for such features as dip and strike, pitching folds, and alluvial valleys. A few other especially outstanding groups of photographs are:

Moses Lake quadrangle, Washington, sand dunes
Cape San Blas and Indian Pass quadrangles, Florida, coastal features
San Juan area, Utah, joint patterns, deep dissection, and incised meanders
Mexican Hat area, Utah, incised meanders
Arco area, Idaho, alluvial fans
Grand Teton quadrangle, Wyoming, for the Gros Ventre slide
Scenic area, South Dakota, stages in the erosion cycle, badlands
Elephant Butte area, New Mexico, volcanic features
Yukon Delta, Alaska, an alluvial plain with shifting meanders
Mauritania French West Africa, an eroded dome
Among the photo index sheets, sheet 11 of 11, Ocean County, New Jersey, showing Barnegat Inlet; sheet 4 of 6, Lee County, Florida, showing Sanibel Island; sheets 4, 5, and 6, Santa Barbara County, California, showing San Miguel, Santa Cruz, and Santa Rosa Islands; and sheets 8 and 9, Bedford County, Pennsylvania, showing a pitching anticline, Wills Mountain, are among those which make effective displays of geologic features.

For several pairs of photographs there are sets suitable for student instruction in fair-sized classes. These sets run up to 24 copies and the number of copies of each are separately listed. Some photographs belonging to the Department of Geography, University of Illinois, and to staff members of the Department of Geology which would be available for occasional loan are also listed, although these are not in the aerial photo files in the department.

PHOTOGRAMMETRY IN SWEDEN

Dr. Bertil Hallert, Royal Institute of Technology, Stockholm

THE area of Sweden is about 450,000 square km (174,000 sq. miles), and compared with the population of about 7,000,000, is rather large. The mapping of the country, with a sufficient accuracy and at a reasonable cost, has been and is still a great problem. Up until 20 years ago nearly all mapping in Sweden was performed with classical methods. The land surveyors have been working for hundreds of years, and their maps have been used fundamentally for topographic mapping too. The topographic map of the whole country at scales of 1:50,000 and 1:100,000, and in some areas of 1:200,000, was completed not too many years ago, but the geodetic network and the accuracy of the details were not perfect in all parts of the country.

In some parts of Sweden another kind of map, called the economic map, was started about 100 years ago, with scales of 1:20,000 and in some areas 1:50,000. This special map contains almost all boundaries of the properties and other details of interest for economic purposes and planning. This work continued rather slowly as it was a difficult and expensive job. About 1930 it seemed impossible to continue this work; perhaps it would have been stopped, if photogrammetry had not come to its aid.

In 1930 Mr. *V. Hernlund*, at present, Director-in-Chief of the Geographic Survey Office, organized the tests to use photogrammetry for civil purposes in Sweden. Together with Directors *H. Malmberg* and *E. Lindeberg* he made a plan for the economic mapping of Sweden with the aid of photogrammetric methods. This plan was accepted by the Swedish parliament in 1937, and from the first of July of the same year photogrammetry was officially introduced in Swedish mapping. The Geographic Survey Office of Sweden (Rikets Allmänna

Kartverk) was reorganized as a civil office, and all maps of scales 1:10,000 and less are prepared with photogrammetric methods. Since this time photogrammetric methods have been used in Sweden in a growing extent. At present, photogrammetry is used in the following governmental institutions:

Rikets Allmänna Kartverk (Geographical Survey Office)
Kungl. Lantmäteristyrelsen (The Survey Board)
Försvarsstabens fotoanstalt (Department of Photography at the General Staff of Defense)
Kungl. Sjökarteverket (Hydrographic Service)
Kungl. Flygförvaltningen (Air Force Administration)
Kungl. Tekniska Högskolan (Royal Institute of Technology)

At the present time private photogrammetric activity is not worth mentioning. During the years just before World War II, a private firm "A/B Svensk Bildmänting" performed a considerable work in aerial photogrammetry.

A brief description of the activities at the different institutions is given below

THE GEOGRAPHICAL SURVEY OFFICE[1]

This institution consists of the Director-in-Chief, at present Mr. *V. Hernlund*, and of six technical divisions: The Economic Map Division, The Topographic Map Division, The Photogrammetric Division, The Division for Private Mapping, The Geodetic Division, and the Military Division. The staff of the Survey Office consists of about 325 officials.

Photogrammetric work is mostly carried on by the Photogrammetric Division which at present possesses the following equipment:

4 airplanes for aerial surveying; (2 Focke-Wulf planes of the type 58 "Weihe" and 2 Siebel planes of the type NC 701
6 Zeiss RMK 20/30 30 surveying cameras
1 Zeiss Stereoplanigraph
1 Wild A-5 Autograph
4 Wild A-6 Autographs
5 Zeiss Multiplex Aeroprojectors with 9 projectors each
6 Zeiss Multiplex Aeroprojectors with 3 projectors each
4 Zeiss SEG 1 Automatic rectifiers
Mirror stereoscopes and sketch-masters etc.

Three types of photogrammetric maps are regularly made in the Survey Office, including the Photo-Map of Sweden at a scale of 1:10,000; the Economic Map of Sweden at a scale of 1:10,000; and the Photo-Map at a scale of 1:20,000. The characteristics of these maps and the methods used in making them are described in what follows.

PHOTO-MAP OF SWEDEN, SCALE 1:10,000

According to a resolution passed by the Swedish Parliament in 1937, a photomap shall be made so as to cover about 60 per cent of the total area of the country. In the first place, this map shall be used as a basis for preparing the "Economic Map." The aerial photographs are taken by means of the above-mentioned cameras, provided with a wide-angle lens, at an altitude of about 4,000 meters above the ground level. Consequently, the focal distance being 20 cm, the scale of the photographs is 1:20,000. The forward lap is fixed at 60 per cent

[1] Some of the following material is excerpted from a report to the International Congress of Photogrammetry at The Hague, 1948.

and the sidelap at 40 per cent. In those cases where the ground is very hilly, an additional intermediate strip is taken, if required, in order that only the central portions of the photographs may be utilized in making the map, so as to reduce the displacement errors due to the topography of the ground.

Aerial triangulation on a scale of 1:10,000, based on control points having an average density of 3–4 points per 100 sq. km, is made with above-mentioned Multiplex instruments. Statoscopes or horizon pictures are not used in this connection. Multiplex triangulation pass points are plotted at the rate of about 1 per sq. km. The pass points are transferred to sheets of tracing paper, and these tracings are used for the photographic rectification of the aerial photographs with a scale of 1:10,000. This operation does not aim at the reduction to a horizontal plane of reference. Its purpose is to ensure that the agreement of the pass points plotted in the orthogonal projection is as close as possible. After that, the rectified photographs are assembled into photo-map sheets on plywood boards covered with drawing paper on both sides. The pass points are transferred to these boards in a square grid of coordinates.

A special method of assembling the photographs has been developed at the Survey Office. This method consists of producing local elongation and shrinkage of the photographs by wetting and hot air drying in the course of fitting, so that the pass points on the photographs exactly coincide with the corresponding pass points plotted on the board by means of their coordinates. This method eliminates the differences at the junctions of the photographs.

The photographs are assembled into map sheets 50×50 cm. in size representing an area of 5×5 km. In those cases where the photo-map is printed, it is provided with names and elevations. For the time being, however, the photo-map is printed only as a special edition of the "Economic Map." At the present time, the Geographical Survey Office produces about 550 sheets of the "Photo-Map of Sweden" per year. If required, the rate of production can be increased by 100 per cent.

ECONOMIC MAP OF SWEDEN, SCALE 1:10,000

This map is made by the Economic Map Division and is based on the above-described "Photo-Map."

The main purpose of this map is to represent the location of territorial properties. The "Economic Map" is used in drawing up plans for the development of agriculture and forestry. Also, this map is partly utilized in carrying into effect the measures taken to promote the practical application of these plans. Moreover, the "Economic Map" is of great value for the administrative bodies which work out regional and general development schemes, for other engineering and industrial undertakings, etc. This map shows the plan of the ground, the boundaries of the estates and their designations, buildings, roads and other communications, etc. The topography is indicated only by the elevations of points which are placed fairly close together.

The "Economic Map" is a print in green color of the photo-map described above. Prior to reproduction, the photo-map is provided with several indications printed in black, such as buildings, roads, and other communications, shorelines, electric power lines, ancient monuments, and the boundaries of fields and gardens, the latter being marked with yellow color. In addition, the indications printed in black comprise the names of the landed properties and the natural features, as well as the boundaries and the cedastral numbers of the estates. Those details indicated in black, which are not directly visible on the photo-map, are obtained from other existing maps and documents, or are determined

by special ground survey. These data are traced with India ink on red-toned photographic copies of the photo-map. The indications drawn in black on these copies, on no-shrinkage paper, can be reproduced directly for printing on the economic map. The Geographical Survey Office publishes about 350 sheets of the "Economic Map" every year. In carrying out the special ground survey operations required for this purpose, one surveyor can examine about 30 sq. km per month.

PHOTO-MAP, SCALE 1:20,000

This special edition of the "Photo-Map," primarily intended for military uses, is prepared by the Topographic Map Division and the Military Division together.

This map consists of a photographic map of the same type as the ordinary photo-map, with the reproduction reduced to a scale of 1:20,000, and is made up of the same sheets as the latter map. Prior to the reduction of the scale, this map is provided with contour lines at an equidistance of 5 m. Before tracing the contour lines, the topographers by means of a stereoscope select a very large number of points characterizing the elevations and slopes of the ground. The number of these points amounts to about 300 per aerial photograph in average hilly areas. The elevations of the characteristic points are determined by the Photogrammetric Division using the Multiplex. The mean error in this determination of the elevations is about $\pm$ 2m. These points are marked on the aerial photographs, and the contour lines are plotted by the Topographic Map Division on these photographs, by topographers specially trained in this work. The positions of the contour lines between the characteristic points are determined by interpolation, while examining the pairs of pictures in a mirror stereoscope. Check measurements have shown that the mean error in the elevations of the contour lines is about $\pm$3m.

With the aid of all the details of the aerial photographs, the contour lines are transferred by the Military Division, from the photographs to a sheet of tracing-paper spread on the photo-map. This tracing is then used for drawing the contour lines in white India ink on a sheet made of transparent material. This sheet is adjusted on the photo-map prior to photographic reproduction.

EXPERIMENTS CONCERNING NEW TOPOGRAPHIC MAP

The existing topographic map of Sweden is no longer up to date, and does not meet the requirements of civil and military users. For this reason, the preparation of a new topographic map on a scale of 1:50,000 is under discussion. It has been decided that this new map should be made by photogrammetric methods, and experiments have already been set on foot to investigate various ways of procedure. These experiments have shown that the configuration of the surface can conveniently be obtained from the "Photo-Map on a scale of 1:20,000." In those districts where special ground survey operations have been carried out for the preparation of the "Economic Map," most of the data required for the plan of the new topographic map can be derived from the results of these ground survey operations. Consequently, the topographic ground survey can be confined to two objects, viz., first to verify the data obtained from the "Economic Map" and the "Photo-Map with a scale of 1:20,000," and second, to supplement and to classify certain details which are peculiar to the topographic map. The maps of high mountain regions will probably be plotted by purely photogrammetric stereo-methods.

SPECIAL MAPS

Since July 1, 1946, the Photogrammetric Division of the Geographical Survey Office includes a special section for making maps to order. At the present time this section is organized as an independent division. The function of this section is to produce maps by methods ordered by state authorities and municipal bodies or by private persons and institutions. These maps consist in part of reproductions and special adaptations based on aerophotogrammetric surveys carried out with a view to the preparation of the ordinary maps issued by the Geographical Survey Office and described above. In addition, the division receives a steadily increasing number of orders for maps which require special aerial photography flights and ground survey operations. In particular, these special maps are used in town planning. The results obtained in this field show that the demand for maps of this kind may be expected to increase very rapidly. The greatest difficulty encountered in making these maps lies in the lack of adequate information of the accuracy required for maps of this kind. The conditions stipulated in respect to accuracy constitute a fundamental economic factor affecting the production of these maps.

THE LAND SURVEY BOARD

This institution is responsible for all cadastral works in Sweden and is the head of the land surveying organization. Until a few years ago all mapping of this organization was made by terrestrial methods. After 1940, however, some investigations were made regarding the use of photogrammetry for large scale mapping, especially from the point of view of cadastral purposes for detailed planning. In this connection, the name of *Professor K. D. Myrbeck* of the Royal Institute of Technology must be mentioned. After some additional tests on private initiative, the Land Survey Board started a series of tests in 1947; these are still in progress. The tests are made in cooperation with the Geographical Department of Photography at the General Staff of Defense, the Geographical Survey Office, and the Division of Photogrammetry of the Royal Institute of Technology. The leading man in this work is now *Sven G. Moller*, Assistant Chief of the Rural Surveying Division of Land Survey Board. About 20 areas in different parts of Sweden have been photogrammetrically mapped at scales between 1:800 and 1:4,000. This summer the Land Survey Board procured their first precision instrument, a Wild A5-Autograph, and together with other institutions has the intention to use other types of aerial cameras.

The method of mapping, used in the tests mentioned and probably in the future, is briefly outlined in the following.

The aerial pictures are taken by the wide-angle camera Zeiss 20/30, 30 principally, from such an altitude that the scale of the original pictures is about half of the map. Often smaller photo-scales are used for the tests. Before taking the photographs a sufficient number of control points and boundary points are signalled.

Enlargements of the same scale as that of the map are made and these are identified in the field. All necessary control and boundary points are checked and mostly all details of interest for the map are drawn on the enlargements. The roofs of the houses are reduced by simple measurements to the dimensions of the walls of the houses, if required.

The plotting is then performed in precision instruments, Stereoplanigraph or Autograph A5. The Autograph A6 has also been used. In connection with the plotting several checks are made of the accuracy of the numerical determination

of coordinates in horizontal position and in altitude, and on the accuracy of the graphic plotting.

Statistical investigations on the economy of the work are made. One of the most important aims of these investigations is to get the material for new prescriptions which are necessary for future use of photogrammetry for cadastral purposes. Although the results of these investigations are not yet published, it is evident that a fully satisfying accuracy of maps is obtained at a lower cost than by terrestrial methods. Photogrammetry will surely have an important place in the Swedish cadastral mapping in the future.

DEPARTMENT OF PHOTOGRAPHY AT THE GENERAL STAFF OF DEFENSE

Here the photogrammetric work is specialized on military photo-interpretation and reconnaissance work and on fast reconnaissance mapping under field conditions. During the war, considerable tests were performed with the slotted templet method for mapping areas with a sparse triangulation net.

The instrument equipment is rather comprehensive i.e. one Wild A-5, full-automatic rectifiers, reproduction cameras, equipment for military photogrammetric mapping under field conditions, surveying cameras and many others.

HYDROGRAPHIC SERVICE

Extensive tests have been carried out since 1943, using photogrammetric methods in making the base-map for hydrographic surveying. First and foremost, the purpose is to break down the triangulation net, and to plot shorelines and other details of interest for the charts. Photogrammetric contouring has been tried in compiling charts for marine radar navigation. These tests are considered successful.

AIR FORCE ADMINISTRATION

This authority is responsible for the aerial cameras, surveying cameras, and other photogrammetric equipment of the Air Force. During the war, hand-operated and full-automatic reconnaissance cameras as well as surveying cameras were designed by the Air Forces Administration. These cameras were manufactured in Sweden.

ROYAL INSTITUTE OF TECHNOLOGY

The Department of Photogrammetry

The activities of the Institute are primarily devoted to teaching and research.

Since 1945 there has been a special chair for photogrammetry at the Institute. Previously photogrammetry had been taught by the professor in high geodesy. The late *Professor E. Fagerholm* (died 1944) was greatly interested in photogrammetry, and it was largely through his efforts that a large and valuable collection of instruments was procured. He published his textbook *Fotogrammetri* in 1943.

Mr. *Bertil Hallert* was appointed Professor of Photogrammetry at the Institute in 1947.

Two courses in photogrammetry are arranged at the Institute. The lower course consists of 28 lecture hours, 28 practice hours and 10 days of field work. The advanced course consists of 42 lecture hours, 49 practice hours and 20 days of field work. The lower course is obligatory for students of the land-surveying and civil engineering departments, but the advanced course is not obligatory.

Plans are being made to expand the course in photogrammetry of the department of land surveying.

The number of yearly students in photogrammetry is about 100 in the lower and about 15 in the advanced course. The field work is generally placed where practical applications of photogrammetric methods are to be found.

The following instruments for teaching and research are now available:

3 aerial cameras (2 are deposited by other institutions)
3 phototheodolites
2 stereocameras Wild (bases 1.2 and 0.40 m)
2 small stereocameras and a number of other cameras
1 Wild A6-Autograph
1 Wild A4-Autograph
1 Wild Odencrants automatic rectifier
1 Stereocomparator Zeiss
1 Multiplex Zeiss with 6 wide-angle projectors (all deposited)
4 Multiplex Zeiss with 3 normal-angle projectors each
Mirror stereoscopes with parallax-bars and other stereoscopes
Theodolites and other equipment for field work
1 Autograph Wild A5 or A7 has been ordered

The cooperation with other institutions, specially the Division of Photography at the General Staff of Defence, is very close.

The following may be mentioned among the investigations at the Department of Photogrammetry:

(a) The use of photogrammetric methods for cadastral surveying (mainly in cooperation with the Survey Board).

(b) Photogrammetric error theory (double point inter-section in space and rectifying). The investigations of rectifying have been made by *R. S. Halonen*, now in Helsingfors.

(c) Theory of aerial triangulation (by *Dr. A. Bjerhammar*).

(d) The inner orientation and the function of aerial cameras in various temperature and air pressure. (by *R. S. Halonen*).

(e) Improvements of the slotted template method for radial triangulation (by *P. O. Fagerholm*)

(f) Model triangulation in Autograph A6, A5, and Stereoplanigraph (by *L. Ekelund*).

(g) Photogrammetry for forestry purposes. (by *E. Welander*)

(h) The use of close-up photogrammetry for several purposes (mine measurements, determinations of volumes, etc.).

(i) Photogrammetry for medical purposes (by *Dr. J. Adams-Ray* and *P. Hjelmström*).

(j) X-ray photogrammetry for dental purposes (by *Dr. N. Berghagen* and *P. Hjelmström*).

(The paper "Fotogrammetriska meddelanden" is published by the Department of Photogrammetry.)

Photogrammetric investigations are made at other institutions too. At the Geographical Survey Office, *Mr. P. Tham*, Head of the Photogrammetric Division in collaboration with *Mr. T. V. Wachenfeldt*, First Assistant Cartographer and *Mr. N. Holmquist*, M.E., has designed a new film-flattening device, based upon the vacuum principle. Further Mr. Tham has investigated the optical distortion in wide-angle lenses and its influence upon the photogrammetric work, and has designed a special arrangement for the correction of the optical distortion in the camera.

Professor A. Odencrants, whose name is well known to many photogram-

metrists, is still at work with several photogrammetric problems especially in optics and rectifying.

For investigations on the use of photogrammetric methods for forestry purposes, a special committee is at work in collaboration with other photogrammetric institutions.

Finally, there are plans to introduce photogrammetry in educational institutions in agronomy and forestry.

TWO PROBLEMS IN PHOTOGRAMMETRY

A. Frey Samsioe, Dr. Techn. and Percy H. Tham, Dr. Techn., Stockholm

DEVICES TO SECURE PLANE FILM SURFACES AND ELIMINATE LENS DISTORTION

IN THE year 1937, the Geographical Survey Office of Sweden—Rickets Allmänna Kartverk—established a special photogrammetric office. To begin with, the map survey of the major part of Sweden to the scale of 1:10,000 was to be based on the use of Zeiss wide-angle cameras RMK 20/3030 and stereo-instruments of the Multiplex type. Later on, precision stereo-instruments were also brought into use, i.e. Zeiss Stereoplanigraphs and Wild Autographs A5 and A6.

The first few years' experience showed, however, that the design of these cameras did not satisfy reasonable requirements of accuracy for aerial map plotting.

The first problem was how to keep the film surface geometrically true. The cameras RMK 20/3030 are built for film which, at the moment of exposure, is pressed by a slight excess air pressure against the supporting plate. The design for performing this operation is shown in Figure 1. The lifting up and pressing down of the plate is effected by an eccentric driven by the camera motor, the force being transmitted by a spring. The excess air pressure, acting on the opposite side of the supporting plate during the exposure, must obviously not be

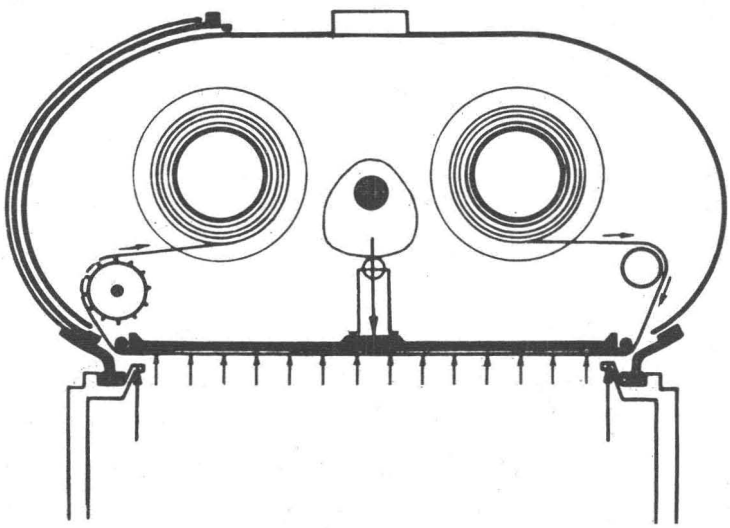

FIG. 1. Section through magazine of aerial camera.