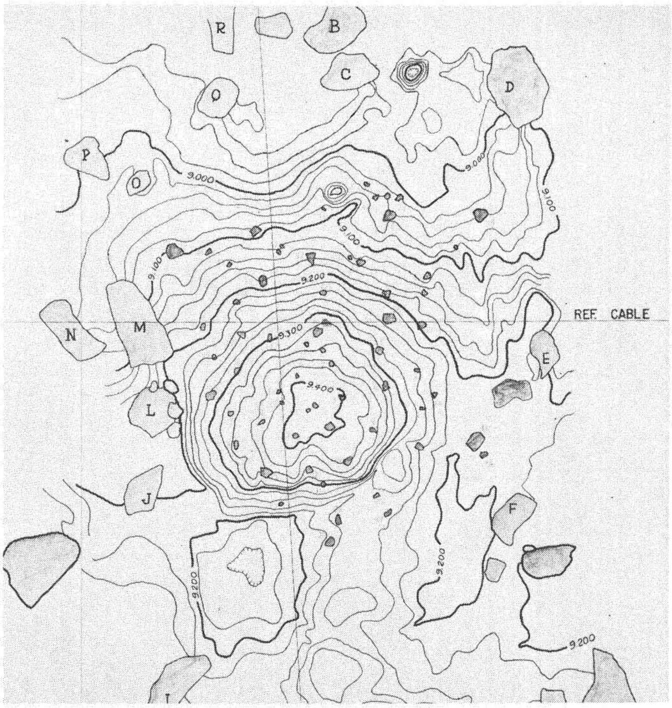

FIG. 12. Soil movement map. Mapping scale of about 1 to 4. Contour interval 0.02 foot.

minus one or two thousandths of a foot, and similar precision should accompany the measured distances between control points on the periodic stability surveys. Finally, when the distances between control points are short, such as in Figure 9, it is almost futile, considering the time required, to measure the angles of the control system with an accuracy compatible with the remainder of the survey.

It is hoped that when these motion studies are completed, one of the questions mentioned earlier, the rate of development of frost patterns, will be well on the way to being answered, and there will be added one more facet to the interpretation of aerial photography.

Use of Aerial Photographs and Field Reconnaissance for Ice Cap Route Location at Narssarssuaq, Greenland

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(*Abstract is on next page*)

DURING the summer of 1957 the terrain between Narssarssuaq Air Base and the Greenland Ice Cap was studied in detail, an overland route from the air base to the ice cap was located and surveyed, and an engineering report was prepared. The route is approximately 45 miles long and goes from near sea level to an elevation of about 4,000 ft. at the ice cap margin. This paper describes the combined use of aerial photographic interpretation techniques and field and aerial reconnaissance for the purpose of obtaining useful engineering information about terrain conditions, for solving highway engineering problems in this remote mountainous area.

In 1956 a party composed of representatives of the U. S. Army Engineer Arctic Task Force; Office Chief of Engineers; U. S. Army Snow Ice and Permafrost Research Establishment; Transportation Arctic Group, Transportation Corps; and the Danish Government conducted a preliminary reconnaissance of selected areas of South Greenland. The purpose was to select an area with a relatively ice-free port and harbor area, an access to the ice cap that was generally free of crevassing and seasonal melt, and a land area that offered the best possibilities for a road between the port and the ice cap. This was accomplished by study of the southwest coast of Greenland from aerial photographs and high altitude aerial inspection. It was the opinion of the reconnaissance party that the Narssarssuaq area offered the best possibilities for these conditions (1).

ABSTRACT: *This paper is an illustration of the combined use of aerial photographic interpretation techniques with field and aerial reconnaissance for the purpose of obtaining useful engineering information about terrain conditions for solving highway engineering problems in a remote mountainous area. The purpose of the study was to locate and evaluate an access area from the sea to the ice cap in southern Greenland. The summer of 1957 was devoted to field checking predictions made in a preliminary study of small-scale aerial photography from which a tentative route was located, and location and survey of the route on the ground. Use of aerial photography for study prior to and while in the field resulted in obtaining the maximum amount of information in a minimum of time for location of the road and preparation of an engineering report.*

Narssarssuaq Air Base is located about 40 miles inland near the southern tip of Greenland (Figure 1). The air base is on a large gravel terrace in a deep glacial valley which abuts an inland bay near the junction of this bay and a fjord which extends to the coast. Narssarssuaq is located in about the geometric center of a near-circular land indentation into the Greenland Ice Cap. The high mountains of this area restrain the glacial advance except for the valley glaciers that drain into the upland lakes and fjords.

Early in 1957 it was decided that additional efforts would be made to obtain more detailed information and data of the area. This would include location and survey of the overland route, and study of the problems that would be encountered in construction of such a road. Responsibilities for these efforts were as follows: U. S. Army Snow Ice and Permafrost Research Establishment, location of the route and preparation of the final report; U. S. Army Engineer Arctic Task Force, survey for plan, profile, and cross-section; and U. S. Army Engineer Arctic Construction and Frost Effects Laboratory, direction of the survey effort.

The aerial photography (USAF) available to USA SIPRE in 1956 was determined to be inadequate for road location work from Narssarssuaq Air Base to the ice cap. Consequently additional aerial photographs were obtained from the Geodetic Institute of Denmark, Copenhagen, for study, and a preliminary report (2) was prepared; this provided an engineering evaluation of the terrain and contained recommendations for the most practical access route to the ice cap.

Due to the lack of geologic or engineering literature pertaining to the area, the preliminary study was compiled exclusively from information obtained from the study of small-scale aerial photographs. The approximate scale of these photographs was 1:40,000, and while not optimum for a study of this sort they provided information obtainable by no other means prior to the field effort. The aerial mosaic (Figure 2) revealed the mountainous terrain (Figure 3) that was heavily fault-scarred, and the many indications of former glaciation by the general rounding of the major topographic features and the scattered deposits of glacial debris. The present glaciation was now limited to a few valley glaciers.

When the photographs were studied in detail stereoscopically the surface characteristics and configurations of the landforms provided a means of identifying the materials of the area. Such analysis foretold the igneous

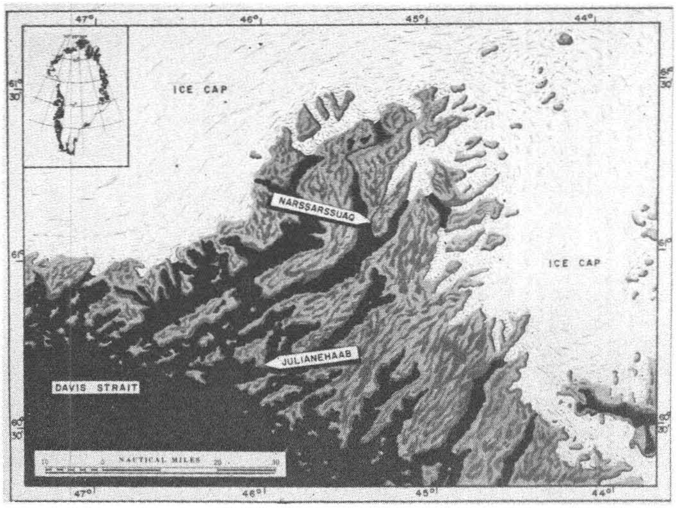

FIG. 1. Location of Narssarssuaq Air Base.

and metamorphic composition of the uplands, with sedimentary rocks occupying a small portion of the area in the vicinity of the air base, whereas the majority of the minor forms of significance resulted from glacial or fluvio-glacial origin.

From this study, a list of all the landforms of the area was compiled, and each form was assigned a mapping symbol. Landforms on the individual photographs were then bounded and annotated with the proper symbol, so that when the photographs were arranged again into a mosaic the result would be an overall picture of the distribution of the landforms and materials of the area. This was accomplished prior to becoming concerned with the route location so that an unbiased evaluation of the terrain and its related highway engineering problems could be made. Whole areas could then be pronounced as being less desirable for location of the route and thus allowing more study in areas with fewer or relatively minor problems. Several possible route locations utilized the more desirable areas for a road from the air base to the ice cap, each having some advantage over another location. These advantages and disadvantages were related to the factors of alignment and grade of the roadway, soil and rock subgrade conditions, necessary cut and fill sections, distance of borrow material from the work section, number and length of the bridges and drainage structures, snow drift conditions, and snowslide and rockslide areas. A route, with a few alternates, was then selected as offering the best possibilities based on overall consideration of good alignment with a minimum of steep grades; best available subgrade conditions; minimum number of stream crossings requiring bridging; minimum possibility of snow drifting onto the roadway; avoidance of major rockslide areas; and avoidance of potential snowslide areas.

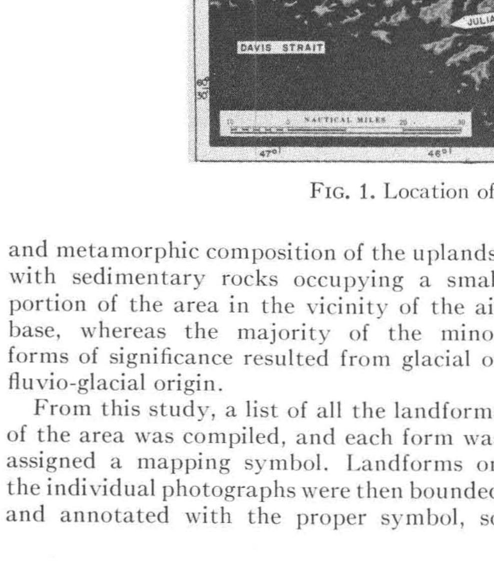

FIG. 2. Aerial mosaic showing location of access route and related USA SIPRE reports.

As determined from the photo study, this location of the route had only a few grades to be estimated greater than 8% and no curves of short radius. Only 13 stream crossings required bridging and these were located so as

FIG. 3. Typical upland and valley terrain.

to have suitable foundation conditions and span lengths. Discussion of the selected route in the preliminary report gave a running description of the engineering problems and their possible solution from the air base to the selected ice cap access point.

The aerial photographs annotated with the selected route location and the landforms were then reproduced and plasticized. These served as base maps in the field because the largest scale map available (1:250,000) was inadequate for transfer of the detail from the photos. This ended the preliminary phase of the project; a phase in which all information was obtained from the aerial photographs prior to entering the field.

Prior to departure for South Greenland, arrangements were completed for including an air section in the project requirements and planning. These aircraft of the U. S. Army Transportation Corps were two H-34 helicopters and two fixed wing L-20 type. This was a welcome addition that saved much time and effort; moreover, the project most certainly could not have been completed in one summer had the project personnel been required to backpack equipment and supplies over the 45 miles of rugged terrain.

Another fortunate advantage for the project concerned the use of the air-base facilities for rations, quarters, office space, and fuel for the aircraft; not to mention the transportation to and from the United States by the Military Air Transportation Service. At that time base personnel were in the process of placing the base on caretaker status; the base had served the purpose of a ferry stop for the U. S. Army Air Force in World War II and was no longer needed in the jet age.

Upon arrival at the air base project personnel busied themselves with preparations for the field. The fjord ice was late breaking up that year. Since the project aircraft was due to arrive by ship, the project could not be started in earnest. Until the arrival of the aircraft, time was utilized by making overland hikes in the area, studying the aerial photography, locating about the first ten miles of the route, studying the port facility, and establishing procedures to be used in the project to insure efficient and rapid completion.

It was evident at the outset of the field effort that the study of the aerial photography was the key for obtaining preliminary useful information about the terrain conditions for solving highway engineering problems in this remote area. In this respect, the preliminary photo study and report proved to be a valuable building block for the project. The first low-altitude reconnaissance flight justified the prior efforts and proved the validity of the conclusions drawn from the study of the small-scale aerial photography. In fact, so much faith was placed in the photo study that location and survey of the center-line on the ground was begun before the route was reconnoitered over its entire length from the air. This was justified because the only economically feasible route had to utilize the valleys and their generally easy grades (Figure 4). Knowing the general location of the route, the problem then was reduced to the physical location on the ground; the survey of the center-line and cross-sections; the definition of the engineering problems to be encountered in the construction of the route; and the preparation of a comprehensive report.

Location of the road was accomplished through a study of the aerial photography supplemented by high- and low-altitude aerial reconnaissance flights and by walking the proposed route. The ground reconnaissance party marked the selected location with cloth strips and numbered tags tied to rocks or

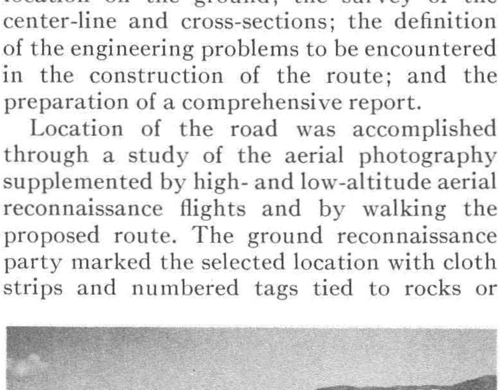

FIG. 4. Valley location of the route.

brush along the proposed center-line, as a guide for the survey party which followed. Tags were always placed on the intended center-line and at or near a change in terrain conditions which would reflect a change in construction practice. For example, where it was necessary to change the center-line location from a level granular terrace to a talus slope along the lower portion of a valley wall, a numbered tag would be placed at the transition point. The tag number would be recorded in the field notes, and a description of the soil or bedrock condition as it affected the road location would be included with the recommended construction practice. Thus, as in the above example, if a cut or a fill was needed in the transition zone for the purpose of maintaining an easy grade, it was recommended.

It was not always possible to choose the terrain that provided the best grade for the intended road, because so doing might have prompted an even larger problem. Therefore, the marked center-line in many locations required judgment as to which would present the lesser construction problems in this remote area, and also require the least maintenance once constructed. Major decisions, calling for more data than was at hand, usually resulted in location of alternate portions of the route.

As stated, the survey party followed the reconnaissance party. Additional to their duties of surveying the center-line and obtaining cross-sections at 100 ft. intervals, they recorded the stationing of the numbered tags. This linked the engineering notes obtained by the reconnaissance party to the survey data.

Project utilization of the helicopters was considered unique. They were used to move personnel, supplies, and equipment. Their capabilities of carrying twelve passengers without equipment or about seven passengers with their equipment meant that they could carry the complete party into the field at once (Figure 5). Initially the field crews were moved into the field in the morning and back to the air-base each night. This proved to be unsatisfactory when poor weather at the air-base curtailed flying but allowed field work. Thus, parties remained in the field for three or four days at a time and used the helicopters to move the camps and air lift crews and equipment across rivers. Each morning an H-34 would take the reconnaissance party on low flights over terrain to be covered in the succeeding two days. Prior photo study made these reconnaissance flights very valuable.

After locating the route to the ice cap access point the reconnaissance party obtained low-altitude photography of the entire route with a Speed Graphic camera. These photographs, about 500 in all, supplemented the small-scale aerial photographs, and selected photos were used to illustrate the final report.

FIG. 5. A H-34 helicopter which supported the project.

Thus, the location and its preliminary survey were completed. The road, if constructed, would be about 45 miles in length and extend from the air-base, which is near sea level, to an elevation of about 4,000 ft. at the edge of the ice cap.

For the final report the route was organized into sections (Figure 6) each being in a separate physiographic feature or portion of the road where engineering problems would be somewhat similar. For example, the Lower Falls Section extends from station 483/00 to station 626/89, a distance of about 2.7 miles, in which the road climbs from about an elevation of 500 ft. to 2,500 ft. The route in this section is located on the northeast side of the narrow steep valley, in which the river flows over numerous waterfalls. Two of these waterfalls are fairly high and indicate the steep gradient of the valley (Figure 7). To keep the road grade generally uniform and not to exceed the maximum in any portion, it was necessary to traverse some terrain which otherwise would be avoided, such as steep slopes along bedrock walls. The road in this section will be largely sidehill cut-and-fill, but some parts will be entirely fill areas.

Thus with the route restricted to a portion of the river valley that contained many falls, the predominating engineering problems of this section are sidehill cut-and-fill areas and fairly steep grades. Road sections at each end of this section are located on outwash plains that were designated the Lower Outwash Section and the Middle Outwash Section.

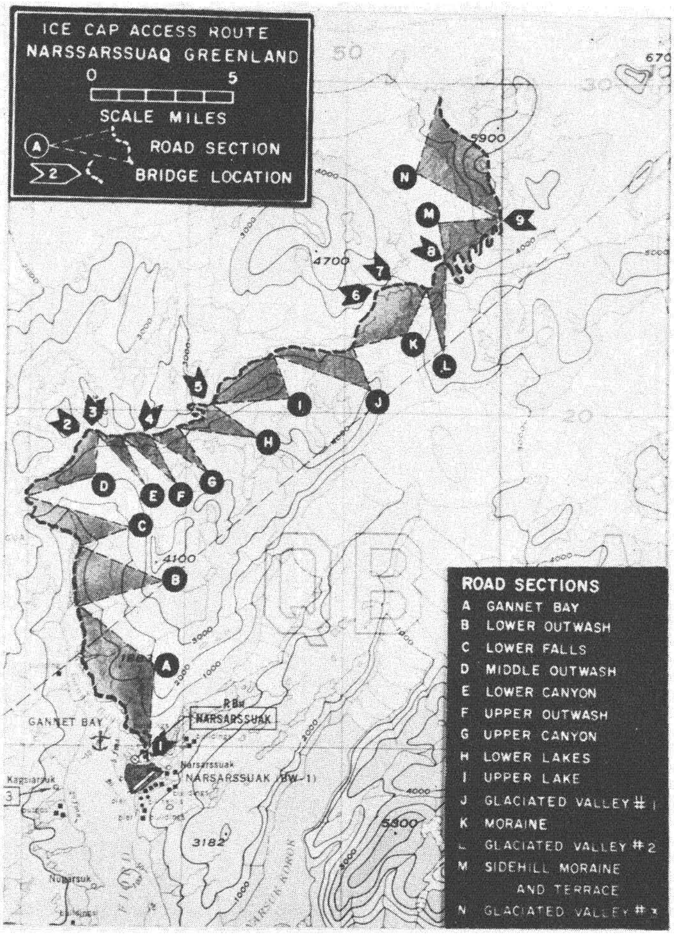

FIG. 6. Road sections and bridges along ice-cap access route.

Here the road is located on granular terraces throughout the greater portion of its length and the engineering problems are relatively minor.

Each section was then subdivided into lengths where the engineering problem was discussed in detail (Figure 8). For example, in the Lower Falls Section, lengths are designated by names which indicate the topography upon which the route is located, or the general construction practice to be employed along this length. The final report then discussed in detail each length of road in each section from the air base to the ice cap access point and pointed out the engineering problems that would be encountered and their recommended solutions. The final report (3) and field notes, along with all photographs, are available if needed in the future.

In summary the project illustrated that combined use of aerial photographic interpretation techniques with field and aerial reconnaissance can be used to obtain useful

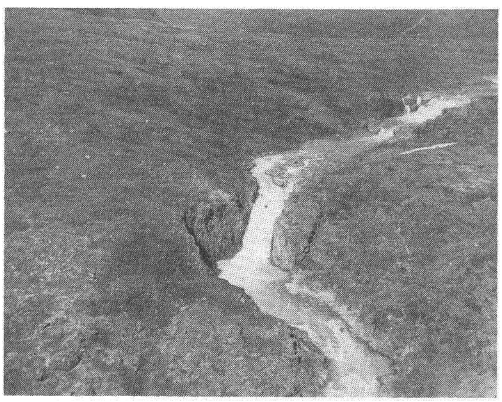

FIG. 7. Waterfalls in the Lower Falls Section.

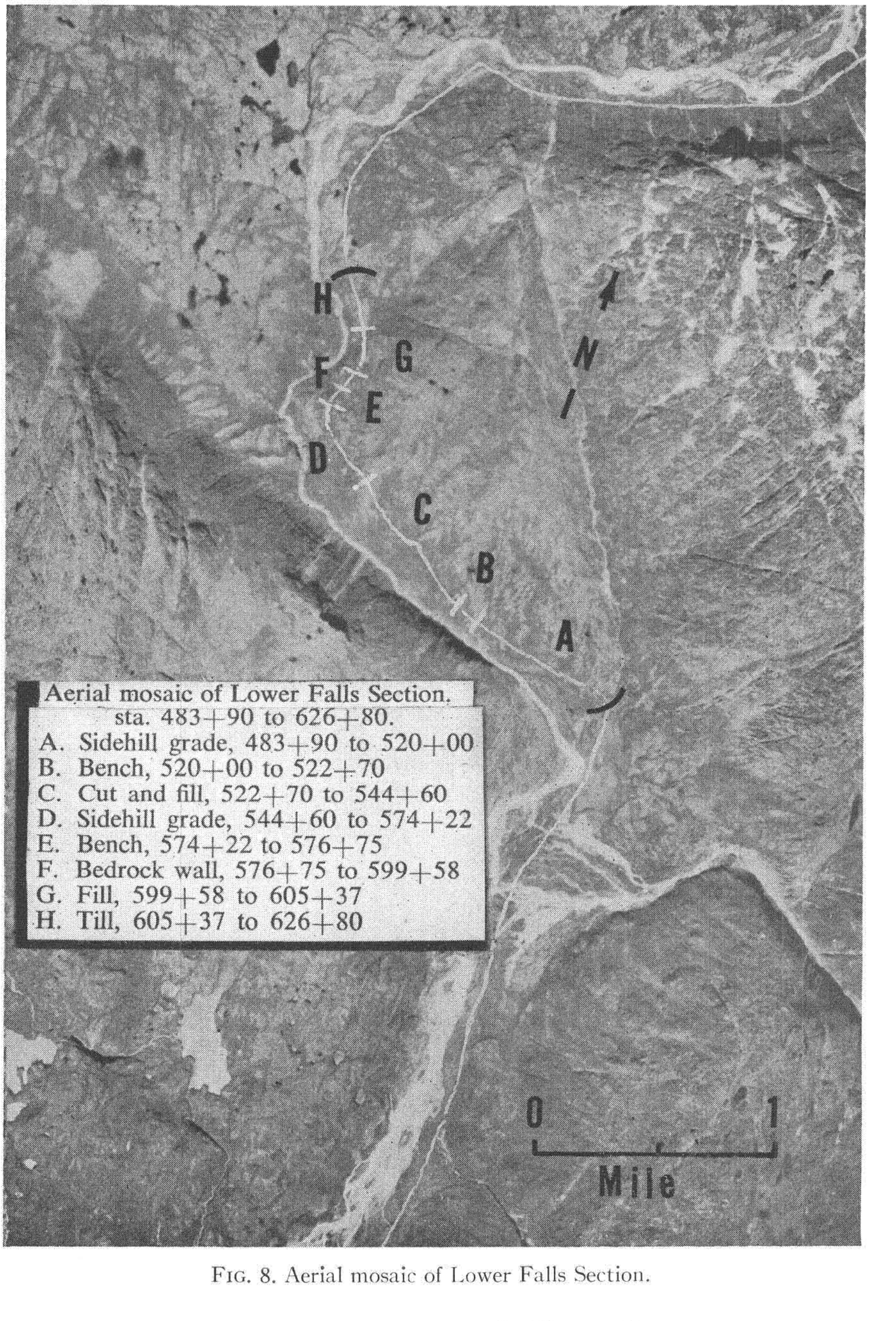

FIG. 8. Aerial mosaic of Lower Falls Section.

engineering information about terrain conditions for solving highway engineering problems in a remote mountainous area.

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