Photographs taken at intervals as short as a single day show interesting changes on the beach. For example, the beach cusps shown by Figure 2 are ephemeral features, developed by waves striking normal to the coast, and are destroyed by a change in wave direction. Excellent use can be made of aerial photos in studying shoreline changes caused by related tsunamis (so-called tidal waves) and by hurricanes or other storms (Fig 10).

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GEOLOGICAL MAPPING OF THE ROSS LAKE AREA, USING AIR PHOTOGRAPHS*

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THE Ross Lake area in the Northwest Territories was especially suitable for use of air photographs in geological mapping, because it showed a maximum amount of rock exposures, which were well glaciated and rendered bare by recent forest fires. The maximum relief is about 200 feet and generally less than 100 feet. The area had received a priority for geological mapping on a scale of 1 inch to 1 mile, because of its diverse mineral deposits.

No proper base map was available. The area was covered by oblique air photographs from which had been compiled a manuscript map of 2 miles to the inch, published at 4 miles to the inch. A geological map of the reconnaissance type, 4 miles to the inch, was available.

It was decided to photograph the area from the air, by a member of the Geological Survey with an ordinary camera to which a bull's eye level was attached. Individual air photographs were enlarged to an approximate scale of 1/6 mile or 880 feet to the inch. About 80 per cent of the area was thus covered by vertical air photographs which could be used as field maps, the geology of the remaining 20 per cent to be recorded on the foreground of oblique air photographs or recorded in notes along pace and compass traverses between points covered by vertical air photographs.

A photostat enlargement of the 2-mile manuscript map to 1 mile to the inch was made on which was traced the area covered by each 880-foot vertical air photograph. This was called an index map.

For the purpose of description the uses made of the vertical air photographs may be classified under three headings: Planning, Field Use, and Compilation.

PLANNING

Investigation of air photographs before actual field work permitted: A—to outline roughly the geology, B—to infer hypotheses later to be investigated in

* No base map available.

the field, and C—to plan field work economically. The major data thus obtained were plotted on the index map.

A—The geology was roughly outlined (using also the 4-mile geological map) by using the following features on the verticals:

- a—Topographic lines:
  - General lineaments (depressions, long lakes, valleys, lines of lakes, muskegs):
    - Faults: especially if showing truncation and displacement of other features
    - Diabase dykes: if lineaments were in certain directions
    - Geological contacts: if lineaments marked contacts of contrasting features, some of which alined parallel to lineaments
    - Finer lineaments:
      - Bedding structures in sedimentary rocks: if fine lineaments in uniform exposures, or with alternation of colours, or parallel curves.
      - Glacial grooves: checkered forms of outcrops, same orientation.
    - Tabular features:
      - Volcanic bands and sills: if parallel to other lineaments such as bedding.
      - Pegmatite dykes: white, elongated, lenticular, contacts not parallel, relatively short.
      - Diabase dykes: long, following depressions.
    - Absence of lines in large uniform mass: intrusive or extrusive; suspect absence of bedding.
- b—Colours
  - Light colours to white: granite, acid volcanics, eskers.
  - Grey: sedimentary rocks.
  - Dark: basic dykes and basic volcanics.
- c—Relief
  - High ridges: basic volcanics and dykes
  - Even with rounded contours: granites
  - Uneven: sedimentary strata, high areas generally marked by coarser beds and larger amount of greywackes, whereas lower areas are marked by finer greywacke beds.
- d—Systems of orientation
  - Diabase dykes: NNW and NE
  - Pegmatite dykes: clusters or radiation from large white masses of granite.
  - Glacial grooves, eskers: NE.

B—Hypotheses were formulated from the rough outline of the geology obtained and which could be later checked in the field. Without the help of air photographs it is only after accumulation of data recorded in the field and after a good part of the field season is spent that geological features are recognized as falling into systems and generally little time is left to check on any hypotheses formulated to explain such orderly occurrences.

For example, in one part of the area it was known that a biotite granodiorite, appearing as light grey to white on verticals, was crossed by a multitude of parallel basic dykes, appearing as dark lines on verticals. Nearby a white mass on the verticals was not traversed by such dark lines or bands, and tabular to lenticular white bodies radiating from the white mass were cutting across the dark bands in the biotite granodiorite. Before field season it was inferred that such bodies were pegmatite satellites radiating from a granite of younger age than the granodiorite. This was easily checked and confirmed in the field. It was also known from other areas that pegmatites of the late granite carry rare-element minerals of economic importance like tantalite-columbite. So at the outset of the field season close examination was made and this resulted in the finding of tantalite deposits.

Pre-field examination of verticals revealed that the regional trend of bedded rocks formed a horseshoe curve, and that folds followed the same trend so that it, the horseshoe structure, appeared to have been formed after the other folds, which it apparently deformed. With this in mind a study was made in the field of directions of schistosity which are usually indicative of direction of stress in folding. In the field it was subsequently found that a uniform direction of schistosity was parallel to the axis of the horseshoe structure whereas other schistosities followed the lesser folds around the horseshoe structure.

C—Planning of economic mapping through pre-field examination of verticals was realized by

- a—Giving priority to localities judged strategic in information on geological relationships and on structural features.
- b—Assigning areas to student assistants basing the choice on individual qualifications versus complexity of geology as revealed by verticals.
- c—Spacing traverses according to amount of rock exposures, complexity of geology, and extent to which structures appeared on the verticals.
- d—Speeding travelling by choice of portage routes, and ascertaining rendezvous with supply planes by examination of landing lakes for reefs, islands, shore line, etc.

FIELD USE

In the field it was possible on the average to fix one's position on the 880-foot verticals within 3 paces or 15 feet. Consequently pace and compass traverses were reduced to a minimum and men worked individually instead of in couples, and were not restricted to a linear path, thus increasing the man-hours spent on geology and the scope of traverses. Folds and geological contacts could be drawn in their true shapes by following them on the ground instead of intersecting them at distant points. Beds could be followed for many hundreds of feet and their trend was recorded on the verticals by lines related in length to the distance they had been traced in the field.

Where observation data were ample and geological features were clear on verticals it was judged unnecessary to survey them completely in the field as interpolation between localities of observation could be guided by the verticals and made accurately. Time was thus saved. For instance where a fold was well defined on verticals, it was necessary only for a man to make a dip and top determination at a couple of points on each limb and at the crest to define the geometry of the fold and its nature (whether an anticline or a syncline). Where beds were poorly defined on the verticals a man would walk along a bed fixing its location, dip, and top at different points on the photograph so that folds became well defined.

Pegmatites could be easily picked out on the verticals and their examination was made more efficient by assigning areas with pegmatites to the more experienced members of the party.

All survey data were recorded on the verticals, and were interpreted at night. The interpolations of contacts and structural lines were made using the verticals as guides. Any discrepancy in observations could be easily checked the next day in the field. Possible explanations of structural anomalies could be tested by picking up on the verticals critical areas or features to be examined the next day.

The progress of geological mapping was followed by transferring free hand on the index map the main geological features recorded on the verticals.

COMPILATION

Each vertical was examined for the data recorded and all possible interpolations made. If any interpretation were necessary, i.e. inference of faults through displaced geological contacts, it was based on the features (depression, muskeg, etc.) shown on the verticals, and proper conventional signs were used to distinguish on the verticals speculative inferences from data recorded in the field.

The verticals used in the field varied in scale and showed tilting. The transferring of geological data from them onto a base map might have revealed difficulties. However, vertical air photographs at an approximate scale of 1,800 feet to the inch were later provided by the R.C.A.F. from which a manuscript map of $\frac{1}{2}$-mile to the inch was compiled with proper ground control and with the help of the "Sketchmaster."

Because of the clearness of details on both 880-foot and 1,800-foot verticals it was easy to transfer in the office and without loss in accuracy, field data recorded on the 880- to the 1,800-foot verticals. Also geological data compiled on obliques were easily transferred free hand to the 1,800-foot verticals. Traverses were plotted on the 1,800-foot verticals by interpolating between two known points fixed on the 880-foot verticals and located on the 1,800-foot verticals afterwards. At this stage all field data had been plotted on the 1,800-foot verticals and were ready to be projected onto the $\frac{1}{2}$-mile base map by the Sketchmaster. The base map carried centre points of the 1,800-foot verticals but the marginal control points were not used because the number of lakes contained on each vertical was judged sufficient for control. Thus the geological data were projected on the base map in the same manner as the topographic data, using the same verticals and the same projection instrument.

The method used permitted a six-fold reduction (for final publication) for over 80 per cent of the data obtained and which was generally located accurately as individual outcrops.

AIR PHOTOGRAPHS IN GEOLOGICAL MAPPING OF CORDILLERAN REGION, WESTERN CANADA*

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I HAVE used air photographs a great deal in connection with geological mapping in the mountains and interior plateau country of B.C., and in the Foothills of Alberta where the mapping was done as an aid to oil prospecting. Most of this mapping has been done for publication on a scale of one inch to one mile, when I have been provided with a topographical base map on a scale of two inches to one mile with the principal point of each picture plotted. I consider the photographs almost indispensable.

The main uses are:

1. Preliminary office examination.
2. Use in the field.
   (a) Planning traverses.
   (b) Plotting boundaries of outcrops.
   (c) Obtaining a rough idea of rock types.
   (d) Plotting of geological boundaries.
   (e) Interpreting structure.
   (f) Extrapolating geological boundaries and structures between traverses.
   (g) Physiographic studies.
3. Use in office compilation.

The photographs supplied for mile to the inch mapping have a scale of about 1500 feet to an inch and cover an area of about two miles square. The flights overlap by about one-third and each photograph in a flight overlaps about two-thirds. When the photographs are viewed in a stereoscope each photo is used, but when they are used without a stereoscope it is only necessary to use each alternate photograph.

1. *Preliminary office examination.* Before leaving for the field it is useful to examine the photographs to get an idea of the amount of outcrop, kind of structure, and amount of dense forest, swamp, and burn. This helps in planning the party and equipment, and the geologist goes to the field with a mental picture of the area.

2. (a) *Planning traverses.* In camp, the photographs for the next few days' work are studied carefully with a large folding stereoscope. Outcrops and large areas of exposed rock (either cleanly-burnt areas or areas above timberline) are noted, and either transferred to the work sheet or the photograph itself may be carried on the traverse. Thus, instead of running a straight traverse and hoping to find rock, the traverse is planned in a zig-zag fashion that will be sure to encounter rock and to cross the structures in the most suitable manner. It is

* Base maps were available.