INTERNATIONAL GEOGRAPHICAL UNION

- - - -

SPECIAL COMMISSION ON CARTOGRAPHY

SUBCOMMISSION ON AIR PHOTO INTERPRETATION

- - - -

AIR PHOTO INTERPRETATION

OF

GLACIAL GEOMORPHOLOGICAL FEATURES

1964

INTERNATIONAL GEOGRAPHICAL UNION

SPECIAL COMMISSION ON CARTOGRAPHY
SUBCOMMISSION ON AIR PHOTO INTERPRETATION

AIR PHOTO INTERPRETATION OF GLACIAL GEOMORPHOLOGICAL FEATURES

Introduction:

Brief reports from ten different national representatives are included in the body of the main report. The time available for contacting representatives from different countries and for compiling the individual reports was hardly adequate for a thorough study. Thus the present study should be taken as preliminary in nature; both the number of countries covered and the amount of detail on each should be increased. I would like to thank all my collaborators for their kind co-operation. I have performed a minimum of editing on their reports, having tried to leave them as close to the original wording as possible. In many cases the bibliographies are not absolutely complete. This is especially true in the case of the Canadian report, but at least the bibliographic coverage will provide a representative sample and many of the references will contain their own bibliographies.

Jack Ives

J. D. Ives,
Director, Geographical Branch,
Department of Mines and Technical Surveys,
Ottawa, Canada.

INTERNATIONAL GEOGRAPHICAL UNION

SPECIAL COMMISSION ON CARTOGRAPHY
SUBCOMMISSION ON AIR PHOTO INTERPRETATION

AIR PHOTO INTERPRETATION OF

GLACIAL GEOMORPHOLOGICAL FEATURES

CONTENTS

A U S T R A L I A

Report by Edward Derbyshire
Geography Department, Monash University, Clayton, Victoria

Introduction

The renewal of interest in the Pleistocene glaciation of Australia which has become evident in the last seven years reflects the increasing availability of good quality vertical aerial photography demanded by the mapping activities of state and federal agencies.

Study of photographs has suggested that much of the work done in this field prior to 1945 is invalid: over wide areas features hitherto mapped as of glacial origin are now considered to be due to periglacial or other non-glacial agencies. Moreover, the evidence for multiple glaciation can now be accounted for as the result of one glaciation, and that of late date, for most deposits appear fresh, both on aerial photographs and in ground exposures.

The recent arrival of good quality vertical photography, coinciding as it did with an increase in the number of trained geomorphologists in Australia, has meant that work on glacial features is still in the reconnaissance stage, although detailed photo-ground correlation has been undertaken in several areas, notably in the course of geological mapping at the one inch or smaller scales in Tasmania.

The interpretation of glacial features from aerial photographs is used both as a preparation for, and as a confirmation of, field work, usually on a local scale. To date, it has been used as a regional reconnaissance tool only by Banks and Davies in Tasmania, although an extension

of this technique is now planned (see below). Interpretation has been undertaken by workers in University departments of Geography and Geology, by members of the Commonwealth Scientific and Industrial Research Organization (Division of Land Research and Regional Survey), by geologists of the Tasmanian Department of Mines, and (in unpublished reports) by the Hydro Electric Commission of Tasmania.

Work completed and in progress

1. New Guinea

Glacial geomorphological features of the Mount Wilhelm area were mapped by Reiner (1960). These included moraines, cirques, rock basins, and incipient cirques as well as periglacial features. Interpretation was by way of stereoscopic pairs at 1:40,000 scale, ground control being established so that interpretation could be extended beyond the field work area. A morphological map was constructed by tracing and reduction.

Bik has completed work on glacial features of Mt. Giluwe, Mt. Hagen and Mt. Sugarloaf in Australian New Guinea. An account is in preparation for publication. Photography at 1:30,000 scale withstood enlargement to 1:15,000 and further 4.5 x stereoscope enlargement to give a working scale of 1:3,300 with no discernible grain. Washboard moraines only a few feet high were reliably correlated.

2. Snowy Mountains, New South Wales

Galloway (1963 in press) has re-appraised earlier work on the glaciation of the Snowy Mountains, using vertical stereo pairs at scales of 1:40,000 and 1:25,000 for the determination of likely areas of former

nivation, which were then examined in the field. The presence of small snow patches at the time the photographs were taken greatly enhances their value for such purposes. The re-appraisal necessitated the examination of features purported to be glacial cirques, moraines, cols, roches moutonnées, valley steps, hanging valleys and truncated spurs.

Air photographs will be used to define key areas in a study in progress by Galloway on the relationships of nivation hollows and true glacial cirques in the Snowy Mountains.

3. Tasmania

(i) Central Plateau

Air photographs were an invaluable aid in plotting stoss and lee slopes as a guide to ice movement in a study dealing with the origin of the lakes of the western part of the central plateau (Jennings and Ahmad, 1957). This was particularly valuable in that the whole area is underlain by a single rock type (dolerite) which weathers so readily that glacial striae and erratics provided practically no field evidence of ice movement. While the few linear moraines were easily mapped, it was found impossible to map reliably the extent of the ground moraine although zones of dominant erosion and deposition were demarcated. The photographs proved of little value in determining whether lake basins were rock-bound or partially moraine-dammed. Areas of dense forest provided difficulties of interpretation for the ice-limits lay in these areas; this difficulty was accentuated by the absence of moraine ridges and the importance of periglacial effects. Vertical photographs at 1:30,000 and 1:15,000 were used in the

laboratory and in the field, the former being of better quality.

In mapping the geology of the Middlesex area, Jennings and Burns (1958) of the Tasmanian Department of Mines paid particular attention to the boundary between dolerite bedrock and drift deposits. Where a clearly defined joint pattern was evident on the photographs, such areas were designated "bedrock": areas not displaying this pattern were designated "drift". Photographs at scales of 1:23,760 and 1:31,680 were used to take advantage of variation in resolution. The boundaries were tested in the field where they needed little revision: the least satisfactory situation was where loose blocks were sufficiently numerous on the surface to obscure the joint pattern of the bedrock. Large glacial grooves were discernible on the photographs in one area.

(ii) The Great Western Tiers

This northern escarpment of the central plateau provided some special problems which have been investigated with the aid of vertical air photographs at a scale of 1:30,000. Jennings and Burns (1958) recognized ice-overflow channels notching the escarpment (often with rock glaciers below them); moraines deposited as a blanket from broad ice-cap spill-overs giving rise to an ice-abraded scarp top (these moraines blanket, or have removed, the horizontal bedrock benches so common on this scarp); frost-shattered nunatak areas and arêtes below which are spread fossil block fields; and modern periglacial fans. Major rock streams are shown on the published map.

Jennings and Sweeting (pers-comm.) note that, due to the wide-

spread occurrence of wet sclerophyll forest with patches of temperate rain forest, photo-interpretation of the deposits on the lower slopes of the Western Tiers has been found to be unreliable.

At the foot of the Western Tiers the occurrence of limestone displays some interesting karst-glacial relationships. In plotting limestone bedrock and overlying drift, the technique used in the Middlesex area was employed except that the structure used to distinguish bedrock areas was a tectonic cleavage (Burns, pers. comm.).

(iii) Cradle Mountain, Black Bluff, Tullah Areas

This area, covered by the Mackintosh map-sheet, is at present being compiled by the Tasmanian Department of Mines with the aid of vertical photographs at 1:31,680, 1:23,760 and 1:15,840. The area, which appears to have suffered ice-sheet glaciation (Burns, unpublished), is extremely rugged with many precipitous slope faces. For this reason and because of the presence of much sclerophyll forest, oblique photographs are being taken of selected locations from light aircraft, helicopters and ground stations. In mapping gorges up to 3,000 feet deep, the plateau surface, free faces and river beds are ground-mapped leaving the mapping of the intervening slopes almost entirely to air photo interpretation. Particular attention is paid to the upper limit of ice-smoothed bedrock, the lower limit of frost-shattered bedrock and the extent of periglacial block fields. The extent and nature of the drift poses difficult mapping problems common to most of Western Tasmania.

(iv) South, West and North-eastern Tasmania

Glacial features of Ben Lomond, Mt. Field, Mt. La Perouse and

the Flankland Range have been plotted by J.L. Davies, while M. R. Banks has plotted glacial phenomena for the Hartz Mountains, Adamson's Peak, Mt. Bobs, Ironbound Ranges, Federation Peak, the eastern and western Arthur Ranges, the Frankland Range, King William Range - Butler's Gorge area, and Mt. La Perouse - Pinders Peak areas, with preliminary studies on the Denison Range, Hamilton Range, Mt. Curley area and the West Coast Range. Particular attention was paid to end and lateral moraines, till plains, plucked walls, cirque walls, roches moutonnées, mammillated surfaces and drumlinoid forms. Extent and direction of ice movement, location of ice-divides and overridden divides have been inferred. Vertical photographs at scales of 1:15,840, 1:23, 760 and 1:31, 680 were used. Resolution was sufficiently good for the reliable mapping of all glacial features greater than 10 feet in diameter. Some of the conclusions drawn from this work have been summarized in two papers (Jennings and Banks 1958: Davies 1962:).

Preliminary moves are now in progress to enlarge this work. A committee has been set up and sample areas are being interpreted for purposes of categorization and correlation with a view to arriving at a set of symbols appropriate for all areas. These will then be incorporated in the proposed Glacial Map of Tasmania (scale 1:250,000) to be produced within the next 2 1/2 years under the general editorship of E. Derbyshire.

(v) The Du Cane Range and Lake St. Clair

This area is covered by 1 inch scale maps of the Tasmanian Department of Mines (McLeod et al, 1961 and Gulline et al 1963) which

show the meeting ground of the central plateau ice-sheet and the glacial system which flowed southwards from the Du Cane Range along the Lake St. Clair trough. Both maps attempt to show drift and bedrock, their differentiation being important from the engineering viewpoint. Drift-bedrock boundaries are tentative due to the thick, and often very uniform, vegetation on hillslopes. Some of the larger glacial features (such as end moraines) have been plotted and are indicated by appropriate letter-symbols.

A glacial map of the area has been produced (Derbyshire, 1963) at a scale of approximately 1:95,040 showing end moraines, drift mounds, fluted drift, ice movements deduced from erosional evidence, cirques, and probable meltwater routes. Frost-shattered crests marking probable nunataks of the last glaciation were also recognized together with two distinct sets of hillside taluses. Detail was plotted in the first instance on to maps at 1:31, 680 from 1:30,000 scale stereo pairs, field checked, revised with the aid of 1:15,000 stereo pairs, plotted at that scale on contoured maps and finally photo-reduced. In sedimentary areas lacking the usual dolerite capping, it is impossible to demarcate upper ice limits with any certainty due to the readiness with which the sandstones, in particular, weather into smooth slopes. As noted by other workers, wet sclerophyll forest and temperate rain forest render photo interpretation difficult. Areas under trees of uniform height in close stands yield little data of value, while patches of burn and stands of tall Fagus spp. further complicate the pattern. At the same time, differences in ground drainage

between end moraines and inter-morainal tracts result in thin stands of Eucalypt spp. on the former and button grass (Gymnoschoenus spp.) on the latter which greatly facilitates plotting. To some extent this is true also of areas of hummocky moraine. The alignment of degraded end moraines can be discerned on the photographs due to lines of boulders and the presence of a line of trees and shrubs within a button grass plain. Areas of blocky ablation moraine stand out due to the uneven texture yielded by small ponds within hollows in the peaty surface above which large erratics stand (Derbyshire, 1963, mimeo.).

This work is now being extended to the south and east where the plotting of moraine crests is complicated by low eminences of tree-covered dolerite bedrock adjacent to button grass plains and by some pseudo-glacial forms of probable periglacial origin. Differences in the age of end moraines suggested by field exposures is not apparent on the photographs where moraines are fresh in appearance throughout the area and consistent with a single glacial episode. (Derbyshire, 1964, in preparation).

Photographic and Map Coverage

Work on the photo-interpretation of glacial geomorphological features has been handicapped to some extent by inadequacies in the quality and coverage of both photographs and maps. The present position is here summarized by regions.

1. Australian New Guinea

Adastra photography at scales between 1:40,000 and 1:50,000 is excellent technically but is often hampered by adverse weather conditions.

Coverage of likely areas of Pleistocene glacial and periglacial activity still has some large gaps. The production of photogrammetric maps lags far behind the available photography. Some photo-mosaics are available.

2. Snowy Mountains

Good quality prints are available at a scale of 1:40,000 of all the glaciated country, and other photography is available at 1:25,000 scale. It is proposed to re-photograph the whole area during 1964. This area is covered by contour maps at the 1:63,360 scale and at a variety of scales on photogrammetric maps of the Snowy Mountains Authority.

3. Tasmania

The whole island is covered by prints of only fair quality at a scale of about 1:15,000 produced in the period 1946 - 1953. Occasionally overlap between the photographs is insufficient for the use of the slotted template technique. Gaps between runs also occur in places. A new series of photographs at the 1:125,000 scale is now in hand and about one half of the island is covered. This coverage, which is of much better quality, includes all the glaciated area. Map coverage tends to follow this new photography series and about one third of the island is mapped at a scale of 1:31,680, including a large area of glaciated country. In the past, work in glacial geomorphology has been hampered by lack of contoured maps in parts of the central plateau, the Ben Lomond massif, the Hartz Mountains and large areas of the south and west. However, this deficiency is now largely being filled by the issue of provisional photogrammetric maps at the 1:63,360 scale and the availability of dyeline prints of much of the

glaciated country at scales of 1:63,360, 1:31,680, and (for more restricted areas) 1:15,840.

4. Australian Antarctic Territory

Photo-coverage of the whole of the coastal region (except for that area between Davies and Mirnyy) and for a broad sub-meridional zone in western Mac-Robertson Land was completed by the end of 1962. Small areas only have been photographed with RC9 cameras, the bulk of the photography being trimetrogon (K17 camera) at a scale of 1:20,000. Quality varies from good to poor, cloud cover and icing of camera ports largely accounting for the latter condition. The same broad zone has been mapped at the one million and 1:500,000 scales, and sixteen sheets at 1:100,000 scale have been compiled for the area west and south of Mawson. This is a planimetric series however, available in compilation form only. The only contour maps available for sale are those for the Vestfold Hills (1:100,000) and Simpson Peak (1:250,000).

There is no vertical photo coverage of Macquarie Island, although generally poor quality oblique prints are available for the coastline and for selected inland locations. Consistent cloudy weather is largely to blame for this unfortunate deficiency. Complete vertical coverage would be of great value in resolving the present divergence of views on the glacial history of this small sub-antarctic island.

Techniques and Methodology

Geomorphologists in Australia have shown little tendency to experiment with techniques and problems have been approached from the

regional rather than the phenomenalogical viewpoint. This is undoubtedly a reflection of the small number of geomorphologists in this field in Australia, and the fact that so little is known about the nature of the Pleistocene glaciation, that work in progress is still very largely (and quite appropriately) of a reconnaissance type.

The need to show drift cover on the 1:63,360 series geological maps of Tasmania has led to the incorporation of symbols denoting distinctive glacial landforms such as the more obvious end and and marginal moraines. As mapping proceeds into the more severely glaciated areas this practice is likely to give way to more sophisticated mapping techniques. It seems probable that separate "drift editions" compiled in consultation with trained photo-interpretars of glacial phenomena will be demanded.

Work in Key Areas

The elucidation of the glacial history of Tasmania will shed light upon the Pleistocene sequence in southeastern Australia as a whole. From this point of view, the glaciated portions of Tasmania merit close study and the recent renewal of interest in it, therefore, is commendable.

Tasmania is an island of high climatological gradients, precipitation and insolation varying in such a way that the climatic snowline declines rapidly from northeast to southwest. Air photo interpretation reveals that the lowest areas of ice accumulation occur in the southwest of the island (Davies, pers. comm.). Marked asymmetry of the ice-masses has been reported in the west centre (Jennings and Ahmad, 1957; Derbyshire, 1963) while ice developed in the northeast only where uplands

were high enough to yield sufficient cloud and precipitation and where summits were sufficiently large to form collecting grounds. It is difficult to single out key areas: the range of conditions is so wide in Tasmania that each glaciated district tends to display relationships special to itself. However, the southwest and the northwest centre may prove critical.

Outstanding areas demanding ground control are:-

1. The Frankland Range
2. Federation Peak and the Arthur Ranges
3. Mt. La Perouse
4. Hartz Mountains (work will begin in 1964 - Derbyshire)
5. Ben Lomond

These areas promise to shed considerable light on the nature and sequence of the final deglaciation and data on Pleistocene snowlines. Moraines are very clear and erosional forms very fresh.

Key areas in process of re-examination are:-

1. Du Cane Range - Lake St. Clair - Southeastern edge of the central plateau.
2. Cradle Mountain area - Mersey and Forth gorges.

These two major centres of ice outflow appear key areas in the search for evidence of multiple glaciation. They also display a rapid transition from upper glaciated valleys to lower glacierized gorges, and a wide variety of erosional and depositional forms.

Paradoxically, it is the area most likely to yield valuable results in photo-interpretation of glacial features that has received the

least attention. Despite the availability of suitable photography of large areas of the Australian Antarctic Territory, photo-geomorphology has been neglected except as an ancillary study in work on the regional geology. The photographs are housed in Melbourne and await a glacial geomorphologist able to give them his full-time attention should he be given the opportunity for ground control studies on the Antarctic mainland.

Bibliography

DAVIES, J. L.

1962 : "Geomorphology and Glaciation" in "The Geology of Tasmania", Jour. Geol. Soc. Australia, v. 9, part 2 107 - 362.

DERBYSHIRE, E.

1963 : "Glaciation of the Lake St. Clair District, West - Central Tasmania", Austr. Geogr., v. 9, No. 2 97 - 110

1963 : mimeo. "Selected Aerial Photographs of Central Tasmania" 16 pp.

1964 : "A Map of Moraines of the Southeastern Lobe of the St. Clair Glacier, Tasmania", in preparation

GALLOWAY, R. W.

1963 : in press. "Glaciation in the Snowy Mountains : a Re-appraisal", Proc. Linn. Soc. N.S.W.

GULLINE, A. B. et al.

1963 : "St. Clair", Sheet 59, 1-Mile Series, Geological Atlas of Tasmania.

JENNINGS, I. B. and K. L. BURNS

1958 : "Middlesex", Sheet 45, 1-Mile Series. Geological Atlas of Tasmania.

JENNINGS, J. N. and N. AHMAD

1957 : "The Legacy of an Ice Cap", Austr. Geogr., v. 2, No. 2, 62-75.

JENNINGS, J. N. and M. R. BANKS

1958 : "The Pleistocene Glacial History of Tasmania", Jour. Glaciol., v. 3, No. 24, 298-303.

McLEOD, W., et al.

1961 : "Du Cane", Sheet 52. 1-Mile series. Geological Atlas of Tasmania.

REINER, E.

1960 : "The Glaciation of Mount Wilhelm, Australian New Guinea", Geogr. Rev., v.50, No. 4, 491-503.

B E L G I U M

Report by Dr. A. Pissart
University of Louvain

Bien que la question ait parfois été controversée, il n'existe en Belgique aucunes formes glaciarires car l'Islandais nord européen s'est arrêté avant d'atteindre notre pays et nos sommets (700 m) étaient trop peu élevés pour déterminer l'apparition d'un glacier local. Par contre, les conditions climatiques trés rigoureuses qui ont existé au cours des périodes froides du Quaternaire ont déterminé l'apparition de formes périglaciaires dont l'importance dans la morphologie est considérable quoique toujours difficile à apprécier.

L'emploi de photographies aériennes dans l'étude de cette morphologie périglaciaire est chose courante, du moins en Haute Belgique. Ces documents fournissent en effet une image du relief beaucoup plus détaillée que celle donnée par les cartes topographiques; elles sont utiles pour localiser les coupes à étudier sur le terrain et permettent parfois de suivre un microrelief ou une structure superficielle non apparente au sol.

Les photos aériennes servent donc essentiellement à préparer le travail de terrain. En Belgique, où vu l'exiguité du territoire, le stade de la reconnaissance est depuis longtemps dépassé et où les études sont toujours des recherches poussées, elles constituent le plus souvent une approche extrêmement aisée des problèmes, permettant de diminuer considérablement le temps consacré à l'étude sur le terrain. Il en est

ainsi pour l'étude des aplanissements partiels quaternaires façonnés sous l'influence de la cryergie, pour celle des terrasses considérées le plus souvent ici comme des formes climatiques d'origine périglaciaire, pour les vallons à fond plat, la reconstitution de dunes continentales anciennes, l'analyse des vallées asymétriques, etc...

Dans deux cas de recherche périglaciaire, l'examen des photos aériennes est à l'origine de l'étude elle-même. C'est en effet sur ces documents que nous avons découvert les cicatrices de "pingos" du plateau des Hautes Fagnes. Ces traces peu élevées, réparties sur un plateau très calme, tourbeaux en bien des endroits, sont en effet souvent peu visibles du sol. Les photos aériennes, par contre, les montrent avec une clarté remarquable à cause des différences de végétation et d'humidité et indiquent leur caractére d'enceinte circulaire. Les replats périglaciaires du Pays de Galles que nous avons étudiés récemment ont également été observés pour la première fois sur photos aériennes et c'est également de cette manière que leur répartition et certains de leurs caractères ont été reconnus.

Plusieurs couvertures aériennes complètes de notre pays ont été réalisées. Certaines sont excellentes et constitueraient des outils de travail de grande valeur, s'il était possible de se les procurer aisément. Malheureusement, l'achat de chaque photo nécessite une autorisation du Ministére de la Défense Nationale qui a trop fréquemment, jusqu'ici opposé son veto. Malgré cet obstacle, les géographes belges sont conscients de l'utilité de cet outil de travail qu'ils emploient de plus en plus.

Bibliographie

ALEXANDRE, J. -

1957 : Les terrasses des bassins supérieurs de l'Ourthe et de la Lesse. Ann. Soc. Géol. Belg., T.80, p. 317 à 332.

1958 : Le modelé quaternaire de l'Ardenne Centrale. Mém. Soc. Géol. Belg., T.81, p. M 213 à M331.

BEGHIN, H.,

1960 : Vallon à fond plat et à forte pente longitudinale. Ann. Soc. Géol. Belg., T. 83, p. 285 à 297.

CHAPELIER, A.

1957 : Nouvelles observations sur les niveaux de terrasse de la Vesdre. Ann. Soc. Géol. Belg., T. 80, p. 379à 394.

CLAIRBOIS, A. M.,

1959 : L'évolution de la Meuse entre Liège et Anseremme au cours du Quaternaire. Ann. Soc. Géol. Belg., T. 82. p. B 213 à 233.

EK, C.,

1957 : Les terrasses de l'Ourthe et de l'Amblève inférieures. Ann. Soc. Géol. Belg., T.80, p. 333 à 353.

GULLENTOPS, F.,

1957 : Quelques phénomènes géomorphologiques depuis le Pleni-Wurm. Bull. Soc. Belge Géol., T.66, p. 86 à. 95.

HUFTY, A.,

1958 : Formes quaternaires dans le bassin de la Semois Jurassique. Ann. Soc. Géol. Belg., T.81, p. B 441-455.

MACAR, P.,

1957 : Résultats d'ensemble d'études récentes sur les terrasses fluviales et les formes d'érosion associées en Haute Belgique. Ann. Soc. Géol. Belg., T.80, p. 395 à 412.

PISSART, A.,

1961 : Les terrasses de la Meuse et de la Semois-La capture de la Meuse lorraine par la Meuse de Dinant. Ann. Soc., Géol. Belg., T. 84, p. 1-108.

1956 : L'origine périglaciaire des viviers des Hautes Fagnes. Ann. Soc. Géol. Belg., T.79, p 119 à 131.

PISSART, A.,

1963 : Les traces de "pingos" du Pays de Galles (Grande Bretagne) et du plateau des Hautes Fagnes (Belgique). Zeitschrift für Geomorphologie, - Band 7, Heft 2, S. 147 - 165.

1963 : Les replats de cryoturbation du Pays de Galles. C.R. Somm. Acad. Sciences, T. 256, p. 222-224.

SERET, G.,

1957 : Les terrasses et les formes associées dans le bassin de la Lesse inférieure. Ann. Soc. Géol., Belg., T.80, p. 355 à 378.

C A N A D A

Report by Dr. J. D. Ives
Director, Geographical Branch
Department of Mines and Technical Surveys

Introduction

Canada, on account of its vast size and the difficulty of access of much of its territory, has presented a special challenge to cartographers, topographical engineers, geologists and geographers. The challenge was taken up initially in the inter-war years with the development of aerial surveying techniques. The apparent impossibility of ever completing the task of mapping the country, both topographically and geologically, forced Canadian workers into using all available resources. One of the greatest of these resources was the air photograph. Today practically the entire country is covered by vertical photography at scales varying between 1:40,000 and 1:60,000 and the earlier trimetrogen coverage continues to serve as a useful supplement.

The national program of reconnaissance topographic mapping at a scale of 1:250,000 is well advanced. Proceeding hand-in -hand with this is the reconnaissance bedrock geological mapping program; this involves extensive air photograph interpretation and widespread helicopter-supported field reconnaissance.

For the geographer Canada has presented a three-fold challenge. Added to size and inaccessibility is the extreme youthfulness of the country's geographical institutions, the small number of physical geographers availability, and their predominantly European origin. The

immigrant geographer, trained frequently in densely populated European countries has been brought up on the 1:50,000 scale map. Tremendous readjustment to the Canadian scene has been necessary. Dr. F. K. Hare, then of McGill University, early took up the cry for reconnaissance geographical mapping on an extensive scale with dependency on the air photograph. Hare's group completed a study of the glacial features of Labrador-Ungava (Hare, 1955; 1959). Working concurrently, Dr. J. T. Wilson of the Toronto University, Department of Geophysics, initiated the air photograph mapping of glacial features which led to the publication of the "Glacial Map of Canada" in 1958. These two projects represent the first major Canadian achievements in the application of air photograph interpretation techniques to the study of glacial geomorphology. Only limited field checks were possible and much of the work did not even entail stereoscopic examination of the photographs. Only the grosser features were plotted, using topographic maps at a scale of 1:500,000 as a plotting base. The simplification in reduction to this base scale, and in the further reduction to the publishing scale, throws a serious limitation on the value of the end products. Extensive systems of end moraines, glacial lake shorelines, raised marine shore features, etc., were often omitted. Important diagnostic features, such as glacial meltwater channels, could not be included in the legend at all. Much misinterpretation is evident.

It is stressed, however, that the two projects were enormous pioneer endeavours and they have been invaluable in providing a base from

which most other work has developed. Numerous other projects have been initiated as a direct, or indirect, result of this work. The responsible agencies working in this field are primarily the Geographical Branch and the Pleistocene Section of the Geological Survey of Canada, both of the Department of Mines and Technical Surveys, Ottawa, and several of the provincial Research Councils (notably those of Alberta and Saskatchewan). Many university geography and geology departments have also contributed, but principally the Geography Departments of McGill, Toronto and of the University of British Columbia.

The air photograph has become the indispensable tool of the physical geographer, and no field work is contemplated without prior scrutiny of the available coverage. The problem of vast area continues to place serious limitations on the glacial geomorphologist, however, and much of the earlier work of the Geographical Branch for instance suffered severely from the geographer succumbing to the natural tendency to examine too many photographs too quickly. This is perhaps pardonable when major end moraine systems up to 600 kms. in length are still being discovered in the northlands (Ives and Andrews, 1963; Blake 1963).

Canadian work in this field will be broken down into specific areas.

1. <u>Labrador-Ungava</u>:

The initial major work is that cited above (Hare, 1955, 1959) and carried out through the initiative of McGill University Geography

Department with support from the Arctic Institute of North America and the Geographical Branch. It was a multi-purpose project with air photograph interpretation of glacial geomorphological features being only one of the major objectives. The final map produced in colour at the scale of 1:4 Million is basically a map of the physiographic divisions of the peninsula. However, it includes many glacial landforms such as:

glacially-moulded hilly terrain
undifferentiated drift-plains
drumlinized or fluted drift-plains
rippled till-plains
eskers
sand plains
linear ridges (origin undetermined)

(many of the "linear ridges" are, in fact, moraines of the De Geer type- cf. Hoppe, 1952; Lee, 1962).

That section of the "Glacial Map of Canada" covering the peninsula is in part a repeat of Hare's work, although the two legends have several differences and the one is a gratifying corroboration of the other in the overall accuracy of the gross outline. Particularly important is the portrayal of the peninsula-wide pattern of eskers and drumlins.

Hare's group resorted to a reasonable minimum of field checking to obtain ground control of representative areas. Since completion of the work the McGill Geography Department set up a field research laboratory in the centre of the peninsula. This has facilitated the formulation of a

co-ordinated field research program involving the detailed investigation of numerous selected critical areas. To date the program has seen the production of a dozen Masters' and Doctoral theses and numerous published papers (Andrews, 1963; Barnett and Peterson, 1964; Derbyshire, 1958, 1962; Ives, 1956, 1959 a and b, 1960 a, b and c; Løken, 1962; to quote a few). Systematic mapping of the distribution and direction of slope of glacial drainage channels, major systems of glacial lake shorelines, end moraine systems and raised marine shore features has ensued during photograph interpretation and field investigation in representative areas ranging from the Torngat Mountains in the extreme northeast, to the central tracts between Schefferville, Labrador City and Grand Falls, to the Wolstenholme - Sugluk area of the northwest. An initial picture of the progressive deglacierization and changing palaeogeography over the past 20,000 years has emerged. Ultimate compilation of these individual studies is planned as a joint venture by the Geographical Branch and the McGill Geography Department, and should result in a glacial map showing major differences to, and advances on, the existing Glacial Map of Canada.

2. Baffin Island

Since 1961 Baffin Island has been the major objective of Geographical Branch research in physical geography, with emphasis being placed upon glacial geomorphology and glaciology. To date two-thirds of the island has been covered by reconnaissance air photograph interpretation; maps of the extent of present-day glaciers and recent moraines have been

prepared for the northeastern section (Falconer, 1963) and detailed field and photograph interpretation studies are well underway in the north-central tract, including the Barnes Ice Cap (Andrews, 1963 a and b, 1964; Ives and Andrews, 1963; Ives, 1963, 1964). The joint paper by Ives and Andrews includes two multi-coloured maps of an experimental nature at scales of 1:500,000 and 1:250,000. These show glacio-morphological and glacial features. Ultimate production of a 1:1 Million series of maps of glacial features is planned for the entire island. Of the more significant features plotted from the air photographs of Baffin Island is the Cockburn moraine system which has been shown to extend for a distance of more than 600 kms roughly parallel to the heads of the Baffin Bay fiords. Large sections of moraine have been traced westwards to the base of Brodeur Peninsula, down the west coast of Melville Peninsula and westwards along the mainland for several hundred kilometres to Bathurst Inlet. This aspect of the study has not yet been published and the chronological relationship of the different stretches of end moraine remains to be established.

3. Queen Elizabeth Islands

Scattered studies involving air photograph interpretation of glacial features have been undertaken throughout this high arctic section. Most extensive and notable is the work of J. G. Fyles and B Craig (1960) of the Pleistocene Section of the Geological Survey of Canada. This work has involved systematic reconnaissance mapping of glacial features and Pleistocene deposits. G. Hattersley-Smith of the Defence Research

Board, and his colleagues have undertaken extensive field studies in northern Ellesmere Island involving glaciology and glacial geomorphology (Hattersley-Smith, 1961), while the Geographical Branch has concentrated on the mapping of the periglacial morphology of this area (Robitaille, 1960; St-Onge, 1964; Cook and Raiche, 1962). The Jacobsen-McGill Axel Heiberg Expedition under the scientific leadership of F. Müller has made a major contribution to glacier mapping through the production of a group of very detailed maps involving special air photography and photogrammetry (Blachut, et alia, 1963).

4. The Islands South of Parry Channel

Extensive reconnaissance studies have been carried out by both the Geographical Branch and the Pleistocene Section of the Geological Survey of Canada (Fraser and Henoch, 1959; Craig and Fyles, 1960). Of the most important studies are those of Fyles covering Banks and Victoria Islands (Fyles, 1962, 1963). The latter work includes a multi-coloured map of glacial features prepared from field work and air photograph interpretation.

5. Keewatin and the north-central mainland

Extensive helicopter-supported field study of the Pleistocene deposits has been undertaken by the Geological Survey of Canada and the publication of a series of preliminary maps of the surficial geology has involved much use of the available air photographs. This work has led to the delimitation of the late-Wisconsin Keewatin ice divide and a good reconnaissance knowledge of the major area (Craig and Fyles, 1960;

Craig, 1960, 1961; Lee, 1959; Blake, 1963). Additional work has been completed for the Geographical Branch by Bird (1953), Bird and Bird (1961); Mackay (1958); Sim (1960); Fraser (1964).

6. Mackenzie Delta and lower river

Work in the Mackenzie Delta area for the Geographical Branch has been carried out by Mackay over the past ten years. This has involved detailed field studies and air photograph interpretatin of many aspects of the physical geography. Special attention has been paid to the distribution and mode of formation of pingos as well as glacial landforms, ground ice sheets and glacio-fluvial channels. Several other members of the staff have assisted (e.g., Henoch, 1960), and the major compilation by Mackay includes a full bibliography (Mackay, 1963).

7. British Columbia and the Rocky Mountains

Much scattered work has been done throughout this area, especially on a reconnaissance scale; but use of air photographs has been incidental and there has been a cencentration on detailed glacier studies in the field. Attention is drawn to the work of Armstrong and Tipper (1948).

8. Southern Canada

This represents an extremely large area and cannot be covered adequately in a short report. Outstanding work has been done by the Alberta Research Council under the guidance of Gravenor (1956, Gravenor and Meneley, 1958), in the Alberta section of the Prairies, and by the Geological Survey of Canada throughout the general area (Lawrence and

Elson, 1953; Stalker, 1960). Independent work in southern Ontario has stemmed from the Geography Department of Toronto University (Chapman and Putnam, 1949; Dean, 1956), although the greatest amount of work has been associated with ground water studies and the mapping of surficial deposits by the federal and provincial government agencies.

The Saskatchewan Department of Highways has supported an extensive study of glacial landforms covering 48 map sheets at a scale of 1:50,000. Extensive use was made of air photography and the work is presently in the form of an unpublished Master's thesis prepared for Cornell University by E. K. Sauer.

9. Canada as a whole

The single major work covering the entire country is the Glacial Map of Canada inspired and directed by J. T. Wilson and published by the Geological Association of Canada in 1958. This has already been discussed as far as concerns its relationship with F. K. Hare's work in Labrador-Ungava (Hare, 1959). The Glacial Map covers practically the entire country; in addition it contains an inset showing a drift map of a large proportion of the country.

Since its publication a great amount of additional work has been completed and better vertical photograph coverage for large areas has become available. Thus in eight short years there is already a pressing need for a new edition or total revision of the existing map. From the writer's personal experience it can be stated with confidence that the whole of Labrador-Ungava and most of the eastern Canadian Arctic, if

covered with a revised map would show a pattern scarcely recognizable in its wealth of detail on the existing map. And it should be pointed out that this area is practically equal to that of Western Europe.

Additional work covering extensive areas includes a series of reports produced for limited circulation. These are the mimeographed reports of the United States Research and Development Corporation (Rand) prepared under the direction of J. B. Bird of the McGill University Geography Department. They cover Baffin Island and most of the arctic mainland west of Foxe Basin and Hudson Bay (Rand, 1962, 1963).

10. General Comments

As already implied in the introduction and body of the report, much of the air photograph interpretation of glacial features in Canada has been of a reconnaissance nature. And a large volume of the work has not even involved stereoscopic examination. In a few cases more than casual use has been made of the photographs. In one instance an attempt was made by use of a parallax bar to differentiate between systems of glacial lake shorelines (Ives, 1960 a) and the success of this has since been shown by Barnett and Peterson (1964). Andrews has relied upon vertical photographs in north-central Baffin Island to make statistical analyses of the horizontal spacing of the cross-valley moraine systems (Andrews, 1963 a and b.) However, the wealth of detail contained in the National Air Photo Library situated in Ottawa has scarcely begun to be tapped.

Perhaps the next vital step will be a total revision of the existing Glacial Map of Canada. This could best be done by just completing more detailed stereoscopic studies with more extensive field checks of specific areas. Examples of such studies already completed or well underway are Baffin Island (Ives and Andrews, 1963), Victoria and Banks Islands (Fyles, 1962, 1963) and large tracts of Labrador-Ungava. Extension of this work and ultimate compilation of the individual maps would probably be the most constructive and reliable method of revising the existing national map. For this objective to be reached in a reasonable length of time collaboration on a national scale will be necessary.

Bibliography

ANDREWS, J. T.,

1963 (a) "Cross-valley moraines of the Rimrock and Isortoq River valley, Baffin Island, N.W.T., A descriptive analysis." Geog. Bull., No. 19, pp. 49 - 77, Geog. Branch Ottawa.

(b) The cross-valley moraines of north-central Baffin Island: a quantitative analysis. Geog. Bull., No. 20, pp. 82 - 129, Geog. Branch, Ottawa.

(c) End moraines and late-glacial chronology in the Northern Nain-Okak section of the Labrador coast. Geogr. Annaler, Vol. XLV. No. 2-3, pp. 158 - 171.

1964 : Lichenometrical study of the northwestern margin of the Barnes Ice Cap: A geomorphological technique. Geog. Bull., No. 22, IN PRESS.

ANDREWS, J. T. and E. M. MATTHEW,

1960 : Geomorphological studies in northeastern Labrador-Ungava. Geog. Branch Paper No. 29, 29 p. Ottawa.

ARMSTRONG, J. E. and TIPPER, H. W.,

1948 : Glaciation in North Central British Columbia (Dept. of Mines and Resources). Am. Jour. Sci., Vol. 246, No. 5, pp. 283 - 310.

BARNETT, D. M. and PETERSON, J.,

1964 : The significance of Glacial Lake Naskaupi 2 in the deglaciation of Labrador-Ungava. Paper read at 1964 annual meeting of the Canadian Association of Geographers.

BIRD, J. B.,

1953 : The glaciation of Central Keewatin, Northwest Territories, Canada. Am. Jour. Sci., Vol. 251, No. 3, pp. 215 - 230. (McGill).

1955 : Terrain conditions in the Central Canadian Arctic. Geog. Bull., No. 7, pp. 1 - 16, Geog. Branch, Ottawa.

BIRD, J. B., and BIRD, M. B.,

1961 : "Bathurst Inlet, Northwest Territories. Geog. Branch, Memoir 7, 66 p., Ottawa.

BLACKADAR, R. G.,

1958 : Patterns resulting from glacier movements north of Foxe Basin, N.W.T. Arctic, Vol. 11, No. 3, pp. 156 - 165.

BLACHUT, T.J., HAUMANN, D., McKORTEL, T.A., and MULLER, Fritz
1963 : Photogrammetric and cartographic results of the Axel Heiberg Expedition. Canadian Surveyor, Vol. 17, No. 2, pp. 79-122. (with three special glacier maps)

BLAKE, Weston Jr.,
1956 : Landforms and topography of the Lake Melville Area, Labrador, Newfoundland. Geog. Bull. No.9, pp. 75-100. (McGill) (DRB project 1952/3)

1963 : "Notes on glacial geology, northeastern District of Mackenzie", Geol. Surv. Can., Paper 63-28, 12p, Ottawa.

BOSTOCK, H.S.,
1948 : Physiography of the Canadian Cordillera, with special reference to the area north of the Fifty-fifth parallel. Geol. Surv. Can., Memoir No.247, 106p. Ottawa.

CHAPMAN, L.J. and D.F. PUTNAM,
1949 : The Recession of the Wisconsin Glacier in Southern Ontario. Trans. Roy. Soc. Can., Vol. XLIII Ser.3, Sec. IV,23-52.

COOK, F.A., and RAICHE, V.G.,
1962 : Simple Transverse nivation hollows at Resolute, N. W. T. Geog. Bull., No. 18, pp. 79-85, Geog. Br., Ottawa.

CRAIG, B.G.,
1960 : Surficial Geology of north-central District of Mackenzie, Northwest Territories. Geol. Surv. Can. Paper 60-18, 8 p., Ottawa.

1961 : Surficial geology of northern District of Keewatin, Northwest Territories. Geol. Surv. Can. Paper 61-5, 8 p., Ottawa.

CRAIG, B.G. and FYLES, J.C.,
1960 : Pleistocene Geology of Arctic Canada, Geol. Surv. Can., Paper 60-10, 21 p., Ottawa.

DEAN, W.G.,
1953 : The Drumlinoid Landforms of the "Barren Grounds", N. W. T., Can. Geog. No. 3, pp. 19-30. (United Coll. Winnipeg).

1956 : Glacial Features of the Hearst-Cochrane Map Sheet area. An aerial photograph reconnaissance, Can. Geog. No.8, pp. 35-45. (Univ. of Toronto).

DERBYSHIRE, E.,
1958 : "The identification and classification of glacial drainage channels from aerial photographs." Geog. Annaler, Vol.60, Ht. 3-4, pp. 188-195.

1962 : "Fluvioglacial erosion near Knob Lake, central Quebec-Labrador, Canada." Bull. Geol. Soc. Am., Vol. 73, pp. 1111 - 1126.

DOUGLAS, Mary C.V. and R.N. DRUMMOND
1953 : Glacial features of Ungava from air photographs. Trans. Roy. Soc. Can., Vol. XLVII Ser. III, pp. 11-16 (McGill Univ.)

1955 : Map of Physiographic Region of Ungava-Labrador. Can. Geog., No.5, pp.9-16. (Arctic Inst. of N. America).

DOWNIE, M.J., EVANS, A.G. and WILSON, J.T.
1953 : Glacial features between the Mackenzie River and Hudson Bay plotted from air photographs. Bull. Geol Soc. Am., V.64, No. 12, pp. 1413-1414. (abst. only).

DRUMMOND, R.N. and M.C.V. DOUGLAS
1953 : Glacial landforms of Quebec-Labrador, as seen from air photos. Paper given to the Geol. Soc. of America, Toronto.

DOWNIE, M.J., EVANS, A.G., WILSON, J.T.
1953 : Glacial features between the Mackenzie River and Hudson Bay plotted from air photographs. Bull. Geol. Soc. Amer., Vol. 64, No. 12, pt.2.pp. 1413-14 (abst.).

DUNBAR, M. and GREENAWAY, Keith R.,
1956 : Arctic Canada from the Air, 541 p. Defence Res. Bd., Ottawa.

FALCONER, George
1963 : Glaciers of Northern Baffin and Bylot Islands. Geog. Branch Paper, No. 33, 31 p., Geog. Branch, Ottawa.

FORTIER, Y.O.,
1948 : Flights in 1947 over the region of the north Magnetic Pole and the mainland between the Arctic coast, Great Slave Lake and Hudson Bay, Northwest Territories. Geol. Surv. Can., Paper 48-23, 11 p., Ottawa.

FRASER, J.K.,
1958 : Physiographic Regions of Boothia Isthmus, N. W. T., Geog. Bull., No. 12, pp. 19-37, Geog. Branch, Ottawa.

FRASER, J. K. and W. E. S. HENOCH
1959 : Notes on the Glaciation of King William Island and Adelaide Peninsula, N.W.T., Geog. Branch Paper No. 22, 39 p., Ottawa.

FRASER, J. K.,
1964 : The physiography of Boothia Peninsula, Northwest Territories: A study in terrain analysis and air photo interpretation of an arctic area. Unpub. Ph.D. thesis, presented to Clark University, May, 1964, 260 p.

FYLES, J. G.,
1963 : Surficial Geology of Victoria and Stefansson Islands, District of Franklin. Geol. Surv. Can., Bull. 101, 38 p., Ottawa.

1962 : IN Thorsteinsson, R., and Tozer, E. T., "Banks, Victoria and Stefansson Islands, Arctic Archipelago," Geol. Surv. Can., Memoir 330, pp. 8 - 17, Ottawa.

GEOLOGICAL ASSOCIATION OF CANADA
1958 : Glacial Map of Canada. Ed. J. T. Wilson et alia.

GRAVENOR, C. P.,
1956 : Air photographs of the Plains region of Alberta. Research Council of Alberta, Prelim. Report 56 - 5. 32 p.

GRAVENOR, C. P. and MENELEY, W. A.
1958 : Glacial flutings in Central and Northern Alberta. Am. Jour. Sci., Vol. 256, 715 - 728.

HARE, F. K.,
1955 : Mapping of Physiography and Vegetation in Labrador-Ungava. A review of reconnaissance methods. (McGill Univ.) Can. Geog. No. 5, pp. 17 - 28.

1959 : A photo reconnaissance survey of Labrador-Ungava, Geog. Branch Memoir 6, 83 p., Ottawa.

HATTERSLEY-SMITH, G.,
1961 : Geomorphological studies in Northwestern Ellesmere Island. 19 pp. Def. Res. Bd. D. Phys. R (G), Report No. Misc. G-5, Ottawa.

HAUMANN, Dieter,
1960 : Photogrammetric and Glaciological Studies of Salmon Glacier, Arctic, Vol. 13, No. 2, pp. 75 - 110. (N.R.C. Ottawa.)

HENDERSON, E. P.
1959 : A Glacial Study of Central Quebec-Labrador. Geol. Surv. Can., Bull. 50. 93 p., Ottawa.

HENOCH, W. E. S.,
1960 : Fluvio-morphological features of the Peel and lower Mackenzie rivers. Geog. Bull., No. 15, pp. 31 - 45, Geog. Br., Ottawa.

HILLS, T. L.,
1963 : Topographical Map and Air Photograph Interpretation. Can. Assoc. Geog., Ed. Comm. Bull. No. 4, 19 p.

HOPPE, Gunnar,
1952 : Hummocky moraine regions, with special reference to the interior of Norrbotten. Geog. Annaler, Vol. 34, Ht. 1 - 2, pp. 1 - 72.

IVES, J. D.,
1956 : "Till Patterns in Central Labrador", Can. Geog. No. 8, pp. 25 - 33. (McGill).

1959a : "Glacial geomorphology of the Torngat Mountains, northern Labrador", Geog. Bull., No. 12, pp. 47 - 75. Geog. Branch, Ottawa.

b : "Glacial drainage channels as indicators of late-glacial conditions in Labrador-Ungava: A discussion." Cahiers de Géog. de Qué., 3ième Ann., No. 5, pp. 57 - 72.

1960 (a) Former ice-dammed lakes and the deglaciation of the middle reaches of the George River, Labrador-Ungava. Geog. Bull., No. 14, 44 - 70. (McGill Subarctic Res. Lab.), Geog. Branch, Ottawa.

(b) "Glaciation and deglaciation of the Helluva Lake area, central Labrador-Ungava". Geog. Bull. No. 15, pp. 46 -64, Geog. Branch, Ottawa.

(c) The deglaciation of Labrador-Ungava - an outline. Cahiers de Géog. Qué. No. 8, pp. 323 - 343. (McGill Subarctic Res. Lab.).

1962 : Indications of recent extensive glacierization in north-central Baffin Island. J. Glaciol. Vol. 4, No. 32. pp. 197 - 205.

1963 : Determination of the Marine Limit in Eastern Arctic Canada. Geog. Bull. No. 19, pp. 117 - 124, Geog. Branch, Ottawa.

IVES, J. D. and ANDREWS, J. T.
1963 : Studies in the Physical Geography of North-Central Baffin Island, N.W.T., Geog. Bull., No. 19, pp. 5 - 48, Geog. Branch, Ottawa.

IVES, J. D. and KIRBY, R. P.,
1964 : Fluvioglacial erosion near Knob Lake, central Quebec-Labrador, Canada: A discussion with an illustration from Baffin Island. Bull. Geol. Soc. Am., (IN PRESS)

IVES, J. D.,
1964 : Deglaciation and land emergence in northeastern Foxe Basin, N.W.T., Geog. Bull., No. 21, pp. 54 - 65, Geog. Branch, Ottawa.

JENNESS, J. L.,
1952 : Problem of Glaciation in the western islands of Arctic Canada. Bull. Geol. Soc. Amer., Vol. 63, No. 9, pp. 939 - 952.

KIRBY, R. P.,
1961 : Movements of ice in central Labrador-Ungava. Cahiers de Geog. de Que., Vol. V., No. 10, pp. 3 - 16.

KRETZ, R.,
1960 : Geological observations in northern New Quebec. Geol. Surv. Can., Paper 60 - 12, 17 p., Ottawa.

LAWRENCE, D. B., and ELSON, J. A.,
1953 : Periodicity of deglaciation in North America since the late Wisconsin Maximum. Geog. Annaler, Vol. 35, Ht. 2, pp. 83 - 104.

LEE, H. A.,
1959 : Surficial geology of southern District of Keewatin and the Keewatin ice divide. Geol. Surv. Can., Bull 51, Ottawa.

1962 : Method of deglaciation, age of submergence, and rate of uplift west and east of Hudson Bay. Bulletyn Peryglacjalny, No. 11, pp. 239 - 245.

LØKEN, O. H.,
1962 : The late-glacial and postglacial emergence and the deglaciation of northernmost Labrador, Geog. Bull. No. 17, pp. 23 - 56, Geog. Branch, Ottawa.

LØKEN, O. H., and LEAHY, E. J.,
1964 : Small moraines in southeastern Ontario. Can. Geog., Vol. 8, No. 1, pp. 10 - 21.

MACKAY, J. Ross,
1958 : The Anderson River Map-area, N.W.T. Geog. Branch, Memoir 5, 137 p., Ottawa.

1963 : The Mackenzie Delta area, N.W.T., Geog. Branch, Memoir 8, 202 pp., Ottawa.

MAWDSLEY, J. B.,
1936 : The Washboard Moraines of the Opawica-Chibougamau area, Quebec. Trans. Roy. Soc. Can., Vol. 30, sec. 4, pp. 9 - 12.

McCUTCHEON, M. K., LANGMAN, R. C. and SMITH, H. A.,
1953 : Interpretation of Landforms from Air Photographs. Can. Geog., No. 3, p. 16 (abs. only). (Univ. of Toronto).

MOLLARD, J. D.,
1960 (a) Airphoto analysis and interpretation. A laboratory manual of selected airphotos showing landforms and soil conditions in Western Canada. 80 pp. (Univ. of Alberta).

(b) Proc. Sixth Muskeg Res. Conf. April, 1906. Nat. Res. Council Associate Comm. on Soil and Snow Mechanics. Technical Memorandum No. 67. Guides for the interpretation of Muskeg and Permafrost conditions from Aerial Photographs. pp. 67 - 87.

NICHOLS, D. A.,
1932 : Solifluction and other features in Northern Canada shown by photographs from the air. Trans. Roy. Soc. Can., Vol. 26, 3rd Ser. Sect. IV, pp. 267 - 275.

RAND CORP.
1962 : A report on the physical environment of Northern Baffin Island and Adjacent areas, Canada. Memorandum R. M. - 2706-PR, 303 p. prepared for USAF Project Rand by Dept. of Geog. McGill Univ. (see Physiog. and Terrain 73 - 290).

1963 : A report on the physical environment of the Thelon River area, N.W.T. Canada. Memorandum RM-1903-1-PR. 307 pp. prepared for USAF Project Rand by Dept. of Geography McGill Univ. (see Physiog. and Terrain 97 - 291.

RAND CORP.
1963 : A report on the physical environment of southern Baffin Is., N. W. T., Canada. Memorandum RM-2362-1-PR. 375 pp. prepared for USAF Project Rand by Dept. of Geog. McGill Univ. (see Physiog. and Terrain 113-357)

A report on the physical environment of the Great Bear River area, N. W. T., Canada. Memorandum RM-2122-1-PR 326 pp. prepared for USAF Project Rand by Dept. of Geog. McGill Univ. (see Physiog. and Terrain 105-317).

A report of physiographic conditions of Eastern Victoria Island and Adjacent areas, N. W. T., Canada. Memorandum RM-2707-1PR. 200 pp. prepared for USAF Project Rand by Dept. of Geog. McGill Univ. (see Physiog. and Terrain 57-187)

A report on the physical environment of the Quoich River Area, N. W. T. Canada. Memorandum RM-1997-1-PR. 284 pp. Prepared for USAF Project Rand by Dept. of Geog. Univ. McGill (see Physiog. and Terrain 141-272).

A report on the physiographic conditions of central Baffin Island and adjacent areas, N. W. T. Canada. 270 pp. Memorandum RM-2837-1-PR prepared for the USAF Project Rand by Dept. of Geog. McGill Univ.

ROBITAILLE, Benoit,
1960 : Presentation of a Geomorphological map of the Mould Bay area, Prince Patrick Is., N. W. T., Can. Geog. No. 15, pp. 39-43. (transl. June 1961).

SAGER, R.C.,
1954 : Aerial Photo Analysis of Permanently frozen ground. The Canadian Surveyor, Oct. pp. 311-315.

ST-ONGE, D.,
1965 : Geomorphologie de l'ile Ellef Ringnes, T.N-O. Geographical Branch, Memoir No. 11, Ottawa, IN PRESS

SIM, Victor W.,
1960 : A preliminary account of late "Wisconsin" glaciation in Melville Peninsula, N. W. T., The Can. Geog., Nov., No. 17, pp. 21-34.

SMITH, H.T.U.,
1948 : Giant glacier grooves in Northwest Canada. Am. Jour.Sci., Vol. 246, No. 8, pp. 503-514.

STAGER, J.K.,
1956 : Progress Report on the analysis of the characteristics and distribution of Pingos east of the Mackenzie Delta. Can. Geog. No. 7, pp. 13-20.

STALKER, A. MacS.
1960 : Ice-pressed drift forms and associated deposits in Alberta. Geol. Sur. Can. Bull. 57, 38 pp., Ottawa.

THOREN, Ragnar,
1959 : Frost problems and photo interpretation of patterned ground, Photogram. Eng. Vol. 25, No. 5, pp. 779-786. (Int. Soc. Photogram.)

THORSTEINSSON, R. and E.T. TOZER,
1962 : Banks, Victoria and Stefansson Islands, Arctic Archipelago. Geol. Surv. Can., Memoir 330, 85 pp. Ottawa.

WHEELER, J.O.,
1961 : Whitehorse map area, Yukon Territory, Geol. Surv. Can., Memoir 312, 156 p. (see Ch.II 6-20), Ottawa.

WILSON, J. T.,
1938 : Drumlins of Nova Scotia. Trans. Roy. Soc. Can., Ser. 3, Vol. 32, Sec. IV, pp.41-47.

1939 : Eskers northeast of Great Slave Lake. Trans. Roy. Soc. Can., Vol. 33, Sec. IV, pp. 119-130.

1945 : Further eskers north of Great Slave Lake. Trans. Roy. Soc. Can., Vol. 39, Sec. IV, pp. 151-153.

WOOD, H.A.,
1959 : List of maps and air photos depicting landforms and regions of Canada. Can. Assoc. Geog. Ed. Comm. Bull. No. 1, 26 pp. (McMaster Univ.).

DENMARK - GREENLAND

Report by Dr. Børge Fristrup
Geography Department, University of Copenhagen

In Greenland air photographs have been used for mapping purposes since the early 1930's and a complete coverage now exists for the entire area outside the main ice cap.

Because 4,000 metres was the maximum ceiling for the pre-war aircraft and because many of the Greenlandic mountains approach this elevation early vertical coverage was impossible. Oblique photographs (23 degrees from the horizon) were used and still are for most purposes. For special regions vertical coverage is available and for most areas several sets of obliques, flown in different years, are in existence.

For information on the activities of the Geodetic Institute the reader is referred to N.E. Nørlund (1939), Einar Anderson (1956) and J. V. Helk, (1961).

In connection with the Danish contribution to the "Expedition Glaciologique Internationale au Groenland," special photogrammetric work was undertaken in Greenland. Photograph coverage at the scale of 1:65,000 was provided of the drainage basin of Kangerdlugssup sermerssua (lat. 71° 30' N; long. 51° 00' W.), and at the scale of 1:50,000 for the border of the ice cap between 68° and 72° North on the west coast. Coverage at the scale of 1:50,000 was provided of the outfall of the more significant glaciers in this area and repeated after a period of 8 to 14 days.

Based upon this photography a topographic map at the scale of 1:50,000 with a 10-metre contour interval is currently being prepared for

publication. The photography of the ice cap border will be repeated from time to time to obtain precise information on frontal oscillations; the first operation of this nature is planned for 1964.

Air photography has been used:

(1) for planning glaciological expeditions (e.g. Fristrup, 1960)

(2) for registration of glacier oscillations (e.g. Fristrup, 1950, 1960; Weidick, 1958, 1959, 1963).

(3) for mapping the glacial geology and morphology (e.g., Møller, 1959; Weidick, 1963).

(4) for calculating the tapping of ice-dammed lakes (e.g., Helk, unpub. M.S.).

(5) for determination of ice movement (e.g., Baussart, 1958; Hofmann, 1958; Bauer, 1961).

The following note has been provided by Dr. Frank Ahnert:

"I accompanied the U.S. Army's Operation Lead Dog in the summers of 1959 and 1960 on its expeditions from Thule to Nyeboe Land, Peary Land, and Kronprins Christian Land as a consultant on terrain problems (accessibility and traversibility). Field experience, USAF trimetrogon photos and photos taken with hand cameras from helicopters and small aircraft on these expeditions were combinedly used for an assessment of the physical geography of parts of North Greenland in general, and for a terrain analysis with respect to possible camp sites, aircraft landing sites, and routes for vehicular traverses in particular. In a more academic vein I wrote a paper on "The Terminal Disintegration of Steensby Gletscher" (1963) which was based entirely on photo interpretation, and have started some time ago the compilation of a landform map of southern Nyeboe land from air photos. Work on this map has recently stalled because of other commitments, but I expect to complete it eventually. My terrain analysis work for the U.S. Army has been published in the following places" (added to the general bibliography).

Bibliography

AHNERT, F.,

1959 : "Notes on the Physical Geography of North western Greenland" in U.S. Army Transportation Corps, Arctic Projects: Greenland, pp. 68-92.

1960 : "The Accessibility and Traversibility of Southern Peary Land, Greenland" in: U.S. Army Transportation Board, Report of Environmental Operation Lead Dog, pp. 102-133.

1962 : "The Physical Environment of Nyeboe Land, North Greenland" Publ. by U.S. Army Transportation Board, 85 pp.

1963 : The terminal disintegration of Steensby Gletscher, north Greenland, Journ. of Glaciology, Vol. 4, No. 35, pp. 537-545.

ANDERSON, Einar,

1956 : L'Institut Géodésique de Danemark de 1928-1955. Geogr. Tidsskr. 55, 12-20.

BAUER, A.,

1961 : Commentaires de stereogrammes des glaciers du Groenland. Soc. Franc. Photogramm Bull. No. 3.

1961 : Interpretation des resultats obtenus sur les vitesses des glaciers du Groenland. Soc. Franc. Photogramm. Bull. No. 3.

BAUSSART, M.

1958 : Essai de determination par photogrammetrie de la vitesse superficielle d'un glacier du Groenland. Publ. No. 47 de A.I.H.S. Symposium Chamonix, 8-10

FRISTRUP, Børge,

1950 : Peary Land. Geogr. Tidsskr. 49. 41-66

1960 : Studies of four glaciers in Greenland Geogr. Tidsskr. 59 89-102.

HELK, J.V.,

1961 : The mapping of Greenland by the Danish Geodetic Institute. Folia Geogr. Danica IX 128-130.

1961 : Some questions on the ice-topography on The Greenland Maps made by the Danish Geodetic Institute. Folia Geogr. Danica IX 131-132.

HOFMANN, Walther,
1958 : Bestimmung von Gletschergeschwindigkeiten aus Luftbildern. Bildmessung. u. Luftbildwesen, 3,pp. 71-88.

MØLLER, J. Tyge,
1959 : Glaciers in Upernivik Ø. with special reference to the periglacial phenomena Geogr. Tidsskr., 58, pp.30-53.

NØRLUND, N.E.,
1939 : Kortlaegningen af Grønland og Island. Geogr. Tidsskr., 42,pp. 21-30.

WEIDICK, Anker,
1958 : Frontal variations at Upernaviks Isstrøm in the last 100 years. Medd. Dansk. Geol. Foren., 14, pp. 52-60.

1959 : Glacial variations in West Greenland in historical time. Medd. om Gronland, 158, nr.4, 196p.

1963 : Ice margin features in The Julianehåb district, South Greenland. Medd. om Grønland, 165, nr.3, 133p.

1963 : Some glacial features at the inland ice margin south of Sdr. Stromfjord. Medd. Dansk. Geol. Foren., 15,pp. 189-199.

G R E A T B R I T A I N

Report by Roger P. Kirby
Geography Department, University of Edinburgh

Air photo interpretation of glacial geomorphological features is a fairly limited practice in Great Britain, even when taking into account the small number of geographers and geologists working in this field. The areas covered by such interpretation are small and piecemeal.

There are obvious historical reasons for this present neglect: mapping and discussion of glacial phenomena started in Britain long before air photographs were available (e.g. Hall, 1812; Geikie, 1863); so that there is a tradition of ground methods of landscape description and mapping; the close road network over all except parts of north Scotland has assisted ground-investigations; and the excellent Ordnance Survey topographical maps with complete modern coverage at 1:10,560 and several smaller scales, has again not placed any premium on the air photograph as a primary source of information. Conventional ground field methods have been evolved, and the increasing supply of air photographs in the last fifteen years has not changed them very much.

There is now complete coverage of good quality air photographs at 1:10,000 (approx) for England and Wales and for Scotland, available from separate authorities. In addition there are substantial coverages at 1:5,000, 1:20,000 and miscellaneous smaller scales and some oblique photography; also commercial companies will make available photographs of selected areas at various scales.

For reasons noted above, air photographs are still only a supplementary tool in glacial geomorphology and, as in the case with all new methods, it is still common for some workers to ignore them completely. But as in other field sciences, the utility of air photographs is becoming recognized more widely; their main uses are proving to be in the planning, or pre-fieldwork, stage of a project, in place of a rapid ground reconnaissance, and in the illustrating of published material. There is yet no British reference text more relevant than the general introduction provided by Walker (1953); articles and texts from American and Scandinavian sources are relied upon almost exclusively.

Consideration of the literature and personal discussion seems to indicate that glacial geomorphologists in universities are in the van in the use of air photographs. Governmental bodies with personnel concerned with glacial geomorphology are less able or less willing to experiment with new techniques, although there is liaison and interchange of ideas with universities. However, there is no national scheme of working in glacial geomorphology, partly because there are insufficient qualified personnel available, and partly because those that are available are attached to autonomous organizations.

The one scheme designed to provide a map of the whole of Great Britain is the project of a Geomorphological Map for Great Britain, mooted in 1961 and under the direction of Professor D.L. Linton of Birmingham University. This map is being produced at the British "National Atlas" scale of 1:625,000, as a reduction from original 1:250,000 mapping, and provides a general pattern of distribution of geomorphological, including

glacial geomorphological, features. Although this project is little more than a reconnaissance survey, there are sufficient geomorphologists familiar with their particular areas, especially in England, for the map to be compiled by field mapping alone with little assistance from air photographs (personal communications). The obvious use of air photographs for reconnaissance mapping has thus been excluded almost entirely, in spite of their equally obvious value for this type of work.

For the dozen or so British universities with staff researching in glacial geomorphology, the common pattern has been for a concentration of research in areas centred around the university. Scotland with only three university working groups provides greater aerial scope than England and Wales, and Edinburgh, with a larger than average working group of about six persons, appears to make more use of air photographs than any other department.

The Edinburgh group, directed by Dr. J.B. Sissons, has concentrated on areas adjacent in east-central Scotland with a view to nationalization of the glacial chronology. The main elements of this project are: (i) a study of the glacial erosional features, especially glacial drainage channels, in parts of the Southern Uplands, Midlothian and East Lothian (e.g. Sissons, 1958; Price, 1960); (ii) The complementary study of glacial deposits, especially in the Midlothian Basin (Kirby, unpub.): and (iii) the mapping and detailed heighting of raised beaches around the Firth of Forth.

The Edinburgh workers have the advantage, along with London and Cambridge, that the national air photo collection is housed locally,

and is accessible for post-graduate and approved under-graduate students. In the project outlined above, air photographs have proved very useful for (i) and (iii), but for (ii), on cultivated ground, can best illustrate only the presence or absence of drift and the outline of large depositional features. The method of preliminary study of air photographs outlined below is that practiced at Edinburgh.

Prior to any fieldwork, the photos are viewed at a desk, usually stereoscopically with a mirror - or hand-stereoscope. Glacial information is then transferred to field maps, the transference being either by eye, by matching corresponding reference points on photograph and map, or, where there are few reference points available, by the Sketchmaster type of single-image plotter. The marked maps are then taken into the field and the markings modified or confirmed (e.g. Sissons, 1963). Less frequently, after the initial laboratory inspection, detail is mapped in the field directly on to a transparent overlay of the air photographs and the detail from the overlay subsequently transferred to maps (e.g. Sissons, 1961a). This reverse procedure is more likely in open upland areas lacking field-boundaries and other specific information recorded on Ordnance Survey maps; in these areas, finding one's position and pin-pointing glacial features is easier from air photographs than from maps.

At other British university centres, the literature suggests that air photographs are not used very widely, although it is certain in a few instances that they have been employed incidentally but their employment has not been recorded. In no papers other than those already mentioned

have air photographs been described as a mapping base. In a few papers, a single air photograph has been included for illustration purposes (e.g. Drury, 1953; Common, 1954; Linton, 1954 Sissons, 1961b); the cost of good quality reproduction indicates why they are not more used. A stereo-pair has yet to be used as illustration in this field, in Britain, although very common elsewhere.

The direct heighting from air photography by photogrammetric methods of such glacial geomorphological features as raised beaches and glacial drainage channels is often theoretically possible, but has been used in very few cases. Contemporary projects usually require accurate heighting, often to one foot in the case of raised beaches. To achieve this by photo-grammetric plotting requires good photographs and plotting equipment, good control heights, and skill in measuring parallaxes; it is not surprising that most workers find field levelling faster and more accurate. Peel used parallax methods on a single stereo-pair of photographs to help contour a glacial drainage channel (Peel, 1949). and similar work is also carried out elsewhere as a student exercise, but it seems unlikely to rival ground surveying methods in Britain.

Other than in the universities, there exist only the beginnings of glacial geomorphological interpretation from air photographs. The Soil Survey of Great Britain is experimenting with air photographs in uncultivated areas as a supplementary tool to distinguish alluvium, glacio-fluvial deposits and some soil types (Ragg and Bibby, 1963). Detail is transferred from the air photographs at 1:10,000 to the field maps at 1:25,000 by a Sketchmaster,

the scale reduction ensuring adequate accuracy. Also, the Geographical Survey of Great Britain use air photographs to assist in mapping at 1:10,560 such glacial features as large drainage channels (personal communications). They do not use any quick method of transferring detail to maps.

Bibliography

COMMON, R.
1954 : The geomorphology of the East Cheviot area. Scot. Geogr. Mag., Vol. 70, pp. 124-38.

DRURY, G.H.
1953 : A glacial breach in the North Western Highlands. Scot. Geogr. Mag., Vol. 69, pp. 106-117.

GEIKIE, A.
1863 : On the phenomena of the glacial drift of Scotland. Trans. Geol. Soc. Glasgow, Vol. 1, Part 2, pp. viii + 190.

HALL, J.
1812 : (Description of glacial flow pattern in vicinity of Edinburgh). Trans. Roy Soc. Edin., Vol. 7, pp. 139-211.

LINTON, D.L.
1954 : Some Scottish river captures re-examined. III. Scot. Geogr. Mag., Vol. 70, pp. 64-78.

PRICE, R.J.
1960 : Glacial meltwater channels in the upper Tweed drainage basin. Geogr. Jour., Vol. 126, pp. 483-89.

PEEL, R.F.
1949 : A study of two Northumbrian spillways. I.B.G., Trans. and Papers, No. 15, pp. 75-89.

RAGG, J.M. and BIBBY, J.S.
1963 : Soil Survey of Scotland. Report for 1962. South-East Scotland. Sheets 24 (Peebles) and 32 (Edinburgh). Soil Survey of Great Britain, Report No. 15, 1962, pp. 38-39.

SISSONS, J.B.
1958 : The deglaciation of part of East Lothian. I.B.G. Trans. and Papers, No. 25, pp. 59-77.

1961a : A subglacial drainage system by the Tinto Hills, Lanarkshire. Trans. Edin. Geol. Soc., Vol. 77, pp. 175-93.

1961b : Some aspects of glacial drainage channels in Britain. Part 2 Scot. Geogr. Mag., Vol. 77, pp. 15-36.

1963 : The glacial drainage system around Carlops, Peebleshire. I.B.G., Trans. and Papers, No. 32, pp. 95-111.

WALKER, F.
1953 : Geography from the air. Methuen, London, pp. 111.

ICELAND

Report by Dr. Sigardur Thorarinsson
Museum of Natural History, Reykjavik, Iceland

Iceland has been covered almost entirely by air photography on three separate occasions. In 1937 and 1938 the Danish Geodetic Survey undertook extensive air photography of the interior from a flying height of 3,600 metres: it was from this photography that the 1:100,000 topographic maps of the interior were produced. During 1945 and 1946 the United States Air Force photographed the entire island at an approximate scale of 1:44,000. These photographs were used in the preparation of topographic maps at a scale of 1:50,000. The mapping depended upon the Danish triangulation of 1901 which, although very good for its time, proved insufficient for modern work and the Danes and Icelanders initiated a new triangulation in 1955 - 1956. During the same period the U.S.A.F. began rephotographing the island and have practically covered the entire country. Since 1950 the Iceland Geodetic Survey have photographed parts of the country at different scales and for different purposes. This work has covered the margins of many glaciers such as the southern outlet glaciers of Vatnajökull and Hofsjökull.

The Icelandic air photography has not been fully utilized in glacial geomorphological studies. However, Thorarinsson, (1956) has used them for his studies of glacier variations of Svinafellsjökull, Skaftafellsjökull and Kviarjökull in Öraefi; for investigation of ogives, and for studies of the Katla and Grimsarvötn areas. E. Todtmann has used the USAF and Icelandic

photography in the preparation of her book (1960), which deals with the glacial morphology in front of the north and south outlet glaciers of Vatnajökull. The Swedish geographers, Hjulström, Arnborg, Sundborg and others have used air photographs in their examination of the sandar areas of Iceland, principally Hofellssandur and the sandar of the Markarfljot River and Lake Hagavatn.

Bibliography

ARNBORG, L.,
1955 : Ice-marginal lakes at Hoffellsjökull. Geog. Annaler, Vol. 37, pp. 202-228.

HJULSTRÖM, F.,
1954(a): An account of the expedition and its aims. Geog. Annaler, Vol. 36, pp. 135-145.

1954(b): Geomorphology of the area surrounding the Hoffellssandur. Geog. Annaler, Vol. 36, pp. 169-189.

JONSSON, J.,
1954 : Outline of the geology of the Hornafjördur region. Geogr. Annaler, 36, pp. 146-161.

1955 : On the formation of frontal glacial lakes. Geogr. Annaler 37, pp. 229-233.

THORARINSSON, S.
1956 : On the variations of Svinafellsjökul, Skaftafellsjökull and Kviarjökull in Öraefi. Jökull, Vol. 6, pp. 1-15.

TODTMANN, E.M.,
1960 : Gletscherforschungen auf Island (Vatnajökull). Hamburg. Cram, De Gruyter and Co., 95p.

SUNDBORG, Åke
1954 : Map of the Hoffellssandur. Geogr. Annaler,36, pp. 162-168.

NEW ZEALAND

Report by Professor R.S. Waters
University of Canterbury, Christchurch, N. Z.

1. Published material:

For many years techniques of air-photograph examination have been employed by officers of the New Zealand Geological Survey and by academic geologists and geomorphologists to supplement field mapping and interpretation of both contemporary and relict (Pleistocene) glacial features.

Air photographs have been used in connection with the preparation of the new 1:250,000 Geological Map and of various 1:63, 360 map sheets and accompanying bulletins.

University geologists, geomorphologists and post-graduate research students continue to make increasing use of air photographs in their researches into the Pleistocene history of the major drainage basins of South Island and in connection with a project for the geomorphological mapping of South Island recently initiated by the Geography Department of the University of Canterbury.

2. Work in progress or recently completed and as yet unpublished:

Air photograph interpretation of glacial geomorphological features is being, or has been, employed by the following research workers: Miss Jocelyn K. Adamson (University of Canterbury) - Lake Rotoiti District, Nelson. Mr. Lee S. Clayton (University of Illinois) - Hope and Waiau Valleys, Nelson. Professor R. Goldthwait (Ohio State University)-

Lake Pukaki Area, S. W. Canterbury. Mr. Colin Moore (University of Canterbury) - Geomorphological mapping, Canterbury High Country. Professor W. E. Powers (North Western University) - Hurunui Valley, N. Canterbury. Dr. R.P. Suggate (Geological Survey of New Zealand) - Westland.

Bibliography

GAGE, M.,
1958 : Late Pleistocene Glaciations of the Waimakariri Valley, Canterbury, New Zealand. N.Z.J. Geol. Geophys. 1, 125-55.

McKELLAR, I.C.,
1960 : Pleistocene Deposits of the Upper Clutha Valley, Otago, New Zealand. N.Z.J. Geol. Geophys., 3, pp. 432-60.

SOONS, Jane M.
1963 : The Glacial Sequence in part of the Rakaia Valley, Canterbury, New Zealand. N.Z.J. Geol. Geophys., 6, pp. 735-56.

SPEIGHT, J. G.,
1963 : Late Pleistocene Historical Geomorphology of the Lake Pukaki Area, New Zealand. N.Z.J. Geol. Geophys., 6, pp. 160-88.

WELLMAN, H. W.,
1955 : The Geology between Bruce Bay and Haast River, South Westland. N. Z. Geol. Surv. Bull., n.s. 48 (2nd Edition).

NORWAY

Report by Dr. Just Gjessing

Geography Department, University of Oslo

During the last 20 years the use of air photos has become an integral part of every geomorphological investigation.

Studies of this kind are carried out at the University of Oslo, at the University of Bergen, and at the Polar Institute and the Geological Survey. The universities are mostly concerned with geomorphology in the proper sense.

Southern Norway is covered by vertical air photographs at an approximate scale of 1:40,000, and also certain (mostly urban) areas by photographs at scales of 1:30,000 to 1:15,000. The coverage of Northern Norway is scattered. In geomorphological studies with non-practical interests, the use of air photographs is restricted to the existing series. No photographs of high standard have so far been taken for scientific purposes only.

The forms studied are of all kinds: forms in bedrock due to glacial erosion; valleys, cirques, strandflat area; as well as forms due to glaciofluvial erosion, glacial deposits, end moraines, drumlins and glaciofluvial accumulations of different types, frontal, lateral, subglacial. The photographs are used with stereoscope for orientation before fieldwork, in the field, as well as for preparation of reports. The stereoscopic photographs have proved valuable for sketching and mapping of geomorphological features and to some extent determination of altitudes.

Some features may be taken directly from the photographs, but in most cases it is preferable to use them as a supplement to field work - never as a substitute.

Most often papers do not refer to the use of air photograph interpretation, though it may have been used to a great extent.

During the last 10 years a research program has been carried out on glaciofluvial, erosional and accumulative forms of the dead-ice down-wastage of the inland area of Southern Norway, (only partly published). Such features are well recognizable in districts which are not heavily forested.

Further studies of drumlins in Finmark can be mentioned. In Northern Norway as well as in Southern Norway end moraines have been traced on air photographs.

Features connected with recent glaciers, especially their retreat, their moraines etc., have also been studied on air photographs.

Bibliography

ANDERSON, Bjørn G.

1954 : Randmorener i Sørvest-Norge. Norsk. Geogr. Tidsskr., XIV, pp. 273-342.

1960 : Sørlandet : i sen - og postglacial tid. Norg. Geol. Und., 210, 142p.

GJESSING, Just

1953 : Skuringsanalyse til Belysning av Isrecessionen ved Oslofjorden. Norsk Geogr. Tidsskr., XIV, pp. 77-99.

1955 : Om Iserosjon, Fjorddal - og Dalendedannelse. Norsk Geogr. Tidsskr., 15, p. 243-269

1960 : Isavsmeltmingstidens drenering, dens forløp og formdannende virkning i Nordre Atnedalen. Ad Novas, Nr. 3, (Skr. fra det Norske Geogr. Selskab) 192p.

LEISTØL, Olav.

1962a : List of the areas and number of glaciers. Norsk Polarinst. Skr., 114, 35-54.

1962b : Special investigations on Hellstugubreen and Tverråbreen Norsk Polarinst. Skr., 114, 175-207.

MANNERFELT, C.M.,

1945 : Några Glacialmorfologiska.Formelement. Geog. Annaler, Vol. 27, 239 p.

NORGES GEOGRAFISKE OPPMÅLING AND AMUND HELLAND

1962 : The Investigation of glaciers. Norsk Polarinst. Skr., 114, pp. 28-34.

ØSTREM, G.

1959 : Glaciers and moraines in the Jotunheim District, Norway. (English summary) Norsk. Geogr. Tidsskr., 17, pp.237-243.

SWEDEN

Report by Dr. Harold Svensson
Geography Department, University of Lund

1. Methodological Procedures used in Photointerpretation

No Swedish keys with the objective restricted to glacial geomorphology have been prepared, although the Geography Department of Lund University is currently experimenting with the production of keys for the wider field of physical geography.

In many investigations special glacial geomorphological features have been studied from the characteristics provided by the aero-visual image. With the interpretation criteria for the respective landforms that are stated in papers resulting from these studies, they indirectly take on the appearance of photo interpretation keys and can be used as such for studies in areas of similar terrain. Thus the work of Mannerfelt (1945) has been of great importance for later investigators of glacial drainage channels and other glacio-fluvial forms within the Scandinavian mountains.

2. Technical methods involved in air photography

There is currently in progress in the Geography Department of the University of Stockholm a project aimed at determining the value and limitations of photo interpretations. Different scales, kinds of film (panchromatic, infra red, colour) etc., are closely studied for specially chosen areas.

Comparative studies of sets of air photographs of a specific area taken under different weather conditions (e.g. after seasons of drought and heavy precipitation) have provided valuable information on

significant differences of ground conditions and their morphological origin (Geography Department, University of Lund). The regular air photography of Sweden provides opportunity for obtaining variations in the weather conditions.

Detailed analysis of the morphology of the floor of shallow lakes and areas of the sea has been greatly assisted by the stereoscopic study of photograph negatives. The negatives provide significantly superior information to the orthodox positive prints.

Air photographs have been of great importance in the inventory of eskers and the computation of their volume in Middle Sweden. This has involved measurements by parallax bar in conjunction with field survey (Geography Department, University of Uppsala).

All the projects referred to above depend upon stereoscopic use of air photographs. In the field the Simonsson model lens stereoscope has proved very useful.

For transferring morphological details from the photographs to base maps sketchmaster equipment is used. Single measurements are made by parallax bar and mirror stereoscope. The Stereopret and Stereotop are also used.

More comprehensive work, such as that involving the preparation of contour maps, depends upon the use of Stereo autographs and has been carried out by the Geographical Survey Office of Sweden and the Division of Photogrammetry, Royal Institute of Technology, Stockholm. Most of these maps treat glacial morphological features in North Sweden (Geography Dept., University of Stockholm).

3. Glacial geomorphological features investigated

The following list is not quite complete and refers to the bibliography:

(a) End Moraines: Bergdahl, 1959, 1961, 1963; Hoppe, 1947, 1948, 1950(b), 1957 and 1959(b), Schytt, 1958a, 1961; Svensson, 1959(a) and (b), 1963(a); Østrem, 1960, 1962, 1963.

(b) Drumlins and fluted moraine surfaces: Hoppe, 1948, 1951, 1957; Schytt, 1961, Svensson, 1963(b); Svensson - Frisén, 1964.

(c) Hummocky and ridged moraines other than above: Hoppe, 1948, 1957, 1959(a) and (b); Mannerfelt, 1945; Schytt, 1956(b).

(d) Meltwater channels: Holdar, 1953, 1957; Hoppe, 1948, 1950(a), 1952, 1957, 1959(b), 1963(b); Mannerfelt, 1945, 1949, 1960; Schytt, 1956(b).

(e) Glaciofluvial deposits: Hjulström, 1954; Holdar, 1953, 1957; Hoppe, 1959, 1963(b); Hoppe, Kindblom, Klein and Klingström, 1959.

(f) Glacier movement: Svensson, 1963(b).

(g) Glaciers: Schytt, 1956(a) and (b) 1959, 1961; Vilborg, 1962; Østrem, 1960, 1963.

(h) Ice-marginal lakes: Arnborg, 1955.

(i) Progress of deglaciation (Würm ice sheet): Blake, 1961; Holdar, 1953, 1957; Hoppe, 1948, 1950(a) and (b), 1957, 1959(b); Mannerfelt, 1945, 1949, 1960; Svensson, 1959(a) and (b).

(j) Inventory and mapping of gravel deposits: Bergström, 1960; Bergström, Hoppe and Vilborg, 1961; Hoppe, 1959(a), 1960; Olsson, 1963.

4. Maps

Sketch maps drawn from air photographs showing special glacial forms and their distribution occur in many of the papers listed in the bibliography.

Contour maps have also been produced as a result of some of the investigations. They are usually large scale maps intended to give a detailed view of glacial and glacio-fluvial landforms within specially chosen small areas. Such maps occur in the following papers, amongst others: Holdar, 1957; Hoppe, 1948, 1950(a), 1957, 1963; Ljungner, 1945; Mannerfelt, 1945, 1949, 1960; Svensson, 1959(b); Sundborg, 1954; Woxnerud, 1951; Østrem, 1962(a) and (b).

A contour map of the Mikka Glacier (1:8,000, contour interval 5 m - in steep sections 25 m) is in preparation (Geography Department, University of Uppsala). Contour maps of glaciofluvial deltas in Southern Norrland (Institute of Quaternary Geology, University of Uppsala) and late-glacial sandar (Geography Dept., University of Uppsala) are in preparation.

The new topographical map of Sweden (Geographical Survey) at a scale of 1:50,000 and with a 5-metre contour interval, is of particular importance for the study of the larger and more complex glacial landforms.

Geological Maps The Geological Survey of Sweden is using air photographs interpretation to support mapping of Quaternary deposits, especially in northern Sweden. Multi-coloured maps at a scale of 1:200,000

are to be published for the northern areas (Lundqvist, 1958; Fromm, 1961). In combination with field studies the photograph interpretation is used to determine type and distribution of Quaternary deposits. The moraine morphology in northern Sweden stands out most prominently when the numerous peat bogs are carefully outlined on the photographs.

In connection with the location of water power plants, regulation of rivers, road planning, etc., especially in the river valleys of northern Sweden (Swedish State Power Board) the mapping of surficial deposits has been undertaken with the aid of air photographs (Geography Department, University of Stockholm). The work has involved the search for special soil types and the mapping of surficial deposits. The most suitable scale is 1:15,000. A total area of about 10,000 km^2 has so far been mapped.

(The report is compiled on the basis of information received from the institutes where air photograph interpretation is used in investigations of glacial morphological features).

In the bibliography, papers are listed which are based on air photographs or in some part contain photographic interpretation. Papers which include contour maps of glacial forms, plotted from aerial photographs are also listed. The capital in brackets after each paper refers to the institute to which the author now is affiliated.

L = Department of Geography University of Lund
S = Department of Geography University of Stockholm
S.g.u. = Geological Survey of Sweden
U = Department of Geography University of Uppsala

Bibliography

ARNBORG, L.,
1955 : Ice marginal lakes at Hoffellesjökull. Geogr. Ann, 37. (U)

BERGDAHL, A.,
1959 : Glaciofluvial estuaries on the Närke plain. Svensk Geogr. Arsbok, 35. (L)

1961 : Glaciofluvial estuaries on the Närke plain. II The lower Kvismar valley. Svensk Geogr. Årsbok, 37. (L)

1963 : Glaciofluvial estuaries on the Närke plain. Svensk Geogr. Årsbok, 39. (L).

BERGSTRÖM, E.
1960 : Some experiences of mapping surficial deposits in Northern Sweden by means of air photo interpretation. Svensk. Lantmäteritidskrift, nr 3, 1960. (S)

BERGSTRÖM, E., HOPPE, G. and VILBORG, L.
1961 : Sea Kungl. Vattenfallsstyrelsen.

BLAKE, Weston jr.
1961 : Radiocarbon Dating of raised beaches in Nordaustlandet, Spitsbergen. Im "Geology of the Arctic", (S)

FROMM, E.,
1961 : Jordartskarta över Norrbottens län, Sveriges Geologiska Undersökning. Ser Ca, nr 39. (S.g.u.)

HJULSTRÖM, F.
1954 : The Hoffellssandur. An account of the expedition and its aims. Geogr. Ann., 36. (U)

HOLDAR, C.G.,
1952 : Flygfotografier som hjälpmedel vid glacialgeografiska undersökningar. Globen,31. (S)

1953 : Problemet Torne-Issjön. Summary. The problem of Glacial Lake Torneträsk. Geogr. Ann.,34. (S)

1957 : Deglaciationsförloppet i Torneträsk-området. Summary. Geol. Foren. i Sthlm. Förhandl, 79. (S)

HOPPE, G.
1947 : Ändmoräander och isrecessionen i Norrbotten. Geol. Foren. i Sthlm. Förhandl, 69. (S)

HOPPE, G.,
1948 : Isrecessionen från Norrbottens kustland i belysning av de glaciala formelementen. Summary. The Ice Recession from the lower Regions of Norrbotten as Illustrated by the Land Formations. Geographica, 20. (S)

1950a : Några exempel på glacifuluvial dränering från det inre Norrbotten. Summary. Some examples of glacifluvial drainage in the interior of Norrbotten. Geogr. Ann., 32. (S)

1950b : Les formes de recession glaciare de Bothnie septentrionale (Suedé) Rev. de Geomorph. Dynam. 1950:2 (S)

1951 : Drumlins i nordöstra Norrbotten. Summary. Drumlins in northeast Norrbotten, North Sweden. Geogr. Ann., 33. (S)

1952 : Nagra glacifluviala erosionsrännor på Sydsvenska höglandet. Geol. Foren. i Sthlm. Forhandl, 74. (S)

1957 : Problems of glacial morphology and the Ice Age. Geogr. Ann., 39. (S)

1958 : Flygbilden såsom vetenskapligt hjälpmedel. Summary. The air photograph as a scientific tool. Svensk Naturvetenskap. 1957-58. (S)

1959a : Om flygbildstolkning vid jordartskartering jämte några erfarenheter från jordartskartering i norra Lappland. Abstract. Geol. Foren. i Sthlm. Forhandl, 81. (S)

1959b : Glacial morphology and inland ice recession in northern Sweden. Geogr. Ann., 41. (S)

1960 : Mapping surficial deposits by air photo interpretation in Northern Sweden. Abstract. of papers. International Geographical Congress in Norden, 1960. (S)

1963a : I den stora inlandsisens spår: terrängformer i Lappland. I "Natur i Lappland". (S)

1963b : Subglacial sedimentation, with examples from Northern Sweden. Geogr. Ann., 45. (S)

HOPPE, G.,
1959 : KINDBLOM, B. -O., KLEIN, K. KLINGSTRÖM, A. and E., Glacialmorfologi och isrörelser i ett lapplandskt fjällområde. Summary. Glacial morphology and inland-ice movement in a mountain area of Swedish Lapland. Geogr. Ann., 41. (S)

HOPPE, G., MAARLEVELD, G.C.,
1957 : Aardrijkskunde uit de lucht. Tijdschrift van het Kon. Nederlandsch Aardrijkskundig Genootschap

KUNGL.
1961 : Vattenfallsstyrelsen (State Power Board): Kvartärgeologiska kartor över älvdalar i Norrbottens län. Upprättade på grundval av flygbildstolkning vid Kungl. Vattenfallsstyrelsen år 1957-61 genom E. Bergström, G. Hoppe och L. Vilborg (S)

LJUNGNER, E.,
1945 : Den sista nordiska nedisningens förlopp. Zusammenfassung: Verlauf der letzten nordischen Vereisung. Geol. Fören. i Sthlm Förhandl. 67.

LUNDQVIST, J.,
1958 : Jordartskarta över Värmlands län. Sveriges Geologiska Undersökning. Ser. Ca., nr 38. Summary. Studies of the Quaternary history and deposits of Värmland, Sweden; published in ibid. Ser. C, nr 559. (S.g.u.)

MANNERFELT, Carl M. son.,
1945 : Några glacialmorfologiska formelement och deras vittnesbörd om inlandsisens avsmältningsmekanik i svensk och norsk fjällterräng. Summary. Some glacialmorphological forms and their evidence as to the downwasting of the inland ice in Swedish and Norwegian mountain terrain. Geogr. Ann.,27. (S)

1949 : Marginal drainage channels as indicators of the gradients of Quaternary ice caps. Geogr. Ann.,31. (S)

1960 : Oviksfjällen. A key glacialmorphological region. Ymer årg., 80. (S)

OLSSON, G.,
1963 : Rullstensåsarna och deras utnyttjande i Kopparbergs län. Länsutredning för Kopparbergs län. (U)

SCHYTT, V.,
1956a : Bilder från grönländska isar. Summary. Glaciological pictures from Greenland. Ymer., 76. (S)

1956b : Lateral drainage channels along the northern side of the Moltke Glacier, Northwest Greenland. Geogr. Ann.,38. (S)

SCHYTT, V.
1959 : The glaciers of the Kebnekajse-Massif. Geogr. Ann.,41.(S)

1961 : Blue ice-fields, moraine features and glacier fluctuations. Norwegian-British-Swedish Antarctic expedition, 1949-52. Scientific results, vol IV: Glaciology II:E. (S)

SUNDBORG, Å.,
1954 : Map of the Hoffelssandur. Geogr. Ann.,36 (U)

SVENSSON, H.,
1957 : Ra-moräner vid Helgelandskusten? Norsk Geol. Tidsskr, Vol. 37. (L)

1958 : Fluviatil-glacial dalutveckling. Några synpunkter på uppkomsten av hängande bidalar med exempel från Svalbard. Svensk Geogr. Arsb. Arg.,34. (L)

1959a : Syv Søstre. En glacialgeografisk studie av ett fjällområde vid Nordlandskusten. Norsk Geogr. Tidsskr.,Vol. 16.(L)

1959b : Glaciation och morfologi. En glacialgeografisk studie i ett tvärsnitt genom Skanderna mellan södra Helgelandskusten och Kultsjödalen. Summary. Glaciation and morphology. A glacialgeographical study in a section of the middle Scandes. Medd. fr. Lunds univers. geogr. inst. Avh. nr 36. (L)

1963a : Information on subakvatisk morfologi enligt flybilder. Summary. Information on subaquatic morphology from aerial photographs. Svensk Lantmateritidskrift, nr.3, (L)

1963b : Glacier movement as revealed by aerial photographs. Photogrammetria, Vol. 18. (L)

1964 : Flygbildens användning i skolans geografiundervisning. Geogr. Notiser, 22. (L)

SVENSSON, H., FRISEN, R,
1964 : Hällmorfologi och isrörelser inom ett alvarområde vid Degerhamn. Summary. Rock morphology and glacier movement in a limestone area on the island of Öland. Svensk Geogr. Arsb., 40. (L)

VILBORG, L.
1962 : Bidrag till kännedom om den recenta glaciationens utbredning i Sverige. Summary. The recent glaciation in Sweden. Some contributions to the knowledge of glacier distribution. Ymer,82. (S)

WOXNERUD, E.,
1951 : Scientific investigations in the Kebnekaise Massif, Swedish Lappland. III Kartografiska arbeten i Kebnekaise. Geogr. Ann.,33. (S)

ÖSTREM, G.,
1960 : Breer og morener i Jotunheimen. Summary. Glaciers and moraines in the Jotunheimen district, Norway. Norsk. Geogr. Tidsskr, 17. (S)

1962a : Ice-cored moraines in the Kebnekajse area. Biuletyn. Peryglacjalny, II. (S)

1962b : Nya metoder för aldersbestämning av andmorander. Ymer, 82. (S)

1963 : Litt om breene i Storsteinsfjell-området. Summary. The glaciers in the Storsteinsfjell area. Norsk Geogr. Tidsskr., 18. (S)

FRANCE

LA CARTE DES PYRENEES au 1:50,000

F. TAILLEFER
Institut de Géographie de la Faculté des Lettres. Toulouse

Dans les Pyrénées, les glaciers actuels, simples reliques, sont si peu étendus que leur intérêt du point de vue des ressources hydrauliques est presque négligeable. Il n'en est pas de même des glaciers quarternaires qui ont buriné tout le centre de la chaîne, créé d'innombrables lacs, multiplié les dénivellations et les ruptures de pente, préparant ainsi les sites des réservoirs de haute altitude et l'emplacement des chutes. De plus, les moraines et les alluvions fluvio-glaciaires accumulées dans les valées constituent l'essentiel des terroirs agricoles. Une bonne partie des ressources naturelles des Pyrénées dépend donc du travail des glaciers quaternaires et de leurs eaux de fonte.

Aussi une carte de la morphologie glaciaire des Pyrénées doit-elle faire partie de l'inventaire des ressources naturelles de ces montagnes actuellement peu et mal utilisées, et souvent d'apres les méthods d'un autre âge. Pour cet inventaire, les photographies aériennes verticales sont un document essentiel. Il est en effet possible d'identifier sur les photographies, en vision stéréoscopique, la plupart des formes d'erosion glaciaire et des reliefs morainiques ou alluviaux construits et, dans une moindre mesure, de percevoir les rapports qui les unissent.

Les photographies utilesées

La partie française des Pyrénées est entièrement couverte par les missions photographiques de l'I.G.N., [1] à une échelle comprise entre le 1:25,000 et le 1:40,000, suivant les missions. Aucune restriction n'est apportée á la diffusion de ces photographies, bien qu'il s'agisse d'une

---

[1] Institut Géographique National.

région frontière. La partie espagnole est couverte par des missions exécutées par les forces alliées pendant la Seconde guerre mondiale et par des missions plus récentes dont nous n'avons pu connaitre l'étendue exacte. Ces photographies, appartenant au Servicio Cartografico y Fotografico del Ministerio del Aire, sont longtemps restées secret militaire. Il nous a été possible, grace a l'obligeance de M. José Maria Albareda, directeur du Consejo Superior de Investigaciones Cientificas, et a l'appui de M. le directeur général du Centre National de la Recherche Scientifique francais de pouvoir utiliser les photographies d'une partie du versant espagnol. Mais des régions entières, correspondant a 15 feuilles au 1:50,000 de la Carte topographique espagnole, restent frappées d'interdit. Et, pour les mêmes raisons, parmi les épreuves communiquées, certaines ont été découpées ou tronquées lors du tirage a l'aide d'un cache. Il existe donc des trous importants dans la documentation. Ils correspondent presque toujours a des régions intéressantes, car c'est dans la zone frontière que l'action glaciaire a été le plus vigoureuse.

Pour combler ces lacunes, la carte topographique espagnole au 1:50,000 n'est d'aucun secours. Des levers détaillés sur le terrain sont impraticables. Mais il est permis d'espérer que les autorités espagnoles, qui ont déjà fait preuve d'une large compréhension des nécessités de la recherche scientifique, assoupliront leur attitude et lèveront les derniers interdits.

L'interprétation des photographies

C'est évidemment l'opération essentielle. L'examen des photographies se fait à l'aide d'une plaquette stéréoscopique de grossissement 2. Lorsque c'est nécessaire, un plus fort grossissement est utilisé. L'opérateur doit être un morphologue entraîné, capable d'identifier les différentes

formes de la morphologie glaciaire. Parfois cette identification se fait du premier coup d'oeil, dans d'autres cas, elle réclame un examen attentif et répété. Il reste enfin un certain nombre de formes douteuses, dont la photographie permet le repérage, mais non l'identification. Un déplacement sur le terrain est alors nécessaire. L'interprétation est effectuée sous ma direction, par un collaborateur technique du C.N.R.S. licencié de Géographie et ayant suivi un entraînement de quelques mois. L'examen de chaque couple stéréoscopique doit être répété au moins une fois et souvent deux ou trois, afin de n'omettre aucun détail, de rectifier les interprétations inexactes et d'assurer une liaison correcte avec les couples voisins. Tous les résultats sont ensuite revus au stéréoscope sur les photographies elles-mêmes par l'auteur de cette note.

Les formes du relief glaciaire identifiées sont non seulement celles dues au travail direct des anciens glaciers, mais aussi celles qui, dans l'environnement de ces derniers, sont l'oeuvre du système d'érosion glaciaire. Certaines d'entr'elles ont été façonnées par les eaux de fonte, sous les glaciers ou en aval de leur extrémité. D'autres, sur les versants au voisinage immédiat des glaciers, ou sur les crêtes qui les dominaient, sont proprement périglaciaires ou supraglaciaires.

Les formes rocheuses et les formes d'érosion, résultant du travail de sculpture glaciaire, sont les plus faciles à identifier, surtout lorsqu'elles se trouvent au-dessus de la limite supérieure de la fôret. Niches de nivation et cirques glaciaires, arêtes résultant du recoupement des cirques, anciennes diffluences ou transfluences, versants d'auge avec leur replats, vallées suspendues, verrous, gorges sousglaciaires, cuvettes rocheuses, îlots rocheux séparés du versant voisin par une gouttière, se laissent en général bien repérer. Cependant, en particulier dans les

roches friables, le remaniement des formes glaciaires par les torrents et le grand développement des bassins torrentiels rendent parfois l'interprétation délicate. Parmi les formes construites, celles qui sont actuelles ou récentes ne posent en général pas de problème d'identification c'est le cas des éboulis actuels, qui apparaissent sur les photographies comme des plages trés claires, des guirlandes de névé et des moraines du tardiglaciaire, des cônes de déjection. Les moraines anciennes latérales ou frontales, plus ou moins démantelées par l'érosion et aux formes modifiées par l'évolution des versants doivent presque toujours être examinées sur le terrain. Pour les terrasses et les glacis d'érosion, la difficulté est d'un autre ordre: si les formes topographiques souvent mieux conservées que celles des moraines, sont bien apparentes, la distinction entre terrasse construite, glacis d'érosion ou même replat structural ne peut pas toujours être faite sur les clichés. De plus, il serait trés imprudent de relier entre eux les fragments de terrasses et de glacis d'une même région d'après leur seul aspect topographique et leur altitude. Dans ce cas la photo - interprétation ne peut suffire.

Report des formes sur la pré-minute

A chaque type de forme identifiée on a fait correspondre un signe conventionnel. 58 signes, dont 3 sont utilisés pour le fond topographique, ont été nécessaires pour représenter la diversité des formes d'érosion ou des formes construites (voir la légende ci-jointe fig.1). Les signes sont reportés au fur et à mesure de l'identification sur un fond topographique préparé à l'avance. Il s'agit d'un fond en courbes de niveau, du type oro-hydrographique. L'échelle utilisée, habituellement le 1:50,000, est donc plus petite que celle des photos. Dans les régions de relief très compliqué, on utilise un fond au 1:20,000; cette échelle

est plus grande que celle des photos.

Les feuilles de la Nouvelle Carte de France au 1:50,000 et les coupures au 1:20,000 constituent des fonds excellents. Mais elles sont loin de couvrir l'ensemble de la région étudiée. Au contraire, l'agrandissement au 1:50,000 de la vieille carte d'Etat-Major française et les feuilles au 1:50,000 de la carte espagnole donnent des fonds médiocres et même, pour certaines régions, complètement inutilisables. La planimétrie doit être alors restituée entièrement d'après les photos, à l'aide d'un stéréoplan, en s'appuyant sur quelques points repères. L'adaptation de la planimétrie au relief représenté sur les fonds de carte se fait au juger. On ne peut éviter des distorsions, mais le but de la carte est de présenter un tableau cohérent des formes glaciaires: on ne l'utilisera jamais pour pointer des canons.

Travaux ultérieurs

La pré-minute contient les résultats de l'analyse et de l'interprétation des photos. Elle n'est que la première étape de la préparation de la minute définitive.

1° Elle comporte, on l'a vu, des lacunes et surtout un lot de formes non identifiées avec certitude. Celles-ci repérées sur la pré-minute à l'aide d'un signe spécial, doivent être examinées sur le terrain.

2° Les formes identifiées ne sont pas toutes du même âge. Elles ont été élaborées au cours de phases successives, qu'il est utile de distinguer. Par exemple, les moraines et les terrasses les plus anciennes, par l'état de leur matériel plus ou moins altéré et la nature de leur sol, diffèrent profondément des moraines et des terrasses plus récentes. Cette distinction ne peut être faite que sur le terrain.

Aussi, sur les pré-minutes, la plupart des formes construites, en particulier les terrasses, dont la photographie a permis de tracer les contours, sont repérées par des numéros d'ordre, en vue d'une identification ultérieure d'après les méthodes habituelles de la morphologie. Une deuxième phase d'interprétation, ou la photographie n'intervient plus, permet donc de passer de la pré-minute à la minute de la carte. Celle-ci est alors livrée au dessinateur qui lui a donner sont aspect définitif (voir l'extrait ci-joint fig. 2).

La carte du relief glaciaire des Pyrénées comprendra 50 feuilles au 1:50,000, correspondant au découpage de cartes topographiques françaises et espangnoles à la même échelle (fig. 3). Pour faciliter l'étude de certaines régions, des assemblages de parties de feuilles au 1:50,000, ou de coupures au 1:20,000 ont été réalisés. Afin d'obtenir une représentation d'ensemble de certains faits particuliers, par exemple la distribution des reliefs dus a la phase tardiglaciaire, des généralisations au 1:200,000 ont également été tentées. Actuellement les minutes de 4 feuilles au 1:50,000, celles de Foix, Vicdessos, Aulus et Ax les Thermes, sont terminées. Une trentaine d'autres sont a l'état de pré-minutes partiellement complétées. Elles correspondent, en la débordant quelque peu, a la moiteé orientale de la chaîne des Pyrénées, versant français et versant espagnol, avec, pour ce dernier, des lacunes dues a l'interdiction de consulter les photographies.

Conclusion

Dans le domaine de la morphologie glaciaire des montagnes, l'interprétation des photographies aériennes est un moyen d'investigation particulierement précieux. Elle permet un inventaire quasi exhaustif que

l'on ne pourrait réaliser a l'aide des cartes topographiques les plus précises. Or, dans une région comme les Pyrénées, ces cartes elle-mêmes font particulièrement défaut. Cet inventaire n'est pas seulement beaucoup plus complet que tout ce qui pouvait être obtenu auparavant, il est aussi moins coûteux, car l'interprétation des photos prend beaucoup moins de temps que les levers sur le terrain. Et si elle ne supprime pas tout travail sur le terrain, elle permet de la préparer de telle sorte que sont rendement est multiplié plusieurs fois.

L'utilisation de la photo interprétation en morphologie glaciaire ne correspond donc pas a un simple progrès, c'est une révolution de grande portée.

Bibliographie

Taillefer, Francois.
1963 : La carte de Morphologie Glaciaire des Pyrénées au 1:50,000, feuilles de fois et de vicdessos, Rev. Geog. des Pyrenees et du sud-ouest, XXXIV. 1. pp. 5-10.