BULLETIN 54

HELICOPTER OPERATIONS OF THE GEOLOGICAL SURVEY OF CANADA

Officers of the Geological Survey of Canada

1959

HELICOPTER OPERATIONS OF THE GEOLOGICAL SURVEY OF CANADA

3,000-1959-1413

GEOLOGICAL SURVEY
OF CANADA

BULLETIN 54

HELICOPTER OPERATIONS OF THE GEOLOGICAL SURVEY OF CANADA

By

Officers of the Geological
Survey of Canada

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1959

Price 75 cents Cat. No. M42-54

PREFACE

The development of the helicopter as a versatile and reliable instrument for assisting geological investigations has been one of the more important advances in recent years. The Survey first used helicopters in 1952 to aid reconnaissance geological mapping and, over the years, has acquired considerable experience in their use for many purposes and under widely varying conditions.

This publication makes these data available to the public and gives an assessment of the advantages and disadvantages of various methods of operation.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, June 11, 1959

CONTENTS

PAGE

CHAPTER I

Introduction 1

CHAPTER II

Light helicopter reconnaissance in the barren grounds, Northwest Territories (Operations Keewatin, Baker, Thelon)
Introduction.. 7
Organization.. 9
Field operations.. 9
Costs.. 12
Conclusions.. 13
References.. 14

CHAPTER III

Light helicopter reconnaissance in New Quebec (Operation Fort George)
Introduction.. 15
Organization.. 16
Field operations.. 16
Conclusions.. 17
References.. 19

CHAPTER IV

Light helicopter reconnaissance in interior plains and mountains (Operation Mackenzie)
Introduction.. 21
Objectives.. 21
Nature of terrain and geology.. 23
Organization.. 24
Personnel.. 24
Equipment.. 24
Utilization of aircraft.. 24
De Havilland Beaver.. 24
Bell helicopters.. 25
Field operations.. 28
Logistics.. 29
Costs.. 31
Conclusions.. 31

PAGE

CHAPTER V

Light helicopter mapping on a plateau, Cape Breton Island

Introduction.......... 33
Field operations.......... 33
Costs.......... 35
References.......... 35

CHAPTER VI

Light helicopter mapping in Coast Mountains, British Columbia

Introduction.......... 37
Equipment and personnel.......... 37
Field operations.......... 38
Conclusions.......... 39
References.......... 41

CHAPTER VII

Light helicopter mapping in mountainous regions (Operation Stikine)

Introduction.......... 43
Organization.......... 44
Field operations.......... 44
Helicopter-supported fly camps.......... 44
Foot traversing and back-packing with aerial support.......... 46
Combined pack-horse and helicopter method.......... 48
Pack-horse party supplemented by helicopter.......... 49
Logistics.......... 50
Conclusions.......... 52
Reference.......... 53

CHAPTER VIII

Heavy helicopter reconnaissance in the Arctic Archipelago (Operation Franklin)

Introduction.......... 55
Organization.......... 56
Geographical factors 56
Older methods 56
Personnel 57
Choice of helicopters 57
Selection of localities for detailed study 58
Field operations.......... 58
Plan and schedule.......... 58
Conclusions.......... 58
Costs.......... 59
References 60

			Page
Table	I.	Principal Geological Survey of Canada helicopter-supported surveys	2
	II.	Summary of costs for light helicopter operations in barren grounds	13
	III.	Statistical summary of Operation Fort George, 1957	18
	IV.	Division of flying time, Operation Mackenzie	25
	V.	Summary of use of aircraft, Operation Mackenzie	27
	VI.	Summary of costs, Operation Mackenzie	31
	VII.	Operational data, in Coast Mountains	40
	VIII.	Summary of logistics, Operation Stikine	50
	IX.	Distribution of helicopter flying time, Operation Stikine	51

Illustrations

			Facing page
Plate	I	A. Operation Keewatin, complete survey base camp	14
		B. Operation Keewatin, typical break-up conditions	14
	II	A. Operation Keewatin, barren ground cariboo	15
		B. Operation Fort George, typical burnt-over forested area	15
	III	A. Operation Mackenzie, Mackenzie Mountains, headwaters of Root River	21
		B. Operation Mackenzie, northwest arm Great Slave Lake, mid-June	21
	IV	A. Northern Cape Breton Island tableland	36
		B. Typical landing sight, Pitt Lake area, B. C.	36
	V	A. Operation Stikine, helicopter on ridge at 6,500 feet	54
		B. Operation Franklin, two-man field station about to be moved	54
	VI	Operation Franklin, south coast Devon Island	56
	VII	Operation Franklin, Bathurst Island	57

Figure	1.	Areas and locations of helicopter operations for the Geological Survey of Canada 1952-58 ... *Facing page*	1
	2.	Helicopter operations in the barren grounds, showing transportation routes and operational areas	8
	3.	Basic radial traverse net used in barren ground operations	11
	4.	Index map of area of Operation Mackenzie	22
	5.	Patterns of operation, Operation Franklin ... *Facing page*	58

HELICOPTER OPERATIONS OF THE GEOLOGICAL SURVEY OF CANADA

Abstract

This report describes the use of helicopters by the Survey as an aid to geological mapping and gives the operational and cost data for helicopter-supported parties in several areas of Canada under widely varying conditions. The advantages and disadvantages of various methods of operation are set forth.

Résumé

Le présent rapport traite de l'emploi que la Commission géologique du Canada fait de l'hélicoptère dans ses travaux de cartographie géologique; il renferme aussi des données sur les opérations et le coût des équipes qui disposent d'hélicoptères dans plusieurs régions canadiennes et selon des conditions très variables. On y décrit les avantages et les inconvénients de diverses méthodes de travail.

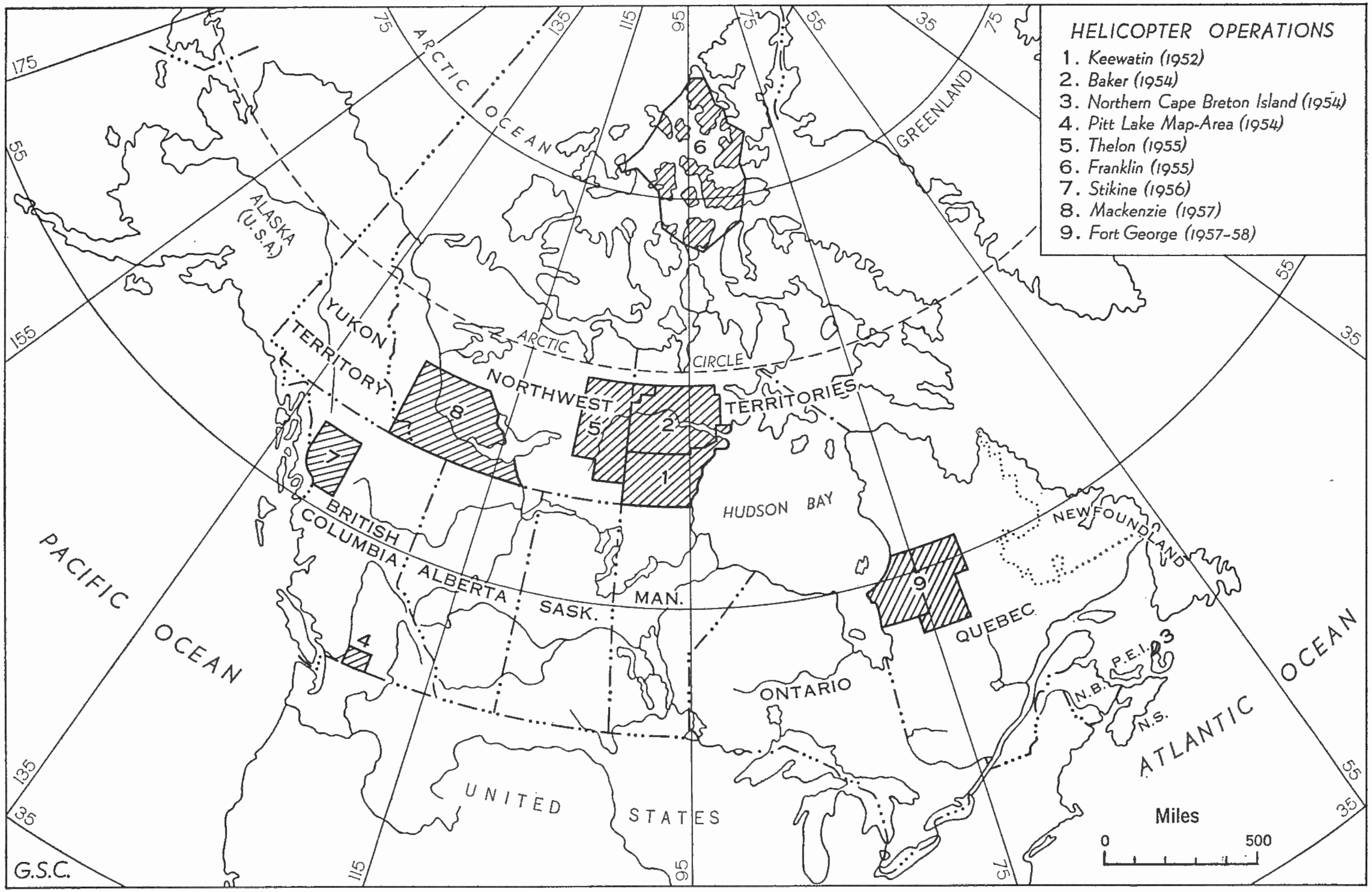


Figure 1. *Areas and locations of helicopter operations of the Geological Survey of Canada, 1952-58.*

Chapter I

INTRODUCTION

by *C. S. Lord*

This report is an account of the part played by helicopters in Geological Survey of Canada field work since their first trial in 1952: it describes the organization, logistics, field techniques, and other operational features of the principal helicopter projects (Operations) undertaken since that date, and points out lessons learned from some 4,600 helicopter-hours of flying required to map geologically nearly half a million square miles in widely separated and diverse parts of Canada.

About 10 years ago, as Survey parties were being assigned to more and more remote northern areas with extremely short field seasons, it became apparent that the Geological Survey of Canada was faced not merely with a long laborious task but, rather, with a task hopelessly beyond the capabilities of the field methods then in use. That task was to complete, at an early date, an economical and otherwise acceptable geological reconnaissance of Canada. The facts to be faced were that, after more than a century of effort, only about a third of Canada's 3.6 million square miles of land was mapped even on reconnaissance scales, and that conventional field work in increasingly remote areas was rapidly becoming prohibitively slow and expensive. Yet there was no denying the urgent need for a complete geological reconnaissance if the obviously imminent exploration, development, and exploitation of the North was to proceed in an orderly and efficient manner. A radically new field technique was clearly required. Helicopters promised to provide the basis for that new technique. They were tried, successfully, in 1952, and their experimental use at that time now appears to have marked the beginning of a new era in the reconnaissance geological mapping of Canada.

Overall policy that guided the adoption and development of the helicopter technique was that these aircraft would first be used in areas presenting the minimum of operational and terrain problems so as to promptly and surely demonstrate their suitability and to build up operational experience; and that thereafter the technique would be adapted, in so far as practicable, to the more difficult conditions of other large, unmapped parts of Canada.

The relatively accessible, low-relief, barren grounds of southern District of Keewatin were selected for the Survey's trial helicopter project (*see* Table I) known as Operation Keewatin (1952). Operating conditions there were almost ideal for these aircraft. The experience and lessons of this initial thoroughly successful Operation were applied to the planning and conducting of Operation Baker (1954) and Operation Thelon (1955) in similar but slightly more remote parts of Northwest Territories mainland. These surveys were entirely within the Canadian

Table I

Principal Geological Survey of Canada Helicopter-supported Surveys (Operations), 1952-58

Operation	Keewatin (1952)	Baker (1954)	Cape Breton (1954)	Pitt Lake (1954)	Thelon (1955)	Franklin (1955)	Stikine (1956)	Mackenzie (1957)	Fort George (1957-58)	Totals
Location	Southern District of Keewatin, N.W.T.	Central District of Keewatin, N.W.T.	Nova Scotia	Southern British Columbia	Eastern District of Mackenzie, N.W.T.	Arctic Islands, N.W.T.	Northern British Columbia	Upper Mackenzie River, N.W.T.	New Quebec	
Main terrain type	Barrens	Barrens	Wooded plateau	Rugged mountains	Barrens	Barren Islands	Plateaux and mountains	Plains and mountains	Bush and barrens	
Area mapped (sq. mi.)	57,000	67,000	850	1,600	61,000	100,000	25,500	100,000	70,000	482,950
Publication scale, miles	8	8	1	4	8	8	4	4 and 8	8	
Total cost ($)	207,000	144,000	31,400	16,000	135,000	317,000	221,000	167,500	142,000	1,380,900
Cost/sq. mi. mapped ($)	3.63	2.15	36.94	—	2.21	3.17	8.65	1.68	2.03	—
Hours flown by helicopters	515	563	200	76	520	520	759	880	557	4,590
Number and type of helicopters	2xHiller 360	2xBell 47D-1	1xBell 47D-1	1xBell 47D-1	2xBell 47D-1	2xSikorsky S-55	2xBell 47D-1	2xBell 47D-1	1xBell 47G-1	
Hours flown by fixed-wing aircraft	626	450	—	—	542	175	654	500	555	3,502
Total hours flown	1,141	1,013	200	76	1,062	695	1,413	1,380	1,112	8,092
Persons engaged, all classes	16	16	9	7	16	28	52	29	15	
Officer in charge	C. S. Lord	G. M. Wright	A. S. MacLaren	J. A. Roddick	G. M. Wright	Y. O. Fortier	E. F. Roots	R. J. W. Douglas	K. E. Eade	
Detailed account	Chapter II	Chapter II	Chapter V	Chapter VI	Chapter II	Chapter VIII	Chapter VII	Chapter IV	Chapter III	

Shield. The two helicopters of each project (two Hiller 360 on Operation Keewatin, and two Bell 47D-1 on each of Operations Baker and Thelon) were used solely as low-flying observation platforms, enabling the geologists to make their observations from aircraft rather than from canoes or on foot. Where critical detail was required the geologists were flown slowly within a few feet of the ground, or were landed and made observations on foot. The aerial traverses radiated outward from each operating camp. About 185,000 square miles were mapped by the three Operations, at an average cost of about $2.63 [1] a square mile. Several advantages of this form of the helicopter technique in this part of Canada were immediately apparent. The short open-water field season was successfully extended to include the break-up period and the ideal operating period immediately preceding it. Coordination and uniformity of geological coverage were much better than attained in any practicable system based on canoe transportation. All geological observations were made by experienced staff geologists. The work performed in three field seasons would otherwise have required 40 party-years, and it was completed at significantly less cost than would have been practicable by conventional methods.

Operation Franklin (1955), whereby 100,000 square miles within a 200,000-square-mile area of the Queen Elizabeth Islands were mapped for publication at 1 inch to 8 miles, presented requirements and problems radically different from those of Operations Keewatin, Baker, and Thelon. The underlying rocks are mainly sedimentary strata. Attitudes range from nearly horizontal to steeply inclined. Many of the stratigraphic and structural features are displayed with unique clarity on aerial photographs. Detailed studies of stratigraphy and structure at appropriately distributed localities, combined with airphoto interpretation, thus promised to provide geological data appropriate to the scale of mapping. Aircraft were needed for transport of geological parties to points selected for detailed study, and for moving base camps. They required range and load-carrying ability commensurate with the area under survey, and had to be capable of landing where and when required on islands devoid of lakes or landing fields, and separated by sea with ice conditions that varied widely from time to time and place to place. Fixed-wing aircraft or light helicopters failed to meet these requirements and two Sikorsky S-55 helicopters were accordingly chosen and proved to be entirely suitable. These aircraft operated from mid-June to mid-September, without support from fixed-wing aircraft, from bases previously supplied by a DC-3 aircraft. The helicopters were subject to the regulation prohibiting flying over extended open water without floats, and operations had, therefore, to be scheduled to proceed ahead of the disappearance of sea ice. Although the cost per square mile mapped was slightly more than $3.00, this figure is not directly comparable with the costs of other projects because of the use made of the services of other government agencies; because the work was done on scattered islands with much non-productive flying over intervening sea areas; and because of other unique conditions.

[1] Costs quoted are approximate, and are the costs of field work exclusive of staff wages, cost of equipment, and overhead. They do not include the cost of pre-field office planning and preparation, nor of post-field preparation of maps and reports.

In 1954 a Bell helicopter was used by a party assigned to urgent 1-mile mapping in northern Cape Breton Island. The area is wooded and mainly inaccessible by any conventional means other than laborious back-packing. The aircraft was used mainly to transport geologists to and from their places of work and the time thus saved enabled them to do in one season what would otherwise have required four to six. This was the only occasion on which the Survey has used a helicopter to support detailed geological mapping.

A 30-day trial of helicopter-assisted 4-mile mapping in the mountains of Western Canada was made in 1954 in the Pitt Lake map-area near Vancouver. The experience so gained was then applied in planning Operation Stikine (1956) whereby a 52-man party supported by two helicopters, one to two fixed-wing aircraft, and pack-horses, mapped the geology of about 25,500 square miles of northwestern British Columbia for publication on a scale of 1 inch to 4 miles. The area surveyed includes parts of the Coast Mountains, the Interior Plateaux, and the Cassiar Mountains, thus containing the variety of terrain required for a thorough test of various techniques of helicopter-supported geological mapping in the Cordillera. The project was organized as five separate mapping parties and an administrative party, each equipped with two-way radio. Each field party adopted an organization and working technique designed to fit the peculiar geological and physical requirements of the area allotted to it, and, in this way, a wide variety of operational experience was obtained for comparison, evaluation, and adaptation to future mapping projects in the mountains. Aircraft, both fixed-wing and helicopter, were used primarily as a means of transport and supply, and only incidentally for directly gathering geological information. The area was mapped at several times the pace, in terms of geologist-seasons, of any previously available field method, and at comparable or less cost. The standard of accuracy and detail of the map produced is more erratic than it would have been had the mapping been done more slowly by a number of smaller parties working by conventional methods. This was due, at least in part, to difficulties inherent in a large, complex, rapidly moving organization engaged in a 'crash' program aimed at starting and completing an involved project in one field season. Current plans for other major helicopter-assisted projects in the western Cordillera are to extend these projects over two or more field seasons, to obtain readily accessible and key geological data during an initial reconnaissance season with support from light relatively inexpensive, fixed-wing aircraft, and thereafter to make full use of helicopters to map rapidly the remaining less accessible areas by applying the key data obtained during the previous reconnaissance season. These proposed modifications are expected to result in better economy and increased quality, at some sacrifice in speed.

In 1957, in line with the continuing policy to adapt the aerial technique to as many as practicable of the very large unmapped areas of Canada, a helicopter project known as Operation Mackenzie was assigned to the upper Mackenzie River basin and adjacent mountains. Much of the area is heavily timbered. The geological requirements were those of a potential oil and gas area. The objectives were thus to obtain and collate precise stratigraphic data from appropriate points throughout the area, and to prepare geological maps of the plains areas on a scale of 1 inch to 8 miles, and of the mountains on a scale of 1 inch to 4 miles. The two helicopters were used for two main purposes: traverses during which geological observations were made from the aircraft or during stops of short duration, and the movement of geologists and camp equipment to places where lengthy ground observations were required. The supporting Beaver aircraft, when available and where suitable, aided in these tasks. Field work started before break-up and extended throughout the summer. About 100,000 square miles were mapped, and approximately 225,000 feet of stratigraphic section measured and studied in detail. The cost, about $1.68 a square mile, is the lowest attained by any major Geological Survey helicopter project. The survey provided more information in one season than the same number of geologists would have acquired in three or four seasons of conventional work; a substantial part of the information accumulated would have been almost unobtainable by conventional means.

Operation Fort George, a modest version of Operations Keewatin, Baker, and Thelon, was started in 1957, continued in 1958, and is scheduled for completion in 1959. It is a start towards the reconnaissance of one of the largest unmapped areas of the Canadian Shield—New Quebec west of the Labrador Trough. It differed from previous helicopter projects in the Shield in that it involved one instead of two helicopters, employed three instead of five geologists, and mapped 35,000 instead of some 60,000 square miles each season. Furthermore, the formerly standardized system of radial helicopter traverses was abandoned in favour of a system whereby the aerial traverses were parallel and spaced at intervals of 6 miles. In addition, the officer-in-charge had the advantage of a preliminary reconnaissance in 1956, prior to the helicopter phase. The Operation has been highly successful, and unique in several respects. The costs, about $2.03 a square mile, are the lowest so far achieved by a Survey helicopter project in the Canadian Shield. The use of only one helicopter and a relatively small party resulted in a highly flexible, readily coordinated project. Furthermore, by using only one helicopter, it was possible to assemble and compile geological data as rapidly as they accumulated. Thus, a month or so after the close of each field season, copy for a preliminary geological map of some 35,000 square miles was in the hands of the editor. Finally, the system of parallel traverses achieved excellent uniformity of geological coverage. On the other hand, an obvious disadvantage of using only one helicopter is the decreased rate of mapping.

Geological Survey experience with helicopters has not yet reached the stage where detailed comparisons are warranted between various projects, for the reason that these aircraft have to date been used intentionally under a wide variety of geological and operating conditions in an effort to develop techniques applicable to many parts of Canada. On all projects, the helicopters were supplied, operated, and maintained by commercial organizations under contract to the Department of Mines and Technical Surveys. In no instance was an Operation seriously retarded by unserviceability of helicopters. All helicopter-supported projects have been thoroughly successful. Although the helicopter was in all cases the major operational factor contributing to this success, all projects made full use, where appropriate, of many other aids and techniques, including light and heavy fixed-wing aircraft support, dropping of supplies by parachute, photogeology, aeromagnetic reconnaissance, and the usual methods of geological mapping of the ground. It is encouraging to note, for what it may be worth, that the two most recent Operations, Mackenzie (1957) and Fort George (1957-58), have shown the lowest costs in terms of dollars a square mile mapped. There is little to suggest, from the operational problems and geological results of the seven major projects, that any overall advantage would be gained by using larger parties or more than two helicopters to a party. There is, on the other hand, some evidence that under certain conditions slightly better results at equal or less cost might be had from relatively modest parties of simple flexible organization taking full advantage of a season or two of preliminary reconnaissance prior to the expensive helicopter phase.

In any event, the impact of the helicopter on the rate of reconnaissance geological mapping in Canada has been truly spectacular. In the period 1842 to 1951 the Geological Survey mapped somewhat more than a million square miles. From 1952 to 1958 field work was completed within nearly half a million square miles by seven major helicopter Operations—in addition to much other field work accomplished by some 530 party-years' effort. Thus, since 1952, the Survey's staff mapped about half as much of Canada as in the previous 110 years—due, in large measure, to the helicopter. Clearly, this achievement represents the first major break-through in the Survey's century of effort to complete the initial or reconnaissance phase of the geological mapping of Canada. Less than a decade ago it looked as though a century or two would be required to complete this phase. Now there is reason to expect that it will be nearly completed in a decade or two.

A precise comparison of the results of helicopter surveys with those obtained by conventional means is impractical without many qualifications. Thus, although most helicopter surveys have afforded maps on a scale of 1 inch to 8 miles, instead of 1 inch to 4 miles common in conventional reconnaissance, the helicopter surveys result in more uniform coverage; they commonly provide results many years sooner than would otherwise be possible, a valuable factor but one not readily described in terms of dollars a square mile; they make possible the maximum use of the most experienced personnel in a flexible, thoroughly coordinated party; and they permit a greatly accelerated pace of mapping without a proportionate increase in senior professional staff—a factor that was particularly significant in recent years when the short supply of experienced geologists precluded any drastic increase in suitable Survey staff. In general, however, the helicopter technique, in its various modifications and in appropriate combinations with a host of other aids, is making possible professionally acceptable reconnaissance geological maps much more rapidly, and more economically in terms of cost per unit mapped, than any other field method known to the Geological Survey.

Chapter II

LIGHT HELICOPTER RECONNAISSANCE IN THE BARREN GROUNDS, NORTHWEST TERRITORIES

(Operations Keewatin, Baker, Thelon)

by *G. M. Wright*

Introduction

Between 1936 and 1955 the Geological Survey of Canada completed about 85,000 square miles of 1-inch-to-4-miles mapping in the Precambrian parts of the Northwest Territories mainland. These surveys used conventional canoe-foot traversing methods, and were supplied and supported by bush aircraft (such as Norseman) operating on floats from bases at Yellowknife, Fort Smith and Lake Athabasca. In this type of work, the gathering of geological data is of necessity concentrated along the better canoe routes. Owing to the limited range of loaded bush aircraft, and the necessity of re-positioning the several canoe-teams of a survey party within the area to be mapped in conjunction with fortnightly supply trips, the maximum feasible range for this type of survey is about 200 miles from the aircraft bases (Figure 2).

The advent of commercially available light helicopters in the late 1940's led to a reappraisal of the problem of geological mapping in the more remote areas of the Canadian Shield, particularly between Hudson Bay and Great Slave Lake. This country seemed most suitable for mapping by helicopter because of its low relief and almost complete lack of trees. It was decided to mount an experimental, self-contained operation, with two helicopters and one Norseman attached, in the southeastern part of this region near Churchill, Manitoba, and to follow it with others, farther afield, if the method proved successful.

The three helicopter surveys carried out to date, Operation Keewatin, 1952 (Lord, 1953 a, b), Operation Baker, 1954 (Wright, 1955 a, b), and Operation Thelon, 1955 (Wright, 1957) have mapped approximately 185,000 square miles in the barren grounds in three field seasons (Figure 1). The centre of the area mapped is 400 miles from the nearest railhead (Figure 2). There are no roads and, except for half a dozen very small communities (Hudson's Bay Company posts, Department of Transport radio and weather stations, and two mining camps), no internal facilities. Previous to 1952, no systematic geological mapping had been done anywhere in the operational areas.

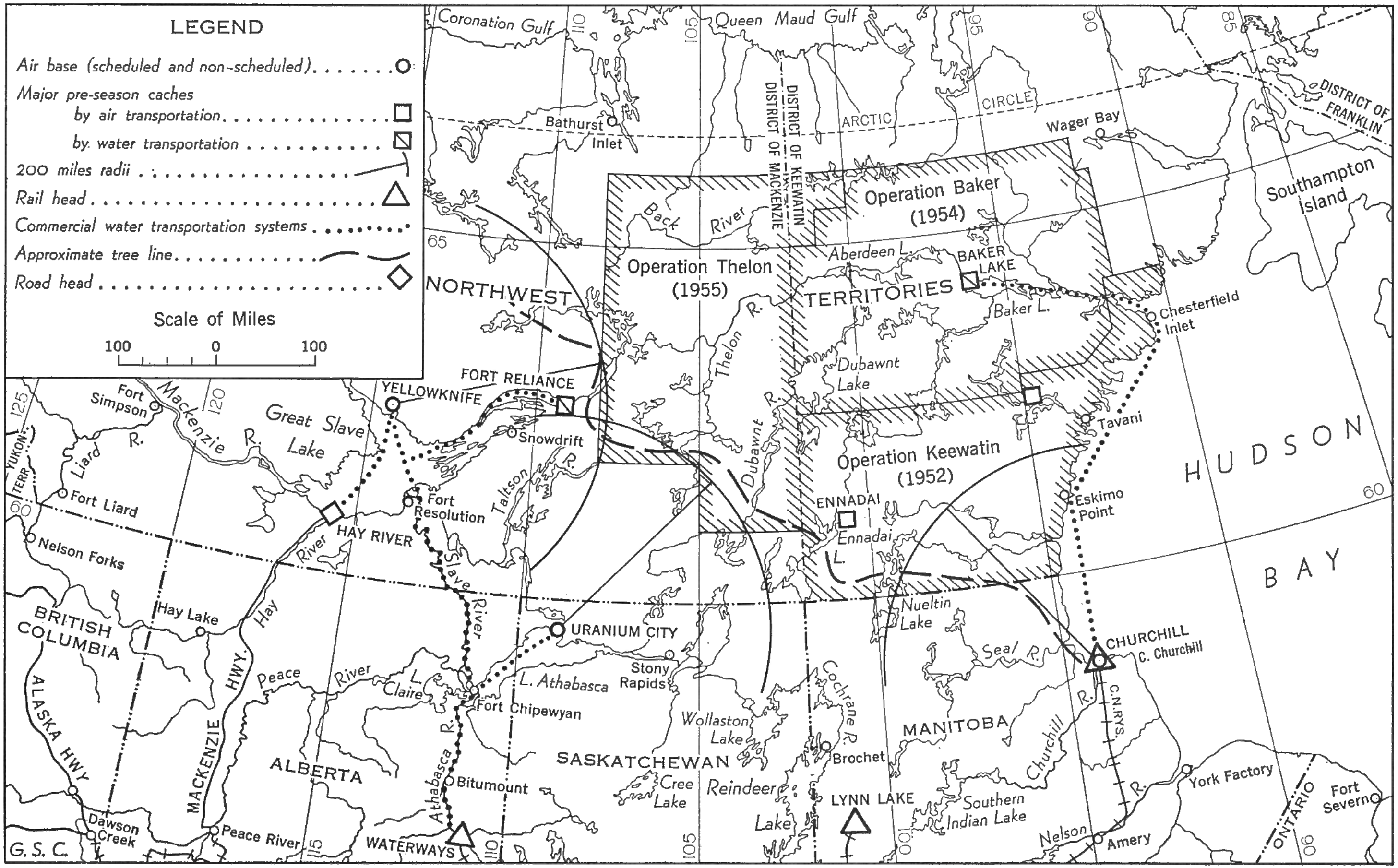


Figure 2. *Helicopter operations in the barren grounds, showing transportation routes and operational areas.*

Organization

Each party consisted of sixteen persons, as follows:

4 bedrock geologists
1 Pleistocene geologist
1 radio operator
2 helicopter pilots
2 helicopter engineers
1 Norseman pilot
1 Norseman engineer
1 cook
1 cook's helper
1 labourer
1 expediter (based at Churchill).

All extra duties relating to administration, equipment and operations were shared among the geologists, in addition to their geological and flying duties.

The parties were equipped with tents designed to withstand the high winds of the 'barrens', special tent poles and pegs, gasoline stoves for cooking and heating, and light, collapsible, rubber assault boats for use during the break-up period. One-hundred-watt, crystal-controlled, multi-channel radio equipment with special aerials, was used to maintain daily contact on a dependable basis with outside stations, and on a less dependable basis with the low-powered sets in the helicopters. With these exceptions, no special equipment was needed (Plate I A).

Airphotos of the entire region to be mapped were studied in advance of each operation, with particular attention paid to outlining areas of outcrop or lack of it and to features of surficial geology. In all some 25,000 or more photos were examined.

Large caches of gasoline, oil and some food, averaging about 100 tons, were established in advance of each field season close to or within the area to be mapped. For Operation Keewatin, this was done by air transportation (Bristol Freighter) and for the two subsequent operations, largely by boat or barge, at a substantial reduction in cost.

Field Operations

It is doubtful if any combination of terrain and geological conditions can be found anywhere in Canada that is more ideally suited to direct geological mapping by helicopter than in the barren grounds of Northwest Territories (Plate I A, II A).

Although terrain and other conditions do vary somewhat within the region already mapped and in the country south of the Arctic Ocean remaining to be mapped, the differences are of degree only. Thus low or gentle relief, absence of trees, low altitude above sea-level, cool operating conditions, and relative abundance of lakes (important as campsites and as aids to map-reading) combine to provide a near-perfect operational framework. Further, the geological conditions are such—mainly moderately to steeply dipping crystalline rocks with good outcrops over much of the region—that the prospect of geological mapping by continuous low-level observation supplemented by occasional landings seemed to be feasible.

In general, the snow-free field season in this region may be taken as extending from the last part of May to early September. The plan in all three operations was to start the survey while the lakes were still frozen although much of the rock was already free of snow. The Norseman operated on skis at this stage, and returned to Churchill to change to floats over the break-up period. The surveys were thus able to use several weeks of excellent traversing weather in each season before canoe routes were open, and this extension of the field season over that available to conventional canoe methods probably accounts for nearly one third of the total mapping completed.

The helicopters used float-landing gear throughout. The air-speed and payload penalties over wheels or skids were accepted, the safety factor involved in flying over an abundance of ice-cold water being decisive; the float-equipped aircraft landed readily on snow, ice, water, muskeg or rock.

Traversing Systems

The light helicopters employed were used almost exclusively for systematic geological traversing, the crew consisting of one pilot and one geologist. At the start of Operation Keewatin, an attempt was made to fly a 'grid' of rectangular traverses in the outline of a square around the base camp. The limited range of the aircraft then employed (Hiller 360) imposed the necessity of pre-planning and pre-caching each such traverse or small group of traverses, and the method, although theoretically offering the most uniform coverage, was abandoned on operational grounds.

The basic method used thereafter was to fly a series of thin, triangular traverses, with gaps of about 10 miles at their outer ends and with a radius of 40 to 50 miles from a central base camp, and to square off the resultant circle with four long traverses requiring gasoline caches (Figure 3). This radial traverse system has the advantage of simplicity and speed, and it reduced the caching problem; its obvious disadvantage was the relative over-concentration of data near the centre.

In 1954 and 1955, Bell 47D-1 helicopters replaced the Hiller 360's used in 1952, and the longer range (without refueling) of the Bell machines made it possible to consistently increase traverses from a radius of 40 miles (90 linear miles) to 45-50 miles (100-110 linear miles) with a greater reserve of fuel for contingencies. This change resulted in a moderate increase in flying time and coverage per helicopter day, and an increase of from 8,100 to 10,000 square miles in maximum coverage per camp. In addition, the fact that in 1954 and 1955 the helicopters used the same gasoline as the support aircraft led to a con-

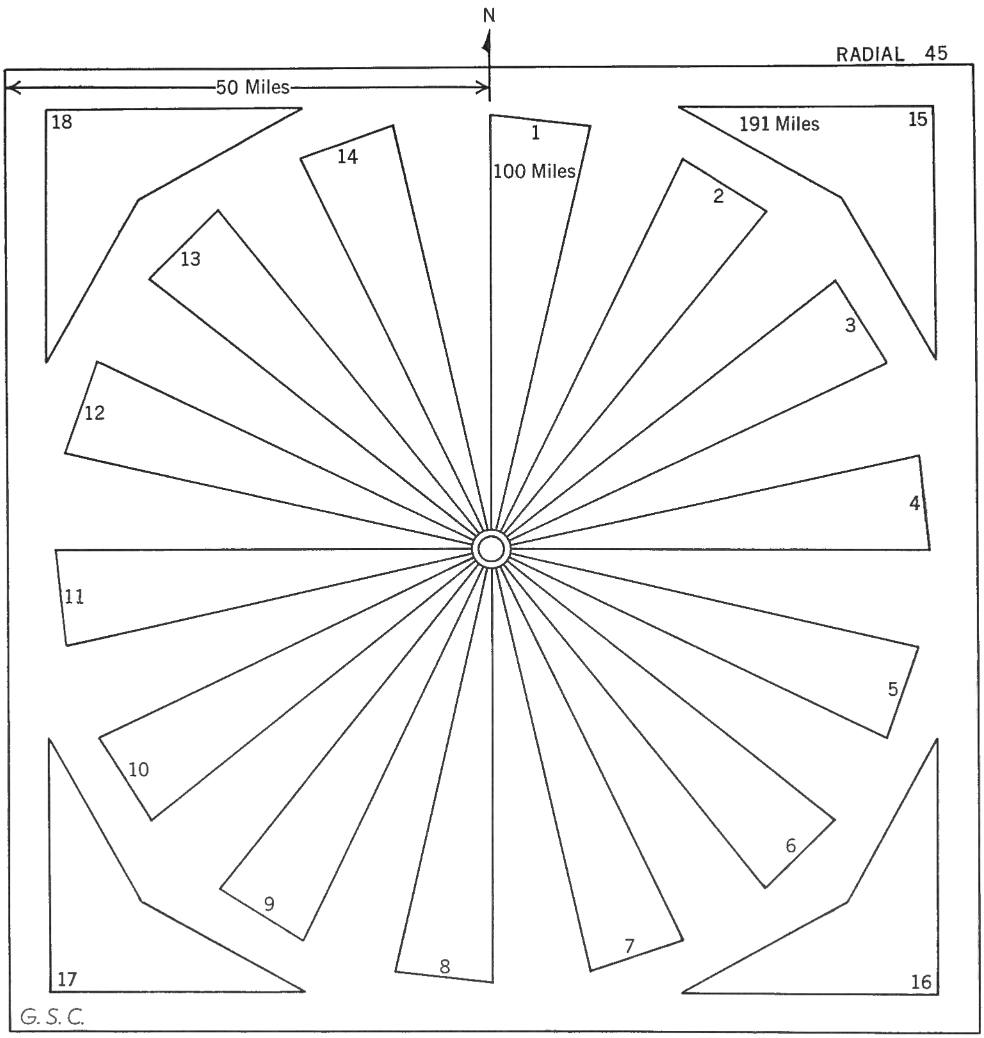


Figure 3. *Basic radial traverse net as used in the barren grounds. Ideally this would be surrounded by similar squares.*

siderable simplification of supply arrangements, caching problems and operational procedures. The Hiller and Norseman aircraft employed in 1952 used different gasolines.

Where complex geology was found in flying the standard radial net, extra traverses of similar or irregular shape were flown as needed. Groups of rectangular traverses were also used on occasion to meet special requirements.

On the completion of each camp 'square', the Norseman aircraft was used to move the survey base camp to the next location, about 100 miles distant, and the whole process was repeated. Moving days were not wasted geologically, as the helicopters ran survey traverses from one camp to the next. Eight to ten base camps were thus occupied in one season. In addition to moving camps, the Norseman supplied the necessary gasoline, oil and food to current and future camps, and made many caching and a few long exploratory flights.

Each radial traverse produced geological data based on an average of 15 to 20 landings, perhaps twice as many low and slow passes (5 to 25 feet; 5 to 15 mph), and an essentially continuous high level observation (100 to 300 feet). The low relief and almost complete absence of trees in 95 per cent of the area mapped meant that the helicopters could fly continuously at low levels with relative safety, and could land the geologists on or close to outcrops, thus ensuring maximum use of traversing time for geological purposes. Approximately 5,000 landings and 10,000 low passes were made in the three barren ground operations.

During the aerial traverses, the geologists plotted their observations directly on 1-inch-to-2-miles base maps. At base camp the material was then compiled on the scale of 1 inch to 8 miles, the publication scale.

As a general rule, only one traverse was made per machine each flying day. Although light conditions, in so far as map reading was concerned, would have permitted considerably more flying, geological observations from the air were restricted to those parts of the day (9 a.m. to 5 p.m. approximately) when light conditions were most favourable. Other factors affecting this decision were cost, personnel, size of party and quality control of mapping.

Costs

Table II gives a summary of operational and cost data for the light helicopter surveys in the barren grounds. It should be noted that, although helicopter unserviceability did occur and was troublesome at times, the average 'availability' of aircraft was good to excellent, and the serviceability problem probably delayed the operations to a lesser extent than did break-up, wind and weather.

Considering the distances from aircraft and supply bases, and the shortness of the field season for canoes in the central barren grounds, it is unlikely that the cost of canoe reconnaissance of comparable quality in this region could be brought lower than the average of $2.63 per square mile of the three helicopter surveys completed to date. It probably would be substantially higher, in the order of four to five dollars per square mile.

Table II

Summary of Costs for Light Helicopter Operations in Barren Grounds

	Keewatin (1952)	Baker (1954)	Thelon (1955)	Totals and Averages
Area mapped (sq. mi.)	57,000	67,000	61,000	185,000
Favourable prospecting ground (sq. mi.)	14,100	6,100	5,500	25,700
Cost ($)	207,000	144,000	135,000	486,000[1]
Cost ($ sq. mi.)	3.63[2]	2.15	2.21	2.63
Days in field	113	98	92	303
Cost ($ day in field)	1,830	1,470	1,470	1,600
Helicopter hrs.	515	563	520	1,598
Helicopter cost ($)	92,073	73,222	54,147	219,442
Fixed-wing hrs.	626[3]	450[4]	542[4]	1,618
Fixed-wing cost ($)	37,832	30,760	38,907	107,499
Total flying hrs.	1,141	1,013	1,062	3,216
Sq. mi. mapped per helicopter hr.	111	119	117	116
Sq. mi. mapped per double helicopter day (approx.)	814	837	813	826

[1] Excluding salaries of geologists and radio operator, equipment and general overhead.
[2] The higher costs of Operation Keewatin were due almost entirely to the higher costs of renting helicopters in 1952 and of establishing pre-season gasoline caches by air freight.
[3] Approximate, includes use of Bristol Freighter in establishing gasoline caches.
[4] Includes some use of DC-3 (Dakota) aircraft.

Conclusions

If it is assumed that the average canoe reconnaissance party would cover about 4,500 square miles in one field season in the barren grounds, it is clear that the combined coverage of 185,000 square miles in the three helicopter surveys is equivalent to at least 40 party-years using conventional methods. Five trained geologists were used on each of the helicopter parties. Had an attempt been made to cover the same ground in three field seasons using canoe reconnaissance parties, it would have required forty-five to sixty trained geologists and as many geological assistants per year, in addition to a mass of equipment and heavy utilization of fixed-wing aircraft. Under such conditions uniformity in mapping and efficiency in administration would have been impossible.

The helicopter method has several distinct operational and technical advantages over canoe-foot traversing methods. In general these are:

1. A longer field season is attained by commencing field work before break-up, and by working through the break-up period. In 1954, by the time waterways were open for canoe travel, Operation Baker had already mapped 25,000 square miles.

2. Flexibility is much greater in helicopter operations, both in the individual traverse where the geologist can make deviations in minutes rather than in hours, and also in the ability of the whole survey to change its degree of coverage quickly in order to meet changing geological complexity. Furthermore, the helicopter surveys are completely independent of canoe routes and refreshingly free of portages.
3. Only experienced geological personnel are used; the system requires no 'junior' assistants.
4. Uniformity in mapping is much easier to achieve, as any geological problems can be discussed daily by all the geologists concerned; such close control is impossible in canoe reconnaissance. The whole region involved in these three helicopter operations was covered in an elapsed time of only 39 months, so that some of the same personnel were available to carry continuity of geological thought and operational treatment through the entire project.
5. The preliminary results of geological study of this large, previously unmapped part of Canada are available to the public now rather than over the next 25 or more years.

References

Lord, C. S.

1953a: Geological Notes on Southern District of Keewatin, Northwest Territories; *Geol. Surv., Canada,* Paper 53-22.

1953b: Operation Keewatin, 1952. A Geological Reconnaissance by Helicopter; *Bull. Can. Inst. Min. Met.*, April 1953, pp. 224-233.

Wright, G. M.

1955a: Reconnaissance by Helicopter in the Barren Grounds; *Can. Min. J.,* vol. 76, No. 4, pp. 53-55.

1955b: Geological Notes on Central District of Keewatin, Northwest Territories; *Geol. Surv., Canada,* Paper 55-17.

1957 : Geological Notes on Eastern District of Mackenzie, Northwest Territories; *Geol. Surv., Canada,* Paper 56-10.

Quinn, 11-2-1952

A. Operation Keewatin, 1952. Complete survey base camp, with aircraft. Note low relief, treeless terrain. The essential 'working parts' of such a camp could be moved 100 miles in one day with one Norseman.

Plate I

B. Operation Keewatin, May 17, 1952. Typical break-up conditions: ice melting around shores, but still suitable for ski-equipped Norseman. The addition of small rubber boats in 1954 and 1955 helped to make the enforced break-up delay shorter and more manageable.

Wright, 1-12-1952

Wright, 6-7-1952

A. Operation Keewatin, 1952. Barren ground cariboo as seen from a low-flying helicopter. Note flat country and perfect visibility from the aircraft.

Plate II

B. Operation Fort George, 1957. Typical forested area that has been burnt over giving excellent rock exposures and a wide choice of landing places for the helicopter.

Heywood, 2-6-1957

Chapter III

LIGHT HELICOPTER RECONNAISSANCE IN NEW QUEBEC

(Operation Fort George)

by ***K. E. Eade***

Introduction

During 1957[1] the Geological Survey carried out the first part of Operation Fort George (Eade, *et al.*, 1957), a geological reconnaissance by light helicopter covering approximately 35,000 square miles in the southwestern part of New Quebec (Figure 1). One Bell helicopter (Model 47G-1) and one fixed-wing aircraft (De Havilland Beaver) were used in this work. In many respects the operation was similar to the three previously carried out in the barren grounds of the Northwest Territories, but within this region of Quebec the variation in forest cover from barren ground to heavy coniferous forest required some changes in technique. A preliminary reconnaissance of the general region during the previous summer by one geologist with an assistant aided in the planning of the operation. In particular, degree of forest cover was ascertained as well as availability of landing places for a helicopter in wooded areas and an overall picture of logistic problems.

The area mapped adjoins and in part overlaps the Eastmain area (Shaw, 1942, 1943) where geological reconnaissance mapping was carried out in 1941. This earlier work comprised not only normal canoe reconnaissance but also aerial observations of the geology from a fixed-wing aircraft taking air photographs. This was one of the first attempts to use air observations extensively in reconnaissance geological mapping.

The centre of the area covered lies approximately 270 miles from the nearest railhead and, although at a relatively southern latitude, it is an inaccessible region, except by air transportation. During the summer months, limited ship transportation for supplies is available along the James Bay-Hudson Bay coast, from railhead to the two small coastal settlements in the area, Great Whale River and Fort George. Other than sites of the Mid-Canada Line, which traverses this area, there are no inland facilities.

---

[1] Since this was written the 1958 season's work has been completed with operational results and conclusions similar to those presented here.

Organization

Three staff geologists, two concentrating on bedrock geology and a third on surficial deposits, along with three geology students comprised the technical staff. In addition the party consisted of a radio operator, cook, labourer, two canoemen, two helicopter aircrew (pilot and engineer) and two fixed-wing aircrew (pilot and engineer).

No special camping equipment was required for the operation, for here, in contrast to the barren lands, campsites could always be found with sufficient wood available for tent poles and fuel. As in the past, a one-hundred-watt radio transmitter in the base camp was used to maintain daily contact with outside stations and with the two aircraft when they flew. In addition, small five-watt transmitter-receivers were used for contact between subsidiary camps and the main base camp.

A cache of gasoline and oil was put in by air transportation during the winter prior to the operation, for use before shipping started the following season. The bulk of the gasoline, oil and food was brought in to the coastal posts by ship immediately the ice left James Bay-Hudson Bay.

During the winter months before the field work began air photographs of the region were examined but not in exhaustive detail.

Field Operations

Field work was begun in the northern part of the area prior to break-up as the previous operations in the barren grounds of Northwest Territories indicated the success of an early beginning. Unfortunately, in this area of Quebec where snowfalls continue through May and early June, the period is limited when lakes are still frozen solid enough for ski-equipped fixed-wing aircraft but rocks are free of snow. This condition may in part be due to the prevailing westerly winds crossing Hudson Bay-James Bay. Considerable work was accomplished in May and June when fixed-wing aircraft could not operate; this was in large part made possible through the use of the facilities of the previously established Mid-Canada Line.

The helicopter, a Bell 47G-1, was used entirely for systematic geological traversing. The two bedrock geologists did most of the traversing but the Pleistocene geologist did some regular traverses in addition to special traverses concentrating on obtaining Pleistocene data. Two different traverse nets were used. From two of the four camps occupied a series of thin, triangular traverses were flown similar to the method used in the barren grounds of Northwest Territories. From the two remaining camps, a rectangular net was flown, with north-south traverse lines spaced at 6-mile intervals along the east-west base line. This method sometimes necessitated placing of gas caches along the base line, but the somewhat extended range of the 47G-1 model Bell (over the 47D-1) meant that all traverses could be longer than in previous operations. The rectangular net for traversing offers definite advantages in that there is no concentration of traverse lines at a central point and geological structure (here east-trending) may be crossed at a high angle on all traverse lines.

In the northern part of the area, where tree cover is slight, the work was not different from that in the barren grounds of Northwest Territories. The southern section has relatively abundant forest cover but much of the region has been so thoroughly burnt by forest fires (Plate II B) that over large areas only bare dead trunks are left standing. The soil too is burnt out so that second growth is limited. The fires have cleared rock outcrops of moss and lichen leaving excellent exposures. In general, lichen cover on rocks is far less in this region than is found in Northwest Territories, which considerably increases certainty and ease of rock identification from the air.

In treed areas in the south, however, it was not always possible to find landing space for the helicopter adjacent to an outcrop selected for ground observation, but usually a landing could be made within a half mile. This might be in a swamp or on a lake, with some clearance near the shore for the helicopter blades. It must be emphasized that the excellent rock exposures made identification from low aerial passes so certain that landings were necessary only for checks and to obtain detailed information. Rarely did a ground check show an aerial identification to be wrong.

Originally the plan was to use two of the geology students, both with field experience, in canoe reconnaissance work of the normal type, carried out in conjunction with the helicopter work. Early in the season it became apparent that canoe routes were poor and frequent air moves would be necessary, many of these far from the base camp. This extra demand on fixed-wing aircraft time made it almost impossible to coordinate the two methods, and thereafter the students were employed in checking geology on the ground in restricted areas where helicopter work indicated more detail was desirable. From three to ten days were spent on such jobs with daily radio contact maintained between the subsidiary camps and the main base camp. This contact assured that the subsidiary camps could be moved by aircraft, weather permitting, as soon as work in any one place was completed. With the method finally adopted the Beaver aircraft proved entirely satisfactory for the operation despite its smaller capacity compared to a Norseman aircraft. By flying every day that weather permitted, the aircraft was able to meet all transportation requirements. The short take-off characteristic of the Beaver proved particularly valuable in placing the men for ground work on small lakes inaccessible to larger aircraft.

Base maps on a scale of 1 inch to 2 miles were used throughout for the geological field mapping, except for certain detailed ground work where mapping was done directly on the air photographs. All geological information was compiled on maps of 1 inch to 8 miles.

As the field work progressed, it was found advisable to carry out further studies of the air photographs in advance of the mapping but in the light of information already obtained.

Conclusions

As with the helicopter operations in the barren ground of Northwest Territories, certain advantages of this method are readily apparent. Three geologists and three assistants obtained in one year results that would take many years to accumulate using normal canoe-and-foot reconnaissance. Furthermore, the results have uniformity and continuity difficult to attain if mapping were spread over a number of years. The cost of mapping per square mile by helicopter is less than by ground methods.

The overall results obtained with the helicopter are better than those obtained by canoe-and-foot reconnaissance. With the latter method, more detailed information would be obtained in restricted areas, along canoe routes and within walking distance of them, but in this area of poor canoe routes serious gaps would occur in the coverage. In part, this could be remedied with frequent moves by air of canoe groups but this would increase mapping costs.

Loss of time due to bad weather during this operation amounted to 41 per cent, a relatively high figure. Much of this was due to rain or fog with some high winds, all of which, however, would also seriously interfere with mapping by normal reconnaissance methods. Such weather would disrupt aircraft schedules, a serious matter with canoe groups dependent on scheduled servicing from an outside point. With the method used on this operation, working as a self-contained unit, even short periods of good weather could be utilized by the aircraft.

In treed areas, visibility on ground traverses is limited whereas from the helicopter outcrops can be observed, though not as easily seen as in barren grounds. Furthermore, when flying, it is only a matter of minutes to deviate from the traverse line to observe outcrops off line. On a ground traverse, even if such outcrops could be seen, deviations are too time consuming if the traverse is to extend far. From a low elevation in the helicopter the general structure pattern of gneissic rocks is more readily discerned than by walking over the same rocks.

In summary, the outstanding advantages of the helicopter method in this region are: the ability to systematically and uniformly cover all the region, concentrating efforts in restricted areas if the geology requires; the results can be obtained in a short time with limited staff; geologists can concentrate more on mapping and less on problems of travel.

Table III

Statistical Summary of Operation Fort George, 1957

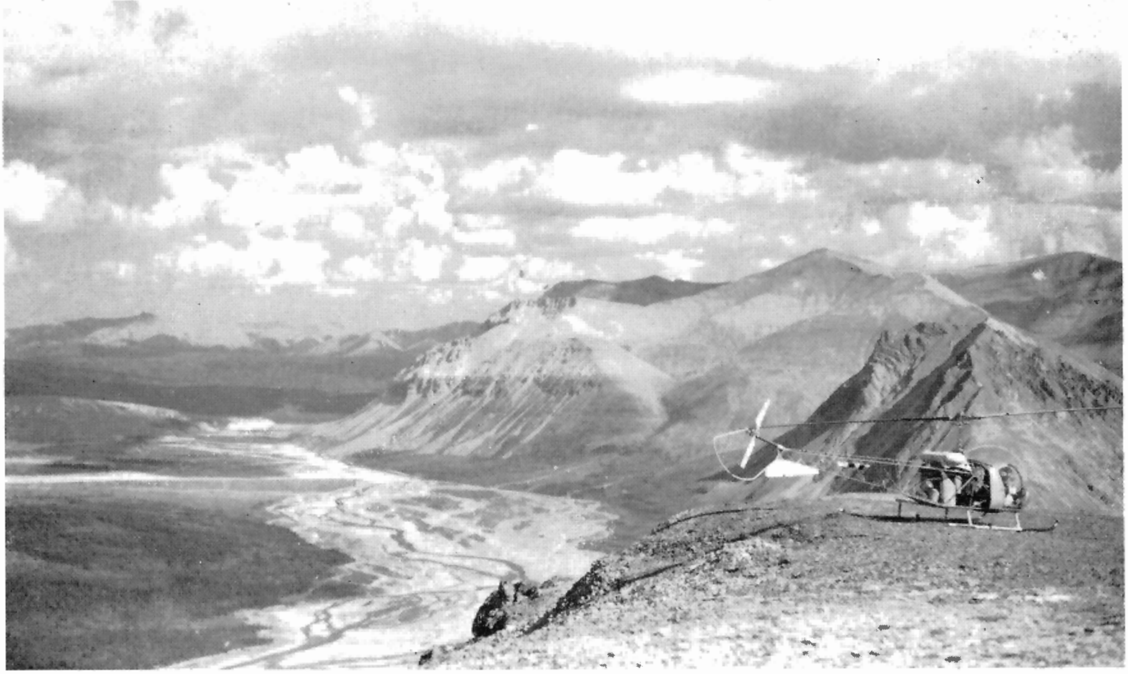
Coverage (sq. mi.)	35,000
Favourable prospecting ground (sq. mi.)	750
Cost (approximate, figures incomplete) ($)	68,000[1]
Cost ($ sq. mi.)	1.95
Fixed-wing hrs.	270
Helicopter hrs.	281
Days in field (with helicopter)	114
Days helicopter traversed (%)	54
Days lost through bad weather (%)	41
Days lost through unserviceability (%)	5

[1] Excluding staff geologists' salaries, equipment, and general overhead.

References

Eade, K. E., Heywood, W. W., and Lee, H. A.
1957: Sakami Lake Area, New Quebec; *Geol. Surv., Canada,* Map 23-1957.

Shaw, G.
1942: Preliminary Map, Eastmain, Quebec; *Geol. Surv., Canada,* Paper 42-10.
1943: An Experiment in Reconnaissance Mapping: *Trans. Can. Inst. Min. Met.,* vol. 46, 1943, pp. 85-96.

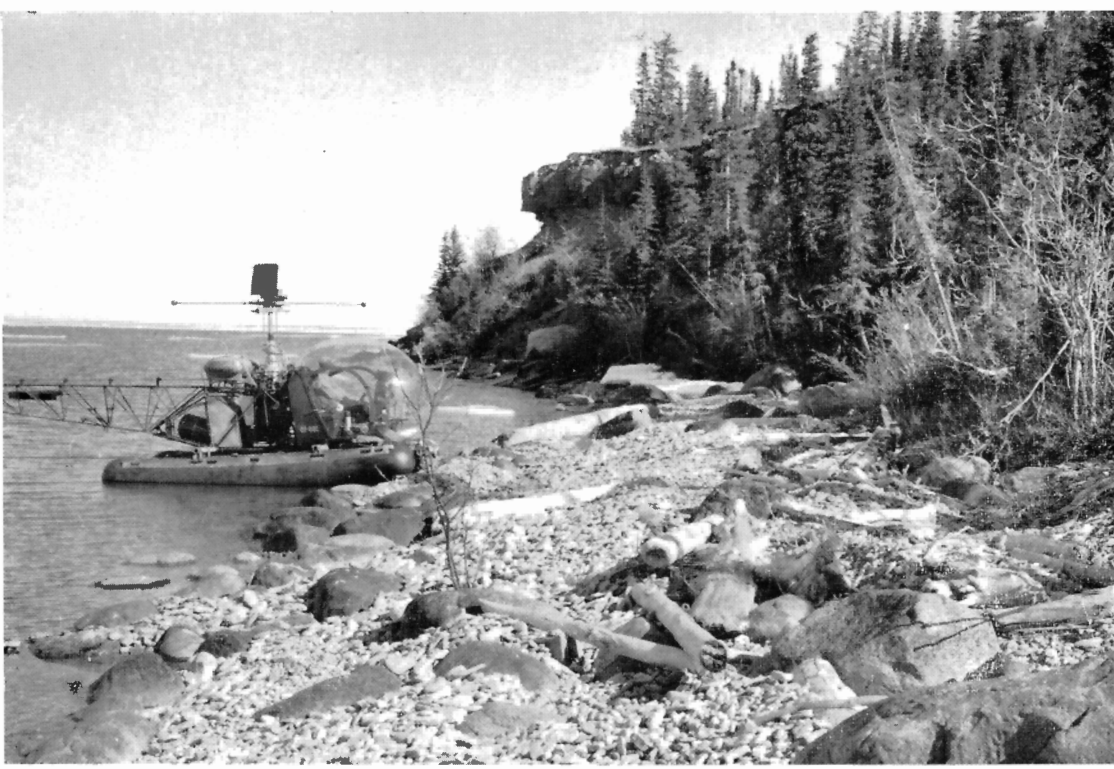


Norris, 9-6-1957

A. Operation Mackenzie, 1957. Mackenzie Mountains near headwaters of Root River. Helicopter with skid landing gear engaged in mapping traverse.

Plate III

B. Operation Mackenzie, 1957. Northwest arm of Great Slave Lake in mid-June. Helicopter with float landing-gear permits alternate landing on shore or water near typical exposure in heavily tree-covered plains. Note ice in lake.



Norris, 10-3-1957

Chapter IV

LIGHT HELICOPTER RECONNAISSANCE IN INTERIOR PLAINS AND MOUNTAINS

(Operation Mackenzie)

by ***R. J. W. Douglas***

Introduction

The western part of District of Mackenzie, Northwest Territories, embraces the northern continuation of the oil- and gas-bearing sedimentary rocks of Western Canada. Geological investigation of this northern region has been difficult and for many years was restricted to parts reached by canoe or boat, although the region has been looked upon as potentially oil- and gas-producing since the discovery of oil at Norman Wells in 1920. In recent years much surface geological investigation and geophysical exploration have taken place and several wells have been drilled. In 1957, the Geological Survey of Canada embarked on a helicopter-assisted geological reconnaissance of 100,000 square miles of southwestern District of Mackenzie in order to provide basic geological information for general distribution and to assess the oil and gas possibilities.

The region surveyed (*see* Figures 1 and 4) extends from lat. 60°, the north boundary of the provinces of Alberta and British Columbia, to lat. 64°, a distance of some 275 miles, and from the boundary of the Interior Plains on the east to long. 126° on the west. This longitude lies about 100 miles within the Franklin and Mackenzie Mountains. A part of Liard Plateau in southeast Yukon lies within the area.

Objectives

The principal objectives of the Operation were:

1. To acquire stratigraphic information on the sequence of bedrock formations throughout the area, to effect their correlation and to study their variations and mode of origin.
2. To prepare geological maps of the plains part of the area on a scale of 1 inch to 8 miles, and of the mountains on a scale of 1 inch to 4 miles.
3. To assess the economic possibilities of the area as a source of oil, gas, coal and minerals.
4. To collect data on the surficial deposits and also such other information as may have a bearing on the economic development of the area.

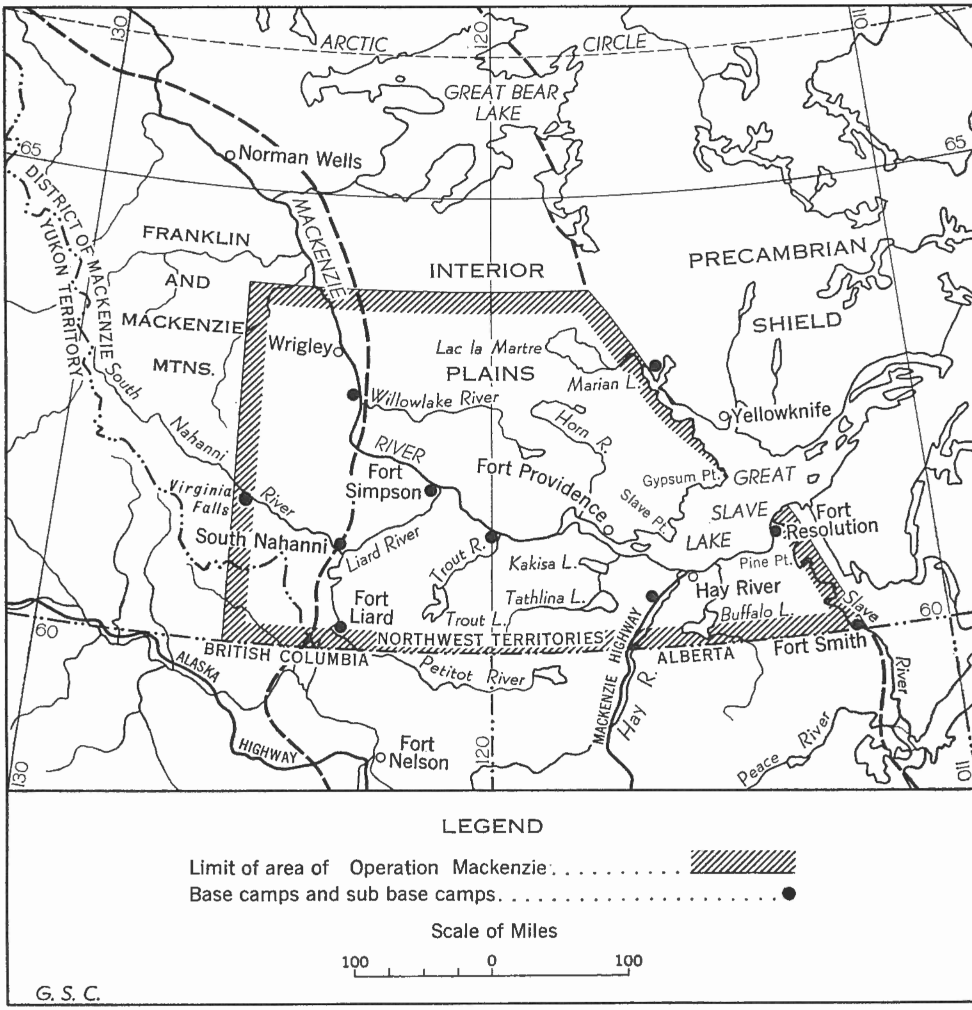


Figure 4. **Index map of area of Operation Mackenzie.**

Nature of Terrain and Geology

The greater part of the area of operation lies within the Interior Plains, an area of low-lying, poorly drained, muskeg-ridden ground and shallow lakes, broken by the high tablelands of the Cameron Hills and Horn Mountains and several low escarpments. The Plains are heavily tree covered (Plate III B), except the higher ground and more northerly parts which are tundra. Some grass land prevails west of Fort Smith. Lakes in the eastern part are saline or playa and are bordered by broad flats of white mud. The Plains are underlain by flat-lying to gently dipping strata of Ordovician, Devonian and Cretaceous age. The succession is thickest in the west where as much as 10,000 feet of strata may be present. In the east, where the sediments are thin, hills and ridges of the underlying Precambrian basement rocks protrude through the sedimentary cover. The bedrock is nearly everywhere mantled by Laurentide glacial deposits and lacustrine beds. These deposits appear thickest where overlying the softer bedrock formations and are thin to absent on the low escarpments where the more resistant formations outcrop. Outcrops of bedrock are scarce and throughout vast expanses are absent. Exposures occur along the rivers, escarpments and shores of Great Slave Lake and in sink-holes. Most are small and isolated; the best occur in the river gorges.

Mountains occupy the western quarter of the area. The eastern ranges are known as the Franklin Mountains and the more westerly as the Mackenzie Mountains. The southwest corner of the area, mainly within Yukon Territory, is termed the Liard Plateau. The Franklin Mountains are narrow, linear, north-trending ranges, commonly rising abruptly on east-facing scarps to elevations of 3,000 to 5,000 feet. Trees reach the crests of the lower ranges. Mackenzie Mountains are separated from the Franklin Mountains in the north by the broad lowland of the Mackenzie Plain, which is not unlike the Interior Plains in general aspect. The mountains consist of a rugged mass of north- to northwest-trending ranges and broad dissected plateaux. The northern ranges are mainly bare, rise to 6,500 feet in elevation and are separated by broad tree-covered valleys in which the principal rivers have carved broad gravel-covered flats (Plate III A). South of South Nahanni River the mountains are more compact, reach an elevation of 5,000 feet and are mostly tree and grass covered. Liard Plateau lies at about 3,000 feet elevation. Relief is low and the country flat and rolling, tree cover is heavy and exposures are limited to the higher ridges and low canyons along the rivers. Lakes are rare in the interior of the mountains but are fairly common within the eastern ranges and Mackenzie Plain.

The mountains are formed of strata ranging in age from Proterozoic to Upper Cretaceous with only beds of the Triassic and Jurassic missing. More than 40,000 feet of strata may be present in the west, but the thickness decreases to the east. Middle Devonian and older strata are mainly of carbonate composition whereas younger beds are predominantly shale and sandstone. The structure varies from gentle folds in the plateau areas to broad anticlines and synclines corresponding roughly to the northerly trending ranges and valleys. The folds are broken by easterly and westerly dipping thrust faults. Some ranges, particularly those of the Franklin Mountains, are underlain by west-dipping thrust faults and the strata are locally closely folded. The Laurentide glaciers occupied the plains and penetrated deeply into the mountains where there is also evidence of Cordilleran ice having flowed from the higher country to the west. Some of the higher ranges of the Mackenzie Mountains were the sites of local glaciers.

Organization

Personnel

The field party consisted of 29 men: 9 officers of the Geological Survey of Canada, 9 survey assistants, 3 aircraft pilots, 3 aircraft engineers, a boatman and a crewman, a radio operator and 2 cooks.

Equipment

Associated Helicopters Ltd. supplied two Bell 47D-1 helicopters under contract. These were equipped with floats for operating on the plains and with skids for the mountainous terrain. A DeHavilland Beaver was chartered for the summer from Pacific Western Airlines Ltd. It was equipped with ski-wheels at the beginning of the field season and with floats following break up. An 85 h.p. river boat and a 10-ton-capacity barge, chartered from G. P. J. Turner of South Nahanni, N.W.T., were used for moving gasoline, equipment and supplies on the Mackenzie and Liard Rivers, and the boat alone was used for geological traverses. A Radio Communication and Engineering TR100 portable set was used for communication with Royal Canadian Corps of Signals stations within the area, the Pacific Western Airlines base at Hay River, the Beaver in flight, and ground parties. Spillsbury and Tindall Model P12 portable radios were used to establish communications with ground parties camped some distance from base camp. The helicopters were equipped with VHF radios and carried Sarah as emergency equipment.

Utilization of Aircraft

DeHavilland Beaver

The Beaver aircraft was used for the following purposes:

1. *Establishing gas and oil caches.* These caches were used as refuelling points for the helicopters when on long traverse flights or setting out and moving subcamps, and as meeting places for the Beaver and helicopters.
2. *Establishing subcamps.* Subcamps of geologist and assistant were established and moved by Beaver alone where the geology could be readily reached from the Beaver landing place. More commonly subcamps were

set out in conjunction with the helicopters, the Beaver being used to expedite the move by lifting the entire party to a lake close by the proposed campsite.

3. *Moving base camp.* Much of the base-camp equipment, supplies and gasoline were moved by barge, but essential equipment and personnel were moved by Beaver. Sub-base camps were established in most part by Beaver.
4. *Trips for supplies and mail.* The town of Hay River was the main supply point. After leaving initial base camp at Hay River return trips for supplies averaged about one per week.
5. *Geological observations.* Aerial geological observations from the Beaver, both of the bedrock and surficial deposits, were made by one or more observers accompanying the aircraft on flights for the above purposes and also on a few independent flights. About three quarters of this type of information was obtained on gas cache flights, and the bulk of the remainder on supply and independent flights. The Beaver was used on the plains for day set-outs, taking up to three two-man parties, setting them off at lakes where exposures or sections could be reached on foot. The parties were moved during the day and picked up in late afternoon (*see* Table V).

In addition to the Beaver flying, some flying was done by Norseman on gas caching in vicinity of Hay River in late April and some by Otter in moving base camp from Marian Lake to South Nahanni (Figure 4). Approximate division of flying time is given in Table IV.

Table IV

Division of Fixed-Wing Flying Time, Operation Mackenzie

Gas caching and geological reconnaissance	135 hours (plus 30 hrs. Norseman)
Establishing subcamps	135 hours
Moving base camps	120 hours (plus 15 hrs. Otter)
Trips for supplies	65 hours
Total	455 hours (plus 45 hrs.)

Bell Helicopters

The helicopters could carry about 500 pounds useful load. This varied somewhat, depending on the weight of landing gear, altitude, nature of take-off and landing places, and the weather. The load was made up of either geologist and extra gasoline for long traverses, or geologist and assistant with emergency camp gear for day set-outs or with regular camp gear and supplies for subcamps.

Table V summarizes data pertaining to the geologists' use of the helicopters and also other methods of travel. Total time flown by both machines was 880 hours. The helicopters were used for:

1. *Traverses with geologists to*

(*a*) Obtain stratigraphic data (group A, Table V). Made mainly on the plains where the geological objectives were primarily the description and sampling of the rock and collection of the fossils. Landings were made either on the outcrop or within a half hour's walk (Plate III B).

(*b*) Map the bedrock and structure (group B, Table V). Made mainly in the mountains where the geological objectives of traverse flight were primarily mapping. These traverses were in large part combined with moving subcamps. Aerial observations were nearly continuous from low or high levels and stops of short duration were made for observations on the bedrock and sketching of structural details (Plate III A).

(*c*) Map the surficial deposits (group C, Table V). Made mainly on the plains with the objective of checking by ground observations and low passes, where vegetation prevented landing, the previous observations made either from the Beaver or by study of aerial photographs. In addition to the landings, approximately 110 low passes were made.

2. *Day set-outs*

The geologist and assistant, with emergency camp gear and food, were set out where ground observations of a day or part day were required. This was usually done in one or two trips directly from the geologist's camp. One or two, rarely three, parties could be accommodated in this manner in a single day by a single helicopter, provided flying times were not too great and good weather conditions prevailed.

3. *Establishing subcamps*

Subcamps were established and moved by one or two helicopters, or by the Beaver with one or both helicopters. Many combinations were possible, the most practicable depending mainly on availability of gas caches, distances involved, other aircraft commitments and the weather. As the weight of equipment usually amounted to about 600 pounds, exclusive of the two men, two trips or both machines were required to set out or move a subcamp, one man and part of the equipment and supplies being moved on each flight. Subcamps were established mainly where stratigraphic sections were available; more rarely where ground traverses were required. Examination and description of sections, together with sampling and collecting the fossils, usually took 3 or 4 days. Thick sections took up to 12 days and the subcamp was moved once or twice during that time in order to keep the geologist close to his work. On the plains subcamps were few and widely separated and the party returned to base after each subcamp. In the mountains many subcamps were used and parties were moved to several in succession before returning to base camp.

Table V

Summary of Use of Aircraft, Operation Mackenzie

1	2		3				4							5		6	7							8	9	10	
Group	Number of Helicopter Traverse Stops		Number of Set-outs				Number of Subcamps							Helicopter Hours with Geologists		Beaver Hours on Geological Reconnaissance	Number of Days Engaged in Geological Observations							Man Days in Field	% Time Engaged in Geological Observations	Feet of Stratigraphic Section Measured	
			Plains		Mtns.		Plains			Mtns.			Ground and Boats														
	Plains	Mtns.	B	H	B	H	B	B/H	H	B	B/H	H		Plains	Mtns.		Base	Set-outs	Subcamps	Boats	Beaver	Helicopter	Total			Plains	Mtns.
A	259	92	4	15		31	10		12	6	16	32	32	180	176	40	44	47	189	91	15	75	461	682	68	14,000	208,000
B	57	163	12	1		5	3		2					63	160	170	22	*	16		47	55	140	236	59	2,000	2,000
C	69	4											10	50	5	110	11			17	34	16	78	115	68		
Totals	385	259	32		36		27			54			42	293	341	320							679	1,033	66	226,000	

Abbreviations: B, Beaver; H, Helicopter; B/H, Combined; *Included elsewhere.

Group A—Geologists engaged mainly on stratigraphic work.

B—Geologists engaged on stratigraphic work on plains and mapping in mountains.

C—Geologists engaged in mapping surficial deposits.

(*a*) By helicopter and Beaver. Where suitable lakes were available near the proposed campsite the party and their equipment were taken to the lake by Beaver and thence set out at the site by helicopter. Moves from the site were made by the same method, or by helicopter alone.

(*b*) By helicopter. Subcamps were established and moved by helicopter where there were no landing places for the Beaver or where gas caches were available and distances involved were such that the Beaver was not necessary. The latter were short moves to new locations and moves along the section; these formed a large part of all subcamp movements (Table V). On these flights the helicopter was accompanied by an observer engaged in mapping. Where no lakes, and consequently no gas caches, were available the subcamps were established by both helicopters, or by one machine in two trips, at distances within their normal range. For a move by one machine, a load of gas was taken in, together with food and supplies, sufficient to move the party to the next campsite. For long moves a supplementary gas cache was established by the helicopter in one or two trips. Where the two helicopters worked together the subcamps were moved in a very short time, thus decreasing the risk of a camp split and enabling the geologist to commence work at the new location almost immediately. Two or three parties in the same general vicinity could be moved the same day. In these cases, the helicopter, in establishing and moving the subcamps, was unaccompanied by an observer and independent traverse flights were made for mapping purposes.

Field Operations

During the winter preceding the Operation a study was made of all available published and unpublished geological literature pertaining to the area and adjacent regions, and of vertical aerial photographs covering the area. Much of the unpublished information was supplied through the courtesy of several oil companies. The advance study provided an invaluable background with which to commence field work and assisted in the assessment of the work to be done and allotment of the available time.

For the surficial deposits, vertical aerial photographs and mosaics were used to indicate areas where stratigraphic sections might be obtained and for the compilation of maps of the physiographic features that indicated direction of movement and former positions of the glaciers, former lacustrine submergence and post-glacial aeolian activity. In the field, the glacial stratigraphy and the composition, dimensions and relationship of the various physiographic features were studied in the course of a general checking of the advance compilations.

For the plains part of the area, the location of and means of access to the outcrops were studied in aerial photographs and consequently field examination of exposures commenced immediately by ground parties and from the helicopters according to prearranged assignments. This work was mainly stratigraphic; preparation of geological maps of the plains part of the area is essentially a compilation of this data.

For the mountains, advance work was mainly interpretation of aerial photographs. The stratigraphic succession was divided into units which could be recognized and traced in the photographs and these units were equated with established formations in mapped areas. Advance geological maps were compiled, and at the same time the best locations to study sections, oldest and youngest beds, apparent lateral variations in the units and areas of complex structure were noted, and an estimate was made of the time required for these studies. This work was incomplete in certain areas, particularly those heavily tree covered, where tracing of units and unravelling the structure are extremely time consuming and difficult. The detrimental effects of this lack of information were felt in conducting the field work.

At the beginning of operations in the mountains and at each new base or sub-base camp, reconnaissance flights by Beaver were made to search for lakes suitable for Beaver operations and bordered by a landing place for the helicopters. During the flights observations were recorded on the advance geological maps, mosaics or photographs and the pre-selected locations for stratigraphic sections were checked for suitability and accessibility. After appraisal of the data by the geologists and the pilots, subcamps were established. During flights to set out, move, and resupply the parties, geologists accompanied the helicopter and mapped directly on the aerial photographs. Co-ordination of the results of the stratigraphic work with the mapping was effected as well as possible during visits for moving or supply. Where necessary independent helicopter flights for mapping and structural purposes were made. Thus geological mapping was generally completed ahead of stratigraphic studies.

Co-ordination of the activities of the nine geologists and the three aircraft was accomplished by means of an 'operations board'. This was a sheet of beaver-board about 3 by 4 feet, with the names of geologists on the left side and columns for the days of a two-week period with cards bearing the appropriate dates at the top. Opposite each geologist's name, cards bearing data on the nature of the project and aircraft requirements were placed below the appropriate dates for commencement and completion of the project. This schedule prevented conflictions of aircraft commitments and effected maximum utilization of aircraft. Also changes in individual geologist's schedules could be made with minimum interference with other work. The value of radio communications between subcamps and base can readily be appreciated in arranging such a schedule.

Logistics

Gasoline and oil for use by the aircraft were purchased in 1956 and stored with Imperial Oil Limited agencies at Hay River and Fort Simpson so that they would be available before and immediately following break-up in the spring. From Hay River some was moved by truck during the winter to a proposed base at Marian Lake and some was moved by Norseman in April to the southeast part of the area for helicopter operations during break-up. About half that at Fort Simpson was moved by barge in May and June up Liard River to a proposed base at South Nahanni.

The town of Hay River (Figure 4) was the assembly point and main supply base for the season. Most of the party and the helicopters arrived in early May. Work during the break-up period in May was satisfactory, the weather being mainly fine and the ground free of ice. Water levels were high and a few exposures were inaccessible. Break-up occurred in three stages: on the main rivers such as the Hay, at the beginning of May; on the small lakes of the interior from middle to end of May; and on Great Slave Lake about the middle of June.

From Hay River base geological work centred mainly on the part accessible by car along Mackenzie Highway and a newly constructed road leading west to Fort Providence. The adjacent interior was reached by helicopter traverses, and to a minor extent by daily set-outs and from subcamps. One helicopter and two subparties were stationed at Fort Smith and Fort Resolution. The Beaver, which was operating on ski-wheels from the Hay River airstrip, moved their camps to airstrips at Fort Smith, Fort Resolution and Pine Point. At that time the airstrips were the only available landing sites for the Beaver as break-up was well under way on the lakes. Slave River south of the area was traversed by canoe. The northwest shore of Great Slave Lake was examined from Slave Point to Gypsum Point by combination helicopter traverses and ground work from a subcamp which was moved along shore. Great Slave Lake was filled with ice, although rotten and broken, and the helicopter was equipped with floats. After break-up it would have been hazardous to engage in daily flights across the lake even with floats.

As work progressed westward beyond the limits of operation from Hay River base a sub-base camp was established by Beaver at the mouth of Trout River. From there three parties with one helicopter continued work, ultimately moving to Fort Simpson and thence to South Nahanni by early July. Exposures and surficial deposits on Mackenzie River above Fort Simpson were examined by canoe. The geology was done by helicopter traverses, daily set-outs and from subcamps on the tributaries of Mackenzie River. The upper part of Trout River, the largest tributary, was done by a 17-foot, square-stern, prospector canoe flown in by helicopter. It was loaded keel side up over the undercarriage frame of the right side and rested on the skid. This position was found easiest to load and unload and there was less danger of damage on landing. The canoe did not noticeably interfere with the flight.

In mid-June, shortly after break-up, the remainder of the party was moved by Beaver to Marian Lake. Parties, one with a canoe, were set out by Beaver and moved to lakes and rivers of the interior. The Beaver was also used for day set-outs. The helicopter was used for traverses along the shore of Great Slave Lake and to reach into the interior to places inaccessible by Beaver. Work was completed at Marian Lake by end of June and camp moved to South Nahanni, the Beaver being assisted by an Otter from Yellowknife. Base supplies left at Hay River were moved to South Nahanni with the boat and barge. En route most of the sub-base camp at Fort Simpson was picked up as work there had also been completed.

Two parties had left Hay River for South Nahanni in early June, shortly after the Liard River was free of ice, to examine sections accessible from the river. This enabled a start to be made on the mountains while the remainder of the party completed work on the plains. On arrival of the helicopters these parties and a third were set out in the mountains southwest of South Nahanni and moved progressively west and south, being withdrawn in late July to a sub-base camp at Fort Liard.

The mountains northwest of South Nahanni were reached directly from the base with the aid of gas caches on small lakes within the eastern part of the mountains and at Deadmen Valley on South Nahanni River, where the Beaver could land during high water. For the last two weeks of July a sub-base camp was set up above Virginia Falls on South Nahanni River from which three parties and one helicopter operated. Thick sections exposed on several mountains in the vicinity were examined from a subcamp and directly from base, the geologists and assistants being lifted to the tops of the mountains as required. Working the sections downhill saved a great deal of time and energy.

Old Fort Island on Mackenzie River near Wrigley was the site of the last base camp. During the move most parties were established at subcamps in the intervening region. They were subsequently moved into the western ranges of the Mackenzie Mountains and, as the season drew to a close, to locations within the eastern ranges and Franklin Mountains. The surficial deposits and exposures on Mackenzie River were examined by boat as far north as Norman Wells. By the end of August most of the objectives had been met and operations ceased. Equipment was taken out by barge to Fort Nelson, B.C., and the party returned via Yellowknife.

Costs

Table VI summarizes costs of the Operation: not included are geologists' salaries, equipment and general overhead.

Table VI

Summary of Costs, Operation Mackenzie

Flying	
Helicopters	$ 79,200
Fixed wing	37,100
Gas, oil and containers (net)	12,300
Boat and barge (including fuel)	7,300
Field	
Transportation	6,400
Subsistence	8,300
Wages	12,700
General	4,200
Total	$167,500

Conclusions

1. In an area of 100,000 square miles the bedrock and surficial deposits were mapped and about 225,000 feet of stratigraphic section examined in a period of nearly four months by a party of nine geologists at a cost of $167,500.

2. In so far as the stratigraphic work is inseparable from the geological mapping the cost of obtaining both types of information only slightly exceeds the cost of obtaining either independently. Accordingly, the total cost of the operation may be assessed as $1.68 per square mile mapped or $0.75 per vertical foot of section measured. An approximate division of total cost according to time spent on the plains and in the mountains results in costs of: for the plains, $0.90 per square mile and $4.20 per foot of section; for the mountains, $4.00 per square mile and $0.48 per foot of section.
3. From a comparison of work done by these methods with that using conventional methods of travel, it is estimated that a large part of the stratigraphic data on the plains and a small part of that in the mountains could have been acquired in three or four seasons by the same number of geologists working independently. Where it could be readily done most data were gathered by conventional methods. For all practicable purposes, the remaining information, mainly from the stratigraphic sections beyond the outer ranges of the mountains, systematic mapping in the mountains, and isolated exposures in the interior of the plains, could not have been obtained by conventional methods.
4. The heavy tree cover of much of the plains and southern mountains had a considerable effect on the time spent by the geologist in reaching bedrock exposures and prevented close examination of many of the surficial features. More complete coverage than that obtained would be possible with higher-powered helicopters, more time at the disposal of the geologist in travelling from available landing sites, and operating at a time of year when water levels on creeks and rivers are low and gravel bars exposed.
5. With helicopters, profitable use can be made of the break-up and pre-break-up seasons, whereas canoe and ground work cannot start until the rivers and lakes are free of ice and the ground is dry.
6. The operational methods used were found satisfactory. Of these the day set-outs were least satisfactory, mainly owing to the uncertainties of being stranded by weather changes or aircraft unserviceability. With a large party continuous helicopter traversing cannot be maintained without loss of geologists' time except where most of the party are engaged in other work. In this regard, the versatility of the Bell helicopters of the type used or similar models is ideal for work with objectives comparable to those of the Operation. It is powerful enough to lift men and equipment in the mountains and small enough to operate economically on traverses and land at restricted locations. The Beaver is an excellent support aircraft, particularly with regard to its ability to operate in and out of small lakes, a consideration which more than offsets the limited useful load. For base-camp moves a barge or periodic assist from other aircraft is required.
7. The area covered by the operation is but a part of the 400,000 square miles underlain by similar sedimentary rocks of the northern plains and mountains of Western Canada which have been scarcely examined geologically. Similar investigations in the remaining area could furnish additional reconnaissance and detailed information within a few years.

Chapter V

LIGHT HELICOPTER MAPPING ON A PLATEAU, CAPE BRETON ISLAND

by *A. S. MacLaren*

Introduction

The Geological Survey of Canada carried out a 1-inch-to-1-mile helicopter-assisted mapping program in northern Cape Breton Island during the summer of 1954. The purpose of this survey was to assess the mineral potential of Cape Breton Highlands National Park. E. R. W. Neale and the writer were in charge of the project.

The map-area, covering some 850 square miles, extends from 40°30′ N lat. to the northern extremity of the island and includes St. Paul's Island.

Northern Cape Breton Island is mainly a tableland (Plate IV A) lying at an elevation of 1,000 to 1,500 feet above sea-level. Minor lowland areas fringe part of the plateau and extend for short distances up some of the brooks and rivers. The tableland is deeply dissected by streams flowing in V-shaped valleys which, in places, have been cut down 500 to 1,000 feet below the average level of the plateau. These streams are so full of rapids and waterfalls that canoe travel is impossible. The southern part of the plateau is so densely wooded that it is not readily accessible by pack-animals and there again streams are not navigable by canoe. The lowlands are underlain by sedimentary rocks of Mississippian age whereas the highlands are underlain by resistant metamorphic and intrusive rocks.

By using a 200 h.p. Bell helicopter, model 47D-1 equipped with floats, nine men were able to examine the major part of this area in one field season. It is estimated that, without the helicopter, it would have required from four to six field seasons for the same number of men to have completed the area.

Between July 1 and September 30—a total of 92 days—192 flights were made with the helicopter. The helicopter was grounded for 18 days, with non-operational weather accounting for 13 days, repairs to aircraft for the remainder. Maintenance was carried out between flights or at night.

Field Operations

The helicopter proved invaluable in carrying out three main types of field operations: in work along brooks, on outcrop in the interstream areas, and in establishing fly camps.

70607-7—4

More than 90 per cent of the rock outcrop in this area is found in the brooks and rivers so that most of the field work was confined to geological examination along the water courses. The helicopter speeded up this work. Two men were flown to the headwaters of a brook and landed either on a lake or in a small swamp—a flight operation lasting usually 10 to 20 minutes. The traverse along the stream on the other hand required 5 to 9 hours to complete. Once at the coast, the men returned to base camp either by pre-arranged truck transport or on foot. Using this method the helicopter could set out and pick up four two-man parties in one day. There were some streams not readily accessible from fly camps on the plateau, or from which it was impractical to walk to the coast. Certain others could not be traversed in one day and had to be completed in sections. In such cases low passes over the stream areas were made and a day's work laid out, taking into account the amount of outcrop, traversability of the brook and availability of landing and pick-up points such as gravel bars in the streams, small swamps and lakes.

In the interstream areas outcrops are few and widely scattered. Here again the helicopter was a time saver. Instead of traversing the whole area on foot two men were landed at an outcrop area, completed the mapping and were then flown to the next outcrop area. In this way more individual areas were reached without traversing large areas barren of outcrop and with minimum time lost.

In establishing fly camps the helicopter was able, in three trips, to transport four men, camp equipment and sufficient food for 7 to 10 days from base camp into the fly campsite. Similarly fly camps were moved on the plateau. The helicopter was never based at fly camps. Using the helicopter, two four-man fly camps of two two-man traversing teams could be kept in operation concurrently.

In other ways the helicopter proved useful. It was able to land on small swamps measuring 70 by 100 feet. This was particularly advantageous in reaching outcrop areas or in stream traversing in the densely wooded southern part of the area (Plate IV A). It was also able to land on narrow flat ridges for checking rock types. The helicopter was found to be unstable on slopes greater than 10 degrees.

Along coastal areas where cliffs had not been mapped from canoe, the helicopter would fly 50 to 75 feet off the cliff face enabling rock types and contacts to be easily identified and mapped. It was also used to fly over water from Cape North to St. Paul's Island, a distance of approximately 16 miles.

The range of the 47D-1 Bell helicopter equipped with floats and carrying two men plus the pilot is from 120 to 140 miles, or two hours flying time under average weather conditions. When only one man accompanies the pilot extra fuel can be carried on the pontoons, thus extending the flying time. It was found impractical to operate the helicopter in winds exceeding 25 miles an hour or in dense fog.

The 47D-1 Bell helicopter proved to be a valuable aid in mapping this plateau where use of canoes and pack-animals was impractical. Use of this machine in other half-mile or four-mile mapping programs over similar terrain is recommended.

Costs

The total cost of this project was $31,400 excluding geologists' salaries, equipment and overhead. This included a cost for the helicopter of $25,900 ($7,000 per month fixed charges, plus $20 per operating hour), and $900 for helicopter transportation to and from the field. The major part of the remainder was charged against wages, travelling expenses, and board and lodging.

References

MacLaren, A. S.

1955 : Geological Mapping on a Plateau using a Bell Helicopter; *Can. Min. J.*, vol. 76, No. 4, pp. 55, 56.

1956 : Ingonish, Nova Scotia; *Geol. Surv., Canada,* Paper 55-35.

1957 : Cheticamp River, Nova Scotia; *Geol. Surv., Canada,* Paper 55-36.

Neale, E. R. W.

1955 : Dingwall, Nova Scotia; *Geol. Surv., Canada,* Paper 55-13.

1956a: Cape St. Lawrence, Nova Scotia; *Geol. Surv., Canada,* Paper 55-22.

1956b: Cape North, Nova Scotia; *Geol. Surv., Canada,* Paper 55-23.

1956c: Pleasant Bay, Nova Scotia; *Geol. Surv., Canada,* Paper 55-24.

70607-7—4½

A. S. MacLaren

A. Interior Cape Breton Island, 1954. Cape Breton tableland looking across the upper northeast Margaree River. Swamps like the area in the right foreground can be used as helicopter landing areas.

Plate IV

B. Typical landing site in central part of Pitt Lake map-area, southern British Columbia, 1954.

J. A. Chamberlain

Chapter VI

LIGHT HELICOPTER MAPPING IN COAST MOUNTAINS, BRITISH COLUMBIA

by ***J. A. Roddick***

Introduction

During the 1954 field season a helicopter was employed for 30 days to facilitate the 1-inch-to-4-mile mapping of the Pitt Lake map-area, which borders most of Lower Fraser valley on the north (*see* Figure 1). The region is rugged, almost entirely in the Coast Mountains, with the ridges reaching an average height of 6,000 feet above sea-level, and some peaks approaching 9,000 feet. Although relatively close to Vancouver, access to the area is limited and movement within it is extremely difficult. Logging roads are present at the north ends of Harrison and Pitt Lakes, but trails leading away from these two main valleys are non-existent. The valley walls usually consist of a series of sheer cliffs (Plate IV B) and the higher ridges are narrow and serrated. To traverse them, elaborate climbing equipment is often required. Both on the valley floors and on the ridges travelling is slow and arduous. As dense forest and underbrush cover all but the steepest slopes up to about 5,000 feet elevation, much time is wasted by surface methods in unproductive traversing of ground containing few or no out-crops. Nor is it possible to travel any considerable horizontal distance above tree-line, because of the deep saddles which frequently dissect the ridges.

The 1954 season was the second in which the Geological Survey employed helicopters in the Coast Mountains. The first time was at the end of the 1953 season when a helicopter was engaged (in the Pitt Lake map-area) for a few days on an hourly basis. This experience was useful in planning the following season's work.

Equipment and Personnel

The helicopter used was a 200 h.p. Bell, model 47D-1. This is a 3-place machine, equipped for this operation with skids. Floats could have been used but they considerably decrease flying speed, manœuvrability, and operational ceiling. With skids, the cruising speed is 60 to 70 miles per hour. The fuel tank holds 24 gallons, and consumption is about 11 gallons per hour. Maximum flying time was often extended to about 4 hours by carrying an additional 20 gallons in four 5-gallon cans lashed to the freight nets.

In addition to the geologist in charge, the personnel included the helicopter pilot and enginer, three survey assistants and a cook. Apart from the flying crew, this was a normal-size survey party, and during most of the season (when no helicopter was available) it operated in the normal manner. The assistants were somewhat exceptional in that each was an experienced mountain climber, and each was capable of conducting routine traverses independently.

Field Operations

The operation was carried out from two base camps, one at the north end of Harrison Lake, and one at the north end of Pitt Lake. At both places, several weeks of preliminary work covering the more accessible areas was done prior to engaging the helicopter, which was used for the higher and more remote areas.

In the morning the helicopter carried three of the men to the beginning of their traverses. Then during the rest of the day, one geologist with the helicopter made as many spot landings and examinations as possible. At the end of the day the men doing surface traverses were picked up and returned to camp. This resulted in the area being covered by many spot examinations and a much fewer number of surface traverses. The traverses were usually along ridge tops and were inspected first for climbing difficulties from the helicopter. In case the weather turned bad during the day, an alternative, low level, pickup point was designated, usually a gravel bar on the valley floor.

The operation in the Pitt Lake area was influenced by circumstances peculiar to the area, and to a certain extent peculiar to the season of 1954.

1. The area is situated close to the major helicopter base of Vancouver. This meant that replacement helicopters and rescue facilities were readily available.
2. Even during bad weather the lower parts of the valleys were generally flyable by helicopter. Thus, even if ridge-top pickups could not be made because of low clouds, the alternative points in the valley bottoms were clear.
3. The general nature of the geology was known from surface work done during the previous season. Most of the area is underlain by granitic rocks of varying complexity, consequently more significant information is derived from many spot examinations more or less equally spaced than from the same number of examinations made on a relatively small number of ground traverses.
4. Because of the heavy forest growth, landings were not possible between the ridge tops and the valley floors. In the valleys, landings were limited to gravel bars in the larger stream beds.
5. During the summer of 1954 the weather along the southern coast of British Columbia was the worst ever recorded. Thus effective flying and survey time were greatly curtailed, necessitating increasing use of the most rapid method of covering the area (that is, the sacrificing of some ground traverses for a greater number of spot examinations).

Owing to the small number of technical personnel, the helicopter could not be used full time for transporting supplies and men to fly camps. Nor was this method desirable because of the nature of the geology and the short period of helicopter time available.

Certain observations could be made from the air, but only major rock units (such as granitic and non-granitic rocks) could be distinguished. During flight, observations of outcrops were made from 50 feet or less. For safety, the helicopter generally was flown slightly above and slightly to one side of the ridge crests, giving excellent view of both the tops of ridges and cliff faces. Because of the high relief it was not necessary to maintain 300-foot clearance above the surface, which is the altitude normally required for safe auto-rotational landings in case of engine failure. In emergencies the air space needed could be gained by slipping off towards the valleys. The highest landings were made at 7,800 feet, but because of the relatively high temperature (70°F), this was equivalent to 10,000-foot pressure-altitude. With two passengers, no landings or take-offs were made above 4,000 feet actual elevation. Landings were greatly facilitated by snow patches, which remained fairly abundant until late August. The rocky ridges, when bare, are in many places too uneven to be suitable for landing. Although single-man traverses are not generally advisable in the Coast Mountains, the mountaineering capabilities of the assistants combined with feasible alternatives in case of bad weather, nearby rescue facilities in case of accidents, and thorough pre-examination of routes, reduced the risks often to levels below those encountered by two-man traverse teams unsupported by helicopter.

Conclusions

In comparison with the surface methods, previously employed in the area, the helicopter offers many advantages, most of which arise from its speed in transporting the geologist to the geology.

1. Instead of expending much of his time and occasionally nearly all of his energy making his way to the outcrops, the geologist's actions can be dictated primarily by the requirements of the geology rather than by problems of access.
2. A regular distribution of examinations is possible, instead of the highly irregular distribution inherent in all methods dependent upon routes of access. This is particularly important in large areas of granitic rocks where a regular sampling is required, and 'critical' areas demanding detailed examinations are rare.
3. Reliance on inexperienced personnel is greatly decreased.
4. Maximum advantage can be taken of short breaks in periods of bad weather, and the field season can be extended if desirable.
5. Increase in safety results from the elimination or reduction of back-packing, which entails considerable risk since it greatly complicates normal climbing problems.

6. The cost per square mile of mapping is about equivalent to surface methods in regions of average geological complexity, and less where the geology is simple.
7. Adequate specimens can be taken from remote localities.
8. Physical hardships incidental to mapping in mountainous country are much reduced.

Some disadvantages are also involved with the use of a helicopter:

1. The necessity of making rapid decisions, and abiding by those of the pilot, lessens to some extent the geologist's control over the mapping.
2. Financial risk in helicopter operations cannot be entirely avoided. The expense of planning, organizing, laying out gas caches, etc., may be lost in part if the project is unable to proceed as planned, because of weather, mechanical or other difficulties.
3. Men may be placed in positions from which they cannot extricate themselves without the helicopter.

Table VII

Operational Data, in Coast Mountains

Area mapped during season	1,600 sq. miles
Nature of geology	mostly granitic
Surface travel	very difficult
Time with helicopter	30 days
Full utilization	8 days
Limited utilization because of low clouds	10 days
Limited utilization because of mechanical trouble	3 days
Total helicopter flying time	76 hours
Time flying in good weather	37 hours
Time flying in poor weather[1]	33 hours
Time spent on ferrying flights	6 hours
Total cost of helicopter including fuel	$ 9,592
Helicopter stand-by charge for 1 month	$ 8,000
Cost of gas and oil	$ 500
Flying time charge as $12/hour	$ 942
Cost of provisions for helicopter crew	$ 150
Cost per hour of survey flying	$ 135
Total cost of season's survey	$16,200
Cost excluding helicopter operation and salary of party chief	$ 6,608
Cost per square mile of mapping[2]	$10 approx.

[1] 'Poor weather': low hanging clouds prevented flying over the ridges.

[2] This is about equivalent to normal cost in average seasons in the southern Coast Mountains. In a season of very poor weather such as 1954 the cost of surface methods would probably have run as high as $20 per square mile.

Although comparisons of helicopter methods with older surface methods are relatively easily made, the evaluation of various ways of using the helicopter is more difficult. The variables of geology, personnel, weather and terrain are decisive factors (probably in the order listed). The method used in the Pitt Lake area is generally applicable where the helicopter is merely a short-term addition to the facilities of a normal field party. In such instances the general aspects of the geology are known before the helicopter is employed, and will govern the emphasis placed on surface traverses as opposed to spot examinations. In general, where the helicopter is incorporated into a field party geared primarily for normal surface methods, the lack of personnel will compel the helicopter to be used more as a traversing than as a freighting vehicle, but as the complexity of the geology or the detail of the mapping increases, so will the use of the helicopter for freighting purposes. The cost is high on a time-unit basis. Work which normally would proceed slowly and consequently at a low cost per season, is greatly accelerated and is accompanied by a parallel increase in the season's cost.

References

Roddick, J. A.
1955: Geological Surveying by Helicopter in the Coast Mountains of British Columbia; *Can. Min. J.*, vol. 76, No. 4, pp. 51-53. Also published in *Can. Oil and Gas Industries,* vol. 8, No. 5, pp. 39-41.

Roddick, J. A., and Armstrong, J. E.
1956: Pitt Lake Map-Area, B.C.; *Geol. Surv., Canada,* prel. map and descr. notes, 8-1956.

Chapter VII

LIGHT HELICOPTER MAPPING IN MOUNTAINOUS REGIONS

(Operation Stikine)

by *E. F. Roots*

Introduction

The study of the geology of the mountainous parts of northwestern Canada faces peculiar logistic and technical problems. Established transportation and communication systems are lacking and, although distances to regular transport routes are not great, mountainous terrain, unnavigable rivers, and dense forest make many places very difficult of access. There are about 4½ months during the summer when the ground is sufficiently free from snow for effective field work. Geological surveying has been done by parties traversing on foot, back-packing or using pack-horses for transport, with aircraft bringing supplies at intervals to lakes along the route, or dropping supplies directly to the parties. Such mapping, in terms of cost per square mile mapped at a given standard of detail, has been among the most expensive in Canada, and, as the more accessible parts are completed, becomes increasingly more expensive.

The geology of the northwestern Cordillera, although magnificently exposed in three dimensions and commonly straightforward if studied in sufficient detail, is for the most part exceedingly complex in the gross picture. A wide variety of rocks of many ages, of very complex structure and oftentimes at first glance haphazard arrangement, may outcrop on a single mountainside; generalizations of the geology are in many cases impossible or meaningless. Consequently the Geological Survey of Canada has standardized its mapping there on a scale of 1 inch to 4 miles (1/253,440).

The Geological Survey has considerable experience in using both helicopters and airdrops from fixed-wing aircraft to aid geological parties. Operation Stikine was planned for 1956 specifically to make use of these techniques in doing standard 4-mile mapping of a representative part of the Cordillera, and to appraise the capabilities, requirements and relative efficiency of the helicopter technique for geological surveys in mountainous regions.

The area investigated includes all Canadian territory between lat. 56° and 59°N, long. 128° and 132°W—an area of approximately 28,900 square miles.

For about a third of the area, the general features of the geology were known from early exploration; the remainder was geologically unknown. Topographic maps on a scale of 1/250,000 and contour interval 500 feet, and vertical aerial photographs were available for the entire region.

In a field season of 127 days, the operation succeeded in mapping about 90 per cent of the assigned area, or 25,540 square miles.

Organization

The area mapped by Operation Stikine embraces a wide variety of topography, climate, and geology. To map this in a single field season, a combination of airborne techniques and older methods of survey was used. The detail of mapping required, the complexity of the geology, the abundance of cliffs, and the extensive forest and snow cover limited the use of geological interpretation of aerial photographs and aerial observations and demanded that geological information be gathered mainly from ground traverses. The aircraft, both helicopter and fixed-wing, were primarily means of transport and supply, and only incidentally used for directly gathering geological information.

The operation employed sixteen geologists, of whom seven were members of the Survey staff; assistants and other personnel, including aircraft crew, completed a total party of fifty-two. Two Bell 47D-1 helicopters, and one Beaver and one Cessna 180 fixed-wing aircraft were used, as well as three strings of pack-horses of 12 to 18 animals each.

In April 1956 the fixed-wing aircraft, equipped with skis, established dumps of helicopter fuel at strategic places, so that mapping operations could begin before the break-up of the ice, which on some of the higher lakes is not until July. The mapping parties moved into the field at the end of May and worked until early October.

During the field mapping phase, the operation was divided into five mapping parties, and a headquarter's unit that coordinated the aircraft movements between parties and attended to the rather complex logistic details. All parties and aircraft were equipped with two-way radio.

Field Operations

Each of the mapping parties on Operation Stikine had a distinctive working method, adapted to its particular conditions of terrain and geology. Four main techniques were employed.

Helicopter-Supported Fly Camps

A technique of helicopter-supported fly camps was developed, and proved well suited to the conditions in the southern part of the area. This includes some of the Coast Mountains, part of the rolling, heavily wooded depression of the Nass Basin, and the large, intricately dissected region of the Skeena Mountains. Relief is commonly about 5,000 feet and the mountains, although steep, are mostly smooth in outline. The climate is moderately humid, and has produced scattered cirque glaciers and small ice-caps on many peaks; valleys are well wooded to altitude of about 4,500 feet. The district is little travelled, and most of it is devoid of trails. The mapping parties were entirely dependent on aerial transport.

Most of the required geological information could be obtained by traversing ridges above timber-line. A series of fly campsites, preferably above timber-line at the intersection of ridges, was selected in advance and so distributed that all of the country to be traversed could be covered in one-day traverses. From a base camp, established and stocked by fixed-wing aircraft, two-man traversing teams were set out at the fly camps by helicopter. The geologist in charge of the party operated from the base camp, and on a typical working day would fly to each of the fly camps by helicopter. There he would receive a report on the previous day's work from the traversing geologist, report the geological findings of the other traversing teams, and discuss the next traverse. The traversing team would then be taken by helicopter over their traverse route and left at the end of it to spend the rest of the day working their way back to their fly camp. The geologist in charge would proceed by helicopter to the next fly camp, where the process would be repeated. After all the traversing teams had thus been visited and set on their traverses, the geologist in charge would be free to spend the rest of the day traversing by helicopter in places where it was not practical to set fly camps. When all the traverses from a particular fly camp had been completed, the traversing team and camp would be moved to the next fly campsite; thus the teams advanced, leap-frog fashion. In practice it was found that one helicopter could service four fly camps by mid-morning, thus giving ample time for a full day's geological work.

This method had several advantages:

1. The geologist in charge was in daily control of his party and of the work, and in a position to act on geological or operational problems where they arose.
2. The traversing teams could spend all their energies on profitable geological work. They had no need to carry heavy packs, and were never more than a day's walk from their camp.
3. They had examined their whole traverse route in advance and could spend the most effort on critical places.
4. All geologists in the party were kept informed of one another's findings, and could confer in the field upon short notice.

Some of the disadvantages of the method were:

1. The method was restricted to terrain and geology where, on the average, it was worth while to make two or more traverses from each fly camp. If the geology was very simple or the outcrops widely spaced, the method was inefficient; in very rugged country it could not be used at all.

2. The method was most satisfactory in areas where the geology could be investigated satisfactorily by traversing of ridges, supplemented by spot investigations in other places. If much critical geology was on slopes or in canyons the method broke down.
3. A relatively large amount of helicopter flying time per ground traverse was required.
4. The efficiency of the method was directly dependent on the average flying weather during the season. A short period of very bad weather had little effect on the program, but prolonged poor or marginal flying weather could mean that only spasmodic work, of little value, was done. Compared with other methods, it was difficult to take full advantage of a short period of good weather.
5. The parties were totally dependent on air transport, and in case of accident or mechanical failure were not equipped to improve their position.

Foot Traversing and Back-Packing with Aerial Support

A system of two-man traversing teams moved and supplied by air was used in the western part of the area. This lies across the main axis of the Coast Mountains, which there rise to 10,000 feet above the heads of the Pacific Ocean fiords, and include some of the most rugged Alpine terrain in North America (Plate V A). The climate is wet and unstable, with a heavy snowfall at high elevations, so that ice-caps and glaciers occupy much of the high land, whereas the valleys below 3,000 feet are choked with dense rain forest. Travel is difficult in the Coast Mountains; trails are few and short-lived; at high altitudes mountaineering techniques are essential; flying conditions are generally poor.

The technique of helicopter-supported fly camps could not be used in this country, because (1) the difficulties of ground travel and weather are such that it is not safe for a man to be separated from his camp, (2) there are very few places where more than one day's traversing can be done from a single high camp, and (3) an adequate picture of the geology cannot be gained from a study of the ridges alone. Much investigation had to be done in places such as cliffs, valley slopes, canyons, acute peaks and nunataks that are inaccessible to the helicopter because of air turbulence, forest cover or lack of flying room. The weather is so unpredictable that any technique requiring the aircraft to fly to a schedule is impractical.

The country was mapped by two-man teams who were flown to the beginning of their traverse and picked up at the end by helicopter, but who carried out the actual traverse on foot. In places it was possible to run one-day traverses, and use the helicopter as a taxi to 'commute' from base camp; but for the most part the teams resorted to back-packing traverses of two to ten days' duration, using caches established along the route by helicopter and airdrop. The traverse route was selected in advance from a study of air photographs, and the general location of each intended campsite chosen. The traversing geologist then flew along the proposed route, checking its feasibility and apparent geological problems, making alterations in plan if necessary, and leaving a dump of food and, if needed, equipment, at each campsite. The traversing team were then left at the beginning of their traverse, and were free to carry out their investigation without further visits from aircraft. The men carried sleeping bags, tent, and stove, but a minimum of food and fuel, and used the dumps along the way. Specimens collected were usually left at the caches. After an agreed number of days, the helicopter went to the end of the traverse to pick up the team. The specimens left at the caches were retrieved by helicopter, and thus the traversing geologist had a final opportunity to check his work.

A light fixed-wing aircraft was used at times in place of a helicopter for reconnoitering the route and establishing the caches by airdrop. It was equally effective for this purpose and less expensive, but the traversing team had then to carry all their specimens to the end of a traverse or to a suitable lake.

This technique is the most versatile of all those used by Operation Stikine, and enables all parts of an area to be studied, regardless of their accessibility by air. It is potentially very efficient, although in practice it was difficult to control, with resultant lack of coordination and wasted working time. Although an enormous improvement in speed and geological efficiency over back-packing without aerial support, the method is so arduous that it will rarely be used if any other technique will serve.

Some of the advantages of the technique were as follows:

1. The pace and detail of the work, and the places investigated, could be governed almost entirely by geological consideration, with a minimum of conditions imposed by logistic factors. It was the only 'airborne' method suited to the continuous mapping of difficult geology (as opposed to the study of separate critical areas).

2. The safety factor was high. Each team was self-sufficient and well equipped at all times, and never more than a day's journey from a reserve food supply. Each cache normally contained sufficient food for the team to wait out a period of bad weather. There was no need for concern if the party was delayed by geology, terrain, or weather; if on the appointed day the helicopter arrived at the final cache and found that the team had not reached there, it was but a matter of minutes to fly back along the route until the party was found. In case of failure of the aircraft or other emergency, the team was mentally and physically equipped to look after itself; this led to a confidence that increased enthusiasm and work output.

3. Frequently, the traversing teams could carry on with geological work on days when the weather was too poor for flying, and when geologists using other methods were inactive.

4. The method was well adapted to take advantage of a short period of good flying weather.

5. The traverse program could be arranged so that the party kept working if the helicopter had to be withdrawn at intervals or shared with another party.
6. Less helicopter flying time was required for the same amount of ground traversing than in the helicopter-supported fly camp method. One helicopter could keep five or more back-packing teams serviced.

Some of the disadvantages of the method were:

1. It was difficult to keep effective control and coordination of traversing teams and aircraft movements. The man responsible for planning and for decisions in emergencies was sometimes out of contact with his party for several days.
2. Despite careful planning, there was a tendency for flying requirements to become 'bunched'. If one party was held up for any reason its flying needs overlapped those of parties that had continued working, and there was a 'concertina effect' of one traverse team after another being delayed.
3. Intercommunication within the party was poor. Geologists on the traverse teams, coming to the main camp at different times, sometimes did not see their colleagues for weeks and gained little from each other's geological findings.
4. The method could not in itself take advantage of stretches of easy geology or terrain. It was best adapted to and only justified in areas of complex, difficult geology, where continuous ground observation was required and the country was so rugged that important outcrops were inaccessible to the helicopter.
5. The method demanded very hard work, both physical and mental, from geologists and assistants. It would be a waste of time and money to employ this technique unless the personnel possessed a higher-than-average energy, competence, and enthusiasm.

Combined Pack-Horse and Helicopter Method

The central and eastern parts of the area cover the north end of the Skeena Mountains and part of a dissected upland, the Stikine Plateau. Local relief is in places more than 6,000 feet but the mountains are less rugged than to the west and south, the valleys are broad and smooth and rolling uplands cover extensive areas. The climate is relatively dry; forests are open and confined to the valleys, and there are large tracts of open grassland, muskeg, and tundra. The region is well suited to travel by pack-horse, and trails are numerous.

The plan was to map this part by a pack-horse party with support from a helicopter at intervals. In practice, the party had the use of a helicopter for 2 or 3 days every 10 or 15 days and the working schedule of the party devolved around the periodic visits of the helicopter. Because of the relatively simple stratigraphy, and the well-exposed rock structures, the mapping could be speeded without loss of geological accuracy. Under such conditions the comparatively slow pack-horses were at a disadvantage, and commonly more country was mapped in 2 days with a helicopter than could have been reached in 8 days by pack-horses. The helicopter was used to visit a number of pre-selected outcrops in succession; the geologists worked independently, each studying his outcrop while the other was being moved, and thus they advanced in leap-frog fashion. At the end of its stay with the party, the helicopter usually set out teams that made back-packing traverses of 2 or 3 days to the pack-horse camp. In most cases the entire party then moved directly to the next site to await the next visit of the helicopter.

This method failed to achieve an efficient combination of pack-horse and helicopter means of geological surveying, mainly because the geology of the area was such that the pace of the work could have been increased greatly without lowering the standard of mapping. By means of helicopters the work proceeded with such speed that the pack-horses could not keep up, and the area was mapped by a party that was spending only half its time doing useful geology. Had the geology been such that closely spaced continuous traverses were needed, the relative advantages of horses and helicopters undoubtedly would have appeared in a different light; but in this area, the horses were of little use to the party.

Pack-Horse Party Supplemented by Helicopter

The northeastern third of the area includes part of the Stikine Plateau and the Cassiar Mountains. There, irregular mountain masses with local relief up to 5,000 feet and relatively rugged summits are separated by deep, generally broad, heavily glaciated valleys. The climate is moderately humid, and the valleys well forested. Travel by pack-horse is possible in most parts.

This country was surveyed by two parties that for most of the season relied on pack-horses for transport, with supplies being brought at intervals by fixed-wing aircraft. These parties were given the use of a helicopter at the beginning and at the end of the season only. At the beginning of the season, the helicopter was used to make an intensive study of a critical area, in an attempt to work out the stratigraphy that would serve as a basis for mapping during the summer. At the end of the season the helicopter was used to range widely, visiting areas difficult of access and to fill in 'holes' left in the mapping by the pack-horse party.

This method was well adapted to the terrain and type of geology where it was employed. The geology of the district was sufficiently difficult that pack-horse transport could keep pace with the rate of advance of the work. By having the available helicopter time in 'blocks' at the beginning and end, instead of distributed throughout the season, the parties were able to make effective use of each means of transport employed.

The disadvantages of the method were:

1. The method is relatively slow.
2. When working with pack-horses, the party could not increase its pace to take advantage of easy geology.
3. The method is vulnerable to bad weather coinciding with visits of the helicopter.

Logistics

A summary of pertinent logistics of Operation Stikine is given in Table VIII.

Table VIII

Summary of Logistics, Operation Stikine

Method of mapping	I Helicopter-supported fly camps	II Foot traversing and back-packing with aerial support	III Combined pack-horse and helicopter party	IV Pack-horse party supplemented by helicopter survey	Total
Area mapped, square miles	5,910	6,030	3,820	8,780	25,540[1]
Nature of geology, for mapping on scale 1/253,440	Easy	Very difficult	Fairly easy	Fairly difficult	
Ease of ground travel	Difficult	Very difficult	Easy	Moderate	
Number of days in field[2] (from first to last traverse inclusive)	92	124	87	125	
Number of days actively engaged on geology	62	114	51	88	
Number of geologists available to run independent traverses	3	4 to 6	2	4 to 6	16[3]
Total number of traverses run	143	305	85	278	824[1]
Average number of traverses per geologist	48	61	43	56	
Hours flown with helicopter	225	249	60	66	759[4]
Square miles mapped per hour flown with helicopter	26[5]	24[5]	64[3]	133[5]	34[4]
Hours flown with fixed-wing aircraft[6]	165	239	79	64	654[7]
Number of flights required of fixed-wing aircraft	156	280	93	99	
Cost of helicopters, including fuel	$26,900	$30,120	$7,040	$7,880	$71,840[4]
Cost of fixed-wing aircraft, including fuel	15,270	21,710	8,300	8,730	54,242[7]
Cost of pack-horses			5,521	6,411	11,932
Wages[8]	10,955	13,366	9,677	12,029	49,480[9]
All other costs (supplies, accommodation, travel to field, freight, etc.)[10]	7,086	9,950	5,096	8,144	33,156[9]
Approximate total cost	60,211	75,146	35,364	43,194	220,650
Cost per square mile mapped	$10.45[11]	$ 12.80[11]	$ 9.58[11]	$ 5.06[11]	$ 8.65

[1]Includes areas mapped by geologists and parties temporarily not organized according to one of the methods listed.

[2]Excluding days spent in organizing at beginning and disbanding at end of field season.

[3]Includes geologist with headquarters unit.

[4]Includes ferrying and other non-productive flights.

[5]Excludes ferrying and other non-productive flights.

[6]When fixed-wing aircraft other than Beaver were used, an adjustment of flying time has been made, according to the payload carried, to give equivalent time for Beaver aircraft (payload 1100 pounds).

[7]Includes flying for headquarters unit and all incidental service flights.

[8]Includes salaries of staff, for field season only.

[9]Includes expenses of headquarters unit.

[10]Excludes cost of equipment and general overhead before and after field season.

[11]With cost of administration and headquarters unit divided proportionately according to size of party using each mapping method.

Despite the unsettled and at times consistently poor weather experienced in parts of the area, the aircraft maintained an excellent record of serviceability and performance. The demands of the operation were such that each serviceable machine (except the light fixed-wing Cessna aircraft, which was engaged part time only) was used every day that weather permitted. There were only 12 days of ideal flying weather during the season, yet throughout the period of 126 days when the aircraft were available to parties in the field engaged on geology, one helicopter was held inactive on account of the weather for only 16 days, and the other for 11 days. The machines were mechanically unserviceable for a further 15 and 10 days, respectively. During the same period, the Beaver fixed-wing aircraft was kept inactive 12 days because of the weather, and a day through mechanical unserviceability. There were of necessity many changes of plan caused by the weather, but for all aircraft only 25 flights, mostly very short, were abortive.

Table IX shows the distribution of helicopter flying time according to the use made of the machines.

Table IX

Distribution of Helicopter Flying Time, Operation Stikine

(Total Flying Time in Hours, Both Machines)

Method of mapping	I Helicopter-supported fly camps	II Foot traversing and back-packing with aerial support	III Combined pack-horse and helicopter party	IV Pack-horse party supplemented by helicopter survey	Total
Flying for geological purposes (transportation of geologists on traverses, moving of fly camps, establishing traverse caches, retrieving specimens)....	197	247	59	65	568
Flying to service base camps	28	2		2	32
Ferrying between parties...					47
Ferrying to and from field..					83
Miscellaneous service flights					29
Total...........					759

The detailed planning for Operation Stikine was begun in October 1955. One staff geologist worked on the plans throughout the winter, and four staff members spent about two months making final preparations in the spring of 1956.

About 500 man-days were spent in the field, making preparations and establishing fuel dumps and camps, before all mapping parties were engaged on geology.

During the field mapping phase, about 2,100 man-days were spent directly gathering geological information, and 3,600 man-days in supporting activities.

70607-7—5½

Conclusions

Conventional geological mapping in northern British Columbia and Yukon on a scale of 1 inch to 4 miles has cost from $7.00 to $15.00 per square mile in recent years. The overall cost of Operation Stikine was $8.65 per square mile. Because of its geological complexity and the relative inaccessibility, the area mapped would undoubtedly have been expensive to survey by conventional methods.

A party led by one staff geologist commonly takes four or five seasons to a 4-mile map-area (approximately 5,060 square miles). Operation Stikine corresponds to six such map-areas requiring twenty-four to thirty party-seasons to complete by traditional means. Operation Stikine was equivalent to about ten normal field parties, and thus may be considered equivalent to ten party-seasons. Therefore it enabled the mapping to be done 2½ to 3 times as rapidly as by conventional methods.

The standard of accuracy and detail of the map produced by Operation Stikine is more erratic than it would have been had the mapping been carried out by conventional methods. This is due mainly to three factors, which are inherent in the method:

1. The size of the operation made it necessary that a fairly definite schedule of mapping progress be maintained. This restricted the flexibility of planning and operating, and the momentum of advance of the entire operation was such that several times mapping teams had to be moved out of an area at a certain date, regardless of whether or not they had finished.
2. The rate of accumulation of geological information was so great that it was difficult to synthesize and assimilate the data so that each man could take advantage of them to aid his own work.
3. The speed with which geologists could be moved by helicopter, and the interlocking schedules developed for logistic reasons, meant that geologists were repeatedly by-passing one another and rarely had the opportunity to follow through their own work for any distance. Clearly it is necessary to balance the advantages of speed against long-term efficiency and thoroughness.

If the field methods used by Operation Stikine are compared with conventional methods, the following points may be noted:

I. The area where the helicopter-supported fly camp method was employed would have been slow and costly to survey by conventional means, because of its inaccessibility, but it is estimated that the helicopter technique enabled the work to be carried out four or five times as fast and at a somewhat lower total cost than it could have been done by any other method, and without loss of accuracy.

II. The system of back-packing with abundant aerial support used in the Coast Mountains enabled this region to be surveyed in half, or less, the time it would take by conventional methods and it is considered the method allows a better job to be done at comparable or less cost.

III. The combined helicopter and pack-horse system proved to be inefficient because the simple nature of the geology enabled the work to proceed by helicopter at a pace too fast for the horses. The region could have been surveyed more cheaply by pack-horses alone, but it would have taken two or three times as long. If helicopters had been used exclusively, the cost per square mile would have been perhaps 30 to 50 per cent greater, but the work could have been done in half the time. This method gave a convincing demonstration that the nature of the geology is of equal or greater importance than terrain or accessibility in determining the most efficient means of geological survey.

IV. The pack-horse party supplemented by helicopters proved to be very efficient and was the cheapest method employed on Operation Stikine. The leaders of the parties using this method benefited from knowledge of adjacent areas more than any other geologist on the operation. In any area suitable for pack-horses and where the pace of the work is restricted by geological considerations rather than by transport, the method gives better results, faster, and at no greater cost than survey by conventional means.

Reference

Roots, E. F.
1957: Stikine River Area, British Columbia; *Geol. Surv., Canada,* Map 9-1957.

Baragar, 3-1-1956

A. Operation Stikine, 1956. Helicopter on ridge at 6,500 feet during a rare fine day in the Coast Mountains.

Plate V

B. Operation Franklin, 1955. A two-man field station about to be moved.

Roots, 1-1-1955

Chapter VIII

HEAVY HELICOPTER RECONNAISSANCE IN THE ARCTIC ARCHIPELAGO

(Operation Franklin)

by *Y. O. Fortier*

Introduction

In 1955, the Geological Survey of Canada made an initial geological investigation of a large part of the Canadian Arctic Archipelago, Operation Franklin, using two heavy (Sikorsky S-55) helicopters. Because of the remoteness and large size of the territory, its relative inaccessibility from without and within, and the almost unique display of its stratigraphic and structural features on air photographs (Plate VII) the project was analogous to the establishment of a primary and relatively closely spaced geodetic control. The project essentially consisted in the establishment of a network of localities studied in detail for their stratigraphy and structure. Recourse was made to interpretation of trimetrogon air photographs both to organize the investigation and to map on a scale of 1 inch to 8 miles the regional distribution of formations and their structures by extrapolation from field stations. Further features peculiar to the project were the seasonal timing and strict adherence to a tight schedule, both of which were imposed by the Arctic, the insular character of the territory and the changing ice cover of sea straits and sounds within it.

Because the project had a specific aim and a special mode of implementation, its rate of progress and its cost per unit of area are compared with difficulty with that of other helicopter-supported methods tried by the Geological Survey of Canada. At any rate, the project greatly hastened the geological investigation of the north-central part of the Canadian Arctic Archipelago over tried and strictly ground methods. The operation extended over some 200,000 square miles, more than half of which is covered by the sea. The geology, although without great complexities over extended areas, covers all systems of the geological column except the Mississippian, which is absent, and possibly some Tertiary systems. The series lie within three main geological provinces, the most extensive of which has witnessed three periods of orogeny since the end of Precambrian time and can be subdivided into a number of stratigraphic structural regions.

Organization

The prime task in planning the project was to select a method of operation that would best meet both the aim of the project and the difficult and specialized geographical conditions.

Once the apparently best, but not the unattainable ideal, method was conceived the second step was concerned with shaping the geological program according to the potentialities of the method as geographical conditions cannot be altered. In so doing full and valuable use was made of air photograph interpretation (Plates VI and VII), as the same geographical environments, which present a travelling geologist with many handicaps, have exposed features of bedrock geology in such a manner that air photographs give the investigating geologist information to an almost unique degree.

Geographical Factors

The main geographical factors of prime consideration in the selection of a method of operation were:

1. The *insularity* of the territory with ice cover of the sea varying in time and space (Plate VI).
2. The *topography* of the land ranging from low plains to mountainous regions perhaps over 7,000 feet above sea-level, the whole land practically devoid of lakes.
3. The *climate,* which is wintery and covers the ground with a mantle of snow, slight but widespread for nine to ten months. There is a limited, snow-free summer season, with a humid, maritime climate resulting in extended periods of fog and low clouds.
4. The scarcity of permanent *settlements.*

Older Methods

Under such conditions, the Geological Survey of Canada has conducted and still pursues geological investigation of some parts of the Archipelago in Arctic-tried fashions:

1. By dog-team travel on sea ice from early spring till late June and mainly along coasts. The method works well where the light snow cover does not completely mantle regions of moderate to high relief, but is handicapped where the relief is low and the snow cover extensive.
2. By canoe travel feasible along the coasts of a few northern islands at most for 6 weeks in a year.
3. By inland foot travel whereby a geologist must carry on his back all living necessities including fuel, a painstaking, time-consuming and unversatile method by itself.

A combination of these methods has some effectiveness within limited areas but lacks versatility in covering extended inland areas. Consideration was given in the planning of the project to dividing the territory into a number of areas

RCAF T441R-208

Plate VI. *Operation Franklin, 1955. South coast of Devon Island, looking east. The one vertical section studied in the area of lower left-hand part of photograph can give information that can be extrapolated for long distances in such terrain.*

RCAF T420L-2

Plate VII. *Operation Franklin, 1955. Bathurst Island, looking east. Oblique air photo of gently folded strata. The one traverse made in detail across the middle part of this photograph determines the geology of much of the area within the photograph.*

each consisting of an island or group of islands, and to investigating simultaneously each area by a combination of the three above methods and some support by aircraft. The advantage here would have been a more extended ground cover of some parts by geologists each of whom would become more proficient with the local geology of his assigned area. Factors against such a scheme were its lack of effective coverage of inland areas, and supply and local airlift could not be carried out simultaneously over a widespread region under conditions imposed by Arctic geography and ice cover of the sea.

Personnel

The personnel employed during the helicopter phase of the operation comprised eleven geologists, eight or nine of whom were on the field teams while the remainder served as field coordinators, ten geological assistants, including one on each team, a radio-engineer for base communications, two helicopter pilots with a part-time third one acting as relief, with generally only two maintenance-engineers required, and two cooks. Sundry chores performed by professional and technical personnel cut out employment of labour.

Two human factors in particular condition the success of such an operation. Pilots should be of a temperament that allows them to explore fully the versatility of the helicopters, to stand a most irregular daily schedule and to cater to the observation needs of geologists. Geologists should be as mature and energetic as possible, because local stratigraphic observations have regional implications, opportunities to record features may not repeat themselves and the time element is always a major concern in an overall tight schedule.

Choice of Helicopters

Factors that pointed to the use of helicopters were: only one year-round airfield for aircraft on wheels, the scarcity of lakes and the unpredictability of open sea water for float-equipped aircraft, the unsuitability or unpredictability of sea ice in summer time for a ski-equipped aircraft, the necessity of using relatively light aircraft flying below the overcast with ability to land at will when banks of fog or low clouds were encountered. Factors in the choice of specific helicopters, besides availability, economy and proven performance, were the size and configuration of the territory to be surveyed and a balance between an adequate geological field program and load capacity and range of helicopters. This amounted to deciding whether to use light helicopters, to map more systematically and by slower progression within a territorial limitation, imposed by the danger of crossing from island to island over open sea water; or to use heavier helicopters of greater load capacity and range, to spend less time in thoroughness of mapping but to study in detail key localities judiciously chosen through an extended territory. The information supplied by air photographs indicated that adequate reconnaissance maps could be compiled by using heavier helicopters to establish a stratigraphic and structural control network over an extended territory. Thus Sikorsky S-55 helicopters were chosen.

Selection of Localities for Detailed Study

The selection of localities to be studied in detail and a general orientation of the geological program were obtained through the study of trimetrogon air photographs, aided over limited parts of the region by sundry observations and collections of early explorers and by rare investigations of geologists. Preliminary photo-geology maps that incorporated all available information were compiled of the region. They depended essentially on the traceability of indicated map-units. Thus structural patterns were outlined and a stratigraphical sequence of indicated units was tentatively made. Field localities to be studied in detail were then chosen, the density being related, on the one hand, to the minimum number required to define all major elements of the stratigraphy within individual islands or extended parts of the larger islands and, on the other hand, to the maximum number physically permissible by the mode of operation. Otherwise, factors entering into the selection of localities were: availability, extent and content of exposed bedrock sections, indicated unconformities and structural complexities. A few traverse lines were selected across folded ranges along routes of indicated maximum exposures and display of geological features. Because the air photographs of the region contained valuable information, the selection of localities was most rewarding and led, it is believed, to a comprehensive preliminary survey of all major stratigraphic units of the region.

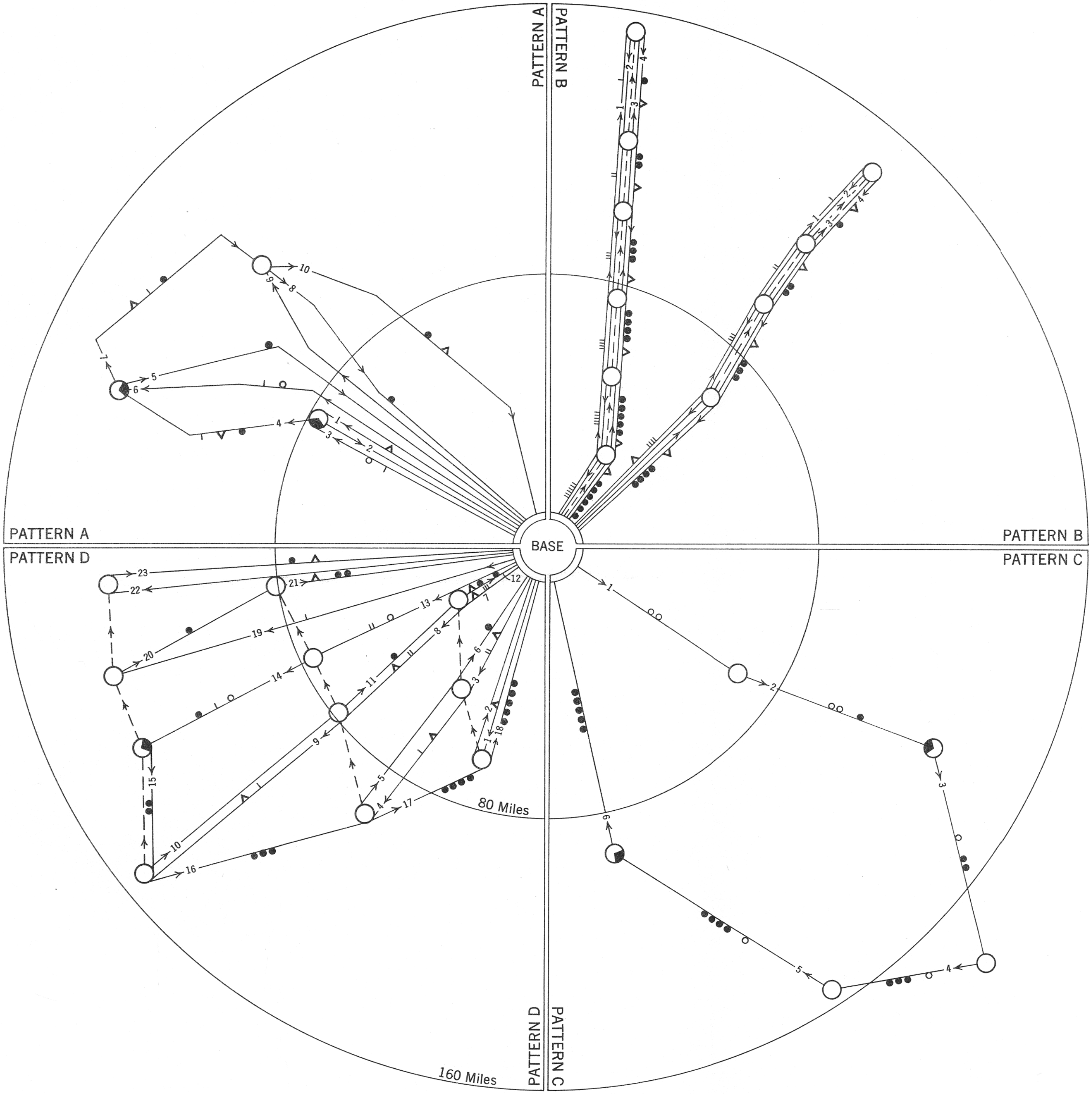
Field Operations

Plan and Schedule

In essence the scheme devised was for eight to nine geological teams, each of 700 to 800 pounds net weight, to successively leap frog by helicopter from field station to field station (Plate V B) within a radius of 160 miles or so of a base of operation, four such bases, 220 miles apart, being occupied in a counter-clockwise manner in order to remain abreast of the disappearance of sea ice. At times it was advantageous for teams to traverse by foot across folded ranges, helicopter support being given before and after the traverse. A DC-3 aircraft, operating from the permanent establishment of Resolute Bay, stocked other bases with aviation fuel and other stores, but had to withdraw from the operation on commencement of the main survey because of the deterioration of the sea ice on which it landed with ski-wheels. Then two helicopters, without fixed-wing aircraft support but capable of supporting each other, placed teams at field stations and airlifted operational personnel and material from base to base. Twenty-four hours of daylight, permitting around-the-clock operation, in part compensated for most improper weather and permitted 520 hours of helicopter flying time from June 13 to September 15.

Conclusions

The versatility, ruggedness and capability of the S-55 helicopters enabled the project to meet satisfactorily the difficult conditions of operation. The main handicap was weather adverse to flying and it is believed that these helicopters



PATTERN A

The standard model of the actual survey. Ground party transported from station to station and left at each station for three days to three weeks.

PATTERN B

Limited application. Ground party walks from cache to cache previously established on islands of folded strata.

LEGEND

Flights shown in numerical order (direction indicated) .... —4→—

Flight with one ground party .... —Λ—

Flight with supplies for 1 to 6 stations .... ⊥ to ⊥⊥⊥⊥⊥⊥

Flight with field specimens from 1 to 6 stations .... • to ••••••

Flight with 1 or 2 gas drums .... o .. oo

Path of walking party (direction indicated) .... — — → —

Refuel at station from carried drum .... ◓

Station .... ○

PATTERN C

Very limited application and mainly in conjunction with Pattern A. Aircraft out all day with only one geologist landing here and there.

PATTERN D

Not used. Ground parties supplied as they walk from station station, on islands of folded strata.

If weather conditions had permitted more flying time, all four patterns would have been applied simultaneously and with good results, Pattern A still remaining the standard practice.

Prepared by Y.O. Fortier

Figure 5. Operation Franklin 1955. Four contemplated patterns of operation within range of any one field base

were the aircraft most proper to contend with it. The only relevant handicap to the project resulting from the use of helicopters was the regulation whereby any helicopter without floats is prevented from flying over extended areas of water. Floats were not employed because there was no use for them otherwise and they would have taxed the carrying capacity of the helicopters. The result was that airlift from island to island had to take place when the intervening sea was still covered with ice. The necessity of scheduling the operation to proceed ahead of the disappearance of sea ice and the slowing of progress by weather adverse to flying had the effect of reducing the density of field stations. However, these factors had been taken into account in planning as best as could be estimated without previous operational experience.

Costs

Transportation within the field area was the most costly item, although transportation between the area and railhead or port of loading substantially added to the total expenditures. Salaries and wages can be paid at rates prevailing elsewhere in Canada. Equipment costs are only slightly above those obtaining in northern regions of the mainland; food largely dehydrated, and fuel can be purchased, say, in Montreal at current prices. However, the net price of employment or consumption of the above items in the region was substantially increased by transportation costs.

Five hundred and twenty hours of combined flying time by the two helicopters cost some $201,080. It should be noted that in such an undertaking availability of the helicopters rather than their actual use represented the expensive commitment. A fixed fee of $189,638 was paid for the charter of the two helicopters for a guaranteed period of four months, inclusive of transportation time from and to contractor's base. The fixed fee included, besides a standard tariff rate for a four-month contract, special costs of mobilization and demobilization. To the fixed fee was added an hourly flying charge of $22.00. Under these conditions the helicopters would have had to fly a total of over 860 hours, an unpractical and unrealistic goal, for the usage cost to amount to 10 per cent of the availability cost. However, under these conditions a decrease in net hourly flying costs through increase in usage is theoretically possible without substantially adding to the total flying cost. Yet it must be remembered that the single largest handicap to usage was the unmanageable weather.

Approximately a third of helicopter flying time was used in freighting between field bases during the summer. This freighting was in addition to over 100 tons airlifted within the area in the spring through some 130 hours of flying by the DC-3 at a cost of $24,500, cost of required fuel excluded as in the case of helicopters. The DC-3 freighted fuel, food, and heavy items of camp equipment, while the helicopters freighted instruments, aviation fuel, some camp equipment, and personnel.

The foregoing gives a scale of transportation costs within the field area itself. These costs are more easily accounted for than the costs of transportation into the area, as heavy recourse was made to opportunism in using existing services and creating services to carry this phase of the project.

For instance a York feighter aircraft capable of airlifting 10 tons from Churchill to Resolute Bay in 5.3 hours cost $389 per hour and a DC-3 air freighter, capable of airlifting 2 tons from Churchill to Resolute Bay in 8.3 hours cost $196.50 per hour. Yet other airlifting was required for which costs are not available. To wit, it was found most practical in the spring, and a necessity in the autumn, to airlift the two helicopters. The smallest air freighter capable of carrying one of these is a C-119 (Flying Boxcar) aircraft, of which none was available commercially. Such costs are subject to administrative arrangements greatly varying with circumstances so that no approximate practical figures can be stated here.

The same obtains with shipping as no commercial rates are available from points south to the area. Sent by ship from Montreal a year ahead of the field project were 154 tons of aviation fuel and containers, 4 tons of aviation oil, and 7 tons of food, all goods purchased in Montreal.

The 520 hours flown on operation by the helicopters occasioned a net consumption in aviation fuel of 21,677 gallons, whereas 143.5 hours and 5.3 hours flown out of Resolute by the DC-3 and the York required respectively 12,017 and 1,153 gallons. This represented a total consumption of 34,847 gallons out of the 35,790 gallons field stock shipped from Montreal. To the gallon price at Montreal must be added the price of containers and the shipping expense. The heavy steel drums required for the sea voyage cost as much as the aviation gasoline and were non-recoverable in the field. In the absence of available shipping rates, one might gather its scale by the fact that aviation gasoline shipped and stored in bulk was made available to Operation Franklin at Resolute at a gallon cost price that was some 3.5 times the price paid in Montreal exclusive of containers.

References

Blackadar, R. G.

1956: Operation Franklin; *Arctic Circular,* vol. 9, No. 2, pp. 10-18.

Fortier, Y. O.

1955: Arctic Islands Yield to the March of Science; *Northern Miner,* Dec. 8, pp. 83, 92.

Roots, E. F.

1956: Canadian Operation Franklin, 1955; *Polar Record,* vol. 8, No. 53, pp. 157-160.

Woakes, M. E.

1956: Reconnaissance Survey in the Canadian Northwest Territories; *The Mining Mag.,* vol. 95, No. 3, pp. 144-150.