GEOGRAPHICAL EXPLORATION FROM LITTLE AMERICA III, THE WEST BASE OF THE UNITED STATES ANTARCTIC SERVICE EXPEDITION 1939-1941

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INTRODUCTION

GEOGRAPHICAL exploration in 1940 from Little America III, West Base of the United States Antarctic Service, was carried on by aerial reconnaissance and by sledging parties. During the three months' summer period, five major sledging units explored considerable portions of the coastal mountain regions east of Little America between longitudes 164° W. and 136° W. These parties began by following the routes pioneered by the Marie Byrd Land Sledging Party in 1934 toward the Edsel Ford Ranges, but they added considerably to the detailed knowledge of the region lying beyond the original trail.

From West Base eastward along the trail, the parties established barometric elevations, baselines, solar fixes, and major peak intersections to serve as ground control for aerial reconnaissance. Two of the parties operated on the King Edward VII Peninsula, two in the Edsel Ford Ranges of Marie Byrd Land, and the fifth penetrated to Mount Hal Flood. These sledging operations were supported by supply caches laid by tractor and airplane.

Aerial reconnaissance was carried on by two airplanes. Five major flights were made to the eastward, mapping the coast and inland features to near the 123rd meridian W. Three major flights were made westward and southwestward across the Ross Shelf Ice from the Barrier front to the abrupt southern articulation with the Austral Cordillera.[1] Many local flights conducted within a radius of 100 to 200 miles from the Bay of Whales yielded a more comprehensive knowledge of the origin, structure, and movement of the shelf ice.

Approximately 2,600 oblique photographs were taken during these survey flights, tying into ground control by means of aerial plane-table circles and affording continuous photographic records to the right and left of the plane track over most of the flight legs. The photographs provide an unbroken coverage from within sight of Mount Erebus, about longitude 167° E., eastward along the coast to a new and equally prominent landmark estimated to lie near latitude 73°15′ S. and longitude 123°30′ W. This is a total of over 70 degrees of longitude or a great circle distance of 1,215 statute miles. The area was observed or photographed for an average of more than 200 statute miles inland from the coast. A total area of not less than 220,000 square miles was thus covered.

The eastern area of Marie Byrd Land is represented by 1,200 aerial photographs, 500 of which are of the Edsel Ford Mountains region, lying be-

[1] The author suggests this term as an appropriate title for the entire Antarctic horst.

tween latitudes 76° and 78° S. and between longitudes 142° and 150° W. The western, or Ross Shelf Ice area, is represented by about 720 pictures and the Austral Cordillera region by 154 pictures. The remaining photographs are of the Edward Peninsula region. From these pictures it will be possible to map in detail an area of Antarctica approximately equal in size to the State of California. However, owing to curtailment in the program of the United States Antarctic Service until after the war, the only regions which have thus far received careful attention are the Edsel Ford and Rockefeller Mountains areas, where the principal geological surveys were conducted.

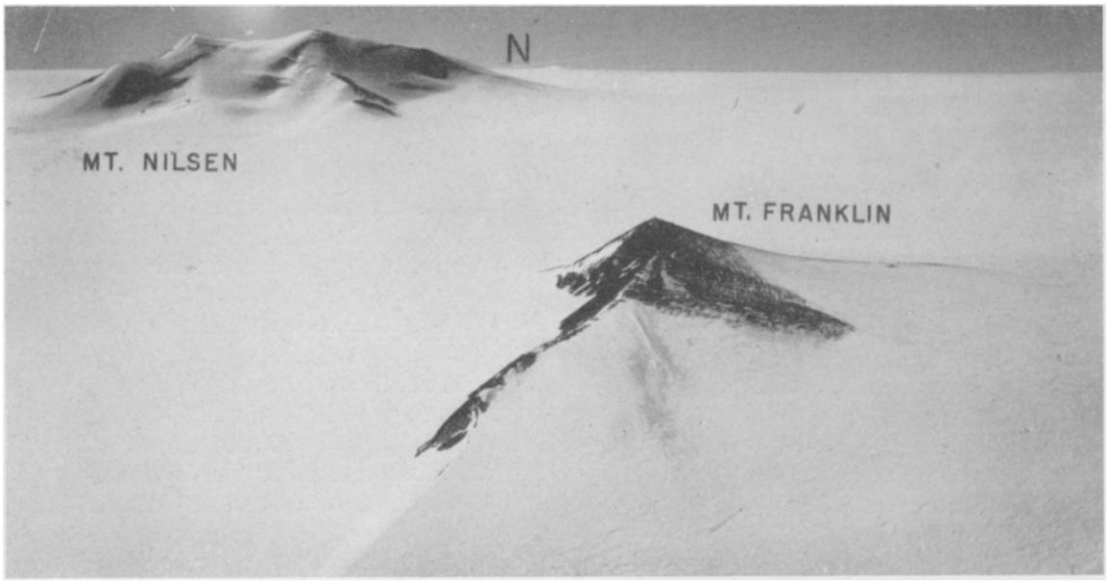
Although the names of the men who actually participated in this exploration will be occasionally mentioned, it should be always borne in mind that the program could not have been successfully accomplished except through the combined efforts of *all* the members of West Base. Members of the radio department and the commissary department, meteorological observers, the scientific staff, the airplane ground crew, the tractor personnel, the machinists, and the carpenter, each contributed essential aid to the program without which neither the individual exploratory units nor the program as a whole could have succeeded.

Gratitude is also expressed to the co-operating Government agencies and the private institutions which made available the equipment necessary for the achievement of this exploration. And a word, too, must be said for the 70 stout-hearted sledge dogs who gave much of their life energy, and in some instances their lives, as their contribution to the successful accomplishment of our work.

EXPLORATION BY GROUND PARTIES

With the exception of the Rockefeller Mountains Geological Party, all of the sledging parties departed from West Base within a day or so of October 15, 1940, proceeding along the eastern trail to 105-Mile Depot, which had been established by a tractor party in September. Here all members of the trail units, together with the army tank and tractor which supported them, assisted in transporting the Seismic Station equipment to Mount Franklin, located in the Rockefeller Mountains about 11 miles from the depot.

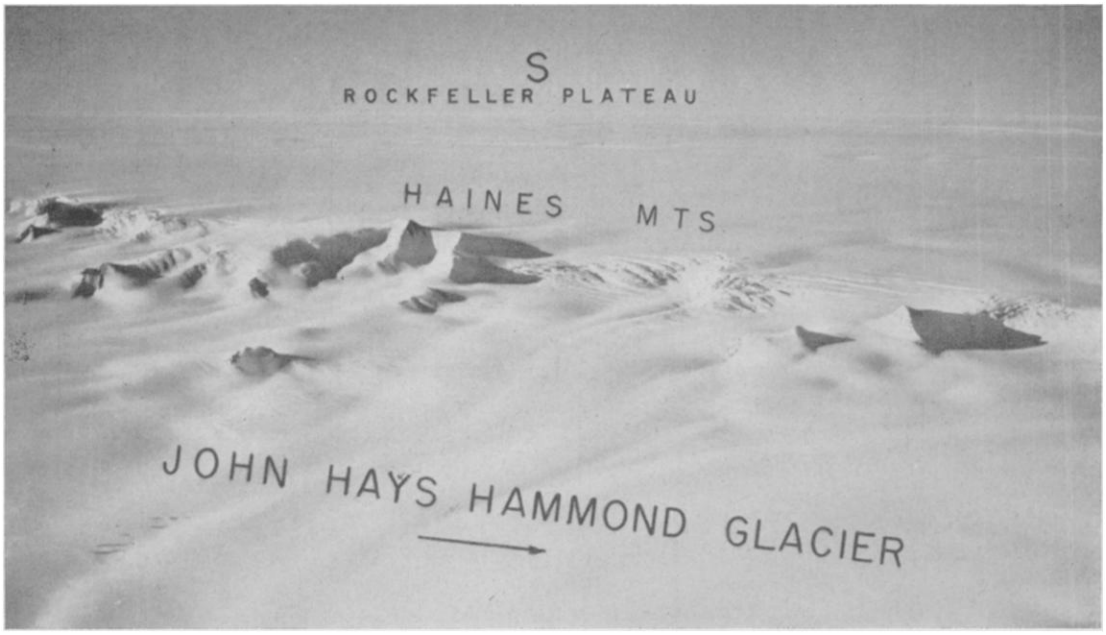
The trail parties, accompanied by the small International tractor, then proceeded eastward to Mount Grace McKinley. At this point the three sledging parties continued eastward, and the tractor returned to West Base for a load of aviation gasoline, which it brought back to Mount Grace McKinley. On termination of the latter trip, the tractor with its crew members, Felix Ferranto and Clyde Griffith, remained for several weeks at the Grace McKinley Cache, serving as a meteorologi-



Official U. S. Antarctic Service photo, by the author.

FIG. 1. (B-34)* Mount Franklin and Mount Nilsen in the Rockefeller Mountains, King Edward VII Peninsula. The Seismic Station, established on the former in November 1940, may be seen near the end of the right-hand spur of the mountain.

* Symbols in parentheses indicate photographic circles on map 1.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 2. (AA-133) The southwestern end of the Haines Mountains. Characteristic ice flow patterns (indicated by small glaciers flowing out between peaks) join the main stream of John Hays Hammond Glacier. Plane altitude 7,000 feet.

Official U. S. Antarctic Service photo, by the author.

FIG. 3. (H-99) The blocklike Raymond Fosdick Mountains seen from the end of Ruppert Cape, looking southeast. Crevasses in the foreground indicate shore line of the cape and the flow of piedmont ice into Paul Block Bay. Mount Marujupu is a residual ridge between two small glaciers. Main peaks of the Southern Edsel Ford Ranges are in the distant background. Plane altitude 7,000 feet.

cal observatory outpost and otherwise assisting the planes during eastern flight operations.

THE ROCKEFELLER MOUNTAINS SEISMIC STATION

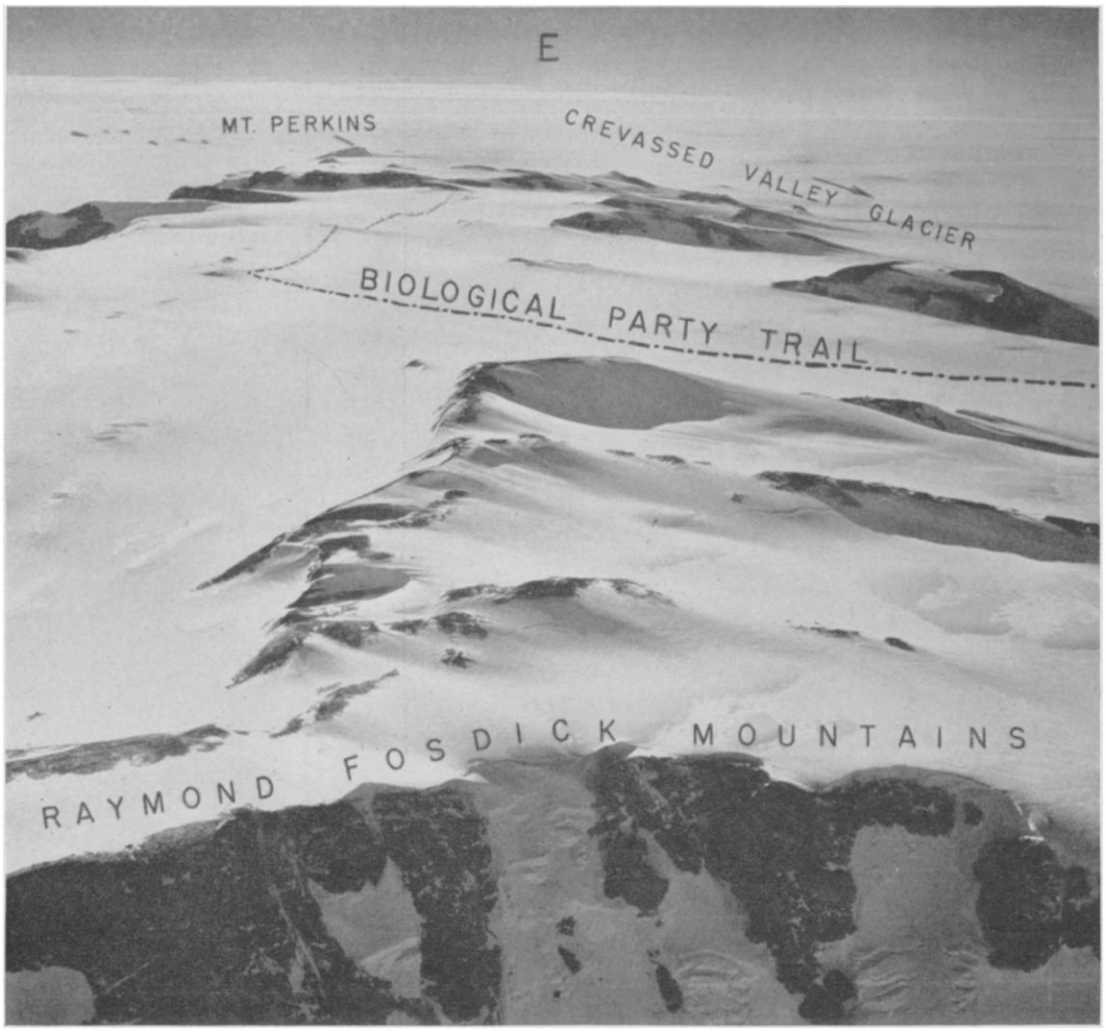
The Seismic Station Camp was established in the central Rockefeller Mountains on a small, igneous nunatak, later named Mount Franklin (fig. 1). Roy G. Fitzsimmons, physicist, was leader in charge of the camp, assisted by Isaac Schlossbach and Raymond Butler. A seismograph was set up on November 17 and remained in continuous operation for 41 days.

During the sojourn of the Seismic Station party on Mount Franklin, the members visited all the peaks within convenient skiing range. Plane-table intersections of all peaks of the Rockefeller Mountains were made, and Butler established ground-camera stations at several points. Fitzsimmons, aside from his seismic observations, made a valuable collection of gulls, Snow Petrels, and Antarctic Petrels and gathered many eggs.

The station was evacuated by returning trail parties on December 27, the members joining with the sledging units at 105-Mile Depot for the journey back to West Base.

THE EDSEL FORD MOUNTAINS BIOLOGICAL PARTY

The Biological Party, consisting of Jack E. Perkins, leader and biologist, Harrison H. Rich-



Official U. S. Antarctic Service photo, by Shirley.

FIG. 4. (A-214) Looking eastward along the crest of the Raymond Fosdick Mountains from a point about 4,000 feet above Mount Marujupu. Mount Perkins is volcanic, as are many neighboring small peaks.

ardson,[2] meteorological observer, Louis P. Colombo, observer, and E. E. Lockhart, radio operator, continued in company with the Edsel Ford Mountains Geological Survey Party until they reached the northwestern end of the Haines Mountains (fig. 2), about 30 miles northeast of Mount Grace McKinley.

After descending into John Hays Hammond Inlet, the party headed north for the Low Hills lying due west of Mount Saunders. From there it crossed the mouth of Crevassed Valley Glacier, visiting the southwestern corner of Mount Iphigene and neighboring peaks (fig. 3). The next stop was at Mount Marujupu, which provided the richest locality for biological reconnaissance. Here, on the dioritic rocks, they found abundant plant life and a rookery of Snow Petrels.

Skirting the southwestern corner of the Raymond Fosdick block, the party ascended the isolated plateau on its crest (figs. 4, 5). From this high elevation, surrounded by steep rock exposures on all sides, they traveled for nearly 15 miles, visiting a region which had been at one time seriously disrupted by volcanism. This fact had been first disclosed by the 1934 Marie Byrd Land Sledging Party, which touched on the southern side of the Fosdick block. From this point the party started its return journey to West Base, arriving on Christmas Day. It brought with it a considerable quantity of biological and geological specimens, photographs, a well-written journal describing the country through which it had traveled, and a thorough record of meteorological conditions encountered.

[2] Richardson joined the Biological Party at 105-Mile Depot, transferring from the Pacific Coast Survey Party.

THE EDSEL FORD MOUNTAINS GEOLOGICAL SURVEY PARTY

After the Geological Party separated from the Biological Party, it crossed directly to the Mount Rea Cache (figs. 6, 7), which had been laid by airplane early in November.

Since the Biological Party was operating north of the region explored by the Marie Byrd Land Sledging Party of 1934, Byrd Antarctic Expedition II (map 1), the Geological Party had as its objective the detailed geological reconnaissance of the mass of nunataks lying south and east of that area.

Lawrence Warner, leader of the party, and Charles Passel, radio operator, were the geologists. The former gave his particular attention to igneous rock problems, while the latter concentrated upon the problems of the sediments in the region. Details of their findings are explained in their sepa-

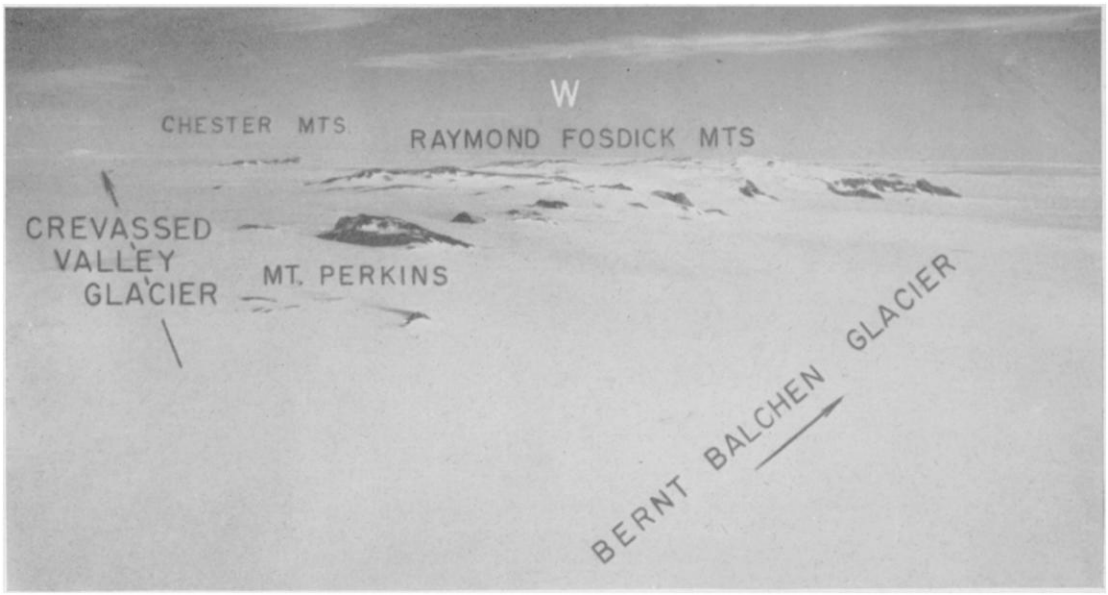


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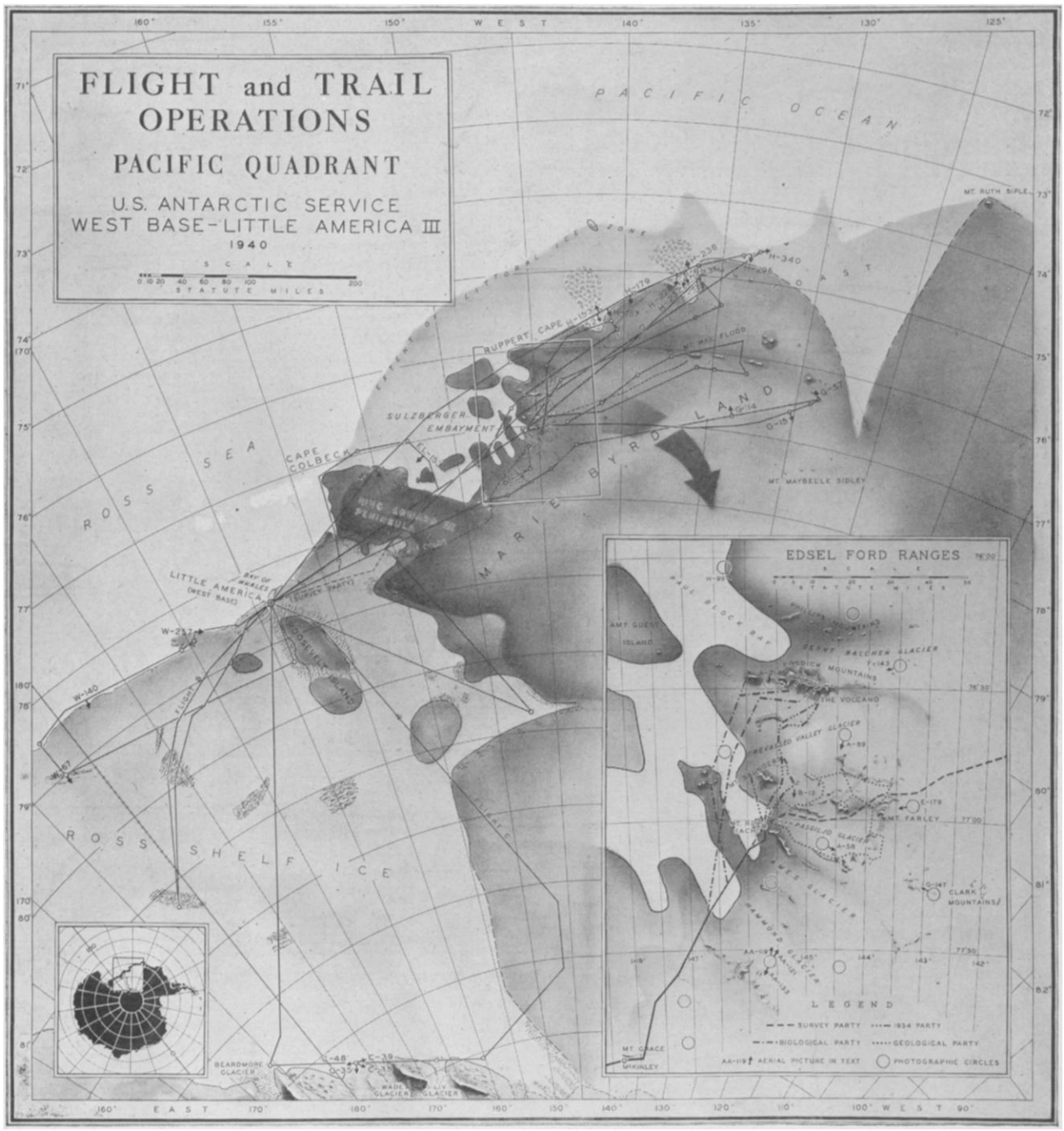
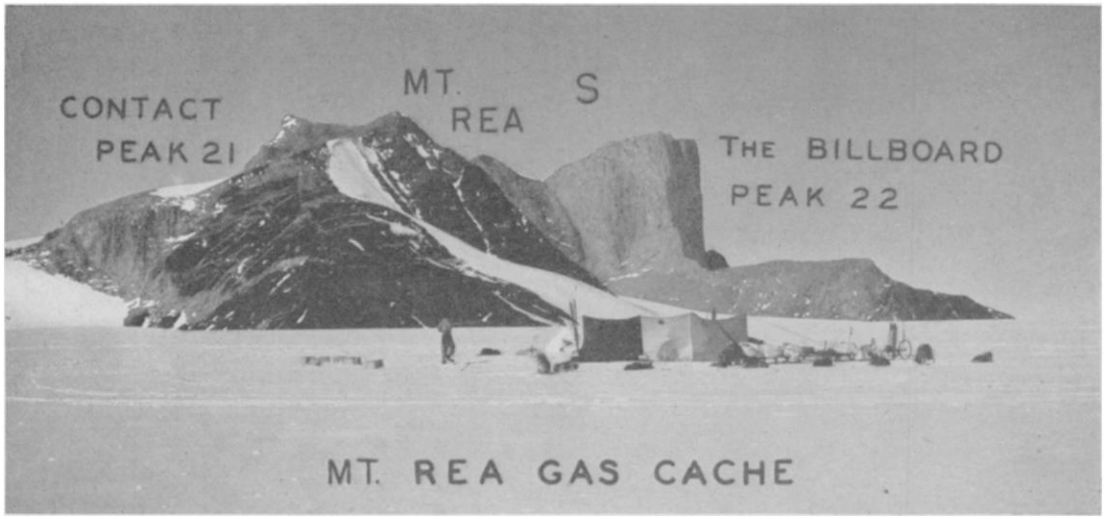
FIG. 5. (F-143) The Raymond Fosdick Mountains, looking westward from the south side of Bernt Balchen Glacier. Mount Perkins and neighboring small peaks are the remnants of extinct volcanic flows. Plane altitude 7,000 feet.

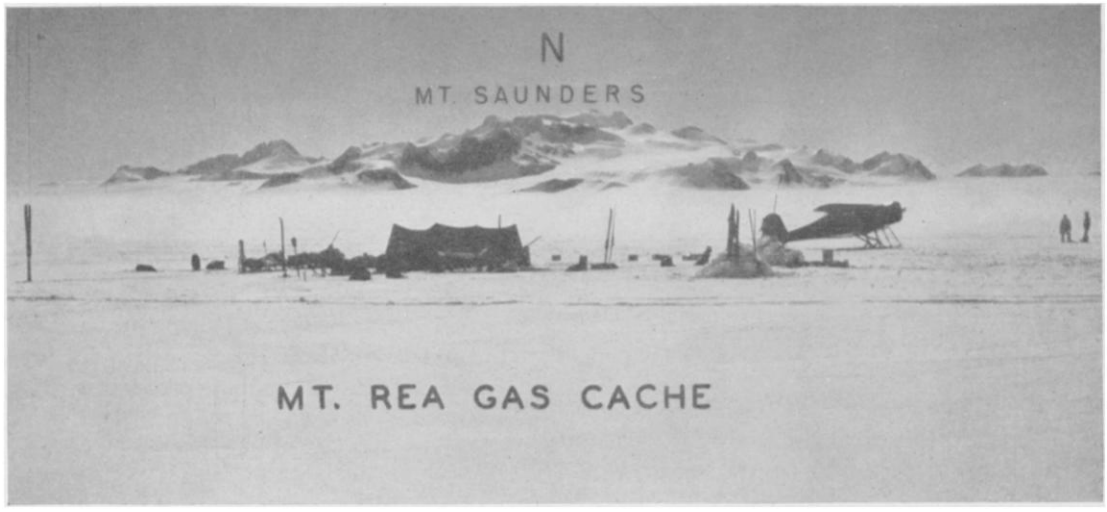

FLIGHT and TRAIL OPERATIONS
PACIFIC QUADRANT
U.S. ANTARCTIC SERVICE
WEST BASE-LITTLE AMERICA III
1940
SCALE
STATUTE MILES
PACIFIC OCEAN
ROSS SEA
ROSS SHELF ICE
MARIE BYRD LAND
RUPPERT COAST
SULZBERGER EMBAYMENT
CAPE COLBECK
KING EDWARD VII PENINSULA
LITTLE AMERICA (WEST BASE)
BAY OF WHALES
ROOSEVELT ISLAND
BEARDMORE GLACIER
MT. RUTH SIPLE
MT. MAYBELLE SIDLEY
EDSEL FORD RANGES
AMT. GUEST ISLAND
PAUL BLOCK BAY
BENNY BALCHEN GLACIER
THE VOLCANO
DEVASTED VALLEY GLACIER
MT. FARLEY
PASSUIO GLACIER
CLARK MOUNTAINS
MT. GRACE MCKINLEY
LEGEND
SURVEY PARTY
1934 PARTY
BIOLOGICAL PARTY
GEOLOGICAL PARTY
AERIAL PICTURE IN TEXT
PHOTOGRAPHIC CIRCLES

MAP 1.



Official U. S. Antarctic Service photo by the author.

FIG. 6. (B) Mount Rea Gas Cache, looking south. Note the finger-like contacts on Peak 21.



Official U. S. Antarctic Service photo, by the author.

FIG. 7. (BX) Looking north from Mount Rea Gas Cache to Mount Saunders. Note alpine type of glaciation. Mount Saunders is about 3,300 feet above sea-level. The gas cache is at an elevation of only 300 feet. The Beechcraft plane has landed at the cache for refuelling. Camp is that of Geological Survey Party.

rate reports; therefore no attempt at elaboration of these subjects will be made in this paper. Briefly, the region is a highly eroded and glaciated area exhibiting coarse-grained remnants of a batholitic intrusion of leucogranite, granodiorite, and associated rock types. Occasional remnants and contacts of a highly metamorphosed sedimentary covering, now almost entirely removed, appear black in contrast to the red, gray, and brown igneous rocks. Warner and Passel were assisted by H. P. Gilmour and Loran Wells, the former serving as recorder for the party and collector of biological specimens, and the latter serving as photographer and observer.

Before visiting the Claude Swanson Mountains (fig. 8), the largest of the sedimentary groups, the party laid out a baseline and shot intersections on the major peaks to test the accuracy of an aerial map made of the region during the preceeding Winter Night at West Base.

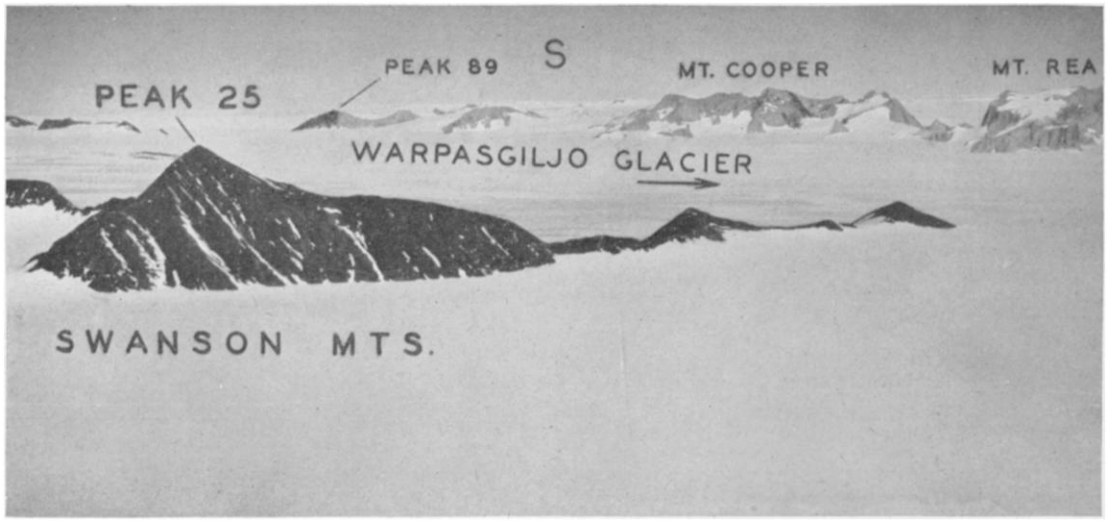


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FIG. 8. (B-12) Part of the Southern Edsel Ford Ranges. Peak 25 is the northern extremity of the Swanson Mountains. The metamorphic sediments of these mountains are black. Note contact on Peak 89 of the Mount Cooper group (a pink leuco-granite range). Many dry (as well as active) glacial cirques exist on the eastern side of Mount Cooper and Mount Rea.

From the Claude Swanson Mountains, the party visited most of the exposures lying south of Crevassed Valley Glacier (fig. 9) and surrounding the head of the Warpasgiljo Glacier (figs. 10, 11). In all, the party contacted 57 of the mapped peaks, made groundwork for a detailed geological map of the area, and brought back large quantities of geological and biological specimens.

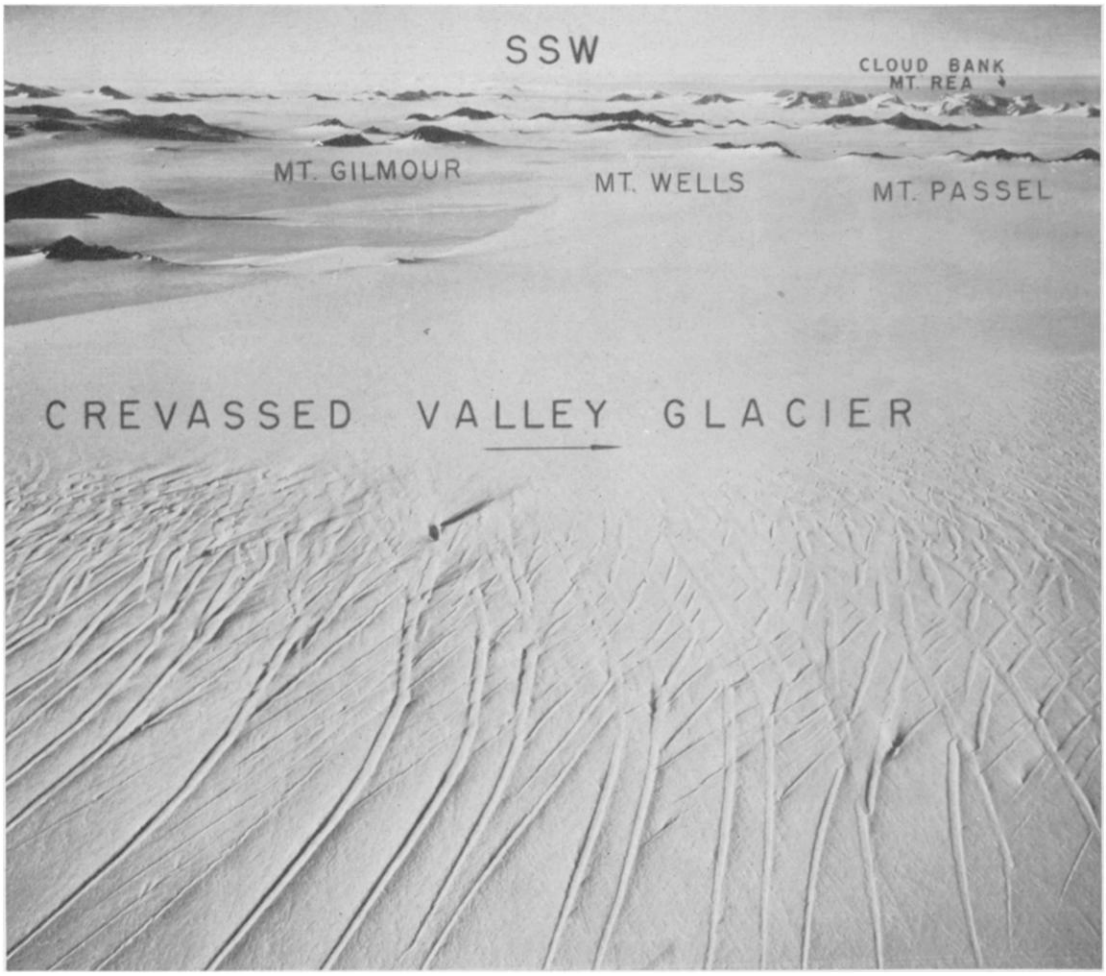
On December 14, its field work completed, the party returned to Mount Rea Cache, being joined on the following day by the Pacific Coast Survey Party. The two parties proceeded in company to Mount Grace McKinley, where they convoyed the tractor back to 105-Mile Depot across an area becoming increasingly dangerous because of the opening of seasonal crevasses. Traveling from 105-Mile Depot as part of a caravan consisting of the Pacific Coast Survey Party, the Rockefeller Mountains Geological Party, and members of the Rockefeller Mountains Seismic Station, the Edsel Ford Mountains Geological Survey Party arrived at West Base on January 7, 1941.

THE PACIFIC COAST SURVEY PARTY

The Pacific Coast Survey Party, with Leonard Berlin, leader, assisted by Dick Moulton and Jack Bursey, dog-drivers, and the strongest dog teams of West Base, streamlined their unit for speed. It proceeded from 105-Mile Depot to Mount Grace McKinley in company with the Biological and Geological Parties. Leaving Mount Grace McKinley, the party was able to establish a lead, arriving at Mount Rea Cache a day ahead of the Edsel Ford Mountains Geological Survey Party. Keeping a course almost due east, passing along the northern side of the Warpasgiljo Glacier, and following its northeastern head between Mounts 325 and 310 (fig. 10), the party soon had climbed above and beyond the Edsel Ford nunataks, the highest of which has an approximate elevation of 4,000 feet.

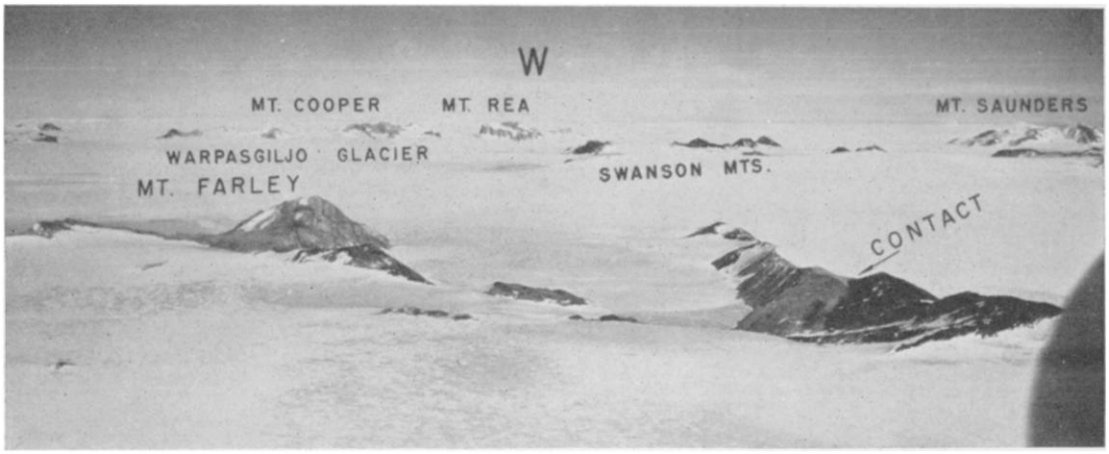
The party continued climbing on its northeast course toward Mount Hal Flood. Unfortunately, the barometer carried by the leader ceased to give accurate readings above 5,000 feet, but it is certain from airplane estimates that they ascended to an elevation close to 6,000 feet.

On December 1 the party reached its last outward camp, about 14 miles southwest of Mount Hal Flood. Here the men chained a 2,400-foot baseline, but were forced to wait several days for good weather in order to establish the exact location of the mountain. The location of its highest peak was determined as latitude 76°03′51.6″ S., longitude 135°49′54.6″ W. It rises 5,427 feet above the camp, which itself was estimated (barometrically) to be at least 5,000 feet above sea-level (figs. 12, 13, 14, 15).



Official U. S. Antarctic Service photo, by Shirley.

FIG. 9. (A-89) Looking south-southwest toward the central nunataks of the Southern Edsel Ford Ranges. Crevasses in foreground are evidence of the activity of Crevassed Valley Glacier. Plane altitude 7,000 feet.



Official U. S. Antarctic Service photo, by the author.

FIG. 10. (E-179) Looking westward across the Southern Edsel Ford Ranges from the Rockefeller Plateau of Marie Byrd Land directly east of Mount Farley (foreground). Note contact between sedimentary and igneous rock in right foreground. Plane altitude 7,000 feet.

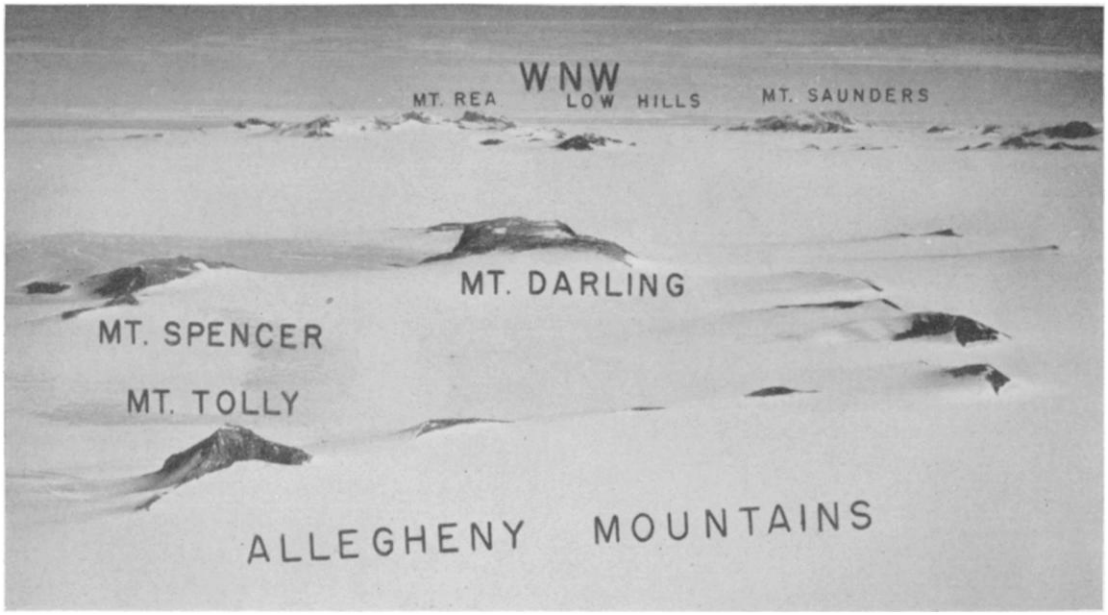


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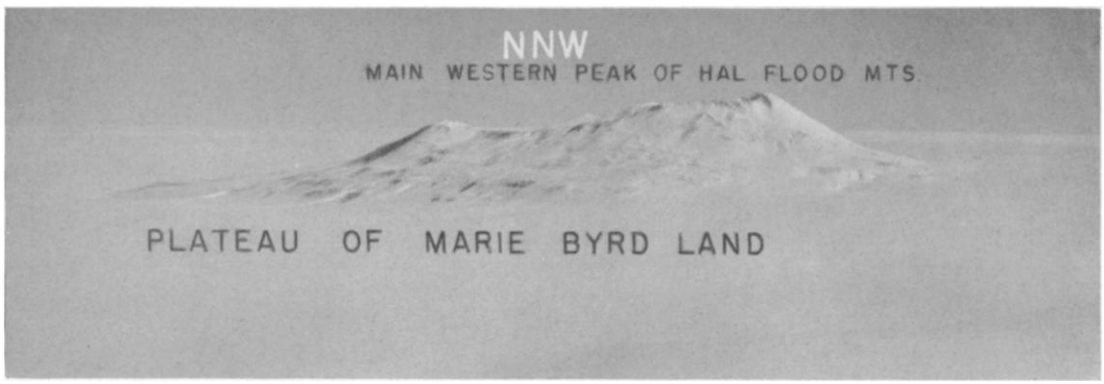
FIG. 11. (G-147) Looking west-northwestward across the Allegheny Mountains in the Southern Edsel Ford Ranges. The Allegheny Mountains are as high as Mount Saunders and Mount Rea but are nearly inundated by the snow of the Rockefeller Plateau. Plane altitude 7,000 feet. Tolly in the photograph should be Tolley.



Official U. S. Antarctic Service photo, by the author.

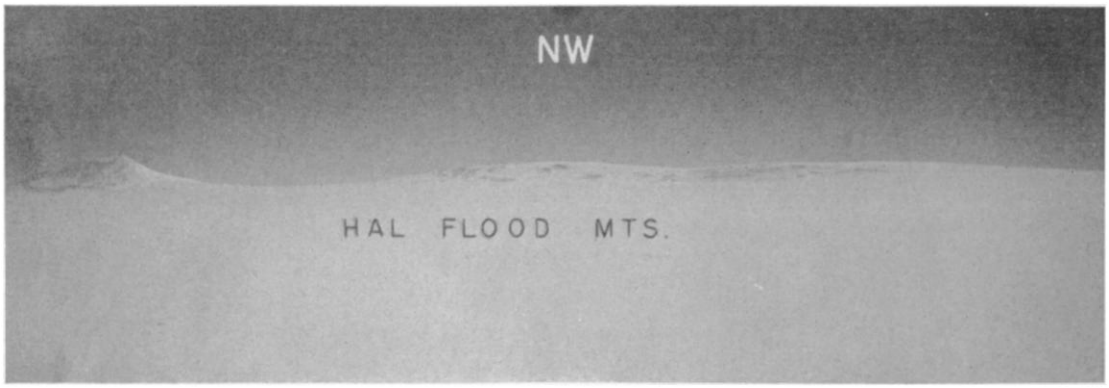
FIG. 12. (E-3) The main western peak of the Hal Flood Mountains from about 14 statute miles to southeast. The highest peak, as determined by the Pacific Coast Survey Party, is 5,427 feet above the plateau surface. Behind the mountain the plateau descends sharply to the coast 60 miles distant. Plane altitude 8,500 feet.

Mount Hal Flood rises, therefore, to a total elevation in excess of 10,000 feet, and it is an important landmark in the background of pictures taken on the four major eastern flights made in this region.

The peak showed evidences of igneous origin and former volcanism. Specimens of the rock were collected.

After erecting a cairn and setting a monument marker in the rock, as had also been done at Mount Grace McKinley, the party headed back over its outward trail to the cache at Mount Rea, where, as previously mentioned, it joined the Geological Party for the remainder of the return journey to West Base via 105-Mile Depot.

The sledge meter indicated that the party had traveled approximately 1,200 statute miles in making the round trip.

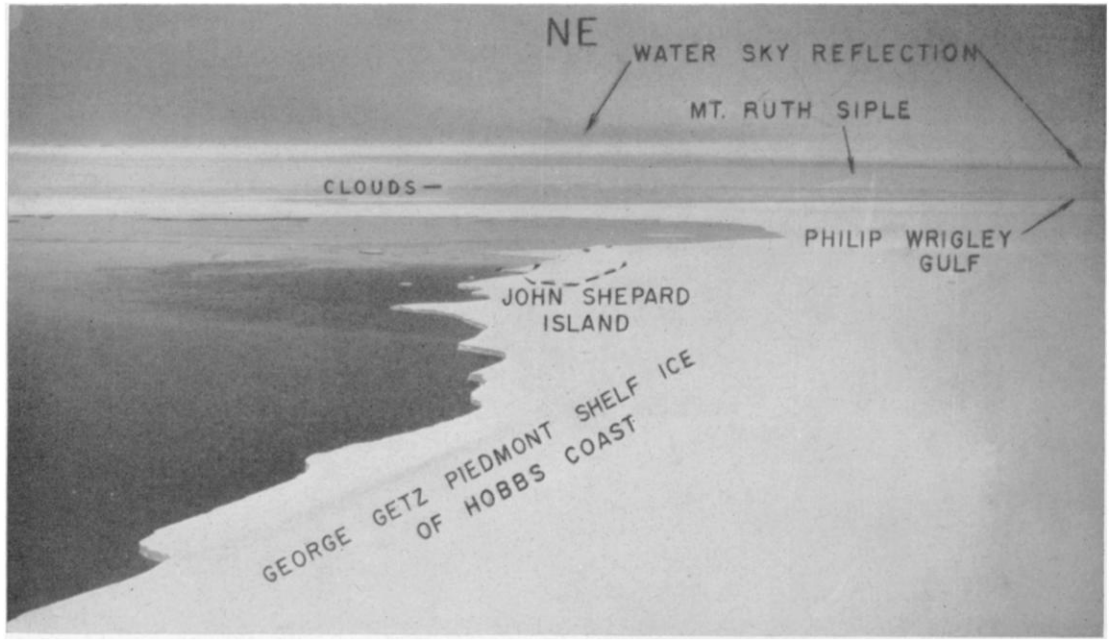


Official U. S. Antarctic Service photo, by the author.

FIG. 13. (G-114) Hal Flood Mountains as seen from a distance of about 43 statute miles southeast of the main peak at the left. In the foreground is the inland ice plateau rising to an elevation of 6,000 or 7,000 feet above sea-level. Plane altitude 8,500 feet.

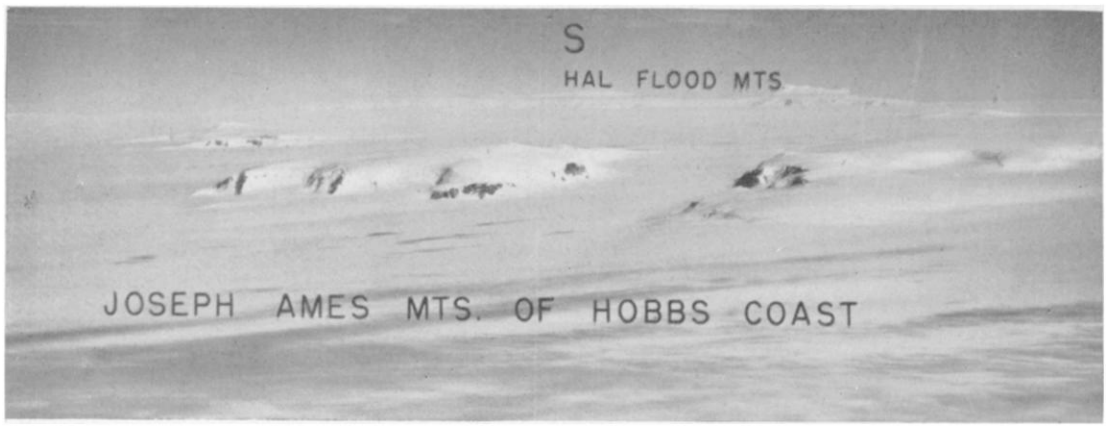
Official U. S. Antarctic Service photo, by Shirley.

FIG. 14. (H-231) A midway view of Cordell Hull Glacier, approximately 20 miles wide, lying between rocky head walls along the Hobbs Coast of Marie Byrd Land. An area of at least 3,000 square miles of ice is drained through this glacier. Plane altitude 7,000 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 15. (H-340) Looking northeast from the homeward-turning point of Flight H along the Hobbs Coast near latitude 74° 35′ S., longitude 133° W. The height of Mount Ruth Siple is estimated at 15,000 feet. Its shape and location suggest volcanic origin. An ice tongue extends out into the sea, and a gulf or embayment extends inland to beyond the right hand limits of the picture. Plane altitude 6,000 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 16. (H-295) Low coastal mountains of Hobbs Coast rising out of the piedmont shelf ice previously noted in figure 15. The highest peak of the Hal Flood Mountains rises above 10,000 feet. Plane altitude 7,000 feet.

THE ROCKEFELLER MOUNTAINS GEOLOGICAL PARTY

The Rockefeller Mountains Geological Party, with Dr. F. Alton Wade, leader, and Dr. Russell G. Frazier, observer, left West Base on November 15, 1940. After measuring a 14-mile baseline between West Base and the Winter Night Auroral Camp, the party continued to 105-Mile Cache. Here it restocked provisions and proceeded into the southern Rockefeller Mountains, making a detailed study of each rock exposure. This gave Dr. Wade an opportunity to continue the study he had begun in 1934, proving the region to be a counterpart of the Edsel Ford Mountains. In the meantime Dr. Frazier collected plant specimens, extending the range of certain mosses and lichens

that had been collected on the previous Byrd expeditions.

This party completed its work in time to join the returning caravan of eastern parties, all of whom reached Little America on January 7, 1941.

WEST BASE FLIGHT OPERATIONS

Aerial exploration and survey from West Base were conducted by means of two planes: one, a twin-motor Condor whose flight log included five years of service with the U. S. Marine Corps, and the other, a new, single-motor Beechcraft. The Beechcraft, originally scheduled to operate in conjunction with the Armour Institute of Technology's "Snow Cruiser," became available for West Base use when the cruiser failed to operate satisfactorily.

Flight personnel was provided by the U. S. Navy and the U. S. Marine Corps. Assigned to the Condor were James C. McCoy, chief aviation machinist's mate (NAP), U. S. Navy, as pilot; Walter R. Giles, technical sergeant (NAP), U. S. Marine Corps, co-pilot and radio operator; and Orville Gray, aviation machinist's mate, first class, plane captain. Theodore A. Petras, master technical sergeant (NAP), U. S. Marine Corps, was assigned as pilot of the Beechcraft, and Charles C. Shirley, chief photographer, U. S. Navy, was assigned to West Base as official photographer. Dr. Paul A. Siple, base leader, served as navigator on all major flights and was responsible for the geographical program and report of observations; he was occasionally assisted by Dr. F. Alton Wade, senior scientist, and others.

Whenever possible during photographic surveys, the plane was kept at a uniform elevation of 7,000 feet, and every effort was made to maintain a straight course. Ground speed generally averaged about 90 miles per hour.

Photographs between circles were generally taken in pairs, one turning forward and one turning aft in rapid succession. The sides of the plane were alternated to give as wide a field of vision as possible. Photographic plane-table circles, of 15 to 20 pictures, were taken at strategic points, allowing considerable overlap in the foreground.

THE EDSEL FORD MOUNTAINS REGION

Flights from West Base

Flight A, February 9, 1940.—On this date, the first major flight east into Marie Byrd Land was made. The express purpose of this flight was an aerial survey of the Edsel Ford Mountains in order that a map might be constructed of the area during the winter night to serve as a base for a detailed geological survey the following summer.

The flight line passed over the Rockefeller Mountains. Low clouds and fog covered most of the Sulzberger Embayment, but 100 miles beyond the peaks of the central Edsel Ford Mountains appeared in bright sunshine. However, photography was not possible until after passing to the east of Mount Donald Woodward.

The first photographic circle was made in the vicinity of latitude 77°06′ S. and longitude 144°45′ W. This circle is over the central portion of the glacier later named Warpasgiljo (figs. 10, 11, 17).

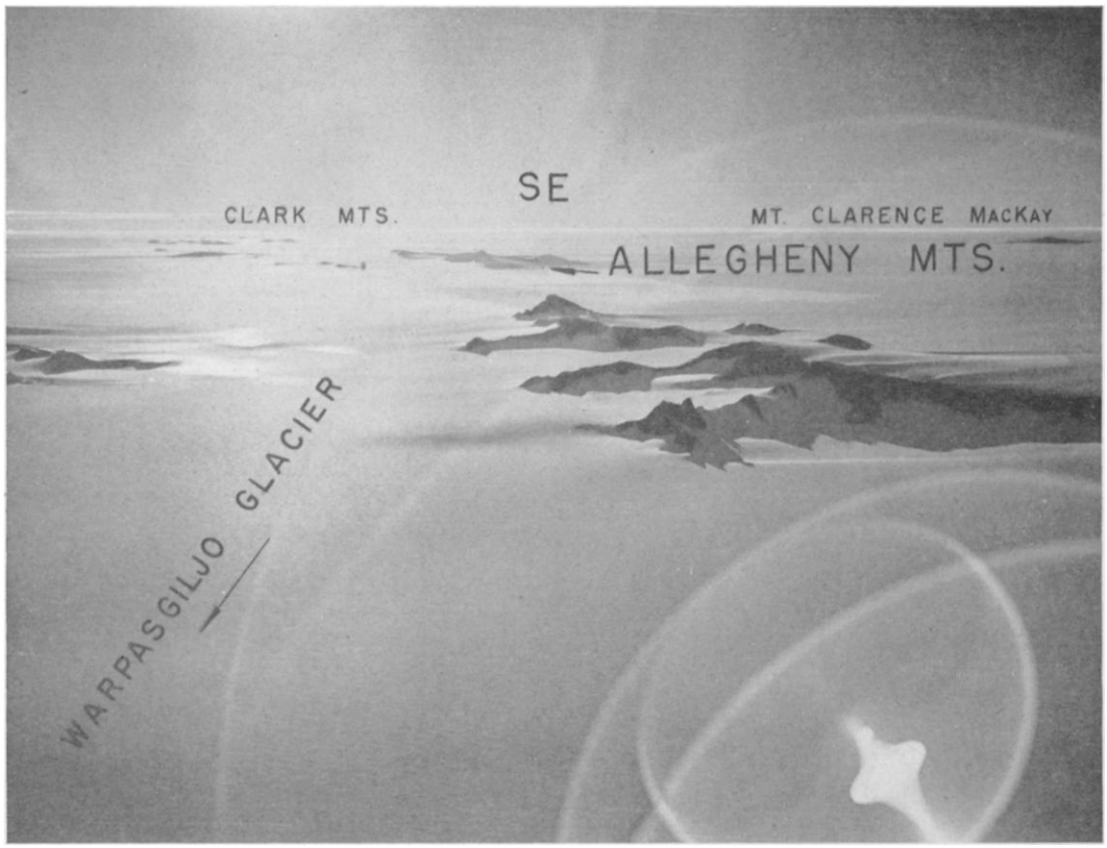
The glacier is flanked along both sides for a distance of about 25 miles by nunataks of red granite with occasional patches of black metamorphic sedimentary rock.

Leg 2 of the flight turned NNE., and a strip of photographs was taken looking eastward. After a flight of 25 miles, circle 2 was taken over the center of Crevassed Valley Glacier (fig. 9).

The flight continued northward across the Raymond Fosdick Mountains. When the head and northern side of Bernt Balchen Glacier above the Phillips Mountains were reached, circle 3 was made (figs. 3, 5). Here the flight turned northeastward to the coast and continued along it near the head of the glacier later named in honor of Admiral Land. After a large peak, later christened Mount Alma McCoy (fig. 18) was circled, heavy clouds moved in fast from the north, forcing the plane to begin its homeward journey. Just before the plane turned, the massive Mount Hal Flood (fig. 12) was seen rising above the clouds in the distance. Its identity, however, was not made certain until the summer flights.

On the return flight an important strip of photographs was taken northward along Bernt Balchen Valley. The seventh photographic circle was taken over Mount Marujupu (fig. 4), and the eighth and last circle of photographs was taken near latitude 76°45′ S., longitude 146°20′ W.

Throughout the winter night, Leonard Berlin, Raymond Butler, and the base leader worked with these aerial photographs, establishing the location of the major peaks of the region and completing a hand-drawn map of the central mountain exposures lying south of the Raymond Fosdick Mountains to latitude 77°25′ S. and between longitudes 143° and 146° W. Details of areas lying outside of this zone were still lacking on account of time



Official U. S. Antarctic Service photo, by Shirley.

FIG. 17. (A-58) Southeastern extension of the Southern Edsel Ford Ranges. The pattern of circles is due to optical properties of the camera lens when faced directly into the sun. Note glare across hard glacial ice.

or cloud conditions and because some of the exposures had been photographed at too great a distance. It was therefore determined that on all later flights to or near this region additional photographic circles would be made at advantageous points to extend this control. It was also desired that the trail parties check the preliminary map for accuracy by laying a baseline within the area. As previously mentioned, this was carried out by the Geological Party.

Flight AA, November 13, 1940.—Flight AA was made into the same region as Flight A. Excellent visibility permitted the taking of a strip of photographs from the Rockefeller Mountains of Edward Peninsula to the Haines Mountains, looking northward into Sulzberger Embayment.

A circle was taken just south of the main exposure of Garland Hershey Ridge. The main line of the flight continued and passed over the center of the Haines Mountains. Another circle was made in latitude 77°35′ S. near longitude 145°40′ W., in the center of the John Hays Hammond Glacier (figs. 2, 19, 20), and a third and last circle was made above and just to the east of Mount Donald Woodward.

The purpose of this flight was to lay a gasoline and man-food cache just north of Mount Rea (figs. 6, 7). The objective accomplished, the plane turned back toward West Base from that point, flying through the center of the Sulzberger Embayment while pictures were taken to the right and the left of the course.

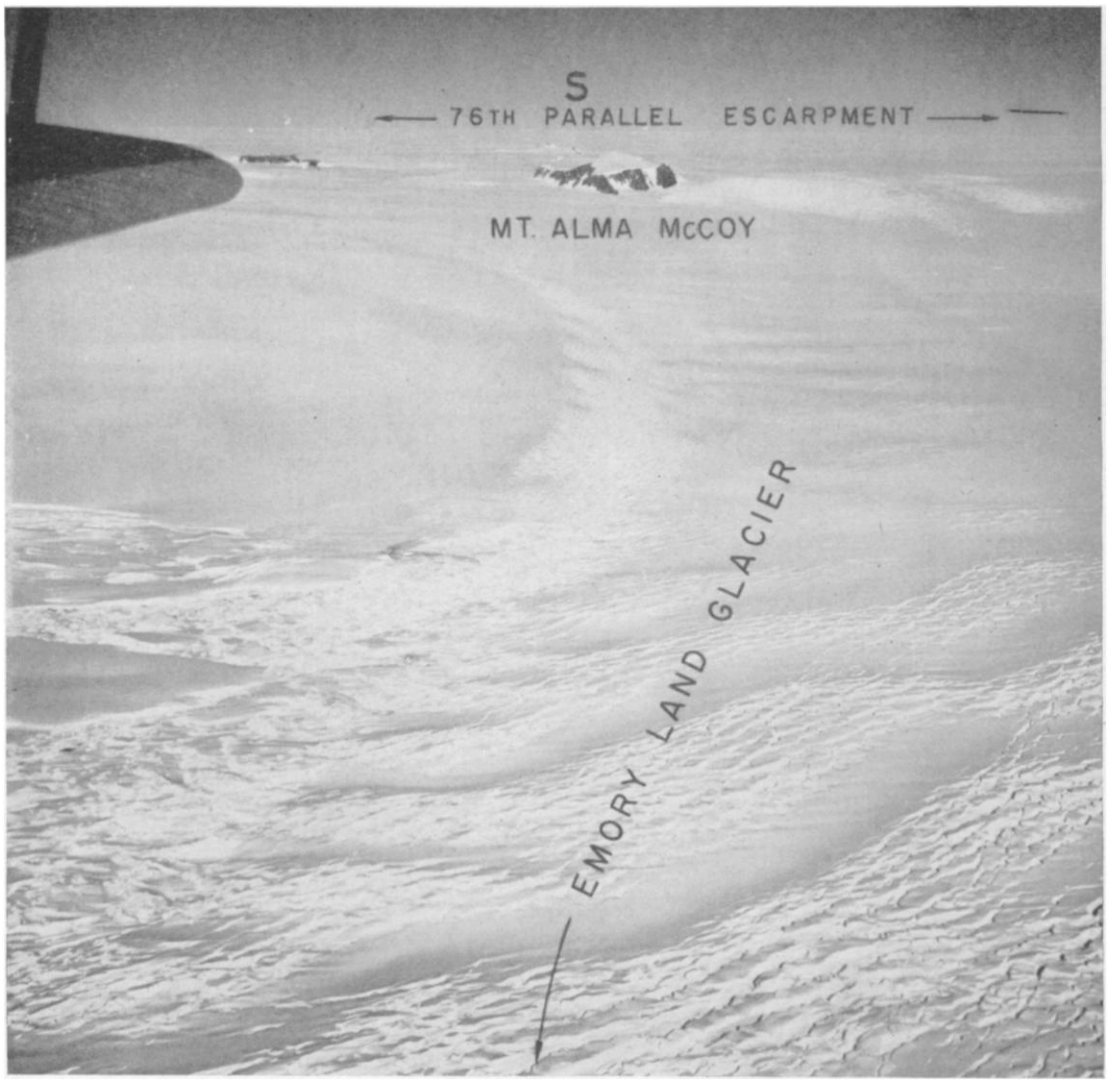
Additional Photographic Circles in Edsel Ford Mountains Region.—In the four eastern flights projected across the Edsel Ford Mountains to the unknown area lying beyond, a total of 9 new photographic circles of importance were made.

Flight E.—During the course of this flight a circle was made at latitude 77° S. near longitude 143°30′ W., just east of Mount Farley (fig. 10),

and a valuable strip of photographs was taken of the north side of the mountains lying south of Warpasgiljo Glacier.

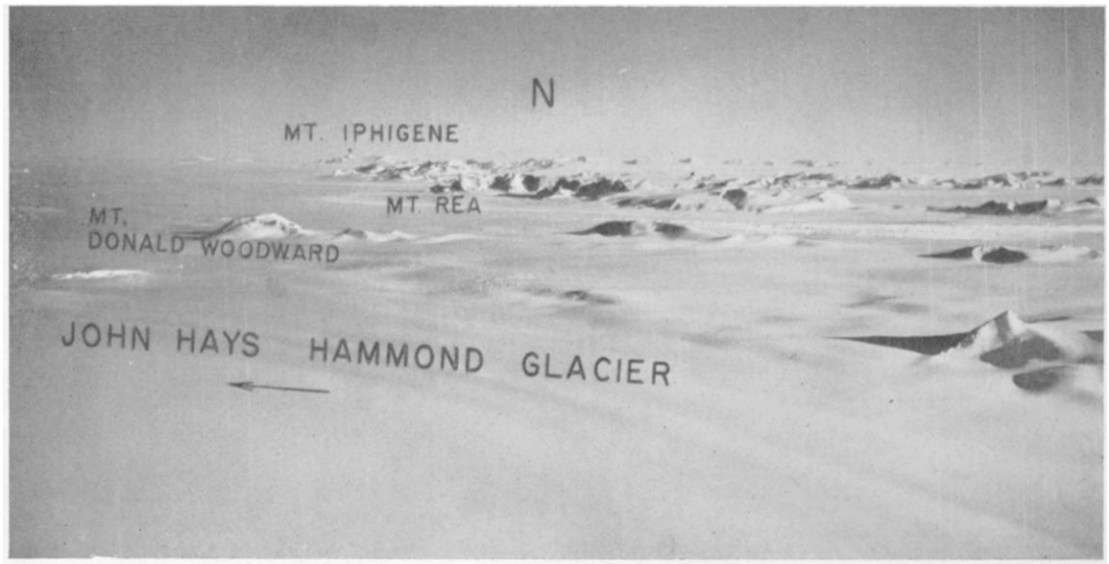
Flight F.—A circle was made near the southern head of Bernt Balchen Glacier (fig. 5) near latitude 76°25′ S., longitude 143°30′ W., and a semicircle was taken between Mount Passel and the Claude Swanson Mountains (fig. 8) near latitude 76°50′ S. and longitude 145° W.

Flight G.—Pictures were taken close aboard the Clark and Allegheny Mountains (fig. 11), lying in latitude 77°15′ S. Another circle was taken on this leg near longitude 142°50′ W., and detail pictures were taken of Mount Clarence McKay and neighboring peaks of the southern Haines Mountains (fig. 2). Two more important circles were added, the first near latitude 77°35′ S., longitude 144°25′ W.; and the second near latitude 77°50′ S., longitude 147°10′ W. The last photographs of this region were taken during Flight H, a circle being made at the end of Ruppert Cape (fig. 3) near latitude 76°05′ S., longitude 146°20′ W. Circles farther to the east tied the region into the Hobbs Coast and Mount Hal Flood, while pictures

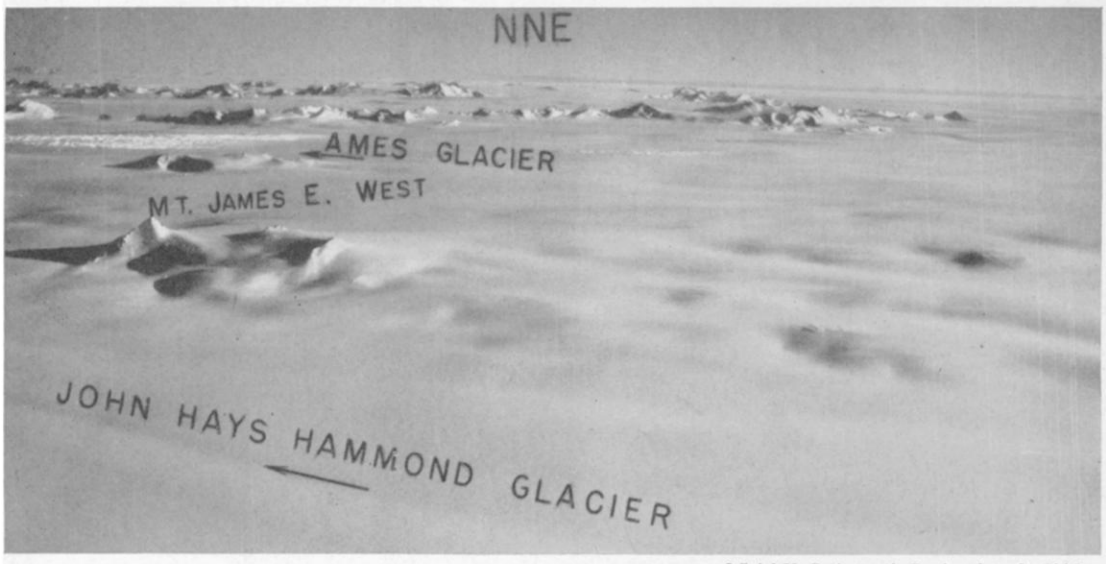


Official U. S. Antarctic Service photo, by Shirley.

FIG. 18. (H-157) The eastern gateway of Emory Land Glacier along Hobbs Coast of Marie Byrd Land. The release of tension is seen as the glacier pushes seaward into a broad semipermanent field of littoral ice. Mount Alma McCoy rises to 3,500 feet. On the sky line is the 5,000-foot escarpment extending along the 76th parallel from Ruppert Cape to Mount Hal Flood. Plane altitude 7,000 feet.



Official U. S. Antarctic Service photo, by Shirley.



Official U. S. Antarctic Service photo, by Shirley.

FIGS. 19 and 20. (AA-122, AA-121) Looking north and north-northeast over the Southern Edsel Ford Ranges of Marie Byrd Land from above John Hays Hammond Glacier. The active Ames Glacier opens out northwestward between Mount Donald Woodward and Mount Rea.

to the west tied the region into the Sulzberger Embayment and the Edward Peninsula.

It is probable that no uninhabited region of its size has been so thoroughly surveyed as that of the Edsel Ford Mountains. A total of about 700 usable photographs were taken. Some of these photographs have recently been used in the construction of a map of the region which is now complete, but there has been no attempt as yet to use the vast amount of data which are available for a large-scale study of the region. The map which has been completed is primarily to serve as a base for the detailed geological map.

Summary of the Edsel Ford Mountains Region

The Southern Edsel Ford Mountains region comprises an area of 21,000 geographical square miles (27,809 statute miles), and lies between

longitudes 140° W. and 150° W. and between latitudes 75°30′ S. and 78° S. Most of the northern and western borders of this area are occupied by shallow seas, islands, and semipermanent littoral ice. The only navigable water, however, is in the extreme northwestern section of the region, where the U. S. S. *Bear* entered for the first time in 1934 and again in 1940.

The southern and eastern boundaries of the region are intimately joined to the high inland plateau of the continent, characterized by undulating highland ice which lies conformably over mountain peaks rising 4,000 to 5,000 feet high. Shortly beyond the southern and eastern limits of the Edsel Ford Mountains region as outlined above, the landscape assumes the characteristics of unbroken inland ice, with an average altitude ranging between 5,000 and 7,000 feet.

In general aspect, the region exhibits nine or more large outlet glacier systems, draining ice from the inner highlands. Small subsidiary glaciers of the valley and cirque types feed the larger glaciers. There is a main mountain front running north and south (figs. 19, 20) and terminating in Ruppert Cape (fig. 3), which marks the east-west trend of the Pacific Ocean coastline.

The highest of the western frontal mountains are Mount Iphigene, Mount Saunders, Mount Rea, and Mount Cooper. Each of these rises well above 3,500 feet. Their glacial sculpture shows them to be remnants of existent erosion, and the great glacier streams are directed around their bases. Headward erosion of the glacial outlet valleys and relatively faster glacial movement seaward accentuate these mountain masses until they become the most outstanding features of the landscape. However, closer examination will show that the nunataks lying to the east are in many cases equally high, although comparatively drowned by the higher level of highland glacier ice. (Figs. 10, 11.)

As would be expected, the igneous rocks have shown in general much greater resistance to glacial erosion than the sedimentary rocks. The sediments apparently resist erosion best when the dip is steepest or when protected by blocks of granite from the full force of ice movement over them. Contacts between the intrusive rocks and the sediments are blocky and irregular. In many instances the igneous material has fingered into the sediments. Such contacts are exposed at each end of the Rea-Cooper Range, which is composed essentially of granite. High on the crest of Mount Cooper there are huge blocks of sediment which were stoped into the intrusive melt. These phenomena suggest that glaciation has done little more than remove the sedimentary cover, exposing the underlying granite. The residual granite has forced the glacial streams into new channels, and mountain type glaciation has begun to sculpture the bared portions of the higher mountains.

Climatically the region lies in the zone where mean temperature does not rise above freezing. However, in the vicinity of the mountains, local heating is sufficient to melt large quantities of snow, forming lakes in the low areas. Skuas and Snow Petrels frequent the northern mountains, and, wherever quantities of melt water are sufficient around the rocks, lichens and mosses are abundant. It is likely that when the new material brought from these mountains is identified or described, the total number of plant species in the region will exceed one hundred.

This region, which was practically unknown prior to 1929, is now considered one of the best-known regions of Antarctica, surpassed only by South Victoria Land and the Palmer Peninsula.

THE HOBBS COAST REGION

Exploration by Admiral Byrd

In January, 1940, Admiral Byrd, operating from the U. S. S. *Bear* in a Barkley-Grow seaplane, sighted a coast trending northeastward from Ruppert Cape. To this coast he gave the name Hobbs in honor of the geologist and Antarctic historian, William H. Hobbs. By January 25, 1940, the *Bear* had reached latitude 75°43′ S., longitude 143°52′ W., the deepest penetration ever made by a ship into this region. Several short reconnaissance flights were made in this region, but adverse weather and inadequate photographic equipment made it impossible to make a suitable survey.

One of Admiral Byrd's flights reached the proximity of longitude 135° W. and approached the coast. Mount Hal Flood could be seen in the distance, but bad visibility gave the impression that the coast was swinging sharply northward beyond this point.

Flights from West Base

During the month of December, 1940, four major flights were projected across the Edsel Ford Mountains into this unknown region lying to the east.

Gasoline caches had been laid at 105-Mile Depot, and at Mount Grace McKinley and Mount Rea. In the meantime, however, the Condor had broken a heavy spring in its tail landing-gear. In the lack of suitable replacements, a more or less temporary repair job had been effected and it was found by test that the plane could not carry an overload sufficient to make a flight of over 1,000 miles. The Beechcraft was then considered for service in lieu of the Condor, and it was found that, by utilizing the three caches for three or more flights, the small plane could reach approximately the same distance as could the Condor in one flight. A flight pattern was then laid out to cover as much territory as possible between the coast and Mount Sidley.

Flight E, December 9, 1940.—Bad visibility had prevented the projection of any major summer flights eastward prior to this date. After leaving West Base, the Beechcraft was re-gassed at 105-Mile Depot and topped off with a full load at Mount Rea Cache. From Mount Rea the course was set directly for Mount Hal Flood, from which the Survey Party had departed only a few days before.

The plane reached Mount Hal Flood two hours

Official U. S. Antarctic Service photo, by Shirley.

FIG. 21. (H-236) Debouched ice leaving the mouth of Cordell Hull Glacier. An extensive ice tongue runs northward just to the right of the picture. It is believed the fracture pattern of this ice is caused by the release of tension as the blocks are pushed through shallow water. Recementation and drifting are partly responsible for holding the area together. The debouched ice forms an expanded lobe pattern. Plane altitude 7,000 feet.

and fifteen minutes after leaving Mount Rea. Photographs were made of the southern side (fig. 12) as the plane headed eastward for about 100 miles. Mount Flood was found to be the first in a series of high, almost snow-covered blocks, massive in shape, without alpine glacial carving similar to that in the Southern Edsel Ford Mountains. The range forms a great ridge, lying on the 76th parallel and broken occasionally by glaciers which drop steeply toward the sea over 60 nautical miles away. The plane passed northward through one of these gaps (fig. 13) at approximately longitude 133°15′ W., which was the second gap eastward from Mount Hal Flood.

To the north, open water was visible in the vicinity of latitude 74°30′ S. (fig. 21). The plane was flying above a tremendous glacial basin (fig. 14) pouring out through a gap in a low coastal range of mountains. This great glacier, later named in honor of Secretary of State Cordell Hull, was found to be 20 miles wide at its narrowest constriction. There is a lobate tangle of gnarled ice where it debouches into the littoral zone of semipermanent sea ice.

The plane turned back toward Mount Rea, skirting the northern side of Mount Hal Flood. From observations made on this flight, it was apparent that the Flood Mountain ridge was almost continuous in form all the way to Ruppert Cape. At no place did it appear to drop below 5,000 feet elevation.

Flight F, December 13, 1940.—Flight F in the Beechcraft followed the pattern of Flight E and was projected into the area lying between the Hal Flood ridge and the coast. Its purpose was the examination of this piedmont area. The plane refuelled at Mount Grace McKinley and again at the Rea Cache. It then proceeded to a point just south of Mount Alma McCoy, pictures back of the coastline being taken en route. Two circles were taken over the Hull Glacier region, but heavy clouds to the eastward obscured the trend of the coastline beyond this area. The clouds appeared, however, to be lying in an embayment cutting southward into the coast beyond the 130th meridian.

The flight was of particular interest in that all of the field parties were sighted and several landings were made to contact them.

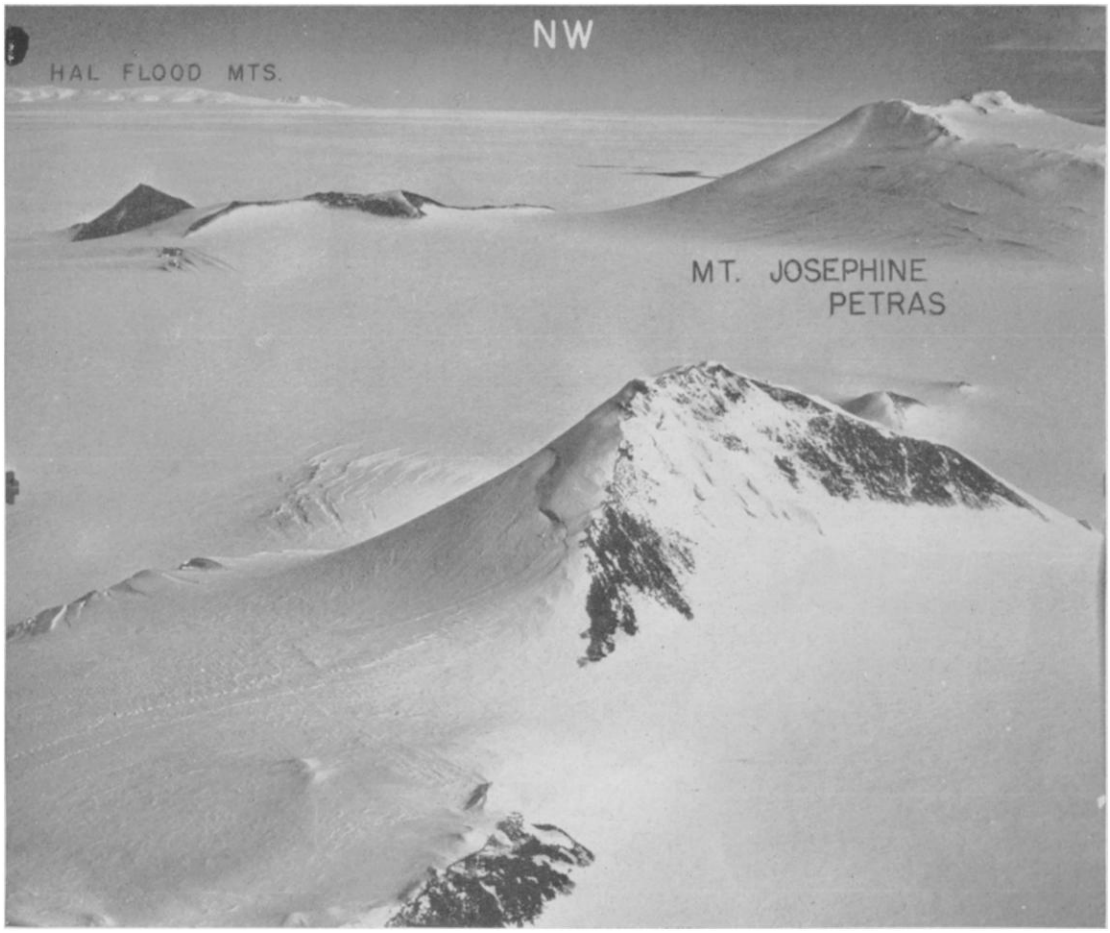
Flight G, December 14–15, 1940.—Shirley and Petras departed from West Base in the Beechcraft on December 14, with the intention of making two or three survey flights to the coast to augment the work accomplished by Petras and the base leader in Flights E and F. However, in the landing at Mount Rea the tail skid was broken. Emergency field repairs were made to the plane so that it could return to West Base.

On the following day, after full repairs had been made, Petras and the base leader projected a flight into the area lying between Mount Hal Flood and Mount Sidley for the purpose of tying this vicinity together photographically. After leaving Mount Rea Cache, the plane flew directly east along the 77th parallel until it reached a point directly south of Mount Hal Flood. Mount Sidley came into view, and, after the plane reached a point approximately halfway between Mount Hal Flood and Mount Sidley, the first of a series of three photographic circles was taken (fig. 13). The area beneath the plane having progressively risen to an elevation of about 7,000 feet, the plane was forced to fly at an altitude of 9,500 feet to permit a suitable photographic range.

To the south, four mountain groups appeared in the vicinity of Mount Sidley, lying in a linear pattern running a little north of east, and apparently marking the edge of a depression (fig. 22). The

Official U. S. Antarctic Service photo, by the author.

FIG. 22. (G-15) A distant view of Mount Maybelle Sidley and neighboring mountains, sighted for the first time in 1929. This interesting range appears to rise to an elevation of 10,000 or 12,000 feet above sea-level. Plane altitude 9,500 feet.



Official U. S. Antarctic Service photo, by the author.

FIG. 23. (G-57) Looking northwestward toward Mount Josephine Petras, elevation about 12,000 feet. The smaller peak shown in foreground is probably of volcanic origin. These peaks form the eastern limits of the Hal Flood Ridge. Plane altitude 9,500 feet.

highest of these peaks were estimated as rising to an elevation of 12,000 feet. The last outward circle was taken near latitude 76°20′ S., longitude 128°30′ W., beside some high outliers of the Hal Flood Ridge (fig. 23).

The largest of these mountains, Mount Josephine Petras, was considerably higher than the plane elevation and was estimated to be about 12,000 feet above sea-level. The peak closest to view showed black, with weathering characteristics similar to those of the volcanic peaks of the Raymond Fosdick group in the Edsel Ford Mountains.

To the east the land appeared to descend; it was broken only by a few scattered nunataks. The Hal Flood Ridge seemed to end at this point, and the surface took on the features of an embayment. However, from this position the ice covering still appeared characteristic of inland ice, having none of the highland characteristics indicative of a sharp drop toward the sea. Photographs later revealed evidences of a huge coastal mountain on the horizon to the northeast, but this was not actually observed until three days later on Flight H.

Flight G was the deepest penetration to the east of any flight, and therefore the return had to be made in an almost straight line to Mount Grace McKinley.

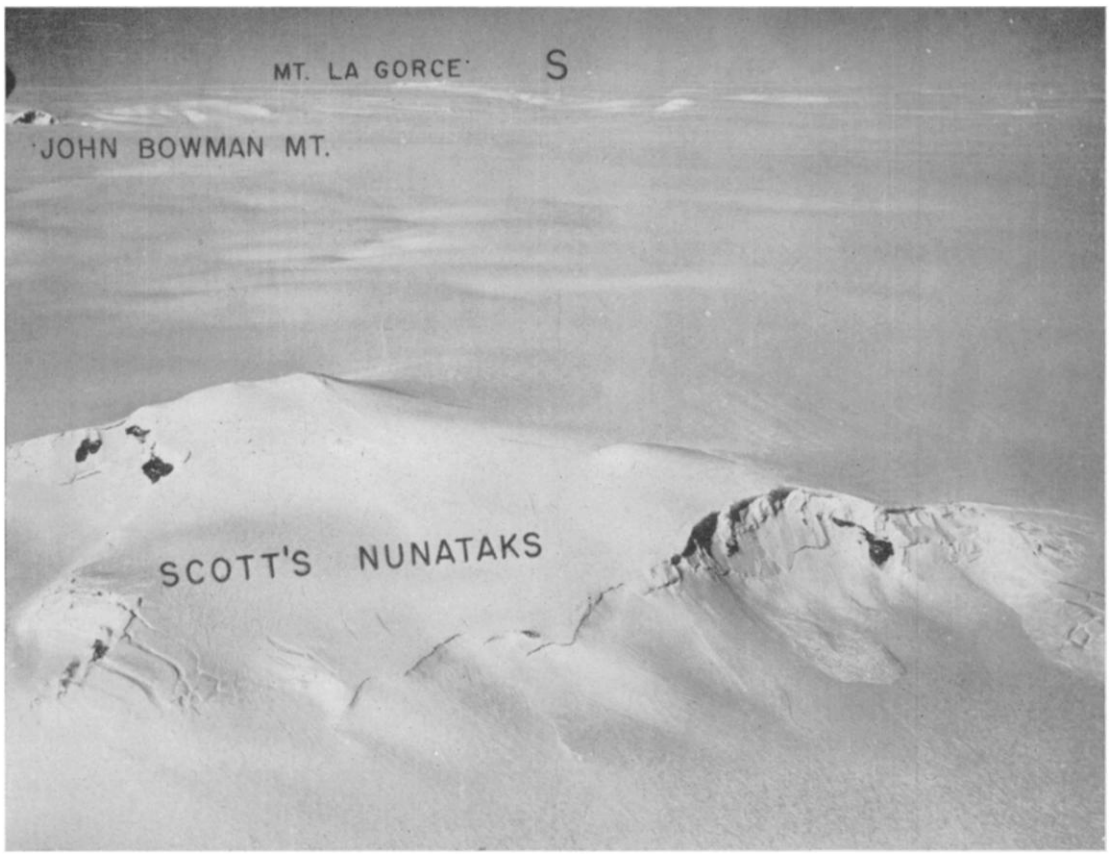
Flight H, December 18, 1940.—The Condor, with its customary crew of four, was on this date groomed for a final flight to the east. With Shirley once again in charge of the aerial camera, the plane skirted the edge of the Barrier to King

Edward Land. A continuous strip of pictures was taken from Scott's Nunataks to Ruppert Cape, looking south into Sulzberger Embayment. The first photographic circle was taken on the end of Ruppert Cape to tie in the flight to the Edsel Ford Mountains (fig. 3).

The plane continued northeastward, following the coast. Strip photographs were taken seaward and landward. Open water to the north could be seen across a belt of semilittoral sea ice extending northward at least 35 miles. Shortly beyond Land Glacier (figs. 18, 25, 26), near latitude 75°15′ S., longitude 139°30′ W., the second circle was taken. Low coastal mountains, ranging to an elevation of not more than 1,000 or 2,000 feet, extend to within a few miles of the ice-covered coast between Land and Hull Glaciers (fig. 27). Between these glaciers there was a belt of littoral ice at least 35 miles wide; it was composed of recemented blocks from the glacier, and was probably held in place by shoals, moraines, and islands. The largest of the islands holding the mass was at the very edge of the open water and littoral ice. It had been sighted and flown over by Admiral Byrd and his flight crew in January, 1940, and was plainly visible during the progress of Flight H.

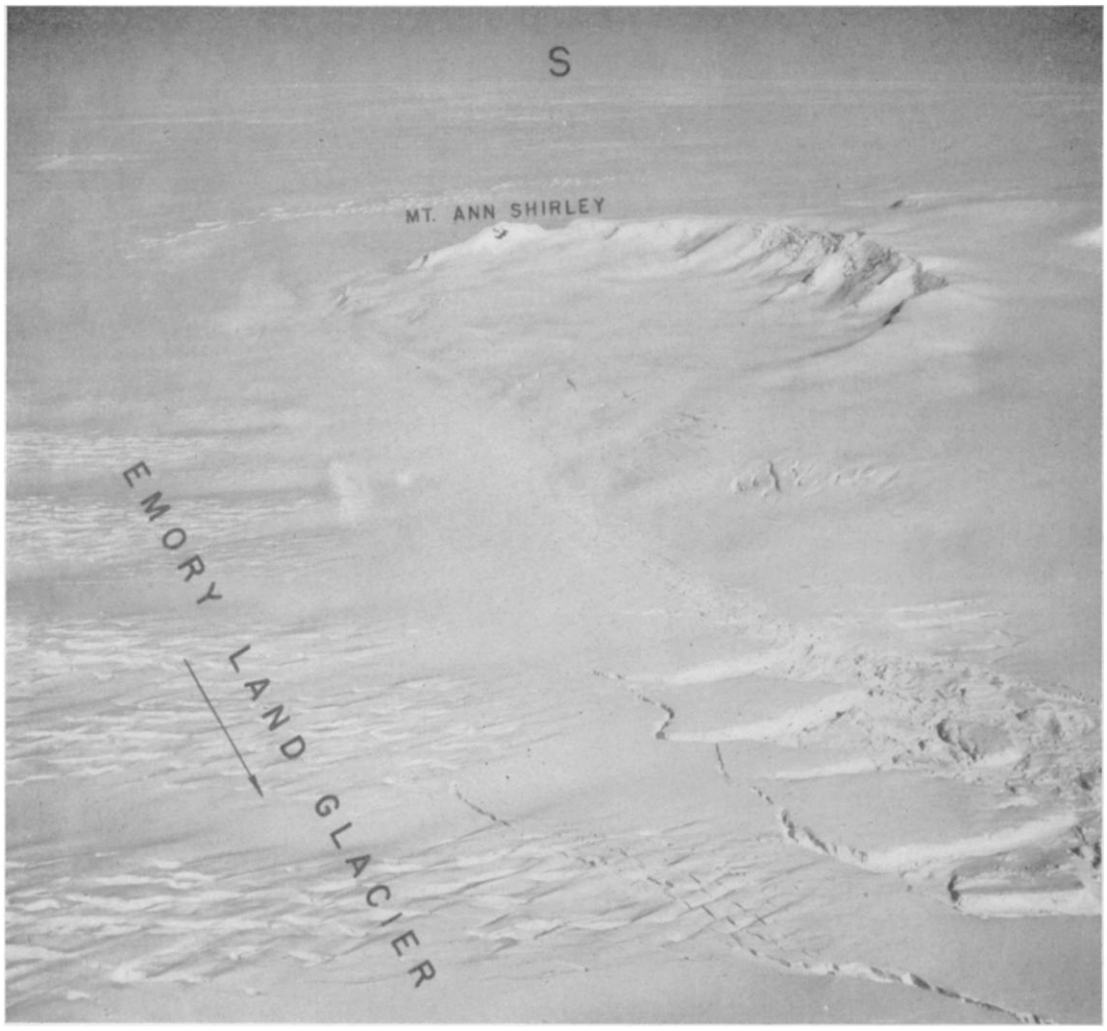
The plane continued to a point near latitude 74°50′ S., longitude 136° W., just beyond Hull Glacier (figs. 14, 21, 28, 29), where the third photographic circle was taken. Here the character of the country changed remarkably. A smooth piedmont or shelf ice extended a short distance from the coast, and open water came to the Barrier edge. This area lies fully 2 degrees farther south than the Barrier reported by the *Thorshaven* in 1934. Either the ship's observations were erroneous or it had sighted an island or a large field of floating ice.

Northeastward, the sea appeared open to the horizon except for several floating icebergs. A tongue of ice, however, projected considerably to



Official U. S. Antarctic Service photo, by Shirley.

FIG. 24. (H-3) Looking south over Scott's Nunataks in King Edward VII Peninsula. Mount La Gorce is over 4,000 feet. Plane altitude 7,000 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 25. (H-152) Mount Ann Shirley, western portal of Emory Land Glacier on Hobbs Coast near longitude 141° W. The beginning of a zone of deficiency as the glacier pushes out into the sea is shown at lower right. Plane altitude 7,000 feet.

the north and just east of Hull Glacier before it recurved sharply to the shelf ice mentioned. The plane continued flying approximately the same course, but veered slightly more to the east and kept behind the Barrier edge.

At longitude 134° W. a circle was made. Far in the distance, across an intervening ice tongue and an embayment, could be seen a huge mountain apparently situated on the coast (fig. 15). Later, intersections indicated that this mountain, named Mount Ruth Siple, was at least 150 miles away at the time of observation. Its location was determined as in the vicinity of latitude 73°15′ S., longitude 122°30′ W., and its elevation was estimated as close to 15,000 feet. In appearance it was very similar to Mount Erebus, being conical in form but with a rounded dome.

Overhead clouds forced the plane to drop 1,000 feet in elevation, but the course was continued toward this big mountain for another 20 minutes, when it became absolutely essential to turn back because of lack of fuel. A small rock outcrop appeared at the edge of the open water in the Barrier just ahead of the plane before it turned, and the clouds mirrored the open bay extending inland (fig. 15). Fairly heavy clouds forming to the

southeast made it difficult to determine how rapidly the land descended beyond the Flood Mountain ridge.

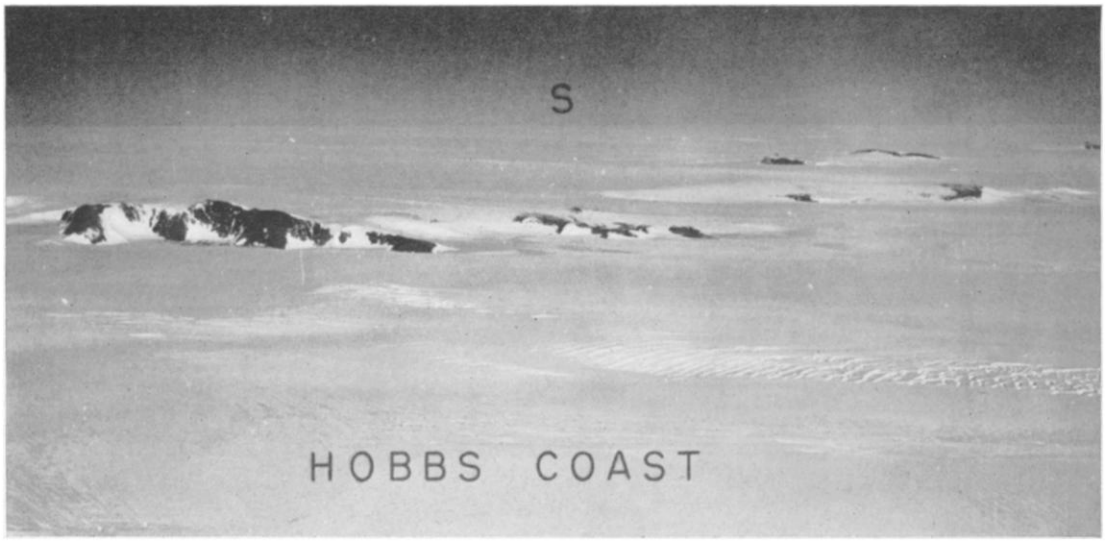
On the return trip the gyroscopic drift sight, which had been used to check ground speed and drift on the outward course along the coast, was turned to advantage by measuring ground elevations while crossing the coast. The most interesting cross-section was made from the surface of Emory Land Glacier (1,300 feet) up over Mount Alma McCoy (3,500 feet) to the glacial level above it (2,600 feet), thence southeastward up over the escarpment of the ridge between Hal Flood Mountains and Ruppert Cape (5,400 feet) to the head of Bernt Balchen Glacier (4,300 feet). The plane proceeded on a direct course to 105-Mile Depot, where it landed for refueling before continuing to West Base. Our flight program in the region lying beyond the Edsel Fords was thus completed.

Summary of the Hobbs Coast Region

The Hobbs Coast region appears to extend in a fairly uniform line striking northeast and is,

Official U. S. Antarctic Service photo, by Shirley.

FIG. 26. (H-153) View, facing north-northwest, of the debouched ice of Emory Land Glacier as it pushes out into the littoral zone of semipermanent ice which makes Hobbs Coast unapproachable. Plane altitude 7,000 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 27. (H-179) Low coastal mountains lying between Land and Hull Glaciers along the Hobbs Coast. Along the sky line is the 5,000-foot escarpment along the 76th parallel noted in figure 18. Plane altitude 7,000 feet.

more or less, on a projection of a line from Cape Colbeck past Ruppert Cape. The coast is definable, although ice-covered, and it is unapproachable by ship west of approximately the 135th meridan. The coast is characterized by the principal features, Land Glacier and Hull Glacier, and by low coastal mountains near the shore. Back of the coast the land rises steeply to the Hal Flood Ridge, which continues along the 76th parallel to the Phillips Mountains and the Ruppert Cape, the maximum elevations ranging from 5,000 to 12,000 feet.

Beyond the 135th meridan, facing eastward, the land to the south appears to indent in the form of a large gulf. A few nunataks appear in the piedmont and terminate in shelf ice. One tongue of this ice extends as far north as 73°45′ S. in the vicinity of longitude 131° W. It appears possible that ships, or at least airplanes, could make a landing along the coast east of the 135th meridian, and that it would be a valuable area for further detailed study.

THE ROSS SHELF ICE AREA

Previous Exploration

Since discovery of the Ross Shelf Ice in 1841, several surveys of its front have been made from shipboard. Because of the advance and retreat of the Barrier edge, none of these have closely agreed. The eastern and western sides of the Shelf have each been crossed at least ten times by various trail parties of the Scott, Shackleton, Amundsen, and Byrd Expeditions; they have also been flown over by Admiral Byrd and members of his various expeditions. However, except for a brief penetration by Royd's trail party in 1903 and a short flight by Byrd in 1929, there was no definite knowledge either of the vast central area of the Shelf or of its articulation with the Austral Cordillera to the south between longitudes 173° E. and 170° W.

The area has seldom attracted explorers, for it has been generally accepted as a flat, floating sheet of ice, probably without islands or mountains of any kind to break the monotony of level expanse. Nevertheless, to geographers and glaciologists it remained a challenge of the unknown, and it appeared advisable to explore as much as possible of the gap between the well-known South Victoria Land and the Bay of Whales to the north and Queen Maud Mountains to the south.

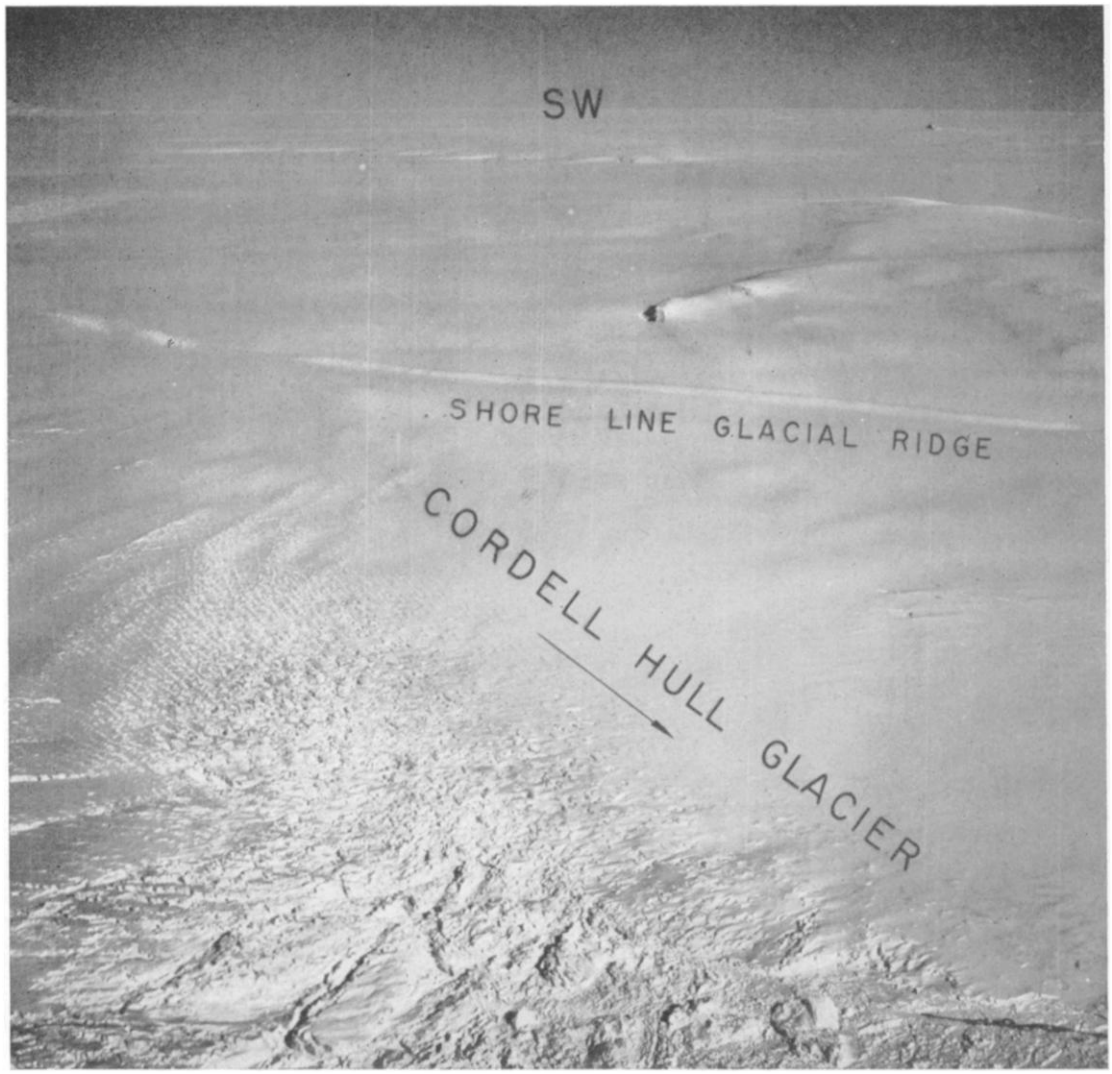
Flights from West Base

Although by Presidential orders West Base was to concentrate its flight operations over the area lying east of the Bay of Whales, permission was granted to fill in unknown gaps lying as far west as the 180th meridian if time permitted. Therefore, on three occasions when clouds or other weather conditions made it impracticable to fly

eastward, major flights were made across the Shelf Ice.

Flight B, February 13, 1940.—Dr. Wade and the base leader, with Petras as pilot, flew in the Beechcraft toward Discovery Inlet. A bank of low clouds obscured the Barrier front area lying west of Lindbergh Inlet, so the plane headed southwestward to skirt the southern edge. Numerous changes in course were made until we reached a wide zone of crevasses lying in and approximately filling the area between latitudes 79°30′ S. and 80° S., and between longitudes 175° W. and 176° W. These crevasses, with occasional haycock formations among them, lay almost parallel (SW.–NE.) to the course. This evidence implied a release in tension due either to an obstruction to the southeast or to two obstructions, one lying to the south and the other to the east. From an altitude of about 2,500 feet there were no clear indications of any appreciable rise, although the plane crew surmised that the surface of the Shelf Ice was higher to the south of the area than to the north.

As the plane flew southwest for another hundred miles, an even larger broken area in the surface was reached. From a position near latitude



Official U. S. Antarctic Service photo, by Shirley.

FIG. 28. (H-232) Some of the details of the western portal of Hull Glacier as it passes Mount Carrol Kettering. The almost horizontal line, just back of center, is a typical feature marking movement of a glacier past a snow-covered shore line. Plane altitude 7,000 feet.

Official U. S. Antarctic Service photo, by Shirley.

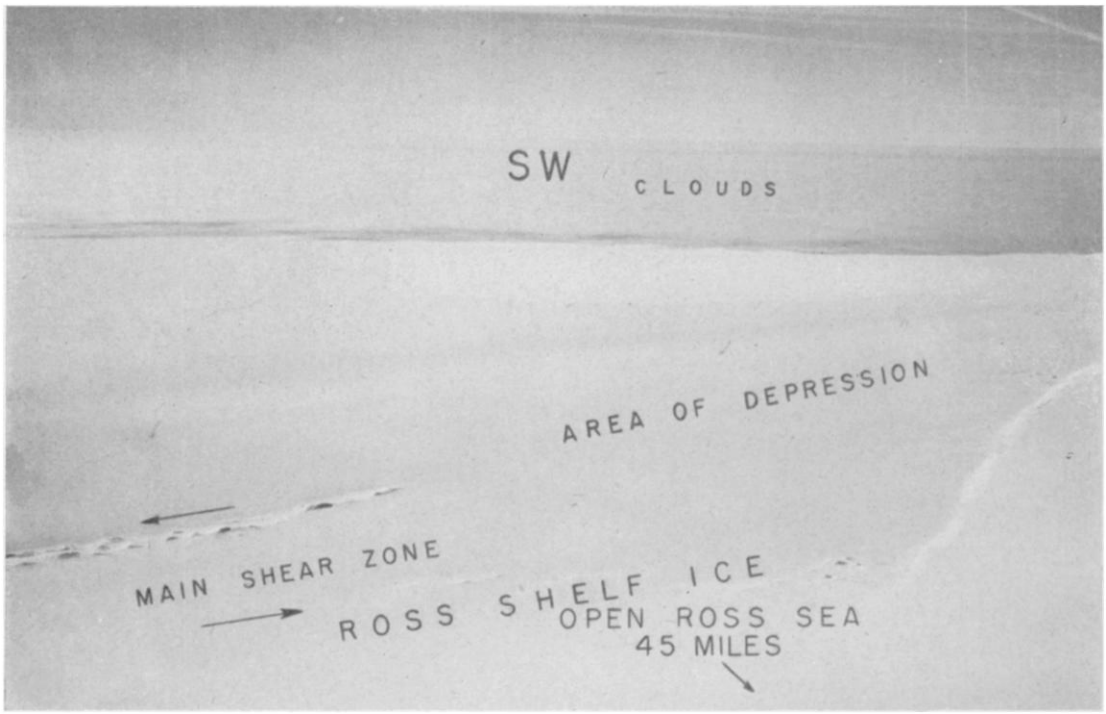
FIG. 29. (H-228) Mount Carrol Kettering from the western side of Hull Glacier. Note distortion of the glacial ice as it is released into the ice-choked sea. Plane altitude 7,000 feet.

81°20′ S., longitude 178° E., the gigantic peaks of South Victoria Land, more than 150 miles to the south and west, were seen as a semicircle. The broken country beneath the plane appeared to extend from about the 180th meridian, at latitude 81°30′ S., northwestward beyond the 177th meridian E. and the 81st parallel. Some of the tension crevasses appeared to run east and west. The zone was at least 15 to 20 miles wide and rather rambling in character, with numerous areas of haycocks. There was unmistakable evidence of land rising close to or above sea-level, presumed by the observers to be a zone of numerous small islands.

The gasoline supply for the outward trip having become exhausted, the plane was headed homeward without further investigation. The zone of crevasses on the 175th meridian W., 10 miles farther north than on the outward trip, was flown over, and it was again observed that the crevasses to the south were at a higher elevation than those to the north.

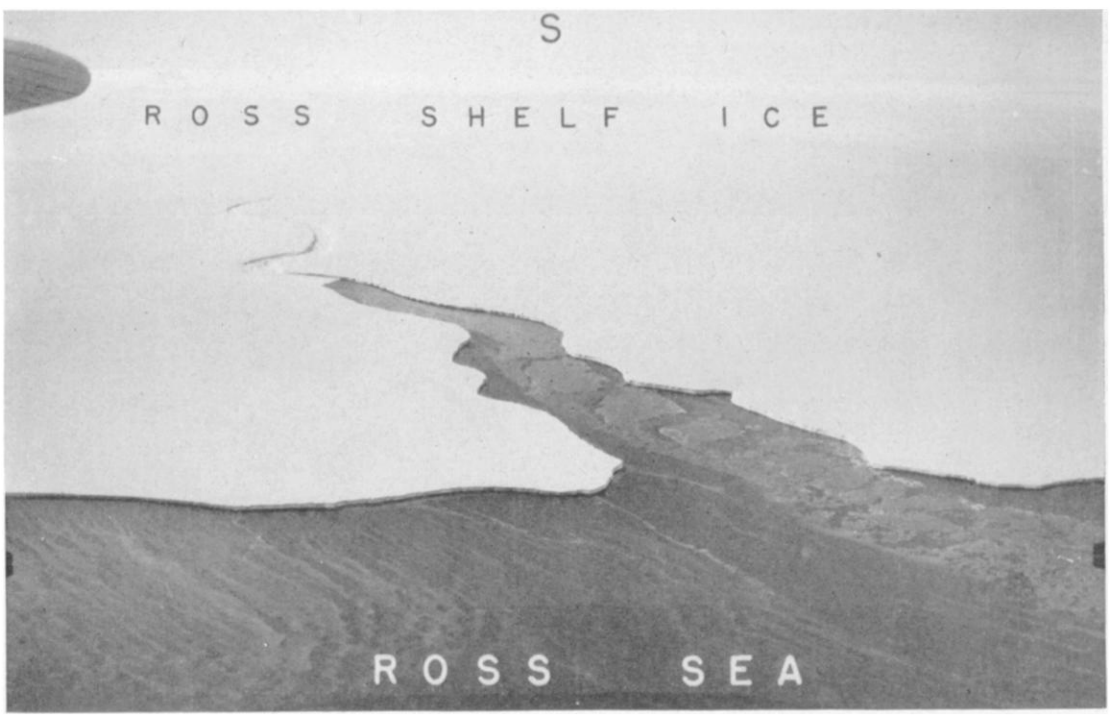
The last discovery of note was the appearance of a rise in the Shelf Ice between longitudes 166° W. and 168° W., and near the 79th parallel. The rise seemed to be of about the prominence of Roosevelt Island, although much smaller in area. It appeared as a gently rising hill against the horizon, as the plane passed to the north at an altitude of not more than 400 to 500 feet above the surface.

Flight W, December 12–13, 1940.—The Condor, with its customary crew of four, headed south



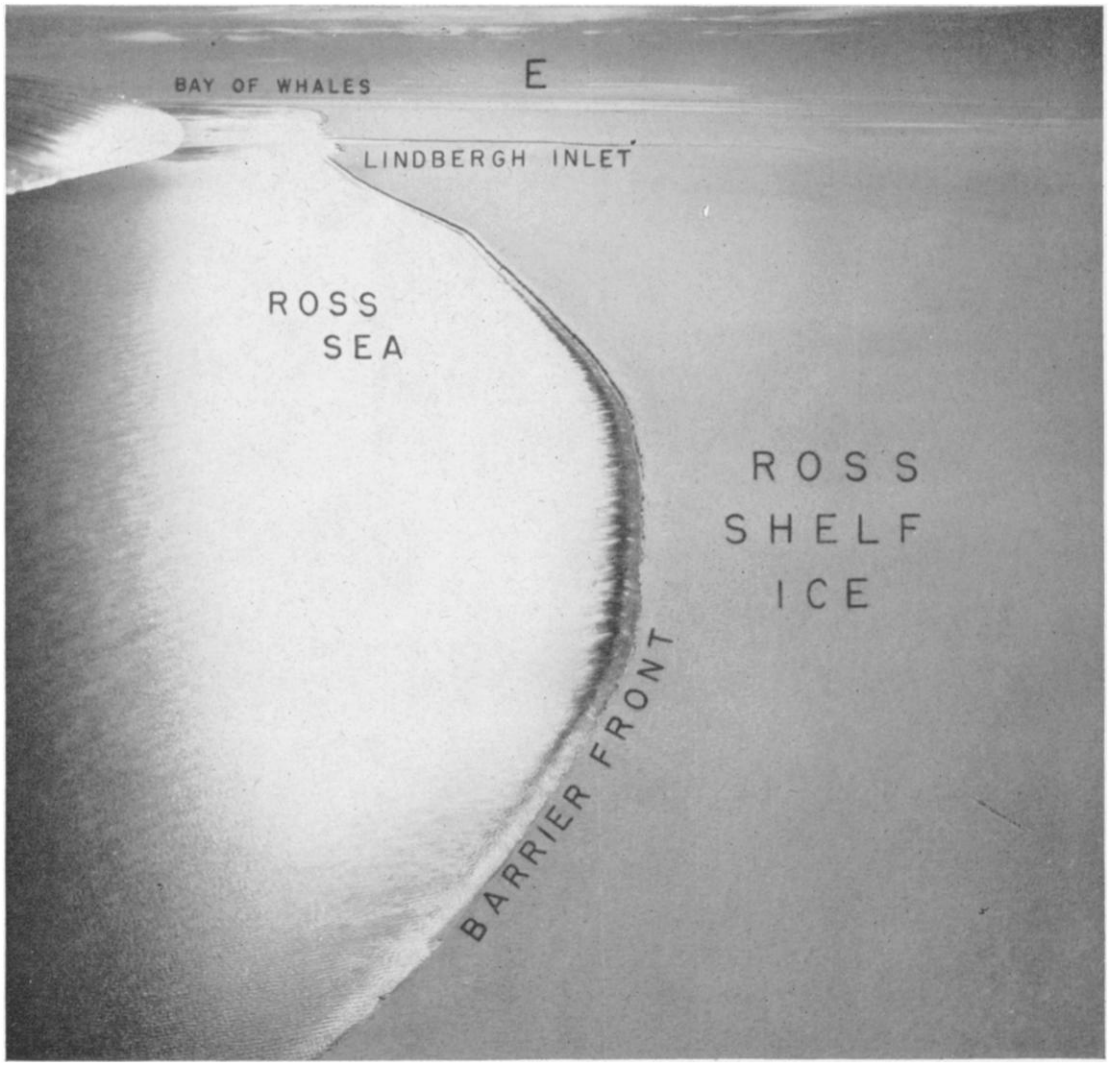
Official U. S. Antarctic Service photo, by Shirley.

FIG. 30. (W-67) Part of the disturbed zone of the Ross Shelf Ice lying about 45 nautical miles south of the barrier front near longitude 178° E. This zone extends over more than 30 miles, exhibiting shearing and evidence of land rising above sea-level. Plane altitude 7,000 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 31. (W-140) One of the numerous tension bays along the face of the Ross Shelf Ice near the 178th meridian. The mouth of the bay is approximately 1 nautical mile wide. Plane altitude 7,000 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 32. (W-257) Looking eastward from Discovery Inlet along the barrier front of the Ross Shelf Ice. The barrier cliff has an average elevation of over 100 feet above sea-level. Plane altitude 7,000 feet.

in an effort to map the western side of Roosevelt Island and the articulation of the Shelf Ice and Marie Byrd Land to the east. Our first attempt was thwarted about 50 miles south of the mouth of the Bay of Whales, where a glacial saddle almost bisects the island, because of a heavy cloud bank lying to the east and west. Vision was mostly obscured to the south; so photography was practicable only to the north.

The plane turned and followed a course almost due west, flying at an altitude of 7,000 feet, which made it difficult to see low rises in the Shelf Ice. However, elevations of the surface were taken from time to time by means of the gyroscopic drift sight. The snow-covered island noted during Flight B on February 13 was seen again, though indistinctly, owing to the higher elevation of the plane.

No features broke the level surface of the Shelf Ice until the vicinity of the 175th meridian had been reached. Here, directly north of the zone of crevasses sighted on Flight B, but now obscured by clouds, was a series of long pressure rolls striking northeast-southwest, similar to the strike of the crevasses noted in the broken zone. Immediately beyond and to the west ran a single "hinge line" or straight-line valley, usually associated with Shelf Ice over deep water. This line ran east-

west, straight and unbroken for 10 or 15 miles and within easy photographic range.

Later, from the coast, other hinge lines to the northwest indicated that part of this area at least was afloat, although the significance of the pressure rolls was uncertain. Such rolls or parallel ridges generally build in front of an obstruction over which ice tries to pass, but here there was no evidence of release of pressure with its attendant tension crevasses.

Farther on, shortly after crossing the 180th meridan, we observed new fractures on the Shelf Ice where a 30-mile-wide zone of shearing became strikingly apparent. The zone lay near the 79th parallel and extended on a true bearing of 97°–277° between longitudes 177° E. and 180°. The western end was partly obscured by low clouds. Almost 150 miles to the west, Mount Erebus, Mount Terror, and Mount Discovery could be seen rising above the clouds.

The broken area below the plane showed typical S-shaped tears in the surface, evidence of shearing along the axis of the zone. Relative movement was to the west on the north side and to the east on the south side. A wide, low, triangular area (fig. 30), without features, suggested a drifted-over deficiency zone where the ice had pushed around some obstruction. The area was lined by slopes. However, from the plane's elevation of 7,000 feet, and in the short time available for observation, it was impossible to determine with certainty the significance and cause of the shear zone, although it seems to indicate an important region holding the Ross Shelf Ice in position on the western side comparable to Roosevelt Island on the eastern side. Closer study of the photographs will probably yield more information.

After making an astronomical fix, taking bearings, and making a photographic circle, we turned due north and within 30 minutes reached the Barrier front at a point near longitude 178° E., where the front attains one of its southermost positions in a shallow bight. A narrow tension bay appeared to be forming at this point, indicating that the movement in this area is one of lateral expansion.

After another photographic circle, the plane turned eastward toward the Bay of Whales in position for a continuous survey of the Barrier's front facing southward. Numerous small tension bays (fig. 31) broke the monotony of the front (fig. 32), and several long hinge lines suggested that the area immediately east of the turning point was afloat over deep water. The hinge lines disappeared, however, as we approached Discovery Inlet, suggesting that at least some of this area west of Lindbergh Inlet is grounded, perhaps resting on a flat shoal of morainic material over which it may gradually move almost without resistance.

Photographic circles were made at the mouth of Discovery Inlet and at the base of the adjacent peninsula. Closer study of these may yield a better knowledge of this strange ice tongue. Small hinge lines on the peninsula hinted that parts of it were afloat and parts grounded, although why it should persist in such an unprotected position is a mystery.

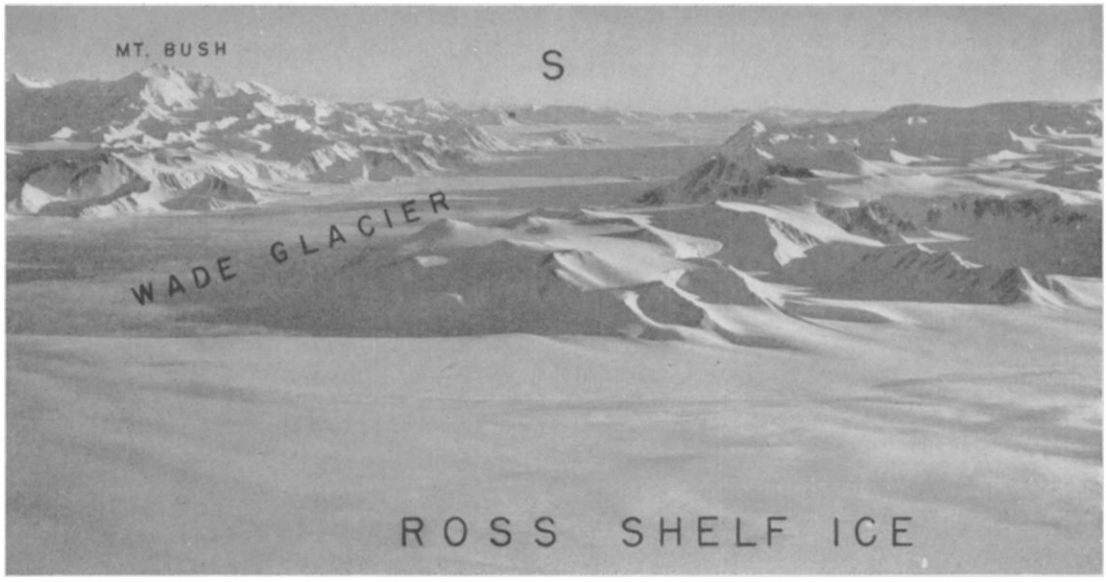
With the termination of Flight W the entire front of the Ross Shelf Ice had been completely photographed from Edward Peninsula to within sight of Ross Island. When the photographs are reduced to maps, the resultant survey of the Barrier should be the most accurate yet made; and, when combined with earlier surveys, it should yield valuable information concerning the movement of the Ross Shelf Ice.

Besides concluding that only part of the Shelf Ice is afloat, we observed that little, if any, large-scale calving of bergs is taking place along the Barrier front. In all the flights along the front only very few icebergs were sighted, and none of them appeared to have been originally a part of the Ross Shelf. Further, upon comparison of photographs taken in 1929 with photographs taken in 1940 of seaward-exposed points near the Bay of Whales, it was discovered that sharp facets of the Barrier face had remained unchanged during the 11 years. This proves that the Ross Shelf undergoes little erosion at its front and at the present time must be considered relatively quiet, despite available data proving its northward movement.

Flight C, February 29 to March 1, 1940.—The longest flight from West Base was taken just before the close of the fall flight season. This flight headed directly across the Ross Shelf Ice on a great circle course for the eastern portal of Beardmore Glacier. A heavy cloud cover lay across the west central portion of the shelf, but its eastern limit did not prevent a view of the edge of the crevassed area lying west of the 170th meridian W., near latitude 80°45′ S. This had been described by Admiral Byrd in 1929. The parallel crevasses ran southwest and northeast, but low scattered clouds beneath the plane made it impossi-

Official U. S. Antarctic Service photo, by the author.

FIG. 33. (G-39) Mount Bush, Prince Olaf Escarpment, and Queen Maud Mountains of the Austral Cordillera. Mount Bush (about 15,000 feet) is capped by Beacon sandstone. Note the even crest-line of the foothills, suggesting a former surface of erosion in front of the escarpment. Foothills are of igneous and metamorphic origin. Plane altitude 9,500 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 34. (C-38) The newly discovered Wade Glacier, striking along the 175th meridian W. and extending to the polar plateau 100 miles farther south. The sudden termination of the high elevation of Mount Bush and the straight-walled Wade Glacier suggest a faulted end of an *en echelon* block in the great Austral Cordillera. Plane altitude 9,500 feet. (View from the same location as in figure 33.)

ble to tell where the obstructions lay that were responsible for the deformation.

Near this same area, but five degrees of longitude farther to the east, the historic 81st-parallel crevasses were plainly visible in the bright sunshine—the same crevasses that caused Amundsen, Gould, and Blackburn so much trouble in crossing. There appeared to be no direct connection between the area of deformation to the east and that to the west, although incipient crevasses may extend throughout this entire region.

After we crossed the 82d parallel near longitude 175° W., the lofty peaks of the Austral Cordillera became dimly visible 150 miles to the south. The most outstanding landmark was a huge mountain, due south, which later proved to be Mount Bush

(figs. 33, 34). Situated to the north of most of the range, this gigantic peak apparently rises to an altitude of about 15,000 feet, for it was never out of view during the next four hours of flying.

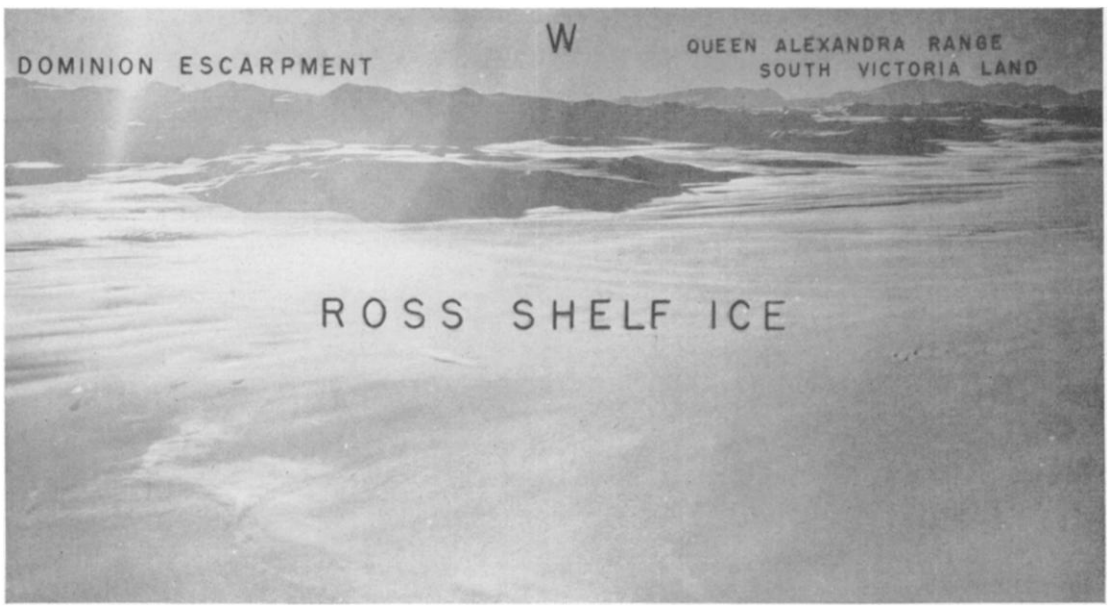
Near latitude 82°15′ S., longitude 176° W., an area of crevasses, striking approximately east and west, was crossed. Directly south of this area was a series of pressure rolls (one of them quite distinct), also bearing east and west. These features were interpreted as indicating a ridge 15 or 20 miles wide over which the Shelf Ice was forced to pass, thereby yielding tension crevasses on the north side.

Continuing a southwesterly course for another hour and fifteen minutes, we reached the eastern portal of Beardmore Glacier. After the plane climbed to an altitude of 9,500 feet, the first photographic circle was taken overlooking Beardmore Glacier and the Queen Alexandra Range of South Victoria Land. Photographs and maps from the Scott and Shackelton expeditions aided in the identification of Mount Hope, Mount Cloudmaker, and many of the other peaks of the region.

Turning southeastward, we laid a course just north of the junction of the Ross Shelf Ice with the foothills of the Austral Cordillera and took photographs to the south. However, a lowering sun to the south cast severe shadows over the area, making it impossible to obtain pictures of good quality. It was unfortunate that the flight had, of necessity, been projected at a time when neither weather nor other circumstances would permit the flight to reach this region during a period when the sun was to the north. Nevertheless, our first sight of these magnificent mountains, extending several thousand feet above the altitude of the plane, was one never to be forgotten.

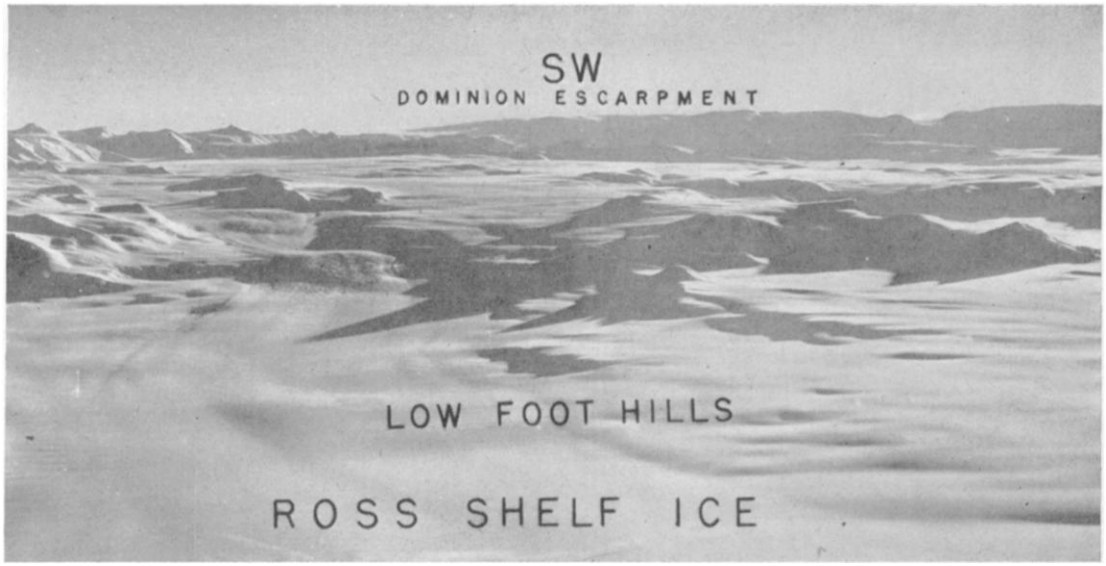
Immediately ahead of the plane lay the major objective of the flight—a wide gap in the Austral Cordillera. The gap had been left unexplored between the time of the expeditions of Scott and Shackleton to the west and of Amundsen and Byrd to the east. As the plane flew on to the southeast, the significance of this area, viewed now for the first time, became apparent.

The Dominion Range, named by Shackleton, is a great, flat-topped ridge running southeastward along the Beardmore Glacier and extending to the polar plateau, which it reaches near the 180th meridian in latitude 85° S. (fig. 35). The northeastern side forms a more or less unbroken escarpment. Well below the contact line of the flat-lying Beacon sandstone series, the gently sloping and nearly snow-covered series of foothills (fig. 36) fan out northeastward to form an almost straight line parallel to the junction of the Ross Shelf Ice. It reaches from the mouth of Beardmore Glacier to the mouth of Wade Glacier.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 35. (C-48) Looking west toward South Victoria Land. Beardmore Glacier lies just beyond first major escarpment of the Dominion Range. Plane altitude 9,500 feet.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 36. (C-35) A view from the same circle as figures 33, 34, 35. Low mountains in the central foreground and the indicated trend of the Dominion Escarpment are offered as further aerial evidence that the Austral Cordillera is broken into one or more *en echelon* blocks in this vicinity. Plane altitude 9,500 feet.

These low foothills rise slightly as they approach the 175th meridian W., where they are suddenly breached by the beautiful, straight-walled Wade Glacier, running north and south (fig. 34). This glacier may occupy a fault zone, for directly to the east and rising abruptly above the foothills is the gigantic bulk of Mount Bush and the northwestern end of an escarpment that extends to the southeast, past Mount Fisher and Mount Fridjof Nansen, and on to the Queen Maud Range (fig. 33). The author suggests that this escarpment be designated the Prince Olaf Escarpment in view of the name given by Amundsen to the range of mountains immediately west of Liv Glacier.

The discontinuity of the Prince Olaf Escarpment with the Dominion Escarpment suggests that the Antarctic horst in this region is *en echelon* in character. The Thomas Watson Escarpment, east of Thorne Glacier, appears to be another block rising southeast of the Olaf block, although all of them strike in the same general direction. Possibly a similar block faulting takes place west of Beardmore Glacier. As previously mentioned, Wade Glacier appears to lie in the fault zone at the end of Prince Olaf block, and such an origin might account for the location of Beardmore and Thorne Glaciers at the end of the Dominion and Watson Escarpments.

Each of these blocks has at its front a characteristic zone of foothills which progressively become more extensive as they extend eastward. The foothills of the Prince Olaf block were of great interest because the plane flew directly above them. These foothills extend a distance of 50 to 75 miles east and west and have remarkable uniformity in the elevation of crestline peaks (fig. 33). This suggests a former erosion surface, possibly at sea-level, before the whole region was uplifted. The crestline surface rises to the southward in a gentle slope intersecting the escarpment below the Beacon sandstone series at an elevation of about 8,000 feet. The foothills were unmistakably metamorphic in character, a striking contrast to the flat-lined sediments.

Photographic circles were taken near Wade, Liv, and Amundsen Glaciers, the last of which is just south of the 85th parallel near longitude 160° W. From here the flight turned northeastward on the homeward leg. We had desired to return along the 150th meridian, examining the nature of Marie Byrd Land and its articulation to the Ross Shelf Ice. However, heavy clouds beneath the plane not only prevented this accomplishment but cut off the entire view of the surface for the next 150 miles. Several important observations were nevertheless made before the surface view was blanked out.

The foothills beyond the Watson Escarpment extend much farther north than previously observed. The escarpment appeared in several iso-

lated patches with uniform crestlines. The more easterly exposures near the horizon lay directly in the path of a break which might exist between Marie Byrd Land and the Austral Cordillera. North of these outcrops, none of which could have been more than 2,000 feet high, began the gently rising slope of the inland ice cover of Marie Byrd Land. This gigantic ice stream, first described by Gould as coming from the southeastern corner of the Shelf Ice, is further evidence that the region is a glacial head, receiving ice from three directions. From the south, Thorne Glacier and the other great streams of ice coming from the polar plateau are bent westward. From the east the depressed area at the foot of the Cordillera drains directly westward, while from the north Marie Byrd Land drains its gently sloping piedmont ice into the westward flowing stream. Great pressure rolls, valleys, moraines, and crevasses exhibit the confluent pattern of the component parts.

When latitude 84°40′ S., longitude 152° W., was reached, the snow surface beneath the plane had risen, exhibiting the dimpled appearance of highland ice and giving definite proof of land above sea-level with a relatively thick covering of ice.

The clouds disappeared before the plane reached the 82d parallel near longitude 152° W., where highland ice with occasional patches of crevasses was easily visible beneath the plane. Toward the 81st parallel the elevation of the land dropped to approximately that of shelf ice, and the slope of the land, marked by ice falls and crevasses, could be seen extending like an escarpment off to the east. The plane crossed a large insular mass partially outlined by crevasses on the northern side. The plane crew, however, were much happier to see Roosevelt Island and the Bay of Whales ahead of them, for by this time the gasoline supply was running dangerously low. Landing was made at West Base without the formality of a circle, for less than 15 minutes' supply of gasoline remained in the tanks after a flight of over 11 hours.

Flight C completed our surveys of the Ross Shelf Ice, except for local flights to its northeastern corner. From the three major flights, which had afforded at least a distant view of almost the entire shelf, it was possible to report definitely at least six newly discovered areas of deformation in the central Ross Shelf and to supply a complete series of pictures of its northern and southern boundaries.

LOCAL FLIGHT OPERATIONS

The Southeastern Gas Cache Flights

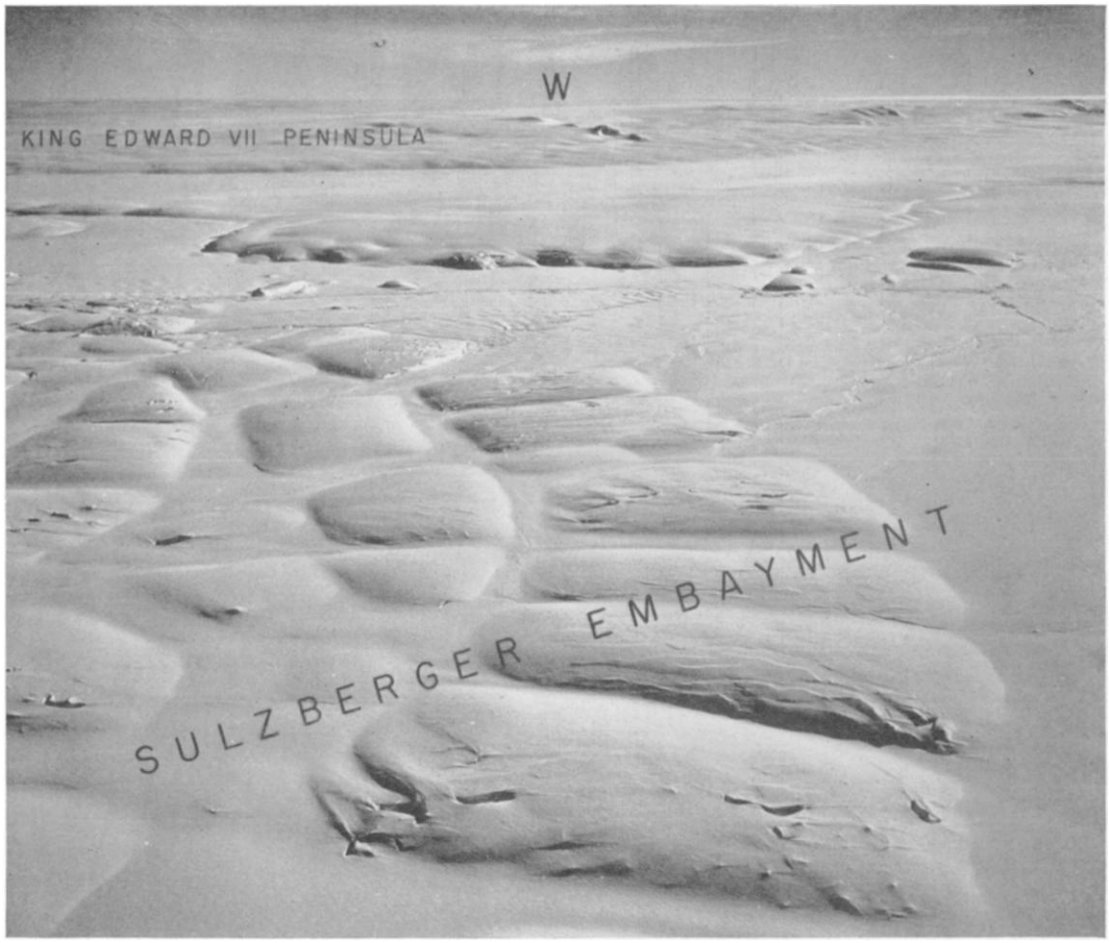
Early in the spring of 1940 several flights were made in the Condor and the Beechcraft for the purpose of laying gas caches. The first of these was on October 24, when Petras and the base leader flew southeast to the Horseshoe Crevasses near latitude 80°45′ S., longitude 147° W., where a suitable location for a gasoline cache was chosen. This flight turned north-northwest to 105-Mile Depot, permitting the plane crew to observe the indefinite eastern coast line of Prestrud Inlet.[3]

The coast of the mainland here runs almost southeast and northwest, ending in a cape south of the Rockefeller Mountains at latitude 78°45′ S., longitude 157° W. The land rises gradually to the eastward as it forms the so-called Rockefeller Plateau. Between the cape just mentioned and the southwestern corner of the Edward Peninsula, a glacial embayment extends eastward for at least 30 nautical miles. It was used by sledge parties en route to the Edsel Ford Mountains.

On November 4 the Condor flew to the position selected by the Beechcraft crew for the gasoline cache and there deposited 200 gallons of gasoline. A theodolite was set up, and the position of the cache was determined. The line of flight to the gasoline cache lay through a gateway between two areas of crevasses—one caused by a projection on the mainland, the other by an island previously mentioned as lying to the southeast of Roosevelt Island. Constriction of the ice flowing between the two points of land causes considerable disturbance, resulting in a series of even, parallel crevasses at right angles to the axis of flow in the central valley between.

The land lying to the south exhibits a series of ice falls along the 81st parallel to the east. Where the southern escarpment approaches the northwest-trending coast, there is a large glacial stream draining the land rising to the north and south of it. This region was first seen by Admiral Byrd and his plane crew in 1934 and was named Horseshoe Crevasses because of the semicircular shape of the crevasses curving around a point of land. The unusual amount of glacial activity at this junction suggests that perhaps there is an extended depression running eastward or northeastward from this point. It is considered possible

[3] The name Prestrud Inlet has been suggested for the area lying between Roosevelt Island and the mainland, first crossed by Prestrud in 1912.



Official U. S. Antarctic Service photo, by Shirley.

FIG. 37. (EL-153) A view westward over Sulzberger Embayment showing a portion of its complicated ice pattern.

that this depression may connect with the depression believed to exist near the Sidley Mountains just east of Mount Hal Flood. Should this be true, then Edward Peninsula and northwestern Marie Byrd Land may be, in effect, an isolated block. The depression is so narrow, however, that it is a question whether it reaches sea-level. It is therefore doubtful whether the region could be considered insular.

The Southeastern Gas Cache was laid expressly to support a proposed flight, comparable to Flight C to the Austral Cordillera, in the vicinity of longitude 120° W., where the Horlick Mountains lie. At least half a dozen attempts were made during the summer, on days when flying weather at West Base seemed propitious for the flight. But on each occasion a bank of fog concealed the gas cache, making it not only impracticable but hazardous to carry the flight to conclusion. It is regretted that this flight could not have been accomplished. Each of the abortive attempts, however, was turned to good account by continuing examination of interior areas lying in the vicinity of the Bay of Whales.

Edward Land Survey—Flight EL

Although Edward Peninsula was partly surveyed on each of the Byrd expeditions, it was desired that additional photographs be made in order to gain more detailed information. On November 4, 1940, Shirley and Petras completely circled the peninsula in the Beechcraft, taking pictures and photographic circles at strategic points.

The peninsula was passed, crossed, or circled on at least twenty occasions, so that considerable

familiarity with the region was gained. Among the more important discoveries was that the land is higher than had been conservatively estimated by the Second Byrd Antarctic Expedition.

The central plateau rises between 3,000 and 4,000 feet above sea-level, and Mount La Gorce, the highest landmark, is about 4,500 feet as measured by altitude readings of passing planes.

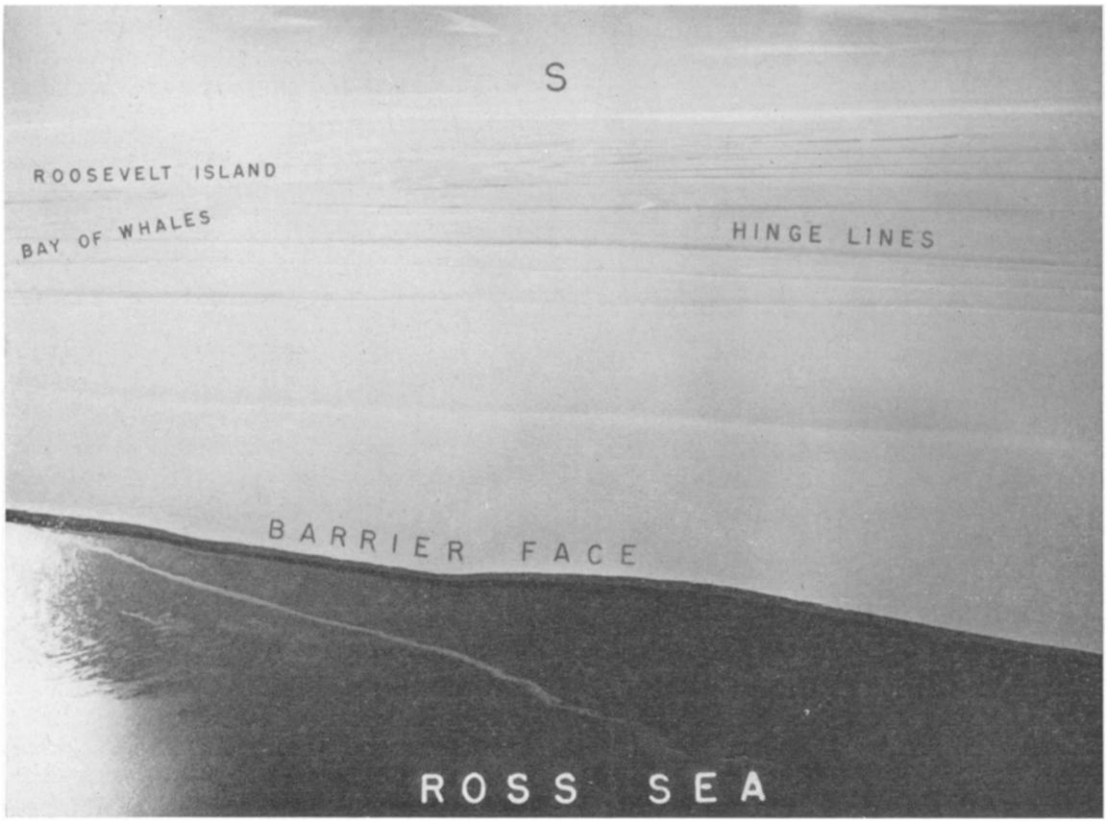
The eastern side of the peninsula, facing Sulzberger Embayment, is deeply cut by two glaciers, one of which, near John Bowman Mountain, has a drainage area extending well back toward the center of the peninsula. Geologically, the Rockefeller Mountains are an adjacent section of the Edsel Ford formation, and almost all of the nunataks fringe the edge where the ice is dropping away to the sea. The neck, connecting the peninsula to the mainland, is being cut from each side by glaciers, an action that will undoubtedly reduce the peninsula to an island in a short time, geologically speaking.

Cape Colbeck is a low, snow-covered projection extending northwestward from the main body of the peninsula—an impression one would not get from previously published maps of the region. On the western side of the peninsula the piedmont ice field flows off into the sea as a sheet, broken only occasionally by specific glacial formations. This undoubtedly indicates that beneath the snow cover the land is smooth and gently sloping.

Okuma Bay, the junction of the shelf ice with King Edward VII Peninsula, is very active and loses its ice early in the spring, leaving sheer cliffs which offer no opportunity for ship landings such as is found in most of the other bays along the Barrier front.

SULZBERGER EMBAYMENT

In 1929 Admiral Byrd named the embayment area lying east of Edward Peninsula, Arthur Sulzberger Bay. Some subsequent maps have



Official U. S. Antarctic Service photo, by Shirley.

FIG. 38. (X-7) A section of Ross Shelf Ice about 10 miles west of the Bay of Whales. Note the interesting pattern of parallel valleys extending for a distance of 20 or 30 miles. Such parallel lines appear in the shelf ice when it is floating freely. They may represent hinge lines caused by tidal action. Plane altitude 7,000 feet.

restricted this name to a minor feature, leaving the area as a whole without a suitable name. In order to give it a name, Sulzberger Embayment is suggested.

This area, lying between Edward Peninsula and the Edsel Ford Mountains and extending south to Mount Grace McKinley, forms a large island-filled bay. It is entirely snow-covered, with shelf ice and glaciers passing between islands, so that crossing it by sledge is rather impracticable. Our many flight crossings of this embayment led to the unquestionable proof that many of the features labeled "ice islands" on maps made from Byrd Expedition data, are actually true islands, having relatively thin caps of ice. Rock exposures were seen on the edges of many of them, and it was apparent that a considerable portion of the embayment was occupied by a low land or morainic deposit, over which the ice was riding. A map of this region in full detail should prove of considerable interest to glaciologists and physiographers.

BAY OF WHALES AREA

Because of its complexity, the Bay of Whales area has always been fascinating to the expeditions that have based there. It is defined as a zone lying between and including Kainan Bay to the east and Lindbergh Inlet to the west, and extending southward to the middle of Roosevelt Island. This comprises an area of approximately 4,000 square miles. Aerial surveys were made of the region in 1929, 1934, and again by the United States Antarctic Service in 1940. During this 11-year period, constant motion within the bay has greatly altered the physiography, giving indisputable proof that the bay is closing.

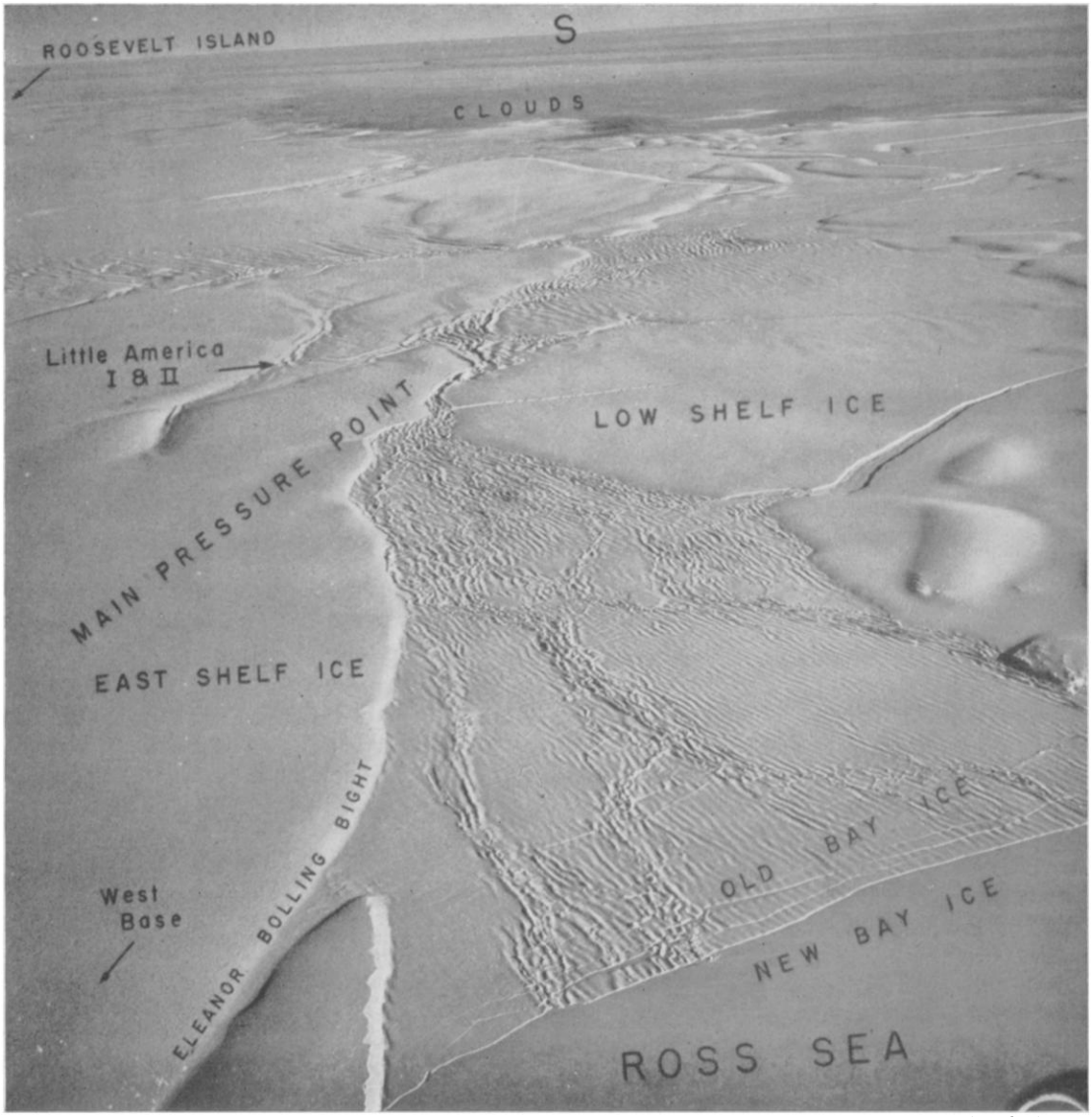
Leonard Berlin, surveyor at West Base, was able to check the relative movement by taking several prominent points within the bay. From his observations it appeared that West Cape had an average daily angular change of 45″ of arc, amounting to nearly 6 feet a day. However, it was not until a comparison of the solar fixes at the bases of the three American expeditions had been made, that a true estimate of directions was possible. These comparisons showed that the east side of the bay has moved approximately 4.25 statute miles to the west, but only about 2,000 feet northward. The movement in the period between 1929 and 1934 amounted to about 8 feet per day, but it decreased considerably as it met stronger opposition on the west side of the bay, so that between 1934 and 1940 the approximate movement dropped to 3.3 feet per day.

The ice from Prestrud Inlet, moving around the eastern side of Roosevelt Island, apparently strikes an obstruction some distance to the southeast of Little America. Kainan Bay lies beyond the obstruction, although apparently at least some of the obstruction is in the southern end of the bay itself. It is believed that possibly the shelf ice of Prestrud Inlet is moving over or is obstructed by a bank of morainic material which it has transported from the south. This is based partly upon the assumption that long valleys, termed hinge lines, develop in the shelf ice parallel to the Barrier face whenever the ice is flowing over deep water. Hinge lines are very prevalent in the shelf ice east and west of the Bay of Whales, except in the area to which the ice is believed to be tied. It is felt that if the tying was due to a rock ridge of any size, the surface would be badly broken. However, this is not true, and the fact that the shelf is resting on submerged land was proved by Dr. Thomas Poulter in 1934.

The west side of the Bay of Whales forms an entirely different picture. Here the movement is northward. Water under the Barrier surface is known to be deep, and hinge lines extend 20 to 30 miles westward (fig. 38) almost to Lindbergh Inlet. Thus we see the Bay of Whales is really the meeting-place of two shelf-ice systems—the western area being fed from the south and the eastern area being fed from the southeast. They are meeting all seasonal bay ice that forms over deep water and are crumpling between the shelves (figs. 39, 40).

The deformation patterns formed by the crumpling ice are similar in form to crustal fractures in the earth's crust. Consequently, interest has been aroused through the geological and geographical divisions of the National Research Council [4] to study existing photographs with great care. The Geological Society of America has provided a grant for the construction of maps, and it is hoped that within a year or so the intricate pattern of deformation in the Ross Shelf Ice surrounding the Bay of Whales area will be mapped in large scale. From these maps, it is hoped that glaciologists and structural geologists will be able to interpret the stresses causing the deformations. Although a

[4] Committee on the Deformation of the Ross Shelf Ice: Walter Bucher (chairman), Max Demorest, Laurence Gould, François Matthes, Paul A. Siple, and F. Alton Wade.



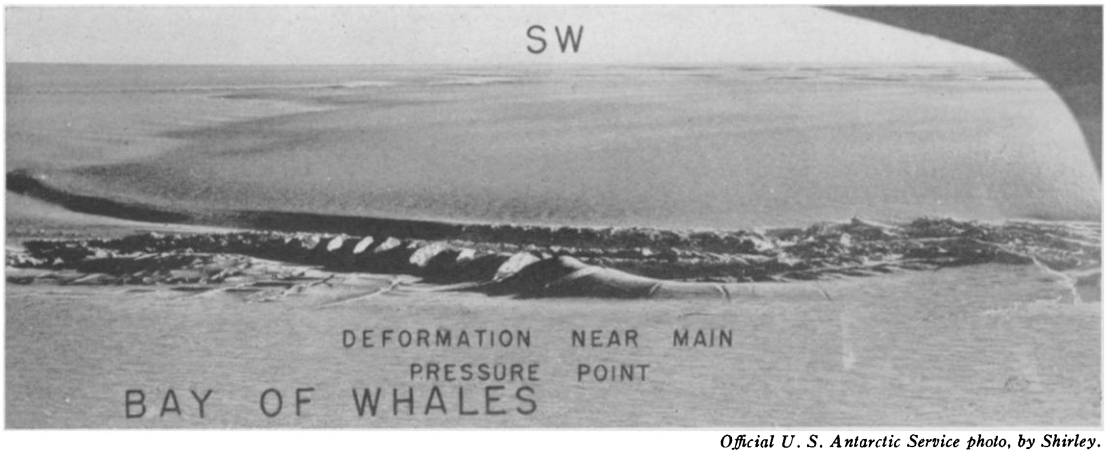
Official U. S. Antarctic Service photo, by Shirley.

FIG. 39. (L-160) Looking southward over Bay of Whales from an altitude of 10,000 feet. Heavy pressure in the old bay ice indicates gradual closing of the bay. The bay is the result of two ice shelf systems moving from either side of Roosevelt Island. On the right is the Ross Shelf Ice proper, moving northward. On the left the shelf ice from Prestrud Inlet is moving almost due west.

detailed study of the Bay of Whales area might be of little intrinsic value, the principles of deformation to be derived from such a study may be applied to morphological features in the earth's crust, which, in a larger sense, is a relatively thin layer floating on plastic medium. Thus, from the study of ice in the Antarctic it is possible that we may better understand the origin of mountains and other physical features of the earth in regions generally considered more valuable to man.

No discussion of flight operations from West Base would be complete without passing reference to the altitude flights made in the Beechcraft. These flights were for the purpose of making cosmic-ray observations, and on one such flight the plane reached an altitude of over 21,000 feet.

It is interesting, also, that the Beechcraft was flown as early in the spring of 1940 as August, shortly after return of the sun, and during a



Official U. S. Antarctic Service photo, by Shirley.

FIG. 40. (RI-54) One of the zones of pressure in the Bay of Whales area. The ice of two barrier systems meets here near the northwestern end of Roosevelt Island. The anticlinal blocks rise to an elevation of 50 to 150 feet above the shelf ice surface. Plane altitude 800 feet.

period when the temperature was 60° to 70° below zero.

The final flight of the Condor was on January 3, 1941. This flight was made to a point 92 miles east of West Base by McCoy, Giles, and the base leader for the purpose of freighting back some of the equipment and supplies which the trail parties and tractor found impossible to handle owing to soft sticky surface.

The plane landed without difficulty and loaded on board the excess material. A normal take-off was made, but within a few minutes the starboard engine had developed a distinct knock which grew steadily worse as the plane gained altitude. A thick blanket of ground fog hung over the surface between 105-Mile Depot and Okuma and Kainan Bays. As the Condor reached the edge above the fog, the starboard engine literally exploded. The switch was cut, and pilot McCoy brought the plane to a safe landing a quarter of a mile from the Eastern Tractor Trail.

As the plane was in constant radio contact with West Base (as on all flights), Petras and plane captain Gray were off to the scene of the accident within a few minutes after being advised of the situation. Gray found the damaged motor was beyond repair, and the Condor was therefore abandoned. The airmen were flown back to the base in the Beechcraft, and on two subsequent flights Petras succeeded in salving all valuable instruments from the Condor as well as the major portion of its flight load. The Condor itself remains where it last landed—near latitude 78°30′ S., longitude 157°30′ W.

SUMMARY

Geographical exploration was projected from West Base in 1940 by means of five reconnaissance field parties and two aircraft. The routes followed but extended considerably beyond those opened first by the Byrd Expeditions of 1929 and 1934. The operations of the field parties were limited to the coastal mountains east of Little America from longitude 164° W. to longitude 136° W. The parties were occupied mainly with surveying, geology, biology, and meteorology.

Aerial reconnaissance and surveying extended eastward to longitude 120° W. and included major land features to a distance of nearly 200 miles south of the coast. This was accomplished by six flights, during which more than 1,000 usable aerial survey photographs of the area were taken and made available for subsequent map construction. Exploration to the west of Little America included three major flights over previously explored portions of the Ross Shelf Ice, crossing in each case into meridians of east longitude in the vicinity of latitudes 78°30′, 79°20′, 81°, 83° and 84° S. Six newly discovered areas of internal disturbance were studied, and 15 bays and inlets were photographed in the continuous aerial survey of about 400 miles of Barrier face from an altitude of 7,000 feet.

Southern exploratory operations were confined mainly to filling in the gap of mountains in the Austral Cordillera between Beardmore and Liv Glaciers. However, the character of land formations east to the 120th meridian W. indicated no sea-level connections between the Ross and Weddell Seas.