The Icefield Ranges Research Project, 1971

The 1971 Icefield Ranges Research Project (IRRP) field season again was something of a paradox and, as in past seasons, weather was the guilty agent. Projects that were carried out on the continental slope of the St. Elias Mountains enjoyed relatively good weather; those pursued under the direct influence of Pacific maritime air masses suffered through possibly the worst season weatherwise since the inauguration of IRRP in 1961.

Research activity at Kluane Lake camp continued year-round during 1970-1971 for the first time in ten years of operation. Throughout the fall, winter, and spring the log house, which was built in 1967 and which has since been modernized and winterized, provided quarters and laboratory space for two research programs by Ph.D. candidates from the University of British Columbia, Vancouver, and The University of Michigan, Ann Arbor. The investigations were initiated in 1969 and 1970 and concern large mammal studies and studies in climatology and micrometeorology respectively.

Base camp is situated on the southern end of Kluane Lake (el. *c.* 780 m.) and was the hub from which two full-time and four short-term field camps were supported. Air support was provided by the Arctic Institute's versatile STOL supercharged Helio Courier aircraft equipped with ski-wheels aided substantially by a Canadian Forces DeHavilland Buffalo and by two fixed-wing and two rotary-wing aircraft which were chartered locally when necessity demanded. In early July the DeHavilland Buffalo dropped over 4 tons of supplies and equipment to the Mount Logan physiology laboratory (el. *c.* 5,335 m.). Aircraft flew approximately 270 hours in support of IRRP programs in 1971.

All base camp facilities were opened for summer field research parties mid-May and were closed 12 September. As in past summers, however, maximum utilization of facilities and research activity occurred between mid-June and mid-August. Principal investigators, senior scientists and graduate students plus their assistants numbered over 70 persons. In addition, there were 20 people involved in operations and logistics in the field (5 full-time, 15 part-time or short-term), and 10 Canadian Forces volunteers who took part in the High Altitude Physiology Studies (HAPS). In all more than 100 men and women representing 30 Canadian and American colleges, universities, and research institutions and agencies participated in IRRP field investigations in physical, biological, medical, and social sciences.

GLACIER STUDIES

A nominal program was carried out from mid-July to mid-August on the Rusty Glacier and two neighbours the Backe and Trapridge glaciers, three small surge-type glaciers for which there is evidence of a history of surging. (Names approved by the Canadian Permanent Committee on Geographical Names 20 October 1971: Rusty Glacier for "Fox" glacier; Backe Glacier for "Jackal" glacier; Trapridge Glacier for "Hyena" glacier.) Although they are neighbours within the Steele Valley watershed, there is as yet no apparent relationship linking their surging activity, and at the present time they are in widely varying phases of the surge cycle.

Survey — Rusty Glacier

In 1967 a net of surface markers was set out on the Rusty Glacier and in 1969 on the Trapridge Glacier to survey surface movement. Markers also were drilled into the Backe Glacier in 1967 and 1968. However, because that glacier was in the last stages of surge, its surface proved to be too extensively crevassed to allow placing markers in any significant network. They were placed only in order to compute the rate and direction of movement of its snout.

In 1971 surface markers were checked and extended where necessary on Rusty and Trapridge glaciers, and a complete survey was made of surface motion since 1970. Little change in rate occurred on the Rusty Glacier. Net balance was estimated to be slightly positive. A thickening in part of the upper region of the Trapridge Glacier was measured but no computations have yet been completed for height or extent of thickening. A single measurement of the snout of the Backe Glacier shows that it continues to lose momentum, and though still moving very slowly, it most probably is entering the quiescent phase of this type of glacier.

Englacial Temperature Measurements — Rusty Glacier

Measurements were made of the ice temperatures in the two deep holes drilled early in 1970 by hot point method at the sites of predicted "hot spots" in the Rusty Glacier.[1] The measurements were made to verify that the 1970 temperatures measured at the end of the summer field season were true equilibrium values and were not influenced by slow refreezing at the bottom of the holes.

Pit Study — Upper Seward Glacier

During the period of least stability near the end of July a 4.7 m. deep pit was dug into the firn of the Seward Glacier at an elevation of about 1,600 m. Mean firn density approached 0.5 mg./km.[3] equivalent to about 2,350 mm. of water. This approximation of precipitation for 1970-1971 is higher for that elevation on the Seward Glacier than for any year previously measured.[2]

KLUANE LAKE STUDIES

During the 1971 summer field season investigations continued into significant changes in the level of Kluane Lake and shifts in direction of drainage as suggested by Bostock.[3] During 1970 a number of raised beaches, about 3 m. and 13 m. above lake level, were recognized and briefly inspected. From aerial reconnaissance, examination of aerial photographs and on-site observations, drowned forest was judged to be at depths estimated at 2 m. and 6 m. Along the Duke and Kluane rivers terraces were found to be nearly at heights corresponding to the raised beach levels. Only a portion, however, of the ± 320 km. of shoreline could be explored in the time available.

Raised Beaches; Drowned Forest

The work of identifying raised beaches on the flanks of the hills continued in 1971. This was followed by transit levelling and plane-table mapping of terraces, sediment sampling, vegetation transects, increment borings from selected trees on the two major terraces, and a ground and air reconnaissance of the very large Slims River valley for evidence of terraces. In addition, scuba divers investigated selected littoral sites and were successful in cutting logs from the butts of trees for ^{14}C dating. These tree trunks were in-place on a drowned terrace 8.2 m. below present lake level.

LOESS TRANSPORT AND DEPOSITION

Active loess transport and deposition studies began 30 May on the wide, dry floor of the Slims River valley. Deposition plots were surveyed in and towers were built and instrumented. During the first three weeks of preparation there were periods when there was so much loess in the air impairing visibility that surveying had to be curtailed. But fickle lady luck in the garb of weather failed to cooperate. Daily showers kept the valley floor moist and meltwater from the glaciers filled the shallow braided river channels. As the river began to flood laterally and saturate the valley fill, it became evident that no significant airborne transport study of loess could be completed.

An investigation of loess deposition, therefore, was initiated along the eastern flank of the Icefield Ranges in the region around Kluane Lake. Sixty-two samples of surface loess were collected from the Slims River flood plain and 25 pits were dug at intervals around the shores of the lake. From the surface the pit profile showed unweathered neoglacial loess, Slims soil, and Kluane loess lying over glacial till.[4] All the samples of loess collected are in the process of being analysed by particle size and x-ray defraction method in an attempt to delineate source area, i.e. perhaps from the flood plains of the Duke and Donjek rivers as well as the Slims River.

CLIMATOLOGY

Examination of climate continued on three scales of observation here defined as micro-, meso-, and synoptic. To investigate micro-scale climatology, continuous full complement energy flux parameters were measured for sixteen months beginning in early May 1970. The instrument station was located between the shore of Kluane Lake and the aircraft runway and west of the log hut which housed the wintering-over researchers and was shop and laboratory for recording equipment. Heat/energy balance studies in the mesoscale were accomplished by maintaining thermograph stations at intervals along a snow line transect from the Slims River valley floor up the flank of Sheep Mountain plus an automatic weather recording station near the summit (el. *c.* 1,860 m.). The third scale tied in with regular three-hour weather observations at base camp. Close coordination continued with the Department of Transport weather office in Whitehorse.

BIOLOGY

Large Mammal Study

Research on Dall sheep with emphasis on its range relationship continued throughout the winter. The study area encompasses Sheep Mountain (el. 1,945 m.). Plant community plots were fenced and sheep were marked in 1969. Plots with comparable plant communities were established, and during part of December 1969 and February 1970 vegetation and soil samples were collected and analysed. Beginning in the early spring of 1970 vegetation was clipped at intervals through the following 18 months to determine productivity and nutrient value both within the enclosed plots and comparable plots used

by sheep, 12 species of grasses were mapped over the entire mountain, and effect of altitude and exposure on rate and extent of plant growth was investigated.

One hundred and sixty snow stakes were set up on Sheep Mountain and at midday throughout the 1970-1971 winter sheep were counted and distribution checked with regard to exposure, snow depth, wind (facing into), position and activity (lying, feeding), and make-up of groups. During the spring and summer vegetation clipping continued and temperature and moisture content of the soils was measured at depths of 10, 30, and 50 cm.

Botany

Phytogeographical studies in the Icefield Ranges, begun in 1965 on nunataks and in the alpine zone above the 1,500-m. level, were continued in 1971. Critical to a successful completion of the study was an examination of the flora of isolated nunataks within the perimeter of Seward Glacier.

During a 5-day period in late July a camp was established on the Seward Glacier by a fixed-wing aircraft aided by a Bell helicopter which remained with the researchers and support personnel. In 3 days of favourable weather and by using the helicopter 5 nunataks separated by as much as 15 miles were visited, the flora examined, and the program completed.

HIGH ALTITUDE PHYSIOLOGY STUDIES

Prolonged bad weather which shrouded the Mount Logan laboratory (el. *c.* 5,330 m.) at critical periods and damage to the Helio Courier aircraft at the outset of the program made the fifth season of the Mount Logan physiology studies unusually difficult. Yet the project was successful despite severe obstacles.

In mid-June the support party was landed in the trench at an elevation of about 3,200 m. from where the 9 mountaineers slowly climbed the remaining 2,130 m. to the laboratory. In 1971 for the first time the support party included an experienced mountaineer/physician who — fully acclimatized by the time the volunteer subjects arrived — would be responsible for the health and welfare of the entire mountain party. Upon reaching the laboratory the support party opened the camp and got all housing, equipment and supplies in readiness for the studies to begin in July.

During the first week in July, 5 scientist investigators, 2 technicians, and 10 volunteer subjects arrived at Kluane Lake base camp. Baseline studies began immediately.

Field laboratory studies were planned to build upon and expand work which had been done in previous years and were for the most part directed towards better understanding of the role of water and salts in acclimatization to hypoxia and in acute mountain sickness. The following determinations were performed: body water distribution; electrolyte and water content of red cells and plasma; capillary pH, pCO_2 and pO_2; angiotensin-renin-aldosterone levels in blood and urine; retinal photographs and retinal circulation times; carbon dioxide response curves; venous compliance; pulmonary closing volumes; and electroencephalograms during sleep. All the studies were performed in 1971, though some are incomplete. Moreover, although all experimental subjects were studied before ascent, due to unusually bad weather and scheduled commitments no end-project baseline studies could be obtained.

In past summers some individuals flown directly to the Logan laboratory without advance preventative medication have experienced severe reactions. Since, however, it has been satisfactorily shown that acetazolamide (Diamox) does prevent or diminish most severe reactions to altitude, all individuals who are flown directly from Kluane to Mount Logan are required to take Diamox for 36-48 hours before and for 24-36 hours after ascent. Others are routed through an acclimatizing period at intermediate altitude.

In each of the previous years we have seen ataxic gait, cerebral or pulmonary edema, intractable headache, nausea, vomiting and anorexia, or urinary retention, mental confusion and collapse among both scientists and subjects, when taken to Logan High directly and without medication. Though acute mountain sickness is notoriously subject to emotional influence, these symptoms were too striking to be passed over lightly, and we were determined to avoid them by the measures noted above. As a result, this year we observed only mild effects: slight to moderate headache for a few days, two instances of transient gait ataxia, and two individuals with retinal hemorrhages. We saw nothing suggestive of acute pulmonary edema or cerebral edema in individuals at Logan High. Two persons required emergency evacuation from altitudes below Logan High, and these deserve a brief note.

One member of the support party became increasingly tired during the first few days of ascent from 10,500 feet (3,200 m.) towards Logan High. He became drowsy, was unable to carry his pack, or even to move upwards. Since no physician was available to the pro-

ject during the support party's climb and because his symptoms resembled the early symptoms observed several years ago in a member of that support party who subsequently developed cerebral edema, the leader of the group wisely decided to call for emergency evacuation; this was accomplished rapidly and the patient was asymptomatic on arrival at Base Camp, and in retrospect we believe his condition was never serious.

A young mountaineer, member of a climbing party unrelated to the project, was taken ill at 14,200 feet (4,330 m.) on the fourth day of rapid climbing from 10,500 feet (3,200 m.). He developed a severe cough productive of bloody sputum, bubbling noises in his chest and extreme weakness. His companions brought him down to the 10,500 foot (3,200 m.) level where fortunately a physician who was with this project had arrived the previous day. The diagnosis of pulmonary edema was made and his condition seemed to deteriorate and emergency evacuation by helicopter was accomplished. On examination at Kluane Lake he was found to have extensive bilateral pulmonary edema and bilateral retinal hemorrhages; he improved rapidly, and had completely recovered after one week, although the hemorrhages are expected to require several months for disappearance.

It is worth noting here that of 10 individuals sufficiently affected by altitude to require emergency or semi-emergency evacuation in the five project years, 6 were members of the support party or of other unrelated mountain expeditions, while only 4 were experimental subjects or scientists flown directly to Logan from Kluane Lake. An analysis of these individual cases is in preparation.

It is our privilege and pleasure to acknowledge here the enthusiastic support and cooperation of the Canadian Forces. Scientists and technicians from the Armed Forces were on loan to the project. Ten experimental subjects volunteered from the Forces, and were provided with complete food and equipment for the entire program. A large STOL aircraft (Buffalo) made two trips from Edmonton to Kluane (approximately 1,500 miles) to bring personnel and equipment to Base Camp. After the second of these flights the aircraft dropped approximately 8,000 pounds of essential supplies to Logan High. At project end three Buffalo flights were made from Edmonton to Kluane and back to remove all personnel and equipment. Not only has this large and costly support been provided on schedule, and to the extent needed, but we have also felt that the Forces were enthusiastic and interested in the entire project. Without their help it is obvious that the project would be very difficult.

WORKSHOP FOR ENVIRONMENTAL PREDICTION IN ALPINE, ARCTIC, AND SUBARCTIC REGIONS

The Advanced Research Projects Agency (ARPA) and the Arctic Institute convened a workshop at Kluane Lake camp further to refine and amplify the contributions of energy and mass balance studies. The workshop was held from 23 to 28 August.

The Kluane Lake research camp for eleven years has served as the base for multidisciplinary and interdisciplinary research in the alpine and subarctic environments of the St. Elias Mountains and environs. A broad spectrum of physical and biological environments may be observed and studied within relatively short distances. Thus, it was felt that the workshop participants would benefit by exposure to such an environmental complex in an area where detailed research has been accomplished in geology, glacial geology, geomorphology, glaciology, botany, small and large animal ecology, hydrology, limnology, meteorology, climatology, and human physiology. Particularly for those not acquainted with such landscapes, it provided an opportunity to understand the true magnitude of the landscape, associated natural processes, and the problems of logistics and operations.

The objectives were *inter alia:* 1) to identify significant questions regarding the terrestrial environment, the answers to which would have impact on defence and military operations; 2) to address these questions in the context of the stress environments found in alpine, subarctic and arctic regions; 3) to recommend research directions.

Participants were invited on the basis of their expertise and methodological bent, although there was an intentional emphasis on personnel concerned with energy and mass balance research. Maximum interaction was anticipated by mixing the participants to insure the inclusion of the following counterpoints: empirical and theoretical; academic and operational; surface-oriented and atmosphere-oriented; and senior and junior investigators.

The workshop was scheduled to provide maximum background information while permitting adequate opportunities for work groups to develop recommendations. Much of the work was accomplished in smaller groups, but all participants came together for background lectures and discussions which evaluated reports of the subgroups.

Opportunities were provided for field orientation and familiarization by the drive or light plane flight between Whitehorse and Lake Kluane, overflights of the environmental spectrum of the St. Elias Mountains and adjacent periglacial regions, and local walks.

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University of Colorado: 1971 Summer Field Season in East Baffin Island

Research was continued by University of Colorado faculty and graduate students in the area of Cumberland Peninsula, Baffin Island, Northwest Territories. The work was divided into four main phases: 1) studies on the glacial chronology of the Penny Ice Cap and local mountain ice caps; 2) the mass balance of the Boas Glacier; 3) air-sea interactions using ground stations, instrumented aircraft and satellite data; and 4) evaluation of climatic trends. These various activities were supported by grants from the National Science Foundation #GV-28220, GV-28218, and GA-28003 and the U.S. Army Research Office, Grant DA-ARO-D-31-124-71-G80.

1) Four two-man parties were involved in Quaternary geological investigations in the following areas: Maktak Fiord and the trough between Maktak and Narpaing fiords; the fiord system centred on Nedlukseak Fiord; Okoa Bay; and raised marine cliffs consisting of interbedded tills and fossiliferous marine strata extending between Quajon and Narpaing fiords. The relationship in terms of response of the Penny Ice Cap and the local ice caps and valley glaciers is one primary research topic. A lichen curve has been developed for *Rhizocarpon geographicum* that allows dating back to approximately 7,000 BP. Results indicate that the Early Wisconsin ice was the most extensive of the Wisconsin glaciations and that the late-Wisconsin ice only extended a limited distance down fiord. Numerous samples were collected for radiocarbon dating.

2) The mass and energy balance of the Boas Glacier was the subject of detailed investigation in 1970[1]; a more limited study was carried out in 1971. The general characteristics of cirque basins with and without glaciers are being investigated and a total of approximately 500 cirque basins have been delimited on the Okoa and Cape Dyer map sheets. A computer program has been developed by L. Williams, University of Colorado[2] which takes into account the topographic shadowing effect on slope receipts of clear-sky global radiation. Results indicate that there is a small but significant difference, on average, between the global radiation being received in present ice-free and ice-filled cirques. Using the same program, attention is currently being focused on the magnitude of the Milankovitch variations. Indications are that they may be quite significant for this area. After the very positive mass balance year of 1969-70, the 1970-71 balance year resulted in an average winter mass balance of approximately 25 cm. water equivalent. Heavy melt was experienced during the summer and preliminary results suggest that all the 1970-71 snow was ablated, but that much of the 1969-70 accumulation was not affected.

3) In late May 1971 a program of airborne measurements at elevations of 100 to 1,000 feet was carried out over the Davis Strait east of Cape Dyer using a Queenair of the National Center for Atmospheric Research in Boulder (which is supported by the National Science Foundation). Instrumentation included a vertically-mounted time lapse camera, PRT-5 airborne infrared thermometer, Eppley pyranometers, a Swissteco linear net radiometer and temperature and dew point sensors. Attention was focused on variations in energy budget over sea and ice surfaces. Profile measurements were made during each flight over a micro-meteorological station operated on the ice in Sunneshine Fiord. The primary aim of this program is to investigate the applicability and resolution of satellite data for determining synoptic energy budgets in the eastern Arctic. From June to August 1971 a micro-meteorological