and developments of tomorrow may radically change the picture. For one thing the effect of radar altimeter measurements on photogrammetry is not fully assessed. Dr. Lyle G. Trorey touched on the subject in his paper before your Society on January 11, 1950. Mr. T. J. Blachut of the National Research Council, Ottawa, gave a paper on the subject before the International Congress of Photogrammetry in September of last year. Mr. Blachut is continuing his investigation. Developments along other lines are probably in the making. At any rate it seems safe to say that before the Canadian Arctic is completely mapped, mapping processes will be much simpler than they are today.

Mapping in the Arctic*

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SYNOPSIS

This paper discusses briefly the mapping and charting of Alaska from 1898 to the present time. It emphasizes the development of methods and techniques used principally by the Geological Survey in conducting Arctic mapping operations, with special emphasis on the use of Trimetrogon coverage combined with earlier planetable surveys to produce the 1:250,000 map scale coverage of Alaska, as well as the use of shoran altimetry, the helicopter and new photogrammetric techniques for modern mapping in the Arctic.

Arctic Alaska has been of interest to explorers and geographers since Captain James Cook made his famous voyage into the Arctic Ocean in 1778 in search of the "Northwest Passage." In 1826 Captain F. W. Beechey charted the north coast of Alaska to Point Barrow. There is little evidence that the Russians pushed north of the Arctic Circle in Alaska in quest of fur, although the Hudson Bay Company established trading posts on the Upper Yukon in 1847 and explored much of the Porcupine River basin.

In the period between 1843 and 1853, the British Government sent out several well-equipped expeditions to bring relief to the ill-fated expedition of Sir John Franklin on the Arctic coast. These expeditions prepared many maps and charts of the Arctic coast.

One of our first inland explorations after the acquisition of Alaska from Russia in 1867 was undertaken in 1869 by a small Army party under Captain C. W. Raymond. The mission of this party was to determine the position of the Alaska-Canadian boundary. As a result of Captain Raymond's observations at Fort Yukon, the Hudson Bay Company was forced to move its important trading post 50 miles up the Porcupine River. Two more moves and ten years later the post was finally established on the 141st meridian.

In 1881 the U. S. Signal Service established a meteorological and magnetic station at Point Barrow where observations were made for longitude and latitude. During the period between 1883 and 1886, officers of the Navy conducted noteworthy expeditions into the Arctic. Lt. George M. Stoney explored Kotzebue Sound, and the Kobuk, Noatak, and Koyukuk Rivers. One of his officers, Ensign W. L. Howard, led a party of 4 men from the Noatak River northward through the mountains and down the Etivuluk River to the Colville River near the present site of Umiat. The party portaged to the Ikpikpuk River and thence to Point Barrow.

In 1889, J. H. Turner and J. E. McGrath of the Coast Survey ascended the Yukon River to Fort Yukon where they separated. Turner continued up the Porcupine River to Rampart House where he established an astronomical observatory on the boundary, and then continued north to the Arctic coast by dog team. McGrath continued up the Yukon to Eagle where he made position observations for the boundary.

The Geological Survey began topographic mapping in Alaska in 1895. Field parties were small and, usually, topographic and geologic mapping was combined, work being concentrated in areas of potential mineral value. For 35 years, with a few exceptions, little attention was given to mapping north of the Arctic Circle. Peters and Schrader arrived at Alatna on the Koyukuk River by dog team in the spring of 1901, and, after the break-up crossed the Brooks range through Anaktuvuk Pass to the Colville drainage, finally arriving at

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Point Barrow in the late fall. During the same year Mendenhall and Rayburn traversed the headwaters of the Koyukuk and the lower Kobuk. In 1911 Smith and Giffin made exploratory maps of about 16,000 square miles covering portions of the Koyukuk, Alatna, and Noatak Rivers.

In 1905, the Norwegian polar explorer Roald Amundsen, on completing his famous journey through the long-sought "Northwest Passage," made an overland journey from Herschel Island on the Arctic coast to Fort Yukon.

From 1909 to 1912, the International Boundary Survey carried on work in the Arctic and completed the first triangulation arc to the Arctic Ocean.

Mapping of Naval Petroleum Reserve No. 4 was started by the Geological Survey in 1923, in cooperation with the Navy, and continued until 1926. In 1927, reconnaissance mapping was continued on the Porcupine River and its tributaries in the northeastern portion of Arctic Alaska.

Mapping methods used in Arctic Alaska for reconnaissance work were similar to those used by the Geological Survey in western United States since the 1880's. Ordinarily, equipment consisted of a planetable, a telescopic alidade with micrometer eye-piece, and a light mountain transit. Triangulation was nonexistent except for the 141st meridian and a few spot areas along the Arctic coast. The topographer therefore determined his initial horizontal position by longitude and latitude observations and often determined his elevation by aneroid barometer. After measuring a base line, instrumental or graphic triangulation was expanded over the area to be mapped. Special insulation was used on instruments where work in sub-zero weather was required, and most of the planetable work was done on sheets of celluloid or painted zinc to prevent damage by rain or snow.

Until the advent of modern aircraft, transportation of Arctic survey parties was by pack train, poling boat, or canoe during the summer, and dog team and snowshoes during the winter. Nearly always, the success or failure of a reconnaissance surveying party in the Arctic depended upon the effectiveness of the transportation.

As most of the field parties were "on their own" during the season, camp equipment was carefully selected and consisted of small, light, mosquito-proof tents, sleeping bags, cooking utensils, axes, guns and ammunition. The equipment and food for a party of three men for a period of three months would generally weigh about 1,000 lbs.

Field work was usually carried on at a scale of 1:180,000 with a contour interval of 200 feet. Exploratory maps were published at a scale of 1:500,000 and reconnaissance maps at 1:250,000.

During World War II, much of Arctic Alaska was covered with Trimetrogon photography and numerous astronomic positions were determined with the astrolabe. This work, originally required for aeronautical charts, formed the framework for a good general-purpose small-scale map of northern Alaska and also provided a series of mile-to-the-inch reconnaissance maps needed for preliminary geologic studies of Naval Petroleum Reserve No. 4.

Although surveying and mapping in Alaska has been greatly expanded during the post-war period, relatively little new topographic mapping has been done north of the Arctic Circle. New arcs of adjusted triangulation however have been completed for all the Arctic coast as described by Commander Paton of the Coast & Geodetic Survey.

One of the Geological Survey's most important post-war projects was the design of a uniform series of topographic maps on a scale of 1:250,000 to replace the forty sheets of various sizes at this scale which had been published before the war. The new sheet layout contains 153 quadrangles of which 42 cover areas north of the Arctic Circle. A provisional issue based on existing source material has already been compiled and published. However, in spite of the early exploratory and reconnaissance mapping available and the Trimetrogon compilation prepared during the war, most of the quarter-million series covering Arctic Alaska are very much generalized and sub-standard, particularly in respect to contour information. For this reason the Geological Survey considers mapping in the Arctic to be a major problem and we look forward hopefully to the day when our military aviation can afford the time and equipment to provide us with high-altitude, shoran-controlled mapping photography covering all of northern Alaska, together with a closely spaced

network of control elevations by improved radar altimetry. We can then make full and effective use of modern photogrammetric and electronic methods and aerial transportation to provide maps for the defense and development of Alaska. I agree with Mr. Waugh that new methods and techniques now being studied or perfected may very greatly expedite our mapping of the Arctic. Here, perhaps, is a field where photogrammetry can make one of its most spectacular contributions to modern mapping at greatly reduced cost.

U. S. Mapping in the Arctic and Sub-Arctic Regions of the Western Hemisphere

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Because of the short time available, this discussion will be limited to the "Why," rather than the "How," of Military Mapping in the Arctic.

The graphic story of mapping in the arctic and sub-arctic areas of the world, and specifically in the Western Hemisphere, parallels closely the search for economic resources, and the establishment and operation of military defense facilities therein. Accomplishment of such mapping, generally, has been extremely difficult, time-consuming, and beset with many dangers. These conditions have been due to many factors, such as the lack of communications facilities, the limited season for surveying and flying activities, the complexities of logistical support, the adverse weather conditions, and the rugged terrain. In addition to these reasons, the unique and characteristic requirements of the civil and military, and the lack of funds, have also affected the attainment of optimum mapping coverage of the arctic areas.

Historically speaking, active participation of U. S. military forces in arctic and sub-arctic mapping began with the efforts expended in Alaska soon after its purchase from Russia. Later, during World War II, a more intensified program was undertaken, both in Alaska and in Greenland. In spite of these efforts and those of others, the results from the standpoint of military adequacy were far from satisfactory. The situation could be summarized as follows: map coverage available for military use was, in many cases, of irregular and widely separated areas; field surveys, in many instances, were local and isolated in nature; and topographic maps did not generally meet standard accuracies nor were they adjusted to a common datum.

In 1947, the General Staff of the Department of the Army, confronted with new military requirements and recognizing the deficiencies in the military mapping of the northern outposts of this hemisphere, initiated the preparation of a consolidated map plan to meet military needs, and took steps to implement it. In the preparation of the plan consideration was given to many factors, the more important of which will be discussed at this time.

One of the most important concepts pertaining to the strategic defense of the Western Hemisphere is the necessity for the direct physical control of the large masses of land lying on the northern extremities of that hemisphere. Relative to these same masses of land are certain other important factors as well; namely, their size, shape, relative location and geographical characteristics. Considered from the standpoint of the defenders of the Western Hemisphere, such areas become important as listening and early warning posts; as bases for air defensive measures; as weather observing outposts; as bases for ground troops protecting existing military facilities; as natural barriers to mass-movement of opposing forces; and, finally, as possible sources to fulfill the subsistence, shelter and survival needs of the military forces operating therein. When considered from the standpoint of a country contemplating offensive action against the Western Hemisphere, such land masses offer strategic obstacles to both the overland and the overhead movement of military forces toward the U. S.; in addition these land masses afford sites from which ground and air operations could be launched against such an attacking nation.

Alaska may aptly be considered just such an area as described. From the U. S. standpoint, it has natural barriers to land inva-