapidly expanding and the activity is to be followed to try to apply improved systems or new techniques when available for civilian use to the research of fossil periglacial phenomena.

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